PROCEEDINGS

Volume 1

VIII IWRA WORLD CONGRESS
ON W[illegible]R RESOURCE[illegible]

SATISFYING FUTURE NATIONAL AND GLOBAL WATER DEMANDS

Cairo, November 21 - 25, 1994

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(Volume 1)

INTERNATIONAL WATER RESOURCES ASSOCIATION

NATIONAL WATER RESEARCH CENTER
Ministry of Public Works and Water Resources, Cairo, Egypt

INDEX OF TECHNICAL SESSIONS

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<u>Key</u>
T = Topic
S = Session

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2	045	14:45 - 15:00	Changes in Water Demands in Germany - Challenge and Chance By : Schumann, A.H.
3	158	15:00 - 15:15	Egypt's Efforts Towards Management of Agricultural Water Demand By : Abu-Zeid, M.A.
4	114	15:15 - 15:30	Water Productivity in Egyptian Agriculture: Scenarios for More Sustainable Use By : Kishk, M.A. and J. Lundqvist
5	082	15:30 - 15:45	Potentials of Drainage Water for Agricultural Reuse in the Nile Delta By : Abdel-Dayem, S.
6	030	15:45 - 16:00	Water Resources as a Locational Factor of Human Activities to Satisfy Demands Under Water Drought Conditions, Examples From West Africa By : Lindskog, P.

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3	068	17:00 - 17:15	Land Reclamation Plans in Egypt and Water Requirements up to Year 2012 By : El-Shibini, F., W. F. Mankarious and M.N. Bayoumi
4	056	17:15 - 17:30	An Attempt to Estimate the Industrial Water Demand By : Benedini, M. and F.M. Spaziani
5	067	17:30 - 17:45	Control of Water Consumption of Rice By : El-Quosy, D.E.
6	168	17:45 - 18:00	Water Demand Management for Navigation Uses Within River Nile By : Saleh, A. and M. Abu-Zeid
7*	087	18:00 - 18:15	Meeting the Water Demands in Egypt: A Future Challenge By : Attia, B., S. Abdel Dayem and F. Attia

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Topic 2: Institutions for Managing Water Demands

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2	028	9:55 - 10:10	Management of Water Demands in Rural Australia By : Pigram, J.
3	052	10:10 - 10:25	Organizations for Irrigation Management By : Ankum, P.
4	131	10:25 - 10:40	The Critical Role of Irrigation " Learning" and Improved System Performance in Meeting Future Water and Food Demands By : Skogerboe, G.V. and D.J. Bandaragoda
5	169	10:40 - 10:55	Organized Water Research in Egypt: The Role of the Academy of Scientfic Research and Technology By : Abu-Zeid, M.A. and G. Abdel-Samie
6	127	10:55 - 11:10	The Role of Wastewater Recycling and Reuse in Water Resources Management Under Conditions of Scarcity By : Shuval, H.

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Coordinator : Shaden Abdel Gawad

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2	122	11:45 - 12:00	The Need for Strategic Research on Water Supply and Demand in Egypt By : Fahmy, H., A.K. Biswas and P.M. Pelletier
3	071	12:00 - 12:15	For An Efficient Management of Water Demand: Farmer Training Service (CES System) in the Lower Seyhan Irrigation Project Area, Adana-Turkiye (A Case Study) By : Tekinel, O. and A.Yazar
4	144	12:15 - 12:30	Towards Integrated Water Management in the Fringes of the Nile Valley By : Attia, F. and H.M. van Leeuwen
5	083	12:30 - 12:45	Technical and Organizational Changes in Irrigation Rehabilitation Programs: Management of the Water Delivery System in Irrigation Improvement Project (Egypt) By : Oad, R.
6	050	12:45 - 13:00	The WUA Approach to Improved System Performance: Experiences from Egypt By : Hvidt, M.

Topic 2: Institutions for Managing Water Demands

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Place : Amneris Salon
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Coordinator : Shaden Abdel Gawad

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• 3	093	15:00 - 15:15	Regional Integration of Water Demands for Adequate Development of Resources in South Africa By : Barta, B.
4	148	15:15 - 15:30	Institutional Development for Water Demand Management in Semi-Arid Zones-Nigeria's Experience By : Sonuga, J.O.
• 5	135	15:30 - 15:45	Appropriate Policy Instruments For Managing Water Demands in Nigeria By : Oyebande, L.
6*	051	15:45 - 16:00	Water Resources Management - The Kenyan Dilema By : Ndege, M. M.

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Session 1

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Coordinator : Maha Tawfik

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2	032	9:55 - 10:10	Cost Allocation Among Water Service Sectors for Egypt's Nile System By : Elassiouti, I. M. and A.S. El - Zaher
3	005	10:10 -10:25	Extended Economical Standpoint on Flood Control Works By : Botzan, D.A. and T. Botzan
• 4	091	10:25 - 10:40	Medusa Bag Projects for the Ocean Transport of Freshwater in the Mediterranean and Middle East By : Cran, J. A.
5	059	10:40 - 10:55	A Plan for Cost-Recovery of Water Facilities in the Irriagtion System By : El-Shibini, F.
6	060	10:55 - 11:10	Cost-Recovery for Demand Management of Water: Economic Perspective in Egypt By : Nasr, M. L.

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Session 1

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Coordinator : Hossam Fahmy

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2	017	9:55 - 10:10	Integrating Socio-Economic and Environmental Aspects in Water Resources Planning and Management By : Mohorjy, A. M.
3	086	10:10 - 10:25	Drainage Water Quality and Environmental Issues By : Abdel-Gawad, S.T.
4	075	10:25 - 10:40	Valorisation des Eaux Usées Dans Sud Tunisien By : Makni, H., F. Brissaud, S. Tajina and H. Ben Dhia
5	095	10:40 - 10:55	Effect of Waste Discharges on the Water Quality of Bahr El-Baqar Drain System, Eastern Nile Delta By : El - Sayed, A., S.T. Abdel Gawad, S. M. Abdel Gawad and K. Ibrahim
6	149	10:55 - 11:10	Assessing Performance of Irrigation and Drainage; Examples From Egypt By : Bos, M.G., S. Abdel Dayem and F.A. Attia

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Date : Thursday Nov. 24
Place : Eugenie Lounge
Time : 11:30 -13:00

Coordinator : Hossam Fahmy

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2	049	11:45 - 12:00	Potential Climate Change Impacts on Nile Basin By : Saleh, M., K. Strzepek and D. Yates
3	166	12:00 - 12:15	Fertilizer Abuse as a Possible Threat to Water Quality in Egypt By : Abdel Monem, M., M.A. Abdel Khalek and M.B Abdel Ghani
4	110	12:15 - 12:30	Environmental Impact of Drainage System on Lake Qarun in Fayoum By : El-Atfy H. and M. Eissa
5	065	12:30 - 12:45	Matching Evolving Water Quality Management Strategies to Monitoring System Design By : Soliman, W. R. and R. C. Ward
6	046	12:45 - 13:00	Dealing with Water Demand Margins By : de Haas, A. W.

Topic 4: Environmental Aspects of Demand Management

Session 3

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Place : Eugenie Lounge
Time : 14:30 - 16:00

Coordinator : Hossam Fahmy

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2	035	14:45 - 15:00	Limits to Hydropower Development in the Himalayan Rivers of Nepal By : Shrestha, D.L. and P. K. Mool
3	013	15:00 - 15:15	Improving the Hydrologic Cycle and Water Environment in River Basins Undergoing Urbanisation By : Takahashi, W. and K. Kamitakahara
4	150	15:15 - 15:30	Groundwater Management With Different Irrigation Demand Alternatives By : Dabbagh, A.E. and W. A. Abderrahman
5*	161	15:30 - 15:45	Impact of Development Irrigation in Central Asia on the Problem of Aral Sea and Ways of Solution By : Dukhovny, V.

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Coordinator : Hesham Kandil

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• 2	029	9:55 - 10:10	Non-Conventional Water Resources Development Alternatives to Satisfy the Water Demand in the 21st Century By : Murakami, M. and K. Musiake
3	159	10:10- 10:25	Satellite Based Distributed Operational Hydrometeorological Forecast System for the Nile River By : Attia, B., M. Andjelic and C.B. Barrett
• 4	124	10:25 - 10:40	Study of Hydrological Situation in Gaza Strip By : Abu - Mailah, Y.
5	140	10:40 - 10:55	Flow Forecasting for Flood Control and Water Management. By : Ogink, H. J. M., R.A.H.A. Thabet and M.E. Nur
6	054	10:55 - 11:10	Water Resources Development in Gash Delta , Sudan By : Ahmed, A.A.

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Date : Thursday Nov.24
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Coordinator : Hesham Kandil

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2	121	11:45 - 12:00	Water Demand Management in Canada - Past, Present, and Future By : Tate, D. M. and A.M. Kassem
3	164	12:00 - 12:15	Water Resource Management in the Mediterranean Basin By : Hamdy, A., M. Abu - Zeid and C. Lacirignola
4	136	12:15 - 12:30	Stochastic Modeling of the Nile River Flows By : Salas, J.D., M.W. Abdel Mohsen and B.B. Attia
5	069	12:30 - 12:45	Southeastern Anatolia Project (GAP) of Turkey: Water Resources Development Within the Context of Integrated Regional Socio Economic Development. By : Unver, O.
6	109	12:45 - 13:00	Water Resources and Water Demand Assessment in the Salawin River Basin in Thailand By : Onta, P.R., R. Loof, A. Das Gupta and R. Harboe
7	009	13:00 - 13:15	Techno-Political Decision-Making for Water Resources Development: The Jordan River Watershed By : Wolf, A.T. and M. Murakami

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5	058	15:30 - 15:45	Evaluation of Optimal Stochastic Operational Policies for the High Aswan Dam By : Abdelkader, H., J.W. Labadie and D.G. Fontane
6	084	15:45 - 16:00	Fast Basin Model for Management of the Resrvoirs on the Seine River and Tributaries By : Morel - Seytoux, H. J.
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5	108	10:40 - 10:55	Optimal Conjunctive Use of Surface and Groundwater Resources in Egypt By : El-Beshri, M.Z. and J.W. Labadie
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6	038	10:55 - 11:10	The Strategic Measures for Satisfying Water Demand in Future By : Liu, Z. and G. Zonglou

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43	Guillaud, Ch.	M. Tremblay and A.K. Krishman	KEOPS - A Model for Optimizing the Use of Natural Water Resources	T6 - S1	7	Thurs., Nov. 24	16:00 - 16:15	Empress Salon
44	Gupta, I. C.	B. L. Jain	Environmental Pollution of Ground Waters and Soils Due to Textile Industrial Effluents in Thar Desert.	T4 - S3	1	Thurs., Nov. 24	14:30 - 14:45	Eugenie Lounge
45	Haddad, M.		Meeting Future Water Demands in Palestine through Population Redistribution	T7 - S1	2	Fri., Nov. 25	9:55 - 10:10	Radames Salon
46	Hamdy, A.	M. Abu-Zeid and C. Lacirignola	Water Resource Management in the Mediterranean Basin	T5 - S2	3	Thurs., Nov. 24	12:00 - 12:15	Empress Salon
47	Hvidt, M.		The WUA Approach to Improved System Performance: Experiences from Egypt	T2 - S2	6	Wed., Nov. 23	12:45 - 13:00	Amneris Salon
48	Karam, G.E.	I. Najjar	Multi-Purpose Irrigation Canals - Generation of Micro Hydro Electric Power	T6 - S2	6	Fri., Nov. 25	10:55 - 11:10	Amneris Salon

	Author's Name	Co-authors	Paper Title	Topic /Session	Paper No.	Date	Time	Place
49	Khafagy, A. A.	A. M. Fanos, M. G. Naffaa and M. N. Anwar	Socio-Economic and Environmental Impact of Coastal Processes on Future Water Demand in Egypt	T4 - S2	1	Thurs., Nov. 24	11:30 - 11:45	Eugenie Salon
50	Khouzam, R.F.		Strategic Water Planning *An Exercise Case Study: Egypt*	T6 - S1	3	Thurs., Nov. 24	15:00 - 15:15	Empress Salon
51	Kishk, M. A.	J. Lundqvist	Water Productivity in Egyptian Agriculture: Scenarios for More Sustainable Use	T1 - S1	4	Tues., Nov. 22	15:15 - 15:30	Amneris Salon
52	Lee, S.	S. Ahn	Flood-Flow Management System Model of River Basin	T6 - S3	3	Fri., Nov. 25	14:30 - 14:45	Amneris Salon
53	Lindskog, P.		Water Resources as a Locational Factor of Human Activities to Satisfy Demands Under Water Drought Conditions: Examples from West Africa	T1 - S1	6	Tues., Nov. 22	15:45 - 16:00	Amneris Salon
54	Liu, Z.	G. Zonglou	The Strategic Measures for Satisfying Water Demand in Future	T7 - S1	6	Fri., Nov. 25	10:55 - 11:10	Radames Salon
55	Lobanov, V. A.		Methods of Computations and Forecasts of Water Resources for Demands Management	T6 - S3	1	Fri., Nov. 25	14:00 - 14:15	Amneris Salon

	Author's Name	Co-authors	Paper Title	Topic /Session	Paper No.	Date	Time	Place
56	Lowdermilk, M.K.	E. Barakat	Benefits and Costs of Private Water User Associations for Large Gravity Systems: The Egyptian Experience	T3 - S1	1	Wed., Nov. 23	9:40 - 9:55	Radames Salon
57	Makni, H.	F. Brissaud, S. Tajina and H. Ben Dhia	Valorisation des Eaux Usées Dans le Sud Tunisien	T4 - S1	4	Thurs., Nov. 24	10:25 - 10:40	Eugenie Lounge
58	Metawie, A. F.		Construction Management: The Bottle-Neck for Irrigation Improvement in Egypt.	T7 - S2	3	Fri., Nov. 25	14:30 - 14:45	Radames Salon
59	Mohorjy, A.M.		Integrating Socio-Economic and Environmental Aspects in Water Resources Planning and Management	T4 - S1	2	Thurs., Nov. 24	9:55 - 10:10	Eugenie Lounge
60	Mohtadullah, Kh.	R. Bhatia	Conflicts of Water-Use Between Irrigation and Other Sectors: How to Assess the Performance of Irrigation Agriculture?	T1 - S1	1	Tues., Nov. 22	14:30 - 14:45	Amneris Salon
61	Morel-Seytoux, H.J.		Fast Basin Model for Management of the Reservoirs on the Seine River and Tributaries	T6 - S1	6	Thurs., Nov. 24	15:45 - 16:00	Empress Salon
62	Murakami, M.	K. Musiake	Non-Conventional Water Resources Development Alternatives to Satisfy the Water Demand in the 21st Century	T5 - S1	2	Thurs., Nov. 24	9:55 - 10:10	Empress Salon

	Author's Name	Co-authors	Paper Title	Topic /Session	Paper No.	Date	Time	Place
63	Nasr, M.L.		Cost-Recovery for Demand Management of Water: Economic Perspective in Egypt	T3 - S1	6	Wed., Nov. 23	10:55 - 11:10	Radames Salon
64	Ndege, M. M.		Water Resources Management - The Kenyan Dilema	T2 - S3	6	Wed., Nov. 23	15:45 - 16:00	Amneris Salon
65	Niemczynowicz, J.		Issues to Address for Relieving Problems of Water Scarcity in Drought Conditions.	T7 - S2	2	Fri., Nov. 25	14:15 - 14:30	Radames Salon
66	Oad, R.		Technical and Organizational Changes in Irrigation Rehabilitation Programs: Management of the Water Delivery in Irrigation Improvement Project (Egypt).	T2 - S2	5	Wed., Nov. 23	12:30 - 12:45	Amneris Salon
67	Ogink, H.J.M.	R. A. H. A. Thabet and M. E. Nur	Flow Forecasting for Flood Control and Water Management.	T5 - S1	5	Thurs., Nov. 24	10:40 - 10:55	Empress Salon
68	Onta, P. R.	R. Loof, A. Das Gupta and R. Harboe	Water Resources and Water Demand Assessment in the Salawin River Basin in Thailand.	T5 - S2	6	Thurs., Nov. 24	12:45 - 13:00	Empress Salon
69	Oron, G.	A. Mehrez and J. Brimberg	Progressive Marginal Water Sources Development in Arid Zones	T6 - S2	1	Fri., Nov. 25	9:40 - 9:55	Amneris Salon

	Author's Name	Co-authors	Paper Title	Topic /Session	Paper No.	Date	Time	Place
70	Osman, S.M.		UNEP Program on Environmental Management of Inland Waters.	T4 - S1	1	Thurs., Nov. 24	9:40 - 9:55	Eugenie Lounge
71	Ould Moine, S. M.	J. Llamas and G. Morin	Planification D'un Réseau Météoroloique Application a la Mauritanie	T6 - S3	6	Fri., Nov. 25	15:15 - 15:30	Amneris Salon
72	Oyebande, L.		Appropriate Policy Instruments for Managing Water Demands in Nigeria.	T2 - S3	5	Wed., Nov. 23	15:30 - 15:45	Amneris Salon
73	Özis, Ü.		Supply and Demand Management in Euphrates-Tigris Basin.	T5 - S2	1	Thurs., Nov. 24	11:30 - 11:45	Empress Salon
74	Pigram, J.		Management of Water Demands in Rural Australia	T2 - S1	2	Wed., Nov. 23	9:55 - 10:10	Amneris Salon
75	Preul, H.C.		Rainfall-Runoff Water Harvesting Prospects for Greater Amman and Jordan.	T7 - S1	3	Fri., Nov. 25	10:10 - 10:25	Radames Salon
76	Reynolds, P. J.	A. M. Mohorjy	Middle East Cooperation to River Basin Plans: An Example of the Jordan and Yarmuk Rivers.	T5 - S1	1	Thurs., Nov. 24	9:40 - 9:55	Empress Salon

	Author's Name	Co-authors	Paper Title	Topic /Session	Paper No.	Date	Time	Place
77	Salas, J. D.	M.W. Abdel Mohsen and B.B. Attia	Stochastic Modeling of the Nile River Flows.	T5 - S2	4	Thurs., Nov. 24	12:15 - 12:30	Empress Salon
78	Saleh, A.	M. Abu-Zeid	Water Demand Management for Navigation Uses within River Nile	T1 - S2	6	Tues., Nov. 22	17:45 - 18:00	Amneris Salon
79	Saleh, M.	K. Strzepek and D. Yates	Potential Climate Change Impacts on Nile Basin	T4 - S2	2	Thurs., Nov. 24	11:45 - 12:00	Eugenie Salon
80	Schultz, G. A.		The Need for a Change in Water Resources Systems Planning Philosophy	T2 - S1	1	Wed., Nov. 23	9:40 - 9:55	Amneris Salon
81	Schumann, A. H.		Changes in Water Demands in Germany - Challenge and Chance	T1 - S1	2	Tues., Nov. 22	14:45 - 15:00	Amneris Salon
82	Shata, A. A.		Low Saline Groundwater in Egypt and Satisfying Demands in the New Agricultural Land Areas.	T7 - S1	1	Fri., Nov. 25	9:40 - 9:55	Radames Salon
83	Shrestha, D. L.	P. K. Mool	Limits to Hydropower Development in the Himalayan Rivers of Nepal	T4 - S3	2	Thurs., Nov. 24	14:45 - 15:00	Eugenie Lounge

	Author's Name	Co-authors	Paper Title	Topic /Session	Paper No.	Date	Time	Place
84	Shuval, H.		The Role of Wastewater Recycling And Reuse in Water Resources Management Under Conditions of Scarcity.	T2 - S1	6	Wed., Nov. 23	10:55 - 11:10	Amneris Salon
85	Sidhom, M.	G. S. Ebaid	Simulation of Bed Changes and Flow Conditions Due to Suspended Sediment at River / Reservoir System " 4 - D Sidhom Model".	T6 - S3	7	Fri., Nov. 25	15:30 - 15:45	Amneris Salon
86	Sivanappan, R. K.		Water Demand and Management in Water Deficit Areas - A Case Study.	T7 - S2	1	Fri., Nov. 25	14:00 - 14:15	Radames Salon
87	Skogerboe, G.V.	D. J. Bandaragoda	The Critical Role of Irrigation "Learning" and Improved System Performance in Meeting Future Water and Food Demands.	T2 - S1	4	Wed., Nov. 23	10:25 - 10:40	Amneris Salon
88	Soliman, W. R.	R. C. Ward	Matching Evolving Water Quality Management Strategies to Monitoring System Design.	T4 - S2	5	Thurs., Nov. 24	12:30 - 12:45	Eugenie Salon
89	Sonuga, J. O.		Institutional Development for Water Demand Management in Semi-Arid Zones - Nigeria's Experience.	T2 - S3	4	Wed., Nov. 23	15:15 - 15:30	Amneris Salon
90	Takahashi, W.	K. Kamitakahara	Improving the Hydrologic Cycle and Water Environment of River Basins Undergoing Urbanization	T4 - S3	3	Thurs., Nov. 24	15:00 - 15:15	Eugenie Lounge

	Author's Name	Co-authors	Paper Title	Topic /Session	Paper No.	Date	Time	Place
91	Tate, D.M.	A. M. Kassem	Water Demand Management in Canada -- Past, Present and Future	T5 - S2	2	Thurs., Nov. 24	11:45 - 12:00	Empress Salon
92	Tawfik, M.	J.W. Labadie	A Real-Time Stochastic Dynamic Programming Model for Multi-Purpose Reservoir Operation.	T6 - S3	2	Fri., Nov. 25	14:15 - 14:30	Amneris Salon
93	Tekinel, O.	A. Yazar	For An Efficient Management of Water Demand: Farmer Training Service (CES System) in the Lower Seyhan Irrigation Project Area, Adana-Türkiye (A Case Study)	T2 - S2	3	Wed., Nov. 23	12:00 - 12:15	Amneris Salon
94	Ünver, O. I.		Southeastern Anatolia Project (GAP) of Turkey: Water Resources Development Within the Context of Integrated Regional Socio-Economic Development	T5 - S2	5	Thurs., Nov. 24	12:30 - 12:45	Empress Salon
95	Wolf, A. T.	M. Murakami	Techno-Political Decision-Making for Water Resources Development: The Jordan River Watershed	T5 - S2	7	Thurs., Nov. 24	13:00 - 14:15	Empress Salon
96	Zaghlool, A. S.	U. C. Chaube and G. N. Yoganarasimhan	On-Line Irrigation Demand Forecasting Model.	T6 - S3	5	Fri., Nov. 25	15:00 - 15:15	Amneris Salon
97	Zaki, A. F.	M. Sh. Elmanadeli, M. F. Helwa and H. A. Ibrahim	Representative Rainfall Pattern Suitable for Hydrologic Design in Sinai.	T6 - S3	4	Fri., Nov. 25	14:45 - 15:00	Amneris Salon

CONFLICTS OF WATER-USE BETWEEN IRRIGATION AND OTHER SECTORS: HOW TO ASSESS THE PERFORMANCE OF IRRIGATION AGRICULTURE?

Khalid Mohtadullah and Ramesh Bhatia[1]

This paper reviews some evidence on emerging conflicts in water-use between irrigation and other sectors such as households, industry, power and environment. Since irrigated agriculture in developing countries has to provide a major share of the required increases in food and fibre production, it is absolutely essential to ensure adequate water supplies and financial resources for this sector. The paper argues the need for appreciating the role of irrigation in meeting the objectives of food-sufficiency, income growth, regional development, employment creation and poverty alleviation. The paper presents IIMI's efforts in developing and using a comprehensive "Performance Assessment System" for irrigated agriculture. This assessment methodology quantifies indicators for evaluating the performance of irrigated agriculture in terms of productivity, equity, financial viability and environmental sustainability. The paper also describes successful cases of water conservation and improved water quality through appropriate mix of legislation, regulations, water tariffs, pollution charges and investment incentives.

1. Increasing Water Scarcity

According to a recent estimate[2], by 2025, thirty four countries will face water scarcity, i.e. per capita availability of freshwater supplies will be less than 1000 M^3/person/year. Two most populous countries in the world. India and China will have less water than is considered essential for meeting the demand for households, agriculture and other sectors. For example, 1.5 billion persons in India will have less than 1400 M^3/person/year of water available by 2025. In China, the estimated availability is slightly higher, i.e. 1700 M^3/person/year in 2025. Compared with these, per capita availability in the USA, will be 7170 M^3/person/year in the year 2025.

2. Rising Demand For Households and Industries

Rising demand for urban and industrial water supplies poses a serious threat to irrigated agriculture (Table 1). During the next twenty five years, substantial quantities will be diverted from irrigation to urban and industrial uses in many states of India, in the Jabotabek region of Indonesia, and in many countries in the Middle East. For example, in the Subernarekha river basin in Eastern India, irrigation will receive only 70 percent of its water needs in 2025 if priority is given for urban and industrial uses. In the Jabotabek region of Indonesia, in 2015, irrigation supplies will have to be reduced by 30 percent if water demands for household, industry and flushing have to be met (Table 2). In Malaysia, the share of domestic and industrial demand in total demand will increase from 23 percent in 1990 to 32 percent in 2000.

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1 International Irrigation Management Institute(IIMI). Paper prepared for the VIII IWRA World Congress on Water Resources, Cairo. November 21-25,1994,

2 Sustaining Water: Population and the Future of Renewable Water Supplies: By Robert Engelman and Pamela LeRoy: Population Action International, Washington, DC.1993

However, the challenge for irrigated agriculture does not come only from competition from other water users. Equally important is the crunch for financial resources. Despite massive investments in the past[2], the public irrigation systems are facing dwindling financial resources for new projects and for managing existing projects. This is because irrigation agencies and governments have been reluctant to raise irrigation charges to cover O&M and capital costs. International agencies are also reluctant to give more money for irrigation in view of rising real costs, falling foodgrain prices in the international market and opposition from environmentalists.

Despite these twin challenges of reductions in available water supplies and in financial resources, irrigated agriculture has to meet the rising demand for foodgrains to avoid large scale hunger. Irrigated agriculture will have to meet 70 to 75 percent of the additional foodgrain requirements in many developing countries. Besides, irrigation will be needed for food and cash crops to meet objectives of self-sufficiency, employment creation, poverty alleviation and development.

3. Water Pollution and Environmental Impacts

Apart from the water scarcities and shortage of funds, the water resources sector also faces a very serious challenge; and that is related to a serious threat to water quality. This comes from contamination of water by industrial toxics, agricultural chemicals, untreated sewage and mining. Developing countries have generally paid too little attention to water quality and pollution control. Using polluted water for human consumption is the principal cause of many health problems such as diarrhoeal diseases, which kill more than 3 million people each year--mostly children--and render sick more than a billion more.[3]

For example, in Indonesia, in the Ciliwung river, average biochemical oxygen demand (BOD) was about 15 mg per litre, 150 percent higher than the norm. A review of water pollution level in selected rivers in Java shows that the level of fecal coliform is, in some cases, more than 4000 times the conventional standards. The situation is similar in many rivers and lakes in the vicinity of urban centres, in India and other developing countries.

There are serious environmental consequences of current irrigation practices. These are reflected in large tracts of land affected by waterlogging and salinity in Pakistan and parts of India. These are also evident in rising groundwater table in some areas while a mining of water in some other regions of India. The whole issue of sustainability of agro-ecological system is at stake. Then, there are social issues of resettlement of people affected by large scale water resources

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[2]In India, irrigation investments of over $2 billion up to 1990 amount to about 30 percent of total public investments. In Mexico, irrigation projects have taken 80 percent of agricultural investments. Development assistance agencies have been heavy investors; irrigation accounted for 28 percent of all World Bank agricultural lending in the late 1980s.

[3]The World Bank: Water Resource Management: A Policy Paper, 1993, P32.

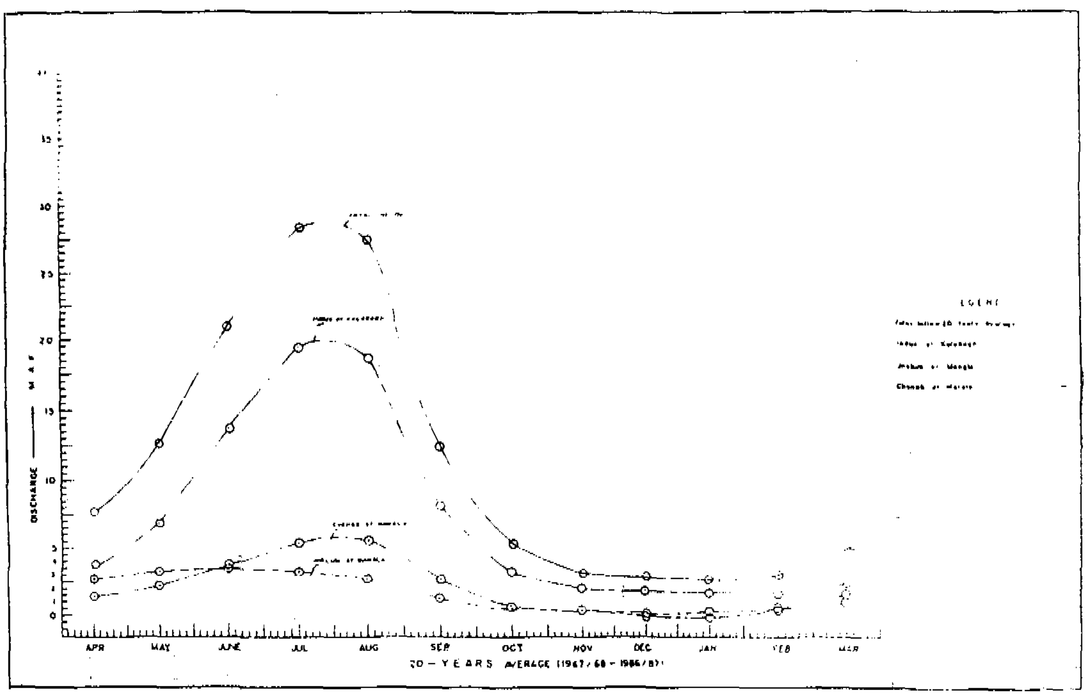
projects, adverse impacts on women. children and marginal farmers. Furthermore, water-related diseases such as malaria, filariasis etc. are common in Sub-Saharan Africa.

4. A Case of Competing Water Uses

Take the example of the Indus system, it has two main reservoirs: one at Tarbela on the main stem Indus, and the other at Mangla on the Jhelum river, which is a tributary of the Indus. They together provide about 17.6 billion m^3 of storage which allows the regulation of the natural inflows for irrigation purposes and hydro generation. According to estimates, 77% of the stored water in the dams is used in the Winter months and the remainder is shared equally between early (April-June) and late (September) Summer months. Because these rivers derive their water mainly from ice and glacial melt, availability varies quite considerably during the seasons (Fig. 1). The problem arises particularly during Winter months when the base flow in the rivers decrease. At this time the irrigation water requirements and power needs begin to compete. Competition becomes acute in December and January when irrigation water demands decrease dramatically and power demand increases due to Winter temperatures. Every drop of water that is released from storage at this time leads to reduced availability for irrigation during the most critical early and the later part of Summer months which seriously affects productivity of irrigated agriculture in the Basin.

The third factor relates to water requirements in the system for environmental protection of the estuary, preventing salinity intrusion and saving mangroves. In a water short system like the Indus, such competition for water often presents great difficulty in water allocation. Population pressure places increasing demand for municipal water use. Similarly, development requires more power generation. These factors make water allocation more complex and threaten historical supplies for irrigation. Yet, the demand for food for the rapidly rising population continues to mount and the challenge becomes serious when irrigated agriculture (80% of all arable land in Indus Valley is under irrigation) is required to produce more and more with less and less water. This makes the system very vulnerable. Production increases through improved management of water in agriculture help up to a point, beyond that, the system becomes unsustainable.

Figure 1



Source: WSIP Study, FCP, Lahore, December 1990

5. Policies and Actions Required to Meet the Challenges

The situation as described above is not sustainable, even over the medium term of 10 years, in many developing countries. Hence, the most important question is: Can something be done to improve the situation? If so, what should be done and how?

The first and foremost issue is to recognize that water resources have to be used in an efficient, equitable and environmentally sustainable manner.

However, awareness of the issues is only the first step; although a necessary first step. Concerted efforts would have to be made in several directions. Action will have to be taken at least on three fronts:

- **Legislation and Regulation** to protect water quality and depletion of resources;
- **Incentives** to water users to encourage water conservation and recycling/reuse; and
- **Institutional changes** to take a holistic view of water resources management and to encourage user participation, financial autonomy and decentralization.

The experience in many developing countries has shown that the "fragmented, Command-and-control" approach to management of water resources has failed, both economically and environmentally. Hence, there is a need to use economic incentives and fiscal instruments in achieving economic efficiency in the use of the resource. Further, it is necessary to show that better economic management of this resource will greatly assist in improving the environment. Thus, a policy package is urgently required with a judicious mix of legislation and regulation; water tariffs, pollution taxes, effluent charges and groundwater extraction charges; and providing tax benefits or investment support for water conservation and effluent treatment plants.

6. Legislation and Regulation should be Effective

In each country, the foremost requirement is to create an institutional setting within an effective legal and regulatory framework to ensure optimum use of water resources. This would require defining water rights and allocation for surface water and groundwater; legislation on groundwater withdrawals, protection of water quality etc. The regulatory framework should take coordinated actions regarding prices charged by utilities; pollution charges and taxes; and competitiveness of entry to water service industries. Even where such regulations are present, implementation of these is not very effective. Concerted efforts are required to set environmental standards and enforce them so that potential health hazards can be avoided.

7. Raising Water Tariffs Gives Right Signals

The Dublin Conference on Water and the Environment held in January 1992 emphasized that "water has an economic value in all its competing uses and should be recognized as an economic good". The implication of this is that water rates (or tariffs) should reflect its scarcity value or its value in alternative use. If water tariffs are raised to reflect their real costs, a substantial saving in water use will result. This is true not in industrialized countries--in the USA, Canada or Israel. This is also true in developing countries.[4] In Bogor, Indonesia, the water utility tripled water prices to encourage households to conserve. Between June 1988-April 1989, average monthly residential water use dropped nearly 30 percent. In Jamshedpur, the Steel City of India, a 100 percent increase in water tariff will reduce water demand in industries by 49 percent through investments in water conservation and recycling (of treated water). This increase in water tariff will increase cost of production by less than 5 percent. Further, this will eliminate dumping of untreated toxics and acidic discharges, thus improving the water quality in the Subernarekha river.

8. Savings in Industry have been Achieved

A fertilizer plant in Goa, India, consumes only 10.3 m^3 of water per ton of nutrient compared with 24.4 m^3 of water per ton of nutrient in a similar-size factory in Kanpur, India. This lower consumption in the Goa plant reflects a much higher price of water at Rupees 2.50 (8 cents) per m^3 compared with Rupees 0.2 (less than 1 cent) per m^3 in Kanpur. In Madras, India, a refinery and a fertilizer plant responded to the high cost of water obtained by tankers by increasing the number of cooling water cycles and by using treated municipal wastewater and, thus, achieved reductions ranging from 10 percent to 100 percent in unit water consumption. In Mexico, increased water price and an imminent shortage encouraged wastewater reuse.

However, increasing water tariffs alone will not be enough. These changes will need to be reinforced by non-price measures such as stipulating standards, quotas, restrictions as well as publicity and education campaigns.

In Sao Paulo, Brazil, when pollution charges were based on the amount of pollutants, managers of several industrial plants introduced conservation measures to reduce both pollution loads and water consumption.

In many industrialized countries, (including Netherlands, Sweden, USA) water consumption per unit of output has been reduced by 40 to 50 percent or more (notably in paper and pulp industry). In addition to water savings, it has encouraged pollution abatement practices by recycling and reuse of treated effluents. This is a WIN-WIN situation where both water savings and environmental benefits are achieved. Policy makers, industrialists, NGOs, and consumer groups should take note of this key result of the experiences in both industrialized and developing countries.

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[4]For many examples of the effect of price increases on demand, see Ramesh Bhatia, Rita Cestti and James Winpenny: Water Conservation and Reallocation: "Best Practice" Cases in Improving Economic Efficiency and Environmental Quality, forthcoming, World Bank, Washington DC, 1994.

9. Large Savings in Agriculture are Possible

There is significant scope for water conservation in irrigated agriculture. Higher water rates for water-intensive crops such as rice and sugarcane can encourage shift towards other crops such as maize, wheat, barley etc. Since irrigation charges are generally much lower than the value of water in alternative uses, these low prices do not encourage efficient water use on the farm. Further, efficiency will improve by a more equitable distribution of water between farmers at the head of the distribution system and those at its tail-end. In some situations of water scarcity (and high value commercial crops), the use of sprinklers and drip irrigation may also be economic. Some technological options such as the tertiary development in the Muda irrigation scheme in Malaysia have resulted in raising productivity per unit of water. Water efficiency in agriculture can also be increased by jointly managing surface water and groundwater as in the case of the Gangetic plain in India.[5]

10. Improving Performance of Existing Irrigation Schemes

In the context of the threats of water shortages and declining financial reserves, the productivity of existing irrigation systems will be the primary determinant of sectoral performance in the short run, and the sustainability of physical resource base in the long run contribution of irrigation. The International Irrigation Management Institute (IIMI) considers the introduction of performance assessment methodologies an effective and necessary first step in bringing about changes in irrigation management practices. Consistent use of performance indicators generates information which provides the basis for defining and evaluating improved operational procedures for existing systems and for determining what further investments in irrigation, if any, are justified.

A five-year Performance Assessment and Improvement Program has been initiated at IIMI. The main components of this Program are :

(i) Developing and Applying a comprehensive Performance Assessment System;

(ii) Evaluation of Performance-enhancing Management Practices/Interventions.

As outlined in Figure 2, the major components of the performance assessment systems are :

- Identification of objectives and performance indicators;
- Development of practical and cost-effective methodologies for measurement of performance over large irrigation systems;
- Quantification (measurement) of these performance indicators in selected systems;

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[5]See Sandra Postel: Last Oasis, Facing Water Scarcity, the Worldwatch Environmental Alert Series, W.W. Norton Co., New York, 1992.

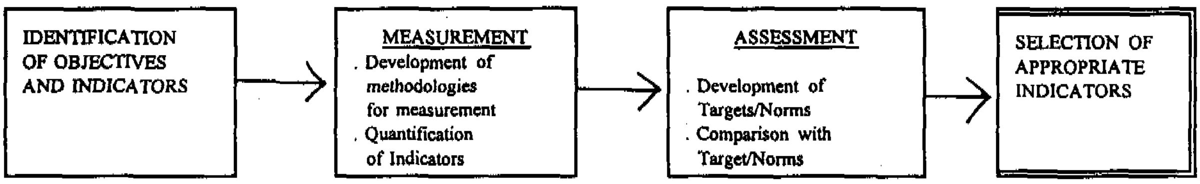
- Development and specification of targets or assessment norms/standards against which the actual values of performance indicators are to be compared;

- Comparison of "actual values" of performance indicators with targets and assessment norms to derive conclusions regarding the "performance level" of the scheme/sub-scheme (or a group of schemes) for a given year and/or changes over time.

- Selection of "appropriate" indicators for a given scheme.

Figure 2

STEPS IN PERFORMANCE ASSESSMENT



It is essential to use performance indicators which are optimally appropriate for the objectives of the user. For example, the objectives of the policy maker may be one or more of the following: maximizing irrigated area from given supplies of water; maximization of productivity per unit of land/water/labour; meeting targets of food self-sufficiency, employment; providing benefits to small farmers, and for livelihoods of rural people including women; enhancing farmers' profitability and ensuring environmental and financial sustainability. The performance indicators will have to be so selected as to reflect such concerns. Table 3 illustrates some of the linkages between various objectives and corresponding performance indicators. The selection of "relevant" performance parameters will depend on the interest of the policy maker in assessing the contributions made and to be made by irrigated agriculture.

Field research for quantifying various performance indicators has been initiated in six selected irrigation systems. These are :

(i) Chishtian Sub-division of the Fordwah-Eastern Sadiqia Irrigation System, Punjab, Pakistan;

(ii) Mahi Kadana Right Bank Canal, Gujarat, India;

(iii) Muda Irrigation Scheme in northern Malaysia;

(iv) Rahad Irrigation Scheme in Sudan;

(v) Moulouya ORMVA in Morocco; and

(vi) Rio Tunuyan system in Argentina.

Each of these systems differs in terms of agro-ecological conditions, rainfall, crop pattern, performance efficiency and management structures. It is expected that in-depth studies of these systems will provide generic conclusions regarding the determinants of the performance of irrigated agriculture. This research will also suggest a set of performance-enhancing recommendations regarding water delivery and allocations (e.g. fixed rotation); decision-support systems; and water conservation activities.

11. Increasing New Investments in Irrigation

Although improving the efficiency of existing irrigation schemes is a must, this will not be sufficient to meet the additional requirement for food and fibre in the next two decades. Large scale new investments in irrigation schemes will be required for providing adequate food and fibre to meet the objectives of poverty alleviation and development. During the last decade, real investment in irrigation schemes has declined as the cost of new schemes have increased, while international prices of foodgrains have declined. In view of large contributions required from new schemes, concerted efforts are needed, both at national and international levels, to increase real investments in new irrigation schemes.

12. Conclusions

During the next twenty five years, substantial quantities of fresh water supplies will be diverted from agriculture to industrial and households in many regions. It will be necessary to implement legislative measures and increase industrial water tariffs to encourage water conservation and recycling.

Irrigated agriculture will face two challenges of water shortages and dwindling financial resources in the coming decades. Despite these challenges, irrigated agriculture will have to provide 70 to 75 percent of the additional foodgrain requirements to developing countries. This will not be possible without (i) substantial improvements in the productivity of existing irrigation schemes, and (ii) investments in new irrigation projects.

The International Irrigation Management Institute (IIMI) has developed effective methodologies for assessing and improving the performance of irrigated agriculture. IIMI's Performance Assessment System evaluates the contributions and impacts of an irrigation scheme in terms of production, self-reliance, employment, poverty alleviation, financial viability, farmers' profitability and environmental sustainability. The application of such a comprehensive assessment procedure will enable policy makers and irrigation managers to implement effective management practices and allocate necessary financial resources to this important sector.

Table 1

Rising Share of Non-Agricultural Demands for Water in the World

	(Percent of Total Demand)	
	Demand in 1993	**Estimated Demand in 2025**
1. Households	6 - 8 percent	15 - 20 percent
2. Industries	26 percent	30 percent
3. Agriculture	66 - 68 percent	50 - 55 percent
Sustaining Water: Population and the Future of Renewable Water Supplies by Robert Engelman and Pamela LeRoy. Population Action International, Washington, DC. 1993		

Table 2

Competing Uses of Water in River Basins in India and Indonesia

	Million Cubic Meters	
	Subernarekha River Basin, India	**Jabotabek Region, Indonesia**
Estimated Demand	**2025**	**2015**
Households	180	1790
Industry & Power	1200	540
Irrigation	1720	2400
Others (e.g. flushing)	0	600
	3100	**5330**
Estimated Population	**2585**	**4620**
Deficit	**- 515**	**- 710**

Sources:
(i) G. Anandalingam, R. Bhatia and R. Cestti: Policy Implications of Intersectoral Linkages in Water Resources Management: Case Study from India, Water & Sanitation Division, World Bank. Draft. October 30, 1992.

(ii) Rita Cestti: Policies for Water Demand Management and Pollution Control in the Jabotabek Region in Indonesia, Water & Sanitation Division, World Bank. Draft. March 5, 1993.

Table 3
LINKAGES BETWEEN OBJECTIVES AND PERFORMANCE INDICATORS

USER GROUPS	TYPE OF OBJECTIVE	TYPE OF PERFORMANCE INDICATOR
1. **POLICY MAKER**	Productivity	- Irrigated area by year - past and projected - Irrigated Area Per Unit of Water - Gross Value of Output Per Ha/M3 (at international prices)
	Self-Sufficiency	- Food requirements by year - past and projected - Foodgrain Production as Ratio of Demand, past and projected - Food imports - past and projected - Foreign Exchange Earnings/Savings for this scheme
	Social Indicators	- Benefits to Small Farmers - Benefits to Tail-End Farmers - Addtiional Employment
	Environmental and Health Impacts	- Area under Waterlogging - Area under Salinity - Level of Water Table - Area where Groundwater is within 1.5m - Water Quality (Surface and Groundwater) - Number of Persons Affected by Malaria
	Financial Viability	- Return on investments (Financial and Economic) - Revenues as Ratio of Costs - Maintenance expenditures - past and projected
2. **IRRIGATION MANAGER**	Provision of Targeted Supply	- Delivery Performance Ratio
	Adequacy of Water Supply	- Relative Water Supply
	Predictability	- Actual Duration/Planned Duration
	Productivity	- Production Per Unit of Water/Land
3. **FARMERS**	Predictability	- Actual Duration/Planned Duration
	Profitability	- Net Value of Additional Output

For details on measurement of these and other indicators, see Appendix Table 2

CHANGES IN WATER DEMANDS IN GERMANY - CHALLENGE AND CHANCE

Andreas Schumann, Ruhr University Bochum, Bochum, Germany

ABSTRACT

Two changes of water management conditions are discussed: the socio economic impacts and climate change. The discussion of socio-economic developments in its impacts on water demand and supply show at the example of Germany the dependency of water price and consumption and the importance of institutional changes in water management. The effects of water quality problems as limiting factors for further utilization of groundwater resources on the concentration in water industries and a re-organisation of water management are discussed. The uncertainty of a forecast of regional impacts of climate change is shown in an example.

Increasing dynamics of changing conditions of water management caused by changes of water demand, natural climate variability or anthropogenic climate change reduce the period of validity of water management schemes and rules. The future performance of existing or planned water management facilities depend much on the possibilities to introduce flexibility in their operation. As an example a tool is presented which helps water managers to adapt the operation rule of reservoirs to changing conditions and targets, but also to close the gap between long-term operation planning and short term management. By combination of time series analysis, Stochastic Dynamic Programming and simulation an operational useable instrument of reservoir management planning was developed which will be presented in a case study.

1. SOCIO-ECONOMIC IMPACTS ON WATER DEMAND AND SUPPLY

The political changes in Europe in the nineties are connected with extreme alterations of socio-econonomic developments in many countries. Socio-economic impacts can be studied in their effects on water demand, supply and the institutional framework of water management. At present water demand in Germany mirrors the impact of economy on the consumption. By extrapolation of the development in the early seventies the domestic water demand for the year 2000 was forecast to approximately 200 litres per inhabitant and day in West Germany. Now the development has shown that this forecast was wrong since it did not consider the increase of water prices. The domestic water consumption in the last ten years stabilized on a level between 140 and 150 l/inhab. day (Figure 1) (Stadtfeld, 1989). Besides the reached high level of sanitation the increase of water prices between 1970 and 1987 by 160 percent is cause for this development. Today the German water price per cubic meter is the highest in Europe and is still on an uprising trend (Financial Times, 1993). Between 1992 and 1993 the price was increased by 17,4 %. How important the regulation of consumption through price is, can be shown with the example of East Germany. After the re-unification in 1990 the subsidies of staple food were cut. In the socialist economy low prices for these goods should demonstrate the welfare of the state towards it's citizens. Also the drinking water was subsidized and as a result of this policy the total consumption per inhabitant and day in East Germany was 30 % higher than in West Germany.

The system of subsidizing gave higher benefits to consumers of large water amounts and many industrial users gained from the consumption of public supplied drinking water.

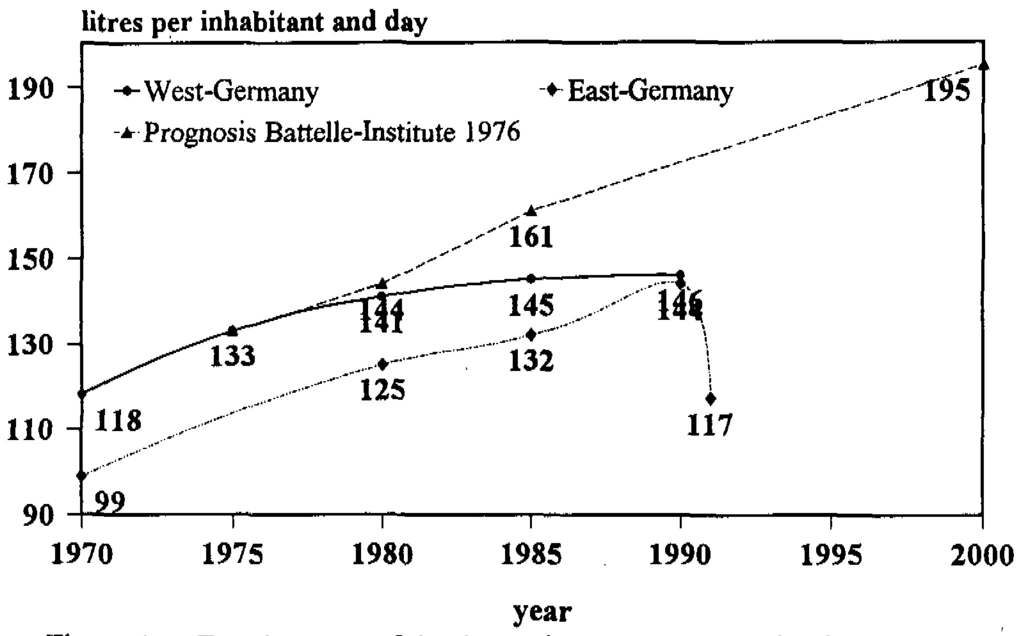


Figure 1. Development of the domestic water consumption in Germany

By comparing the domestic water consumption in East Germany between 1990 and 1991 (Fig.1) the reduction of individual water consumption and losses in the water supply system, stimulated by a new price system becomes obvious (Jahresbericht der Wasserwirtschaft, 1992). The water consumption was reduced by 19 % to the level of 1970 in West Germany because of the lower level of sanitation in the East.

Discussing the German water price development in future the institutional changes in water management should be considered. In West Germany there is a trend towards centralization in water supply stimulated by the increasing problems of drinking water processing in connection with new standards and increasing concentrations of nitrate and pestizides in groundwater. Small water works are not able to ensure a sophisticated and expensive treatment of water and are therefore closed down. As a result the spatial re-distribution of drinking water is of growing importance. In East Germany the existing highly centralized water management is not used anymore. The present sub-division of existing large water supply institutes into smaller regional parts which seems to be profitable for the communities will cause many serous problems for the development of water prices in regions with unfavourable natural conditions. A large water supply system combines resources of expensive and inexpensive treatment and ensures on the average a moderate water price. The separation of such a system causes an increase of water prices in regions with high processing costs but does not ensure a reduction of prices in regions with low treatment efforts. As the water quality conditions are changing as well as the quality of drinking water standards the further development of water prices can not be foreseen if such institutional changes are planned.

This problem will be aggravated by the agricultural activities which effect the main source of drinking water in Germany, namely groundwater. The itensification of agriculture in Germany during the last decades is mainly based on an extended use of fertilizers and pesticides. In West Germany between 1950 and 1985 the use of nitrogen fertilizers has increased from 24 kg nitrogen per acre of agriculturally used area and year up to 81 kg/ac. yr. (Mehlhorn, Röhrle, 1990). Compared to the nitrogen output in the produced biomass (40 to 57 kg/ac. yr.) a surplus of nitrogen is accumulated in the soil, respectively the groundwater, which adds up to an estimated total amount of 850 kg/acre (Wiesorek, 1990). In 85 % of agriculturally used areas in Germany the nitrate concentration of percolated soil water exceeds the limiting value for drinking water (50 mg NO_3/litre) (UBA, 1989). These data are of high relevance for water supply as 65 % of the drinking water comes from groundwater. The regional importance of this development differs much as the local groundwater resources have different states of natural protection but in general the spatial distribution of water resources to improve local aggravated water quality conditions becomes increasingly necessary.

2. CLIMATE CHANGE AND WATER SUPPLY IN GERMANY

Studying the literature the impacts of climate change on many processes in hydrology and water management, starting with runoff conditions (Gleick, 1986, Bultot et al. 1989) and ending with lake stratifications (Meyer et al., 1994) seems to be well known. Mostly these articles begin with a reference to a sophisticated General Circulation Model (GCM) which has computed changes in temperature and (in some cases) also precipitation. If these discussions would begin with the GCM's ability of describing the regional climate conditions the results would be very doubtful. GCMs are not able to describe regional climate conditions, a statement made many times by climate modelers (e.g. in (IPCC, 1992)) but not considered by hydrologists. In Figure 2 the monthly averages of precipitation for a river basin in Germany, computed by a GCM (ECHAM 3 model with T42 resolution of the Max-Planck-Institute of Meteorology in Hamburg) in combination with a stochastic weather generator (Bardossy and Plate, 1992) for downscaling are shown for present climate conditions, together with the measured values for the period of 1970 to 1987. It is obvious that the seasonal distribution of rainfall is not represented by the GCM and the computed monthly values are too small as well. The measured yearly mean of precipitation in this river basin was 880 mm, the computed value only 680 mm. If the computed precipitation values after CO_2-doubling are compared with the long-term measured values we have a reduction in yearly precipitation of 18 % but the model error describing today's precipitation was 22 %. This example shows that even the most developed climate models in connection with a statistical downscaling of the results are unable to describe regional climate conditions with sufficient accuracy. As the intercomparison of 14 GCMs (WMO, 1991) has shown, the same result would be reached if another GCM would be used instead of the GCM ECHAM 3. This approach is not able to separate the model error from the signal of climate change. If we consider the need for a complex prognosis of meteorological parameters such as air humidity, radiation and wind velocity or the unknown impacts of a changing vegetation on the water balance, the future hydrological conditions can not be forecast. The problem will be complicated as the impacts of climate change on water management will not be limited to hydrological conditions. The socio-economic impacts caused by a possible climate change will affect the future water management conditions as well as their ability to react to such changes. Nevertheless the possibility of climate change which cannot be neglected should be a sufficient reason to judge the sustainability of water related planning and the vulnerability of our water management facilities.

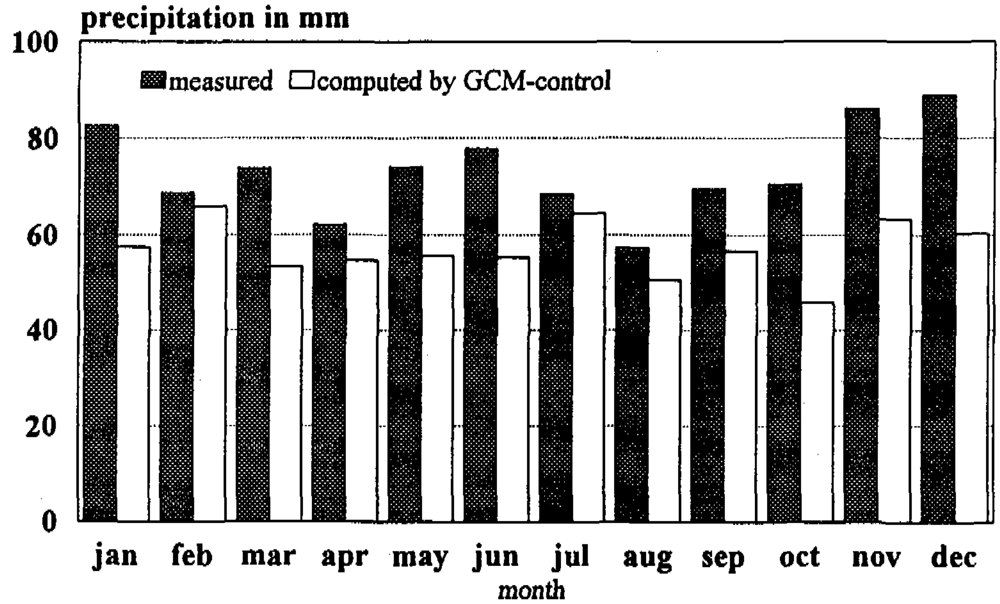


Figure 2. Seasonale Distribution of Precipitation (measured and computed by a GCM) (yearly means: measured = 880 mm, computed by GCM- control = 681 mm)

The actual discussion of climate change can be helpful to bring the problem of a changing world into public awareness. The risks of these discussions consist in the propagation of an unjustified certainty about future developments forced by a general confidence in computer science. As water management is confronted with changes which never happened before in the short live time of water related sciences the extrapolation of the accumulated knowledge into future cannot produce more than an uncertain scenario.

The development of socio-economic conditions and the uncertainties about climate change demonstrate the need for flexibility in water management. Flexibility is not only needed to ensure the main objectives of a water management system under changing conditions in future but also to realize new objectives, e.g. ecological targets. In the following chapter the problem of flexibility will be discussed for one branch of water management, i.e. for reservoir management.

3. FLEXIBILITY IN RESERVOIR MANAGEMENT

Reservoirs change the temporal distribution of water resources and are usually the starting point of a spatial re-distribution of water. If the water demand is changing in its spatial and temporal distribution as well as the inflow in quantity and quality the adaptation of water management in its structural and non-structural components becomes necessary. The flexibility of reservoir systems to changing conditions depends on two factors:

- on structural dimensioning of the system in relationship to its utilization (structural reserves)
- on reservoir operation (operational reserves).

In the following sections both aspects of flexibility will be discussed with examples of German reservoirs used for drinking water supply.

3.1 The Structural Basis of Flexibility

In Fig. 1 the development of domestic water consumption was shown. In this figure a prognosis of the drinking water demand is included showing the significant increase in demand expected in the year 1976. In Figure 3 the result of such a prognosis is shown. The storage capacities of reservoirs were increased but the amount of water supplied by these reservoirs stagnated since 1980 (Stadtfeld, 1989).

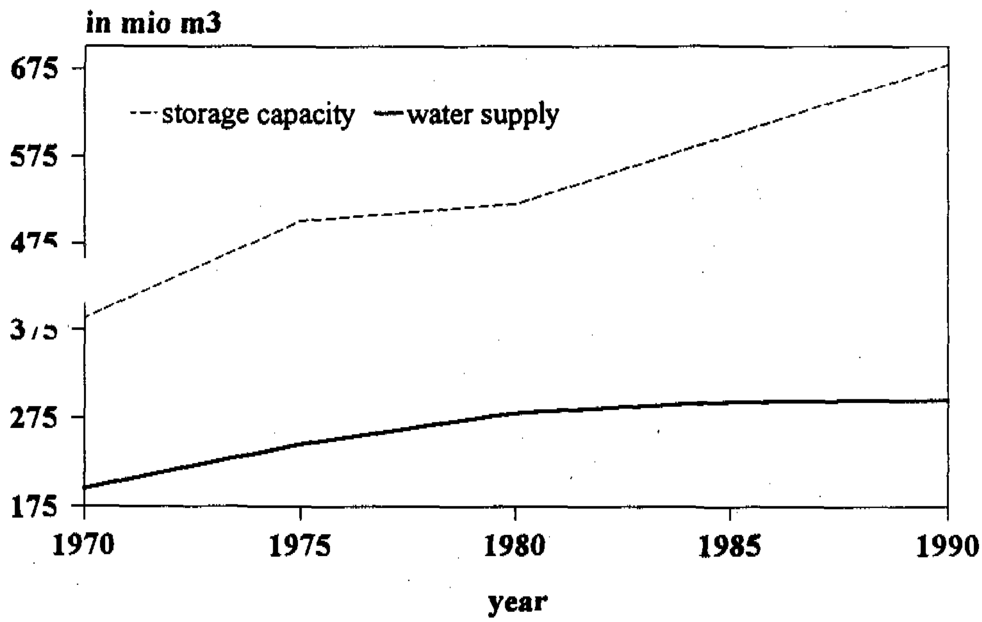


Figure 3. Development of storage capacity of reservoirs used for drinking water supply and total amount of drinking water supplied from these reservoirs in West-Germany 1970- 1990

A nearly constant amount of water is provided from an increasing storage capacity. Analyzing 12 reservoirs in northwest Germany used for drinking water supply only (one- objevtive management) large differences in their utilization can be seen if two parameters are compared (Figure 4):

- the ratio of storage capacity (without reservoir capacity used for flood control) to yearly inflow,
- the ratio of the yearly volume of drinking water supplied by the reservoir to the yearly inflow (i.e. level of development).

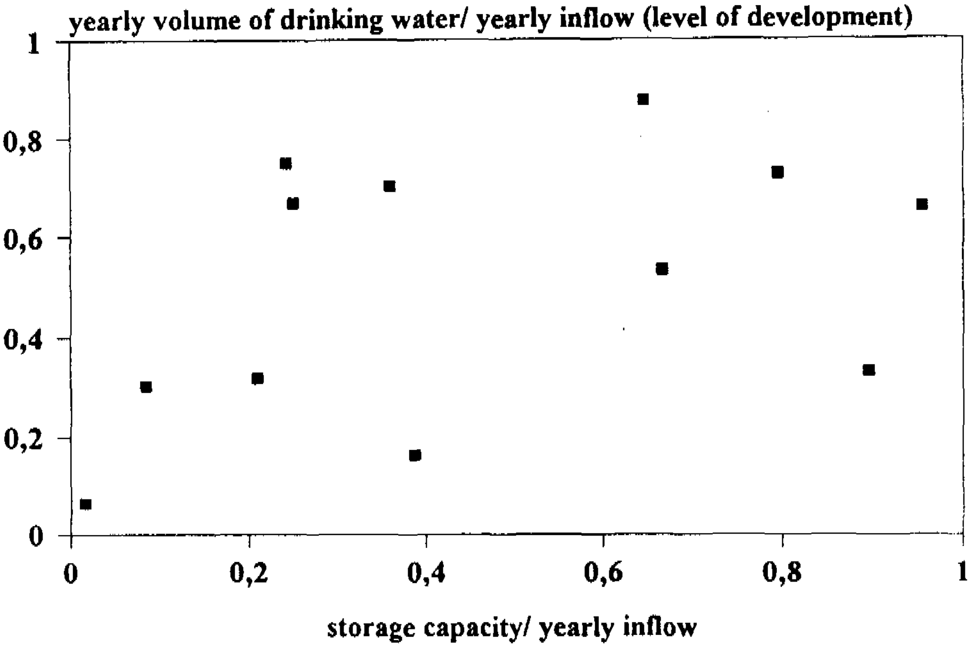


Figure 4. Ratio of yearly volume of drinking water to yearly inflow versus the ratio of storage capacity to inflow for 12 reservoirs used for drinking water supply only in north-west Germany

For reservoirs with nearly the same relative size the level of development varies between 0.9 and 0.3. The utilization of existing structural facilities (reservoirs) is very uneven although these reservoirs are situated in the same region. By improving water management the drinking water supply could be increased significantly (under consideration of the different firm flow targets) without a need for new storage capacity. The utilization of structural reserves which become obvious if the efficiency of water management facilities is compared includes important possibilities for flexibility in future.

3.2 Flexibility in Reservoir Operation

The first step in adaptation of a water management system to changing conditions consists in the recognition of these changes. Operation depends on the management planning. The need to rectify planning becomes obvious if the realized and planned operations are compared. The experiences of operation give us the confirmation or rejection of planning assumptions, e.g. the water demand. Changes in hydrological conditions can be detected by monitoring hydrological time series. Although for time series analysis a strong theoretical background exists the operational use of this methodology is unusual. Mostly water managers hesitate to apply very complex mathematical methods because they are not familiar with the theoretical aspects. For operational purposes the hydrological data analysis should be simplified to ensure its application. Good results can be realized by a combination of statistical parameter tests which could be applied as a first indicator for changing hydrological conditions. In Fig. 5 the output of a computer program developed for these purposes is shown.

```
Result 2:    Sample1 L=144 from 1821 to 1964  Sample2: L= 21 from 1965 to 1985
Mann-Whitney-Wilcoxon-test:     Alpha(comp.) = 0.9888   1-Alpha/2 (given) =0.9750
Both samples differs significantly.
Chi-Square-test:                Alpha(comp.) = 0.1520   1-Alpha (given) =0.9500
The first sample is normaldistributed.
Supposition for following tests ist given !
 F-Test:        Standard deviations:  s1= 517.5     s2= 649.0
                                Alpha(comp.) = 0.0671     Alpha/2 (given) =0.0250
The hypothesis of equal variances is not rejected.
 double T-test:    means : mean1= 2052.3  mean2= 2357.8
                                Alpha(comp.) = 0.0078     Alpha/2 (given) =0.0250
The hypothesis of equal means is rejected.
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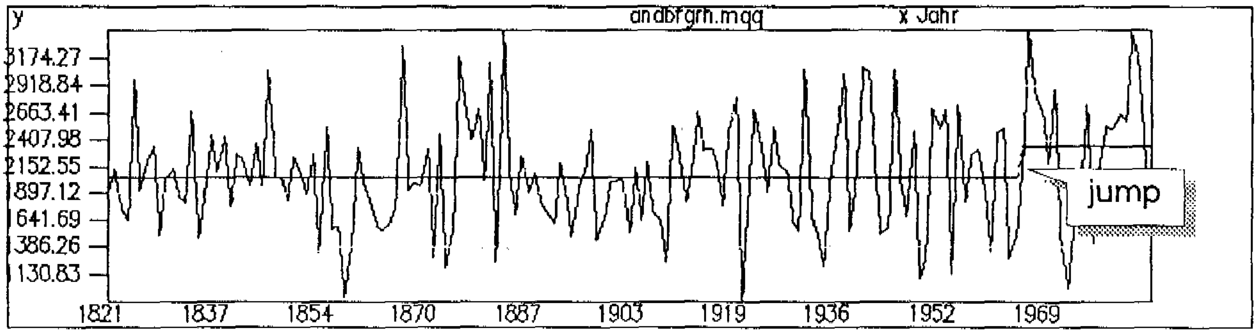

Figure 5. Automatic estimation of significant differences of the statistical parameters in hydrological time series.
The example shows the yearly runoff data series of the gage Andernach/ Rhine. A jump in the means was estimated 1964/1965.

This program divides a time series in two split samples, compares the statistical parameters (means and variances) after the pre-condition of normal or log-normal distribution is tested and moves the splitting point along the time scale. If significant differences are detected the results are stored and shown on the monitor. A complete time series analysis can be done afterwards to analyse these series which showed significant changes in their parameters. The advantage of this procedure consists in its ability to do a screening of large data amounts in a short time.

The second step in adaptation of a water management system should be an analysis of its operation. Reservoir management is based mostly on an operating scheme developed with large efforts for its optimization. As a result the operator will hesitate to change it, especially if changes of the framework of water management are perhaps only temporary. To overcome this problem of inflexibility two possibilities are seen:

- the operating rules should be adjustable with less effort to offer the possibility of reacting also to medium term changes,

- a set of different operating rules could be prepared, furnished with different assumptions about the range of changing parameters and impacts.

Both possibilities can of course only be provided for a limited range of changes. In the following case study the chances of introducing flexibility into an operating scheme will be demonstrated.

The reservoir discussed here is situated in southeastern Germany and has a storage capacity of 70 mio m^3. The objectives of water management are drinking water supply and low flow augmentation (a firm flow in the river reach directly below the reservoir should be ensured). The ecological function of the reservoir in the landscape requires high probabilities for a mostly well-filled reservoir. For adaptation of the operating rule to changing water demand and to changes in the other objectives of reservoir management Stochastic Dynamic Programming (SDP) (Loucks et al., 1981) was used. The system's performance was described by a weighted distance function from goals (targets for storage, water supply and low flow augmentation). A decision support system was developed consisting of the following components :

- an user interface in which the objectives of reservoir management can be changed interactively (target values and weights for optimization),
- the optimization procedure (SDP),
- a simulation tool to test the optimized operating rule with a historic inflow series or stochastic generated time series,
- a statistical analysis of the simulation results in order to estimate the reliability of drinking water supply, firm flow and certain storage values,
- a routine which presents and stores the results.

The computer program runs on a 486- PC and is used in the water management authority responsible for the reservoir operation. The discussions with practitioners have shown that also a sensitivity analysis is needed to explain the effects of one changing objective on the reliabilities of the other objectives. E.g. under fixed targets for storage and firm flow and with fixed weights the water supply target can be increased step by step. In each step the operating rule will be optimized and the reliabilities of reservoir management are estimated by simulation. As a result the trade-off between different management targets can be discussed very effectively. In Figure 6 the reliabilities of three target values in dependency on the amount of drinking water supplied by the reservoir are shown.

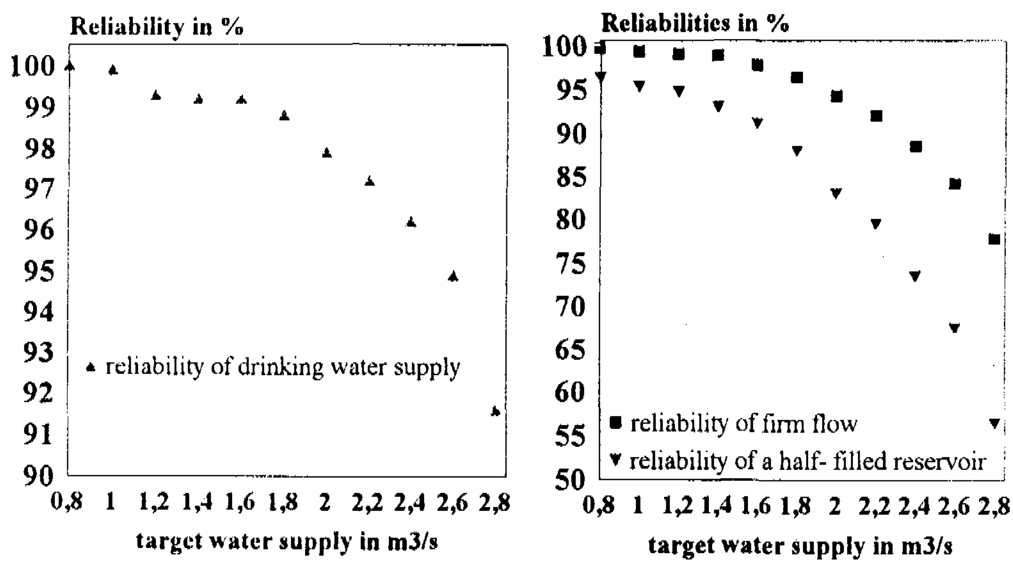

Figure 6. Reliabilities of reservoir management targets in dependency on the amount of drinking water supplied by the reservoir (Reservoir Eibenstock, Germany)

For each point of these curves an optimized operating rule exists which could be used if the amount of water supply should be changed. After a decision about the future target value for drinking water supply is made (e.g. from an acceptable risk of failure) the other management targets can be adapted as shown in Figure 7. In this example the reliabilities in dependency on the firm flow target are shown for fixed targets of drinking water and storage. Again for each point an optimized operating rule exists. Other pre-fabricated solutions exist for changes of monthly storage targets. The advantage of this methodology consists in its transparency for water managers who can try the possibilities and limits of changes in reservoir operation in an interactive way. The operationalization of such tests ensures flexibility of reservoir operation in the basic level of decision making.

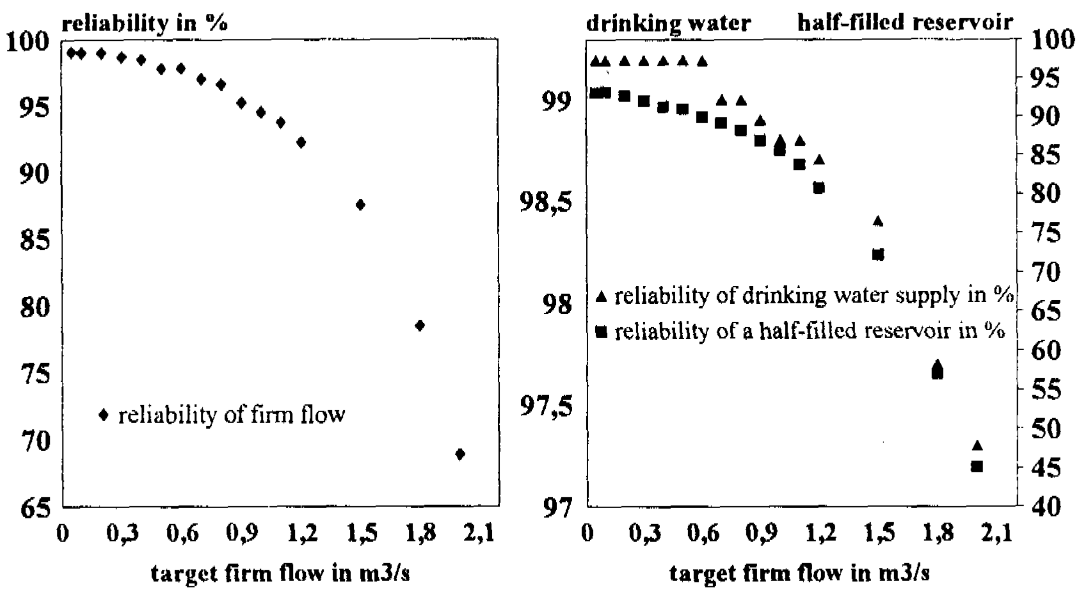

Figure 7. Reliabilities of reservoir management targets versus firm flow target (Reservoir Eibenstock, Germany)

4. SUMMARY

Two types of changes affecting water management in future were discussed, namely socio-economic impacts and climate change. Both are very uncertain in their future development. Nevertheless water management can be prepared for these changes. The possibilities of reacting range from economical tools such as water price over institutional changes like centralization to the development of new scientific tools for water management. The main problem of these possible reactions consist in the realization of their needs. Analysing the developments and extrapolation them into the future becomes more and more important. Examples of such analyses were discussed. The development of scientific knowledge in computer sciences and human resources, also in water mangement, promote operationalization of research results into practice as shown in the example of reservoir management. The need of flexibility and utilization of existing reserves are challenges for the near future.

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EGYPT'S EFFORTS TOWARDS MANAGEMENT Of AGRICULTURAL WATER DEMANDS

Mahmoud Abu-Zeid[1]

ABSTRACT

Historically, water has always been a critical component for the development of Egypt. With increasing population and improvement of the standard of living, water will become an even more critical resource in the future than it is at present. Clearly, it is water, and not land, which is the major constraint to expand the total agricultural area of Egypt, which could contribute to tighten the country's food gap.

Most of Egypt's present water resources have been exhausted. Future demands, and for some years to come, will depend, to a great extent, on demand management and better utilization of such present water resources. Towards that goal, the country has launched several challenging water management programs both on the macro and micro levels which are directed towards minimizing water losses and raising the efficiency of water use.

Some major environmental, sociological and institutional issues have to be addressed beside the huge investment requirements.

This paper summarizes those programs and discusses the issues and constraints.

INTRODUCTION

Egypt's agricultural sector is unique in that over 95% of its agricultural production is derived from irrigated land and its irrigation waters originate outside of its borders.

On the macro level, the last two centuries of modern Egypt have witnessed considerable development starting by the construction of the Delta Barrage (1898) to assure summer cotton irrigation in the Nile Delta, and the establishment of an intensive canal networks for irrigation, and ending by the construction of the Aswan High Dam in the sixties of the nineteenth century.

The High Aswan Dam was constructed to assure the long term availability of water for both Egypt and Sudan. However, the average annual flow during the last decade has been slightly decreased than the long term average.

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The concentration on the macro level was on the hardware part of the system, while the present and the future will concentrate on the software of the system. Such activities include improvements in operation and maintenance, demand management, re-cycling, capacity building, and users participation.

Present agricultural water use accounts for about 84% of the total water use while industrial, municipal and navigational use accounts for 8%, 5%, 3% respectively. Percentages of water use by agriculture and municipal sectors are expected to remain by the year 2000 almost similar to the above mentioned values while for industry it is expected to increase by about 50% and navigational use will decline very substantially.

1. WATER SUPPLY AND DEMANDS

1.1 Water Supply

Surface water resources are limited to Egypt's share of the flow of the River Nile. In accordance with terms of 1959 Nile water agreement between Egypt and Sudan, Egypt's present annual share downstream Aswan Dam is 55.5 billion m^3. The High Aswan Dam, commissioned in 1968, provides over-year storage to guarantee regulated water supplies. This Nile Water discharge constitutes more than 95 % of Egyptian total water supplies.

Egypt has no effective rainfall except in a narrow bond along the northern coastal area where the average rainfall is 200 mm. The groundwater aquifer underlying the Nile Valley and the Delta is entirely recharged and is dependant on deep percolation of irrigation water and seepage for the irrigation system. Some limited renewable and non-renewable groundwater within the Western Desert and Sinai are currently used and the potential for the future depends on economical feasibilities.

The Nile system below Aswan can be considered a closed system with a single input from the High Aswan Dam and five outlets, Which are: Evapotranspiration, non-recoverable municipal and industrial consumptions, evaporation, agricultural drainage water to the sea, and non recoverable inland navigation water released to the sea. Using this concept, the valley and Delta groundwater extractions and drainage re-use would be considered as internal mechanisms to increase the system overall efficiency and not as added resources.

The exact nature and details of these inter-relations are not clear yet. A new factor that adds to the complexity of the issue is the water quality changes. These are subject to research studies now conducted by the Water Research Center (WRC) in Egypt.

1.2 Water Demands

Agriculture is the largest water user in Egypt. It is essentially dependant upon irrigation, and consumes the bulk of the available water (about 84%). The total irrigated area now amounts to 7.4 million acres. The future expansion programs depends very much on the availability of additional water resources.

Surface irrigation systems are used in most old agricultural lands of Egypt, with an application efficiency which is still considered low. Excess irrigation water applications contributes to the groundwater shallow aquifers and to water logging problems. Water pumped from such aquifers or re-used through re-cycling of agricultural drainage water brings up the overall water use efficiency to a reasonable value (65-75%).

The Ministry of Public Works and Water Resources (MPWWR) does not give any irrigation permits for new lands, within the program of land reclamation, unless evidence is given that modern irrigation systems will be used.

Present annual Municipal, industrial and navigational water demands amounts to 3.1, 4.6, and 1.8 million m^3 respectively. Future requirements in such demands depends very much on population growth. The population of Egypt now is about 58 million and is expected to increase to 70 and 90 million by the years 2000, and 2025 respectively.

This paper is not addressing the projections of demands and supplies for the future. Reference is made to work carried out by the planning sector of the MPWWR.

Preparation of Water Policies for Egypt dates back to 1933 when a policy was set up to make use of additional capacity due to the second heightening of the old Aswan Dam. The most recent update for the year 2000 that took place was in June 1994.

The present assessment of the implementation of the 1990 policy indicates that the expectations of the year 2000 are not going to be met. Some of the major reasons for that are as follows:

1. Jongli Canal in the southern Sudan regions may not be completed by the year 2000.

2. Pollution hazards are seriously affecting the quality of agricultural drainage water for potential re-use.

3. Environmental groups are strongly opposing the storage of fresh water releases to the sea into the northern lakes on the basis of potential impacts on fish and birds life in the lakes.

4. The rate of implementation of the national irrigation improvement programs are slower than anticipated.

The Ministry of Public Works and Water Resources is currently reviewing its water policy considering these new factors, Meanwhile the year 2000 is becoming too close for planning purposes and the year 2025 is the new target for planning.

2. PRESENT AND FUTURE PROGRAMS FOR MANAGING DEMANDS FOR AGRICULTURAL USERS

The Water Research Center (WRC) has carried out a detailed study (1977-1984) to identify the major constraints that hinder the efficient use of water for irrigation, and to propose a water management strategy for Egypt. The principal constraints were found as follows:

- Fragmentation of land into small and separate holdings have limited the establishment of efficient irrigation methods.
- Misuse of Canal banks, degradation and sedimentation have contributed to changes in water levels and canal discharges.
- The use of the rotation system has its limitation for better water control and use of modern irrigation systems.
- The lack of an efficient water extension service.
- Excessive losses from the irrigation system between main points of distribution and farm outlets.
- Diversity of crops within areas served by one canal.
- Abundance of night irrigation
- Poor land leveling
- Lack of adequate funds for maintenance and the absence of a charging or cost recovery system which would provide funds for that purpose.

with limited renewable fresh water resources and a continuous increase in water demands for agriculture, the issue of satisfying such demands becomes very serious. The per capita water share of fresh water resources is expected to drop from a current value of about 930 m^3/year to about 350 m^3 by the year 2025. Based on present lessons and constraints, the country has to implement rigorously several management programs. The realization of these programs will require considerable commitment from policy makers, technicians and water users.

The existing demand management programs have two dimensions. the first deals with the hardware of the system and the second with the software part. Each is implemented on the different levels of the system: macro, meso and micro, mostly in areas related to the policy, management, planning, design control, operation maintenance and institutional issues.

The identified constraints of the demand management as well as improvement in the performance of the Nile system have been tackled through one of the intensive Irrigation Management System (IMS) programs which has 10 project components:

1. Regional Irrigation Improvement Project (RIIP)
2. Structural Replacement
3. Preventive Maintenance
4. Main System Management (Telemetry)
5. Planning Studies and Models.
6. Professional Development
7. Research and Development (Water Research Center)
8. Project Preparation
9. Survey and Mapping
10. Miscellaneous TA and Commodity Procurement.

These 10 components involve a large number of participating departments, agencies, and farmers.

In the following, the main features of some of the important components are presented.

The Regional Irrigation Improvement Project (RIIP)

The RIIP is to establish and field test an organizational structure within MPWWR capable of providing technical assistance, construction assistance, economic analysis, on-farm development assistance, and user involvement to remodel selected irrigation canal commands. The objective is to make the system more responsive to the needs of farmers and to assure that water is available in the quantities required at the time it is needed to support increased agricultural output.

In 1984 a National Program for irrigation improvement had been approved. The program started in an area of 40,000 acres forming the first phase of the RIIP. The plan of 1992/97 covers an additional area of 350,00 acres with an estimated cost of 120 million $. Establishment of farmers organizations and irrigation advisory services were found necessary for the success of the program and for the future operation and maintenance of the farm irrigation systems.

The Project is forming water users association (WUA) and implementing an irrigation advisory service (IAS). Both of these concepts have been identified and successfully tested under EWUP on a pilot basis. They are now being implemented on a large scale.

The improvement and modernization works vary from realignment of water courses and distributor canals with reconstruction of their section to lining and use of elevated precast water courses or use of buried pipeline systems. The present average cost/acre is around 500 $ which will bring up the total cost to cover the presently cultivated old land of about 6 million acres to 3 billion $.

The expected saving of water is between 10-15% with an average increase in agricultural productivity of 30%.

Because of the time and high investment requirements a crash programs that deal with some control structures was initiated (SR).

Structure Replacement (SR)

The SR component is aimed at the smaller structures in the irrigation system-intake regulators, head regulators, weirs, tail escapes, spillways, bridges and crossing structures. It is also aimed at improved quality of structures and assuring that they are built up to MPWWR specifications.

This program will be completed by the end of 1994 covering about twenty thousand structures

Preventive Maintenance

The preventive maintenance is being carried out in some selected irrigation directorates and it is to install the procedures to plan for, manage, and control higher levels of maintenance.

The end result of this program is a preventive maintenance program, tested, accepted, functional, and fully staffed in at least six directorates.

Main System Management (Telemetry)

Management decisions to increase or diminish water flows at key points throughout the irrigation delivery system is improved by a telemetry data collection system. This system is now providing real time data to the managers of the system resulting in improved management and reduction of waste and irrigation shortages.

The telemetry system is to provide detailed data (water level, flow rates, water quality) and communications in some specific points in the irrigation system. Data are assembled utilizing meteor burst transmission of collected data to computerized stations at both Cairo and Aswan. This appropriate technology was selected because of its low cost, and its relatively simple operation and maintenance requirements.

Planning Studies and Models

The MPWWR through its water planning group (WPG), has developed a number of computer models that are designed to increase the operating efficiency of the whole system.

These models fall into two groups; one group concerns inflow simulation to predict flows into lake Nasser from the area above the lake, i.e. the basic source of water supply. This group also concerns the operating rules of the High Aswan Dam (HAD), i.e. how stored water supply is to be released in accordance with power, navigation, irrigation and other needs.

The other group of models is concerned with the service area between the HAD and the Mediterranean Sea. They are used to analyze the impact of the water delivery system on agricultural policy programs, and vice-versa; plan the distribution of water through the system; and provide detailed operating parameters, such as gate movement schedules for operating the system within a specified set of system operating constraints.

Professional Development

This component institutionalizes a multi-disciplinary training program to serve the total manpower training development requirements of the MPWWR. The National Irrigation Training Institute (NITI) concept was found to be the best cost alternative to meet the MPWWR training needs. The Institute is completed now and is ready to serve Egypt and the Region.

The Water Research Center (Research & Development)

The scope and complexity of the MPWWR responsibilities for the irrigation system involves a wide range of scientific disciplines and widely varying subject matter areas. The main objective of the WRC is to carry basic research and to be the reservoir of knowledge on all aspects of the irrigation system. To serve this purpose, eleven research institutes are fully operational. The WRC and its institutes are to support all the sectors and the authorities of the MPWWR in many areas starting from decision making, technology transfer planning, modernization,...etc., and ending at helping in solving day to day operational problems of the system.

Fresh Water Saving Program

The second feasible water management program is through the minimizing of fresh water spilling to the sea mainly during the closure period. Through the construction of the new Nag-Hammadi navigation lock, the construction of New Esna barrage, and the improvement of the river navigable channel, the spilling of fresh water to the sea is restricted to 70 million m^3/day during the closure period of about 3 weeks every year. This minimum discharge is necessary to provide intake levels for municipal water supply pumps along the river course and to satisfy municipal and industrial water requirements. An annual amount of 1.5×10^9 m^3 from the total spilling estimated at 1.8×10^9 m^3 annually is proposed to be utilized through supplementary irrigation within the northern western coastal zone, and partial storage in the northern lakes.

Water Quality Issues

While a reasonably clear picture exists in terms of salinity of water, availability of usable information on other water quality parameters is very limited. There is an essential need for a rational water data collection and management program. Large volumes of domestic and untreated industrial effluent are still discharged into the river and water channels. In addition, significant proportions of fertilizers and pesticides used is leached into the water system. Potential groundwater contamination from fertilizers could be a concern. Applications of nitrogen, phosphate and potassium fertilizers in the Egyptian agriculture increased nearly 4-fold during the 1960-1988 period.

Use of pesticides has increased as well, but not at the same rate of fertilizers. In early 1991, use of herbicides to control aquatic weeds in Egypt was stopped.

Increasing water pollution from industrial and domestic sources, if allowed to grow unchecked, is likely to reduce the amount of water available for various uses in the future.

Legal basis of controlling water pollution already exists through law 48 of 1982 on the "Protection of the River Nile and Water Ways from Pollution". The law established stringent effluent standard for various organic and inorganic pollutants. Lack of proper funds for treatment of industrial wastes and for providing adequate municipal wastewater treatment plants, has hindered, so far, the full enforcement of the law.

Salinity and waterlogging from irrigation practices has been a problem. However, Egypt has embarked on the construction of an extensive drainage system, a significant part of which is already operational (3.9 x 10^6 acres). For the long term sustainability of agriculture, drainage should continue to receive priority.

3. RE-USE OF AGRICULTURAL DRAINAGE WATER

The amount of agricultural drainage water presently re-used in irrigation is 5.0 billion m^3 annually of which 4.0 billion m^3 in the Nile Delta, 1.0 in Fayoum in addition to the return flow to the Nile from the Upper Egypt drainage system. This re-used drainage water in the Delta is expected to increase gradually to reach 7.7 billion m^3 by the year 2000. The total annual volume of agricultural drainage water for the year 1993 amounts to 12 billion m^3 which varies in both quantity and quality with time of the year and the location. It is to be noted that part of this water is from industrial and municipal wastes discharge to the drainage system. Within the northern part of the delta, where most of drainage pumping stations exist, considerable contribution to the drainage system comes from upward seepage of saline groundwater. Several studies carried out by WRC institutes confirmed this observation.

The debate on the extent the country should depend on in the policy of agricultural drainage wastewater is strongly affected by the following facts:

a. The potential savings from improved water management, and increasing drainage water re-use are not mutually exclusive. There is a real danger that the salinity of drainage water could increase steadily over the years. Thus, a cautious approach to increasing the use of drainage water, especially in terms of water quality, is likely to be the long term interest of the country.

b. The total salt balance of the Nile Delta requires continuous leaching. This is evident when comparing a total salt load within the irrigation water to the Delta of about 18 million tons with a total salt load of 31 million tons with the drainage water pumped out of the Delta.

c. Salt water intrusion will increase from the sea to the northern delta if serious reduction of the net deep percolation in the irrigated area takes place.

The present scenario adopted by the MPWWR is to move carefully in the two national program i.e., water management and improvement of the irrigation system, and the agricultural drainage water re-use program within the 7.7 billion m^3 figure.

4. RE-USE OF TREATED MUNICIPAL WASTE WATER

The first use of treated waste water in Egypt was in 1915 in the eastern desert north east of Cairo. An area of 2500 acres are still under irrigation with waste water which receives only primary treatment. With the scarcity of water resources, it is planned to irrigate 150,000 acres with treated waste water up to the year 2000.

All urban waste water projects include facilities for treatment up to the tertiary level and allows re-use for irrigation. Many of the rural areas are still laking such facilities. It is estimated that by the year 2000, the amount of wastewater from major cities and urban areas are as given.

Table 1. Waste Water from Urban and major cities

Area	Year 1992 billion m^3/year	Year 2000 billion m^3/year
Cairo	1.36	1.70
Alexandria	0.53	0.65
Other Urban areas	1.54	2.58
Total	3.43	4.93

Currently in Egypt, detailed criteria for waste water re-use in agriculture is under review and preparation. Several pilot programs have started and under continuous monitoring for some years.

5. COST RECOVERY OF IRRIGATION IMPROVED PROGRAMS

The issues of cost recovery have started receiving increased attention in Egypt. It is considered as an approach to generate additional revenue which could be used to operate and maintain irrigation systems, and even repay some, or all, of the investment costs. It could help also in conserving water uses by the farmers. The effectiveness of a costs recovery policy to achieve its expected objectives is dependent on many factors, among which are the system through which water consumption is measured, and the relation between existing taxation and water subsidy and the proposed water charging one. Farmers reactions to such changes in policies are not easy to predict in advance of the implementation of such policies. The identification of beneficiaries and the possibilities of charging the external costs like damages to the environment should be explored. Consideration has to be given to what type of system could be instituted that would be equitable, generate revenue and simultaneously promote more efficient water use than is the case at present.

While complexities of implementing a functional cost recovery system in Egypt should not be underestimated, in the longer term the country has no other feasible alternative but to go along this route.

A very serious work on cost recovery is underway now by the MPWWR. Resistance to implementing any system is anticipated from beneficiaries, appropriate groundwork is required in advance to the transition process. This should be backed by continued strong political support.

In July 94 the Egyptian people's assembly passed a law to charge the MPWWR to implement a cost recovery law on the Mesqa level. The same law sets the procedures to establish farmers water users association and the irrigation advisory service.

6. CONCLUDING REMARKS

1. Egypt being an arid country has limited water resources beside depending mainly on one single source - The River Nile.

2. It is evident now that Egypt consumes all of its share from the river to satisfy water demands for different users, and for a present population of about 58 million. Further increase in water demands is expected beyond the year 2000.

3. Egypt has launched several demand management programs which depend on maximizing the benefits of the present fresh water resources and adopt technically and environmentally sound re-use program.

4. The inter-relations between the different components of the water balance equation is complex and continuously changing in Egypt. The water use patterns, diversity of crops within the cropping pattern, recycling of agricultural drainage water, and pumping from shallow aquifers are becoming the concerns for formulating demand management program.

5. For future agricultural uses, the reuse of treated wastewater and drainage water are considered important elements of the water policies. Both these resources have health and environmental implications, and hence, a functional system of monitoring and continuous evaluation is absolutely essential. Long-term potential environmental impacts of reuse of drainage water and criteria for use should be clearly identified. Institutional and legal implications of establishing a water quality data monitoring and management system has to be prepared and implemented.

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WATER PRODUCTIVITY IN EGYPTIAN AGRICULTURE: SCENARIOS FOR MORE SUSTAINABLE USE

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ABSTRACT

In Egypt, a lot of efforts have, and being, made to make more beneficial and more sustainable use of the country's limited water resources. The rapidly growing population and increasing food demand made both vertical and horizontal expansion of agriculture more urgently needed. Agriculture is, and will remain, the largest consumer of water in Egypt since it is completely dependent on irrigation. Any efforts to make more efficient use of water in the agriculture sector will have more impact in saving water resources for future generations.

This paper discuses the need and challenge to improve efficiency and productivity of water. It examines the ways in which water is currently used in the Egyptian agriculture, comparing water requirements and actual use for different cropping patterns and relating this to yields and the economic value of water in different uses.

Considering the national goals and needs with regard to self-sufficiency of some food stuff, the need for export and the limitations for imports of strategic crops, the paper examines several scenarios for different cropping patterns to see what will be the impact of each scenario on the water use, the erea irrigated and the national economic return.

the results showed that a radical change in the agricultural land use patterns is possible and should be considered very seriously in the near future. The paper indicates the changes needed to make better use of water in agriculture based on calculated water productivity in different uses which should be the criterion used for land and water use planning in Egypt.

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1. INTRODUCTION

Egypt suffers scarcity of both arable land and water. The per capita share of both land and water resources is declining all the time. The result is that in spite of the obvious developments in the agricultural sector, the level of self sufficiency of major food commodities has worsened. As from 1973, Egypt has become a net importer of agricultural products. The challenge ahead is double. Overall production should increase to turn the trend of a deteriorating degree of self-sufficiency. This is especially the case for strategic crops like wheat, maize, sugar and meat (table 1).

This is just one challenge Egypt is facing now. The other challenge is that competition for the Nile waters is bound to increase. It will increase both between sectors and areas within Egypt as well as between Egypt and other countries along the Nile. Changing patterns in the competition for water (and land and other scarce resources) is partly a result of structural and spatial changes in the economy, urban growth and reduced possibilities for labor export to neighboring countries. A tighter financial situation amplifies the competition. But the overriding factor is population increase. On a per capita basis, the quantity of water available to Egypt will be reduced in proportion to population increase or by about 2% annually. In order to illustrate the gradual impact of population increase, it might be compared with the additional water that Egypt was entitled to after 1959. That increase and the more regular supply following the High Dam, both of which certainly took a lot of efforts to accomplish, might be nullified within a couple of decades if no significant improvements are made in resource management.

Agriculture is the major user of water in Egypt since it uses more than 90% of the Nile water (Abu Zeid, 1989). Many efforts have been, and are being made towards better use of water in agriculture. These include irrigation improvement projects, reuse of drainage water, promotion of modern water saving irrigation methods in new lands, pricing (or rationing) of irrigation water ... etc. There is, however, a general agreement about several facts related to these efforts. They are usually very expensive, too complicated to run easily, will take a very long time and many of them will have serious social and environmental consequences, and their results so far have not met the expectations.

Making better use of the limited water resources through changing or modifying cropping patterns can really make a difference. Yet, this area of action has not commanded adequate priority. It was only touched upon lightly in several occasions and moreover it has been completely ignored in many important documents.

The purpose of this paper is to illustrate the significant variations in water requirements of various crops in Egyptian agriculture and to relate current cropping pattern to economic returns. Moreover, an attempt is made to show the potential to improve the economic return per unit of water by shifts in crop composition. By calculating yield per hectare and per consumed amount of water, the returns can be related to the two most scarce resources in Egypt, i.e. land and water.

2. RESULTS AND DISCUSSIONS

2.1 Food Situation in Egypt

Data in table (1) show the level of self-sufficiency of some major food commodities in Egypt between 1970 and 1990. It is obvious that the country is facing a serious deterioration in its ability to feed the growing population. In spite of some increases in crop areas and yields, imports in 1990 accounted to 72% of the wheat, 28% of the maize, 37% of the sugar and 30% of the red meat. Possibilities for improving this situation in the near future are limited by many physical, socio-economic, institutional and environmental constraints. The bottle neck, however, is the limited, and seriously threatened, water resources. There is every reason, therefore, to believe that the food shortages in Egypt will be worsened unless the population stabilizes.

Table (1) Percentage of Self-sufficiency of major food commodities in Egypt, 1970 - 1990

Year	Wheat	Maize	Rice	Sugar	Red Meat
1970	37	97	164	117	89
1971	38	98	142	126	87
1972	37	96	137	99	89
1973	36	97	125	111	88
1974	34	87	110	91	82
1975	34	86	107	81	87
1976	34	86	116	80	75
1977	27	82	118	84	81
1978	25	81	110	74	75
1979	27	85	112	80	79
1980	24	77	107	65	75
1981	20	74	111	57	66
1982	21	70	108	50	66
1983	21	68	106	58	72
1984	19	71	105	52	63
1985	17	71	101	60	62
1986	17	71	111	62	66
1987	18	66	106	65	71
1988	24	70	111	58	74
1989	24	75	108	62	71
1990	28	78	114	63	70

Source: Goueli and El-Miniawy, 1993.

2.2 Current Cropping Patterns and Water Consumption

A limited number of crops in Egypt may be considered as major crops in terms of the land area occupied and the amount of water consumed. The crops that occupy more than 5% of the total irrigated area are clover, wheat, maize, rice , cotton and fruit trees (table 2). They are also the same crops that consume more than 5% of the total consumptive use of water (table 3). The only exception is sugarcane which occupies 2.29% of the total crop area but consumes 6.72% of the total water consumptive use.Those seven crops including sugarcane occupy together 80% of the total crop area and consume also about 79% of the total consumptive use in the Egyptian agriculture. It makes sense then that most of the following discussions will focus on those crops. Other minor crops will not make an important difference as far as resources utilization is concerned. However, tomatoes and potatoes are very efficient crops in using water, so they will be mentioned as possible alternatives for less efficient water consuming crops. Regarding yields per hectare, table (2) shows that for many crops they are at a fairly high level by an international comparisons. However, yield per water unit, which is the main concern of this paper, is relatively low for most of the crops as will be discussed soon.

2.3 Level and Variation in Water Use Efficiency

A comparison with cross-country data from FAO on water utilization efficiency (WUE) shows that Egypt has above average efficiency only for wheat and about the same efficiency for potatoes whereas for most other crops the relative WUE ranges between 0.50 to 0.80 (table 4). Cross-country comparisons are only crude measures on the performance of irrigated agriculture in various countries. Variations in soils, topography, irrigation technology and, of course, climate complicate such comparisons. However, one clear implication of the figures given in table(4) is that there might be an opportunity for improving cultivation and irrigation practices to increase water utilization efficiency.

2.4 Economic Return per Unit of Water and Land for Various Crops

As have been discussed above, agriculture in Egypt is carried out under two limiting factors, availability of arable land and water, or rather, the combination of both, i.e. the irrigated land. To manage these scarce resources in the best way possible is an important priority both for the individual farmer as well as for the Egyptian nation as a whole. In this perspective the water requirements of various crops, and their contribution to national production per unit of land and water, is an interesting aspect. Since the economic return of water varies between crops, a high WUE is no guarantee for best management. A low WUE in the growing of a high value crop may compensate a high WUE in connection with a low value crop.

The best cropping pattern can, of course, not be derived from consumptive use and area cultivated only. An important objective must be to optimize the net revenue of harvests within the restrictions dictated by the limited supply of land and water. Net revenue is defined as the

Table (2) Area, yield and net revenue of various crops in Egypt, 1990

Crop	Area 1000 ha	Yield Ton/ha	Land Net Revenue $/ha	Total Net Revenue Million $
Clover, Permanent	639	?	472	302
Clover, Transitory	515	?	263	135
Wheat	821	5.20	715	587
Broad Beans	145	2.95	398	57
Winter Tomato	66	22.38	1703	112
Barley	53	2.42	138	7
Sugar Beet	14	40.13	432	6
Others	96	?	?	
Total Winter Crops	**2349**			
Maize, Summer	649	6.23	577	374
Rice	436	7.26	566	247
Cotton	417	1.95	562	234
Sorghum	131	4.69	380	50
Summer Tomatoes	53	30.49	987	52
Soybeans	42	2.57	273	11
Summer Potatoes	29	25.00	1024	30
Sesame	18	1.19	427	8
Groundnuts	12	2.13	433	5
Others	218	?		?
Total Summer Crops	**2005**			
Maize, Nili	180	4.17	282	51
Potatoes, Nili	50	17.42	297	15
Tomatoes, Nili	37	31.76	2926	108
Others	66	?	?	?
Total Nili Corps	**333**			
Sugarcane	116	100.34	1112	129
Fruit Trees	217	?	?	
Total Permanent	**387**			
Total Crop Area	**5074**			

Sources: USAID ,1992 and CAPMAS , 1992.

Table (3) Consumptive use and crop duration of various crops in Egypt.

Crop	Consumptive Use m^3/ha	Total Consumptive Use billion m^3	% of Total Consumptive Use	Crop Duration days
Clover, Permanent	6616	4.227	12.62	215
Clover, Transitory	2514	1.295	3.87	150
Wheat	4605	3.781	11.29	162
Broad Beans	3698	0.536	1.60	150
Winter Tomato	4052	0.267	0.80	135
Barley	4571	0.242	0.72	160
Sugar Beet	6500	0.093	0.30	190
Others		0.506	1.50	
Total Winter Crops		**10.947**	**32.70**	
Maize, Summer	6230	4.043	12.08	117
Rice	10987	4.790	14.32	105
Cotton	7976	3.326	9.93	185
Sorghum	6546	0.858	2.56	110
Summer Tomato	4565	0.242	0.72	105
Soybeans	6100	0.256	0.75	90
Summer Potatoes	4565	0.132	0.39	90
Sesame	4552	0.082	0.25	90
Groundnuts	4832	0.058	0.18	150
Others		1.126	3.37	
Total Summer Crops		**14.913**	**44.55**	
Maize, Nili	5579	1.004	3.00	105
Potatoes, Nili	2863	0.134	0.42	90
Tomato, Nili	2863	0.106	0.32	105
Others		0.204	0.61	105
Total Nili Corps		**1.457**	**4.35**	
Sugarcane	19372	2.247	6.72	365
Fruit Trees	14432	3.911	11.68	365
Total Permanent		**6.158**	**18.40**	
Total Crop Area		**33.475**	**100.00**	

Source: Ministry of Irrigation/UNDP/IBRD, 1981.

Table (4) Water use efficiency and water net revenue in Egypt, 1990

Crop	Water Use Efficiency, kg/1000 m 3 Egypt (1)	FAO figures (2)	% of World figures	Water Net Revenue $/1000 m3 /day
Clover	?	?	?	0.52
Wheat	1.13	0.80	1.41	0.96
Broad Beans	0.80	?	?	0.74
Winter Tomato	5.52	11.00	50.18	3.11
Sugar Beet	6.18	7.50	82.40	0.35
Maize, Summer	1.00	1.20	83.33	0.79
Rice	0.66	0.90	73.33	0.49
Cotton	0.24	0.50	48.00	0.38
Sorghum	0.72	0.80	90.00	0.53
Summer Tomato	6.58	11.00	59.81	2.06
Soybeans	0.42	0.55	76.36	0.50
Summer Potatoes	5.48	5.50	99.63	2.49
Sesame	0.26	?	?	1.04
Groundnuts	0.44	0.70	62.86	0.60
Maize, Nili	0.75	?	?	0.48
Potatoes, Nili	6.90	?	?	1.16
Tomato Nili	11.09	?	?	9.73
Sugarcane	5.18	6.5	79.69	0.16

(1) Calculated from data in Tables 2 and 3
(2) FAO (1986)

revenue a farmer will obtain for his yield minus the costs of agricultural inputs like labor, seeds, pesticides, herbicides and fertilizers. It is thus calculated in terms of the farmers interests, not the Government's. This value depends to a large extent on the market price of the crop . As far as the price at the market reflects the real price, undisturbed by externalities, subsidies or governmental interference, it will reflect the value of the output. This value is then calculated for a unit of land or water to obtain the productivity of the limiting factor. Figures in tables (2 and 4) show the marginal productivity of land and water respectively for a number of crops.

As can be seen, the most water intensive crops are also the crops that give the lowest return, both to land and water. To improve the efficiency of agricultural water use in the country and make agriculture add more to the national production with the same or even with less amounts of water, a change in the cropping pattern is needed. The highest water net revenue crops are wheat, tomatoes and potatoes with wheat as the only crop that is grown on large areas, 821,100 ha in 1990, compared with 235,190 ha for tomatoes and potatoes. The figures of net revenue can be more meaningful when they are expressed in terms of water net revenue per day (table 4). This measurement is very important because it considers not only the water requirements, but also the duration time of the crop. When land is scarce, the time that each crop requires to mature is essential , both for the individual farmer and at the national level. Taking duration time into consideration further highlights the differences between crops in their water use efficiencies. It is crops with low water needs and short duration time, like tomatoes and potatoes that will stand out. Sesame, wheat and summer maize also have quite good values, indicating that an increase in the cultivation of these crops, at the expense of rice, cotton and sugarcane would be beneficial to the improvement of water management.

The relative limited acreage of crops showing a high water net revenue are due to several factors. Among these factors is that water is next to free to the farmers. A low return on water is not a primary concern of the individual farmer. But the low return per acre should give an incentive to farmers to change their cropping pattern to raise income. Reasons for not doing so can be attributed to the uncertainties associated with cultivation of certain crops, extension miss-guidance and high costs of inputs, particularly seeds for high yielding varieties ... etc. Additional explanations can be concern about difficulties in marketing of tomatoes and taste preferences against potatoes as staple food. Another aspect is storage and market facilities, which might not be developed enough to make marketing of these crops in a large scale possible. When there is a surplus of for example tomatoes, the price on the local market decrease to very low levels. Besides the facilities for processing the surplus are weak or lacking. The potential for exporting tomatoes is not very promising because of problems with transports and serious competition on the international market. The same goes to some extent for potatoes. To improve water management these bottle necks must also be widened.

2.5 Scenarios for Better Use of water and Higher National Income

In table (5) the various crops' percentage of total crop land area and total water consumption and total net revenue are calculated. If the percentage of total net revenue for a single crop is larger that its percentage of total water consumption, its contribution to national income is larger than other crops per unit of water. For example, wheat consumes only 11.29 of the country's water resources but accounts for 23.29% of the total net revenue. This is also the case for tomatoes and potatoes as they add much more to the national net revenue as compared to their use of the water. On the other hand, rice, and particularly sugarcane, use a larger part of the available water as compared to their contribution to national income.

The group of cereals (excluding rice) should be encouraged for they are using land and particularly water in an efficient way. They occupy 35% of the total land and consume only 29% of the total water but contribute more than 40% to the national revenue. On the other hand , rice and sugarcane are the worst crops in this respect as occupy 11% of the land area but consume 21% water resources and yet they add only 15% to the national net revenue. In terms of land use they are not bad, but they should be considered as water wasting crops. The same goes for fruit trees.

Table (5) Relative crop area and consumptive use and net revenue for major crops in Egypt, 1990.

Crop	% of Total Crop Area	% of Total Consumptive Use	% of Total Net Revenue
Clover	22.75	16.49	17.34
Wheat	16.18	11.29	23.29
Broad Beans	2.86	1.60	2.26
Winter Tomato	1.30	0.80	4.44
Maize, Summer	12.79	12.08	14.48
Rice	8.59	14.32	9.80
Cotton	8.22	9.93	9.29
Sorghum	2.58	2.56	1.98
Summer Tomatoes	1.04	0.72	2.06
Maize, Nili	3.55	3.00	2.02
Tomato, Nili	0.73	0.32	4.29
Sugarcane	2.29	6.72	5.12
Fruit Trees	5.34	11.68	?
Cereals (without rice)	35.10	28.93	42.13
Cereals (with rice)	43.69	43.25	51.93
Cotton + Rice +			
Sugarcane	19.10	30.97	24.21
Sugarcane + Rice	10.88	21.04	14.92

Source: From date given in the above Tables

(1) The average of permanent and transitory clover

The obvious implication of such calculations is that crops like cereals, tomatoes and potatoes should be favored while areas under rice, sugarcane, fruit trees and perhaps cotton should be reduced. This conclusion may be criticized by being oven simplified, which is true. The optimum cropping pattern for more efficient and sustainable use of the limited water resources can only be defined by a serious and devoted work of a multidisciplinary team. What is given here, however, may be considered as just guidelines or rather a conceptual framework which might be useful in dealing with a complicated situation like this.

The scenarios given in table (6) are therefore only examples which might show some important facts. In these scenarios, the intensive water using crops will be replaced, either partly or entirely, by one or more of the crops which use water more efficiently. The impacts of this replacement in terms of areas irrigated and net revenue are then calculated.

Table (6) Scenarios for better use of water and higher income

Present Situation (1990)			Possible Alternatives		
crop	**area 1000 ha**	**net revenue million $**	**crop(s)**	**area 1000 ha (1)**	**net revenue million $**
Rice	436	**247**	**1-Maize**	**769**	**444**
			2-Tomatoes	525	518
			+Tomatoes	525	538
			2-Total	**1050**	**1056**
			3-Wheat	**1040**	**744**
			4-Rice	300	170
			+Tomatoes	327	323
			4-Total	**627**	**493**
Cotton	**417**	**234**	**1-Maize**	**534**	**308**
			2-Tomatoes	364	359
			+Potatoes	364	373
			2-Total	**728**	**732**
Sugarcane	**116**	**129**	**1-Sugar beets**	**346**	**149**
			2-Wheat	**488**	**349**
			3-Maize	**361**	**208**
			4-Wheat	300	215
			+Maize	136	79
			4-Total	**436**	**294**
			5-wheat	300	215
			+Tomatoes	189	187
			5-Total	**489**	**402**

(1) The actual areas will be a little less than those given because of the losses from the larger areas.

As just mentioned, the scenarios in the table are just examples. Many more scenarios can be done including fruit trees as well. It is needles to say that in all possible scenarios, many considerations have to be taken into account with great care. These will include, among many others, the local consumption of food items, possibilities and difficulties for imports/exports, the international market prices, regulations and conditions , spatial distribution of crops, land and water ... etc.

The question now is how the planners and policy makers are going to make the required changes in cropping patterns to save water and gain more income for the nation? The Egyptian farmers now are completely free to grow whatever crops they like. It is no longer acceptable that the government imposes certain crops to meet the nations' interests. The conflicting interests between the individuals and the nation have been always the case in many societies. There are, however, many possible policies that can save the nations' interests for both current and future generations. Pricing and taxing policies can be successful in this respect. Water may be given free up to a certain limit, but the growers of the water wasting crops should pay for the extra water they use. This should be a good motivation for farmers to grow water saving crops.

This is, however, a very delicate political issue in Egypt. What is even more interesting in this respect that the current policies reflect a certain bias against the poor farmers and consumers as well. The water wasting crops, i.e. rice, sugarcane and fruit trees are mainly grown and intensively consumed by the rich. On the other hand, cereals are mainly grown by the poor farmers and they are the main food for the majority poor. Someway, this trend has to be changed and then will provide the political well to change the cropping patterns to save the most precious resource of the nation.

In case of sugarcane, some people argue that reducing the areas under sugarcane will harm the sugar industry and let more people unemployed. They add that sugar is an important food and Egypt imports about 40% of its requirements of sugar. In the light of the shortage of water Egypt is facing now, and certainly more in the future, such arguments should be considered as false and invalid. The benefits of not growing sugarcane in terms of more areas to be cultivated and higher national income are more than enough to compensate for the losses involved. Instead of importing huge amounts of wheat, Egypt can import more sugar. Development of the infrastructure required for processing, marketing and exporting of alternative crops like tomatoes and potatoes (and other vegetables) may offer a good employment opportunities.

As nicely stated by Abu Zied, 1989, "It is time that Egypt changes the concept that water is a free gift to be haphazardly used, wasted or polluted, according to one's wishes". Furtionatly, in this issue there is no conflict between being fair and being efficient.

3. SUMMARY AND CONCLUSIONS

The need and challenge to improve efficiency and productivity of water in the Egyptian agriculture have been discussed. The paper examined the ways in which water is currently used in the Egyptian agriculture, comparing water requirements and actual use for different cropping patterns and relating this to yields and the economic value of water in different uses.

The results showed that a radical change in the agricultural land use patterns is possible and should be considered very seriously in the near future. The paper indicated the changes needed to make better use of water in agriculture based on calculated water productivity in different uses which should be the criterion used for land and water use planning in Egypt. To make better and more sustainable use of water, these changes should include reducing the areas under the water wasting crops like rice, sugarcane, fruit trees and perhaps cotton. The amount of water saved will be used to expand the areas under crops which use water more efficiently like wheat, tomatoes, potatoes and other vegetables. Several scenarios were given as examples and showed that alternative ways for using water will result in substantial increase in the areas irrigated and the income generated.

It was also indicated that making the proper changes in cropping patterns is not a technical problem. It is rather a political issue and it needs the political well to face the challenge of water stress in Egypt for both the current and future generations.

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POTENTIALS OF DRAINAGE WATER FOR AGRICULTURAL REUSE IN THE NILE DELTA

Safwat Abdel-Dayem[1]

ABSTRACT

With a continuous increase in population, and almost constant amount of water resources, Egypt will face a critical situation not very far from now. The per capita share will soon fall below the reasonable limits for meeting the various water demands for living. There is no other alternative on a short term basis other than maximizing the water use efficiency in order to meet the increasing demands.

Increasing the on-farm and off-farm irrigation efficiencies is one way for achieving savings in water use. However, the relatively old irrigation system and the inherited outdated water management practices requires long time and high investment before they are improved on a wide scale. The progress made since the mid eighties is still very limited. A faster and costly way to increase the water use efficiency is the re-use of agriculture drainage water in irrigation.

There are plans to increase the re-used drainage water to about 7.0 billion cubic meters by the year 2000. The potentials to increase this re-used quantity beyond that depends on many factors among which is the salinity of the drainage water, the location where this water is available, the salt balance of the Delta and the tolerance of the cultivated crops. The measured drain discharges to the sea are not entirely excess irrigation water. They include brackish groundwater, sea water, and domestic and industrial wastewater discharges. The ingredient of the drainage water as far as those waters are concerned can not be easily determined.

In this paper, an effort is made to quantify the water from each origin in order to determine the potentials for reusing drainage water in the future. The analysis of water management in the middle Delta using the SIWARE model for six years interval (1985-1990)for which field data are available for checking the validity of results, revealed several features about the generation, reuse and disposal of drainage water.

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INTRODUCTION

The population of Egypt, which is currently at 58 millions, has doubled since the construction of the High Aswan Dam (HAD). Shortly before that, the 1959 agreement with Sudan was signed to allocate the shares of both countries from the Nile water. Egypt and Sudan annual shares were fixed at 55.5 and 18.5 billion m^3/yr, respectively on the basis of the long term average flow arriving at Aswan estimated as 84 billion m^3/yr. About 10 billion m^3/yr was estimated as evaporation losses from the reservoir. Until, the Upper Nile water conservation projects are implemented these shares will remain unchanged.

In Egypt, the Nile water is almost the only renewable fresh water resource. Consequently, the per capita share has drastically dropped from 2561 m^3/yr in 1955 to 1123 m^3/yr in 1990. It is expected that this share will continue to decrease with further population increase to reach a value between 680 and 585 m^3/yr in 2025 depending on different population projections (Engelman and LeRoy, 1993). The widening gap between supply and demand in Egypt is a main concern of planners and decision makers (Abu-Zeid and Rady, 1990, Attia, et al. 1989). One of the main strategies for facing the challenge of filling in this gap is by reusing water, probably several times before it disappears in a sink or to the atmosphere.

Abstraction of Groundwater and agricultural drainage water are currently the main two forms of fresh water reuse in Egypt. In the Nile Valley and delta, they both originate mainly from the Nile water used in irrigation. The exploitation of these waters on sustainable bases requires careful investigations and planning. Valuable research work and analysis were carried out to determine the available quantity and quality of groundwater and drainage water and their temporal and spacial variability (El-Quosy, 1990; Abdel-Dayem and Abu-Zeid 1991; Abu-Zeid and Abdel-Dayem 1993; DRI, 1993; RIGW, 1993).

The crucial issue in meeting future demands through water reuse is to reach the maximum exploitable quantities of the available groundwater and drainage water without upsetting the physical system or causing environmental damage. A simple analysis of the salt load brought into the Nile Delta by irrigation water and the corresponding salt load carried away by drainage water (Abdel-Dayem and Abu Zeid, 1991) showed a substantial increase of the quantity of salts going out than the salt added to the Delta every year. Since, the status of soil salinity of a major part of the Delta is either at or near a state of equilibrium, the big difference between the input and output of salt loads has been attributed to upward seepage of saline groundwater of undefined quantity. A more complicated analysis was required to quantify the different components of the water and salt balances of the Nile Delta.

At present, the quantity of groundwater abstracted for domestic, industrial and agricultural uses is about 5.3 billion m^3/yr. Meanwhile, about 4.0 billion m^3/yr of drainage water is officially reused in irrigation. This paper is intended to present an analysis of the supply, use and disposal systems focusing on the factors involved in generating, reusing and disposing the drainage water in the Middle Nile Delta. Hopefully, it can highlight the possibilities of maximizing the volume of drainage water reused in irrigation without any adverse effect on the soils and crop yields.

1. WATER MANAGEMENT IN THE NILE DELTA

The Nile Delta can be divided into three geographic regions. They are located to the east, between and to the west of the two branches of the Nile (Figure 1). Nevertheless, the three regions are hydrologically connected. It is possible to distinguish three distinct systems through which the Nile water moves from the moment it enters the Delta till it disappears. The three systems are the supply and distributary system (main irrigation system), the on-farm irrigation system and the disposal system (drainage system). For a better understanding of these systems and their performance, the following analysis will identify the components of each system in terms of gains and losses or inputs and outputs. Assuming that each of the three mentioned systems is in state of equilibrium over a certain long period (e.g. one year) then gains and losses should be balanced or:

$$\text{Inputs} = \text{outputs}$$

Losses leaving one system may become gains to another system. However, there are some losses which disappear entirely from the system along the course of water from the Delta Barrages to the sea. The components of the water management systems in any region in the Delta could be diagrammatically sketched as in Figure 2.

1.1 The Irrigation System

The supply and distributary system consists of a network of main and secondary canals which divert the water from the river to the Delta. They originate mostly upstream the Delta barrages to the North of Cairo and flow by gravity to the north. A part of the area further northward, however, gets its share of Nile water through canals which off-takes directly from the two Nile branches. The main command canals, comprises upto 3 or 4 orders. They are under a continuous flow regime. Distributary canals, branching from any main command canal, are on the other hand under rotational flow. While, water supply for drinking and industrial purposes is provided from the main canals, water for irrigation is provided through the distributary canals. The flow of canals is controlled by gated structures and based on water distribution proportional to water requirements.

At various locations in the Nile Delta agricultural drainage water is lifted by pump stations from the main drainage canals into irrigation command canals. Similarly, groundwater at some locations, mostly in the south of the Delta is pumped from the underlying aquifer for domestic and industrial uses or for irrigation. The canal flows are determined from the water requirements in their command areas including the irrigation, municipal and industrial needs. The water surface of some main canals are maintained at a certain level even during periods of least requirements for navigation purposes.

The allocation of Nile water for each command canal accounts for gains (drainage water, groundwater,and precipitation) as well as losses (evaporation, seepage, spillway and tail-end losses) along the course of the canal. Another gain which is not accounted for is the unofficial reuse of drainage water by farmers. They use mobil diesel pumps for lifting water from the drains to their farm irrigation ditches. They

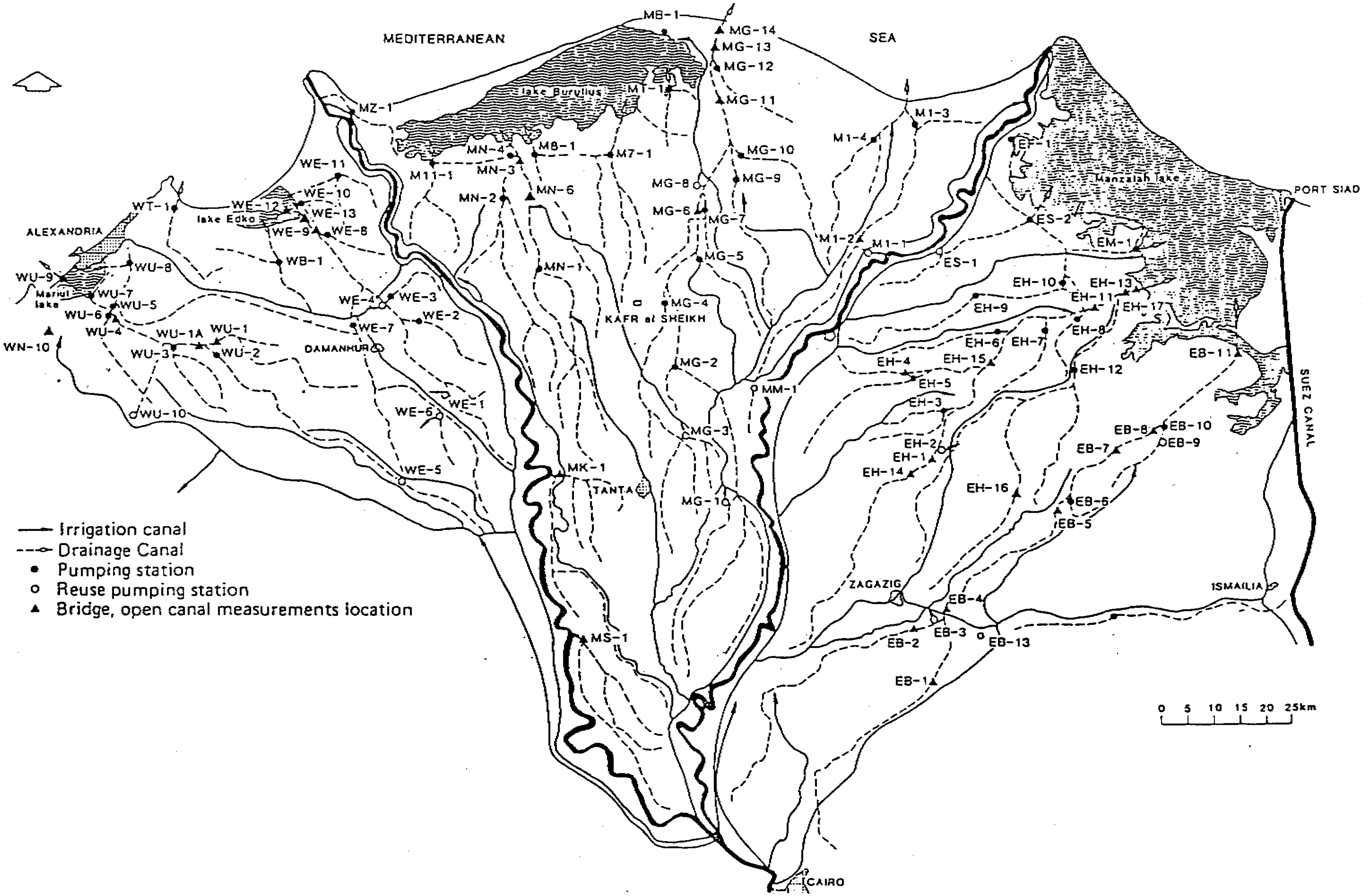

Figure 1. Irrigation and Drainage System in the Nile Delta

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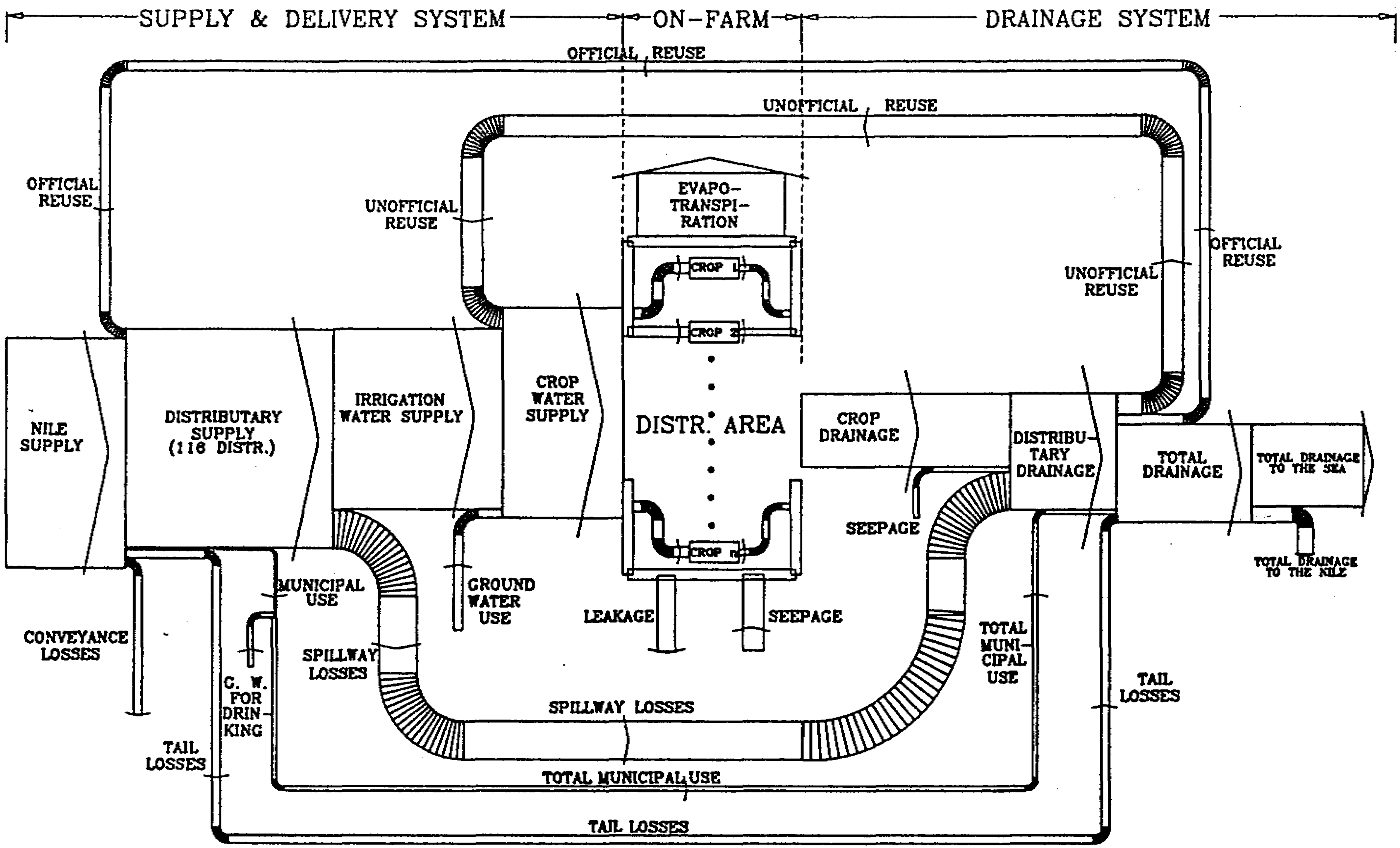

Figure 2. Schematic Diagram of the Water Balance of the Nile Delta

often do that to supplement a deficit in fresh water supply at the tailends of irrigation canals.

In terms of a water balance between water entering and leaving the supply and distributary system which starts at the main headworks diverting water into a region and ends at the farm gate, the water balance equation may be written as follows:

$$N + D_{or} + D_{ur} + GW = I + M + CL + TL + SL \quad (1)$$

where,

- N = Nile water supply
- D_{or} = drainage water officially reused through state's pumps
- D_{ur} = drainage water unofficially reused by farmers
- GW = groundwater abstractions for irrigation and other purposes
- I = irrigation water delivered at the farm-gate
- M = municipal and industrial water uses (Nile water)
- CL = conveyance losses
- TL = tail-end losses of the main system
- SL = spillway losses from the distributary canals (including 'meskas')

1.2 The On-farm System

It is represented by the farm lands starting from the farm-head gates and ending with the field outlets to the drainage system. It is the system comprising the interface between water, soil and plant. Water is diverted to the farm to satisfy the crop evaporative demands. It is usually lifted from the mesqa (tertiary canal) by diesel pumps or water wheel (Sakkia) to a farm ditch (marwa) and applied to the land by gravity irrigation. Sprinkler and drip irrigation systems are limited to the newly reclaimed desert lands at the fringes of the Delta.

Irrigation water infiltrates through the land surface and percolates through the soil voids filling them up to their maximum holding capacity. The excess water percolates further deep to the groundwater causing rise in the water table levels. In case the irrigation rate exceeds the infiltration capacity of the soil, water flows on the land surface until it may reach the tail end of the field. The excess water either in the form of surface runoff or subsurface flow ends into the drainage system.

The top layer of the Delta lands consists of the alluvial soils historically developed by the sediments brought in by the Nile water before the construction of HAD. It has a relatively low permeability and overlays a more permeable aquifer of sand and gravel. The water pressure (piezometric head) in the groundwater reservoir exhibits regional distribution that allows downward flow (leakage) of groundwater in the south of the Delta and upward flow (seepage) in the north (Farid et al, 1979). In other words, there is a loss of water to the deep aquifer in the south and gain in the north. The groundwater in the north of the Delta is brackish due to sea water intrusion at the coastal areas (Attia, 1988).

The water balance within the on-farm system may be expressed on the basis of gains and losses as follows:

$$I + R + S = ET + D_f + L \quad (2)$$

where,

I = irrigation water delivered at the farm-gate
R = rainfall
S = upward seepage of groundwater
ET = evapotranspiration
D_f = Field drainage water
L = Deep percolation (leakage)

The salt balance within the farm lands can be expressed on the basis of equation 2 as follows:

$$I \cdot C_i + S \cdot C_s = D_f \cdot C_d + L \cdot C_l \pm \Delta Z \quad (3)$$

where,

C_i = salt concentration in irrigation water
C_s = salt concentration in seepage water
C_d = salt concentration in drainage water
C_l = salt concentration in deeply percolating water (leakage)
ΔZ = changes in salt content of soil

Good water management in well established reclaimed lands should have no changes in soil salinity (i.e $\Delta Z = 0$). For lands still in the process of reclamation, the water management should be directed towards leaching of the accumulated salts. On the other hand, poor water management would lead to salt accumulation in the soil profile.

1.3 The Drainage System

The drainage system in the Nile Delta consists of field and main drains. The field drains consist mostly of covered drains except in some parts at the north which are currently drained by open ditches. Covered drains will be extended to cover all the old lands by year 2010 (Abdel-Dayem and El Safty, 1993). The main drains are man-made deep ditches flowing northward where pump stations are used to lift their water to the lakes or the sea. The main drains, also receive the tail-end and spillway losses of the irrigation canals. The water levels of the main drains are maintained at 2.5 m depth below the land surface to allow gravity flow from the field system. As the main open drains cut deep into the soil profile, their levels are usually below the water table levels. Therefore, they receive flow directly form the groundwater. The water of these drains is not limited to the discharges mentioned earlier but they receive also domestic and industrial wastewater. More than 90 percent of the water abstracted for these uses returns back to the drainage system.

The water of the main drains is reused for irrigation both officially and unofficially. Some main drains may discharge their water into the Nile branches, thus their outflows are considered as a part of the official drainage water reuse. Obviously, the drainage water may be reused several times before it is finally disposed to the sea.

The balance of the water entering (gain) and leaving (loss) the drains according to the above analyses may be expressed as follows:

$$D_f + S_d + M_r + TL + SL = D_{or} + D_{ur} + D_s \tag{4}$$

where,

- D_f = surface and subsurface field drainage water
- S_d = groundwater intercepted by main drains
- M_r = return flow of municipal and industrial uses
- TL = tail-end losses of the irrigation main system
- SL = spillway losses from the distributary canals
- D_{or} = drainage water officially reused through state's pumps
- D_{ur} = drainage water reused unofficially by farmers
- D_s = drainage water flow to the sea

1.4 Regional Water and Salt Balances

The three system described above constitute together the water management system in any region of the Delta. The three water balance equations described above may be combined together to express the regional water balance which reads:

$$N + R + GW + S + S_d = ET + CL + L + D_s \tag{5}$$

where,

- N = Nile water supply downstream the regional headworks
- R = rainfall
- GW = groundwater abstraction
- S = upward seepage of groundwater at farm level
- S_d = groundwater intercepted by the main drains
- ET = evapotranspiration
- CL = conveyance losses of the irrigation canals
- L = deep percolation of irrigation water to the groundwater aquifer, and
- D_s = drainage water flow to the sea

When the groundwater abstraction (GW) and upward seepage (S, S_d) are balanced by the recharge of the aquifer through deep percolation of canal seepage water (CL) and percolation of irrigation water (L), equation 5 may read:

$$N + R = ET + D_s \tag{6}$$

The terms of Equation 6 on the left hand side represent the renewable water resources entering the region while the terms on the right hand side represent the non-recoverable water leaving the region. Obviously, drainage water reused for irrigation as well as groundwater pumped from the aquifer are recoverable losses for internal reuse within the region. The only non-recoverable losses from the system are the evapotranspiration to the atmosphere and the drainage water flowing to the sea. The renewable resources to the Delta are the Nile water flow and the rainfall mainly along the coastal shores.

The salt concentration in each water component of the balance equations (Eq. 2, 4 and 5) is different. The Nile water although being of very good quality , still contains some dissolved salts. The drainage water to the sea contains the same amount of salts brought in by the irrigation water plus the salt leached from the soil profile and the salt load of the groundwater upward flow. Meanwhile, rain water contains negligible salt load and only pure water evaporates or transpirates to the atmosphere. Thus, the salt balance corresponding to equation 5 reads:

$$N \cdot C_n + GW \cdot G_g + (S + S_d)\, C_{gs} = D_s \cdot C_d + CL \cdot C_n + L \cdot C_g \qquad (7)$$

where C_n, C_g, C_{gs} and C_d are the salt concentration of the Nile water, fresh groundwater, and drainage water respectively.

Equation 7 shows that the main sink to which the salts are removed, is the sea as the salt load removed by natural drainage (leakage) is usually very small compared with the total salt load brought in by the Nile water and the groundwater upward seepage. This implies that a certain quantity of drainage water has to be discharged to the sea otherwise the soils of the Delta will get salinized. The diagram shown in Figure 3 shows the components of the salt balance in any region of the Nile Delta.

2. WATER MANAGEMENT ANALYSIS AND EVALUATION

Some of the water management components described above are continuously measured such as the Nile water diverted from the river to the irrigation system and the drainage water flowing to the sea and officially reused. Other components can not be measured but may be estimated to a reasonable extent such as the crop ET. A third category is neither possible to calculate nor easy to estimate such as the unofficially reused drainage water and to a certain extent the spillway losses. Another set of parameters needs difficult to obtain physical or chemical constants for calculation. However, an assessment of all the water management components can be made through simulation of the water management and all the processes involved along the pass of water from the river to the sea in the Nile Delta. The SIWARE model is a powerful computational tool which was developed for making such analysis (Abdel-Gawad et al, 1991 and 1992).

With input data collected for several years in the middle delta, the SIWARE model was calibrated and validated separately for each Delta Region. The input data includes, the water allocated to the region, the crop pattern, the crops water duties, the climatic data, the groundwater abstractions, drainage water officially reused, the piezometric pressure in the aquifer and other physical and chemical characteristics of the water management system and the soil. The model calculates both the quantity and salinity of each water component including the drainage water flowing to the sea.

The following analysis and discussion will be limited to the simulation results of the water management in the region between the two branches of the Nile (Middle Delta) during the period starting in 1985 through 1990. The results of these 6 years were validated against the measured officially reused drainage water and the discharge of drainage water flowing to the sea (Table 1) and their salinities. The

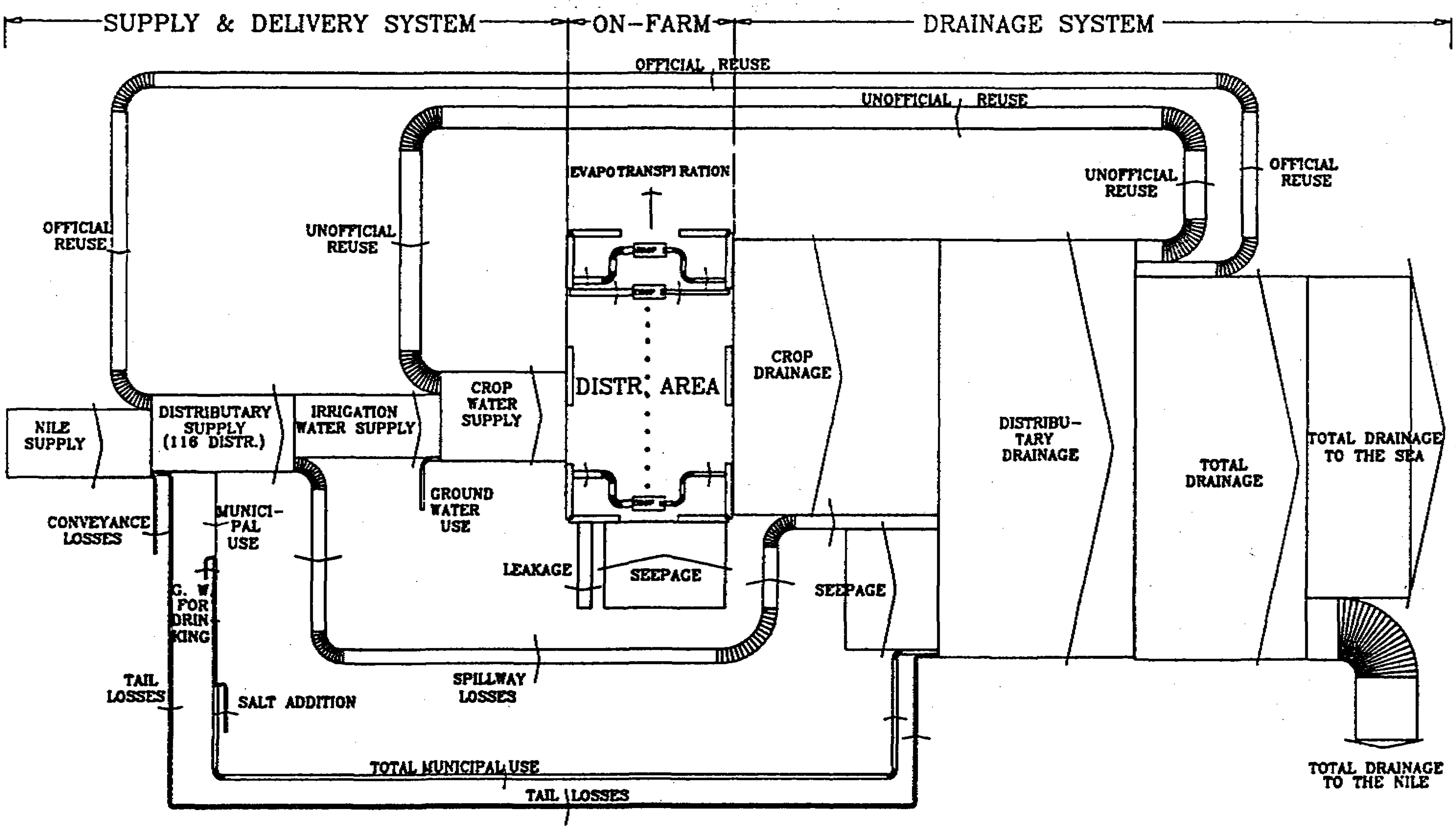

Figure 3. Schematic Diagram of the Chloride Balance in the Nile Delta

simulation was carried out on the basis of the Nile water allocated to the middle Delta and the crop pattern during the simulation period.

Table 1. Measured and simulated drainage water annual flows (million m^3)

Year	Nile Water	Reused Drainage Water (1)		Flow to the sea	
		measured	simulated	measured	simulated
1985	11552	777	753	5057	4737
1986	11354	721	733	5264	4558
1987	11112	719	761	5080	4285
1988	10310	686	633	4361	3772
1989	10345	673	647	4546	3713
1990	10448	1360	1236	4476	3665

(1) includes the drainage water flowing to the river branches.

Agreement between measured and predicted reused drainage water and water flowing to the sea is quite satisfactory. It should be clear that the flow to the sea is measured at the pump stations which are located at a distance upstream the mouth of the drain to the sea. Thus, the unofficial drainage water reuse downstream the pumping stations is not accounted for and the flow to the sea is overestimated. On the other hand, the model is capable to estimate the unofficial reuse and therefore, it gives lower values than those measured at the pumping stations as shown in Table 1. Nevertheless, the maximum differences between estimated and measured values did not exceed 20%.

The simulation results are obtained on decades (10 days), monthly and yearly basis. In addition to the drainage water quantities and their salinities, the other water management components referred to in Figures 2 and 3 and included in equations 2 through 7 during the simulation period were obtained. The values of the water management components and their corresponding salinities revealed several facts about the water management systems or quantified some parameters that are usually difficult to be determined by simple means. The flowing discussion will highlight the findings.

2.1 The Water Supply System

The estimated conveyance losses from the main irrigation canals and their tail end losses were relatively low and were within 3-4 percent, each, of the total quantity of Nile water allocated to the middle Delta. On the contrary, the distribution system losses was comparatively high and were between 14-19 percent. These high losses are mainly due to the little irrigation practiced at night and hence the canal water flows over the spillways to the drainage system. Thus, about 1.5 - 2.2 billion m^3 of fresh water is lost in the middle Delta to the drains every year. The salinity of this water is almost same as the Nile water. Obviously, this is a main weakness in the current practices and therefore efforts for improving the irrigation system in Egypt is now focusing on this issue.

On the other hand, the supply system recovers part of the losses in the form of drainage water reused both officially and unofficially as well as groundwater. Table 2 gives a comparison between the losses and gains of the supply system as estimated by the model. It clearly shows that there is even a decrease in the balance between losses and gains in the favor of gains indicating to an improvement in the system operation and the overall water use efficiency with time. The irrigation system efficiency and the water use efficiency over the period 1985-1990 are shown in Figure 4. The system efficiency is computed as the ratio of the total losses to the original Nile water supplies. The water use efficiency is calculated as the ratio between the total water used, which consists of the domestic and industrial uses as well as the water delivered for irrigation at the farm gates to the total supplies which consist of the Nile water, ground water and drainage water both officially and unofficially reused.

Table 2. Losses and gains in the supply system upstream the farm gates in the middle Delta (million cubic meters)

Year	System Losses (-)				System Gains (+)				Balance
	Convey-ance Losses	Tail-end losses	Spillway losses	Total	Official reuse(1)	Unofficial reuse	Ground water	Total	
1985	474	430	2165	3069	410	1028	663	2101	-968
1986	468	415	2054	2937	384	1022	663	2069	-868
1987	471	396	1847	2714	409	1015	663	2087	-627
1988	450	351	1454	2255	341	999	663	2003	-252
1989	453	332	1496	2281	320	1029	663	2012	-269
1990	412	547	1663	2622	885	1038	663	2586	-36

(1) Does not include the drainage water discharged into the river branches.

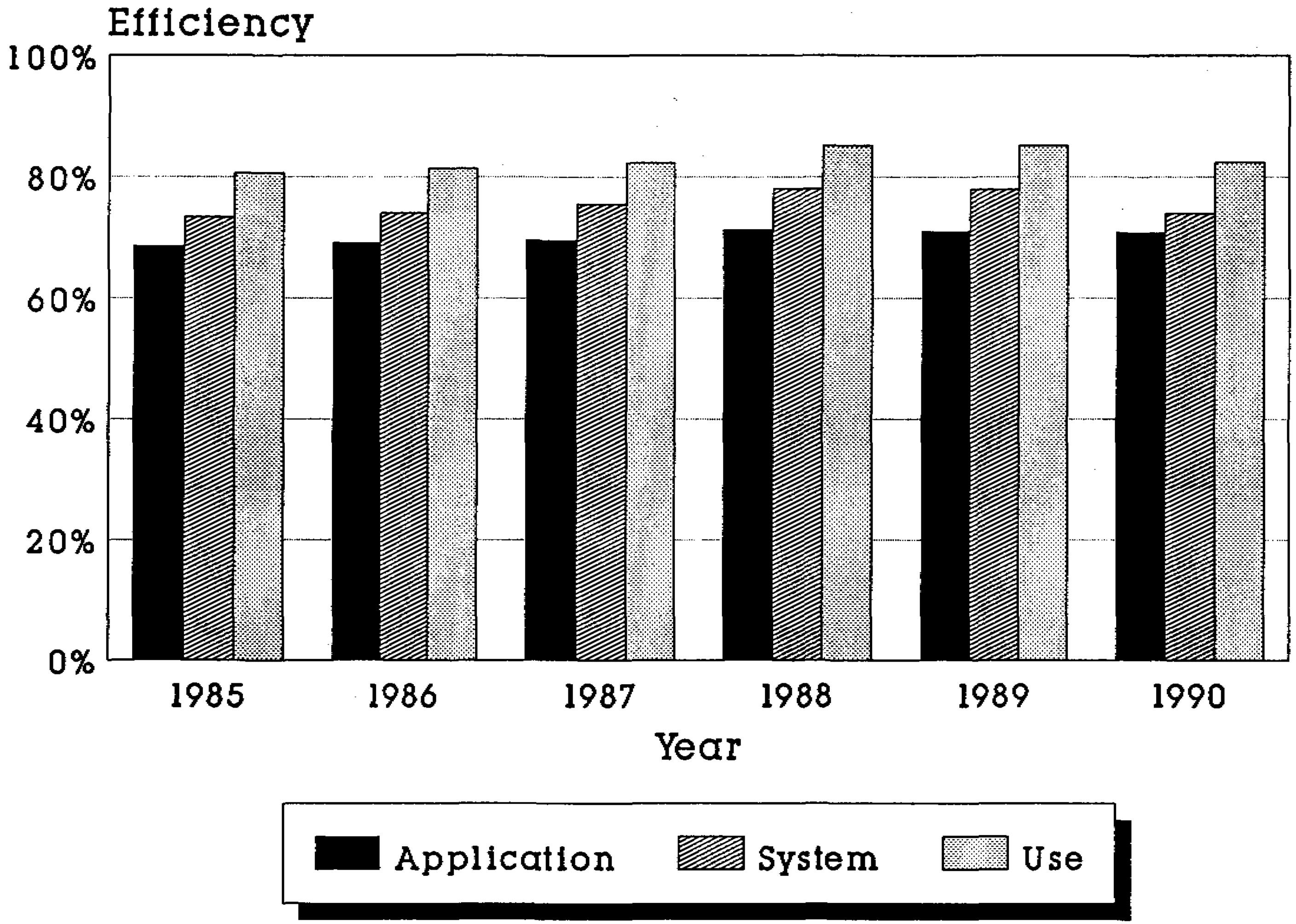

Fig (4) Field Application, Irrigation System and water Use Efficiencies in the Middle Delta.

2.2 The On-farm System

The cultivated area in the middle Delta between the Nile branches is about 1.5 million feddans[2]. The main crops are berseem and wheat in winter and rice, maize and cotton in summer. The crop intensity at any cropping season is almost 100 percent. The global annual water supply at the farm turnout consists of a mixture of Nile water, drainage water and groundwater. However, the fresh Nile water is the main supply. The on-farm water and salt balances are given in Table 3. They reveal that the global average on-farm irrigation efficiency (regional basis) is much higher than many expectations and in the range of 68 - 71 percent (Figure 4). It is calculated in this analysis on the basis of the ratio between the actual crop evapotranspiration and the total water delivered at the farm gates. Less local application efficiencies should be expected in some areas in a region of the size of the middle Delta.

Table 3. Annual on-farm water and salt balances in the middle Delta between 1985 and 1990

Year	Water Balance (1), Eq.2					Chloride Salt Balance (2), Eq.3				
	+ Irrigation	- Evaporation	- Leakage	+ Seepage	- Drainage	+ Irrigation	- Leakage	+ Seepage	- Drainage	ΔZ (2)
1985	10210	7056	854	1002	3302	649	230	1787	2338	-132
1986	10112	7061	828	1000	3223	649	218	1803	2356	-122
1987	10111	7079	841	1006	3197	698	211	1793	2334	-54
1988	9686	6959	760	1013	2980	673	204	1843	2364	-52
1989	9704	7015	761	1014	2942	681	203	1831	2402	-93
1990	10036	7141	794	1000	3101	715	211	1763	2297	-30

(1) Quantity x 10^6 m^3
(2) Quantity x 10^6 kg

Although the difference between the volume of leakage water percolating deeply below the root zone and the upward seepage of groundwater is not much, the quantity of salt brought in by the seepage water is between 8-9 times bigger. It is the main source of salts in the drainage water, compared with the salt load brought in by the irrigation water. The salt balance also shows that the practices over the period 1985 -1990 caused an overall leaching effect of salts out of the soil profile. However, the quantity of salts leached from the soil (L) is decreasing with time and it was at its minimum level in 1990. It may be recalled that the official drainage water reuse has substantially increased in 1990 (Table 2) after the construction of a weir at the outlet of the Gharbia main drain. Nevertheless, the salt load in the mixture of waters used for irrigation did not significantly increase. The average conditions in the middle

2 1 feddan = 0.9524 acre

region of the Delta were still showing salt leaching from the soil profile equivalent to 0.3 million tons of chloride. Further analysis of water management for more years and on the level of discrete catchment areas is necessary to determine the salinity status in a more detailed fashion which leads to the safe limit for reusing drainage water for irrigation in this region.

Another important feature of the on-farm water management system is that the field drainage accounts for the excess irrigation water as well as upward seepage of groundwater. Thus, its discharge does not solely represent the irrigation application losses. Part of these losses disappears by deep percolation recharging the groundwater aquifer. The effects of natural drainage in the south of the Delta and upward seepage in the north are reflected on the spatial distribution of the drainage rates as shown in Figure 5, and as was discussed by Abdel-Dayem et al (1993).

2.3 The Drainage System

In the case of the Middle Delta, some of the main drains have their outlets to the Nile branches. Tella and Sabel outfall drains discharge their water into Rosetta branch. Also part of the drainage water from El-Gharbia main drain and Drain No.1 is pumped to the Domietta branch. As almost all the waters of the two Nile branches are used, except during the closure period, these drainage waters is considered part of the official reuse.

The main drainage system receives effluent of different quantities and salinities. Water of low salinity reaches the system through the spillways and tail end escapes of the irrigation canals. The spillway losses are relatively high and may reach up to 65-80 percent of the field drainage water which is moderately to highly saline. The less spillway losses which were recorded in 1988/89 indicate that it is possible to achieve better management, and hence improved efficiency through controlled operations of the distribution system. The quantities of direct groundwater seepage intercepted by the main drains and municipal return flow are relatively small but the salt load expressed by the chloride content in the seepage water is high. A mixture of these waters is reused for irrigation. The part officially reused is pumped into irrigation canals of the distribution system and mixed with fresh water. After mixing the salinity of the blend is usually about 600 ppm which is tolerable by most sensitive crops.

The quantity of unofficial drainage water reused in irrigation as estimated by the SIWARE model (Table 2), was often bigger than that officially reused in the middle Delta including the part discharged to the Nile branches (Table 1). This state continued until the construction of El-Gharbia main drain weir in 1990. Thereafter, the official drainage water reuse became more than the unofficial reuse. The problem is that the unofficial reuse is uncontrolled, both as quantity and quality. Its quantity depends on the needs of farmers to overcome the shortage in irrigation supplies (Nile water, groundwater and officially reused drainage water). This usually happens at the tail end of some irrigation canals. On the other hand, the salinity of the unofficially reused drainage water is almost twice that officially reused. The risk remains in reusing that water directly in irrigation without mixing with fresh water

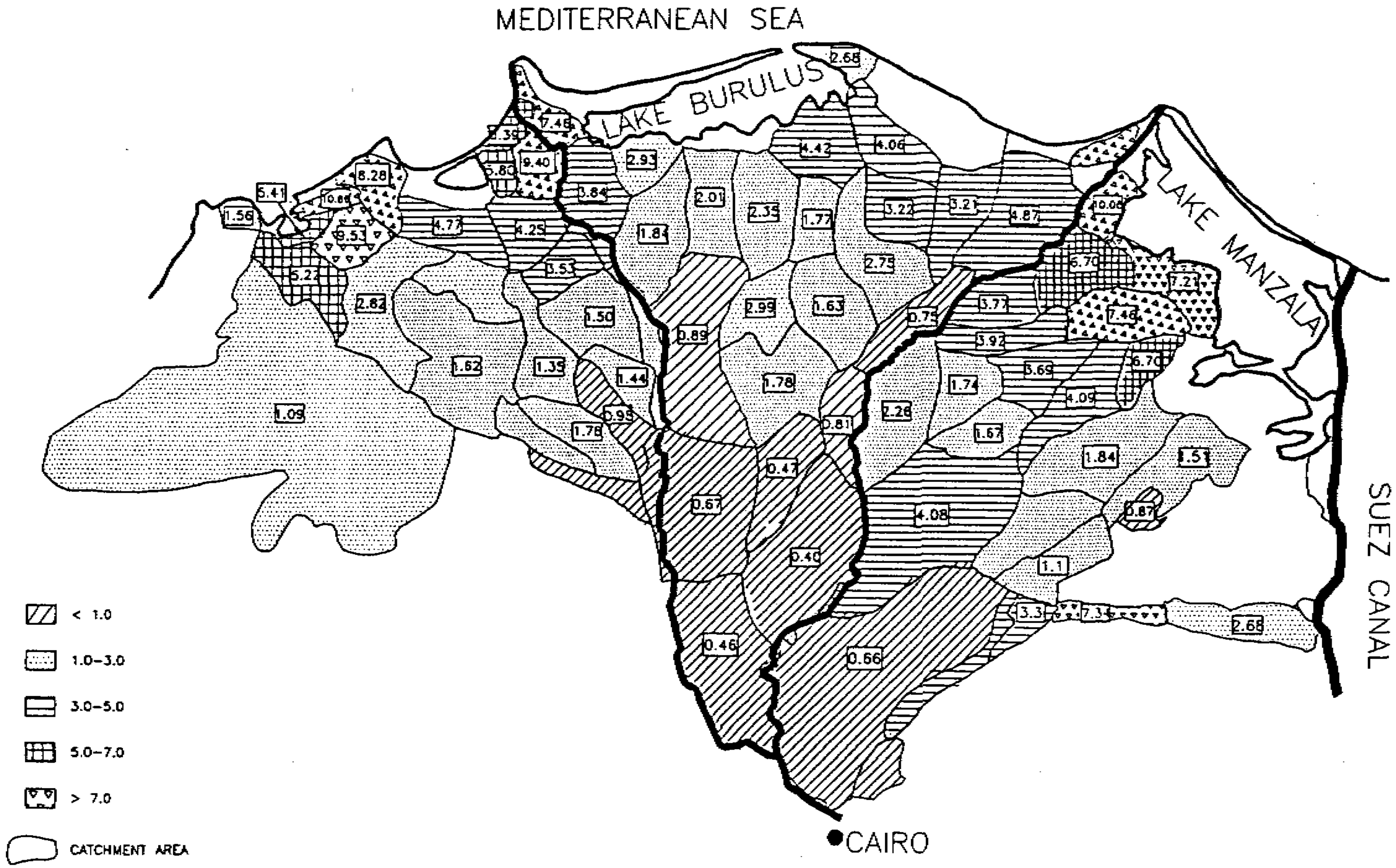

Figure 5. Drainage Rates of Different Catchment Areas in the Delta
(source: Monitoring Program data yearbook, DRI)

for prolonged periods. It may cause soil salinization and crop losses on the long run. Apparently, the farmers are taking care of this problem through using enough water to account for salt leaching.

A part of the drainage water flows unused to the Mediterranean sea and lake Brullus. The salinity of this water which is monitored around the year changes both with time and space. The classification of drainage water flowing to the sea according to its salt concentration (Table 5) shows that a part of this water is of low salinity. Considering the portion with salinity less than 1500 ppm, its quantity was still about one billion m^3 in 1990 after utilizing all the flow of El-Garbia drain. This quantity can be still reused for irrigation. However, this depends on when and where it is available as well as the availability of lifting facilities. A further analysis is required to determine these possibilities.

Table 5. Quantities of drainage water (million m^3) flowing to the sea from the middle Delta classified according to their salinities[1]

Year	Total Dissolved Salts (g/m^3)					
	<1000	1000-1500	1500-2000	2000-3000	>3000	Total
1985	321	1190	1644	849	1053	5057
1986	617	988	1695	832	1132	5264
1987	938	483	2095	705	859	5080
1988	283	782	1832	273	1191	4361
1989	332	850	1563	691	1110	4546
1990	172	881	1462	102	1859	4476

(1) Source: Monitoring Program Data Yearbooks Actual Measurements.

CONCLUSIONS

It is not easy to determine the limit between the drainage water that can be safely used and that which should be disposed to the sea due to the complex nature of the water management system and the many interventions involved. Three subsystems have been identified and discussed to recognize the characteristics and nature of the whole system. Many of the system parameters and components can not be easily measured or quantified.

An analysis of the water management system through mathematical simulation was carried out for the middle Delta, using the SIWARE model developed at the Drainage Research Institute. Inspite of the simplification and approximation involved, the model was able to quantify the unmeasurable components of the water and salt balances. It was possible therefore to highlight several features of the processes and interventions which are involved in the generation, reuse and disposal of the drainage water.

A significant part of the drainage water in the main system comes from the spillway and tail end losses of the irrigation system. An another significant part comes from upward seepage of groundwater in the northern parts of the Nile Delta. While the former is of low salinity the latter is medium to highly saline. Improved irrigation practices may decrease the losses and consequently decrease the drainage water and increase its salinity. Until such improvement is achieved, reuse of drainage water will remain inevitable to keep the cropped area at its present size and to reclaim more new lands.

The unofficial reuse of drainage water in the middle Delta, was more than the official reuse until the official reuse was almost doubled in 1990. They became of the same order of magnitude and their total quantity is about 2.3 billion m^3 per year. It seems according to a salt balance that the reuse of drainage water in the middle Delta is slightly increasing the salt load in the irrigation water and this can be further analyzed on catchment area basis and for longer time interval after 1990.

The drainage water flow to the sea is in fact less than the measured quantities due to the unmeasured - unofficially reused drainage water downstream the final measuring stations. The actual flow to the sea could be 10-20 percent less than the measured flow. Furthermore, about half the drainage flow to the sea is highly saline groundwater in the form of upward seepage to the irrigated lands or intercepted by the deep drains. The drainage water flow to the sea in 1990 was about 4.0 billion m^3 of which about one billion m^3 was of salinity less than 1500 g/m^3.

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WATER RESOURCES AS A LOCATIONAL FACTOR OF HUMAN ACTIVITIES TO SATISFY DEMANDS UNDER WATER DROUGHT CONDITIONS EXAMPLES FROM WEST AFRICA

Per Lindskog

ABSTRACT

Water resources are generally neglected as a factor which influen-ces, if not determines, the location of human activities in West Africa. Yet, if the availability of water resources in sufficient quantities and of acceptable qualities are taken into account when planning and designing the future location of human activities, especially in urban areas with high water demand, many constraints to development may be avoided and better services can be provided. This is especially relevant in warm, arid regions like the West African Sahel.

The capitals of West Africa are often located where the water resources of the country are most scarce, e. g. Dakar in Senegal. The location of the capitals has mostly been determined not because of their suitability as capital today but due to historical rea-sons. However, geographical inertia makes it very difficult to relocate a city after hundreds of years. Still, it could be worth-while to consider such relocations if one takes into consideration that the site of a capital will remain the focal point of the country for hundreds, if not thousands, of years to come.

With such a relocation to a more favourable site from the point of view of the water resources, the costs for the country in providing infrastructure facilities like drinking water and sewerage but also for construction of roads could be drastically reduced. Equally, the costs to assure urban activities in inundated areas could be reduced through a relocation of capitals, sometimes only a few miles away from present sites to sites which are not inundated but which will facilitate urban development.

RÉSUMÉ

Les ressources en eau ne sont pas en général considérées comme des facteurs déterminants, ou dans la moindre mesure influents la localisation des activités humaines en Afrique Occidentale. Pour-tant, si l'accessibilité des ressources en eau, aussi bien enquantités suffisantes qu'en qualités, est prise en compte dans les décisions de planification de la localisation future des activités humaines, surtout dans les régions urbaines où il y a une forte demande en eau, la plupart des contraintes de développement pourraient être évitées, aussi de meilleurs services pourraient être assurés. Cette politique est surtout importante dans les régions chaudes et arides comme le Sahel en Afrique Occidentale.

Les capitales de l'Afrique Occidentale sont souvent situées là où les ressources en eau du pays sont rares, par exemple Dakar au Sénégal. La localisation des capitales est pour la plupart déterminée^U par des causes historiques et non par des convenances actuelles. Cependant, l'inertie géographique fait qu'il est difficile de déplacer une ville après des centaines d'années. Bien qu'il est utile de revoir de tels déplacements si on tient compte du fait que le site d'une capitale va continuer à être l'élément déterminant le développement du pays pendant des siècles, même des millénaires.

Les dépenses des pays en infrastructures d'approvissionement en eau potable et en systèmes d'évacuations des eaux usées seraient réduites avec une politique de relocalisation des activités humaines vers les sites plus favorables. Enfin dans les cas des capitales inondées, les dépenses de fonctionnement pourraient être réduites si on oriente les activités urbaines vers sites non in-ondés, dans certains cas, il suffirait de déplacer la capitale vers un milieu non inondable situé à quelques kilomètres pour que le développement d'une ville soit plus favorable.

It is evident that human activities are located where people live. However, it is not equally evident that water-related activities take place, where water is most easily available at maximum bene-fits and lowest cost, not even in drought-stricken areas. The minimum benefit cost location, as well as sustainability of the water supply, are frequently not even taken into consideration when man plans his water-related activities.

Take for example human settlement in the form of cities, especially capitals. What factors influence the location of capitals in the Sahel-region of West Africa, a region which during the period 1968 to 1985 have suffered a reduction of the rainfall of between 10 and 50 % compared to the period 1950 to 1967? It is mainly historical reasons which explain their location. The colonial power either chose a site, or commercial activities started and the colonial power later was established at that site.

A location which may have been appropriate at one time, may have become a heavy burden upon a country in terms of providing the growing population with drinking water supply. This is e.g. the case with Dakar, located at the site chosen by the first colonizers of the West African coast more than 500 years ago. The very fist capital of Senegal was Gorée Island, less than a km from Dakar. The location of this capital on a narrow 20 km long peninsula in the sea today creates a serious problem to provide all the 2 million inhabitants with a drinking water supply.

Geographical inertia makes it very difficult to relocate a city, the more difficult the bigger, even if there are ever so good reasons for a relocation. The benefits and costs for the city, and the country, to remain at the same location are usually based on calculations of a few years.

If the benefits and costs of remaining at the same site were compared with those of a total or partial relocation, based upon long term calculations, i.e. hundreds of years, many cities would at least relocate new constructions, if not decide to make a total relocation, to sites more favourable from the point of view of providing water for human consumption as well as raw water to industries.

Such a relocation would be equally relevant for capitals which are inundated during the rainy season, e.g. Cotonou in Bénin and Lomé in Togo, where in both cases a city expansion only a few km away from the present city centre would provide non-inundated capitals. In neighbouring Nigeria, Abuja has already replaced the old and chaotic capital Lagos, located at an unfavourable site not only in terms of providing drinking water but equally from the point of view of transport, land for construction etc. The same applies to Dakar.

Another example from the semi-arid zone of West Africa is the site of the capital of Burkina Faso, Ouagadougou. Aquifers as well as surface water in this Sahel country on the continental shelf, one of the poorest countries in the world, are very limited, which makes it necessary to transfer water over long distances to the nearly one million inhabitants of the capital.

The present drinking water supply system for Ouagadougou does not manage to provide the 900 000 or so inhabitants with drinking water but there is a chronic water shortage. Studies are at the moment undertaken to construct a dam some 50 km northeast of Ouagadougou at Ziga on the Nakambe river, formerly the White Volta. If and when it is constructed, its capacity to supply drinking water to this capital, which presently has a growth rate of 8-10 %, will not be sufficient for more than 10 years. Further, one should not neglect that with a dam, thousands of ha would be inundated and lost for the villagers.

What then to do: divert the only remaining perennial river in the country, Mouhoun or the Black Volta (whose source is close to the second biggest town of the country, Bobo Dioulasso), or else start war against neighbouring Mali and try to take control of the Niger river? Not a venture with terribly good prospects.

If the present rate of population growth (net-migration plus net natural increase) of this capital will remain at the same rate, it will create unsurmountable problems in one or two decades, which will only contribute to increased tensions in the society. There is already now a certain unrest due to the permanent water drinking problem, especially among the lower middle class.

The second biggest town, Bobo Dioulasso, is located in the south-west of the country, where rainfall is about 50 % higher than around Ouagadougou. As mentioned above, the source of the largest river of the country, the Mouhoun, is only some 20 km from Bobo Dioulasso. If this town was permitted to expand faster, if there was a decentralisation of government offices to Bobo Dioulasso, it could supply drinking water more easily accessible and much cheaper than Ouagadougou, not to talk about the impact a relocation of the capital or a development policy favouring rural and agricultural development would have upon the strain on infrastructure facilities of the capital.

Such solutions would save huge amounts of money to one of the poorest countries in Africa. The money saved could be invested in soil and water conservation activities, which would preserve the now rapidly diminishing water resources through increased infil-tration instead of run off. It could increase agricultural produc-tion and reduce migration of rural population into the cities.

The snag to such a benefit-cost maximizing solution may be ethnic. The largest ethnic group of the country resides around Ouagadougou and may find it hard to accept that the capital moves to the area of another ethnic group. Even a development policy favouring a decentralised development, in which Ouagadougou remains the capital but with a slower population growth rate, may be too much to the pride of leading politicians.

Thus, the development of the country as a whole may be hampered due to historic reasons of the choice of the site of the capital. And due to the inertia of the society and the curtain of ignorance which together prevent decision-makers, administrators and donors to regard water resources as a locational factor to be considered in the planning of the country with the aim to search for the opti-mum location of human activities, e.g. cities. If this curtain, which conceals the significance of water resources in attaining development aims, is not pulled up, satisfying the water demands of future generations may become a very difficult if not impossible task.

All too often, one attempts to solve the problem of water scarcity in cities today by half-measures, short-term solutions, rather than search for less accessible but lasting, and radical, solutions. If water resources, due to lack of understanding of their significance among decision-makers and donors, are continued to be neglected as locational factors of importance in all planning processes, they may create unsurmountable problems in the future, e.g. tensions between those groups who have and those who do not have access to water resources within as well as between countries and continents.

MANAGING AGRICULTURAL WATER DEMAND TO SECURE WATER AVAILABILITY IN THE ARAB REGION[1]

EXTENDED ABSTRACT

The growing water scarcity and the misuse of the available water resources in the Arab Region are nowadays major threats to sustainable agricultural development sector which accounts for about 80 to 85 % of the water consumption. The majority of the Arab Region suffers from water shortages due to evident mismatches which exist between the demand and supply of water in this region which is characterized in general by arid and semi-arid climate.

During the last decade this situation has worsened further due to the occurrence of occasional droughts which hit very often the Arab Region and caused negative impacts on surface water and groundwater reservoirs, thus resulting in devastating effects on crop production and food crisis. These developments are placing enormous pressure on agricultural policy-makers and farmers.

Throughout the Arab Region, governments assume the prime responsibility for ensuring food security, and because agriculture depends increasingly on irrigation, food security is closely linked with water security.

Over 50 percent of the total value of agricultural production comes from the irrigated 15 to 20 percent of the total cultivated land. Irrigation projects can contribute greatly to increase incomes and agricultural production compared with rainfed agriculture. In addition, irrigation is more reliable and allows for a wider and more diversified choice of cropping patterns as well as the production of higher value crops. Irrigation's contribution to food security in most of the Arab states is widely recognized, but in view of the water shortages in most of the Arab Region, irrigated agriculture is expected to produce more in the future while using less water than it uses today. This implies, of course, that the security and efficiency of irrigated crops will become more important to the sustainability of the agricultural sector.

This water dilemma to produce more in a sustainable way with less water, points to the need of water demand management mechanisms to reallocate existing supplies and promote more efficient irrigation uses.

Presently water shortages have led most of the Arab states to increase food imports because the local agricultural sector is not able to produce sufficient food to fill the existing food gaps. These increasing food gaps which concern both national governments as well as the

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[1] Paper to presented by the Arab Organization for Agricultural Development

international and regional agencies which provide assistance in this field, appear nowadays to pose serious challenges beyond the economic and political capacity required for the necessary adjustments concerning the allocation and use of water in agriculture.

Despite the considerable efforts undertaken so far by most of the Arab states to mobilize their available water resources to ensure food self-sufficiency on one hand and the difficulties which the water authorities and users face in coping with the need to manage water so that it brings a sound economical return, there appear very serious indicators of a forthcoming water crisis in most of the Arab states which may worsen the situation in the future. Added to this complex water crisis context of the Arab region, is the fact that more than 50 % of the global water demand is supplied by surface water resources shared with neighouring countries. Also there exist several extended groundwater aquifers shared with these neighouring countries and which are subjected to a severe over exploitation which might have very serious negative impacts on the available ground water resources.

In order to cope with these water crisis threats, water issues in the Arab region have been the focus of increasing national and regional debates. Recently, the Social and Economical Council of the League of Arab States has charged the specialized Arab organizations, among them the Arab Organization for Agricultural Development, to prepare a Regional Arab Water Security Master Plan which should define innovative approaches to the assessment and national management of water resources and which involve the integration of sectoral water plans and programmers within the framework of national and regional economic and social policies. These approaches imply therefore the development of range of strategies and policies based upon the management of the agricultural sector water demand, which represent the largest water demand, about 80 % to 85 % of the available water resources.

In the past, irrigation water supply approaches in the Arab Region dominated irrigation water resources management practices. But today, meeting growing irrigation water demand by developing new supplies is becoming extremely difficult. In this water crisis context, there are today tendencies to shift from the water policies based totally on irrigation water supply management to new policies which rather privilege irrigation water demand. One aspect of this management may be in taking into account the economic value of water in irrigation projects. This is a very important prerequisite to management of water demand because it is noticed that despite the observed water shortages, misuse of water in agriculture is widespread in the current irrigation management practices. This is due to the failure in the past to recognize water's economic value and the real cost of water services provision. It is therefore now widely believed that managing water as an economic good is an important way to achieving efficient and equitable water use as well as encouraging the conservation and protection of scarce water resources. Yet still that for many Arab states, it is difficult to reconcile the concept of water as an economic good with the traditional idea of water as a basic necessity and human right.

Adequate water demand management in the agricultural sector necessitates also the establishment of a structure of incentives, regulations and restrictions that will help guide, influence and coordinate how farmers use efficiently water in irrigation while encouraging innovations in water saving technologies. Why irrigation water demand is indeed necessary to secure water availability ?

The package of measures being generally implemented in managing irrigation water demand tend to improve water management in general and its conservation. The main reasons which militate in favour irrigation water management comprise: a limitation of water uses; deterioration of available water resources; high costs associated with the mobilization of new water resources; and water resources shortages. Its main objectives are: the reduction of irrigation water losses; the conservation of water resources; the selection of the best water allocation scheme; the improvement of irrigation economical return; the management of drought; and finally the sustainability of agricultural development.

OPTIMIZATION OF WATER USE IN ARID AREAS

Abdullah Arar[1]

1. GENERAL BACKGROUND

1.1 Extent of Aridity in the Near East Region

The Near East Region's ecology and production are largely determined by the total amount and seasonal incidence of rainfall and, to a more limited extent, by soil type, topography and elevation. Rainfall is low, unpredictable and highly variable, and extended droughts are more the rule than exception; temperature and evaporation rates are high. Table 1 shows that rainfall is low to very low in most of the region: arid and semi-arid areas amount to about 96 percent of the total geographic area in North Africa and the Near east and 87 percent in the Middle East, i.e. Iran, Afghanistan and Pakistan.

Aridity is a major constraint to production and there is very little that can be done to change it. However, man could control his actions with respect to the hydrological cycle so that given amount of water would serve his needs without undesirable side effects such as desertification. Since it can be transported, stored, diverted and recycled, water is the most manageable of the natural resources. But interference with the hydrologic cycle involves more than hydrology and engineering; it also includes ecological fundamentals and forces beginning at the time a raindrop strikes the earth's surface and ending when it re-enters the atmosphere.

1.2 Irrigation and Productivity

The potential of irrigation water in raising both food production and the living standards of the rural poor has long been recognized. Irrigated agriculture represents only 13 percent of the world total arable land but the value of crop production from irrigated land is 34 percent of world total. This potential is more pronounced in semi-arid and arid areas like the Near East Region. In this Region the provision of irrigation water is one of the most important factors for increasing agricultural production. The present irrigated area in this Region is only 30 percent of the cultivated areas, but its production amounts to 75 percent of the total agricultural production. In large parts of the Region no crops can be grown without irrigation water.

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* Submitted at "Expert Consultation on Water Harvesting for Improved Agricultural Production" held in Cairo, 21-25 Nov., 1993. Organized by Land & Water Division, FAO Rome & FAO Near East Regional Office in Cairo.

The irrigation systems in this Region belong to the oldest in the world. Irrigation has led to considerable and sometimes dramatic increases in agricultural production. It can bring independence from erratic rainfall and thus reliability of production and stable incomes.

On the other hand, past and existing trends in food and agricultural production in the Region had led to a situation which, despite noticeable achievements, is fundamentally unsatisfactory. At present, the Region is importing more than 50 percent of its food requirements and the rate of increase in demand for food exceeds the rate of increase in agricultural production. Because aridity is the major constraint for increased agricultural production, most of the countries in the Near East Region consider irrigation development a prime way of raising agricultural production.

Although the production on irrigated lands is now a multiple of that on rainfed lands (about 7 times) it is generally believed that it could be at least doubled. This could be achieved if the fallow was reduced, the irrigation practices improved, water logging and salinity kept under control and such inputs as fertilizers, seeds, weed and pest control, and related cultural practices were brought up to adequate levels.

To achieve the production potential, the available water resources must be developed to provide more irrigation water to areas where it is scarce. Rehabilitation of supply systems is needed where designs do not permit enough water to reach the farmers' fields. Physical improvements are also needed at the level of the farms where the distribution system needs to be upgraded and controlled structures introduced, a suitable drainage system installed, the farms' fields graded or leveled, and water should be given to the crop at the right time and in the right amount. This should be accompanied by intensive training programmes for farmers and field irrigation personnel as for advisory staff and scheme operators.

To provide for this and, in general, for the effective programming and implementation of farm irrigation improvements, the setting up of irrigation services at the Central Government level is considered indispensable. These agencies should work in close cooperation with the managers of the water supply on the one hand, with organizations covering such typical agricultural fields as extension, credit provisions, marketing, transport and storage facilities on the other.

1.3 Countries' Action Programs in the Field of Irrigation

Until the end of the Second World War, the expansion rate of land and water development in the Region was very low. A rapid development started in the 1950s and gained full momentum during the 1960s. Many countries introduced national development plans in which the agricultural sector, and particularly the development of irrigation was allocated top priority. Consequently the easily accessible water resources such as river flows and shallow groundwater of good quality have now been almost entirely committed.

At present, great efforts are being made in the Region to make additional water available. In all large river basins, major surface storage reservoirs have been built or under construction (Indust, Euphrates and Nile). In other parts of the Region (Iran, Afghanistan, Syria, Jordan, Saudi Arabia, Yemen and North Africa) a number of smaller dams are in different stages of planning or execution. Saudi Arabia and Yemen Arab Republic are planning to convert the traditional spate irrigation to perennial irrigation by better control of flood water of these seasonal wadis and the use of the groundwater reservoirs in the alluvial plains of these wadis. The large groundwater basins known so far (Egypt, Sudan, Libya, Algeria, Tunisia, Saudi Arabia and Arab Gulf States) are being developed.

This process of rapid agricultural development under irrigation was accompanied by the process of desertification as marked by increasing micro-aridity and declining productivity. In many countries of the Region desertification manifestations of waterlogging and salinity of irrigated lands are major problems due to poor management of irrigation water in the conveyance system as well as in the field. Also increasing salinity of underground water and falling water tables due to overpumping is another serious problem. In Saudi Arabia and the Gulf States, for example, the artesian flow of springs and wells is decreasing, the water quality deteriorating and the water level is falling due to increased extraction and perhaps decreased recharge; thus causing seawater intrusion. On the other hand, the scarcity of water supplies, which are badly needed to meet the needs of population growth and rapid development in agriculture as well as industry has given cause for concern in formulating of national development plans in these countries. It is gratifying to report that decision makers are being increasingly involved in devising ways to optimize the use of the available supplies as well as augmenting the available water resources by non-conventional means. The latter includes two programmes, one is for increasing domestic water supply through desalination of saline water, and the other is for the treatment of the sewage effluent and its use for irrigation purpose.

2. SOME TECHNIQUES FOR INCREASING AVAILABLE WATER SUPPLY

From the above discussion it becomes evident that there is an urgent need to introduce appropriate technologies that will result in increasing water supply in arid and semi-arid areas as in the case with the Arab Countries. Such techniques are being developed and could be listed under two main headings, namely, Water Development and Management Practices and Water Conservation Measures.

The Water Development and Management Techniques include:
- Water harvesting
- Recycling of Water
- Utilization of ground Water
- Conjunctive use of water resources

- Desalting of brackish and saline water
- Use of brackish water
- Weather modification

The Water Conservation Measures include:
- Improved irrigation methods and water management at the field level.
- Reducing evaporation from water surfaces
- Conservation of water in soils
- Underground water recharge
- Controlled environment
- Reducing transpiration

In this paper the most important techniques will be discussed somewhat in detail, while others will be briefly touched upon.

2.1 Water Development and Management Techniques

2.1.1 Water harvesting

Introduction

Water harvesting can be defined as the process of collecting water from areas that have been treated to increase runoff and snowmelt. It is an ancient practice which was used over 4000 years ago by farmers in south desert of Palestine. They cleared hillsides of rocks and gravel to increase runoff, and constructed ditches to collect the water and carry it to lower-laying fields. The amount of land under cultivation was determined by the area of hillside or rainfall - collecting surface available. Although imperfect, this method permitted the development of agricultural civilizations in a region having an average rainfall of about 100 mm. Collection of runoff from rooftops is another historical method of harvesting precipitation, although the development of central water supply systems has caused it to be abandoned and forgotten in many parts of the world.

The potential for developing new water supplies by means of water harvesting is tremendous. Though the rain falls infrequently in arid lands it comprises considerable amounts of water. 10 mm of rain equals to 100 000 liters of water per ha. Although we will never capture all precipitation, we can certainly collect more than we do now. Rainwater harvesting is possible in areas with as little as 50 - 80 mm average rainfall. In arid areas and semi-arid areas the average annual rainfall vastly exceeds the stream flow. Some of this lost water is transpired by useful vegetation or percolates into underground aquifers, but most of it soakes into dry soil and then evaporates directly from the soil or is used by low-value vegetation.

Harvesting rainwater can provide water for regions where other sources are too distant or too costly or where wells are not practical because of unfavorable geology or excessive drilling costs. Rainwater harvesting is practically suited to supplying water for small villages, schools, household, livestock, and wildlife. Water harvesting by contour terraces have been used effectively in establishing orchard trees in sloping lands and in afforestation.

The livestock-carrying capacity of many arid rangelands is limited more by a lack of drinking water than by lack of feed and water harvesting can play a major role in this regard. However, livestock water development in arid ranges must be a part of an overall range management plan, including control of livestock of numbers. Indiscriminate water development has led to increased livestock numbers, overgrazing and desertification as it happened in sudan.

Methods and Material used for Water Harvesting

a. Land Alteration

One of the simplest method of water harvesting is to clear the vegetation from the land and collect the runoff from natural drainage. Smoothing and compacting the soil after the vegetation has been removed will usually further increase runoff. Another simple method is to construct contour ditches to collect runoff from hillside before it reaches natural channels and is lost.

An elaborate form of cleared soil catchments is used in western Australia. These are called "roaded catchments", for the soil is graded into a series of parallel road-ways, or gently sloping ridges, about 24 feet wide, The ridges drain into the ditches, separating them, and the ditches discharge into a collecting drain. Several thousand acres of these catchments have been installed in areas having from 12 to 14 inches average annual rainfall.

b. Vegetation Management

Changes in vegetal type or modification of cover on a water-shed also result in a corresponding change in the hydrological regime. These changes may be beneficial or disastrous depending on the circumstances and objectives. Water yield from many watersheds can be improved by vegetation managements. A summary of studies conducted throughout the world indicates that, on the average, runoff from areas with precipitation in excess of 11 inches annually can be increased by vegetation management.

c. Chemical Treatments

Treating soil surfaces with chemicals that prevent water from soaking into the soil is an intriguing approach to building low cost catchments. Runoff bare soil can often be increased by dispersing its aggregated particles with sodium salts to reduce permeability. In Arizona, it was possible to increase rainfall runoff by treating cleared and smoothed sandy loam and clay loam soils with sodium carbonate. It was also found that erosion was excessive and that treatment effectiveness was lost in about one year. Other studies at the University of Arizona have used sodium chloride on uncleared land. Initial observation indicated an increase in runoff with little or no erosion. The use of sodium salts to increase runoff is very promising, because of the low initial cost.

Highly encouraging results have been obtained recently by spraying the soil surface with sodium methyl silanolate, a material used to waterproof concrete. The silicon chemically reacts with the soil to form the inert, water repellent resin which is supposedly not biodegradable and is unaffected by temperatures up to 93 cg.

d. Ground Covers

Impermeable pavements can be constructed with asphalt. The lowest cost pavement is one already in existence for some other purpose, such as a highway. Asphalt pavements have been built on non-swelling soils by spraying asphalt compound on the soil surface. In USA, six operational catchments built in this way are in good condition after 4 to 6 years' exposure to freezing and thawing and high solar radiation.

Another type of asphalt catchment is made by placing a layer of fiberglass matting on the soil and coating it with asphalt compounds. This type of catchment is advantageous in that it is more durable than regular asphalt treatment, and it can be placed on almost any type of soil. Water running off asphalt pavements is often coloured by asphalt oxidation products which are not easily removed. The coloured water is usually odorless and tasteless and it believed to be harmless; however, the water cannot be recommended for human consumption. Research is now under way to develop spray coating to protect the asphalt against degradation and prevent the formation of contaminating oxidized materials. This coating also extends the life of the asphalt.

The plastic films can be used as low-cost ground covers to collect rainfall, but they are easily destroyed by wind. Various types of weights, including old automobile tyres, have been used to hold down plastic films; these films can also be bonded to the surface with asphalt. At the University of Arizona a study was carried out on a catchment covered by plastic films with gravel. It was found that the gravel protects the plastic against both wind and damage from weather. However, it also reduces the runoff by holding back part of the water which is then lost by evaporation. These catchments should be useful where gravel is available and maximum runoff is not required.

Reinforced artificial rubber sheeting can be rapidly and easily laid over moderately rough surfaces. Nylon rain-forced sheeting has been successfully installed over sharp cinders, about 1 inch in diameter, and on slopes up to 40 percent.

Many of the first structures made specifically for collecting precipitation in recent times were built of standard construction materials such as concrete, prefabricated asphalt planking and glavanized sheet iron. Soil cement has also been tried in a process similar to that used in reservoir seepage reduction but with limited success.

Storage of Harvested Water

In most cases, water harvesting must be provided with water storage facilities. Where water supplies are limited and water use rates exceed the supply rate, a means of storing harvested water becomes an essential part of the water harvesting system. The storage generally means confinement in either excavated pits (hafiers), cisterns, ponds, bags or tanks. One exception to this type of storage is direct storage in the soil profile associated either with recharge of groundwater and / or with runoff farming.

Even with runoff farming, conventionally storing water for later controlled release to the crop may be necessary if precipitation uniformity and / or variability do not meet the crop requirements.

Storage requirements can be readily estimated by considering the purpose for which the water will be used and the use period. Storage requirements should be balanced against the quantity of precipitation for the area and the reliability of receiving this precipitation. The precipitation quantity and dependability generally are often more difficult to determine due to inadequate precipitation records.

Water loss through evaporation and seepage are important elements to be considered in water harvesting endeavour, which are discussed, elsewhere in this paper.

Choice and Cost of Water Harvesting Methods

Water harvesting methods are site specific and before a system can be installed, the soil characteristics (water holding, infiltration, erodability), topography (slope, surface roughness), precipitation characteristics (amount, reliability), and the climate should be known. In addition, factors such as land, labour and material costs, water use rate and distribution, water quality desired and availability of materials should also be taken into consideration.

None of the rain water harvesting has been subjected to a long-term economic analysis. Large field trials in different areas are needed to build up a data base that could lead to a better understanding of the economic viability of different methods in different economic environments. Developing countries particularly need the data, because most of the technology was designed for Australia or the United States. With adaptive research to fit the needs, economic and materials of developing countries, rainwater harvesting methods may be of exceptional and immediate value. The major technical research need is to reduce the cost of sealing catchments soils and to make the treatment practical for a wider variety of soils and situations.

In the USA, despite the relatively small amounts of time and effort devoted to research, excellent progress has been made in reducing the cost of catchment structures and showing the potential value of water harvesting. In 1960 the initial cost of catchments was US$ 2 to 3 per square yard and annual maintenance cost were about 10 cents per square yard. At the present the initial cost is about 10 cents per square yard and annual maintenance costs 2 cents per square yard. The average cost of harvested water in the USA in 1975 was about US$ 65 per acre foot. This figure however varies greatly depending on the amount of rainfall, methods and materials used for water harvesting and water storage and the location and size of the project and value of land.

The cost of harvested water, reported by the University of Arizona, after extensive studies, as related to the type of catchment treatment and range and average rainfall is summarized in Table no. 2.

2.1.2 Recycling of Water

In arid areas, water reuse may have a great impact on future usable water supply than any of the techniques discussed in this paper. Reusing water can greatly lower the overall demand for water resources. Waste water, such as sewage, drainage and irrigation runoff, can be used for irrigation, industry, recharge of groundwater; in special cases, properly treated wastewater has been used for municipal supply. In the Gulf States as well as in several other Arab countries, big plans are being formulated for the use of the sewage water for irrigation. One of these schemes is already operating in Kuwait involving about 900 ha. It is reported that the most promising source of water for irrigation in Kuwait is treated sewage effluent. It is also estimated that in 10 years time, Kuwait can put 3000 ha of land under irrigation with treated sewage effluent. Similarly all Arab Gulf States have now a policy to treat and reuse all wastewater mainly for irrigation purposes.

Another striking example on the importance of the use of treated sewage effluent for irrigation is Jordan. It is projected that by the year 2010 all the available water resources of the country (surface and underground) will be fully utilized for domestic, industrial and agricultural purposes. At this time, the domestic and industrial requirement will amount to about 400 million cubic meters (MCM), which amounts to about 30% of the total available water resources (surface and underground). After proper treatment a large percentage of these huge quantities of water could be made available for meeting the increasing demands for water by industry and agriculture. It is estimated that 36 MCM of wastewater were used in 1990 for irrigation purposes in Jordan. It is also projected that this amount will increase to 70 MCM & 140 MCM in the year 2000 and 2015 respectively.

When contemplating to wastewater for irrigation, appropriate sewage treatment has to be chosen that will produce effluent which meets the recommended microbiological and chemical quality guidelines for unrestricted irrigation, both at low cost and with minimal operational and maintenance requirements. It is because of the great importance of recycling water for irrigation that the FAO Regional Commission for Land and Water Use in the Near East recommended to FAO to organize a Regional Seminar on the Treatment and Use of Sewage Effluent for Irrigation. This Seminar was held in Cyprus in early 1985. The purpose of the Seminar was to exchange worldwide information and experience on the treatment and reuse of sewage effluent for increased agricultural production without hazards to public health and the environment. Twenty four papers from countries throughout the world were presented covering the following topics:

- Irrigation water standards (chemical and biological) and the required degree of sewage treatment for irrigation.

- The short and long term effects of the use of sewage water for irrigation on soil productivity, public health and the environment.

- Appropriate sewage treatment in connection with irrigation, such as the use of waste stabilization ponds, aerated lagoons, deep maturation ponds, soil profile and the recharge of underground water.

- Sludge treatment and disposal in connection with its agricultural utilization.

- Case studies for several countries inside and outside the Near East Region.

The proceedings of this seminar were published in 1988 by Butterworths in a book which is available at F.A.O.

2.1.3 Utilization of Ground Water

Several productive aquifers in the Arab World are storing large quantities of water that can be tapped. The development of such aquifers of this type is now proceeding in several parts of Egypt (New Valley and other oases), Algeria, Libya, Tunisia, Saudi Arabia, Jordan and the Gulf States. Since the recharge of such aquifers is either too small or nil, its development must be undertaken with the full understanding that usually the supply is depleted within a few decades and capital investment must be amortized within that time. Under such conditions, agricultural development must be associated with industrial and / or tourism development to avoid ghost towns in the future.

Large international ground water aquifers exist in the Near East Region, such as :

i. The Nubian Sandstone Basin in Chad, Egypt, Libya and Sudan.
ii. The deep aquifers of the Arabian Peninsula.
iii. The Taoudani Basin in Mali, Mauritania, Algeria and Niger.
iv. The Northern Sahara Continential Intercalaire Basin in Algeria, Tunisia and Libya.

There is a need to carry out studies on the utilization of these basins which will include, among other things, the optimum use of groundwater resources, control of over-extraction, alternative choices and a time scale for the exploitation of aquifers. There is a need to formulate an action programme for the execution of feasibility studies to arrive at an agreed approach in the development of the desert areas, aquifers, sociological and ecological aspects acceptable to the countries concerned.

The use of groundwater for irrigation to supplement rainfall and surface water can result in reliable and high yields. However, most of the shallow groundwater has been exploited in the ARAB World, but several Arab countries have initiated development projects based on water from deep wells.

Recent studies carried out by FAO showed that the cost of water from deep wells is high and might reach US Cents 25 per cubic meter (see table no. 3). Nevertheless, if the quality of this water is good, its cost is cheaper than the cost of desalted water from brackish or seawater, which is now more than US$1.0 per cubic meter. However, irrigation projects based on ground water derived from deep wells are expensive (more than $4000 /ha) and normally fall in the category of high to very high expensive irrigation projects. Hence, if groundwater from deep wells has to be used for irrigation purposes, advanced agricultural technology and high value crops have to be introduced so as make this enterprise economically viable. On the other hand, in special circumstances, social and food security considerations may play a major role in justifying the use of groundwater from deep wells for the production of food at present time.

2.1.4 Conjunctive Use of Water Resources

A study was carried out in 1984 by Arar for ICARDA on the role of supplementary irrigation in increasing productivity from rainfed agriculture in the Near East Region. This study showed that supplementary irrigation on cereals, particularly wheat, will guarantee a minimum yield of more that 3.5 t /ha in the wheat growing areas of the region (350 mm rainfall and above) with an amount of water varying from 50 to 200 mm depending on the zone and the amount and distribution of the seasonal rain. The present average yield in the region 1.5 t / ha. This means an increase of more than 100%. In addition to securing relatively high and reliable yield, irrespective of the seasonal rainfall, supplementary irrigation can also provide the conditions which are suitable not only for using high inputs (high yielding varieties and high rate of fertilizers) but also for more intensive cropping.

The conjunctive use of water resources (i.e. irrigation water to supplement rainfall) will increase considerably the efficiency of the utilization of water resources as a whole for the production of food and fibers. It has been found that a linear relationship exists between cereal yields and the amount of rainfall during the growing season. This relationship is represented by the following regression equation:

$$Y = C(R - Ro)$$

Where
- Y = Yields of grain t / ha
- C = Coefficient varies from 0.014 to 0.016 (is a measure of water use efficiency of the crop)
- R = Total water in mm (rain and / or irrigation) up to 600 mm
- Ro = The minimum amount of water in mm which is required to produce cereal vegetative growth with no grains. This ranges between 100 to 150 mm.

From the above it becomes evident that the first 100 to 150 mm of water (Ro) will produce no grains, and every mm above that (whether from rain or supplementary irrigation) will produce about 14 to 16 kg of grain / ha. Hence the efficiency of the conjunctive use of supplementary irrigation with rainfall becomes evident. This irrigation water could be from surface water, ground water, treated sewage water and from water harvesting etc.

2.1.5 Desalting of Brackish and Saline Water

Desalting of brackish water from surface and underground water sources and sea water offers inexhaustible sources of water for arid and semi-areas. In the early 1970s and before the steep rise in the cost of energy it was projected that by 1990 the cost of desalted water from the sea will drop to 5 US Cents per cubic meter from desalination plants with a capacity of more than 4 million cubic meters per day. However, due to the rise of oil price after 1973, this projection is no longer valid. At present the cost of desalted water from brackish water of 3 000 to 10 000 ppm using the reverse osmosis process (the most suitable for such water) is just about US $1.0 / cubic meter. While the desalted water from the sea using multistage flash (the most suitable) cost about US $1.5 m^3. This cost is still higher than the cost of groundwater from deep wells. But in the absence of a local fresh groundwater sources, desalination of salty water for domestic and industrial purposes is the only alternative for many locations in the arab world.

At this point it may be mentioned that the latest developments in the field of desalting of water in the USA indicate that the freezing process is the most promising method in terms of coastwise and energy savings. This is followed by reverse osmosis, then the flash methods.

Finally, the developments of the past 15 years have brought about significant changes in the science of desalting the sea and the momentum of advance is such that further improvements are certain to occur. The most important step, however, will be the transition to large- scale equipment and the use of atomic energy as a source of power for desalting water and electricity generation. But the rate of such transition will be governed by the policies of governments, i.e. by commitments to develop new land which relies on desalted water sources, by water pricing policies and by subsidizing of the initial steps in the scale-up of units. In the next 15 to 20 years, we will begin to reap the fruit of our labours to make the deserts green and millions of people will face the future with new hope and confidence.

2.1.6 Use of Brackish Water

Beneath many of the world's desert there are huge reserves of brackish water, and - such as landlocked lakes and irrigation return flows - also contains fairly large amounts of salt. If saline water could be used for irrigation more desert land could be cultivated, and non-saline water now used in agriculture could be released for human consumption. This would also reduce the need for expansive desalination schemes now contemplated for supplying urban areas.

New appreciations of soil science and plant physiology and new irrigation techniques show that with careful management saline water can be used to grow a variety of crops. In Abu Dhabi, United Arab Emirates, more than 10 000 ha of plantations have been established using saline ground water (up to 10 000 ppm of salts) to irrigate mainly forest trees on deep sandy soils of undulating and sometimes steep slopes. This was made possible by the introduction of the drip irrigation method.

2.1.7 Weather Modification and Fog Harvesting

Certain cloud formations contain super colled water; rainfall augmentation hastens precipitation of this water. Adding ice, frozen carbon dioxide and silver iodide causes dramatic ice-crystal formation and produces rain. This method is known as cloud seeding.Though there is a keen interest in cloud seeding in arid lands, experience indicates that the best opportunities for increasing precipitation are in areas where cold, wet air masses are swept upward over mountain ranges. Prospects for increasing precipitation over lowlying arid lands do not seem promising, primarily because of the scarcity of water rich clouds. Arid lands that benefit from cloud seedings will probably be those fed by streams originating in mountains.

The results of cloud seeding are difficult to predict because of the still imperfect knowledge of the physical process causing precipitation. Detailed physical analyses of some cloud systems may in the future allow one to predict the effects of cloud seeding, but research is in the very early stages.

Fog harvesting is another technique which may well be an important source of water for some coastal and mountainous areas. This technique is being developed in Chile since 1987 with financial support from the Canadian International Development Research Center.

The fog collectors used consist of rectangular frames of about 2 meters high with lengths of a few to several meters. It is a triangular weare of flat nylon threads one mm wide into a mesh with a pore size of about 1 cm. Under Clile conditions, it was found that about 5 to 10 litres of fresh water could be collected from each meter square of the frames per day and the present cost was found to be about \$ 1.1/ m^3. The present loss of water to the people in the trial site is U.S.\$ 8.0 m^3. More details on this technique, including the design of the fog collectors as well as the meteorological and geographical considerations and the costs could be obtained from:

- Atmospheric Environment Service, Downsview - Ontario, Canada M3H5T4
- University of Chile, Casilla 2777, Santiago, Chile.

2.2 Water Conservation Measures

In arid areas, measures to increase the efficient use of available water resources are as important as finding additional sources of water. In these areas, the greatest opportunity of increasing water supplies is by improving existing water systems, thus making more water available without a completely new installation. Significant amounts of water can be saved by improving water management on the farm, a topic agriculturalists in many areas often neglect. Fields are often inadequately levelled and very small undulations can waste large amounts of water. Precise landshaping and skilled labour are required. The following is a summary of the different measures that could be used for conservation of water.

2.2.1 Improved Irrigation Methods and Water Management at The Field Level

Conveyance losses of irrigation water could be reduced by lining open canals or conveying water in pipes. However, standard irrigation methods are particularly wasteful of water in arid areas because the extended areas of wetted soils greatly encourage evaporation. Furthermore, field application losses through deep seepage and evaporation range from 30 to 50 percent. By the use of trickle irrigation, evaporation and deep seepage losses are minimized. In the case of sprinkler, convenience and application losses could be minimized while evaporation losses could be high under semi-arid and arid conditions, especially during the day and in windy areas. Trickle irrigation is potentially important for many irrigated crops in arid lands. It has been used successfully on trees, vines and row crops, especially vegetables. It has particular promise for slopes, or rocky areas where land levelling for conventional irrigation is very expensive. The efficient use of this system compared with surface irrigation and sprinkler irrigation is high. This means that with the same amount of available water, more area can be cultivated and the yield per unit area might also be higher as compared to the conventional irrigation methods. With trickle irrigation it is also possible to use relatively poor quality water.

Rising energy and labour costs and water shortage are creating an urgent need for the development of new energy, labour and water efficient irrigation systems in many areas. Irrigation systems are needed which maximize irrigation distribution and application efficiencies, and at the same time, minimize the energy and labour required for operation. The newly developed automated surface irrigation systems in western USA are highly efficient, not only with labour and energy saving, but also with water distribution. These irrigation systems include level-basins and surge-flow for automated surface irrigation (both of which are suitable for field crops grown in flat and / or furrows), and a low-head bubbler system which seems to be promising for the irrigation of orchards.

2.2.2 Reducing Evaporation From Water Surface

The invisible loss of water through evaporation from surface water in arid areas is much more than one would think. To give an example; the estimated losses of water from Lake Nasser, through evaporation, is about 10 milliard cubic meters per year. Hence this aspect of water conservation in arid and semi-arid areas is very important but it has not received serious attention, so far.

Many methods have been investigated to control evaporation from free water surface. These methods are categorized by energy-reducing treatments, like changing the water color, using wind barriers, shading the water surface and floating reflective covers. Of the four energy-reducing categories, floating covers have been the most widely researched and certain materials seem most promising for use in water harvesting storage facilities. These include covers of continuous paraffin wax, polystyrene rafts, and foamed rubber. All these three covers reduce evaporation by 85% to 95%. The use of spreading films over the water surface also provides a physical barrier to evaporation. Straight chain fatty alcohol including hexa and octa-decanol were found to be effective in reducing evaporation. These substances form one-molecule thin layer on the water surface and are not toxic to fish or humans.

The selection of one of these methods will depend mainly on economic considerations and local conditions. Normally, the cost of water saved in high evaporation areas compares favorably with alternative water sources. Wind damage to these floating covers can be a disadvantage. Joining the polystyrene rafts together helps to minimize the wind problem, as does maintaining an adequate freeboard with the foamed rubber.

In case of monomolecular film cover (octa-decanol) wind and wave action, was found to destroy the film making frequent application necessary. Critical analysis of the economic feasibility of using this method, by United States Bureau of Reclamation (USBR) to increase water yield indicated that value of water saved should exceed US$ 70 per acre-ft to break even. The repetitive application necessitated by the winds is the largest factor in the high cost of evaporation. On small reservoirs or ponds, less than 500 acres, the wind and wave action is not severe and use of monomolecular film appears to be a feasible means of water savings in most areas.

2.2.3 Conservation of Water in Soils

Many techniques are used to conserve moisture once it reaches the soil in the field. Evaporation from soil surface could be reduced effectively by the use of covers or mulches (plastic or friable top soil).

In sandy soils, the use of a thin layer of bitumen placed at about 60 - 90 cm below the ground surface by special machines has resulted in reducing considerably the percolation losses below this layer.

The use of hydrophylic soil amendments will reduce evaporation losses from soil surface and deep seepage losses. Soils with mixed hydrophylic (water attracting) chemicals can absorb water, thus keeping it safe from evaporation or deep seepage and making it available to plant roots for an extended period.

2.2.4 Ground Water Recharge

There is a growing interest in artificial recharging of groundwater because it provides ready made storage reservoirs free from evaporation and protected from pollution. In arid areas rain usually comes in sudden storms and flows down naturally occurring river channels called wadis. These wadis invariably have an impermeable layer at about 30 cm below the river bed, which prevents any water from reaching an aquifer that may lie beneath it. It has been estimated that about 80% of runoff in a typical storm is lost to man's use because of high evaporation. The critical operation then is to divert as much as possible of the available water to the ground water aquifer or wells as quickly as possible.

Rainwater harvesting can be combined with artificial recharge of ground water. Runoff from local rainstorms could be collected in depressions, then artificially recharged to groundwater.

2.2.5 Controlled Environment

High agricultural productivity has been achieved with small amounts of water in arid regions such as El Saadyyat in Abu Dhabi and Kuwait, through the use of controlled environment. The system consists of growing crops within watertight but transparent enclosures; the amount of water normally lost can be greatly reduced and the atmosphere around the plants can be manipulated to maximize productivity. These are costly systems, but high agricultural productivity can be achieved with small amounts of water in very inhospitable regions.

Furthermore, such systems do not require fertile soil and crops are grown in the desert and on beach sands, as the necessary nutrient are mixed with water and delivered by timer-contolled trickle irrigation. Greenhouses can be evaporatively cooled and humified during the summer with raw seawater or brackish groundwater, further reducing irrigation requirements. Due to the well controlled environment, year-round plant growth is maximized in the abundance of desert sunlight. Area unit production of greenhouse vegetables can be increased over open field production by a factor of ten to forty because of these controls and prolonged growing seasons.

2.2.6 Reducing Transpiration

Only one percent of the water absorbed by roots is incorporated into plant tissues as 99% moves up through the plants and passes into the atmosphere as water vapour. This process, called transpiration, differs from evaporation in that it takes place on living tissue and is influenced by the physiology of the plant.

One hectare of growing vegetation can transpire as much as 100 cubic meters of water per day. If a practical way of reducing transportation could be found without affecting the crop yield, a substantial reduction in water demand could be achieved, especially in arid lands. Plant breeding to produce strains of high water use efficiency is needed. It is claimed that, in the future, with developed crops of high water use efficiency, growing controlled environment, it will be possible to produce one man food for day with only 200 liters of water.

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Table 1. EXTENT OF ARIDITY IN COUNTRIES LISTED BELOW AS REFLECTED IN RAINFALL DATA

Region or Country	Total area	Amount of Rainfall				A + B
		A Less than 100mm		B 100 - 400 mm		% of
	1000 sq.km.	Area (1000 sq.km)	%	Area (1000 sq.km)	%	total
North Africa 1/	5 751	4 864	85	653	11	96
Near East 2/	3 705	3 033	79	589	16	95
Middle East 3/	3 100	548	18	2 132	69	87
Sudan	2 625	764	29	500	19	48
Somalia	637	170	27	300	47	74
	15 818	9 379	60	4 174	26	86

1/ Algeria, Egypt, Libya, Morocco and Tunisia
2/ Bahrain, Cyprus, Iraq, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen Arab Republic
3/ Afghanistan, Iran and Pakistan

Table 2. WATER HARVESTING CATCHMENT CONSTRUCTION: WATER COST* (IN DOLLARS) PER THOUSANDS OF LITERS OF RUNOFF FOR VARYING ANNUAL PRECIPITATION RATES

CATCHMENT TREATMENT		Range (mm)	100-200	200-300	300-450	400-600	400-850	600-900	600-1200	800-1200
		Average (mm)	(150)	(250)	(375)	(500)	(625)	(750)	(900)	(1000)
I	EARTH STRUCTURES									
	Land Clearing		0.28	0.17	0.11	0.08	0.07	0.06	0.05	0.04
	Road Catchments		0.51	0.31	0.20	0.15	0.12	0.10	0.09	0.08
II	CHEMICAL									
	Sodium Chloride		0.36	0.21	0.14	0.11	0.08	0.07	0.06	0.05
	Sodium Carbonate		0.59	0.35	0.24	0.18	0.14	0.12	0.10	0.09
	Wax (Paraffin)		2.02	1.21	0.81	0.61	0.48	0.40	0.35	0.30
III	ASPHALT									
	Fiberglass Asphalt Chipcoated (FAC)		0.60	0.35	0.24	0.18	0.14	0.12	0.10	0.09
	Asphalt-Plastic-Asphalt-Chipcoated (APAC)		0.80	0.48	0.32	0.24	0.19	0.16	0.14	0.12
	Asphalt-Rubber		1.06	0.64	0.42	0.32	0.25	0.21	0.18	0.16
	Asphalt-Concrete		3.01	1.81	1.21	0.90	0.72	0.60	0.52	0.45
IV	SYNTHETIC MEMBRANES									
	Graveled Polyethylene Plastic		0.88	0.53	0.35	0.26	0.21	0.17	0.15	0.13
	Reinforced Mortar-Covered Poleythylene Plastic		1.65	0.99	0.66	0.50	0.40	0.33	0.28	0.24
	Sheet Metal		2.48	1.48	0.99	0.74	0.59	0.49	0.32	0.37
	Chlorinated Polyethyline (PCE)		5.04	3.03	2.02	1.88	1.21	1.01	0.86	0.76
	Artificial Rubber		6.26	3.75	2.50	1.88	1.50	1.25	1.07	0.95

* Water costs are based on capital cost, average catchment efficiency, annual maintenance and average 20 year annual amortization at 8% interest rate. Water costs do not consider storage losses.

TABLE 3. COMPONENT OF WATER COST FROM DIFFERENT DEPTHS OF WELLS - SYNTHESIS OF WELL DATA

TD	Q	Pump L	Q * TD	Equip. cost	Total Well cost	Energy cost *		Average annual energy cost (10^3 $)			Capital & Replacement costs (10^3$)			GW cost (US$ /10^3m^3		
						diesel	elect.	h. of pumping			Well**	Pump***	Total Incl. 4% mainten.	h. of pumping		
(m)	(M3/H)	(m)	(10^3 US$)	(10^3 US$	(10^3 US$	($ /h)	($ /h)	2880	3600	4200				2880	3600	4200
100	50	80	5	5.5	44.5	0.64	0.69	1.93	2.41	2.81	5.67	3.75	9.79	81	68	60
200	100	150	20	12.6	61.5	4.66	5.00	13.83	17.28	19.57	7.10	8.59	16.31	105	93	85
300	150	200	45	20.4	91.7	9.33	10.00	27.65	34.56	40.32	10.36	13.90	25.23	122	111	104
400	200	300	80	28.7	132.6	18.66	20.00	55.58	69.12	81.06	15.10	19.57	36.05	159	146	139
500	250	400	125	37.4	185.0	31.12	33.30	92.16	115.20	134.40	21.44	25.83	48.78	196	182	174
600	300	500	180	46.5	250.0	46.67	50.00	138.24	172.80	201.60	37.14	31.07	70.93	242	226	216
800	400	600	320	56.1	416.0	74.60	79.90	221.80	277.20	323.40	64.80	61.60	131.50	114	91	78
1000	500	700	500	65.4	628.7	108.80	116.60	322.60	403.20	470.40	95.00	103.30	206.20	143	115	98

* Energy cost calculated on the basis of: overall pump eff. x motor eff. = 0.6
diesel oil cost: $0.26/lt.; electicity: $0.08/kwh

** Capital cost I = 5; N = 20. Replacement cost I = 10; N = 20

*** Capital cost I = 5; N = 20. Replacement cost I = 10; N = 7

TD = total depth

Q = well discharge

GW = groundwater

LAND RECLAMATION PLANS IN EGYPT AND WATER REQUIREMENTS UP TO YEAR 2012

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ABSTRACT

Egypt is importing a large portion of its food needs, hence increase in food production becomes a national goal. Horizontal expansion through land reclamation projects is essential to satisfy the food requirements for a population of over than 58 millons increasing at the rate of 2.5%. Reclamation projects will ease pressure on old lands as compensate the land lost in urban development. The River Nile represents the main source of water for Egypt. No other natural resource, apart form groundwater is available except some rainfall along the coastal strip which does not exceed 150 to 200 mm/ year. Groundwater is also limited in quantity and quality at certain locations.

This paper focuses on the investigation of land reclamation plans in the sight of present water requirements and in the future considering the increasing needs of the cultivated area. Suggested approaches for the tools and alternatives are discussed. Regarding land, per capita of arable land in Egypt has been decreased from 0.48 in year 1887 to 0.13 in year 1990 despite the land reclamation programs. The Ministry of Public Works and Water Resources (MPWWR) suggested that, Water Master Plan Project (1983), an area of about 2.8 million feddans could be irrigated in addition to the 5.9 million feddans under cultivation in 1982. Data related to land reclamation is collected. The data is assembled and an inventory of reclaimed lands since 1950, the present and anticipated future projects is presented. The second limiting major constrain in the reclamation process is water availability. Under the limited share of Egypt from the River Nile, the optimum utilization of water resources is vital. The water needed to satisfy the reclamation plans is calculated on the basis of the prevailing cropping patterns. Two scenarios have been addressed 1) for improving the irrigation systems in the new lands and its related influence on the water requirements up to year 2012 2) for modifying the reclamation plans for cropping pattern consideration related to the water quality at different agricultural seasons and located areas.

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Plans d'Amendement des Terains en Egypte
et Besoins de l'Eau jusqu à l'année

ABSTRAIT

L'Egypte importe une large potion des ses besoins alimentaires. De là, l'augmentation de la production alimentaire deviant un but national. L'expansion horizontale par les projects d'amendement des terrains est essentielle pour satisfaire les besoins alimentaires d'une population de plus de 58 millions cette année et augmentante à un taux de 2.5%. Les projects d'amendement soulageront la pression sur les anciens terrains et compenseront la perte des terrains causée par le développment urbain. Le Nil représente la source principale de l'eau pour L'Egypte. Il n'y a plus d'autre ressource naturalle sauf l'eau souterraine et la pluie sur le long de la bande côtiere. La pluie ne dépasse pas 150 à 200 m/an. La quantité et la qualité de l'eau souterraine sont aussi limitées à certaines régions.

Cet article concentre sur l'investigation des plans d'amnedement avec la considération des présents et futurs besoins de l'eau conformément à leur augmnetation aux régions cultivées. Les approaches proposées pour les outlits etles alternatives sont discutées. La surface des trrains arables par personne a diminué de 0.48 en 1887 à 0.13 en 1990 malagré les programmes d'amendement des terrains. Le Ministére de Travaux Publics et de Ressources d'Eau a proposé, selon le project Water Master Plan (1983), qu' une région de presque 2.8 millions feddans peut être irriguée en plus de 5.9 millions feddans qui sont au cours d'être cultivés depuis 1982. Les données concernant l'amendement des terrains sont collectées. Les données sont assemblées et un inventaire des terrains amendés depuis 1950 et des projects prèsents et futurs est présenté. Le seconde principle contrainte qui limite le procès d'amendement est la disponsibilité de l'eau. Avec une part limitèe de l'eau du Nil pour l'Egypte, une utilisation optimale des ressources d'eau devientvitale. Le calcul de l'eau nècessaire pour satisfaire les plans d'amendement est basé sur la dominance des surfaces cultivées. L'utilisation quantitative et spatiale des ressources d'eau non convetionnelles comme le re-usage de l'eau originairement utilisée en agriculture ou celle des égouts en irrigation ou même en expansions des projects d'eau souterraine est discutée. Deux scenarios sont adresssés: 1) pour améliorer les systèmes d'irrigation aux nouveaux terrains et l'infulence apparentèe sur les besoins d'eau jusqu' à l'année 2012 2) pour modifier les plans d'amendement conformément à la qualité des l'eau ax différentes régions et saisons agricoles.

1. INTRODUCTION

In the light of Egypt's growing population there is a great necessity for increasing domestic food production. Egypt has reached a stage where land reclamation projects have become essential to satisfy food requirements, and to reduce dependency on food imports. Such projects will also ease pressure on old land as well as compensate for the land lost to urban development. On the other hand effective use of water through the increase of efficiency and application becomes a matter of major concern in Egypt.

Construction of the High Aswan Dam in the sixties enabled the country to intensify land use to year-round cropping and to expand the irrigable area further. The progress in the gross cultivated area in the period between the year 1950 up to the year 1989 is shown in Figure 1 which indicates an increase in reclaimed lands by about 1.73 million feddans through this period.

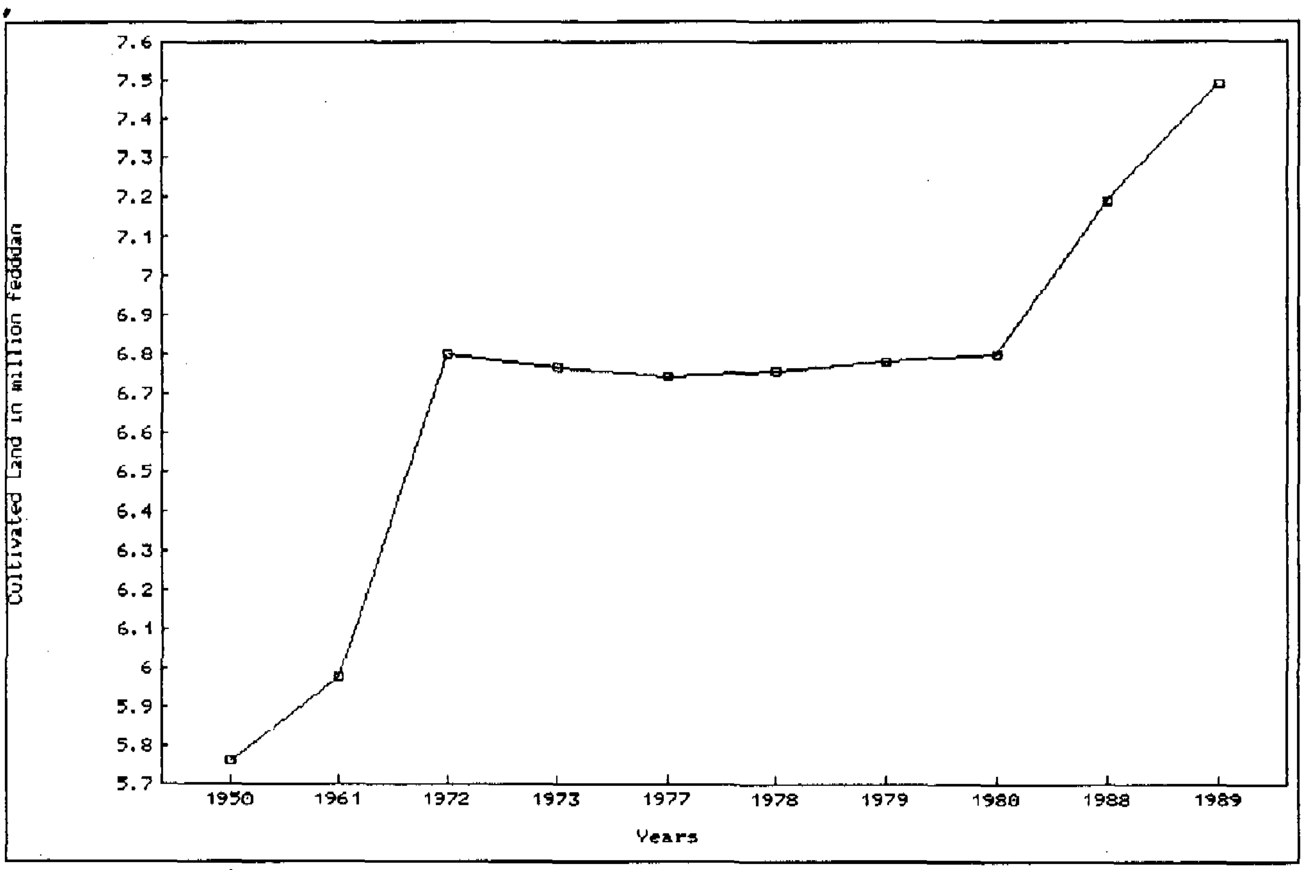

Figure 1: Progress in Land Reclamation in Egypt

The main constraint for land reclamation in Egypt is the water availability. In 1800 the population of Egypt was 2.5 million, the cultivated area was 2.5 million feddans (1.0 feddan = 0.42 hectare) and the Egyptian water quota was about 48 billion cubic meter per year coming up with a per capita share per annum to about 20,000 m^3. In 1990 the population increased to about 55 million with a total cultivated land estimated at 7.4 million feddans and a water quota of 55.5 billion cubic meter per year. Consequently the per capita share in Egypt of agricultural land reduced from almost 1.0 feddan in the year 1800 to less than 0.14 feddan (about 600 m^2) in the year 1990. In mean time the per capita share of water declined to a slightly more than 1000 m^3/year; just on the border of the so called water poverty line. By the year 2020, the Egyptian population which is now growing at a rate of almost 2.5% every year; is expected to rocket to some 100 million.

Other minor water resources include small quantities of rain which falls on the northern coastal strip of the country parallel to the coast of the Mediterranean Sea with total intensity of 150-200 mm/year in addition to some fossil groundwater reservoirs in the Western Desert.

The potential of increasing Nile water supply through the reduction of evaporation from the huge swamps and marches in Sudan is promising. However, the political crisis in the southern part of the country which lasted for the past decade restricts the development of this potential.

From the above mentioned, it is obvious that Egypt is approaching an era of water starvation rather than water poverty at the mean time land reclamation is an essential target to sustain food for the rapidly increase in population.

The paper objective is to highlight the actual land reclamation potentials in Egypt with respect to surface water resources and presetnts two scenarios which may aid in meeting future water demand to fulfill the government plans.

2. EGYPT'S LAND RECLAMATION PLANS

Intensive land reclamation projects in Egypt started early in the fifties and continued until the mid-sixties. Since then a clear slow down in these projects was observed up to the year 1980. From 1980 and onward and owing to the ambitious plans adopted by the state; a sharp increase in land reclamation took place.

However, newly reclaimed lands and the lands to be reclaimed during the coming few decades have to be defined with respect to their areas (gross and net), cropping patterns (winter and summer) and the status of development of these lands in order to quantify their actual water requirements. The sources of data on which this study is based on are the records of both Ministry of Public Works and Water Resources (MPWWR), Ministry of Agriculture (MOA), General Authority of Reclamation Projects and Development (GARPAD) and other published studies such as The Land Master Plan conducted by Pacer/Euroconsult, 1983.

The Land Master Plan (LMP), a survey for the available lands suitable to be reclaimed indicated that for the short feasible term plans an area of about 1.8 million feddan can be reclaimed and a total area of about 2.8 feddan for the long term plans. Most of the land reclamation plans has considered Pacer's study as a base. However, the actual data indicated that some lands have already been reclaimed out of the suggested areas by LMP.

3. DATA ANALYSIS

Reclaimed lands in Egypt are classified through this study into four groups according to its reclamation age and productivity as follows:

3.1 Old New Lands (ONL)

The lands reclaimed from more than 10 years is considered in this study as ONL. That is because, these lands should have reached their ultimate production. This assumption considers all the reclaimed lands before 1982 to be classified under this category. Table 1 shows the reclaimed areas before 1978 and during the first five year plan 1978/82 for different regions. The reclaimed lands up to year 1978 are estimated at 685,600 feddans, followed by 112,300 feddans in the period from 1978 to 1982.

3.2 New New Lands (NNL)

This category of classification considers the lands that has been reclaimed from less than ten years ago and did not reach the ultimate productivity, i.e. during the two National Development Five Year Plans 1982/87 and 1987/92, as new new lands. The total reclaimed area during the period 1982/87 is estimated at 140,260 feddans, while 412,300 feddans were reclaimed in the period of the five year plan 1987/92.

3.3 Present Plan for Land Reclamation (PPLR)

Egypt has decided to continue the national program for development which includes the land reclamation as part of its activities through five years plans. The lands proposed to be reclaimed in the Third Five Year National Development Plan 1992/97 are classified as the reclaimed lands in the present plan. The amount of land proposed to be reclaimed during this current plan is estimated at 882,700 feddans.

3.4 Future Plans for Land Reclamation (FPLR)

The remaining reclaimable lands after the year 1997 will form the future land reclamation potentials in Egypt. The total available lands for reclamation is estimated by about 1,881,600 feddans. The study assumed that the land reclamation plans will continue by the current inertia in the future. So it is expected that this remained area is to be reclaimed by year 2012. However, due to the increase in population, these future plans land reclamation is a hope where water will be the only constraint. Table 1 shows the reclaimed areas in each region considered as ONL, NNL, PPLR and FPLR.

Table 1. Previous, Present and Future Land Reclamation Plans in Egypt (area in 1,000 feddans)

Period	East of Delta	Middle of Delta	West of Delta	Upper Egypt	Total
1. Old New Lands (ONL)					
Up to Year 1978	91.3	153.7	289	151.6	685.6
1978-1982	60.01	1.6	46.92	3.85	112.38
2. New New Lands (NNL)					
1982-1987	19.73	12.78	98	9.75	140.26
1987-1992	109.4	39.3	215.9	47.7	412.3
3. Present Plan for Land Reclamation (PPLR)					
1992- 1997	523.17	62.5	176.5	120.7	882.87
4. Future Plans for Land Reclamation (FPLR)					
After 1997	608.93	11.7	330.6	930.4	1881.63
					4115.04

Accordingly, the total cultivated lands in Egypt if the Development Plans continues up till year 2012 could be as shown in Table 2

Table 2. Egypt Cultivated lands According to Expected Land Reclamation Plans (area in 1,000 feddans)

Year	Reclaim. Land	Acc. Reclaim. Land	Considered NNL	Considered ONL	Total Cultv. Area
1978	685.6	685.6	685.6	0.0	5,938.4
1982	112.4	798.0	112.4	685.6	6,624.0
1987	140.3	938.3	252.7	685.6	6,764.3
1992	412.3	1,350.6	552.6	798.0	7,176.6
1997	882.0	2,232.6	1,254.3	938.3	8,102.0
2002	610.6	2,843.2	1,492.6	1,350.6	8,712.6
2007	572.6	3,415.8	1,183.2	2,232.6	9,285.2
2012	698.3	4,115.0	1,271.8	2,843.2	9,983.0

4. WATER REQUIREMENTS ESTIMATION

Calculation of water requirements for reclaimed lands is based on the following considerations: location of the reclaimed area related to different regions; age of reclamation, i.e. old new land or new new land; irrigation efficiency; and cropping pattern.

Since climatic conditions in Egypt do not vary considerably from one year to the other, the area of cultivated "old" land is almost constant, the crops grown are more or less the same and the crop water requirements throughout the year are very well known. Consequently, it is easy to determine the monthly and annual water requirements for irrigation in the old lands which is expected to remain unchanged during the coming years expect of minor reduction in the area due to its conversion into residential and public buildings and other utilities and facilities.

4.1 Cropping Pattern

To estimate the water demand for old new lands, a representative cropping pattern has been chosen according to field visits and consulting of concerned authorities. Table 3 shows the chosen cropping pattern for old lands .

Table 3. Cropping Pattern in Old New Lands

	EAST OF DELTA		MIDDLE OF DELTA		WEST OF DELTA		UPPER EGYPT	
WINTER	WHEAT	20%	WHEAT	50%	BERSEEM	22%	BERSEEM	35%
	BERSEEM	15%	BERSEEM	40%	VEGETABLE	22%	WHEAT	25%
	VEGETABLE	5%	VEGETABLE	10%	CITRUS	34%	VEGETABLE	15%
	ORCHARDS	60%			ALFALFA	22%	ORCHARDS	25%
SUMMER	MAIZE	20%	RICE	60%	PEANUT	22%	PEANUT	15%
	PEANUT	10%	VEGETABLE	15%	VEGETABLE	22%	COTTON	20%
	VEGETABLE	8%	COTTON	25%	CITRUS	34%	VEGETABLE	25%
	PEANUT	2%			ALFALFA	22%	MAIZE	15%
	ORCHARDS	60%					ORCHARDS	25%

Cropping pattern for new new lands, is governed by the following aspects: 1) Soil type and properties; 2) Choice of crops which improve soil properties, maintain fertility and alleviate socdicity or alkalinity problems while regarding previous experience in land reclamation projects, and 3) Choice of crops that allows the application of modern irrigation methods and tend to resist weeds. Table 4 shows a suggested cropping pattern for new new lands as described in LMP study, scanning of Nubaria area and Sinai feasibility studies.

Table 4. Cropping Pattern in New New Lands

	EAST OF DELTA		MIDDLE OF DELTA		WEST OF DELTA		UPPER EGYPT	
WINTER	BARELY	20%	BARELY	35%	BARELY	15%	BERSEEM	30%
	BERSEEM	10%	BERSEEM	35%	VEGETABLE	30%	BEANS	10%
	VEGETABLE	20%	VEGETABLE	30%	ORCHARDS	35%	VEGETABLE	15%
	ORCHARDS	30%			ALFALFA	20%	ALFALFA	20%
	ALFALFA	20%					ORCHARDS	25%
SUMMER	PEANUT	10%	RICE	65%	OIL CROPS	30%	SORGHUM	10%
	VEGETABLE	20%	SORGHUM	35%	VEGETABLE	15%	PEANUT	30%
	OIL CROPS	20%			ORCHARDS	35%	VEGETABLE	15%
	ORCHARDS	30%			ALFALFA	20%	ALFALFA	20%
	ALFALFA	20%					ORCHARDS	25%

4.2 Consumptive Use

The considered values of consumptive use in the study for different crops planted in different regions are the lowest of the three following values: 1) Approved figures by both MOA and MPWWR; 2) Water Master Plan Project, Technical Report No. 17; 3) A study conducted by the Water Distribution and Irrigation Systems Research Institute, Ministry of Public Works and Water Resources, Egypt. Tables 5,6 shows the considered values for consumptive in the study.

4.3 Irrigation Efficiency

According to Pacer/Euroconsult (Land Master Plan, 1983) the application efficiency on the farm level is estimated at the following values:

Method of Irrigation	Application Efficiency
Surface	0.70
Sprinkler	0.75
Drip	0.90

Table 5. Consumptive Use for Old New Lands Crops

	CROP	EAST OF DELTA		MIDDLE OF DELTA		WEST OF DELTA		UPPER EGYPT	
		C.U. m^3/fed.	WATER REQ. m^3	C.U. m^3/fed.	WATER REQ. m^3	C.U. m^3/fed.	WATER REQ. m^3	C.U. m^3/fed.	WATER REQ. m^3
WINTER	WHEAT	1608	536	1608	1340	2364	867	2192	913
	BERSEEM	2364	591	2346	1576			3120	1820
	VEGETABLE	1356	113	1356	226	1356	497	1608	402
SUMMER	MAIZE	2430	810					2806	702
	PEANUT	3160	527			3160	1159	3860	965
	VEGETABLE	1919	256	1919	1174	1919	704	2340	975
	OIL CROPS								
	RICE	4690	156	4690	480				
	COTTON			2818	4690			3881	1294
PERMANENT	CITRUS					4015	1870		
	ORCHARDS	4015	3300					5380	2242
	ALFALFA					6600	2420		
TOTAL			6289		9486		7517		9313

Table 6. Consumptive Use for New New Lands Crops

	CROP	EAST OF DELTA		MIDDLE OF DELTA		WEST OF DELTA		UPPER EGYPT	
		C.U. m^3/fed.	WATER REQ. m^3	C.U. m^3/fed.	WATER REQ. m^3	C.U. m3/fed.	WATER REQ. m^3	C.U. m^3/fed.	WATER REQ. m^3
WINTER	BARELY	1408	440	1408	770	1408	330		
	BERSEEM	2364	369	2364	1293			3120	1463
	VEGETABLE	1356	372	1356	557	1356	557	1608	330
	BEANS							1827	285
SUMMER	SORGHUM			2338	1279			2751	430
	PEANUT	3160	494					3860	1809
	VEGETABLE	1919	526			1919	394	.2340	481
	OIL CROPS	2048	640			2048	960		
	RICE			4690	4763				
PERMANENT	ORCHARDS	4014	1650			4014	1925	5380	1842
	ALFALFA	6600	2063			6600	2063	7820	2444
TOTAL			6554		8662		6229		9084

5. FUTURE WATER DEMAND FOR AGRICULTURE IN EGYPT

5.1 Scenario I

In this scenario, the estimation of water demand up till year 2012 when all reclaimable lands should have been reclaimed are considered the demands for Old Lands, Old New Lands and New New Lands.

As the old new lands reclaimed before 1982 has already converted to surface irrigation. The same consideration will be considered for all the old new lands. The average conveyance efficiency through the irrigation system is considered as 0.85; i.e. the overall efficiency throughout this study for this category of lands, will be 0.85 x 0.7 = 0.6

However, for new new lands MPWWR confined the irrigation systems to modern systems only. The calculation of anticipated future irrigation water demand is based on the assumption that, old new lands will proceed with surface irrigation, while new new lands will apply modern irrigation systems.

Tables 7,8,9,10 show the estimated water demand for agriculture up till 2012 including the additional amount of water required after 1997 to cultivate all reclaimable lands in Egypt. It is expected that the total demand for irrigation will be 61 billion m^3 in 2012.

5.2 Scenario II

However, assuming that the improvement in irrigation management for surface irrigation will increase the overall efficiency to reach a value of 0.7 as indicated in studies conducted by Egyptian Water Use and Management Project (EWUP) and Irrigation Improvement Project (IIP). The assumption is considering that the farmers will use sprinkler irrigation for new new lands to overcome the non-uniform land topography. After the end of the life time of the sprinkler systems, 10 to 15 years, and under continuous planting, it is expected that the land will be of acceptable land levelling which enable the application of surface irrigation methods with the aforementioned efficiency. Table 11 shows the expected total water demand for old agricultural lands in Egypt according to the improvement water management and the existing situation of demand for the old land. Figure 2 indicates the amount of water saving between alternatives 1 & 2.

Table7. Water Requirements for Land Reclamation for East of Delta

Year	Reclaimed Land. x1000 feddans	Considered ONL	Considered NNL	Scenario I m.m³/yr	Scenario II m.m³/yr
1978	91.3	91.3	0.0	598.2	593.5
1982	60.1	60.1	91.3	968.0	938.5
1987	19.7	79.8	91.3	1,097.2	1,066.7
1992	109.4	129.1	151.4	1,798.2	1,747.7
1997	523.2	632.6	171.1	5,221.0	5,138.7
2002	356.6	879.8	280.5	7,528.7	7,401.9
2007	40.8	397.4	803.7	7,658.4	7,405.5
2012	211.5	252.3	1,160.3	8,950.4	8,601.9

Table 8. Water Requirements for Land Reclamation for Middle of Delta

Year	Reclaimed Lands. x1000 feddans	Considered NNL	Considered ONL	Scenario I m.m³/yr	Scenario II. m.m³/yr
1978	153.7	153.7	0.0	1,331.3	1,075.9
1982	1.6	1.6	153.7	1,471.9	1,010.3
1987	12.8	14.4	153.7	1,582.7	1,099.9
1992	39.3	52.1	155.3	1,924.5	1,374.2
1997	62.5	101.8	168.1	2,476.4	1,805.3
2002	11.7	74.2	207.4	2,610.1	1,867.5
2007	0.0	11.7	269.9	2,661.6	1,836.3
2012	0.0	0.0	281.6	2,671.3	1,830.4

Table 9. Water Requirements for Land Reclamation for West of Delta

Year	Reclaimed Lands x1000 feddans	Considered NNL	Considered ONL	Scenario I m.m^3/yr	Scenario II m.m^3/yr
1978	289.0	289.0	0.0	1,800.2	1,878.5
1982	46.9	46.9	289.0	2,464.3	2,038.9
1987	98.0	144.9	289.0	3,074.7	2,675.9
1992	215.9	313.9	335.9	4,479.9	4,055.8
1997	176.5	392.4	433.9	5,705.5	5,154.0
2002	63.1	239.6	649.8	6,376.4	5,456.2
2007	136.0	199.1	826.3	7,450.7	6,252.0
2012	71.3	207.3	889.4	7,976.0	6,683.9

Table 10. Water Requirements for Land Reclamation for Upper Egypt

Year	Reclaimed Lands X1000 feddans	Considered NNL	Considered ONL	Scenario I m.m^3/yr	Scenario II m.m^3/yr
1978	151.6	151.6	0.0	1,377.3	985.4
1982	3.9	3.9	151.6	1,447.1	935.0
1987	9.8	13.7	151.6	1,535.7	998.3
1992	47.7	57.5	155.5	1,969.9	1,306.4
1997	120.7	168.4	165.3	3,068.7	2,086.1
2002	179.2	299.9	213.0	4,707.6	3,227.1
2007	395.8	575.0	333.7	8,330.8	5,739.4
2012	355.4	751.2	512.9	11,600.3	7,959.9

Table 11: Progress of Land Reclamation and Related Total Water Requirements

Year	Recl. Lands (1000's) feddans	Accum. Recl. Lands (1000's) feddans	Consid. New New Areas (1000's) feddans	Consid. Old New Areas (1000's) feddans	Egypt Total Cultiv. Area (1000's) feddans	Water Requir. Scenario I (1000's) m.m^3	Water Requir. Scenario II (1000's) m.m^3
1978	686	686	686	0	5,938	41,107	40,533
1982	112	798	112	686	6,624	42,351	40,923
1987	140	938	253	686	6,764	43,290	41,841
1992	412	1,351	553	798	7,177	46,173	44,484
1997	882	2,233	1,254	938	8,102	52,472	50,184
2002	611	2,843	1,493	1,351	8,713	57,223	53,953
2007	573	3,416	1,183	2,233	9,285	62,102	57,233
2012	638	4,054	1,211	2,843	9,923	67,198	61,076

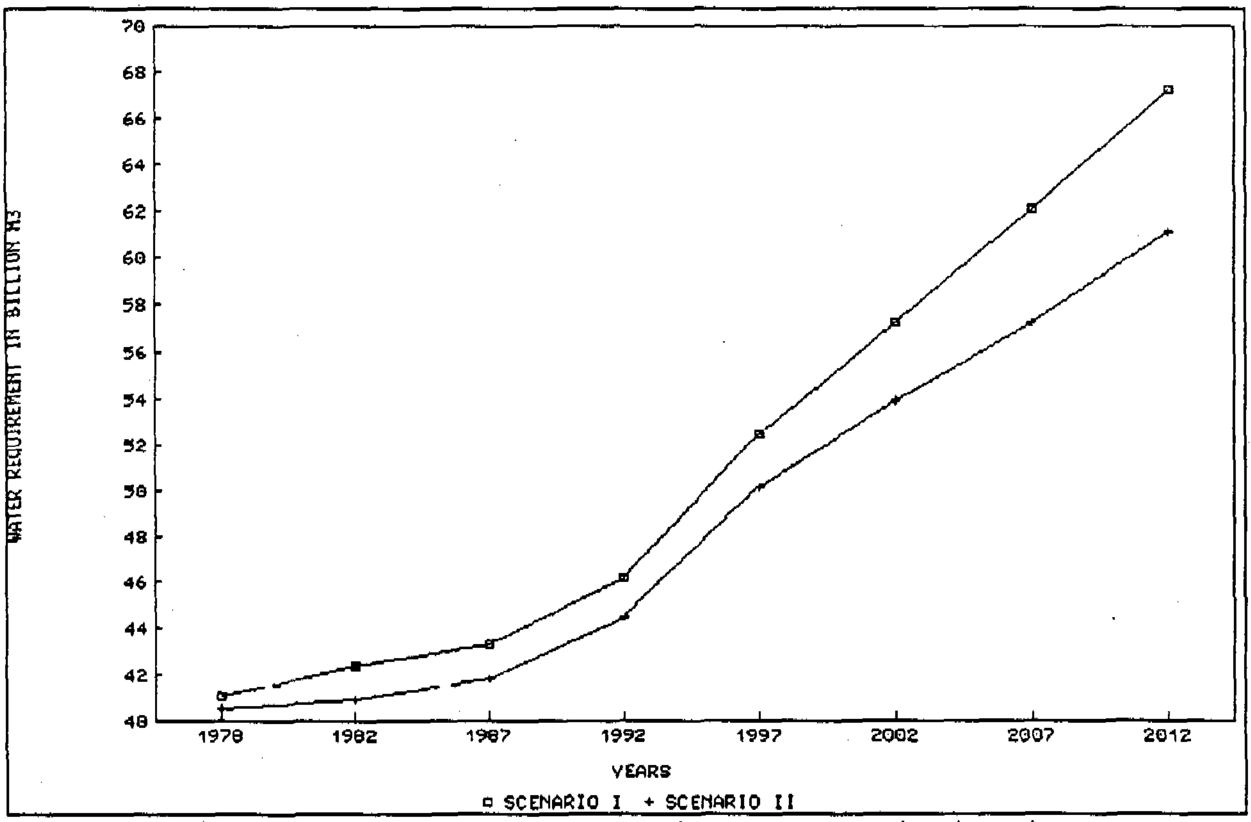

Figure 2: Future water requirement for irrigation

6. CONCLUSIONS

Land reclamation is one of the urgent targets for Egypt to be achieved through the coming two decades. Increasing in population and increasing in type of food demand due to the people welfare put the stress on agricultural land which is about 7.4 million feddans. The history of land reclamation indicates great jump in reclaimed areas in the last 10 years. However, the future plans up to year 2012 get the total agriculture land to reach about 9.3 million feddans due to reclamation of more than 2 million feddans. The only constraint is the limited water resources in Egypt. River Nile which is the only source of water provides Egypt annually by 55.5×10^9 cubic meter. Agriculture sector demand today is estimated at about 46 billion m^3/year. The study discussed two scenarios for agricultural water demand: one considering conventional methods of irrigation which gives projection of the total water demand to be 67.2 billion m^3 in year 2012. The second scenario suggests more efficient water use on the farm level and through the delivery system which reduces total demand to about 61.1 billion m^3 in year 2012. Other scenarios such as changing the cropping patterns or using less water consumption crop varieties are not discussed in this study.

Accordingly Still the search for increasing the water resources is an urgent requirement for Egypt. Increasing the re-use of agricultural drainage water, re-use of sewage water after treatment, reducing losses through potable water net, increasing ground water pumping and desalination of salt water are different alternatives for water sources sustainability for agricultural water demand in the future. Some of these alternatives are in the utilizations phase, while others are in the stages of research.

ACKNOWLEDGMENT

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AN ATTEMPT TO ESTIMATE INDUSTRIAL WATER DEMAND

M. Benedini[1] and F. M. Spaziani[2]

SUMMARY

Water demand for industrial use is of particular interest in planning and management activities. Unlike the other water utilisations, it can be evaluated only with a very poor reliability. The industrial use of water encompasses different destinations within the production plant and many factors affect the problem. With the data available so far, even though largely incomplete and scattered, a comparative analysis of existing situations in this sector has been conducted. A survey has pointed out values of water demand expressed in terms of cubic meter of water withdrawn per ton of goods produced within the industrial plant. Another survey has pointed out values expressed in terms of cubic meter per employee engaged in the production process. The two values are not always one another in agreement and reflect different conditions and approach to the problem.

Data were also collected on how much of the water withdrawn is recycled and some recycling coefficients have been determined. By means of the evaluation criteria pointed out, an analysis of the situation occurring in Italy has been performed.

RÉSUMÉ

Au niveau du management et de la planification, il est extrêmement important que les décideurs puissent disposer d'une évaluation fiable de la demande en eau inhérente aux besoins industriels. Or, contrairement à ce qu'il en est pour différents autre usages, il est difficile d'obtenir un haut degré de fiabilité pour ce type précis d'évaluation. Au sein des implantations, les usages industriels sont divers et les facteurs susceptibles d'influer sur les quantités d'eau nécessaires sont nombreux. Grâce aux données dont nous disposons, et bien qu'elles soient largement incomplètes et plutôt hétérogènes, nous avons cependant mené une analyse comparative des différentes situations qui se côtoient dans le secteur. Une étude a donc permis de tracer une évaluation de la demande en eau, exprimée en mètre cubes d'eau utilisés par tonne de biens produits dans les implantations industrielles. En parallèle, une autre étude a fourni une évaluation supplémentaire, exprimée en mètre cubes d'eau utilisés pour chaque employé impliqué dans le processus de production. Ces deux évaluations ne concordent pas toujours et elles reflètent à la fois une certaine disparité des conditions et une différente approche du problème.

Par ailleurs, d'autres données collectées concernent la quantité d'eau utilisée puis recyclée, ce qui a permis de mettre au point des coefficients de recyclage. Grâce aux critères d'évaluation ainsi définis, nous avons donc pu analyser la situation telle qu'elle se présente en Italie.

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1. Introduction

The evaluation of the quantity of water that is necessary to perform the various human activities is a fundamental step in all planning and management procedures. It is essential to match the available resources to the typology, density and location of all the economic factors.

To assess this quantity there are different evaluation criteria and degrees of accuracy, and the results are extremely variable from one situation to the other. Very often the initial projections are not respected at the operational stage and, besides the identification of new sources, also the problem of defining appropriate operation criteria for the existing conveying and delivering facilities becomes increasingly unwieldy. This is not only because of the difficulty of predicting aspects and factors that are likely to come into play some time in the future, but also because the implementation of water supplies elicits a "reactiveness" of its own in the behaviour of a number of users, thus encouraging the growth of initially unpredictable initiatives having high water requirements.

Industrial activities require water for different purposes, namely for (1) process, (2) cooling, (3) steam generation and (4) services. Within the industrial plant the water path consists of one or several steps, which make up the relevant components of a specific balance (Figure 1):

- *feed water*: the quantity withdrawn from the original water body which, after preliminary treatment whenever required, is conveyed to the plant;
- *used water*: total quantity of water effectively utilised within the plant;
- *recycled water*: quantity reused after recovery from the output of the same use, with or without treatment;
- *discharge water*: quantity returned to the natural water bodies, with or without treatment;
- *consumed water*: quantity of water transformed during the productive process or incorporated in the final output of the productive plant;
- *losses*: quantity of water neither returned to the original body nor used in the productive process.

The amount of water required depends on several factors, among which the type and potentiality of the plant, its degree of modernisation, the scheme and efficiency of the process. They play a very important role, without neglecting other less conspicuous factors, like the quality of both the feed and discharge water, as well as personnel training and sensitivity. This means that an accurate evaluation of the required quantity can be achieved only at the stage of the design of a well-defined production plant for which all the fundamental terms and parameters are known. In this respect, a number of estimates are available in textbooks and in the scientific literature and can help to determine reasonable figures. An investigation recently carried out under the auspices of the EEC (SAST, 1991) provides detailed values for the most current productive sectors in terms of demand per unit of production output. Vice versa, at the stage of a general planning procedure, particularly in a large area, any effort aiming at a precise value is practically meaningless, even considering the refinements that a thorough statistical analysis can provide in the manipulation of large sets of consistent data. A feasible evaluation at this stage is therefore confined within the reasonable limits of an overall view, for the main purpose of emphasising trends and criteria for long term policies, in the frame of acceptable scenarios.

Nevertheless, in such a context a survey of the existing situation is necessary to assess the starting point and the reference terms for a possible intervention in the hands of a responsible authority.

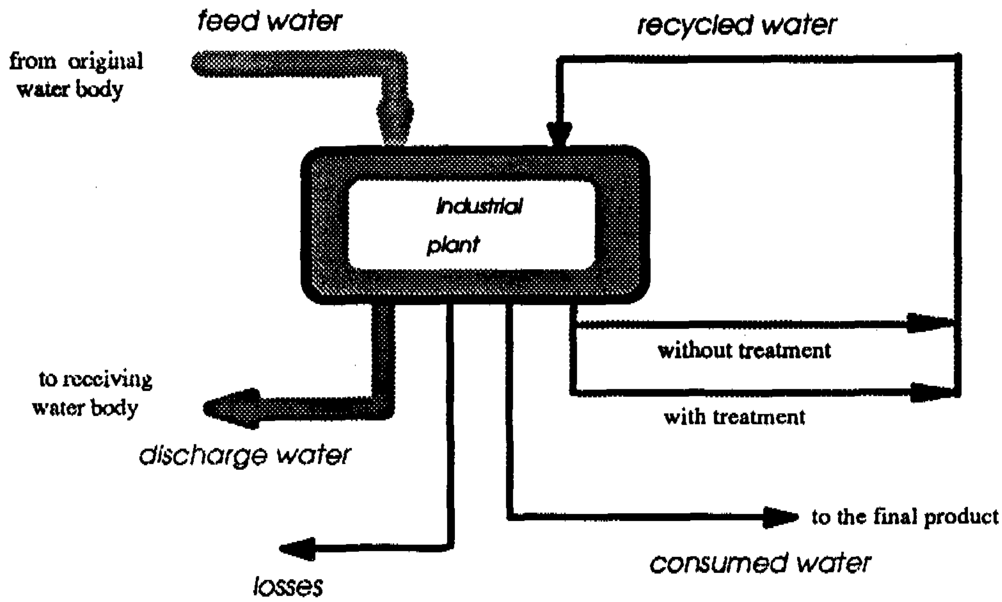

Figure1. A typical case of industrial water use.

2. The Overall Surveys Conducted In Italy

Starting 1970 and in successive stages until 1990, the governing and administrative authorities in Italy have carried out a number of surveys of industrial water supply, both nation-wide and at the level of single catchments (Giuliano & Spaziani, 1985). These surveys involved some representative samples of productive units belonging to well-defined sectors of industrial activities. Initially it was considered necessary to make a breakdown into productive units using freshwater alone and those using totally or partly sea water. The use of sea water, whenever possible, can be a valid alternative, saving huge amounts of freshwater, which can be reserved for other uses with more rigorous quality requirements.

The values obtained from these surveys refer to the *most frequently occurring average*, disregarding the optimal utilisation of water and the technologies applied in or applicable to the productive process. These are thus values that can be economically attained under normal conditions of water use.

As initial evaluation criterion, the demand of freshwater was expressed as a specific requirement in terms of *water volume per unit output produced in the plant*, as shown in Table 1 ("unit output criterion"). This can be a reliable approach to the problem, keeping in mind that statistical surveys of industrial production are available every year. It should be noted that for the sectors characterised by a high degree of fragmentation and scattering of productive units the official data cover only the more economically significant production.

Table 1. Mean specific water withdrawal per unit output.

SECTOR OF ACTIVITY	Water withdrawal (m^3/ton)
Preserved foodstuffs	10.5
Frozen foodstuffs	161.8
Beer	23.8
Chemicals	84.3
Paper	184.6
Rubber	148.3
Steel	10.9
Cast iron	90.2
Metal sheet (iron alloys)	41.3
Coke	3.3
Hides and leather	443.5
Oil	1.4
Metal industry	21.7
Glass	21.2
Mining	3.4
Textiles	147.8
Textiles - Dyeing	333.2
Ceramics refractories	9.3
Abrasives	25.0
Cement	0.5
Asbestos cement	6.0

On the other hand, the consideration that a General Census of Industry and Trade is available every ten years and provides detailed information on the number of employees for these sectors, suggested attempting to find a criterion of freshwater demand in terms of the personnel engaged in the production sectors. A survey conducted according to this criterion led also to specific water requirement values expressed as *quantity of water supplied every year per employee in the plant* ("unit employee criterion").

The results of this survey are shown in Table 2. Also these values correspond to the mean technological level of the national industries and may be related to the situations that occur most frequently in the industrial sector.

As far as freshwater *consumption* is concerned, i.e. the quantity of water not returned to the water bodies, the observed data often consist of estimates rather than measured values. The existence of meters or known pumping ratings generally allows the amount of water withdrawn to be measured; vice versa, since there are usually no flow meters on the outlet pipes, the values given for discharge are mostly estimations. However, after considering some significant samples, the overall mean value for water actually consumed is of the order of 4-5% of the amount of water withdrawn.

Table 2. Mean specific water withdrawal per employee.

SECTOR OF ACTIVITY	Water withdrawal (m^3/employee year)
Cereals and "pasta" manufacture	3500
Confectionery	500
Food preserves	2200
Cheese making	1100
Vegetable and animal fats	6600
Sugar refineries	4000
Wines and spirits	3500
Non alcoholic beverages	1800
Tobacco	350
Textiles	1500
Leather	1200
Wood	1100
Metalworking	3900
Metal industry	550
Vehicle construction	600
Non metallic minerals	1700
Chemicals	5500
Rubber	1700
Synthetic fibres	5000
Paper	16000
Photography	280
Plastic products	1100

To obtain information concerning the ways water is used within the industrial plant, data were collected also in order to assess how much of the water withdrawn was recycled. Some *recycling coefficients* (ratio between total quantity of water used and quantity of water withdrawn) for plants supplied solely with freshwater are shown in Table 3.

3. Water Demand At The National Level

The above criteria have been applied repeatedly in various planning schemes, as in the projects for Southern Italy, in the water reclamation and river basin plans, and practically in all the initiatives of the Ministry of the Environment.

A country-wide analysis carried out in 1971 on the basis of the requirement per unit output indicated industrial supply of the order of 7,000 Million m^3/a (excluding cooling in thermoelectric plants). This figure does not represent the global requirement, but only that of the "thirstier" industries and corresponds to about 90% of the overall national requirement. The total value of the latter comes to above 7,800 Million m^3/a.

A similar estimate confirmed that the overall demand for 1981 was of the order of 7,500 Million m^3/a.

Table 3. Recycling coefficients for some typical industrial sectors

SECTOR OF ACTIVITY	coeffic.
Preserved foodstuffs	1.20
Frozen foodstuffs	1.12
Paper	1.78
Beer	1.14
Ethyl alcohol	1.22
Chemicals	1.89
Steel	2.34
Cast iron	1.51
Metal sheets, iron alloys	1.71
Coke	3.24
Oil	6.05
Engineering	1.30
Glass	3.38
Mining	1.40
Textiles	1.06
Textile-dyeing	1.01
Non ferrous metals	1.34
Rubber	1.12
Leather and hides	1.00
Cement	1.89
Asbestos cement	1.06
Ceramics, refractories	1.16
Abrasives	1.01
Dyeing	1.00

The possibility of recycling at least part of the water discharged from several industrial processes allows a saving in the water withdrawn. Recycling allowed approximately 15% saving already in 1981, so that the effective withdrawal for industrial purposes in that period could be as low as 6,800 Million m^3/a. The quantity of water withdrawn for some industrial activities in 1981 is shown in Table 4.

These considerations are even more remarkable in the case of future projections in view of the general tendency for new industries to adopt innovative technologies involving a greater degree of water recycling. The specific amount of water per unit employee could consequently decrease with time.

4 - Some Particular Cases

The results achieved so far in an aggregate form at the national level have suggested developing a more detailed analysis, regarding well-defined productive sectors. This can be justified also considering the availability of large data series collected continuously by the Central Institute of Statistics throughout the country for all production lines. To enhance significance, attention was concentrated on those productive sectors for which data both on annual output and decade censuses of employees were available.

Table 4. Estimated water withdrawal for industries with large water requirements in 1981

SECTOR OF ACTIVITY	WITHDRAWAL (Million m^3/a)
Vegetable fats	179.8
Cattle slaughter and meat processing	73.2
Cheese and dairy	33.2
Conservation of fruit and vegetables	62.8
Conservation of fish	1.6
Noodles and "pasta"	67.8
Bread, confectionery and biscuits	40.9
Sugar production and refining	57.2
Cocoa, chocolate, sweets and ice-cream	45.1
Wine	14.0
Beer	21.2
Mineral water and non alcoholic beverages	16.0
Ethyl alcohol, spirits and liqueurs	29.8
Tobacco	5.8
Coke	21.8
Oil related	313.3
Mining and preparation of metallic minerals	18.0
Mining and prep. of non metallic minerals	76.7
Production and prelim. process. of metals	750.2
Processing of non metallic minerals	479.0
Chemicals	2112.4
Prod. of artificial and synthetic fibres	134.1
Metal fabrication	705.3
Constr. and assembly of mot. vehicles, body work	137.0
Constr. of other means of transport	69.7
Textiles	641.4
Tanning and dyeing of hides and leather	36.2
Shoemaking	5.0
Wood and wooden furniture	492.6
Pulp, paper and cardboard production	583.5
Transformation of paper and cardboard	7.3
Printing	6.8
Rubber	113.9
Plastic products	136.5
Photography	3.2
TOTAL	**7492.3**

By adopting the specific values of table 1 and table 2, the analysis eventually led to the results indicated, for example, in Figures. 2, 3 and 4, which prompt several considerations.

Firstly, some productive sectors (e. g. chemicals) denote a good concordance of the values obtained by means of the unit output criterion and that of the unit employee. Other sectors denote a remarkable discrepancy and the unit employee values generally exceed the unit output ones. This can be explained principally by underlining the difficulty encountered during the census, which aims at taking into consideration, at the same time, both the production and the number of employees.

Vice versa, a census of the number of employees, conducted at a very general perspective on a country-wide scale, cannot distinguish always between the personnel involved directly in production activity and those employed in secondary and subsidiary jobs, or working in the same plant but dealing with a different productive line. In these circumstances, if there is a discrepancy between the two ways of proceeding, the unit output criterion seems to be more reliable, provided the specific demand value has been correctly determined. The values resulting from the application of the unit employee criterion should be therefore adjusted by adopting a smaller value for the specific demand.

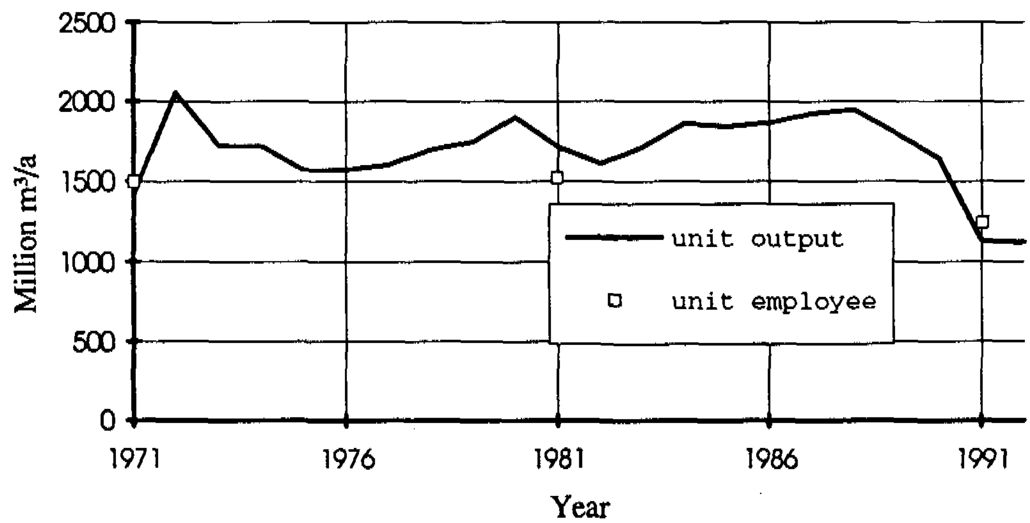

Figure 2. Water demand for the chemical industry.

The accuracy of the surveys carried out to determine the figures of the unit employee criterion -as explained in the previous chapter and in spite of the difficulties repeatedly underlined- does not justify considering the overestimated results in the graphs as entirely wrong. As pointed out before, the specific demand per employee takes into consideration not only the personnel working in the productive process, but all the people involved in the production, including those working in the secondary and subsidiary activities, which can hardly be distinguished from the "primary" one and are sometimes quite exacting in terms of water withdrawal. In other words, from the viewpoint of estimating the quantity of water necessary for running a single plant an evaluation in terms of unit output is appropriate, while for a more general consideration, especially in view of an overall balance in planning procedures, the evaluation in terms of unit employee could be more realistic.

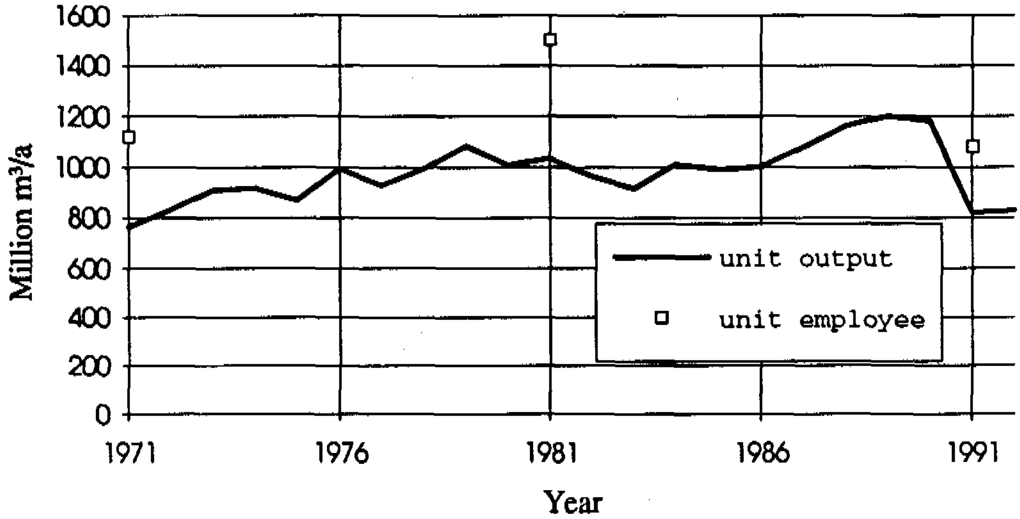

Figure 3. Water demand for pulp and paper industry.

It follows that in the case of discrepancy as shown before, i. e. when the water demand values obtained by means of the unit employee procedure are higher than those obtained by means of the unit output tool, an intermediate figure would be more correct. In any case, the unit output values can be considered a reasonable threshold for assessing the quantity of water to be reserved for the implementation of an efficient industrial settlement.

5 - Future Projections

Another consideration stems from figures 2, 3 and 4 and is related to the possibility of expanding the analysis to all the other production sectors in order to obtain a country-wide overview.

The time-dependent variations recorded over a period of more than twenty years are a reliable source of data suitable for developing a reasonable forecast of water demand in the near future. The graphs show that, after a slight increase during the early seventies, the general trend is towards a constant value or a slight decrease. This is due primarily to the alternation of recessions and prosperous periods that have forced the economic life to settle into a stable equilibrium around average values. Such an observation encourages us to say that in Italy the industrial water demand will not increase.

So far these statements are based upon a constant specific value of unit output (or, respectively, of unit employee), without taking into consideration the possibilities of recycling, which, as already proved in previous chapters, can provide a remarkable saving of water. Due to these further considerations, the future perspectives of water demand in Italy can be regarded rather optimistically, in the certainty that the industrial use, even though in a desirable improvement of economic life in general, will not hamper other possibilities of water utilisation.

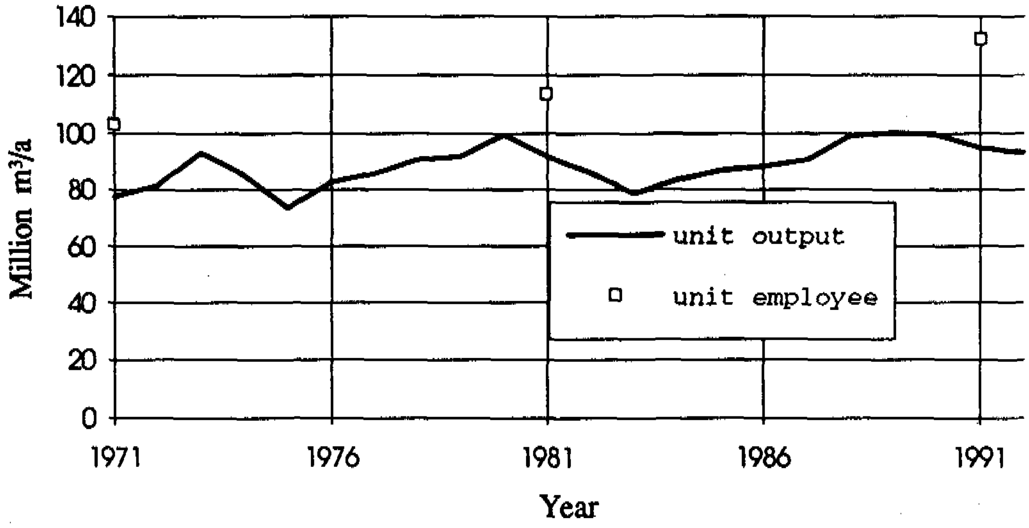

Figure 4. Water demand for rubber industry

Obviously, the problem of water supply for industrial purposes must be tackled in conjunction with the risk of a gradual deterioration of available resources due to pollution. Not infrequently an industry that benefits from good quality water taken from a river returns it polluted to the same river and industries located downstream are therefore obliged to undertake costly treatment before using the abstracted water.

6 - Conclusions

The availability of large data series has provided an opportunity to carry out some investigations on the amount of water for industrial use in Italy which have led to different criteria of evaluation being established. The first criterion is based on a specific quantity expressed in terms of unit output by the production plant; another concerns a specific quantity in terms of unit employee in the production process.

The two criteria are not always in a good agreement and reflect different considerations about the problem. The former is mainly concerned with the single production plant, the latter with more general considerations in planning procedures. The same investigations have also estimated the amount of water recycled within the industrial plant, which is very useful for reducing the withdrawal from the original sources.

The evaluation criteria identified have allowed some forecasts to be made on industrial demand in Italy. A stable assessment in the industrial production, together with the increasing possibilities of recycling, supports encouraging perspectives for the near future.

It should be recommended that the authorities responsible for water utilisation and protection should pay great attention to the need of collecting new data, with a view to defining up-to-date and more precise values for assessing the specific water demand in this sector.

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CONTROL OF WATER CONSUMPTION OF RICE

Dia El Din El Quosy [1]

ABSTRACT

Rice is grown in Egypt for four different purposes:

(i) as a food crop
(ii) for reclamation of saline soils
(iii) to prevent sea water from intruding the strip close to the Mediterranean sea.
(iv) production of fish in the standing water layer.

However, rice is a water loving crop. The area cultivated with rice in Egypt is almost 1.0 million feddan (1.0 feddan = 0.42 hectare). This area forms 7% of the total cropped area. Rice consumes 8800 m^3/feddan i.e, the total area consumes about 8.8 x 10^9 m^3 or 15% of the total inflow of the Nile to the country. International reports on rice cultivation state the possibility of reducing the crop consumption of water especially during certain stages of growth, without affecting its productivity.

An experiment on this was carried out in three experimental stations in the East West and Middle Delta.

This paper explains the methodology of the experiment and the main results obtained in the field of the effect of water saving on the productivity of rice.

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1. INTRODUCTION

Rice is one of the major crops which contribute heavily to the national economy of Egypt. The area cultivated with rice in Egypt every year rotates around 1.0-1.5 million feddans (420000 - 63000 hectares). Production of rice in Egypt is as high as 3.2 tonnes per feddan, i.e. almost 8.0 tonnes per hectare which is one of the highest production levels in the whole world.

Rice is cultivated in the northern part of the Nile Delta at an intensity of about 50%. This intensity decreases to 40,30,20 and 10% southwards. Rice cultivation is not allowed in the most southern part of the Nile Delta and in the Nile Valley except of small area in Fayoum Governorate (see Fig.1). Vast amount of rice is consumed locally while 200000 - 300000 tonnes are exported every year.

Net return of rice fields in Egypt is the best among other summer crops raised during the same period namely cotton and maize. The reason for this is four fold:

a- The relatively low productivity of cotton and maize

b- The fixed price of cotton which is controlled by government authorities

c- The high value by-products of rice such as: straw and fish catch which can be raised during the growing season

d- Rice is a reclamation crop which enables leaching of accumulated salts and prevents plants in the mean time from the withdrawal of highly saline water from shallow groundwater tables.

Planting of rice in Egypt starts during the months of May-June while harvesting takes place in October-November. This means that the mature plant exists during the hotest two months of the year: July and August.

In the mean time, preparation for rice cultivation takes place after the harvesting of winter crops like wheat, the irrigation of which is stopped at least one month before harvesting. With heavy clay soils like those of the Nile Delta, cracking is developed at large scale and the preparation of rice fields, therefore, consumes large quantities of water.

Third, rice is cultivated under standing water layer conditions. Evaporation from the free surface of this standing layer is appreciable ; and losses due to deep percolation are inevitable.

In view of the above mentioned three factors water supply to rice fields may reach

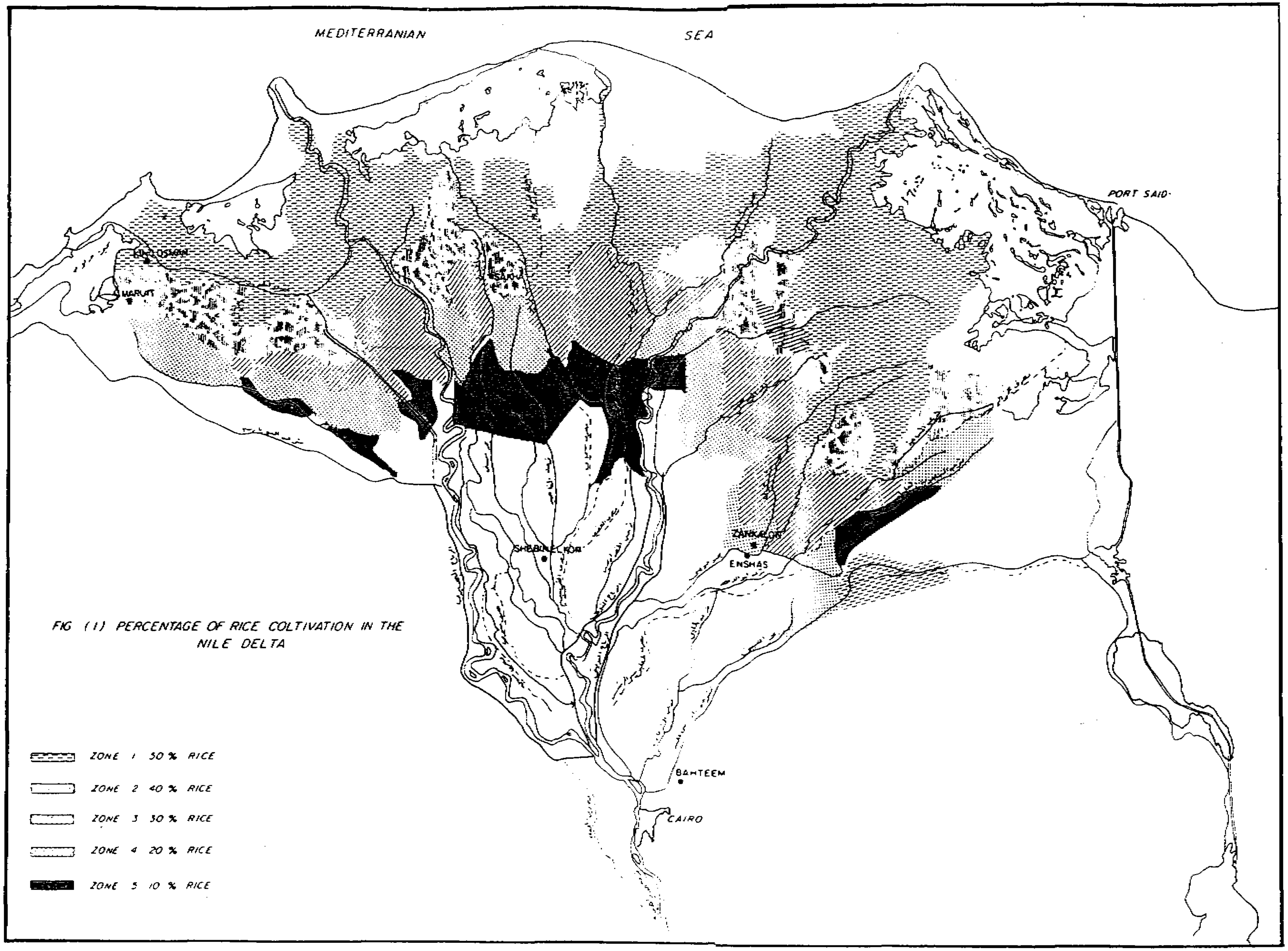

FIG (1) PERCENTAGE OF RICE COLTIVATION IN THE NILE DELTA

16% of the Egyptian water budget while the area grown with the crop does not exceed 6.7% of the total cropped area.

With the present situation of water scarcity in Egypt, water saving techniques are practiced on large scale. Obviously these techniques concentrate on the two major water consuming crops ; namely rice and sugar cane.

This paper throws some light on the consumptive use of rice and means and measures which can be taken to control its irrigation water consumption without affecting productivity.

2. CONSUMPTIVE USE OF RICE

Many attempts have been made to determine accurately the water consumption of rice under the Egyptian conditions. Some of these attempts are listed below.

2.1 Irrigation and Productivity of Rice in Abu Rayah-Kafr El Shiekh

This study was carried out under the activities of the Egypt Water Use and Management Project (EWUP ; 1978-1984). It compares between the consumption of rice as determined from fields irrigated by farmers, rice grown in lysimeters and the consumptive use calculated from the well known equations. Following are the results of this study

Year	Water Supply (mm)		
	Fields Irrigated by Farmers	Lysimeter	Consumptive Use
1978	1975	-	-
1979	1363	-	-
1980	1838	1660	830
1981	-	1817	817

The average water supply to the farmers fields and lysimeters is almost the same (1725 and 1738 mm respectively). Consumptive use is less than half this amount.

Obviously the other half is lost in surface runoff, deep percolation and evaporation from free water surface. The total supply of 1725 and 1738 mm is equivalent to 7245 and 7300 m^3/feddan.

The water duty given to rice fields by the Ministry of Public Works and Water Resources (MPWWR) is 8800 m^3/feddan

2.2 Water Consumption of Rice in Zankalon-Sharkia Governorate

This experiment was carried out in the research station of the Water Distribution and Irrigation Systems Research Institute (WDISRI) in Zankalon about five kilometers south of the capital city of Zagazig of Sharkia Governorate.

Rice was grown in the station for three successive years from which the following results were obtained:

Year	Water supply (mm)	Consumptive use (mm)
1985	1536	823
1986	1345	849
1987	1269	-

Because of the fact that this experiment was carried out under controlled conditions the amount of losses is reduced considerably from about 1730 mm in the previous study to an average of 1383 mm, while the consumptive use of both investigations is almost the same.

2.3 Water Management in Rice Fields

An investigation conducted jointly by the Drainage Research Institute (DRI) in Egypt and the Institute for Land Reclamation and Improvement (ILRI) in the Netherlands in the North Western Governorate of Behiera. Results were obtained from three experimental sites (one installed with tile drainage, the two others were not) during the period 1977-1978. These results can be presented as follows:

Site	Year	Water Supply (mm)	Consumptive use (mm)
Anwar Hammad	1977 1978 1979	1350 1500 1340	660 750 845
Nokrashy (With tile Drainage)	1977 1978 1979	1260 1270 1180	670 750 770
Bassal	1979	1185	775

Again, this study was carried out in farmers fields where there was no control on supply. Climatic conditions in this area are less sever than Abu Raya and Zankalon. This could explain the difference in water supply. Consumptive use is smaller in this site as well, because of the same reason.

2.4 Comparison Between Water Requirements of Rice Grown in Areas Installed with Traditional and Modified Drainage Systems

A joint research between WDISRI and DRI carried out in three experimental stations: Zankalon in Sharkia Governorate, Sakha in Kafr El Shiekh Governorate and King Othman in Behiera Governorate. The water supply figures obtained for plots drained by conventional systems were 1598, 1376 and 2268 mm in the three stations respectively. When the drainage system was modified by plugging field drains during certain periods the obtained figures were 881, 719 and 1548 mm respectively.

These results reveal that the losses can be reduced to a great extent if drainage is stopped during certain periods of the stage of growth.

3. ACTUAL WATER SUPPLY TO RICE FIELDS

Fig. (2) shows a comparison between actual water supply to rice fields as given by the Ministry of Public Works and Water Resources (MPWWR), the consumptive use given by the two entrusted research institutes: WDISRI and SWRI (Soil and Water Research Institute) and that calculated by adding the surface water evaporation and crop evapotranspiration as proposed by (penman, 1948) and (Rijtema and Abu-Khaled, 1975).

The comparison shows that the figures adopted by WDISRI and SWRI appear to be in close proximity to the consumptive use calculated by equations from the prevailing climatic conditions.

However, the quantities given by the MPWWR appear to be reasonable during the stage of vegetative growth (June through to mid July) where actual supply exceeds crop water requirements by 15-20%. This percentage represents the operation and on farm losses.

From mid-July to the end of August when flowering and grain formation takes place, water delivery is too high when compared with actual requirements. This means that losses from the system can be as high as 100% which is generally not the case. Therefore, delivery during such periods can be reduced appreciably.

It should be noted that the figures given by MPWWR assume that planting and harvesting of the whole area cultivated with rice takes place during a certain period of time which does not exceed 15-30 days. However, many farmers deviate from this rule and distribution of planting and harvesting is, therefore, stretched over a wider time span.

The difference between supply and demand during the early stages of the crop (April) can be explained by the fact that during this period only 10-15% of the rice area is occupied with nurseries from which transplants are transferred to the field late in the month of May

4. CONTROL OF WATER CONSUMPTION OF RICE

In view of the previous data obtained from researchs carried out at farmers fields and experimental stations ; and with regard to the actual delivery and calculated values of crop consumptive use, a number of experiments were designed to allow for the identification of the optimum quantity of water which has to be supplied to rice fields in order to get the highest yields if other factors which affect productivity are kept constant.

The experiments were carried out in three experimental stations:

(i) Bahteem Station in Qalubia Governorate

(ii) Sakha Station in Kafr El Shiekh Governorate

(iii) King Othman Station in Behiera Governorate.

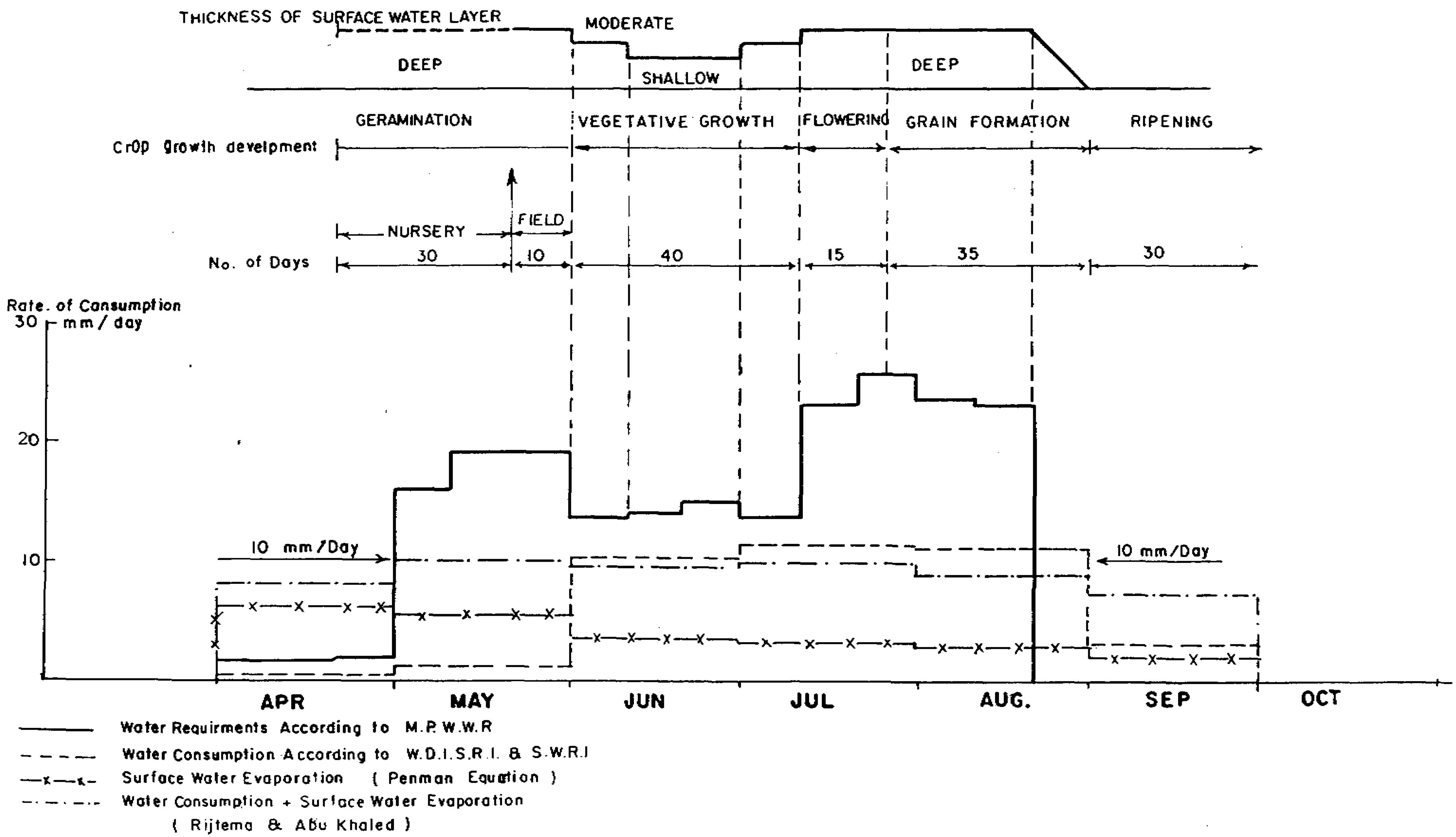

FIG. (2) CROP GROWTH DEVELOPMENT VS. WATER CONSUMPTION OF RICE

The idea behind these field experiments was to control the depth of the standing water layer during different stages of plant growth. Depths ranging from 100 mm down to 0.0 (just saturation) were applied. Under certain conditions soil moisture was reduced further till the field capacity level. In all treatments crop yields were accurately estimated.

It was observed that the crop in the first station had been subjected to heavy contribution of groundwater and therefore the results obtained from this station were excecluded from the analysis.

5. RESULTS

5.1 Sakha Experimental Station

Table (1) gives the results obtained from the experiment carried out at Sakha Experimental Station. From these results the following conclusions can be drawn:

a- During all stages of growth, the best yield has been obtained when the largest amount of water was applied, except in the germination stage where the 50 mm standing water layer produced better yields than the 70 and 100 mm layers.

b- The largest drop in yield takes place with the reduction of water supply during the flowering stage.

c- Except of reaching the field capacity and saturation levels, water savings are proportional to the reduction in yield. This does not apply to the grain formation stage.

d- The relationship between the quantity of water applied and its depth is not linear because of ground slope and irregularities in ground surface.

e- The quantity of irrigation water given the MPWWR (about 8800 m^3/feddan) is overestimated. This quantity can be reduced to 6000-6500 m^3/feddan without drastically changing yields. However this conclusion will be confirmed after repeating the experiment which is taking place this season.

f- Optimum production of rice can be obtained if the depth of the standing water layer is changed with the stage of growth. The most sensitive stages are the flowering and grain formation. Ample supply should be applied during these two stages.

Table (1) Results obtained from Sakha Experimental Station

Treatment Water Depth (mm)	Quantity of Water m^3/feddan	Crop Yield kg/feddan	Water Utilisation Efficiency kg/m^3	% of Crop Deficit	% of Water Saving
1-Germination					
30 mm	5613	3120	0.56	12%	17%
50 mm	5905	3540	0.60	0	13%
70 mm	6357	3360	0.53	5%	6%
100 mm	6757	3200	0.47	10%	0
2-Vegetative Growth					
Field Capacity	3901	2040	0.52	45%	28%
Saturation	3992	2360	0.59	36%	26%
10 mm	4463	3290	0.74	11%	17%
20 mm	4697	3270	0.70%	11%	13%
30 mm	5009	3610	0.72	2%	7%
40 mm	5248	3580	0.68	3%	3%
50 mm	5382	3680	0.68	0	0
3- Flowering					
10 mm	6238	2720	0.44	29%	7%
20 mm	6394	3380	0.53	12%	5%
30 mm	6429	3510	0.55	9%	4%
70 mm	6708	3850	0.57	0	0
4- Grain Formation					
30 mm	5551	3460	0.62	12%	28%
50 mm	6055	3800	0.63	3%	22%
70 mm	6741	3820	0.57%	2%	13%
100 mm	7761	3910	0.50	0	0
5- Ripening					
Saturation	5108	3830	0.75	3%	17%
20 mm	5536	3790	0.68	4%	10%
30 mm	5656	3860	0.68	2%	8%
50 mm	6164	3950	0.64	0	0

5.2 King Othman Experimental Station

The experiment in this station was carried out in a different way. Treatments were divided into five classes in which the thickness of the standing water layer was changed according to the following schedule.

Stage of Growth	Depth of Standing Water Layer				
	1	2	3	4	5
Germination	100	70	30	50	10
Vegetative Growth (a)	50	30	10	0	Fc
Vegetative Growth (b)	30	20	10	0	Fc
Vegetative Growth (c)	50	20	10	0	Fc
Flowering	70	70	70	70	70
Grain Formation	100	70	50	30	10
Ripening	50	30	0	0	Fc

The results of the experiment are shown in Table (2) from which it can be observed that the amount of water applied gradually decreases from one treatment to the other except of treatment no.5 which required large amounts of water during the vegetative growth stage in order to maintain soil moisture content at field capacity.

The rate of production was proportional to the amount of water supplied, however ; the reduction in water use efficiency in the first four treatments is relatively small. This means that under water shortage conditions, water supply to rice fields can be reduced without getting large reduction in the production of unit water quantity. Obviously the total production will be reduced but in proportion to the quantity of water supplied.

Table (2) Results Obtained From King Othman Experimental Station

Stage of Growth	Date		No of Days	Quantity of Water (m^3/f)				
	From	To		1	2	3	4	5
Nursery and Germination	16-5	20-6	36	1011	995	952	948	952
Vegetative Growth	21-6	15-8	56	2724	2048	1351	735	2432
Flowering	16-8	31-8	16	1173	840	878	872	859
Grain Formation	1-9	30-9	30	1263	1496	1390	1520	835
Ripening	1-10	15-10	15	320	216	189	252	127
Total			153	6491	5595	4760	4327	5205
Crop Yield (kg/feddan)				**3720**	**3212**	**2964**	**2580**	**2265**
Water Utilization Efficiency (kg/m^3)				**0.57**	**0.59**	**0.62**	**0.60**	**0.43**
Reduction in Productivity (%)				**0**	**11**	**20**	**31**	**39**

6. CONCLUSIONS

Although the experiments carried out still have to be confirmed, preliminary results show that the potential of reducing water supply to rice fields through the control of the thickness of the standing water layer throughout different stages of growth appears to be promising.

These experiments are repeated for the second season (1994) in four experimental stations which represents almost all climatic conditions, soil types and hydrologic situations in the Nile Delta.

WATER DEMAND MANAGEMENT FOR NAVIGATION USES WITHIN RIVER NILE

A. Saleh[1] and M. Abu-Zeid[2]

1. INTRODUCTION

The last two centuries of modern Egypt have witnessed a lot of development starting by the construction of the Delta Barrage and the digging of an intensive network of irrigation canals during the eighteenth century and ending by the construction of the High Aswan Dam (HAD) in the sixties of the twentieth.

In between those times a series of barrages have been built, also a new program for rehabilitation of the Barrages is starting now through the construction of the New Isna Barrage and Naga-Hammadi Barrage lock.

The Old Aswan Dam was built and it was heightened two times and dams were constructed in Sudan for guarding and saving lives and satisfying different water requirements.

So, modern Egypt strategy has started by building the infrastructure of the irrigation and drainage network two centuries ago as a hard ware of the system. Now the existing strategy which is a continuation of the previous one is more of soft ware development to improve the efficiency and the performance of the system to meet the increasing demands on the Nile water due to the increase in population and their activities. One of the soft ware development of the Nile is the navigation system. Nile is now used as a water way for both cargo and people, specially tourists. The number of touristic boats has increased substantially in the last few years. Ultimate development of the river for navigation requires enough depth for safe navigation of the ships having biggest draft along the course of the whole river.

The High Aswan Dam (HAD) has guaranteed an annual flow from its reservoir of 55.5 km^3 of water annually. This flow is daily controlled according to actual needs. Some modifications is needed specially at the time of winter closure. These modifications will give better performance to the Nile navigation. At the present time the Nile cruses realized about 400 million U.S.A. Dollars. Modifications, of the system could substantially increase this revenue.

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2. EGYPT WATER REQUIREMENT

Water requirements in Egypt are estimated to satisfy the water use downstream of HAD for all purposes such as; agriculture, domestic needs, industry, navigation and power. The total annual water use in Egypt was estimated on the water-year[1] 92-1993, (61.60 km^3) of which (50.7 km^3) for agriculture use, (5.89 km^3) for Industrial use, (2.91 km^3) for municiple use and (2.1 km^3) for navigation use.

In order to satisfy future water demands taking into consideration the anticipated land reclamation and other water requirements, several management and development plans have to be realized. One of these plans is to minimize navigation water use. The daily water flow which is released down-stream HAD varies according to the daily water requirements. During the winter closure time the flow decreases to its minimum mainly to maintain navigation levels therfore most of it is usually discharged to the Mediterranean sea. This paper presents proposals of safe navigation systems beside other modifications with propeller types in order to save good part of such spellings going to the sea.

3. NAVIGATION WATER REQUIREMENTS

From February to September, water releases for irrigation is sufficient to maintain water levels in the Nile for navigation. Irrigation demands during October to January are minimal hence, are not enough to maintain appropriate navigational levels in the River. This period also is the peak touristic season, where numerous tourist boats make regular sailings between Aswan and Luxor. On the year 1993, some 2.1 billion m^3 of water has to be released to maintain navigational levels. Nag Hammadi new lock and the New Isna Barrage have been re-built, which should provide better control of the Nile water levels. It is expected that by the year 2000, annual navigation water requirements could be reduced to only 0.3 billion m^3 by better control of water levels and implementation of storage in the northern lakes.

4. WINTER CLOSURE

During the period of minimum water requirement in the winter season, major maintenance and construction activities needed along the River Nile and the various canals usually take place. Canals are closed in January or early February for general maintenance. During this closure period water still has to be released from HAD to provide minimum flows for navigation, to generate power and to satisfy domestic requirements. Efforts are made to minimize the water which is not actually consumed during this period, so minimizing the water losses to the sea (Fig.1).

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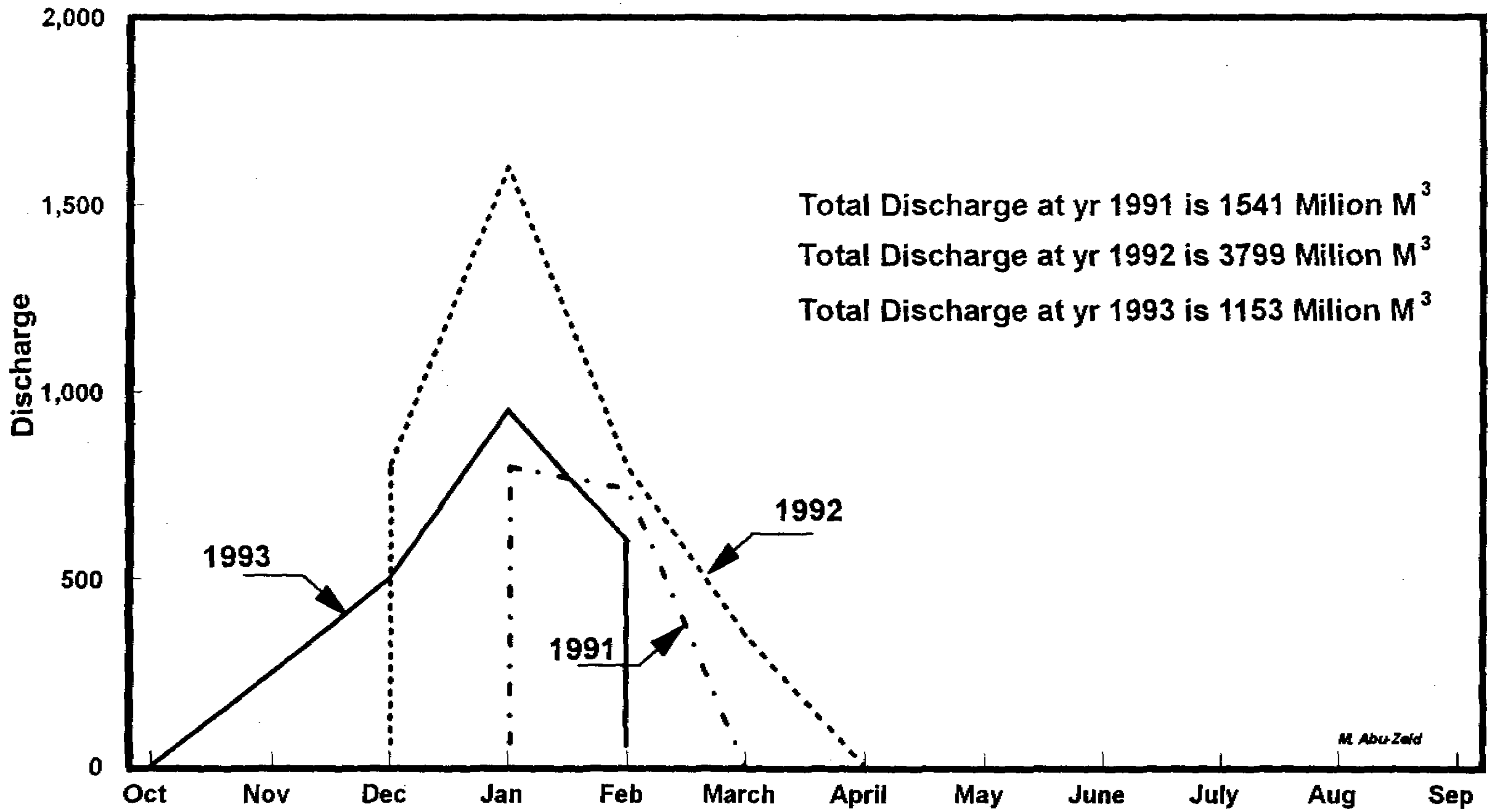
[1] Water Year: Starts from 1st August and ends by 31st July of the following year



Fig(1) The Discharge of Nile Water Flow to the Sea During Winter Clouser Period

The winter closure periods differ from region to another in the country. This is due to the change in climatic conditions and the land slope, as in Fayum region. Current normal closure periods are;

- Upper Egypt	5 January to 30 January
- Middle Egypt	12 January to 7 February
- Lower Egypt	19 January to 14 February

Navigation in canals are very much affected during this period. In practice, canal releases are increased by about 50% for the week preceding and following the closure period. Table (1), shows the total annual water releases to the sea during the last 20 years.

5. MAJOR ACTIONS TAKEN TO MAINTAIN RIVER WATER LEVELS

The Ministry of Public Works and Water Resources (MPWWR) has taken several actions in order to maintain river water levels for navigation purpose such as;

- Hydrographic surveys along the River Nile course are carried frequently by the Water Research Center (WRC)

- Construction of Nag Hammadi new lock. It is 150 m long, 17 m wide and a still water level is (55.40)m, i.e. lower than the old one by 3.1 m to cope with the present and any future drop of water levels due to degradation with considerable reserve.

- Construction of new Isna Barrage and lock to improve navigation facilities, a first class modern lock has been constructed on the west bank with a useful length of 150 m, width of 17 m and a minimum draft of 3.0 m.

- River Nile telemetering system one of the most uses of this system is to maintain river water levels along its course and to manage regulations and operations of major structures along the Nile.

6. NILE RIVER VESSELS SPECIFICATIONS

On the River Nile there are the following types of river vessels:

- Towing vessels
- Cargo vessels
- Passenger vessels
- Sailing vessels

This paper will deal with Passenger vessels only which have the major impact on water requirement during the winter season.

Table (1): Total annual water release to the Sea during the last 20 years

Water year	Discharge downstream HAD km^3	Water release to the sea (million m^3)									
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
74 - 1975	55,797	44	40	740	1980	929	396				4129
75 - 1976	53,218	23	20	446	2084	180	132				2885
76 - 1977	56,140	531	340	1341	2060	1130	430	103	84		6019
77 - 1978	61,785	973	704	2091	3365	1174	1114	1203	949		11573
78 - 1979	59,724	861	895	1966	2221	898	461	262	144		7708
79 - 1980	56,710	384	287	1472	2248	1309	387	35	105		6227
80 - 1981	56,600	242	443	1114	1916	839	316				4870
81 - 1982	59,000	426	532	1279	2382	1412	559				6590
82 - 1983	58,730	485	674	1354	2702	1589	856				7660
83 - 1984	57,055	141	382	925	2547	88	95			233	4411
84 - 1985	56,282	675	430	875	1754	695	179				4608
85 - 1986	55,523	109	166	711	1460	687	34				3167
86 - 1987	55,263	101	516	864	1497	518	169				3665
87 - 1988	52,880	4		404	1385	857	34				2684
88 - 1989	53,335		7	483	1499	783					2772
89 - 1990	53,995			199	945	698				7	1849
90 - 1991	53,795			0	778	689	62	12			1541
91 - 1992	54,245			786	1577	1000	318			117	3798
92 - 1993	55,295	18		497	938	632					2085
93 - 1994				10	673	470					1153

Passenger Vessels

At present time there are more than 250 passenger vessels registered at River transport Authority. These vessels were constructed from steal with several decks. Some of them having swimming pools for the purpose of classification and recreation. Many of them have 5 stars grade.

The most common type of power installed is diesel engine with four stroke with a closed circuit cooling system. The engine order is transmitted by using engine telegraph. No modern control panels are used or even remote control system for controlling engine and helm.

Very few old vessels still using steam in steering. No steam engine vessels are built over the past 10 years. The installed engines deliver speed up to 15-20 km/h according to type of engines and their horse-power.

The size and/or shape of propellers in use depend upon engine speed and the delivered power. The propellers are mainly traditional screw type, although other types may give better performance in such a narrow water way. Usually, the cost and the method of construction play a major role in choosing the types of propellers.

For economical reasons, there is no tendency for employing the controllable pitch propeller or the Kort nozzle types.

The most common type of rudder in use is the unstable rudders. The ratio of rudder's area to the wetted area of vessels is very small. Therefor, the use of propeller effects during a manoeuvre is very important. The turning circle is relatively large for a narrow water way such as the Nile.

The height of the super construction with its several decks form an ideal windage area. The windage area is between 100-350 m^2. For that reason, wind is a main factor affecting manoeuvring and mooring. Wind in general is the most important uncontrollable factor in manoeuvring.

<u>The Passenger Vessels Specifications</u>

The following are the most common specifications:

Type I	Length	44 - 49 meters
	Beam	7 - 8 meters
	Draught	1.7 - 1.9 meters
Type II	Length	59 - 64 meters
	Beam	9 - 10 meters
	Draught	1.8 - 2.1 meters

The Displacement of Passenger Vessels

There are five main kinds of tonnage in use in shipping business. These are deadweight, cargo, displacement, gross and net tonnages.

Deadweight tonnage expresses the number of tons (of 1000 k.g) a vessel can transport of cargo, stores, and bunker fuel. It is the difference between the number of tons of water a vessel displaces, when it is light and when it is submerged to its load line. Cargo tonnage is expressed either in terms of weight or volume.

Displacement of a vessel is the weight of water in tons (of 1000 k.g) which the ship and its contents displaces.

Gross tonnage applies to vessels, not to cargo. It is determined by dividing by 100 the volume in cubic feet of the vessel's closed spaces, and is usually referred to as the gross registered tonnage.

This paper deals with the displacement criteria for type I vessels of weight between 500-600 tons and type II vessels of weight between 600-800 tons.

7. THE WATER DEMAND FOR FLOATATION

(a) In case of still water

The average displacement for a passenger vessel in fresh still water is 700 tones (700 m^3) but in fact, the vessel needs under keel clearance 20% more of that volume. Totaling 840 m^3 for floating statement only.

(b) In case of a steaming Vessel

In steaming, the vessel suffers from the following:
- The loaded draught
- River discharge
- Squat

The loaded draught: The loaded draught is the design depth of water when the vessel is loaded to the load line or plimsolmark at midship while stationary in mean summer fresh water. However, the trend toward increased draught must be taken into account.

River Discharge: The water depth should facilitate vessel travel at all river discharges.

Squat: When a ship enters shallow water there is a rapid increase in the height of the waves produced by the ship. Accompanying this increase in wave height is a results in an average decrease in the water surface along the profile of the ship relative to the still water level. This causes the ship to squat relative to the channel bottom. Other factors affecting the amount of squat are the distance between the keel and the bottom, the trim of the vessel, the cross-sectional area of the channel and whether the channel is located in a wide or narrow waterway. Squat can be calculated by the following formula:-

$$\Delta t=3.75C_B\left(\frac{1}{(bh/BT)-1}\right)^{3/4}\left(\frac{V}{V_o}\right)^{1/12}\frac{V^2}{2g}$$

Δt - Changing of trim in meter
C_B - Blok Co-officiant
b - Channel width in meter
h - depth of water in meter
B - Width of a ship in meter
T - Mean draught in meter
V - Speed of a ship in km/h
V_o - Speed of stream in km/h
g - Gravity

In the condition of the Nile the squat of a passenger vessel with a speed up till 10km/h is between 30-40 cm.

(c) The management of water demand for safe navigation: Management of water demands for safe navigation could be accomplished by marine traffic management and by using new types of propellers.

Marine traffic management:

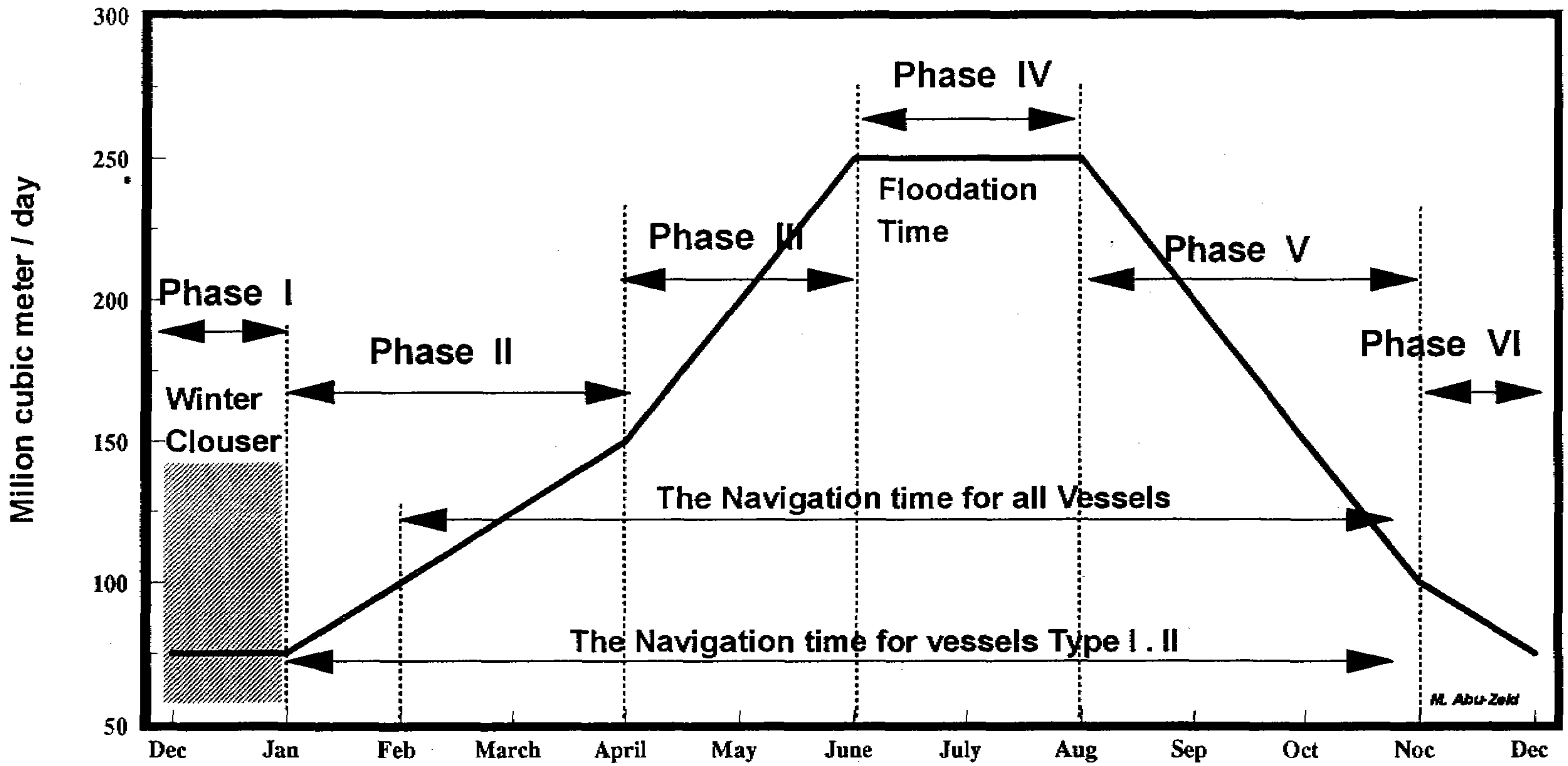
Marine traffic management depends on the following factors:

- The width of the channel.
- The safety margine between steaming vessels.
- The number of vessels in a convey: this number could be calculated by the following formula

$$Nv=\left(\frac{Wa}{Ws_t+Sm}\right)$$

Nv = Number of vessels
Wa = Average working width
ws_t = Vessels width of type (t)
Sm = Safety margin, which is equal to 1.5 wider vessels beam into formation.

Selecting the number of vessels in a convoy should be accompanied by fixing the navigation path which will allow calculation of stream discharge to provide safe and effecient navigation (Fig.2).



Fig(2) Traffic Management

New Types of Propellers:

All the present River Nile motor vessels use the traditional type of propellers although the water ways are narrowed and the other types of propelers may give better performance. Examples of other propellers are the controllable pitch propeller and Kort nozzle propeller.

Controllable pitch propeller: Most propellers are of fixed pitch and are designed for optimum efficiency at some specific operation conditions. The adoption of a propeller in which the pitch can be altered to satisfy a range of operation conditions has some advantages in certain types of ships such as tugboats and passenger vessels. In these ships the use of controllable pitch propellers enables the machinery to run at constant revolutions in the different conditions so that full power can be developed when steaming.

Kort nozzle propeller: This type of propellers is used in case of increasing the thrust provided by a propeller of a given diameter at low speed and high slips. Single propeller vessels are often fitted with the patent kort nozzle.It provides an increase in spead without a nead to increase the power installed which means no increase in weight. Every increase in speed corrosponds directly to a bigger engine and larger tanks for fuel. Consequently more draught and more water for floatation purposes.

Marine Traffic Control System on the Nile

The management of the traffic control system in the river Nile will facilitate the supervision and administration of the following activities:

- Increase the safety and facilitate the navigational processes on the river Nile.
- Monitor and direct vessels in the navigational stream according to river Nile regulations.
- Locate vessels sending emergency signals and provide assistence.
- Face and manage expected increase in traffic flow.
- Supervise the dredging work in the navigational channel.
- Controlling the motion of any vessel moved from one place to another

RECOMMENDATION

The following observations and recommendation can be drawn from the study:

- Procedure are available to calculate the minimum amount of water which forms safe navigation.
- There are new types of propellers which provide an increase in speed without increasing in the power required such as the kort nozzel propellers and the controllable pitch propellers.
- The River traffic control system is necessary to realize the principles of water demand management.
- The optimum solution between the water demand for safe navigation and winter clouser period can be realized.

For the present, the following recommendations can be concluded:

- Hydrographic surveys to be carried out along the selected navigational channel on the Nile.
- Preparation of the navigational charts which cover the distance from Aswan to Cairo.
- Establish Nile navigation data bank
- Initiate river transportation education systems.
- The river traffic management plan should be implemented as soon as possible.
- Adoption of the use of the new types of propellers by the passengers vessels owners and river shipyards.

For the Future the following recommendation are presented:

- Prepare a master plan for the next 5 years including all processes of the navigation and traffic control systems.
- Design new River vessels with new types of propellers and minimum draught.
- Continously update the navigation and trafic control data bank.

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"THE NEED FOR A CHANGE IN WATER RESOURCES SYSTEMS PLANNING PHILOSOPHY"

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ABSTRACT

Conventional planning philosophies for water project design try to find an optimum solution with the aid of a known hydrology and a given forecast of water demand. The result is usually one single "optimum" solution. The application of the principle of sustainable development to water resources systems planning requires, however, consideration of changes in the hydro-ecological system as well as changes in society's attitudes to be expected in future. Thus not only forecast of water demand, but forecasts of many other potential changes have to be considered. Furthermore not only one development path for one parameter is considered, but several scenarios of potential development paths are estimated for each parameter. Planning for sustainable development means that all those scenarios of potential changes have to be considered. Therefore a significant part of the paper deals with the quantification of changes in the hydro-ecological system as well as in society's attitudes to be considered for project design . Six examples of scenarios, forecasting such changes are discussed including hydrology, ecological aspects, climate, water demand, forest damage, water quality and reforestation of agricultural areas. Some ideas about the type of methodology to be developed for sustainable development planning are presented. One major issue here is to condense the information given by the large number of scenarios to solutions with higher probability of occurrence for a restricted planning horizon. The principle of flexibility of design is postulated and specified.

1. CLASSICAL VERSUS SUSTAINABLE WATER RESOURCES PLANNING TECHNIQUES

Conventional Techniques for planning and design of water resources projects try to establish an agreement between

(a) the hydrological conditions expressed by the available hydrometeorological data and

(b) society's requirements concerning water, expressed by water demand for various purposes (e.g. drinking water, hydropower, navigation, irrigation, low flow augmentation) and requirements concerning flood protection.

Thus for a given hydrology and given requirements of society an optimum design alternative can be found. Frequently known trends of various variables are extrapolated into the future up to a given planning horizon. Uncertainty usually enters the design only in form of known probability distributions describing parameter variability.

The philosphy of design behind this approach, which is still popular all over the world, contains one fundamental error, namely the assumption that things will stay as they are in future, or that present trends will continue in future as they were in the past. This assumption is made for the hydrological conditions as well as for the demands and the value system of society. In recent times we learned, however, from observations all over the world that neither nature, e.g. represented by the water cycle, nor society's demands and value systems are stable or follow known trends. Due to this fact many water resources systems planned on the basis of the principles mentioned above became a failure. In order to avoid this, the principle of "sustainable development" was created and advocated by prominent individuals (e.g. the philosopher Hans Jonas) or groups (e.g. the group which prepared the Brundtland report (Brundtland, 1987) or the International Water Resources Asscociation). This principle of sustainability postulates a "development that meets the needs of the present without compromizing the ability of future generations to meet their own needs". The application of this principle is certainly one important component of a changed planning philosophy as postulated in the title of this paper. The requirement for a change in the water resources systems planning philosophy goes, however, beyond this principle. In planning and design of water projects we have to consider not only the prevention of exhausting or damaging natural resources but also changes in society's behaviour over time. This means, that the planning process has to consider potential changes in water demand (e.g. demand increased due to population increase or demand decrease due to recycling), changes in the demand for improved water quality and other environmental parameters, desire for recreation at water bodies etc.. Such changes usually are a consequence of a change in society's value system.

The accumulation of such changes in hydrology as well as in society's attitude renders the above described classical philosophy of design for water resources systems as not appropriate anymore. Thus the question arises, which philosophy of design would be appropriate for present and future planning of water resources systems. In this paper it will certainly be impossible to give a complete answer to this question, but some ideas will be presented, which changes are relevant for planning of water projects, how these changes may be quantified and how such changes as well as changes which can not be predicted in a quantitative way, yet, or are not known at all at present, could be incorporated into the planning process. Planning based on these criteria require different methodologies which are not yet developed and new types of decision support systems in order to give decision makers some guidelines.

2. THE ANTICIPATORY APPROACH - CONSIDERATION OF CHANGES

As mentioned above the postulated planning philosophy should consider expected - and as far as possible unexpected - changes in the future of hydrology and society's attitudes, which has been called "anticipatory approach" (OECD 1991). In the following sections examples will be given dealing with such changes in hydrology and social behaviour which usually could not be predicted in the past, but now tools are available allowing, to a certain extent, to quantify those changes. Therefore new planning techniques should certainly make forecasts of such changes as accurately as possible.

2.1 Change In The Hydro-Ecological System

2.1.1 Example of hydrological changes

There are many causes which give rise to changes in the water balance of a river basin. Here only one example will be given, which shows a change of river runoff in the past, and presents the application of a water balance model (Schultz 1994) for forecasting the expected future development. The process causing the change in runoff is urbanization, i.e. the growth of a metropolitan area. The hydrological model is a distributed system model working on the basis of pixels in the order of magnitude of 50 x 50 m. Data of a digital elevation model, Landsat remote sensing data and digital maps are used in order to specify the relevant parameters in the catchment area with a high resolution in space. The computation is carried out for the Alzette river in Luxembourg with a catchment area of 680 km^2. Figure 1 shows various states of development of the Luxembourg metropolitan area. In Figure 1a we see the situation of August 1975 which was classified on the basis of a Landsat MSS scene. Figure 1b (based on a Landsat TM scene) shows the same catchment in August 1989 where an increase of the metropolitan area by about 100 % can be observed. In order to estimate potential future development two scenarios were computed: one scenario for the situation in the year 2010 (Figure 1c) and one for the year 2040 (Figure 1d), both under the assumption that the growth of the urban areas will continue at the same rate as observed between 1975 and 1989.

The water balance model was used for simulating the hydrometeorological process in the catchment area for 18 years of available data. Figure 2 shows a comparison of mean monthly runoff values (diagram on top of Figure 2) for the conditions of 1975, 1989 and the year 2040. The figure shows that there will be in future a significant increase of mean monthly flows in summer while there is some decrease in winter. This is probably due to the fact that particularly for the convective rainstorms in summer the higher percentage of sealed areas in the growing city gives rises to higher runoff rates. These higher summer flows cause a lower groundwater recharge, which in turn gives rise to lower flows in winter. Figure 2 (bottom diagram) shows furthermore that there are decreases in lower flows and increases in high flows in the scenario of the year 2040. Both processes, the higher discharges and decrease of basin recharge in summer, as well as the general decrease of lower flows and increase of floods must be considered as negative effects. Planning and design of water projects in river catchments with such siginificant growth of urban areas have to consider such future effects already in todays planning procedure.

2.1.2 Example of ecological changes

Sensitive ecological systems in river catchments often suffer from men's activities. Such negative ecological effects often have an impact on hydrological variables which can be quantified. In various parts of Europe and elsewhere in the world we observe large-scale forest deseases which often give rise to the complete death of large forest areas. While we observe complete damage of forests in eastern Germany this danger exists also for forests in western Germany which are still reasonable healthy. In order to quantify the hydrological effect of a potential forest damage the water balance model mentioned above was used for the catchment of the Prüm river (Germany). Figure 3a shows the landuse classification of the Prüm catchment area based on a Landsat TM scene of August 1989. Since forest deseases usually occur in higher altitudes it was assumed that in the Prüm catchment all trees located at higher altitudes than

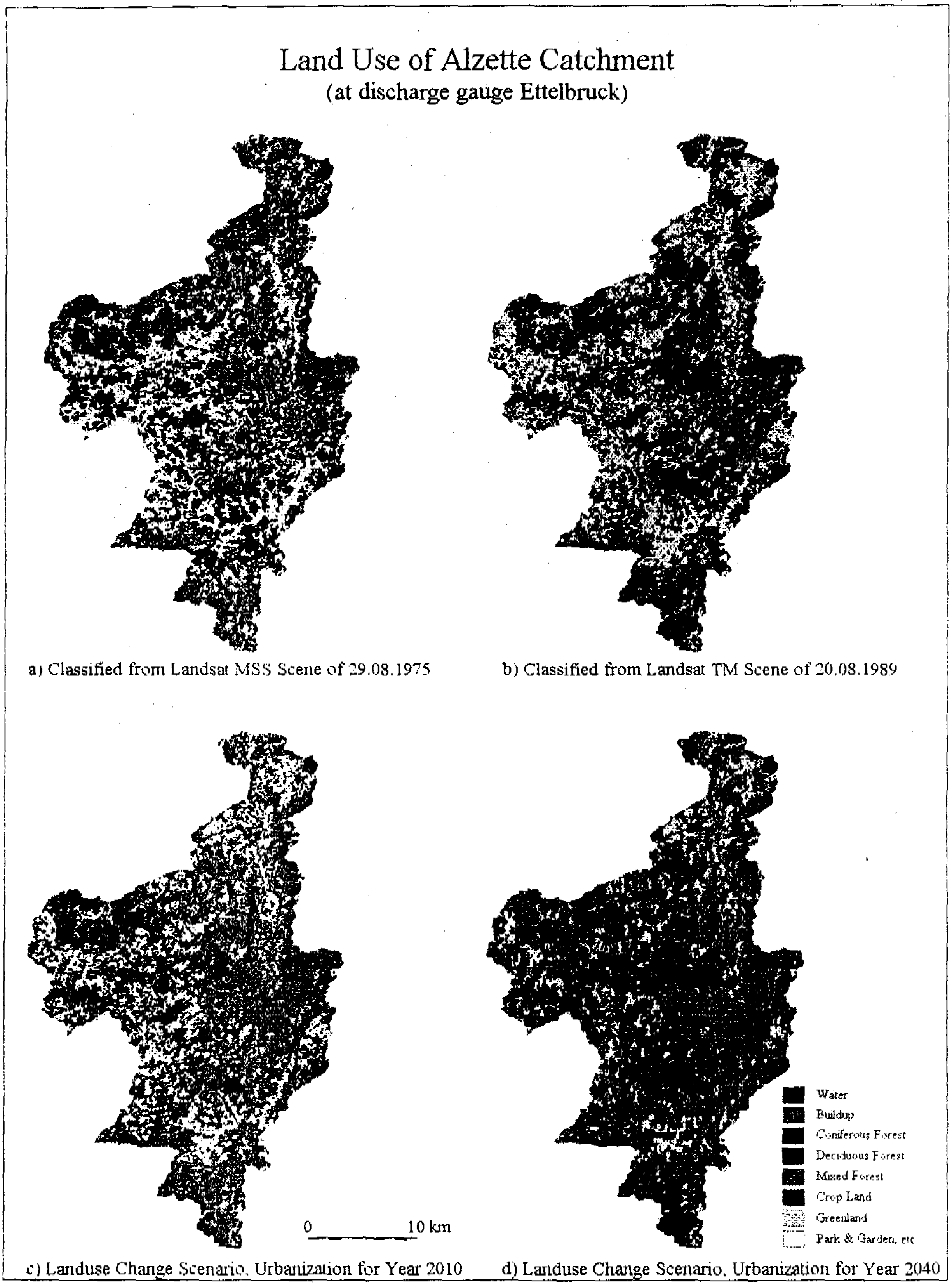


Figure 1 Development of the Luxembourg Metropolitan Area 1975, 1989 and Forecasts for 20 and 50 years in the Alzette Catchment

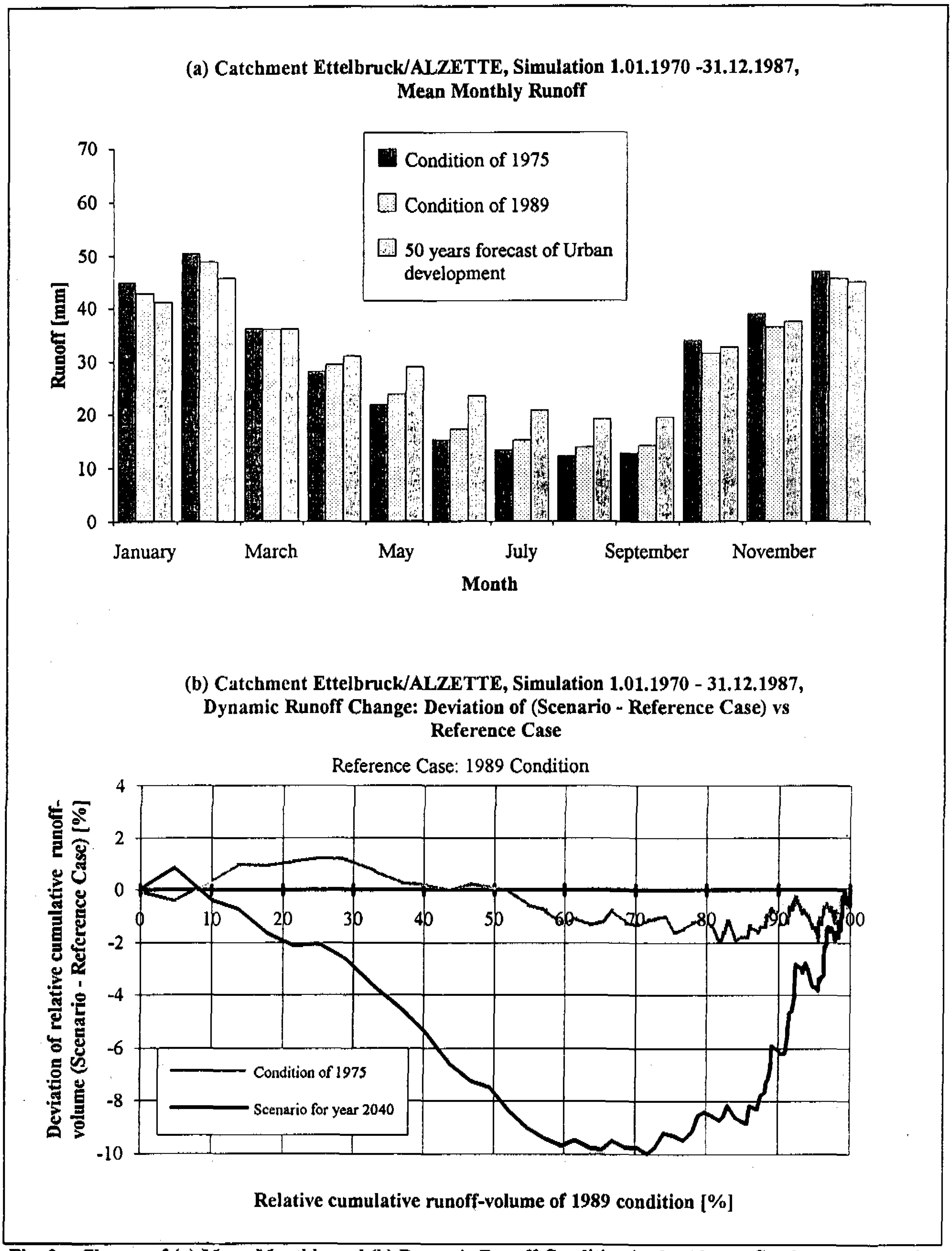


Fig. 2: Change of (a) Mean Monthly and (b) Dynamic Runoff Condition in the Alzette Catchment due to the Growth of the Luxemburg Metropolitan Area

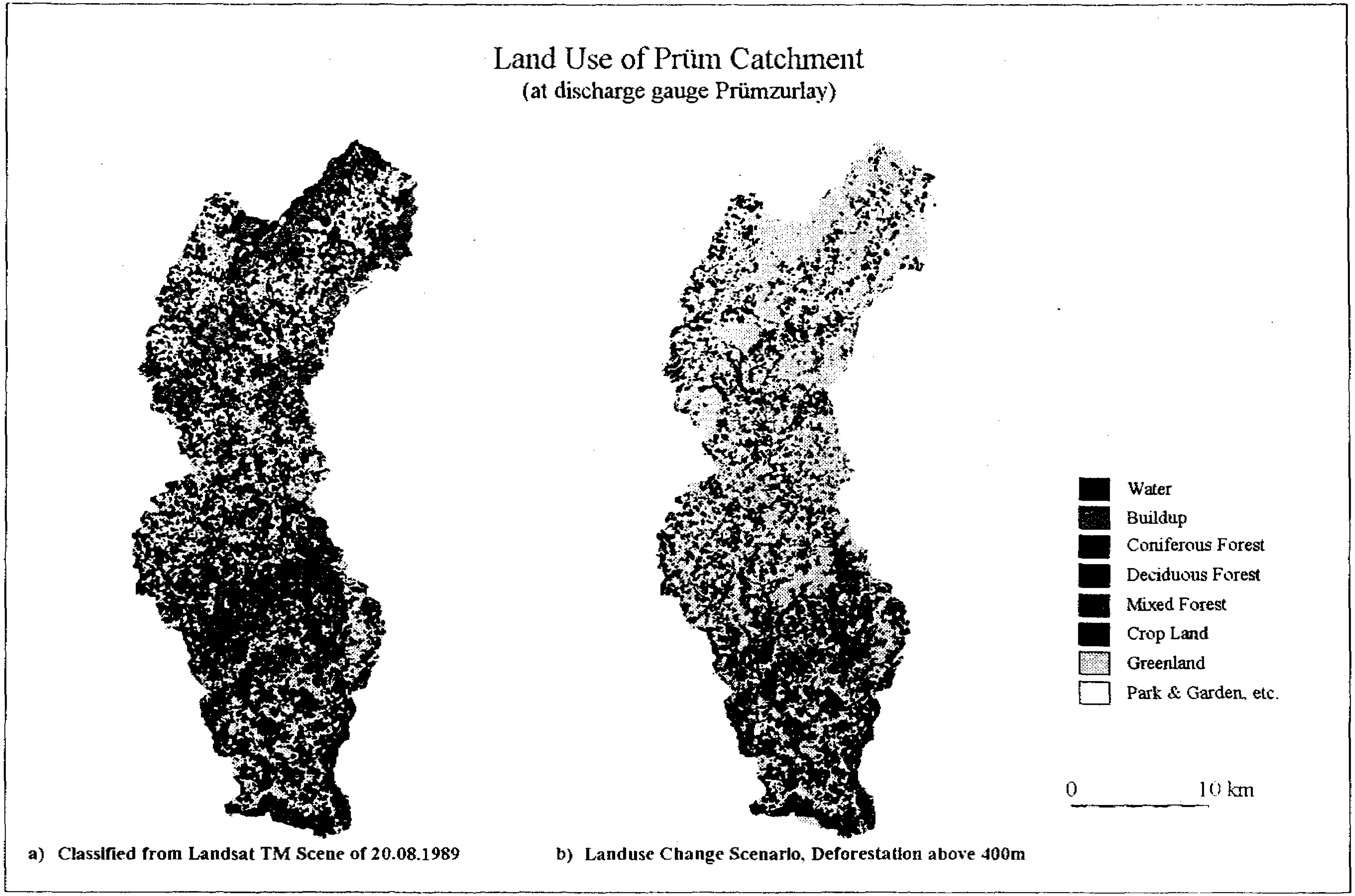


Figure 3. Landuse Classification, Prüm River Catchment, Germany
Present Condition vs Forest Desease Scenario

400 m above sea level were killed by the forest desease. This scenario is given in Figure 3b. Figure 4 shows the hydrological effect of such a forest desease for monthly mean values in Figure 4a and in the dynamic runoff change in Figure 4b. Here we see a significant increase in the already high winter flows due to the forest damage (figure 4a) and we also observe a decrease in the low flows (figure 4b) and an increase in floods, both of which have to be considered as negative effects.

2.1.3 Climate changes

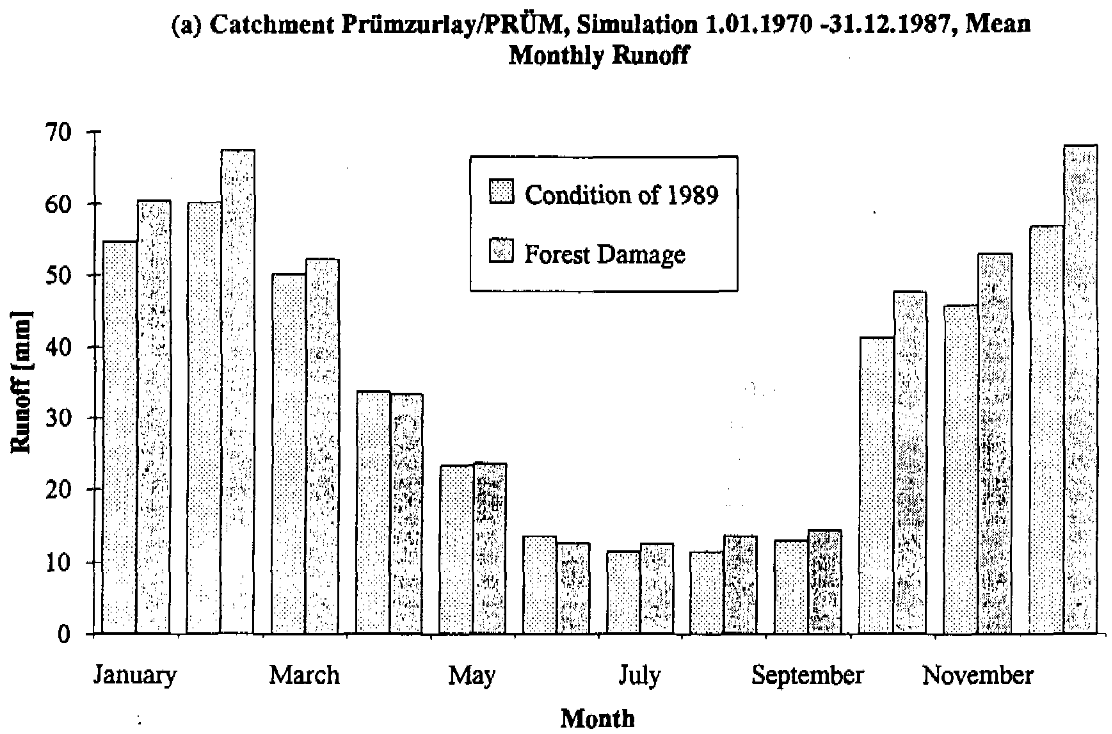
Worldwide we observe an intense discussion on potential climate changes and the impact such changes may have on hydrological conditions. Many "horror-scenarios" are presented - usually based on the output of climate models (GCMs) - and catastrophic impacts are predicted. Such activities have to be disqualified as misleading society which is partially based on a lack of understanding model accuracy or on the persuit of certain interests. It has to be clearly stated, that all existing GCMs are not able to represent the present state of the climate, particularly precipitation and processes depending on precipitation, e.g. runoff, with an acceptable accuracy. The errors in the climate models are much larger than the difference which can be predicted for the change from a 1 x CO_2 to a 2 x CO_2 scenario. The consequence is, that no reliable statement about the hydrological impact of climate change is possible at present. If Figure 5 now shows a scenario of the effect of a potential climate change (2 x CO_2) on the river Prüm in Germany the numbers can by no means be taken as accurate predictions. The figure can be only interpreted as a potential trend associated with a high degree of uncertainty. In future we hope, however, to have better GCMs available allowing us to produce more reliable forecasts of hydrological effects of climate changes, which then should be incorporated into the planning process of water projects.

2.2 Changes In Society's Value System

While the previous section 2.1 dealt mainly with changes in the natural hydrological, ecological and climate systems this chapter focuses on impacts of society's attitudes and activities on the hydro-ecological systems. The major stimulator for these activities of society was the desire for economical growth. The activities in this context caused many negative effects on the hydro-ecological systems:

- industrial and urban developments required more and more water which was withdrawn from rivers and groundwater causing worse lowflow conditions
- for the same reason pollution was increased significantly giving rise to deteriorated river water quality
- flood conditions deteriorated as discussed in section 2.1.1
- increasing food demand caused water withdrawal for irrigation with the consequence of deteriorating lowflow conditions
- irrigation using fertilizers caused pollution of rivers and groundwater
- deforestation and subsequent use of the deforested areas for agriculture caused less favourable lowflow and flood conditions as well as worse water quality
- disposal of industrial and municipal waste worsened groundwater and surface water conditions.

Many more negative impacts on hydro-ecological valuables could be mentioned due to man's activities.



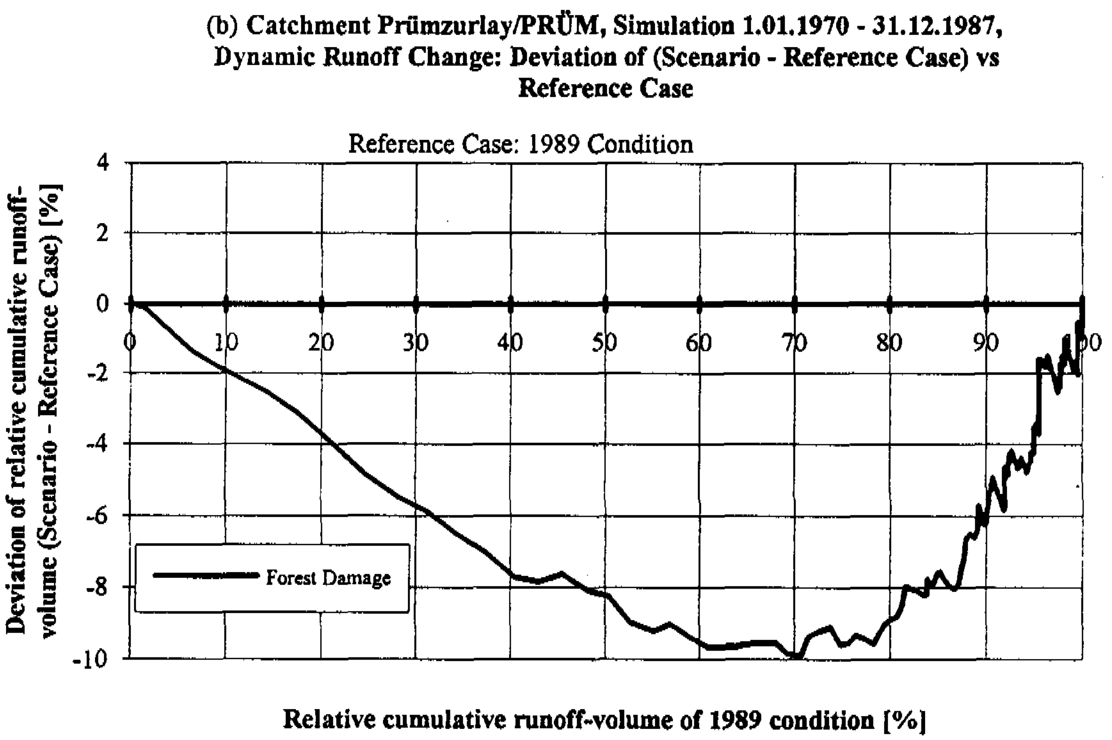
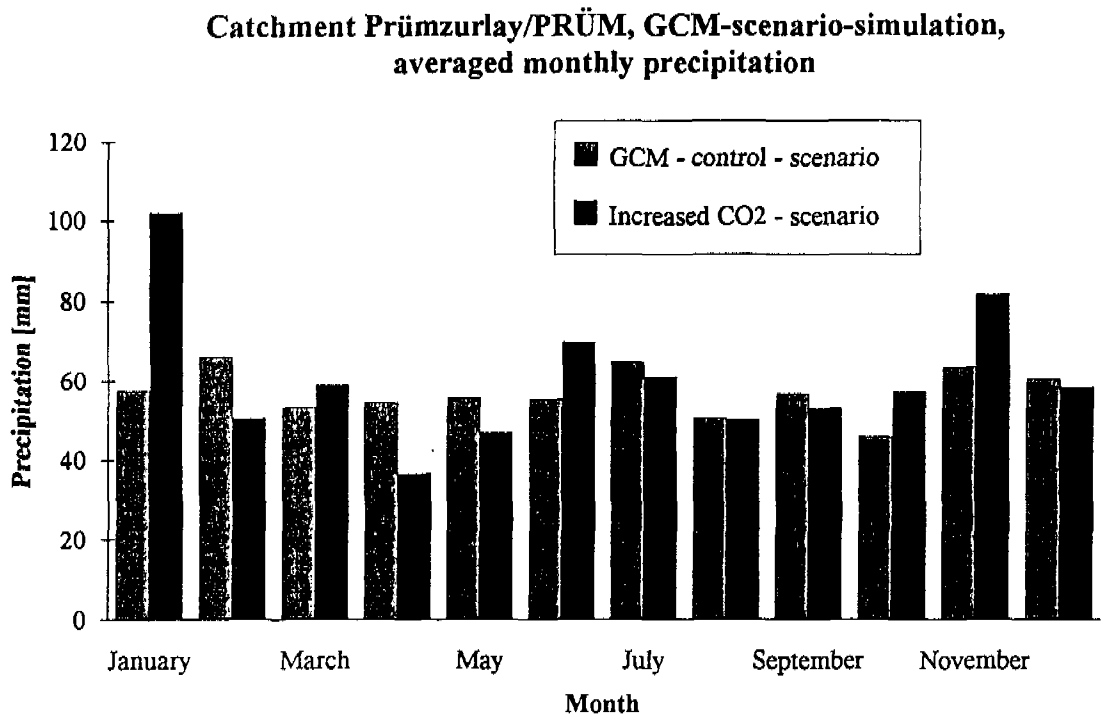


Fig.4: **Change of (a) Mean Monthly and (b) Dynamic Runoff Condition in the Prüm Catchment due to the Forest Damage**



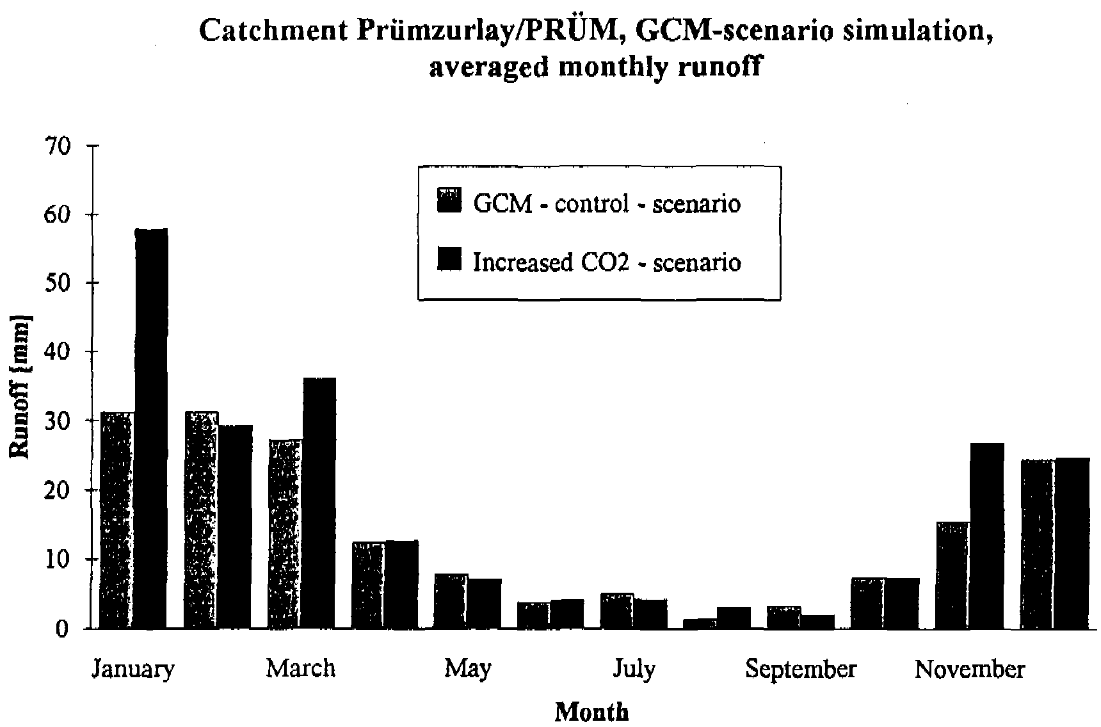


Fig. 5: Hydrological Impact of a Potential Climate Change Scenario (Rainfall and Runoff), Prüm River Germany; $1xCO_2$ (Control) vs $2xCO_2$, Based on the ECHAM-GCM (Diagrams to be considered not by numerical values, but only as rough tendency indicator)

Since the emphasis of this paper and this congress is on sustainable development this chapter will focus now on options society can develop for the creation of positive changes in hydro-ecological systems. This requires acceptance of the principle of sustainability by society with the consequence that on the political level laws will be implemented which enforce activities for improvement of the hydro-ecological conditions. In the following sections three examples will be given, how such positive changes were required by the society and introduced by political bodies in Germany.

2.2.1 Reduction of drinking water requirements in favour of improved lowflow conditions

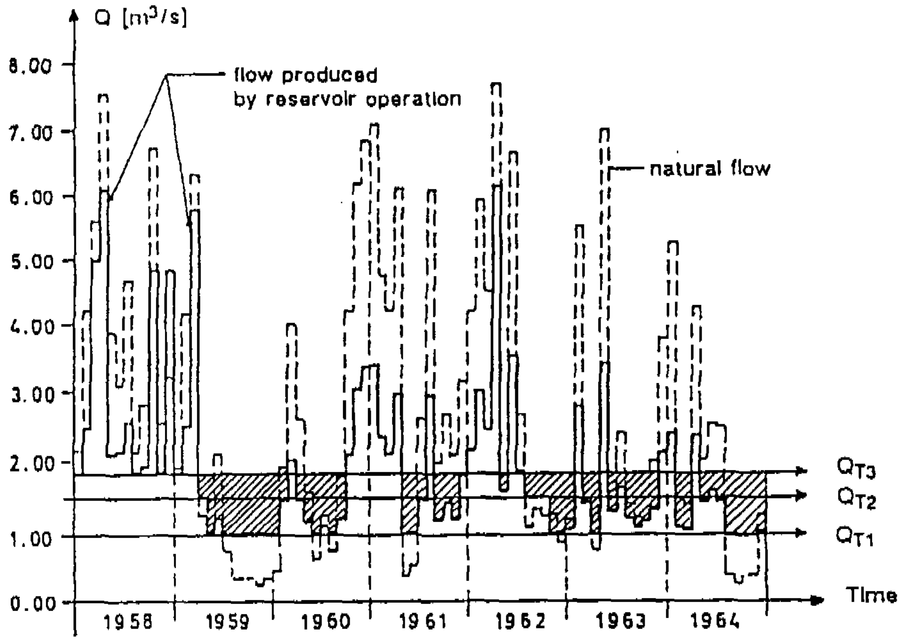
In the 1960s the drinking water demand tendency in the area of responsibility of the Wupper River Authority was extrapolated with the consequence that an additional drinking water reservoir was designed which had to supply 40 Mio m^3/a. The reservoir, the task of which was also flood protection and lowflow augmentation, was constructed for a capacity of 80 Mio m^3. After finalization of the construction in the 1980s it became apparent that two changes in society's value system had occured:

- the rate of increase of the population had gone down to almost 0 % and industry had reduced water consumption due to recycling and other measures. Both processes lead to a significant reduction in water demand rendering the designed reservoir capacity as much too large,
- society had become thoroughly aware of the importance of ecological problems between 1960 and 1980. This gave rise to the postulate of improved water quality in German rivers.

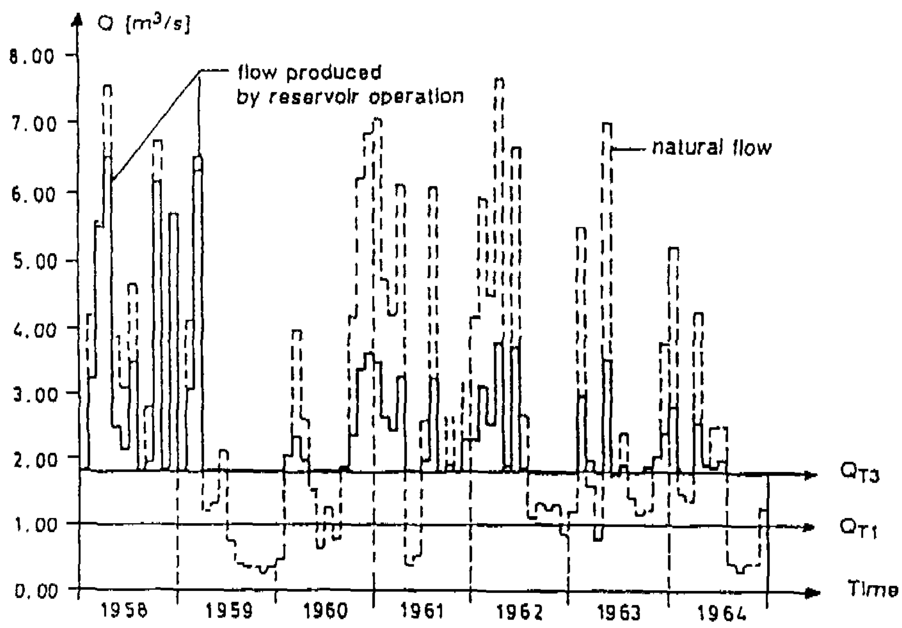
Fortunately both changes - the reduced water demand and the demand for improved water quality - are complementary to each other, i.e. it is possible to use the reservoir capacity not required for water supply anymore in order to increase lowflow augmentation in the river below the reservoir with the positive effect of better water quality and protection of various types of biotopes.

The effect of these changes in society's attitude can be shown with the aid of various computer simulation runs of the operation of the reservoir. Results of those computations for two different objectives: (1) priority is given to the drinking water supply of 40 Mio m^3/a which allows also to meet a lowflow target of 1 m^3/s below the dam with almost 100 % reliability and (2) priority is given to meet an optimum lowflow target of 1,8 m^3/s with a reliability of almost 100 %, which allows a drinking water supply of 28 Mio m^3/a with nearly 100 % reliability. Figure 6 shows a section of the computer simulations of reservoir operation of 7 years. Figure 6a shows a solution for the situation of drinking water supply priority and we can see that only the lowflow target of 1,0 m^3/s can be met permanently. In Figure 6b lowflow augmentation has priority (1,8 m^3/s) and this way only 28 Mio m^3/a can be guaranteed as drinking water.

This example shows that more responsible use of drinking water allows to meet ecological requirements which were postulated by society in recent times.



(a) drinking water supply ($42 \cdot 10^6 m^3/a$) has priority
Q_T = low flow targets



(b) low flow augmentation has priority (Q_{T3} = 1,8 m^3/s),
drinking water supply: $28 \cdot 10^6 m^3/a$

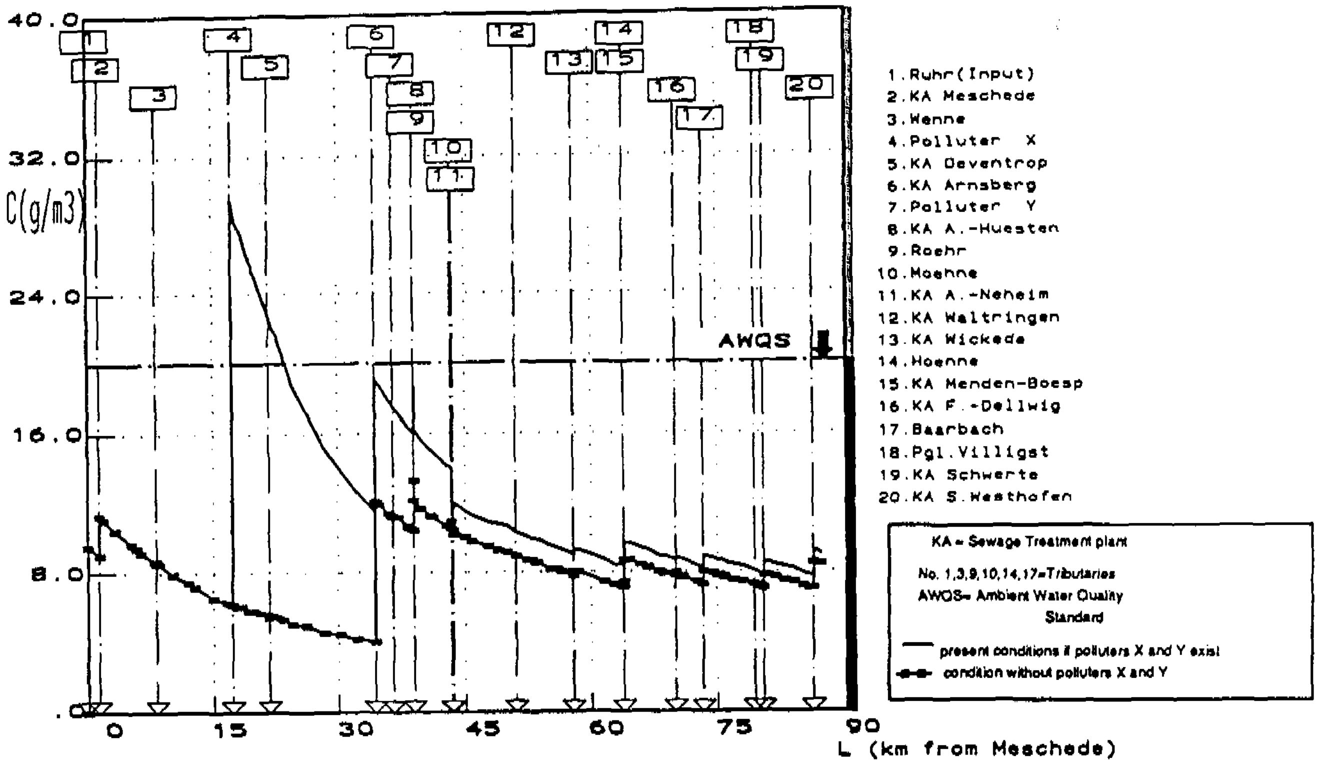
Figure 6. Hydrology downstream of a reservoir depending on priority of water management purpose (Dhünn reservoir, Germany).

2.2.2 Requirement of improved river water quality

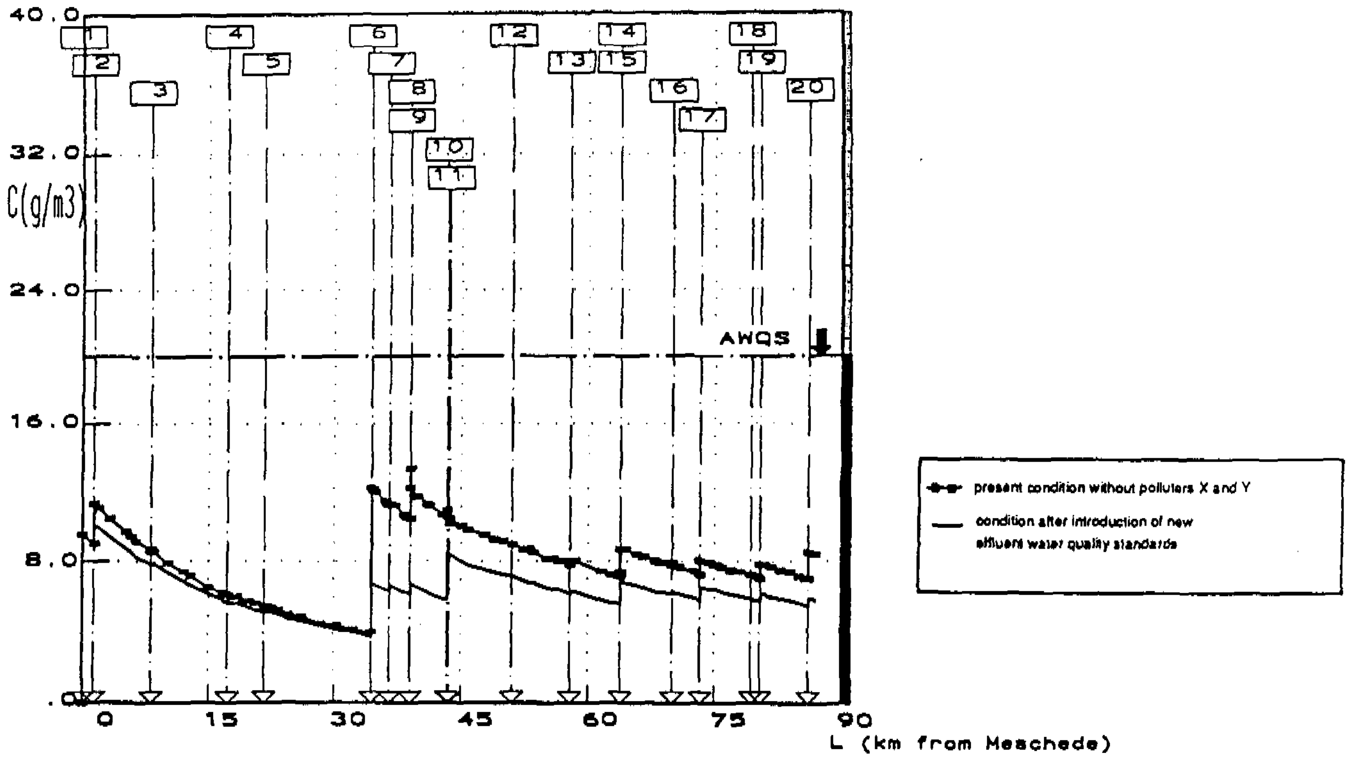
The German water law postulates that within this decade all rivers should reach a water quality of "Water Quality Standard 2", i.e. the second best standard out of 4. This fact reflects the growing awareness of society of the need of improved ecocigal conditions. The consequence of this law is the necessity of improving sewage treatment plants and withdrawal of some licences for production of certain industrial goods causing excessive pollution. The effectiveness of measures for reaching the goal of water quality standard 2 can be checked with the aid of water quality models. Figure 7 shows the longitudinal section of water quality conditions in the Ruhr river in Germany for two different situations. Figure 7a shows the present condition of the water quality parameter chemical oxygen demand (COD), where certain potential industrial polluters are included in the simulation. COD is only one parameter out of many simulated in the water quality model. It can be seen that at least in two cases the critical COD level is reached or exceeded. For less favourable hydrological conditions (lower flows than mean annual runoff of Fig. 7) the situation would be certainly much worse. Figure 7b shows the COD concentrations for the same river reach under future improved conditions with improved performance of the existing sewage treatment plants and after removal of the potential industrial polluters. It can be seen from Figure 7b that only a fraction of the critical COD level is reached, meaning that the water quality is sufficient even for smaller flows. This example should indicate that it is possible to apply water quality models for forecasting future water quality conditions which meet the requirements of society's changed attitude towards ecological conditions.

2.2.3 Reforestation of agricultural areas

Within the countires of the European Union (EU) we observe for several decades now an overproduction of agricultural goods, which gave rise to the so-called "Tomato Mountains", "Milk Lakes" etc.. In order to recognize the absurdity of this procedure one should know that farmers producing this overproduction are subsidized by the EU and taxpayers are charged again for destroying those mountains and lakes. Since this situation is certainly in disagreement with society's value system politicians have thought about means to overcome these unfavourable conditions. The solution consists in the creation of economic incentives for farmers to put out of service certain areas used for agriculture and reforest them. This economic endeavor has also positive hydrological and ecological consequences. An investigation of hydrological changes of reforestation of agricultural areas was carried out for the Prüm river catchment in Germany. Figure 8 shows three landuse scenarios for the catchment, Figure 8(a) for the situation in 1975, (b) in 1989 and (c) for a landuse change scenario in which 30 % of the agricultural areas is transformed into forest. Figure 9 shows the hydrological consequence of such a reduction of agricultural area and its transformation into forest. Figure 9a shows the mean monthly runoff data and we can see a clear reduction of flows in winter and an increase of summer flows. Figure 9b shows the deviation from the condition in 1989 (horizontal line at 0-level). The situation of 30 % reforestation shows (upper curve in Figure 9b) an increase in lower runoff values and a decrease in high flows. Both conditions, the changes in monthly flows and the changes in low and high flows can be considered as positive effects, both in a hydrological and ecological sense. This means, that in this case new requirements and changes in society's value system are met, i.e. an economical and ecological improvement.



a) Present conditions, with (——) and without (-■-■-) certain potential industrial polluters



b) Future conditions, if potential industrial polluters are eliminated (-■-■-) and after introduction of new effluent water quality standards (——).

Fig. 7. Longitudinal Section of Water Quality Conditions (COD).
Ruhr River in Germany (Mean Annual Runoff, Mean Annual Pollution Loads)

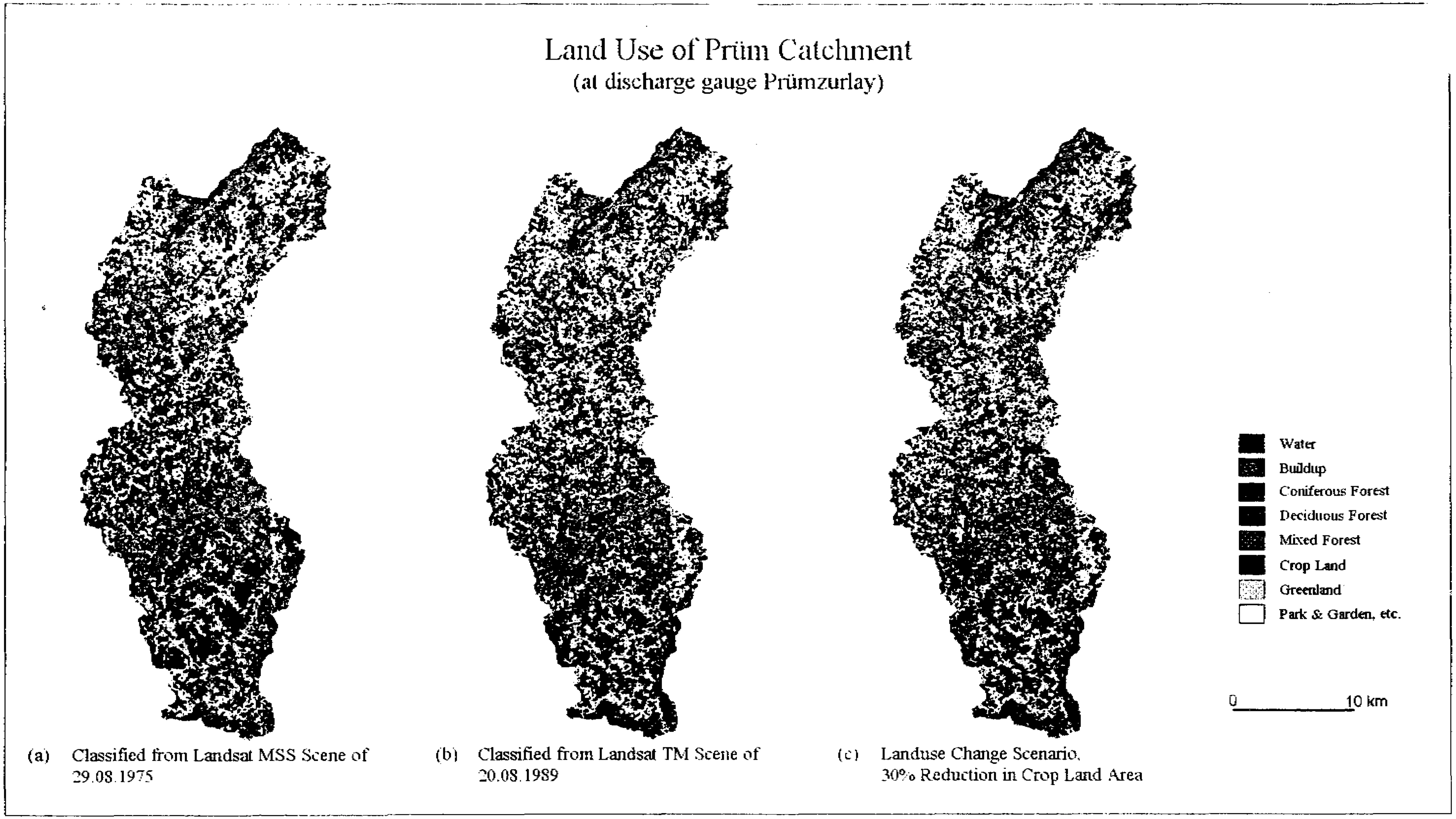
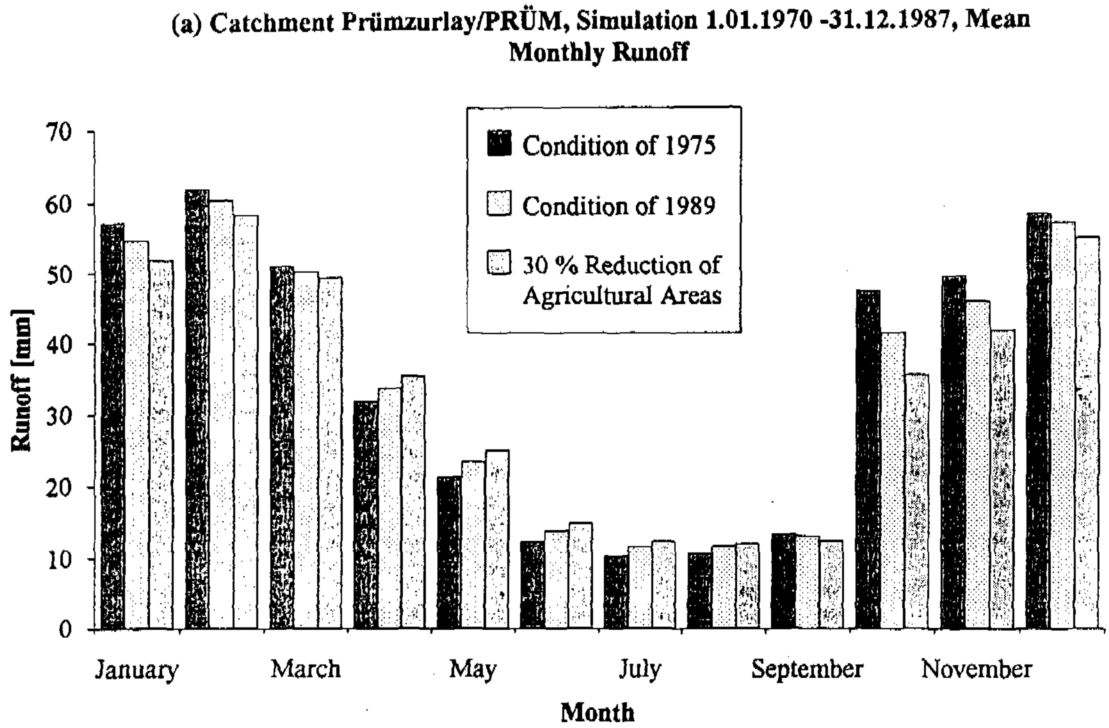


Figure 8. Scenario of Reduction (Reforestation) of Agricultural Areas, Prüm River Catchment. Historical Data for (a) 1975 and (b) 1989 and (c) Scenario for 30% Reduction of the Agricultural Areas



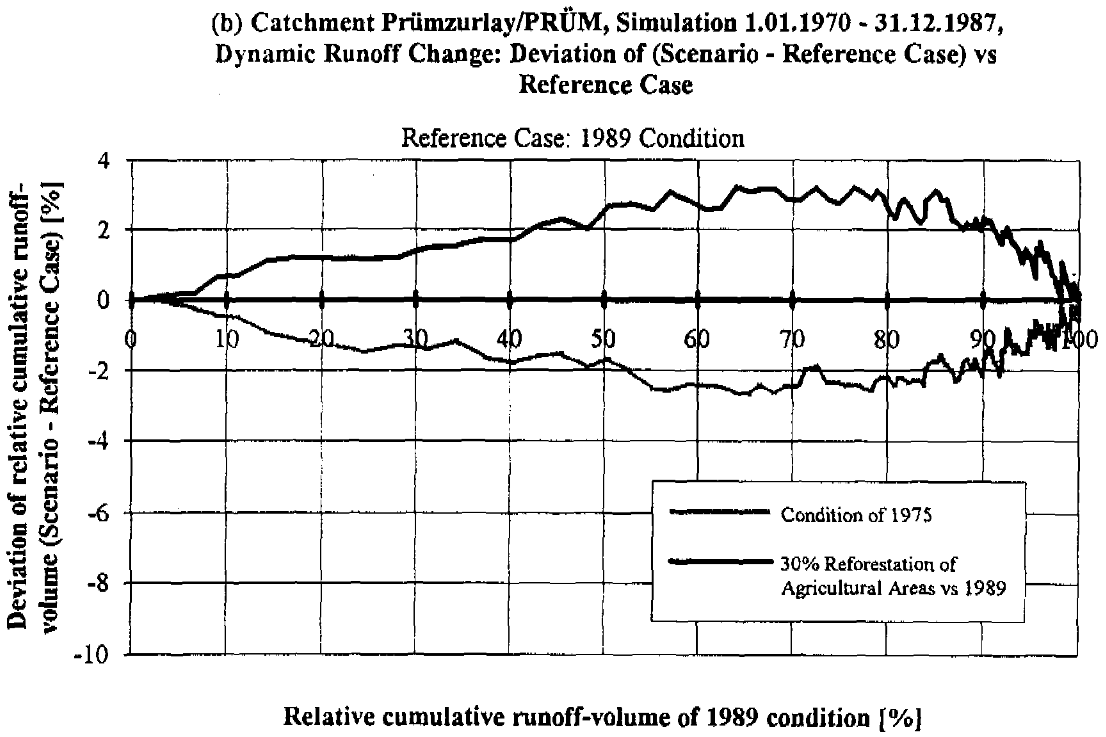


Fig. 9: Change of (a)Mean Monthly and (b) Dynamic Runoff Condition in the Prüm Catchment due to the Reduction of (30%) Agricultural Areas (Reforestaion)

2.2.4 Combination of changes

In chapter 2.1 we have seen changes in hydro-ecological systems, where all three examples showed negative effects. In chapter 2.2 we have seen that changes in society's value system, i.e. in social, ecological and economical fields can be quantified and forecast in their impact on hydrological conditions. All three examples given in chapter 2.2 showed positive effects. It was the author's desire to show, that despite the many negative effects on hydrological conditions we observe also a possibility for positive changes in the direction of stustainable development and that there are cases where such positive effects were achieved if society desires so.

In the six examples given above single changes were discussed and their hydrological effects demonstrated. In real-world hydrological and water management systems we never have isolated effects but usually a combination of many effects, some of which may be positive, others negative. All of these have to be considered in planning sustainable development.

3. PLANNING SUSTAINABLE DEVELOPMENT IN A CHANGING WORLD

If one draws a very brief résumé of the principles discussed above, the following statements can be given:

(1) The principle of sustainability postulates a development that meets the need of the present without compromising the ability of future generations to meet their own needs,

(2) sustainability requires the consideration of changes in natural hydro-ecological systems and their quantification and forecasting for a planning horizon,

(3) consideration of changes in society's value system including their impact on hydrological and water management conditions and their quantification and forecast.

If modern planning and design of water resources systems has to incorporate all these aspects of sustainable development, conventional planning techniques are not appropriate anymore. They have to be replaced by methodologies which are in agreement with the requirements of sustainable development. This has been stated very often in the literature and "Sunday Speeches", but the truth is, that such new planning techniques are not availabe yet. Also the author is not able to present a methodology for planning and design of water resources systems meeting all requirements of sustainable development. Here only some ideas will be given, how this problem may be approached in the future.

3.1 Ideas About a Methodology For Planning Of Sustainable Water Resources Systems

While conventional design techniques often claim to have produced the "optimum" solution, the application of the sustainability principle will yield a wide spectrum of potential solutions depending on assumptions of future developments and changes, which enter the computations. In the following sections a potential sequence of activities in the design process is presented, which produces a large potential solution space. In order to make a decision, this information has to be condensed in some fashion with the aid of a new type of decision support system (DSS).

3.1.1 The scenario concept

Since in the planning process changes have to be considered it is necessary to make forecasts for the future development of all relevant parameters. Depending on assumptions on future changes for each parameter various development paths can be computed. Figure 10 (top diagram) shows the forecast of two parameters (A and B) producing various development paths. If we have n parameters, a n-dimensional forecast would be created comprising all relevant parameters and their forecast changes in future. Such parameters (A or B) could be those discussed in chapter 2.

3.1.2 Probable developments

The procedure discussed under 3.1.1 leads to a very large n-dimensional space of possible conditions where all potential solutions are equal. It is known, however, that certain development paths usually seem to be more likely than others. This would require to develop probability distribution functions (pdf) for each parameter and a specified planning horizon. Since it is usually not possible to formulate such a pdf adequately, one could specify simple triangular pdf's which may be subjective or membership functions in the sense of fuzzy logic. This way the n-dimensional space of conditions would have regions of higher and lower probabilities. In Figure 10 this is indicated in a diagram (center left) for two variables.

3.1.3 Design scenarios

While the diagrams in Figure 10 (center left) may be considered as input to hydrological or water management models all the produced scenarios may be run through models which simulate the hydrological system in order to produce a new n-dimensional space of design relevant variables. The relevant probabilities or fuzzy membership functions could be allocated again.

3.1.4 Project alternatives

In order to identify relevant project alternatives it is necessary to run the design relevant variables shown in the diagram in Figure 10 (center right) through project management models or project assessement models. The result of this procedure is indicated in the diagram of Figure 10 (bottom). In this diagram we see contours describing the performance level of potential project alternatives for different conditions. Here "project alternative" does not mean a structure (e.g. a dam) with exact design of all its elements (storage capacity, spillway, bottom outlet etc.) but rather a system (e.g. location of a dam or group of dams) where the dimensions of the elements are still open and flexible and where a large number of possible operation rules could be applied. Small circles can be identified which are suitable only for those developments which are given high probability (e.g. option A) in Figure 10 (bottom)). Such a project design shows only low flexibility as far as less probable development paths are concerned. Project alternatives B and C comprise larger areas of decisions spaces representing medium and high flexibility, where flexibility means the ability of a project design to be valid for a wide range of potential future developments and changes. The methodology for transition from Figure 10 (center right) to Figure 10 (bottom) could be a large number of simulation runs in order to have enough points in the solution space. It may be, however, also possible to apply a stochastic multi-objective decision

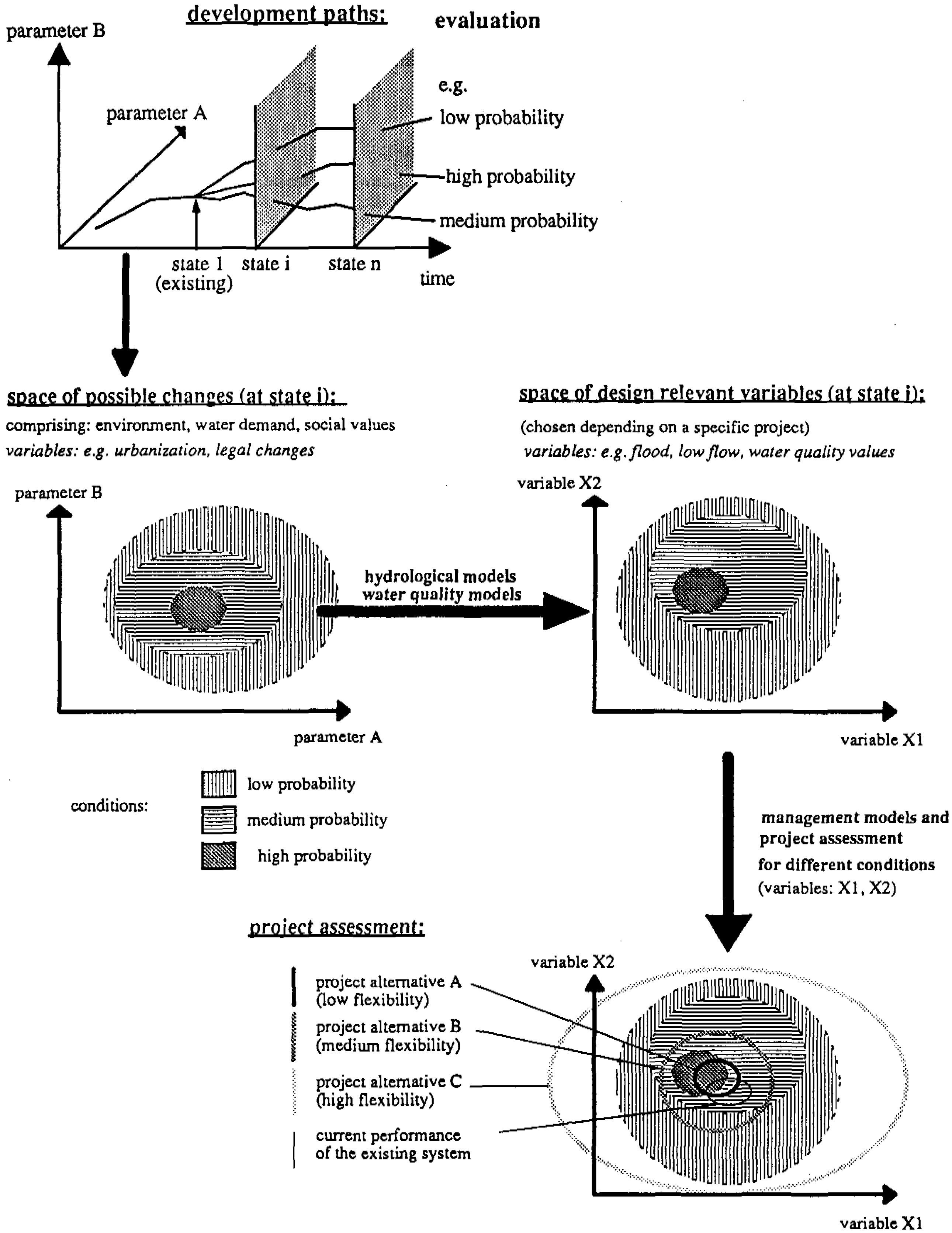


Fig. 10 Concept of a Decision Support System (DSS) for Water Resources Project Planning under Changing Conditions

making technique. This may be rather complex and requires development of new mathematical procedures.

3.2 Decision Support System (DSS)

The various procedures discussed under section 3.1 deliver contours of project options in an n-dimensional decision space with various degrees of probability or flexibility. This type of information is certainly not good enough in order to enable a decision maker to make a good sustainable decision. Therefore it would be necessary to condense the available information of Figure 10 (bottom) to such an extent that a decision can be made more easily.

Here we are faced with a difficulty: since the principle of sustainability requires consideration of most potential changes in the future it would be necessary to design a project such, that it will be able to handle not only those changes having a high probability, but also the less likely changes. This would require choice of solutions with high flexibility (Figure 10 (bottom)), which means the design structure has to meet an extremely wide diversity of potential operating conditions. Therefore the "principle of flexibility" as design criteria is desirable, but it will certainly be a solution which is much more expensive than structures being able to handle only situations of higher probability of occurrence. The difficulty then arises that the decision has to be made in consideration of the trade-off between flexibility and costs. At present nobody knows how much increase in project flexibility is worth how much in additional costs. Here a demand for further research certainly exists.

The principle of flexibility comprises project design as well as operation. If a project design with high flexibility requires e.g. a reservoir to be small as well as big, flexible design could mean construction of a concrete gravity dam such that it is rather small at the beginning but the dam contains already the holes required for the steel cables which are needed for a dam rise in form of pre-stressed concrete. Flexible design could also mean provision of a phosphate elimination plant in the inflow reach of a reservoir if some scenarios of medium probability forecast a significant increase in the use of fertilizers in agricultural areas upstream of a dam.

The uncertainty in the whole design procedure as discussed above increases with longer time horizons for the planning. Since sustainable development requires that also our grandchildren would agree to a design decision made now we have the dilemma of the necessity to produce long term forecasts under very high uncertainties. Since there is no objective solution to this dilemma the author would suggest the following procedure: make a long-term forecast for all design relevant variables and find the n-dimensional solution space as presented in Figure 10, but make the decision such that it can be corrected after a certain period of time. The author's suggestion is to make the design suitable (in form of a flexible design) for a forecast period of 10 years without need of major structural changes in the project. This means that only the operating rules have to be changed in order to meet the impacts of changes within the next ten years. After ten years a new forecast and decision has to be made following the principle given in Figure 10.

4. CONCLUSIONS AND FUTURE PROSPECTS

The paper postulates the need for a change in water resources system planning philosophy. Following the principle of sustainability it was shown that it is necessary to consider expected future changes in the natural hydro-ecological system as well as in society's attitudes. Examples for quantification and forecast of such changes are presented. Consideration of these changes requires a new type of planning process for which some basic ideas are given. The principle of "flexible design" is postulated and explained. It should lead to projects which are flexible enough to meet most of the potential and more likely changes up to a time horizon of at least 10 years.

The methodology required for such new design procedures is presented only in a very basic and still vague form. There is an urgent need for development of the theory required for a modern Decision Support System applicable for planning and design of water resources systems in the sense of sustainable development.

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MANAGEMENT OF WATER DEMANDS IN RURAL AUSTRALIA

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ABSTRACT

Demand for water has always been an important consideration in the economic and social development of Australia. More recently, pressure on the nation's water resources has intensified and with supply options limited, the emphasis has shifted to resource management to satisfy these demands. In the Murray-Darling Basin of southeast Australia, the case for water demand management is compelling, both on economic and environmental grounds. A range of management measures is in place aimed at containing overall demand and redistributing water use in space and time. Care will be needed to ensure that the rural communities involved are consulted in the process to ensure that social dislocation is minimised and the measures necessary to promote structural adjustment are implemented.

En Australie on a toujours regardé comme important le rôle de l'eau dans la vie économique et sociale. Pendant les années récentes la demande sur les ressources de l'eau nationale est devenue plus fort, et parce que les choix d'aujourd'hui sont plus bornés, on a été forcé de se servir d'aménagement des ressources afin de satisfaire les besions. En Australie Sud-Est, dans les vallées du Murray-Darling, on exige fortement l'aménagement de l'eau, d'une part à cause des questions économiques, d'autre part à cause de l'environment. On a établi plusieurs projets qui ont, comme objectif, la limitation des demandes sur l'eau et la répartition encore de l'eau de place en place et de temps en temps. Il faudra délibérer avec les gens ruraux intéressés pour assurer que la discolation sociale soil-minimale et que les ordonnances nécessaires soient mises à point.

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INTRODUCTION

The opening words of the 1992 Dublin Statement on Water and Sustainable Development underline the critical importance of global demands on water.

> Scarcity and misuse of fresh water pose a serious and growing threat to sustainable development and protection of the environment.
>
> (World Meteorological Organisation, 1992, 3)

These words have particular significance for Australia; a continent which is recognised as one of the driest on earth. Rainfall and run-off are low by comparison, snowmelt is limited by world standards, and the climate, generally, is typified by marked irregularities in space and time in the availability of water. Even as this is being written (July 1994), more than half the country is seriously affected by drought, described in some areas as the worst this century.

Given these circumstances, it is easy to understand why water has always been an important consideration in the economic and social development of Australia. The history of settlement of the continent records ongoing concern for water supplies. For thousands of years, Aboriginal settlements and activities were linked to the availability of water, and even today, water is the focus of many sacred sites of the first Australians.

From the earliest days of European settlement more than two hundred years ago, a secure water supply was seen as essential to cope with inevitable periods of scarcity. As the settlers moved away from the coast the question of a reliable water supply became critical to the choice of town sites and resource use. Continued occupation and development of the inland brought with it the realisation that an effective means was necessary for harnessing and sharing the scarce and highly variable water resources available.

Water storages were constructed across the continent for every conceivable purpose. At last count nearly 400 large dams had been built and where surface water was unavailable, groundwater was tapped to provide an alternative source of supply. Water resource management was equated with water resource development and endorsed by generations of politicians and engineers, and a generally water-sensitive population (Pigram, 1986).

RESOURCE REAPPRAISAL

It is only in the past two decades that attitudes to water management have undergone substantial change in Australia and serious questions have been directed towards further large scale manipulation of the hydrologic cycle.

Growing demands from agriculture, industry and a highly urbanised population, together with rising expectations about the quality of life and the environment, have intensified pressure on the nation's water resources. Yet, no longer can these demands be met merely by boosting supply. The pervasive developmental approach to water issues has been challenged and the emphasis on structural solutions to water inadequacy has, in a relatively short space of time, been replaced. Increasingly, water is recognised as a multifunctional resource amenable to alternative means of management to satisfy a diverse spectrum of uses.

In the more densely settled and developed areas of the continent, economic and physical infeasibility now preclude the building of more dams, and groundwater reserves are stressed in several areas. Moreover, attitudes are changing and engineers and politicians can no longer anticipate automatic and enthusiastic endorsement of proposals for more developmental works. Community demands on available water resources are also increasing, in terms of the quantity, quality and level of service, as well as in respect of alternative water uses relating to environmental values for nature conservation and outdoor recreation and tourism.

In these circumstances, the emphasis has shifted rapidly from development of water resources to better management of available supplies. The focus is now on implementation of integrated management strategies to influence the level and structure of demand for water in order to achieve policy priorities and community objectives, and maximise efficiency in water use. More effective management of demand represents the most economic and environmentally acceptable means of improving the availability and reliability of Australia's water supplies to meet an increasing and varied range of functions.

MANAGEMENT OF RURAL WATER DEMANDS

Demand management applies both to surface water and groundwater, to irrigation, urban and industrial use, and even to water allocated for environmental purposes. The emphasis in this paper, however, is on management of rural water demands, specifically in irrigation where water is a primary component of production. The focus of the study is on the Murray-Darling Basin in southeast Australia where management of water demand is crucial to the viability of irrigation agriculture, as well as to the mitigation of pressing ecological problems in the region (Figure 1)

Management of rural water demand implies adoption of measures to satisfy agreed social, economic and environmental objectives. This means not merely containing overall demand, but redistributing demand among existing and emerging uses, sectorally. It also may entail redistribution of demand in time and space, to less environmentally sensitive sites, and to more economically viable areas. Moreover, rural water demand management might well embrace not only a share allocation of the water resource but, in some circumstances, a share of drainage capacity, or discharge rights for accessions to the water table.

In the Murray-Darling Basin, the argument for water demand management is compelling, because of overcommitted resources and the need to address productive inefficiency in some areas, coupled with concern to redistribute water use from stressed ecosystems in other areas. In either situation environmental water needs might also be met as a corollary of more efficient water use.

The case for management of rural water demands in the Murray-Darling Basin can be made on both economic and environmental grounds. However, implementation of demand management techniques to achieve economic and environmental sustainability raises a number of social issues. The challenge is to achieve sustainability in a way which is socially acceptable and avoids community disruption and inequitable outcomes.

These issues were considered at a Workshop on Rural Water Demand Management in Australia (Australia Water Resources Council, 1992). The following comments draw in part, on the outcomes and recommendations of that workshop, for which the author acted as Rapporteur.

ECONOMIC RATIONALE

The major demand for water in rural Australia is in irrigation which accounts for at least 75 per cent of use. Over 80 per cent of the nation's irrigated land is in the Murray-Darling Basin which accounts for more than A$3 thousand million dollars in irrigated production. Much of the water is used on relatively low value enterprises with only a small area in high value horticulture and cotton production.

There are marked differences in the returns per megalitre of water across the Basin. For example, on the southern riverine plains, some two-thirds of the irrigated areas had gross returns of A$60 or less per megalitre of water applied (Table 1).

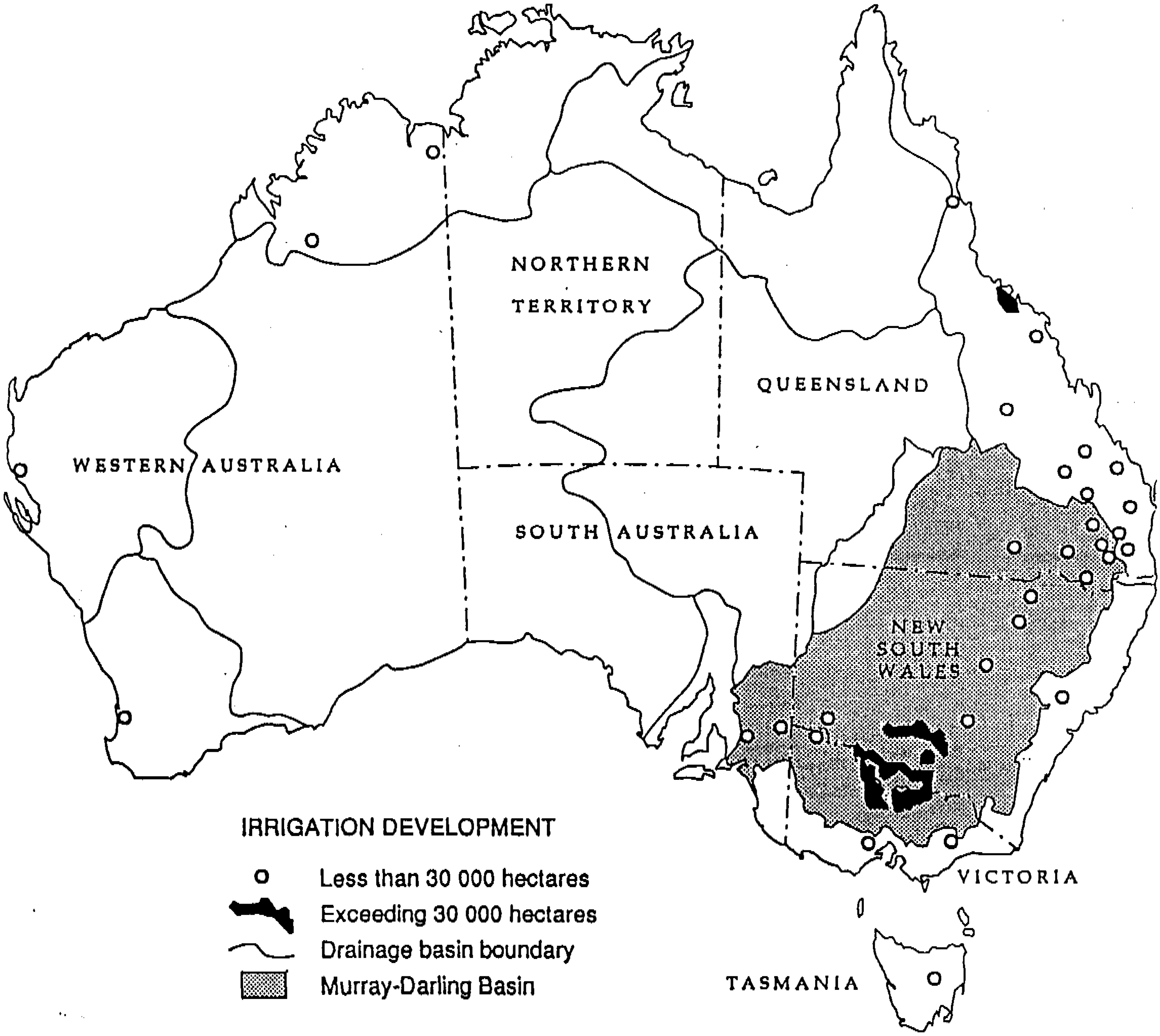

Figure 1 Australian Irrigation and Catchment Areas: The shaded area is the Murray-Darling Basin, the major catchment and drainage area in Australia

Table 1 IRRIGATED CROPS AND GROSS RETURNS (1987-88) MURRAY-DARLING BASIN

IRRIGATED CROP	GROSS RETURNS (A$/ML)
Rice	60
Wheat	83
Dairy	110
Stone Fruit	500-700
Citrus	300-700
Dried Fruits	1200
Cotton	250

Source: Australian Bureau of Agricultural and Resource Economics

The major parts of the area under irrigation, particularly in the southern parts of the Murray-Darling Basin, do not achieve reasonable returns per megalitre for water. In addition, yields obtained by the average irrigator are generally of the order of 60 per cent of yields when compared with irrigated areas elsewhere in Australia and the world with similar environmental conditions.

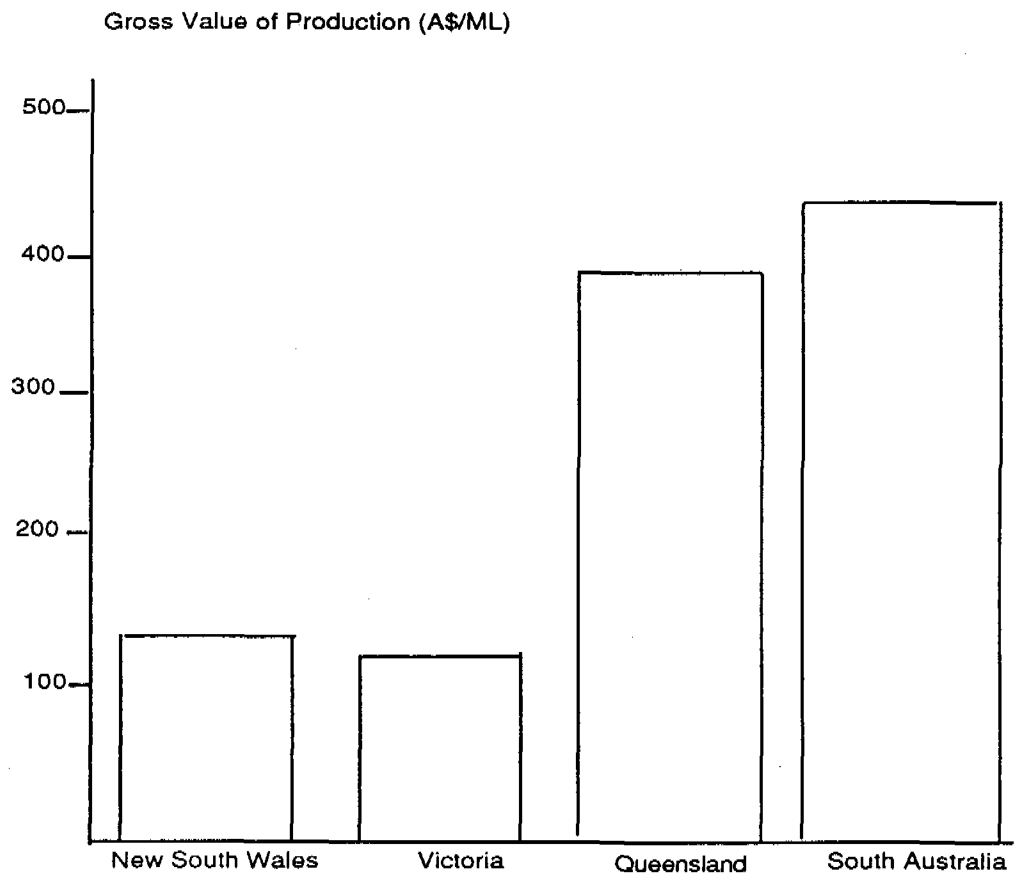

Figure 2 A comparison of yearly values of production per unit of irrigation water in Australia

Source - Australian Water Resources Council, 1992

Figure 2 suggests that the yearly value of agricultural production from irrigation is between approximately A$100 and A$450 per megalitre. In an international context, these figures compare well with California, but fall well short of the standard set by Israel at $1200/ML/year from high levels of management and high quality produce (Australian Water Resources Council, 1992). These variations and comparisons suggest further that opportunities exist for shifting the demand for irrigation water away from lower value uses and towards more efficient water use practices.

Given that most of the water resources of the Murray-Darling Basin are fully developed and in some areas, over-committed, attention is now being directed towards the most economic allocation and use of water . The challenge is to increase either the output for the same water input, or to "do better with less" and reduce the water input, while maintaining or increasing the output. This requires irrigation interests to consider the potential of squeezing more efficiency gains from economies in water use. Irrigators in the northern parts of the Basin for example, deservedly have a reputation already for being among the most efficient in Australia. However, as economic pressures increase and emerging claims on water are recognised, the irrigation industry must take a fresh look at its share of the resource and become a leader in "best practice" in water use.

ENVIRONMENTAL RATIONALE

The Murray-Darling Basin is now subject to extensive environmental degradation with rising water tables, salinisation and structural decline of soils, and eutrophication of waterways (Meyer, 1992). The area of shallow water tables in the southern irrigation areas of the Basin is predicted to increase from 59 per cent in 1990 to nearly 100 per cent of the irrigated areas by 2010 (Lyle, 1992). Current costs of waterlogging and salinity are estimated to reduce annual irrigated production by A$65 million. These losses are expected to double by 2010 if no remedial action is taken. Apart from salinity, water quality may be further degraded by nutrients and pesticides, with associated effects on wetlands and the riverine environment.

These environmental problems are, in part, attributable to the geological and geomorphological features of the Basin. However, there is no doubt that the amount of water regulated and diverted for irrigation use has been a major factor in resource degradation. An important question then becomes the extent to which changes in the demand for water might lead to a more sustainable water-related environment.

Moderating or redistributing demand has the potential to assist in addressing resource degradation problems in the Murray-Darling Basin. River regulation for irrigation can have marked effects on flow patterns. with consequent changes to biophysical processes. The ecological productivity and biodiversity of the riverine environment may be affected leading to a decline in habitat conditions and species composition. Recognition of instream needs will involve changes in allocation procedures and the management of river systems to satisfy ecological requirements. In other words, redistribution of water commitments is called for, from extraction to meet productive rural uses such as irrigation, to retaining water in the rivers for instream purposes.

The development of irrigation must also take a large part of the blame for the emergence of waterlogging problems and salinisation of soils and water bodies in the southern parts of the Murray-Darling Basin. The clearing of native vegetation for irrigation contributes to rising water table levels as drainage water recharges groundwater systems. These rising water levels mobilise high concentrates of salts occurring naturally in the underlying soils and redistribute them through the root zones of plants. In some parts of the Basin, saline groundwater, concentrated at the surface by evaporation has created extensive salt pans. Excessive concentrations of salt in the root zone can retard or even kill plant growth.

Of greater long-term significance are accessions of salt to major waterways from surface and subsurface drainage of irrigated land. The salinity level of the Murray River as it flows westward can become high enough to cause significant production losses when used to irrigate horticultural crops downstream. Not all inputs of salt to the river are from drainage of saline water from irrigation areas. However, on average, more than one million tonnes of salt are estimated to enter the river annually. More than 50 per cent of these inputs are believed to be attributable to human activities.

Clearly, the impacts of waterlogging and salinity present a major environmental threat in the Murray-Darling Basin. Added to these is the risk of damage to soil structure and declining productivity in other parts of the Basin from the effects of intensive cultivation, monoculture, and the failure to match soil types with water application.

Management of demand for water can encompass measures to influence areas irrigated, crop types, application rates, irrigation methods, and drainage practices. In this way, demand management can facilitate a shift in irrigation pressure away from sensitive environments, a reduction in water applied, and an improvement in water quality in streams. Coupled with deliberate allocations of water for instream needs, these measures should leave more water in the rivers for environmental purposes, and contribute to more sustainable stream environments.

IMPLEMENTATION STRATEGIES

Effective management of rural water demands calls for an integrated range of strategies embracing water allocation measures, pricing policies, and complementary procedures. Ideally, the community affected should be consulted and involved in the implementation process to achieve a proper balance between government direction and self-regulation. Moreover, the redistribution of water demand will inevitably involve questions of equity and social values, and the potential need for compensatory mechanisms and conflict resolution.

In the developmental phase of Australia's water resources, command-and-control methods for managing demand and regulating use were acceptable. Increasingly, such a regulatory approach is considered unlikely to provide for socially, economically and environmentally optimal use of water. A market-based approach to water resource allocation and use is now seen as preferable to one based on regulation and centralised control. The challenge remains for the development of an institutional framework for the management of river systems and irrigation enterprises which will maximise opportunities for water users to act in their own self-interest within logical limits set by regulatory agencies.

Already some far-reaching reforms have been implemented marked by a shift towards a user-pays regime for water, and the introduction of tradeable water entitlements.

Water Pricing

More realistic pricing of water should contribute to reduced water demand through more efficient irrigation practices, less water-demanding enterprises, reduced irrigation acreage, minimisation of waste, increased recycling of water, possible shifts to dryland production, or retirement of irrigated lands altogether. More expensive water inputs should also lead to improved management of ecological problems and the potential to set aside the water saved for environmental purposes (Pigram, 1993).

Moves towards use of market mechanisms for management of water demand might well be taken further to increase the exposure of water users to the consequences of such use for the environment. This is not easy when point sources of pollution or salinity cannot be accurately identified. However, incurring of charges for the discharge of drainage water, or for licensed accessions to the water table, would help focus attention on the benefits of more effective watering methods and the merits of recycling.

Implementation of pricing policies based on full cost recovery may require some qualification. In the first instance, agreement needs to be reached on what constitutes an appropriate level of costs to be recovered. Some water users might argue, for example, that current costs incurred by water management authorities are excessive and economies in operations are possible. Again, although water charges, typically, are not a major cost of production, some sectors of the irrigation industry may find it difficult to meet any increases and remain viable. The same comments apply to the financing of infrastructure refurbishment, and asset maintenance and replacement in irrigation schemes (Bryant and Pigram, 1993). In some circumstances, reform of tariff structures to meet some predefined objectives might have greater impact than imposition of socially or politically unacceptable price rises.

Tradeable Water Entitlements

To operate effectively, a market-orientated system for water demand management must provide for freely tradeable water entitlements between users and alternative end uses. In the past decade several Australian states have introduced more flexible arrangements for the transfer of water rights in order to achieve more rational and equitable management of water resources (Pigram, et.al., 1992). The case for freely tradeable rights assumes that water will move from less productive to more productive uses and hence be justified on economic grounds.

The move has been marked by certain constraints imposed by administering authorities on trade in water rights. Typically, transfers apply only to water users along the same stream, and often to specified reaches of that stream. This condition has been relaxed recently in southern parts of the Murray-Darling Basin where intervalley transfers and even isolated interstate transfers have been approved. In other situations, conditions have been imposed to avoid third party effects, or the encouragement of additional water use in environmentally sensitive areas.

Scope remains for expansion of the system of tradeable water rights to provide for intersectoral transfers, eg. from irrigation to industry, or to the environment. There seems no good reason to prevent environmental interests from entering a water market to acquire rights to satisfy instream needs. Moreover, the fact remains that substantial shifts in the pattern of water use are unavoidable in the interests of economically efficient irrigation production and the mitigation of environmental damage.

Despite constraints, the institution of transferability, when liberalised in appropriate ways, will be important in facilitating desirable modification of land and water use and the ensuing structural adjustment necessary across the Murray-darling Basin. Given more clearly defined property rights to water, tradeability can provide less viable water users with capital either to adjust to a new enterprise, or to upgrade the efficiency of their operations.

MANAGEMENT OF DEMAND THROUGH WATER ALLOCATION

Apart from market-based approaches such as pricing and tradeable water rights, a more direct influence on demand can be realised through the system of water allocation. Moves are already in place in several Australian states to give more flexibility to the allocation of water for irrigation and to link the price charged to security of supply. Irrigators with high value, high risk crops, for example, pay a higher price for a high security allocation.

A further refinement is the consideration being given to the deliberate allocation of water in a river system for environmental purposes. In Australia, claims on water resources for instream uses, such as wetlands replenishment, habitat maintenance and water-related recreation, are increasingly accepted as legitimate concerns of water managers. No longer is it acceptable to rate such needs as residuals after conventional uses of water are met (Pigram and Hooper, 1992).

In the State of New South Wales, the issue is being addressed through the adoption of a system of assessment of environmental flows for each river system. The assessment, termed an Environmental Contingency Allowance, is a flexible benchmark related to a number of specified ecological needs. These include, for example, maintenance of water levels in bird rookeries and flushing flows for water quality. The Environmental Contingency Allowance is currently under trial in several of the State's rivers, supported by regular monitoring and close consultation with water users and conservation groups.

Provision of water for environmental purposes and improving water quality and the condition of aquatic ecosystems raises the question of where is the water to come from. Despite the opportunities noted earlier for meeting environmental claims on water from economies in other forms of water use, serious questions remain. Significant tradeoffs may be involved and economic and social costs incurred in integrating competing and conflicting demands for water (Dudley, 1994).

Current mechanisms for allocating and administering water are not conducive to establishing and underpinning the value of water in various uses, or specifying the trade-offs involved in sharing the resource. The concept of capacity sharing has been put forward as an innovative approach to water allocation (Dudley and Musgrave, 1988). Capacity sharing, or partitioning entitlements at the source in the reservoir, rather than at the point of delivery, specifies property rights to shares in the capacity of the storage which are secure and flexible, and freely tradeable. The mechanism offers a ready means for individuals or groups of water users to modify their demands for water in response to changes in conditions of supply. Capacity sharing stimulates the management of demand by integrating supply and demand management for the allocation and use of water either for conventional purposes or instream needs. There is growing evidence that water authorities in Australia are prepared to consider such innovations and move away from a strictly regulatory approach to resource management.

The introduction of environmental allocations of water, coupled with the mechanism and means for environmental interests to enter a market to acquire water rights, represent useful reforms. Allocation or acquisition of shares in the water resources of a region, whether for the environment or for irrigation, is a further step, but carries with it an obligation to develop an acceptable management plan for the use of that water. In any redistribution of demands for water, the emphasis remains firmly on the management of the water to satisfy agreed economic, environmental or social objectives.

SOCIAL ISSUES AND WATER DEMAND MANAGEMENT

Water demand management implies change, and possible resistance to change. Increases in charges for water may threaten the viability of irrigation enterprises. Freeing up trade in water entitlements could deprive particular areas or productive sectors of irrigation water. These changes could accelerate the process of change already under way in rural reas of Australia and have significant social effects. Redistribution of water-using activities may lead to redistribution of income and population with consequent impacts on individuals, rural centres, local government areas, the provision of essential services, and the community quality of life.

Water managers have to be aware of the prospect of social change, and the need to involve the community in management decisions which affect it. Community consultation and endorsement of proposed water demand management measures are essential. Involvement of stakeholders will help ensure that they acknowledge the need for demand management and accept ownership of the "problem" and responsibility for its resolution.

The community should be involved in the selection of appropriate change mechanisms offering a sound mix of regulatory and free market approaches (Table 2). In this way, those with claims or demands on the water resources of a river valley or region can identify the constraints to be

Table 2 DEMAND FOR RURAL WATER - CHANGE MECHANISIMS

TYPE OF POLICY	REGULATION	EVOLUTION/CONSTRAINED MARKETS	FREE MARKET
MAIN FEATURES	Strong Government control	Markets are set up within prescribed framework.	Minimal government intervention.
	Formal enquiries and decisions.		Control mechanisms by common law and market forces.
	Formal consultative mechanisms.		
	Compensation for losers.		
LIKELY STRENGTHS	Losers are protected.	Encourages people to take initiative (within limits)	Responsive to market demand.
	Perceived centainty once decisions made.	Provides for security of and protection of environment.	Price of water set by market demand for product.
	Strong control over resource.	Attempts to provide commercial freedom of choice within a framework that ensures good long term resource management.	Premium products able to buy supply.
	Strong mechanisms to protect environment and manage resource in a sustainable way.		
LIKELY WEAKNESSES	Cumbersome and slow.	Limited protection to losers should be in line.	Unsustainable resource management and likely loss of proteciton for the environment.
	May stifle initiative.	Many individuals unprepared for change in direction.	Uncertain maintenance and renewal of system.
	Economically inefficient.	Frameworks are complex to devise and administer.	No assistance to losers.
		Danger of weakening controls to the extent that sound resource management is jeopardised.	Towns disrupted by rapid changes.
		Complexity may hinder market movements.	May lead to real social disruption which society then has to pay for.
			Vulnerable to market demand.

Source: Australian Water Resources Council, 1992 overcome in meeting those demands and the incentives or sanctions needed to implement a workable demand management strategy. Where groups of water-using interests contribute to the design of the institutional framework for demand management, the system will have a better chance of success.

With change comes the inevitability of the need for structural adjustment. From a social perspective, an effective rural water demand management strategy must provide a clear support system for structural adjustment. Once again, water users need to be involved in monitoring the effectiveness of management procedures for sharing the demand for the resource. More importantly the community concerned should be consulted regarding the evolving implications of the process for the economic and social environment of the region.

CONCLUSION

Australia's water economy has entered a mature phase with much reduced emphasis on resource development and more attention to resource management. In a country where a large part of the water resources is already fully committed, new claims are emerging to compete with established water uses, particularly in rural areas. In the absence of measures to improve water supplies, demand management is the logical answer to growing pressure on the resource.

Mechanisms are already in place, or are being considered, to facilitate the sharing of water among competing demands. Changes to tariffs and charges have been introduced to reflect the cost of provision of water services and drainage, and to focus attention on the value of water in various uses. Tradeable water entitlements are being used to free up the movement of water between users and even valleys and sectors to promote more effective allocation of the resource. Further market mechanisms and revised administrative arrangements are being considered to achieve a better balance between government regulation and self-management of water use.

The end result should be an improvement in the matching of water demand with available supply and a keener appreciation of the value of water to the community in a widening array of uses, both for productive purposes and instream needs. Yet, the changes under way, and those envisaged, inevitably involve disturbance to established patterns of water use and possible dislocation of the communities and regional economies dependent upon that use. The final measure of success of water demand management policies will be the extent to which rural communities accept and endorse the process, and the manner in which the benefits and the costs of the necessary adjustments are shared.

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ORGANIZATIONS FOR IRRIGATION MANAGEMENT

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SUMMARY

Normally, dual-managed irrigation systems are developed in a top-down approach. The water users in their "tertiary units" have to follow the technical and the institutional innovations made by technicians. Recent rehabilitation programmes have not improved the irrigation in the expected manner, and water users have not yet become the "partners in irrigation management".

Good irrigation management appears to be difficult, as conflicting interests are normal in irrigation, and there are different parties have each their own responsibilities.

It is elaborated here that irrigation management comprises six main components, which should receive equal attention during the rehabilitation process: (i) the main system, (ii) an Irrigation Agency for operation and maintenance (O&M) of the main system, (iii) the tertiary system, (iv) the Water Users Associations for O&M of tertiary units (v) a "highest authority" for decision-making and law enforcement, and (vi) the legal framework, for guidance of the highest authority.

The highest scheme authority can be formed by either: (i) the Local Administration through an "Irrigation Committee", (ii) the Water Users through a "Water Board", or (iii) an Autonomous Enterprise. A warning is made to assign the engineers of the Irrigation Agency with this highest authority.

RÉSUMÉ ET CONCLUSIONS

Normalement, les systèmes d'irrigation à double gestion sont développé avec une méthode d'approche 'top-down'. Les utilisateurs d'eau dans les compartiments tertiaires doivent suivre les innovations techniques et institutionelles faites par les techniciens. Les programmes de réhabilitations récentes n'ont pas encore amélioré les systèmes d'irrigations comme prévu, et les utilisateurs d'eau ne sont pas encore considéré comme des 'partenaires professionels équivalents' dans la gestion de ces systèmes d'irrigation.

Une gestion bien guidée d'une système d'irrigation quelqonque, semble encore difficile, car les intérêts et les responsabilités des différents parties sont divers et souvent opposé.

Dans cet article la gestion d'une système d'irrigation est divisé en six élements majeures, qui doivent recevoire une attention égale les uns vers les autres, pendant le procès de réhabilitation: d'abord (i) le système d'irrigation principale, puis (ii) l'Agence d'Irrigation pour l'operation et l'entretien (O&E) de ce système principale , (iii) les compartiments tertiaires, (iv) l'Association des Utilisateurs d'Eau pour l'operation et l'entretien des compartiments tertiaires, (v) une Autorité Supérieure pour le maintien de la loi et la préparation des décisions ('decision making'), et finalement (vi) un cadre législatif, pour assister cette Autorité Supérieure.

L'Autorité Superieure qui décide sur les allocations des courants d'eaux, peut être formé par soit: (i) une Administration Locale, par l'intervention d'un Comité d'Irrigation, ou (ii) par les

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utilisateurs d'eau, par l'intervention d'un 'water-board', ou (iii) par une Entreprise Autonome. Finalement, un avertissement est donné, pourque la designation des ingénieurs d'une Agence d'Irrigation à une Autorité Superieure est fait avec beaucoup de prudence.

1. INTRODUCTION

1.1 Responsibilities

1.1.1 Dual-managed Canal Systems. Many large-scale irrigation systems in developing countries are under dual-management. It is the task of an Irrigation Agency to provide irrigation water at the level where the water users take over the responsibility, i.e. at the tertiary offtake.

It means that these irrigation schemes are divided into: (i) the "main system", which is under control of the Irrigation Agency, and (ii) the "tertiary units", which are under the control of water users, grouped in Water Users Associations.

1.2 Irrigation Development

1.2.1 Colonial era. The above concept of dual-managed systems was introduced in many Asian countries during the 19th and the early 20th century by European engineers.

It appeared that both rainfed agriculture as well as small-scale and village-managed systems could not meet the requirements of increasing population in many deltaic areas and floodplains. Periodic mass starvation of the population was the result. Moreover, the cultivation of many cash crops required a more reliable supply of water.

The operation of these technical irrigation systems was done successfully by strict discipline under European engineers.

1.2.2 Irrigation after Independence. The Second World War and the struggle for independence led to less attention to the maintenance of these systems, while also other social rules between the Government and the population evolved.

Thus, it was experienced that many dual-management systems were not functioning satisfactory. General criticism concentrated on an inequitable distribution of irrigation water, and especially on water shortages in the tail-ends.

The cause of these water problems were initially considered to be found in the poor physical condition of canals and structures.

1.2.3 Rehabilitation programmes. The problems of water shortages in tail-ends of the system were initially redressed by rehabilitation programmes which focused on restoring the condition of the main system as per original design. Examples are the PROSIDA programmes (some 800,000 ha) in Indonesia in the 1960s and 1970s, and the Ganges-Kobadak project (130,000 ha) in Bangladesh during the 1980s.

These programmes were often not very successful as e.g. (i) initial design mistakes were made again, (ii) the population has increased considerably since the first construction, and required a more intensified irrigated agriculture, and (iii) the cropping pattern and the type of crop had often changed and required a more precise water management.

It was learned that a "modernization" of the system is more appropriate than just restoring the system again in its initial condition through a "rehabilitation" programme (Ankum, 1989).

Furthermore, it was observed that the staff of the Irrigation Agency did remain a weak link in the performance of the main system. Thus, training programmes on Operation and Maintenance (O&M) of the main systems were initiated.

1.2.4 Staff training programmes. Large scale O&M training programmes for the staff of the Irrigation Agency were initiated since the 1970s as a next step in irrigation development. These programmes were often dealing with the production of training aids and with the training of trainers, such as the World Bank's PLAV-project in Indonesia from 1975 to 1980.

Other programmes called for coordination and integration, but can often be considered as placebos only (Chambers, 1988).

1.2.5 Tertiary Unit Development. It was also felt since the 1970s that the water distribution within the tertiary unit did not follow the improvements made on the main system level.

Although the tertiary unit infrastructure does not belong to the responsibility of the Government but to the water users, it was decided that the Irrigation Agency should develop the tertiary system on behalf of the water users.

Thus, extensive tertiary unit development programmes were initiated. The costs were born by the Government, and designs were made by consultants with limited time available for consultation of the users. Success of such a tertiary unit development programme was generally very limited, e.g. World bank's programme in Indonesia (Horst, 1984).

1.2.6 Water Users Training Programmes. Gradually, it was acknowledged that also non-technical aspects play a role, such as the "ignorance" of water users, the poor organization of the water users, the lack of discipline of the water users, the absence of water users in the decision-making process, etc., etc.

Since the 1980s, training programmes for water users are undertaken in many countries in South and in South-East Asia. Topics are: the organization of the water users association, the construction and maintenance of the tertiary infrastructure, the operation of the tertiary unit, the water management at farm level, etc.

1.2.7 Sustainable Development. Despite all efforts, the performance of many large-scale irrigation schemes has often not improved in the expected manner (Chambers, 1988; Uphoff, 1991).

The above activities have required vast sums of money, and often vast foreign exchange. Questions arise on the financial sustainability of irrigation, and on whether water users could bear the future costs of irrigation improvement and of regular O&M through an "irrigation service fee".

Still more efforts have to be made to improve large-scale irrigation. The question is now, whether more rehabilitation, training and tertiary development is required, or that other ways have to be followed?

2. IRRIGATION MANAGEMENT

2.1 Irrigation Management as socio-political process

2.1.1 Available literature. The subject of irrigation management appears to be very complex, and the nature of the literature is unstructured, divers, little concrete and showing all characteristics of a subject in full development (Jurriëns and de Jong, 1989).

2.1.2 Human resources management. Furthermore, it can be observed that the institutional and the socio-political context has widely been neglected in the above efforts to improve irrigation (Diemer and Slabbers, 1992).

Poor functioning of operation staff cannot be corrected by training when motivation, and/or unclear working orders are the real problems. Water-theft by farmers can also not be solved by training when water shortage is the real problem.

2.1.3 Vehicle for change. The method for correcting the problems in dual-managed irrigation systems might come from the organization management discipline. Here different components of an organization are distinguished, such as the corporate strategy, staffing and skill, style and culture, and the structure of the organization.

The correct way for changes seems to be a "crafting strategy" (Minzberg, 1987). The components of the organizations resemble a lump of clay in the hand of a craftsman. The craftsman changes the clay, i.e. all components, gradually until a sculpture, i.e. a better organization, is created.

2.2 Components of Irrigation Management

2.2.1 Six Components. Irrigation management is composed of six main components. These components are, see also figure 1: (i) the main irrigation system, (ii) the tertiary irrigation system, (iii) the legal framework, (iv) the "highest authority", (v) the Irrigation Agency for operation and maintenance (O&M) of main system, and (vi) the Water Users Associations for O&M of tertiary units.

All these components have to be improved gradually in a process to obtain Good Irrigation Management. Improvements are not obtained by changing only some of the components.

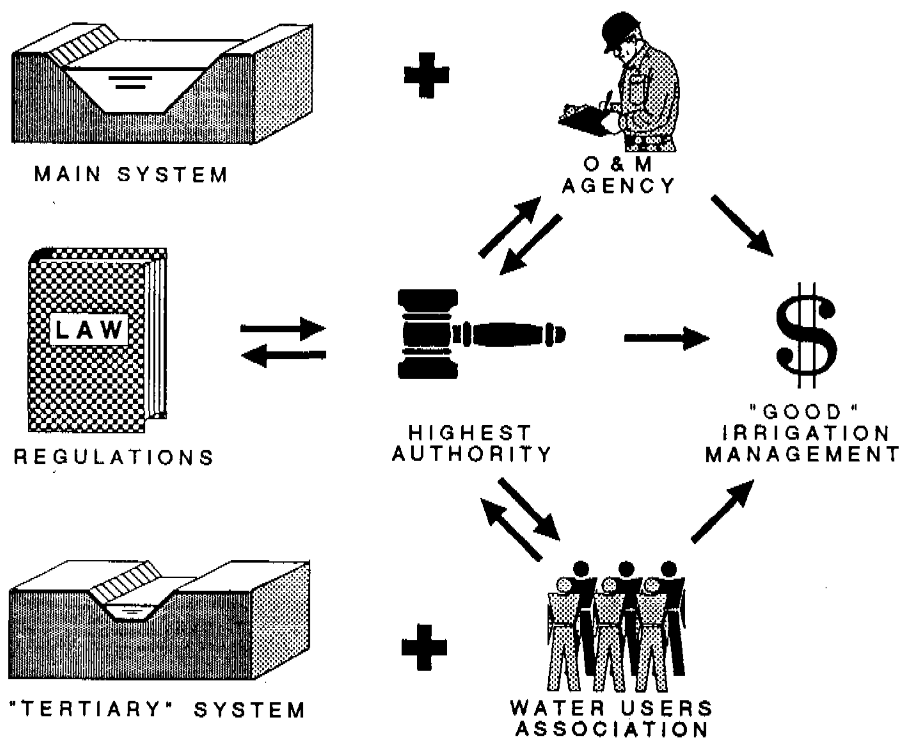

Figure 1. Components of Irrigation Management.

2.2.2 Good Irrigation Management. In fact, "good" irrigation management is not well defined: what is good for one farmer, might not be good for another farmer. Even, what is good for all farmers, might not be good for the Irrigation Agency. Thus, conflicts on the objectives of irrigation might be even normal (Uphoff, 1991).

Basically, irrigation management should follow the aspirations as set by the politicians, economists and the water users. Together, they should determine what is "good" irrigation management.

2.2.3 O&M Manual. It might be wise to emphasize more on the preparation of O&M manuals by the designers of (modernized) irrigation systems, as to elaborate on the design philosophy and the design considerations. A table of contents of a typical O&M manual may comprise:

- Introduction (e.g. pre-project condition, rationale for development);
- Description of the Scheme (e.g. location and mapping, boundaries of tertiary units and villages, soils, hydrology and meteorology, location of canals and structures);
- Objectives of the Irrigation System (e.g. cropping calender, water requirements);
- Operation of the Main System (e.g. type of structures, flow regulation, flow of information, data processing, procedures, performance monitoring);
- Maintenance of the Main System (schedule and type of routine works, design of special maintenance works, budgeting, force account and tendering, supervision);
- Tertiary Units (e.g. tertiary unit development, organization of water users associations, extension to water users, O&M within the tertiary unit);
- Organization of the Irrigation Agency (e.g. tasks and job descriptions, required staffing, human resources management);
- Institutional Setting (e.g. decision-making process, conflict handling).

3. ORGANIZATION OF IRRIGATION MANAGEMENT

3.1 Legal Framework

3.1.1 Historic background. In the end of the 18th and in the early 19th century, many large-scale irrigation systems were managed by engineers to the best of their knowledge. However, it was felt by them that operation of these schemes could never be a pure technical matter, and that also socio-political decisions have to be made. Several of these decisions appeared to be lasting, and could be written down. Thus, the North India (1873) and the Bengal Acts (1876) were promulgated in South Asia.

Indonesia followed a bottom-up approach. Local O&M matters were covered by Operation Regulations concerning the Irrigation Districts, e.g. "Regulations concerning the Irrigation District Pemali-Comal" (1929). The legal framework of these regulations was created by the introduction of the General Water Law (1936) and subsequently by the Provincial Water Laws (East Java in 1938, West Java in 1940, Yogyakarta in 1949 and Central Java in 1959).

3.1.2 Preparation of O&M Regulations. It appears to be relative easy to update old National and Provincial Water Laws. They are prepared in general terms, and state e.g. that "water should be controlled by the State and that delegation of power is possible". They also state that "utilization of water resources shall be in the interest of the People, and may follow established priorities".

It is more difficult to prepare the Operation Regulations for individual schemes. These regulations have to outline the operation procedures and to make clear decisions on the irrigation scheduling, the authorization of cropping patterns, how to react during water shortages at the source, cost recovery, etc.

The Regulations should be based on the O&M Manual as prepared by the designer of the system. However, the proposed O&M practices cannot be translated directly into the new Regulations because they have to be placed first into the socio-political context. It means that decisions on procedures have to be taken by a wider forum than only by the engineer. Finally, the O&M Regulations have to be endorsed by the Local Administration.

3.1.3 Content of Regulations. The O&M regulations of an irrigation scheme have to delineate the rights and the duties of all parties, as well as the required procedures. A typical table of contents may comprise:

- Definitions (e.g. scheme area, responsibilities on main and tertiary systems);
- Right of Control (e.g. water utilization with/without permission);
- Supply of Irrigation Water (e.g. manner, timing and quantity of supply, irrigation season, procedures, flow of information);
- Utilization of Irrigation Water (e.g. O&M in tertiary units, Water Users Associations);
- Financing (e.g. budgeting for O&M and construction, cost recovery);
- Penal provisions.

3.2 Highest Authority

3.2.1 Tasks. All irrigation schemes require a highest authority who can take not only decisions on conflicting matters, but who can also impose sanctions if necessary.

It is a mistake to assign the Irrigation Agency as the highest authority. It is true that the technical knowledge is available here, but the Irrigation Agency should not implement decisions that have been made by them alone. Moreover, the Irrigation Agency can usually not impose sanctions by means of a police involvement.

3.2.2 Workable choices. The choice for the highest authority depends to a major extent on the ownership of the system. There are three workable options:

- the Water Users through a "Water Board" are usually the highest authority of the irrigation scheme, when the scheme is the property of the water users themselves. Such an organizational form is found in most of the village-managed system, but also in the Water Board ("Waterschap") in the Netherlands, where farmers developed the lowlands without government involvement;
- an Autonomous Enterprise, like the Tennessee Valley Authority, is created when income can be generated through e.g. selling of hydropower. Thus, these schemes are financially independent from the Government and from the water users. Experiences with these organizations for rural development are not very successful as they operate outside the power of the local politics;
- the Local Administration is the highest authority in many large-scale systems in developing countries when the Government considers irrigation development as part of its efforts to develop the rural population. The Government is the owner of these irrigation schemes and its financial involvement is permanently required.

  An "Irrigation Committee" as part of the Local Administration, is applied in Indonesia since 1920 and is a good forum for solving problems.

3.2.3 Irrigation Committee. Such an Irrigation Committee may have the following organization, see also figure 2: (i) the Head of Local Administration as Chairman, (ii) the Head of the Irrigation Agency as Secretary, and the members are (iii) the representatives of the water users, and (iv) the officials from all relevant Departments, such as the Heads of Agriculture Extension Services and of the Regional Planning Office, the Police Commander, etc, etc.

Irrigation Committees may exist at different levels, e.g. at the Provincial, District and at the Sub-District level. The Committee at the Provincial level may provide the general guidance, formulates policies, etc.

The Irrigation Committee at the District level may cover an area of one or more irrigation schemes (25,000 - 100,000 ha) and is in charge of regular decision-making. At this level, policy decisions must be made operational regarding cropping pattern, planting dates, etc., and if necessary decisions enforced. The District Irrigation Committee may meet at least twice-a-year, but meetings are more frequent if special problems must be dealt with, such as unexpected water shortages or floods.

The Irrigation Committee at the Sub-District level may have a main task on the coordination and the implementation of the orders received from the District level. Farmers should actively participate also here.

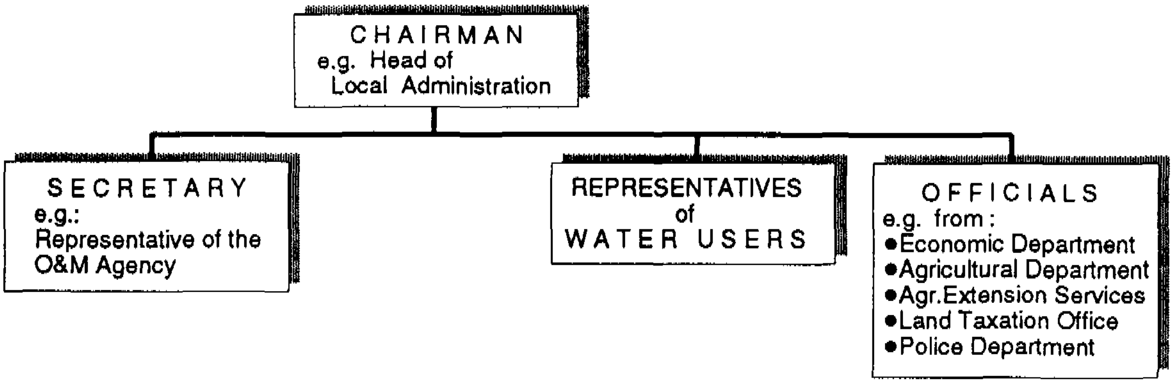

Figure 2. Organization chart of an Irrigation Committee.

3.3 Irrigation Agency

3.3.1 Tasks. The Irrigation Agency is the executive body between the highest authority and the field, and is responsible for implementing the operation and maintenance (O&M) of the main irrigation systems.

Furthermore, the Irrigation Agency should provide data on water availability, water requirements, land use, performance of irrigation, etc., to permit proper decisions by the highest authority.

3.3.2 Different levels. A typical Irrigation Agency has offices at different levels, see figure 3:
- Provincial level, with administrative tasks and supporting technical tasks on survey, design and construction, and on supervising and programming O&M;
- District level controlling one or more irrigation schemes (25,000 - 100,000 ha), and is charged together with its sub-district offices with the actual O&M of the system;
- Sub-District level controlling some 5,000 ha, charged with the executive tasks on O&M.

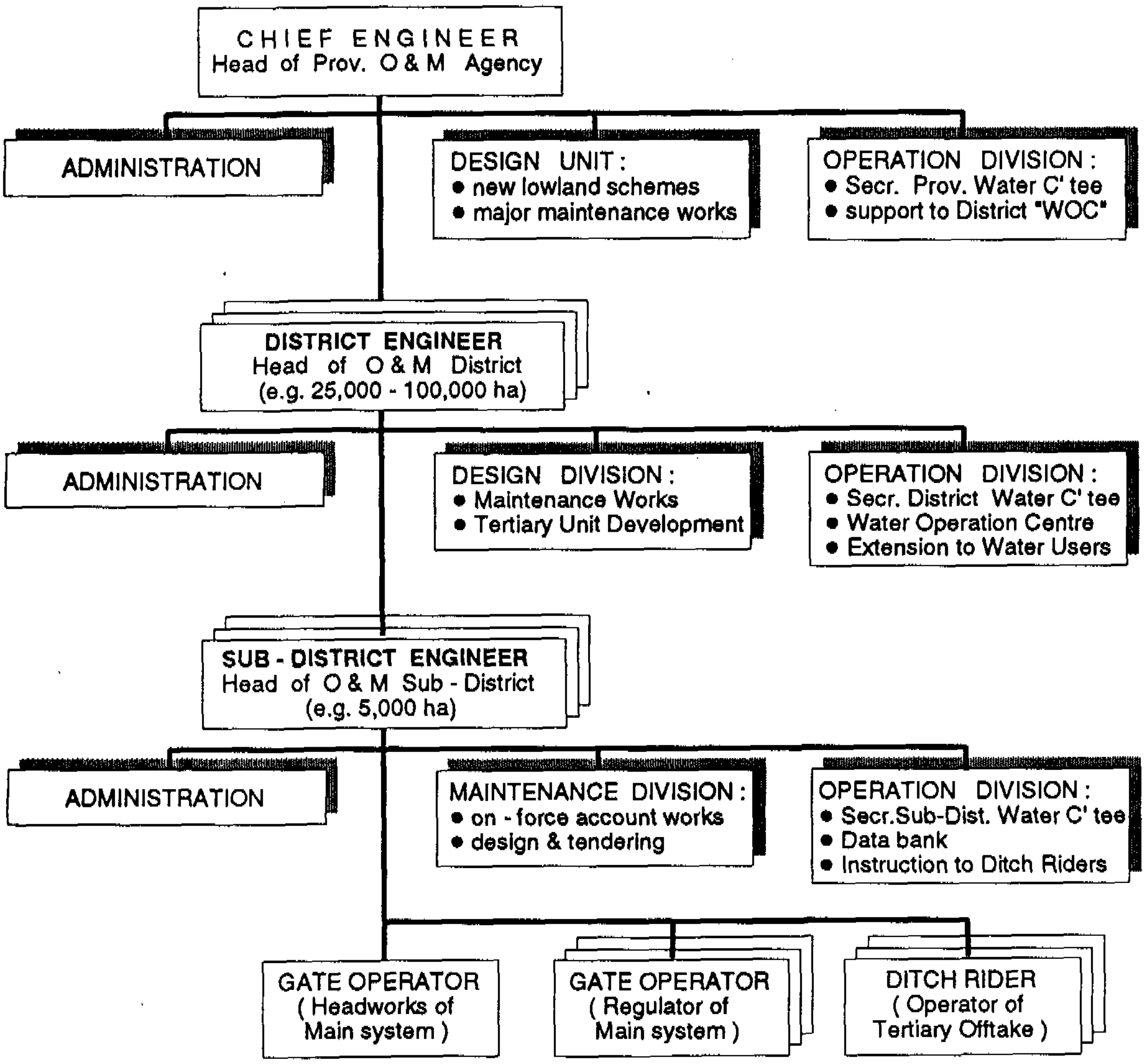

Figure 3. Organization chart of an Irrigation Agency.

3.3.3 Water Operation Centre. Basically, the Irrigation District office is the core for the implementation of the operation decisions.

Here, a "water operation centre" have to process the data on water availability and water requirements, and should determine the required water distribution for the coming period. Ultimately, detailed instructions are issued to gate operators and ditch riders. Although such a centre is not widely applied, it can be stated its role is essential.

An issue for smaller schemes is whether this centre should be located at the Sub-District level, or that one centre at District level covers successive different smaller schemes. The latter option may have higher preference as higher educated staff with computerized equipment is more appropriate at District level.

3.3.4 Extension to Water Users. Irrigation extension to water users is most important and is a routine activity. Part of the extension concerns the pure agricultural matters and should be covered by the Agricultural Extension Services.

Other communication with the water users concerns the day-to-day operation of the systems and is related to authorization of cropping patterns, water requests and information on water supply. These activities have to be done through the field staff of the Sub-District irrigation office.

A third form of extension is periodically and concerns the long-term needs of the water users. Such extension is the follow-up of requests from the water users association and can be given by a specialized training staff of the offices at District level. Topics may cover:

- organization of the water users (e.g. structure of the organization, the issue of village and water boundaries, financing, external contacts);
- tertiary unit development (e.g. layout, need for infrastructure, design and construction, assistance from Irrigation Agency);
- operation of the tertiary unit (e.g. planting scheduling, role of water master, water distribution techniques, water management at farm level);
- maintenance of the tertiary unit (e.g. routine and incidental works, costs, maintenance techniques, organization of works).

3.4 Water Users Associations

3.4.1 Tasks. Water management below the tertiary offtake belongs to the responsibility of the water users. The irrigation main system becomes cheaper for larger sizes of the tertiary units (e.g. > 100 ha), but there becomes an increasing need for the population to (i) organize themselves and (ii) to construct a tertiary unit infrastructure.

A typical organization structure will comprise, see also figure 4: (i) a board of a chairman with a secretary and a treasurer, (ii) water masters as executives for the day-to-day works in the field, and (iii) the owners and/or water users as the members.

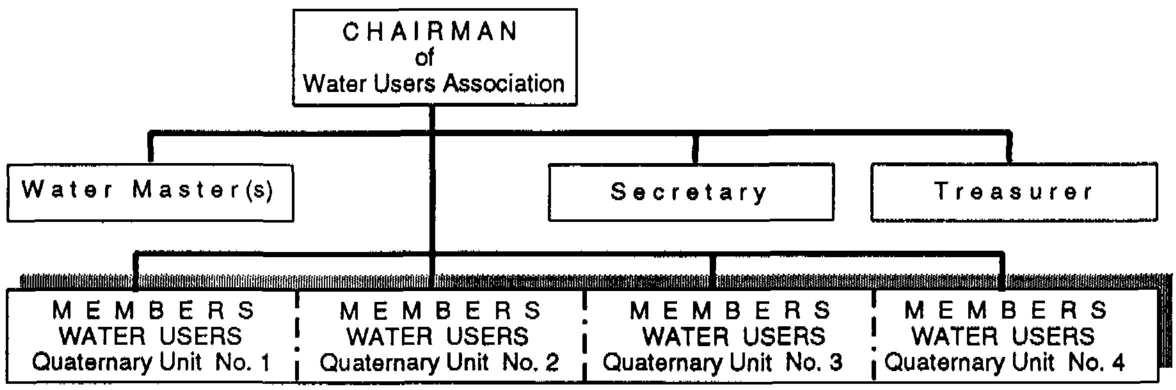

Figure 4. Organization chart of a Water Users Association.

3.4.2 Water Users Association and the Village. Basically, organization of water users is already existing within the village: the village leader and the village officials have tasks on different functions. The O&M of the tertiary system may or may not be done by this existing organization.

When the area of the village comprises one or more tertiary units, it is obvious that the village leader can just appoint the board of the Water Users Associations, following the current procedures. However, the "boundary issue" plays a role when different villages are located in one tertiary unit. The authority of the village leader becomes then not valid any more.

3.4.3 Types of Water Users Associations. Comparative studies between different water users associations have been made in Indonesia at the time of the construction of the dual-managed irrigation systems during 1890-1910, in order to decide on the best water management at the lowest cost.

Before 1850, the *"ulu-ulu desa"* system was used for the Operation and Maintenance within the tertiary unit of all irrigation systems on Java, Indonesia. The village water master *("ulu-ulu desa")* belongs to the village government and is appointed by the village head. The ulu-ulu desa system is still functioning well in farmers managed systems.

The "Pemali Water Users Association" was finally selected as the most optimum and was a reaction to earlier ideas that the involvement of the Irrigation Service could be limited to the operation of the main irrigation system only. In the Pemali system, water management in the tertiary unit is carried out by a water master *("ulu-ulu pembagian")*, who is selected by the water users, regardless of the boundaries of the villages in the tertiary unit.

The salary of the water master in the early days was paid by the Irrigation Service from the *ulu-ulu* fund, for which the water users had to contribute. Therefore, the farmers often regarded him as belonging to the Irrigation Service staff, which gave him more status.

3.4.4 Water Users Association as a Partner. Normally, dual-managed irrigation systems are developed in a top-down approach. Technicians and economists introduce the new irrigation system with the objective of cultivating higher-yielding crops. The population cannot easily be have an active role in such a technical innovation.

The irrigation development has to become sustainable, also in the meaning of cost recovery. It means that the population who are the ultimate beneficiaries, have to pay for the development direct or indirect. A continuing top-down approach will lead easily to unacceptable situations on system management, budget-spending and inequitable water distribution.

It is obvious that the water users associations have to evaluate gradually into partners in irrigation management. A bottom-up approach should be propagated where the water users associations play an active role in the scheme management. Ultimately, more business-like approaches may be followed, like the introduction of water contracts, discussions with the Irrigation Agency about system improvements, employment by the water users of third parties for tertiary unit development (Gerards, 1992).

4. CONCLUSIONS

Dual-managed irrigation systems are normally developed in a top-down approach, and deal mainly with the construction of the irrigation main system, i.e. the part that is government-managed.

The next steps to improve the other components, such the institutional aspects and the tertiary systems have not been very successfully in the past.

It is better to follow a gradual approach of improving all of the six components, instead of aiming directly at final solutions in a top-down approach. It should be acknowledged that operation of irrigation systems have to fit in a legal framework. The decisions on good irrigation management should follow the decisions of a "highest authority", i.e. usually not the Irrigation Agency but the Local Administration.

Ultimately, the water users associations have to become active partners in irrigation management. They may take over the position of the "highest authority".

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THE CRITICAL ROLE OF IRRIGATION "LEARNING" AND IMPROVED SYSTEM PERFORMANCE IN MEETING FUTURE WATER AND FOOD DEMANDS

Gaylord V. Skogerboe [1] and D. J. Bandaragoda [1]

ABSTRACT

Growing populations, increasing food demands, rapid urbanization and slowly but steadily rising industrialization efforts all portend tremendous competition for water. The situation in many cities has become deplorable. Irrigated agriculture is expected to satisfy much of the increased demand for food, but the physical infrastructure is deteriorating in many countries; thus, the diversion of irrigation water to cities will result in decreased food production. This dilemma can only be solved by continually improving the performance of existing irrigation systems, so that small reductions in available water can be compensated by improved management practices that will result in increased agricultural productivity. Yet, in so many cases, those who are responsible for the performance of irrigation facilities and organization lack the managerial and institutional capability for achieving continued improvements. Learning processes are needed that provide guidance in adapting appropriate solutions to the site-specific situation of each irrigation system, with the "learning" involving all parties, including irrigation and agriculture agencies, but especially farmers. This "learning" should lead to the creation of "visible" success stories that provide a viable regional model for irrigation development.

RÉSUMÉ

Dans le contexte actuel d'accroissement démographique et d'augmentation de la demande en produits alimentaires, d'urbanisation rapide et d'industialisation, l'eau est l'objet d'une compétition de plus en plus intense. La fourniture en eau potable dans de nombreuses villes est devenue alarmante. Le transfert d'eau d'irrigation vers ces villes pourraient résoudre ce problème, mais serait contraire à l'objectif principal du secteur de l'irrigation, i.e. produire plus pour répondre aux besoins alimentaires croissants de la population, et ceci, malgrè des infrastructures qui se détériorent dans de nombreux pays. Pour résoudre ce dilemne, une amélioration constante de la performance des périmètres irrigués existants est nécessaire. Des réductions même marginales des quantités d'eau allouées aux périmètres irrigués pourraient ainsi être compensées par les gains de productivité d'une gestion améliorée de ces périmètres. Malheureusement, dans de nombreux cas, les capacités de gestion et d'organisation à la base de ces améliorations semblent être réduites ou tout simplement absentes. Des processus d'"apprentissage" sont nécessaires pour obtenir des solutions adaptées aux situations locales charactéristiques de chaque périmètre irrigué. Cette phase d'"apprentissage" concernera tous les acteurs impliqués dans la gestion des périmètres, mais plus particulièrement les exploitants agricoles eux-mêmes. Elle devrait conduire à l'identification d'approches réussies qui fourniront des modèles viables de développement régional du secteur irrigué.

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1. FUTURE FOOD AND WATER DEMANDS

1.1 Food Demands

Following World War II, the population of the globe more than doubled, increasing from 2.5 million in 1950 to 5.3 billion in 1990. Most of this increase took place in the poorer countries of the world where the population grew from 1.6 billion in 1950 to 4 billion in 1990.

The largest population increases will be in Asia where the annual growth rate will be 56 million from 1990-2000. Then, the population rate will decline. But, by the year 2050, it is expected that Asia's population will exceed the world population in 1990 (Yudelman, 1993).

The most important food in the developing world are cereals, which include rice, wheat, corn, millet, sorghum, rye and barley. About 52 percent of the global supply of cereals is grown in developing countries including 94 percent of the world's supply of rice, 50 percent of the global wheat supply, and 40 percent of coarse grains. Overall, cereals accounted for about 83 percent of the major food production in developing countries during 1980. Regionally, Asia is the largest producer and consumer of grain, accounting for 75 percent that is produced and consumed in developing countries. The consumption of cereals in the developing countries has risen from 170 kilograms (kg) per person per year in 1960 to 236 kg/person/year in 1990 (Yudelman, 1993).

The possibility of increasing farmers' yield depends on the present level of yields and the technologically "potential" yield. The technologically potential yield can be enhanced with research, but there are physiological limits to the process that science has not yet overcome. In fact, plant breeders are rather skeptical about achieving the type of scientific breakthroughs that launched the green revolution.

In the late 1970s, scientists believed that there was a significant amount of "untapped yield potential" in irrigated production system. Moreover, they observed that much of this could be captured by improvements in crop management in general and water management in particular. Surprisingly, by the end of the 1980s, some researchers were observing a stagnating or declining trend in the productivity of major food grains grown mainly under irrigation.

For rice, recent studies indicate that the technological yield frontier has stagnated and shown signs of long-term decline. Farm level evidence indicates that farmer yields are catching up to the yield frontier in a few countries and that further exploitation of the present yield gap is not economical. Incremental costs of achieving further yield gains exceed the incremental returns. Similar declining rice yield trends have been observed in other experiment stations in India, Thailand and Indonesia (Pingnali, et. al 1990).

Yet to meet projected food demands by the year 2025, rice yields in developing countries will have to exceed average yields presently being achieved in developed countries.

For other cereals, present yields in developed countries must be achieved by developing countries in 2025 (Yudelman, 1993).

1.2 Urban Water Demands

By the turn of the century, half of the world's population will be living in urban areas. There will be 21 megacities (more than 10 million people), of which 18 are located in developing countries.

The water supply situation for many cities in the developing countries has become deplorable. Many neighborhoods only receive water 1-4 hours per day. Certainly, obtaining clean water is an increasing problem for many urban areas.

In many arid countries, 80-90 percent of the available water resources are diverted for irrigated agriculture. With time, some portions of these water supplies will have to be diverted from agricultural uses to urban uses. In many cases, surface water supplies will be diverted to groundwater recharge basins. A crude estimate is that each million of additional urban dwellers will require a water supply comparable to 10,000 ha of irrigated land. Thus, if the urban population increases by 2.5 billion people from 1990-2025, then 25 million ha of land would have to go out of production unless much higher management practices can be implemented on existing irrigated croplands.

2. SITUATION

2.1 Groundwater Development

A very large proportion of surface irrigation projects in the developing countries are large-scale public-sector projects funded by government or state revenues and managed by public-sector officials. However, recent technological changes have brought an important private-sector component into the picture. The development and diffusion of inexpensive, internal combustion engines and pumps have made it possible for individual farmers, or groups of farmers, to use small wells to exploit shallow groundwater aquifers, and to use low lift pumps for drawing water from rivers and channels to irrigate rice in the "dry season." Expansion has been most pronounced in Asia (Yudelman, 1993).

There has been a proliferation of wells owned by individuals in South Asia and by groups in China (Yudelman 1989). Private groundwater development has enabled large areas with good land and irrigation potential to be brought under production quickly, almost certainly more rapidly than would have been the case in state-controlled projects. In Thailand, there are more than 5 million small pumps used primarily to lift water from canals and rivers to use on rice paddies. The spread of private wells has been most notable in India where the number of wells increased from 459,000 units in 1968 to 3.3 million units in 1984/1985. Within India, in the state of Uttar Pradesh, privately owned tubewells increased more than tenfold from 120,000 to 1.6 million during this period. About 1.1 million of the 1.6 million tubewells are diesel-powered with the remainder using electric pump units. About half of the irrigated area is now said to be served by underground water.

Much of this is in command areas, and complements the use of surface water (Yudelman 1989).

The spread of privately owned wells has increased dramatically during the past decade. Private groundwater development in places like central India and parts of Bangladesh appears to have been a great success. However, there is a significant lag in the institutional, legal and technical arrangements for managing this phenomenon in such a way as to safeguard the natural resource base, promote equity and optimize the use of water (Le Moigne et al. 1991). This is partly due to a lack of adequate information to make sound judgements about the extent to which the groundwater table is being depleted (Mohtadullah, et al. 1994).

2.2 Irrigation Development and Agricultural Productivity

There are many difficulties with statistical data for irrigated lands. However, the total estimated land under irrigation is approximately 225 million hectares (ha). Slightly more than 60 percent of this land lies in Asia, with China, India and Pakistan accounting for half of the world's irrigated cropland. During the time period 1960-90, the amount of irrigated land increased by 71 million ha, while Asia alone increased by 60 million ha according to FAO statistical data.

Between 1950 and 1982 the World Bank loaned $10 billion for irrigation development, with 90 percent of these loans being made in the 1970s. These loans averaged around 40 percent of total project costs, so World Bank support represented a total investment of $25 billion. Donor investments have declined considerably since their peak in 1979 (Yudelman, 1993).

In most countries, the potential for expanding the area under irrigation is diminishing rapidly mainly because of the escalating cost of tapping and developing new sources of water -- the easy and cheaper sources are already in use. Also, because of the decline in grain prices during the 1980s, the major donors have reduced the level of funding for irrigation development - especially for new construction.

Expanding the "effective irrigated area" by increasing cropping intensity would be an economical option for areas where further expansion in the irrigated land frontier is constrained due to financial problems, limits in water sources or supply etc. Increases in cropping intensity can be done effectively in several ways: (a) Introducing early maturing crops, thereby increasing the effective area planted to those crops per unit of time; (b) Multiple and relay cropping; and (c) Cultivating 2-3 crops per year by adopting water-saving techniques. Staggering of land preparation, planting and other cultivation methods is a common phenomenon in many irrigation systems.

A great deal of development outside the traditional mono-crop farming is necessary not only to optimize the financial and economic returns to investment made in the irrigation sector, but also to improve the living standards of the growing populations in developing countries. Recently, crop diversification has been assigned a prominent place among the avenues available for improving land and water productivity. A limited water supply condition not adequate to meet the requirements of rice during the dry season is experienced in many schemes with favorable soil conditions. Related to this is the distinct uni-modal dry season rainfall pattern which makes it possible to have a well-aerated favorable environment for irrigated crop diversification. Water productivity, in general, can be increased under a diversified cropping pattern. Moreover, limited water available in the soil is better utilized by a mix of crops. Economic viability of such systems, therefore, may be maintained by diversification. The progress in a program of diversified cropping, however, depends on a variety of factors: (a) compatibility of the selected crop mix and land, water, climate, etc; (b) expected fluctuations of profits due to price shifts; and (c) problems associated with markets and marketing risks associated with a particular cropping pattern, farmers' resource endorsements, etc. (Mohtadullah, et al, 1994).

2.3 Trends in Sustainability

Presently, there are a number of indicators that imply that many of our irrigation systems located in developing countries are not sustainable. In other words, the agricultural productivity is stagnant and in some locations declining. Yet, there is an urgent need to increase the agricultural productivity of irrigated croplands.

One of the first obvious indicators of a lack of sustainability is declining agricultural productivity, particularly at the lower periphery of an irrigation system. Another visual indicator is soil salinity.

The strongest indicator that an irrigation system is not being sustained is a deteriorating infrastructure. The majority of the irrigation systems constructed from 1950-1990s are not being properly maintained. Often, rehabilitation is viewed as the only mechanism for correcting deferred maintenance deficiencies, which is quite similar in cost to the original investment in constructing the irrigation system.

A deteriorating infrastructure results in a declining capability for properly operating the system in a predictable, reliable and equitable manner. This, in turn, limits the management options for farmers, including crop diversification.

When groundwater levels continue to decline for more than one decade, then the indication is that the present levels of pumping are not sustainable. Also, if the salinity concentration in the pumped water continues to rise year-after-year, even gradually, the indication is the pumped discharge rates cannot be sustained.

When the domestic water supplies for cities are inadequate, both in terms of quantity and quality, with the situation worsening year-by-year, then the urban water system is not sustainable.

There are an alarming number of indicators that irrigated agriculture is facing a deteriorating situation. Many irrigation systems are not presently sustainable. This situation needs to be reversed so that irrigated agriculture can partially satisfy urban water needs while increasing agricultural productivity on existing croplands. In a very practical sense, all of this has to be achieved in the context of sustainability.

3. SYSTEM PERFORMANCE

3.1 Maintenance of Irrigation Systems

The major agricultural focus in the future for most countries in the world will be on improving management practices in order to increase crop production on existing agricultural lands. However, for irrigated agriculture, deteriorating irrigation channels and inadequate operating procedures often preclude any significant improvement. Improving the performance of an irrigation system begins with correcting maintenance deficiencies that impede good operating procedures.

The following comments are an outline of thoughts regarding how various maintenance programs impact the performance of an irrigation system. The roles of maintenance options 1, 2 and 4 are illustrated in Figure 1, with option 4 consisting of two combined maintenance programs.

1. Normal or Routine Maintenance;
2. Preventive Maintenance;
3. Rehabilitation; and
4. Essential Structural Maintenance (ESM) and "Catch-up" Deferred Maintenance.

The maintenance terminology in Figure 1 explains the difference between options (1) and (2). The usual emphasis upon using available resources to correct major maintenance deficiencies appears to be very logical; however, this is much more expensive than training the field staff in order to develop "maintenance eyes" wherein minor problems are mentally perceived as to how they grow in time to become major maintenance problems and that it is much more economical to correct maintenance problems when they are only minor. There is a need to document the difference in cost between these two options.

Option 3 (Rehabilitation), which is not really a maintenance program but rather a construction program, is by far the most expensive of all options. Consequently, this option leads to an increased national debt burden. Usually, a rehabilitation program is done by the Construction Division of an Irrigation Agency, rather than the field O&M staff, which means that the field staff do not "learn" from this program. Also, the O&M field staff inherit an improved system, but still only have the same resources for annual maintenance as prior to rehabilitation. There is a need to identify the necessary components of a rehabilitation program that will sustain the system in good condition.

The combination of Essential Structural Maintenance (ESM) and "Catch-up" Maintenance (Option 4) were developed as an alternative to rehabilitation. The expected

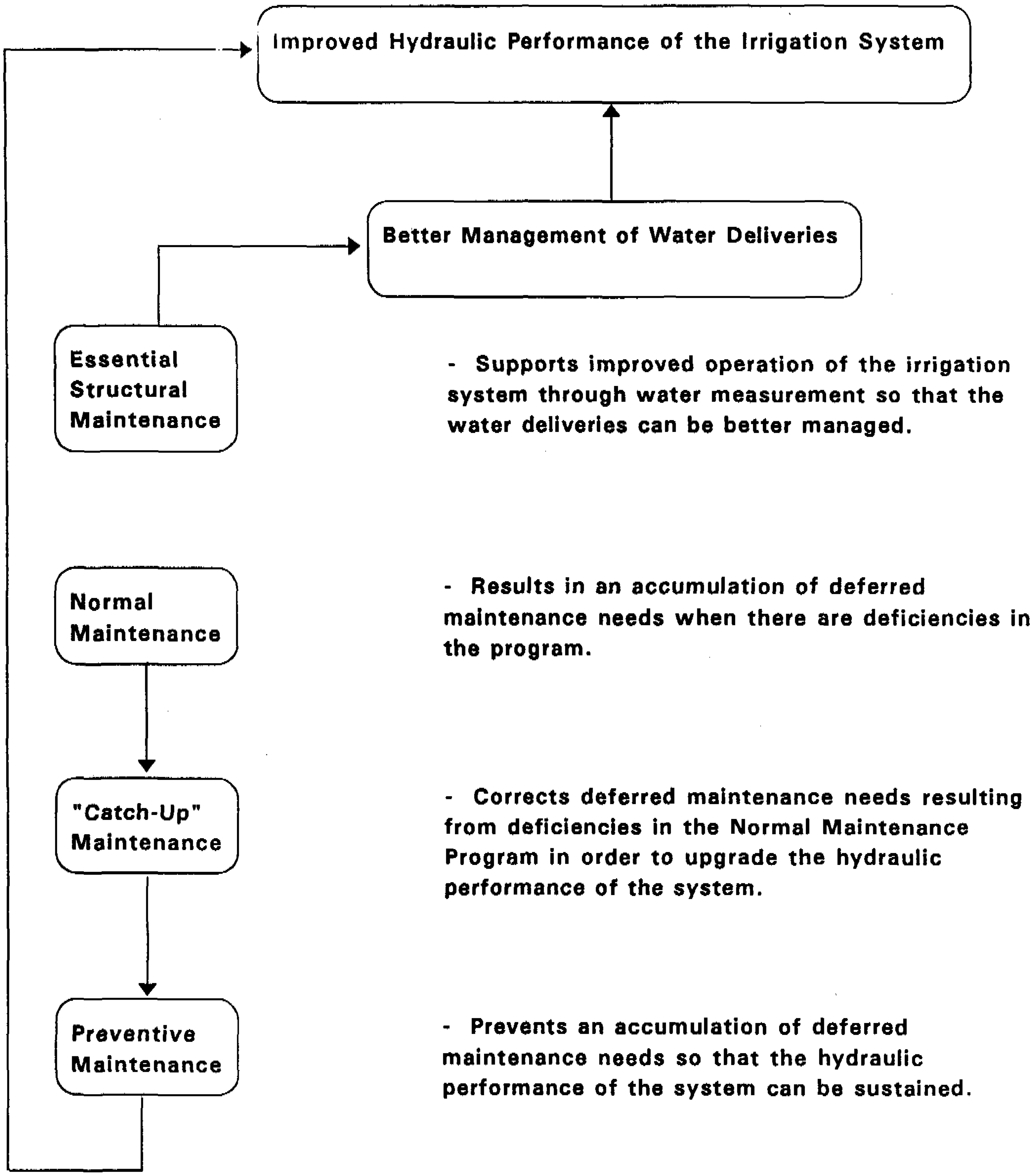

Figure 1. Role of maintenance programs for improving the hydraulic performance of an irrigation system.

costs are about one-third of rehabilitation. Field experience in Sri Lanka and Thailand verifies this cost. In fact, ESM is considered the minimum level of investment that should be made in order to improve water deliveries (Skogerboe, 1990).

3.2 Impact of Maintenance Options on Irrigation System Operations

There are three major topic areas to consider: (1) inadequate maintenance; (2) inadequate operations practices; and (3) inadequate organizational management. The following is not an exhaustive listing of concerns in each topic area, but does illustrate the issues.

A number of inadequate maintenance practices lead to increased channel losses. Other deficiencies lead to reduced channel capacity. Often, the channel capacity is only 80 percent, or less, than the design discharge capacity.

Inadequate operations practices result, first of all, from not knowing the discharge ratings at flow control structures, of using design equations which are usually in error by 10-30 percent. Secondly, the water losses are not known; the change in water loss with operating water level should be known for each reach in the system. There is a lack of monitoring, so that the discrepancy between planned and actual water deliveries is unknown. Inadequate monitoring also results in a lack of knowledge about system performance -- is hydraulic performance improving each succeeding year, static, or declining? The final result is inequitable water deliveries to each of the outlets (turnouts) serving a tertiary subsystem.

Deficiencies in organizational management result, most of all, from an emphasis on administrative paperwork management rather than technical matters of maintenance, operations, and water management. An almost universal problem in developing countries is the lack of field experience -- more field training and field experiences are required. There is a lack of communications between project management, field staff, and farmers. There is also a lack of accountability. All of these deficiencies lead to a major credibility problem by project field staff with (1) farmers; and (2) the central headquarters of the irrigation agency.

3.3 Impact of Operation Practices on System Performance

To truly evaluate the impact of the various maintenance options, it is necessary to not only relate the impact of each option on operations practices, but also to relate the impact of operation practices on many larger issues; agricultural productivity; economic distribution; social organization; sustainability; and urban water transfers. Only general comments follow. The details need to be developed and specified on how to relate operations practices with each of these major issues for each irrigation system.

3.3.1 Agricultural productivity

The vast majority of irrigation systems in developing countries provide water supplies to surface irrigated fields -- most commonly basin irrigation. The hydraulics of surface irrigation, combined with hundreds of field evaluations, discloses that irrigation application efficiencies will be low if a variable discharge rate is inflowing onto the field.

Unreliable and erratic water deliveries also has a highly significant impact on the crops a farmer will plant and also their resulting yield.

For countries seeking crop diversification (e.g., the majority of countries in Asia), inadequate operations practices greatly discourages farmers and agri-business from investing in higher cash value crops. Thus, crop diversification can only be successful in irrigation systems than can deliver equitable, reliable and predictable water supplies.

Agricultural development programs are unknowingly doomed to dismal results because of inadequate operations practices. Yet, if an irrigation system is being properly operated, then investments in the tertiary subsystems, agricultural production, marketing and food processing have a very high payoff.

3.3.2 Economic distribution

When walking around inside an irrigation system, one of the most appalling features is the tremendous disparity in family incomes -- from poverty to being fairly wealthy. Numerous examples can be cited, from abandoned lands, one crop every other year, no water when needed, and flooded land when there is a plentiful rainfall. Sometimes, these are indicators of an inadequate water supply, but more frequently they are indicators of gross mismanagement of the available water supplies, and the distribution of socio-economic power among the farmer families.

3.3.3 Social organization

There is a growing emphasis on turning over agency-managed irrigation systems to farmers. There are many good reasons for this movement. But, on many systems operated by irrigation agencies, the farmers are already in control and the irrigation engineers have lost control for a variety of very understandable reasons. The problem is that anarchy exists on these systems -- only some groups of farmers are benefiting while others are suffering. A major reason for this dilemma is inadequate operating practices by the irrigation agency and political interference.

3.3.4 Sustainability

Sustainability is an important concept to be applied in irrigated agriculture. Answering the question of sustainability requires that the operating procedures be specified as a long-term, or time dependent, objective. Because of the "site specific" nature of irrigated agriculture, the hydraulic performance criteria would be different for each irrigation system in order to assure sustainability.

3.3.5 Urban water transfers

In the early stages of development within a river basin, most of the emphasis is on hardware solutions. As resources use continues to rise, an increasing emphasis has to be placed upon software solutions.

In many countries, irrigation is the greatest consumer of water. In such cases, if urban population growth is high, and new sources of water supply are extremely difficult to obtain, then water transfers from irrigated agriculture to urban areas may be highly desirable. However, if an irrigation system is being poorly operated, thereby limiting crop production, then diverting a portion of the irrigation water supply to an urban area will significantly reduce crop production. In contrast, a highly productive irrigation system could more readily adapt to a slightly reduced water supply, and at the same time, further increase agricultural productivity.

3.4 Institutional Influences on System Performance

The institutional framework for irrigation in a country characterizes how irrigation system performance is generally perceived in that country. In their functioning, the institutions tend to portray the value that is attached to performance and its assessment, and the way in which performance is assessed and how the results are used. They also help to identify the different roles played by different individuals and groups, and specify the underlying rules of the game. In many developing countries, particularly in South Asia, irrigation institutions are found to be rigid, embedded in deep-rooted "irrigation culture", and therefore less responsive to performance assessment and related needs for change (Bandaragoda 1993b). Thus, most of the problems of maintenance and operations mentioned in the foregoing section are directly linked with the institutional framework.

Legal Framework, Governance, Organizations, and Finance can be identified as the four main aspects, which form a basis for analyzing and understanding the range of variations of irrigation institutions that can be seen in different contexts (Merrey 1993). Outlined below are some features of each of the main aspects, in the order of importance attached to them in most developing countries.

3.4.1 Organizations

Organizational arrangements for irrigation can be seen in three categories:

* Organizations for water delivery and related services, usually the irrigation-related public agencies, such as the Irrigation and Agriculture Departments, which play a dominant role in many aspects of irrigation in developing countries;
* Agency-farmer interface, which is still a fairly weak link in the institutional framework; and

* Organizations for water use and related functions, such as water users associations (WUAs) which have been increasingly emphasized in recent times.

The major issue impacting performance is the sharing of power and authority for irrigation management decisions among these three categories of organizational mechanisms. Often, the dominance of public irrigation organizations derived from the deep-rooted administrative culture in many developing countries has tended to ignore the important contribution that the users themselves can make in improving performance. Apart from the dominance of this sector, the lack of coordination among the various agencies in interacting with farmers compounds the difficulties in achieving adequate benefits from the water delivery subsystem. The resultant complacency on the part of both agency staff and the farmers, and their respective isolation from one another, have not been helpful in creating effective user organizations. This situation of general neglect affects most seriously the desired equity in water distribution and use, and particularly under conditions of water shortage, which is most often the case, inequity affects adversely on overall performance.

3.4.2 Legal System and Governance

The presence of "soft state" conditions in many developing countries have made whatever the legal framework available for supporting irrigation management totally ineffective, and almost operational as a major impediment to performance. Water thefts are rampant, pressure from the influentials and the related rent-seeking behavior by the field level officials accentuates inequity, and long procedures in arbitration mechanisms discourage the aggrieved parties from seeking remedies. Informal rules have superseded the formal rules (Bandaragoda 1992). Although the traditional legal base has tried to stabilize a system of water rights, the informal behavior has disturbed it considerably, and the emerging market pressure is making it redundant. A review of the legal framework, including the laws and procedures governing the various irrigation organizations, is due in many developing countries, to ensure that it promotes improved performance.

Governance, which basically determines the allocation of power and authority, explains who is responsible for what functions of irrigated agriculture and within what bounds. The overall nature of governance in a country plays a significant role in defining governance for irrigated agriculture. The will to share power and responsibility among various agencies, and between agencies and users, is a direct derivative of the prevailing form of governance. A shift from the remote centralized authority system to a secondary and tertiary subsystem is considered more advantageous to the users and having a greater potential for improved performance.

3.4.3 Resource Mobilization and Allocation

This is yet another important aspect which primarily affects the institutional performance, and through it, the overall performance of irrigation. Adequacy and timeliness of the availability of financial and manpower resources greatly influences the organizational behavior, individual motivation and the interaction processes. These behavioral aspects in turn affect performance, irrespective of other managerial influences. Similarly, the payoff to many delivery functions fashions the willingness of beneficiaries to pay even part of the cost of irrigation services. The effect of this vicious circle pervades the irrigation scene in developing countries.

4. IRRIGATION "LEARNING"

4.1 Irrigation Maintenance and Operation Learning Process

An important **strategy** for increasing the agricultural productivity of existing irrigation systems is, first of all, to evaluate the maintenance deficiencies on any particular irrigation system and then **correct all maintenance deficiencies** that interfere with the proper operation of the irrigation channels. Secondly, **improved operations practices should be developed** that will provide reliable, predictable and equitable water deliveries to each outlet (turnout) structure serving a tertiary subsystem. Thirdly, when operations practices have been improved, then **technical assistance should be provided to the farmers** so they can improve their water management practices in order to increase crop production.

> STRATEGY
> for improving
> Existing Irrigation Systems
>
> 1. **Correct Maintenance deficiencies;**
> 2. **Improve operations** practices to provide more reliable, predictable and equitable water deliveries to outlets serving farmers groups;
> 3. **Provide technical assistance to farmers** for enhancing tertiary subsystem management;
> 4. **Sustain a Preventive Maintenance Program** that avoids the need for Rehabilitation; and
> 5. **Continually improve operations** practices to support an increasingly more diverse, productive and sustainable agricultural system.

The Irrigation Maintenance and Operations (M&O) Learning Process has been developed (Skogerboe, 1990) to provide guidelines that will : (a) **identify problems** which commonly prevent irrigation systems from delivering reliable and equitable supplies; (b) **develop solutions** which on implementation would be able to treat the causes of the problems, rather than just the symptoms; and (c) **provide field experience** and insights for further improvements in the irrigation system. This process is meant to develop appreciation and create awareness among technical staff of the irrigation agency, as well as farmers and senior officials, by creating visible **success stories** at those irrigation systems selected for improvement.

Recognizing the "site specific" nature of irrigated agriculture, where **each project area is uniquely different**, an effective **approach must be process oriented**, rather than an approach which emphasizes technology alone, or a "prescriptive" approach that lists step-by-step procedures that are to be used on every irrigation project. Although a "prescription" is usually preferred by most irrigation officials, the disadvantages are: (a) the procedures will lead to less than optimal results for most projects; and (b) project field personnel do not "learn" how to accommodate the unique characteristics within their project area in order to improve the performance of the system. Instead, **a process** (or a series of processes) **is required** that is capable of being adapted to each "site specific" situation in order **to be transferable.**

The maintenance and operations "learning process" provides one technological approach for effectively sustaining an irrigation network over a long time period. This process emphasizes:

(a) maintaining rather than rehabilitation;
(b) documenting maintenance needs to improve financial management and accountability;
(c) using existing flow control structures in irrigation channels for water measurement;
(d) developing more detailed physical knowledge about what is occurring within the system;
(e) increasing sensitivity about operating the system to meet the needs of farmers; and
(f) documenting the needs and costs for irrigation system improvements.

In discussing maintenance and operations (M&O) issues, it is useful to subdivide the water delivery subsystem into the main canal and branch canal (principal canal subsystem), the secondary canal subsystem consisting of distributaries and minors, and the tertiary subsystem which is a watercourse. The tertiary subsystem is the land served by the last flow control structure (outlet) along the secondary subsystem. An irrigation project consists of a principal and secondary subsystem channel network (called main subsystem) that serves many outlets.

This process is focused upon the water delivery subsystem, but the same principles would apply to the water removal subsystem (surface and subsurface drainage channel network). Most likely, the farmers would be responsible for maintaining the drainage channels in the tertiary subsystems, while the appropriate government agency would maintain the main drains and the branch drains flowing into each main drain. Generally, the maintenance of drainage channels is quite neglected because few funds are provided for this purpose.

4.2 Turnover of Irrigation Systems to Farmers

In recent years, more and more publications on irrigated agriculture are stressing that the most important activities in the near future should be "main system management" (e.g., Chambers, 1988 and Walker, 1990) and "maintenance" (e.g., World Bank 1991). In fact, the two activities go hand-in-hand. Maintenance is a support activity to facilitate operating the irrigation channels, or main system management.

This increased emphasis by donors and other organizations has resulted from a recognition that, in general, irrigation infrastructure is deteriorating, particularly in those cases where irrigation projects are managed by government agencies. In viewing the situation world-wide, one obvious conclusion is that the best-operated irrigation systems are managed by farmers, not government agencies. This is not only true for small irrigation systems, but for large systems as well.

An irrigation project is usually typified under three types of management: (a) agency-managed irrigation system (AMIS); (2) jointly managed irrigation system (JMIS); and (3) farmer-managed irrigation system (FMIS) (Manor, Patamatamkul and Olin, 1990). The focus herein is to move from AMIS to FMIS using JMIS as the driving mechanism. For the Indus Basin Irrigation System, the authors perception would be that a process is required that gives farmers control of the secondary and tertiary subsystems.

A learning process has been developed wherein both farmers and agency field staff will develop field experience together with improved M&O practices. More importantly, this is a process for creating and then strengthening farmers water users organizations (WUOs). At the same time, the field capability of the agency staff will be enhanced. For the sake of brevity, the details of this process are not described. The interested reader can consult the reference (Skogerboe, Poudyal and Shrestha, 1993) to obtain more details.

The successful implementation of this process is expected to result in turnover to the farmers (FMIS) after 2-5 years. Limited success may result in continued joint management for decades. Failure to develop credibility between farmers and agency field staff while implementing this process will result in the project being farmer-managed, but under anarchy, rather than having effective farmers organizations that can equitably distribute the irrigation water supplies and sustain the physical infrastructure.

4.3 Improving Irrigation Water Management on Farms

Once the main system is being properly managed, then it becomes highly beneficial to focus on the tertiary subsystems, including the croplands. This is much more complex than the main system, not only because of the numerous government and private organizations involved, but also the complex physical and social phenomena. There does exist an interdisciplinary approach that is client-oriented for improving water management practices and agricultural productivity in tertiary command areas (Skogerboe, et al., 1982)

4.4 Irrigation Salinity Management

An important measure of sustainability for many irrigation systems is salinity. For example, the Imperial Irrigation District (160,000 ha) monitors the annual salt balance for the entire system as a highly important performance parameter that indicates whether salts in the soil profile are accumulating or being leached. Again, there is a process available (Skogerboe, Walker and Evans, 1979) that can be used as a guide in developing cost-effective solutions for managing salinity on irrigated croplands.

5. SUMMARY AND CONCLUSIONS

For irrigated agriculture, the question of sustainability is one of resource management. At the same time, irrigated agriculture is "site specific", so that resource management practices must be appropriate to the physical and institutional environment.

To increase crop yields and cropping intensities on existing irrigation systems requires continual improvements in water management practices to meet future food demands. Maintaining the physical environment for a productive agricultural system also requires continual improvements in agronomic (including irrigation) practices.

To continue pumping groundwater on a sustainable basis requires the proper combination of groundwater and irrigation practices that will also have to be continually improved over time.

Irrigation water supplies can be partially diverted to urban areas, without decreasing agricultural productivity, only if water management practices are further improved. In fact, a highly productive and sustainable irrigation system should be capable of increasing crop production with reduced water supplies, provided the management practices are properly adjusted to the decreased water supply.

A major question being addressed in many countries is the turnover of operations and maintenance activities for irrigation projects from public agencies to water users organizations. Turnover processes are being experimentally implemented in a number of Asian, Latin American and African countries. Many recent studies by IIMI have investigated farmer-managed irrigation systems. (Manor, et. al, 1990; Yoder and Thurston, 1990). Serious discussions are underway in Pakistan regarding privatization of the world's largest irrigation system, but of course, there is considerable resistance.

A number of organizations have made important strides in developing improved procedures for computer operation of irrigation systems. The implementation of this technology is now gaining momentum. Research has clearly shown that perturbations of water levels and discharges in canals are magnified as these flows move into the lower secondary and tertiary channels.

Likewise, research on surface irrigation of croplands shows that fluctuating discharge rates applied to croplands results in low application efficiencies. This, in turn, limits crop yields and reduces crop quality, thereby lowering profits.

In many developing countries, agricultural policies benefit urban consumers at a significant cost to rural farm families. Often, these policies are a definite deterrent to increasing agricultural productivity.

For irrigated agriculture, there is a formidable task ahead in the next 10-30 years. Rapidly increasing populations, the necessity for improved diets, and limited potential for expanding the amount of land that can be irrigated present a major challenge. But,

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ORGANIZED WATER RESEARCH IN EGYPT
THE ROLE OF THE ACADEMY OF SCIENTIFIC RESEARCH AND TECHNOLOGY

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ABSTRACT

Realizing the importance of research as a major input to develop water programs, the Government of Egypt has started since the seventies to heavily support the Research institutions financially and institutionally.

Accordingly, the Water Research Center (WRC) was established in 1975 consisting of eleven Research Institutes specialized in the different branches of water. It is considered now as one of the leading scientific institutions in this field in Africa and the Middle East.

The Academy of Scientific Research and Technology (ASRT) which started about 20 years earlier represents successful developed researches on a national scale, including water problems, within its chart and activities, whether as a research council, division or committee.

Other Research institutions implement researches in Egypt dealing with water; such as; Agriculture Research Center with its soils and water research institute, Ministry of Health Water Laboratory, Civil Engineering Departments of the Universities, Navigation Department (Arab Mritime Academy), ... etc.

In this paper, the Authors describe, in brief the various aspects of research problems, projects and priorities which provide a comprehensive program of research in water problems in Egypt with an interdisciplinary approach and with close cooperation and coordination with the WRC of the Ministry of Public Works and Water Resources (MPWWR).

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The Supermen Council for Scientific Research or Ministries of Scientific Research all of which were formed in the processes of organizing scientific research, on a national level, since late 1940's in Egypt.

The following paragraphs outline, in brief, some details of major research Institutions and programs developed with respect to water resources and uses during various stages between 1972 and 1994 within the concerned councils and committees of the Academy.

2. WATER RESEARCH CENTER (WRC) FORMATIONS

WRC was established in 1975; one of the major objectives of WRC is to outline and implement long-term policies for managing the water resources in Egypt in order to cope with national demands. The Center also aims at solving the technical and applied problems associated with the general policy for irrigation and drainage.

Moreover, the Center is concerned with investigations and research work connected with the extension of agricultural land and water resource assessment, both surface and groundwater. It attempts to find a means for utilizing the water resources of the country in the most efficient and cost-effective manner. One other goal the Center strives for is to study the main side effects of the High Aswan Dam after its construction and develop appropriate means for alleviating them. The WRC consists of eleven Research Institutes that read like a list of the problems facing Egypt's improvement and water resources development. These are

1. Water Distribution and Irrigation Systems Research Institute
2. Drainage Research Institute
3. Hydraulics and Sediment Research Institute
4. Water Resources Development Research Institute
5. Weed Control and Channel Maintenanc Reserach Institute
6. Groundwater Research Institute
7. Nile Research Institute
8. Mechanical and Electrical Research Institute
9. Survey Research Institute
10. Soil Mechanics and Foundations Research Institute
11. Coastal Protection Research Institute

3. SCIENTIFIC FORMATIONS IN THE ACADEMY

Problems of national or principal impact, and which may require organized research, are discussed in the Academy by one or more of the Academy's four main scientific formations. Necessary to mention that these scientific formations include members of high caliber, each in his own field, representing as much as possible the concerned institutions and the main disciplines.

Water research is discussed within the following councils, divisions, national committees or societies;

a) Specialized Research Councils(R.C^s.)

- Soils and Water Resources Council (R.C.)
- Food, Agriculture and Irrigation R.C.
- Environmental R.C.
- Health R.C.
- Housing and Building Technology R.C.
- Energy R.C.
- Transportation R.C.
- New Communities R.C.
- Economics R.C.

b) Joint Research Divisions

- Joint Division for manicipal and Waste Water Research.

This division is concerned with technical aspects of purification of drinking waters, sewage treatment, and, reuse of treated waters and sludge.

c) National Committees for International Scientific Unions

These Committees are formed by the Academy and contribute significantly to coordination and exchange of knowledge between international scientific bodies and the Academy. Examples of Committees involved in water are:

- The National Committee for Research on Water Protection against pollution.
- Permanent National Committee for International Hydrological Program (IHP). This Committee is now affiliated to the Ministry of Public Works and Water Resources (formerly the Ministry of Irrigation).
- National Committee for Geological Sciences.
- National Committee for Conservation of Nature and Natural Resources.
- National Committee for Environmental Issues.

d) Scientific Societies

The scientific societies in Egypt are, according to the law, registered in and, hence, supervised by the Ministry of Social Affairs. In practice, however, these societies are actively linked to the Academy which supports them financially and professionally although they are considered as non-governmental organizations. Many of these societies include water as an area of concern, for example:

- Egyptian Society for Soil Sciences
- Engineering Society for Irrigation
- E.S. for Groundwater
- E.S. for Environmental and Health legislations.
- E.S. for Environmental Science
- E.S. for Conservation of Natural Resources
- E.S. for Conservation of the Environment.
- E.S. for Geology
- E. Health Society
- E. Medical Society
- E.S. for Combatting Bilharziasis

e) Other Committees

- The Principal Committee for Combating Decertification
- The Shore Protection Committee.

4. MAIN CONTRIBUTIONS TO WATER RESEARCH

The above formations in the Academy deal with water problems from various aspects and with varying degrees of details. However, since water-use for irrigation constitutes about 85% of the total demands in Egypt, the role of committees, divisions or councils involved in this sector, i.e. with food and agriculture is most significant. The following paragraphs reveal, in brief, the activities of the Academy during various stages of organization between 1972 and present (1994):

1972-1979

During this period, problems of water on a national scale were discussed in the soils and Water Research Council. This council outlined its task in Water Resources to include mainly the following:

a. Research on Development of Water Resources:

These include studies of ; Nile hydrology from Equatorial lakes plateau till Aswan for the purpose of maximizing the out flow arriving in Aswan, reliability of groundwater resources in Egypt, Reuse of agricultural drainage waters in irrigation, saline water desalinization and efficient uses of water by reducing water wastes and applying irrigation management programs.

b. Research on the impact of the High Aswan Dam (HAD):

These included the evaluation of HAD side effects on irrigation, drainage, groundwater, aquatic weeds, bank erosion, invironmnetal impacts...etc. The following, three subject-matter Committees were formed to define the problems, needed research, contract with scientific institutes and follow up:

- Research and investigation on the HAD side effects
- Research and investigations on groundwater in the Nile Valley and Delta
- Salt waters desalinization

Priorities for execution were set-up for selected water research projects in the following order:

- Evaluation of Modern Irrigation Methods in Newly reclaimed Sandy Soils ..
- Optimum operation of the HAD to satisfy agriculture needs, and hydro-power generation.
- Operation of the HAD with respect to other proposed projects in the Upper Nile.
- Influence of the HAD on the groundwater levels in Nile Valley and Delta
- Design of stable channels after the HAD construction
- Water requirements

In the meantime, the soils and Water Research Council jointly with the University of Michigan, U.S.A. signed an agreement to work on the following research program:

- Environmental conditions and life dynamics in Lake Nasser
- Aquatic weeds
- Sedimentation in the HAD reservoir
- Evaporation in the HAD reservoir
- Changes in constituents of Nile water, quantitatively and qualitatively, as a result of storage in Lake Nasser, with special emphasis on the impact of these changes.
- Agriculture development on Lake Nasser region
- Water-balance in Lake Nasser

Towards the end of this period, the Council approved a research project concerning groundwater investigation in Greater Cairo area.

1979-1987

In November 1979, the Academy re-organized its Councils. Accordingly, water research became the responsibility of the Resources Division under the New Research Council for Food and Agriculture.

For facing the challenges which encounter Egyptian irrigated agriculture in meeting with increasing demands for foods as a result of increasing population, changes in food habits and consumption, it was thought to stress on the following objectives :

- Integration of the science and technology policy, programs of scientific research and the national socio-economic development plans.

- Adopt new applicable technological advancements in agriculture including irrigation, use of non-conventional of water resources and development of soil and water resources.

The Resources Division continued implementation of its previous research programs, with special emphasis on the following:

- Determination of water requirements for main crops in the old and newly irrigated lands.
- Evaluation of new irrigation technologies used in sandy and calcareous soils.

1987-1994

The organizational changes, that took place during this period were in the form not in substance and came in 1987 to show more recognition to water research and to irrigation problems. The name of the Council is at present; " The Council of Food, Agriculture and Irrigation " under which there is a "Division of Water Resources and Irrigation".

This Division realized the necessity of more coordination between the Ministry of Public Works and Water Resources, the Water Research Center with its Research Institutes and the Academy of Scientific Research and Technology in defining the national problems, planning for the necessary research projects and partial financing of recommended studies.

Priority was given to support research and development in the following fields:

1. Water Resources

a. Develop conventional water resources, with special emphasis on its management and conservation.
b. Use of non-conventional water resources.

The specific approved topics in this field includes the following:

- Review of water policy, and defining the rights of water uses.
- Develop surface and underground water resources in the Egyptian deserts, Sinai, Nile Valley and Delta.

- Desalinization of salty and brackish waters.
- Utilization of non-renewable confined underground water aquifers.
- Use of non-conventional and renewable energy resources and economical considerations.
- Workout an integrated strategy to meet with drought possibilities in the long and short terms.

2. Optimization of Water uses and development of appropriate tools

The following priority projects aim at ensuring the appropriate uses of water economically, and developing the tools and instruments necessary to provide maximum efficiency.

a. Optimization of water uses on a national scale: including conservation of winter-closure water wastes, protection of coastal underground water aquifers and control of salt water intrusion.

b. Develop water conveyance and distribution structures.

c. Develop irrigation systems.

d. Detailed studies on water requirements and irrigation duties under different irrigation systems with the aim of minimizing water losses.

e. Set the appropriate basis for irrigation frequencies (scheduling).

f. Impact of water management program on quality and quantity of drainage water.

g. Control of aquatic weeds in canals.

3. Third Five-Year Research Plan

The current five-year 1992/97 research plan on water includes financing the following six research programs:

a. Assessment of underground water aquifers in the fissured limestone rocks.
b. Study of winter-closure and it's impact on water and irrigated agriculture.
c. Updating of hydrogeologic maps of Egypt.
d. Study of possible drought problems and means of mitigation.
" Proper management of available water resources in Egypt for irrigation purposes in cases of drought".
e. Losses and gains of water along the Nile course downstream the HAD.

f. Management of irrigating water in new reclaimed desert lands and its economics.
g. Evaluation of water losses due to navigation in the main irrigation canals and the means of controlling these water losses.
h. Reuse of drainage water.

5. SUMMARY AND CONCLUSION

Organized and coordinated scientific research in Egypt is a relatively recent entiative of serving the various production and services sectors to implement the socio-economic development plans. Although individual attempts were carried out, particularly in agriculture, to explain irregular or abnormal events as early as the first decade of this century, yet the first recognized government body responsible for research was established only in the late 1940's.

The developments which took place since then included organization, targets, training of personnel and means of defining problems of research, their priorities, impacts, financing and sources of funding. However, throughout the various stages of research development, water was always a priority target relevant to irrigation, at first, yet to all other aspects of water uses including environmental and socio-economical.

The Academy of Scientific Research and Technology is part of the chain of changes in organized research in Egypt. Because of the nature of its mandate, it gave water research top priority in its organization. The 14 research councils within the Academy provide suitable media for discussing water problems from various angles in an interdisciplinary approach. Hence, it does not conflict with the plans or policies of the Water Research Center which was established later, in 1975. Needless to say that the Chairmanship and membership to the various councils, divisions and committees in the Academy is always given to selected personnel of high scientific and/or executive caliber. Hence, representatives of the Ministry of Public Works and Water Resources, the Water Research Center and its Institutes constituted the proper and most effective links between the Academy and the Ministry.

The afore-mentioned system proved to be efficient presenting and discussing water problems in Egypt for all aspects, not only relevant to irrigation but also to health, energy, navigation, pollution, industry, housing ...etc.

The paper lists the research programs that was adopted during the period between 1972 and 1994. Due to space limitations, it was not possible to give more details about all the research activities and the main results. It is worthy to stress that the mandate of the Academy in effectuating better coordination and cooperation in research among various institutions, the scientific societies which are sponsored by the Academy and the National Committees of the International Scientific University play an important role in planning and implementation of water research and development in areas which require inputs from disciplines other than those of hydraulic engineering and construction. It is clear from the afore mentioned brief discussion of water problems during the period 1972 to 1994 that priorities were given during the 1970's to HAD side effects, during the 1980's; to water pollution, efficiency of irrigation systems and application of new technologies. In 1990's top priority is given to water management use of non-conventional water and energy resources, and environmental and socio-economical aspects.

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THE ROLE OF WASTEWATER RECYCLING AND REUSE IN WATER RESOURCES MANAGEMENT UNDER CONDITIONS OF SCARCITY

Hillel Shuval[1]

ABSTRACT

A number of countries in the Middle East will face, severe water shortages which may bring them to well below the "water stress" level. For example, within a 30 year period, with an estimated doubling of their population, the Jordanians, Israelis and Palestinians will have available to them, from their current water reserves, just about the limit of what is needed for survival based solely on domestic, urban and industrial use, with no fresh water available for agriculture. For such peoples in arid regions and others, the recycling and reuse of about 65-80% of the waters supplied for urban/industrial use can often generate the only significant additional low cost water resources for agricultural/industrial and urban non-potable purposes. Desalinated sea water, estimated to cost about $1.00/cu.m. will not normally be economically feasible for agricultural use. The capital investment in sewerage infrastructure is high, about $300-$500/person, which means that an investment of as much as $500 million dollars/million urban residents will be required. However, in such densely populated countries, a high level of wastewater collection and treatment is essential, in any event, to protect the public health and to prevent environmental pollution. Thus, the additional marginal cost of treatment, storage and conveyance of purified wastewater required for unrestricted agricultural reuse, meeting strict WHO health criteria will be only a fraction of the total wastewater treatment and disposal cost-about $.10 out of a total of $.35/cu.m. Recycling of wastewater can have the multiple benefit of protecting the environment and serving as a major source of water. Israel's urban areas are 85% sewered with 65% of the flow recycled to agriculture. Jordan likewise has a strong recycling policy and reuses 75% of the wastewater flow.

1. INTRODUCTION

1.1 Emerging Water Short Areas in the Middle East

A recent study by Population Action International(1) has reported on the annual renewable fresh water available per person for 100 countries based on data available for 1955, and 1990 with extrapolations as to estimated available water in the year 2025 assuming certain increases in population with no change in the total available renewable fresh water resources (See Table 1.).

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Table 1. Annual Renewable Fresh Water Available per Person in Middle Eastern and Selected Countries. Ranked by 1990 availability (1).

COUNTRY	RENEWABLE FRESH WATER IN CU.M./PER/YR (CM/P/YR)		
	1955 CM/P/Yr	1990 CM/P/Yr	2025 (MEDIUM) CM/P/Yr
DJIBOUTI	147	23	9
KUWAIT	808	75	57
QATAR	1,427	117	68
BAHARAIN	627	179	89
U.ARAB EMIRATES	6,195	308	176
SAUDI ARABIA	1,266	306	113
JORDAN	906	327	121
YEMEN	1,098	445	152
ISRAEL	1,229	461	264
TUNESIA	1,127	540	324
ALGERIA	1,770	689	332
LIBIYA	4,105	1,017	359
MORROCO	2,561	1,123	590
EGYPT	2,561	1,123	630
OMAN	4,240	1,266	410
CYPRUS	1,698	1,282	996
LEBANON	3,088	1,818	1,113
IRAN	6,203	2,025	816
SYRIA	6,500	2,087	732
TURKEY	8,509	3,626	2,186
IRAQ	18,441	6,029	2,356
UNITED KINGDOM	2,344	2,090	1,992
CHINA	4,597	2,427	1,818
GERMANY	2,843	2,516	2,284
FRANCE	4,260	3,262	3,044
SWITZERLAND	10,040	7,449	6,492
UNITED STATES	14,934	9,913	7,695

As can be seen from Table 1. many countries in the Middle East now face or will be facing severe water shortages as their populations grow and their water resources remain fixed.

The data from the P.A.I. study(1) is presented here for comparative purposes, but experts in any given country's water resources may not be in full agreement with these figures, drawn from official United Nations and World Bank sources. For example, according to my own studies(2) the 1990 figure for Israel is closer to 300 cubic meters/person/ year (CM/P/Yr) while the extrapolation to the year 2025 should be about 150CM/P/Yr. I also calculated that the 1990 figure for the Palestinians (not included in the P.A.I. study) is about 160 CM/P/Yr which will go down to 60CM/P/Yr by 2025, if they continue having available to them, only the water resources that they currently are using. Of course they are presently in the process of negotiating for a larger share of the transboundary ground and surface water from their neighbors, Israel and Jordan.

Actually, the situation may be more severe than as presented in table 1. since it is not unlikely that there be will be an effective decrease in water resources available, for a number of important reasons. One, serious and ubiquitous, reason for the decreased availability of water for specific uses is the continual degradation of water quality as a result of growing contamination from urban and industrial wastewater and increasing water pollution caused by runoff and drainage from agricultural areas carrying toxic agricultural chemicals and brackish irrigation water return flows. Such changes in quality can reduce the utility of the available water resources, by making portions unsuitable for domestic water supply and/or agricultural use. In effect this results in a reduction of the quantities of water available to meet the specific essential demands.

Another possible cause of a decrease in the available water resources for certain countries, may be the result of increasing demands for a greater share in water allocations by other neighboring countries who draw upon the same transboundary water resources on international river basins. There are a number of such disputes over water rights in the Middle East, such as between Ethiopia and Egypt; Turkey, Syria and Iraq and Syria, Jordan, Israel and the Palestinians.

The question that must now be addressed is: How much water does a nation living in an arid zone actually need so as to assure a reasonable level of economic development and human welfare?

1.2 Minimum Water Requirement for Survival in Arid Areas

1.2.1 <u>The debate over the "Water Stress" index</u>

The question of the amount of water required by people living in arid zones has been widely discussed and debated. Falkenmark (3) has defined the concept of a "water stress index" based onher estimated minimum level of water required per capita/year to maintain an adequate quality of life in a moderately developed country in an arid zone. Falkenmark estimates that while only 100 liters/person/day (or 36.5 CM/P/Yr) are the rough minimum for basic household needs required to maintain good health, that a water efficient, and moderately developed country requires at least 30-45 times that quantity to satisfy all the requirements of agriculture, industry and energy production.

Thus, according to Falkenmark, a level of 1700 CM/P/Yr is considered adequate, however, she holds that when fresh water availability falls below 1,000 CM/P/Yr, countries experience "chronic water stress" and when countries fall below 500 CM/P/Yr they experience "absolute water stress." Falkenmark's pioneering concept of "water stress" has been much debated and the numerical levels suggested have been challenged. However, a number of authorities including the World Bank (4) have accepted the 1000 CM/P/Yr level as a benchmark which they claim can serve as a general indicator of water scarcity. Gleick (5) has called it the "approximate minimum necessary for an adequate quality of life in a moderately developed country" However, all of these authors assume that a major allocation of water is necessary for agricultural purposes both to supply local food requirements and/or assure employment for those who have traditionally lived in rural areas and made their livelihood from agriculture.

In some countries in arid areas where supplemental irrigation is required and sufficient water is still available, as much as 80% of the water supply is utilized for such agricultural purposes and some 70- 80% of the population derive their livelihood from agriculture, directly or indirectly. Can this ratio of water allocation to agriculture continue as populations grow, along with rapid urbanization and with the water resource potential remaining the same?

Some countries profess that their national agricultural policy is based on a concept of "food security" which dictates self-sufficiency in most food products as a matter of national security. They claim that this is necessary in case of a long term embargo, siege or blockade which would prevent food imports. A few oil rich countries have embarked on a program of seawater desalination for agricultural use on the basis of just such a "food security" policy.

It has been reported that in part the motivation of certain oil rich countries to initiate programs of "food security" resulted from an unofficially reported statement by someone in one in one of the main oil importing countries, which also is one of the main wheat exporting countries, suggesting that there might be a grain export embargo in response to the oil embargo initiated by the oil exporting countries during the late 1960's. Such a grain embargo was never actually initiated. It is not clear whether those countries who initiated programs to grow grains with desalinated sea water to meet local grain demand, so as to achieve " food security" carefully evaluated the alternatives for achieving the same goal. One alternative, might be to build cold storage warehouses and grain silos capable of storing most of the food requirements to meet periods of need. The Bible records that one of the Pharaohs of Egypt did just that when he built grain silos over 3 thousand years ago. It is indeed difficult to comprehend the rationale of one of the countries that built desalination plants to produce water for irrigation and to achieve "food security" that now has become a major grain exporting country, at a tremendous cost to its weakened national treasury which subsidies the grain.

What about those less prosperous countries that do not have enough renewable fresh water supplies for agriculture? Is is economically and socially rational to desalinate seawater so as to grow crops, including wheat for local consumption and even export, when the actual cost of the locally grown subsidize wheat is 5 times that of the world market price? The modern rational economic approach to this question is that countries with little water should import most of the high water consuming food they need, particularly the staples which can be shipped easily and stored for longer periods, from those countries with plenty of water from natural renewable sources and sufficient areas of arable land.

It is difficult to accept these concepts and numbers of "water stress" as being applicable for the really water scarce areas of the Middle East. The view of persons in the Middle East on concepts of adequate amounts of water should be quite different than that of persons from countries with plentiful amounts of year round rainfall, rivers for hydroelectric power production and transport, and copious sources of low cost water for supplemental irrigation.

The 1,000 cubic meter benchmark level supported by some authors from the countries with more temperate climates assumes that major amounts of water must be used for agriculture. However as we have shown previously in Table 1. there are a number of Middle Eastern countries who are already well below the 500 CM/P/Yr level and are at, or are approaching the 100-200 CM/P/Yr level. After the urban and industrial demand is fully met, such countries have little or any water left over for agriculture. With time that list will grow.

The question that must be asked is: Can countries facing such severe water shortages, and whose main option for increasing water supplies is seawater desalination costing about $1.00/CM, consider agriculture as an essential endeavor or an economically rational way to use such expensive water? When water is really scarce the first task is to meet the needs for domestic and urban use as well as the water needed by commerce and industry so as to supply employment for the population.

What is the real minimum amount of water for community and national survival under arid area conditions?

1.2.2 <u>The "minimum water requirement" -MWR for arid zones.</u>

A number of Middle Eastern countries are already facing situations under which the available water supplies are now sufficient only to support most of the population in urban settings where trade, commerce and industry are the main sources of employment. Similar to the situation in such water and land scarce places as, Baharain, Hong Kong and Singapore. As populations grow in the future, and the urban/industrial demands for water grow, the relatively limited quantities of water available for agriculture, whose economic return per unit of water consumed, is relatively low, will by the nature of things have to be used to cope with the growing demands of the urban/industrial sector which can pay a much higher price for water. Unless water is supplied to meet these urban,commercial and industrial needs there is likely to be serious unemployment as well as social and even political unrest.

How much water is required for a reasonable standard of living to meet domestic/urban/industrial demand? In the United States the USEPA reported that in 1981(6) the mean annual household water use was about 90 CM/P/Yr. Total urban use is usually twice that figure or about 180 CM/P/Yr. Some urban areas consume as much as 300 CM/P/Yr. In the water rich areas of Europe which support a high standard of living, domestic/urban/industrial demands are lower than in the United States and range between 100-150CM/P/Yr/.

Experience in Israel indicates that a high standard of life can be maintained with a domestic/urban/industrial water consumption of about 100 CM/P/Y. This has been achieved by water metering, charging for the full combined cost of water supply and wastewater collection and disposal as part of the urban water bill, punitive increases in prices for overly high domestic water consumption as well as public education on water conservation. Water conservation measures such as the introduction of water saving fixtures in the home, and requiring all industries to recycle cooling water and process water wherever technologically feasible has been partially successful. It has been estimated in Israel that this figure might increase to 125CM/P/Yr within a 30 year period (2).

In one study in the United States(6) it has been estimated that the potential water savings that would result from the rigorous introduction of water saving devices in the home could be as great as 33% resulting in a mean household water use of 60 CM/P/Yr. For example with proper water saving devices the amount of water used for toilet flushing alone could be reduced by 50% or by about 16 CM/P/Yr. These studies indicate that domestic water consumption can be kept low while maintaining a very high standard of living.

As a preliminary estimate for planning purposes in arid Middle Eastern countries I have proposed that the minimum water requirement (MWR) for survival in an urban/industrial communities in the severely water short areas of the Middle East be assumed at the 125 CM/P/Yr level(2).

In the earlier stages of urban/industrial development such a quantity of water might also cover the use of very limited amounts of water, say 25 CM/P/Yr for the supply of truck garden type of fresh vegetables for local consumption. Based on fresh vegetables consumption patterns in Israel and data on crop requirements for water, 25 CM/year would be sufficient, using modern irrigation techniques, to meet the water requirement for the irrigation of the supply of such fresh vegetables crops for local consumption.

While the MWR concept does not include any direct allocation of water for agriculture, recycled and treated wastewater from the urban/industrial sector can provide a major source of additional water for agriculture.

2. WASTEWATER RECYCLING AND REUSE

2.1 The Water Resource Potential of Wastewater Recycling

Recycled wastewater is the only source of additional water for agriculture, industry and urban non-potable reuse that actually increases in quantity as the population grows and more and more water is demanded by the urban/industrial sector.

If we assume that the total domestic/urban/industrial water supply eventually reaches 125 CM/P/Yr, then it is not unreasonable to estimate, based on experience in various countries, that any where between 65-80% of the incoming water supply can be recycled and reused. Thus for example, a city with a population of one million would require a water supply of 125 million cubic meters/year (MCM/Yr) and under optimal conditions some 80% of that amount could be collected in the central sewerage network, treated and recycled for reuse in adjacent agricultural areas. In this case some 100 MCM/yr of recycled wastewater might be made available to agricultural areas adjacent to the city.

That amount of water would be sufficient to irrigate between 10 to 20 thousand hectares depending on the irrigation technology used and the type of crops. If achieved, such recycling and reuse of wastewater can add significant amounts of water to the agricultural sector. Alternatively, it could be used for higher valued industrial purposes and even for still higher value, urban, non potable purposes such as the irrigation of greenbelts, football fields, parks, gardens and recreational areas. In some cases treated recycled wastewater has been successfully used for flushing of toilets in municipally managed multi-storied buildings.

2.2 The Need to Construct a Sewerage System Infrastructure

A precondition for achieving this or any level of recycling and reuse of wastewater is the construction of a sewerage system infrastructure to collect the wastewater from domestic/commercial and industrial sources for all the major urban areas.

2.2.1 Public health and environmental protection

For urban areas with central water supply to the homes and domestic water consumption of over 50 liters/p/day, local wastewater disposal methods such as septic tanks and percolation pits, can only serve as temporary palliatives. Eventually, as population density increases and as water supply and wastewater flows increase, overflowing septic tanks and percolation pits become the rule, rather than the exception and the urban environment becomes saturated with the stench and mosquito breeding sites of health menacing wastewater pools and streams. The only solution is the construction of a central sewerage network and wastewater treatment plants which should be considered as an absolutely essential part of urban environmental protection to assure the public health and welfare regardless of the needs to recycle and reuse wastewater as a water resource.

Urban wastewater carries with it the full spectrum of pathogenic bacterial, viral and protozoans of the diseases endemic in the community, and can as well carry pathogenic agents of disease such as cholera, introduced by visitors to the city, coming from epidemic areas as occurred in Jerusalem in 1970(7). Pools and streams of wastewater in urban areas have in certain tropical countries become the main breeding sites of the Culex pipiens mosquitoes that transmit the disease- filariasis which can lead in extreme cases to the disfiguring elaphantisis condition.

From the public health point of view alone, a central sewerage system for the collection and treatment of wastewater is vital. However, even if the wastewater is collected in a central sewerage system providing a reduction of public health risks for the urban residents, but latter dumped untreated into open rivers, dry river beds (wadis), or lakes there is the danger of the pollution of surface or ground water sources of drinking water for down stream users with the disease causing microorganisms from the upstream urban areas.

In addition untreated wastewater dumped into the environment can cause serious ecological imbalances, oxygen depletion, odor nuisances and fish kills in receiving bodies of water such as lakes, rivers and the oceans. Further the pathogenic microorganisms and toxic chemical wastes from industrial sources can pollute the water and present serious health problems to recreational areas, sea-food and fish harvested from such polluted waters. That same wastewater, if treated, recycled and reused on the land can be prevented from ever reaching down stream populations and can become a resource.

Under conditions of plentiful year round rainfall and large flowing rivers the most commonly practiced solution is treatment of wastewater to a degree that will allow it's disposal and dilution in the nearest water bodies. However in the arid areas of the Middle East most rivers are small or have only seasonal flow and the disposal of wastewater effluent to dry river-beds (-wadis) can create serious environmental problems. Under such conditions, wastewater recycling and reuse through land application or irrigation can solve both the environmental problems as well as create a valuable additional source of water and nutrients for the soil.

A World Bank study (8) estimates that the fertilizer value of the natural nutrients in wastewater(nitrogen, phosphorous and,potassium) is worth about three cents/CM which can save the farmer about $130/Ha/Yr in fertilizer costs if he irrigates the land with treated wastewater. For poor farmers in arid areas the fertilizer value alone of wastewater can be an attractive incentive.

2.2.2. The cost of sewerage systems and recycling of wastewater

Without central sewerage systems there can be no recycling and reuse of wastewater, but such systems are very expensive. Based on costs in Israel and elsewhere, it is estimated that the construction of new central sewerage systems in urban areas costs about $300-$500 per person on the average. The cost can be higher in rocky mountainous areas and lower in flat sloping areas with low costs of excavation. This means in order to install a sewerage system in an unsewered urban area, a capital investment of some $500 million per million persons is required.

World Bank reports indicate that the annualized cost of central sewerage systems (capital and operating costs combined) in developing countries can range from $100-$200/person/Yr.

However, in addition to the cost for the central sewerage system of pipes and pumping stations to collect the wastewater it is essential to provide proper wastewater treatment or purification. Wastewater, treatment to effectively remove or inactivate most of the pathogenic microorganisms and to reduce the amounts of environmental pollutants and oxygen consuming organics that might cause serious ecological imbalances, is also expensive. It is beyond the scope of this paper to go into any depth as to alternative wastewater treatment systems for environmental protection and reuse. However the costs may range from $.05-$.45/CM. At the low end are simple and robust, earthen, land extensive, solar energy driven stabilization ponds systems, suitable where plentiful land is available, in warm and sunny arid areas, designed to meet the World Health Organization new microbial wastewater guidelines for unrestricted agricultural irrigation (9). At the extreme high end at $.45/CM are the costly high-tech equipment and energy intensive types of conventional and tertiary wastewater treatment plants such as the activated sludge process followed by additional treatment processes such as sand filtration and disinfection with various additional backup systems designed to produce wastewater effluent of a bacterial quality equal to that of drinking water, as advocated in the recent USEPA/USAID Guidelines on Water Reuse(10).

Let us assume that the annualized cost of a modern central sewerage system is $100/person/ year. If we assume that the amount of wastewater collected is 100 CM/P/Yr. (80% of the water supply of 125CM/P/Yr.= 100.CM/P/Yr). Then one might say that the cost of generating recycled water without treatment is $1.00/CM? Proper treatment might cost between$.05-.30/CM bringing the total to as much as $1.05- $1.30/CM. Is this the correct way of looking at the costs of recycled water? This question will be examined in what follows.

At such high costs for sewerage systems and wastewater treatment is wastewater reuse an economical option for low income arid zone countries or any country for that matter? The answer is only indirectly associated with the question of water resource conservation and reuse needs. The primary and often sole criteria for building central sewerage systems and wastewater treatment plants are public health, environmental protection and urban development considerations. In densely populated major urban centers such as Cairo, Amman, Teheran, Tel Aviv, Tunis and Rabat central sewerage systems are the only way of handling the growing environmental and health problems associated with the accumulation of pathogen laden wastewater from overloading and overflowing local wastewater disposal systems that have saturated the centers and residential neighborhoods of these cities.

The consumers of the water,should also cover the costs of the disposal of the dirty water that results from water supply. In economics, such costs for the disposal of the wastes generated from an essential input stream are referred to as externalities. In line with these considerations it should be clear that the costs of central sewerage systems for urban areas as well as the cost of wastewater treatment so as to provide proper environmental protection at the site of the disposal of the urban wastewater is a social or environmental cost of the urban dwellers and industries who created the wastewater and who must be responsible for all costs associated with its environmentally safe disposal.

Assuming the above, then the economic question of the cost of the water for reuse becomes much clearer. Only those additional costs associated with treating, storing and transporting the wastewater for reuse which are above and beyond the costs of environmentally safe disposal should be charged to the cost of water for agriculture. All other costs should be covered by the urban and industrial areas that generate the wastewater. These environmental disposal costs will vary from situation to situation depending on the local regulations as to the degree of treatment required for discharge of wastewater into the environment and the options open for environmental disposal.

For example in Israel, The Ministry of Health has established regulations requiring all wastewater to be treated prior to disposal into the environment so that it will meet the following criteria as shown in Table 2.

Table 2. Israel Ministry of Health Effluent Standards for Wastewater Disposal into the Environment with or without Reuse

Biological Chemical Demand (5 days)	20 Mg/l
Total Suspended	30 Mg/l
Total Coliforms	1000/100 Ml

In the case of reuse of treated wastewater effluent for the irrigation of vegetables crops normally consumed uncooked such as lettuce and tomatoes, the Israel Ministry of Health requires additional treatment of the wastewater effluent so as to reduce the total coliform concentration to less than 10/100 ml. To achieve such low concentrations of coliforms in the effluent, might require additional filtration and/or disinfection of the effluents which is above and beyond the treatment required by the Ministry of Health for environmental disposal alone.

Additional expenses associated with a wastewater recycling and reuse project might be the construction of an inter-seasonal storage reservoir to allow for storage for a period of as, much as 8-10 months to catch the winter and non- irrigation season wastewater flows for use during the peak 2-4 summer irrigation months. There are some 100 such wastewater inter-seasonal storage reservoirs in operation in Israel. A further additional expense, other than pumping to a more distant irrigation site. might be special filtration and anticlogging disinfection prior to use of the effluent for drip irrigation. The labyrinth small diameter emitter/pressure reducing value at the site of each dripping orifice often gets clogged with suspended solids and as a result of the biofilms- biological growth caused by the nutrients in wastewater. Thus, special additional treatment of wastewater effluent may be required when drip irrigation is practiced.

Shelef (11) has calculated the approximate costs of all the expenses associated with the treatment and storage of wastewater effluent for reuse by conventional high tech activated sludge systems to meet the very rigorous Israeli reuse standards, and the share of that cost that should be covered by the urban and industrial sources of the wastewater to meet the environmental and public health disposal costs. He estimates that the total treatment costs are about $.35/CM while only $.10/CM of that can be considered the additional cost associated with meeting the needs of wastewater reuse. Thus using this economic approach of cost allocation, the resulting cost of water for unrestricted agricultural irrigation meeting the very strictest microbial standard as required in Israel, is not unreasonably expensive at all. According to Israeli agricultural calculations, farmers can afford to pay up to $.20-.25/CM for the water needed to irrigate most crops. For some high water consuming crops such as cotton this figure may be high but $.10/CM is still a very reasonable cost for additional water in an arid zone where the next alternative water source may be from desalination of seawater at about $1.00/CM.

2.2.3 Percent of population served by central sewerage systems

The availability of wastewater for reuse will always be a function of the percentage of the population served by central sewerage systems. In addition it will be a function of the official policy and regulations concerning the encouragement of recycling and reuse of wastewater. In Jordan for example their is a declared policy encouraging reuse and as of 1993 75% of the urban wastewater was treated and reused for agricultural irrigation. In Israel in 1993 85% of the population was served by central sewerage systems and 65% of the available flow was treated and recycled mainly for agricultural irrigation with some reuse going for industrial purposes.

These two examples provide an indication of what can be achieved in countries in arid areas who both have a declared policies concerning maximizing regulated wastewater reuse, both as an environmental protection measure and for water conservation and reuse in agriculture. Other Middle Eastern countries with a declared public policy to support and promote wastewater recycling and reuse are Morroco, Algeria and Egypt. There may well be others, details about which are not known to the author at this time.

The percentage of the population served by central sewerage system in the developed industrialized countries is shown in Table 3.

For long term water resources planning purposes it would be a wise step if all of the water resource authorities in arid countries included in their inventory of potential sources of additional water, the estimate of potential available water for irrigation and other purposes derived from wastewater recycling and reuse.

As a schematic basis it might be appropriate to estimate the rate of urbanization and the expected urban population some thirty years hence, say in the year 2025. Next it is possible to estimate the rate of construction of central sewerage systems or the amount of money required annually for investment in this purpose, so that in a thirty year period the goal of say 80% of the population served by central sewerage systems and wastewater treatment with recycling is achieved.

Table 3. Percent of the Population Served by Central Sewerage Systems and Wastewater Treatment Plants (World Link).

COUNTRY	PERCENT
DENMARK	98
SWEDEN	95
W.GERMANY	90
SWITZERLAND	90
NETHERLANDS	89
ISRAEL	85
UK	84
USA	75
FINLAND	75
AUSTRIA	72
CANADA	66
ITALY	60
FRANCE	52
SPAIN	48
NORWAY	43
JAPAN	39
OECD- MEAN	60

Based on the estimated rate that new sewered areas and their populations come one line and the estimated water use and wastewater production it is possible to estimate the availability of recycled wastewater for use in agriculture or other purposes.

3. WASTEWATER TREATMENT SYSTEMS FOR RECYCLING AND REUSE

As mentioned previously it is beyond the scope of this paper to analyze in depth the various technological options for wastewater treatment systems that can meet the recommended health guidelines required for irrigation. For the warmer sunny countries of the Mediterranean basin and Middle East and where land is available, low cost, multi-celled stabilization ponds have demonstrated their ruggedness and stability in providing a very high efficiency in pathogen removal. Well designed and operated multi-celled stabilization ponds with detention periods of 25-30 days, in warm, sunny climates can normally produce an effluent meeting the new World Health Organization Guidelines (9), of no helminth eggs in one liter and a log mean of 1000 Fecal coli/100 ml. In such warm and sunny areas low cost stabilization ponds can often be the most cost effective treatment method.

In other areas with colder temperatures, less sunlight and/or limitations of the areas of land available, ponds may not be appropriate. However, conventional wastewater treatment processes, such as activated sludge are not necessarily the proper alternative, since their efficiency in removal of helminth eggs, bacterial and viral pathogens is not high, while both the construction and operating cost are very high. The conventional wastewater treatment processes where developed mainly to remove the oxygen consuming fractions of the wastewater (BOD-Biochemical Oxygen Demand) to protect the fish in the rivers and to prevent them from developing foul smelling anaerobic conditions. High levels of BOD removal are not normally required for wastewater irrigation. What is needed is a process that has assured and reliable removal of suspended particles, including helminth eggs, which prepares the effluent for efficient disinfection by such processes as chlorination, ozonation or ultra violet light treatment.

One newer approach which has been highly successful in over one hundred treatment plants in the Scandinavian countries is chemically assisted primary sedimentation followed by disinfection(12). Such a process would consistently produce a very clear effluent that can be effectively disinfected. The total cost of such chemical-physical treatment would be less than the so called conventional biological methods while providing a more reliable quality of effluent that could meet the strictest health standards. The study of alternative treatment methods, aimed primarily at meeting microbial effluent standards, rather than the non-relevant BOD standards should be pursued intensively so as to develop inexpensive and safe methods of treatment, specifically designed to meet the appropriate health regulations for wastewater reuse.

4. HEALTH GUIDELINES FOR WASTEWATER REUSE IN AGRICULTURE

4.1 California: the First Wastewater Reuse Standards

In 1918, the State Health Department of California in the United States, was the first to draft modern regulations to control the public health aspects of wastewater reuse. These were revised and made more strict in 1948 (13). Apparently, the rational of the officials who drafted and approved the California standards was based on the judgement that a microbial standard that is safe for drinking water would obviously also be safe for agricultural irrigation. Even though it was generally agreed at that time that an epidemiological basis for establishing a quantitative microbial standard was not available. Members of the committee have informed me that the majority were motivated by apprehension about being criticized for being too lenient and felt safe in recommending microbial wastewater reuse standards equal to those required for drinking water. In that way no official could be accused of drafting too lax a standard based on this essentially " zero exposure=zero risk" approach.

This might be a considered and example of the so called "Acheson Law" which states that "Committees usually are more concerned with protecting themselves than achieving more worthy goals." In any event, since the California Standards were the first quantitative microbial standard promulgated it was quickly copied by many of the other States in the United States and then after World War II by many of newly created developing nations of the world. Many of those nations were in arid areas and in need of developing additional water resources. They found it expedient to copy standards, such as this one from the developed nations. In the process of copying standards from the United States which were the result of a unique combination of social and political circumstances, the developing countries rarely gave any thought to their economic implications.

The late Professor Thomas Sedgwick of MIT, an eminent pioneer in the field of Environmental Engineering one wrote. "Standards are often the best guess of one man quoted and requoted so often that they assume the semblance of authority. This certainly was the case with those first California wastewater irrigation standards.

One result of the adoption of the overly strict California effluent standard regulations, in certain developing countries, has been, to block plans for improvement, since to build treatment plants to meet such strict standards involves very expensive, high technology, equipment and high operational costs. Intermediate level treatment using appropriate low cost technology may not be approved since they will not meet those standards which the Government innocently become committed to when it copied the California standard. Such intermediate level, lower cost treatment can nonetheless provide a high level of health protection. This has, on occasion, resulted in that tragic situation where nothing at all is done to improve the situation since "insisting on perfection or the best often prevents achieving the good".

4.2 The New International World Health Reuse Guidelines

The World Bank and the World Health Organization became concerned about this anomalous situation and sponsored studies by several independent groups of public health experts and environmental engineers in England, the United States, Switzerland and Israel to reevaluate the scientific basis for wastewater irrigation guidelines and standards. They carried out an extensive scientific evaluation of the epidemiological evidence on health effects associated with wastewater irrigation and developed a scientifically sound, new approach for establishing new and revised health criteria for wastewater irrigation. The Engelberg Report of 1985(14) summarized these findings and presented a radical departure from previous policy in the area of wastewater reuse guidelines and standards. On the one hand it introduced a strict new approach and numerical standard for removal of helminths eggs from wastewater effluent for agricultural reuse, based on firm epidemiological evidence that helminth-worm diseases caused by protozoans such as ascaris, trichuris and hookworm, were the number one health problem associated with wastewater irrigation in the developing countries.

On the other hand, based on the new epidemiological evidence, and their analysis, they called for a major liberalization of the earlier severe zero risk "California" bacterial guidelines which had evolved unwittingly into the world's most widely accepted standard, even though its was illogical. irrational and unfeasible from its inception. The WHO carefully coordinated its efforts in developing international wastewater reuse guidelines with all the other United

Nations agencies including the FAO, UNEP, UNDP and the World Bank. They also sent out the draft proposals for the new guidelines for review and comments to over 100 health scientists and engineers and to Ministries of Health all over the world.

In November 1987, The World Health Organization convened a Scientific Group on "Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture" (9) The group carefully reviewed all the previous studies, the new epidemiological evidence, comments received from many experts and governments and decided to adopt the Engelberg approach and microbial guidelines for wastewater irrigation. The new microbial, health guidelines for unrestricted irrigation of all crops now recommended by the WHO are:

Table 4. 1989-WHO Guidelines for Unrestricted Wastewater Irrigation.

1. No helminth eggs (the cause of worm diseases such as ascaris) per liter of effluent
2. A mean of 1,000 fecal coliforms per 100 ml of effluent.

One of the important features of the new WHO guidelines is that they are generally attainable in many tropical countries in low cost systems such as multi-celled stabilization ponds under most conditions.

Thus, by 1989, when the report was fully approved and published (9) the highest international public health authority had given its official stamp of approval to the fundamental, and in some ways revolutionary, revisions in the health guidelines for wastewater reuse in agriculture. France is one of the developed countries that has formally adopted the recommended WHO guidelines.

4.3 USEPA/USAID Proposed New Stricter Water Reuse Guidelines

In 1992 the United States Environmental Protection Agency together with the United States Agency for International Development decided, to propose Water Reuse Guidelines which were an even stricter version of the California Standards on wastewater irrigation (10). This proposal was based on a report drawn up by the American consulting engineering firm of Camp Dresser and Mckee, The new American Guidelines recommended that the type of treatment and the quality of effluent used for the agricultural reuse by spray or surface irrigation of any food crops including crops eaten raw which are not commercially processed should be as follows:

Table 5. 1992 -USEPA/USAID Recommended Treatment Requirements and Quality of Effluent for Irrigation of Crops Eaten Raw.

Type of Treatment: Secondary + Filtration+ Disinfection	
Effluent Quality:	
Bod	10 mg/l
Turbidity	2 NTU
Microbial	No detectable fecal coli/100ml
Chlorine Residual	1Mg/l Cl2 (after 30 minutes)

The guidelines also recommend very strict requirements to assure treatment reliability including reserve-back up/standby units, automatic recording monitors, alarms and automatic by-pass systems.

These new recommended guidelines are not based on any new epidemiological evidence of negative health effects from wastewater irrigation but similar to the original California standards they are more or less based on the" zero exposure= zero risk " concept regardless of costs. It is understandable that with the mounting pressure and influence of the environmental and "green" groups in the United States any liberalization of an environmental standard would be politically untenable and in fact the pressure is almost always for stricter standards. The USEPA/USAID defended their new stricter standards by stating that Americans insist on a very high safety factor in matters of health protection and are prepared to pay for it.

Those early precedent setting California standards, and the new even stricter USEPA/USAID guidelines evovled from them, are in the opinion of this author seriously flawed by being illogical, inconsistent and unreasonably strict. One example of the fundamental inconsistency of this "zero exposure=zero risk" approach is obvious when one considers the fact that few if any natural rivers in the United States, Europe, Africa or Asia could ever meet such a standard (which is equivalent to the microbial drinking water standards), but nevertheless such river waters are accepted as an unrestricted source of irrigation water. Recent World Health Organization studies have shown that the mean coliform count of the rivers of Europe ranges between 1,000-10,000 Fecal coli/100 ml. Similar conditions exist in many American rivers and in 1973 the USEPA together with the American Academy of Sciences recommended that river water be considered safe for unrestricted agricultural irrigation if it's mean coliform count did not exceed 1000/100 ml(15)

Another example is that some of the States of the United States allow bathing in waters with mean coliform concentrations of 100-1,000/100 ml. The European Community-EEC allows bathing in sea-water with coliform counts of up to 10,000 /100ml. Can it be considered logical or consistent to allow the human body to be immersed in water with 1000 or even 10.000 coliforms/100ml while forbidding irrigation of crops with such water? After all irrigated crops are exposed to the disinfection action of UV radiation from the sun and microbial inactivation due to dissication before marketing.

The big American consulting engineering firms, such as the one that proposed the new EPA/AID wastewater reuse guidelines, favor such rigorous standards, which require the construction of expensive advanced high technology treatment plants. While they may claim that such plants are also feasible for lesser developed countries, such claims are questionable. Such treatment plants as required by the new American wastewater reuse guidelines are expensive to build and operate and require a high technology infrastructure to operate and maintain. Even if funds to build such equipment and energy intensive plants become available to developing nations, experience indicates that the chances of long term reliable, sustainable, operation are slight. While these new very rigorous guidelines may be achievable in the United States it is questionable whether they are technically or economically feasible in the less developed countries of the world.

The World Health Organization made several attempts to persuade the USAID to join it and the other United Nation agencies in supporting the new internationally developed wastewater reuse guidelines, particularly with the goal of avoiding conflicting guidelines and double messages going out to the developing countries most desperately in need of promoting economically feasible wastewater recycling and reuse projects. The USAID refused on the grounds that the new guidelines were those of the USEPA and intended primarily for internal United States use. Nevertheless the AID has distributed these new US guidelines to all of the developing countries in which they operate. Despite a foot note in small print in the Guideline document, that USAID will not insist on the United States Guidelines when providing financial support for reuse projects, it is only natural that governments in developing countries, which are dependent on US aid, are now confused over the conflicting USA and WHO guidelines.

It would be wise for countries to make their own independent judgements in establishing health regulations for wastewater reuse, free from the social, economic and political forces that shaped the American standards. The new World Health Organization wastewater reuse guidelines can serve as a sound health basis for setting such standards. The WHO Guidelines, which have been widely accepted by the United Nations agencies, World Bank, and a number of countries where drafted based on rational health criteria and the latest scientific evidence with the goal of providing the requisite degree of health protection coupled with important general environmental considerations and goals for the prevention of environmental pollution and the promotion of resource recycling and recovery.

5. SUMMARY AND CONCLUSIONS

A number of the countries in the Middle East and Asia will face, growing, severe water shortages which may bring them to well below the "water stress" level. Such countries will have just about the limit of what is needed for survival based solely on domestic, urban, commercial and industrial use, with no fresh water available for agriculture. If total urban/industrial water consumption is estimated at 125CM/P/Yr and 80% is recycled, it would thus be possible to generate an additional 100 CM/P/Yr for agriculture or other non potable purposes. For countries in arid regions and others, the recycling and reuse of waters supplied for urban/industrial use can be the only water resource whose quantity will continue to increase as more and more water-even desalinated water-is used by the urban/ industrial sector and can thus provide a rational and sustainable basis for a limited level of agriculture in such severely water short countries.

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INTEGRATED WATER RESOURCES MANAGEMENT: THE BRAZILIAN EXPERIENCE

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ABSTRACT

In recent years the subject of sustainable development has gained a substantial evidence among water resources professionals. It is clearly accepted that sustainable development will be achieved in the water sector only after the recognition that the traditional water quantity supply and demand analysis alone is not sufficient for good water resources planning and management. An effort should be made to develop methodologies that encompass both, quantitative and qualitative aspects of water resources management. Besides that, social, economic and political aspects must be explicitly considered in the analysis. This lead to the development of the concept of integrated water resources management in which all the multidisciplinary aspects are taken into account. In this paper the necessary measures to achieve integrated water resources management are discussed. These include technical, legal and institutional aspects. Recent developments in the Brazilian context are presented showing that even in less developed countries the concept has a great potential for implementation.

RÉSUMÉ

Le sujet du développement soutenu a gagné dernièrement une grande importance parmi les professionnels qui travaillent dans le domaine de la ressource en eau. Ainsi, aujourd'hui il est amplement agrée que le développement soutenu sera obtenu après la reconnaissance du fait que seulement l'analyse offre-demande de l'eau n'est pas suffisante pour l'adéquate planification et gestion de la ressource en eau. Il devrait être fait un effort pour

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développer des méthodologies qui envisagent les deux aspects, quantitatif et qualificatif, pour la gestion de la ressource en eau. Par ailleurs, les aspects social, économique et politique, doivent être explicitement considérés. Cela abouti au développement du concept de gestion intégrée de la ressource en eau, dans lequel tous les aspects pluridisciplinaires sont mis en valeur. Dans cet article sont discutées les mesures requises pour obtenir cette gestion, y compris les aspects technique, legal et institutionnel. Les récentes innovations dans le contexte brésilien sont presentées, en montrant que même aux pays non développés ce concept a un grand potentiel d'implementation.

1. INTRODUCTION

Water resources management plays a definite role in the development of any society, specially in the developing world. Excess or deficit of this precious and vital resource are equally important and of concern to any responsible government. In the past the question of development was treated from an economic standpoint alone. Lately, due to public awareness towards environmental preservation the situation has changed drastically. It is not uncommon to find, even in less developed societies, examples of projects that have been restrained due to failure in passing environmental impact statements. Besides that, social and political issues tend to be more explicitly considered in the decision process.

It is clear that the age of analyzing water resources development plans from a quantitative point of view alone has passed. Water quantity and water quality are absolutely tied together and sustainable development imposes social, political and environmental considerations at early stages of the analysis.
The Brazilian experience is no exception to this rule. Public pressure, after the democratization process in the early 80's, forced congressmen to propose a new Federal Constitution in 1988 in which environmental and water issues are explicitly considered.

Professional associations related to water resources, lead by the water management commission of the Brazilian Water Resources Association, played a definite role in the technical and institutional arrangements for implementation of integrated water resources management in the country. The involvement of the International Water Resources Association was very important in providing the international experience to the discussions at the national level. This paper discusses the technical, legal and institutional aspects of integrated water management in the Brazilian environment.

2. TECHNICAL ASPECTS OF INTEGRATED WATER MANAGEMENT

Integrated water management may be understood as a process of complex allocation of limited resources among competing uses. On top of this, the decision process involves multiple objectives and multiple decision-makers. In general the basic conflict of objectives arises between economic efficiency and environmental preservation. Moreover, in less developed countries this issue is particularly complex due to the fact that basic social welfare needs are not yet fulfilled and the world ecological conscience calls for preservation of the natural environment. It is clear that if the natural systems in these less developed countries are to be left in a laisser-faire style, the result, according to the second law of thermodynamics, will be maximum entropy and consequent deterioration of the natural ecosystems in the same manner as it has been observed in the developed countries of the western world.

A multitude of methodologies have been proposed to systematize the decision process in this complex environment. Cohon (1978) review critically these techniques, Goicoechia et al. (1982) propose the use of a particular method (ELECTRE) which can accomodate the consideration of a large number of objectives for watershed planning. Common to all these proposals is the existence of a clear set of objectives and decision-makers. This, however, is not sometimes the case in many decision process in water resources. The difficulty in capturing the subtleties of socio-political factors and the difficulty of quantifying these factors are major drawbacks in the existing multiobjective and multi decision-maker techniques.

There are basically three important aspects that, from a technical point of view, must be considered in integrated management. First, is water charges to incentivate proper use and efficiency. Second, is cost allocation in multipurpose developments and third is an appropriate system for issuing permits. The latter is the basis of water management at the watershed level. Geographic information systems coupled with remotely sensed information play a definite role in establishing a Decision Support System for water permits. These simulation systems with no clear objectives defined, generate a series of possible scenarios that can be properly analyzed by the decision-makers. Recent advances of informatics are propitiating the frequent use of this technique for integrated water resources management (Labadie et al., 1989; Vlachos and Fontane,1990; Braga and Barros, 1992). It is clear, however, that implementation of alternatives analyzed under DSS can only take place if an appropriate legal and institutional framework is available. This issue is discussed in item 4 for the Brazilian case.

3. PHYSICAL AND SOCIO-POLITICAL BRAZILIAN ENVIRONMENT

Brazil is a federal republic of 8.5 million km2 located between the equator and the Tropic of Capricorn. Its extension both, from north to south and east to west is approximately 4,400 km. The Brazilian coastline extends for some 7,500 km. The country is divided in 5 natural regions and politically into 25 States, 2 federal territories and a Federal District (Figure 1). Approximately 50 percent of the population is under 19 years of age and unevenly distributed among the regions and between rural and urban areas (Table 1).

Figure 1. Political Division and Major Watersheds of Brazil

Table 1. Comparative Statistics on Demography for Different Regions in Brazil

REGIONS	STATES	POPULATION	URBAN POP. (%)	RURAL POP. (%)	INFANT MORTALITY (/1000)	ILLITERACY RATE
NORTH	ACRE	417,165	61.8	38.2	31.8	NA
	AMAPÁ	288,690	80.9	19.1	25.1	NA
	AMAZONAS	2,102,901	71.4	28.6	84.9	NA
	PARÁ	5,181,570	50.4	49.6	53.9	NA
	RONDÔNIA	11,30,874	58.2	41.8	60.6	NA
	RORAIMA	215,950	64.6	35.4	32.8	NA
	TOCANTINS	920,116	57.7	42.3	43.2	NA
	Sub-Total	**10,257,266**	**58.0**	**42.0**	**NA**	**NA**
NORTHEAST	ALAGOAS	2,512,991	59.0	41.0	66.2	42.2
	BAHIA	11,855,157	59.1	40.9	43.7	34.7
	CEARÁ	6,362,260	65.3	34.7	65.0	38.5
	MARANHÃO	4,929,029	40.0	60.0	60.2	40.7
	PARAÍBA	3,200,677	64.1	35.9	70.9	37.6
	PERNAMBUCO	7,122,548	70.8	29.2	102.3	33.7
	PIAUÍ	2,581,215	53.0	47.0	55.3	43.3
	R.G.DO NORTE	2,414,121	69.1	30.9	100.0	35.8
	SERGIPE	1,491,867	67.2	32.8	60.7	38.2
	Sub-Total	**42,470,225**	**60.6**	**39.4**	**NA**	**39.1**
SOUTHEAST	E. SANTO	2,598,505	74.0	26.0	38.7	20.1
	M. GERAIS	15,731,961	74.8	25.2	37.5	19.8
	R.DE JANEIRO	12,783,761	95.2	4.8	41.7	11.8
	SÁO PAULO	31,546,473	92.8	7.2	30.9	12.4
	Sub-Total	**62,660,700**	**88.0**	**12.0**	**NA**	**11.2**
SOUTH	PARANÁ	8,443,299	73.3	26.7	33.5	15.3
	RIO G.DO SUL	9,135,479	76.6	23.4	17.0	11.7
	S. CATARINA	4,538,248	70.6	29.4	26.7	12.9
	Sub-Total	**22,117,026**	**74.1**	**25.9**	**NA**	**11.0**
CENTRAL WEST	D. FEDERAL	1,598,415	95.0	5.0	23.8	11.7
	GOIÁS	4,012,562	80.7	19.3	25.8	20.9
	MATO GROSSO	2,022,524	73.2	26.8	27.1	22.3
	M. G.DO SUL	1,778,741	79.4	20.6	26.8	17.1
	Sub-Total	**9,412,242**	**81.2**	**18.8**	**NA**	**17.6**
	BRAZIL	**146,917,459**	**75.5**	**24.5**	**60.0**	**19.6**

Eleven hydrographic zones have been established for water resources monitoring and management which corresponds to the major watersheds of the country. In Figure 1 it is possible to appreciate that these zones do not coincide with the political division of the country into States. Hence, good water management will imply in articulation among neighboring States. A preliminary water balance for these major watersheds is presented in Table 2. A demand/supply balance including demands for domestic, industrial and irrigation uses is presented in Table 3. States where demands are in the range of 10 to 15 percent of the long term mean average flow are in a condition that requires intervention to provide water in satisfactory quantity and quality.

From Table 3 it is possible to identify three major regions of the country of interest for sustainable development: a) Amazonia, northeast and central-west Brazil which need economic development to offset regional disparities; b) the ecological sensitive areas of Amazonia, Pantanal and southern coastline and c) the degraded urban and rural watersheds of the south and southeast in view of their need for conservation, restoration and environmental control.

The urbanization process is one of great relevance to integrated water management. More than 70 percent of the Brazilian population leave in urban areas where the sanitation infrastructure is almost inexistent. The largest urban conglomerate of the country, the Metropolitan Region of Sao Paulo, with an estimated population of 16 million has only 60 percent of this population served with wastewater collection network. Treatment is provided for 2.9 m3/s which represents 12 percent of the sewage collected.

4. LEGAL AND INSTITUTIONAL ASPECTS

4.1 Water Resources and Environmental Issues in the Brazilian Constitution

The current Federal Constitution of Brazil, issued on October 5, 1988, emphasizes the environmental theme with a special Chapter dedicated to the subject. Chapter VI, section 225 presents the National Environmental Policy which was based in the Federal Law 6.938 of August 31, 1981. According to this section, all citizens have the right to an ecologically equitable environment. This is a major asset of the people of the country and is essential to a healthy quality of life. The government and the general public have the charge of defending it and preserving it for the present and future generations. According to first paragraph, to assure the effectiveness of this right, the federal government has some important obligations with significance to water resources, such as:

. preserve and recover essential ecological processes and provide for the ecological management of species and ecosystems

. define, in all federative units, physical space to be specially protected

. impose environmental impact studies for licensing of civil works or any potentially harmful activity

Table 2. Water Balance for the Major Brazilian Watersheds (DNAEE, 1984)

Basin	Area (km^2)	Average rainfall (m^3/s)	Average discharge (m^3/s)	Evapo-transp. (m^3/s)	Disch./ Rainf. (%)
1. Amazon	6,112,000	493,491	202,000	291,491	41
2. Tocantins	757,000	42,387	11,300	31,087	27
3A. Atlantic North	242,000	16,388	6,000	10,388	37
3B. Atlantic Northeast	787,000	27,981	3,130	24,851	11
4. S.Francisco	634,000	19,829	3,040	16,789	15
5A. Atlantic East	242,000	7,784	670	7,114	9
5B. Atlantic East	303,000	11,791	3,710	8,081	31
6A. Parana	877,000	39,935	11,200	28,735	28
6B. Paraguai	368,000	16,326	1,340	14,986	8
7. Uruguai	178,000	9,589	4,040	5,549	42
8. Atlantic South	224,000	10,515	4,570	5,549	43
Total	10,724,000	696,020	251,000	5,949	36

Table 3. Supply/ Demand Water Balance for Brazil (Barth et al., 1987)

State/ Region	Total Discharge (Km^3/y)	Urban Discharge (Km^3/y)	Irrig. (Km^3/y)	Indust. Discharge (Km^3/y)	Demand/ Avail. (%)	Urb+Ind Avail.-Irrig. (%)
Rondônia	150.2	0.03	0.00	0.01	0.03	0.03
Acre	154.0	0.02	0.00	0.00	0.00	0.01
Amazonas	1848.3	0.10	0.01	0.03	0.00	0.01
Roraima	372.3	0.01	0.00	0.00	0.00	0.00
Pará	1124.7	0.19	0.05	0.06	0.00	0.02
Amapá	196.0	0.01	0.00	0.00	0.01	0.01
North Region	**3845.5**	**0.36**	**0.06**	**0.10**	**0.00**	**0.01**
Maranhão	84.7	0.22	0.01	0.02	0.30	0.28
Piauí	24.8	0.12	0.09	0.01	0.89	0.53
Ceará	15.5	0.29	0.96	0.09	8.65	2.61
R.G.Norte	4.3	0.14	0.23	0.05	9.77	4.67
Paraíba	4.6	0.15	0.27	0.04	10.00	4.39
Pernambuco	9.4	0.45	0.98	0.16	16.91	7.24
Alagoas	4.4	0.11	0.18	0.04	7.50	3.55
Sergipe	2.6	0.06	0.12	0.02	7.69	3.23
Bahia	35.9	0.52	1.07	0.12	4.76	1.84
Northeast Region	**186.2**	**2.06**	**3.91**	**0.55**	**3.50**	**1.43**
M.Gerais	193.9	1.22	1.63	0.59	1.77	0.94
E.Santo	18.8	0.18	0.22	0.08	2.55	1.40
R.Janeiro	29.6	1.03	0.63	0.73	8.07	6.08
S.Paulo	91.9	2.74	1.81	4.16	9.48	7.66
Southeast Region	**334.2**	**5.17**	**4.29**	**5.56**	**4.49**	**3.25**
Paraná	113.4	0.70	0.28	0.35	1.17	0.93
S.Catarina	62.0	0.33	0.65	0.40	2.23	1.19
R.G.Sul	190.0	0.71	6.32	0.70	4.07	0.77
South Region	**365.4**	**1.74**	**7.25**	**1.45**	**2.86**	**0.89**
M.G. Sul	69.7	0.10	0.13	0.03	0.37	0.19
M.Grosso	522.3	0.08	0.03	0.02	0.02	0.02
Goiás	283.9	0.28	0.25	0.06	0.21	0.12
D.Federal	2.8	0.13	0.04	0.03	7.14	5.80
W. Central Region	**878.7**	**0.59**	**0.45**	**0.14**	**0.13**	**0.08**
Brazil	5610.0	9.92	15.96	7.80	0.60	0.32

. control the production, commercialization and usage of techniques, methods and substances that imply threat for quality of life, life itself and for the environment.

Other constitutional statements related to water resources in section 225 are:

. the exploitation of mineral resources implies the obligation to restore the degraded environment, in compliance with the techniques suggested by the related public agency

. the conduct and activities harmful to the environment will subject the infractor to criminal or administrative sanctions, independently to the obligation to mitigate the damage generated

. the Amazon Forest, the Atlantic Forest, the Pantanal and the coastal zones are a national asset which utilization will be done under conditions that warrants the preservation of the environment including the use of natural resources

Other sections of the Federal Constitution are related to the environment. Since our interest is specifically to water resources planning and management, the next items will discuss the constitutional precepts related to water.

4.2 Water as a Public Good in Brazil

Brazilian Civil Law (section 65), states that all goods in the territory belonging to the Union, States or Municipalities are public, all other goods are private. Public goods are classified as (section 66):

I - peoples common use goods such as rivers, lakes, seas, roads and streets;

II - special use goods, such as buildings or lots serving the federal, state or municipal government;

III - dominical goods, that is, those goods belonging to the Union, States or Municipalities.

An important change introduced in the Federal Constitution of 1988 was the division of waters into Federal and State property. Federal waters are those flowing in rivers that flow through two or more states or that divide two states. State waters are those flowing in rivers that flow solely in the state territory. In this way, municipal waters envisioned in the Water Act of 1934, no longer exist. According to this same constitution (section 225) the environment shall be considered a public good. Federal law 6938 of August 31, 1981, in accordance with these precepts, considers the environment as public ownership defining it as: "the set of physical, chemical, and biological conditions, laws, influences and interactions that allow, hold and reign all forms of life". Among the environmental resources this law includes the interior waters, surface and groundwater, the estuaries and the territorial seas (section 3).

According to the Civil Code (section 67) the public belongings cannot be transferred to the private sector. Pompeu (1992), quoting other counselors, states that public goods of common use are not susceptible to the right of ownership, although the tradition allows the usage of the term to designate the holder of the judiciary relationship to whom it is trusted the care and management. In this respect the public agencies are the holders and the people and the State the beneficiaries of the public goods. Section 68 of the Civil Code states that the common use of public goods can be free or charged according to specific legislation at the Federal or State level. Similarly, the Water Act (section 36) states that the common use of waters can be charged in accordance with laws and rules of the administrative region where they belong. Public goods can be used by the private sector through specific authorization from the holders. In this situation the user shall pay the public agency for the right of use.

4.3 Water Use and Water Permits

According to the Federal Constitution (Section 24-VI) the Union, the States and the Federal District are jointly responsible for the legislation regarding forests, fisheries, nature conservation, protection of the soil and natural resources, protection of the environment and pollution control. However, the Union has the charge of legislating privately with respect to water and energy as well as to fluvial, lake and coastal navigation. Section 22 allows the States to legislate complementary through specific legislation regulating these matters. The current constitution, however, does not allow the States to legislate supplementary to attend the peculiarities of such a large territory as Brazil. Section 21-XII states that the Federation shall explore, directly or through authorization, concession or permission the hydroelectric potential of the water courses. This exploitation, however, must be performed in articulation with the States where the development is planned. Although the form of articulation depends on specific law, the constitutional principle opens the possibility of States to condition the permits to their own interests.

It is a Federal duty to implement the National Water Resources Management System. Section 21 - XIX required the creation of this system by the Federal Government which is also responsible for defining criteria for issuing water permits in the country.

The Water Act is a pioneering legal instrument enacted in 1934. Many of its precepts are still valid even after the promulgation of two Constitutions in the mean time. However, many precepts have not been put into practice due to the lack of specific legislation to regulate them. According to section 36, any citizen has the right to use public waters and the use of highest priority is domestic supply. In section 43 it is stated that public waters can not be derived for agriculture, industry or hygiene without administrative permit except in cases of insignificant derivation. These permits are given for a fixed period of time never longer than 30 years.

4.4. The National Water Resources Policy and Management System

Complying with the statement of section 21, XIX of the Federal Constitution, the Executive Office sent to the National Congress the project of law 2,249 in 1991. This project proposes the National water resources policy and creates the National water resources management system. This project is being analyzed by the commission of Consumers Protection, Environment and Minorities at the house of representatives in Brasilia.

According to this project the National Water Resources Policy (NWRP) seeks to assure the integrated and harmonic use of water resources towards the promotion of development and social well being of the Brazilian society. Section 4 presents different instruments of the NWRP such as:

. the concession of the right of use complying with criteria and priorities established in the Water Act and subsequent legislation

. water charges for water resources utilization

. cost sharing in multiple use water resources works

. institution of areas for the protection of watersheds for domestic water supply

The National Water Resources Management System proposed will have a national collegiate, basin commissions and an executive secretary. The directives of the system as stated in section 6 impose:

. consideration of physical, hydrological, social, economic, cultural and political peculiarities common to large countries as Brazil

. integration of federal, state and municipal initiatives in the planning of water use adopting the watershed as the base for regional actions

. promotion of decentralization of some federal actions through the delegation to States and the Federal District as long as there is explicit interest between the parties

. fomentation of technical, institutional and financial cooperation among water users to achieve a larger participation in construction, operation and maintenance of hydraulic works of common interest

. stimulation of public participation in the decision process

Although the above directives show a typical decentralization proposal in other parts of the document there are contradictory rules restraining the participation of State governments as well as water users in the decision process. In this respect section 12 attributes to the National Collegiate, formed with representatives of the Federal government, the:

. approval of the water utilization plans of federal rivers in whole country

. approval of the classification of water courses according to priority uses

. creation of watershed commissions establishing norms and procedures for their implementation

5. CONCLUSIONS

Integrated water resources management is a major issue towards sustainable development in any region of the world regardless of its degree of development already achieved. Quantitative and qualitative aspects should be considered with equal emphasis. Equivalently technical aspects should be treated together with legal and institutional aspects to form a model that is truly applicable. Essential instruments to effective implementation of integrated water resources management include: an efficient water permits system that encompasses modern technology of geographical information systems and legal expert systems, a water charging scheme that allows the existence of a water resources fund to finance actions in the watershed and a cost sharing mechanism for multiple use hydraulic works.

The case study presented in this paper shows that many important steps have been taken towards the effective implementation of integrated water resources management in Brazil. It is clear that in such a large territory decentralization measures are necessary to accommodate regional differences in terms of hydrologic, social, political and cultural conditions. Legal instruments including sections in the Federal Constitution provide the base for a sound implementation of integrated water management in the country. Care must be exercised, however, since the project of law instituting the national water policy and management system gives excessive power to federal agencies. This will make it very difficult to effectively implement the decentralization of the decision process. In this respect, the participation of non governmental organizations of the water sector is fundamental to provide guidance to the political sector responsible for analyzing and approving the project.

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THE NEED FOR STRATEGIC RESEARCH ON WATER SUPPLY AND DEMAND IN EGYPT

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The River Nile provides over 95% of Egypt's water supply and almost all of it is being used to meet present demands, which are increasing as Egypt's population continues to grow. There is some potential for increasing the supply through completion of the presently stalled Jonglei Canal in the Sudan, increase in groundwater use, re-use of agricultural drainage water and non conventional approaches such as treated waste water, desalinization and water harvesting. But opportunities for increasing the supply are extremely limited.

There is potential for reducing consumption through use of more efficient irrigation practices, but implementing such improvements is very complex and expensive, since it will involve convincing and helping many individual farmers. Also there are complex interactions between reducing irrigation water consumption and the amount and quality of re-used agricultural drainage water and groundwater in the Nile Valley and Delta.

Water demands are pressing on the available supply, and although an overall deficit is not an immediate threat, Egypt is closer to a water deficit than any other country in the Nile Basin. Careful strategic planning will be needed to match supply and demand. But the issues involved are complex, considerable uncertainty is involved and there are many unresolved questions that need to be answered before planning to make optimal use of the available water. To help answer these, a Nile Water Strategic Research Unit is being set up under a co-operative agreement between Canada and Egypt. This paper outlines the approach that the unit will take to research and some of the key research areas that it will focus on initially. Probably the approach will include modelling long term trends at an overview, aggregate level using both deterministic and probabilistic models.

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1. INTRODUCTION

Many strategic units have been created in the military operations and large multinational cooperations to improve the medium to long term planning and hence increase management and operation efficiency. The urgent short term problems are not usually excluded from the strategic units' duties since they are characterized by their high capabilities, independence, and not being overwhelmed by every day operation.

As far as is known there are not strategic units in water resources field in the world. Nevertheless the establishment of strategic unit with the WRC is not completely a new concept. The main technical office of the WRC used to play the role of a strategic unit for the WRC Chairman and the Minister. A lot of urgent short term problems and long term issues have been referred to the WRC Chairman on *adhoc* basis. The Chairman usually transfer the problem to one of the WRC research institutes if it is within a single institute mandate. If the issue has a multi-institutional nature the Chairman usually react with whatever technical capabilities he has in the main office and use the consultance of the relevant institute directors. In both situation the main office technical staff and the involved institutes are distracted from their everyday duties and their preset research agenda.

In order to deal with some of the global wider water related issues where seems to be a gap and to institutionalize the previously described process the NWSRU has been created. NWSRU is a separate unit housed within the WRC, reporting directly to the Chairman. The NWSRU is quite different from other units in the WRC and the Ministry, each of which has a well defined role. It thus represents a radical departure from traditional research units. Accordingly, NWSRU has to be dynamic unit, willing to change its research agenda and/or its organizational structure as and when deemed necessary.

2. MISSION STATEMENT

Conceptually, and in terms of operation, NWSRU should be radically different from any of the existing research institutes of the WRC. It would thus enhance the present capability of the WRC to take a strategic overview of the existing problems and constraints to efficiently manage Egypt's very limited water resources under increasingly scarce conditions. Accordingly, NWSRU would complement the current activities of the WRC research institutes: it certainly should not compete or duplicate them.

In terms of its overall mission, NWSRU should consider the following critical but interrelated tasks:

i) Act as a synthesizer and integrator of knowledge that is generated by the various research institutes of the WRC and the other components of the MPWWR;

ii) Analyze water resource issues on a broader and holistic perspective for the overall benefit of the nation as a whole;

iii) Act as a catalyst to initiate new multi-institute, multi-disciplinary research programs;

iv) Identify priority areas where urgent research may be necessary, and also identify potential problems before they arise;

v) Increase the knowledge-base of the decision-makers and their understanding of the complexities of the water problems that the country is facing at present and/or likely to face in the future; and

vi) Contribute to enhancing the public awareness of the importance of rational management of the nation's limited water resources, so that if necessary some tough decisions can be made with full public support.

3. SHORT- AND LONG-TERM OBJECTIVES

Within this overall mission statement the following short- and long-term objectives are recommended.

The short-term objectives of NWSRU could be the following:

i) Through an extensive process of consultation, identify critical problem areas which are not being handled adequately within WRC at present;

ii) Initiate strategic research in a few select areas in full cooperation with the other institutes;

iii) Build up an expertise within WRC on strategic research through multidisciplinary and multi-institutional team work;

iv) Broaden the knowledge base of the decision-makers so that decisions made to improve a specific situation do not contribute to deterioration of other linked problems; and

v) Stimulate public debate on the critical importance of water to the Egyptian society.

The long-term objectives of NWSRU could be the following:

i) Availability to the Chairman, WRC, and other senior decision-makers a cadre of well-trained and experienced professionals who are respected for their strategic analyses and thinking;

ii) On request, provide strategic advice to the senior officials as and when necessary;

iii) Identify periodically critical water problems that the country may face in the future, and their possible solutions;

iv) Provide a forum for debate on controversial and/or complex issues by all the major parties involved;

v) Act as a main source of unbiased information for professionals as well as general public; and

vi) Enhance public awareness of all important water issues.

4. RESEARCH AGENDA

The NWSRU developed its research agenda using an advisory approach. In light of consultance of local and international experts in water resources and other related disciplines, the following major and minor topics were selected to form the research agenda for the NWSRU.

Major Topics

a. Water for development of Egypt in the 21st century;

b. Development and utilization of fossil groundwater;

c. Prospects of and constraints to privatization in the water sector;

d. Potential for introducing modern irrigation systems in old lands;

e. Implications on irrigation systems of changing from rotation to continuous flow;

f. Interrelationships between three major programs of MPWWR: irrigation improvement, drainage water reuse, and drainage programs.

Minor Topics

a. Institutional aspects of optimal water management;

b. Data reliability and accessibility;

c. Management of international waters;

d. Impact of global warming on water management in Egypt;

e. Decision-support system for WRC's Chairman, and/or MPWWR Minister's;

f. Health risks in water uses; and

Because of the resources and manpower constraints, only one major topic and two minor topics are selected at this initial stage. The major research topic that is selected as the first research project for the NWSRU is clearly defined and focussed in the following section.

5. WATER FOR DEVELOPMENT OF EGYPT IN THE 21ST CENTURY

Current analyses indicate that water is one of the major resource constraints for sustainable development of Egypt in the 21st century. Not only is more water needed for domestic purposes for a rapidly growing population and for more people attaining higher living standards, but also for increasing agricultural and industrial production, electric power generation, and land reclamation as well as for navigation, and proper ecosystem and environmental management. While the common resource thread connecting all these major development components is water, this resource has explicitly not been considered to be a key element of national planning which may seriously constrain, and even threaten, all future socio-economic developments in Egypt because of its severe scarcity.

This study could start with the current agreed plans of all the appropriate Egyptian Ministries, and their development targets for the years 2000, 2010 and 2020, and then translate these targets in terms of water requirements for their fulfillment. This will include, but not necessarily limited to, the development of the following estimates of water requirements to satisfy the planning targets proposed by various Ministries in terms of:

- Agricultural production to account for multiple cropping, higher yields and expansion of agricultural areas;

- Industrial production;

- Domestic water needs for a higher number and increasing more affluent population;

- Cooling water requirements for proposed thermal and nuclear power plants for increasing hydroelectric production;

- Navigation and tourism requirements; and

- Ecosystem and environmental requirements.

Having estimated and then aggregated these water requirements, the study could Analyze if these target expectations of the various Ministries can be fulfilled economically and realistically for the years 2000, 2010 and 2020 in terms of objective forecasts of water availability, including reuse. For example, the prospect of getting 2 milliards from the Jonglie Canal, by the year 2000 should now at best be considered to be a dream. This transfer feasibility by 2010 or even 2020 can be seriously questioned. Also, to what extent can water be reused continuously over time without sacrificing quality and certain types of water uses? What technological innovations could change water availability and requirements within the next 5 to 25 years? How will all these factors affect water availability? All these and other related factors need to be identified and properly considered within the overall framework of this macro strategic study.

It should be noted that what is proposed here is very different from the existing activities of the Planning Sector, or what is currently being proposed by SRP under its water conservation Program. NWSRU will carry out strategic analysis at the broad, macro level, where overview modelling techniques like STELLA can be successfully used.

A direct and relatively quick results of this study could be the efficacy and validity of macro planning at the national level that is being carried out in Egypt at the present time. If the study indicates that the requirements of a very critical resource like water have not been properly integrated at the national planning level to ensure that the existing targets of various Ministries can be met, clearly the existing planning framework cannot be considered efficient. In this case, the study could then propose how the existing policy-making and planning frameworks be altered so that national aggregated demands for water in the future can be met successfully.

This type of overview macro strategic studies simply have not been carried out on a national basis in terms of a critical resource like water in any developed or developing country thus far. If NWSRU selects this topic as a major area of research, this could be a real breakthrough. Results should be available within 12 to 18 months, and they will in all probability attract significant national and international attention, as well as media interest. The later is important since the Workshop participants felt that the public awareness of the critical importance of water for the future development of Egypt is absolutely essential. The results of this study should be used to build public interest and awareness in Egypt on the absolute necessity of efficient management of the nation's scarce water resources.

6. MODALITIES OF OPERATION

For NWSRU to be really effective, special efforts need to be made to emphasize its unique character as well as its modalities of operation. It also must be results-oriented, and the results must be of good quality.

In contrast to SRP that is being supported by USAID, whose "principal customer" is explicitly identified as the "planning sector of MPWWR", it is recommended that the NWSRU's client-base should be considered in the following hierarchial order:

i) WRC itself;

ii) other parts of the Ministry, including the Minister, Planning Sector, PJTC, etc.;

iii) other government ministries, universities and research institutions; and

iv) general public and the media.

NWSRU, as it is envisaged at present, will be a small but highly capable unit. It will have a very focused research agenda. Thus, for it to succeed, NWSRU must have close working relations with other WRC institutes. Under any circumstances it should not compete with such institutions in terms of research areas or expertise.

The strength of NWSRU will come from the expertise it should be able to draw upon from the research institutes. It is thus essential that the NWSRU staff continually think of active collaboration with its partners. Accordingly, it is necessary to have formal and informal interactions and periodic consultations with its partners on a regular basis.

The goodwill generated during the preparation of the research agenda and the modalities of operation must be maintained, and where possible, reinforced. Routinely, the institutes should receive information and invitation to the appropriate NWSRU workshops and seminars. They should also receive NWSRU newsletters and publications. Interactions must not be restricted to the Director level only: working level would be equally important.

Since NWSRU will need appropriate professionals from other institutes to conduct its own research, it must have a good idea of who are the competent professionals in the different institutes. It must avoid recruiting "deadwood" and trouble-causers, since NWSRU work would be highly complex and specialized, and would invariably involve team-work. Thus, some negotiations would be necessary with the "right" experts as well as their Directors in order to ensure they are available and become an integral part of the team. Joint publications between NWSRU staff and professionals from other institutes should be actively encouraged. Because of the breadth of the research work that is to be carried out by NWSRU, good relations will be necessary with most, if not all, institutes.

FOR AN EFFICIENT MANAGEMENT OF WATER DEMANDS: FARMER TRAINING SERVICE (ÇES) IN THE LSP IN TURKEY

Osman Tekinel[1] Attila Yazar[2]

ABSTRACT

Agricultural extension services are the major channels for conveying and transmitting up-to-date technologies to farmers. The role of the extension agent in the agricultural development process lies on the top of the list as a major tool in executing the agricultural development plans.

A special agricultural extension unit (ÇES) was set up for farmers in the Lower Seyhan Irrigation Project area (LSP) during the stage I of the project and provided one of the earliest tests of the now widely used Training and Visit system of extension, with the aid of World Bank technical assistance. However, because ÇES was set up in isolation from existing extension services and government administrative structures, it could not be sustained in the long term; following the completion of Stage II of LSP in 1978.

During the development stages I and II of the project, periodic coordination meetings of different agencies involved with irrigation activities (such as State Hydraulic Works, Soil and Water Conservation Service, Agricultural Supply Agencies, Technical Agricultural Office, research organizations, and even private sector companies) became a regular feature. As a result of these services, ÇES has contributed greatly to increased production in general. Successes and weaknesses of the ÇES have been discusses in this article.

SOMMAIRE

Les services de vulgarisation ont aidé à favoriser l'acquisition par paysans des techniques modernes agricole. Les vulgarisateurs occupent une place primordiale dans les actions politique dans le cadre du developpement agricole.

A l'occasion du Projet d'Irrigation du Seyhan a été crée à l'aide de la Banque Mondiale un service de Vulgarisation Specialisé (ÇES) qui but adopte un systeme de visite et d'éducation. Mais ÇES avait été independant de la politique governementale et aussi des autres systeme de vulgarisations. Par consequent il n'a pas duré jusqula nos jours.

Durant les premieres et deuxiemes phases du projet de ÇES, le ÇES organise, dans le bureau du centre, des reunions periodiques avec les agents concernés (Direction d'Irrigation, Direction du Sol et de l'Eau, Direction Agricole, Office Agricole du Fournisseur de l'Etat et sector prives). En effet on peut dire que le ÇES a permis une augmentation de la production agricole. Dans cet article, nous avon analyse les avantages et les inconvéniants des projet de ÇES.

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1. INTRODUCTION

Agricultural extension traditionally has referred to the work of a professional body of agricultural experts, often government employees, teaching improved methods of farming, demonstrating innovations, and helping farmers to organize and solve their problems. Extension has also served as a link between farmers to transfer the "best practices" of one farmer to another, and as a channel to introduce-agricultural policies. The basic functions of agricultural extension have been informally applied throughout human history.

Agricultural extension activities currently encompass a wide range of activities but the exchange of information continues to be the primary focus of extension activities. Private sector involvement in the provision of extension services has been studied little compared to the wealth of literature and practical knowledge available on public sector extension.

In most countries, except those which are entirely centrally planned and controlled by government, there are extension activities in both the private and public sectors. Significant public funds have been invested in extension services by governments around the world. Public sector extension has also been an increasingly large employer. The number of extension employees in the developing world increased dramatically after independence in many countries. This was largely due to absorption into the extension service of employees of private firms related to agriculture and owned by expatriates which discontinued business after independence.

Overall there are about 600,000 active extension workers in the world. About 90% of these extension workers are employed by Ministry-based extension organizations, 6% employed by public universities, 4% by commodity groups, farmers organizations. This does not include technical field staff working for marketing/processing firms, salespeople for input suppliers, and private consultants advising on agriculture, or cooperatives, (Schwarts, L. 1993).

Public sector extension has gone through numerous transformations of approach and international donor agencies have tended to align themselves with one form of extension or another. FAO's primary extensive support for extension is provided throught field projects. "More than 500 such projects, under implementation in 1980-1986 were concerned mainly or partially with extension" (FAO, 1989, p.14). From 1975-84 USAID had 1,065 projects involving extension and 266 focusing on extension (World Bank, 1989).

In order to generate benefits in accordance with a certain objective such as increased production, increased sales, better use of the product, access to a specific type and quality of fruit for export etc. extension must be a channel through which appropriate technology flows.

In summary the mission of increasing agricultural production to sustain food and fiber requirements of rapidly increasing populations could be facilitated through management of water, land and human resources.

In order to increase production in irrigated agriculture in the Lower Seyhan Plain, a special Farmer Training Service (named as ÇES) was established in the Lower Seyhan Irrigation Project area in 1966. This service was the first of its kind in Turkey. This farmer's training service has provided services forseen in its establishment goals in close co-operation with the related organizations in areas such as cropping pattern with project, controlled irrigations etc,. As a results of these services, Farmer's Training Service have contributed greatly to increased production in general in the area at years between 1966-1986.

2. ÇES: AS A CASE SYSTEM OF EXTENSION

A special agricultural extension unit (ÇES) was set up for farmers in the project area during the first stage of the project and provided one of the earliest tests of the now widely used "Training and Visit" system of extension, with the aid of World Bank technical assistance (Tekinel et al., 1989).

Farmer's training service was established in 1966 by the requirement of the financing organization (World Bank) for the project in order to disseminate the information modern technology and on the increased production situations to the farmers in the area. Although there were a number of extention organizations in the Lower Seyhan area, this special unit was founded.

The Farmer's Training Service has started its services with 4 specialits and 23 foremen in 23 villages on 9.480 Ha area. In 1976, the number of personnel of the ÇES has consisted of 13 agricultural engineers, specialits, 58 permanent and 7 temporary foremen serving in 86 villages on 110.000 ha area.

This extension service was sponsored through financial and personnel aid of the Ministry of Agricultures by the Technical Agricultural Directorate, Regional Plant Protection and Quarantine Headquarter and Soil and Water Conservation Service of Lower Seyhan Planning Regional Directorate in the project area.

During its establishment years, ÇES has put more emphasis on cotton production due to the characteristics of the Lower Seyhan Plain. The reason for emphasizing its services on cotton was because cotton was the major crop in the irrigated part of the region with 60-98 % of the area planted to cotton. In the following years, extension services for other crops were provided though cotton has dominated the cropping pattern for long long time.

In order to provide efficient services at the village level, well-known agricultural extension methods have been modified and adapted to the local conditions by technical specialists of the ÇES. The final form of the information was disseminated to the farmers by the Agricultural Engineers and foremen. The principal means extension service was training local farmers while working on their field. This was accomplished through close co-operation technical personnel and foremen with the farmers in the region.

Maximum or optimum crop production can only be attained by applying the right amount of water at the right time. Deviation from this golden rule, inevitably leads to decreases in crop production. Farmer, though years of observation and learned tradition, developed irrigation practices that are often very close to the actual needs of the crop. However, every time that a farmer tries an new crop, a time-consuming learning process starts and, until the moment when a satisfactory level of skill is reached, a considerable crop production potential may have been wasted. Farmers are aware of this problem and it is one of the reasons why they are often reluctant to crops with which they do not have previous experience. This is a characteristic problem of newly established irrigation schemes, where most of the farmers have little or on experience with irrigated crops. Technical advice can be instrumental in shortining this learning of the "full production" stage of the project.

Once the problems have been properly idenfied, the corrective measures can be explained to farmers, who can be convinced in this respect, extension services could be carried out effectively.

In addition, demonstrations and field days have provided other means for extension services. Slide shows in the village coffee-house, simple brochures on various agricultural issues, radio talks and other written means have been effective training services. However, above mentioned means of extension services should be utilized all together in order for a rational extension.

2.1 History of Agriculture at Lower Seyhan Area

In the Lower Seyhan, agriculture and farming goes back to ancient times. Farmers believe that they have sufficient knowledge about the irrigated agriculture. For this reason they do not readily accept new approaches or new technologies easily so that they can be considered as conservatives. However, farmer's experience and knowledge are key issues for the extension specialists.

Farmers in general believe and follow the successful neighbor farmers. These practices have provided valuable information for the extension personnel. Extension agents have emphasized close co-operation with these lead-farmers in the project area, as a result, successful training have been provided for other farmers.

Although the extension service has provided succesful services towards increased production, irrigated agriculture etc., on/one issue, which is the cropping pattern, extension service has failed. Because, farmers of the region have not been convinced for changing cropping pattern which was forseen in the irrigation project. Farmers have continued to grow crops that have suitable and ready markets. For instance, farmers have not quit growing cotton despite of numerous production problems, due to ready marketing conditions higher income for per unit area with cotton cultivation on their lands. Wheat for this reason has remained in the second place next to the cotton.

Soil and climatic condition in the Lower Seyhan in suitable for obtaining two, even three crops in a year under irrigated conditions. However, these resources have not fully utilized or realized by the farmers at the potential rate. Farmer's Training Service has started studies on new crops, however, due to lack of the marketing conditions for these crops, farmers have not readily convinced to from these crops.

For many years, the cropping pattern in the project area continued to be dominated by cotton, which accounted for over 80% of irrigated cultivation in most years, against the projects design assumption of 35 % for this crop. It was not until 1982 before the percentages of cotton began to decline to the current level of around 40 %. It is likely that declining prices, and worsening pest situation especially the cotton white fly, also with the introduction of a second (late-season) crop are contributory factors to this shift in cropping pattern. However, second crop cultivation is still only caried out on, no more than 10 % of total area in spite of existing very suitable land, water and climatic conditions. The reason for this low percentage is the lack of markets for these crops.

2.2 Existing Bottlenecks for Such an Extension System

Consequently, public irrigation schemes establish their own applied research or demonstration farms, or they may do it in cooperation with research institutes, where the behaviour of newly irrigated crops can be monitored and the data used to provide essential information to extension service agents.

A more serious problem is the lack of proper technical training in irrigated agriculture. Most of the extension agents have a general training in agriculture, but no special training in irrigation techniques and practices.

The same applies to field formen (assistant), who have only completed elementary school plus one or two years training in general agriculture.

In order to provide proper assistance on irrigated agriculture, a close dialogue is necessary between the farmer and agricultural extensionist: Hence, a considerable number of staff is needed, especially during the initial stages of the irrigation projects.

However, because ÇES was set up in isolation from existing extension services and government administrative structures, it could not be sustained in the by long; following the completion of stage II of the project in 1978, it went into a period of decline and was finally dissolved in 1986. Its fuctions are being replaced by ÇEY (Farmers' Education and Information Department) at the provincial level, whose activities will be supported by the expanded Agricultural extension and Applied Research Project of the Ministry of Agriculture and Rural Affairs (MARA). It should be mentioned that during the development of stages I and II of the project, periodic co-ordination meetings of different agencies involved with irrigation activities (such as DSI, TOPRAKSU, ÇES, Teknik Ziraat, Agricultural Bank, resesearch organizations and even private sector companies became a regular feature). However as was the case with ÇES, such a practice also gradually faded away, and was discontinued by around the late 1980's.

2.3 Present Status of Extension Services

The Agricultural Extension Service is under the responsibility of Ministry of Agriculture and Rural Affairs (MARA). Irrigation extension is considered as a part of agricultural extension. Irrigation practices and on-farm management of soil and water resources are critical to the successful operation of irrigation schemes. At present these aspects do not receive particular priority or attention in the extension improvement programs of MARA. Irrigation practices and on-farm water management are not satisfactory in most areas except in some more developed Western provinces.

There had been some attempts to build a viable extension service particularly for irrigation schemes in 1970s and 1980s with the support of World Bank, in particular on Koprüçay, Silifke, Tokat, Seyhan II, Ceyhan-Aslantaş, and Çorum-Çankırı projects.

The activities of "regular" Ministry extension personnel, however, were additional to the TOPRAKSU extension service geared specifically to on farm water management and irrigation practices as well as to the specialized services of the Plant Protection Service, particularly in cotton growing areas. But there was a notable lack of coordination between the various field services.

The reorganization within the Ministry of Agriculture and Rural Affairs, led to the creation of additional general directorates and to various other reforms at the provincial level, greatly affecting the extension service and agricultural research. A causality of the reforms has been the abolition of what in the past was the rather direct responsibility of specialized organization TOPRAKSU, now in GDRS, for irrigation research and on-farm development activities, as well as the training of farmers for better water and irrigation management practices. GDRS now, no longer handle these rather specialized irrigation extension services themselves. They are supposed to be carried out through the Provincial Directorates' Farmer Training and Extension Sections. It is doubtful whether the unification of extension services had the right effect in the case of irrigation schemes.

Irrigated areas in general benefitted from the World Bank assisted research-extension programmes, Agricultural Extension and Applied Research Project (AEARP I) which was carried out almost in half of the country's provinces from 1984 to 1991. The aim of this programme was to strengthen research-extension links and the extension service available to farmers.

Although feedback to the extension service personnel from the research institutes of Ministry and GDRS was quite successful, particularly in the period of 1988-1989, the development of its planned extension infrastructure (village extension centres, field staff accommodation, meeting halls, etc.) has fallen behind schedule. At present, over a hundred village Group Technician Centres have been vacant for more than a year. One problem is to get, good technicians on government payroll to actuall relocate to village level and live and work there.

AEARP II (at US$ 154.4 million) is to run for the period 1990-1997. It is further attempt at overcoming the problems encountered with AEARP I. Considerable investment in the expansion of extension infrastructure and equipment will be made.

In August 1991, in another reorganization of the former General Directorate of Planning and Implementation (GDPI) was abolished. Instead, two new main service directorates were created. General Directorate of Agricultural Planning and Development (GDAPD) has assumed wide-ranging responsibilities for the preparation of rural agricultural development projects, including the rehabilitation and reclamation of land and water resources with agricultural production potential. General Directorate of Agricultural Research (GDAR),a directorate abolished in 1981, has been reinstated to assume overall responsibility for all agricultural research activities of 52 agricultural research institutes, 9 plant protection research institutes, 30 veterinary institutes and laboratories, 6 foodstuff and food processing and preservation research institutes. GDRS remains in charge of its 11 soil and water research institutes.

The research institutes of Agricultural Extension and Applied research Program located in the region took active part in the Agricultural Extention and Applied Research Projects (AEARP) programs to foster improved research-extension links.

It is the task of General Directorate of Agricultural Research (GDRS) to carry out on-farm development and this requires effective extension and demonstration work with the farming communities. It is recommended to strengthen the country subject Matter Specialist (SMS) team with a qualified and motivated irrigation specialist/engineer to be stationed for one to maximum two seasons in newly commissioned irrigation schemes. Duties of the irrigation specialist would be especially to provide direct advice to contact farmers and farmers groups and plan and lay out demonstrations. The same officer could play a vital role in supporting on-farm development.

Another approach could be re-organization of the existing Water Users' Groups (WUG) as Water Users' Association (WUA) in one or two pilot areas (such as Gediz River Basin and Çukurova Lower Seyhan Plain Irrigation projects) and providing them with legal power such as collecting water charges and hiring their own Irrigation Specialists etc. Similar organization in the Western World and Far East can serve as examples. But for the success of these associations, it is necessary for them to get the financial support of the government for a certain period of time.

The advantages of active users participation in water management in irrigation schemes may be summarized as follows:

- It reduces the cost of Operation and Maintainance to the government and therefore to the public.

- It improves day-to-day water distribution planning and implementation particularly during the peak seasons.

- It improves the management of conflicts over the use of water and enhances users responsibility toward the system.

3. CONCLUSIONS

In the public sector, there are two types of obstacles to the provision of optimal extension services; those inherent to the nature of government and bureaucracy and practical problems which could be overcomed through changes in policy.

In general, the inability of public extension services to effectively work toward accomplishing the objectives set is primarily due to a combination of: (1) a lack of funds; (2) bureaucratic inefficiency; (3) an inappropriate extension strategy; and (4) the lack of a meaningful relationship between extension implementors and clientele-e.g.accountability.

So, it is becaming increasingly recognized that poor performance is not only a consequence of technical deficiencies (though this is also sometimes an important factor), but that many of the problems stem from weaknesses in the organization and management of the scheme.

Only a comprehensive analysis of all the factors that may be contributing to poor performance at the lower levels of the system can indicate the correct mixture of remedies required, in the correct sequence. In other words, organization and management at the project level needs to be fully reviewed, as well as constraints at the farmers' level.

There is an urgent need for an effective agricultural extension service in the initial phase of projects in which farmers are unfamiliar with irrigated agriculture, and these services should be an integral part of the water management organizations.

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TOWARDS INTEGRATED WATER MANAGEMENT IN THE FRINGES OF THE NILE VALLEY

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ABSTRACT

This paper presents a diagnosis of a number of deficiencies in the water management and drainage conditions in the fringes of the Nile valley, i.e: the reclamation areas and the adjacent old lands in El Fashn, Samalut, and Esna. Irrigation water is pumped from the Nile to the reclamation areas that have sandy soils. Large irrigation gifts with a low irrigation frequency result in percolation losses that recharge the aquifer below the reclamation areas. As a consequence the groundwater table has been steadily rising causing waterlogging and salinization in the adjacent old lands and a decline in agricultural productivity.

Several remedial measures with regard to the waterlogging and salinity problem are discussed in this paper. Much has already been improved, e.g. an increase in groundwater extraction in the reclaimed and in the Khufug areas, and through horizontal drainage measures implemented in the valley over the last five years. Despite these improvements considerable scope exists for reduction of costs of irrigation and drainage systems and for strengthening the operational and managerial capacity of the water management and water users organizations. These are believed to be improved through integrated water management.

Résumé

L'article établit le diagnostic de plusieurs déficiences au niveau de la gestion de l'eau et du drainage dans la zone située aux confins du désert et de la vallée du Nil. Cette zone comprend à la fois des terres récemment récupérées (flancs et sommet de versants) et les anciennes zones de culture de El Fashn, Salamut, et Esna (en contre-bas). Les nouveaux travaux de mise en valeur ont accru les problèmes d'engorgement dans les anciennes terres de la vallée. L'eau d'irrigation est pompée du Nil, puis véhiculée vers la zone de récupération constituée de sols sableux. Les doses importantes et les fréquences réduites de l'irrigation entraînent des pertes par infiltration qui alimentent la nappe phréatique sous cette zone. Les conséquences sont une remontée continue du niveau de la nappe, des phénomènes d'engorgement et de salinisation dans les anciennes terres ainsi qu'un déclin de la productivité agricole.

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L'article analyse plusieurs mesures susceptibles de remédier à ces problèmes. Des progrès très marqués ont été réalisés les cinq dernières années, notamment en accroissant les extractions d'eau souterraine dans et autour des "nouvelles" zones récupérées et en pratiquant un drainage horizontal dans la vallée. En dépit de ces amendements, des améliorations importantes peuvent encore être réalisées au niveau de la réduction des coûts des réseaux d'irrigation et de drainage ainsi que du renforcement des capacités opérationnelles et managériales des organismes chargés de la gestion de l'eau et des organisations d'irrigants.

1. INTRODUCTION

1.1 General

The Nile valley of Upper Egypt extends from Aswan to Cairo, a distance of about 900 km. The valley lays in a tectomorphic graben with a width ranging from 15 to 30 km. The escarpments that limit the valley are composed of Upper Mesozoic to Lower Tertiary sedimentary rocks. In the graben these rocks are overlain by a thick layer of Pliocene clay. During the Pleistocene the graben was further filled by rather coarse sand and gravel deposits with few lenses of clayey material. These deposits form an excellent aquifer.

Prior to the construction of the High Aswan Dam (HAD), the Nile flooded yearly in the period July till October large parts of the valley. The flood season is commonly known as the Nili season and the flood is referred to as the Nili flood. The floods carried besides water large amounts of clay that settled when the floods spread over the valley floors. The resulting clay layer has a maximum thickness of 15 m.

For thousands of years, agriculture in the Nile valley was restricted to the clay soils along the river that were annually flooded. This traditionally irrigated strip of land is known as the "old land". The area between the old land and the escarpment, the so-called desert fringes, is overlain by wind blown sand that increases in thickness as the land surface rises slowly towards the escarpment.

The construction of the Aswan High Dam permitted the regulation of the river flow and provided a more secure year round irrigation water supply. This made it possible to introduce perennial irrigation in the traditionally irrigated old land and also to increase the irrigated area by reclamation of part of the desert fringes and of parts of the tributary wadi floors.

The increasing demand for more agricultural land to feed a rapidly growing population and the better availability of surface water after the completion of the Aswan High Dam were the major accelerators of desert reclamation in Egypt.

Along the Nile valley, one of the first reclamation schemes was executed in the early sixties in Kom Ombo (Figure 1). Extension of the cropped area for sugarcane was required to cope with a growing demand for sugar and with a relative decline of the productivity of the older sugarcane fields.

In 1963 the Land Reclamation Authority (GARPAD) under the Ministry of Agriculture and land reclamation (MALR) started with desert reclamation projects along the Nile valley in Esna, Samalut and El Fashn (Figure 1). The main infrastructure was completed in 1967.

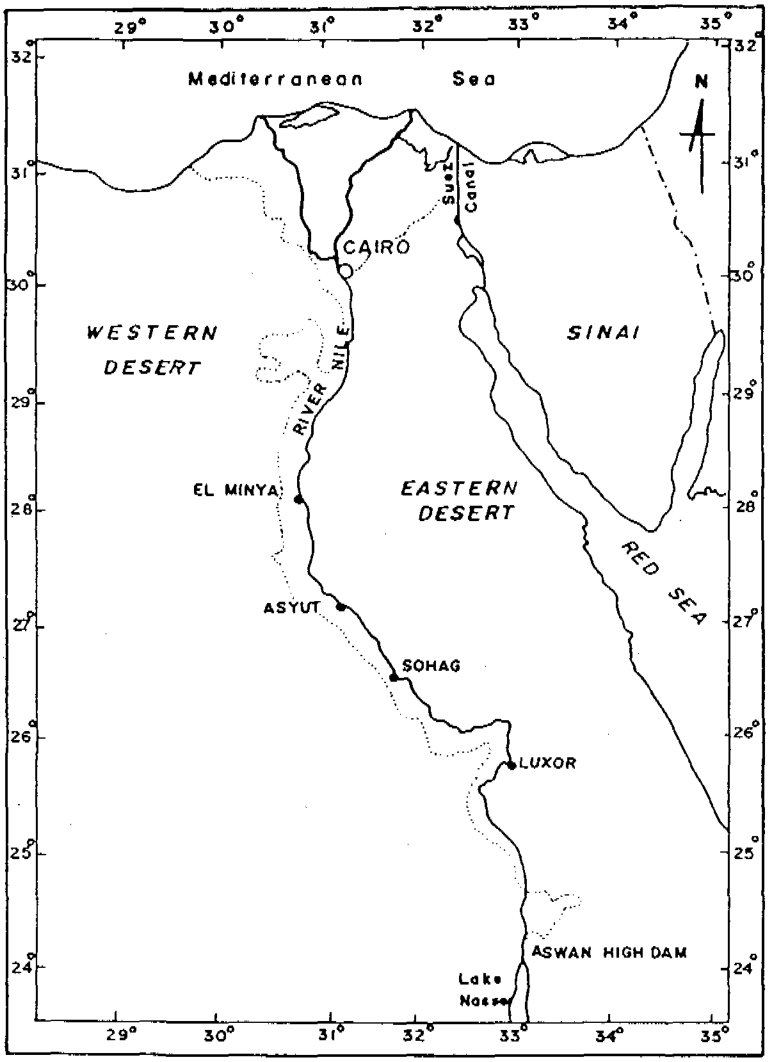

Figure 1. Land reclamation projects along the Nile valley.

The major ill side-effects of desert reclamation are the waterlogging and salinization of the adjacent low-lying old cultivated lands. The initial leaching of desert land and excess irrigation applications cause a rise of the groundwater table, resulting in groundwater flow towards the adjacent old lands and a rise of the piezometric level. This reduces the natural drainage in the old land and causes a rise of the water table and consequently waterlogging. Then salinization of the root zone might occur through capillary rise.

1.2 Geomorphology

The reclamation areas and adjacent old lands in the valley on the west bank of the river show the following morphological units between the Nile and the escarpment (Figure 2):

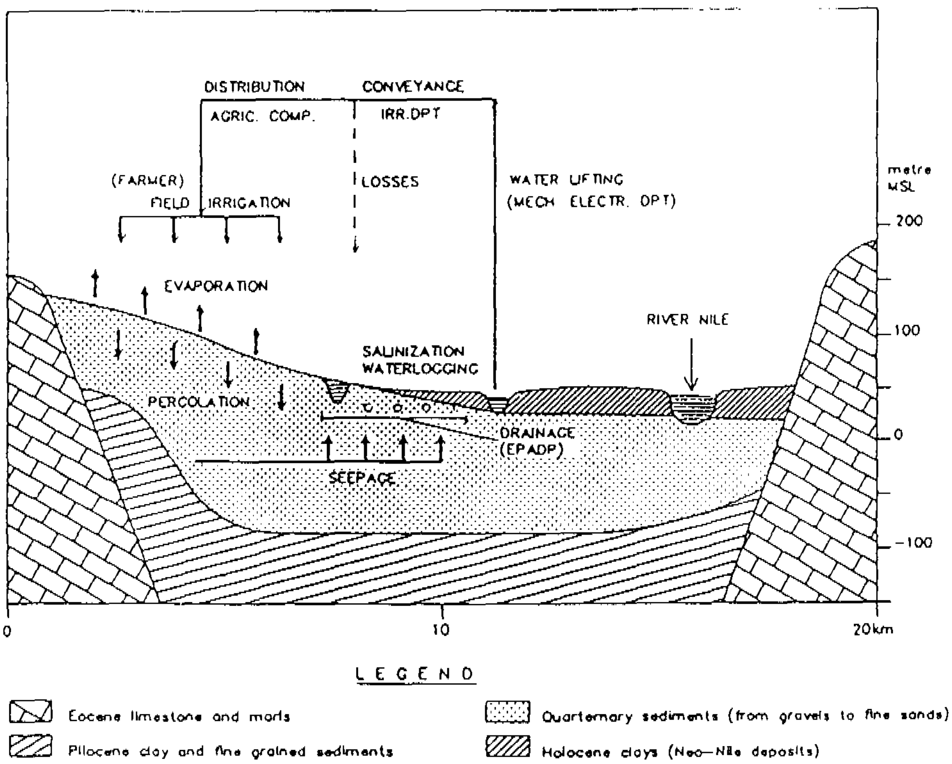

Figure 2. Cross-sectional view of the Nile valley.

- The old land is dissected by former natural water courses, like the Bahr Yousef, that are currently used as irrigation canals or drains. The clayey soils have a large water holding capacity and are irrigated once every 10 - 14 days. Since 1976 these lands are provided with horizontal subsurface drainage systems.

Several years after the construction of the reclamation projects the old land west of Bahr Yousef developed waterlogging problems.

- The Khufug is a 1 to 2 km wide strip of land characterized by depressions with very shallow water table and inundations during winter. The area is partly covered by active dunes. In the Khufug of the Samalut and El Fashn areas traces of an old Nile branch, e.g. oxbow lakes, are clearly visible. The Khufug is situated at the western fringe of the Nile valley, between the old lands and the desert.

The Khufug is traditionally not irrigated and used for extensive grazing. This practice is changing, because the Khufug is gradually brought under cultivation by land hungry farmers, using groundwater extracted by shallow wells as irrigation water supply.

- The reclamation areas are clearly a desert fringe consisting of gently rolling sandy plains. The average elevation of the ground surface is 10 - 30 m higher than the adjacent old cultivated land. The land consist of a mineral sandy soil. Sometimes farmers mix clay from the old land with the sand to improve the soil physical conditions. The reclamation areas are irrigated by surface water. The percolation losses cause a rise in the groundwater level below the reclamation area and consequently a groundwater flow toward the old land. It is assumed that this has aggravated the waterlogging problems in the Khufug and is the cause of the waterlogging of the old land west of Bahr Yousef.

- Adjacent desert lands are the sandy non-reclaimed desert areas between the Khufug and the outcrops of the limestones of the escarpment. In these areas private farmers have settled recently and groundwater-based irrigation is rapidly expanding. They construct wells that allow the installation of a centrifugal pump just above the water table at the bottom of the open part of the well.

1.3 Groundwater Flow In The Nile Aquifer

The aquifer below the valley floor has a thickness that varies from tens of meters near the escarpment to several hundred meters in the central part of the valley. The transmissivity ranges from several hundred m^2/day near the escarpment to more than 20,000 m^2/day in the central part of the valley. The aquifer is leaky below the old land and unconfined below the desert fringes. A hydraulic connection between the water in the aquifer and that in the surface water courses exists, especially at locations where the confining top layer is absent or very thin. In addition, excess irrigation water, supplied by the surface canal system, percolates to the aquifer. This recharge creates a lateral piezometric gradient perpendicular to the river Nile, that forms the drainage base for this flow.

Changes in storage volume in the aquifer are small in comparison to the Nile inflow at Aswan and the outflow at Cairo. If groundwater was to be abstracted at a significant scale, this would reduce the drainage flow towards the Nile. If even more groundwater would be abstracted, the groundwater flow direction would be reversed and the Nile and its branches would lose water towards the aquifer.

1.4 Irrigation

The irrigation system in the old lands of the Nile valley is a combined gravity and lift system. The main canal system takes its water from head regulators, situated upstream of the Nile barrages. The flow of water is regulated and distributed among branches and distributaries, by means of cross regulators and gated intake structures. The main system and branches have continuous flow, while the water supply to the distributaries is allocated according to a rotation schedule.

At the tertiary intakes, water is supplied to the meskas, i.e: private irrigation ditches, serving an area ranging from 10 to 300 feddan. The larger meskas have a sub-rotation along the marwas, i.e: small irrigation ditches.

Water is generally applied to the fields by means of pumping. Most farmers replaced their traditional saqias by mobile diesel pumps. The field application method is ponding of level basins. Every 15 days some 120 to 200 mm of water depth is applied.

The irrigation efficiency is between 60% and 70%, when sufficient irrigation water is available. This is generally the case in the head reaches of the canals. In the tail ends of the canals, however, chronical shortages of irrigation water may occur. Most farmers compensate these deficits by pumping supplemental water from a drain or from groundwater.

The Khufug area has almost no irrigation infrastructure. Farmers, who irrigate scattered plots in this area, obtain their water from private wells, from the so-called "cut-off" drains, or they pump from one of the main irrigation canals of the reclamation areas.

The desert reclamation schemes are provided with a lift irrigation system. Irrigation water is supplied by one of the main canals in the old land and lifted by a series of pumping stations to the sub-command areas in the reclamation scheme. The total lifting height is between 20 and 30 meters.

In El Fashn and Samalut, most of the main and branch canals have recently been lined. In Esna the canals have no lining and suffer from high percolation losses. The uniformity of water distribution along the main and branch canals is low. Water distribution is generally disproportional to the actual cultivated area in each of the sub-command areas.

The tertiary canals are not lined, although recently farmers started to line their own meskas. The conveyance loss in unlined canals was determined from measurements. These losses amount to 20 - 35 % in the meskas and 20 - 30 % in the main canals.

The commonly used irrigation method is basin irrigation. Sprinkler and drip irrigation systems were introduced in one third of the command areas. However, most of the farmers abandoned these systems because of their high maintenance costs and returned to basin irrigation. The field application efficiency of basin irrigation on the desert soils is low.

Measurements were made in Esna and Samalut. The results revealed that per irrigation some 80 to 140 mm is applied. The water holding capacity in the root zone is only about 50 - 70 mm. As a consequence, percolation losses were in the order of 60 to 80 mm per irrigation. Depending on the availability of water, the irrigation interval varies from 3 days to 12 days. The average field application efficiency, derived from the field investigations, ranges from 40 % to 60 %. The overall scheme efficiency ranges from 20 % to 30 %.

1.5 Drainage

Perennial irrigation of the old land caused a general rise of the water table and waterlogging in large parts of the Nile valley, which moreover was aggravated by groundwater flow from adjacent desert reclamation areas. To combat the rise of the groundwater table and the resulting waterlogging the Egyptian Public Authority for Drainage Projects (EPADP) installed horizontal pipe drainage systems in the old land. The design was based on perforated corrugated plastic lateral pipes, that were installed at a depth ranging between 1.2 and 1.5 m and at a spacing ranging between 40 and 80 m, calculated according to the design criteria commonly used in Egypt: a discharge of 1 mm/day and a hydraulic head midway between the laterals of 0.4 m. Surplus discharge in view of seepage flow from the desert reclamation areas was not taken into account.

In the Khufug area open interceptor drains were constructed, which often suffered from unstable slopes due to the pressure created by the groundwater seepage flow from the reclamation area and the light sandy texture of the soil.

2. WATER MANAGEMENT PROBLEMS

2.1 Waterlogging and Salinization

Definition of waterlogging

Waterlogging is the condition where the upper boundary of the saturated zone (i.e. the water table) reaches into the root zone.
For practical purposes, under the prevailing conditions in the Nile valley, the following specific definition of waterlogging is suggested:

A waterlogged condition exists, if the water table depth is less than 80 cm below ground level for a period of more than two months in the winter season.

Causes of waterlogging

Waterlogging in the old land and Khufug regions is caused by four phenomena:

- Percolation of excess irrigation water in the desert reclamation areas resulting in groundwater seepage and a rise of the piezometric head in the aquifer. As a consequence, the (natural) vertical drainage diminishes.

- Topography; depressions in the Khufug have a land level that is below the adjacent old land. Consequently these areas have no natural drainage outlets.

- Backwater effects in open drains and at drain outfalls. The conversion from seasonal irrigation to perennial irrigation and the increase in water duties caused a rise in water levels in both canals and drains. Open drains that formerly discharged by gravity into Bahr Yousef require now a low lift.

- An increased percolation rate from irrigation in the old land, after the increase of water duties.

The extent of waterlogging

A few years after the implementation of the reclamation areas waterlogging started to occur in the old land west of Bahr Yousef and aggravated in the "traditionally" waterlogged areas in the Khufug.

In Samalut and El Fashn, waterlogging occurs in the Khufug area (42000 feddan), between the old land, west of Bahr Yousef, and the desert reclamation area. About 3400 feddan (8 %) of the Khufug becomes inundated in winter, while 17000 feddan (40 %) is waterlogged. In the old land, west of Bahr Yousef, only 2 % suffers from waterlogging.

In Esna, waterlogging only occurs in some 200 to 500 feddan in the Khufug.

The extent of salinization

A soil survey made by the Research Institute for Groundwater (RIGW) and the Soil Laboratory of Minia University revealed only minor salinity problems in the old land. In the uncultivated parts of the Khufug salt crusts at the land surface were observed. Measured soil salinity at locations with less than 1 m groundwater table depth ranged from EC= 0.2 to 3.2 dS/m, while the salinity of the groundwater varied between EC= 0.5 and 4.2 dS/m.

The consequence of waterlogging

The consequence of waterlogging is a decline in crop production. The agro-economic study carried out in Samalut and El Fashn, revealed the following net farm incomes:

Old land with a drainage system	L.E. 1500 /feddan/year;
Waterlogged areas	L.E. 520 /feddan/year;

2.2 Unproductive Evaporation

Unproductive evaporation in the Khufug zone of El Fashn and Samalut occurs mainly in the lakes, swamps (3400 feddan) and areas with a water table depth of less than 50 cm below ground level (5600 feddan). The annual loss of reusable groundwater is estimated at 40 million m^3. This is the equivalent to a volume of irrigation water that can cultivate some 6000 feddan.

2.3 Low Return From Investments and O&M Costs

The cost of surface irrigation water in the Nile valley amounts to L.E. 30 per 1000 m^3. The additional O&M costs for lifting to the desert reclamation schemes is about the same. Under optimal water management, an irrigation efficiency of 70 % could be achieved, requiring an application of irrigation water of some 6700 m^3/fed/year. This implies that the cost of irrigation water would be L.E. 400/fed/year. The current water management conditions result, however, in an irrigation efficiency of less than 30 %, and consequently the cost of net irrigation water applied per feddan increases, with a factor of 2.3, to L.E. 920/fed/year.

The net farm income, excluding the irrigation costs amounts to L.E. 1200/fed/year, including the irrigation costs L.E. 280/fed/year.

2.4 Deterioration of The Aquifer

Private farmers started to reclaimed desert lands outside the reclamation areas. Their only irrigation water supply is from tube wells. The well inventory concluded in January 1993, revealed that in the Esna area nearly 400 and in the El Fashn and Samalut areas nearly 900 private wells are in operation and that the number of new wells is still increasing. The majority of such wells are implemented without licenses. This situation is affecting the continuity of the resource due to the limited recharge of the aquifer.

A secondary effect of large scale groundwater abstraction is the decline of groundwater quality. The leaching fraction, containing the dissolved salts of the irrigation water, percolates back to the aquifer and as a consequence the salinity of the groundwater will increase.

2.5 Institutional Constraints

The organization of water management in the reclamation areas suffers from the following constraints:

- Insufficient capacity to monitor the quantities of surface water actually supplied to the desert reclamation areas and an absence of a procedure to evaluate the quantities supplied versus the quantities actually needed and delivered.

- Absence of a formal assignment of responsibilities and the related authority for the management of the reclamation areas and a lack of staff in the Irrigation Directorates to execute O&M.

- Lack of facilities and support services to assist desert farmers with the improvement of on-farm water management. Insufficient organization among farmers for systematic and efficient water distribution at the tertiary level.

With respect to the management of groundwater resources, the following constraints were observed:

- Insufficient capacity for groundwater monitoring and management at the Irrigation Directorates or other MPWWR agencies at the Governorate level.

- A lack of implementation capacity to apply and to enforce the licensing system for groundwater extraction.

With respect to improvement of drainage conditions and to the conjunctive use of surface water and groundwater for irrigation, additional constraints were observed:

- Separate planning mechanisms within the different agencies, leading to insufficient coordination of plans.

- Mutual roles of research institutes and executive agencies are not sufficiently specified.

- Insufficient consideration to take broader aspects of water management into account in the selection and priority ranking of areas for construction of irrigation and drainage systems.

3. POSSIBLE REMEDIAL MEASURES

Waterlogging problems can be remedied in two ways: with an **effect approach**, i.e. removing the excess water in the fringes of the valley by drainage measures and by a **source approach**, i.e. preventing excessive recharge. The combination of the two approaches involves the conjunctive use of surface water and groundwater for irrigation. The combination can be considered as a first step towards integrated regional water management.

3.1 The Effect Approach

The removal of the excess water that causes waterlogging in the fringes of the old land and in the Khufug can be achieved by any or a combination of the following means:

- Horizontal drainage by open drains.
- Horizontal drainage by a subsurface perforated pipe system.
- Vertical drainage by pumping from wells specifically constructed for this purpose.
- Vertical drainage as a side benefit of pumping from irrigation wells.

Horizontal drainage

To alleviate the waterlogging problems open cut-off drains were constructed, but required an excessive amount of maintenance because the walls collapsed due to the groundwater pressure. Topographic levelling by the project revealed that the Mazura South drain was constructed above the level of the Khufug.

In 1992, EPADP started the construction of open drains, cutting through the Khufug, perpendicular to the old interceptor drains. The new open drain in Mazura was connected to the Delhanes drainage pumping station. One year after construction, the drain was still functioning effectively and no side slopes slumping was observed.

Although vertical drainage was foreseen, EPADP constructed in 1991/92 in most of the old land west of Bahr Yousef of El Fashn and Samalut a pipe drain system with a design depth of 1.50 m. The design discharge of the system was established at 1 mm/day. At the same time the open main drains in these areas were enlarged. The actual discharges observed in 1993 were 0.3 mm/day in the collectors and 0.7 mm/day in the open drain.

The annual cost of horizontal drainage amounts to L.E. 280/feddan.

Vertical drainage by tubewells

Vertical drainage have been constructed in the El Fashn and Samalut areas in 1987/89 (63 and 74 wells in the respective areas). Pumps are not yet installed in El Fashn area, being recently fixed in Samalut. Electricity is not yet provided.

In 1991 ten wells in the Samalut pilot well field were provided with pumps and diesel engines. They were extensively pumped by the RIGW. The rate of pumping executed was only 70% of the designed discharge rate due to the limited capacity of the supplied mobile units. The pumped water was disposed into the nearest (unlined) canal and used directly for irrigation of each specific canal command area. The results of the test pumping was as follows:

- Only during the closure period the pumping of the main aquifer is effective in lowering the phreatic water level. Data to evaluate to what extent the drop of the phreatic level is caused by horizontal flow to the empty drains and irrigation channels are not available.

- During the irrigation season, i.e. during the rest of the year, continuous pumping has no effect in five out of seven shallow midpoint wells.

- The main reason, specific for the Samalut well field, is the occurrence of an aquifer with high transmissivity (KD ranging from 5000 to 10,000 m^2/d), combined with the resistance of the clay cap (c ranging from 200 - 1000 d). The second reason is that percolation losses from surface irrigation (0.5 - 3 mm/d) are of the same magnitude as the vertical flow rate through the covering layer and the limited capacity of the mobile pump units. The third reason is the direct recovery of pumped water through seepage from the unlined canals.

- The effectiveness of the pumping for vertical drainage is determined by the difference between the vertical flow rate through the clay layer (q_v) and the percolation losses (p_i) of irrigation water to the water table (seepage from canals and subsurface drainage). The value of q_v is given by the equation:

$$q_v = \Delta h/c = K_v^*(\Delta h/D')$$

During the closure period $p_i = 0$ and q_v is taken from storage in the covering layer, which results in a decline of the water table.

During the irrigation period three situations may occur:

$p_i < q_v \rightarrow$ water table declines

$p_i = q_v \rightarrow$ water table stable

$p_i > q_v \rightarrow$ water table rises

The value of q_v depends on the saturated thickness of the covering layer (D').

- The effectiveness in lowering the water table by pumping the aquifer is expressed by the ratio of the drawdown of the water table (s_w) and the drawdown of the piezometric level (s_p).

If the ratio (s_w/s_p) is close to one the head difference between water table and piezometric head will be rather constant and consequently the effectiveness is high, provided that s_p is large enough.

If the ratio is relatively small, this implies that the effect of pumping on the water table is also small; the head difference will have a tendency to increase during the pumping period, resulting in a slow increase of the value of q_v.

If the initial piezometric head is above the water table there will be upward seepage (q_s) and consequently $q_v = (p_i + q_s)$.

- The performance of the pilot well field indicated that under the prevailing conditions in this specific area (hydraulic properties of the aquifer and the canals) vertical drainage would not be feasible. However, elsewhere in the fringes of the Nile Valley the conditions may be more suitable.

- Results from model simulations performed by the project revealed that if the main canals are in "open" hydraulic contact with the aquifer, percolation losses from these water courses might provide most of the water that is pumped from the well field.

- Site selection procedures for vertical drainage well fields should include a detailed hydrogeological and geomorphological survey, including a detailed estimation of the aquifer characteristics, a careful estimation of the percolation losses and the soil physical properties i.e. the specific yield. The water behavior in the unsaturated zone and the influence of large canals need more attention, because of their influence on the recharge.

- The financial and economic comparison of the vertical and horizontal drainage option should also be taken into consideration.

  The cost of water, pumped from deep tubewells amounts to L.E. 23 per 1000 m^3 for electric units and L.E. 39 per 1000 m^3 for diesel units. The annual costs for vertical drainage amount to L.E. 160/feddan for electric pump units and L.E.p 280 /feddan for diesel units.

Vertical drainage by irrigation wells

In areas without a surface water irrigation system, but with a waterlogging problem such as the Khufug, the groundwater development by small farmers may help to lower the water table. Moreover part of the water that otherwise would be wasted by non-productive evapotranspiration will be beneficially used.

3.2 The Source Approach

The source approach means reducing the percolation losses that feed the groundwater mound below the reclamation area, or reduction of this mound by pumping from wells in the reclamation area.

Reduction of the percolation losses

Reduction of the percolation losses and at the same time improving the low irrigation efficiency, requires an improvement of the water distribution and application system:

- Lining of main canals and branches; it is recommended to reshape the non lined canals and provide these sections with a suitable lining. This will reduce conveyance losses from 30 % to 10%.

- Lining of meskas; it is recommended to convert the meskas into masonry flumes, as is already done by private farmers. This will reduce the meska losses from 25 % to 10 %.

- Reduction of the irrigation interval and the application rates. Recommended average (depends on the growing crop) field application rates per irrigation are:
  200 m^3/fed every 5 days in summer;
  200 m^3/fed every 10 days in winter.

- Introduction of water saving field application methods. It is recommended to convert surface irrigation methods to systems using gated pipes or sprinklers. The introduction of sprinkler irrigation systems will require credit facilities for procurement by farmers, the establishment of a spare parts and service center for maintenance, and a demonstration/training programme. Drip irrigation requires high investments and high technical skills. Drip systems are only recommended for commercial farms, which grow high value crops in greenhouses, or in orchards.

The current overall (annual) irrigation efficiency of the desert reclamation schemes ranges between 25 % and 35 %. Reduction of percolation losses of unlined canals, through a lining programme will result in conveyance losses of about 10 % of the gross intake. Part of the saved water, however, will be lost in the meskas and during field irrigation. To make the savings, obtained from lining effective, it is recommended to improve the meskas and the field irrigation methods as well. The net result will be that more land can be cultivated with the same quantity of water, lifted to the reclamation area.

The effect of various improvement measures on the scheme efficiency is presented in Table 1.

Pumping at the source

The phreatic level of the unconfined aquifer under parts of the reclamation area is presently about 10 to 30 meters below ground level. This makes it feasible for farmers to construct their own wells to develop groundwater-based irrigation systems. Such development will lead to a reduction of the growth of the groundwater mound below the reclamation areas.

4. TOWARDS INTEGRATED WATER MANAGEMENT

4.1 Objective

Integrated water management generally comprises the quantitative and qualitative management of water resources, including the institutional framework, planning procedures, environmental aspects and the legal framework that governs the obligations and benefits of the water users.
With respect to the water management in the fringes of the Nile valley, the specific objective of integrated water management is defined as follows:

The objective of integrated water management in the Nile valley is to maximize sustainable crop production with the available surface irrigation water and groundwater.

Prerequisites for sustainable crop production are:

- Crop water- and leaching requirements can be met in each command area during the whole year;
- The leaching fraction is evacuated effectively, ensuring that no salt accumulation occurs in the root zone of the cultivated area;
- Abstraction of groundwater for irrigation is compensated sufficiently by recharge of the aquifer, ensuring that no depletion of the aquifer occurs;
- The water quality of the aquifer is maintained above acceptable standards;
- The costs of irrigation water are minimized, thus permitting a favorable benefit/cost ratio.

Table 1. The effect of improvement measures on the irrigation efficiency.

Scenario	1	2	3	4	5	Remarks
Canal losses	30	10	10	10	10	% of gross intake
Meska losses	25	25	10	25	10	% flow entering meska
Field losses	50	50	50	25	25	% flow entering field
Total losses	74	66	60	51	39	% of gross intake
Not available for crop evapotrans.	26	34	40	49	61	
Scheme efficiency	26%	34%	40%	49%	61%	

1. Situation before lining of main canals and meskas, with basin irrigation.
2. Main canals and branch canals are lined, meskas not lined, with basin irrigation.
3. Lining of meskas, with basin irrigation.
4. Meskas not lined, with basin irrigation converted into sprinkler and drip.
5. Meskas lined, with basin irrigation converted into sprinkler and drip.

A first step to meet this objective is to combine measures at the source and measures that alleviate the effects. This will result in a more effective and efficient use of water and energy. The combination of these measures comprise the following elements:

- Improvement of water distribution by increasing the conveyance efficiency of transport canals and distributaries, by lining;
- Improvement of field application efficiency and simultaneously reduction of percolation losses by applying modern irrigation methods and improved irrigation scheduling;
- Conjunctive use of surface water and groundwater in areas with a structural shortage in surface irrigation water;
- Reuse of percolation water by pumping groundwater for irrigation from private wells in the Khufug zone;
- Reuse of tail end losses of the irrigation system in the reclamation area by recirculation by the main lifting stations;
- Reuse of drainage water discharged by the horizontal drainage system in the old land in the valley.

The relative contribution of the above mentioned elements are interdependent. If, for example, the percolation from the surface irrigation system is reduced, then the recharge of the aquifer will be less and consequently less groundwater abstraction can be sustained. The aspect of water quality also requires attention. Percolation of a mixture of (Nile) irrigation water and reused drainage water will in the long term result in a higher salinity of groundwater and consequently affect the sustainability of groundwater use.

The combined approach requires the mutual adjustment of development plans for surface irrigation, groundwater abstraction and horizontal drainage. This will involve not only the water managers, i.e., the Irrigation Department, EPADP, the Central Groundwater Department, the research institutes of the Water Research Center and GARPAD, but also the water users.

4.2 Institutional Requirements

The integration of planning and operational procedures of the involved parties can only be implemented successfully when the flow of information between the parties is effective and when a legal framework for planning procedures and mutual responsibilities is established.
An important tool to support these procedures is a Monitoring and Evaluation (M&E) programme and a Management Information System (MIS). Essential to the establishment and operation of a M&E/MIS programme, is the review and adjustment of cadastral and irrigation and drainage information.

The development of integrated water management could be initiated at regional levels under the auspices of the MPWWR. The Under-Secretary of State for Irrigation would be proposed to chair a committee, comprising representatives of the Irrigation Department, EPADP, Central Groundwater Department, MALR and Agricultural Cooperatives. The relevant institutes of the Water Research Center can play an important role in the development of the M&E/MIS programme, the analysis of irrigation and drainage performance, assessment of sustainable groundwater abstraction and in training of the regional staff.

A legal basis for the establishment of Water Users Associations is in preparation by the MPWWR in the framework of the Irrigation Improvement Program (IIP). This legal basis should include procedures for water scheduling, system maintenance, irrigation fees, groundwater abstraction and extension services. The water users associations will have to participate in data acquisition with respect to the (legal) cadastral status of farm holdings, the contribution of groundwater to irrigation and to cropping plans.

The establishment of water users associations is also a step in the direction of privatization. Until recently, planning, implementation and operation and management of the desert reclamation schemes was entirely a Government responsibility. The same situation applied to the implementation and operation of the large capacity tubewells. Following the global trend to promote privatization, it is recommended to transfer the responsibilities for operation, maintenance and management of tubewells and tertiary irrigation systems to (private sector) water users organizations and to discourage the planning and implementation of new Government operated tubewell fields.

The Water Security Plan and the Environmental Action Plan are currently under implementation by the MPWWR. These two national plans both aim at the sustainable use of Egypt's scarce water resources. Regional integrated water management plans could be formulated within the framework of the two national plans.

4.3 Implementation Requirements

The implementation of a regional integrated water management plan will require a considerable effort in staff training and the establishment of an extension programme for the water users.
A very important issue is the comprehension and acceptance of the concept of desert irrigation and agronomy.

> Desert irrigation differs fundamentally from the traditional flood irrigation in the old lands of the Nile valley and delta. The clay soils of the old lands have a low infiltration capacity and a high water holding capacity, permitting flood irrigation in level basins. The sandy soils of the desert reclamation areas, on the other hand, have a high infiltration capacity and a low water holding capacity. Under these conditions flood irrigation will result in a low uniformity of field application, high percolation losses and soil moisture stress towards the end of an irrigation interval.
> Irrigation of the desert reclamation areas requires the lifting of water at considerable energy costs, while in the valley the conveyance system is a gravity system.

The mineral soils of the desert have a lower natural fertility and require higher fertilizer applications than the soils of the old lands. Micro-climatological conditions in the desert are less favorable than in the valley. As a consequence, traditional crops of the old lands will yield less in the desert, while the costs of farm inputs are higher. Improvement of net farm income in the desert will require more suitable crops and crop varieties, different cultivation practices (mulching, soil conditioning, tillage, wind protection, etc.) and more economic water application.

A second important issue is the development of groundwater resources and its sustainable exploitation. Monitoring and evaluation of groundwater abstraction and its effect on the aquifer requires the qualified input of the RIGW. On a medium term, however, the regional water management organization should develop a capacity to manage groundwater resources themselves, in order to integrate conjunctive use of groundwater for irrigation in the regional water management plan.

The specialized institutes of the Water Research Center of MPWWR could play an important role in training the staff of the water management organizations and the water extension officers, who advise the water users. The RIGW could train the regional staff who will be involved in the monitoring and management of groundwater resources.

5. CONCLUSIONS AND RECOMMENDATIONS

The major problems associated with land reclamation in the fringes of the Nile valley can be summarized as follows:

- Surface irrigation in the desert areas results in excessively high percolation losses. Subsequently the irrigation efficiency of desert reclamation schemes is less than 30 %, while the cost of net volume of water used by the crop ranges between L.E. 400 to L.E. 900 per feddan per year.

- Waterlogging in the fringes of the old land of the valley is caused by:
  - seepage from the reclamation areas;
  - topographic features, i.e: local depressions;
  - backwater effects in open drains;
  - increase of water duty in the old land.

- New land reclamation schemes or extensions are mainly dependent on locally pumped groundwater. Due to lack of recharge sources and increases unplanned extractions, the groundwater resource is deteriorating, both in quality and quantity. This results in a loss of investments.

- Private initiatives and investments helped to solve waterlogging problems in the Khufug zone. It is recommended to encourage the private operation of tubewells by transferring the responsibility for O&M from the Government to the farmers. A similar transfer of responsibilities is anticipated for the tertiary irrigation units in the reclamation areas.

• The major gain in curtailing irrigation water losses in the reclamation areas is the improvement of the on-farm water management. Reduction of both the irrigation interval and the application depth will yield significant water savings. The use of modern irrigation equipment should be encouraged in areas with light textured soils.

• The objective of integrated water management in the Nile valley is to maximize sustainable crop production with the available surface irrigation water and groundwater. A first step to meet this objective is to combine measures that reduce problems at the source and measures that alleviate adverse effects.

• Integrated regional water management will require the institutional strengthening of both water managers and water users. Training and extension on the concept of desert irrigation and agronomy are considered essential.

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TECHNICAL AND ORGANIZATIONAL CHANGES IN IRRIGATION REHABILITATION PROGRAMS: MANAGEMENT OF THE WATER DELIVERY SYSTEM IN IRRIGATION IMPROVEMENT PROJECT (EGYPT)

Ramchand Oad[1]

ABSTRACT

The fundamental theme of this paper concerns the intertwined relationship between the physical facilities and the institutional arrangements for improving performance of irrigation systems. In this context, it analyzes the necessity and the management requirements for institutionalizing on-demand water availability for irrigated agriculture in Egypt.

The Irrigation Improvement Project (IIP) in Egypt provides a good example for highlighting the relationship between the social arrangements and the physical facilities of an irrigation rehabilitation program. The IIP has introduced major physical changes at the outlet level where the Irrigation Department delivers water to private water user groups. For these physical changes to be successful, it is necessary that the water users have water continuously rather than on a rotational basis. Some policy makers in the Irrigation Department are doubtful about the need and benefits of changing to the continuous flow method of water delivery to farmers. The paper analyzes the necessity, perceived benefits and operational requirements of continuous flow delivery method to support the IIP program.

1. INTRODUCTION

Irrigation rehabilitation programs usually include improvements of main delivery canals as well as technological changes in irrigation works managed by the farmers groups. Because physical facilities of an irrigation system and the social structure of its use are highly interrelated, rehabilitation projects run a high risk of failure if the technical changes are planned but the necessary social changes are ignored or merely assumed (Coward, 1985). If system rehabilitation proceeds without a comprehensive understanding of its social aspects, then the post rehabilitation state may not have a set of social arrangements to complement the new or rebuilt physical system.

The Irrigation Improvement Project (IIP) in Egypt is a good example to highlight the intertwined relationship between social arrangements and physical facilities in an irrigation

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rehabilitation program. The IIP has introduced major physical changes at the outlet level where the Irrigation Department delivers water to users groups. The traditional low-level mesqas (farm level water delivery channels) are being replaced by raised gravity flow channels or by buried low-pressure pipelines. In either case, water from the branch canal is pumped into the mesqa and flows to the farmers' fields by gravity. This single-point pumping replaces multiple pumping by individual farmers on the old low-level mesqas.

The fundamental premise of this paper is that to successfully operate these redesigned and rehabilitated systems, farmer groups must be able to have water from the branch canal continuously rather than on a rotational basis. This important organizational change, though identified in the project design, was not fully analyzed as to its operational requirements.

This paper analyzes the necessity, perceived benefits and operational requirements of continuous flow delivery method within the context of IIP. It is argued that the continuous flow method of water delivery is an essential organizational change to support the physical changes being introduced by IIP. And, as such, its merits and demerits must be viewed within the context of all IIP improvements. Towards the end of the paper, practical aspects of implementing the continuous flow are analyzed.

2. METHODS OF IRRIGATION WATER DELIVERY

2.1 General

In most large-scale water deficient irrigation systems, a combination of both continuous and rotational method of water delivery is practiced. The main canals are mostly operated continuously, whereas the distribution channels deliver water to their command areas on a rotational basis. To the extent possible, main canals must be operated continuously because of the large volumes of water needed to satisfy crop water requirements of large command areas. At the distribution level, however, there is a choice: whether to meet the crop water requirements on a daily basis (continuous flow), or to satisfy the crop water requirements after a certain number of days -- week to ten days, for example -- in a relatively short time period (rotational delivery).

A primary advantage of the rotational delivery method is its potential for obtaining a fair distribution of the limited available water among various water users. This is so because water supplies to the distribution channels are regulated at their intakes from the main canal and few control structures are provided along the distribution channels. Also, operational losses of water may be reduced in rotational delivery since relatively large amounts of water are delivered in relatively short time period.

Major disadvantages of the rotational system appear on the water use side primarily because of the difficulties of matching crop water requirements to the water supply schedule. Whereas the quantity of water supplied during each irrigation turn may remain the same, crop water requirements vary over time for a given crop and the requirements are different for different crops. As such, planning and management of a diversified cropping pattern is often difficult with rotational water delivery method. Even in the case of a simple cropping pattern, crops may be stressed due to long irrigation intervals. Consider for example cotton crop grown on a clay loam soil in Upper Egypt.

Rootzone depth for cotton = 100 cm
Water holding capacity of clay loam = 0.16 cm/cm
Total available water = 0.16*100 = 16 cm
Management allowed deficit = 0.5*16 = 8.0 cm
Peak crop water requirement = 0.75 cm/day
Maximum irrigation interval = 8.0/0.75 = 10.6 days.

In a typical 5-day on and 10-day off rotation, interval between two successive irrigations for a certain landholding is 15 days. The above example shows that in a 5-days on and 10-days off rotation, the cotton crop will be stressed and yields may be reduced. The problem of water deficiency is often exacerbated by unreliable water supplies in the rotational method of water delivery.

2.2 Irrigation Water Delivery in Egypt

Irrigation main canals in the Nile Basin of Egypt operate continuously except during the closure period (January month each year) for routine maintenance. A number of branch canals receive water from a certain main canal on an intermittent basis. Typical water receiving schedules for the branch canals are,

5 days on and 10 days off in the Upper Egypt,
7 days on and 7 days off in the lower Egypt, and
4 days on and 4 days off for rice growing areas.

These schedules are formulated for various main canal commands taking into consideration the cropping patterns and the consequent water requirements in their service areas.

The branch canals in turn supply water to the farmers' field channels locally called the mesqas. Water surface level in a branch canal and its service mesqas is designed to be lower than the field level by about 50 to 75 cm. As such, farmers must lift water from a mesqa in order to apply it to their fields (Figure 1-a). The design was adopted to discourage wasteful use of irrigation water. In practice, the low-level mesqas are long narrow reservoirs in which water flows from the branch canal only when some farmers are lifting water out of it. Over the years, the mesqa sections have been enlarged and deepened to the point where serious concerns are being raised about the excessive amount of land area occupied by the mesqas. Also, the standing pools of water raise many environmental concerns.

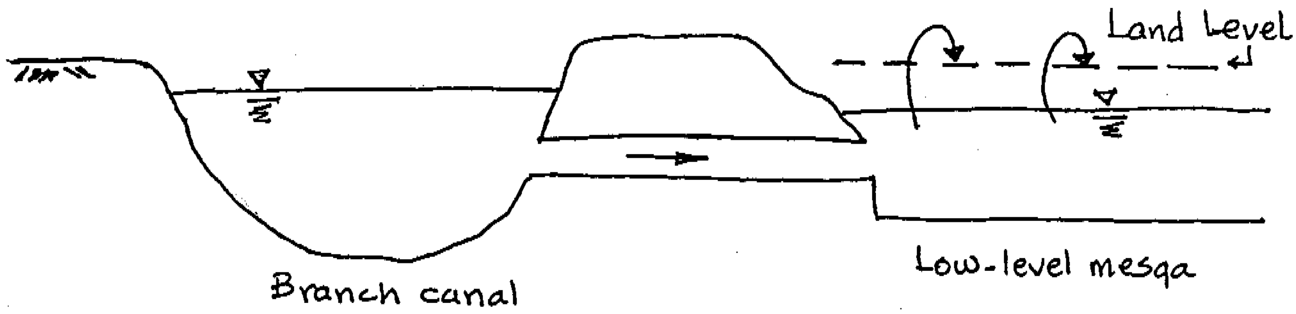


Figure 1-a Traditional low-level mesqa

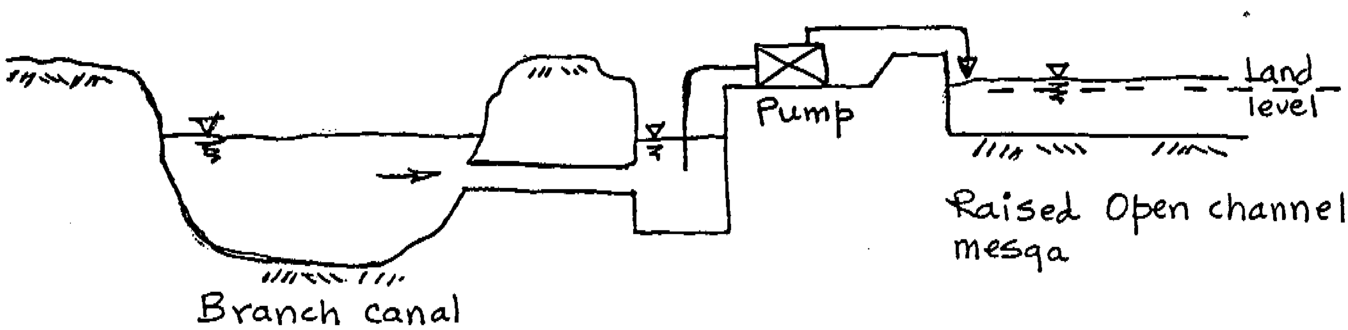


Figure 1-b Improved Raised Open Channel Mesqa

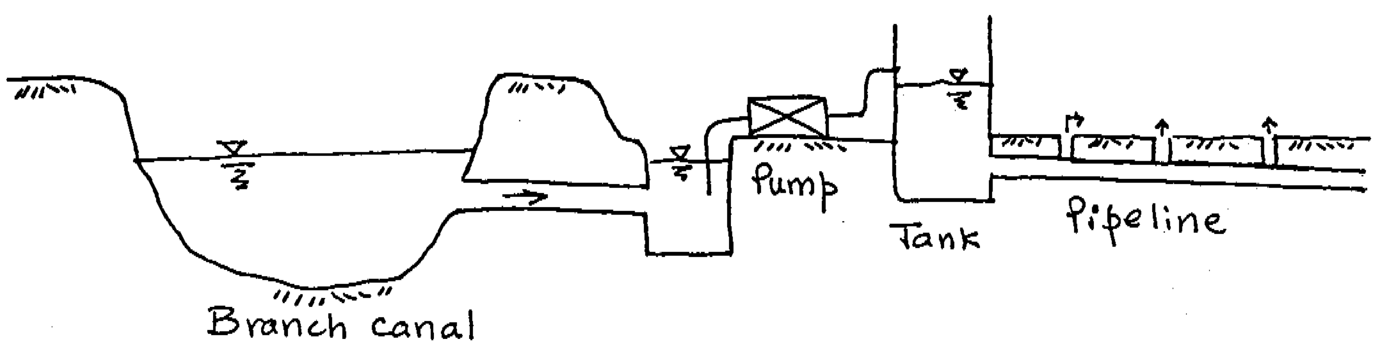


Figure 1(c)- Improved Pipeline Mesqa.

The Irrigation Improvement Project was formulated and implemented in response to these concerns. The fundamental physical change introduced by the project is to replace the low-level mesqas by raised gravity flow open channel mesqas (Figure 1-b) or by buried low-pressure pipe line mesqas (Figure 1-c). From the raised open channel and the pipeline mesqas, water can flow to the farmers fields by gravity. However, water must be lifted from the branch canal to the mesqa collectively at a single point at the head of the mesqa.

It was realized from the beginning of the project that for successful operation of the improved mesqas, appropriate organizational changes will also be necessary. Most important of these are the development of water users associations (WUA) that can organize the collective pumping of water from the branch canal, and its distribution among various users within a mesqa command. Also, to satisfy crop water requirements of a mesqa command with single point pumping, water needs to be pumped from the branch canal on a daily basis. The implication is that the branch canals must have water continuously rather than on an intermittent basis.

To provide leadership in formulating and implementing these organizational changes, Irrigation Advisory Service (IAS) was instituted within the Irrigation Improvement Project. IAS has been quite successful in advising farmers on organizational and financial aspects of WUA formation. It has also approached farmers for more productive and efficient use of irrigation water at the farm. However, the issues of better water management and successful operation of the water users associations are critically influenced by the ability of the Irrigation Department to provide water in the branch canals on a continuous basis. The appropriate physical and organizational changes to implement continuous flow water delivery in branch canals are not in place yet.

3. THE NEED FOR CONTINUOUS FLOW DELIVERY -- CONTEXT OF IRRIGATION IMPROVEMENT PROJECT

To understand the need for continuous flow water delivery, it is helpful to review the IIP objectives, design assumptions and specific means for achieving the project objectives. Primary objectives of IIP are to increase farmer welfare through increased agricultural productivity, and better use of land and water resources. Based on a literature review and discussions with key informants, the design assumptions for achieving these objective are as follows.

* Most of the high value cash crops are very sensitive to the amount of water applied and the timing of irrigation. The existing rotational water supply to the mesqa commands often constraints the choice of crops farmers can grow.

* In the existing low-level mesqas, irrigation water distribution among farmers is not fair and equitable. Access to irrigation water is basically determined by access to a pump since all irrigation water must be lifted to the land level.

* Individual use of pumps on the mesqa wastes farmers resources (time, labor and fuel) and national resources (inefficient use of fuel energy).

Based on these design assumptions, the fundamental change introduced by IIP is to replace individual farmer pumping (at multiple points along the low-level mesqa) by collective pumping from the branch canal (single point pumping). Towards this end, IIP uses the following physical and organizational means.

* Replace the low-level mesqa by a raised gravity flow mesqa so that water from the mesqa will flow to the farmers' fields by gravity. An alternative is to use low-pressure buried pipe line mesqas from which farmers can obtain water at certain outlets through control valves. In both cases, water is pumped from the distribution canal into the mesqa by using a large size pump (design discharge 60 L/s). For mesqas with large command areas, two or even three pumps may be required.

* In a gravity flow mesqa, potential for inequitable water distribution is at least as high as in multiple pumping from a low-level mesqa. A water users' association (or a similar organization) is necessary for managing both mesqa and pump operations.

* The duration of pumping will be much longer in single point pumping, compared to each farmer pumping from a low-level mesqa, to satisfy crop water requirements of a mesqa command. Consider the case of mesqa number 33, Herz Numania command in Minya (Upper Egypt).

irrigated area = 64 feddans = 26 ha
available water supply = 100 L/s (two pumps operating)
maximum daily pumping hours = 8 hours
daily volume of water = 100*8*3600/ 1000 = 2880 m^3
daily crop and soil water requirement = 1.0 cm/day
land area over which crop water requirement can be met in one day = (2880/.01)/ 10000 = 28 ha

This simple calculation shows that farmers must pump water daily from the branch canal to satisfy crop water requirement of all farmland. Implication is that branch canals must be operated continuously to support single point lifting mesqas.

* With small flow rates in the branch canal and the need to maintain a certain water level, water level control structures will be necessary in the branch canals.

It may be noted that the concept of continuous flow is really continuous availability, and not more water. The volume of water to be delivered to a given area over a period of time is the same, but since it is delivered continuously the flow rate in the branch canal can be much smaller. For example, instead of delivering a monthly volume over a period of ten days (in a 5-day on and 10-day off rotation), it will now be delivered over a period of month. The flow rate in such branch canals, therefore, can be reduced to one-thirds in the continuous method of water delivery.

It follows from the above analysis of IIP objectives and design assumptions that physical and organizational changes -- such as continuous flow method of water delivery, downstream control gates and water users associations -- are all essential means for achieving the IIP objectives. It is only logical, therefore, that merits and demerits of continuous flow water delivery method must be considered to be the same as those perceived for the Irrigation Improvement Project.

The IIP performance monitoring program is well established and some data are available to evaluate perceived benefits of the project improvements. Much of these benefits, by the design of IIP, directly accrue to the farmers. However, these benefits should result in increased farmers' productivity which is good for the Irrigation Department and for the nation.

4. BENEFITS OF IIP IMPROVEMENTS

4.1 Benefits for the Farmers

As a part of the project performance monitoring program, direct benefits to the farmers (such as cost of irrigation, irrigation time, and cost of mesqa maintenance) resulting from IIP improvements are documented. The data reported in Table 1 show that farmers' monetary cost of irrigation was reduced by 33 to 57 percent. The labor savings (time spent on irrigation water management) are also impressive -- 16 to 45 percent. The most beneficial effect of IIP, as expected, appears to be the reduced cost of mesqa maintenance. Farmers reported cost savings of at least 80 percent for mesqa maintenance. These savings combined with increased water control and reliability of water delivery should help farmers increase crop yields.

Table 2 presents data on yield increases as reported by farmers in the Herz-Numania IIP command area. All sample farmers on improved mesqas reported 6 to 20 percent more yield. These are significant yield increases considering the fact that the increases occurred immediately after the improvements were completed. More yield increases can be expected few years (four to five) after the project improvements.

4.2 Benefits for the Irrigation Department

At the national level, primary IIP benefits include water and land savings. Low-level mesqas occupy a large amount of highly productive land compared to the raised-lined gravity flow mesqas. The average size of the low-level mesqas is very large perhaps to obtain some storage capacity which helps in meeting crop water requirements. Table 3 shows amount of land area saved for mesqas improved through the project. The raised open channel mesqas save about 25 to 50 percent land and the pipeline mesqas almost 100 percent of the land (compared to the land area occupied by low-level mesqas). The larger land savings for the

TABLE 1: Perceived benefits of the Irrigation Improvement Project

IIP Command Area	Herz	Bani eb	Qiman	Sadiya	Qahwa
Cost of irrigation (I.e/fd.)					
-Before IIP	12	14	10	6	4
-After IIP	6	6	6.4	4	2.5
Saving (I.e//fd.)	6	8	3.6	2	1.5
Percentage saving	50%	57%	35%	33%	37%
Average time to Irrigate (hrs./fd.)					
-Before IIP	5.7	4.5	4.5	3	2.8
-After IIP	3.1	2.5	4	2.5	1.8
Percentage saving	45%	44%	11%	16%	35%
Annual cost of Mesqa maintenance (I.e/fd.)					
-Before IIP	4	23	10	6	10
-After IIP	0.4	not yet	2	not yet	not yet
Saving (1.e/fd.)	3.6		8		
Percentage saving	90%		80%		

I.e means Egyptian pound and 1 $=3.35 I.e
fd. means feddan, a unit for land area, and is approximately equal to one acre (0.405 hectares)

TABLE 2: Crop yields in Herz and Nomanya (Minya) command areas of the Irrigation Improvement Project

Crop	Crop Yield Before IIP	Crop Yield After IIP	Percentage Increase in yield
Sugarcane	28 (ton/fd)	32	16.4%
Maize	6.2 (ardab/fd)	7.2	14%
Cotton	4.6 (kintar/fd)	5.1	9.3%
Beans	6.4 (ardab/fd)	6.7	6.5%

fd.feddan, and is approximately equal to one acre (0.405 hectare) raised lined mesqas occur in the delta region where the low-level mesqas tend to be much larger.

Water use in the agricultural sector can be made more efficient by decreasing conveyance losses in mesqas and marwas and through improved irrigation practices at the farm level. Limited data collected in some IIP command areas do indeed confirm the water saving potential of IIP. Figure 2 shows mesqa conveyance efficiencies before and after the IIP improvements. It is seen that mesqa conveyance efficiencies increased from a low of about 65 percent to a high of about 90 percent.

The IIP water management monitoring program documents the amount of water used by mesqa commands as compared to the crop water requirements. The ratio of crop water requirement and the amount of water used (called the water use index in Table 4) is a good indicator of the existing water saving potential. Table 4 shows the amount of water used during the summer 1993 crop season compared to the crop water requirements in Minya and Tanta. The two command areas are selected to compare the two different agroclimatic zones of Egypt, the Upper and the Lower Egypt. In the Bani-Ebed command area of Minya, the seasonal average water use index is about 1.5.

The data from the Qahwagi command area (Tanta) gives the water use index to be 2.5 to 3.0. The large amount of water use in the delta region is because of the rice crop where farmers keep the rice basins flooded with water. These data indicate that their is a significant potential to conserve water presently used at the farm level.

5. IMPLEMENTATION OF THE CONTINUOUS FLOW DELIVERY

Implementation of the continuous flow method of water delivery in IIP commands is a difficult task for the District Irrigation Engineers. They must answer to all water users why few branch canals (IIP command areas) can get water continuously while all other branch canals must follow the long established rotational method of water delivery. In theory, it is said that the total volume of water supplied to a mesqa is the same because flow rate in the continuous water delivery method can be reduced. In practice, however, there are technical difficulties. The channel crossection of the IIP branch canals have not been appropriately reduced to carry the lower flow discharge. If the flow discharge is reduced, then water level in the branch canal may be too low for water to enter the sump well of the pump.

These operational difficulties perhaps explain why IIP branch canals do not yet receive water on a continuous basis even though all mesqas have completed physical improvements. In Figure 3, water level in the IIP branch canal Qiman Arus (Bani Suef) is shown as function of time (June 1 to July 7,1993). It is clearly seen that the branch canal is not supplied water continuously, but rather on a five days on and ten days off rotational system of water delivery. Another observation from the data is that mesqas located near the upstream part of the branch

TABLE 3: Land savings through The Irrigation Improvement Project in Minya

Command Area	Land area (m^2) Before IIP Mesqas area	Before IIP Average	After IIP Mesqas area	After IIP Average	Percentage Savings
Bani ebed pipe line mesqas:					
1. Mesqa #19	3600		0		
2. Mesqa #29	3000	3300	0	0	100%
Bani ebed raised lined mesqas:					
1. Mesqa #4	2795		1820		
2. Mesqa #8	1600		1300		
3. Mesqa #11	2790	2440	2170	1795	26%
4. Mesqa #20	2717		2002		
5. Mesqa #21	2280		1680		
Oahwagi pipeline mesqas:					
1. Station #B	2250		0		
2. Station #D	2840		0		
3. Station #E	2280	2356	0		100%
4. Station #G	1800		0		
5. Station #H	2610		0		
Oahwagi raised lined mesqas:					
1. Station #F	3172		1692		
2. Station #J	6360	4094	2565	1859	54%
3. Station #L	2750		1320		

Figure 2 Conveyance Efficiency of Improved Mesqas in IIP

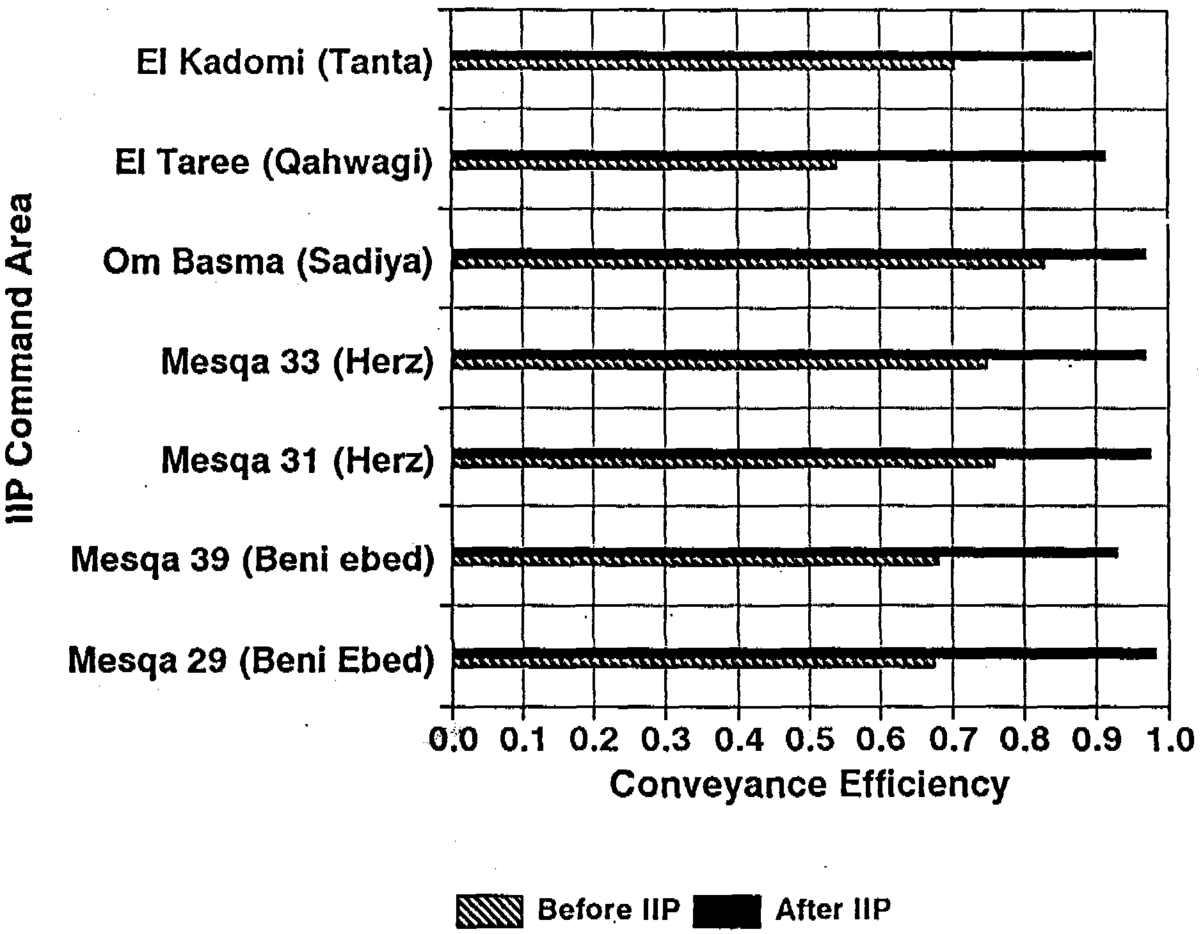


TABLE 4: Water Deliveries to Mesqas and Crop Water Requirement (Water Use Index) in Minya

Command Area	April 1993			May 1993			June 1993			July 1993			August 1993		
	W.D.	C.W.R.	W.U.I.	W.D.	C.W.R.	W.U.I.	W.D.	C.W.R.	W.U.I.	W.D.	C.W.R.	W.U.I.	W.D.	C.W.R.	W.U.I.
Bani ebed:															
1. Control mesqa	20300	13618	1.49	25680	22119	1.16	32290	27324	1.18	41343	32654	1.27	30184	14280	2.13
2. Mesqa #29 (pipe line)							21628	13814	1.56	60833	37693	1.61	35736	23340	1.54
3. Mesqa #39 (raised lined)							38087	27224	1.39	65863	46019	1.43	49636	34002	1.45

W.D. = Water deliveries to mesqa in m^3.

C.W.R = Crop Water Requirement

W.U.I. = Water Use Index = W.D/C.W.R.

(cont'd)
TABLE 4: Water Deliveries to Mesqas and Crop Water Requirement (Water Use Index) in Tanta

Command Area	April 1993			May 1993			June 1993			July 1993		
	W.D.	C.W.R.	W.U.I.	W.D.	C.W.R.	W.U.I.	W.D.	C.W.R.	W.U.I.	W.D.	C.W.R.	W.U.I.
Qahwagi:												
1. Mesqa el-kadomy (pipeline)	51089	21367	2.38	109322	21890	5	150081	49655	3	152459	50710	3
2. Mesqa el-tarce (pipe line)	39873	25036	1.59	115207	68910	1.66	213714	77891	2.7	271762	68911	4
3. Control mesqa							373360	167242	2.2	600645	203797	2.94

Farmers are using the old mesqas because the new ones are under construction.
The old mesqas are opened to drain.
W.D. = Water deliveries to mesqa in m^3.
c.W.R = Crop Water Requirement.
W.U.I = Water use Index

Figure 3a. Water surface level in Qiman Arus branch canal - downstream reach

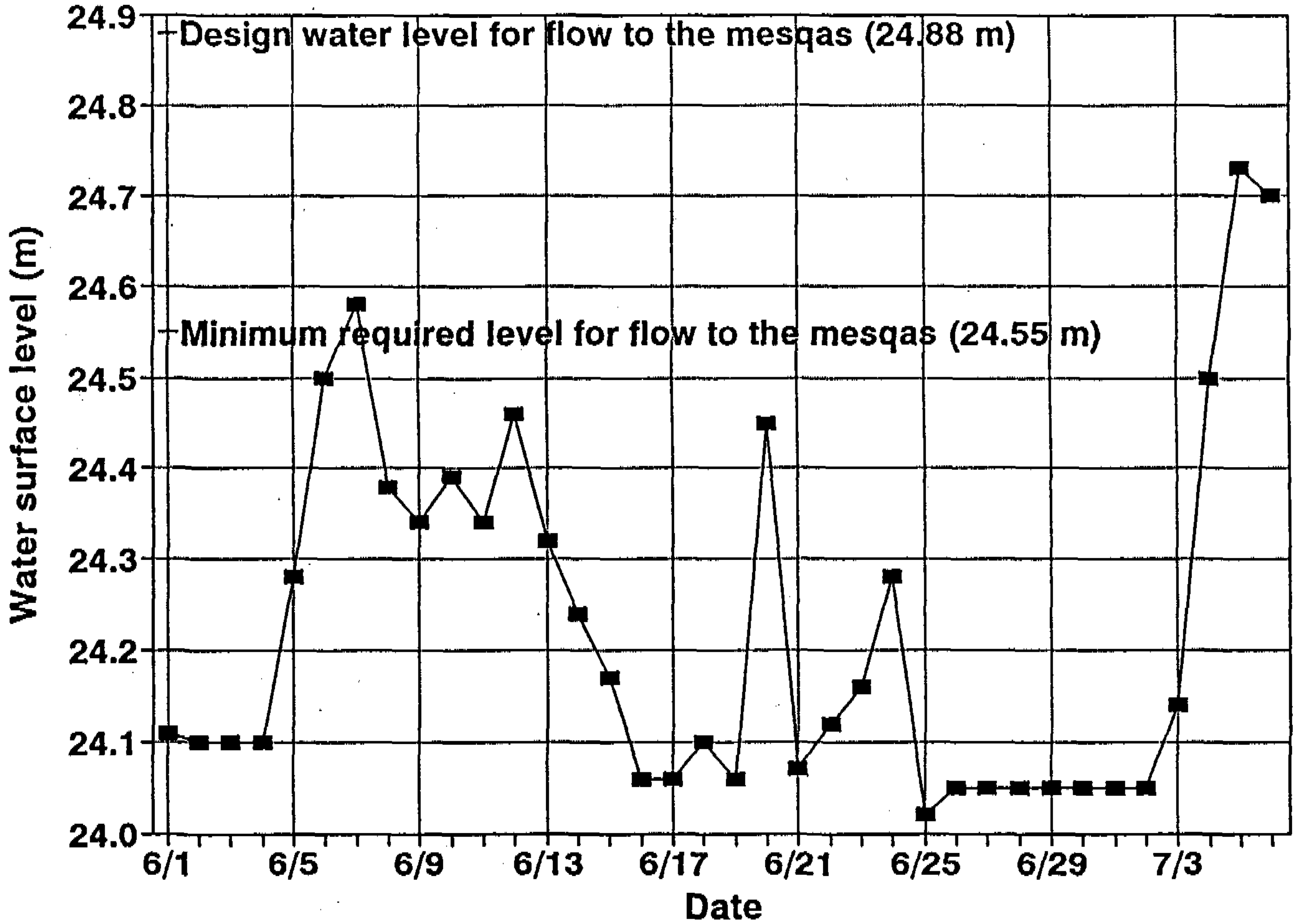
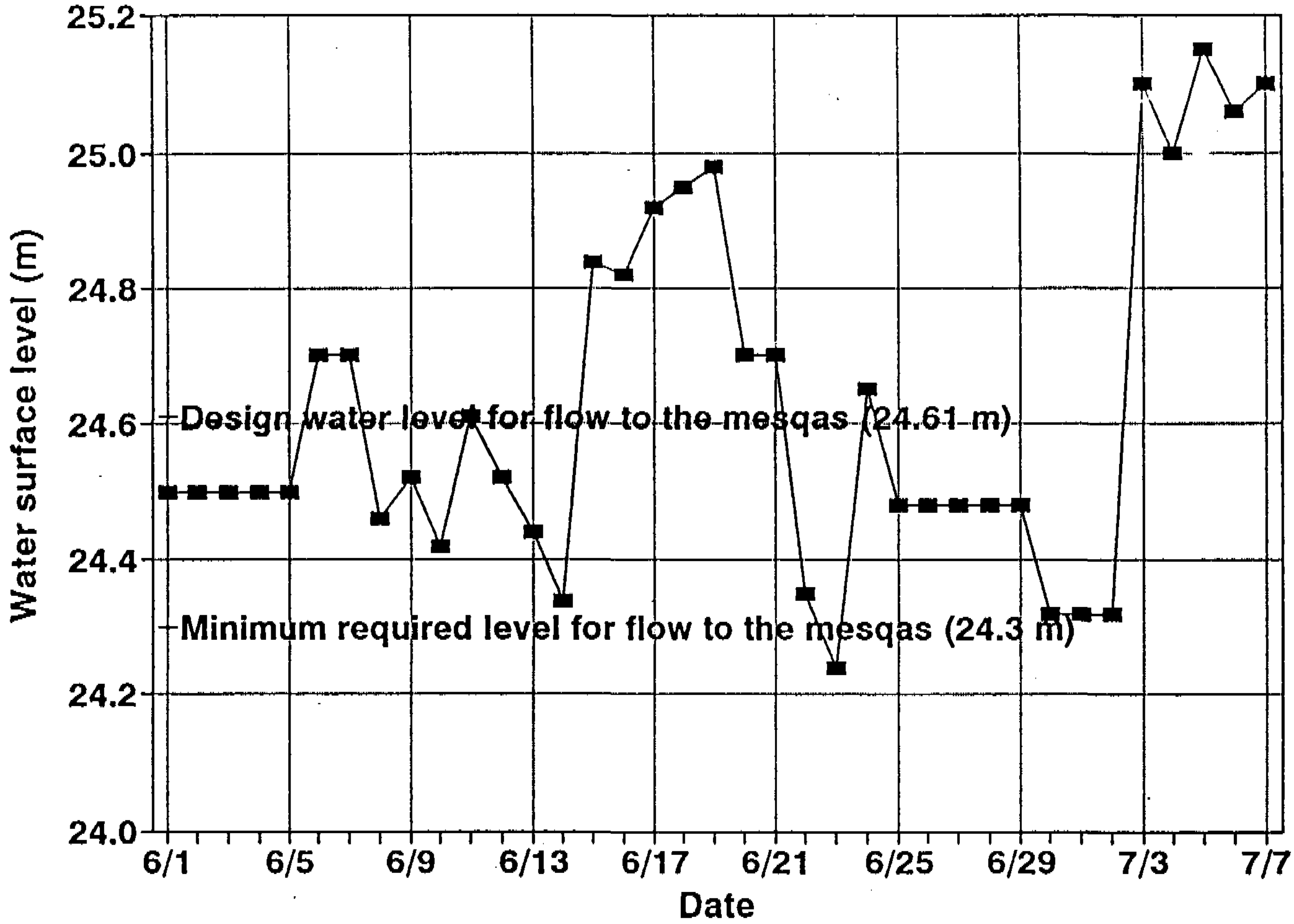


Figure 3b. Water surface level in Qiman Arus branch canal - upstream reach



canal get appropriate water level during their turn. However, mesqas located downstream on the branch canal do not get appropriate water level; in the critical month of June, branch canal water level was above the minimum required for only one day.

6. CONCLUSIONS

Much of the development efforts in irrigation are directed towards improving systems that already exist. In all cases of existing irrigation systems, there are some type of social arrangements for organizing such fundamental tasks as distributing water among farmers and maintaining canals. After rehabilitation, the final state will also have a set of social arrangements to complement the physical irrigation facilities.
Many times, the social arrangements may be implicit in the design as illustrated by the case of appropriate water delivery method to support the physical improvements in IIP.

Projects to rehabilitate irrigation systems should ideally proceed with a good understanding of the physical irrigation facilities and the associated social arrangements. There should also be a comprehensive understanding of the proposed physical changes and social arrangements necessary to support the physical changes. Often, rehabilitation projects fall short of their potential because the project planners incorrectly assume that necessary social arrangements will be in place.

This paper has presented a case study to illustrate the importance of the sociological aspects of irrigation system rehabilitation. The Irrigation Improvement Project in Egypt has quite successfully completed physical improvements in the farmers' water distribution and use system (mesqa commands). The improved mesqa commands are beneficial both for the farmers and for the Irrigation Department. When the new mesqas function properly, the farming communities are pleased with them.

The proper functioning of the improved mesqas is fundamentally influenced by the organizational arrangement of maintaining continuous water supply in the branch canals. This social arrangement has not been implemented in all IIP command areas in a proper organized way. The Irrigation Department engineers are concerned about the apparent preferential treatment of the IIP command areas compared to the rest of the irrigated area.

Some remedies to the problem of continuous flow water delivery method are being tried but these are hardly long-term
solutions. This is because the remedial solutions basically give the IIP branch canals more water compared to other branch canals, and this cannot be self sustaining. For example, in the case of Qiman Arus, proposed solution was to institute a "modified continuous flow" -- flow regime of ten days on and five days off compared to five days on and ten days off for other branch canals.

What is perhaps needed, for the long-term solution, is a careful analysis of physical and social changes necessary to support continuous flow water delivery in the branch canals. For example, the branch canals may need rehabilitation to carry much lower discharges compared to what they were designed to carry in rotational method of water delivery. From this analysis ought to emerge a complete understanding of problems associated with implementation of continuous flow, and a strategy for solving those problems.

7. REFERENCES

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THE WUA APPROACH TO IMPROVED SYSTEM PERFORMANCE: EXPERIENCES FROM EGYPT

Dr. Martin Hvidt*

Abstract

This paper analyzes the extent to which Water Users Associations (WUAs) contribute to secure farmer water control.

Drawing extensively on field data collected in command areas rehabilitated by the Egyptian "Irrigation Improvement Project" (IIP), the author documents key features of the WUA formation process and increase in water control resulting from the main and micro-system improvements.

WUA organizational strength is found to play a decisive role in securing farmer water control in situations where main system water supply is unstable.

It is argued that the impact of WUA organizational strength on water control is likely to increase in the future when the farming system has developed a highly diversified and moisture sensitive cropping pattern.

Résumé

Dans cette étude, l'auteur propose une analyse des Associations des Utilisateurs d'Eau (l'AUE) et de la mesure à laquelle elles mènent au contrôle des agriculteurs sur la distribution d'eau.

L'Auteur base son analyse sur des données empiriques des "domaines commandes" qui ont été réhabilités par le Projet d'Amélioration de l'Irrigation en Égypte. Il identifie les traits caractéristiques du processus formateur des AUE aussi bien que leur contrôle d'eau plus important, résultat d'une amélioration des systèmes principaux et micros.

L'Étude indique que la force organisatoire des AUE joue un rôle décisif en guarantissant le contrôle des agriculteurs sur la distribution d'eau, dans les cas où le système principal de l'approvisionnement d'eau est instable.

Puis, il soutiens l'idée que la force organisatoire des AUE concernant le contrôle d'eau augmentera dans l'avenir à la condition que l'agriculture develope un système de cultures très diversifié et sensible à l'humidité.

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1. THE WUA APPROACH TO IMPROVED SYSTEM PERFORMANCE: EXPERIENCES FROM EGYPT

Water Users Associations (WUAs) are a relatively new concept in irrigation management. Many scholars and irrigation practitioners term the concept "revolutionary" because it offers new insight into the way irrigation systems can be designed, operated and maintained.

The WUA approach to improved systems performance has emerged out of experience gained in practical field application. It offers a set of guidelines of how to involve farmers and how to institutionalize the relationship between farmers and irrigation bureaucrats. Ultimately the approach promises to solve what is probably the main operational problem in irrigation systems, how to provide farmers with adequate water control.

Involving farmers through WUAs has proven very successful on a number of smaller irrigation systems around the world i.e. Spain, Indonesia, Philippines and Sri Lanka. Experiences with large-scale systems are more diversified and generally less encouraging i.e. in Pakistan where the WUA building process has largely failed.

Worldwide Egypt is the place where the WUA approach is being implemented most forcefully today. And at the same time Egypt possesses a large scale irrigation system. This makes the experiences from Egypt extremely useful.

This paper analyzes the first experiences with the WUA approach in improving irrigation system performance in Egypt. It seeks to answer the questions: 1) What is the WUA approach - and what problems does it promise to solve? 2) How has the approach been implemented in Egypt? and 3) Which effects are attributable to the WUAs in securing farmer water control?

First the paper summarizes the WUA approach; its historical background and the special problems related to applying it to large-scale systems. Secondly, the key issue of "farmer water control" will be addressed and viewed in the context of Egypt. Thirdly, the experiences with implementing the WUA approach in Egypt is analyzed. After a brief description of the current implementation program, an analysis of the experience of WUA formation, and the effects attributable to WUAs in securing water control is carried through. This analysis is based on data collected by the author in three canal commands in Upper Egypt; Herz-Numaniya, Beni Ibeid and Qiman el Arus.

1.2 The WUA Approach - A Literature Review

1.2.1 Historical background

The notion of farmer involvement in managing irrigation systems stem back to the Philippines in the early 1970's, when it became increasingly evident that irrigation system performance ranged far below its potential.

A micro-focused and development-oriented research carried out in the Philippines at that time emphasized studies of small scale community irrigation systems, the irrigation agency's past involvement with such systems and its interest in improving assistance to them.

The search for new approaches to assist community systems led to the initialization of the Laur project, which became the first project implemented with an explicit objective to maximize farmer involvement.

Two reasons were accountable for the emphasis on farmer involvement: First to include the considerable knowledge and skills possessed by the farmers in designing, operating and maintaining irrigation works in the improvement process of the systems and second; to recover funds from the farming community to pay for irrigation improvements (Coward, 1983:213ff.).

These two sets of reasons continue to be the fundamental motivation behind the involvement of farmers in irrigation system management today.

Since then, the merits of involving farmers in irrigation management on small scale irrigation systems (less than 1000 hectares) have been extensively studied and documented (see i.e. (Korten, 1982; Maass and Anderson, 1978; Uphoff, Meinzen-Dick, and St. Julien, 1985)

Uphoff et al. (1995:iii) report findings from a study of farmer organization and participation including 50 cases of irrigation management worldwide.

They find evidence that farmer cooperation can contribute to increased flows of water reaching downstream areas, greater area cultivated, higher cropping intensity, lower costs of construction, reductions in water issue requirements, expansion of system capacity, and better operation and maintenance. In the Philippines and Sri Lanka quantifiable benefits related to construction and yields were found (Uphoff, Meinzen-Dick, and St. Julien, 1985:3).

The initial successes of the participatory approaches with small scale systems has prompted interest in applying these to large-scale irrigation schemes (30,000 hectares or more) (Coward, 1983:217). Here a more limited number of cases exist, and the results gained are more diversified and less encouraging.

Uphoff et al. (1985:2) report in relation to the 60.000 hectares Gal Oya Scheme in Sri Lanka, that with organized farmer cooperation the water issue was reduced by one-third and that tail-end farmers, who had suffered from total lack of water during the dry season during the last 10 to 20 years had obtained irrigation water through farmer operated rotations. They further report that in the Pochampad scheme in India (also 60.000 hectares) the irrigable area was extended by 25-35 % through better water rotation.

The Pakistan On-Farm Water Management Project aimed at involving farmers in rehabilitation of a large number of tertiary watercourses through lining of canals, land levelling, and training of farmers. It is still debated whether or not the project resulted in higher yields and savings in water (Steinberg, Clapp-Wincek, and Turner, 1983:53-54). One thing is evident though, the formation of water user associations as stipulated in the project never became successful. One reason was that the WUAs was forced on the farmers[1]. This might have happened in the attempt to get management of the lowest levels of the project out of the government's budget as was the case in Gal Oya and Bicol (Philippines) (Steinberg, Clapp-Wincek, and Turner, 1983:73)

1.2.2 The problems of participation in large-scale systems

There seems to be a good reason why participation in large-scale systems is difficult to acquire and sustain. Steinberg, Clapp-Wincek, and Turner (1983:73:57) point out, that there are often serious difficulties in administering large systems involving extensive populations and complex engineering requirements, and for such reasons government control in opposition to user-control is almost always required .

Uphoff, Ramamurthy, and Steiner (1991:36) agree with this and point out that large scale systems tend to take on a "more prominently bureaucratic form", which tends to "administer" the systems as opposed to "managing" them. Administered systems adopt a high degree of standardization, formalization and routinization.

While this might positively influence predictability and reliability of water flows, it certainly is detrimental to farmer involvement in management of the system. To facilitate participation, one needs "managed" systems that apply a learning approach to system management.

In dealing with the main lessons learned from the participatory experiences in the 1970s Coward (1983:215-216) point out that modifications in the agency's structure and procedures are required to sustain farmer involvement. "Expanding farmer participation in irrigation development requires not only better farmer organization but new agency structures and processes" that allow for farmer involvement in design, construction and operation.

And the issue of involvement of farmers in design and construction phases is especially important in rehabilitation of large-scale public owned systems.

Korten (1982:7-8) i.e. points out that "efforts to organize farmers into water users' associations after the system is completed generally are meet with apathy. Once water is flowing, those receiving it are likely to see little reason to spend their time in organizational meetings. Since no shared sense of commitment to managing and maintaining the system was developed during the creation of the system, an "each man for himself" mentality is likely to reign"[2].

The above statements that summarizes the Worldwide experience of involving farmers thus make two points very clear; First, that in order to acquire a sustained farmer participation in large-scale public irrigation systems, the irrigation bureaucracy must adapt new participatory structures of management. Secondly, the farmers who are supposed to participate, must feel it worthwhile to do so. One way to acquire this is to actively involve the farmers in the design of their own systems

1.3 Water User Associations Defined

I the 1980s and 1990s farmer participation in irrigation schemes has become synonymous with the formation of WUAs - the sine qua non of success of water management, as Steinberg, Clapp-Wincek, and Turner (1983:i) conclude.

A WUA is defined as:

> "a private organization owned, controlled and operated by member users for their benefits in improving water delivery, water use and other organizational efforts related to water for increasing their production possibilities" (IIP, 1990b:3).

Even though the above definition emphasizes farmers benefit it is important to recognize, that the concept of WUAs originates from government and state planners' wish to expand agricultural production and productivity within irrigated agriculture and to make the farmers pay for these improvements. In other words, the initiative does not originate from the farmers themselves. A second obvious point often overlooked is that WUAs can only perform their function(s) if farmers accept, adopt and use them.

This places limits to the way agencies can stimulate the formation process of WUAs. Farmers simply cannot be forced into WUAs. Voluntary membership is a necessity. Furthermore the farmers must be able to see personal benefits as a result of their engagement in order to build and sustain the organizations over time. Freeman (1991:59) i.e. report that farmers are willing to engage in organization if and only if they gain in economic or non-economic terms by doing so .

1.4 What Problems Does The WUA Approach Promise To Solve?

It is unthinkable that an irrigation agency could or would try to manage water all the way down to the field level, because of the cost involved, staff requirements and information needed to do this successfully. The question thus is not whether to have farmer participation, but what kind, how much, and at what levels? Participation should be optimal rather than maximum according to the situation (Uphoff, Meinzen-Dick, and St. Julien, 1985:2).

The general understanding among irrigation practitioners of the objectives for irrigation organizations can be summarized under five headings:[3]

1) Greater production and productivity
2) Improved water distribution
3) Reduction in conflict
4) Greater local resource mobilization, and
5) Sustained system performance

The listed objectives are highly interrelated and their ranking will vary from system to system and over time. Increased production and productivity usually rank as the primary objectives (Uphoff, Ramamurthy, and Steiner, 1991:59-60).

One objective, the improvement of water distribution - or water control as it is termed in this paper, is attracts special attention from researchers within the "irrigation management" school (see i.e. Bagadion and Korten, 1991; Freeman, 1991; Freeman and Lowdermilk, 1991; Freeman et al., 1989; Lowdermilk and Svendsen, 1983; Lusk and Parlin, 1991; Samaha and Abu-Zeid, 1980; Wade and Seckler, 1990).

The interest in water control is stimulated by the understanding, that it is a precondition for improvements in the other four variables. And furthermore most large scale systems do not provide farmers with adequate water control.

In this paper only the issue of WUAs impact on water control will be dealt with.

1.5 What Is Water Control?

Water control is defined as

> "..the capacity to apply the proper quantity and quality of water at the optimum time to the crop root zone to meet crop consumptive needs and soil leaching requirements" (Freeman et al., 1989:10).

The term as used here is set to mean the relative control over quantity and timing of supplies .

As Freeman et al. (1989:12) further point out, farmer control over water in the field is critical because only the farmer is able to combine the factors of production in a particular field to produce a crop. And on the issue of productivity they argue that "if water comes too soon, too late, in amounts too great or too small, the productivity of that water is sharply reduced".

Wade (1990:175) is very explicit when it comes to the consequences of lack of water control for the farmers; ".... the cost to farmers of not receiving adequate and timely irrigation water is very high. Planting and input application decisions are closely related to the farmer's estimate of how much water he or she will receive, and when he or she will get it. Once the planting and initial input applications have been made, the farmer has a substantial investment to protect against non-arrival of the expected supply".

Clemmens (1987:60) seem to summ up the above discussion when he states "That is obvious that in order to optimize the use of farm resources, flexibility in irrigation frequency is essential". He further points to another effect of water control, namely that it increases the efficiency of on-farm water use; If farmers lack water control "... the general tendency of farmers it to irrigate too soon and apply too much water.

To have water control means that the farmers are able to control one of the most important factors of production[4]. Water control is critical to farmers' decisions concerning which crops to grow, when to grow them, and whether or not to adopt new agro-technologies such as fertilizers, pesticides, and high-yielding crop varieties[5]. In other words, water control is of utmost importance for an increase in agricultural production[6].

Water control is both a technical and a social/political endeavor. Technical because the main and mesqa (watercourse) delivery systems must be physically capable of exercising this control[7]. Social/political because water control is an outcome of proper management at all levels of the irrigation system. Ultimately "water control is a function of collective actions and can be enhanced only through disciplined organizations (Freeman and Lowdermilk, 1991:122).

1.6 The Need To Improve Water Control In Egyptian Agriculture

Most large-scale irrigation systems are designed to operate as upstream control systems[8].

The sheer size of the systems, the functions they perform and the organizational levels involved, make them ill equipped in regard to the problems faced by farmers in securing local control over irrigation water (Freeman and Lowdermilk, 1991:119).

The Egyptian irrigation system is enourmous. Around 55 billion m^3 of water is annually stored and distributed to 2.8 million hectares of cultivated land holding 3.5 million individual farms. Further water is delivered for municipal and industrial use. It is used to generate hydroelectricity and facilitate navigation of freighters and tourist boats on the Nile.

Several research projects and studies provide ample evidence of the need for improvement in farmer water control in Egypt i.e. (Abu-Zeid and Rady, 1992:96; EWUP, 1984:11-26; IIP, 1990c:9; Replogle, 1986:119; World Bank, 1993:26).

These studies document how the operation and physical conditions of the delivery system places a significant constraint on improved farm water management. The rigidities of the present system do not allow for satisfying different water demands regarding frequency and quantity for different crops. One study points out that "Increased reliability, predictability and equity of water supplies are needed, especially at middle and tail reaches of canals, from April through August" (IIP, 1990c:9).

An in depth analysis of the water control situation in the three areas in which the field survey reported below was conducted, support the above findings.

Shortages of irrigation water during the peak summer period, severe inequalities in water distribution throughout the system, and deteriorating condition of the physical structures (canal and regulators) with which the water was managed, were found to be factors that all contributed to a near absence of water control in these areas (IIP, 1990a:3; IIP, 1991a:2/12; IIP, 1991b:2/12).

1.7 Methodology Of The Study

The primary data for the subsequent analysis was collected during October and November 1992 in three Canal Commands in Middle Egypt; Herz-Numaniya and Beni Ibeid located close to the city of Minya, and Qiman Arus, adjacent to the city of Beni Suef.

Data was collected through structured interviews undertaken by local interviewers. A total of 137 WUA council members were interviewed each located on different field turnouts (marwas). All the selected respondents had land on mesqas that was improved by IIP and had been in operation for more than 2 months.

The farmer interviews were supplemented by interviews with key informants in the areas, a review of the WUA's financial status and by physical measurements of i.e. land savings.

2. THE IMPLEMENTATION OF WUAS IN EGYPT

Implementation of WUAs in Egypt is conducted by the Irrigation Improvement Project (IIP) within the Ministry of Public Work and Water Resources (MPWWR). The project is financed by USAID and the MPWWR.

The IIP project is a pilot project designed to field test the outcomes of a 15 year research and field trial undertaking. The overall goal of IIP is to increase production and productivity in agriculture. More specifically it aim at improving the water delivery and distribution systems to at least 1200 mesqas (watercourses) commanding more than 38.600 hectares.

The project is designed to give guidance in the development of a process of water control and application to the MPWWR, including construction, training, capacity building, institutional and policy change. It field tests a shift from rotation to continuous flow at the branch canals, new application technologies at the mesqa level, and the formation of 1200 WUAs in a cross section of Egyptian environments (Devres Inc., 1993:xiv).

More specifically this includes

- A strengthening of the institutional capacity of MPWWR in managerial and administrative skills, and in operational policies and procedures
- Development of a rational interdisciplinary approach in planning, designing and implementing the renovation of specific canal commands
- Development of an Irrigation Advisory Service (IAS) to transfer water management technical information and technical assistance to WUAs
- Organization of operational WUAs in all IIP areas whose tasks include; scheduling of water delivery on mesqas, perform maintenance and resolve disputes, increase communication links between farmers and government officials, and the
- Establishment of policies and procedures for the recovery of an appropriate portion of operation and maintenance costs, and 100 percent of the nominal costs of mesqas and on-farm improvements.

Total funding requirement is budgeted at $ 63,389,000 for the period 1988 to September 1995 (Devres Inc., 1993:xviii).

IIP has defined a seven phase strategy to establish WUAs: entry, initial organization, preparation for mesqa improvements, participation in mesqa improvements, regular WUA operations, WUA federation and Monitoring and evaluation (IAS, 1992)[9]. The process is thought to gradually enable the WUAs to assume the feeling of ownership and responsibility for the mesqa improvements. All the surveyed mesqas were in the fifth phase; regular WUA operations.

Utmost care has be taken within IIP to design the WUAs in accordance with the traditional forms of farmer participation and conflict resolution which exist fully or in part today. These encompass the "Munawaba and Taraf" systems of leadership and water allocation at mesqa level, the "Saqia" ring for collective pumping of water, the "Haq ul Arab" (rights of the Arab) which is a traditional Islamic legal system for maintaining peace and resolving conflict, and finally contemporary law which designates water as a public good but the mesqa system as private property belonging to the water users (Aziz, 1994:1-3; Mehanna, Huntington, and Antonius, 1984:18-66 and 92-133).

Building the WUAs on theses traditional forms of participation is thought to increase the farmers' accept of the improvements, and securing a good foundation for building and maintaining strong farmer participation in the irrigation systems over time (Aziz, 1994:3).

From the above statements of goals and from the investigator's field experience, there can be no doubt that in fact a two legged implementation strategy is being followed; one that aims to build new agency structures and processes and; one that seeks to establish WUAs[10].

Emphasis on voluntary WUA membership and WUA participation in design and implementation of the improved mesqa systems has been difficult and has caused a lead time of several years prior to the finishing of the first mesqas[11]. This has however, created trustworthiness on behalf of IAS and farmers on non-improved mesqas are increasingly approaching the project with wishes to join it.

2.1 Experiences With Establishment Of WUAs

Below different sets of data are presented to indicate the strength of the WUAs. First, the degree to which essential organizational and knowledge attributes were implemented.

Table 1. Status of Implementation Organizational Features, by Age Groups, in Percentages.

	3-6 months N=52	7-10 months N=17	20-24 months N=68
Irrigation schedule exist	44,2	94,1	98,5
Accountant appointed	100	100	100
Financial record exist	90,4	100	100
Bank account established	59,6	100	100
Money in reserve fund	73,1	100	100
Pump operator appointed	100	100	100
Pump record exist	65,4	100	100

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The data depicted in Table 1 show that the WUA building process has succeeded in establishing, what is considered by IAS to be the essential organizational features to operate the improved mesqa systems. Basically the features are in place after the systems has been in operation for more than 6 months.

Another way to quantify the formation process of the WUAs is to consider the degree to which knowledge concerning the day-to-day operation was present among the water users.

The data in Table 2 below provide evidence that the level of knowledge concerning these issues improves over time. It is seen though, that the acquired level of knowledge differs according to the issue in question. The general picture is that the issues of most concern for the farmers i.e. the pumping charges, is fully known, while issues more remote to daily operation i.e. of how and where to get the pump fixed in case of a break down, is less well known. The reason for the lack of knowledge about the current irrigation schedule implemented on the mesqas is due to the fact that the schedules were changed quite frequently during summer season 1992 because of instability of the branch canal flows.

The data indicates that communication within the WUA is functioning well i.e. information on the monthly status of the different financial accounts seems to be widespread among the WUA members.

The level of knowledge reflects both the experiences the farmer has gained from operating the system, and the knowledge transferred through the IAS. As a part of the WUA formation process four courses are conducted by the IAS. A basic course in WUA formation and responsibilities, a course in financial accounting, a course in maintenance and finally a course in on-farm water management. The latter course however, was not offered prior to the time of this survey.

Table 2. Level of Respondents Knowledge about WUA Issues/Matters, by Age Groups, in Percentages.

	3-6 months		7-10 months		20-24 months	
	Good	Full	Good	Full	Good	Full
Irrigation schedule	25.0	44.2	58.8	41.2	10.3	88.2
Pumping charges	1.9	98.1		100	1.5	98.5
Repair charges	17.3	34.6	35.3	64.7	19.1	77.9
Where to fix pump	25.0	42.3	17.6	82.4	11.8	83.8
Balance bank account	7.7	59.6		100	1.5	98.5
Balance pump account	7.7	63.5	23.5	76.5	16.2	83.8
	N=52		N=17		N=68	

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Data reveal that 74 % of the respondents had taken part in one or more of these events. 13 % had participated in all 3 courses. Viewed by age groups app. 83 % of the WUA council members of mesqas older than 7 months had taken part in a training event while app. 63 % of the council members on mesqas less than 7 months had done so.

The relatively high level of acquired knowledge and implementation of the organizational features is taken to indicate two things: First, that the knowledge needed to operate the systems at this level of development does not exceed the capacities of the farmers, when they receive appropriate support from IAS. Secondly that the farmers have found it worthwhile to invest valuable time and effort in acquiring these skills and building the organizations.

A final issue in relation to establishing the WUAs is the contacts between WUA members and different categories of field staff.

Table 3. Quantity and Quality of Contacts between Respondents and Categories of Field Staff, Before and After IIP

N=137

	Average # of Contacts pr. month (means)		Usefulness of contacts (means, scale 0 <-> 5)		Pct. of farmers who know:	
	Before*	After	Before*	After	Name of Official	Where to contact official
MOA Extension worker	3.71	3.71	3.6	3.64	84.7	83.9
District Engineer	1.69	1.15	1.56	1.38	51.1	49.6
Gate Keeper	3.99	2.23	3.43	1.82	97.2	94.1
IAS Field Agent	1.4	4.52	1.47	4.53	92.6	91.9
IAS Engineer	1.08	4.04	1.22	4.08	89.7	88.2
IIP Design Engineer	0.72	1.44	0.67	1.57	22.8	25,0
IIP Construction Eng.	1.04	2.04	1.04	2.12	40.4	43.4

Note: A contact is defined as a situation when a water user and an official meet face to face to discuss issues and exchange information.

* "Before" refers to the period before the mesqa + pump started operation, but after WUAs was formed.

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The data depicted in Table 3 above provide evidence of a shift in the direction of farmer communication. Before the IIP improvements, the MOA extension worker, the Gate Keeper and to a lesser extent the District Engineer were the main sources of communication. After the implementation of the mesqa systems the number of contacts and the usefulness of these, has decreased for the latter two categories. One reason for this is that the job of the gate keeper has been made superfluous by the continuous flow system.

It is seen, that the IAS field agents and the IAS Engineer both have more than four face to face meetings with the farmers each month, and, more importantly, that the farmers consider these meetings "very useful". Furthermore both categories of field staff are well known in the areas. This indicates that IAS are doing their job. They are present in the areas on a daily basis, and they have managed to establish themselves as trustworthy and useful in the eyes of the farmers.

The latter two categories of IIP staff, the design and the construction engineers are only supposed to be in the field during the initial phase of construction.

2.2 Do The IIP Improvements Increase Water Control?

In operational terms water control can be analyzed under three headings; adequacy, reliability and fairness of water flows. Two indicators of adequacy will be represented; adequacy and number of days with critical water shortage

2.2.1 Adequacy

Table 4. Estimated Adequacy of Water Supply, Before and After IIP, in Percentages.

N=137

	Before IIP		After IIP	
	Winter	Summer	Winter	Summer
Never adequate	2.2	10.9		
Sometimes adequate	27.7	75.9	5.0	20.6
Adequate	70.1	13.1	95.0	79.4

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The data in Table 4 shows that following the IIP improvements a marked change in the estimated adequacy of water supply has taken place. Most notable is the change in relation to the summer data. From a situation where only 13.1 % found the water supply adequate to a new situation where app. 80 % rated the situation adequate. 74 % of the respondents reported improvements in the adequacy situation following the IIP improvements[12].

From Table 5 below it is seen that the number of days with critical water shortage is reduced following the IIP improvements. Before IIP a total of 2217 days with water shortages were reported. After IIP, the reported number was 322. This is a decrease of 85.5 %[13].

The number of farmers reporting days with critical water shortage before IIP is high. In the 3 critical summer months, more that half of the farmers in the sample (June 57 %, July 73 %, August 69 %) reported days with critical water shortages. Only app. 3% of the sample farmers gave such a report in the after situation[14].

Even though the reported data might be subject to some uncertainty, the differences between the situation before the IIP improvements and after is so distinct, that there can be little doubt that a sizable decrease in the number of days with critical water shortage has occurred as a result of the IIP improvements.

Table 5. Estimated Number of Days when a Critical Water Shortage that Affected Crop Yields Occurred, and Number of Farmers Reporting.

N=100*

	Before IIP # days	# farmers reporting	After IIP # days	# farmers reporting
February	61	5	20	2
March	67	6	20	2
April	76	6	20	2
May	90	9	20	2
June	520	57	44	3
July	704	73	57	3
August	588	69	57	3
September	70	6	42	2
October	41	3	42	2
Total	2217	234	322	21

* No reporting from Beni Ibeid

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2.2.2 Reliability

In the three areas surveyed only one of these, Herz-Numaniya, had an operational continuous flow system at the time of the survey.

Below, data on one aspect of the reliability situation of water flows are depicted. These data focus on the planning of the individual farmer. If an interruption in water supply is communicated to the farmers in advance, or if water arrives the exact day the rotation was supposed to begin, no deviations are reported. On the other hand, if water is not present when the farmer had reason to believe it would be, deviations exist.

This indicator is important because a range of production decisions in irrigated agriculture depends of the access to water at the time required.

Table 6. Estimated Number of Deviations From Planned Irrigations, Before and After IIP, in Percentages

N=137

	Before IIP Winter	Summer	After IIP Winter	Summer
Many deviations	0.7	3.6	1.0	0.7
Often deviations	8.8	22.6	1.0	0.7
Few deviations	41.2	64.2	1.0	16.8
No deviations	49.3	9.5	96.9	81.8

Note: Deviations listed under "Before IIP" refers to deviation in beginning and ending of rotation. In the "After IIP" situation deviation relates both to the main and mesqa system

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The data in Table 6 show that for both winter and summer season, the number of deviations are reduced following the IIP improvements.

For the summer season, prior to the IIP improvements less than 10% reported "no deviations". After the improvements more than 80 % reported "no deviations". At the other end of the scale, 26.2 % of the farmers reported "many or often deviations" before, and only 1.4 % after IIP.

In total, 86 % of the sample farmers report fewer deviations following the IIP improvements for the summer months.

For both winter and summer seasons a major shift has occurred in relationship to the number of deviations from farmers planned irrigations. In other words, the reliability of the water supply has increased.

2.2.3 Fairness

The term fairness as used here, reflects farmers' perceptions of what is fair and what is not fair. Those perceptions might differ from results of a strict physical measurement of water flows in mesqas.

There are technical reasons to assume that there will be only little Head-Tail (H-T) differences along the improved mesqas. The mesqa systems are designed so that the same quantity of water pumped into the system flows out into the marwas. So H-T differences in the delivered volumes of water will occur only to the extent that leakages or friction along the mesqa are factors. Friction decreases the velocity of the stream, but IIP measurements show that this only creates minor differences in the time used to irrigate i.e. one feddan at the head and at the tail reaches of mesqas.

At the old mesqas H-T differences are present if pumping from the mesqas exceeds the inflow to the mesqa. When heavy pumping takes place at the head of the mesqas this reduces the water level in the tail reaches. This implies that tail reach farmers usually cannot irrigate when the head section farmers irrigate.

Table 7. Estimated Fairness in Water Distribution along Mesqas, Before and After IIP, in Percentages.

N=137

	Before IIP	After IIP
Major Head-Tail differences	10.3	
Some Head-Tail differences	61	3
No Head-Tail Differences	28.7	97

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The data in Table 7 indicates a major shift in farmers perception of head-tail differences in water supply along mesqas. The H-T differences depicted before IIP have basically been eradicated.

The data depicts a rather uneven or unfair system of water distribution before the IIP improvements. All 13 persons (10 %) who report "major H-T differences" before IIP, were located at the tails of long mesqas (750 - 1000 m). Findings from a recent study point out, that major H-T differences are found too, in relation to the H - T sections of branch canals (IIP, 1990c:9). In other words the before situation was plagued by H-T differences not only at mesqas but also at canals. As shown in table 7 the former has been eradicated whereas no certain conclusion can be drawn concerning the latter from the survey data.

In summary, the above data have shown, that farmer water control has been increased dramatically following the implementation of the IIP improvements.

2.3 Micro-system Improvements. Do They Increase Water Control?

The IIP technological package included both improvement in the main system; continuous flow in the branch canals; and in the micro systems; improved mesqas with single-point lift and the establishing of WUAs to operate the mesqa systems. Bivariate analysis provide evidence, that above all, improvements in branch canal water supply is the main reason for the increase in farmer water control.

Thus, can the improvements in water control found above only be attributed to improvements in the main systems water supply - or do the improvements in the mesqa system contribute to this as well? In this section an attempt will be made, to differentiate between the effects of the main system and the micro system.

The data in Table 8 give an initial answer to this question.

Table 8. Estimated Adequacy of Water Supply, Before and After IIP, Summer Season, in Percentages.

	Before IIP Rotation (N= 136)	After IIP Without CF* (N=52)	With CF* (N=84)
Never adequate	10.9		
Sometimes adequate	75.9	51.9	1.2
Adequate	13.1	48.1	98.8

* CF = Continuous flow in branch canal

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The data show that at mesqas with non-operational continuous flow the estimated adequacy of the water supply has increased in relation to the before situation.

However with continuous flow in operation the increase is found to be much greater as compared to the situation before, and greater in relation to the after situation without continuous flow.

While this is not conclusive evidence, it is a strong indicator that improvement of the mesqa system in itself has an effect on the adequacy situation. An plausible explanation for the effect without continuous flow is that the adoption of technical, organizational and knowledge related aspects of the IIP technological package has put the farmers in far a better situation to take advantage of the present (unstable) water supply.

There are sound technical reasons to consider the argument to be valid.

First, in the old system mesqas were constructed with an intake pipe at a fixed level in relation to the water surface. This meant that water would only flow into the mesqas when the water rose above a certain level in the branch canal. Upstream or downstream use of water had a marked effect on the water level in a given location. Often it was found that the water level towards the tail of the canal did not allow for irrigation during the first couple of days of the rotations "on" period, while upstream users, took water. Because the intakes at the improved mesqas are lowered considerably in relation to the old intakes, there will simply be more hours out of the 5 days "on period" where water is accessible for the users at the improved systems.

Secondly, larger pump capacity is likely to be an important factor. In the before situation the intake pipe to the mesqa had a fixed diameter which only allowed a certain water flow, i.e. 30 l/sec. If total pumping along a mesqa exceeded inflow, the water level in the mesqa would drop causing the pumping to be reduced. At the improved mesqas, single-point pumping is done directly from the branch canal. Many mesqas have large pump sets which can handle a flow stream up to 120 l/sec.

Thirdly, it is likely that the scheduling of water along the mesqas, distributes the amount of water available more evenly among the farmers.

Further analysis reveal that the same farmers who reported an improved adequacy situation in Table 8, reported less ability to plan water usage, due to fluctuation in canal water supplies and rehabilitation work. This is taken as an indicator that the farmers have been capable of handling the water delivery/distribution with increased flexibility.

In support of this argument, the investigator has in many instances seen how a sudden interruption of branch canal water flows has been counteracted by WUAs operating the pump(s) for longer hours (i.e. 20 hours /day) when the water eventually returned. Farmers furthermore indicated, that in some instances thay have shared the available water by giving each farmer maybe 2/3 of his water needs, thereby providing water for more farmers.

The technical and organizational improvements have in other words improved the flexibility, thus increasing farmer water control.

2.4 WUA Organizational Strength. Does It Impact Water Control?

Based on the field experience, and the data presented above which have shown a consistent reporting of increased water control following the IIP improvements, the investigator is of the opinion that this would not - and could not - have been the case if the mesqa system was established technically but not organizationally[15].

No indications are found that inadequate water delivery was caused by organizational problems. The data provide ample evidence however that technical problems with mesqas, pumps, and lack of continuous flow was to blame for inadequate or untimely water supplies, but nowhere could this be contributed to deficiencies in the WUAs.

The table below provides information that the strength of WUA organizations influences the reliability of the water supply.

Table 9. Stratified Analysis; Continuous flow, Number of Deviations from Planned Irrigation and WUA Organizational Strength, Summer Season, after IIP, in Percentages.

Continuous Flow	# deviations	WUA Organizational strength Weak	Strong
Not in operation	Some deviations	55.9	27.8
	No deviations	44.1	72.2
In operation	Some deviations	3.3	
	No deviations	96.7	100

/M. Hvidt, Odense University, Denmark, 1994

Table 9 shows that for mesqas at branch canals with non-operational continuous flow; respondents with strong WUAs reports far less deviations than respondents with weak organizations. The difference is 28.1 %.

On the other hand, for farmers at branch canals with continuous flow fully operational, no differences is reported in relation to organizational strength.

This indicates that when branch canal water supply is adequate, reliable and fair, the strength of the WUAs does not influence water control. However when the branch canal water supply is not adequate, reliable and fair, the ability of the farmers to plan water usages is dependent (Gamma = 0.53) of the strength of the organizations.

At first sight this is a discouraging finding. If the irrigation agency is capable of supplying continuous flow in the main canals, there seems to be little reason to invest the time and effort in creating strong WUAs. However, is it likely that the agency is capable of doing exactly that? Experiences from the time elapsed since the survey was conducted point to the fact, that it is difficult (maybe impossible) to keep continuous flow in operation without any interruptions.

Besides the technical, operational (and political) issues involved in maintaining continuous flow, demand for water is increasing due to population pressure and scarcity in the Nile system is becoming a threat to agricultural production at the turn of the century (Abu-Zeid, 1992:14). Inevitably the tighter the resource, the more likely fluctuations or interruptions in the flow will be if the capacity to plan and operate the system is not fully developed (Wiener, 1977:78). In other words, there are reasons to believe that water supply interruptions (crisis) are to be seen as a permanent feature of large-scale irrigation systems, at least in peak water demand periods.

A second point is that the farming system was not yet developed to an extent, where organizational strengths of the WUA would be expected to show a major impact on water control.

This survey has dealt with the first two years of experiences of the IIP improvements. Only minor changes in crop patterns in the direction of higher yielding and more moisture sensitive crops (i.e. vegetables) had taken place.

It is to be expected that with the highly diversified (and moisture sensitive) cropping pattern made possible by the IIP improvements, the need for flexibility in water delivery and operational efficiency will grow increasingly essential to the farmers. And to accommodate that end, the dependency on strong and well functioning WUAs will increase. In other words, an increased specialization in the farm production system, demands increased WUA organizational strength.

3. SUMMARY AND CONCLUSION

This paper has dealt with the initial experiences in implementing WUAs in Egypt.

From the literature survey, it was pointed out that WUA approach to improved system performance was a tool invented by bureaucrats and state planners to improve agricultural production/productivity and to make farmers pay for the improvements they receive.

The goals to be achieved by involving farmers in design, operation and maintenance of irrigation were found to encompass 1) Greater production and productivity 2) Improved water distribution 3) Reduction in conflict 4) Greater local resource mobilization, and 5) Sustained system performance.

This paper delimited itself to analyzing the question of WUAs effect on water control, that being a key variable in obtaining the above mentioned range of goals.

The implementation experience of WUA in Egypt was analyzed. It was found that IIP emphasized a two legged strategy aiming both at the creation of agency procedures that allow farmer participation and the actual formation of WUAs. In relation to formation of WUAs it was found, that the strategy was to secure compatibility with traditional ways, in which farmers has been participating in irrigation management at micro-level.

Data on the establishment of the WUA were presented, revealing that a considerable level of both organizational strength and knowledge had been reached among them. This indicated that the farmers had found it worthwhile to invest valuable time and effort in the WUA building process.

Data were presented on improvement in water control following the IIP implementation. In relation to adequacy, reliability, and fairness of water supplies, evidence was found, that the improvements had substantially increased farmer water control. If was found though, that the main determinant of improved water control could be attributed to the improvements in the branch canal water supply.

An analysis of the extent to which the micro-system improvements (technique, organization and knowledge) in themselves had contributed to improving water control was carried through. It was found, that a positive effect on water control was attributable to the micro-systems even without improvements in the branch canal water supply. Further analysis showed that this was due to a higher level of flexibility resulting both from the technical and organizational aspects of the improvements.

Finally the impact of WUA organizational strength on water control was analyzed. It was found, that the strength of WUAs did have an impact on water control in situations when instability in the branch canal water flows occurred.

It was argued that the role of WUAs in securing water control was likely to become more prominent in the future. It was argued that instability in water flows would always occur due to operational problems and increased water scarcity. Further it was argued that WUA organizational strength first becomes really important in relation to exercising water control when the farming system has had time to develop a highly diversified and moisture sensitive cropping pattern. In such a situation the substantial investments the farmers are to foresee if very precise water control is not exercised, places increased demands on the organizational strengths of the WUAs.

Notes

[1] Personal discussion with Dr. Max Lowdermilk.

[2] The issue is felt ownership of the system. For a further elaboration of this point see (Bromley, Taylor, and Parker, 1980; Coward, 1983:218; Lusk, 1991; Lusk and Parlin, 1991)

[3] There seems to be a general consensus about these objectives in the irrigation management literature. See i.e. (Clyma and Lowdermilk, 1988:10). Here quoted from (Uphoff, Ramamurthy, and Steiner, 1991:59).

[4] In arid areas like Egypt.

[5] Studies from Pakistan and India show that improved water control results in higher cropping intensities, larger inputs of fertilizers, higher yields, and greater income per hectare (Lowdermilk, 1990:156).

[6] Other positive effects of improved water control encompass i.e. energy conservation and improved sustainability of the production environment due to lower water use.

[7] For an in depth discussion of this point see i.e.(Burt, 1987)

[8] Scale is defined by the size and tiers of organization of the system. Small-scale systems may have one or two levels of operation and control structures. Medium-scale three or four levels of operation at which water flows can be reduced and/or divided by control structures. Large-scale systems often have five or more levels, and serve an area between 20,000 to over 400,000 hectares (Uphoff, Ramamurthy, and Steiner, 1991:33). The Egyptian irrigation system serves more than 2.8 million hectares!.

[9] For a further explanation of these phases see (IAS, 1992)

[10] For a review of the status of the implementation of both see the following reviews of the IIP project (Devres Inc., 1993; Laitos, 1992).

[11] Encountered problems; i.e. lack of demonstration mesqas, unclear policy on cost recovery, misunderstandings among farmers on the technical features of the system, resistance from farmers who owned pumps and made an incremental income on renting pumping services to other farmers prior to the improvements etc.

[12] Calculated for the summer season.

[13] The decrease of 85 % is thought to be a conservative figure. In Beni Ibeid an average of 19 farmers pr. month reported days with critical water shortage. These data however are not included in Table 5 because of farmers inability to provide exact number of days.

[14] The age of the mesqa improvement influences the finding considerably. For the category of mesqas over 20 months the decrease is from 1607 days to 40 which is equal to a decrease of 97,51 %. For the young mesqas (< 6 months) the decrease was 48 %.

[15] This argument refers to the theoretical point that a technology needs to be developed both technically, organizationally, knowledge vice and product wise if it is to be fully operational. For an in depth discussion of this point see (Müller, 1980: chapter 2)

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PLANNING AND MANAGEMENT MODELS FOR CONJUNCTIVE WATER USE

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ABSTRACT

Selected planning and management models for conjunctive water use are elaborated. First, a three-step modeling approach is presented for comprehensive analysis of the planning problem involving integrated use of surface and ground water in irrigation. Applicability of the approach is illustrated by a case study of the Bagmati River Basin in Nepal. The second case study dealt with the problem of environmentally sound and sustainable utilization of existing sources of water supply for municipal and industrial purposes in Greater Kathmandu, Nepal. A systematic analytical approach based on the linear programming optimization technique and multiple objective is proposed to identify and analyze different alternative management plans and policies for the integrated use of surface and ground water.

Résumé

Les modèles sélectionnées de planification et de gestion pour l'utilisation conjonctive des eaux sont élaborées. Premièrement, une approche de modélisation à trois-pas est présentée pour l'analyse complète du problème de planification concernant l'utilisation intégrée des eaux superficielles et souterraines dans l'irrigation. La capacité d'application de l'approche est illustrée par l'étude de cas du bassin de la rivière Bagmati en Népal. L'étude de cas seconde a traité avec le problème de l'utilisation soutenable en bon état en environnement des sources existantes de l' alimentation en eau aux buts municipals et industriels en Greater Kathmandu, Népal. Une approche systématique analytique, basée sur la technique optimale de la programmation linéaire multiobjective, est proposée pour identifier et analyser des plans et politiques differentes interchangeables de gestion pour l'utilisation intégrée des eaux superficielles et souterraines.

1. INTRODUCTION

Conjunctive use refers to the integrated use of surface and ground water with the objective of attaining an optimum level of utilization of the available water resources. The development

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of such a strategy both at regional and project levels is a complex undertaking involving many scientific, engineering, socio-economic and management aspects. This cannot be successfully achieved by adhoc decisions; it is necessary to base the decisions on scientific analysis or rational judgement. "Systems approach" and its frame work consisting of mathematical models, has long been used in analyzing large and complex water systems. The concept of integrated use originated in the later 1940's in the arid Western United States in response to the growing water problem of that period (Aron et al, 1974). Today, the combined use concept has been widely accepted by water resources planners and is considered to be a prerequisite for optimal water resources utilization of a region.

Several studies have been carried out on the subject of integrated use of surface-and ground- water resources in the past and different approaches of mathematical modeling have appeared in the literature (eg. Buras, 1963; Dracup, 1966; Nieswand and Granstorn, 1971; Aron et al, 1974; Louie et al, 1984; Randall et al, 1990; Onta et al, 1991). In many developing countries, however, efforts are yet to be put together to address this question of integrated water use in a systematic manner leading to the optimum use of available resources. For practical applications, the integrated use model should incorporate important physical, environmental, and socio-economic characteristics of the system while at the same time it should also be less data intensive and computationally feasible. This paper addresses to the need for the integrated water use under two different contexts, one refer to the irrigation development and the other related to the urban water use management. The emphasis is on the development of methodology considering the water resources systems variability and other technical features maintaining an appropriate balance between accuracy and sophistication of methodology so that the derived policies and strategies would be adaptable in practice. Both case studies are taken from Nepal: the water use for irrigation is for the Bagmati River Basin, and the urban water use is for the City of Kathmandu.

2. IRRIGATION WATER USE : BAGMATI RIVER BASIN

The Bagmati River Basin is a medium-sized basin representative of numerous river basins in southern Nepal (Fig.1). The basin has a potential for multipurpose development with primary benefits from irrigation and hydropower. But considering practical issues and the government's policy, only shallow tube wells in conjunction with irrigation canals are considered to be feasible components of the conjunctive-use system. Out of the gross command area of about 2,000 km^2 and the arable command area of 1,200 km^2, the study considers only the first development phase, in which intensive agriculture development plans exist for 680 km^2 of the net command area.

The Bagmati River, predominantly rain fed (by monsoons), is the primary source of surface water. Considering the seasonal variability and inherent uncertainties of rainfall and streamflow, and the expected performance levels of the irrigation project in satisfying the needs of intensive agricultural development programs, natural rainfall and streamflow cannot meet the irrigation water requirements of the basin. Therefore, ground-water use in conjunction with surface water is inevitable. The shallow aquifer, which is the principal aquifer planned for utilization, is alluvial and unconfined. In general, the ground-water potential based on the lithology and water-table information is good. Detailed water resources and water demand

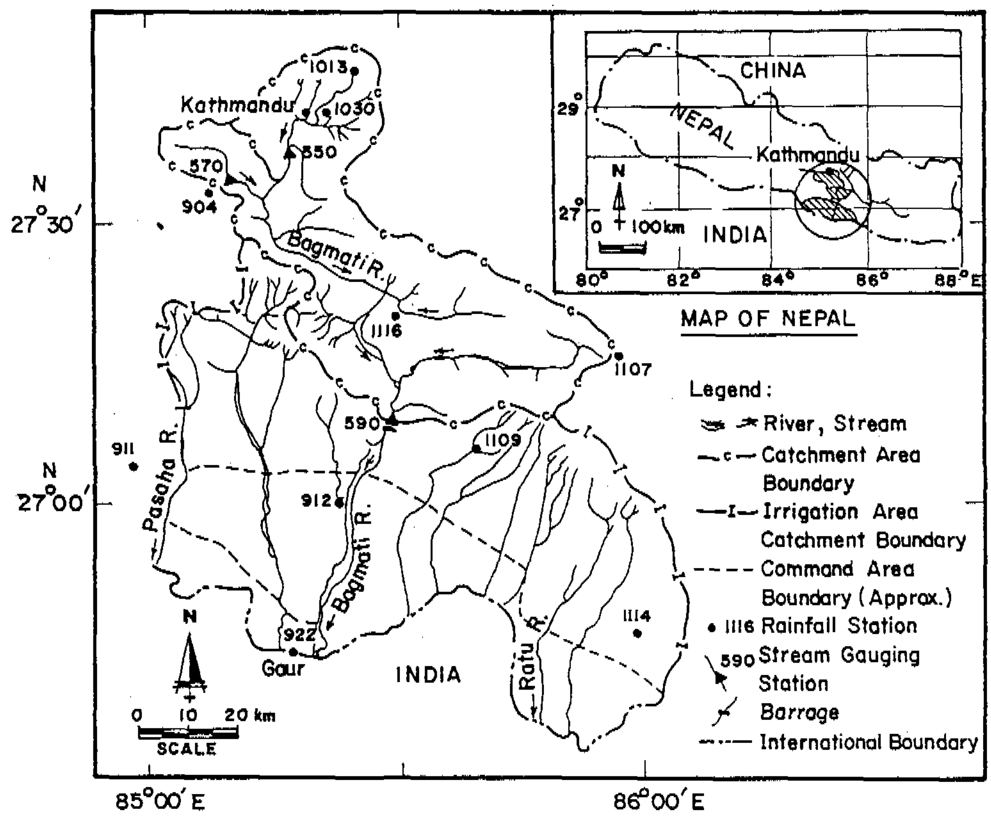

Figure 1. Location map of Bagmati River Basin, Nepal

assessments are presented by Onta (1991).

2.1 Model Formulation

A conceptual diagram of the conjunctive-use system is shown in Fig.2. The conjunctive-use planning problem is addressed through the following three-step analytical procedure : (1) determining the optimal operating policies of the selected conjunctive-use system alternatives by a stochastic dynamic programming (SDP) optimization model ; (2) evaluating performance of the alternatives by simulating the operation of the system over a long period of time ; and (3) choosing the best or most satisfactory alternative design or operating policy by means of a suitable multiple-criteria decision-making technique based on known or anticipated decision makers' preferences.

2.1.1 Step one : stochastic dynamic programming model

A consolidated objective function of minimizing the expected value of total (fixed and variable) costs of developing and managing the conjunctive-use system over the planning period is considered to reflect the different interests of the government and farmers. For a specified planning and design alternative, the objective is to determine a long-term operating policy so that the expected value of the total annual cost of operation is minimized.

$$Min\ Z = E\left[\sum_{t=1}^{T}(W_1 cr_1 QS_t + W_2 cr_2 QG_t h_t)\right] \tag{1}$$

where cr_1 and cr_2 are the unit costs of operating surface-and ground-water system, respectively; QS_t is the surface-water diversion during period t; QG_t is the ground-water pumping during period t; h_t is the lifting head for ground water from surface; W_1 and W_2 are the weights given to cr_1 and cr_2, reflecting the relative preferences or subsidies given to surface-water and ground-water use, respectively; t is the time period (season); T is the total number of planning periods (seasons per year); and E is the expected value of the random variables.

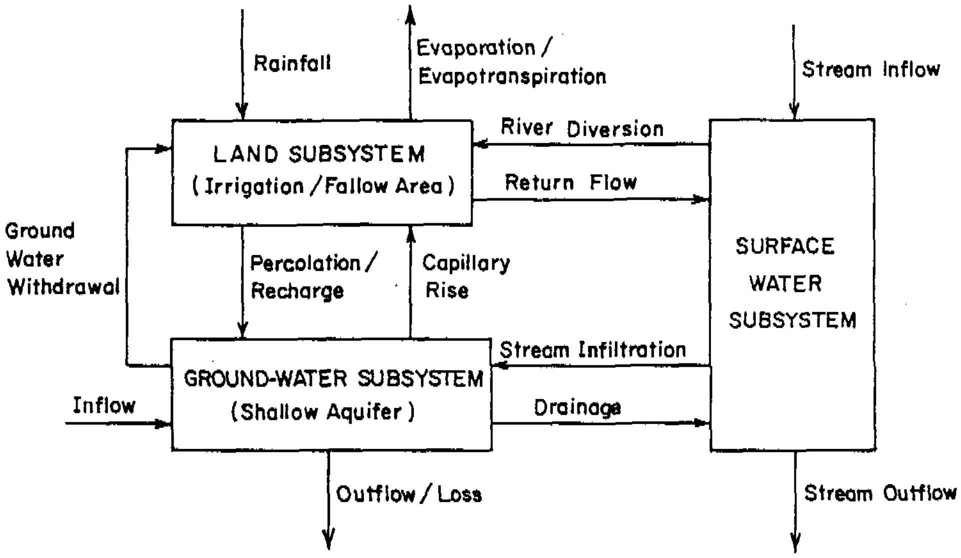

Figure 2. Conceptual model of conjunctive-use system

Since the system performance/functional defined by Eq.(1), subject to specified system and operational constraints, forms a multistage discrete-time optimal control problem, a recursive backward-looking SDP algorithm is used to solve the problem. From a practical point of view, only aquifer storage volume (and not the random natural recharge) is explicitly considered a state variable, and ground-water pumpage is considered a decision variable. Since natural recharge on a seasonal (four-month) basis for the representative basin was found to have low autocorrelation, thus indicating independence between two consecutive recharge values, the SDP recursive equation is expressed in the following probabilistic form

$$f_t^n(SG_t) = \min_{QG_t}\left\{\sum_{R_t} P(R_t)\,[C_t + f_{t+1}^{n-1}(SG_{t+1})]\right\} \tag{2}$$

for all SG_t and QG_t feasible, where $P(R_t)$ is the unconditional probability of recharge in within-year period t; n refers to the total number of periods remaining before the system operation ends; QG_t refers to the feasible pumping policy; R_t denotes the random natural recharge due to rainfall and streamflow; C_t is the cost in period t associated with an initial aquifer storage value of SG_t, a recharge R_t, a pumpage of QG_t (and the related diversion of QS_t) and a final storage volume of SG_{t+1}; and f_t^n (SG_t) is the value in period t of the minimum expected operation costs obtainable in the next n periods when one starts in SG_t denoted by initial state k. The expected value is taken over all possible recharge values.

The system in each period is subject to the constraints on maximum feasible (canal and tube well) system capacities, surface-and ground-water availability, irrigation water demand, maximum and minimum permissible aquifer storage state limits, and mandatory downstream water requirements. The state transformation equation of the dynamic system is described as

$$SG_{t+1} = SG_t+QSr_t+QGr_t+Pr_t+Qr_t+Ar_t+I_t-O_t-E_t-QG_t \tag{3}$$

where SG_t, QSr_t, QGr_t, Pr_t, Qr_t, Ar_t, I_t, O_t, E_t and QG_t are, respectively the ground-water storage at the beginning of the period, surface-water irrigation recharge, ground-water irrigation recharge, rainfall recharge, streamflow recharge, artificial ground-water recharge, ground-water inflow or gain, ground-water outflow or loss, evaporation, and pumpage from ground-water reservoir during period t. It is noted that Pr_t and Qr_t jointly represent R_t.

If Eq.(2), subject to the preceding constraints, is solved recursively, working backward in time for each period in successive years, the policy QG_t (and QS_t) defined in each particular period t will eventually repeat itself in each successive year and the expected annual system performance, which is the difference between the objective function values f_t^{n+T} (k) and f_t^n (k), is constant for all k and t. The operation policy is then said to reach the steady-state condition. In practice, the termination criterion is considered to be satisfied when the preceding differences are within reasonable allowable limits.

2.1.2 Step two : simulation model

The simulation model, lumped in character, is based upon the same state transformation equation, constraints, and set of input data as the SDP model. However, actual values of the state and decision variables are used, rather than the class values. Simulation consists of routing the generated rainfall and streamflow sequences through the conjunctive-use system season by season, obeying the SDP operating rules as far as possible and keeping an account of surface- and ground-water used (which indicates the level of benefit produced annually), number of failures to meet certain proportion (assumed to be 95% in the present study) of the irrigation demand in each season, the shortages involved, and the annual operation costs.

2.1.3 Step three : multicriteria analysis

A popular distance-based technique, called compromise programming (CP) (Zeleny, 1982) has been selected for the present study. CP is an approach that identifies solutions closest to the ideal solution by some distance measure. The measure of distance to ideal value of the objectives, which is minimized in CP, is the so-called L_p - metric, which can be defined, for alternative j, as

$$L_p(j) = \left(\sum_{i=1}^{N} w_i^p \frac{|f_i^* - f_{ij}|^p}{|M_i - m_i|^p} \right)^{1/p} \tag{4}$$

where $L_p(j)$ is the L_p - metric for alternative j ; w_i is the weighting factor for objective or criterion i; f_{ij} is the value of objective or criterion i attained by alternative j; M_i and m_i are the maximum and minimum values, respectively, of f_{ij} for all j; f_i^* is the ideal (preferred) value of objective or criterion i; and p is the parameter reflecting the attitude of the decision maker.

2.2 Model Application

2.2.1 Input and parameter

Summary of model input and system parameters are provided in Table 1 and 2. The total natural recharge was considered to comprise two components : (1) deep percolation from natural precipitation over the aquifer area; and (2) infiltration from various streams (including the Bagmati River) running across the study area. Recharge coefficients for rainfall were computed from a water balance analysis and those for streamflow were based on site-specific information. Aquifer storage values were computed based on aquifer area, specific yield, maximum permissible economic depth of pumping (maximum control depth) and the depth of water table below top at any time period, with the minimum control depth governed by waterlogging conditions. The total maximum canal conveyance capacity was taken as 1183.64 Mm^3 on a seasonal basis. Shallow tube-well capacity, a decision variable for the overall analysis, was considered to range from 300 Mm^3 to 600 Mm^3 with 16 representative class values each.

The surface water availability was based on the seasonal 80% reliable flow of the Bagmati River. The seasonal net irrigation requirements were computed based on the proposed cropping pattern and the crop water requirements calculated using the standard procedure (FAO, 1977) and the site-specific information. The net aquifer loss or gain was assumed to be negligible. However, loss due to evapotranspiration from ground water was considered as a function of the water table depth below ground surface and the potential evapotranspiration. Unit benefit and cost (capital as well as operation and maintenance) figures were used in the form of equivalent uniform annual values (derived as the economic values at the end of 1988, with official exchange rate of 1 US$ = 25.30 NRs, Nepalese Rupees).

Table 1. Seasonal input data for SDP and simulation model

Description	Season		
	Dry	Wet	Winter
Net irrigation requirement (Mm^3)	278.08	454.37	204.27
Evaporation loss rate (mm)	636	592	308
Ground-water loss (Mm^3)	0	0	0
Rainfall recharge coefficient	0	0.22	0
Stream recharge coefficient	0.19	0	0.12
Available streamflow (Mm^3)	124.59	2534.64	282.01
Irrigation water demand (Mm^3)	278.08	454.37	204.27
Note : Dry = February - May ; Wet = June - September ; Winter = October - January			

Table 2. System parameters for SDP and simulation models

Description	Value
Surface-water system efficiency (%)	45
Ground-water system efficiency (%)	45
Surface-water system recharge coefficient	0.1
Ground-water system recharge coefficient	0.1
Aquifer area (km^2)	1,000
SW unit O&M cost (10^3 NRs/Mm^3)	19.3
GW unit O&M cost (10^3 NRs/Mm^3/m)	2.86
Specific yield	0.15
Critical evaporation depth (m)	3.5
Maximum aquifer depth (m)	19
Maximum control depth (m)	9
Minimum control depth (m)	1.5

2.2.2 Results and discussion

The SDP-derived steady-state (pumping and diversion) operation policies for different alternative pumping capacities are obtained as a function of initial storage class or the corresponding depth of ground water below surface. Fig 3 provides policies for different seasons of selected pumping capacity of 450 Mm^3. Results were generally similar for other pumping capacities. As intuitively understood, ground-water pumpage generally decreases (and surface-water diversion increases) with greater water-table depth, signifying the strong influence of nonlinear pumping cost, which depends both on the pumpage and the average pumping depth. Below a certain depth, which varies with seasons, the policy is to not pump at all to minimize costs, and the whole demand tends to be met through surface-water allocation. There is more pumpage in the wet season, when water demand also is high, followed by winter and dry seasons. This can be attributed to the comparatively high recharge in the wet season. This results in a high water table, with the effect that the pumping cost becomes competitive with the cost of diversion. There also is a tendency to pump more to try to maintain the upper control level of the water table at 1.5 m below ground surface to avoid waterlogging.

For each design alternative (pumping capacity), the conjunctive-use system operation policies were evaluated through simulation using five different sets of 50-year, mutually related rainfall and streamflow sequences. The average of five runs provided the average figures for several cost, benefit, and reliability-based performance indices. Reliability-based performance indices are adopted from Hashimoto et al. (1982), and Duckstein and Plate (1987). Overall reliability (OR) is considered as the probability of nonfailure within the planning period. From an irrigation management point of view, shortfalls mostly occur in dry and winter seasons. Cost due to shortfalls are greater in these seasons due to the presence of high-value crops, which are much more sensitive to water shortages than paddy crops planted in the wet season. Therefore, the more severe dry season reliability (DSR) also is considered. Vulnerability (VUL) is the magnitude of the largest deficit during the period of planning or operation. It gives a measure of the significance or consequences of failure. Resiliency (RES) is considered the maximum number of consecutive periods of shortages that occur prior to recovery to an acceptable state within the planning period. These four reliability indices provide a complete picture of risk or reliability in conjunctive-use system performance. Average performance values of the alternatives are presented in Table 3. Conflict among different performance measures generally is observed. Therefore there should be a trade-off among these indices.

Table 3. Average performance values of alternatives

S.No.	Alternatives	Criterion					
		TAC (10^6 NRs)	TABE (Mm^3)	OR (%)	DSR (%)	VUL (Mm^3)	RES (Season)
1	Alternatives 1 (PC = 300 Mm^3)	268.773	1,891.063	65.2	0.0	263.131	1.0
2	Alternatives 2 (PC = 375 Mm^3)	282.551	1,968.774	68.0	4.8	198.697	1.4
3	Alternatives 3 (PC = 450 Mm^3)	301.964	2,035.356	79.9	39.6	181.184	1.8
4	Alternatives 4 (PC = 480 Mm^3)	313.801	2,050.096	87.6	62.8	245.462	2.0
5	Alternatives 5 (PC = 525 Mm^3)	317.960	2,062.708	95.9	88.4	258.327	1.6
6	Alternatives 6 (PC = 600 Mm^3)	323.038	2,063.331	96.0	88.8	274.647	1.0

Note : TAC = total annual cost; TABE = total annual benefit equivalent; OR = overall reliability ; DSR = dry season reliability ; VUL = vulnerability; RES = resiliency ; and PC = pumping capacity.

Table 4. **Input data for compromise programming**

S.No.	Criterion or objective	Relative weightage w_i	Maximum Value M_i	Minimum Value m_i	Ideal value f_i^*
1	Total annual cost (10^6 NRs)	0.250	323.040	268.770	268.770
2	Total annual benefit equivalent (Mm^3)	0.250	2,063.330	1,891.060	2,063.330
3	Overall reliability (%)	0.125	96.0	65.2	96.0
4	Dry season reliability (%)	0.125	88.8	0.0	88.8
5	Vulnerability (Mm^3)	0.125	274.650	181.180	181.180
6	Resiliency (Season)	0.125	2.0	1.0	1.0

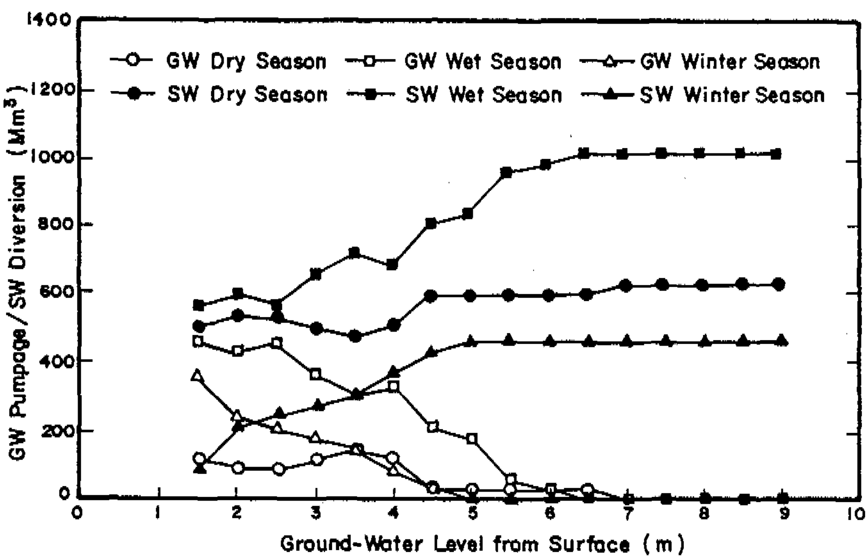

Figure 3. SDP steady-state policies (Pumping capacity = 450 Mm³)

Values obtained after simulation, presented in Table 3 and 4, form the input to the subsequent selection of the "best" alternative. Evaluation of the alternatives was done by computing the distance parameter L_p with the preferences of the decision makers provided by defining the set of weights w_i^p. For each alternative, L_p -metric was computed for several values of p using Eq.(4). Parameter p reflects the decision maker's concern with respect to maximal deviation from the ideal solution. The larger the value of p, the greater the concern and the larger the weight given to larger deviations. For p = 1 all deviations are weighted equally, while for p = 2 each deviation is weighted in proportion to its magnitude. For p = ∞, the min-max alternative is selected (only the maximum deviation counts). Results of the analysis are presented in Table 5.

Evaluation of the compromise programming results indicated that for equal importance of the economic (cost and benefit) and the reliability criteria, alternatives 6, 3, and 2 (pumping capacity, PC = 600, 450, and 375 Mm^3) had the minimum values of L_p for p = 1, p = 2, and p = ∞, respectively. When the economic criteria are weighted heavily (0.7) against reliability indices (0.3), the choice is alternative 3 for p = 1 and alternative 2 for p = ∞. For p = 2, both alternatives 2 and 3 yield the same value of L_p. When reversal of the preference takes place with reliability criteria weighted heavily (0.7) against economic criteria (0.3), alternative 3 is preferred for p = 2 and p = ∞. Alternative 6 is the choice only when p = 1. By weighing each deviation from "ideal" in proportion to its magnitude (p = 2), alternative 3 is found to be the preferred alternative for different relative weights considered. However if economic measures receive more weight, alternative 2 is the preferred one.

Table 5. Evaluation of alternatives by compromise programming

S. No.	Weight w_i	Alterative *j*	Lp(j)		
			p=1	p=2	p=∞
1	w_1 = 0.250	1(PC = 300 Mm^3)	0.610	0.325	0.250
	w_2 = 0.250	2(PC = 375 Mm^3)	0.506	0.230	<u>0.137</u>
	w_3 = 0.125	3(PC = 450 Mm^3)	0.428	<u>0.210</u>	0.153
	w_4 = 0.125	4(PC = 480 Mm^3)	0.508	0.263	0.207
	w_5 = 0.125	5(PC = 525 Mm^3)	0.407	0.260	0.227
	w_6 = 0.125	6(PC = 600 Mm^3)	<u>0.375</u>	0.280	0.250
2	w_1 = 0.350	1(PC = 300 Mm^3)	0.566	0.372	0.350
	w_2 = 0.350	2(PC = 375 Mm^3)	0.464	<u>0.236</u>	<u>0.192</u>
	w_3 = 0.075	3(PC = 450 Mm^3)	<u>0.412</u>	<u>0.236</u>	0.214
	w_4 = 0.075	4(PC = 480 Mm^3)	0.486	0.307	0.290
	w_5 = 0.075	5(PC = 525 Mm^3)	0.426	0.326	0.317
	w_6 = 0.075	6(PC = 600 Mm^3)	0.425	0.358	0.350
3	w_1 = 0.150	1(PC = 300 Mm^3)	0.653	0.328	0.175
	w_2 = 0.150	2(PC = 375 Mm^3)	0.548	0.259	0.166
	w_3 = 0.175	3(PC = 450 Mm^3)	0.445	<u>0.215</u>	<u>0.140</u>
	w_4 = 0.175	4(PC = 480 Mm^3)	0.530	0.256	0.175
	w_5 = 0.175	5(PC = 525 Mm^3)	0.387	0.224	0.144
	w_6 = 0.175	6(PC = 600 Mm^3)	<u>0.325</u>	0.230	0.175

3. Urban Water Use : Greater Kathmandu

The Greater Kathmandu lies in the Central Development Region of Nepal with an area of about 899 sq. km. (Fig. 4). Due to rapid and uncontrolled urbanization during the last decade, associated urban problems - particularly the water related quantity and quality problems - have grown out of proportion. The Bagmati river is the only river system in the valley which collects and drains water from the basin. All Bagmati tributaries originate in the surrounding hills and flow into the Bagmati mainstream. The major tributaries are Nakhu khola (khola means stream), Khodu khola, Balkhu khola, Bishnumati khola, Dhobi khola, Manohara khola, Godawari khola, Hanumante khola. The watershed is intend circular in shape with an area of 585 sq. km. at the outlet of the basin located near Chovar (Fig. 4). The landform of the Kathmandu valley is mainly classified into three categories of flat plains, high relief areas and gently inclined slopes. Based on the physical and geological characteristics, Kathmandu valley may be divided into three groundwater districts, *viz.* Northern, Central and Southern, as shown in Fig. 4.

3.1 Water Supply and Water Demand

The water supply systems managed in the Greater Kathmandu by the Water Supply and Sewerage Corporation (WSSC) can be broadly classified into six categories, i.e. Balaju, Maharajgunj, Bansbari, Sundarijal, Mahankalchaur and Shainbhu. At present there are five main reservoirs for city water supply, viz. Balaju, Maharajgunj, Bansbari, Mahankalchaur and Shainbhu. Existing intake sites are also shown in Fig. 4. Monthly available water for future water supply plans in Greater Kathmandu has been studied by JICA (1990). They have computed the maximum available water at 80% dependability at various points of streams within Kathmandu valley.

With available information on aquifer characteristics, the annual safe yield is estimated at 16.6 Mm^3 (Shrestha, 1990). Most of the rechargeable areas are confined in high flat plains and alluvial low plains and 69% of the total rechargeable area of about 86 sq. km is in the northern district. The central district is confined by thick clay covered by impervious deposits. The abstraction of ground water by private tubewells began in 1960 but the rate of withdrawal was less than 1 million litres per day (Mld) until 1976. Since 1979, the WSSC constructed tubewells under various projects became operational. These tubewells are mostly located in the northern zone and the total ground-water abstraction was about 34 Mld in 1987. According to Binnie and Partners (1989), WSSC tubewells would have an abstraction capacity of 43 Mld by 1991.

JICA (1990) has estimated monthly water demand based on the actual consumption pattern. The estimated average water demand of Greater Kathmandu is 113.8 Mld for the year 2001. Estimated available surface water supply and water demand in the year 2001 are provided in Table 6. It can be seen that severe shortage is likely to occur during dry months.

3.2 Model Formulation

The conceptual diagram of the system is depicted in Fig.5. To simplify the model, all

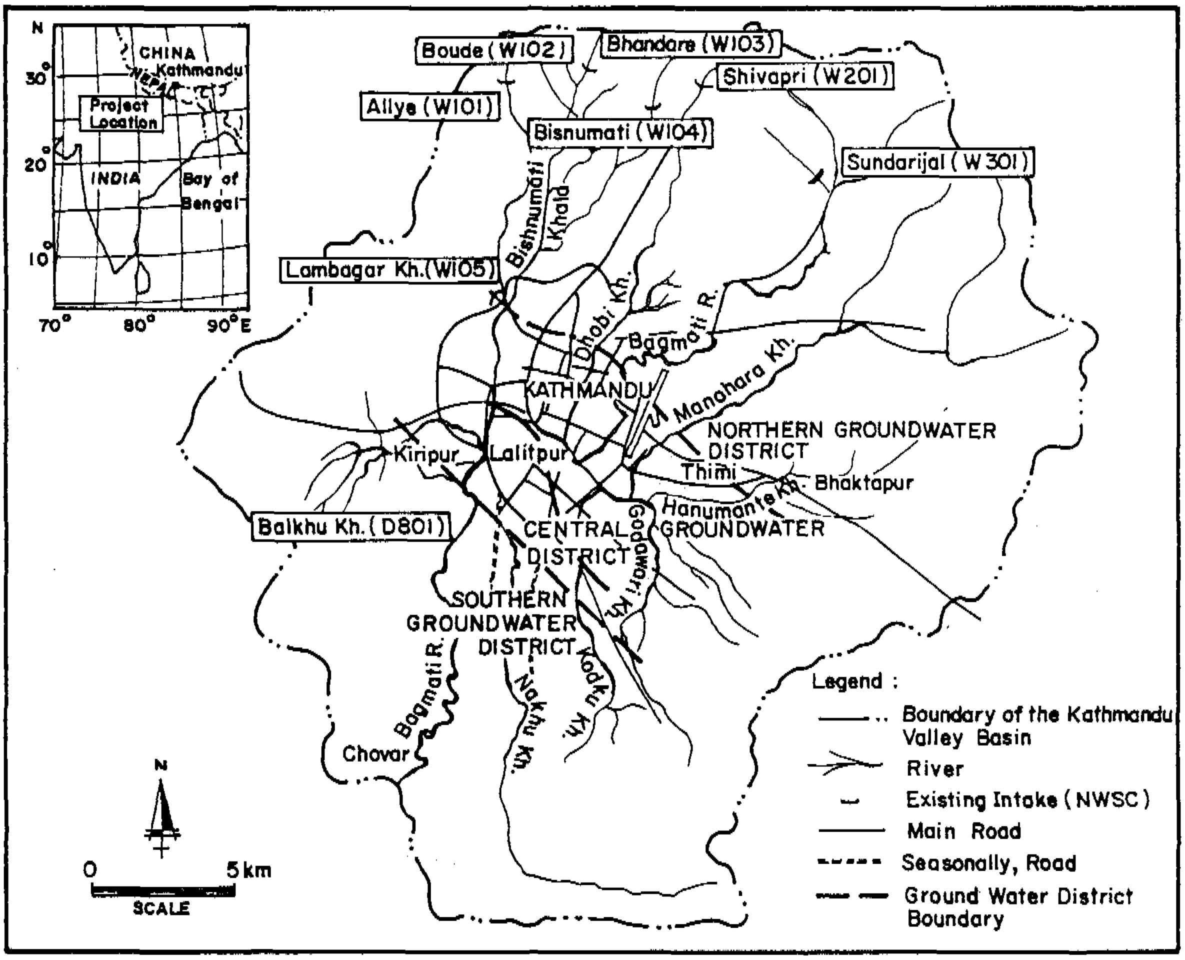

Figure 4. Location map of existing water supply system for Greater Kathmandu

the existing surface water storage systems are converted into an equivalent composite system which will have similar performance. All the storage system are found to be connected in parallel, and hence inflow and storage capacity of the composite system are simply obtained by adding the corresponding values of each individual system. Both the surface-water and ground-water systems are considered as lumped system with all input parameters deterministically known. The economic values of inputs and outputs are assumed to be constant through out the period of analysis. The objective functions are defined as follows :

Objective 1 Minimization of operation and maintenance cost

$$Min.Cost = Min \sum_{j=1}^{3} \left(p_j \sum_{t=1}^{12} x_{tj} \right) \tag{5}$$

Objective 2 Minimization of water shortage in dry season (one-sided deviation)

$$Min.Shortage = Min\left[\sum_{t=1}^{N} Max\left(0, D_t - \sum_{j=1}^{3} x_{tj}\right)\right] \tag{6}$$

Objective 3 Maximization of downstream flow

This objective intends to maximize the total downstream clear water flow at control point in Chovar during the critical period of dry season.

$$Max.\ (D/S\ \ Flow) = Max\sum_{t=1}^{N}\sum_{j=1}^{2} SP_{tj} \tag{7}$$

In equations (5) through (7), t is the time period in month: [t = 1,2,3,4....12] ; index j is for source : 1 for surface water (storage type), 2 for surface water (run-of-the-river, ROR type), 3 for ground-water;x_{tj} is the quantity of water allocated from the source j in time period t in Mm^3; p_j is the unit equivalent annual O&M cost over n years; D_t is the total water demand during period t; SP_{tj} is the unused surface water from source j during period t; N is the number of months (4) in the dry season (February to May).

Table 6. Estimated available surface water and water demand in 2001 (Mm^3)

Month	Run-of-the-river scheme	Storage type scheme*	Total	Demand
Jan	2.269	1.473	3.642	2.976
Feb	1.330	0.749	2.080	2.796
Mar	0.991	0.428	1.419	3.385
Apr	0.881	0.336	1.218	3.508
May	1.017	0.374	1.392	3.784
Jun	2.099	1.140	3.240	3.761
Jul	26.891	21.346	48.237	3.911
Aug	40.577	30.774	71.352	3.897
Sept	24.701	18.947	43.649	3.689
Oct	7.633	6.133	13.766	3.611
Nov	4.633	3.240	7.931	3.180
Dec	2.758	1.982	4.740	3.029

* Sources include Balkhu khola and Bagmati River

The multi-objective linear programming (LP) model is subjected to the following constraints: (1) demand satisfaction; (2) surface-water availability; (3) mass balance; (4) capacity existing; (5) ground-water availability; (6) downstream minimum flow augmentation requirement, and (7) non-negativity of decision variable x_{tj}. The constraint method is adopted for the generation of non-dominated solutions. This method transforms the multi-objective problem into a single objective programming format and then, by parametric variation of the parameters, the

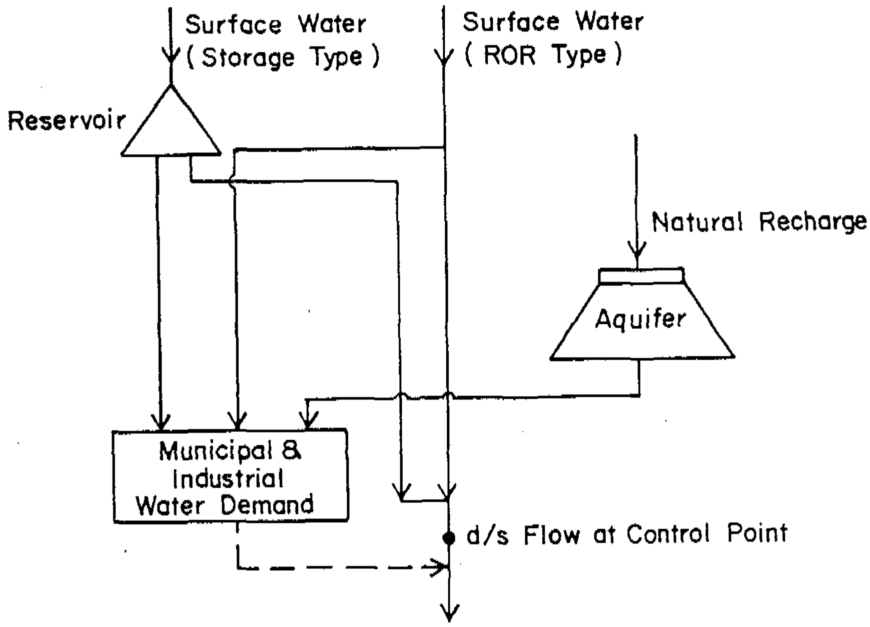

Figure 5. Conceptural diagram of urban water supply system

set of non-dominated solutions can be generated. Compromise programming is used for evaluating the best optimum solution and for each alternatives, the so-called L_p metric is defined by Eq. (4).

3.3 Model Application : Results and Discussion

Relevant study reports are relied upon as the main sources of input data and information. Unit cost figures are obtained based on the concept of Equivalent Uniform Annual Value (EAV) and all the cost figures represent economic prices in US$ (official exchange rate at 1 US$ = 42.8 NRs, Nepalese Rupees) at the end of 1991. Annual operation and maintenance cost includes the cost required for office overhead, facility maintenance, energy and personnel. Annual minimum 7 days mean flow for 2,5, and 10 year return period based on Binnie & Partners (1989) are considered as minimum flows required at the downstream control point. In generating alternative operation policies, satisfaction of 100%, 95%, 90%, 85%, 80% and 75% of the total water demand were considered.

In addition to the existing water supply systems, some new schemes with sources within the valley as proposed by JICA (1990) were also included to augment the existing water supply system. In the proposed new system configuration, the schemes with sources Bishnumati khola, Dhobi khola and Manohara khola were run-of-the-river type and schemes of Balkhu khola and

Bagmati river were storage type schemes. According to the new proposal, the total storage capacity of the whole system will be increased to 0.0407 Mm^3. For details, reference is made to Shakya (1992).

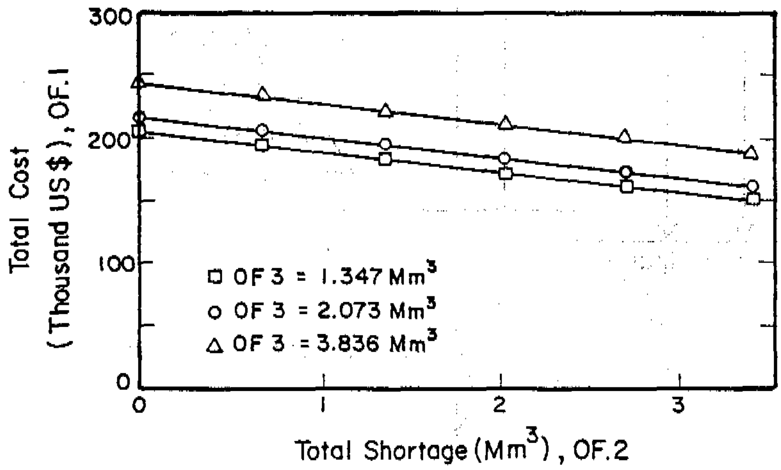

Figure 6. Trade-off curve between OF 2 vs OF 1

The three objective functions were at first treated separately and three single objective problems were optimized by using the conventional "simplex" algorithm of linear programming. Individual optimal "ideal" solutions are presented in Table 7. The three cases had corresponding "ideal" water allocation policies. The results are self-explanatory. It is observed that the three objectives conflict with each other and a trade-off between them can be sought. Table 7 also summarizes the optimal values of the system variables (alternatives) obtained from the planning model for various scenarios.

Between the individual ideal solutions, different operation plans (alternatives) were found by the "constraint" method of generating non-dominated or pareto-optimal solutions. Several LP problems with OF 1 were solved for different fixed values of OF 2 and OF 3. The total dry season water supply shortage was varied between its minimum 0 Mm^3 (100 percent of demand) and maximum 3.369 Mm^3 (75 percent of demand) possible. Again, for each level of shortage, different levels of total downstream flow during dry season were considered between maximum 3.836 Mm^3 and minimum 1.348 Mm^3. Values of the objectives for all possible pareto-optimal alternatives are plotted in the form of a trade-off curve as shown in Fig. 6. Compromise programming results were obtained for all the combinations. Different optimum solutions were obtained for different values of p, which shows that the selection of optimum solution depends upon the attitude of decision maker. However, for the present study, p = 2 was adopted, which implies that each deviation from "ideal" is weighted in proportion to its magnitude.

For equal importance of the three objectives, results indicated that Alternative 16 is the most satisfactory solution vector with minimum deviation from the "ideal point", which comprises all the ideal conditions of the three objectives (but is not a feasible solution under

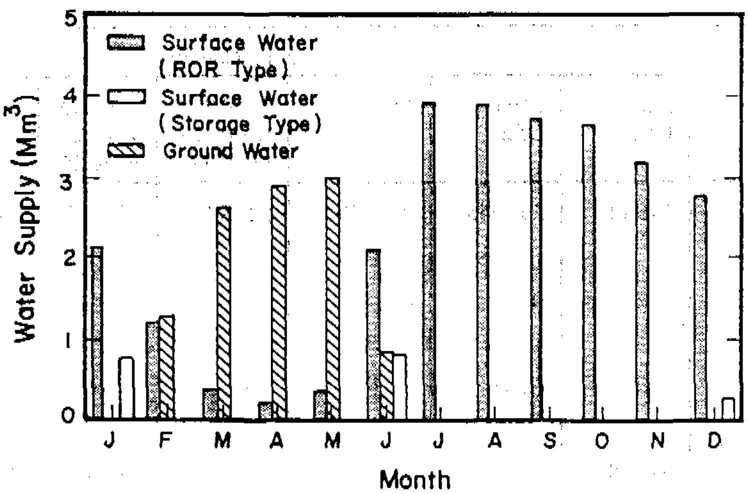

Figure 7. Optimum water allocation policy (Alternative 16)

multi-objective environment). The water allocation policy of Alternative 16 is presented in Fig.7 which highlights the relative importance of surface-and ground-water sources in different seasons. In this distribution policy, surface water (run-of-the-river type) dominates throughout the year as the main source of water supply except for the dry season, 69% of total supply in a year is met from this source. Storage type surface water is found as the first preferable supplementary source used in January, June and December. Due to high O & M cost, ground-water contribution is obtained during dry season only i.e. February-June, when the surface water available is very low. About 27% of total supply in a year comes from ground-water source.

When the cost (objective 1) is given higher weightage relative to the other two objectives (w_1 = 0.5, w_2 = 0.25, w_3 = 0.25), Alternative 8 is found to be "best". Similarly, when the shortage (objective 2) is given higher weightage (i.e. w_1 = 0.25, w_2 = 0.5, w_3 = 0.25), the best solution shifts to Alternative 17. When downstream flow (objective 3) is given higher priority (i.e. w_1 = 0.25, w_2 = 0.25, w_3 = 0.5), the "best" solution obtained is still Alternative 16. The results appear to be sensitive to first two priority cases only. In other words, Alternative 16 appears to be robust enough with respect to the objectives 3 and 2.

4. CONCLUSIONS

Integrated use of surface and ground water, commonly termed as conjunctive use, is recognized as a significant strategy for the optimum utilization of regional water resources, especially when demands are increasing and available resources are limited. Mathematical models based on systems approach are being extensively used in analyzing conjunctive-use problems. The practical applicability of these modeling approach is illustrated through two case studies.

Table 7. **Optimal system variables for various scenarios.**

Description	Optimal Condition						
	Ideal OF1	Ideal OF2	Ideal OF3	w_1=0.333 w_2=0.333 w_3=0.333	w_1=0.50 w_2=0.25 w_3=0.25	w_1=0.25 w_2=0.50 w_3=0.25	w_1=0.25 w_2=0.25 w_3=0.50
1) Total annual O&M cost (thousand US$)	146.946	204.655	244.219	220.935	158.412	232.477	220.935
2) Total shortage during dry season (Mm^3)	3.369	0	0	1.347	3.370	0.673	1.347
3) Total downstream flow during dry season(Mm^3)	1.348	1.348	3.836	3.836	2.073	3.836	3.836
4) Annual SWR (Mm^3)	29.539	29.539	27.634	27.633	29.130	27.634	27.634
5) Annual SWS (Mm^3)	2.464	2.464	1.876	1.877	2.141	1.877	1.877
6) Annual GW (Mm^3)	6.160	9.5296	12.017921	10.670	6.886	11.344	10.670
7) Max. monthly SWR (Mm^3)	3.911	3.911	3.911	3.911	3.911	3.911	3.911
8) Max. monthly SWS (Mm^3)	0.807	0.807	0.807	0.807	0.807	0.807	0.807
9) Max. monthly GW (Mm^3)	1.794	2.74	3.382	3.004	1.981	3.004	3.004
10) No. of months contributed by SWR	12	12	12	12	12	12	12
11) No. of months contributed by SWS	6	6	3	3	4	3	3
12) No. of months contributed by GW	5	5	5	5	5	5	5
13) Alternative	1	6	18	16	8	17	16

SWR = Surface water (Run-of-the-river type); SWS = Surface water (Storage type)
GW = Ground water; OF = Objective function

A three-step modeling strategy is proposed for the planning and management of conjunctive water use for irrigation. The first-stage SDP model is a planning-level tool to determine the operation policy guidelines for each alternative considered. The second stage simulation model, based on a lumped system like the SDP model, is developed for evaluating the SDP-derived reference operation policy. For each planning alternative, simulation is performed with a number of mutually related sequences of streamflow and rainfall, each over a 50-year planning period. Trade-offs among all the relevant performance measures such as cost, benefit, reliability, vulnerability and resiliency are identified to yield information useful in decision making under uncertainty. The third and final stage makes use of compromise programming to select the most satisfactory alternative depending upon the relative preferences of the decision maker or the weights of various governing criteria.

The second case study deals with the application of a multi-objective linear programming optimization technique for the analysis of integrated use of surface- and ground-water resources for urban water supply. The three objectives related to economic, environmental and reliability considerations are found to conflict with each other. Different alternative management policies and their trade-offs are evaluated using compromise programming.

The multi-criteria framework of the models provides more insight to the decision-making process than the conventional use of optimization or simulation models. Trade-off possibilities identified between different criteria help the decision-making body to balance between different measures. The model results form an excellent basis from which the decision-makers can focus on detailed evaluation or implementation aspect of certain plan or policy.

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INSTITUTIONS FOR MANAGING WATER
THE INTERNATIONAL EXPERIENCE OF THE GREAT LAKES

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ABSTRACT

This paper presents and evaluates the institutional framework of the Great Lakes between the U.S and Canada. A historical review of the evolution of water institutions is presneted. Critical issues are raised regarding the regional management of water resoursc. Finally, an explanation of why river basin commissions were terminated is presented.

BACKGROUND

The idea of integrated management of land and water resources is not new. The history of irrigated agriculture can be traced back to 7000 BC in Jericho. Many of the World's greatest civilizations have had close association with rivers. The Hindu-Indian, Egyptian, Chinese and Sumerian civilizations emerged and flourished in the major river valleys of the Indus, Nile, Hwang-Ho and Tigris-Euphrates respectively.

There seems to be a moral in this broad sequence of history a moral which modern societies presently trying to rediscover the ancient art of successful river basin development can only ignore at their own peril. and the moral seems to be this:

> Economic development can be sustained as a continuous process only if it is ecologically sound and socially just (Saha and Barrow, 1981).

The modern history of river basin planning can be traced back to a great event which took place in the 1930s. This event was the creation of the Tennessee Valley Authority (TVA) in the United States in 1934. In the United States, the idea of river basin planning gradually took shape into an operational concept through a progressive synthesis of three interrelated but separately evolved concepts of: 1) multiple-purpose project, 2) unity of the drainage basin and 3) the acceptance of state intervention in the promotion of social welfare.

Despite the unfulfilled promises of the TVA, the concept of river basin planning seemed to have survived in the USA. A series of interstate compacts for unified development of river basin have been signed giving rise to a number of interstate River Basin Commission (Saha and Barrow, 1981).

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1. INTITUTIONAL ARRANGEMENTS FOR GREAT LAKES MANAGEMENT

Recent years have witnessed a revitalization of a regional consciousness among the public officials and citizenry of Great Lakes political jurisdictions. Born of multi-jurisdictional environmental crises and the desire to tap the economic potential of the expansive resource, and ecosystem philosophy had gained credence, and with it the initial indications of an emerging regional identity for the Great Lakes. Accompanying the revitalization is a renewed interest in the institutional arrangements that have evolved to translate this regional consciousness and ecosystem philosophy into implementable programs for management of the water and related land resources of the Great Lakes Basin. The following discussions are based on the work of Donahue M. J (1988).

This renewed interest has been fueled, in part, by the collective thoughts of participants in the interuniversity seminar on the Great Lakes. A 1984 conference theme, "sustainable redevelopment for the future in the Great Lakes region," afforded a welcome opportunity to explore the means by which these positive trends can contribute to the enhanced management of this international resource.

This, and subsequent initiatives of a similar nature provide a refreshing and challenging opportunity to set aside, at least for the moment, our current preoccupation with what is, and to focus instead on what could be. The generation and subsequent application of principles for sustainable redevelopment is indeed a most timely, and perhaps long overdue exercise. It is also a logical precursor to subsequent efforts to generate recommendations for future redevelopment. As Lyle Craine has observed, too often we concern ourselves with how to manage the Great Lakes resource without first determining why it should be managed at all.

Recommendations developed by the interuniversity seminar and related initiatives contribute substantively to the future direction of Great Lakes management. It is essential, however, that the formulation of alternative futures includes a blueprint for achieving them. The blueprint must reflect an understanding of the existing Great Lakes management framework and its potential value as a foundation for change rather than an obstacle to such change. The Great Lakes Basin Framework Study (1975) correctly observes that "the current array of government units must not be viewed as immutable constraints on the formulation of alternative courses of action."(Donahue, 1988, p.116).

1.1 The role of the institution in the Great Lakes management process

An important link exists between the prescribed mission of a given organization and the institutional arrangements and processes created to fulfill that mission. The institutional arrangement as a determinant of goal attainment is capably articulated by the National Academy of Sciences Commission on Natural Resources (1977, p.185):

The characteristics of anticipated problems are shaped by existing institutions, and any attempt to improve matters that ignores this fact will probably come to very little. No amount of monitoring, or science advising, or project modelling is going to improve our record if the relevant problem recognition system, the approaches to mitigate the problems, and the incentive systems to provide alternatives remain unchanged.

Although these remarks were addressed primarily to research and development initiatives at the federal level, their consideration is equally appropriate in a broader policy context.if policy is to be viewed as an output of organizations, the institutional arrangements that shape policy become a critical determinant of the policy's impact upon society. The institution-at any level of government-is not merely a vehicle of operationalizing policies formulated by legislatures of officials of a given administration. The institution itself provides an environment in which policies can be devised, altered, interpreted, advocated, ignored, or otherwise transformed. The institution can determine not only the success or failure of a given policy, but the very essence of that policy (Zigurd, Z., 1977).

The argument that institutional arrangements are a dominant factor in the policy process is substantiated in the arena of resource management in the international Great Lakes Basin. Ostrom et al. observe that existing institutional arrangements are instrumental in determining the political feasibility of Great Lakes management efforts. For this reason, they argue, a thorough understanding of those institutional arrangements, as well as the political influences associated with them is a critical component of any analysis of Great Lakes water resource problems (Ostrom. V., 1970).

Similarly, Hennigan has pointed out that an understanding and subsequent reform of the Great Lakes institutional ecosystem is the critical factor in establishing a "workable system incorporating the action elements of persuasion and education, legal action and economic incentives which can make effective water management attainable (Hennigan, R., 1977). Following an exhaustive analysis of resource based problems and opportunities in the basin, the Great Lakes Basin Framework Study (1970) concluded, " In sum, the critical deficiency in the Great Lakes Basin is that institutional arrangements for arriving at a political consensus do not exist." Clearly, any effort to affect policy change in the absence of institutional analysis will come to very little outcome.

Historically, five principal causal factors for the need for better water institutions are identified:

1- The diversity of regional resource management goals among political jurisdictions.
2- The experimental nature of regional resource management.
3- The complexity of the Great Lakes management framework.
4- The tendency toward institutional inertia.
5- The continuing maturation of the "ecosystem management" concept.

Despite the progression of regional resource management approaches in North America over the last century, there is widespread agreement in the literature with the following statement by Derthick: "None of the different approaches embodied in regional organizations is sufficiently superior to the rest to make it preferable, nor in any approach so clearly successful as to contribute substantially to justification of the regional form." (Derhick, M., 1974). This statement capsulize both the frustration and the challenge associated with institutional design for Great Lakes management. Despite the historical absence of a systematic analysis of the Great Lakes institutional system and its components, there appears to be a compelling, yet inadequately articulated, sense of dissatisfaction with present arrangements.

Donahue, M., (1988, p.121) argues that in the absence of criteria for evaluation, "success" is a matter of personal perception. Furthermore, there appears to exist an unalterable faith that a "preferred approach," albeit yet undiscovered or even understood, holds the promise of resolving the myriad issues present today. Discovering this approach, or simply realizing that we must settle for something less, is the challenge before us.

2. THE EXISTING INSTITUTIONAL FRAMEWORK FOR GREAT LAKES MANAGEMENT

The Great Lakes system is a shared, multipurpose resource intensively used and managed at every level from the local to international arena. Eight states and two Canadian provinces share the basin. Over a dozen federal agencies- on both sides of the border- have a mandated interest in some aspect of the resource. Literally hundreds of governmental entities are charged with some resource management responsibility, including municipalities, county health boards, state departments of natural resources, a variety of regional bodies, and several international bodies. Most are limited in management authority to a defined political jurisdiction or a specific management function, such as water supply, flood control, or water quality, to name a few. A constellation of research institutions, citizen groups, policy centers, foundations, and special interest coalitions have flourished as well, using the various access points to the institutional framework to influence the direction of Great Lakes management.

Full documentation of the management functions of these various entities is clearly beyond the scope of this paper. For example, Haynes and Madau (1978) identified 91 Canadian governmental units involved in Great Lakes management. Bulkly and Mathews (1973, p.872) identified 650 governmental units- from the municipal to the international level- with some Great Lakes management responsibility.

Indeed, the resource management structure in the region is complex one. Yet, one need only be reminded of the immensity, diversity, and geographic expansiveness of the resource to realize that such a management structure is not only inevitable, but in some ways desirable.

The following overview of Great Lakes institutional arrangements will focus on the regional management of institutions. Specifically, reference is made to those institutions that are public, resource-based entities, that possess a basinwide orientation, that are multi-jurisdictional in nature, and that at least attempt to examine issues from what has come to be known as "ecosystem perspective."

The term management is employed rather loosely to describe an institution with one or more of the following charges: planning, research, coordination, regulation, enforcement, monitoring and surveillance, policy making, advocacy, and the like. The existing Great Lakes institutions within this classification include the International Joint Commission, the Great Lakes Commission, the Great Lakes Fishery Commission, and the Council of Great Lakes Governors.

2.1 Description of institutions

Joint institution established under the premier agent of the two governments, the IJC, include three control boards and two technical boards pertaining to management or investigation of Great Lakes levels and flows, one study board on diversions and consumptive uses, and several special committees and groups. The Niagara Falls Treaty of 1950 provided an assured flow of water over Niagara Falls in competition with hydropower interests. The Great Lakes Fisheries Treaty of 1955 brought to a conclusion matters that had been discussed by no fewer than twenty-seven commissions and conferences since 1875. Agreements, lacking the force of treaties but binding nonetheless, were used in 1954 and 1972 for the arrangements then thought necessary to control pollution in the Great Lakes.

The activities of the two countries in the arena of Great Lakes Basin water, land, and environmental resources during the past three-quarters of a century, but primarily during the last thirty years, include boundary agreements; institution building; agreements on levels and flows, diversions, and fisheries; agreements on scenic resources; allocation for hydropower; air quality in the Windsor Detroit area; and water pollution control.

In light of comparable arrangements in similar international arenas, their record is impressive. Of equal importance in the longer term is the inevitable direction of the two countries toward the bilateral multipurpose management of the basin. It is this direction toward comprehensive, integrated, multipurpose water, land and environmental management to which both countries have subscribed, not only in concept but by action, that allows an optimistic outlook for the future management of the basin.

An impressive start toward the development of a modern and effective management plan was outlined by J.W. ManLaren, one of Canada's foremost consulting engineers, and R.F. Clevinger, a former chairman of the Great Lakes Basin Commission, nearly twenty years ago. Their plan laid out the basic reasoning to justify a comprehensive, integrated approach by showing the relationship among seven water use categories. The organizational framework was to be, like the IJC, a coordinating agency. Each country would provide its own planning agents, envisioned as the Great Lakes Basin Commission, then in existence, and a counterpart agency, a Great Lakes Resources Commission, on the Canadian side, to be built upon an agreement of the governments of Canada and the Province of Ontario.

The approach taken by Manlaren and Clevinger towards an integrated arrangement for the Great Lakes was in keeping with the evolution of complex resource management systems in both countries as well as with philosophical realities in the relations between Canada and the United States. Comprehensive, integrated, integrated, multipurpose water resource planning and development by river basins is an idea that has been extant for about a hundred years. Professor Norman Wengert of Colorado State University has traced the concept through three eras.

The first is in the prepetory period from 19th century to the New Deal, during which a set of related ideas were being expressed and tested in the market place of public discussion. Toward the end of this period a variety of ideas were being woven together as a basis for public action, data being accumulated on rivers as systems, and multipurpose projects rather than single purpose projects were being proposed. The second period extends from 1933-1965 when, to ideas about multipurpose integrated planning were added goals for socioeconomic development within regions traversed by major rivers.

At last, the present period from 1965 is that when river basin planning, and programs rationalized in river basin terms, began to be crowded from their previous dominant position with respect to water policy, as new concerns, new goals and objectives, and new concepts with respect to water, to the environment, to development, and to the government role, were articulated and received political support.

The development of institution building to make real the sought after concept of river basin development evolved in three periods as identified by Wengert. The first period was one in which separate agencies were or had been assigned separate tasks: the Army Corps of Engineers was responsible initially for navigation and flood control, and towards the end of the period for selected multipurpose development planning; the Bureau of Reclamation was responsible for western irrigated agriculture, as well as for water and related matters. These assignments continued into the second period, when new tasks for water pollution control were given to the Public Health Service; small watershed protection, to the Department of Interior.

The second period, ending in 1965, saw two reasonably successful efforts at joining together the federal and state agencies. The first, during the 1930s and early and early 1940s, was the establishment of the National Resources Planning Board (NRPB). The board's reports on the several regions of the country were landmarks in intergovernmental cooperation. The second effort, following the demise of the NRPB, was the voluntary formation in 1943 of the Federal Interagency River Basin Committee. Over the next decade, field committees, including state participation, were established in the Columbia, Missouri, and Arkansas-White -Red basins, the Pacific Southwest region, and New England, including New York.

During both of these periods, beginning with President Theodore Roosevelt just after the turn of the century, the concept of comprehensive, integrated, multipurpose development of the river basins of the nation was supported by several attempts to institutionalize the concept.

Finally, as an outgrowth of a 1960 Senate report on the nation's waters, the U.S Congress enacted the water Resources Planning Act of 1965. This act established the United States water Resources Council and authorized the establishment of river basin commissions with federal and state members having equal voting power. from 1965 until 1981, the commissions were established in the Columbia, Missouri, Upper Mississippi, Ohio, great lakes, and New England drainage basins.

2.2 INTERNATIONAL JOINT COMMISSION

The International Joint Commission (IJC) is a permanent bilateral body created under the auspices of the Boundary waters Treaty of 1909 to prevent disputes relating to boundary water usage and to settle questions arising along the common frontier. The commission has provided the framework for cooperation on questions relating to water and air pollution and the regulation of water levels and flows.

Three principal functions are undertaken by the commission:

1- Quasi-judicial: The commission approves or disapproves applications from governments, companies, or individuals for obstructions, uses, or diversions of water that affect the natural level of flow of water on the other side of the international boundary.

2- Investigative: The commission investigates questions on matters of difference along the common frontier, undertaking references that are presented to the commission by the two governments. In such cases, the commission reports to the governments the facts and circumstances of the issue, as well as recommendations for action. these recommendations are not binding; the governments decide whether or not the commissions's recommendations will be acted upon.

3- Surveillance/Coordination: The commission monitors and coordinates the implementation of recommendations of recommendations accepted by the governments. It also monitors compliance with orders of approval for structures in boundary waters.

The next section will present an overview of the Water Resources Planning Act 1985 and reasons for its termination in 1981.

3. WATER RESOURCES PLANNING ACT OF 1965 TO 1981 ACT

This part of the paper will discuss the Water Resources Planning Act 1965 and the termination of River Basin Commissions in 1981 during the Regan administration.

The Water Resources Planning Act of 1965 was passed to provide for greater coordination of water and related land resources planning. It established the Water Resources Council, which assumed the functions of the Inter-agency Committee on water Resources, which was originally named the Federal Inter-agency River Basin Committee.

The Water Resources Planning Act of 1965 provided for several new planning programs: The Water Resources Council itself, river basin commissions, and financial assistance to the states for comprehensive planning programs. The council was to prepare periodic national water assessments; establish principles, standards, and procedures for water projects; and monitor river basin plans. The river basin commissions (RBC) were to coordinate water planning and maintain a "comprehensive", coordinated joint plan" (CCJP) for the development of water and related resources.

The council ceased to function during the Regan administration, and its staff was disbanded. The coordination function was assumed by the Cabinet Council on Natural resources and Environment and an assistant Secretaries Working Group on water. The river basin commissions were disbanded and grants to states were cut off.

To explain the reasons behind the termination of the river basin commissions, Niel Grigg provided the following analysis:

First, the concept of a coordinating council is doomed to failure unless the chief executive gives it support and attention. Unless this happens, top decision makers cease to attend meetings, and they send lower-level people just to watch out to their interests. Since the attendees cannot make decisions, the meetings become meaningless. That apparently ia what happened to the council (Grigg, 1985).

Another historical explanation may be extracted from literature. The Water Resources Council was a 15-year experiment. Its rise coincided with the "great society" programs when the government was expanding. Other programs with the same history were also being cut back: the regional economic commissions, the office of water Research and Technology, and the comprehensive employment training programs. However, the council fell victim to a small-government trend, which also affected water resources development in general.

Henry Caulfield, former director of the water Resources Council, provided several reasons for the demise of federal water development: the rise of the environmental movement, recognition of the futility of reservoir storage, federal policy which encouraged states to develop their own programs, withdrawal from water as the key agent of economic development, and the emergence of an urban majority interest.

To conclude, the following guidelines were identified as means to traverse the gap between the identification of institutional needs and the design of institutions to address those needs:

1. *Institutions in the Great Lakes did not exercise all powers available in the mandate.*

2. A commitment to the cooperative management of a shared resource is the key element for intergovernmental cooperation.

3. Regional arrangements efforts remain experiments and must remain open to change.

4. Integrating the "ecosystem" approach in the Great Lakes management is an opportunity that should be explored.

5. Performance evaluations of existing institutions is very important to provide us with a learning capability.

6. Institutions must be responsive to the political realities and interests of jurisdictions served.

SUMMARY AND CONCLUSIONS

'Hydraulic' civilizations rose because they were successful in organizing a social economic and political system which enabled them to harness the water resources at their disposal. However, lessons from past and present experiences should be evaluated for better resource management.

This paper presents and evaluates the institutional framework of the Great Lakes between the U.S and Canada. A historical review of the evolution of water institutions is presented. Critical issues are raised regarding the regional management of water resources. Finally, an explanation of why river basin commissions were terminated is presented.

The study recommends that the international experience of the Great Lakes be studied and analyzed for its transferability to developing countries. Institutional analysis of existing water institutions in the developing countries is of great importance to allocate shared resources in such a reasonable and equitable manner.

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REGIONAL INTEGRATION OF WATER DEMANDS FOR ADEQUATE DEVELOPMENT OF RESOURCES IN SOUTH AFRICA

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ABSTRACT

The increasing demands for water in various regions of South Africa, arising primarily from the population growth and accelerated by rapid urbanisation processes, have to be met from the limited regional water resources.

In recent years South Africa has been going through an immense political and socio-economic transformation motivated by high expectations and resolute efforts to secure peace and prosperity for the people living in this part of the world. The country's legal, political and administrative structures and also those related to the water resources management of the pre-democratic era, are going through significant changes in respect of new public policies. The mechanics of decision making are being reviewed to adapt the ground rules for a conflict resolution approach mostly omitted in the past.

The inter-sectoral competition for adequate water supply, particularly evident between the agricultural and urban water use sectors, indicates that the regional integration of existing and future sectoral water demands must be promoted together with specific assessments of available regional water resources. The economic benefits of developing the whole Southern Africa sub-region in an integrated manner are high if water and energy distribution are adequately managed.

RÉSUMÉ

On doit satisfaire, des ressources d'eaux régionales limitées, les demandes pour l'eau, dans les différentes régions de l'Afrique de Sud, qui s'augmentent à cause de la croissance de la population et des procès d'urbanisation rapides.

L'Afrique de Sud vient d'expériencer une transformation politique et socio-économique importante qui se characterise par de grandes expectations et par des efforts à assurer la paix et la prosperité pour tous. Les structures judiciares, politiques et administratives, surtout l'administration des ressources d'eau, de l'époque pré-démocratique subissent des changes significantes politiques et publiques. Les méchanismes de décision s'adaptent à manier de permettre la résolution des conflits, largement omis dans le passé.

La lutte pour une ressource d'eau suffisante, qui se montre surtout entre les secteurs d'usage agricole et urbain, indique que l'intégration régionale des démandes d'eau présentes et futures doit être avancée avec les impositions spécifiques des ressources d'eau régionales profitables. Les avantages économiques du développement de la région sud-africaine d'une manière integrée seront grandes si l'administration de l'eau et de l'énergie s'accomplit d'une manière compétente.

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1. INTRODUCTION

South Africa is a developing country rich in many natural resources, but its water resources are limited and poorly distributed. The post-World War II global industrial recovery and technological development enabled South Africa to offer considerable industrial output and extensive raw material exports. However, decades of social engineering manipulated the human, financial and material resources according to the socio-economic scenarios based on the doctrine of separate development. The management and development of the national and regional water resources conformed to this doctrine for many years by allocating water preferentially for irrigation and production of the synthetic fuels to counter-balance the trade sanctions. Besides the political and socio-economic problems the scarcity of water in some regions of South Africa together with the climatic oscillation of the drought periods increased conflicts between people competing for limited financial and material resources and work opportunities. The high population growth and years of selective development caused a serious shortage in installation of adequate water supply and sanitation services in urban and primarily rural areas. The ostensible need to meet the demands for water, predominantly from the agricultural and industrial sectors, justified for many years rapid planning and construction of the large water supply schemes, supplemented in many cases by the inter-basin water transfers.

The socio-legal system of separate development, applied in South Africa for more than four decades, failed to distribute evenly the financial and material resources and increased the disparities in social services between population groups to alarming proportions. The highly diversified and divided South African society inevitably reached a critical historical stage facing a fundamental political and socio-economic change. A major restructuring of the political and institutional systems at the national and particularly regional level is now a reality as the new political order, chosen by a majority of people, started to reconcile the decades of fiscal extravagance, international sanctions, civil disobedience and criminal violence with the Reconstruction and Development Programme (ANC, 1993) under the Government of National Unity. The water resources are therefore once again a most critical element in the present and future development of all available resources in South Africa.

2. POLITICAL AND SOCIO-ECONOMIC PROCESS OF CHANGE IN SOUTH AFRICA

The whole sub-continent of Southern Africa has, in recent years, undergone an immense political and socio-economic transformation motivated by high aspirations and expectations as well as resolute efforts to secure peace and prosperity for the people living in this part of the world. The addressing of various problems in water supply and sanitation features very prominently on the political agendas but the demand for the services presently displaces the supply, in both the urban and rural areas.

The political, legal and administrative structures related to the water resources management of the pre-democratic era are undergoing significant changes in respect of new public policies. The established mechanism of decision making has been radically altered and the local authority administration methods are being reviewed to adapt the ground rules for a conflict resolution approach mostly omitted in the past. The past socio-legal system has undoubtedly slowed economic development and particularly the urbanisation process. As the remaining barriers are now removed, an intensified influx of rural population to the urban areas can be expected. This will place significant demands on the institutional and financial resources and water supply systems in particular (**Hollingworth, 1991**). To highlight the process of change in South Africa, the fluctuation in the major parameters of the national economy during past 50 years is illustrated in the following table.

Table 1. Changes in population and GDP per capita growth rates and fixed foreign investments

Period between Population Censuses	Population Growth Rates (% p.a.)	GDP Per Capita (period av. % p.a.)	Fixed Foreign Investments in SA (period av. % of GDP)
1946-1951	2,1	4,3	?
1951-1960	2,5	4,5	18
1960-1970	2,8	5,8	20
1970-1980	2,8	3,5	26
1980-1985	2,6	1,8	23
1985-1991	2,4	-2,2	18
1991-1996	2,4*	2,0*	20*

Denotation : * Estimate, ? Information not available

The democratically elected government by the legitimate one-person-one vote election culminated the process of bringing South Africa into a new economic era. This will have an immediate impact on the development of South African resources and the whole sub-continent. The South African economy has already improved by approximately one per cent in real GDP during 1993. The economic recovery appears to be substantial on account of an increase in agricultural production following one of the most severe droughts in South African history. The after-shocks of prolonged drought periods of the 1980's and 1990's together with the political and institutional reforms already highlighted the need for contingency plans for maintaining water supplies primarily to the people in rural and peri-urban areas. The high risk of water supply failure has been realised in South Africa, and must be minimised in the future.

The inter-sectoral competition for adequate water supply, particularly evident between the agricultural and urban water use sectors, indicates that the regional integration of existing and future sectoral water demands, particularly with regard to new provincial dispensation, must be promoted together with specific assessments of available regional water resources.

3. RESOURCES AVAILABLE FOR DEVELOPMENT

The greater part of South Africa is a plateau of undulating countryside rising from 900 to 2000 metres above sea level. The country's coastline of some 2500 km is exposed to a warm Mozambique-Agulas current along the east and south coast and the cold Benguela current along the west coast. Except for the most northern tip, the country lies in the southern temperature zone. The early findings of gold and diamonds in the interior of South Africa, began the unrestrained history of the development of the country's people and rich resources.

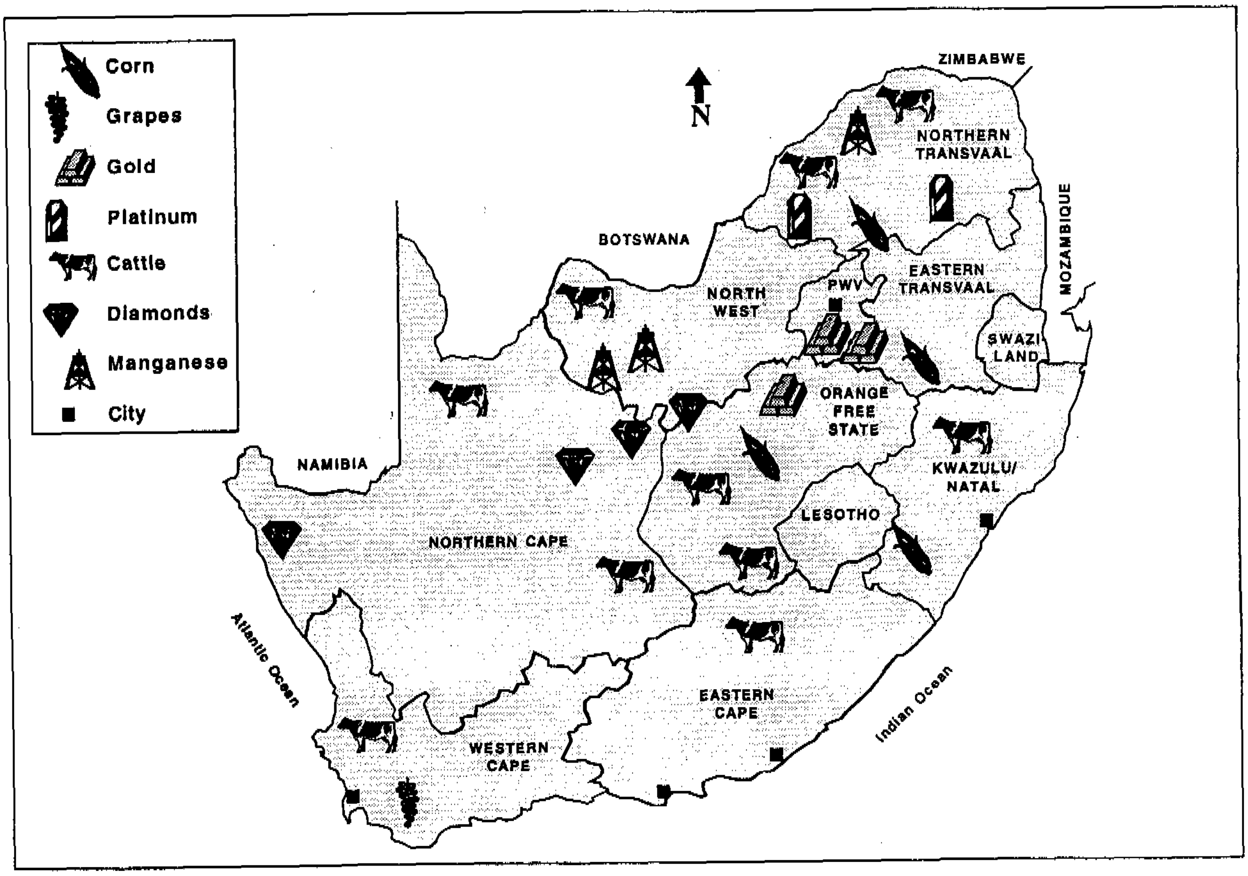

Figure 1. Distribution of natural resources in South Africa

3.1 Human Resources

The total population of South Africa is close to 40 million inhabitants of whom about 65 percent are considered functionally urbanised. Available statistics **(CSS, 1993)** show that only about 43 percent of the total 30 million inhabitants of African descent are presently urbanised. The heart of the demographic problem in South Africa, from the economic point of view, is a high population growth (e.g. 2,44 percent p.a. overall rate between 1985 and 1993). There is, among the population, an inverse correlation between the rate of creating life and the ability to sustain it. The major portion of the population is still steeped in the reproductive and economic traditions symptomatic of developing countries **(Sadie, 1987)**.

Like other developing countries, the South Africa of today faces substantial challenges of expanding urbanisation in all areas that have previously grown rather slowly due to various restricted laws **(Bernstein, 1994)**. The majority of South Africa's economic growth takes place in the urban areas. The largest percentage of educational and social opportunities is concentrated in the six major metropolitan areas.

Table 2. Official urbanization of total population in South Africa

Year	Urban population (%)	Rural population (%)	Total (million)
1970	45	55	22
1980	53	47	29
1991	57	43	38
1993	60	40	40

The inland Pretoria-Witwatersrand-Vereeniging (PWV) complex is the largest metropolitan area housing about 1/5 of the country's total population. It is anticipated that in 30 year's time the population in PWV area will grow to 24 million inhabitants.

3.2 Agricultural Potential

An area of approximately 12 to 15 percent of the total country's area of 1,2 million km^2 can be considered as arable land. Of this area about 3 to 5 percent can be regarded as excellent arable land. These estimates are based on an adoption of the parameters regarding a measure of possible productivity per unit area, per unit of time and achieved with specific inputs of managerial skills.

Table 3. Land use in South Africa (1990)

Land use	Area (km^2)	(%) of total
Natural veld	876 000	73
Cultivation	132 000	11
Forests	12 000	1
Nature conservation	60 000	5
Urban and peri-urban areas	84 000	7
Roads, etc	24 000	2
Other uses	12 000	1

Many less developed areas of South Africa have a high agricultural potential supporting rural people, some of whom are living in varying states of poverty. There are many reasons for this situation, but a scarcity of water is one of the most prominent and on that account the agricultural production levels are only a fraction of the potential. Small-scale farmers have non-viable farms and face many physical and institutional constraints, as well as problems of labour, poor managerial skills and knowledge. Ineffective extension services and qualitative and quantitative deficiencies in agricultural training at high school, college and university level are constraints to human development. The physically important factors that influence agricultural potential, besides a suitable soil type and favourable configuration of arable area, are solar energy and most importantly precipitation.

3.3 Material Resources

Mining has played a dominant role in the development of South Africa. The platinum group elements (PGE) resources in South Africa have a particularly favourable platinum to palladium ratio that cannot be matched at present by any other known deposits **(Benetts & van Dijk, 1992).**

Table 4. Present supply of gold and PGE metals according to the world scale

Country	(%) of total			
	Gold	Platinum	Palladium	Rhodium
South Africa	34,0	74,5	35,0	54,4
North America	35,1	5,0	10,5	4,5
Others	30,9	20,5	54,5	41,1

The ferrochrome industry in South Africa possesses about 60 percent of the world's production capacity. The ferrous metals, ferro-alloys, high-technology ferrous superalloys and special steels are of major importance in the industrial development of most countries signifying now-a-days the degree of industrialization. South Africa's resources of high-grade iron ores are sufficient to sustain large local steel industries and considerable export markets. High-grade silica is being exploited in one of the world's few silicon smelters. Resources of nickel and cobalt provide an adequate base for ferro-alloy and special steel industries. As far as tungsten, niobium-tantalum, zirconium and rare earths are concerned, considerable resource potential exists in various locations in South Africa.

The South African non-metallic mineral production : namely, clay, limestone, aggregates, sand, gypsum, fly ash, vermiculite, asbestos and the refractory oxides (alumina, iron oxide, magnesia, rare earth oxides, silica, thoria, titania and zirconia) is fairly extensive. Most non-metallic resources will continue to be consumed within Southern Africa. New export opportunities exist for products used by high-technology industry. A drive for the expansion of non-metallic exports to the rest of Africa is being strongly emphasized, as this is a natural market for South African products.

3.4 Manpower Resource Utilization

The overall structure of South African industrial sector on the national and regional levels is undergoing a dramatic changes with regard to new labour relations and skills required. The trends in application of advanced Western world concepts, techniques and technologies create vast challenges in manpower eduction in South Africa.
During the recent past South Africa has been classified as an above-average developing economy benefiting primarily from a large component of a growth-creating manpower resource. The economically active South African population, according to sector of activity, is determined presently at about 14,5 million.

Table 5. Economically active population in South Africa (1993)

Sector of economy	Population (million)	(%) of total
State departments	2,0	14
Large businesses	3,4	23
Small manufacture enterprises (formal)	2,6	18
Informal sector	3,5	24
Subsistence living	1,0	7
Unemployed	2,0	14

Long-term solutions are being sought in the national policy to integrate all sectors of the economy. At present the labour supply is outstripping the supply of enterprise from which the manpower derives its livelihood. Special measures and funding are aimed at promoting an informal manufacture sector, small scale urban and rural enterprise. The labour-intensive public projects are widely advocated as solutions to the growing unemployment in South Africa.

For decades South Africa has been considered a harbour for export labour from its neighbouring countries. In the past South African economy absorbed an average 0,5 million of migrant workers annually. Due to high unemployment of the local labour force this figure is presently about one-quarter million annually.

3.5 Energy Resource Development

The development of energy resources in South Africa has been shaped for a number of years according to the objectives of the Southern African Development Coordinating Conference (SADCC) established in 1980 between Angola, Botswana, Lesotho, Mozambique, Swaziland, Tanzania, Zambia and Zimbabwe.

According to the consumer sectors, 70 percent of the total energy consumption is by the industrial and commercial sector, and the public section (i.e. municipal use) accounts for 6 percent. South Africa's net energy demand of 24 percent is for domestic purposes represented by 96 percent of all consumers. On average between 5 and 25 percent of the budget of a low-income family is allocated to the cost of energy. Next to the electrical energy the most popular energy source amongst peri-urban and rural South African are coal and paraffin. The demand for energy in the domestic sector is related to basic needs as cooking and heating.

Table 6. National net domestic energy demand in South Africa

Demand for resource	% of total	Usage
Electricity	13	Mostly developed urban areas
Coal	29	Mostly urban areas
Petroleum	3	Urban, peri-urban and rural areas
Firewood	51	Peri-urban and rural areas
Other	4	Dung, agricultural waste, candles

The process of accelerated urbanisation is yet to gain momentum in South Africa subsequently increasing demand for the commercial energy and lowering somewhat the demand for non-commercial energy use. Research from around the world has indicated that urbanisation does not necessarily lead to a greater increase in energy per dwelling. The major increase in the consumption of energy results primarily from the urban development of a tertiary section (i.e. light industries, transportation network, commercial and recreation facilities).

Electricity supply in South Africa is more than a hundred years old. The Electricity Supply Commission today known as ESKOM operates 25 power stations with a total nominal capacity of about 40 000 MW. Close to 90 percent of ESKOM's total capacity is vested in the coal fired power stations. ESKOM's production represents more than half of the electricity used on the entire African continent.

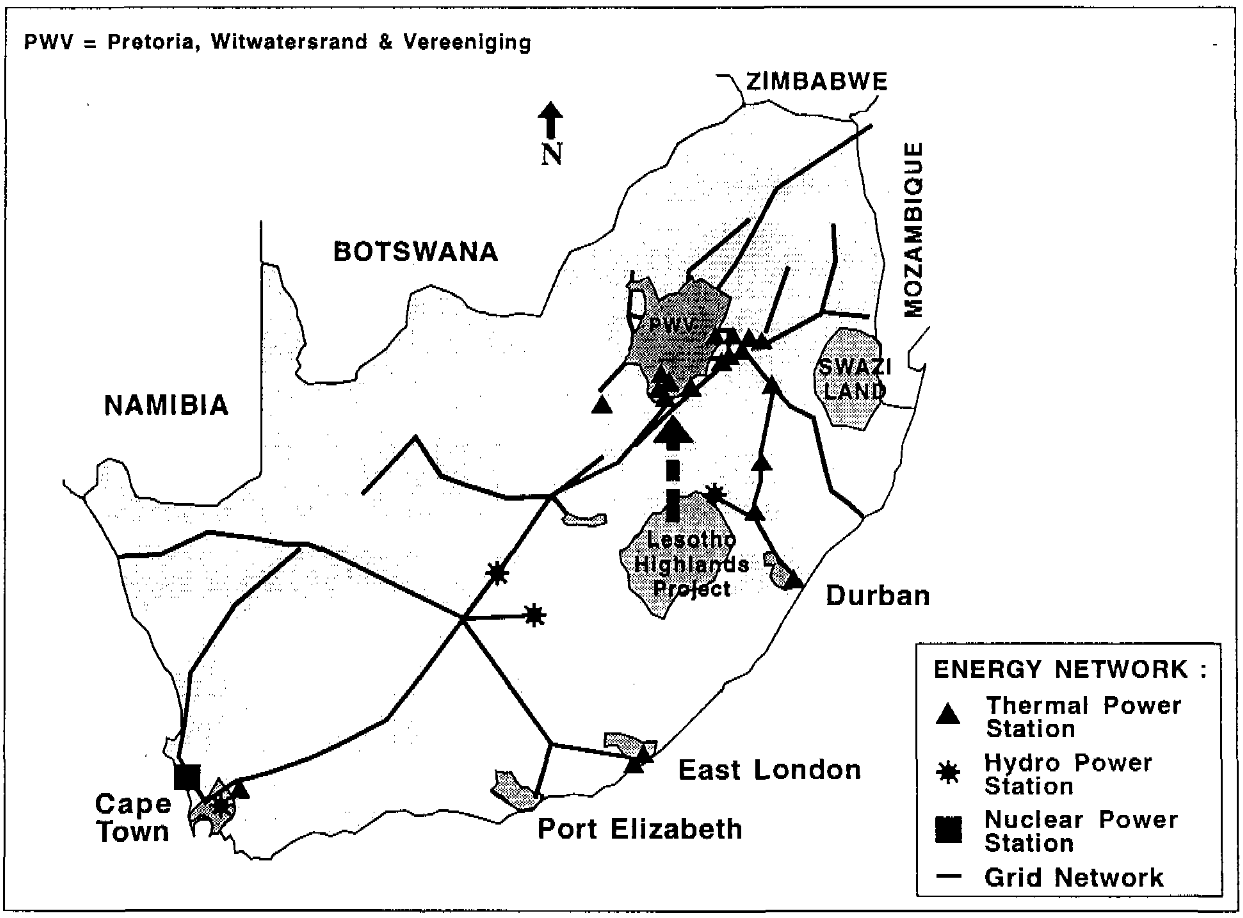

Figure 2. Energy development network in South Africa (1993)

3.6 Financial Resources

The fluctuations of the South African economy may be more frequent than in other parts of the world due to the major influence of weather patterns on agriculture as well as the upturns and downturns in international commodity prices. The integral economic problems in South Africa were seriously increased by the shortage of capital due to the international sanctions and low commodity prices affecting the country's export industries, particularly gold mining.

In the past two decades South Africa needed massive grain imports for drought relief and special feeding schemes. The most recent one has cost Rand 3,4-billion (about US$ 1,0 billion). The impacts on South Africa's Balance of Payment Account have been considerable, especially with regard to the foreign debt payments.

The reduction in local and foreign fixed investments has caused industries, particularly building and construction, to compete for the financial resources. All these factors have reacted on the national and regional economics. The new political dispensation faces the restoration process of the fundamental realities in both urban and the rural context to accommodate shorter time financial horizons.

3.7 Institutional Structures

The Transitional Constitution of the Republic of South Africa Act accepted by the new political dispensation outlaws discrimination on the basis of race or ethnicity. The whole hierarchy of institutional structures in South Africa is changing accordingly.

3.7.1 Central government : In May 1994 a new Central Government of National Unity was formed by the African National Congress (ANC), as the strongest political player emerging from the first democratic elections. The ANC formed a new parliament now responsible for policies and legislation.

3.7.2 Regional government : The Commission on the Delimitation and Demarcation of Regions was established in May 1993 to prepare recommendations on the boundaries of the new regional dispensation. The Commission recommended nine new regions (provinces) as opposed to the four former provinces and numerous homelands.

3.7.3 Local government : At the local level, a total of 950 local authorities are required to proceed to their dissolution and reconstitution as racially integrated Metropolitan sub-structures or Transitional Local councils outside metropolitan areas, by a rationalisation arrangement which ensures equal representation from the non-establishment groups which are free to nominate the local Councillors to represent them.

The local government structures will primarily be engaged in the implementation of the Reconstruction and Development Programme (RDP) to achieve reconciliation of fragmented local authorities. The local government administration will have to be most instrumental in providing upliftment in the water supply and sanitation. The National Water Council **(Asmal, 1994)** is due to be established to increase public involvement in water policy formulation, resources apportionment and financial allocations.

3.8 Water Availability

The average annual rainfall of about 500 mm for South Africa as a whole is well below the world average of 860 mm. A comparatively narrow strip along the coastline is moderately well watered, but the greater part of the interior and the western portion of the country are semi-arid or arid. Sixty-five per cent of the country receives less than 500 mm of rain annually, which is usually regarded as the minimum for successful dry land farming. Twenty-one per cent of the country receives less than 200 mm.

A wide variety of rainfall-producing mechanisms occurs across the country, affecting the reliability and variability of river flow. As it gets drier towards the west the variability increases rapidly. Over most of the country the average annual potential evaporation, which ranges from about 1 100 mm to more then 3 000 mm, is well in excess of the annual rainfall **(MWR, 1986)**. This affects surface run-off from rainfall significantly and causes high evaporation losses from water stored in dams. River run-off is collected within 22 main drainage basins (primary catchments) and large quantities of raw water are transferred annually from the areas with good river run-off, mainly into the semi-arid regions for urban water supply and power generation. There is now substantial evidence available that the desert and semi-desert conditions are encroaching towards the northern and eastern parts of South Africa **(Tyson, 1986)**.

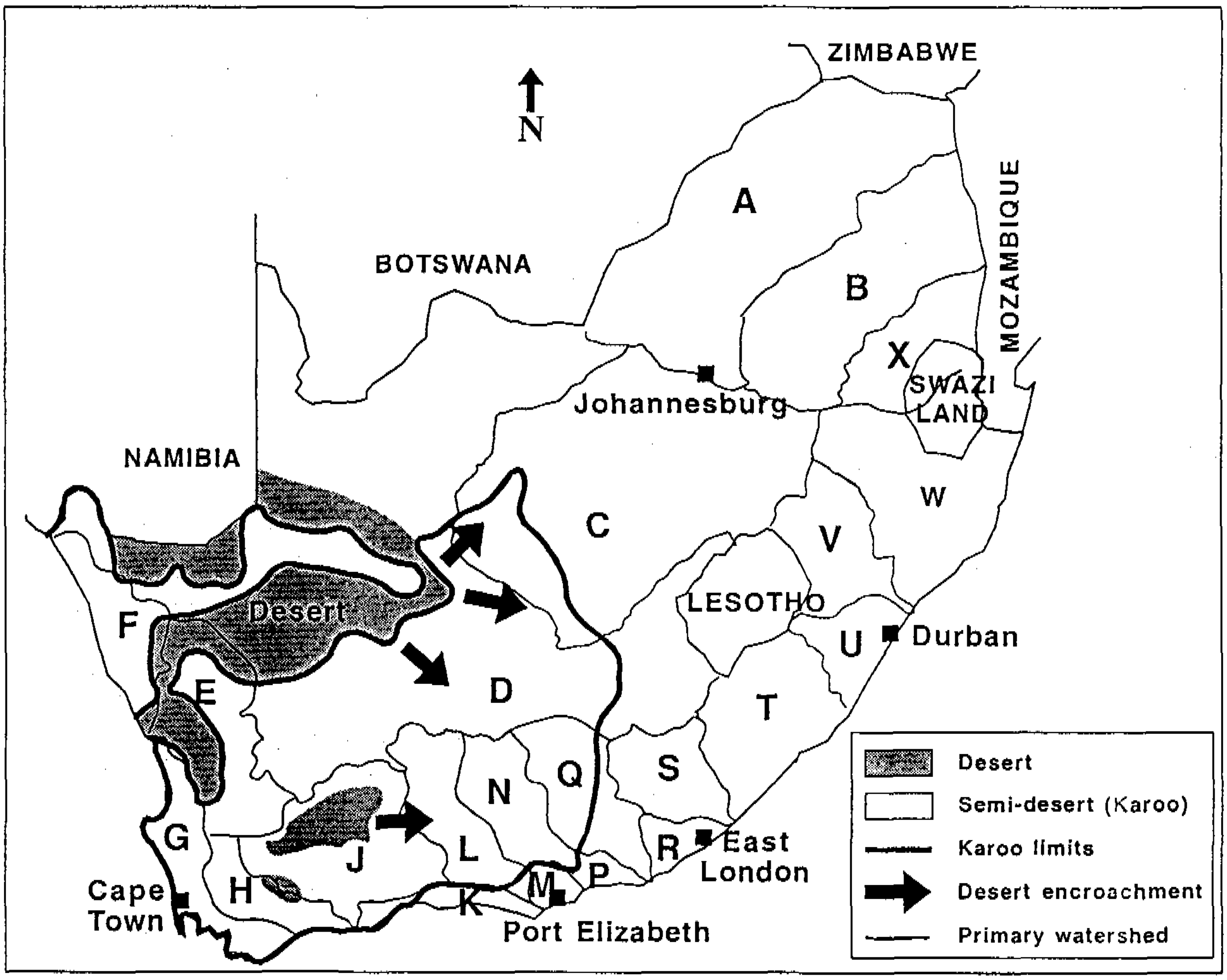

Figure 3. Desert encroachment over primary river regions

The combined average annual run-off of south Africa's rivers is estimated to be 53 000 million m^3. In some areas the highly variable river flow can have periods of up to 10 consecutive years of less than average flow. Such harsh conditions are taken into consideration during planning processes of future water resources development, but the supply of water from existing water systems is often subjected to water restrictions in order to cope with the limited supplies. Because of river flow variability and high evaporation losses it is estimated that, with the present state of knowledge and technology, only about 62 percent (33 000 million m^3) of the mean annual run-off can be exploited economically **(MWR, 1986)**. In addition, about 5 400 million m^3 may be obtainable annually from ground water sources (i.e. primary aquifers). There is an insignificant quantity of water available from unconventional water resources (e.g. desalination), but many rivers with a low base flow are highly dependent on the return flows (i.e. treated effluent discharges) generated within large urban areas.

4. MANAGEMENT OF WATER TO BALANCE DEMAND AND SUPPLY

4.1 The Custodian of Water Development and Management in South Africa

For more than three quarters of a century the custodian for the development and management of the national and regional water resources in South Africa has been the Department of Water Affairs (DWA). The DWA was established under the provision of the Irrigation and Conservation of Water Act, 1912.

At present the major instrument for water management exerted by the DWA is the Water Act, promulgated in 1956. The Water Act has been amended in many ways over the years to accommodate the changing water demands on available water resources and to maintain the operational integrity of about 130 Government Water Schemes administered by the DWA. These schemes provide raw or potable water for various water use sectors in South Africa. The regional water resources management is maintained by the DWA throughout its country-located centres based on the major river run-off areas (e.g. Cape Town, Pretoria, Durban, Upington and Nelspruit).

The decision-making process in water resources management and development in South Africa has been of a highly centralised nature to serve the Government of the day. However during the early 80's the DWA recognised that it would be impracticable to adhere to a master development plan due to changing demands on water resources influenced by many unknown factors relating to the overall political and socio-economical developments in South Africa. Nevertheless there was an urgent need for at least a review of the national water management strategy. Based on the pressing need the DWA compiled, in 1986, a study on the Management of the Water Resources of the Republic of South Africa. The national water management strategy as stated by the study **(MWR, 1986)** is aimed at the indefinite equitable provision of adequate quantities and qualities of water for all groups of users at an acceptable cost and assurance of supply, subject to continuously changing conditions. In view of the national water needs and water resources management practices the historical demands within twenty-two primary river catchments formed by the major watersheds amounted to the relative exploitation of conventional water resources as follows:

Table 7. Relative exploitation of conventional resources (i.e. renewable water)

Year	Total water demand (million m^3)	Relative exploitation (%)
1965	8 300	22
1970	12 488	33
1975	13 972	36
1980	16 290	42
1985	14 695	38
1990	18 300	50

4.2 Existing Water Supply and Retailing in South Africa

Most of the large inland urban settlements in South Africa are situated relatively far from adequate conventional water sources. Traditionally the trend in urban and industrial water supply is associated in one or other way with the mining industry which consumes large quantities of mostly imported raw water. On average 60 percent of the total annual urban water supplies originates from the state owned dams.

Table 8. Dam reservoir capacity according to ownership in 1990

Ownership	Capacity (million m^3)	(%) of total
Private	998	4
State	25 611	89
Board	1 486	5
Municipality	618	2

There are at present over 130 Government Water Schemes situated within the nine new provinces. All these schemes are administered by the Department of Water Affairs. The water from state dams is purchased mainly by the water boards and/or regional water service corporations and retailed by them to the local and metropolitan authorities serving urban areas.

The price of water around South Africa varies at present from Rand 0,5 to about Rand 1,20 per cubic metre. The influence of price on water demand has not been yet fully realised as many water users (primarily in agriculture) are heavily subsidised. The situation is inevitably changing with regard to user choices of alternative water use and sanitation technology as the price of water is rising annually (NUS, 1993).

Table 9. Most recent price increases per cubic metre of water

Year	Price increase (%)	Rate of inflation (%)
1988/89	16,0	15,7
1989/90	14,7	13,3
1990/91	13,8	15,2
1991/92	14,4	15,1
1992/93	11,5	9,9

Three water retailing levels were identified **(Barta, 1993)** among water supply systems in South Africa.

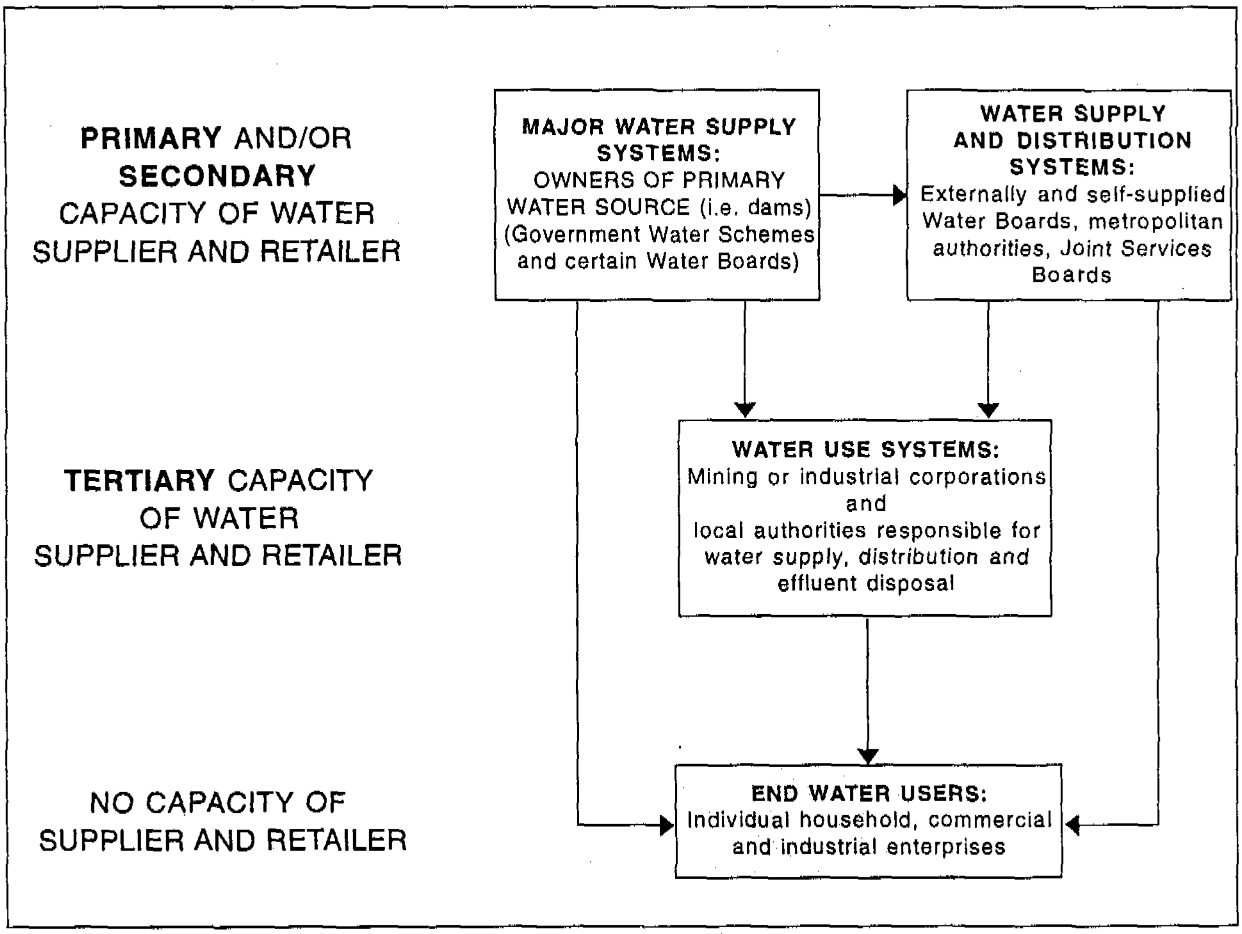

Figure 4. Urban water retailing in South Africa

At present there are sixteen water boards and eight regional water service corporations supplying an average 1295 million m^3 per annum to the urban areas located around the new provinces. Apart from 785 million m^3 obtained from the state schemes, the boards and corporations supplement about 510 million m^3 per annum from their own sources. The water is sold primarily to the local authorities, mines and industries. Although many are externally supplied some also abstract water from their own water sources (i.e. own dams and boreholes).

It must be noted that the primary and secondary water retailers do not generally have any particular responsibility related to the disposal of urban effluent. In South Africa this responsibility is traditionally vested with the metropolitan and municipal authorities operating the urban water use systems. However the large water retailers have an indirect strong influence on the magnitude of return flows. Their awareness about appropriate management of return flows is needed in a process for integrated management of available urban water resources.

4.3 Allocation of Water According to The Use Sectors

The use and allocation of water anywhere in South Africa is subject to the requirements of the Water Act, 1956 (Act 54 of 1956). The development of water resources based on the doctrine of separate development and fragmentation of South Africa into self-governing homelands created a need for the permanent water commissions to provide a coordination mechanism between the states. Over the years the commissions subscribed to the principles contained in a set of rules drawn up by the International Law Association in Helsinki in 1966. These rules were used as the basis for the joint use of water by all states sharing water with the Republic of South Africa. Under the new political order and with the homelands disintegrated and incorporated into the new regional dispensation, the function of permanent water commissions will be somewhat superseded and replaced most probably by the National Water Council.

Historically, agriculture accounted for most of the water used in South Africa. This was reflected in the water law which allocated rights to the water in public streams to the riparian owners subjected to the principles of the Roman-Dutch law. Although agricultural use of water has proportionally decreased, it is still the cornerstone of water rights in terms of South African legislation (**Hiddema, 1989**). The Water Act makes a distinction between public and private water. The private water is meant to be all underground water abstracted artificially or by means of fountains which are not the source of a public stream

Table 10. Present and anticipated water allocation in South Africa (MWR, 1986)

Water use sector	% of total		
	1990	2000	2010
Municipal and domestic	12,0	14,4	17,3
Industrial	7,6	9,1	11,4
Mining	2,7	2,6	2,5
Power generation	2,3	3,5	3,5
Irrigation	50,9	48,9	45,9
Stockwatering	1,5	1,4	1,4
Nature conservation	1,0	0,8	0,7
Forestry	7,5	7,0	6,6
Ecology (i.e. estuaries)	14,5	12,3	10,7

At present the total water demand by all water use sectors is about 18 300 million cubic metres per annum. It is anticipated that in twenty years the demand will increase two-fold. Approximately 15 percent of the total demand is satisfied from the groundwater. In theory the State controls the use of all water found in South Africa. The extent of the control differs between public and private water and between surface water and other categories of water. The control is administered primarily by the water law within the water control areas, in which the State has almost complete control of the water in a public stream. Outside of water control areas the common law riparian rights entitle a land owner to use of as much of the surplus water from a public stream as he can beneficially use on such land for domestic, stockwatering, agricultural and urban purposes. In case of industrial purposes a riparian owner must obtain a permit if a usage is more than 150 cubic metres per day.

4.4 Research and Technology Transfer in Support of Water Development

Water research activities in South Africa are co-ordinated and funded to a large extent by the Water Research Commission (WRC). The commission was established as an autonomous statuary body in terms of the Water Research Act in 1971. The research proposals from all spheres of water resources development and management are financed from a water research fund maintained through levies on all water sold by water supply authorities (i.e. local authorities, water boards, etc.). The WRC maintains a close co-operation in the field of water research with the Council for Scientific and Industrial Research (CSIR), universities, local authorities, industries, private consultants and various international specialists in water matters.

Between 1985 and 1993 the expenditure on water research provided by the WRC in South Africa increased from R17,2 million to Rand 40,3 million with some 260 research proposals submitted in 1993. The priorities in water research as identified by the WRC varied over the years, however most emphasis has been placed on the surface hydrology and quality of the surface waters. According to the Water Research Commission's Master Plan (**Cousens et al, 1988**) the foremost research needs identified by the commission for the late 80's and early 90's were defined as follows:

- **hydrological process** (i.e. precipitation, energy, evapo-transpiration, soil processes, runoff producing mechanism, channel processes).
- **catchment studies** (i.e. experimental catchments, research catchments and regionalisation studies).
- **surface water resources** (i.e. economic of supply and demand, optimisation of water resources systems, characteristics of flow and return flows), and
- **sediment studies** (i.e. sediment yield, model development and testing, remote sensing and instrumentation).

5. DEVELOPMENT STATUS OF THE PROVINCIAL WATER RESOURCES

5.1 Overview of The New Provincial Structures

The political settlement in South Africa took a definite change in direction during 1993 when the Multiparty Negotiating Council reached consensus on a number of major issues, including the demarcation and delimitation of nine new provinces. During the era of separate development South Africa was divided into four provinces but numerous administrative entities (i.e. homelands), with various self-governing status, were situated primarily around the northern and eastern parts of the country. The fragmentation of South Africa into smaller self-governing entities caused numerous problems with regard to water resources development and management. At one time, 15 permanent water commissions existed between the "homelands" and the Republic to maintain communication channels on water issues within shared river catchments. Most of the water projects augmented during the "homelands" era were based on political considerations rather than a sound regional water development policy.

The socio-economic profile ranking of the nine new provinces determined by the Development Bank of Southern Africa (**DBSA, 1994**) and compared according to the denominator represented by the human development index (HDI was devised by the United Nations a few years ago), resulted in an overall picture shown in Figure 5. The HDI's foremost parameters are disposable income per capita, average life expectancy, literacy, etc.

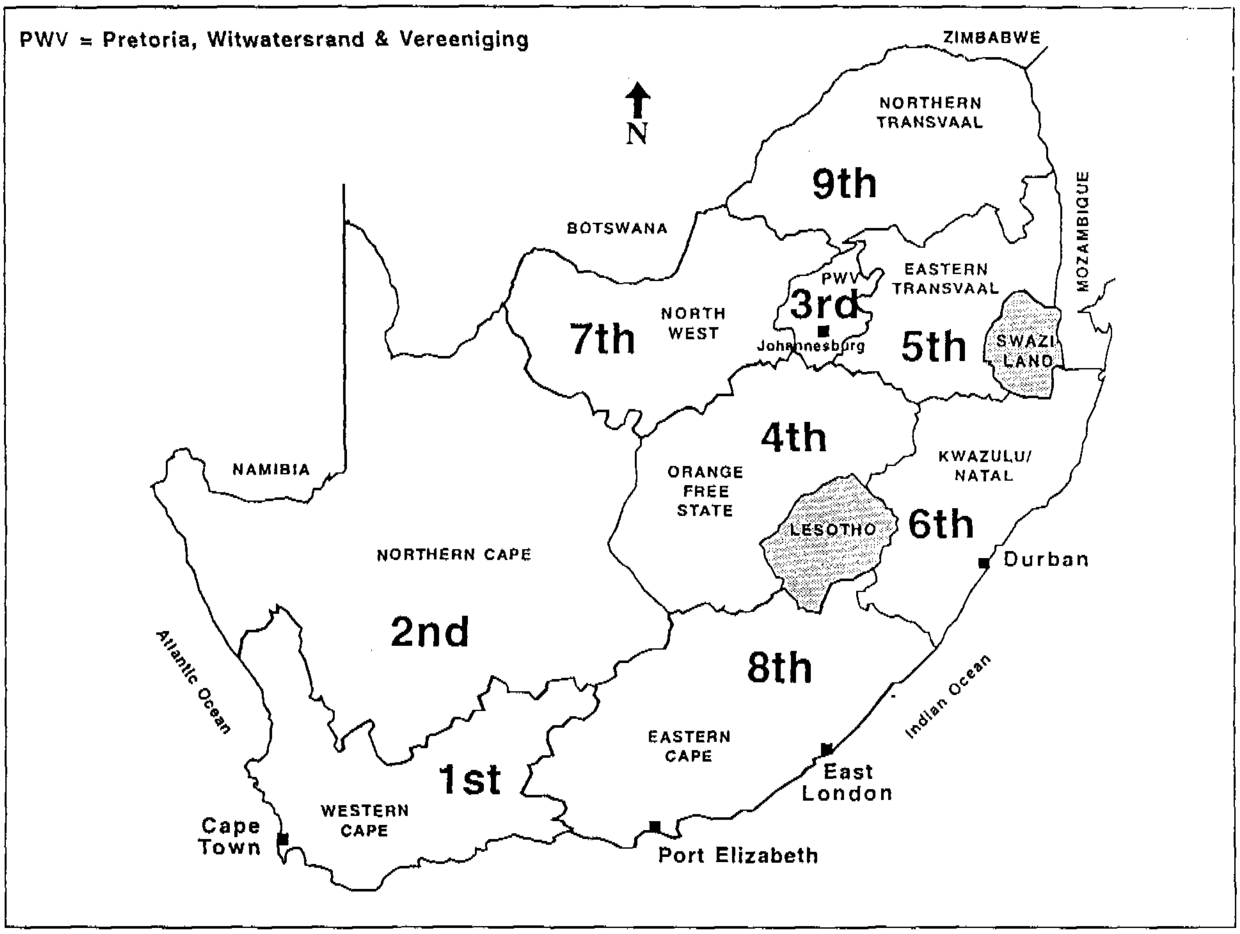

Figure 5. New provincial dispensation and socio-economic ranking in 1994

5.2 The Reconstruction and Development Programme (RDP)

The RDP as a socio-economic policy framework adopted by the new Government is now being implemented by all nine new provincial legislatures. After job creation, education and health services,water and sanitation for all people is the RDP's high priority short-term aim. Within the framework of RDP a national water and sanitation programme has been established with an initial aim of providing all households with a clean and safe water supply of 20 to 30 litres per capita per day within a distance of 200 metres from a dwelling site. This programme has to be integrated with all other urgent demands. It is envisaged that almost Rand 65-billion (i.e. US$ 18-billion) will be spent on social services in 1994/95 fiscal year by all major contributors, with the RDP fund providing Rand 2,5-billion.

The general election in April 1994 resulted in a Government of National Unity represented by a new Parliament consisting of a Senate and the National Assembly. Both houses of the new Parliament consist of 50 percent of members who are assigned from the nine new provinces. As the socio-economic parameters differ vastly among new provinces, the provincial legislatures face different magnitudes of reconstruction and development of provincial resources. The provinces are entitled to an equitable share of the revenues collected at the national level in addition to their own funds. As the provision of water supply and sanitation is a high priority in the Reconstruction and Development Programme (RDP) the capacity of existing infrastructures and water availability will play an important part in implementation of the RDP. The land reform has also a high priority ranking in the RDP inevitably exposing the issues of water rights related closely to the ownership of the land.

Table 11. Proportional comparison of nine new provinces in 1993

Province	(%) of total			
	Area	Population	Contribution to GGP	Available water
Eastern Cape	13,9	16,4	7,5	21,4
Eastern Transvaal	6,7	7,0	8,3	8,5
KwaZulu/Natal	7,5	21,0	14,7	26,3
Northern Cape	29,7	1,9	2,2	14,6
Northern Transvaal	9,8	12,6	3,1	6,6
North West	9,7	8,6	6,9	3,2
Orange Free State	10,6	6,9	7,1	8,2
PWV	1,5	16,7	36,9	1,3
Western Cape	10,6	8,9	13,2	9,8

5.3 Regional Development of Water According to The Use Sectors

South Africa's fast expanding population and unabated urbanisation process place increasing demands on all regional water resources. The retarded urbanisation created conditions contributing to the deterioration in quality of renewable water resources around urban areas. The contribution of agriculture to water quality degradation is not yet fully realised in many areas of the country. The competition between urban and agricultural water demand sectors will gather momentum in the near future. The riparian ownership based on the Roman-Dutch water law principles causes the agricultural sector to slow down the process of more equitable allocation of available water resources. The agricultural sector, due to its traditional subsidy benefits and low irrigation efficiency, will inevitably be in need of wide-spread rationalisation to achieve more efficient use of water resulting in reduction of quantities used.

The assessment of quantitative water demands according to the foremost water use sectors analysed on the background of the new provincial dispensation indicates that the agriculture and forestry sector consumes by far the most water annually. One exception is the highly urbanised and industrialised PWV province, where 90 percent of the total water supplies is utilised by the residential and industrial water categories.

Table 12. Total water demand according to use sectors and new provincial dispensation in 1993

Province	% of total			Total water demand (million m³ p.a.)
	Urban & Industrial	Agriculture & Forestry	Ecology Requirements	
Eastern Cape	8	50	42	2330
Eastern Transvaal	18	80	2	2270
KwaZulu/Natal	20	53	27	3000
Northern Cape	3	75	22	2980
Northern Transvaal	10	86	4	1330
North West	4	96	-	1020
Orange Free State	36	61	3	1180
PWV	90	10	-	1800
Western Cape	14	71	15	2400

Notes: Urban and industrial sector includes water use by mining and power generation categories. Ecology requirements include water quantities for maintaining of riverine and estuarine eco-systems.

The Department of Water Affairs and Forestry has been commissioned by the new Government to prepare a draft legislation to consolidate and rationalise water law issues in South Africa. The numerous amendments promulgated since 1956 are to be revised and the Water Act is going to be updated to reflect the changes and to provide the legislative framework for the equitable and non-competitive allocation of water. A draft White Paper is to be published with invitation to the public to submit comments **(Asmal, 1994)**.

6. NATIONAL WATER MANAGEMENT FROM SUB-CONTINENTAL PERSPECTIVE

6.1 Relative Exploitation of Renewable Water in South Africa

The finite nature of renewable fresh water makes it a critical natural resource which needs to be continuously examined in the context of population growth and water utilisation circumstances. In South Africa at present the renewable water resources (i.e. surface and groundwater) are in relative terms exploited to about 50 percent. This figure is derived by balancing exploitabhle renewable fresh water against water used annually by all sectors of the country's economy. With an overall population growth as high as 2,6 percent per annum between 1980 and 1990 South Africa is heading for tough times as far as water resources development is concerned. According to the United Nations medium population projections to the year 2025 South Africa is ranked by the 1990 fresh water availability as a water-stressed country. By the year 2025 South Africa will be considered to be a water-scarce country **(Engleman & Le Roy, 1993)**.

The future developments of water resources in South Africa's nine new provinces will have to be subjected to well integrated management practices to overcome adverse hydrometeorlogical, physical, socio-economic and financial conditions. Enormous challenges are facing the new provincial Governments together with water resources managers on all levels of regional water supply and sanitation systems.

Table 13. Relative exploitation of renewable water according to provincial dispensation in 1993

Province	Total water demand (million m^3 p.a.)	Total exploitable water (million m^3 p.a.)	Relative exploitation (%)
Eastern Cape	2330	7790	30
Eastern Transvaal	2270	3110	73
KwaZulu/Natal	3000	9580	31
Northern Cape	2980	5310	56
Northern Transvaal	1330	2400	55
North West	1020	1170	87
Orange Free State	1180	3000	39
PWV	1980	490	overexploited
Western Cape	2400	3560	67
Total South Africa	18310	36410	50

6.2 Integration of Water Development and Available National Resources

South Africa entered the period of socio-economic and institutional transformation with the main aim of providing all the country's people with access to the equitable share derived from the development of national resources. At the same time, the country reached the halfway mark in the exploitation of its renewable water and faces all adverse effects associated with retarded urbanisation and serious scarcity of capital for urgent and balanced development of all available resources. The high population growth and a considerable backlog in provision of social services among various population groups are the main problems due to be resolved by the reconstruction and development programme, which can only be successful if a practical and highly integrated management approach is implemented in the future development of all national resources.

The problems of present water resources management in South Africa are primarily related to the adverse distribution of stochastic hydrological conditions and inadequate funding for the development particularly in the rural and peri-urban areas. The people living in these areas were traditionally without relevant representation in a bargaining process to secure an appropriate share in the regional and national developments **(Hollingworth, et al, 1994).** The political climate has changed and the social services, particularly water supply and sanitation sphere, are receiving a high priority in the development process.

The management strategies for the national and regional development of water resources will have to be reconciled with the new emerging objectives based on community participation and a conflict resolution approach. Well co-ordinated and integrated water management mechanisms will have to be implemented and supported by a mixture of appropriate water law legislation, and political and institutional decisions on the regional and national levels to meet the needs of all South Africans.

6.3 Benefits of Resources Integration In The Southern Africa Sub-Continent

The outcome of the first democratic election has thrown South Africa suddenly into the international community as a fully recognised member. This created vast opportunities for the country's economy and a long awaited consistent development of all national and regional resources. At the same time enormous pressures are developing on existing human, institutional and financial resources inside of South Africa. The process of regional integration among eleven countries situated in the Southern Africa sub-contient, started in May 1994 and should culminate in the near future in a framework of adequate regional policy on developing available regional resources. The availability and demand for water should be recognised as critical variables in future developments.

Table 14. Water availability per capita in the countries of Southern Africa

Country	Population (million)	Average population growth (1980-1990)	Water availability per capita in 1990 (cubic metres)
Angola	10,2	2,64	17 200 (water-abundant)
Botswana	1,3	3,75	14 500 (water-abundant)
Lesotho	1,8	2,85	2 300 (water-abundant)
Malawi	**8,8**	**3,54**	**950 (water-scarce)**
Mozambique	15,7	2,61	4 100 (water-abundant)
Namibia	1,8	3,15	6 300 (water-abundant)
South Africa	**40,0**	**2,58**	**1 400 (water-stressed)**
Swaziland	0.8	3,42	9 300 (water-abundant)
Tanzania	27,3	3,77	2 900 (water-abundant)
Zambia	8,5	3,95	11 800 (water-abundant)
Zimbabwe	9,7	3,14	2 300 (water-abundant)

The economic benefits of developing the whole sub-region in an integrated approach, particulary water resources, are very significant with regard to the contribution and potential each country can make available to the process of development. South Africa has many resources to offer but the water scarcity may hamper development of resources in medium to long-term. For such reasons it is imperative for South Africa to participate in Southern Africa's integration.

7. CONCLUSION

As at any previous time, the process of water resources development will have to explore a wide range of feasible solutions to find compromise solutions in consultation with all users depending on shared water resources in particular regions of Southern Africa to maintain effective decision-making process of optimum joint and integrated water development.

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INSTITUTIONAL DEVELOPMENT FOR WATER DEMAND MANAGEMENT IN SEMI-ARID ZONES - NIGERIA'S EXPERIENCE

J O Sonuga[1]

ABSTRACT

Following the wide-spread disaster in West Africa caused by the sahelian drought of 1972-73, the need was recognised for strong management and improved efficiency in meeting the peculiar water demands in the semi-arid zones. The paper describes Nigeria's approach and efforts since the 1972-73 disaster to develop appropriate institutional capacity for the development and management of water resources in the semi-arid area of northern Nigeria. The area constitutes about 28% of the total area of the country and it is prone to incidents of drought. The area also consists of scattered communities and the Local Governments could not adequately take on the responsibility for water supply planning and demand management and for preparing for drought in water resources management. The concept of river basin authorities was adopted. By this, it has been possible to develop a co-ordinated overall approach to water resources development and management.

RESUMÉ

La terrible sécheresse du Sahel qui s'est largement répandue en Afrique de l'Ouest en 1972-1973 a mis en évidence la nécessité d'avoir une gestion efficace de l'eau dans les zones semi-arides. Cet exposé décrit la méthode et les efforts du Nigéria depuis 1973 en vue de se doter des capacités de gérer efficacement les ressources en eau du nord du Nigéria. Cette région qui couvre 28% de la surface du pays souffre de périodes de sécheresse. C'est une zone d'habitat dispersé où les gouvernements locaux n'avaient pas la capacité de gérer les ressources en eau. Le concept de "Autorités de Bassin" a été mis en place permettant ainsi une approche globale de la gestion des ressources en eau.

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1. INTRODUCTION

Drought in semi-arid regions usually results in prolonged occurrences of dry years and associated harsh environmental degradation (collapse of crop yield and loss of life). The Sahelian zone of West Africa is shown here in Fig.1. Severe drought conditions in this zone in 1972-73 caused one of the worst natural disasters of this century (ref. Sonuga, 1977). In Nigeria, the drought event was seriously felt in the semi-arid parts of the country situated north of Latitude 11° 00" N (see Fig 2). This area constitutes about 28% of the territorial area of Nigeria.

The effects of the drought were the more severe because of the virtual absence of water resources development in the region. Thus, the disaster was of grave concern to the national government as well as to international organisations which provided relief and short-term measures. However, because drought is a recurrent phenomenon, occurring in diverse degrees of severity and at varying intervals of time, the short-term measures could not be satisfactory for combating future effects. Indeed, a decade of low rainfall followed the drought event of 1972-73 culminating in another bad year in 1983.

All the above underscored the need by government for a rational planning of the country's water resources. Consequently, serious commitments have been made on the part of both the Federal and State Governments of Nigeria in long-term plans for water resources development and demand management.

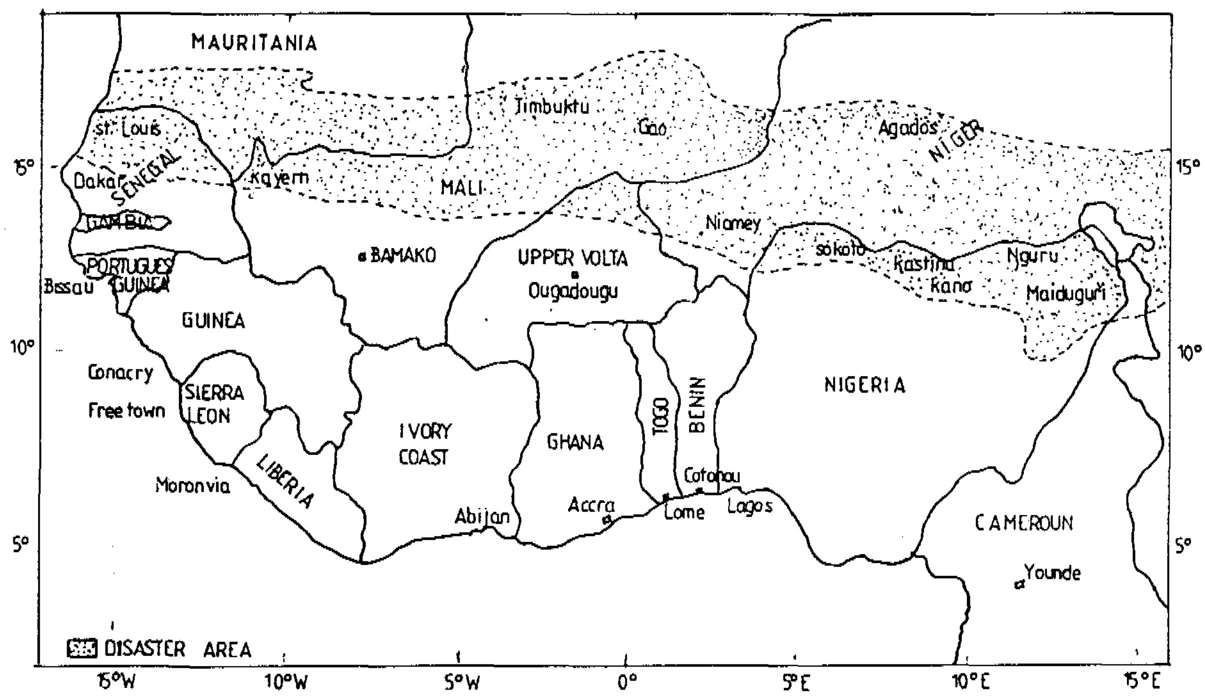

Fig. 1 - Sahel Region of West Africa

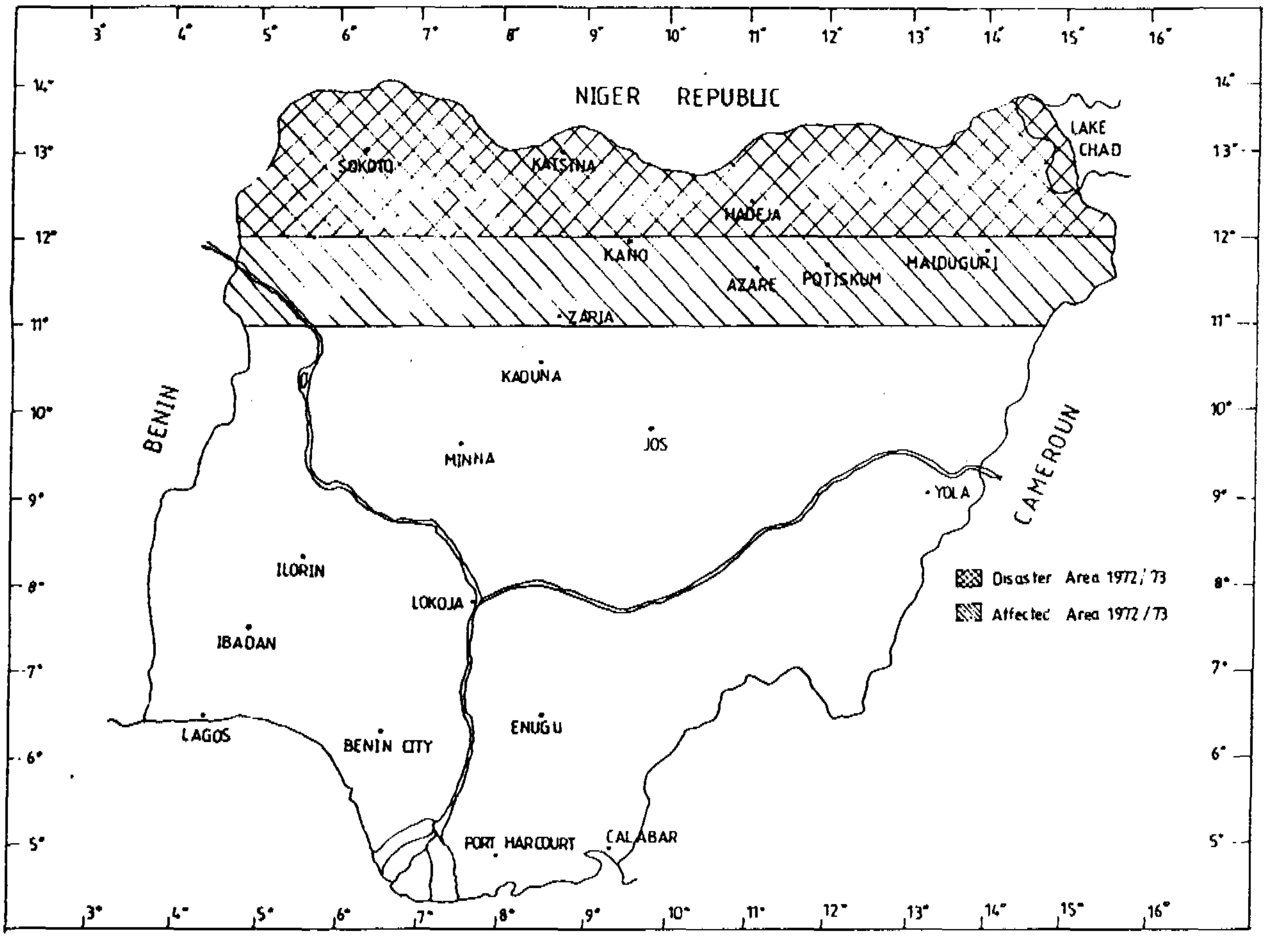

Fig. 2 - Map of Nigeria showing Drought Area

2. INITIAL EFFORTS

An important aspect of the long-term measure involved the assessment of water resources availability in the semi-arid region. It was recognised that by 1973, the hydro-meterological data available were not adequate for the assessment and for the planning of measures to meet demands. There had been very few hydrological stations in the drought prone areas and the records of some of the existing ones were unreliable. Therefore, the Federal Government initiated actions through the Federal Department of Water Resources for:

- expansion of the network of hydrometric stations within the area;
- extensive borehole development for water supply and ground water monitoring;
- promotion of training in hydrometry.

Consultants were appointed as necessary on the programmes for monitoring and management of hydrometric stations, well and boreholes in the river basins within the area. Through these programmes it has been possible to establish a basic network of hydrometric stations for effective data management and water resources studies and planning.

Furthermore, the geological setting in the semi-arid zone is of fundamental importance especially in the appraisal of water availability. The geology of the semi-arid zones as a whole in Nigeria is made up of two major rock types as shown in Figure 3. To the West is a sedimentary deposit known as the **Sokoto Basin Formation** occupying an area of about 63,700 sq.km and to the East is another sedimentary deposit referred to as the **Chad Basin Formation** (over an area of 120,400 sq.km). In the centre, sandwiched between the sedimentary deposits, is an extensive area of **Basement Complex**.

The sedimentary formations comprise soft sands, gravels and clays. They are of low relief and highly permeable with appreciable groundwater storage capacity. The basement complex is a formation comprising granites, gneisses and schists of both igneous and metamorphic origins. It is a hard impermeable strata with a hilly terrain and with little groundwater storage capacity.

The major river system in the semi-arid zone is also presented in Fig. 3.

Studies were undertaken by UN-FAO on the water resources potential of the sedimentary formations of the Sokoto and Chad Basins. The report of the studies recommended the development of reservoir dam projects on the Sokoto-Rima River basins for improved agricultural development and flood control. The study also advised on the establishment of the Sokoto-Rima River Basin Development Authority as an institutional organisation for executing and managing the development projects.

Furthermore, the FAO report proposed the use of water from Lake Chad for irrigation development within Nigeria and recommended the establishment of the Chad Basin Development Authority as the institutional set up for the execution and management of the development projects. The Federal Government accepted the FAO recommendations and in 1973 a decree was promulgated establishing the two River Basin Development Authorities.

The State Governments within semi-arid zones as at 1973 are also shown in Figure 3. It is observed that a large area of the Kano State is underlain by the basement complex in which groundwater potential is very low. The Kano State Government took upon itself to carry out a study of water resources potential of the State. The resulting effort was the establishment of a Water Resources Masterplan for the State. Because of the limited and unreliable groundwater availability in the Basement Complex, the masterplan involved essentially the development of over 22 reservoir dams (varying in size) all over the State. An institutional organisation was established called WRECA (Water Resources and Engineering Construction Agency) to undertake the design and construction of these dams as well as the management of their utilisation.

Some initial efforts were also made at the Local Government level in developing borehole programmes for livestock and small scale irrigation.

Fig.3

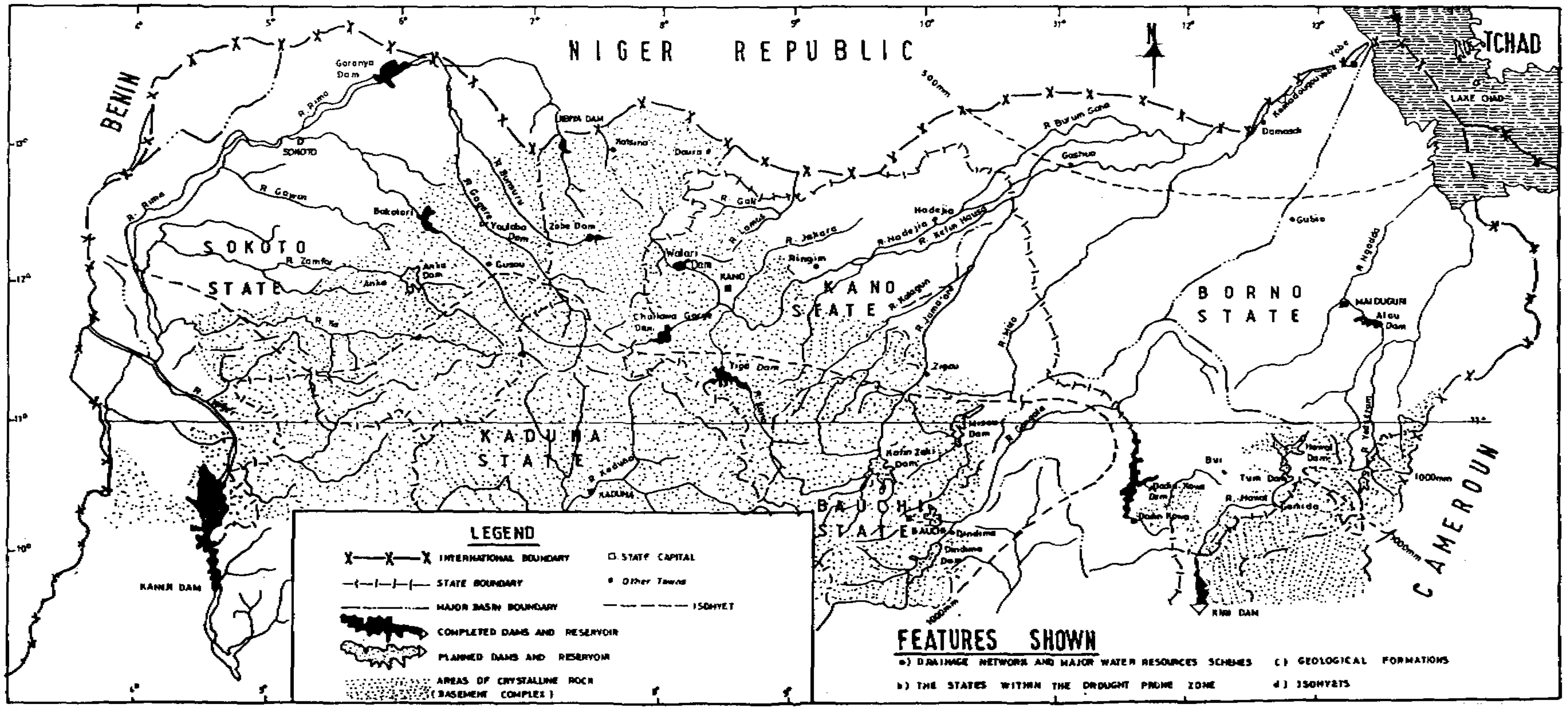

Fig. 3 - Features of the Semi-Arid Zone of Nigeria

3. INSTITUTIONAL DEVELOPMENT

3.1 The River Basin Development Authorities

Following the UN-FAO studies, the Federal Government adopted the river basin approach as a long-term measure generally for water resources development and demand management in the country.

A river basin constitutes a natural aerial unit over which the inter-action of all the phases of the hydrological cycle can be evaluated. It provides a convenient system for an effective study, assessment and development of the integrated totality of the land and water resources within it.

The concept of the river basin as a development unit ensures a co-ordinated development of land and water resources on a regional basis. It also allows an effective management of the utilisation of the available resources.

As mentioned earlier two River Basin Development Authorities (RBDAs) - the Sokoto- Rima River Basin Development Authority and the Chad Basin Development Authority - had been established in the semi-arid region. A decree was promulgated in 1976 establishing other River Basin Development Authorities all over the country making a total of eleven in all. The **Hadejia-Jama'are River Basin Development Authority** became the third RBDA to be established in the semi-arid region. This RBDA took over the major functions and activities on water resources previously performed by the Kano State **WRECA** (Water Resources and Engineering Construction Agency).

Thus, from 1976 to date three RBDA's exist as the three **Federal Institutions** for the regional development of the water resources and management of their utilisation in the semi-arid zone. These are restated as below:

- the **Sokoto-Rima Basin Development Authority** - to the West
- the **Hadejia-Jama'are River Basin Development Authority** - in the centre and
- the **Chad Basin Development Authority** - to the East

The name of each Authority denotes the major river (or lake) basin of jurisdiction.

The three River Basin Authorities have planned and implemented a number of water resources projects to meet current and future demand situations in their areas of jurisdiction. Some of these major projects are also indicated in Figure 3.

3.2 Impediments to Institutional Capacity Growth

The RBDA as organised is no doubt an effective arrangement for regional co-ordination of water resources development and demand management. However, the size of operation and standard of performance of the RBDA will depend to a large extent on the level of its development (that is, capacity building).

The three RBDAs in the semi-arid zone of Nigeria had suffered and continue to suffer from certain problems adverse to their capacity building. The major problems may be summarised as a) inadequate resources (man-power shortage and poor facilities), b) inadequacy of planning data and management information and e) inadequacy of funding.

The existing man-power situation in all the RBDA establishments is grossly inadequate at all levels both in quality and number. The RBDAs have all engaged in ambitious programmes of water resources development within their basins putting further strain on their low human resources. However, the RBDAs and the supervising government Ministry (the Federal Ministry of Water Resources) are fully aware of this problem. There are plans to undertake a proper assessment of the man-power requirements in these establishments and to develop strategies for meeting these objectives. In the meantime, a programme of training and re-training facilities are being offered to staff. But, it is still necessary to give greater attention to man-power development for effective and efficient performance of the RBDAs' functions.

There is the problem of inadequacy of data on which to base the planning, design and management of the various projects being undertaken by the RBDAs. There is a general lack of project data in coverage, quantity and reliability. Some of the water resources projects so far executed have been based largely on generated data or information obtained from investigations conducted over a short period. The RBDAs can have no effective management capacity without a comprehensive data base on land and water resources as well as on socio-economy. The Federal Government and the RBDAs are fully aware of this problem and efforts are being made on a continuous basis to improve the situation as far as financial resources permit. For instance, as stated earlier a significant action of the Federal Government was the programme initiated in 1983 for the monitoring and management of hydromet stations.

However, about a year ago a national water resources inventory survey was carried out by the **Japan International Co-operation Agency (JICA)** as part of its assignment to formulate a **National Water Resources Master Plan** for Nigeria on short-(up to year 2000) and long-(year 2020) term basis. This had given the nation the opportunity to critically review the data and information available in all its ramification. The needs within the respective river basins have been assessed and some of the recommendations of JICA for strengthening the data delivery systems are being considered. A water resources data bank already exists within the Federal Ministry of Water Resources which has been strengthened with the provision of computer hardware and software systems. The RBDAs are being supported and encouraged by the Federal Ministry of Water

Resources to keep up with their data management activities including publication of data year books.

Perhaps the most important problem affecting capacity building of the institutions (the RBDAs) is fund inadequacy. The two problems stated above are also related to fund inadequacy. Most water resources development projects are capital intensive. Furthermore, with the perennial poor economic situation in the country, government has been unable to release adequate funds as and when required.

Furthermore, the failure of the existing projects to meet expected demand and benefits have been traced to a large extent to poor (or lack of) maintenance due to limited funding.

Most of the projects of the RBDA are dams and irrigation schemes on which the Federal Government has made huge investments. In order to ensure safety of the dam and the benefits from the investments, government has recently approved annual allocations of huge sums of money to strengthen the maintenance capacity of the RBDAs.

New projects to meet further demand requirements are being sourced through external financing. In general, it is evident from the efforts of government that the need for adequate funding is accepted by government as a primary key factor for building up the capacity of the RBDAs to be able to cope with their expected institutional functions.

4. DEMAND MANAGEMENT ISSUES

As stated earlier, the RBDAs in the semi-arid regions had embarked on large scale water resources projects planned as a long-term measure to meet water demands for multi-purpose use but principally for irrigation. Indeed, provision of water for irrigation has been a major pre-occupation of the RBDA as it is considered that in the drought-prone area, irrigation facility would provide huge socio-economic benefits.

However, there is now the realisation that most of these large scale irrigation projects can no longer meet the planned targets, thus giving rise to demand management problems. For instance, the South Chad Irrigation Project (SCIP) was planned by the Chad Basin Development Authority to cover a total irrigable area of 67,000ha of flat clay plains in three stages (Stage I covering 22,000ha, Stage II - 27,000ha, and Stage III - 18,000ha) see Fig 4. Water for irrigation is obtained from Lake Chad through an intake channel extending about 38km into the lake. SCIP is planned essentially for small-holder farmers. Stage I was commissioned in 1974 and both Stages I and II have been substantially developed. But after only a few years of operation, the Project suffered heavily from decreasing water availability from the Lake.

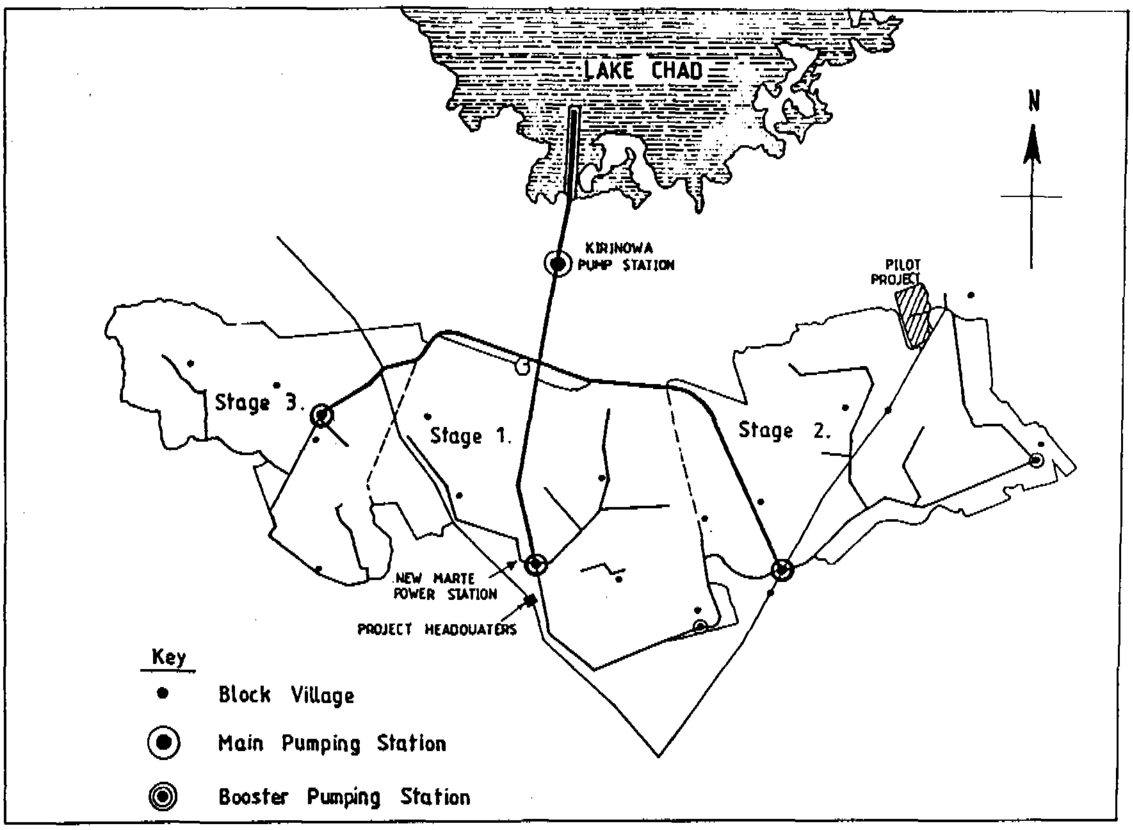

Fig. 4 - Layout of the South Chad Irrigation Project

The primary cause of this declining water availability has been due to the sahel drought (1972-73) followed by prolonged years of low rainfall. The annual rainfall since the Project started (in 1974) has been below the long-term mean. This effect compounded by developments in the Cameroun upstream of the Chari-Legone river system (which contributes 70% to 80% of the inflow to the Lake), the level of Lake Chad has been falling over the years, limiting the water available for irrigation. Fig 5 shows the yearly level of the Lake at the Kirinowa intake channel, displaying the steady decline of the Lake level between 1976 and 1982. The Lake area continues to contract in area at an alarming rate. There is also a gradual depletion of the groundwater reserves in the Lake Basin, thus promoting the formation of saline marsh lands in the foreshore of the Lake.

The other major problem with the Project is related to soil degradation. The prevailing long drought conditions in the Basin area and the lack of sufficient water for irrigation have caused the gradual accumulation of unfavourable salts in the soil surface.

The above two major problems have adversely affected crop production. The present crop yield from SCIP is far below the yield projection estimated for the project in 1975 (ref. MRT 1975).

One of the long-term measures that may be considered will be by inter-basin water transfer of water to augment the water in the Lake. There are possibilities of inter-basin water transfer from sources within Nigeria (River Hawal basin transfer through Ndagga river) and outside the Nigerian borders (Zaire-Chad-Niger Inter Basin Water Transfer). These possibilities are still being studied.

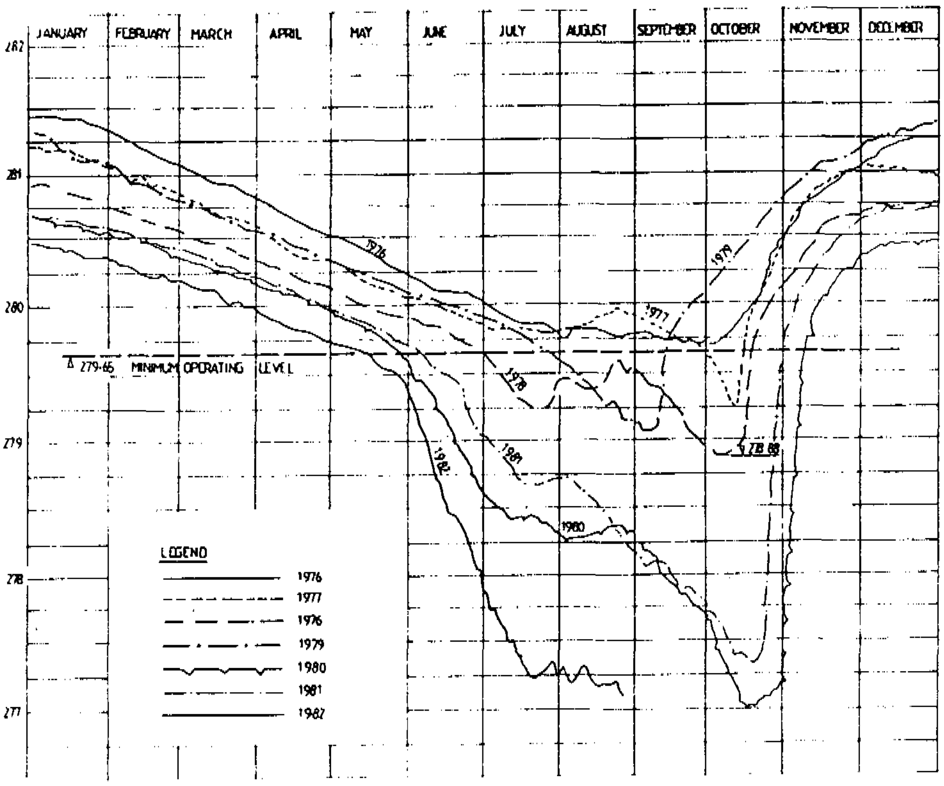

Fig. 5 - Lake Chad Level at Kirinowa Intake Channel (1976 - 1982)

The Hadejia-Jama'are River Basin Development Authority also has its own problems related to demand management. The Authority developed two major dam projects in the upper basin of the Hadejia river system comprising the Tiga Dam on the Kano river and the Challawa Dam on river Challawa, both rivers being large tributaries of the Hadejia river - see Fig. 3. It is planned that water from the reservoir of these two dams will be used for large irrigation projects of i) the Kano River Project Phase I (KRP I) covering 22,000 ha, the Hadejia Valley Project Phase I - 12,500 ha and the KRP II - 40,000 ha. The water demand for these irrigation projects is estimated at 800 MCM.

The Tiga Dam was completed in 1973 and the reservoir water has since been used extensively for KRP I and water supply to Kano city.

The Challawa Dam was completed in 1992. When the two dam projects were planned in early 1970s, the potential surface water resources were estimated at 920 MCM on an average for the Tiga Dam reservoir and 480 MCM for the Challawa Dam reservoir. However, from a recent water use and balance study of the basin area by the Japan International Co-operation Agency (ref. JICA 1993), it has been found that run off at the Tiga Dam has decreased by about 25% over the decade following the sahelian drought. Thus by the 1980s, the potential surface water resources in the Tiga reservoir has reduced to about 690 MCM on an average and 400 MCM in dry year. For the Challawa dam reservoir the reduction is about 30% giving a potential figure of 330 MCM on an average and 200 MCM in dry year. This means that the total water availability in the Tiga and Challawa reservoirs in dry year (600 MCM) cannot supply the irrigation water demand of

800 MCM for the three large irrigation projects mentioned above as planned. There is the need to consider also loss due to evaporation (estimated at 300 MCM) and other uses (water supply). Furthermore, the study of the surface water balance for the basin area by JICA (ref. JICA 1993) has shown that the river basins of Tiga, Challawa, and the other tributaries of Hadejia river and river Jama'are have a water use ratio of more than 40% of average annual runoff and, thus, may face water shortage problems.

The above is a classical demand management issue brought about by drought conditions in the area. It would be necessary to revise the KRP II and also the dry season Irrigation intensity at the KRP I and Hadejia Valley projects on the basis of available reservoir inflow.

The Sokoto-Rima River Basin Development Authority has also engaged in large irrigation projects. Almost all these projects, making up a total of about 112,000ha irrigable area, are distributed mainly in the northern river basins of the Sokoto-Rima system. The irrigation water demand for this area estimated at 1,200MCM is to be supplied by reservoir dams constructed at Bakolori on the Sokoto river, Zobe on the Bunsuri river, Goronyo on the Rima river and Jibiya of the Gada river. But only less than 10% of the planned irrigation area has been actually developed. Other irrigation projects have also been planned covering a total of 71,000ha in the lower reaches downstream of the Goronyo dam. However, a study by JICA (ref. JICA 1993) has revealed that the potential surface water resources at the downstream reaches of the Sokoto-Rima system will decrease appreciably due to seepage and evaporation. Therefore, compensation water releases would be necessary to meet water shortages that would occur at these planned irrigation schemes.

In general, the water balance study for the area by JICA (ref. JICA 1993) reveals that "the river basins of the Gada, Bunsuri, Sokoto and Rima will have a high water use ratio of more than 40% for average annual runoff". Therefore, there is a need to re-assess the projects (both existing and planned) in the river basins to determine water management rules for an appropriate integrated use of the river and dam reservoir water.

5. CONCLUSION

The three River Basin Development Authorities established in the semi-arid region of Nigeria are considered a suitable institutional arrangement to undertake the responsibility for water resources development and demand management in the region. The Authorities are still faced with certain impediments to their capacity growth involving mainly i) man-power shortage, ii) inadequacy of data and information and iii) inadequate funding. But these are being properly addressed.

From the surface water balance studies of the river basins in the region, a high water use of over 40% of the average annual runoff has been observed. There has also been a gradual reduction in inflow into some of the dam reservoirs since completion of the dams. The primary cause has been attributed to the long period (about two decades) of low rainfall following the drought incident of 1972-73. Consequently, there is the risk of water shortages occurring at the planned and existing projects. However, serious attention is being given to this important management issue by the River Basin Development Authorities.

For efficient water demand management in the region, there is a need for the RBDAs to carry out regular monitoring of the projects performance in meeting targets and socio-economic objectives of government. The scope of the evaluation should cover both strategic performance (the process by which available resources are utilised in order to fulfil the specific output targets) and operational performance (level of achievement in meeting set targets and objectives). It is also observed from the foregoing that there is a need for a regular review of water management rules on the basis of changes in water availability and demand.

The experience in Nigeria so far has shown that, within the limits of resources available, set organisational targets and of national policies and objectives, the River Basin Development Authorities have proved to be an appropriated institutional set-up for water demand management in the semi-arid region of Nigeria.

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APPROPRIATE POLICY INSTRUMENTS FOR MANAGING WATER DEMANDS IN NIGERIA

Lekan Oyebande[1]

ABSTRACT

Several agencies are involved in water resources management in Nigeria: from the local to the Federal government. The state governments have primary responsibility for urban and rural water supply. At present, statements of policy objectives are too general and sketchy to provide adequate guidance for water demand management. Some changes which have taken place since 1985 have however shaped significantly the policy horizon for water management as a whole. Nevertheless, acute water shortage is constantly experienced in all sectors of the economy especially in urban areas.

The policy instruments needed to ensure adequate demand management in order to meet future water needs include charging of more realistic water tariffs for all uses in order to promote efficient and sustainable operation and maintenance, and systematic monitoring of water systems both in urban and irrigated areas to minimize system losses. Others tools are multi-purpose approach for the allocation and use of water stored in dam reservoirs, adoption of appropriate and cost effective technologies in water industry as well as sustained investment in gathering, storage and dissemination of hydrometeorological and socio-economic data. The latter is vital for effective management.

RÉSUMÉ

Un nombre des agences sont chargés de l'ammenagement de l'eau au Nigeria: ceci varie du local au gouvement federal. Les états du pays sont responsables pour l'approvissionement en eau pour leur centres urbaines et rurales. Au moment actuel les objetifs et les instruments d'ammenagement de l'eau au Nigeria sont très generaux et inprécis. Depuis 1985 on constate des ameliorations dans l'axe de la direction de l'ammenagement de l'eau. Neanmois il exite encore des crises de l'eau dans tout les sectors de l'economie specialement dans les centres urbaines.

Les instruments d'ammenagement qui doivent se mettre en place pour combattre ce problème a priori doivent être inclus: l'introduction du tarif d'eau pour toutes les usagers pour des bonnes operations du système et d'entretien un suivi du système d'eau dans les régions urbaines et irrigués afin de reduire au minimal la perte du système. Les autres sont la répartition optimale, a tous usages de l'eau dans les réservoirs, le choix des technologies rentables et appropriés, l'investissement dans l'assemblage des donnes hydrometeorologiques et socio-economiques et leur récupérations afin d'avoir un ammenagement en eau efficace.

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1. INTRODUCTION

The coming decades present unprecedented change and challenges on a global scale. Population growth will persist; food production and industrial output and energy will triple worldwide and increase five-fold in developing countries. In particular, domestic water use by developing economies will have to rise six-fold over the coming four decades. The bulk of this demand will come from urban areas where populations will triple. The increase will strain surface and ground water resources and will call for more efficient allocation within river basins. In addition, climate change is expected to aggravate the situation through its impact on hydrological cycle components and hence water resources.

This growth and change will also bring with it the risk of severe environmental damage with increased water pollution, desiccation of urban environments, and poverty especially in developing economies, unless appropriate policy choices based on adequate scientific knowledge are made and implemented. It is also known that previous efforts by the international community to improve water supply and sanitation has been undermined by moderate to acute deficiencies of manpower and other capacity building components in many developing countries.

Nigeria's food balance for 1991 and 2000, for example, is largely one of deficits as the table below shows.

Products	1991	2000
	10^3 tons	10^3 tons
starchy roots	-9,551	-30,596
cereals	1,843	-4,038
oil crops	-617	-1,586

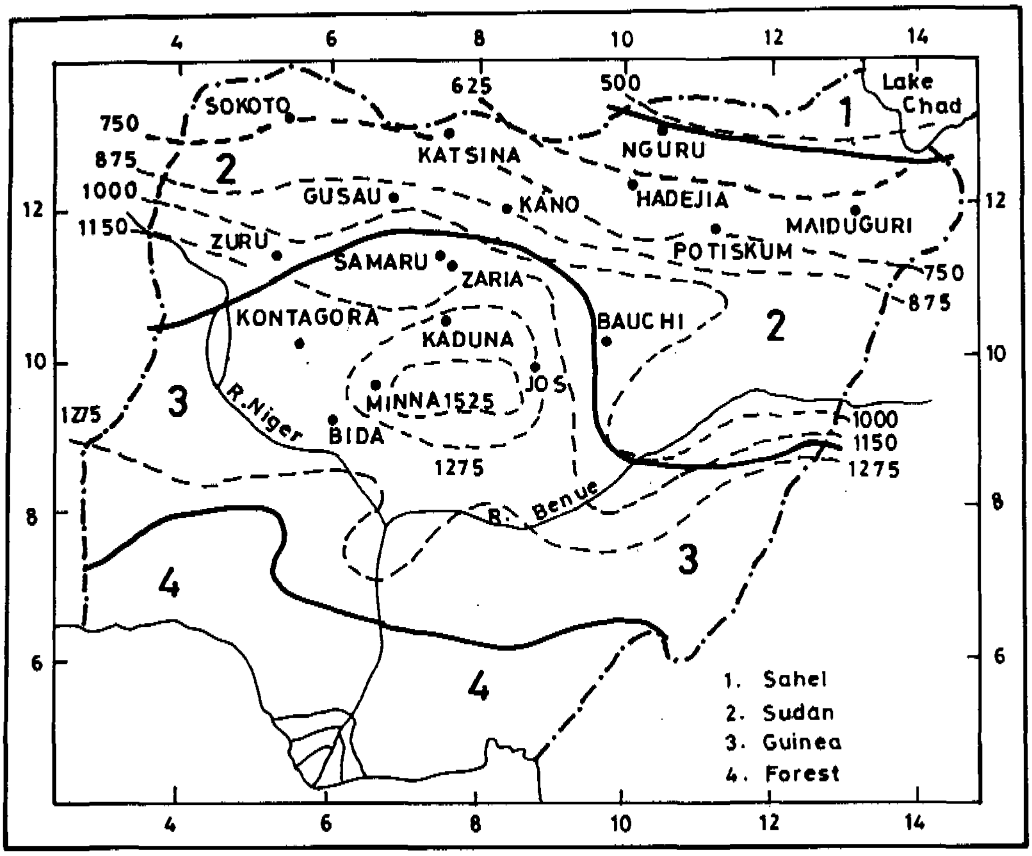
Under conditions of water scarcity, boosting food self-sufficiency and security, and meeting the domestic needs of populations which grow on the average at about 3% a year could be well impossible.

Thus there is need for simultaneous progress along each of several dimensions of sustainable management of water demands. These critical interacting dimensions are economic, human, environmental and technological. Another consequence of sustainability is that sectorial approach in which different categories of water problems, needs (water supply,water quality, hydropower, etc.) are seen and solved sectorally, must give way to a more integrated or holistic view, in which water problems are intertwined with social problems at different levels.

2. CLIMATE, HYDROLOGY AND WATER RESOURCES

Nigeria can be divided into four broad ecological zones: equatorial/tropical forest, Guinea savanna, Sudan savanna and the Sahel (Figure 1). The typical mean annual number of rain days in the Sahel is between 55 and 65 while the amount of rainfall ranges from 300-650 mm per year. The potential evapotranspiration can be as high as 3500mm during the year.

(a) Ecological Zones and Annual Isohyetals (mm)



(b) Desertification in the Northern States of Nigeria

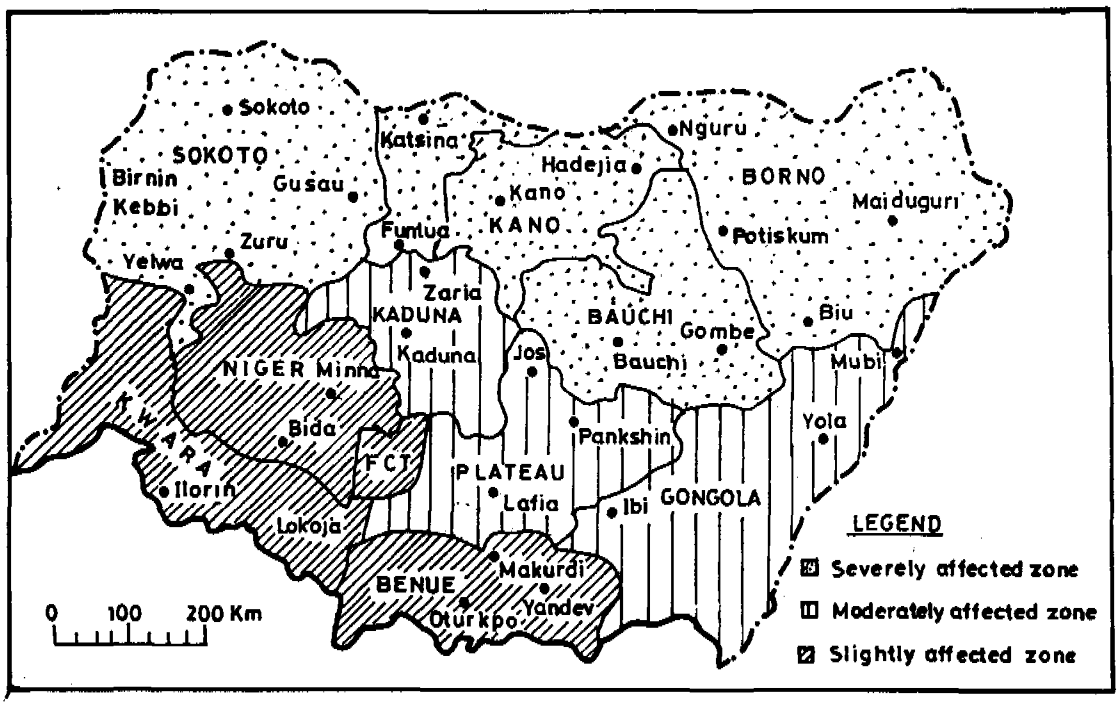


FIGURE : 1: Nigeria : Ecological Zones and desertification

Rainfall in the Sahelian zone of Northern Nigeria is low and variable with the bulk of total annual rainfall occurring in 5 to 10 high-volume, high intensity showers which generate considerable flood flows. Much of the north-west, north-central and north-eastern areas has experienced typical Sahelian climate during the last 25 years, and the cumulative effects of the prolonged desiccation has produced Sahelian ecological conditions even in areas that were formerly more humid.

Even the relatively more humid southern zones with annual rainfall of more than 1100 mm, the problem of variable and highly seasonal distribution of rainfall and high rates of evaporation can be worrisome. The balances between these two elements of climate determine the magnitudes and regimes of both river and groundwater flows. Table 1 shows the levels of evaporation loss from selected man-made reservoirs. The figures indicate that the losses could exceed 30 % of the active reservoir capacity in the drier zones of the country.

Table 1. Evaporation losses from Dam Reservoirs in Nigeria

Dam (1)	Zone (2)	Active Capacity (10^6 m^3) (3)	Evaporation Losses (10^6 m^3) (4)	Loss Capacity Ratio (%) (5)=(4)/(3)
Jibiya	Sahel	121	36.4	30
Zobe	"	170	54.0	31
Bakolori	"	403	96.0	24
Goronyo	"	933	280.0	30
Kotangora	Sudan	200	39.0	20
Omi	Tropical Forest	220	20.6	9
Kiri	Sudan	325	132.0	41
Ikere Gorge	Tropical Forest	225	6.4	28
Oyan	"	254	32.0	13
Challawa Gorge	Sahel	904	120.0	25
Tiga	Sudan/Sahel	1845	214.0	12
K. Zaki	Sudan	2500	300.0	12

The Sahel with the northern Sudan zone is a semi-arid region and is currently studied intensively under the appellation "Sudano-Sahelian zone" (SSZ). It is indeed part of the larger SSZ in Africa that has been described as a large area covering semi-arid and tropical wet-dry regions of the sub-Saharan Africa.

The major sources of surface water in Nigeria are the Niger and Benue river system, Lake Chad with its main catchment area in Nigeria, the K. Yobe-Hadejia river system. The seasonal and long-term variations in the flow of these rivers as shown by the range of the seven-year means and the ratio of the 90% probable flow to the mean annual runoff (1:65

for the Sudan and 1:250 for the Sahel) underline the importance of over-year storage as a means of making optimum use of the water resources. Most of the Sahelian rivers dried up during the 1984 drought, and the existing man-made reservoirs were like oases in the desert.

Altogether 162 large, medium and small dams have been constructed and are being operated in Nigeria. They have a total storage capacity of more than 30 x 10^9m^3, i.e. less than 10% of the country's total potential surface water resources. 85% of the larger dams are located in the Sudano-Sahelian zone of the country. A sample of 52 dams indicates that 79% have domestic industrial water supply components, while 33% have irrigation as a major use to which the stored water is put; 4% are also for hydro-electric power generation (HEP); 29% for fisheries, and 16% for recreation. All the dams contribute to flood mitigation and affect the area of wetlands (floodplain) in their downstream areas.

3. PRESENT APPROACH TO WATER MANAGEMENT

The Federal Ministry of Water Resources and Rural Development (FMWRRD) is charged with the overall responsibility of policy objective formulation, data collection, monitoring and coordination of water resources management at the national level. It supervises the twelve River Basin Development Authorities (RBDAs, now partially commercialized Federal parastatals) whose functions in their areas of jurisdiction include development of water resources infrastructures. This function is carried out through construction of dams and reservoirs, boreholes and irrigation systems to catalyse surface and groundwater development. They are also mandated to provide raw water from their multi-purpose reservoirs for urban water supply systems. All RBDAs use their dam projects for irrigation as a major purpose. The National Electric Power Authority(NEPA) dedicates its own dam projects mainly to electric power generation. The states (30) have primary responsibility for water supply in urban, semi-urban and jointly with other agencies such as local governments in the rural areas. These functions are carried out through the State Water Supply Agencies (WSAs).

Urban and Rural Water Supply

Raw water is obtained either by direct abstraction from a surface or borehole intake. For large-scale systems a dam is built to provide adequate storage. Many large urban centres now obtain water releases from dams constructed by RBDAs through some agreement brokered by the Federal Government. Unrealistically cheap rates are charged for such water, and even such low rates are hardly paid by the state WSAs.

Irrigation Water Supply

The RBDAs and in some cases state authorities design and construct storage dams as well as the associated irrigation systems. Local and other farmers are allocated land in the area commanded by the irrigation project paying nominal charges for water supplied to each hectare of land per season.

It is evident both in the case of urban/rural and irrigation water supply, that raw water is regarded more or less as free social good. The result is that little money is realised by the Agency in charge of the hydraulic structures for proper operation and maintenance of the infrastructural facilities. The WSAs and farmers who obtain cheap water in turn are not constrained to use the water efficiently or to charge high rates for water.

4. AVAILABLE WATER RESOURCES

The latest conservative estimate of Nigeria's water resources potential for a population of over 90 million is of the order of 313 x 10^9 m^3 per year, 87% of which is derived from surface sources (Table 2).

Table 2: Nigeria's surface and groundwater resources potential (1991)

	Groundwater (10^9 m^3)	Surface Water (10^9 m^3)	Total (10^9 m^3)
Northern Region	10.27	28.4	38.67
Central Region	25.48	115.5	146.98
Southern Region	23.76	109.5	133.26
Total	59.51	253.4	312.91

Although Nigeria as a whole still has less than 300 persons per million cubic meters per year, its northern region (about 40%) which is largely Sahelian has over 600 persons per unit and is expected to exceed 1000 by the year 2000 especially as groundwater (36% of its water resources) depletion accelerates. Application of appropriate policy instruments not only to increase the total available water but also the efficiency of its utilisation, especially in irrigation systems will become critical in the next century. Moreover, the downward trend of river runoff since the 1970 of the order of 20 to 30% in the northern region and 10-20% in the southern region has been worrisome.

An additional problem of water management which has made efficiency considerations imperative is the climate change. The main issue here is that decision makers and water managers are faced with increased uncertainty in evaluating future water supply and demand. The appropriate response to the challenge posed by this problem may well be to incorporate into the planning and especially the design of water resources projects all possible uncertainties and risks by increasing the margin of safety in managed systems.

5. WATER DEMANDS AND THEIR MANAGEMENT

Demand management addresses the ways in which water is used and the various tools available to promote more desirable levels and patterns of use it incorporates aspects of conservation and efficient use which are essential for reaching a reasonable balance between growing demands and infinite supplies. Until recently the focus of water resources management was virtually exclusively on the supply side. Fortunately, this narrow viewpoint is yielding to the increasing recognition that demand management is a key element in sustainable water management. The main aspects of demand management include rationalization of consumption, elimination or reduction of misuse and loss control. Others are full use of installed capacity, waste water re-use, and incorporation of efficiency indicators in managerial evaluation and assessment.

In economic terms, water supply is delivered at the entry point to the distribution system and demand is what comes thereafter(Jordaan et al.). Demand is said to include 'social' demand as well as the distribution system for meeting this demand. However water distribution systems exist (in urban and rural supplies) that range from public well or springs and street vendors of water to elaborate city distribution systems involving extensive networks of pipes that are supplied through pumping stations and temporary storage in water tanks.

Estimation of Water Demand

Inaccurate estimation of water demand for irrigation and water supply at the planning stage has undermined the success and efficiency of many existing projects. Even after such problems have been noticed, no review exercise has been undertaken to date, years after some projects have been in operation. Many operation and maintenance staff do not appreciate that water demand varies on weekly, and monthly basis. They thus have difficulty in managing the reservoir outflow at dam sites and the diversion water in the distribution systems of the service area.

Table 3: Water demands and deficits in urban and rural communities

(a) 1991

Item	NW	NE	CW	CE	SW	SE	Total
Urban Water Supply							
Deficit(MLD)	16	10	9	22	246(3)	245(4)	548(7)
" (lcd)	3	1	2	5	15	21	11
Rural Water Supply							
Deficit(MLD)	81(1)	155(2)	59(3)	99(4)	88(3)	128(16)	620 (29)
" (lcd)	15	16	15	19	16	18	16

b) The Year 2000

Item	NW	NE	CW	CE	SW	SE	Total
Population (10^6)	11.4	19.1	12.5	11.2	24.9	22.7	101.8
Projected Water Demand(MLD)	623	992	853	610	2194	1350	6622
Actual Supply Capacity	288	460	522	209	881	269	2629
Deficit Capacity	335	532	331	402	1313	1081	3994

(3) No. of states with large deficit (urban)
(4) No. of states with service population rate less than 10% (rural)
MLD = Million litres per day; lcd = litres per capital per day
NW = Northwest, CE = central east and SW = southwest

Source : FMWRRD(1993).

With the availability of census population data and the recent developments in the water sector, particularly the on-going water resources master plan studies as well as the newly promulgated water law, estimation of water demand and other aspects of water management should improve significantly.

Indeed accurate demand survey and assessment is a pre-requisite for efficient reservoir operation. In Nigeria, the range of purposes served by storage reservoirs include water supply for irrigation, domestic and industrial uses, hydroelectric power (HEP) for increasing water depth for navigation, flood control, reclamation of low-lying lands and recreation. Some of these uses conflict (e.g. flood control and HEP, and other uses) and priorities and proper balancing need to be carefully considered. Multi purpose operation necessitates allocation of specific capacity for each of the uses served by a particular reservoir.

The realisation of multi-purpose dam projects is imperative. However, dam design and the management of the storage system should be based on integrated planning and implementation. In Nigeria, more than 30 x 10^9 m^3 of water is stored in the 162 so-called multi-purpose dams. However, much more attention needs to be given to the maximization of benefits from those water projects, especially through multi-purpose use of the water storage. It is important for such multi-purpose development to be properly coordinated at the planning, design and construction as well as operation phases through active participation of the respective agencies responsible for the sub-sectors. It is also necessary to partition the lump sum cost of a multi-purpose water resources project among the respective project purposes using an appropriate cost allocation formula.

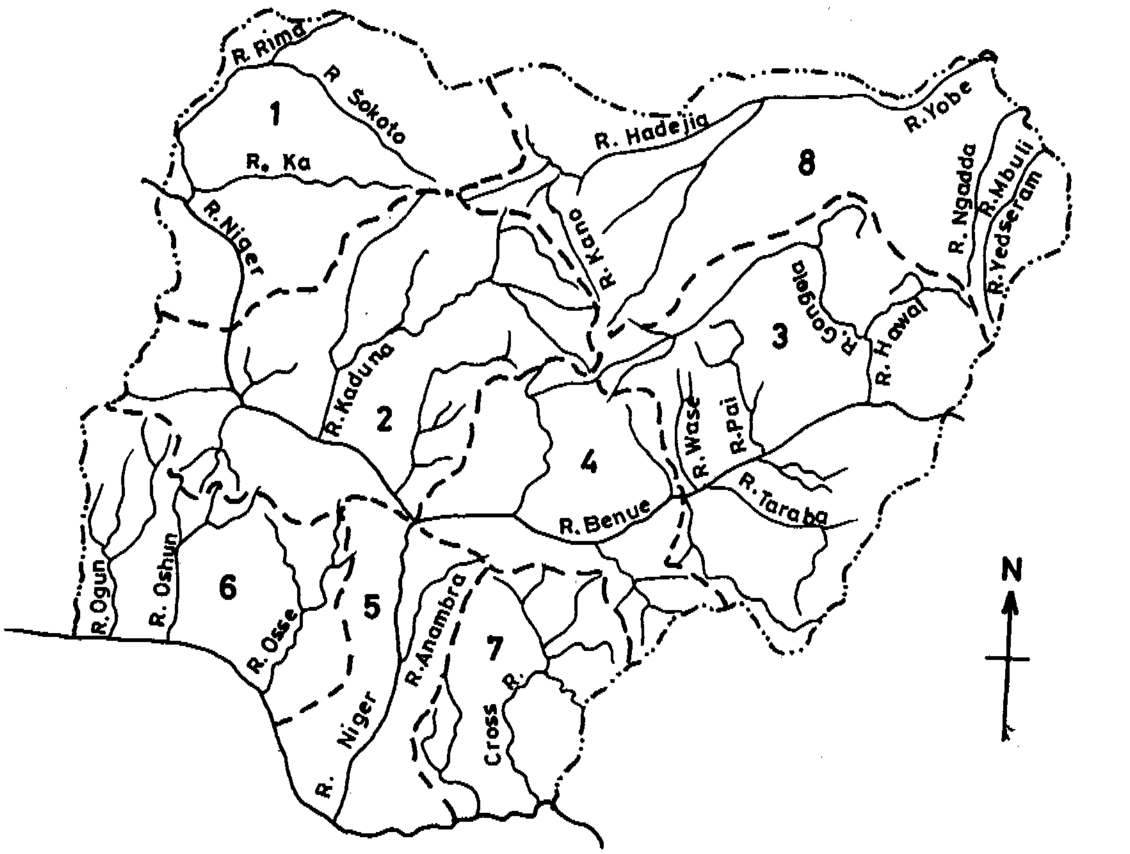
Demand management is examined in the present study in an integrated manner with emphasis on three sectors : irrigation, urban-industrial and rural communities and hydropower.

The balance between estimated water supply and water demand for 1991 (Table 3) shows deficits both in terms of the total quantity supplied and the per capita supply. Of the thirty states that make up Nigeria, seven have deficits in their urban water supply systems, while as many as 19 states could not satisfy the water demand in their rural communities.

For the year 2000, the projected total water demand for both urban and rural areas is 6,622 MLD(2.4 x 10^9 m^3 per year). The quantity will be in excess of the actual supplied capacity by nearly 4000 MLD (Table 3). The demand could be satisfied by that date only if the existing water works are rehabilitated as necessary while at the same time new water supply systems are also installed.

Thus in spite of abundant available water resources, a number of management constraints has restricted the supply level much below the demand for water.

In many cases waterworks are planned with over-designed capacity with respect to both current and future water demand. A number of important factors such as the population to be served, level of water demand and target year to satisfy the demand; operation and maintenance costs as well as amortization of the costs of the waterworks were obviously not incorporated into the planning and design. The result is that the cost of maintaining such



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LEGEND

International Boundary

Boundary of Hydrological Areas

HYDROLOGICAL AREAS (after FMWR 1980)

1 Niger North
2 Niger Central
3 Upper Benue
4 Lower Benue
5 Niger South
6 Western Littoral
7 Eastern Littoral
8 Lake Chad

Figure 2 :DRAINAGE NETWORK OF NIGERIA

large scale works is very high and cannot be covered by the revenues collected from the fewer users served by the much lower actual supply capacity.

Furthermore many waterworks are operated and maintained without an integrated management plan, which consists of a rational implementation plan for operation, maintenance manual, such as periodic check and inspection, schedules for rehabilitation and replacement, reconstruction and expansion (FMWRRD 1993). Often there is also no revenue and expenditure plan for implementing the above plan. Consequently, there is usually no sound basis for determining water charge or tariff that would provide adequate revenue to meet the expenditure incurred on the implementation of such a management plan.

Often too, waterworks make no provision for spare parts for installed equipment in their budget, nor for training of skilful staff for operation and management. Although the new civil service structure designates a percentage of the budget of each department for capacity building, especially training, many establishments in the water sector do not specifically appropriate such general provisions for upgrading the technical level and efficiency of their staff. As a result of the above shortcomings in the management of water works, and especially shortage of funds, many of them have delivered much less than their design capacity. In the case of urban water supply, the actual supply for the 30 states of the Federation and the Federal Capital Territory of Abuja is only 65% (2.5:3.85 x $10^6 m^3 d^{-1}$) of the design capacity. The ratio is as small as 57% in the three Northwestern states. In some cases the prolonged neglect has meant that the design capacity could not be recovered by mere rehabilitation and replacement of components, but by incurring large and perhaps unaffordable expenditures to provide entirely new waterworks.

Irrigation Water Demand

Irrigation water use accounts for over 80% (about 75% in Nigeria) of consumptive water use, yet the average use efficiency is only 37% world wide and much less in many developing countries. In Nigeria as in many developing countries, irrigated agriculture primarily depends on surface water. These irrigation schemes were originally conceived as vehicles for development: self-sufficiency in food, poverty alleviation, rural development, and reduction in urban irrigation. But according to Jordaan et al (1993), irrigation has failed generally to deliver the anticipated benefits. The explanation lies in the more complex situation in Africa. Social, political and policy issues result in low incomes for the farmers ($150-200 per ha/year), and in small land holdings ranging from 0.5 to 5ha per farmer. Nevertheless, while irrigation served only 15% of the lands in developing countries, it produced about 36% of the yield, and food for increased populations in these countries came almost exclusively from the expansion of irrigated land. In the long run, it is envisaged that water demand for irrigation will be limited not only through water supply, but more and more also through the amount of suitable land, as some 0.2 million ha. are lost annually globally to water logging and salinization.

The water demand for the crops is only a part of the demand for the irrigation system, much of which is determined by conveyance losses from leaky canals and faulty distributions and by evaporation. In the Nigerian environment, research is needed to find appropriate conveyance structures based on local materials and local construction skills. There is also by evaporation. In the Nigerian environment, research is needed to find appropriate conveyance structures based on local materials and local construction skills. There is also need for methods for evaluation of the performance of existing systems. Performance monitoring is required to obtain the performance indicators and such results must be translated into management decisions to assist policy formulation and investment decisions.

Table 4: Irrigation water demand of existing irrigation projects

Region	HA**	Existing		Programmed		Total	
Demand m^3		Area (10^6 ha)	Demand+ (10^6 m^3)	Area (10^6 ha)	Demand 10^6 m^3	Area (1000 ha)	10^6
NW	I	118	1,273	45	371	163	1,644
CW*	II	58	495	19	157	77	652
CE	III	63	620	26	241	89	861
CE	IV	15	148	14	130	29	278
SE	V	21	223	0	0	21	223
SW	VI	46	622	0	0	46	622
SE	VII	19	197	0	0	19	197
NE	VIII	185	1,883	127	984	312	2,867
Total		525	5,461	231	1,882	756	7,343

\+ Annual unit of water applied (m^3 ha^{-1}):8,600-13,400 for existing irrigation and 7,750 to 9,250 for formal fadama irrigation projects.
* Includes the new Federal Capital of Abuja(FCT)
** HA = hydrological areas.

Water demand for existing projects

Water demands of existing public irrigation projects (525,000 ha) and formal fadama typed irrigation projects (231,000 ha) are estimated by modified Penman method under the following assumption (FMWRRD, 1993).

- Irrigated crops: rice and other cereal
- Irrigation intensity:

  Public irrigation project: Wet season 100%, dry season 50%
  Fadama typed irrigation project: Wet season 0%, dry season 100%
- Effective rainfall: rainfall in five year return period
- Irrigation efficiency: 50 per cent

  Public irrigation project: 50 per cent
  Fadama typed project: 80 per cent

Table 5: Status of existing irrigation projects ('000 ha)

Region	Fully Developed[1]	Partially Developed[2]	Standstill[3]	Total
North-West	7.7	30.7	79.5	117.9
North-East	27.1	49.1	108.5	184.7
Central-West	11.1	45.7	-	57.5
Central-East	11.7	28.7	37.9	78.3
South-West	1.4	21.0	24.0	46.4
South-East	9.2	21.1	10.0	40.3
Total (percent of total)	68.9(13.1)	196.3(37.4)	259.9(49.5)	525.1(100)

1 Completed irrigation system and area is under irrigated agriculture;

2 Irrigation system only partially completed or under construction, for completion by 2000;

3 Water source works - reservoir dams and pumping stations completed, but studies and designs are yet to be done prior to construction of irrigation system, some 7 to 8 years may be required for completion.

Water demands of existing public irrigation projects is estimated at 5.5 x 10_9 m^3, out of which 0.7 x 10^9 m^3, i.e. 13 per cent of total demands is utilized for the operation of irrigation area with system fully developed (Table 5). In addition, water demands of formal fadama typed projects which are to be operated only in the dry season are about 1.9 x 10^9 m^3.

Total water demands of existing irrigation projects consisting of above projects thus amount to 7.3 x 10^9 m^3 of which 4.5 x 10^9 m^3 or 62 per cent of total water demand is required in the Sahelian NW and NE regions (Table 4).

Table 5 shows the status of existing irrigation schemes in the country. About 50 per cent are designated to have standstill status. In addition to these dormant projects are those in which the irrigation systems are only partially completed or are still under construction because of shortage of funds. In all, less than some 15 per cent of the reservoir water is currently released for downstream irrigation.

Hydropower Water Demand

Nigeria is endowed with fairly abundant hydropower resources, some of which have been developed. Most of the existing and potential sites are located on the Niger-Benue system. The existing hydro-electric plants are Kainji (760 mw) and Jebba (578 mw) both on the Niger; and Shiroro (600mw) on the Kaduna river, a tributary of the Niger. The total installed capacity of the three plants (1938 mw) currently in operation represents about 32% of the total system generation.

The three existing hydropower plants account for 60% of the total dam storage of about 30 x 10^9 m^3. Fortunately the water use is non-consumptive and is compatible with some other purposes, except flood control.

Hydropower generation has been severely affected by a combination of factors: the cumulative effects of the prolonged Sahelian drought (1967-86) and the upstream developments on the Niger which have reduced water availability in Nigeria by 31%; the construction of four dams on the first major tributary of R.Niger in Nigeria (the Sokoto-Rima) between 1982 and 1990 has further reduced the water availability for hydropower generation. These dams store water which are not yet used for irrigation, and much of which is not released downstream. Furthermore the man-made storage is exposed to high evaporation. This evaporation loss is on the average 25% of the total inflow into the dams.

Future opportunities for large scale hydropower development are being limited by upstream developments mentioned above, but installation of small plants of 15 mw can be adopted increasingly at village level to provide decentralised power on sustainable basis are viable supplements. At present small hydropower generation is estimated at 4.5% of the total hydropower capacity. It is likely to receive greater attention and more funding in the future.

6. STRATEGIES FOR SUSTAINABLE WATER DEMAND MANAGEMENT

Water management strategies will require structural changes in water pricing policy and other measures for efficient allocation of water. This is because the core issue of efficient water use is adequate pricing. It has been argued that the most effective means of encouraging the efficient use of water is to raise and enforce charges. On average, households in developing countries pay only 35 per cent of the cost of supplying water. Most of these governments have assumed that people cannot afford to pay the full costs; and they have therefore used limited public funds to provide poor service to restricted numbers of people (World Bank, 1992).This is a consequence of the unsuitable 'top-down' approach to water management. It is at the same time a strong case for water to be developed from 'bottom-up'- i.e by communities that need water.

In Nigeria, the water tariff in urban areas can be summarised as in Table 6.

Table 6: Water Tariff in Urban Centres

(i) Major urban areas (metered supply)	
	Rates per m^3
Domestic	₦2.2 to ₦ 5.5
Industrial and commercial	₦2.8 to ₦11.0
Institutional	₦2.76 to ₦ 5.5
(ii) Major urban areas (unmetered supply)	
Tenement	₦4.8 - ₦6 per room per month
" with toilet cistern	₦7.2 - ₦10.2 per room per month
Flat/apartment	₦ 25 -₦100 per flat per month
Single family house	₦ 25 -₦200 per unit per month
Duplex	₦ 50 -₦100 per unit per month

US $1 = ₦22

A good test of what urbanites are able and perhaps willing to pay for water is illustrated by how much they buy water from tanker water vendors. In Lagos, Abeokuta and most urban centres in the south private water vendors charge ₦300 to ₦400 per 4500 litres i.e. per 4.5 m^3 (or about ₦78 per m^3). This is more than 7 times the highest rate charged metered for supplies. And if the national per capita use of 50 l. per day is applied, it will cost the average household of seven members ₦815.00 per month buy water from tanker vendors. This is again more than 4 to 7 times the highest tenement water rate paid by a household whose water use is in any case a multiple of the national average.

Nationwide survey conducted by Oyebande (1990) indicated that 70 per cent of urban users and 68% of the rural users are willing to pay higher charges if a more reliable and higher level of service can be guaranteed.

Apart from denying public water agencies the much needed revenue for maintenance, operation and upgrading of their services, the subsidized water economy creates no incentive to use it efficiently.

Oyebande (1990) and a more recent survey in a suburban area of Lagos in 1993 list the following as the major sources of wasteful use of water.

Burst pipe - leakage from pipes	- 45%
Wasteful use at individual water connections	- 30%
Archaic (oversize)toilet cistern technologies	- 15%
Others	- 10%

The frequency of burst pipes could be very high and 84% of respondents are of the opinion that it often takes longer than a week before such burst pipes are fixed in that part of Lagos. Unaccounted-for water constitutes some 40-50% in the urban centres. Available technology should be used for carefully planned and aggressively pursued monitoring programme to detect leaks. The main cause of such leaks is well known : uncoordinated cutting of roads by different Services- water, power,telecommunications and public works- who in the absence of location map or suitable markers to locate water pipes often damage them.

Governments and public water agencies in Nigeria have come a long way from treating water as social service which should be provided free to the people. We are now at a point when it is recognised that water has a cost, that the cost is increasing for a number of reasons, and that the government alone cannot bear the burden of satisfying water demand from its lean financial resources. It is necessary to match water price with water cost (i.e. operating and maintenance cost including adequate provision for replacement). Pricing should also reflect that the increasing scarcity of water as conventional supplies get out of easy reach or deteriorate in quality. A new and flexible structure of water pricing required should provide those willing to pay with a good commercial service. Ways should then be explored of bringing service to those who are unable to pay (who should be fewer than generally thought) by setting carefully targeted "social tariffs". A third approach is to offer people with different incomes a broader menu of options (World Bank, op.cit). The graduated charges in Table 5 attempts to accomplish this objective as residential types reflect income level, and also relates charges to potential water use. The charges are however too low and not sufficiently discriminating between levels of water use or income.

Also time is ripe in Nigeria to initiate a bold step of privatization or at least commercialization of water utilities. As utilities because more autonomous, they will be more accountable for their performance, and will be compelled to attain a sounder financial status through better pricing policies. The private sector must also play a greater role. At least in large urban centres private companies should be allowed to be involved in, or take over, the running of water utility. For a start, components of the water services may be contracted out to the private sector. Examples of trends toward privatization in the developing countries include Cote d'Ivoire, Guinea (both in West Africa) and Santiago; and the three countries seem to have experienced considerable improvement in their water management.

As already mentioned, however, improved management should extend to water abstraction, treatment and pollution prevention and/or abatement. Accelerated manpower development is also required to provide adequate skilled hands to manage the water infrastructures efficiently. Appropriate technology should be promoted particularly for the local manufacture of water equipment, chemicals and other materials. In this regard, there is need for collaboration with the universities and research institutes to orient their activities to the practical problems facing users, and agencies in charge of water supply and irrigation.

Water Research and Technology Development Needs

As demand increases, re-use of treated waste water effluent will become important in water resources strategy of Nigeria, particularly in the drier northern zones, where more than 1000 persons will compete for use of every million cubic meters annually by 2000. This need will also arise in large cities with inadequate supplies.

The supply system for re-used water presents some problems, and separate distribution systems for re-used and freshwater will be required in the Nigerian environment to prevent the mixing of the two kinds of water. This need presents great technology and investment challenges in the poorly planned Nigeria and African urban areas which are in grave environmental crisis (Oyebande 1992).

Examples of local re-used water in individual buildings and small areas of communities however abound in many parts of Asia, particularly India, China and Vietnam for agriculture and landscape irrigation. This may be a good starting point for Nigeria.

The demand management approach with its conservation and efficient water use components does not require much of new techniques, but only more efficient use of existing technology, better management and effective transfers of knowledge and experience between tertiary educational and training institutions and water service agencies. Reductions of water consumption, and hence waste will also reduce the negative impacts of water use both in urban and irrigated lands. There is no doubt however that development plans for new water supplies should include an integrated strategy for water supply management, re-use, as well as comprehensive management of all aspects of the human environment.

7. SUMMARY AND CONCLUSIONS

Nigeria is endowed with abundant water resources. The Federal Government spent large sums of money to build many dams for irrigation mostly in the dry North during the oil boom era, but the related downstream development has subsequently progressed rather slowly with very limited funds. Large quantities of water have been trapped in the extensive reservoirs are wasting away through evaporation. At the same time much harm has been done to the traditional water users in the downstream fadamas area with much disruption to the ecological balance. Even the major hydropower dams are also being starved of 25-30 % of the inflow they require in the last ten years or so.

Appropriate plans for properly coordinated reservoir management of stored water should be established to avoid rapid and irreversible changes in the fadama ecosystem,and to support the sustainability of small scale irrigation, groundwater recharge, wetland cultivation, pastoralism, fisheries, or wildlife conservation. The approach should be integrated to include engineering, ecological as well as socio-economic and cultural aspects of the people in the affected areas.

Finally, the decisions about investment and other related activities should be made by those directly affected. They should be assisted to initiate and implement the plans in a bottom-up approach.

The cost of meeting additional water needs of the ever-increasing population by the turn of the century is prohibitive if the business-as-usual approach is adopted. There is thus need to adopt appropriate policy tools including cost-effective technologies in the water industry to achieve sustainable balances between growing demands and the finite water supplies.

Also proper design and installation adequate hydro- meteorological networks to gather water resources data to be used as basis together with socio-economic information for reliable water demand prediction and quality control is imperative. This is more so in view of the threat of climate change and environmental degradation both of which call for a more robust and efficient design and operation of water-resources projects as well as the need to minimise wasteful use of water through adequate pricing policy and control of environmental impacts.

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BENEFITS AND COSTS OF PRIVATE WATER USER ASSOCIATIONS FOR LARGE GRAVITY SYSTEMS: THE EGYPTIAN EXPERIENCE

Max K. Lowdermilk and Essam Barakat*

ABSTRACT

This paper documents and analyses the costs and benefits of establishing and maintaining a program of private water user associations (WUAs) for public gravity irrigation systems in Egypt under an irrigation improvement proto-type program. The documentation of direct and indirect benefits and costs are provided based on Irrigation Improvement Project (IIP) data and records. Transaction costs for which monetary values cannot be provided are higher than expected in establishing new programs. Orders of magnitude of costs and field data documenting benefits to farmers and the Nation are provided. Water User Associations are defined as " private associations of water users who own, operate, control and manage their organizations for their own benefits in improving irrigation water control for achieving improved production possibilities for increased net farm income". Establishment costs are high and costs for building sustainable WUAs capable of managing new technology and their own micro-systems are substantial until they are fully institutionalized. This far reaching institutional innovation in Egypt is one of the more significant efforts of establishing private WUAs on large public gravity systems in the Asian and Middle East Regions. Lessons learned from this experience may be useful for other countries planning to introduce private water user associations.

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BENEFITS AND COSTS OF PRIVATE WATER USER ASSOCIATIONS FOR LARGE GRAVITY SYSTEMS: THE EGYPTIAN EXPERIENCE

The purpose of this paper is to estimate the costs and benefits of establishing and maintaining a program of private water user associations (WUAs) in Egypt. WUAs constitute a new challenge for both the Ministry of Public Works and Water Resources (MPWWR) and water users. Under Ministerial Decree number 53 of 1989, the MPWWR took the bold innovation of giving water users a larger role and voice in improving the performance of Egypt's large public gravity system. This development has taken place within the context of the Irrigation Improvement Project (IIP) which is the first prototype project of its kind in Egypt. Private WUAs were made legal under Law number 213 passed by the People's Assembly on June 17, 1994. To support this recent legislation, the Peoples' Assembly also approved legislation for cost recovery of micro-system capital costs from water users and a Special Fund for Irrigation Improvement in the MPWWR. Since there is increased interest in the role of water users in improving systems and irrigation performance in many countries, it is important to share the Egyptian experience in terms of estimating its establishment and continuing costs as well as benefits. As is well-known in institutional development, a long-term perspective is needed for building sustainable organizations which require changes in irrigation codes, laws, operational procedures and the reorientation of staff at every level of the irrigation system and its administration.

1. LITERATURE REVIEW

The literature on private water user associations (WUAs) is voluminous. Until recently, WUA literature has been somewhat biased toward small or communal-type run-of-the-river irrigation systems (Hunt, 1987). While there has long been a strong ideology advocating private WUAs, there is now a shift toward viewing them more in a non-ideological or business context. Studies of WUA development typically document benefits but seldom provide information on the costs of establishing and maintaining WUA programs. Major benefits reported include:

-increases in water availability to farmers
-increases in irrigated area served
-increases in cropping intensities and yields
-savings in construction costs
-savings in maintenance costs
-increased equity in water allocations
-resource mobilization from farmers in cash and labor
-reduction in administrative costs
-reduction in corruption and extra legal practices
-increased fee and cost recovery collections
-improved two-way communication between water suppliers and water users

Uphoff et. al. (1985) state that "investments in irrigation hardware are considered justified if they have rates of return in the 10 to 20 percent range. They also estimate that programs of "active farmer participation (WUAs) appear to have payoffs closer to 50 percent per annum". This is a major hypothesis which requires testing in different projects and country contexts. In a related institutional field, Evenson (1992) shows that research and extension types of programs, across a number of countries, have returns of from 30 to 50 percent in developing economies and from about 40 to 50 percent in developed economies. But given the lack of hard data on costs and benefits of WUAS, some water resource scholars and professionals are either ambivalent on the subject or have opposed WUA programs as being too costly or too prone to failure (Young, 1992).

North (1992) shows the importance of transaction costs in institutional development and how various types of transactions impact economic performance. Transaction costs are all those costs incurred in building or operating organizations which are essential to an economy. For example, lawyers, bankers, accountants, clerks, foremen, managers and politicians don't produce anything that individuals can consume but they do determine how well an organization, nation or its economy actually work. Likewise, there are many participants in the economy of water resources who don't produce things that people consume but they are essential to the process of building sustainable programs such as WUAs. For example, policy makers, legal experts, legislators, MPWWR policy makers, IIP engineers, IAS staff, researchers and farmers were all involved in the two-year process of establishing the legal basis for WUAs in Egypt. Many of these costs cannot be quantified in monetary terms, nevertheless, they entail real social and political transaction costs. Since institutions consist of formal rules, informal constraints or norms of behavior, conventions and codes of conduct, there are always costs in changing these and establishing new rules of the game. It is well known that initial program development costs are high but decrease when the legal requirements, policies, procedures, trained staff etc. are in place and when there is wide public acceptance.

2. METHODOLOGY

Data sources include IIP monitoring and evaluation studies, IAS rapid appraisals, WUA financial studies, internal and external special impact evaluation studies, water management studies and IIP accounts. Data are also used from a recent Ph D. research on three Upper Egypt IIP canal commands by Dr. Martin Hvidt of Odense University of Denmark. Dr. Hvidt's field research was done in 1992. The methodology is straight forward in that where actual values can be used for costs and benefits from accounting records and field studies, these are analyzed and presented. Establishment and continuing costs are shown separately. Where transaction costs cannot be assigned a monetary value, an inventory of major activities is presented to provide an idea of time and effort.

3. BENEFITS OF WUAs AND THE NEW TECHNOLOGY

The MPWWR as well as other institutions such as credit banks, donor agencies and legislative bodies along with the new technology affect economic performance because they help determine transaction costs in establishing sustainable WUAs. As with any technology, good organization and management are essential for its successful operations and maintenance. Recent WUA literature has shown that irrigation technology and organizations are intertwined and interdependent in many complex relationships. {See Lowdermilk and Freeman (1981); Uphoff et. al., (1991) and Hvidt (1994)}. This includes the acquisition, allocation, distribution and drainage of irrigation water as well as the design, construction, operation and maintenance of the new technology. These functions require active planning with WUAs, conflict management, communication, resource mobilization and decision making (Uphoff, et. al., 1991). Given the interdependence of software and hardware in irrigation systems, for the purposes of this paper the WUA organization and the new technology are considered as one package.

The new mesqa technology of buried pipelines and raised lined mesqas have a number of organizational requisites which include:

-Organization and maintenance of continuous flow in branch canals
-WUA council members participating in mesqa planning, design and approval
-WUA council members who arrange bank loans pumps
-WUA developed scheduling of irrigations
-Regular WUA maintenance of pumps and mesqas
-WUA record keeping and collection of pumping fees
-WUA establishment of a reserve fund
-WUA training in all aspects of O & M and water management
-WUA leaders management of water related conflicts
-Active involvement of branch canal WUA federation with Irrigation Department

Table 1 presents Hvidt's findings on the status of selected organizational requisites of WUAs on three IIP Canal commands. This indicates that a period of seven to ten months is required for the WUA organization to fully complete these activities. Time is also required for WUA council members to gain adequate knowledge of their new roles and responsibilities. (See Table 2). Recent data from the IIP monitoring and evaluation program (IIP, 1993) confirm these findings. Another indicator of organizational viability is the ability of WUAs to build-up reserve funds for major maintenance, repairs of mesqas and pump replacements. Figure 1 provides data from a study of 31 WUAs which show that they are building these reserves. The different balances in these reserve funds reflect the time elapsed since the WUA operated mesqa became operational.

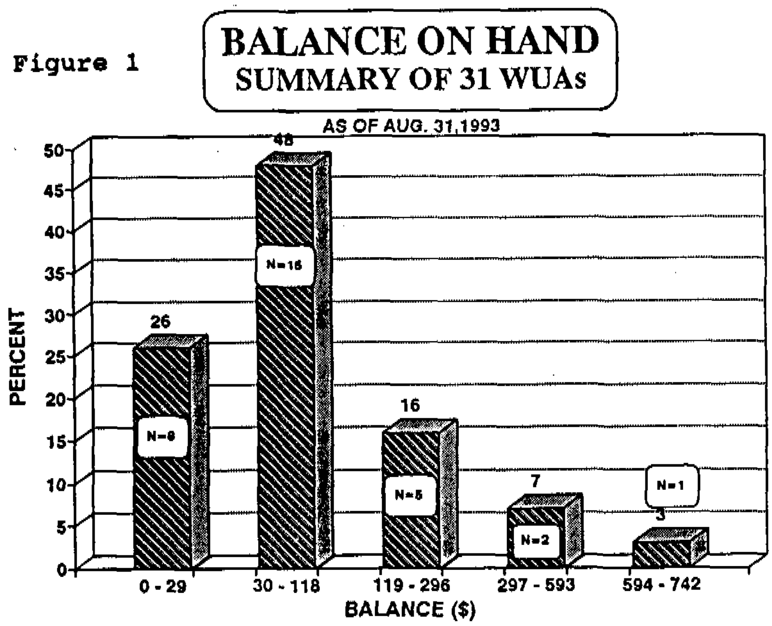
TABLE 1 STATUS OF IMPLEMENTATION OF WUA ORGANIZATIONAL ACTIVITIES COMPLETED BY TIME SINCE MESQA TECHNOLOGY WAS ESTABLISHED (Hvidt, 1994) {Percentages of WUA Council Members Reporting}

ACTIVITIES	BY 3-6 MONTHS (N= 52)	BY 7-10 MONTHS (N= 17)	BY 20-24 MONTHS (N= 68)
Irrigation Schedule Exists?	44.2 %	94.1 %	98.5 %
Accountant Appointed?	100.0	100.0	100.0
Financial Records Exist?	90.4	100.0	100.0
Bank Accounts?	59.6	100.0	100.0
Money in Reserve Fund?	73.1	100.0	100.0
Pump Operator Appointed?	100.0	100.0	100.0
Pump Record Exists?	65.4	100.0	100.0

TABLE 2 WATER USERS WHO DEMONSTRATED FULL KNOWLEDGE ESSENTIAL ABOUT WUA MATTERS BY NEW MESQA ESTABLISHMENT TIME IN PERCENTAGES (Hvidt, 1994)

WUA MATTERS	3-6 MONTHS	7-10 MONTHS	20-24 MONTHS
Irrigation Schedule?	44.2 %	41.2 %	88.2 %
Pumping fees?	98.1	100.0	100.0
Repair Charges?	34.6	64.7	77.9
Where to Fix Pumps?	42.3	82.4	83.8
Bank Balance Account?	59.6	100.0	98.5
Pump Account Balance	63.5	76.5	83.8
	N = 52	N = 17	N =68

Figure 1



3.1. Major Direct Benefits to Water Users

Data in the form of graphics are provided to document these and other benefits. About one-third of the water users owned private pumps which they are now selling. This, however, is not considered a savings but the disposal of a farm asset.

3.1.1 Reduced Labor in Irrigating and Improved Water Availability

As Figure 2 indicates, given larger and more reliable flows of water from the WUA pumps, the average time to irrigate one hectare of land for wheat, maize and berseem crops have been reduced by more than one half. For example, before the new technology and WUA organization, on the average about 13 hours were required to irrigate one hectare of wheat. After improvements this was reduced to about five hours. Using Hvidt's (1994) estimate of about 23 days of labor savings per two crop seasons and a labor rate of about $2 per day, this amounts to a savings of $46.00 per hectare per year. Figure 3 shows that given continuous flow and improved mesqa technology, water availability as reported by farmers has greatly increased after improvements.

Figure 2

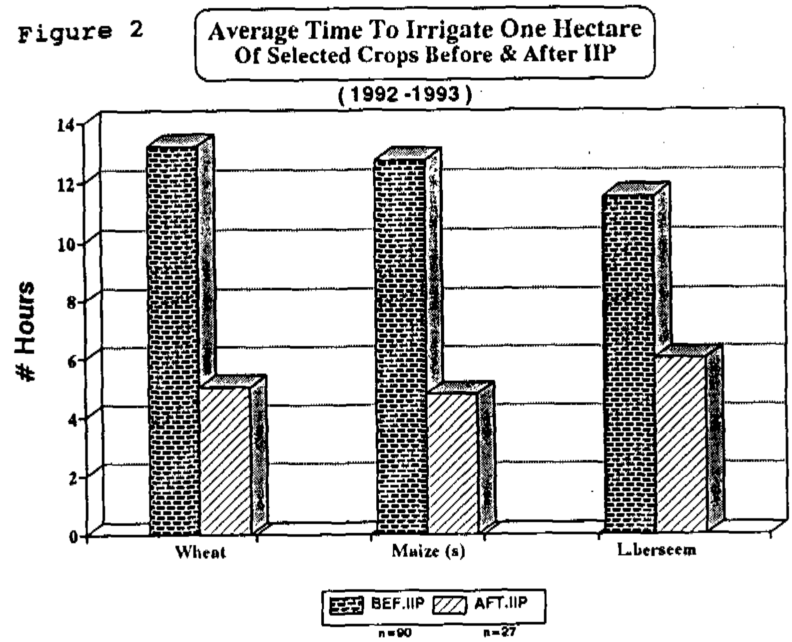
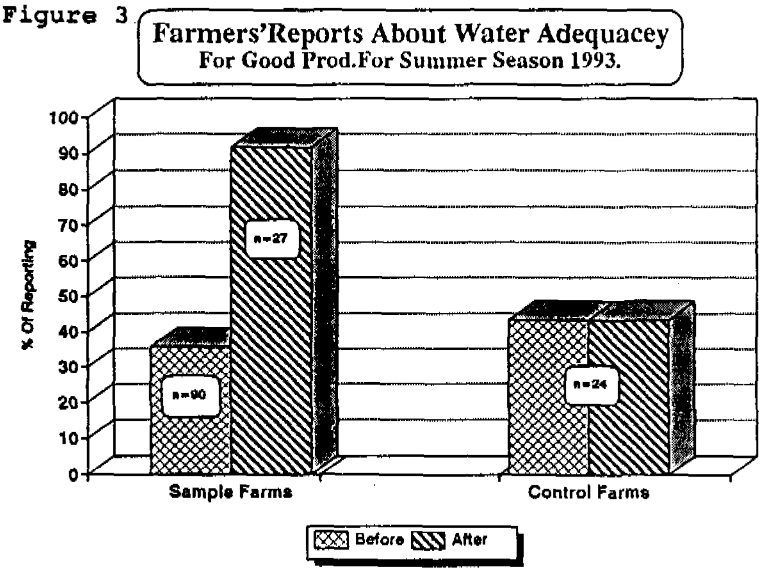


Figure 3



3.1.2 Delivery Efficiencies and Uniformity

Figure 4 shows the changes in mesqa conveyance efficiencies before and after the improved mesqas and the WUA organizations. Figure 5 shows that there was also a greater uniformity of water distribution between the head and tail reaches of the mesqas. The tail ender problem has been virtually eliminated during the peak Summer months given improved technology and organization.

Figure 4

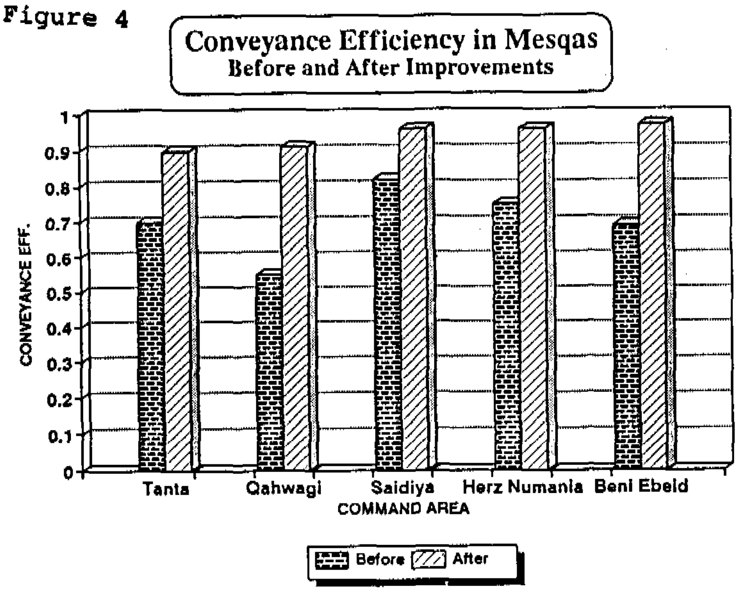
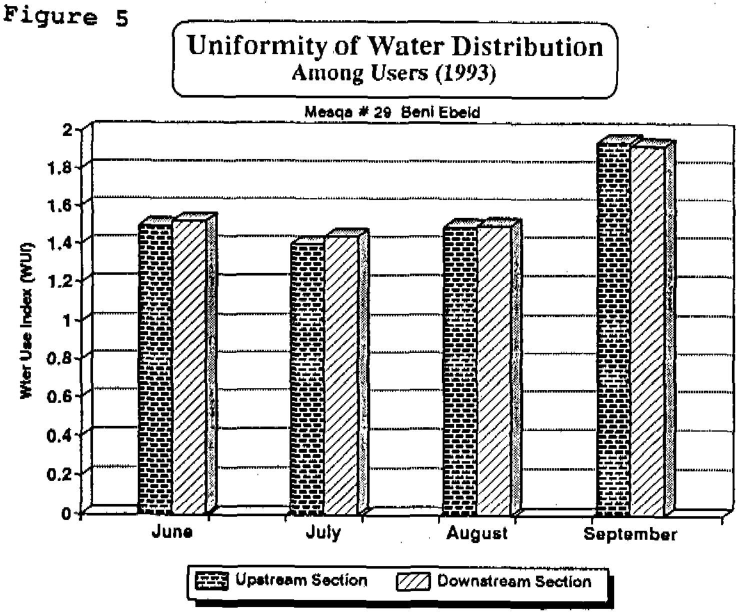


Figure 5



3.1.3 Savings in Pumping Costs, Maintenance and Land

As shown in Figure 6, water users have also benefitted by a reduction in pumping costs of about 61 percent. When this is estimated for one hectare for two cropping seasons, the savings per hectare are about $68 dollars. Figure 7 provides estimates of savings in mesqa maintenance costs on a per hectare basis. Unlike in many countries where farmers clean their own mesqas in Egypt given the depth of the mesqas and large cross sections, farmers tend to hire labor crews or a tractor with a backhoe for annual mesqa cleaning. The estimated savings of about $5.00 per hectare is somewhat premature because not enough time has elapsed since mesqa construction to ascertain true mesqa maintenance costs.In addition, as shown in Figure 8, the estimated land savings, especially for the buried pipeline mesqas, range from about .05 to 2.0 percent of the total command area. The average is about 1.0 percent. This constitutes both a direct benefit to those farmers who incorporate the land saved into their farms and an important indirect benefit when this saved land area is used for new or improved roads for better access to fields. With present delta land values of $35,000 to $43,000 per hectare, the savings per average mesqa (38 ha) would be 0.38 ha. or an estimated $13,300 to $16,340

Figure 6

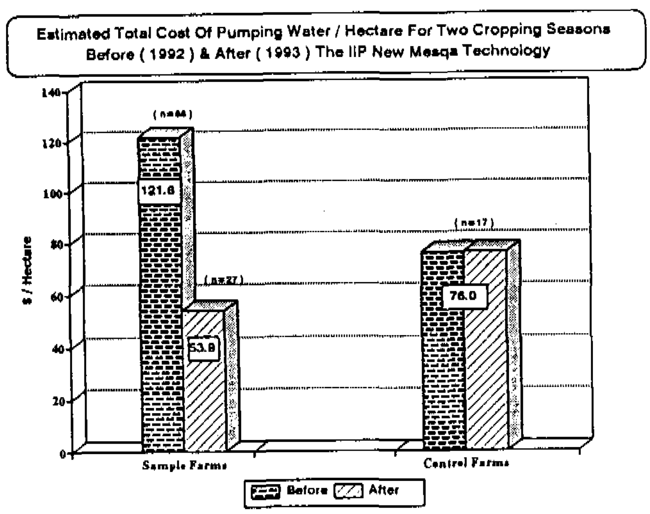


Figure 7

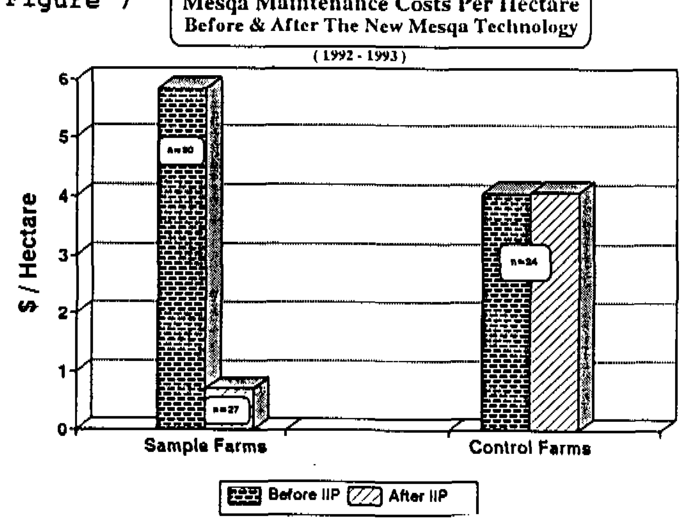
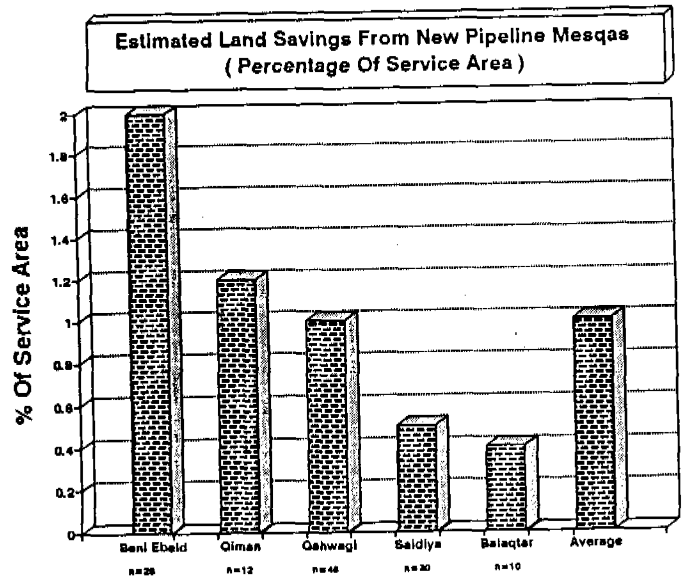


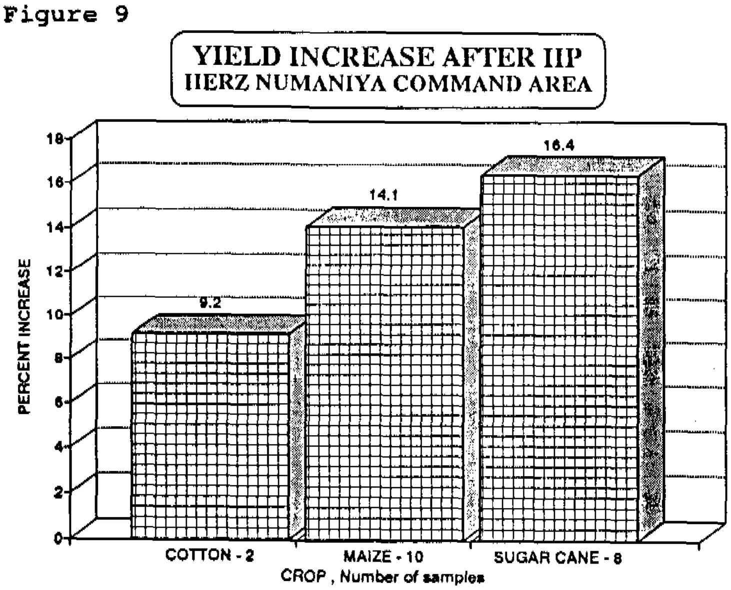
Figure 8



3.1.4 Crop Yields and Higher Value Crops

Though it is early after completion of most new mesqas and the organization of WUAs to estimate real changes in crop yields, Figure 9 show farmers' estimated yield increases of about 9 percent for cotton, 14 percent for maize and about 16 percent for sugar cane. IIP monitoring and evaluation studies (IIP M/E Report, 1994) show similar increases of 16-20 percent for wheat and 8 percent for long berseem. Though these farmer reported increases appear reasonable, future crop cutting experiments will be made for more reliable yield estimates. The Devres study of late 1993 has estimated that incremental value of increased crop yields and higher value crops generate cash earnings of about $315 per hectare per year. The shift to higher quality crops now possible given improved water control requires more time than two to three cropping seasons. But Hvidt (1994) found in 1992 that about 35 percent of sample farmers interviewed on three IIP canal commands had plans for cultivating higher quality crops in the future.

Figure 9



In addition to the direct benefits discussed above, there are a number of indirect benefits which include: access to farms via new or improved mesqa roads, convenience in irrigating in terms of less time and not having to hire pumps or transport pumps from homes to fields, less night irrigation, less conflicts in deciding who irrigates when and how long, services provided by the IAS such as training, demonstrations etc. for improving water management.

Table 3 provides estimates of cash earnings of farmers on a per hectare basis per year using the same base data for gross income with no project and input costs. These are derived from the data presented and three special studies by Devres (1993), Hvidt (1994) and Pacer (1993). Note that the same without project net returns are used for this comparison. Note that the same base figures for without the project are used. The Devres study has estimated a savings of $143/ha. in pumping costs as compared to only $54 and $57 by Hvidt and Pacer. The IIP 1993 monitoring and evaluation study estimated $69/ha. as the savings in pumping costs. Devres (1993) and Pacer (1993) do not include maintenance costs because inadequate time since completion of the new mesqa has elapsed to ascertain these costs.

These estimates based on different studies suggest that the change in income of from $400 to $500 is a substantial increase.

TABLE 3 ESTIMATES OF CASH EARNINGS PER HECTARE PER YEAR

ITEM	DEVRES,1993	HVIDT,1994	PACER, 1993
WITHOUT PROJECT			
Gross Income	$1,992	$1,992	$1,992
Total Input Costs	1,055	1,055	1,055
Net Returns	937	937	937
PROJECT BENEFITS			
Incremental Benefit	315	316	332
Reduction in Pumping Costs	143	54	57
Reduction in Labor Costs	46	27	46
Reduction in Maintenance Costs	NA	6	NA
CHANGE IN INCOME	504	403	435
Labor Returns (50% Family Labor	441	441	441
TOTAL CASH EARNING	$1,882	$1,781	$1,813

3.2. Benefits to the Nation

The assumed benefits to the MPWWR and the Nation for which there are some indicative data include the following:

-Potential for Water Savings and Land Savings

-Resource Mobilization and Advances in Rural Welfare
-Mitigation of Some Micro Environmental Problems
-Elimination of Direct Canal Pumping and Large Mesqas
-Improved Communications with Farmers
-Promotion of Private Sector and Building Local Capabilities
-Increased Satisfaction of Farmers

3. 2.1 Water Savings

Table 4 shows the potential for water savings if a strong water management program can be developed to compliment the WUA organization and the new technology. Note that the water use index (WUI) is derived by dividing the measured water deliveries to the mesqa (WD) by the crop water requirement (CWR) for that mesqa. A WUI of about 1.2 indicates that water is adequate to meet the CWR plus an adequate amount for leaching requirements and typical operational losses. Where the WUI is about 1.5 and above, this indicates over irrigation and losses to drains. As noted these are only preliminary indicative data. Special long duration studies are needed to provide hard data on water savings. It should be noted, however, that the Egyptian Water Use and Management Project also found much over irrigation where water was available (EWUP,1986).

Table 4 WATER USE INDEX FOR A SAMPLE OF IMPROVED MESQAS BY MONTHS (1993)

Mesqa	February	March	April	May	June	July
#31 (RL)	1.7	1.2	1.5			
#33 (RL)	2.0	1.3	1.4			
Kadomy (PL)			2.4	5.0	3.0	3.0
Tareer (PL)			1.6	1.7	2.8	4.0
Control					2.2	2.9
Ebied					1.7	1.6

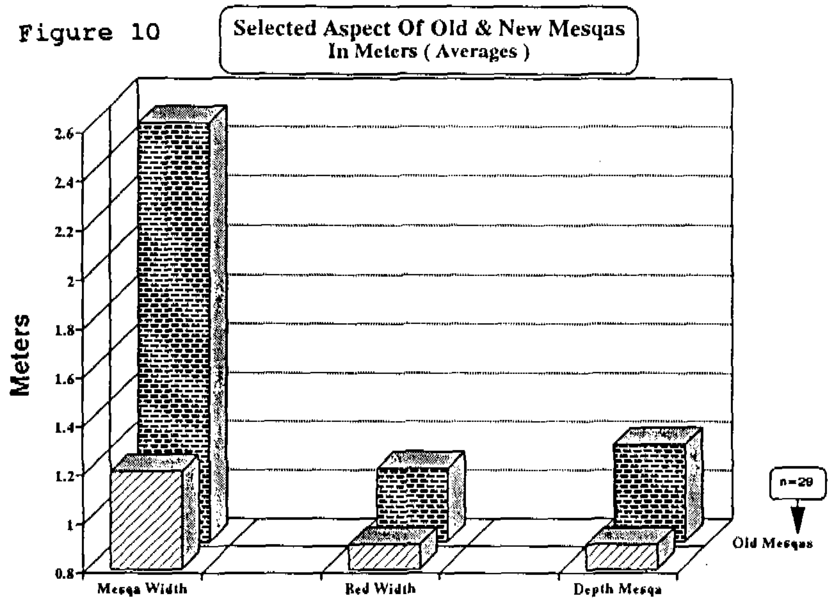
3.2.2. Land Savings

Land savings as shown earlier in Figure 8 are important in a country where arable agricultural land is only about 0.05 ha. per capita. As shown, Delta Land prices are high and rising and the development of new desert lands is expensive. Using a hypothetical example, if one percent of roughly 2.9 million hectares of land could be saved by improved mesqas and better farm layouts, this would amount to about 29,000 hectares of valuable land. The value of this savings can be estimated by using prevailing Delta land prices of between $35,000 to $43,000 per hectare plus the additional value added by productive crops over time.

3.2.3. Environmental Impacts

Though studies to date have not been made to document the positive environmental impacts of the new technology, field observations show the elimination of old low lying mesqas with stagnant water. Where new raised lined and buried pipeline mesqas have been implemented, breeding places for mosquitos and the snails which cause bilharzia have been reduced. This is especially important where mesqas pass through settled areas where children once played in contaminated mesqa water. Figure 10 shows the cross-sections of the old versus the improved mesqas. This suggest large changes in both cross sections and depths between the old and new mesqas.

Figure 10



3.2.4 Extra Legal Direct Pumping From Canals

Direct pumping from canals has been virtually eliminated by improved mesqa systems with single point pumping. IIP data show that roughly six to ten percent of the farmers were pumping directly from canals while at Qahwagi and Bahr el Saidi canal commands 46 and 60 percent respectively were pumping directly.

3.2.5 Communications Between Water Supplies and Water Users

With the introduction of WUAs and the upcoming establishment of WUA federations on branch canals, two-way communications between the MPWWR have greatly improved. For example, recently information has been made available to WUA leaders via leaflets and newsletters in Arabic. WUA leaders in a series of canal based one-day workshops have shared their views about cost sharing, loans for pumps, organizational problems and water management issues such as marwa (farm channels) improvements, land leveling etc. Through the IAS and WUAs, a good communication network is being established between the MPWWR and water users which should become even stronger when the first branch canal federated WUAs are formed in the months ahead.

3.2.6 Role of Private Sector

It is estimated that over 80 percent of the total investments of the IIP have been in the private sector. About 60 percent of the construction is by private sector companies and this is expected to increase in relationship to future construction, materials, equipment, maintenance and repairs.

3.2.7 Farmer Satisfaction

Finally, an important benefit to the Nation is satisfied farmers who have not only improved their production but increasingly have gained new knowledge and skills in solving their own problems and managing their own mesqa affairs. Table 5 shows the comparisons of the old mesqa technology and no formal organization with the new mesqa technology with formal WUAs. Note that the vast majority of the 90 sample farmers reported less labor for mesqa maintenance and operations, improved crops, financial savings, improved water control and less water conflicts.

Table 5 SAMPLE FARMERS' COMPARISONS OF OLD MESQAS WITH NEW MESQAS
(Percentages Reporting "Agree" and "Strongly Agree"
{1992-1993, N = 90}

Improved Mesqas versus Old Mesqas	"Agree"	"Strongly Agree"
A. Maintenance Labor Less		
1. Own Labor	28.2	71.4
2. Hired Labor		100.0
3. Maint. Mointoring		100.0
B. Operational Labor Less		
1. Own Labor	66.7	33.3
2. Hired Labor	18.2	81.8
C. Crop Yields and New Crops Expected		
1. From Old Crops		6.7*
2. Introduce New Crops		100.0
D. Savings to Farmers		
1. Pumping Costs Less		100.0
2. Land Savings	100.0	
3. Less Time to Irrigate		100.0
4. Less Maint. Costs		100.0
E. Water Control		
1. Irrigation Timing	23.5	76.5
2. Irrig. Flexibility	23.5	76.5
3. Delivery Efficiency		100.0
4. Field Application Efficiency	11.5	88.8
5. Less Complexity		100.0
6. Less Pump Break Downs		100.0
F. Less Water Conflicts Between Farmers		100.0

* Majority of these mesqas had only been operating for one season.
** Questions asked about each of the above items had four responses from which the sample farmers responded either "strongly disagree", "disagree", "agree" or "strongly agree".

3.2.8 Rural Welfare

There are aspects of the WUA program in Egypt which enhance rural development. These include: generation of increased rural income; building up skills and capabilities of water users; decentralization of decision making; active participation of people in development activities; improved communications and use of democratic procedures and principles. (See Lowdermilk and Laitos, 1981). Note that the estimated $1800 of cash earnings per hectare (See Table 3) adds substantially to rural welfare.

4. COSTS TO WATER USERS AND THE NATION

In the analyses of costs, we include the establishment costs of the WUAs and the IAS for the period from January 1, 1989 to September 30, 1995. Also, we provide careful estimates of the costs for continuing the present program for about 104,000 hectares. In addition, there are transaction costs. An example is an inventory of major activities involved in the passing of the WUA law number 213 by the Peoples' Legislative Assembly. There are also costs to water users. Within the context of a cost recovery program, water users have to repay the costs of mesqa improvements of about $735 per hectare over a 20 year period without interest. Given a rate of inflation of about ten per cent a year, the real cost to farmers over a 20 year period is minimal. It is evident from incremental cash earnings per hectare for the improvement package that farmers can repay this easily. Also, the 10 to 15 percent of water users who own pumps and earned extra income from hiring out their pumps, no longer have this option on improved mesqas. The estimated average income for these farmers is about $270 per year but some earn as much as $1000 to $1200 extra income per year from pumping water for other farmers. (See IIP, 1990)

Table 6 below provides estimates of the costs of WUA establishment and program continuation. Space limitations did not allow for the detail costs and types of costs such as TA, equipment etc.. (See detailed breakdown in Annex I) Note that though the IIP started in January , 1989, significant expenditures began only about one year later. Staff salaries for the continuing program are estimated to increase by about 20 percent during the period as indicated by (1). Staff training under must be continued to take care of large turnovers of staff and limited specialized training for existing staff. It is estimated that TA will be needed for a monitoring and evaluation program after the LOP in order to document lessons learned about impacts. Vehicles have been given a life of ten years and all other equipment except motorcycles and vans arrived late in 1994. Computers will arrive in 1995. Under supplies and fuel/transport repairs an estimated 20 percent increase over the period has been added. Miscellaneous includes other estimated expenses on all items except TA increases about 15 percent over the establishment costs.

TABLE 6 SUMMARY OF THE MAJOR ESTABLISHMENT AND CONTINUING PROGRAM COSTS OF THE IAS AND WUA PROGRAM (USA $)

ITEMS	ESTABLISHMENT COSTS (1989 TO 1995)	CONTINUING PROGRAM COSTS (1996 TO 2001)
Staff Salaries/Allowances	229,008	274,810(1)
Staff Dev. & WUA Training	1,566,933	650,000(2)
Management TA and Materials Development	1,162,360	250,000
Special Studies & Monitoring Evaluation	589,065	350,000(3)
MPWWR Orientation & Public Awareness	232,000	150,000
Vehicles/Equipment	838,761	100,000(4)
Fuel/Transport Repairs	257,104	280,477(5)
Supplies	38,500	55,000(6)
Miscellaneous	288,068(7)	320,293(8)
TOTALS	5,219,799	2,430,580

This amount of $5,219,799 (establishment costs) divided by 104,167 hectares equals about $50 per hectare for 5.5 years or $9 per year per hectare. This is only $3.75 or 12.60 LE per feddan per year. The cost using the same method of calculation for the continuing program is $23 per hectare for five years or $4.67 per year per hectare or 6.50 LE/feddan).

In terms of construction costs estimated at about $ 36 million during the life of the IIP, the costs of establishment of the WUA/IAS program is only $5.2 million or less than 7 percent of the total $78 million cost of the project.

Transaction costs have been high but this investment of time and effort in preparing the environment for the WUA legal base and cost recovery especially has been productive. A special note documents major transactions associated with only achieving one objective, i.e. the necessary legal action for WUAs and mesqa cost recovery. Egyptian colleagues at many levels have worked with skill and patience for at least two years to build a suitable environment for the final legislative action.

5. SUMMARY AND CONCLUSIONS OF LESSONS LEARNED AND REFINEMENTS REQUIRED FOR SUSTAINABLE WUAs

The WUA program in Egypt is only about five years old. There is much to accomplish before the end of the IIP in September, 1995 to assure that the program can be sustained. The recent accomplishment of legislation providing for legal private WUAs, a cost recovery program and a special irrigation improvement fund in the MPWWR are important accomplishments. There is now strong support among officials, the public and water users for this new program.

5.1 Major Lessons Learned

Based on the data presented in this paper and major experiences to date, the following are some important lessons for expanding the WUA program in Egypt and for similar programs in other countries:

a. That institution building to help farmers establish private WUAs should be undertaken within the context of a well conceived program of macro and micro-system improvements using proven well designed technologies.

b. The financial and transaction costs of establishing and maintaining a sustainable WUA program are high but in the long run, benefits can far outweigh the costs.

c. Initial WUA establishment costs where substantial TA is required are high but these costs as well as some transaction costs can be greatly reduced for maintaining and expanding programs. Nevertheless, continuous orientation of policy makers and staff development are essential for successful programs.

d. Successful WUA irrigation improvement projects must integrate technology, organization and management into a single package from the initial planning to the achievement of regular operations.

e. Continuous monitoring or process documentation of WUA programs are essential for providing feedback for changes in strategy and program refinements because there are no blueprints or models which can be transferred from one region or country to another.

f. Institution building with the goal of sustainability requires a time period of at least ten to twelve years with continuing policy support and a strong service program such as provided by the Irrigation Advisory Service.

g. Monitoring and evaluation programs to ascertain WUA organizational strength must be built around two questions which are: What is happening to the water? and What is happening to WUA finances?

5.2 Refinements Required for Sustainable WUAs in Egypt

a. A stronger program of communications to provide continuous public awareness for the general public, officials, politicians, engineers and water users.

b. WUAS not using the hourly system for charging pumping fees and do not have adequate financial and pumping records with reserve funds in a bank account need special training and assistance in making changes.

c. Mesqa construction schedules need to be established and maintained with improved quality control. A large number of mesqas are almost completed but finishing touches are required before formal turnover to WUAs.

d. Continuous flows on branch canals need to be monitored on a regular basis and where interruptions take place, solutions need to be found quickly by the Irrigation Departments and the IIP/IAS staff working together.

e. The high turnover of IAS staff due to promotions, transfers and other reasons needs to be decreased based on the new MPWWR guidelines. Between January, 1989 and March, 1994, an estimated 45 trained IAS engineers had left the IAS. This has not only required much extra training but has resulted in a loss of valuable time.

f. Quality training of IAS engineers, field agents, district engineers, water user leaders and council members is required to the end of the IIP and into the future for assuring sustainable WUAs.

g. Given the large costs sunk in the new mesqa technology and main system improvements, the most substantial payoffs come from improved water management by farmers. This is likely the largest source of water savings and increased crop yields. Much greater efforts must be made to the end of the IIP and beyond to institutionalize a sound program of water management.

h. Precision land leveling, improvements of marwas, demonstrations and special training of WUAs in water management should now be made one of the top priorities of the WUA program.

i. The refinement and integration of all aspects of the monitoring and evaluation program (water measurements, rapid appraisals, WUA financial monitoring etc.) is required. Monitoring and evaluation of impacts of WUAs and the new technology should continue at least five years after the current IIP is completed to provide lessons for expanding and improving the program.

Finally, the description of the costs and benefits of establishing WUAs within the context of improvement programs indicates that program establishment costs are high but decrease when programs mature. Efforts must be made on a continuous and systematic basis to find the right mix of policy incentives, an appropriate legal base, the right technology and a continuous process to develop and maintain staff and WUA capabilities. A successful "marriage" between water users and water suppliers requires a carefully designed "engagement" period and continuous efforts to improve the "marriage" relationship into the future.

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NOTE ON TRANSACTION COSTS: LISTING OF MAJOR TRANSACTIONS LEADING UP TO LEGISLATIVE APPROVAL FOR LEGAL WUAs IN EGYPT ON JUNE 17, 1994

COST RECOVERY ACTIVITIES

Negotiation of IIP Agreement between MPWWR & USAID with conditions (1988); CR study by Nathan Associate Economist (1991); USAID initiates other CR studies (1991); Serious dialogue with MPWWR (1991-1994);USAID-MPWWR CR workshop at Ismalia (Dec.,1992);Special study by Pacer on CR (May, 1993) and seminar in June, 1993); TA expert Dr. Leslie Small reviews CR studies (1993); IIP produces Arabic leaflet on CR and distributes 5000 to water users; CR leaflet revised to include by-laws (August, 1994); special training to IAS staff on how to deal with farmers' questions about cost recovery; distribution of IIP monitoring and evaluation reports which provide data on water users' ability to pay mesqa costs etc. (1992 and 1993)

WATER USER ASSOCIATIONS

Decree establishing IAS and introduction of WUAs (1989): special study on WUAs by Pacer (Feb.,1993); special study by Pacer Inc. on proposed legal basis for private WUAs; seminars by Pacer and IIP for MPWWR (1993); special meetings with MPWWR minister by Pacer (1993-1994); IIP seminar to MPWWR on WUA lessons learned (Dec.,1992); study observation tours for senior MPWWR decision makers to Spain, Philippines and Indonesia (1993 and 1994); special workshop on the IIP with University of Minyia for local leaders including political and others as well as officials (1993); distributed 5000 or more Arabic leaflets to water users on WUA related subjects; WUA council member training (1992 to present); Chairman of Peoples' Assembly Agricultural committee and 20 members take field visit to meet with WUA leaders and observe WUA progress (1993); special review of WUAs by outside expert distributed to large number of leaders (1993); USAID top-level dialogue, numerous memorandums and project implementation letters to reach understandings with MPWWR

LOBBYING ACTIVITIES

IIP Director and Egyptian consultant have spent countless man-days providing orientation to MPWWR senior officials related to WUA legal basis, CR and revolving fund; Egyptian consultant spent May 7-9 in providing orientation to the Peoples' Assembly Committees concerned with the legislation; personal interventions and lobbying legislators and others regarding the proposed legislation.

OTHER ACTIVITIES

Special high-level committee established by Minister on CR, WUA legal base and revolving fund (June, 1994); by-laws committee established by Minister (June, 1994); IIP Director and Egyptian consultant asked to prepare draft by-laws (July, 1994); special Management Board to be established for Special Irrigation Improvement Fund in the MPWWR (process); IIP develops plan for implementing new law of June 17, 1994.

Annex I

TABLE 8 ESTIMATED TOTAL WUA/IAS ESTABLISHMENT COSTS (1989-1995) IN USA DOLLARS($)

ITEM DESCRIPTION	USA $	EXPLANATION
STAFF SALARIES*	(229,008)	
Directors	59,104	10 X 5.5 YEARS
Professional Engineers	118,209	30 X 5.5 YEARS
Technicians	47,284	200 X5.5 YEARS
Clerks	4,411	5 X 5.5 YEARS
STAFF DEVELOPMENT	(1,214,000)	
Local Training	413,000	IAS STAFF
Local with Special TA	295,750	TA @ 131% OH
Overseas Short-Term	446,000	Specialized
Overseas M Sc. Degree	59,250	1 Senior IAS
WUA TRAINING	(352,933)	
Training Trainers	259,500	TA @ 131% OH
Training WUA Councils	93,433	1-3 Day Events
MATERIALS DEV.	(926,610)	
Training Modules (Staff)	235,750	TA @ 131 % OH
WUA Materials TA	129,750	•
Mesqa O&M Guidelines	49,669	•
Training of Trainers	37,833	•
Manual	64,875	•
Monitor/Evaluation WUAs	20,000	•
Communication Materials TA	34,800	•
Special Start-Up Materials		
MONITORING/EVAL. PROGRAM	(347,704)	
Special TA	128,500	TA @ 131% OH
Short-Term TA	20,000	•
On-Job Training TA	134,329	•
Rapid Appraisals & WUA Financial	64,875	•
ORIENTATION FOR MPWWR OFFICIALS^	(175,000)	
Study Observation Tours	75,000	Two Overseas Tours
Seminars, Workshops etc.	100,000	IAS + IIP
SPECIAL STUDIES	(241,361)	
Pacer Inc. Studies	181,361	WUA/Legal/Cost Recovery
Internal WUA/IAS Review	60,000	Expatriate TA @131% OH
VIDEO PRODUCTIONS	(92,321)	12 Videos (IAS & WUAs)
VEHICLES/EQUIPMENT#	(838,761)	*Replacement Costs
FUEL/TRANSPORT* REPAIRS	(257,104)	Estimate for 5.5 Years
SUPPLIES*	(38,500)	Estimate for 5.5 Years
MANAGEMENT TA	(235,750)	TA @ 131 % OH
TOTALS	($4,949,052)	Without 15% for items marked*

@ indicates that contractors charge 131 % overhead on TA and includes housing and other allowances.
^ denotes shared costs of IIP seminars/workshops etc. where IAS was involved.
# denotes vehicles, measuring devices, audio visual equipment, computers, printers and copying machines received late in LOP. Vehicles' estimated life of 10 years with remainder about 5 years.

COST ALLOCATION AMONG WATER SERVICE SECTORS FOR EGYPT'S NILE SYSTEM

I.M. Elassiouti[1] and A.S. EL-Zaher[2]

ABSTRACT

The paper presents the results of the cost allocation of the Nile system Operation, Maintenance and Rehabilitation costs (**OM&R**) to the various system users. The criteria for selecting a cost allocation method are economic efficiency and equity. It was found that the Separable Cost - Remaining Benefit (**SCRB**) method is the most appropriate approach that adheres to the two criteria listed above. The results revealed that the costs are mainly allocated to irrigation. This is because the costs of improving Egypt's irrigation system are mostly specific and of benefit to the irrigation system.

RÉSUMÉ

Le papier presente les resultats de l'attribution des frais de l'operation du system du Nile, l'entretien et les frais du renouvellement aux employeurs differents du system. Les regles a choisir la methode de l'attribution des frais sout l'aptitud economique et l'equite. On a trouve que la methode de Frais Separable - Benefice Retenu (FSBR) est laplus pres aux deux regles citer la hant. Les resultats ont declare que les frais sont principalement attribues a l'irrigation. Ce a parceque les frais d'amiliorer le system d'irrigation d'Egypt sont les plus pecifique et de benefice sur le system d'irrigation.

1. INTRODUCTION

The purpose of the cost allocation process was to provide the basis for an eventual irrigation cost recovery program. Considerable effort was devoted to carefully allocating costs to the appropriate water user sectors to assign irrigated agriculture its fair share. The following sectors were considered in the cost allocation: irrigation, rural water supply, navigation, hydropower, ground transportation, recreation and tourism, fishery, and flood control. Water supply to the major urban centers and major industries was not considered. The analysis assumes that the Nile water supply system provides no significant improvements to the water situation of the major metropolitan centers, i.e. Cairo and Alexandria, or industries drawing water from the Nile. This conclusion rests

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on the evidence that these municipal and industrial demands are met even in low flow years.

The criteria for choosing a cost allocation procedure are economic efficiency (getting the most value of output from the value of inputs) and equity (fairness). Although some degree of arbitrariness is involved in any joint cost allocation procedure, one of the two basic approaches is adopted in most cases. One approach, termed the " proportionate use of capacity " method, allocates costs according to physical measure is ambiguous for non-consumptive uses such as hydropower or navigation. Furthermore, the method does not assure achievement of either economic efficiency or equity in the sharing of the costs. For these reasons, the approach was rejected for this study. The second approach, which was chosen, allocates costs according to economic criteria. It is a version of what is called the " Sparable Cost - Remaining Benefit " (SCRB) method. It is a procedure generally required for U.S. agencies by the U.S. Water Resources Council; World Bank authorities also recommended it. In the SCRB approach, costs are classified into two groups. Those costs which are incurred for specific, identified, and separable purpose are allocated to that purpose. The other category, called joint costs (those which cannot be separated by specific service), are allocated in proportion to the lesser of remaining net benefits or the cost of alternative single purpose project.

To allocate joint costs according to the SCRB approach, monetary measures of incremental economic benefits (willingness to pay) for each water use sector or purpose are required. The cost allocation method specifies that benefits are incremental rather than total. The economic literature recommends several approaches to incremental benefit measurement. One approach measures benefits according to the incremental net income with as compared to without the proposed project. This approach is applied mainly to crop irrigation in this study, but is also applicable to other producer's goods. Another approach measures benefits as the cost of the most likely, economically feasible, alternative single purpose project. This latter approach, called the alternative cost method, is applied in this study, for most other sectors, including hydropower, water supply, and navigation.

The overall conceptual approach and the specific definitions of cost categories imply that the costs derived in this study are heavily weighted toward the irrigation sector. This is because the costs of improving Egypt's irrigation system are mostly specific to and of benefit for the irrigation system.

2. COST ESTIMATION PROCEDURE

The overall objective of this study is to determine the operation, maintenance and replacement (**OM&R**) costs of the main irrigation water delivery system in Egypt. The analysis limited to the main system defined as the Nile river together with the main and secondary canals, and excludes the on-farm portions. The study was conducted for each of Four policy scenarios. The first scenario reflects the recent and current budget allocation for **OM&R** in Egypt. Scenario (2) considers the costs of the system improved to an adequate degree. The third and fourth scenarios incorporate planned reclamation of not yet developed "new new lands" into of the first two scenarios. No additional costs are needed for scenarios (3) and (4). The cost Categories considered in each scenario consists of:

a) *Capital costs including the costs* of development, improvement, rehabilitation and replacement.
b) Operation and maintenance costs including the costs of personnel and recurrent cost of maintenance of the facilities.

The costs of tile drains are currently being recovered under separate arrangement. Therefore, all costs related to tile drains are excluded from the analysis.

Cost estimates are expressed in annual terms, so that they can later be presented in per feddan or per thousand cubic meters. The annual costs of each scenario are estimated on the basis of constant prices at the time of the study, December 1991.

3. COST ALLOCATION METHODOLOGY

The problem of cost allocation arises in multipurpose projects because some costs cannot be easily identified with specific project purposes. Some costs are joint in that an element serves more than one purpose. Some way must be found to allocate these costs among project purposes. A certain arbitrariness accompanies all cost allocation procedures, but several methods have been developed which solve the problem in a reasonable way.

The allocation of costs in a multipurpose project is important because it provides the basis for setting the prices or charges for project services. Price is significant for two reasons. First, it provides signal to beneficiaries on the scarcity of the service, and influences the economic efficiency on the use of project output. Second, the charge controls how financing is raised, and consequently, how costs are distributed among beneficiaries, thereby affecting the distribution income.

There are numerous possible methods for allocating *the joint costs of water resources projects*. These methods differ primarily on two considerations or dimensions. One dimension is the measurable unit on which costs are allocated, which can be either physical or economic. This measure is sometimes termed the allocation vehicle. The second dimension is the amount of cost to be allocated, which can consist of either total or only non-separable or joint costs.

Gittinger (1982) recommends several guidelines for the cost allocation process to achieve economic efficiency and equity. Economic efficiency refers to the ratio of the value of outputs and the value of inputs, while equity refers to fairness in the distribution of total project costs among all users served by a multi-purpose development.

Two broad approaches to cost allocation have received the most attention. The first is the Use of Facilities (UoF) or Proportionate Use of Capacity method. The UoF method adopts as its allocation vehicle a physical measure, such as reservoir capacity designated to a purpose. The UoF approach has most often been applied to total costs, although it has sometimes been used to allocate joint cost. However, the UoF method has been criticized because it can violate either or both the first and second criteria listed above.

The second approach employs as its allocation vehicle some monetary measure of economic benefit. This measure may either be net benefit, least cost alternative, or the smaller of the two, which is often termed the justifiable cost. The most frequently used version of this approach is the Separable Cost-Remaining Benefits (SCRB) method. In its recommended version, SCRB allocates joint costs proportionately to the smaller of net benefit or alternative cost. An important modification of this approach is the Adjusted Separable Costs-Remaining Benefits (ASCRB) procedure. It is noted that for nearly forty years the U.S. Government has required the use of the SCRB procedure for its water resources development projects. As well, J.P. Gittinger of the World Bank recommends the SCRB method including (ASCRB) for cost allocation for water projects in his text Economic Appraisal of Agricultural Projects (1982, 2nd edition). For these reasons, the ASCRB procedure was selected for this study.

Figure 1 depicts the cost allocation process for a project with three service sectors: irrigated agriculture, hydropower, and navigation. The project cost at the top of the figures distributed among the service sectors at the bottom of the figure. The project cost is the cost of a well defined infrastructure. It may include the investment costs of the physical works, operation and maintenance, rehabilitation, and management. A large water storage and delivery system may be composed of many projects; that is to say the overall system may be disaggregated into a set of well defined subsystems. In order to allocate costs among service sectors for the entire system the cost allocation process may be applied sequentially to each project in the system, and the costs accumulated.

4. BENEFITS ESTIMATION METHODOLOGY

Estimating project benefits is an essential part of the cost allocation process. Several approaches for calculating direct benefit are available. The best approach to use in a particular instance depends upon the type of benefit involved. So different methods are employed in the various use sectors.

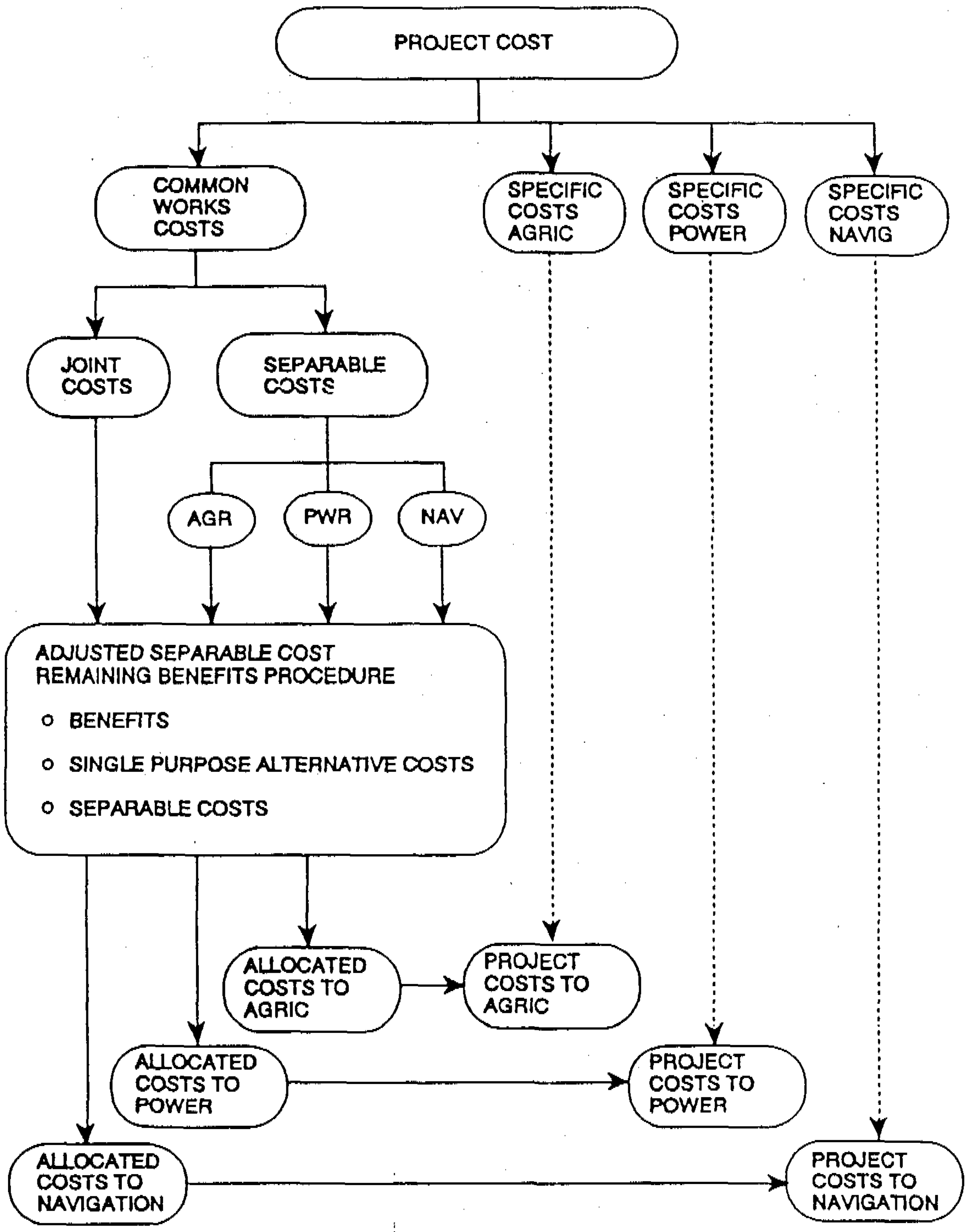


Figure 1. Cost allocation process

Benefit is defined as the amount of a publicly supplied good or service that a rational, informed user is willing to pay for it (Gittinger, 1982). Willingness to pay reflects the user's desire to avoid alternative consumption or not buy the good or service in question.

Benefit estimation requires that two rules be kept in mind. The first rule stipulates that benefits and costs are measured as increments which would occur with as compared to without the project. For example, the incremental benefits between Scenario 1 and Scenario 2 should be attributed to the incremental costs between the two scenarios. The second rule relates to which of two alternative accounting stances, financial or economic, are applied to the analysis. The financial stance measures gains and losses perceived by the individuals receiving them. However, the gains and losses might be influenced by government market interventions such as subsidies and price controls. The economic stance ideally includes social opportunity costs and social willingness to pay as measures of costs and benefits. In this way, financial prices theoretically are corrected for market interventions. Because the financial stance normally reflects the ability of farmers to pay, it is usually is applied in cost allocation studies involving agriculture projects. The study uses the financial price stance.

5. APPLICATION OF COST ALLOCATION MODEL TO NILE SYSTEM

The Nile River system is classified in this study according to the following hierarchy:

1. The High Aswan Dam (HAD) and the Old Aswan Dam;
2. The Nile River main Channel (Main Stem), including barrages and pumps located on the main stem; and
3. The main canals, open drains, pump stations, and associated structures within each directorate.

Ideally, the study would be conducted with the directorate as the basic spatial unit of the project. Costs and benefits would be evaluated and joint costs allocated by directorate and then summed at the main points of diversion from the Nile River. However, this was not possible mainly because the time required to obtain and process the necessary cost and benefit data.

The problem was handled by dividing the project service area into five major regions (Region) and selecting a representive directorate in each of five regions. These regions are Upper Egypt, Middle Egypt, East Delta, Middle Delta and West Delta.

Figure 2 depicts the stages in the modelling procedure. The common works costs within each spatial category are represented by the boxes in the center column of the figure. The costs in each of these categories are allocated among the various system users (or service sectors) represented in the boxes on the right side of the figure. The model uses input data for both the common works and the separable costs of the infrastructures. Separable costs were identified only at HAD. The joint costs are the **OM&R** costs for particular structures.

The computer model begins the cost allocation process with the existing or old lands (see bottom of Figure 2), including new lands. The model works up through the new new land development projects (shown in the figure as "new agriculture"), addressing only the effect of these projects on the costs allocated to existing system users. The model ends at HAD where benefits and allocated costs are accumulated for all system users.

6. SUMMARY OF RESULTS AND CONCLUSIONS

It should be emphasized that the Separable Cost-Remaining Benefit method, which assigns separable or specific costs to the sector receiving the corresponding incremental benefits, largely dictates the proportion of costs assigned to the various service sectors. Because most of the benefits derived from incremental cost to systems **OM&R** accrue to the irrigated agriculture sector, the costs are mainly allocated to irrigation. This is particularly true under scenario 2. The results of the cost estimation and cost allocation efforts are summarized in Table 1. Figure 3 shows the joint cost allocation results under the four scenarios.

In Scenario 1, 83.1 percent of annual system **OM&R** joint costs are allocated to the irrigated agriculture sector, while the next most significant costs, 7.6 percent are assigned to the River Tourism and Recreation sector. Scenario 3, which represents the addition of new new lands to Scenario 1 assumptions, shows a decrease in the share to old agriculture, and a resultant increase in the other sectors.

Scenarios 2 and 4 reflect the estimated costs for providing an adequate level of **OM&R** expenditures. The charges allocated to agriculture increase significantly. The charges allocated to power also increase due to the installation of generating facilities at new Esna Barrages. The percentage shares of the other sectors differ little from Scenarios 1 and 3.

Table 2 summarizes the average costs allocated to irrigated agriculture, first on per feddan basis and then per 1000 cubic meters. These are total costs including drainage. The findings suggest that the nationwide average annual **OM&R** expenditure, in December 1991 prices, allocatable for irrigation is about LE75 per feddan per year. This figure would rise to about LE109 per feddan under the adequate scenario (Scenario 2). The equivalent costs per 1000 m^3 are about LE11 and LE16, respectively.

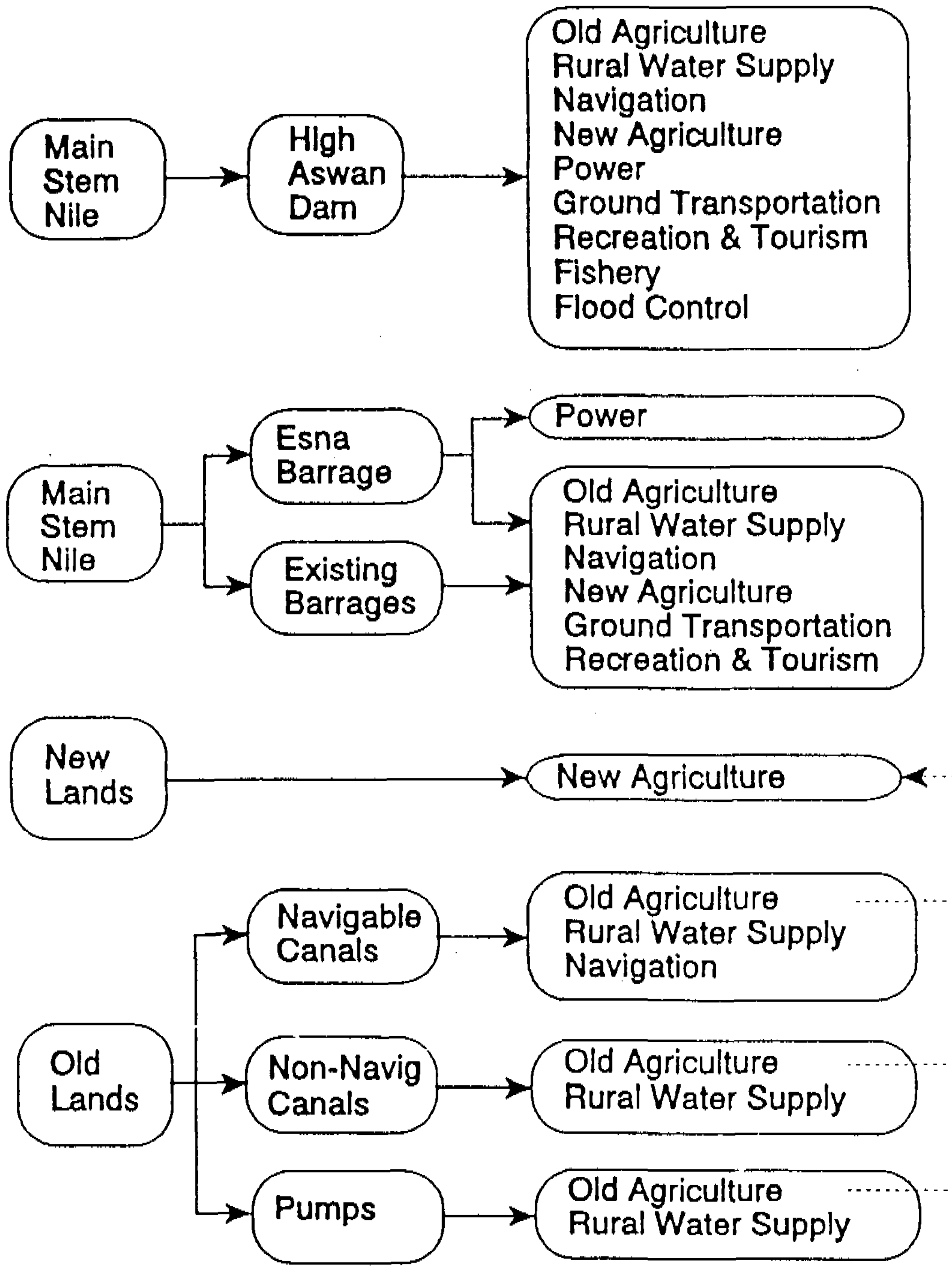
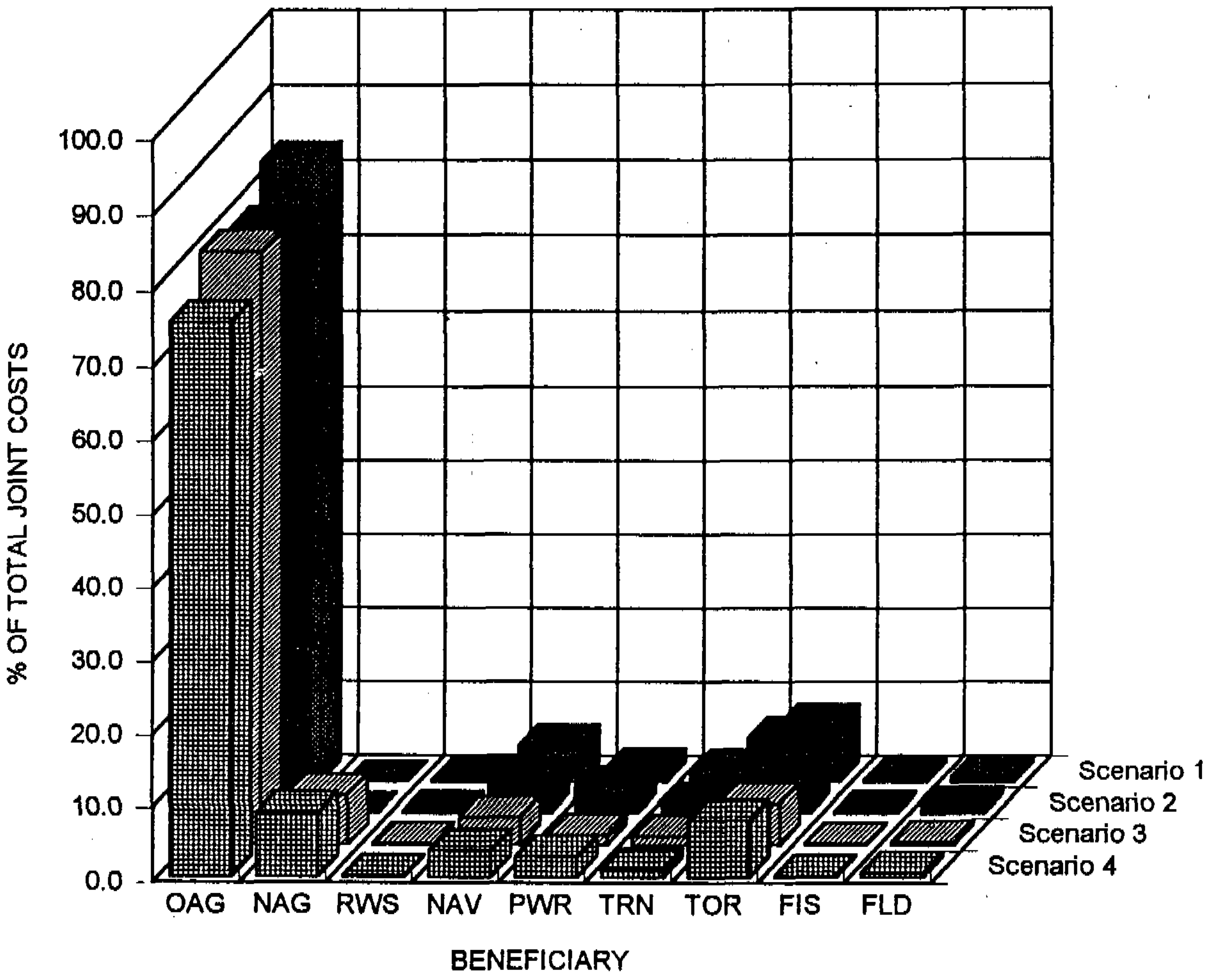


Figure 2. Cost allocation process for the Nile river

(T3-S1) 2.9

Table 1. Allocation of annual OM&R joint cost to beneficiary sectors by scnario (mil LE/Yr)

Beneficiary	Scen 1 (mil LE)	Scen 1 (%)	Scen 2 (mil LE)	Scen 2 (%)	Scen 3 (mil LE)	Scen 3 (%)	Scen 4 (mil LE)	Scen 4 (%)
Old Agriculture	461.3	83.1	624.0	78.8	444.8	80.1	595.2	75.2
New Agriculture	0.0	0.0	0.0	0.0	37.8	6.8	68.6	8.7
Rural Water Supply	1.2	0.2	1.3	0.2	1.1	0.2	1.2	0.2
Navigation	27.0	4.9	36.6	4.6	21.3	3.8	28.8	3.6
Hydro-Power	9.9	1.8	28.8	3.6	7.8	1.4	22.5	2.8
Ground Transport	8.7	1.6	11.3	1.4	6.5	1.2	8.3	1.1
River Tourism & Rec.	41.9	7.6	81.4	10.3	31.7	5.7	60.6	7.7
Fishery	1.2	0.2	2.0	0.2	0.9	0.2	1.5	0.2
Flood Control	3.8	0.7	6.4	0.8	3.0	0.5	5.0	0.6
TOTAL	555.0	100.0	791.7	100.0	555.0	100.0	791.7	100.0



OAG Old Agriculture
NAG New Agriculture
RWS Rural Water Supply
NAV Navigation
PWR Hydropower
TRN Ground Transportation
TOR River Tourism
FIS Fishery
FLD Flood Control

Figure 3. Joint cost propotions for the four scenarios

Table 2. Average Annual **OM&R** Costs Allocated to Existing Agriculture.

SCENARIO	COST/FED	COST/1000 M^3
1	75.22	10.66
2	109.17	15.47
3	72.72	10.30
4	104.81	14.85

On a rough comparative basis, the costs under either scenario do not diverge much from international standard for large, multipurpose water supply system. Moreover it appears from agriculture benefit studies that Egyptian farmers could pay most if not all of the estimated costs once prices for their crops reach international market levels.

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EXTENDED ECONOMICAL STANDPOINT ON FLOOD CONTROL WORKS

Doina Alexandra Botzan[1] and Tudor Botzan[2]

ABSTRACT

Designing an efficient anti-flood system is a tradeoff problem between the investment cost level and the potentiality of damage occurrence. The specific parameters that economically determine the practical solution of the problem should be: the maximum peak discharge (and its associated probability), as well as the close-to-peak shape of a flood hydrograph. To illustrate this statement, classical and newly defined economical factors (including peak and close-to-peak parameters, in a deterministic, respectively probabilistic presentation) are introduced. Associated sensitivity coeffcients were defined to enable a thorough comparison between the classical and lately approaches, for several numerical inputs of discharge and probability.

By examining the values of sensitivy coefficients corresponding to different definitions of economical factors (expressing the unitary flood control expenses), the following general conclusion is to be revealed: initial additional expenses lead to mitigated social-economical impacts due to floods.

SOMMAIRE

Conduire un projet efficace pour la maîtrise des crues est une question de compromis entre l'invesissement et le danger d'inondation. Les éléments caractéristiques qu'influent économiquement sur la solution pratique d'un projet pareil sont: la valeur maximale absolue du débit (correspondant à la valeur critique de la probabilité), ainsi que la configuration près-de-sommet du graphique représentant la crue. Afin d'illustrer ces hypothèses, les grandeurs économiques ont été définies de façon classique aussi qu'innovatrice, attaquant tant la vision déterministique que celle probabilistique (par la considération des risques). Pour les comparer, facteurs de sensibilité conventionnels ont été calculés pour plusieurs valeurs du débit et de la probabilité.

En comparant les valeurs des coefficients de sensibilité definies pour de divers facteurs économiques (indiquant le coût unitaire de l'aménagement), on arrive à la conclusion que des efforts initiales supplémentaires conduisent aux impacts sociales-économiques négatives diminués.

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1. INTRODUCTION

Within the complex management of watersheds, the global multi-purpose investment can be expressed as a summation of component costs for each type of facility in the project as irrigation, drainage, and erosion control on agricultural lands; urban and industrial water supply; water power; river engineering, flood control and adjacent drainage works; and recreational areas.

The key point of a flood control part is to assure a maximum and comprehensive protection by using minimum investment costs and experiencing little damage; this could be a deterministic formulation. The probabilistic one brings into picture the notion of risk, considering for it just two categories: a risk of social and economical losses due to flood effects, and a risk of structural failure of flood control works. In theory, there would be such an investment value, for the flood control part, that could lead to zero-damage expenses or no risk.

Two new approaches are presented and compared, in terms of conventional sensitivity coefficients, to the classical one in which a simple relationship between flood occurrence probability and investment cost used to be established.

2. CONCEPTS

A series of specific concepts are briefly introduced in order to connect flood parameters to flood control economics.

Flood hydrograph is considered any hydrograph susceptible by its effect to produce flood and subsequent damage.

Peak value of a hydrograph is simply understood as a maximum discharge Qp flowing through a river cross section. Probability range associated with any Qp-value regularly lies around P = 2...10 %.

Maximum peak value met in the same river cross section is the maximum-maximorum discharge Qpm. Just as a reference example, suppose the probability associated with Qpm is Pm = 1%.

Close to peak parameters of a hydrograph are entitled to define both the discharge value Qcp and the duration of flood effect Tf corresponding to a percentage e = 90 % out of the peak value

$$Qcp = e\,Qp \qquad (1)$$

$$Tf - t(Qcp) \qquad (2)$$

Flood control works cost is defined as total investment + operation + maintenance cost Ct corresponding to a flood discharge Qp, and considered as susceptible to limit **flood damage cost**

to a minimum amount Cd. Theoretically, a Ct-cost corresponding to the Qpm-value would lead to a zero-Cd. Flood damage cost can be as well looked at as a penalty for under-estimating flood potential.

3. DEVELOPMENT

3.1 Basic Relationships

In a deterministic way, flood discharge magnitude (Q) and cost of anti-flood works (C) are related by means of a function

$$C = f(Q) \qquad (3)$$

Setting t as an elementary time interval that describes a flood hydrograph, the unitary economical effort to prevent damage is defined by a ratio (F1)

$$F1 = C / Q\,t \qquad (4)$$

The classical probabilistic respect used in hydrology correlates each flood discharge value (Q) to its associated probability (P), of the general manner

$$P = P(Q) \qquad (5)$$

Over a n-year period, the risk (R1) to reach flood would be

$$R1 = 1 - (1 - P)^n \qquad (6)$$

Making a risk-based correction in Eq.4, a probabilistic economical effort is indicated by the ratio (F2)

$$F2 = R1\,C / Q\,t \qquad (7)$$

3.2 New Deterministic Approach

A variety of examples could be used to relate parameters in Eq.3, as for instance, a hyperbola

$$C = Q / (a + b\,Q) \qquad (8)$$

that can be made valid for both peak discharge values (Qp) determining the total protection cost (Ct), and close-to-peak discharge values (Qcp) leading to the associated protection cost (Ctcp).

Since flood prevention cost (Ct) and damage expenses (Cd) are dependent, by means of a parabolic equation

$$Cd = x\,Ct^2 - y\,Ct + z \qquad (9)$$

in particular they will fit for the Ct- and Cd-values at close-to-peak level: Ctcp vs. Cdcp.
With respect to the specific economical effort, a ratio F3 is characteristic to this approach

$$F3 = (Cdcp - Cd) / (Qp - Qcp) Tf \qquad (10)$$

in which Tf had been defined in Eq.2.

3.3 New Probabilistic Approach

When planning flood control works, in addition to a risk of not having completely mastered the flood effect (R1), a risk of structural failure of defence work (R2) is expected

$$R2 = c - (1 - R1)^d \qquad (11)$$

The specific economical factor defined with this approach is F4

$$F4 = R2\ Ct / (Qp - Qcp) Tf \qquad (12)$$

4. EXAMPLE

The numerical coefficients (a, b; and x, y, z) in Eqs. 8 and 9 are functions of economical circumstances at a specific epoch. Based on a series of flood hydrographs recorded within the torrential flow regime, characteristic to Romanian rivers, appropriate values have been set to the five coefficients

$$a = 0.3,\ b = 0.0007;\quad x = 0.003,\ y = 6.6,\ z = 3600 \qquad (13)$$

In what concern risk parameters R1 and R2, they indirectly bring into picture a cost index, by means of Eqs.5 and 3. For

$$n = 10 \qquad (14)$$

the adequate range of values for c and d is

$$c = 0.40...1.00,\qquad d = 9...1 \qquad (15)$$

Time step (t) for a flood hydrograph description is

$$t = 0.5 \quad (hrs) \qquad (16)$$

The economical factors (F1 to F4) defined in Eqs.4, 7, 10, and 12 are calculated and presented in Table 1, as comparative effects obtained from some basic input data. Since the purpose od these samples is mainly illustrative, monetary unit used for cost columns in the table has symbolically been named MU.

Table 1. Numerical examples illustrating calculation of three values for economical factors (F1 to F4)

Qp (m3/s)	P (%)	Tf (hrs)	C or Ct (MU)	Cd (MU)	F1 (MU/m3)	F2 (MU/m3)	F3 (MU/m3)	F4 (MU/m3)
1000	1	1	1000	0	2.00	0.17	0.22	0.12
800	2	2	930	57	2.33	0.39	0.23	0.64
500	10	4	770	297	3.08	1.90	0.40	2.00

Mention should be done that the values used for Tf and t had not been converted in seconds on the purpose of simplifying calculi.

5. SENSITIVITY

The values resulted in Table 1 for the economical factors F1 to F4, though relative and conventional, do not put into light the effect of occurrence on the economics aspect.

In order to overcome this deficiency and to make possible more interpretation, a conventional sensitivity coefficient (S_i) is defined of the following manner:

$$S_i = V_1 / V_i, \qquad i = 1, 2, 3 \tag{17}$$

in which V_1 is any first row's F-value (minimum outputs), and V_i is any value of F in the i-row (i equal to any of 1, 2, or 3).

With this definition adopted, Table 2 presents the new conventional values of F1 to F4, keeping the same relativity ratio.

Table 2. Modified values of F1...F4 through the definition of conventional sensitivity coefficients S_i

	F1	F2	F3	F4
S1:	1.00	1.00	1.00	1.00
S2:	1.16	2.24	1.05	5.33
S3:	1.54	10.98	1.80	16.68

This new displaying way enables a complex analysis of the economical effects in terms of conventionally defined sensitivity:

a) Within the same economical factor, the largest range of values is covered by F4. The indication is that sizing flood control works at a peak discharge value equal to half of the maximum peak value (at Qp = 500 m3/s instead of Qpm = 1000 m3/s or at P = 10% instead of Pm = 1%), would lead to a unitary expense level of more than 16 times higher. For the same compared input data, within F2 the effect is just 11 times higher, and within F3 is less than twice.

b) For the new definition of an economical factor compared to the classical one, regarding a deterministic, respectively a probabilistic, approach (F3 to F1, respectively F4 to F2), an enlargement in variation is noticed. The maximum increment is

$$(F3 / F1)_{max} = 1.17, \quad \text{while } (F4 / F2)_{max} = 1.52 \qquad (18)$$

c) Between the probabilistic issue and the deterministic one related to the same definition (F2 compared to F1), or to a different one (F4 compared to F3), a dimensioning of flood control works at a half-diminished peak value of the discharge, will lead to an increase (7 times, respectively 9 times) in the unitary cost plus damage.

Results presented in Table 2 and the subsequent comments done above may appear as paradoxical if misunderstood or misinterpreted. Since the goal of this model was to reveal economical impacts due to undersizing or misplanning flood control works, reference should be made to the Qpm- or Pm-value. Still, as a general remark, risk-based approaches imply more economical effort than deterministic outlooks.

6. SUMMARY AND CONCLUSIONS

A new economical model has been built based on a set of complex concepts. An extended consideration has been given to the hydrological and hydrologic-economical magnitudes associated with the notions of peak value, maximum peak value, and close-to-peak value.

Thus, the maximum peak value has herein been introduced as the discharge value *(corresponding, for example, to an occurrence probability of 1 %)* that, taken as the reference value for flood control planning, would imply just anti-flood works costs, conventionally leading to a flood damage cost equal to zero.

Two categories of risk have been defined as coming into picture within the extended probabilistic approach: the classical one concerning social-economical losses due to flood effects, and the newly defined one with respect to the structural failure of defence works.

A deterministic approach and a probabilistic one are presented in terms of unitary economical efforts or economical factors, in two different ways: a classical one, and a newly one. Thus, comparison is made between the classics and the lately standpoints, by means of conventional sensitivity coefficients, allowing an accurate estimation of variability range.

Conclusions can be drawn that misplanning or undersizing of flood control works might induce economical factor values of more than ten times higher for a probabilistic problem, while for a deterministic one just less than two times higher ones. Results showed, as well, that the new approaches have determined a sensitivity of 1.2 to 1.5 times greater than classics.

MEDUSA BAG PROJECTS FOR THE OCEAN TRANSPORT OF FRESHWATER IN THE MEDITERRANEAN AND MIDDLE EAST

James A. Cran[1]

Abstract

Medusa bags are extremely large, streamlined fabric containers for freshwater. A commercial model would be 650 m long, have a draft of 22 m and contain 1.75 million cubic meters (MCM). It would float in seawater and be towed at 2.2 knots by a 4-5000 Hp tug. While a substantial development program has been completed, no commercially sized model has yet been built.

The project to ship 250-400 MCMY of freshwater from the Manavgat River in S. Turkey to Ashquelon near Gaza has been studied at length. Based on this work, the economics of the Medusa system is derived and compared with those of a used 420,000 DWT supertanker. The cost of transportation alone by Medusa bag is one sixth that of the supertanker. When the cost of the terminals and infrastructure is included, the cost ratio becomes one fourth. Marine shipment is, of course, only one way to augment freshwater supply, and the economics of several methods are compared for the SE Mediterranean region.

In conclusion, the medusa bag cost formula is applied to other potential freshwater movements in the Mediterranean and Middle East. Source rivers considered are: Rhone (France), Acheloos (Greece), Vijose and Drin (Albania), Manavgat and others (Turkey), Indus (Pakistan), and Karoun and others (Iran). The cost of supplying a number of potential consuming points is presented, for example, Tunis and Tripoli 17 ¢/CM, SE Med and Egypt 16 ¢/CM, Arabian Gulf cities 20-25 ¢/CM from Pakistan, 13-20 ¢/CM from Iran.

The cost to supply one point from several sources can be seen. For example, Tel Aviv/Gaza could be supplied in large quantities from Turkey for 16 ¢/CM, from Greece for 22 ¢/CM, from Albania for 25 ¢/CM, and from France for 35 ¢/CM. These numbers are all lower than any alternative to the region.

Description of the Medusa Bag

Several years ago, the Medusa Corporation of Canada noted that there was no water equivalent of the crude oil supertanker, currently the cheapest means of moving anything. Water is worth roughly one one-thousandth as much as crude oil and quite different technology must be employed to move it. This was amply demonstrated by the vain efforts of the Norwegian supertanker owners association, Intertanko, to develop water markets for surplus supertankers in the mid-1980's. Medusa therefore explored mathematically the technology and economics of streamlined nylon bags as flexible barges. Paper studies showed that a bag with the content of five supertankers could be constructed for about 1/80 the cost. After inclusion of the tug and allowing for the very slow speed needed to conserve energy, the effective cost of transport

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works out to about 1/6 the cost of a supertanker per cubic meter and an order of magnitude less than water conduits of similar capacity (see Attachments).

There is nothing magic about water bags; they are tricky to engineer and awkward in operation, but they are cheap.

The medusa bag is streamlined in plan, relatively shallow with large flat areas on the top and bottom. The precise dimensions of the bag for a specific application will be set by mathematical optimization taking into account fabric cost, hauling cost, required annual volume, ocean floor gradients at the coasts, etc. Made from commercially available industrial nylon fabric coated on both sides with long durability PVC (pond liner, roofing membranes), the bags are expected to have a life of at least seven years. A novel network of heavy straps acts to transfer the tow and mooring forces to the fabric and also to prevent propagating rips.

The commercial sized bags would be very large: 650 m long, 150 m wide and draft 22 m. The freeboard is only some 0.7 m, depending on the salinity of the ocean water (sp. gravity 1.025-1.030). Because of the draft, similar to supertankers, the bags cannot approach shore closer than two or three kilometers, except in fjord country. Therefore the bags must be filled and emptied at single buoy moorings serviced by submarine pipelines with pumpstations on shore. The tugs are medium sized, 4-5000 Hp. It would take some two hours to accelerate to the cruising speed of 2-2.4 knots (100 km/d), but with the tug pulling on the stern, the bag could be brought to a halt in less than twice its own length.

In operation a bag will be filled in about 24 hours at a rate of 20 CMS, it will then be taken in tow, following several other bags en route. After emptying, the bags return empty at at least three times the loaded velocity, towed on the surface, collapsed into a narrow crossection. Ideally enough bags would be used so that the cycle is complete and the terminals, which comprise the majority of the investment, are fully utilized. While under tow, a specially designed tug with an empty smaller bag could attach itself to the stern of the big bag and download from it. Typical dimensions for the smaller bags would be a draft of less than 10 m and contents less than 125,000 CM. This would be an appropriate way to service a number of destinations in the Arabian Gulf where the water depth is a serious problem, while preserving the excellent long-haul economics of the large Medusa bags

Development work to-date has involved construction and experimentation with several models in wave and tow tanks, as well as a 100 meter long prototype deployed in the ocean north of Vancouver, Canada. This work has established:

- the optimum shape of the bag in plan
- that the internal pressure is sufficient to maintain shape in tow
- that tow stability obtains at low speed
- the static and wave-induced stresses
- the safety factors for the compound fabric
- the design of a ripstop strapping system
- the strength of the base fabric and straps
- the tow-line attachment device
- that storm waves can be accommodated without damage

that storm waves can be accommodated without damage
that there need be no concern for resonant oscillations
the design of the apertures and their valving
the technique for completely emptying the bag

Participating in this work were Professor Michael Isaacson, Dean of Civil Engineering, University of British Columbia, an expert in marine structures and hydrodynamics, and Dr. Frank Ko, Director of the Fibrous Materials Research Institute, Drexel University, Philadelphia. Commercial technology and costing has been contributed by Avon Rubber (UK), Birdair (NY), a subsidiary of Taiyo Kogyo (Japan), Crowley Maritime (CA), Alexandra Towing (UK), Zim Shipping Lines and Tahal (Israel).

Future development work involves the scale up to 270 meters (100,000 t) in length, including the first implementation of the compound fabric and the strapping system. Aperture and valve design, the freshwater connector and loading buoy and the towing connector must all be finalized, implemented and tested. Towing, mooring and other operating issues appropriate to the Eastern Mediterranean must be demonstrated. Funding for this work, which will require 9 months, is actively being sought. Subsequently a full feasibility study must be carried out employing values established by the preceding program. Large-scale water planning for the region cannot seriously include the Medusa options until this work is completed.

Economics

A comprehensive prefeasibility study has been prepared by an international engineering company of the project to ship 250 MCMY of freshwater per year from the Manavgat river in southern Turkey to Ashquelon just north of Gaza. Six bags costing about $6 million each would be used in a circuit: one bag loading for two days, three loaded bags in transit for six days, one bag emptying for two days and one empty bag in transit back for two days. There would be 6 tugs also. Assumed useful lives were: bags 7.5, tugs 15, and civil works 30 years. Considering interruptions for storm conditions, collisions, tug and pump breakdowns and operational irregularities, a service factor of 80% was assumed, ie., the ideal project capacity was set 25% greater than the desired capacity. Using an interest rate of 7.5%, the cost of the first 250 MCMY was estimated to be about 17¢/CM. A sensitivity study showed that the marginal cost for an additional 150 MCMY would be 9¢. On this basis a project today to ship 500 MCMY over the same distance would have a cost of about 15 cents/CM.

The above study estimated total capital investment at $280 M, including contingency, engineering and interest during construction. As a rough rule of thumb, this is $1 per CMY, compared to $4 per CMY for seawater desalination. Furthermore, in this estimate the unloading terminal comprises 50% of the total because it includes seasonal storage and the pumpstation and 16 km pipe required to inject into the transmission conduit, in addition to the buoy, submarine pipe and unloading pumpstation. These large infrastructure expenditures are normally not included in quotes of the cost of desalination. Note that the bags only comprise one-seventh of the total investment so that large cost overruns on the bags would have only a modest effect on the project economics.

Attachment 1 looks more closely at the economics of a bag-tug pair, in the same way as one looks at a supertanker (Att. 2), neglecting the terminals and land infrastructure. It shows that the bag-tug portion of the Manavgat/Ashquelon haul is only 5.5, say 6 ¢/CM out of the total of 17 ¢/CM for the 250 MCMY project studied or the 15 ¢/CM for the 500 MCMY project, today basis. Since the bag-tug pair is optimized, increase of project scale will not reduce this cost. Thus, 6 ¢/CM is the ultimate marginal cost. The 9 ¢/CM marginal cost quoted above as applying to the increase from 250 to 400 MCMY, contains also the marginal cost of increasing the terminals.

Attachment 3 compares the operating numbers for a Medusa bag-tug pair and a 420,000 DWT supertanker. The tanker's first advantage lies in its loaded velocity which is 6 times that of a bag. The bag is not so slow on its return trip and the terminal times are equal, so the tanker's advantage on the round trip has dropped to 2. When its three-fold higher day cost is figured in, its voyage cost is 50% higher. The bag's cargo is over 4 times larger so its transportation cost is less than 1/6 that of the tanker. By the time terminal costs are included, the bags have only a 4-fold advantage relative to the supertanker.

Attachment 4 extends the comparison to include other means of augmenting the freshwater supply in the SE Mediterranean. The message is loud and clear: only Medusa bags are capable of supplying that region at a price level such that the countries will be justified to plan not to remove water from agriculture, or not to build the high cost means of supply augmentation such as desalination.

Other Projects

In Att. 5 the transportation cost formula for Medusa bags is applied to other possible freshwater movements in the Mediterranean and Middle East. It must be remembered that the cost formula treats all invested capital as debt with a long term payout. If real projects contain equity or must pay off debt sooner (such as BOT projects), then these cost estimates will be low. The terminal charge is taken as 10 ¢/CM in all instances. As explained above, this value contains a lot of infrastructure. Also it is based on a large thruput, at least 300 MCMY, which may be too large. At the same time, two or more destinations may be sharing the loading terminal which will produce some economies. We believe all the rivers can support at least one BCMY of shipments. The south Turkish rivers could support more than 3 BCMY. We do not have an estimate of the demand for many of the markets. It is estimated that the SE Med could absorb about 700 MCMY by 1998, increasing at 100 MCMY per year subsequently. The Arabian Gulf markets could take 500 MCMY, Tripoli 400 MCMY and Malta 50 MCMY.

The cost estimates also do not include any allowance for a royalty to be paid to the supplying country. There are many considerations here. There is no point in a country insisting on a high royalty if it will kill the project. For instance, Turkey stands to receive about $100 M per year in export sales revenue even if it has a zero royalty. It is known that Singapore has an agreement to get water from Indonesia at a royalty payment of 0.5 ¢/CM.

It can be seen that the estimated total cost ranges from 15 to 25 ¢/CM with a low of 13.3 ¢/CM to supply Cyprus from Turkey, and a high of 32 ¢/CM to supply Jeddah from the Indus.

Tripoli and Malta would make a nice project for the Acheloos River in Greece with a total demand of about 500 MCMY at a cost less than 20 ¢/CM. The Acheloos could also supply the SE Mediterranean at a cost about 22 ¢/CM, the same cost at which Turkey could supply Libya, Malta and Gabes. Note that if the Acheloos was not sufficient, reaching to the Albanian rivers the Vijose and the Drin would only add another 2.5 ¢/CM. The SE Med could even be supplied out of the Rhone for about 35 ¢/CM. This cost is far below the cost of desalination, even projecting ahead 25 years and assuming unforeseen technical advances. One should also anticipate a long-term reduction in the Medusa costs.

The Arabian Gulf states could be supplied for roughly 25¢/CM out of Pakistan, and for about 15 ¢/CM out of Iran, assuming in both instances that an acceptable freshwater supply could be developed and brought to a suitable terminal. In comparison, the supertanker formula shows that recently announced supply out of Malaysia (8,000 km) will cost $2.80/CM, compared to $1.00/CM from new desal plants and the $4.00/CMY capital cost of construction of a new plant.

It is hoped that these numbers and ideas will generate enough interest to cause the necessary prefeasibility studies to be carried out.

Attachment 1: ECONOMICS OF WATER SHIPMENT BY MEDUSA BAG

Here we are looking at the cost of movement by one tug and bag, no terminals.

Tug

4000 Hp, capital cost (quantity purchase) $5.4 M each. Life 20 years.
Scrap value 10%. 8% interest, Ann. charge: $530,000, per day $1,500.
Crew (Turkish), maintenance, insurance, admin.: per day $2,000.
Day Rate $3,500.
Fuel, 18 tpd @ $100/t plus lube etc. @ $200/d: $2,000 .

Bag

Capacity, 1.75 MCM. Capital cost (Turkey) $6 M. Scrap value 20%.
Life 7.5 years, Interest 8%, annual charge: $984,000, per day $2,811.
Maintenance and insurance @3% $514/d. Day Rate $3,325.

Tug+Bag

Day rate $6,825, running day rate $8,825

Case: Manavgat R. to Ashquelon, 675 km
Loaded trip time @2.2 knots: 7 d
Unloaded trip time @6.6 knots: 2.3 d, total 9.3 d @ $8825 = $82,213 per trip
Loading and unloading, 1 d each @$6825 =$13,650; total = $95,863 per trip
Over delivered cargo of 1,750,000 cubic meters, cost per CM = 5.5 cents

Formula: Transportation cost only, cents per cubic meter = 0.8 + 0.7/100 km
To this must be added cost of terminalling, ¢/CM = about 10.0

Sources:

Tug cost data: Crowley Maritime, Oakland, CA, largest tug operator on the US westcoast and ZIM shipping, Haifa.

Bag costs: Birdair, Buffalo, NY, world leaders in the design, fabrication and construction of tensioned membrane structures.

Bag velocities: Prof. Isaacson, U of British Columbia, based on tow-tank results from BC Research. There is no doubt about the skin friction portion of the drag (half) since it is calculated.

Bag competancy: Birdair, based on results of wave basin studies carried out by the National Research Council, Ottawa.

Terminal costs: Tahal Engineers, Tel Aviv, pre-feasibility study of the Manavgat/Ashquelon project.

Attachment 2: ECONOMICS OF WATER SHIPMENT BY USED SUPERTANKER

Example: Crude oil ULCC rated 421,000 DWT, cargo capacity 415,000 t (CM)
18 years old, good for 5 more years
Capital value $22 M, plus special cleaning $3 M, scrap value $5.5 M
5 yr. charter interest rate 11%, ann. charge $5.74 M, per day $16,400
Crew, maint'ce, ins'ce, admin, miscell, diesel $1000/d per day $10,000
(Spot rate may be higher or lower) Day rate $26,400
Fuel, 60 tpd @$100/t = $6000/d
Pumping fuel 25 t @$100/t=$2,500

Case: Manavgat R. to Ashquelon, 675 km
Steaming time @ 13.33 kts plus manoeuv 57 h @ $32,400 = $77,000
Port time 2.225 d @$26,400/d plus pumping cost = $63,740
Total voyage cost $140,740
Over cargo of 415,000 CM, cost per cubic meter 34 ¢/CM

Formula: Transportation cost only, cents per cubic meter: 14.2 + 3/100 km
To this must be added the cost of terminals, etc.: at least 25 ¢/CM

Source: Melville Shipping, Ottawa

Attachment 3: BAG-TUG PAIR VS. SUPERTANKER, OPERATING COMPARISON

Voyage specific items refer to the Manavgat - Ashquelon trip, 675 km

	Bag-Tug Pair	Supertanker	Advantage Supertanker
Loaded velocity, knots	2.2	13.33	6
Round trip velocity, knots	4.4	13.33	3
Terminal time, days	2.0	2.0	1
Round trip time, days	11.3	5.6	2
Average day cost, $	8,500	25,700	0.33
Voyage costs, $	95,863	144,000	0.665
Volume delivered, CM	1,750,000	415,000	0.237
Transport cost ¢/CM	5.5	34.7	0.158
Terminal costs, ¢/CM	10	25	0.4
Total delivered cost, ¢/CM	15.5	60	0.25
Cost per 100 km, ¢/CM	0.7	3.03	0.23
Delivered cost formula, ¢/CM	10.8+.7¢/Hkm	39.2+3¢/Hkm	

Attachment 4: AUGMENTATION OF WATER SUPPLY IN THE S.E. MEDITERRANEAN, COMPARISON OF METHODS AND COSTS

METHOD	COST
Desalination	80-120 ¢/CM

Bechtel's study of desalination costs for Baja California estimated the cost at 125 ¢/CM. The World Bank study (Dr. Braverman) estimated the cost to be 100. I was told that an Israeli firm had quoted at 80. A Japanese project to build several plants in Gaza with no return on investment, but charging electricity at 5 ¢/kWh, reportedly cost 65 ¢/CM.

Low cost proposals assume integration of the desalination plant with a thermal power plant. If desalination water is required, power plants must also be constructed, and there is no shortage of electric power in the S.E. Mediterranean at the moment. The Red-Dead proposal primarily generates cheap electric power. For desalination, RO units would have to be constructed in addition. The water cost would not be much lower than the above.

Urban Wastewater Recycling 75 ¢/CM

I do not have good numbers here. First the wastewater must receive secondary treatment which costs roughly 50 ¢/CM, then it must be further processed by low pressure RO (25 ¢/CM) to complete purification and reduce salts. Volumes available are limited to two-thirds of the water entering urban areas.

Small Waterbags 65 ¢/CM

Fabric barges in the 300,000 tonne size range have been proposed by Unitor (Norway) and Aquarius (UK). Both proponents quote this price for shipment from southern Turkey. Because supertankers cost no more and possibly less, there is no incentive to develop these technologies.

Supertankers 55-65 ¢/CM

Melville Shipping of Ottawa have prepared a reasonably precise cost estimate based on a used 420,000 DWT tanker worth $25 M. It shows a cost of 34 ¢/CM plus at least 10 ¢/CM for each terminal. The supertanker terminal under construction at the Manavgat is talking a cost of 20 ¢/CM, and typically unloading costs more. With the rule of thumb 39.2+3/100 km¢/CM, the cost from Greece would be 88 ¢/CM.

Terrestrial Pipelines Jordan Valley 40-60 ¢/CM
Mediterranean Coast 65-85 ¢/CM

Two pipeline projects have been much discussed. The Seyhan and Ceyhan River project, part of the Turkish Peace Pipeline, quoted 60 ¢/CM to Jordan. A more recent proposal takes its water from the Ataturk Dam reservoir and visits several Syrian cities before reaching the Jordan Valley. Quoted cost is 40 ¢/CM. To lift this water to the coast will cost at least an additional 25¢ because a new conduit will be required parallel to the Israeli National Carrier.

Medusa Waterbags Mediterranean Coast 15-20 ¢/CM
Jordan Valley 0 - 5 ¢/CM

These Medusa costs are based on a prefeasibility study done by Tahal with costs adjusted to today and volume increased to 500 MCMY. Interest is assumed to be 7.5% and

Attachment 4, continued

crude oil price $20/barrel. No royalty payable to Turkey is included because there is more than one way for Turkey to be compensated. The sizes of the bags (1.75 Mt) and tugs (4000 Hp) are set by optimization. The large size of the bags is essential to produce these attractive economics. The lower cost of water in the Jordan Valley assumes that Turkish water is delivered there by exchange, ie., water volumes for the Valley delivered to the coast are consumed on the coast but equal volumes are released from the Galilee, thus saving the 15 ¢/CM direct cost of lifting water from the Galilee to Haifa. Whether the savings are passed on to the Jordan Valley consumer is, of course, a matter for negotiation.

Water Conservation 40 ¢/CM

There is obviously a wide range of costs for this activity in the agricultural, industrial and residential sectors. The above implied cost of water for drip irrigation was quoted to me by Prof Daniel Hillel of University of Massachusetts, one of the developers of this technology. Conservation is an obvious way to extend natural supply, but it must be deferred if it costs more than incremental supply.

Acceptable Market Value for Water

Agriculture 10-15 ¢/CM

Agriculture is still the largest consumer of water in Israel, though declining, while it will continue to be the largest in Jordan and Palestine for the next generation. In Arizona, the new canal project is in trouble because farmers will not pay more than 5 ¢/CM. In California farmers have been selling water at 10 ¢/CM. In Israel agricultural water has been subsidized down to 10-12 ¢/CM for many years, with much complaining from the Department of Finance. I have been told that the most intensive ME agriculture cannot afford to pay more than 15 ¢/CM. In Jordan during the drought in was reported that some farmers were paying as much as 35 ¢/CM, but this is obviously an unsustainable situation.

Residential and industrial users will pay considerably more at the wholesale level. For example, the retail cost to residences is currently $1.50/CM in Israel.

In times of shortage, and all the countries of the region are facing long-term, chronic shortages, an irresistible economic trend will see the removal of water resources from agriculture for allocation to residential and industrial users. Israel has officially adopted this as its long-term strategy. This works for Israel since its industry is successful and its agriculture suffering from competition. Such a strategy would be punitive for Jordan in the medium term.

Conclusion

The marginal cost of large new supplies of water to the SE Mediterranean should be at such a level that governments there can continue to subsidize the cost down to the 10 ¢/CM agriculture can afford. A long-term, large volume subsidy of 10 ¢/CM is probably all that can be sustained. (Obviously this is a very loose number.) On this basis the delivered cost of water must be no more than 20 ¢/CM. Water delivered directly to growing urban areas on the coast could command a higher price since it obviates the need to enlarge the supply system.

Medusa, and only Medusa, offers the prospect of supply augmentation to the SE Mediterranean at an acceptable cost. Like it or not, the technology of the very large bags must be developed.

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Attachment 5: MEDUSA BAG TRANSPORTATION COSTS - MEDITERRANEAN AND MIDDLE EAST

Source	Destination	Distance	Transportation Only	Transportation + Terminal
Rhone River	Rabat, Casablanca	1600 km	12 ¢/CM	22 ¢/CM
France	Algiers	720	5	15
	Tunis	880	7	17
	Tripoli	1360	10.3	20.3
Acheloos River	Gabes	1120	8.5	18.5
SW Greece	Tripoli	930	7	17
	Malta	600	5	15
	Alexandria	1280	10	20
	Tel Aviv/Gaza	1600	12	22
Albania Vijose, Drin	to above	+300	+2.5	+2.5
Manavgat R.+others	Tripoli	1760	13	23
S. Turkey	Malta	1530	12	22
	Crete	600	5	15
	Alexandria	625	5	15
	El Arish	700	6	16
	S. Cyprus	350	3.3	13.3
	Tel Aviv/Gaza	675	5.5	15.5
Indus River	Kuwait	2100	15.5	25.5
Pakistan	Jubail	1900	14.1	24.1
	Doha	1700	12.8	22.8
	Abu Dhabi	1500	11.3	21.3
	Muscat	900	7.1	17.1
	Jeddah	3000	22	32
Iranian rivers	Arabian Gulf cities			13-20

A PLAN FOR COST-RECOVERY OF WATER FACILITIES IN THE IRRIGATION SYSTEM

By

Fouad El-Shibini[1]

ABSTRACT

This paper considers water allocation planning based on a simple model for cost-recovery of the facilities provided by the water administration to water users. The water pricing based on the cost of water is not the issue considered. However, the ambitious land reclamation programmes in new lands, imposed the case in which there is limited capability to expand water supply capacities by means of structural solutions. under such conditions, all possible measures that facilitate more efficient water use becomes extremely important. Among the most critical duties of irrigation water planners is the evaluation of the potential for rationalization of water use.

The problem of Egypt's huge and complex irrigation system is that practitioners have limited access to information that describes rationalization options available to individual water users. This fact emphasizes the important role of the Water Users Associations (WUA) to take part in solving such problem. Regarding exact future water requirements, there is no method, at presents to precisely determine their values, and hence irrigation water planners must proceed on the basis of indirect information and personal judgment only. It should also be mentioned that a continuous dialogue between water administration and WUA is always required.

To this end, a cost-recovery model is formulated based on concepts of providing facilities for water accecibility, equity and water users satisfaction. A numerical example illustrates the application of the proposed methodology is given.

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1. INTRODUCTION

Natural Fresh water on earth is a limited renewable resource which is unevenly distributed. This fact has created, during the last few years, some water shortage problems in arid and semi arid regions.

The impact on Fresh water in the middle east is rapidly increasing to the extent that next decade might witness one of the most serious water scarcity problems.

Egypt is also approaching a critical situation in the near future due to the growing agricultural, industrial, municipal and other demands while the natural supply is almost fixed. Egypt's share from the Nile water is limited to 55.5 billion m^3/year, from deep groundwater 0.5 billion m^3/year and from scattered coastal rainfall (100-150 mm/year) about one billion m^3/year. Realizing the fact that almost 85% of Egypt's water is allocated for agriculture and the overall efficiency is within 65-70% after water recycling, which means that on-from irrigation efficiency is relatively low. Whereas, water allocated for domestic and industrial uses are less than 15% but the effluents from both activities are highly polluted. Accordingly, services needed to maintain suitable water quantity and quality for different needs vary with the degree of negative impacts on the whole system.

The engineering approach to tackle the expected water shortage problem in Egypt involves two concepts;

a- improve the system performance through proper management and applying appropriate technologies, i.e. optimize the use of available water.

b- increase the annual amount of available fresh water in the system through, augmenting the natural inflow (upper Nile projects) and/or through water reclamation and possible desalination of brakish and sea water (non-traditional resources).

However, engineering solutions only are not always the tools to solve multidiciplinary problems. It should be supported by and complemented with legal aspects concerning economic, social and traditional habits.

Economic considerations must be based on a thorough review of agricultural land taxation scheme, an imposed or free cropping pattern situation and the nature of the agricultural market for goods and services.

Social and traditional habits considerations must take into account the belief that natural water is a donation from God to mankind, and hence it is free if accesable without management and control services. But since water need to be conveyed, distributed and then partially collected in a drainage system then such services must be shared between the government and the beneficiaries.

Therefore a cost recovery policy based on the preceeding concepts will enable the government to introduce an effective tool for rationalizing the water among activities and help water saving policy in the future.

The backbone for setting such a cost-recovery policy is the reliability, accessibility and monitoring of real field data. The paper assumes that such data and information can be made available in a database for the use of planners and decision makers.

2. WATER ALLOCTATION AMONG ACTIVITIES

The total allocated water is an integration of the fixed Nile water quota (55.5 billion m^3/y), the desert and valley groundwater and the recycled drainage water. The estimated in-put for each activity is given in table 1.

Table 1 input/output for Activities
(billion m^3/y)

Activity	1990		2000		End point
	input	output	input	output	
Navigation	1.8	1.8	0.3	0.3	Med. Sea
Industry	4.6	3.9	7.9	6.1	Drainage System
Domestic	3.1	0.7	3.1	0.0	Drainage System
Agriculture	49.7	12.0	59.9	6.4	Drainage System

It should be mentioned that desert groundwater amount will increase from 0.5 billion m^3/y in 1990 to 2.5 billion m^3/y by the year 2000. Also valley groundwater and reused drainage water will both increase from 2.6 to 4.9 billion m^3/y and from 4.7 to 7.0 billion m^3/y respectively.

Table 1 indicates that navigation causes a loss of 1.8 billion m^3/year but will be reduced to 1/6 of such amount. Navigation may cause slight pollution due to machiene boats effluents as well as possible bank erossion at certain locations in the navigable canals. But, in general water released for navigation is of good quality.

Industrial demands will increase from 4.6, in 1990, to 7.9 billion m^3/y in year 2000. Also, the output to the drainage system will increase from 3.9 to 6.1 billion m^3/y. But the quality of its output is severely polluted to the extent that it might cause harmful impact and health hazards.

Domestic requirements are expected to remain the same in the year 2000 as is in 1990 as a result of saving existing water losses in the distribution system. Also, untreated effluents, i.e. its output, will be negligible after the operation of the treatment plants project.

Eventually agriculture is the predominant water consumer and will remain so in the future. However, its output drainage water, if not contaminated by industrial and domestic effluents, can be recycled to the extent that only 6.4 billion m^3/y will be released to the sea instead of the present 12 billion m^3/t.

3. IMPACTS AND SERVICES NEEDED

3.1 Navigation

* The impact of navigation is mainly on the main system (the Nile and large navigable canals). About 60 to 70 million m^3/d must be released during the winter closure in order to maintain the required depth in the navigable channel. Also, to improve navigation conditions periodical maintenance is needed to protect the bed and banks of navigable channels from scour and erosion and the sailing boats from transverse currents and/or delay at major control structures. The level of the resulting pollution need to be investigated and inspected.

Accordingly the services needed may be summarized as follows:

* Maintain navigation depth all the year around above the minimum required depth (minimum discharges, dredging ....etc).
* Construct suitable large locks when considering rehabilitation of existing old barrages or bridges.
* Protect the Nile and canals beds and side slopes from scour and erosion due to wave action particularly at meanderings.
* Inspect periodically levels of resulting pollution, if any.

3.2 Industry

Industrial wastes are the worest impact on the quality of water. About 230 industries release effluents to the Nile and tributeries. The most serious of all are those located between Hawamdeia and Delta Barrage where steel and iron as well as some food industries are located.

In upper Egypt Factories such as Kima, sugar, paper, phosphat, aluminum, oil and soab ... etc are the main point sources of pollution. In the delta a number of industries are causing heavy pollution. Along Rossetta branch there is Khafr El-Zaiat industrial area (soab, oil, soda, pestisides ... etc), and along Damietta branch Talkha fertilizer factory exist which have been recently provided with a water treatment unit.

According to 1991 estimates, food industry disposes 666 t/d of solid wastes to Nile, chemical industry 241 t/d textile 191 t/d. Some of these wastes are soluable others remain in solid state. The estimated suspended substances from these industries are 168 t/d from food industry, 64 t/d from textile and 27 t/d from chemical industry. Organic chemical compounds form significant amount of the total industrial effluents.

Hence, the services needed for water conservation in connection with the industry are,

* Setting a monitoring network to collect and analyse periodically water samples, and check level of pollution.
* Impose point source water treatment policy and establish centralized or decentralized treatment units.
* Provide isolated drainage system network for industrial concentrated wasts to avoid contamination (surface or underground).
* Introduce water reclamation technology to encourage industrial waste water recycling.
* Construct protected water intakes and outlet release structures.

3.3 Domestic

Heavy leakage losses occure from the domestic water supply network, which may exceed 40 % of the input. Also, leakage occures from the sewage collecting network. These leakages does not only form water losses but also cause water table rising problem and groundwater pollution. Homogenious Pollution occures along water courses (Nile, canals and drains) due to urban and rural raw sewage disposal. At present, greater Cairo sewage treatment plant is under construction, about 29 treatment plants are almost completed and a scheme of 124 treatment plants, at different locations, will be soon executed. Therefore, according to national plans, domestic water saving may cover the expected increase for domestic demand in the year 2000. The western part of Cairo discharges half its raw sewage (300 x 10^3 m^3/d) to Rahawi drain and the other half is treated at Zenain treatment plant. The eastern part of Cairo disposes most of its raw sewage to El-Khosous and Belbais drains. Both end into Bahr El-Bakar drain which ends into lake Manzala .

This causes sever fishary pollution. The services which are needed to potect the environment and make use of treated Sewage water are,

* intakes and outlets for the domestic and sewage systems. If connected to the Nile and tributeries, must be properly constructed.
* Treatment plants for primary and secondry treatments must be provided.
* Proper measurement devices network, and maintenance and protection programes to prevent leakage losses and or water contamination are a must.
* Periodical sampling for routien ckeck up of water quality.

3.4 Irrigated Agriculture

Drainage water to the sea amounts to about 12-13 billion m^3/y. The present policy is to reuse part of the drainage water in the Delta, Fayoum and Sinai. In 1992 about 4 billion m^3 was reused and in the year 2000 it is expected to be 7 billion m^3.

The average annual discharges to the sea is shown in Table 2 (S. Abdel-Dayem).

Table 2. Average Drainage Water Discharge to the sea (million m^3)

Year	Delta Region		
	Eastern	Middle	Western
1984/85	4391.49	5013.33	4320.86
1985/86	4219.36	4883.45	4338.93
1986/87	3815.31	4899.60	3954.79
1987/88	3513.19	4291.20	4030.22
1988/89	3181.10	4141.58	4168.15
1989/90	3651.17	4158.81	4573.70
1990/91	3725.68	3673.99	5115.72
1991/92	3795.00	4092.22	5118.07
Average	3786.54	4394.27	4452.50

However, the salinity of the drainage water varies from one location to another and ranges between less than 1000 to more than 3000 ppm. Table 3 shows an estimate of quantities and salinity in 1992.

Table 3. Classification of Drainage Water In The Delta According to Salinity in 1992

Salinity (ppm)				
	East	Middle	West	Total
less than 100	433	244	66	743
100 - 1500	1820	851	1473	4144
1500 - 2000	994	791	116	1901
2000 - 3000	573	553	319	1445
More than 3000	114	1215	2724	4053
	3934	3654	4698	12286

About 13000 t/y of Nitrate Fertlizer is used to compensate for the entrapped sediment in lake Nasser which used to deposit on agricultural lands and provide natural nutritions to the fertile soil. Also, traces of fertilizers in the drainage system enhance aquatic weed growth in drains and hence act as incubations for harmful bacteria and other pollutents, such as pestisides.

The required services can thus be summarized in the following:

* Raise efficies through irrigation network improvement and modernize systems of irrigation.
* Improve conditions of drains and continue tile drainage programmes.
* Provide necessary control structures to automate and/or modernize management policies and procedures.
* Establish a continuous maintenance, rehabilitation and replacement programme to secure better management.
* Encourage and support WUA and water Advisory services (WAS) to maintain proper communications.

4. SECTORAL ALLOCATIONS FOR COST-RECOVERY

Water utilization concerns more than one sector, while its management and conservation is the responsibility of the MPWWR. The general policy sets no cost for water but services costs must be shared among users. Hence, the principal question is, "What should be the basis of joint cost allocations and inter sectoral charges?". Indeed this cannot be answered in general terms, otherwise it will permit space for controversy. If for instance, the accounting system considers an average cost basis or an incremental cost basis for all services provided, then one sector may be over or under charged compared to another. Therefore, no cost-recovery scheme is satisfactory without managerial understanding of its limitations quantitative and qualitative.

The cost of water services may be viewed as, the storage cost (dams), conveyance cost (large canals and control structures), distribution and delivery cost (branch canals, mesqas .... etc. From the viewpoint of an economy study, a past cost should be thought of as a sunk cost. This because, whatever has happened up to present has already happened and cannot be changed by any choice among scenarios for the future.

Accordingly, it is the writter's point fo view to adopt the "with or without" situations concept at any level, (the main system or the mesqa level). This leads to the incremental or differential cost estimation. Increment costs are not precisely determinable for different sectoral services, and hence, they need to be estimated wherever decisions are to be based on cost. In general, technical alternatives for services are often complicated by the difference between the short-run and long-run view points. This makes increment cost pricing more difficult to estimate. Therefore, personal judgment, trade-off among secoral services and technical compromise between alternatives are the practical tools to develop an acceptable cost-recovery scheme to serve all purposes quantitatively and qualitatively. These tools will help to search for the differences between scenarios which call for a prediction of what will happen with the proposed service and without it, in the future. The types of costs involved in the analysis are, the capital cost to do the service and the Operation, Maintenance and Replacement costs (OM & R).

4.1 A Simple Cost-Recovery Model

Refering to the assumed services needed for water conservation of the different activities (navigation, industry ..... ect), it is possible to formulate each case to fit the suggested simple model.

IF P is the First capital costs (surveys, planning, design and construction of the facilities needed to do a certain service) and corollary initial costs, i.e. costs necessary to place a facility in operation.

n_1 is the construction period of a facility (2 or 3 or 4 years ...)

n_2 is the period of analysis (20 or 30 or 40 years ....)

R is the annual OM & R costs (assumed a fraction of P)

Q is the annual amount of water benefitted (i.e. saved or treated)

Also, if one assumes appropriate discounting factors of 8%, 10%, 12% and 15%, then the present worth method for the analysis will produce the following relationship, $P + R\,(pwf - n_2 - i)\,(\overline{pwf}\ -n_1 - i) = W_c.Q.\,(pwf - n_2 i)\,(\overline{pwf}\ -n_1 - i)$

where, $(pwf\text{-}n_2\text{-}i)$ = the discount factor for the present worth of a uniform series for a discount rate i.

$(\overline{pwf}\ \text{-}n_1\text{-}i)$ = the discount factor for the present worth of a single payment at n_1 years in the future.

W_c = is the cost recovery/unit of water benefitted.

Replacing the factor $F = (pwf\text{-}n_2\text{-}i)\,(\overline{pwf}\ \text{-}n_1\text{-}i)$ the simple model can be written as;

$$P_1 + R.F = W_c.\ Q.\ F \qquad \text{.... (1)}$$

or

$$W_c = (P_1 + R.F)/Q.F \qquad \text{.... (2)}$$

For illustration, if we consider the following data,

time horizon n_2 = 40 years

construction peridd n_1 = from 4 to 12 years

discount rate i = from 8% to 15%

The factor F can calculated, using interest rate tables, as given in Table 4.

Table 4 Values of F

n_1 \ i	8%	10%	12%	15%
4	8.765	6.679	5.239	3.798
5	8.116	6.072	4.678	3.302
6	7.115	5.520	4.176	2.871
7	6.958	5.019	3.729	2.497
8	6.443	4.562	3.330	2.171
9	5.965	4.147	2.973	1.888
10	5.524	3.770	2.655	1.642
11	5.115	3.428	2.370	1.427
12	4.735	3.116	2.116	1.241

Graphical plot of the relation ship between the factor F corresponding to the number of years and discount rates is shown in Figure 1.

4.2 Illustrative Example

The model may be applied for a hypothetical numerical example. The Irrigation Improvement Project (IIP) is selected for presentation as Case Study.

The major problems experienced with the traditional system (i.e. without IIP) include;

1. The non flexibility of the irrigation rotation system which causes crop water stresses.
2. The non-equity between the head and tail reaches of branch canals and mesqas, results in water shortages at the tail ends.
3. Poor maintenance of canals and mesqas.
4. No orderly controls on water scheduling among farmers (i.e. poor management).
5. Excessive water losses to drains due to over-irrigation (mistrust of farmers in water rotations).
6. Excessive water spills to drains due to upstream control rather than down stream control policy.

The IIP calls for the following improvements actions (i.e. with IPP) (Y. Abdel Aziz;

1- Renovation and improvement of the main delivery systems.
2- Converting rotation canal delivery to continuous flow system.
3- Introducing downstream control.
4- Improving canal management using automatic downstream control gates, distributors,

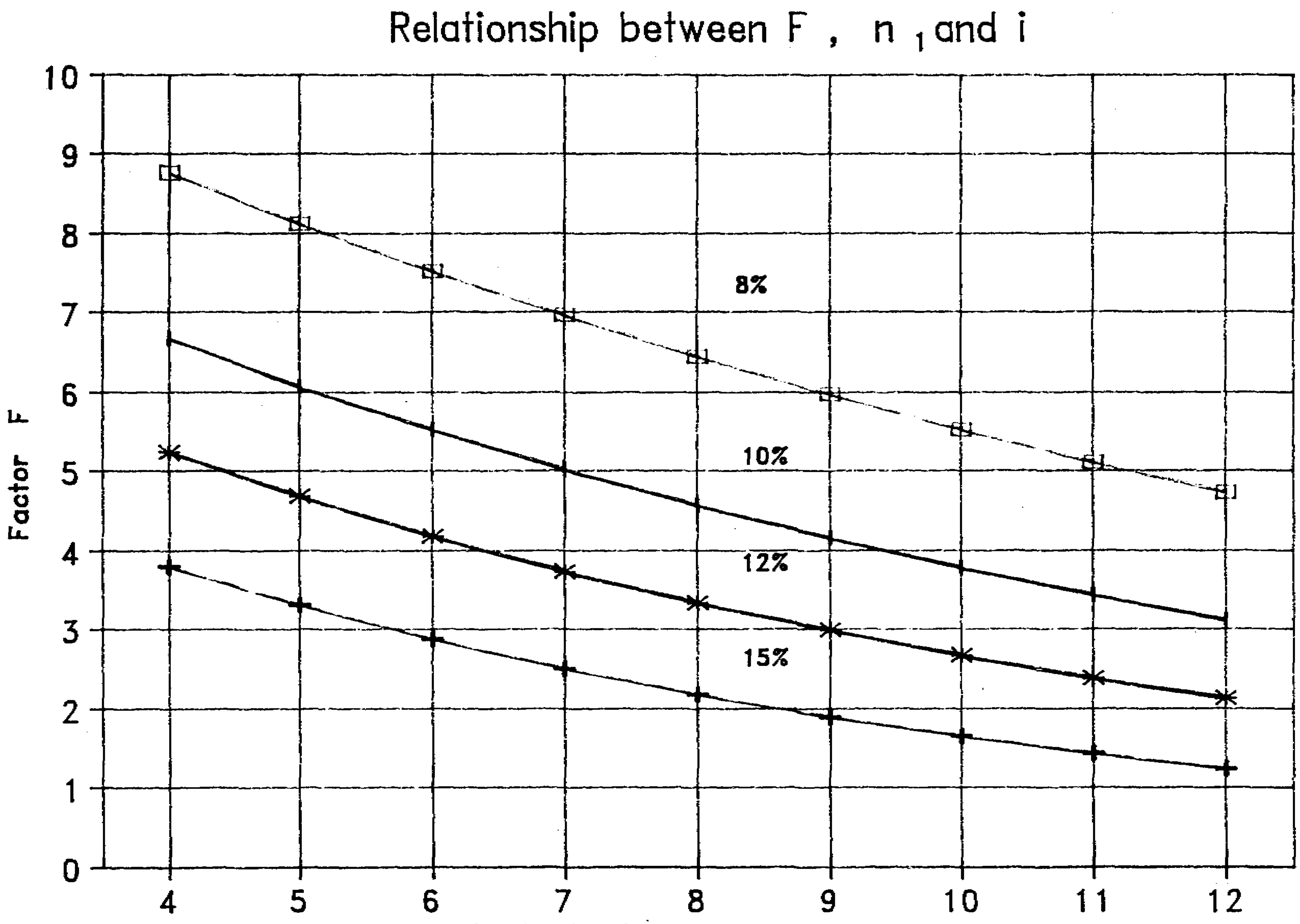

Fig. 1 - Number of years n_1

telemetry and automation.

5- Converting low level (multiple lifting) mesqas to gravity delivery mesqas with a pumping plant at the head (single point lifting).

6- Improving the private mesqas with concrete lining or low pressure irrigation pipelines.

These improvement actions will lead to both tangible and intangible benefits which will pay for a fare cost-recovery scheme. Among these benefits are;

- Improve water delivery and on-farm irrigation efficiencies, reduce operational and management losses and increase agricultural productivity.
- Secure water equity at head and tail reaches.
- Provide a flexible irrigation interval to meet crops and soil conditions, by the continuous flow system.
- Reduce hydraulic cross section under continuous flow policy (probably 1/2 the capacity needed under rotation flow).
- Lined mesqas and/or pipelines reduce seepage losses and facilitated equitable water distribution.
- Land savings particularly if buried pipelines are used.
- Increased crop yields due to timely application of irrigation water.
- Reduce energy costs with single point lifting, rather than multiple operating pumps on one mesqa.
- Reduce the time required for irrigation.

The IIP is concerned with old lands and the pilot project command area totals 400,000 feddans. However the term "Command area refers to the main sub-systems which forms separate units ranging from 10,000 to 50,000 feddans.

In order to calculate the cost recovery for the IIP based on the incremental cost the following problem statement is assumed;

* Consider a unit area of 10,000 feddan.
* The average annual water duty per feddan is 5000 m^3 (without IIP).
* The improved efficiency reduces by 10% of the average water duty/fed.
* Then water saving will be 500 m^3/Fed./y (with IIP).
* If first capital cost is L.E. 1500/Fed. and annual OM & R is 4% of the capital cost, = L.E. 60/Fed./y.
* If the construction period is 4 years and the economic time horizon is 40 years.

The results of calculation are based on solving equation (2) using different factors from table 4. Results are given in table 5 in order to compare the impact of delay in construction period (n_1) and/or the changes in the discount rate (i).

Table 5 IIP W_c (L.E.)

i / n_1	8%	12%	15%
4	0.46	0.69	0.91
6	0.54	0.84	1.16
8	0.59	1.02	1.50
10	0.66	1.25	1.95
12	0.75	1.54	2.54

It is clear if the main system is included, then the cost-recovery per feddan may double or trible the calculated figures depending upon the incremental capital cost and OM & R costs of the main system.

Also from results shown in table 5 the delay in the construction period from 4 to 12 years will increase the assumed cost-recovery by 50% whereas the change in discount rate from 8% to 15%, may be due to inflation, may double or trible the cost-recovery charges.

It is evident that these results are only indicative to explain the procedure, but for real results all assumptions must be verified and justified by thorough analysis. It is also assumed that irrigation water quality meets the criteria, if not, then the costs needed for water cleaning should be allocated to the reason of deterioration of its quality.

It is obvious that the incremental cost-recovery is a function of the amount of water saved or treated, the capital cost, the OM & R cost and the economic time horizon. As the capital cost increases and the amount of water saved decreases, the incremental cost recovery will increase and vice versa.

The WUAs and IAS must take a key role to study the most feasible alternative proposed by IIP for their localities.

The same approach and calculation procedure should be applied for other activities. For instance industry must provide treatment units and pay for their annual OM & R as well as any other capital costs for disposing residuals after treatment. Navigation will have to bear the navigation improvement projects and maintenance programmes. Similarly domestic sector.

The end result will be different cost-recovery schemes for activities and the MPWWR rote will be organizational and technical administration. The government will subsidize the major control structures as well as responsibilities and duties of a national nature.

This may reveal that industry should pay much more for the quantity polluted and discharged back to the system while navigation and irrigation will pay much less. This cost mechanism will help as an effective tool for water rationning in the future and will not form a burdin on farmers who will directly feel the real improvement in water conservation.

5. CONCLUSION AND RECOMMENDATIONS

The valuable Nile water has been missused and seriously abused during the last decade.

Among the most effective measures is cost-recovery allocation for the different uses as one of the means for water protection. The complexcity of inter-sectoral cost allocation for the facilities and services offered by the MPWWR is setting the basis and criteria acceptable to all sectors.

The proper economic analysis in this respect is to consider all facilities built in the past but in this paper it is considered as a sinking fund which the government may contribute as subsidy to water users sectors. However, from present to future all projects to be implemented to conserve the Nile water and preserve its quality must be shared among sectors.

The incremental/differential costs should be allocated on quantitative and qualitative basis. The economic time horizon, interest or discount rates, running costs and any other relevent data are subject to the nature and purpose of water uses.

The cost-recovery can be calculated by using a simple model involving the amount of water saved or treated as a parameter.

Strong recommendation is to start developing data base for the data on sectoral basis including mainly quantitative and qualitative data. Mean time a joint technical committee for all involved sectors, under the umbrella of MPWWR, should set the basis and criteria for the accounting procedure towards a fare and acceptable national targets of the inter sectoral cost-recovery scheme.

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COST-RECOVERY FOR DEMAND MANAGEMENT OF WATER ECONOMIC PERSPECTIVE IN EGYPT

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ABSTRACT

The Ministry of Public Works and Water Resources (MPWWR) adopted an Irrigation Improvement Project which was funded by foreign donors. An Irrigation Improvement Department (IID) was created to implement such project at eleven canal commands. Since the MPWWR is a non-profit organization and has to pay back all investment costs, farmers as the main beneficiaries, have to contribute in cost recovery. A procedure was proposed which relies on " the ability to pay " principle to determine the upper limit which farmers can contribute. Operation and maintenance costs were considered to be the lowest limit whereas investment costs were the reimbursable costs to be recovered. The proposed procedure then used the data available on investment costs and on upper limit of cost (operation and maintenance) and ranked them on a chart. Some rules of analysis were tested to determine the cost-recovery level at different situations of reimbursable cost considering the upper limit of aiblity to pay (O&M). The basis of this rule was calculated in terms of the rent of water captured by farmers at each canal command. Farmers, at low-cost canal command earn high surpluses when the cost-recovery level is below the upper limit in all canal commands.

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1 - INTRODUCTION

The Ministry of Public Works and Water Resources (MPWWR) is responsible for water resources management. Irrigation water is the most important activity the MPWWR has to manage and improve. So, it adopted an irrigation improvement project at eleven irrigation districts spread all over the country and created a new department to carry out and implement such project called "Irrigation Improvement Department" (IID). Most of these improvements are financed by foreign donors whose investment cost has to be refunded by the Egyptian government.

Since the MPWWR is a service ministry and thus a non-profit organization, it is important to find some sources of fund to cover these investment costs in which beneficiaries have to participate. In the case of irrigation improvement, farmers are the first if not the only beneficiaries of such improvement, and so have to pay a substantial part of these costs.

For social and religious beliefs, it is hard to discuss farmers' cost participation. Thus, the problem is how to devise an acceptable way to have farmers participate in cost-recovery which is realistic and equitable.

The proposed procedure, presented in this paper, will help to find how farmers can contribute in improvement cost recovery.

2 - THE INSTITUTIONAL FRAMEWORK

The MPWWR has set-up a new department for carrying out improvement of irrigation activities all called Irrigation Improvement Department (IID) which has to implement all types of irrigation improvement using the interdisciplinary approach whereby four disciplines expertise collaborate. Agronomists, economists, engineers, and sociologists have to collaborate for all types of irrigation improvement.

The IID has to find sources for financing all irrigation improvement as well as refunding donors investment costs. It is presumed that the IID knows the total costs attached to each type of improvement; this includes construction, operation and maintenance, rehabilitation and depreciation. It is presumed also the IID has the authority to determine whether these costs are reimbursable by improvement users and roughly how much they have to pay annually and for how long. The reimbursable costs have to be divided into two parts : capital costs (initial construction and depreciation costs of improvement process for each district) and operation and maintenance costs. In addition to what has been previouly mentioned, the IID being a non-profitable organization, it is expected that revenues from irrigation improvement should not exceed the reimbursable cost (or improvement costs).

3 - THE PROPOSED PROCEDURE

The proposed procedure is mainly taking in consideration the relationship between supply, represented by the IID, and demand, represented by farmers or improvement users. The IID, through its proposed irrigation improvement, has to ensure the availability of irrigation water at farmer fields at proper time and quantity, and farmers have to manage and use irrigation water by which they can achieve high return for all resources available including water.

3.1 Irrigation District And Reimbursable Cost

Since irrigation districts, where improvement is implemented, are different with respect to soil type, farm size, weather condition, crops cultivated, farmers knowledge and expertise, the supply costs of providing irrigation water and/or the value of productivity of irrigation water for a given district might be different from one district to another.

According to the above mentioned, it is presumed that the IID (supply) has a complete set of data for each district which includes the following: a) total reimbursable costs (Rc) per cubic meter of irrigation water delivered to farmers, and b)operation and maintenance costs (O&M) per cubic meter of irrigation water delivered.

3.2 The Ability to Pay Principle

It is a concept expressing how much an individual is willing to pay for a service. It is a budgeting technique which can be used to determine the residual value for non measurable variables. On the demand side, some measurement of irrigation water value productivity is needed. Budgeting, in this case, can be used to derive the water productivity value.

In each district, the budget reflects crop production and sales with and without the irrigation water improvement. Such a budget is done for each crop produced in the district and includes both cost and revenue.

The revenue per feddan represents the expected yield of crop with and without the irrigation water improvement multiplied by the expected market prices. The differences between revenues with and without irrigation water improvement constitutes the increase due to or contributed by the improvement of irrigation water.

On the cost side, estimates have to be made on per feddan basis with and without irrigation water improvement and must include all inputs except irrigation water. Costs related to family labor, management and land rent should be considered and estimated in terms of opportunity cost. Then, the difference between per feddan costs with and without irrigation improvement constitutes the net change in costs. Subtracting change in costs from net change in revenue gives the profit or loss attributable to irrigation water improvement.

Dividing that profit or loss by the amount of irrigation water applied gives an estimate of the average irrigation water value per cubic meter. The above mentioned average estimate of irrigation water should be made for each crop to be cultivated and to which the irrigation improvement is applied. Having made these estimates for each crop at each district, the average irrigation water value would be calculated for each district. This estimated average per cubic meter, weighed against the amount of land to be cultivated with that crop, represents the farmer's ability to pay for each cubic meter of irrigation water.

3.3 Economic Perspective

It is worthwhile to consider some economic perspectives for the proposed procedure with regard to demand and supply. Concerning demand, it was mentioned that the ability to pay is the limit which farmers can afford to cover the reimbursable cost. However, due to the variation in the value productivity of irrigation water between different farmers at a given district and between different irrigation districts, it is worth considering the upper limit as well as the lower limit which can help farmers and the IID authority to meet their objectives. The economic rationale of such limits can be explained graphically as shown in figure 1.

Let us assume that the IID authority delivers a specific quota of irrigation water to a certain district q_R at which one farmer receives a specific amount q_s, and both average value product (AVP) and marginal value product (MVP) of irrigation water are estimated as shown in figure 1. At q_s the AVP of irrigation water is equal to p_s. But at the margin, q_s is not worth p_s for the farmer, it is worth p_m which theoretically means the effective demand price or is the marginal value product. At the point S on the MVP curve, the farmer is capturing rents equal to the area p_m p_s rs on each unit of irrigation water used, and that means, the upper limit of cost recovery on price could be considered as only some fraction of the average value product which will be controlled by the shape of both AVP and MVP curves.

This explanation refers to the importance of setting an upper limit to the cost recovery that farmers can pay and should be as a proportion within the rent area p_m p_s rs.

With regard to supply, since investment in irrigation improvements creates direct benefits to all users in the area, and once the improvement is done all resources used cannot be moved to other areas, which means it is hard to know the returns of such investment in other alternative uses in the economy (in mobile resources, marginal value product can be used). So, in such case to estimate the return of such fixed resources, the economic rent will be the way. A short-run cost-price diagram for an individual firm could help to make clear the economic rent. Figure 2 shows the short-run average curve, average variable cost curve, and marginal cost curve.

If we assume that the market price of the product is p, the firm's output will be x. The total cost of the variable resources (mobile) is OVAX. The average variable cost curve shows the necessary outlays per unit of product that the firm must make for variable resources. The fixed resources get whatever is left from the firm's total receipts ; that is, they receive economic rent. The Total rent for the resources is VPBA. The lower the market price of the product, the less the rent will be and vice versa. With regard to the nature of the SAC curve and considering the firm's investment in the fixed resources, the rent represents the return on the investment in the firm's fixed resources. Only that part of the rent constitutes fixed costs for the firm. Thus, the part of rent represented by VCDA being the fixed costs for the firm, the rest of the rent is considered the net profit.

Economic rent may be equal, greater than, or less than enough to cover the firm's fixed costs. When investment in the firm yields a higher rate of return than investment on the average elsewhere in the economy, rents are greater than total fixed costs ; it can be said that the firm is making profit. When rents equal total fixed cost, that is, when investment in the firm yields the same rate of return as investment elsewhere, the firm achieves zero profit. And when price of product is not sufficient for rents to equal to fixed costs or when investment elsewhere in the economy yields a higher rate of return than it does with the firm, the firm is incurring losses.

From the above mentioned discussion about rent from both viewpoints of demand and supply, it can be realized how important the effect of prices is on the rent which can be captured by the farmer and the IID authority. That makes the proposed set an upper limit for which cost recovery can be estimated within the average ability to pay and at the rent level at which farmer can pay back the costs and for the non-profit IID authority to cover the reimbursable cost.

An economic rationale can also be given for placing a lower limit on cost recovery. In principle, if sources are not to be misallocated, prices should at least cover avoidable supply costs or average variable costs. The operation and maintenance costs (O&M), closely approximate average variable costs. So, it is proposed that O&M costs should be the lower limit on the level of cost recovery for each district.

4 - PROPOSED PROCEDURE APPLICATION TO THE IID

The IID authority has recommended that farmers pay all recurrent annual costs (operation, maintenance, and replacement) and repay all capital investment costs of mesqa and on-farm improvements.

From the eleven canal commands at which irrigation improvements have been started, only nine feasibility reports have been completed at which engineering cost was estimated and can serve as a basis for identifying costs to be allocated between farmers and MPWWR. Table 1 presents a summary of capital and annually recurring costs extracted from the nine completed feasibility reports.

From table 1 reimbursable cost as well as operation and maintenance costs (O&M) can be ranked in order and charted from lowest to highest. On other hand economists working for the IID have estimated crop budgets for all crops cultivated at each district or canal commands. Table 2 presents an example, which shows the incremental difference with and without improvement. These crop budgets needs to includes irrigation water requirements for each crop to help estimating the ability to pay of farmers for each cubic meter of irrigation water.

From the above mentioned, it can be said that all data needed for proposed procedure application are presented. Reimbursable cost (capital investment costs), O&M costs considered the lower limit for cost recovery, and finally the upper limit for each districts or canal commands can be calculated as discussed earlier (a certain percentage of ability to pay).

For simplicity, some values will represent the upper limit of cost recovery and will be charted with reimbursable costs as well as O&M as shown in figure 3.

Given the charted data in figure 3, some definitions are needed, Rc represent reimbursable cost (capital investment costs), O&M represent the lowest limit farmers have to pay back and UL is the upper limit farmers have to pay back and will be expressed as the cost-recovery level (CRL). Now, if we consider an event where the Rc exceed the upper limit UL for some canal commands, some remarks can be deduced, (1) setting cost-recovery level (CRL) at O&M costs will create less revenues to cover Rc. (2) setting cost-recovery level (CRL) at Rc level seems nonfeasible for canal commands whose Rc exceed upper limits UL. From another aspect, setting pay back level at the Rc in canal commands where the upper limit UL exceed the Rc and at upper limit UL in canal commands where the Rc exceed UL may lead to less revenue which cannot cover the Rc of the entire project, (3) setting cost-recovery level (RCL) at the upper limit UL may create revenues in excess of the Rc of the entire project.

To meet the objective of the IID which requires to cover reimbrasuable cost for the irrigation improvements at the nine canal commands, some rules are required for determining the cost recovery levels (CRL) that farmers have to pay back. For the purpose of illustration, let profit be defined as the difference between the cost recovery level (CRL) and the reimbursable cost (Rc) i.e CRL-Rc in those canal commands where the upper limit UL is greater than reimbursable costs Rc, i.e. where UL>Rc and set loss profits in those canal commands where Rc>UL to be defined as Rc-CRL. As the IID is considered a non-profit authority, the following formula explains the situation:

$$(CRL - Rc)W = (Rc - CRL)V \qquad (1)$$

where W and V express the earning and loss profit of irrigation water quota respectively. Applying this formula (1) to all canal commands, it becomes:

$$\sum_{i=1}^{m} (CRL - Rc)_i W_i = \sum_{j=m+1}^{r} (Rc - CRL)_j V_j \ldots \quad (2)$$

where i = 1....., m are the earning profit canal commands and j = m + 1...,r are the loss profit canal commands. It is supposed that the IID authority has all data needed for Rc,W, and V, so, determination of CRL can be easily exercised under some rules which will distribute differently the water rents (earning and loss) among farmers (the most beneficiaries).

For the i canal commands, a rule set the difference between CRL and Rc as a percentage of the difference between the upper limit UL and Rc, equal to x percent of canal commands. This can be expressed as:

$$\left(\frac{CRL - Rc}{UL - Rc}\right)_2 = \left(\frac{CRL - Rc}{UL - Rc}\right)_5 = \ldots, \ldots = X \ldots \quad (3)$$

where X is a percentage of all canal commands, and the difference between UL and Rc can be considered as irrigation water rent. This part of the rule gives a chance to the farmers in the i canal commands to receive the same relative portion of the rent as a surplus, but farmers in low-cost canal commands will receive the greatest surpluses. The following example explains this rule: presume that in the canal command 2, the upper limit UL is equal to 333, the reimbursable cost Rc is equal to 205, and the percent of all canal commands X is equal to 40%. Then $[(CRL-Rc)/(C_1 - Rc)]_2 = X$ becomes (CRL - 205)/(333 - 205) = 0.40, then CRL equal to 256.2. Surplus captured by farmers is 333 - 256.2 = 76.8.

For canal command 5, the upper limit UL is equal to 333, the reimbursable cost Rc is equal to 254, and X is equal to 40%. Then CRL is equal to 285.6, and the surplus captured by farmers is equal to 333 - 285.6 = 47.4. In both cases farmers will capture 60% of the total rent.

For the j canal commands where Rc is greater than UL, the level of X percent may be determined under the condition that those canal commands have a higher cost level at which it is not accepted to have the CRL fall down below the UL, and that means to fix the CRL at the UL. In this case the right hand side of (2) is determined as CRL equal to UL, and solution on the left hand side will be only for the CRL.

5 - SUMMARY AND CONCLUSION

The Ministry of Public Works and Water Resources (MPWWR) has the responsibility of water resources management. Irrigation water seems to be the most important activity the MPWWR has to manage and improve. So, an irrigation improvement project has been adopted at eleven irrigation districts spread all over the country and a new department was created to carry out and implement such project called "Irrigation Improvement Department" (IID). Most of these improvements are financed by foreign donors whose investment costs have to be repaid by the Government of Egypt.

For social and religious beliefs it is hard to discuss the compensation or pay back costs contributed by farmers. So, the problem is how to find a conceivable way to have farmers contribute in cost-recovery which is realistic and equitable. The proposed procedure presented in this paper seems to help in setting a first step in finding a source of financing through farmers' contribution to recover improvement costs.

The proposed procedure relies on "Ability to Pay" principle which sets some limits at which farmers can pay back improvement costs. In addition, it requires data on investment costs, reimbursable cost level, O&M costs and upper limits of farmers ability to pay.

Some economic perspectives were discussed, especially those related to the economic rent which helps in the cost recovery proposed procedure. Then the procedure was discussed and explained using some of IID data available.

The following are some constraints or limitations to applying such procedure, in addition, to some positive remarks:-

1 - The IID has to include water requirements in their estimated crop budgets as well as managerial charge.

2 - The IID has to determine at what level it does need to reimburse capital costs and for how long.

3 - "Ability to pay" principle has some constraints, since it does reflect the average value of irrigation water, where the optimal allocation requires water values for all crops to be equal at margin. But for the time being where no market for water is available it seems reasonably acceptable.

4 - Crop budgets for cultivated crops have to be updated at least once every three years to keep the upper limit of cost recovery level paid by farmers from exceeding the farmer's average ability to pay.

5 - If the Rc exceeds the upper limit UL in all canal commands, the IID has two options: (1) to reduce the Rc, so that the upper limits will exceed Rc in some canal commands i.e. decrease the number of canal commands suffered loss, (2) to accept to charge farmers at the upper limit UL and look for some other source to cover the losses. These two options may lead to the increase of the value of water utilized.

6 - This proposed procedure needs to be tested with real and complete data for each alternative type of improvement suggested by the IID officials, separately at each canal command.

7 - This proposed procedure can be considered dual for irrigation pricing on the long-term basis.

8- The IID has to set a conceivable percentage to be extracted from the water rent which can allow farmers to capture a reasonable surplus, and this may require that farmers in some canal commands pay only the O&M costs.

9 - For accurate and reasonable estimation of ability to pay and costs to be recovered, an extensive and up to date data collection should be pursued on an agriculture-year basis with and without improvements.

10 - A database system needs to be established which serves in updating the estimated values of Rc, UL and O&M costs to ensure for farmers an accurate and equitable level of cost-recovery .

Generally speaking, surpluses captured by farmers in low-cost canal commands will be higher than those available in the high-cost canal commands for the same type of alternative improvement. So, the IID has to increase the percentage of farmer's ability to pay when determining the upper limit, and that will permit the IID to cover part of the loss at the high cost-canal commands.

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INTEGRATING SOCIO-ECONOMIC AND ENVIRONMENTAL ASPECTS IN WATER RESOURCES PLANNING AND MANAGEMENT

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ABSTRACT

Water constitutes a central element of life and vital link in understanding the strong interdependence of the physical and social environments. Humans interact with every aspect of the hydrologic cycle and with far-reaching consequences. At the same time, water as well as other natural resources need to be understood within the context and in relation to a surrounding socio-economic environment. Water acquires its special meaning and importance when socially used for the achievement of certain goals and objectives. Although its physical availability and natural characteristics are major determining factors, its eventual social use makes it a valuable resource.

Thus as part of an integrated social system the use of water must be socially controlled through sets of institutions. This means that the way in which water supply and distribution, patterns of water utilization, aspects of water quality and water reclamation practices are regulated in a given society will depend on the nature, structure, and evolution of its particular water system as affected by the larger socio-cultural environment and by the specific environmental and ecological characteristics of a given region.

Both long and short term water problems are becoming increasingly prevalent in many parts of the world especially in developing countries. Population increases lead to many problems associated with the water supply. Some of these are improved standard of living, expanded agricultural output and increased economic development, all of which require increasingly large quantities of water. It is expected that in the near future 40% of the world's population will face serious water shortages, particularly in arid regions.

It has become clear that several of the water development projects have been planned and designed without taking into account the complex interrelationships between people, water, environment and development. This paper is concerned with the fundamental issue of how to accommodate water resources development and management within the context of environmental preservation and improvement. It is shown that these goals are not exclusive of one another but rather complementary, and in the long run mutually reinforcing.

It aims to help to understand better how to develop public policies and management strategies that are scientifically sound, socially responsive, and ecologically sustainable.

1. INTRODUCTION

The world's population is expected to grow from 5 billion today to 6 billion by the year 2000, and to at least 8 billion by the year 2025, with more than 90% of the increase occurring in the developing world (World Bank, 1991). Achieving food security, alleviating poverty and improving the quality of life in developing countries will, therefore, continue to pose major challenges to decision-makers well into the next century. Expanding agricultural production and enhancing rural incomes, in a sustainable manner, will be a significant strategy in responding to these challenges. Without better water management, the rise in population would be far too large in relation to the productivity of the resource base.

Water is needed in all aspects of life. The general objective is to make certain and maintain adequate supplies of water of good quality for the entire population of this planet while preserving the hydrologic, biological and chemical functions of the ecosystems, adapting human activities to the capacity limits of nature and combating vectors of water-related diseases.

Therefore water supply and sanitation are basic needs required to solve survival problems. However, it is untenable and unbelievable under all situations that water-born diseases still kill on the average 25,000 people every day in developing countries while millions suffer the debilitating effects of these diseases (Muyibi, 1992). Water-related diseases are still a major health problem especially in the developing countries. Diseases caused by the microbiological pollution of water-supplies or transmitted by water associated vectors, and those related to inadequate sanitation and the absence of clean water, are widespread (Agenda 21, 1992). With per capita water use expected to increase significantly in developing countries with high economic or population growth rates, the volume of waste requiring treatment is expected to present a growing problem. To ignore the interactions and linkages between fresh water issues and other sectorial issues could result in severe social, economic and human health consequences. Therefore, the provision of water supply and sanitation in developing countries is not only a vital ingredient of economic and social development but also an important element of environmental protection.

Water is essential for the support of development, especially, in areas of scarce water resources where the entire life support system, the very existence of communities, depends on the capricious presence of water. Furthermore, water is a major "factor of production" since as a resource commodity it permits a higher level of economic and community metabolism. In its varied expressions and presence, water can be directed towards such major goals as:

a) guaranteeing the survival of populations and the carrying out of activities supported by water;
b) assisting overall growth by providing an expanded capacity, wealth, and local, regional, or national stability,
c) through ancillary features adjunct to a specific project (e.g., healthy environment, recreation, flood control, etc.) facilitating a multipurpose policy for integrated efforts of larger social development; and
d) upgrading the "quality of life" through improved services and contributing to the overall "social well-being" of a given community.

Water has produced an extensive network of social activities. There is a great variety of water resources systems resulting from different geographical conditions and cultural circumstances. These systems encompass common elements and mechanisms which result from the following crucial issues:

a) how will the water resources be used in the productive process?
b) who will plan and how will the production facilities be installed and organized?
c) which individuals or groups will exercise control over the acquisition, distribution, use, and reclamation of water resources?
d) what will be the distribution and marketing of goods and services produced, including also the installation and operation of distribution facilities?

2. THE CHALLENGES

In order to better understand the pivotal social role of this precious resource, one has to begin with the serious problems associated with the various water uses.

First of all, it is widely recognized that there is increasing scarcity of water in many lands, particularly in the arid and semi-arid areas.

Second, while scarcity of water seems to be a major problem, equally important is the problem of equity in provision of water supply and sanitation. It requires that limited resources be used to meet basic needs between competing users namely; agriculture sector, municipal sector and industrial sector.

Thirdly, transcending conditions of either scarcity or excess are problems of water quality degradation due to either natural process or human practices. The poor quality of water in many times associated with a fourth problem in water management, namely, misuse and bad practices which accentuate complex problems of natural degradation. A fifth problem has to do with organizational ineffectiveness and the non-rational use of existing water supplies. Even though water may be abundant, in many cases the proper institutional mechanisms or the organizations that could effectively maximize allocation and use of existing natural resources do not exist.

Finally, a persistent problem has to do in many cases with what one may describe as trans-national or transbasin interdependencies, and with the fact that many water supply systems (surface or ground) do not confine themselves within arbitrary national boundaries or other artificial political or administrative divisions. Problems of jurisdiction can become major handicaps for comprehensive water resources management.

Sustainable water development is not an easy task. This is especially true in developing countries which plagued by critical short-term problems such as malnutrition and diseases, high infant mortality, low life expectancy, high illiteracy level and chronic unemployment (World Bank, 1988). Other major obstacles to sustainable water development have been identified by government and the intercommunity as :

1) fragmented sector policies;
2) Weak or non-extent institutions and inadequate coordination among sector agencies;
3) Lack of adequately trained and motivated manpower;
4) Use of technologies inappropriate for developing country conditions, and lack of knowledge of lower-cost technologies;
5) Lack of community involvement;
6) Inadequate operation and maintenance;
7) Problems with resources mobilization and utilization, including cost recovery.

In spite of these difficulties, unsustainable development and use of water resources is a short-sighted policy which can eventually result in a worse situation. This is specially true if the environmental impacts are synergistic or irreversible, or both.

There are also quite a few other problems in water resources management, especially if one looks at particular uses. Taking irrigation as an example one may also point out the lack of integrating structural and non-structural dimensions; the heavy, and in many regards inefficient, consumptive use; the lack of proper technical administration; overemphasis on engineering structures with little consideration of the rate of return; the lack of attention by farmers to adopting and utilizing an appropriate water saving irrigation system and the availability of accessibility to a general market.

At the same time, if one were to isolate some key items in policies and planning affecting water management, the following concerns stand out:

a) the reallocation of water for competing users and new demands;

b) the minimization of groundwater mining especially the non-renewable fossil water in deep aquifers;
c) the maintenance of agricultural productivity for society well being;
d) the minimization of water quality degradation;
e) expanding industries and economies highly dependent on water;
f) a developmental growth outlook; and
g) lack of appropriate institutional and legal infrastructures to meet new and competing water demands.

Vlachos, 1985, discussed thoroughly such remarks and problematic conditions and he pointed out that the pursuit of any particular option for water resources development requires "a much more complex approach, broader institutional capabilities, and alternative organizational units". Indeed, in the literature of environmental management there is agreement that there must be continuous coordination between such conflicting and complimentary purposes as:

- resources planning for substantial economic output,
- regional planning for successful human habitat,
- facility planning for technical efficiency,
- ecological planning for biotic efficiency,
- social planning for community integration,
- organizational planning for policy implementation.

Proper water management organization, technological innovations, and the efficient (and effective) allocation and use of existing resources are crucial factors for the success of resources development, especially in arid and semi-arid areas. However, national growth policies and emerging natural resources policies are also pointing towards more comprehensive, holistic or integrated planning. The positive and intangible benefits to community development, which have always been tactically recognized and acknowledged, must be articulated in more specific terms. Water, as an organizing concept, can play an active role in guiding and stimulating growth; in providing new standards and evaluation criteria for development; and in strengthening its potential as an additional means for achieving larger social goals. At the same time, water becoms part of a broader natural resources policy which recognizes the social needs of the country in a balancing of three important dimensions:

a) efficiency, or the growth in material development so that a solid basis of economic sufficiency may be maintained;
b) equity, or fair access to resources and consumption by all segments of the population, and between competing end users; and,
c) effectiveness, or the overall significance of any project or policy vis-a-vis the pursuing of certain larger social goals.

All in all the water management problem can be formulated this way:

$$P = f(C_i, U_i)$$

where

P = a measure of performance (efficiency) such as controlling and rationalizing water consumption among competing users.
C_i = the controlled variables, such as cultivated farm land area.
U_i = the controlled variables, such as available water.
f = the functional relationship between the variables.

Planning is considered as problem solving for complex sets of problems. If there is only one problem, it can be handled through "problem solving"; if there are several interacting ones, then the process for dealing with them is "planning" (Ackoff, 1978).

Thus technological and social responses to the broad concerns of problems associated with water in developing countries tend to fall under four major categories:

1) Strong incentives for efficient or new uses, including economic benefits, redefinition of water institutions etc.
2) Structural changes, such as new organizational arrangements, creation of new water agencies, etc.
3) "Regulatory counter-incentives", such as stricter enforcement and pricing policies.
4) Changes in "water-intensive" lifestyles and adaptive cultural practices.

Ideally, schemes of water management must combine both "structural" and "non-structural" mechanisms as parts of a comprehensive policy connecting water to development growth. Either through increased supply or diminished demand we should be affecting the extent and rate of change in the surrounding environment of problems associated with water (see Table No. 1). Planning for water development obviously cannot be isolated from the planning of other resources, both natural and human. In this context, the use of the term "comprehensive planning" as applied to water resources is not a recent invention but goes back to the turn of the century.

3. THE FUTURE DIRECTION

What becomes apparent from the previous remarks is that present water management arrangements in developing countries are not well equipped to deal with new planning requirements. The practices which have evolved during the development of a maturing water infrastructure, the increasing trends of economic development and resource exploitation, and the complexity of current circumstances all point out that present arrangements are no longer adequate to meet the demands of a broader framework for economic, social and environmental integrated management. Indeed, additional concepts and tools are needed, or new approaches must be established for developing a better understanding and sensitivity as to diversified issues associated with the effects and consequences of water resources status in today's world.

It is at this point that a multi-objective/multi-purpose emphasis brings forward the general quest for optimization of resources and the search for delineating a new system of calculus combining desirable and feasible alternatives. Such multi-objective approaches and methodologies attempt to bring together the many water functions, many objectives, and many decision makers, all associated with complex water resources systems. In this context water resources planning and management involves decisions as to how water resources should be allocated among various conflicting and competing uses, including agricultural, municipal and industrial water supplies.

In order to deal with these complexities and competing and conflicting demands in water stressed area, multi-objective planning frameworks should be developed to make explicit the underlying affected values and their distribution among different competing and conflicting users, especially at a scale and with a time horizon that would allow both comprehensiveness and long-term perspective. Comprehensive and future oriented plannings become, then, the necessary ingredients of an idealized "holistic" approach.

The driving principle for integrated management emanates from the fact that as developing society becomes more complex and economics more diversified and demands continuously increase and expand in scope and intensity, the wise use of scarce water resources and the preservation of a natural environment are of utmost importance in the planning and evaluation of

Table 1 : Supply-Demand Management Possibilities (Mohorjy, 1987).

SUPPLY MANAGEMENT (Increase the quantity of usable water)	DEMAND MANAGEMENT (Reduce the quantity of water consumed)
1. Increase supply: -Transfer water -Construct augmentation projects (i.e., reservoirs, storages and dams). -Conjunctive use (ground and surface supply and delivery for optimal use of the water resources. 2. Increase efficiency: -Improveexisting water system to reduce evaporation, seepage, unaccounted - for water, and breaks in net-works. -Improve water management system. -Consider the needs of users. 3. Enhance supply using modern technologies -Reuse water -Harvest rainwater -Capture agricultural runoff for reuse in irrigation again. -Irrigation with saline water for very specific crops (non-sensitive crops). -Desalinize water -Use remote sensing (satel-lite and aircraft) to detect water in arid land -Use trickle irrigation.	1.Modify water pricing according to time of use, location of use, amount of use, and incremental cost pricing. 2.Use publicity campaigns. 3.Distribute and install water saving and metering devices. 4.Implement rationing plans (regulations and restrictions). 5.Apply zoning and land use controls. 6.Increase education and persuasion.

any future development efforts (Haimes, 1975). The following problematic situations summarize the need for enlarging the scope of planning and for incorporating a multi-objective, multi-purpose emphasis.

1) Continuously changing socio-economic conditions and the attendant shifting of demands as a result of increasing population, urbanization, industrialization, migration to urban centers, etc.
2) The strong presence of institutional constraints, resulting from enduring historical and cultural practices and proliferation of competing and conflicting policies, judicial doctrines, laws and/or administrative guidelines, or policies.
3) Increasing concern with environmental impacts and "social consequences". These concerns stem also from perceived ecologically fragile environments or from man-made perturbations, such as misuse of resources, despoilation of water supplies, etc.
4) The lack of effective national and/or regional mechanisms for setting priorities for specific water resources investments and the absence of appropriate mechanisms for assuring implementation of plans at all levels of government.
5) The artificial separation between water quantity and quality and temporal and spatial variations in the distribution of water.

Thus, a dynamic social environment with rapidly changing values and societal transformations, and the increasing range of technical alternatives to quantitative and qualitative problems, all call for more definite and comprehensive but flexible approaches to water resources planning and implementation. Such approaches require a heightened sensitivity to changing circumstances, and a responsiveness to shifting priorities as well as to evolving goals and objectives.

4. IDEALIZED PLANNING DECISION PROCESS

In essence, there is a demanding task of achieving through national and regional policies, water resources development and management practices that are technically sound, environmentally non-damaging, economically viable, legally pertinent, socially acceptable, and last, but not least, politically feasible (as shown in Fig. (1)).

Such considerations raise even large concerns with overall water resources policy problems (United Nations, 1971). Important issues here include:

a) How to achieve a rational public understanding of water use problems and opportunities.
b) How to achieve a reasonable approximation of a social optimum through public decision-making.
c) How to alter policies in accord with the changing socio-political environment within which water resources activities are undertaken.

The underlying thrust of the present argument tends to emphasize the need for a systematic accounting of alternatives and their consequencies concerning the role of water development in any given area by considering an idealized Planning-Decision Process as suggested in Figure (2). In particular, some questions emphasize the quest for expanded water management schemes:

1) What types of new environmental and social equilibriums result from water resources planning and developments in the area under study?
2) What are the long-term commitments in terms of required resources?
3) What is the local, regional and national significance of resource commitments in terms of values of goals of various interests at each level?

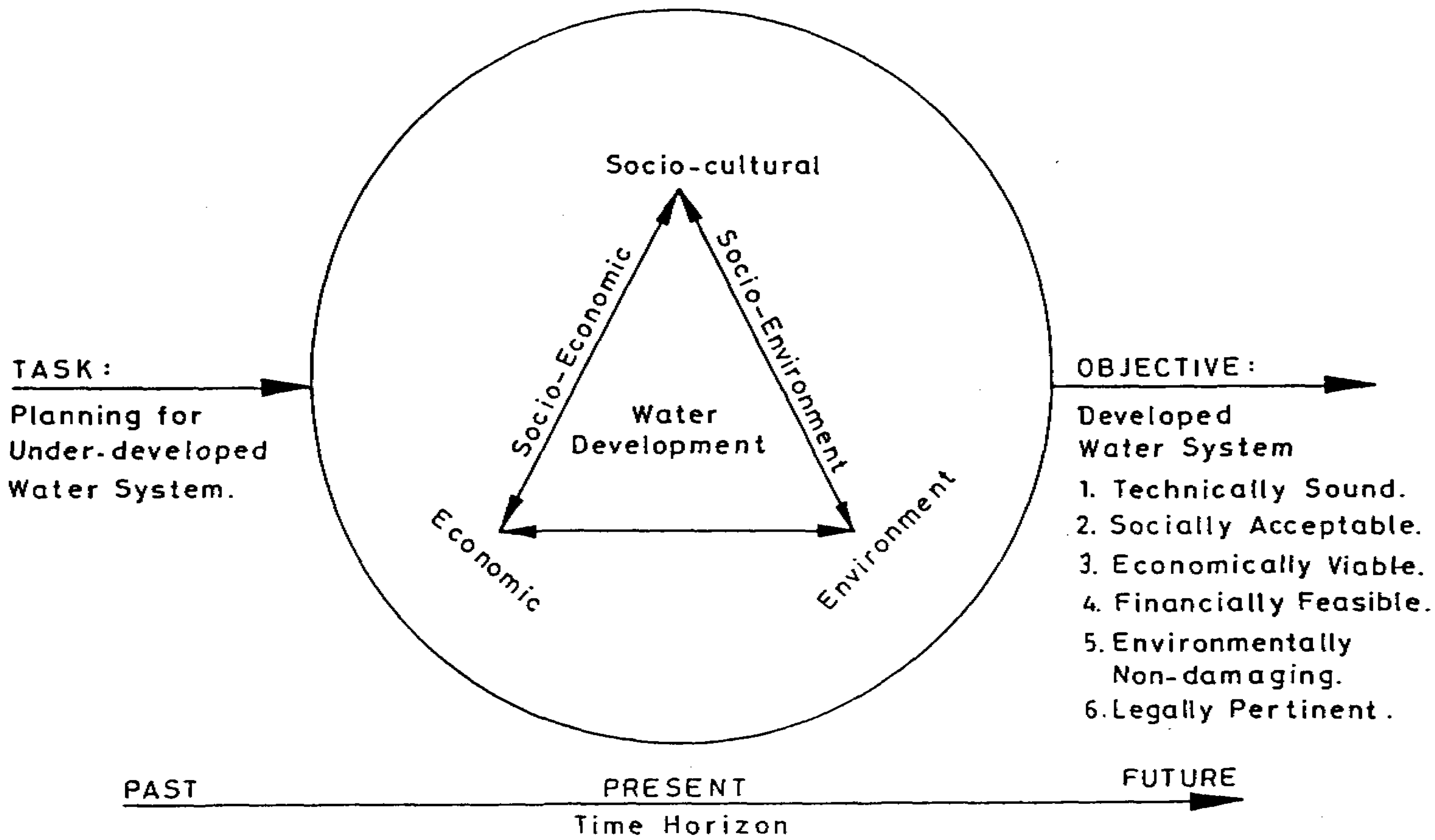

Figure 1: Integrated Development of Water Resources System.

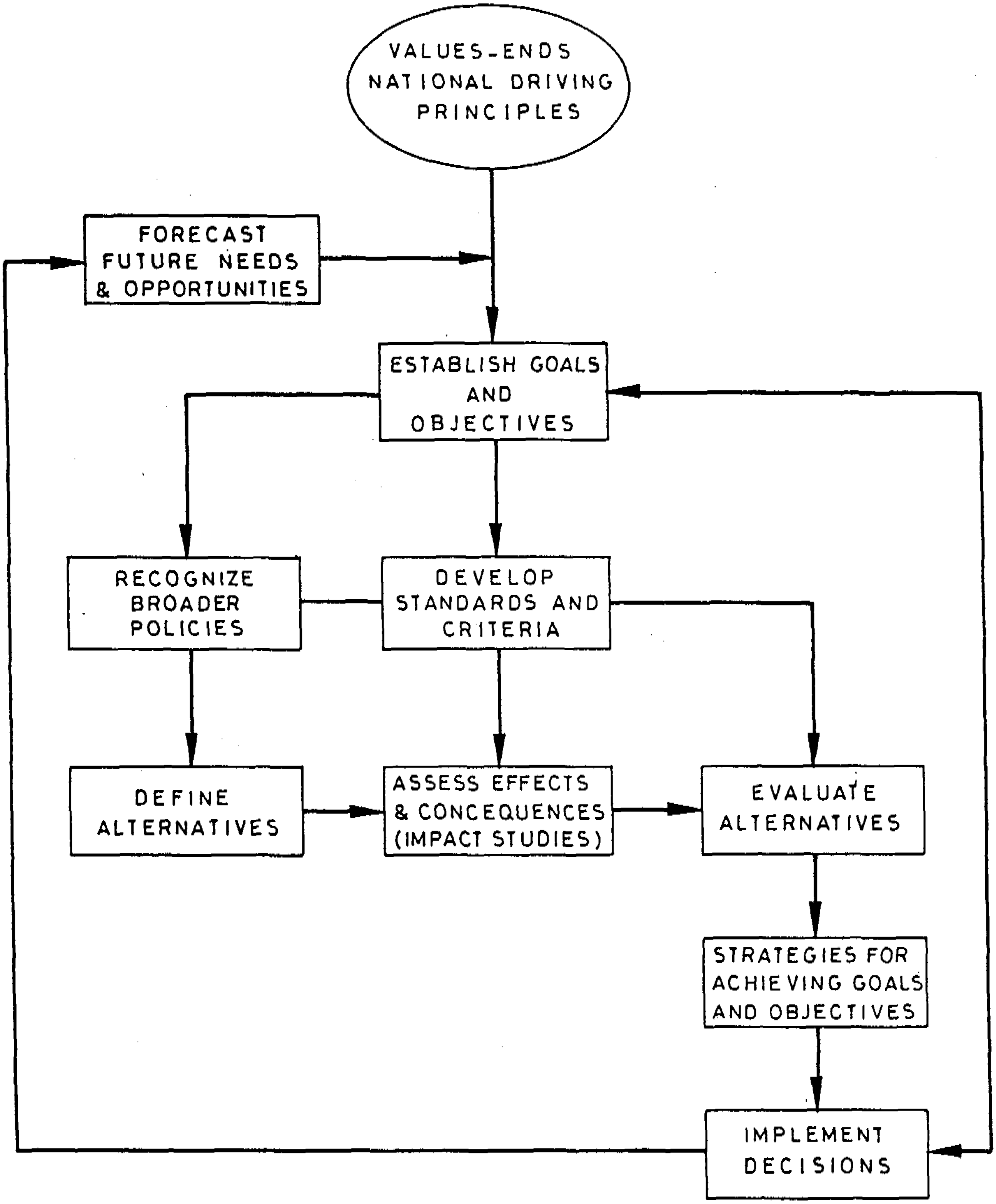

Figure 2: Planning Decision Process.

5. STRUCTURING OF WATER RESOURCES MANAGEMENT

Water is essential for sustaining life, not only for drinking, but also for other domestic and industrial needs, and in vastly greater quantities for agriculture. Equally however water can contribute to significant losses to human and animal lives and can damage crops, homes and industry through storms and floods. There is thus a real need to plan the development of water resources so as to make the most efficient use of them when they are scarce and to control then when they are excessive. But development and management of water resources must always be considered along with other socially desirable objectives.

The ultimate goal of water resources development and management is to serve water users, and to satisfy this goal it has to be ensured that water will be available at the right location, at the right time and at the right price, now and in the future.

The process of water resources development and management is in principle always the same, regardless of the stage of economic and social development of a given country. However, it is important that water management institutions are not too narrowly concerned only with water. They should be sensitive to changes in human preference, habits, desires, aspirations and management abilities.

It is clear that the problems surrounding a lack of clean water and sanitation have reached a critical stage in many parts of the world not only from economic and developmental perspective but from a social point of view. Taking into account expected population growth, there will certainly be a need for new water supply and sanitation projects in the future. But project operation and maintenance, as well as rehabilitation of existing facilities will remain critical issues in the years to come. The developing world is plagued by broken down or badly functioning water and sanitation facilities. Involving the people who are the targets of improvements is an absolute necessity if this unsatisfactory situation is to be turned around.

Viessman, 1990, explains the multidimensional nature of water resources management and states that it"... embraces planning, design, construction, operation, and maintenance" and that its ingredients include "... technologicality, social attitudes, economic realities, political viewpoints, and environmental goals".

Grigg, 1992, elaborates this point by stating that "water resources management is the application of management programs and water control facilities to control natural and man-made water resources systems. Water control facilities include: conveyance systems, diversion structures, dams and storage facilities, treatment plants, pumping stations, wells, and appurtenances". A water resources system is a combination of water control facilities and environmental elements that work together to achieve water management purposes which may be expressed in terms of services to people like farms, industries, and the environment: water supply, wastewater and water quality management, storm and flood water control, hydropower, transportatin and water for the environment, fish and wildlife, and recreation. Environmental elements involved in water resources systems include: the atmosphere, catchments, stream channels, aquifers, lakes, estuaries, seas, and the ocean. The tasks of water resources management are: planning, design, construction, implementation, and operations and maintenance of water control systems.

The question that we must pose right away is that of the structuring of water resources management. Two alternative approaches can guide our thinking: first, we can adapt existing structures to meet emerging questions (reactive approach); or second, we can create new structures in anticipation of emerging natural resources problems (proactive emphasis). In either case, however, the organizational problems of water resources are systems problems requiring for their solution coordinating policies affecting a variety of interactions and sensitivity to local conditions (Grigg, 1985).

If we are to understand "management" as imbedded in institutional structure and expressed in approximate organizational arrangements and processes, experiences gained in many countries and over many years of water resources research have pointed out that:

1) A good institutional arrangement for water resources policy and the basis for implementation is one that ultimately facilitates social choice.
2) Institutional arrangements must facilitate decisions based on an understanding of the far-reaching consequences resulting from a mix of social values and from an expanded time horizon.
3) Institutional arrangements must recognize a decision-making process which takes into account the preferences and interests of those clearly affected by the particular policy decisions.
4) An ideal type of institutional arrangement must have some constraints on the losses that it can impose on the individual and on the cost required for its implementation.
5) A good institutional arrangement must produce decisions which not only are accepted as legitimate, but are also the result of a balance between what is desirable and what is acceptable.

Five key concepts and practices have been slowly evolving in the last decade. Accompanied by major legal, economic, social, and technical developments they have been instrumental in creating basic scientific and engineering tools sufficient to the task of a comprehensive water resources planning and management, (see Figure (3)). These five practices include:

a) the multi-purpose storage project;
b) optimum integrated development maximizing use of all water in an entire area;
c) comprehensive regional development relating water development to all other factors that make up general economic growth;
d) comprehensive land and water programs which are directed towards a more integrated system of administering natural resources on a wider level; and,
e) unified administration, representing the attempt to circumvent the imperfect nature of water as an organizing principle and to blend land and water problems by consigning to both a single agency for administration.

Hence, in order to be able to develop management mechanisms for dealing with questions of implementing water resources policies there is need for an organization that:

1) is sufficiently comprehensive to encompass the problems under attach, in terms of quantity or quality;

2) facilitates coordination of all related efforts;

3) is adaptable to the dynamics of changes (economic, social, technological, environmental and political) and to progressive stages in the solution of problems associated with these multi-changes (operational flexibility); and,

4) is capable of obtaining, evaluating and applying appropriate technologies to a variety of problems.

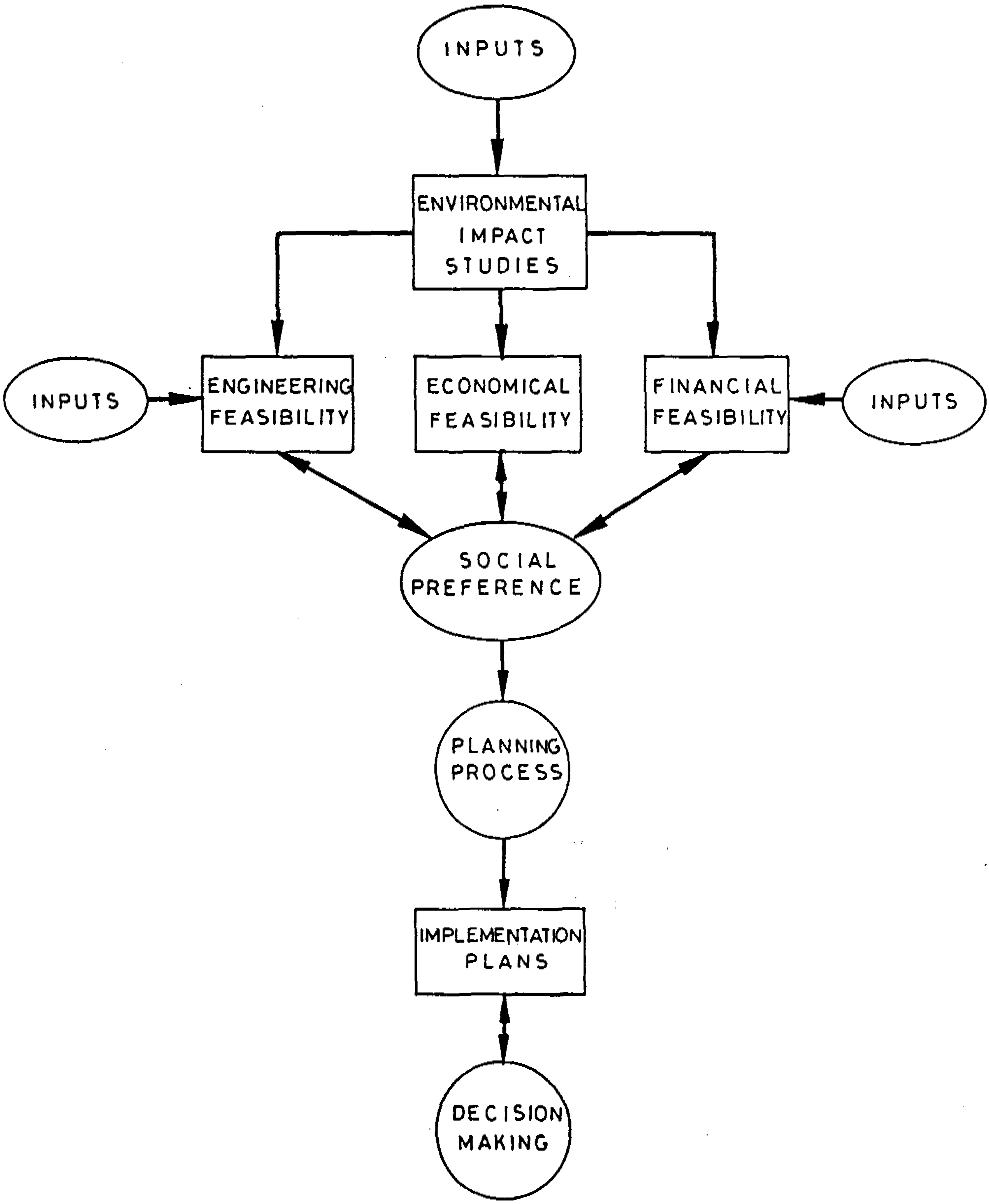

Figure 3: Activity Flow of the Water Comprehensive Planning.

6. IMPORTANCE OF IMPLEMENTATION

In rounding up the general problem of comprehensive water development and management and its relevance to efforts for increasing efficiency and effectiveness, a few remarks must also be made as to the importance of implementation. It has been usually assumed that once a decision has been made, and in particular, after legal imperatives have been outlined, an orderly process of executing the well of the commons will some how be implemented. Yet, problems with implementation are widespread, given the great variety of programs, the interpretation of the law, and the intricacies involved in carrying out the common well. Furthermore, this process is complicated by conceptual and methodological problems revolving around a confusing terminology associated with what one may broadly call "policy implementation". Synonyms that appear here include also the process of "innovation," of "communicating" commonality of interest, of "adopting" new practices, and of "accepting" what are outlined as national goals (Vlachos, 1975).

With regard to water resources planning in developing countries, implementation as a concept and process depends on, what United Nations, 1975 stated as:

a) the capacity to manage the administrative (or regulatory) process;
b) fidelity in pursuing management decisions;
c) clarity and authoritativeness in perceiving and communicating water problems; and,
d) equalization of "external" influences, such as recognition of pressure groups.

Using as a background the general organizational literature on implementation, one can also consider such additional factors as: a) reliability, or the extent to which a water resources program can work as intended and that institutional arrangements devised can adequately function within the context of the expectations for their operation; b) implementation costs, including administration of particular efforts; c) efficiency and efficacy, implying the extent to which the proposed arrangements can avoid short-run technical and allocational inefficiencies, responding at the same time with sensitivity to questions of long-range social effectiveness; d) stochastic flexibility, or what in the literature has been referred to as a response to variations in the stage of the surrounding system and the extend to which that flexibility is valued given its cost and gains; e) dynamic adaptability, or the extent to which organizations can be self-correcting; f) distribution equity and the question of equalization of gains and costs of the proposed programs, both within and among various parties of interest; and g) social and political effects, or the long-range socio-political arrangements and processes that would not injure the viability of other programs and/or other institutions.

7. SUMMARY AND CONCLUSIONS

This paper is directed to analysts and decision makers in developing countries who, in the process of planning or making policy decision, are concerned with environmentally sound sustainable water development and management. The paper is intended to make them:

1) better informed as to the full dimensions of water resources development, the benefits as well as the costs.
2) more sensitive to social and institutional dimensions of water planning and management.
3) Familiar with the main components of the analysis so that they could ask, for each component: Has it been considered? Have appropriate practicable methods of analysis been used?
4) more confident of their ability to offer judgements on such matters.

Few systematic studies exist in terms of short and long term integrated planning which could overcome competing and conflicting demand between various sectors of the economy in developing countries. More central for the present argument is the criticism that water has not been given the major role it deserves as a development factor.

It has been ascertained that not only there is no global view of water problems, but that water resources as a critical management unit have not been accorded the importance they deserve in both socio-economic and land use planning as well as in national policies regarding the environment, health, energy, agriculture, industry and more important, in efforts for regional development. This article has laid emphasis on how water related problems such as regional population growth, a general increase in the standard of living over time, and the development of irrigated agriculture have created a gap between access to and the need for water, which might escalate the disputes over the scantiest resource of the developing countries: water. The problem is discussed in extensive perspective but also relates to the question of establishing institutional arrangement regarding the rational management control and utilization of this valuable resource among competing users. Such an approach includes:

a) the organization of a coherent information system of water use as well as of other natural resources of the region.
b) integrated water resources (surface and ground) planning and its integration in the broader socio-economic development.
c) forward-looking analysis that emphasizes contingency planning within specific subregions.
d) contributions to water resources planing efforts in the region.
e) increased planning, design and implementation capacity in natural resources.

This paper emphasizes the nature of comprehensive water resources planning because water constitutes a central element of life and a vital link in understanding the strong interdependence of the physical and social environments. Human interests interact with every aspect of the hydrologic cycle with far reaching consequences. Its physical availability and natural characteristics are certainly determining factors, but it is its eventual social use that makes it a valuable resource. This means that the way in which water supply and distribution, patterns of water utilization, aspects of water quality, and water reclamation practices are regulated in a given society depends on the structure and evolution of the particular water system as affected by the larger socio-cultural environment and by the specific ecological circumstances of a given region.

Therefore, the pursuit of any particular option for water resources planning requires a comprehensive approach, broader institutional capabilities, and alternative organizational units. Different planning efforts at various levels should take place as:

* Resource planning for substantial economic output.
* Regional planning for successful human habitat.
* Facility planning for technical efficiency.
* Ecological planning for community integration.
* Organizational planning for policy implementation.
* Social planning for community integration.

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DRAINAGE WATER QUALITY AND ENVIRONMENTAL ISSUES

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ABSTRACT

Environmental issues in Egypt, like in most other developing countries, have received little attention in the past. However, with increasing human activities, protection of water resources of the country is becoming a priority consideration.

Agricultural drainage water has great potentials as a source for reuse in irrigation. Reuse of drainage water is recently increasing as attempts are made to use water more efficiently. Currently, about 4 billion m^3/yr of drainage water in the Nile Delta is being reused and it is planned to increase this quantity to 7 billion m^3 by the year 2000. However, pollution of drainage water already is a serious problem and worsening each year. Many drains receive large quantities of inadequately treated domestic and industrial waters and nutrients and pesticides residues, rendering the drainage water unsuitable for agricultural reuse. In many parts of the Nile Delta, this water is currently reused both officially and unofficially, exposing edible crops and local farmers to untreated wastewater.

Pollutants in the drainage water are ranked according to their adverse impact on the environment. The relative risk rankings by decreasing order of concern are pathogens, pesticides, heavy metals and salinity. They affect crop yields, public health and natural habitats. Water quality deterioration can be assessed in terms of water-related diseases.

An integrated water quality program to meet planning, pollution control and identified research needs is urgently required. Actions ought to be taken to reduce pollutants emissions to the drainage system. Among them are monitoring of water quality parameters, application of treatment technologies, limiting the use of pesticides and providing educational programs for farmers or workers who are in direct use of this water.

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1. INTRODUCTION

The Nile Delta water quality reflects the effects of upstream depletion, return flows and waste discharges. At the Delta Barrage, about 33 billion m^3 of water supply with an average salinity of about 250 ppm is distributed primarily for irrigation. Yearly, about 12 billion m^3 of drainage water is discharged to the Northern Lakes and the Sea and nearly 4 billion m^3 of drainage water is officially reused and farmers unofficially pump some 2 billion m^3 from drains. The plan of the Ministry of Public Works and Water Resources (MPWWR) is to increase the amount of drainage water reused to 7 billion m^3 by the year 2000.

The drains receive partially treated and untreated domestic wastes from Cairo and Delta cities and towns, untreated domestic wastes from rural areas that illegally dumped into the drains and from seepage from contaminated groundwater, and untreated industrial wastes from different industries located within the Delta. Agricultural drainage also carries nutrients and pesticides residues.

Increasing water pollution from domestic and industrial sources reduces the amount of drainage water available for reuse for reclamation projects in the future. This is not in the long term interest of the country. In addition, the total health and economic costs to the country due to water pollution would be substantial.

This paper identifies the sources of pollution that deteriorate the drainage water quality, reviews the environmental, health and economical issues related to drainage water quality and assesses, in a general sense, appropriate actions to reduce contamination of drainage water.

2. SOURCES OF DRAINAGE WATER QUALITY PROBLEMS

2.1 Municipal and Domestic Wastes

Many drains are suffering from an alarming increase in the discharge rates of municipal and domestic wastes. The expansion of water supply networks in villages, towns and cities without the parallel construction of new sewer systems or the rehabilitation of existing systems has led to water pollution problem with subsequent public health hazards.

Most villages and rural areas lack any system of wastewater collection or treatment. Raw sewage from about 5000 rural agglomerations, semi-treated or untreated wastewater from Cairo and other urban centers, and mostly raw sewage from the rapidly growing, unserviced areas are discharged into the agricultural drains (World Bank 1990). Currently, an estimated 95% of the 31 million inhabitants living in rural areas have no access to sewer systems or wastewater treatment facilities. Instead they depend on onsite disposal using a leaching pit adjacent to the house or on direct discharge of raw sewage to drains. The pits are periodically emptied and dumped into nearby drains. Presently, an estimated 0.3 billion m^3/yr of raw sewage and pit sludge infiltrates to shallow groundwater and discharges to drains or canals (Welsh et al. 1992).

Many villages are chronically flooded with sewage effluent, contaminating groundwater as well as surface water. Results of recent surveillance programs indicate the widespread fecal contamination of groundwater in the Delta.

Untreated sanitary waste is the single greatest source of human contact with pathogens and parasites in Egypt. Rural residents who daily are in contact with drainage water are at risk. Equally significant is the exposure of edible crops to the domestic wastes discharged to drains where drainage water is generally mixed with irrigation water for agricultural purposes.

Recent analysis on the drainage water were carried out by the Drainage Research Institute to determine the degree of pollution in the drainage system. Table 1 presents water quality measurements for some major drains in the Delta. Traditionally, the coliform group of bacteria has been the principal indicator of the sanitary quality of water. It is always convenient to express the test results in terms of the most probable number (MPN). According to the Law 48 of 1982, if MPN exceeds 10^3/100 ml, this means that water is polluted. The bacteriological tests consistently show fecal coliform counts more than 10^4 MPN/100ml. These high coliform counts are undoubtedly a contributing factor to the high morbidity and mortality rate of infants in rural areas. The high levels of pathogenic organisms also preclude the reuse of agricultural drainage water.

2.2 Industrial Wastes

The industrial wastes are considered as one of the main sources of environmental pollution especially for the water systems. They contribute a wide variety of pollutants, of which heavy metals and toxic organic compounds generate the most concern. A wide range of activities falls under the classification of "industrial" including agriculture, mining, engineering, manufacture of chemicals, biological and pharmaceutical products, oil and petrochemicals, electronics, food processing, textiles, paper, transport and communications.

Egypt has about 20,000 industrial facilities, only 700 of which are major ones. The General Organization For Industrialization (GOFI) of the Ministry of Industry reported in 1992 that the majority of the industrial facilities are publicly owned, with 330 are managed by the Ministry of Industry and 120 by other ministries. Many publicly owned facilities remove water from the River Nile and discharge liquid waste back into the river or drains. Some industries discharge directly to the River Nile or the Northern Lakes, but most of them discharge to drains and sewers.

The nature of industrial wastes depends upon the processes in which they originate. Industrial wastewaters vary in nature from relatively clean cooling water to waste liquids that are heavily laden with organic matter or with corrosive, poisonous or explosive substances.

Heavy metals in the water resources, irrigated soils or crops pose a number of risks. These include animal and human public health risks, accumulation of excessive concentrations in crops which can limit or prohibit their use as foodstuffs, phytotoxicity to plants and excessive salinity buildup in soils. Metals such as cadmium, copper, chromium, lead, mercury, nickel and zinc can all accumulate in crops to concentrations which would limit the use of crops. Selenium also contributes to salinity buildup and is toxic to many forms of livestock and wildlife once ingested.

The actual accumulation of metals in soils and crops depends on several factors, including the type of plant and soil characteristics such as pH and clay or organic matter content.

The heavy metals concentrations in the drainage water such as iron, zinc, boron and cadmium at some selected locations are shown in Table 1. All the concentrations are under the toxicity limit that could cause problems to soils and crops except the cadmium. Conservative limit of 0.01mg/l for cadmium is recommended by the FAO, due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans. High heavy metals concentrations are more likely to be found in sediments because once discharged they rapidly settle to the bottom of the drains. The organic matter results presented in Table 1 show unexpectedly low BOD values and high COD concentrations. These data indicate industrial toxicity in these drains.

Table 1. Drainage water quality in the Nile Delta

Location	Source of pollution	BOD mg/l	COD mg/l	Coliform Bacteria MPN/100ml	Fe mg/l	Zn mg/l	B mg/l	Cd mg/l
Eastern Delta:								
Wadi P.S	Sewage + industry	20	250	10^6	5	0.1	0.1	
Bahr Baqar drain	Sewage + industry	50	180	10^6	5	0.3	0.5	0.05
Mahsama P.S.	Sewage	25	700	10^4	1	0.7	0.3	
Bahr Hadus drain	Sewage + industry	10	120	10^4	1.5	0.1	0.3	
Upper Serw P.S	Sewage	10	160	10^4	1	0.3	0.1	
Middle Delta:								
Hamul P.S.	Sewage + industry	15	120	10^5	1.5	0.1	0.2	
Drain No.1	Sewage + industry	13	200	10^4	1	0.05	0.15	
Western Delta:								
Tabia P.S.	Industry	126	737		0.16	0.1	-	0.01
Max P.S.	Industry	40	250		0.5	0.4	-	0.06
Edko P.S.	Sewage	16	120	10^4	0.3	0.1	0.2	

2.3 Agricultural Chemicals

Nutrients in the drains largely reflect fertilizer application with the unused portions passing through the soil column or as surface runoff from the ends of the fields. Nitrogen and phosphorus are the two most widely applied nutrients. Potassium is also commonly applied as part of N-P-K fertilizers, while sulphur and zinc are less frequently applied in fertilizer applications. Recent figures of the application of nitrogen, phosphate and potash fertilizers in Egyptian agriculture show an increase of nearly 4-fold during the 1960-1988 period (Abu Zeid, 1992). Nutrients contribute to eutrophication of drain water and depletion of dissolved oxygen while nitrates particularly in groundwater from agricultural activities may reach concentrations that cause major environmental health problems.

Phosphorus levels found in many drains range from 0.05 to 0.5 mg/l as PO4 and nitrogen levels of 0.8 to about 6.0 mg/l as NO3. Concentrations appear to be significantly high reflecting increased use of fertilizers and more irrigated lands.

Pesticide application controls pests in most agricultural areas but many contaminate water or food products such as fish. In Egypt, a wide variety of pesticides are used on agricultural crops with about 620,000 tons of 200 different types reportedly used since 1960 (ESG, 1989). Use of pesticides, which are mostly imported, has increased as well but not at the same rate as fertilizers. It is worth noting that the cost of importing pesticides in 1988/1989 was about 55 million Egyptian pounds.

The persistent organochlorine compounds, while banned in the late 1960s, are still detected in Nile branches and Delta drains. A sample collected in early 1991 after the winter closure period showed DDT compounds of 4.6 ng/l. Other samples collected before, during and after the closure period in a number of drains had DDT compounds of up to 1.5 ug/l, although most were about 3 to 5 ng/l, and in several samples none were detected. Concentrations of 4 to 18 ng/l of various organochlorine compounds were found in Bahr Hadous drain in Eastern Delta (Welsh et al. 1992).

Herbicides are used to control aquatic weeds which are a major concern for efficient water management. In 1990, about 1900 km of drains were estimated to have been covered by water hyacinths. Ametryn was used in drains to control water hyacinths. Because of political and public concern, use of ametryn has been discontinued in 1991 and acrolein to control rooted aquatics will be discontinued soon, after which only manual, mechanical or biological means will be used for weed control.

2.4 Salinity

In 1992, nearly 4 billion m^3 of drainage water with an average salinity of 1073 ppm was reused after mixing with fresh water, while 12.2 billion m^3 with an average salinity of 2576 ppm was discharged to the Northern lakes and the Sea (DRI report 37, 1993). Based on field observations, a conservative estimate of 2 billion m^3 was unofficially reused by farmers withdrawing directly from the drains. This unofficial reuse increases the salinity of the drainage water and directly affects the quality of water discharged and reused. Since 1984, both unused and reused quantities have become steadily more saline as shown in Figure 1. In 1984, the reused portions of the drainage water has a salinity of 857 ppm, by 1992 it increases to 1073 ppm. This trend is also seen in the salinity of the unused quantity.

The salt concentration in the drainage water depends on the quantity and salinity of irrigation water, soil salinity, groundwater salinity, distance from saline lakes or sea, climate and water management practices. Figure 2 illustrates the yearly average drainage water salinity within each drainage catchment area in the Delta for the year 1992. It reveals that the drainage water salinity in the southern part of the Delta is low and ranges between 750-1000 ppm as it is only affected by irrigation water salinity. In the middle part of the Delta, where soil salinity is moderate, the drainage water salinity ranges from 1000-2000 ppm. This rise is attributed to the salts originating from seepage of saline groundwater and from desalinization of soils through subsurface drainage.

In the most northern part of the Delta parallel to the sea coast, drainage water salinity is high and reaches more than 3000 ppm in some locations. This is due to artesian upward seepage of saline groundwater as well as sea water intrusion.

Classification of drainage water according to salinity as shown in Figure 3, revealed that about 55% of the unused drainage water quantity has reasonable salinity of less than 2000 ppm. This quantity is readily available for use in irrigation either directly or after mixing with fresh water. However, the inclusion of this quantity of water requires careful and detailed evaluation of its quality and subsequent consideration of environmental and health concerns.

2.5 Sediments

Sediments which leave their source area and enter nearby waterways are considered pollutants. Sediments have many detrimental effects, including clogging water channels, destroying aquatic habitats, increasing water treatment costs and filling lakes and ponds. It also acts as a carrier of other pollutants such as plant nutrients, insecticides, heavy metals and disease organisms. Samples collected from Bahr El Baqar drain in Eastern Nile Delta in early 1994 showed cadmium, iron and copper concentrations in the sediments of 0.78, 17.8 and 7.1 mg/kg respectively, while their concentrations in the drain water were 0.05, 3.7 and 0.09 mg/l.

2.6 Solid Wastes (Refuse)

Low quantities of refuse are discharged into the waterways along drains passing through villages and towns.

3. RANKING OF POLLUTANTS

To rank the pollutants according to their adverse impact on the environment, Kelly (1992) has set up a serious of questions. They are:

- How dangerous are the pollutants to the ecosystem, particularly for human health?
- Are harmful levels of pollutants widespread or localized in the environment?
- Do the pollutants easily decompose to compounds or materials that have little adverse effect?
- Do pollutants accumulate in fish or other food?
- Are current trends likely to increase or decrease human exposure and the risk of harm?

Responding to these questions, pollutants in drainage water were ranked according to their severity as follows:

(T4-S1) 3.7

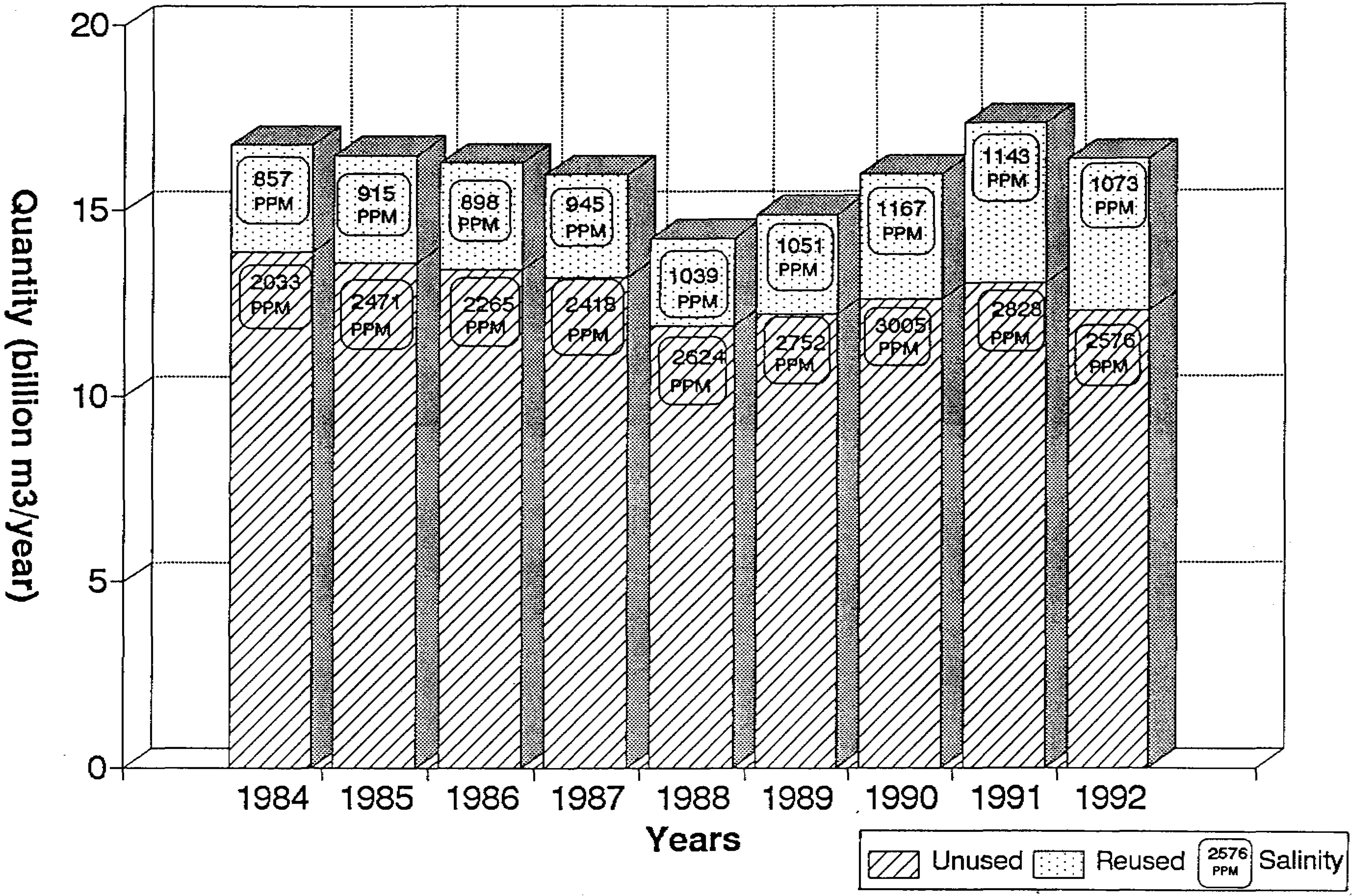

Figure 1. Unused and reused drainage water quantities with their salinities in the Nile Delta for the years 1984 to 1992

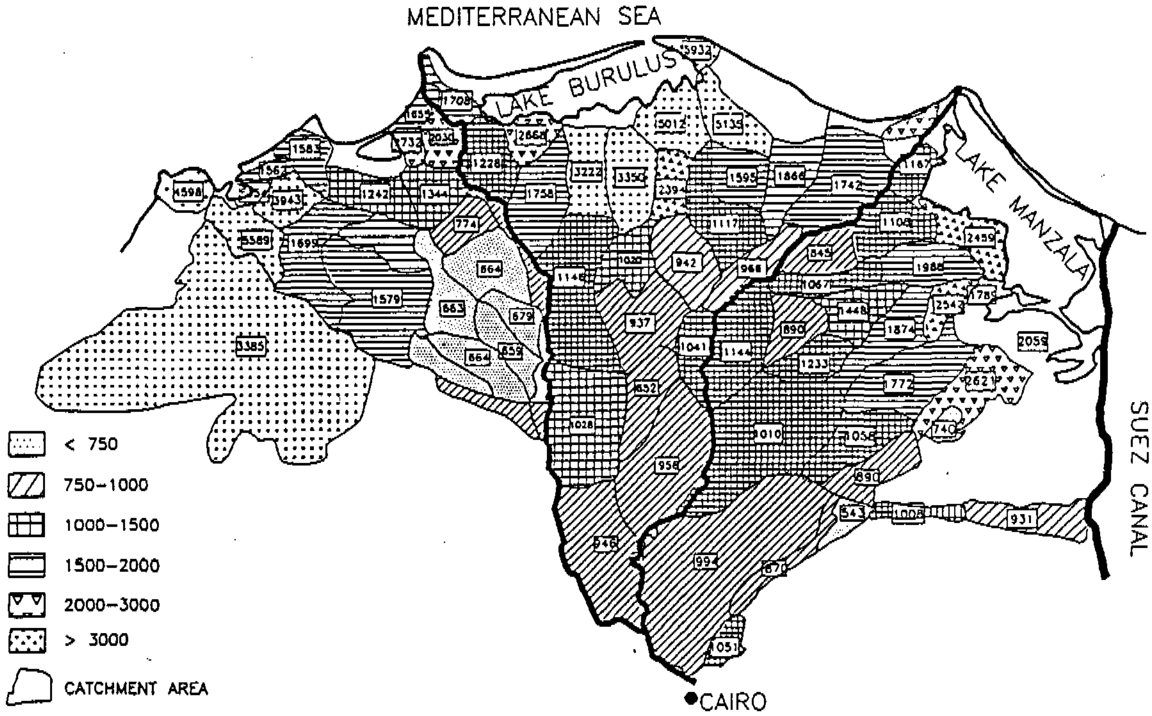

Figure 2. Average salinity of drainage water in the Nile Delta in ppm during 1992

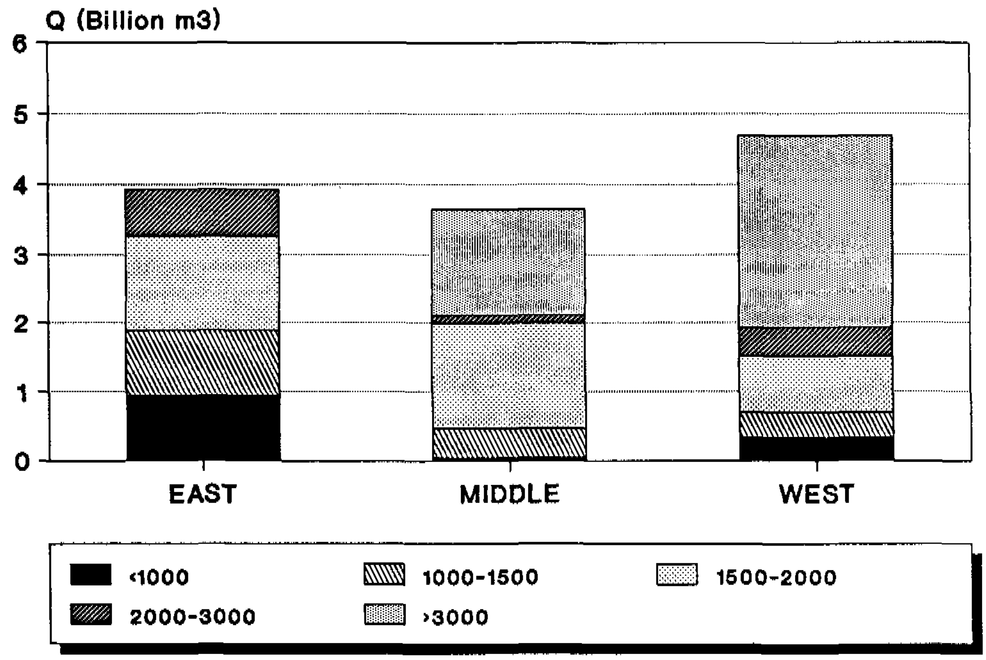

Figure 3. Classification of unused drainage water in the Nile Delta according to salinity during 1992

- Pathogens and parasites
- Pesticides
- Heavy metals
- Salinity

Pathogens and parasites received the highest priority because they are uniformly dangerous to humans as they cause the water borne diseases. They are widespread at harmful levels in the environment and they increase with rapid population growth. With high concentrations of organisms, drainage water will become increasingly difficult to reuse for irrigation purposes.

Pesticides are ranked second because of their widespread overuse in Egypt, their toxicity to humans, their persistency and tendency to accumulate in fish and other foods. The World Health Organization (WHO) reports that millions are suffering from acute pesticide exposure worldwide.

Heavy metals are ranked third because their discharge to the waterway is reasonably isolated and they rapidly settle to the bottom of the waterway. They are toxic, but are primarily discharged at a few places into long drains that probably have high concentrations in their sediments.

Salinity is a unique pollutant and is ranked last. It does not threaten health, but it reduces the suitability for reuse in irrigation purposes. Salinity poses a threat to irrigation especially in the Northern Delta.

4. HEALTH ISSUES

Disease-causing organisms originating in sewage (viruses, bacteria, parasites) are the biggest problem in Egypt because of fecal contamination of surface and ground waters. Data are too limited to accurately assess health risk from exposure to chemical contaminations in water. Heavy metals from industrial waste discharges are believed to be a serious problem, although confirming data are limited.

Water quality deterioration in Egypt can be assessed in terms of water-related diseases such as typhoid, paratyphoid, infectious hepatitis and infant and child diarrhea. These diseases are still considered endemic in Egypt with 90,000 deaths estimated by WHO in 1987. Despite significant improvements in health services, infant mortality (first year of life) remains at the high level of 60 per thousand. Similarly, child mortality (1-4 years age group) has been 7.4 per thousand (Welsh et al. 1992).

Human diseases associated with low drainage water quality used for irrigating crops are dangerous and sometimes deadly. For example, persons consuming salad or vegetable crops irrigated with poor quality water must be wary of ascariasis, trichuriasis and possibly some transmission of enteric bacterial diseases such as cholera and typhoid fever under certain conditions as well as protozoan diseases. Tapeworms may be a problem from eating the meat of animals grazing on pastures irrigated with poor quality water. Pathogenic threats to irrigation workers are ancylostomiasis (hookworm), ascariasis, cholera and possibly to a much lesser extent, infections caused by some other enteric bacteria and viruses.

Lack of rural sanitation is the major health-related water quality problem. Direct discharge of rural wastes into drains and canals contributes to infectious diseases. Human waste contamination of surface water (urine and feces) is still prevalent in rural areas. This is manifested in the prevalence of schistosomiasis (Bilharzia) which remains endemic despite the continuous control efforts. Extensive use of manual weed control would likely increase the incidence of schistosomiasis among the workers used for weed removal.

Table 2 illustrates the number of deaths caused by various water-related diseases (WHO 1987). In addition to parasitic infections, the exposure to serious chemical pollution by industrial discharges may lead to further environmental and health risk for communities in the area.

Table 2. Number of deaths caused by water-related diseases

causes of death	No. of deaths in 1987
Infectious and parasitic diseases	48458
Typhoid fever	102
Other intestinal infectious diseases	40285
Other bacterial diseases	1414
Malaria	4
Other infectious and parasitic diseases	384
Total	90647

5. ECONOMICAL ISSUES

Direct effect of the pollution on the economy has still to be assessed, but they are certainly enormous in terms of:

* medical care of water-related diseases;
* lowering of fish production and quality;
* clearing of weeds in the irrigation canals and drains which is a huge financial burden on the irrigation authorities;
* deterioration of the soils in irrigated land (heavy metals); and
* deterioration of groundwater.

6. CONCLUSIONS AND RECOMMENDATIONS

As the population in Egypt increases, industrial development proceeds and agricultural production intensifies, the demands upon the limited water supply greatly increases. More attention is put on reuse of drainage water. This means that water being reused must be kept clean. Currently, 4 billion m^3/yr of drainage water in the Nile Delta is mixed with fresh water in the canals, and the MPWWR plans to mix 7.0 billion m^3 by the year 2000. by the year 2000. To date, the only water quality parameter used in designing drainage water reuse projects has been the salinity; however, other water quality parameters and environmental concerns must be considered.

In the past, the quantity of water available received more attention than the quality, because quality had not been a constraint. With increases in population; industrialization; use of fertilizers, pesticides and other agricultural chemicals; in addition to domestic water discharges and awareness of the importance of water quality and its effects on public health, research on water quality and environmental issues has become a major concern. Monitoring is the first step in water quality assessment and pollution control.

Pollution of drainage water already is a serious problem and worsening with time. While a reasonably clear picture exists in terms of salinity of water, availability of usable information on other water quality parameters is very limited. Some data are available for few parameters, but their potential use for water quality management is limited since they are collected at random time sequence and only at few selected places.

In order to rank the pollutants according to their adverse impact on the environment, one has to consider how dangerous they are to ecosystem in general and to humans in particular, how widespread they are, whether or not they easily decompose into relatively harmless materials and whether or not they accumulate in fish and other foods. The relative risk rankings by decreasing order of concern are as follows: microbial pathogens, pesticides, heavy metals and salinity. These pollutants affect crop yields, public health, natural habitats and physical facilities. It is important to correlate the probable sources of pollutants with the relative importance of their effects.

The unregulated discharge of sewage and industrial waste effluents in Egypt has created a significant pollution problem with serious health implications. WHO has indicated that the contamination of water resources and lack of adequate water supply and sanitation facilities constitute the most common health problem in Egypt. Pollution of the drainage system effectively reduces the amount of water available for reuse. This is not in the long-term interest of the country. In addition, the total health and economic costs to the country due to water pollution would be substantial.

An integrated water quality program to meet planning, pollution control and identified research needs is urgently required. In the field of agricultural drainage, actions must be taken to reduce the environmental hazards to the drainage systems. Among them are:

* Drainage water quality should be adequately monitored. Monitoring should put much emphasis on pertinent water quality parameters. Sampling sites, techniques, frequency and facilities of analysis should be thoroughly studied.

* Research on identifying and examining the feasibility of alternatives of treatment should be conducted. These alternatives include instream treatment (wetlands), construction of wastewater treatment plants, wastewater treatment by digestors and identification of acceptable alternate crops.

* All discharge points from municipalities and industries should be carefully examined. Treatment before discharging should be provided. A careful program to monitor these outfalls is extremely important.

* Since the agricultural chemicals (fertilizers, pesticides) threaten the environment, their use in terms of types, rates and loads should be reviewed from an environmental point of view.

* Establishment of computerized environmental data bank for information about water resources and their quality is needed. Coordination among all concerned authorities is extremely important.

* Educational programs for farmers on public health, personal hygiene, and sanitation are suggested to reduce the health risk from contact with contaminated water.

* Training of personnel in charge of sampling and analysis is required.

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VALORISATION DES EAUX USÉES DANS LE SUD TUNISIEN

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ABSTRACT

Agricultural wastewater reuse is part of the tunisian strategy for optimum use of water resources. Non restrictive irrigations, i.e. irrigation of public parks, sports fields, vegetable crops, ..., which provide wastewater reuse schemes with high economic efficiency, require the effluents of wastewater treatment plants to be disinfected. Infiltration percolation is a low technology system able to cope with these prospects.

Effluents of the Sfax aerated pond were infiltrated through 1.5 m deep sand columns, in order to determine the highest hydraulic load that can be treated according to the local filtrating material and climatic conditions. A previous study showed that, from spring to fall, an average hydraulic load of 0.15 m^3 of pond effluents per day per m^2 of installed filtrating bed can be applied. New experiments demonstrated that the average hydraulic load can be increased up to 0.23 m/d from april and 0.29 m/d from late april to summer season.

It was also shown that providing more oxygen into the filter through porous vertical walls noticeably improves the quality of the filtrated water and allows to treat up to 0.4 m/d of pond effluents during may and, presumably, later on until early fall.

RÉSUMÉ

La réutilisation agricole des eaux usées est un volet important de la stratégie d'optimisation de la gestion des ressources en eau de la Tunisie. Les irrigations non restrictives - arrosage de parcs publics, de terrains de sport, de maraîchages -, qui permettent d'accroître la rentabilité des opérations de réutilisation d'eau usée, exigent que les effluents des stations d'épuration soient désinfectés. L'infiltration percolation est une technique rustique capable de répondre à cette nécessité.

Des essais d'infiltration des effluents du lagunage aéré de Sfax dans des colonnes de 1,5 m de sable ont été effectués en vue de déterminer la charge hydraulique maximale applicable sur des massifs filtrants constitués du sable local, dans les conditions climatiques locales. Une étude précédente a montré que, du printemps à l'automne, une charge hydraulique moyenne de 0,15 m^3 par jour et par m^2 de massif filtrant installé est acceptable. Les nouvelles expériences indiquent que cette charge peut être accrue jusqu'à 0,23 m/j à partir d'avril et 0,29 m/j de fin avril jusqu'à l'été.

Il apparait aussi qu'une meilleure alimentation en oxygène du massif filtrant au moyen de parois verticales poreuses améliore très sensiblement la qualité de l'eau filtrée et permet de traiter jusqu'à 0,4 m^3 d'effluent du lagunage aéré par jour par m^2 de filtre installé pendant le mois de mai et, vraisemblablement, jusqu'au début de l'automne.

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1. INTRODUCTION

La Tunisie poursuit un plan ambitieux de réutilisation des eaux usées depuis le début des années 1980. Des investissements importants ont été consacrés à la réalisation de périmètres agricoles irrigués par les effluents des principales stations d'épuration. Cependant, le taux d'utilisation de ces équipements reste sensiblement en deçà des prévisions. Celà tient en partie aux contraintes imposées par la règlementation tunisienne, qui trouvent leur justification dans l'absence de désinfection des effluents des stations d'épuration. Il est vraisemblable que l'installation et la mise en oeuvre de systèmes de désinfection amèneraient les autorités administratives à modifier la règlementation et à élargir le domaine d'application des eaux usées vers des usages à plus grande valeur ajoutée: irrigation de parcs publics, de terrains de sport, de zones de loisirs et de cultures maraîchères. Malgré un surcroît d'investissement, l'efficacité économique de la réutilisation des eaux usées s'en trouverait améliorée. Encore faut-il disposer de procédés de désinfection robustes, fiables et point trop onéreux.

Les procédés conventionnels, chloration, traitement par ozone ou ultra-violets, outre qu'ils ne permettent pas de faire face aux risques parasitologiques, requièrent une maintenance contraignante; ils sont relativement coûteux, en investissement ou en fonctionnement. Des procédés plus rustiques, lagunage tertiaire, infiltration percolation ou épandage, moins chers et plus fiables, sont souvent plus appropriés.

L'infiltration percolation consiste à infiltrer les eaux usées dans des sols perméables, généralement des sables, selon un protocole précisément établi. La percolation à travers le milieu non saturé permet d'oxyder l'eau usée et d'éliminer les microorganismes pathogènes. La phase gazeuse du sol, régulièrement renouvelée par de l'air atmosphérique, fournit l'oxygène nécessaire. L'eau épurée recharge la nappe phréatique (Bouwer, 1991, Idelovitch & Michail, 1984). On peut aussi construire des filtres drainés qui permettent de récupérer directement l'eau épurée pour la réutiliser (Brissaud *et al.*, 1991, Brissaud & Salgot, 1994).

La construction d'un filtre drainé (figure 1) mobilise une grande quantité de milieu filtrant, constitué par un sable bien classé, de diamètre moyen de grain compris entre 0,2 et 1 mm. Le massif filtrant représente l'essentiel du coût de l'installation. Ses dimensions doivent donc être soigneusement déterminées. Des bases de dimensionnement ont été élaborées par Schmitt (1989).

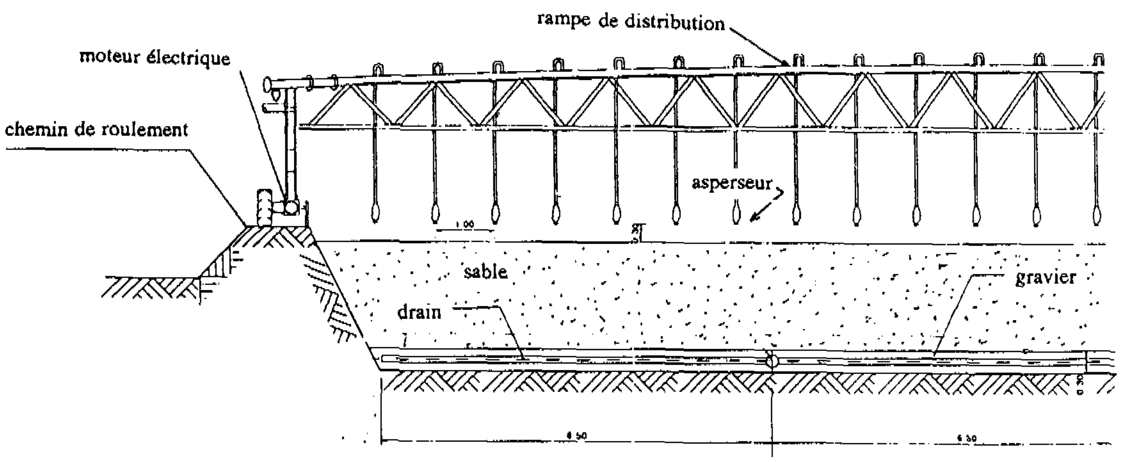

Figure 1. Coupe verticale d'un filtre drainé

La charge polluante d'une eau usée est représentée par sa Demande Totale en Oxygène, ou DTO. C'est la quantité d'oxygène, en milligrammes, nécessaire à l'oxydation d'un litre d'eau usée, soit :

$$DTO = DCO_{dissoute} + 4,57\ N_{TK}$$

Dès lors que la DTO de l'eau usée excède 280 mg/l, la charge hydraulique applicable et, par conséquent, la surface d'infiltration requise sont calculées de manière à satisfaire les besoins en oxygène de l'eau traitée, au moyen d'un modèle déterministe de bilan d'oxygène. La surface du filtre est fonction de la DTO et du protocole d'application de l'eau usée sur le massif filtrant.

La désinfection est évaluée à travers l'abattement des coliformes et des streptocoques fécaux. Elle suppose l'action successive de trois catégories de processus: la filtration mécanique, l'adsorption et la dégradation microbienne. Soit un ensemble beaucoup trop complexe pour faire l'objet d'une modélisation déterministe. La façon la plus efficace de prédire la désinfection en infiltration percolation consiste à utiliser des modèles empiriques déduits du traitement statistique de données recueillies aussi bien au laboratoire que sur des installations pilotes et opérationnelles. Ce traitement fait apparaitre le temps de séjour moyen de l'eau dans le massif filtrant, t_m, comme la variable la plus significative de l'abattement des bactéries témoins de contamination fécale. La charge hydraulique et l'humidité du milieu poreux étant données, t_m est proportionnel à l'épaisseur du massif filtrant. Ainsi l'abattement requis détermine l'épaisseur du massif filtrant.

Bien que déjà utilisés en ingénierie, les modèles précédents n'ont pas fait, jusqu'à maintenant, l'objet d'assez d'efforts de validation expérimentale. Celà explique la prudence avec laquelle ils ont été incorporés à l'*état de l'art* (Agences de l'Eau, 1993, Brissaud & Lesavre, 1993). Par exemple, les modèles déterministes de bilan d'oxygène supposent notamment que les vitesses des réactions d'oxydation et d'adsorption de $N\text{-}NH_4$ sont très grandes par rapport à la vitesse de percolation de l'eau. L'erreur introduite par ces hypothèses dans la simulation du bilan d'oxygène peut ne pas être négligeable quand les charges hydrauliques appliquées sont importantes. D'autre part, le calcul des charges applicables tient mal compte de la cinétique de la respiration endogène. Il suppose aussi que le procédé n'est pas durable si la capacité d'oxydation est inférieure à la DTO, ce qui n'est pas nécessairement toujours vrai. La détermination de la capacité d'oxydation par la modélisation du bilan d'oxygène exige la détermination des caractéristiques hydrodynamiques du milieu poreux et de la capacité de rétention de l'azote ammoniacal sur la phase stationnaire.

Les prévisions de la désinfection effectuées par les modèles empiriques sont médiocres. La variance de l'abattement des coliformes fécaux non expliquée est supérieure à une unité logarithmique.

Dans ces conditions, l'intérêt est grand de procéder à des essais de dimensionnement sur des colonnes de laboratoire avec le vrai effluent à traiter, le sable retenu pour le projet, sous les conditions climatiques locales. Même si le transfert des résultats de laboratoire à l'échelle opérationnelle comporte quelques risques maintenant bien identifiés et que l'on a appris à gérer. Outre son intérêt pratique, cette démarche apporte des références susceptibles de contribuer à la validation des modèles précédents.

Les premiers essais de laboratoire effectués à Sfax montrent que la charge hydraulique moyenne applicable, H_m, du début du printemps jusqu'à l'automne, est au moins égale à 0,15 m^3 par jour par m^2 de plage d'infiltration installée (Makni *et al.*, 1994). Ils montrent aussi que la qualité de l'épuration apparait être fonction de la saison, c'est à dire, vraisemblablement, de la température. On pouvait donc penser que la charge hydraulique applicable augmente du début du printemps jusqu'à l'été. C'est ce qui a été vérifié.

Les échanges entre la phase gazeuse du sol et l'air atmosphérique à travers la surface d'infiltration fournissent une quantité d'oxygène limitée. F. Lefevre (1988) a montré comment l'accroissement des échanges entre le milieu poreux et l'air atmosphérique, au moyen de structures creuses à parois verticales poreuses installées à l'intérieur du massif filtrant, élève la capacité d'épuration du procédé. Ce principe a été appliqué avec succès au traitement des effluents du lagunage aéré de Sfax, à l'échelle du laboratoire.

2. MATERIELS ET METHODES

Les essais sont effectués sur deux colonnes, (a) et (na), de 0,16 m de diamètre, remplies de 1,5 m de sable de l'Oued Chaffar. Les diamètres effectif, d_{10}, et moyen, d_{50}, de ce sable sont respectivement de 0,27 et 0,53 mm; son coefficient d'uniformité est égal à 2,3. Le sable est initialement vierge, c'est à dire dépourvu d'accumulation bactérienne.

La paroi de la colonne (a) est perforée, entre 0,3 et 1,2 m sous la surface du sable, de centaines d'orifices de 2 mm de diamètre, uniformément répartis. Dans cet intervalle, le milieu poreux reste non saturé et l'eau qui percole est à une pression inférieure à la pression atmosphérique. Elle ne peut donc pas échapper au milieu poreux. Par contre l'air atmosphérique pénètre dans la colonne à travers les orifices, par diffusion moléculaire et convection naturelle, et renouvelle latéralement la phase gazeuse du massif filtrant.

L'eau appliquée sur les colonnes est prélevée deux fois par semaine à la sortie du lagunage aéré de Sfax, stockée au réfrigérateur et remise à la température ambiante et homogénéisée avant application. Les colonnes sont alimentées par une pompe péristaltique.

Des phases de fonctionnement de 4 jours alternent avec des phases de séchage de 3 jours (figure 2). La charge hydraulique moyenne, H_m, est égale aux 4/7 de la charge appliquée les jours de fonctionnement, H. Pendant les phases de fonctionnement, les colonnes sont alimentées 10 minutes toutes les 3 heures, soit un nombre d'apports par jour, f, égal à 8. Du 8 mars au 22 avril, soit pendant les 7 premières semaines, la charge hydraulique quotidienne appliquée dans chaque colonne est de 0,4 m/j. Le 26 avril, H est porté à 0,5 m/j par augmentation du débit des pompes. La colonne (na) conserve cette charge jusqu'à la fin de l'expérience, alors que, à partir du 10 mai et pour une durée de trois semaines, la charge hydraulique appliquée quotidiennnement sur la colonne (a) passe à la valeur de 0,7 m/j.

Les colonnes sont installées dans un local non climatisé et très mal isolé thermiquement. Sa température est très influencée par la température extérieure (figure 3). Cette pièce est très bien éclairée par la lumière du jour.

L'eau appliquée et l'eau filtrée à la sortie de chaque colonne sont analysées deux fois par semaines. Les paramètres contrôlés sont les teneurs en MES, la DCO, les concentrations en N_{TK}, $N\text{-}NH_4$ et $N\text{-}NO_3$ et les teneurs en coliformes totaux et fécaux et en streptocoques fécaux. Les teneurs en oxygène dissous de l'eau filtrée ont été mesurées à partir du 7 avril.

La capacité d'infiltration du massif filtrant est observée en mesurant le temps d'infiltration totale de l'eau appliquée, c'est à dire le temps qui sépare la fin d'une alimentation du moment où toute l'eau a disparu dans le massif de sable.

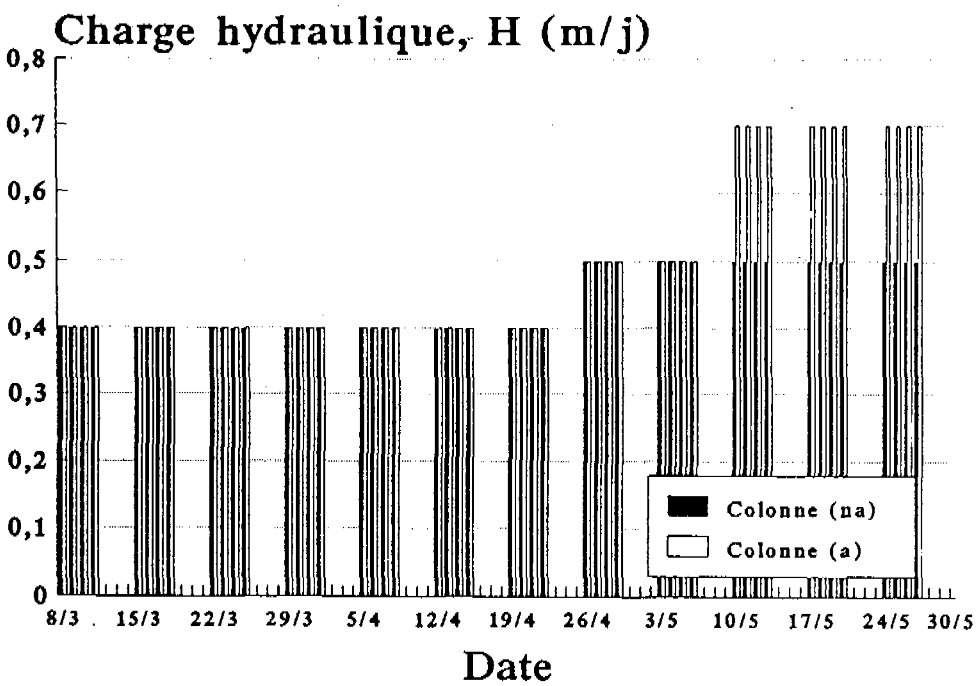

Figure 2. Diagramme d'alimentation des colonnes

Le colmatage du milieu poreux est contrôlé au moins deux fois par semaine, à la fin de chaque phase de fonctionnement et de chaque phase de séchage, en suivant les profils verticaux d'humidité. Pour un même débit, la différence entre l'humidité d'un milieu poreux vierge et celle du même milieu après plusieurs jours ou plusieurs semaines de circulation d'eau usée tient à l'accumulation de biomasse. Un appareillage électrique simple permet de mesurer la résistivité du milieu poreux, laquelle dépend de l'humidité conformément à la loi d'Archie.

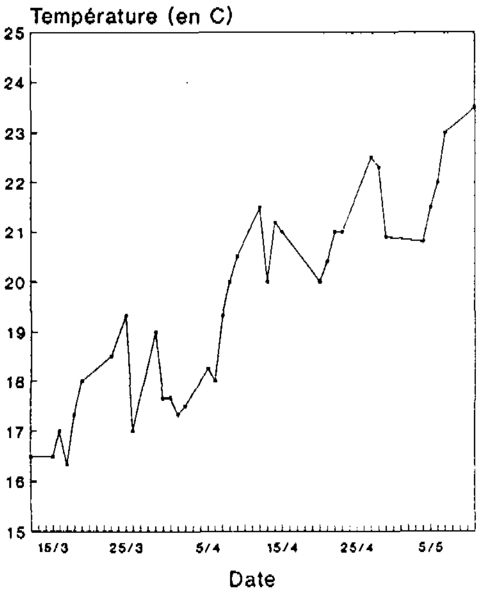

Figure 3. Température de l'eau appliquée sur les colonnes

3. RESULTATS

3.1 Qualité des Effluents du Lagunage Aéré

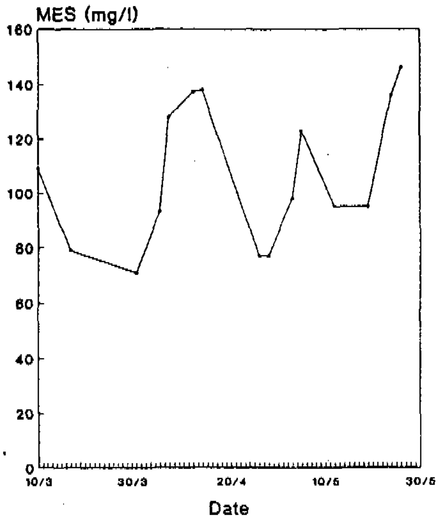

Figure 4. Teneur en MES des effluents du lagunage éré

Les teneurs en MES des effluents du lagunage aéré de Sfax sont élevées (figure 4). Elles sont comprises entre 70 et 150 mg/l et égales en moyenne à 107 mg/l. Constituées par les boues et des algues du lagunage aéré, elles induisent un risque de colmatage superficiel des massifs de sable. Dans les conditions ambiantes, température, éclairage et ventilation du local, ce risque ne s'est pas concrétisé.

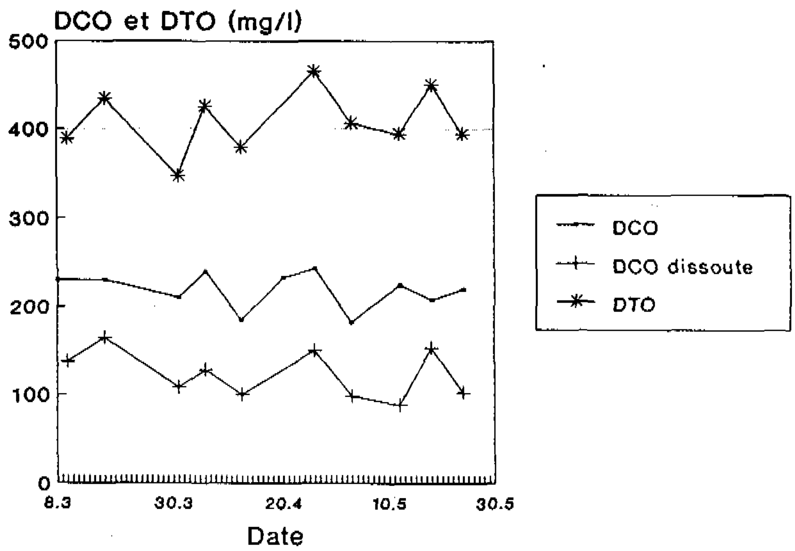

Figure 5. DCO et DTO des effluents du lagunage aéré

La DCO totale est relativement stable, autour d'une moyenne de 219 mg/l (figure 5). La DCO dissoute est plus faible; elle n'est que de 123 mg/l en moyenne. Les teneurs en MES expliquent facilement la différence entre DCO et DCO dissoute.

Les teneurs en azote Kjeldahl sont un peu plus dispersées, entre 55 et 70 mg/l. La moyenne est de 63 mg/l. La Demande Totale en Oxygène est, en moyenne, proche de 410 mg/l. C'est, à cause de la surcharge du lagunage aéré, une DTO plus proche de celle d'un effluent primaire que de celle d'un effluent secondaire.

3.2 Oxydation de l'Eau Usée

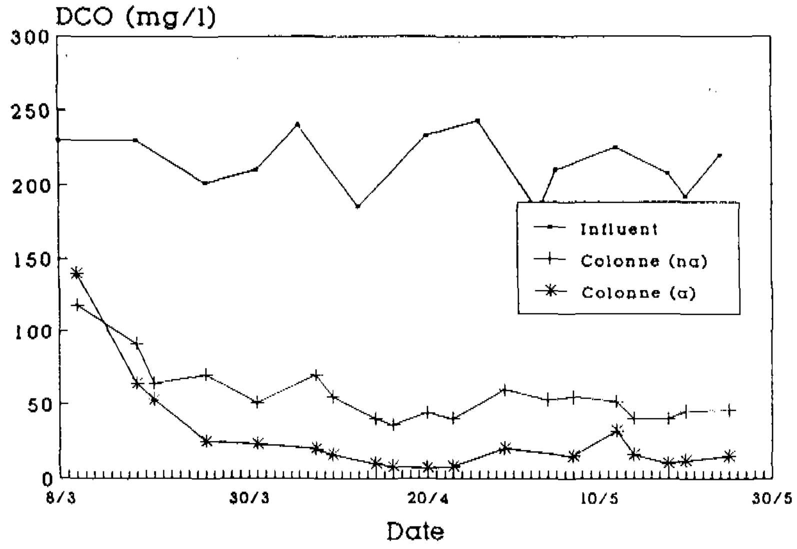

Figure 6. Elimination de la DCO

L'oxydation de la DCO et celle de l'azote suivent des évolutions analogues (figures 6 et 7). Elle se mettent progressivement en place et n'atteignent un régime pseudo-stable qu'à la mi-avril. L'oxydation de l'azote comporte toujours une phase transitoire, qui dure de deux à trois semaines, et correspond à l'installation de la flore nitrifiante. La durée de la phase transitoire est ici sensiblement plus longue. Celà pourrait être expliqué par la présence saisonnière de résidus d'effluents agro-alimentaires longs à dégrader. On peut aussi penser à une augmentation de la vitesse des réactions biologiques responsables de l'oxydation avec l'accroissement de la température. Les résultats obtenus dans des études antérieures donnent beaucoup de poids à cette hypothèse (Makni *et al.*, 1994).

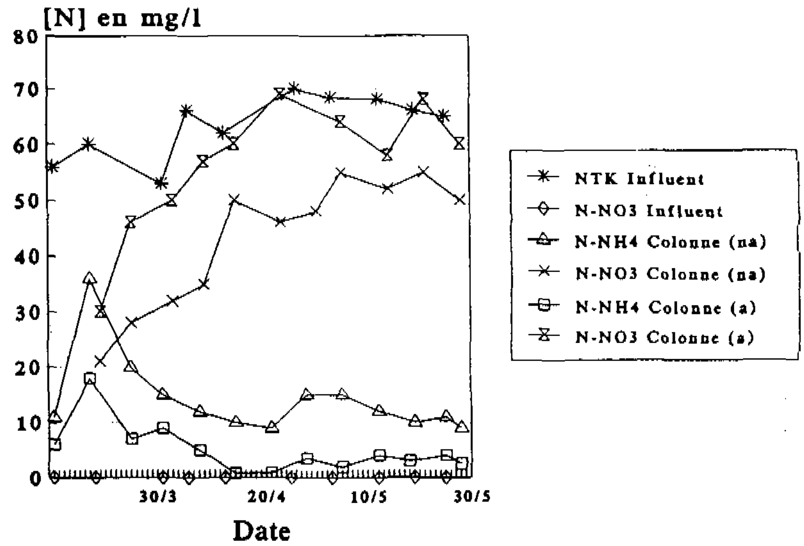

Fig. 7 Oxydation de l'azote

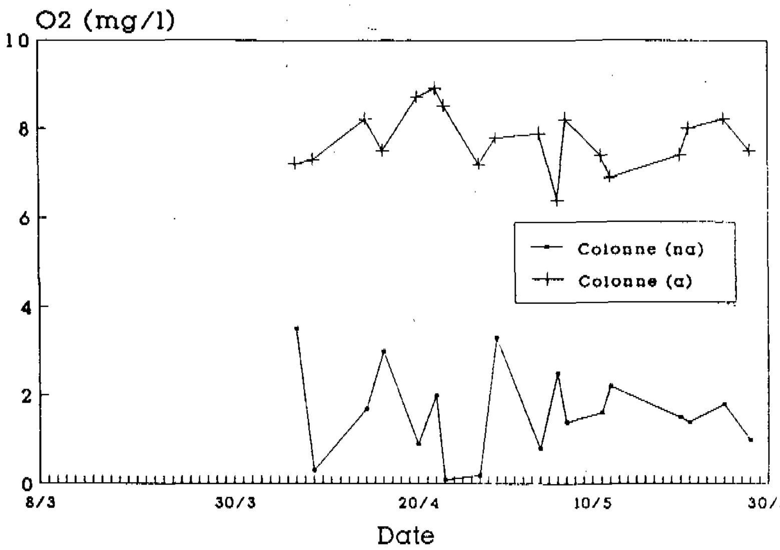

Figure 8. Concentration du filtrat en oxygène dissous

Des différences substantielles apparaissent entre les colonnes (a) et (na). A partir de la mi-avril, l'oxydation de l'eau usée est pratiquement totale après sa traversée de la colonne (a); au contraire, il reste une DCO résiduelle de l'ordre de 50 mg/l et une teneur en N-NH4 voisine de 10 mg/l dans le filtrat de la colonne (na). Ces différences témoignent de l'efficacité de l'aération à travers les orifices de la paroi. Ce système rudimentaire apporte, dans la profondeur de la colonne, l'oxygène qui manque dans la colonne (na) pour achever l'oxydation. C'est ce que confirme la mesure de la teneur en oxygène dissous du filtrat (figure 8). A la sortie de la colonne (a), elle est proche de 8 mg/l, soit une valeur proche de la saturation. A la sortie de la colonne (na), elle varie entre 0 et 3 mg/l, teneurs insuffisantes pour achever l'oxydation de la matière organique dissoute et de l'azote.

L'influence des augmentations de charge hydraulique, intervenues le 26 avril sur les deux colonnes et le 10 mai sur la colonne (a), est peu perceptible. Pour la colonne (na), celà tient en partie à ce que l'effet de la variation de H peut être masqué par les fluctuations de la DTO de l'influent. On peut penser que, là encore, l'effet de l'augmentation de la charge hydraulique est partiellement compensé par l'accroissement de la température. Ainsi, la DTO éliminée à travers la colonne (na) reste, d'avril à mai, voisine de 315 mg/l. Ce résultat est conforme à l'évaluation de la capacité d'oxydation en fonction de la charge hydraulique appliquée par Brissaud & Lesavre (1993). L'aération latérale à travers la paroi de la colonne (a) porte la capacité d'oxydation à des valeurs proches de 400 mg/l, même quand la charge hydraulique, H, atteint 0,7 m/j.

3.3 Colmatage

Pendant toute la durée des essais, les temps de d'infiltration de l'eau appliquée n'excèdent jamais 50 minutes. Il n'y a donc pas eu de colmatage important de la partie supérieure des massifs filtrants, malgré la forte teneur en MES de l'influent. Ce résultat contraste avec celui obtenu deux ans auparavant, en hiver. Pour une charge hydraulique de 0,4 m/j, le temps d'infiltration avait dépassé 2 heures au bout de 3 semaines d'expérience. La figure 9 met bien en évidence le rôle des phases de séchage dans la gestion de ce colmatage. Au cours des phases de fonctionnement, le temps d'infiltration croit rapidement. Si la durée de ces phases était augmentée de plusieurs jours supplémentaires, l'accroissement du temps de submersion de la plage d'infiltration réduirait la capacité d'oxydation du procédé et la qualité de l'épuration s'en trouverait considérablement dégradée. Les phases de séchage permettent de restaurer la capacité d'infiltration en ramenant les temps d'infiltration à leurs valeurs de la semaine précédente.

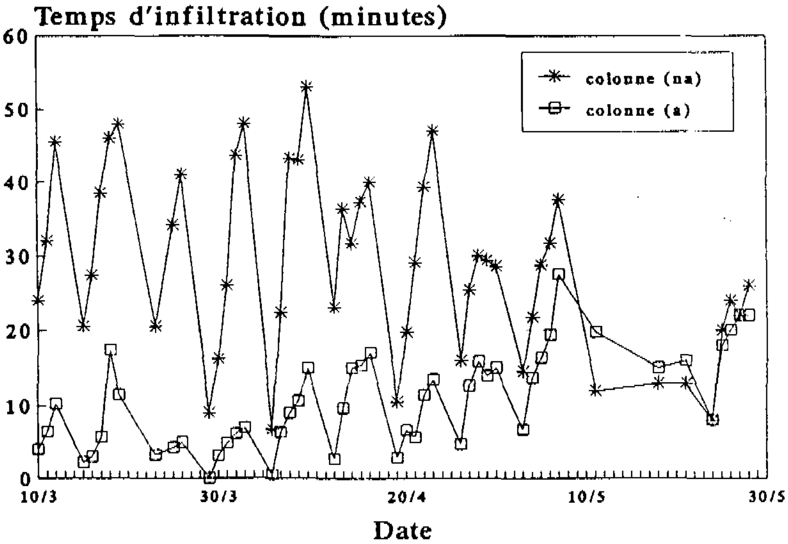

Figure 9. Temps d'infiltration de l'eau appliquée

Si les alternances séchage-fonctionnement se traduisent de la même manière dans les deux colonnes, les temps d'infiltration et leurs évolutions sont très différents, au moins jusqu'à ce que la charge hydraulique soit portée à 0,7 m/j sur la colonne (a). Pendant les 7 premières semaines, les temps d'infiltration sont beaucoup plus faibles dans la colonne (a) que dans la colonne (na). Ce qui signifie que l'accroissement des échanges entre la phase gazeuse du milieu poreux et l'air atmosphérique entre 0,3 et 1,2 m de profondeur influe sur les accumulations organiques y compris dans la partie supérieure des massifs filtrants. Quand la teneur en oxygène de la phase gazeuse est maintenue tout le long de la colonne à un niveau élevé, les accumulations organiques restent modérées. Au contraire, quand l'approvisionnement en oxygène est inférieur aux besoins, comme on le voit à travers la qualité et la teneur en oxygène dissous du filtrat de la colonne (na), les accumulations organiques croissent. C'est que la respiration endogène, qui est responsable de la régulation des accumulations organiques sur toute la hauteur du filtre, est consommatrice d'oxygène. Plus la teneur en oxygène est élevée, plus faible est le colmatage.

Les temps d'infiltration dans la colonne (na) diminuent au cours du mois de mai. Ce que seul l'accroissement de la température parait capable d'expliquer. Dans le même temps les temps d'infiltration dans la colonne (a) évoluent en sens contraire sous l'effet de l'accroissement de la charge hydraulique.

Puisqu'elle est composée d'eau à plus de 90 %, la biomasse accumulée sur toute la hauteur d'un massif filtrant peut être mesurée par la différence entre le stock d'eau dans la colonne, S_W, et le stock d'eau correspondant au même régime hydraulique dans la même colonne vierge; avec

$$S_W = \int_0^L \theta .dz,$$ θ, la teneur en eau, z la profondeur et L, la hauteur du massif filtrant.

Les évolutions des stocks d'eau offrent beaucoup d'analogies avec celles des temps d'infiltration (figure 10). En effet, la respiration endogène est le mécanisme qui régule la biomasse sur toute l'épaisseur des massifs filtrants. Dans les deux colonnes, le stock d'eau, autrement dit le colmatage interne, augmente pendant les phases de fonctionnement, faute d'oxygène - dans la colonne (na) - mais aussi faute de temps. En effet, la colonne (a) ne manque pas d'oxygène; seulement la durée qui sépare deux alimentations est un peu trop courte pour permettre à la respiration endogène de résorber l'accroissement de biomasse qui résulte de l'assimilation, par les bactéries hétérotrophes, de la ration de substrat apportée par chaque alimentation. Il faut la durée d'une phase de séchage pour résorber cet accroissement et pour - dans la colonne (na) - fournir, essentiellement par diffusion moléculaire en phase gazeuse, l'oxygène nécessaire à cette résorbtion. Jusqu'au 10 mai, le colmatage de la colonne (na), moins bien approvisionnée en oxygène, est supérieur à celui de la colonne (a). Cette différence est plus nette en fin de phase de fonctionnement. Après le 10 mai, sous l'effet de l'augmentation de la charge appliquée sur la colonne (a), la quantité de biomasse accumulée dans cette colonne rejoint la valeur de celle stockée dans la colonne (na).

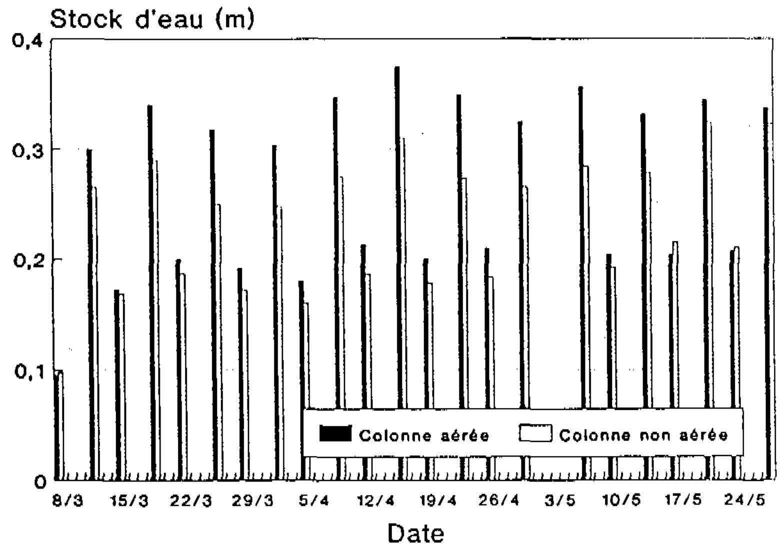

Figure 10. Stocks d'eau dans les colonnes (a) et (na) en fin de phases de fonctionnement et de séchage. (*Le 8/3, les stocks sont mesurés dans des milieux vierges*)

Passées les deux premières semaines, le colmatage interne de la colonne (na) est pratiquement stabilisé. Cette observation est d'autant plus remarquable qu'elle diffère complètement des résultats obtenus au coeur de l'hiver, toutes les autres conditions expérimentales étant sensiblement identiques (Makni *et al.*, 1994). A plus faible température, le colmatage s'accroit d'une semaine sur l'autre, en surface et en profondeur. Cette influence de la température a été bien montrée par De Vries (1972).

Pendant les deux dernières semaines de l'expérience, le stock d'eau de la colonne (a) semble subir le contrecoup de l'augmentation de la charge hydraulique appliquée sur cette colonne. Toutefois, dans la limite de cet essai, aucune menace ne semble peser sur la pérennité du procédé, tant que la température reste suffisamment élevée.

3.4 Désinfection

Si la stabilité du colmatage décide de la pérennité du procédé, la désinfection est son principal objectif. L'abattement des bactéries, $\log_{10}(C_i/C)$, avec C_i et C les teneurs en bactéries dans l'eau appliquée et dans le filtrat, suit des évolutions très analogues à celles de l'oxydation (figures 11, 12 et 13). Le rabattement augmente progressivement pendant les premières semaines, au fur et à mesure que l'oxydation est plus complète. Cette relation entre le niveau de l'oxydation et l'efficacité de la désinfection a été mise en évidence par Lefèvre (1988) et par Schmitt (1989). On la retrouve en comparant les résultats des deux colonnes. Les abattements obtenus sur la colonne (a), à travers laquelle les effluents sont presque complètement oxydés, sont supérieurs d'une unité logarithmique en moyenne à ceux obtenus sur la colonne (na), dont le filtrat a une DTO encore égale à 95 mg/l. La présence de substrat organique est facteur de survie des bactéries. Donc, plus la DCO résiduelle est forte, moins bonne est l'élimination des germes témoins de contamination fécale. On peut aussi penser que plus la respiration endogène est efficace, plus les chances d'élimination des bactéries fécales par les processus microbiologiques sont grandes.

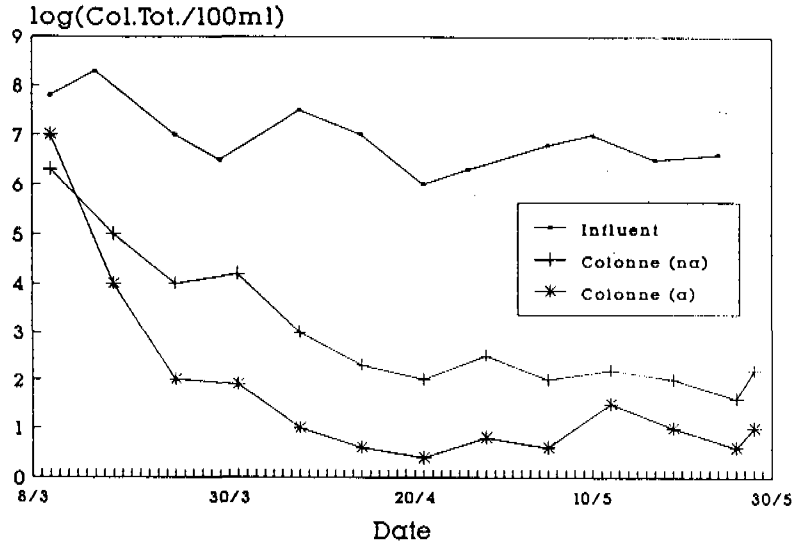

Figure 11. Abondance des coliformes totaux dans le filtrat

Les augmentations de la charge hydraulique, l'accroissement de la température, les variations de la concentration en bactéries dans l'eau appliquée combinent leurs effets de telle manière que, à partir de la mi-avril les teneurs du filtrat et les abattements en coliformes et streptocoques fécaux et en coliformes totaux sont relativement stables. Les abattements moyens des coliformes totaux sont de 5,8 et 4,5 dans les colonnes (a) et (na) respectivement; ceux des coliformes fécaux sont de 4,3 et 3,3. Enfin les abattements moyens des streptocoques fécaux sont de 3,7 dans (a) et 2,7 dans (na). Il y a donc un classement des performances en fonction des bactéries considérées. Les plus abondantes connaissent les abattements les plus grands.

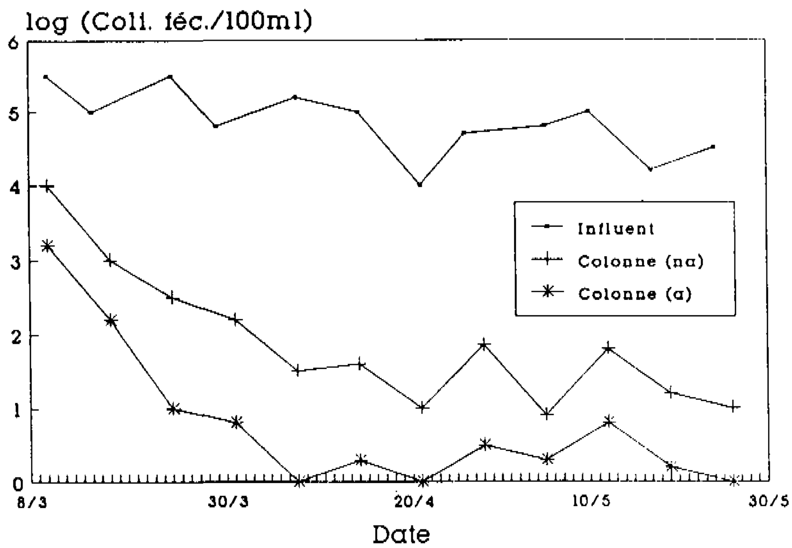

Figure 12. Abondance des coliformes fécaux dans le filtrat

La qualité microbiologique de l'eau obtenue à partir d'avril à la sortie de la colonne (na), avec une abondance en coliformes fécaux inférieure à 10^2/100 ml pour des charges hydrauliques de 0,4 puis de 0,5 m/j, devrait permettre de libéraliser les usages de l'eau filtrée. Le supplément d'oxygène apporté par l'aération latérale permet d'abaisser la teneur en coliformes fécaux à moins de 10/100 ml pour des charges hydrauliques encore plus élevées.

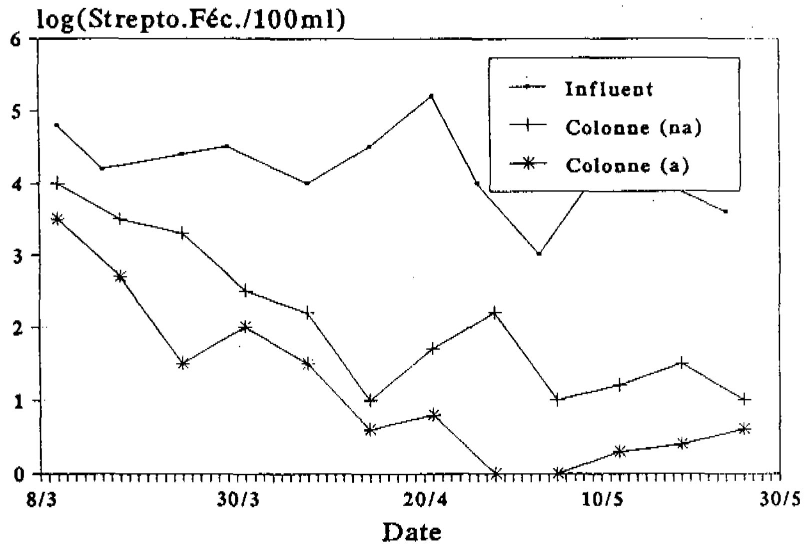

Figure 13. Abondance des streptocoques fécaux dans le filtrat

RESUME-CONCLUSION

Le traitement d'une charge hydraulique, H, de 0,4 mètre par jour d'effluents du lagunage aéré de Sfax par infiltration à travers 1,5 m de sable de l'oued Chaffar permet d'obtenir, à partir du mois d'avril et jusque, vraisemblablement, à la fin de l'automne, une eau filtrée dont la teneur en coliformes fécaux est inférieure à 100/100 ml. A partir de fin avril, la charge hydraulique peut être portée à 0,5 m/j. Compte tenu du rythme de l'alternance des phases de fonctionnement et de séchage, soit 4 jours - 3jours, les charges hydrauliques moyennes, H_m, applicables sont, respectivement, de 0,23 et 0,29 m^3 par jour et par m^2 de massif filtrant. Pour atteindre cette qualité en hiver, il faut réduire la charge hydraulique moyenne en dessous de 0,15 $m^3/(j.m^2)$.

La principale condition de transposition de ces résultats de laboratoire à l'échelle opérationnelle est la conservation des modalités d'infiltration de l'eau usée. En effet, de ces modalités dépend la distribution des temps de séjour de l'eau dans le milieu poreux. Même si cette distribution ne suffit pas à rendre compte complètement de la désinfection, elle y joue un rôle de tout premier plan. Un aspect essentiel de la conservation des modalités d'infiltration est l'homogénéité de l'infiltration de l'eau usée sur le massif filtrant. Pour respecter cette condition, les dispositifs d'alimentation gravitaire doivent être remplacés par des systèmes d'aspersion. Des systèmes pivots adaptés à la distribution d'eaux usées (figure 1) ont été essayés avec succès (Brissaud & Salgot, 1994).

Une meilleure alimentation du milieu poreux en oxygène à travers des parois poreuses permet, pour les mêmes charges hydrauliques, d'améliorer d'une unité logarithmique l'abattement des bactéries témoins de contamination fécale. Ce système permet aussi de porter la charge hydraulique, H, à 0,7 m/j, soit une charge hydraulique moyenne, H_m, de 0,4 m^3 par jour et par

m^2 de massif filtrant à partir du mois de mai. Si ce niveau de performance est lié à la température, cette charge peut vraisemblablement être appliquée jusqu'au début de l'automne. La fourniture accrue d'oxygène conduit, toutes choses égales par ailleurs, à un moindre colmatage du massif filtrant et, donc, à une garantie accrue de pérennité du procédé. Bien que ses résultats soient très convaincants, l'aération à travers des cloisons verticales poreuses n'a été, jusqu'à maintenant, transposée à l'échelle opérationnelle que pour de toutes petites unités d'épuration d'eaux usées domestiques.

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EFFECT OF WASTE DISCHARGES ON THE WATER QUALITY OF BAHR EL BAQAR DRAIN SYSTEM, EASTERN NILE DELTA

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ABSTRACT

The Egyptian water requirements in different fields are rapidly increasing while the water resources are limited. Therefore, the water planner started to consider the reuse concept including both agricultural drainage water and sewage water in irrigation. Bahr EL Baqar drain system in Eastern Nile Delta has been chosen to study the suitability of its water for reuse in irrigation. Field visits to the study area have been made to establish better understanding of the conditions of its surroundings and to identify the sources of pollution to the drain system. A monitoring program has been designed and executed to include five hydrological stations and eighteen sampling stations along the drain. The collected water samples have been analyzed to determine the physical, chemical and microbiological characteristics.

The study shows that the microbiological health hazard is the major pollution problem to the drain system. The average value of coliform bacteria for the drain water was $2.2*10^5$ cell/100ml. while, the concentrations of the heavy metals were usually under the limits which could cause problems to soils or plants except the cadmium. The high salinity within the last reach of the system can cause severe problem to crops and soils. In addition, the high concentrations of sodium and chloride may cause severe toxicity problem to crops.
Keywords: Bahr EL Baqar drain, drainage water reuse, assessment, industrial effluent, domestic wastewater, water quality, contaminants.

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1. INTRODUCTION

A great variety of pollutants affect the majority of the drainage systems which receive domestic, industrial and agricultural effluents. Bahr EL Baqar drain system, which is considered the highest polluted drain system in Egypt, is the major concern of this study. The main sources of pollution in Bahr EL Baqar drain system are the discharges of untreated domestic and industrial wastewater besides the agricultural drainage return flows.

Recently, the water planner has started to consider the reuse concept including both agricultural drainage water and sewage water where mostly all the future development activities will be based on reused concept. In the Eastern Delta, there are official reuse projects managed by the Ministry of Public Works and Water Resources in addition to unofficial reuse practices by the farmers through most of Bahr EL Baqar drain system reaches. This water may be considered unsuitable for reuse and adds products which may be toxic to both aquatic biota and humans. Furthermore, chemicals and heavy metals can affect the soil structure. The reused water can transmit communicable diseases to susceptible farm workers and the product consumers or to those who are in direct contact with this water. Furthermore, the receiving nutrients enhance biological production of plants which seriously reduce the hydraulic efficiency of the drain system.

The objectives of this paper are to assess the impact of industrial and domestic wastewater on the water quality of Bahr EL Baqar drain system and to study the suitability of its water for reuse in irrigation. The study includes hydraulic measurements, water quality monitoring, identification of the sources of pollution to the drain system, comparison between pollutant level and international guidelines and the recommended possible solutions.

2. DESCRIPTION OF THE STUDY AREA

Bahr EL Baqar drain system is located at the Eastern part of the Nile Delta as shown in figure (1). It originates at the confluence of two drains, namely Bilbeis drain and Qalyubia drain. The annual discharge is about $1.2*10^9$ m^3 into Lake Manzala which in turn discharges freely into the Mediterranean Sea. The agricultural area served by Bahr EL Baqar drain and its tributaries is

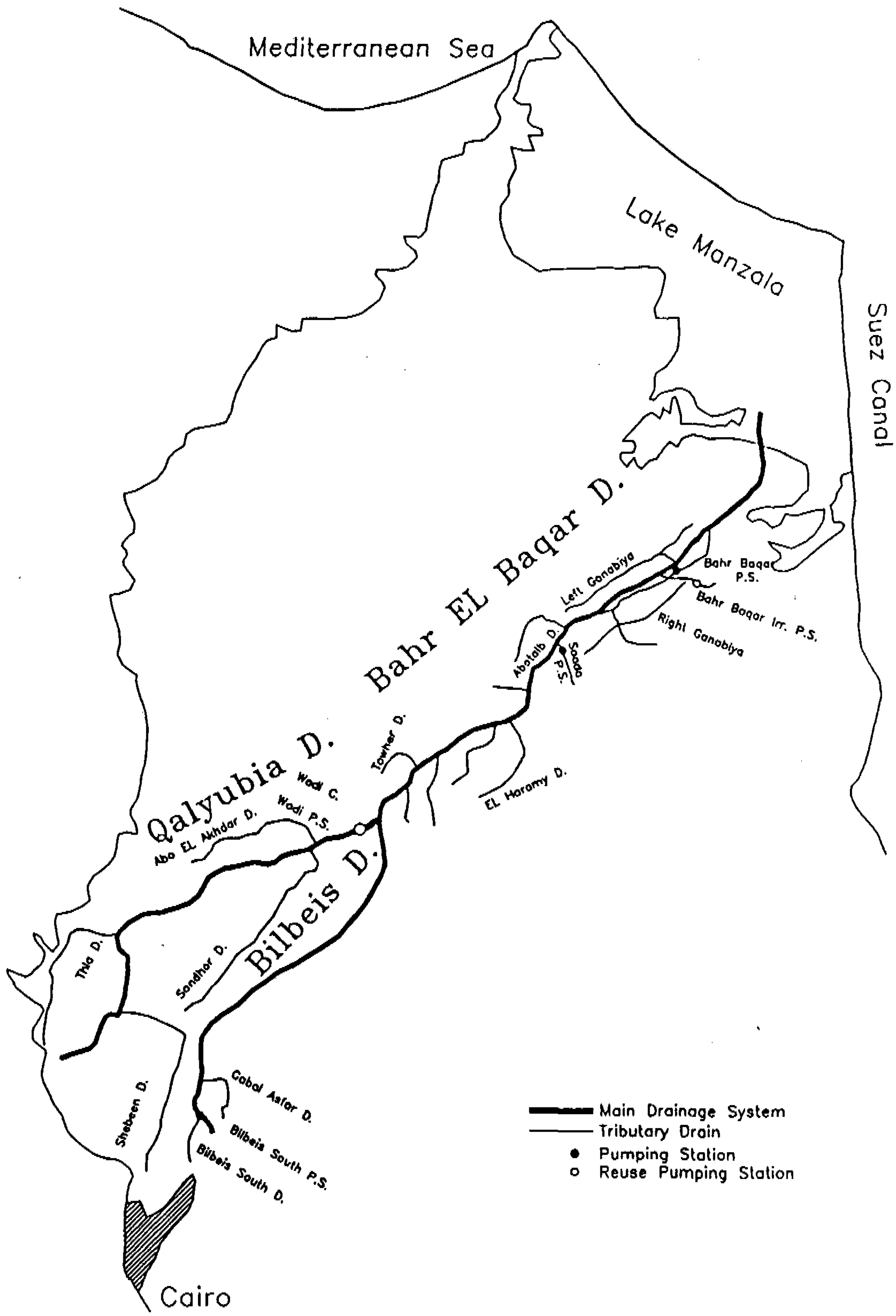

Figure 1. Bahr El-Baqar drain system in the Eastern Delta.

about 760 thousand feddans. Bahr EL Baqar, Bilbeis and Qalyubia drains have lengths of 106.5, 65.98 and 73.35 km respectively. The drain system is currently used for conveying raw industrial and municipal wastewater.

The major industrial area, which impacts the quality of the drainage water in Bahr EL Baqar drain system, is Shoubra EL Kheima. The industrial activities include metal production, food processing, detergent and soap manufacturing, textile finishing and paper production. The wastewater discharges and the organic loads of the industries are presented in figures (2) and (3) respectively. There are some industrial activities in Zagazig city which discharge their wastewaters into EL Aslogy drain and then to Qalyubia drain. Also, in Benha city there are some industrial activities which discharge their wastewaters into Tahla drain and then to Qalyubia drain.

Bahr EL Baqar drain watershed is also used to transport raw wastewater which is discharged from the East Bank of Greater Cairo city. Bilbeis drain receives the wastewater from Gabal EL Asfar, EL Berka and EL Ameria sewerage effluent. Qalyubia drain receives the wastewater from Shoubra EL Kheima, Zagazig city and others small towns like Kalyob, Tokh, Shebeen EL Kanater and Benha. Also, all the rural areas around Bahr EL Baqar drain watershed discharge their domestic wastewater directly to the drain system. The average wastewater discharge is about $2*10^6$ m^3/day (EL Gohary,1993). The East Bank of Cairo only discharges about 92% of the total wastewater discharged to Bahr EL Baqar drain system.

3. HYDRAULIC MEASUREMENTS

Five hydraulic stations have been installed through the drain system as shown in figure (4). Also, the discharges have been measured at the pumping stations. Surface water level, water velocity and discharge have been monitored during this study. Relationship is found between the discharge and the water level for the five stations and a typical example is presented in figure (5) for station no. 12.

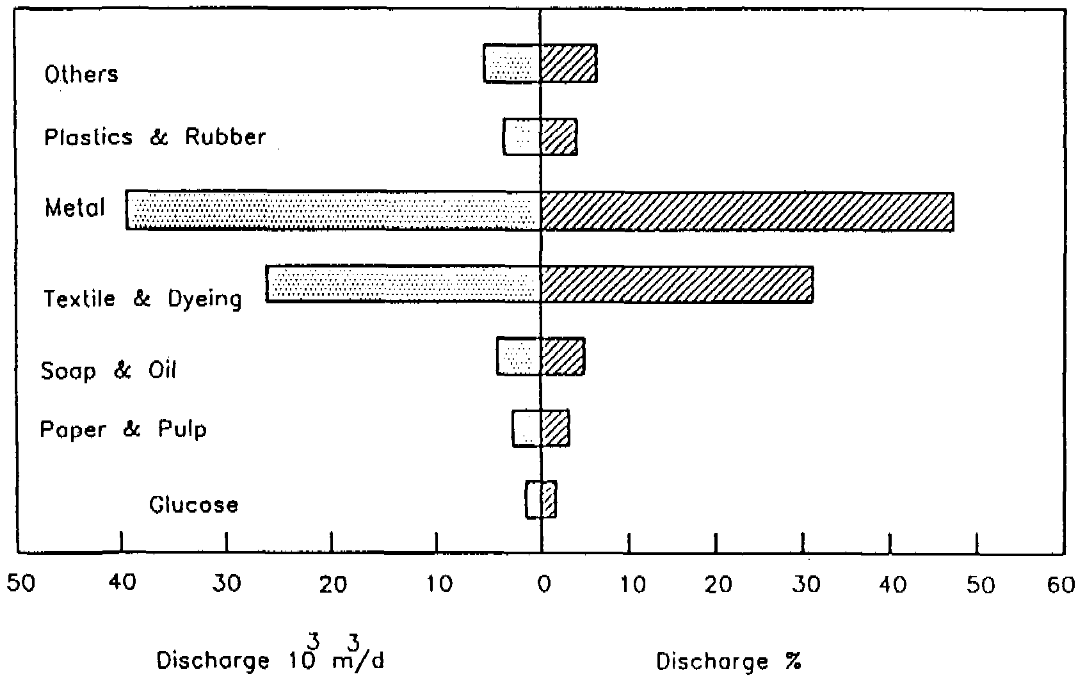

Figure 2. The wastewater discharges of the industries in Shoubra El-Kheima area.

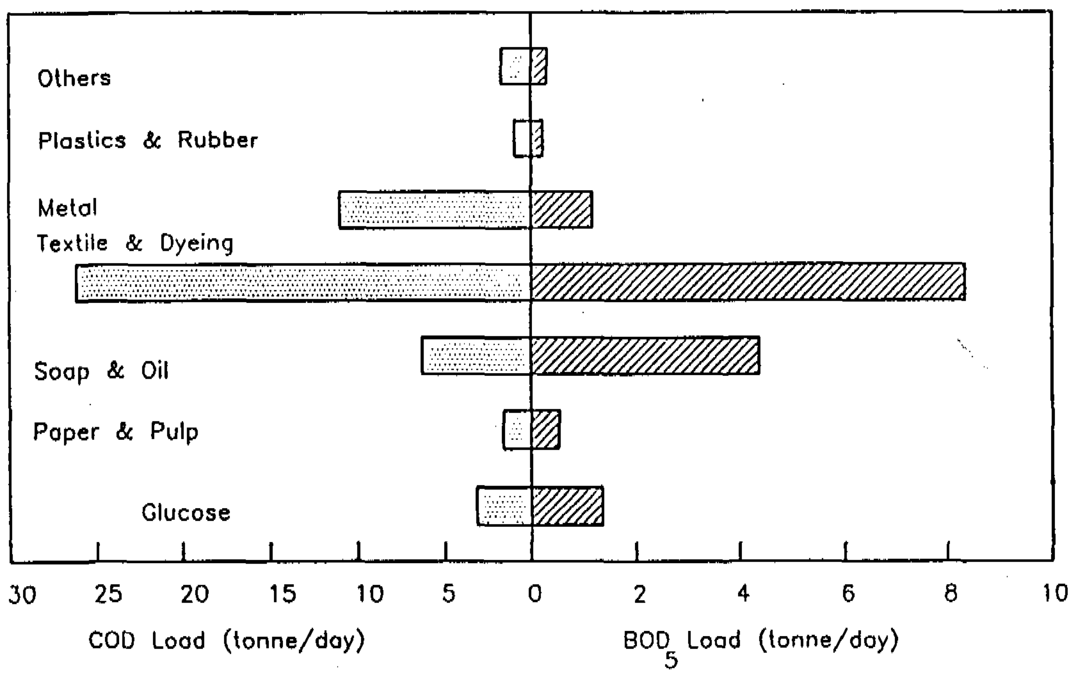

Figure 3. The organic loads contributed by the industrial sectors in Shoubra El-Kheima area.

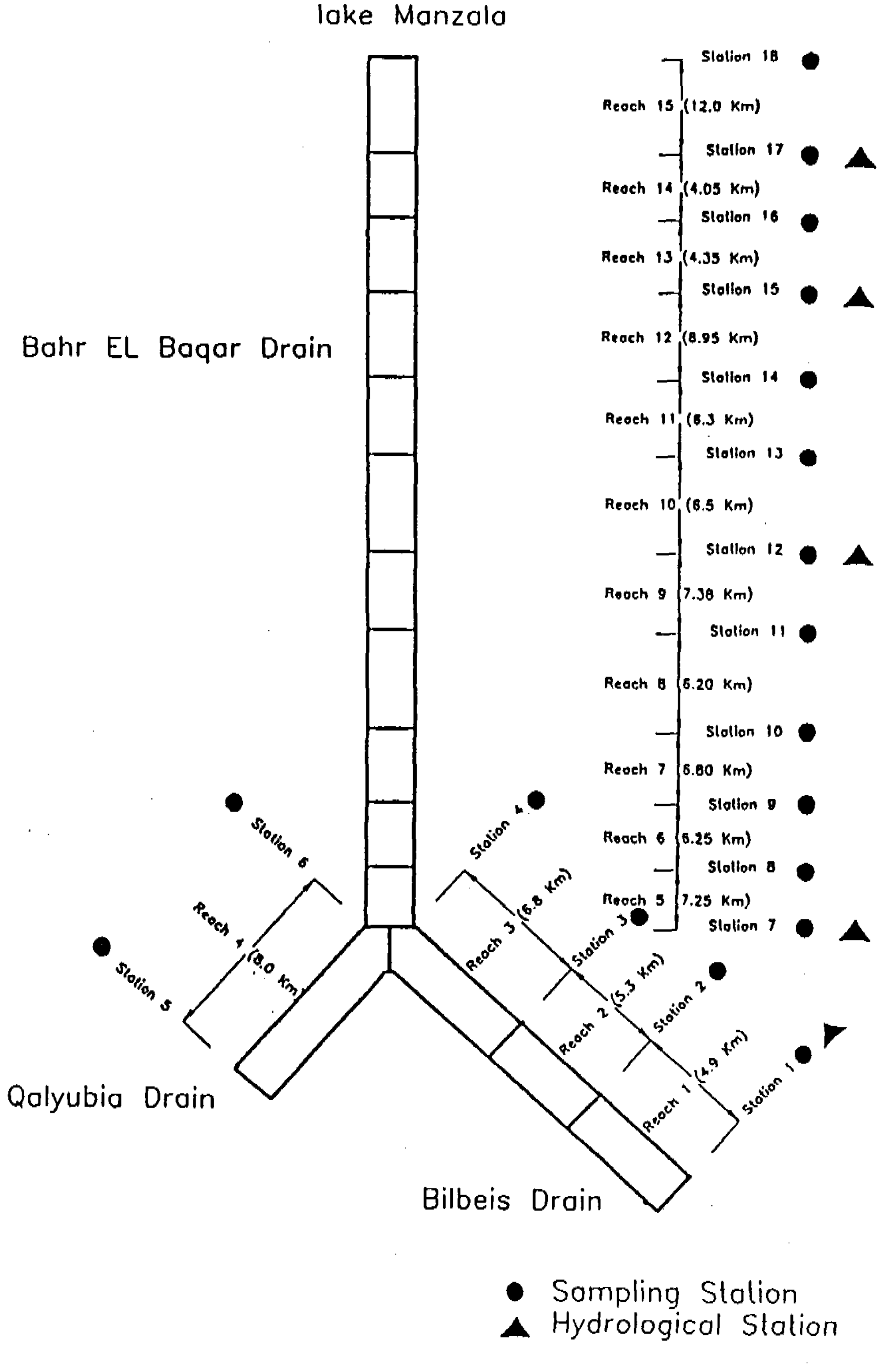

Figure 4 . Scheme of Bahr El Baqar drain System and Measurement network

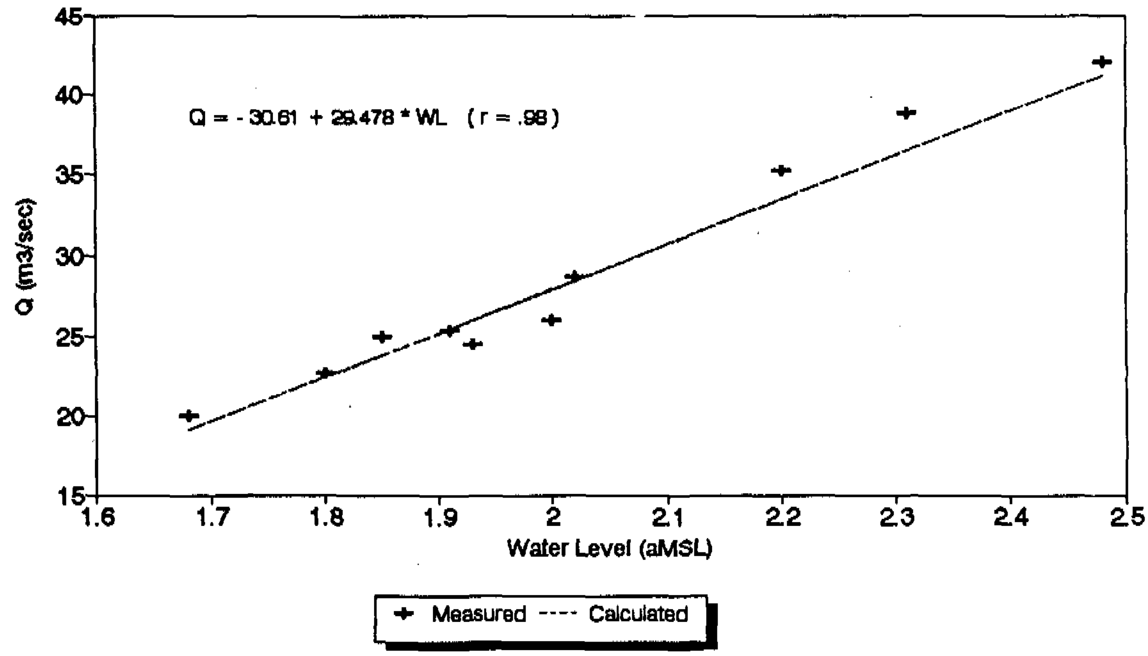

Figure 5. Rating curve for hydrological station no. 12 at saada bridge

4. WATER QUALITY MONITORING

4.1 Water Sampling Station Locations

Three levels of design criteria in selecting sampling station locations are considered in the study (Sanders, 1983):

- macrolocation level which is a function of the study objectives;
- microlocation level which defines a zone of complete mixing and is a function of the hydraulic and mixing characteristics of the drain system;
- representative point locations in the drain's cross section.

The drain system has been divided into 15 reaches and includes 18 sampling stations in such away that the reaches have approximately equal lengths (about 7.0 km) and contain one source of pollution (tributary drain). Scheme of the drain system and the monitoring network are presented in figure (4).

4.2 Monitored Parameters

Water quality can be described in terms of physical, chemical and bacteriological parameters. The monitored parameters were as follows :

Physical parameters

- Temperature - pH - Turbidity

Chemical parameters

- Major ions

  Cations (sodium, calcium, magnesium, potassium)

  Anions (chloride, sulphate, bicarbonate, carbonate)

  EC - TDS - SAR - Adj SAR

- Organic matter

  BOD_5 - COD

- Heavy metals

  Copper - Iron - Zinc - Magnesium - Boron - Arsenic - Cadmium - Mercury - Nickel - Lead - Cobalt - Selenium - Aluminum - Chromium

Microbiological parameters

Total Coliform Bacteria (MPN)

Nutrients

Nitrate - Nitrite - Ammonia - Phosphorus

4.3 Sampling Frequency

For appropriate design frequency the number of samples per year should be 16 samples. Eighteen routine trips have been carried out for 14 months during the period January 1992 to February 1993.

5. RESULTS OF THE STUDY

5.1 Physical Parameters

There are no sources of thermal pollution to Bahr EL Baqar drain system. So, the temperature variations go along with the normal climatic fluctuations. Water odour and color give an authentic indication of its condition. Putrid odour and color are highly noticeable through Bahr EL Baqar drain system. Sulphate is used as an oxygen source by bacteria which convert it to hydrogen sulphide (H_2S) under anaerobic conditions which give rise to the characteristic odour of rotten eggs. PH values for Bahr EL Baqar water range from 7.28 to 7.57 and are within the normal range (FAO, 1985). Turbidity results from the scattering and absorption of incident light by the particles which are caused principally by the presence of colloidal matter, organic matter and microscopic organisms. The results show that the turbidity of Bahr EL Baqar drain system ranges from 16.41 to 29.55 NTU.

5.2 Salinity

This is the most important water quality consideration since it controls the availability of water to the plant through osmotic pressure regulating mechanisms. The results show that the electrical conductivity (EC) ranges from 1.16 to 1.29 dS/m and the total dissolved solids (TDS) from 793 to 891 g/m^3 for Bahr EL Baqar drain system except the last reach where observed values of EC range from 2.67 to 4.48 dS/m and TDS from 1636 to 2724 g/m^3. The salinity increases at the last reach (reach 15) because Bahr EL Baqar pumping station lifts the drainage water into the reach from the northern part of the Eastern Delta. The lifted water is affected by sea water intrusion, seepage of saline groundwater and unofficial reuse of drainage water which causes a corresponding substantial increase in drainage water salinity. The degree of restriction on the use of Bahr EL Baqar drainage water for irrigation is in the slight level but for the last reach, it is in the acute level according to FAO guidelines, 1985.

5.3 Major Ions

The dominant cations and anions in the drainage water of Bahr EL Baqar drain system are in the following order Na > Mg > Ca and SO_4 > Cl > HCO_4 respectively except the last reach which has the following dominant anions order Cl > SO_4 > HCO_4. The major ions presented in table (1), are in the normal range in irrigation water according to FAO evaluation. The average SAR values, which range from 4.11 to 4.79 with average EC value of 1.25 dS/m, give a slight degree of restriction on the use of the drainage water for irrigation. The last reach, which has an average SAR and EC values of 10.38 and 3.28 dS/m respectively, has no effect on infiltration rate into soil according to the FAO guidelines. The normal toxic ions in irrigation water are chloride, sodium and boron. The average Na, Cl and B values are 7.4 me/l, 4.3 me/l and 0.51 mg/l respectively. Boron concentration doesn't cause toxicity problem but sodium and chloride may cause moderate problem for sensitive crops. The average Na, Cl and B values for last reach are 22.69 me/l, 19.52 me/l and 0.62 mg/l respectively. Sodium and chloride in this reach may cause severe problem.

5.4 Heavy Metals

The average Fe, Mn and Zn values are 5.2, 0.12 and 0.31 mg/l respectively. The average Fe value is at the recommended maximum concentration while Mn and Zn concentrations are less than the recommended limits. Al, As, Cd, Cu, Hg and Se are highly toxic while Co, Cr, Pb and Ni are moderately toxic to plant and livestock. The average Al, As, Cd, Cu, Hg and Se concentrations are 0.022, 0.00054, 0.032, 0.096, 0.0038, and 0.021 mg/l respectively. The average Co, Cr, Pb and Ni concentrations are 0.04, 0.0045, 0.154 and 0.039 mg/l respectively. At any rate, the concentrations of the heavy metals in the drainage water of Bahr EL Baqar drain, which are presented in tables (2) and (3), do not reach the value that could cause problems to soil or plants except the cadmium. It is toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l. Conservative limits are recommended, which is 0.01 mg/l, due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.

5.5 Organic Load

Most domestic and industrial wastewater have considerable organic pollution loads, which are measured as the biochemical oxygen demand (BOD_5) and the chemical oxygen demand (COD). The results presented in table (3), show that BOD_5 and COD values range from 50 to 69 mg/l and from 170 to 217 mg/l respectively. The COD values are of an order of magnitude greater than the BOD_5 because the industrial effluents have poor biodegradable compounds.

5.6 Microbial Load

The domestic wastewater represents the major flow of Bahr EL Baqar drain system. It carries faecal pollution which causes the major microbiological health hazards. The data show that the average most probable number (MPN) for Bahr EL Baqar drain system is $2.2*10^6$ cell/100ml and the variation along the drain is insignificant.

6. CONCLUSIONS AND RECOMMENDATIONS

The annual quantity of drainage water in the drain based on 1992 data is 1734 million m^3. The agricultural drainage water discharge is 988 million m^3 which represents 58% of the total drainage water. The industrial wastewater discharge is about 36 million m^3, which represents 2% of the total drainage water, and the domestic wastewater is about 710 million m^3 and represents 40% of the total drainage water.

The official drainage water reuse is 202 million m^3 which represents 12% of the total drainage water. The total losses through the drain system and the unofficial drainage water reuse are 492 million m^3 which represent 28% of the total drainage water.

The change in the drainage water quality of Bahr EL Baqar drain system is insignificant except for the major ions and the salinity in the last reach of the drain system. This reach receives through Bahr EL Baqar pumping station the drainage water from the northern part of the Eastern Delta which is affected by sea water intrusion and seepage of saline groundwater. The high

Table 1. The average values of major ions analysis for water samples.

Segment No.	EC (dS/m)	TDS (g/m3)	PH	SAR	Adj SAR	RSC	Cations (mq/l)				Anions (mq/l)			
							Ca	Mg	Na	K	CO3	HCO3	SO4	Cl
S1	1.26	867	7.44	4.75	9.22	0.00	1.92	3.14	7.58	0.45	0.00	2.54	6.04	4.51
S2	1.26	891	7.45	4.79	9.30	0.00	1.90	3.13	7.57	0.44	0.00	2.47	6.08	4.49
S3	1.25	851	7.35	4.63	9.06	0.00	1.92	3.04	7.46	0.44	0.00	2.51	5.89	4.45
S4	1.24	847	7.42	4.69	8.95	0.00	1.87	3.06	7.25	0.43	0.00	2.51	5.66	4.44
S5	1.26	821	7.46	4.70	7.97	0.00	2.02	3.13	7.00	0.39	0.03	1.61	6.88	4.04
S6	1.29	851	7.46	4.57	8.28	0.00	2.14	3.16	7.30	0.33	0.07	2.14	6.19	4.59
S7	1.16	793	7.38	4.11	7.86	0.00	1.92	3.14	6.56	0.36	0.00	2.34	5.42	4.22
S8	1.21	807	7.48	4.29	8.01	0.00	1.98	3.22	6.66	0.36	0.00	2.40	5.47	4.35
S9	1.20	801	7.33	4.45	7.93	0.00	1.98	3.23	6.55	0.36	0.00	2.41	5.42	4.29
S10	1.21	853	7.33	4.77	8.44	0.00	2.11	3.44	6.97	0.39	0.00	2.57	5.81	4.54
S11	1.20	831	7.45	4.68	8.21	0.00	2.06	3.36	6.77	0.38	0.00	2.50	5.64	4.43
S12	1.21	851	7.38	4.54	8.97	0.00	1.84	3.28	7.30	0.35	0.00	2.64	5.85	4.27
S13	1.18	811	7.38	4.36	8.45	0.00	1.80	3.20	6.84	0.34	0.00	2.58	5.43	4.17
S14	1.26	855	7.28	4.62	8.86	0.00	1.93	3.16	7.42	0.34	0.00	2.35	6.23	4.28
S15	1.27	861	7.47	4.70	8.93	0.00	1.95	3.19	7.46	0.34	0.00	2.37	6.26	4.32
S16	1.28	873	7.47	4.74	9.05	0.00	1.98	3.23	7.58	0.35	0.00	2.40	6.36	4.38
S17	1.24	832	7.41	4.62	8.78	0.00	1.85	3.09	7.28	0.32	0.00	2.35	5.82	4.37
S18	3.28	2059	7.37	10.38	19.85	0.00	3.02	7.00	22.69	0.47	0.05	2.16	11.50	19.52

Table 2. The average values of heavy metals analysis for water samples.

Segment No.	AL mg/l	AS mg/l	Cr mg/l	Cd mg/l	Pb mg/l	Hg mg/l	Se mg/l	Co mg/l	Ni mg/l
S7	0.0222	0.0006	0.0057	0.0185	0.121	0.004	0.021	0.032	0.038
S18	0.0225	0.0005	0.0034	0.047	0.189	0.004	0.022	0.049	0.041

Table 3. The average values of microbiolgical, organic matter, heavy metals analysis for water samples.

Segment No.	BOD mg/l	COD mg/l	MPN Cell/100ml	Turbidity NTU	Fe++ mg/l	Zn++ mg/l	Cu++ mg/l	Mn++ mg/l	B mg/l
S1	69	205	1761000	19.84	5.37	0.28	0.07	0.12	0.59
S2	67	215	2300000	18.14	5.00	0.19	0.11	0.11	0.65
S3	68	217	2060000	17.96	4.62	0.31	0.09	0.12	0.64
S4	67	207	2290000	18.63	4.72	0.38	0.08	0.12	0.51
S5	59	202	2700000	19.57	5.10	0.39	0.10	0.11	0.57
S6	63	201	2410000	19.92	5.14	0.36	0.09	0.10	0.51
S7	65	206	2220000	20.35	3.75	0.31	0.09	0.11	0.48
S8	65	204	2310000	27.48	5.41	0.39	0.16	0.12	0.45
S9	61	207	1450000	24.69	5.00	0.38	0.09	0.17	0.61
S10	62	197	1760000	22.49	6.50	0.42	0.08	0.12	0.61
S11	60	186	2310000	21.98	5.93	0.38	0.11	0.14	0.48
S12	54	190	1702000	23.03	5.29	0.21	0.11	0.11	0.48
S13	54	187	1888800	27.86	5.90	0.35	0.12	0.20	0.54
S14	55	185	1540000	27.36	5.59	0.25	0.11	0.12	0.58
S15	53	181	3590000	25.01	5.36	0.27	0.09	0.10	0.38
S16	50	182	2500000	19.75	5.36	0.22	0.12	0.12	0.56
S17	51	177	2630000	16.41	5.31	0.22	0.07	0.09	0.51
S18	50	170	2870000	29.55	4.73	0.21	0.09	0.11	0.62

salinity at the last reach can cause severe problem to crops and soils. Also sodium and chloride can cause severe toxicity problem to crops.

The major pollution problem of Bahr EL Baqar drain system is the microbiological health hazards. At any rate, the concentrations of the heavy metals in the drainage water do not reach the value that could cause problems to soils or plants except the cadmium.

Drainage water reuse can prevent eutrophication of Lake Manzala, where uncontrolled disposal can contribute to nutrient overloading.

Waste stabilization ponds (WSP) are the recommended methods for destroying pathogens in the receiving domestic wastewater especially in our warm climate wherever land is available at reasonable cost. Following WSP treatment, the effluent can be used for irrigation without a need for further disinfection.

The industrial activities, which produce effluents containing high concentrations of heavy metals especially cadmium, should reduce their wastes by recycling and have their own proper treatment plant.

The deposition, which has been occurred through out the drain system, has high concentrations of heavy metals especially Qalyubia drain. If the maintenance will be carried out for the drain system, the deposition should not be applied to the agricultural land.

The crops are grouped into three broad categories A, B and C with regard to the degree to which health protection measures are required (WHO Scientific Group, 1989). The guidelines for unrestricted use (<1000 faecal coliforms/100 ml and <1 viable nematode egg/l) can be used to irrigate all crops (category A) without further health protection measures. Bahr EL Baqar drainage water exceeds the guidelines limit for category (A). Therefore, wastewater treatment is required to achieve the microbiological quality. In general, protection is required for farm workers and their families who remain at high risk. The recommended crops for the present low microbiological drainage water quality are cereal crops, fodder crops, industrial crops and trees.

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ASSESSING PERFORMANCE OF IRRIGATION AND DRAINAGE; EXAMPLES FROM EGYPT

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ABSTRACT

This paper is a case study on assessing performance of irrigation and drainage, and recommends a specific set of indicators for measuring performance that are generally applicable. The paper gives examples based on data from Egypt. The primary focus is on the assessment of irrigation performance with respect to its impact on the need for drainage. The paper also discusses indicators that can be used for assessing longer term performance, including environmental sustainability.

Key words: Performance, Irrigation, Drainage, Management, System, Egypt

1. INTRODUCTION

Water is one of the precious resources in Egypt, and with the growth of population it will become more precious. In addition, water increasingly will be used by other user-groups than agriculture (domestic, industrial, energy, navigation). Besides, all users tend to pollute water to such an extend that reuse may become a problem. To anticipate on future constraints, current water use must be monitored by using agreed performance indicators and related target levels should be set for these indicators. If a deviation from the target level then is foreseen, correcting measures should be planned and executed.

Since the construction of the Aswan High Dam in 1968, the water balance of Egypt can be summarized as shown in Table 1:

[1] International Institute for Land Reclamation and Improvement (ILRI), P.O.Box 45, 6700 AA Wageningen, The Netherlands.

[2] Drainage Research Institute, Cairo, Egypt

[3] Research Institute for Groundwater, P.O.Box 13621/5, Delta Barrage (El-Kanater), Cairo, Egypt.

Table 1 Water balance for the Nile downstream of Aswam (in m^3x10^9 per year, flow data from World Bank 1992)

	1980-86	1987-88	1988-89	1989-90	1990-91
INFLOW					
Release at Aswan	57.67	52.98	53.34	54.00	53.80
IRRIGATION					
Consumptive use *)	34.13	33.14	33.65	34.16	34.21
Overall efficiency	0.59	0.63	0.63	0.63	0.64
OUTFLOWS					
at Edfina & Nubariya	5.13	2.68	2.77	1.84	1.48
Municipal & Industrial use	2.31	2.77	2.94	3.11	3.29
System Evaporation	2.00	2.00	2.00	2.00	2.00
Drainage to the Sea	14.00	12.39	11.97	12.88	12.82
Drainage over Inflow	0.24	0.23	0.22	0.24	0.24

*) Contains drainage outflows at the tail of some canal systems, being estimated at about 1.3 Bm^3 per year.

The volume of water released at Aswan may increase by about 2 Bm^3/y upon the completion of the Jonglei Canal. However, with the anticipated growth of (agricultural) development in the upstream Nile countries, water availability, both in terms of quantity and quality, may be under pressure.

If we consider the Nile valley and Delta downstream of Aswan as one large irrigation (and water supply) system, the overall efficiency of irrigation water use of 0.64 (64%) is rather good. This value, however, only is attained because drain discharges and groundwater flows from upstream command areas return to the Nile, and are reused again. As such, part of the Nile flow is reused several times before it is delivered to the most downstream command area. Every time water is used, however, its quality will deteriorate. The water quality at the downstream end of the 'Nile System' influences the percentage of water that must be discharged to the sea in order to avoid environmental problems within the irrigated area (Note that this discharge may cause environmental side effects in the sea).

As shown in Table 1, the System Drainage Ratio, being defined as

$$\text{System Drainage Ratio} = \frac{\text{Total Drained Vol. Water System}}{\text{Actually Delivered Vol. into System}}$$

equals about 26% if the considered time horizon is one year. This percentage consists of 24% being drainage to the sea plus 2% being water drained at other location (e.g. Lake Qarun, Aquifers). If the System Drainage Ratio is calculated for each month, these monthly values will fluctuate around the annual value: e.g. it will be relatively low in July and relatively high in January. Immediately the questions then arise:

1 What is the target value of the System Drainage Ratio on an annual and monthly basis?

2 Can the higher values that occur during part of the year be reduced? In other words: what are the causes for the actual value(s) of the System Drainage Ratio, and can these cause be altered?

In this context we should realize that the System Drainage Ratio has a lower limit in order to avoid the accumulation of salts, chemicals and solids within area served by the considered system. Hence, the lower limit assures sustainable (agricultural) development in the considered area.

The volume of water that must be drained (to the sea) to assure sustainability depends on (i) the quality of the water near the downstream part of the system, and (ii) on the level of flow control at the outlet(s). It further depends on the water demands of other users such as (iii) energy production and (iv) navigation.

i If upstream agricultural, urban and industrial users would pollute water to such a level that reuse is not possible, more water needs to be drained (to the sea). Please note that although the discharge of pollutants solves a problem in the drained area, an other problem will be created in the disposal area. To minimize this disposal problem, the volume of discharged pollutants should be as low as practical.

ii One of the major reasons to discharge water to the sea is to avoid sea water intrusion into the river branches, and thus avoid salinity near the most downstream irrigation intake structures. The degree of sea water intrusion basically is determined by the flow velocity in the river branch and by the level of flow control at the river mouth.

Neither the technical characteristics nor the operational schedule of the existing structures is within the scope of this paper. With respect to both, however, the water quality of the incoming flow play a significant role. The water quality should be sufficiently high to avoid that the river reach upstream of the structures becomes a disposal site.

iii The generation of hydro-electric energy is a major user of water. The relative importance of the various water users is recommended to be reviewed regularly. In this context, the effect of the user on the volume (and value) of water that is drained to the sea should be taken into consideration.

iv Navigation demands minimum water depths. These water depths may be produced by a related flow rate or by a system of barrages and shipping locks. The latter solution, however, results to low flow velocities. The water quality then must be sufficiently high to prevent pollution of the river bottom.

The System Drainage Ratio also is a relevant indicator to evaluate the drain discharge from sub-systems. Additional information will become available if the time steps are shortened to e.g. one month. An example for The Fayoum is shown in Figure 1. A review of the data in Figure 1, immediately leads to some questions; e.g.:

1 What is the target (intended) value of the ratio for each month?

2 How wide are the margins of tolerance above and below this target value within which no corrective measures need to be taken?

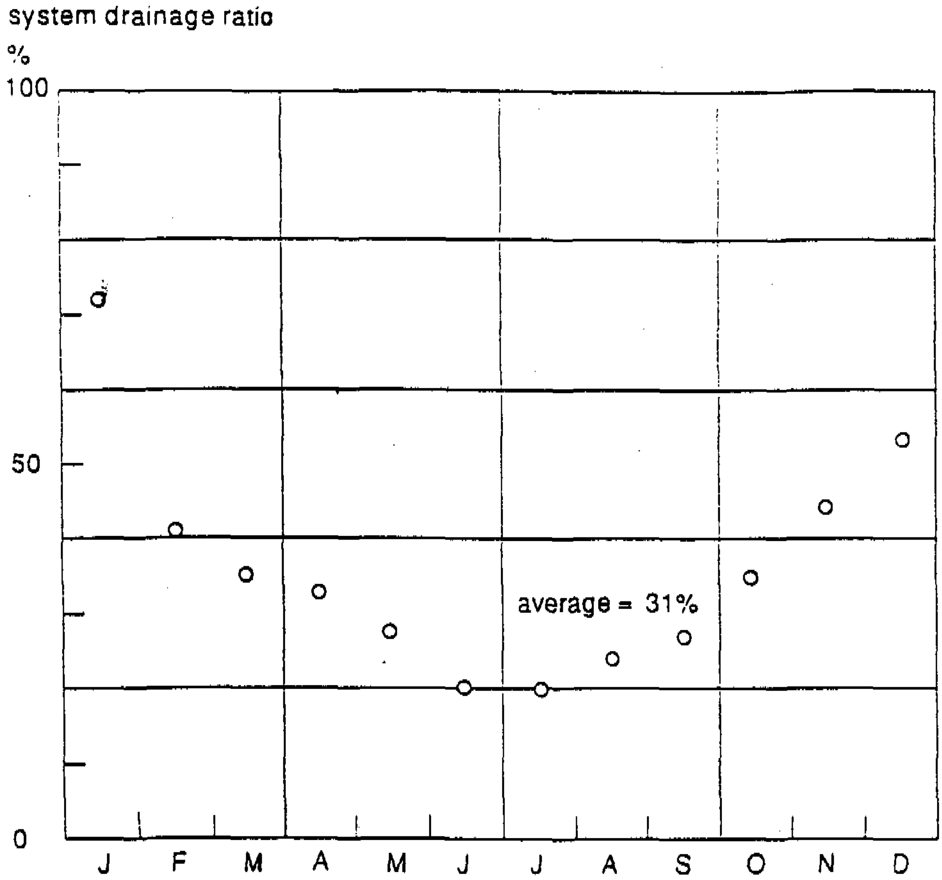

Figure 1 Monthly values of the System Drainage Ratio for The Fayoum (1983-86 averages).

3 By which deviation from the target value are Management, Operation or Maintenance actions needed?

4 By which deviations (different ranges below and above the target) occurs a critical situation?

In this context we thus may stress that performance assessment is possible only if a target level has been established for the performance indicator. Next, the above ranges that trigger action should be established. Both, the target level and the ranges are strongly influenced by the local conditions.

2. PERFORMANCE ASSESSMENT AT SUB-SYSTEM LEVEL

At mentioned above, the entire Nile Valley and Delta may be considered as one large (irrigation) water supply system with the river as its main conveyance channel. Within this larger system, however, we may delineate a number of irrigated areas which (within the classical terminology on 'what is an irrigation system') may be classified as an independent irrigation (sub-)system. Each of these (sub-)systems receive water at one location from the

Nile (or its branches), and discharge groundwater and surface water back to the Nile (or to an aquifer or an evaporation lake).

Irrigation Performance Assessment within such a (sub-)system is based on the interaction between 'irrigation' and 'performance assessment' within the (day-to-day) work of the water supplier, the water user and the (agricultural) community. 'Irrigation performance' can be viewed from different perspectives. In this context we define 'irrigation' and 'performance' as follows:

> **Irrigation** is the *human intervention* to modify the spatial or temporal distribution of water occurring in natural channels, depressions, drainage ways, or aquifers and to manipulate all or part of this *water to improve crop growth* (Small & Svendsen 1990).
>
> **Performance** is the degree to which an *organization's products and services* respond to the *needs of their customers* or users, and the *efficiency with which the organization uses the resources* at its disposal (Murray-Rust & Snellen 1993).

In assessing the performance of irrigation, the above definitions yield a number of key issues (Bos e.a. 1993):

1. Irrigation is a human intervention in which the actors are an organization and its customers.
2. Water is delivered so as to improve crop growth.
3. A level of service has been (or has to be) agreed upon between the organization and its customers.
4. In the use of their resources (water, energy, manpower, funds), the organization and the customers aim to achieve a defined target level of efficiency.

Combining these key issues from a water delivery perspective yields:

$$\textit{Agreed Service Level} = \frac{\textit{Intended Volume of Delivered Water}}{\textit{Required Volume of Irrigation Water}}$$

The value of this ratio may differ from unity for all sorts of reasons:

1. The available water resources may be insufficient to cover the summed (crop) irrigation water requirements within the command area. This water shortage may occur: throughout the growing season, during one or two months of the peak season, or during a dry year (say once every 5 years).
2. The irrigation water is intended to be delivered according to historic water rights. These rights are not necessarily equal per unit (irrigated or cropped) area. Current water rights may be changed during the life of the project because of legal changes or because of changes of water allocation to competing water users (urban and industrial).
3. The cropping pattern and thus the 'required volume' within all or part of the command area may change from time to time as crops with a low water requirement change to those with a high requirement (or vice versa).

The setting of the *'Agreed Level of Service'* involves not only the system designer or the manager and the customers, but also higher level staff in agencies and at national planning and policy level. The Agreed Service Level may differ for systems in the valley, the delta and in the various newly reclaimed areas. The level also may differ from month to month. It is recommended to (re)define the Agreed Service Level for all (sub-)systems at a monthly basis. At a later stage, a shorter period (10 days) might be needed during some critical periods. The Agreed Service Level leads to the intended volume of water that is to be delivered into a canal during a related period. If this intended flow cannot be determined, there will be no yardstick against which performance can be measured!

The 'Agreed Service Level' has a major impact on the design concept of the irrigation infrastructure within the (sub-)system. If the infrastructure has few water control structures it will be difficult to agree on a change in the Service Level at a later date.

3. WATER BALANCE INDICATORS

Water supply performance parameters are concerned with assessment of the water supply function of the conveyance system: they cover the volumetric component that is primarily concerned with matching water supplies to irrigation water demand, as well as the rather more subjective concept of reliability that may affect the users' capacity to manage water efficiently, and the socially oriented aspects of equity. These three aspects all represent facets of the concept of **Level of Service** being provided to water users.

We focus our attention on this "core business" of the organization managing the "main system", the diversion and conveyance of water to the (sub-)systems along the Nile, in the Delta, and in the new lands. The parameters can be divided into a number of sub-groups that address different objectives of operation and maintenance of the system. These include parameters that address conveyance, the utility of water for agriculture, and performance in respect of water allocation.

3.1 Conveyance Indicators

The primary task of the managers of the 'Nile Irrigation System', and of the managers of the (sub-)systems is to deliver water in accordance with a plan (as intended). Indicators in this section are therefore those that guide managers in respect to water delivery performance.

3.1.1 Water Delivery Performance

The simplest, and yet probably the most important, hydraulic performance indicator is:

$$\textit{Water Delivery Performance} = \frac{\textit{Actually Delivered Volume of Water}}{\textit{Intended Volume of Delivered Water}}$$

This measure enables a manager to determine the extent to which water is delivered as **intended** during a selected period and at any location in the system (IIMI 1989; Clemmens

& Bos 1990; Bos e.a. 1991; Wolters 1992; Bos e.a. 1993). The primary utility of the Water Delivery Performance ratio is that it allows for checking of whether the flow at any location in the system is more or less than intended. It is obvious that if the actually delivered volume of water is based on frequent flow measurements, the greater the likelihood that managers can match **actual** to **intended** flows. Over a sufficiently long time frame (e.g., monthly, or over three or four rotational time periods) it can be assumed that if the Water Delivery Performance ratio is close to unity, then the management inputs must be effective. If the Water Delivery Performance ratios for different units within the considered command area have about the same value, the uniformity of water delivery must (because of continuity) be good. The uniformity of actual water delivery may be quantified by calculating the standard deviation of the WDP values.

Figure 2 shows the Water Delivery Performance for five tertiary units within the Bahr Seila command area (Fayoum). The figure informs the irrigation manager that:

1 The Bahr Seila command area actually receives only 75% of the intended flow.
2 The upstream unit B manages to obtain its intended flow.

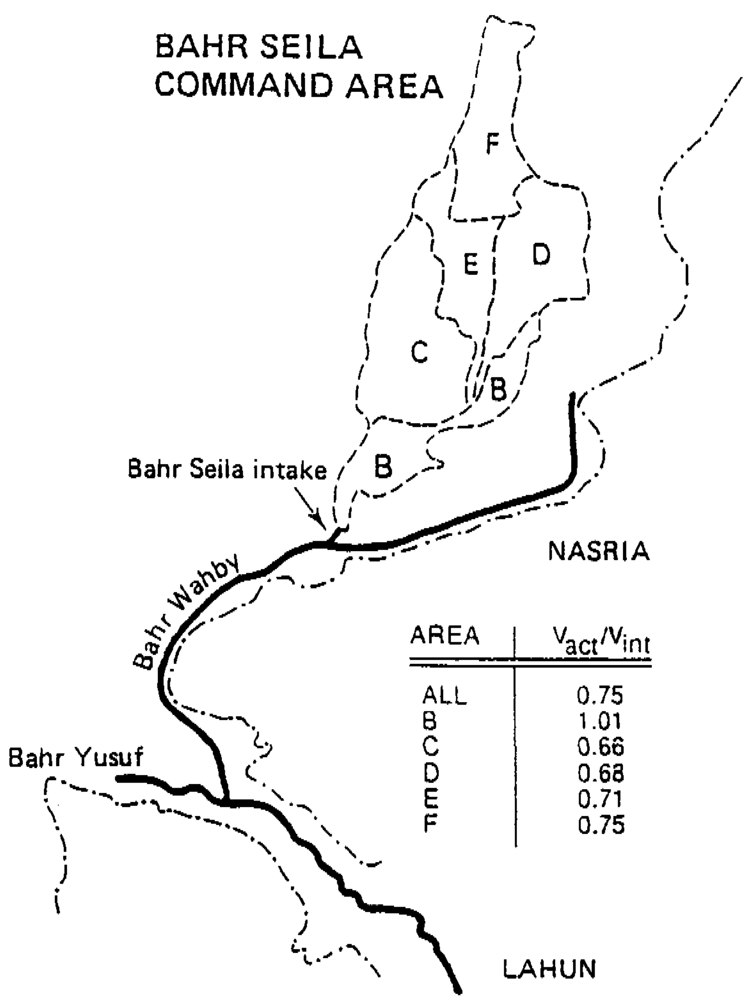

Figure 2 Location of the sub-units of the Bahr Seila, Fayoum

3 The other four units all receive roughly the same flow. The uniformity within these units is reasonable (s = 0.04).
4 The uniformity of water delivery for the entire Barh Seila command area, as quantified by the standard deviation, equals s = 0.14.

3.1.2 Efficiency

A related set of indicators refers to the efficiency of irrigation water use. In general, efficiencies deal with volume delivered within a set time period rather than instantaneous flow rate. Efficiencies quantify components of the water balance in a spatial context over a specific time period. Indicators of efficiency have been discussed in detail by Bos and Nugteren (1974) and Wolters (1992). In this paper we only consider the overall efficiency of irrigation water use within the (sub-)system.

Overall or Project Efficiency

The overall (or project) efficiency quantifies the water balance of the irrigated area. It is defined as:

$$e_p = \frac{V_m + V_2 + V_3}{V_c + V_1}$$

V_c = volume of irrigation water diverted or pumped from the river or reservoir
V_1 = inflow from other sources to the conveyance system
V_2 = non-irrigation deliveries from the conveyance system
V_3 = non-irrigation deliveries from the distribution system
V_m = the volume of irrigation water needed, and made available, to avoid undesirable stress in the crops throughout the growing cycle.

The order of magnitude of the latter volume is difficult to establish because many complicated measurements would be needed. The method which is used to quantify V_m, however, is not so very important provided that the same (realistic) method is used for all (sub-)systems. For practical purposes we may assume that V_m equals the evapo-transpiration by the irrigated crop minus the effective part of the precipitation: ET_{crop} - P_e. Because this volume is entirely determined by the crop, the climate and the interval between water applications, the actual value of the overall efficiency varies with the actual value of V_c being the volume of irrigation water delivered to the (sub-)system(s).

Because the inflows V_c and V_1 are among the very first values that should be measured, together with the cropped area, the cropping pattern and climatological data, the overall efficiency is the first water balance indicator that should be available for each (sub-)system. It is recommended to calculate the overall efficiency at a monthly and annual basis. Figure 3 shows an example for the Fayoum and Esna (data from Wolters e.a. 1989; Euroconsult e.a. 1993).

- Retreat of the shoreline along Damietta promontory: The pattern of retreat is depicted in Figure (7.b) , showing severe erosion in this location thus exerting severe damage to the coastal road and agricultural land in this area.

- Flooding of Damietta-Port Said road: This is a major problem exerted on such vital road thus causing interruption of transportation and various human activities that depend on the availability of such road.

- Salt water intrusion: This phenomena is due to the entrance of sea water into the lagoons thus affecting the water quality and increasing the salinity levels. The mixing of fresh water from drainage outlets along the landward shores of the lakes with sea water affect the water quality and its usage for agriculture and other purposes.

Several protective works to remedy the above problems and data concerning these works have been documented in [4].

2.3 THE EASTERN SECTOR

This sector extends over a length of 200 km, it occupies the area between Suez Canal in the west up to Rafah in the east. The coast in this region has one hump at its middle part ,which is El Bardawil barrier, of about 90 km in length. It separates El-Bardawil lagoon from the sea. El Bardawil lagoon itself has three outlets connecting it to the sea. All three outlets are experiencing siltation and even closure problems. As mentioned the sea level rise is about 3 mm/year [3] at Port Said region which has an effect on the sea level in this sector. Also local rates of subsidence of the ground in this region is about 3.6 mm/year, these are based on tidal records [9]. El-Bardawil lagoon is characterized by a high salinity of its water due to sea water intrusion and due to the lack of inflow of the fresh water. Also evaporation rate is appreciably high. An overview of data for this lagoon is given in tables no. 4 & 5, [4].
Erosion problems and land loss are observed east of El-Zaraneek outlet of El-Bardawil lagoon. Constructions af El-Arish harbour contributed to erosion problems in this sector affecting an area that extends approximately 1500 m long of the coastal zone and about 50 m inland to the east of El-Arish port. This resulted in the loss of a large number of characteristic palm trees in this area. Siltation problems in the lagoon outlet are also experienced. Control measures and protective works are proposed to control such problems. Groins were constructed on the eastern side of El Arish port to protect this area from erosion [4].

Table No. 4: Hydrological Data for El-Brdawil Lagoon

Area (km^2) Wet Dry	 600 100
Inlets	3
Inflow (km^3/year) Rain (km^3/year) Evaporation (km^3/year) Outflow (km^3/year)	0 0.04 1.50 -1.54
Salinity (ppt)	41 - 68
Temperature (°C) Winter Summer	 12.7 30.5 - 34

Table No. 5: Water Body of El-Bardawil Lagoon

Lake	Bardawil
Area in km^2: Wet Dry Total	 600 100 700
Shore in km: Length Protected Roads	 160 75 -
Depth in m: Average Maximum	 1.5-2 3

3. CONCLUSIONS

In this manuscript the different coastal processes and related problems along the Northern Coast of Egypt were discussed. Such problems have a bearing on the social and economical impacts on the land utilization, human activities, and hence on decision related to water qualities and demands in these regions. It is felt that a comprehensive and integrated plan for managing the water demands should take such issues into consideration in order to determine the nature of social and habitat activities, both on a short and long range scales, that take place in these areas.

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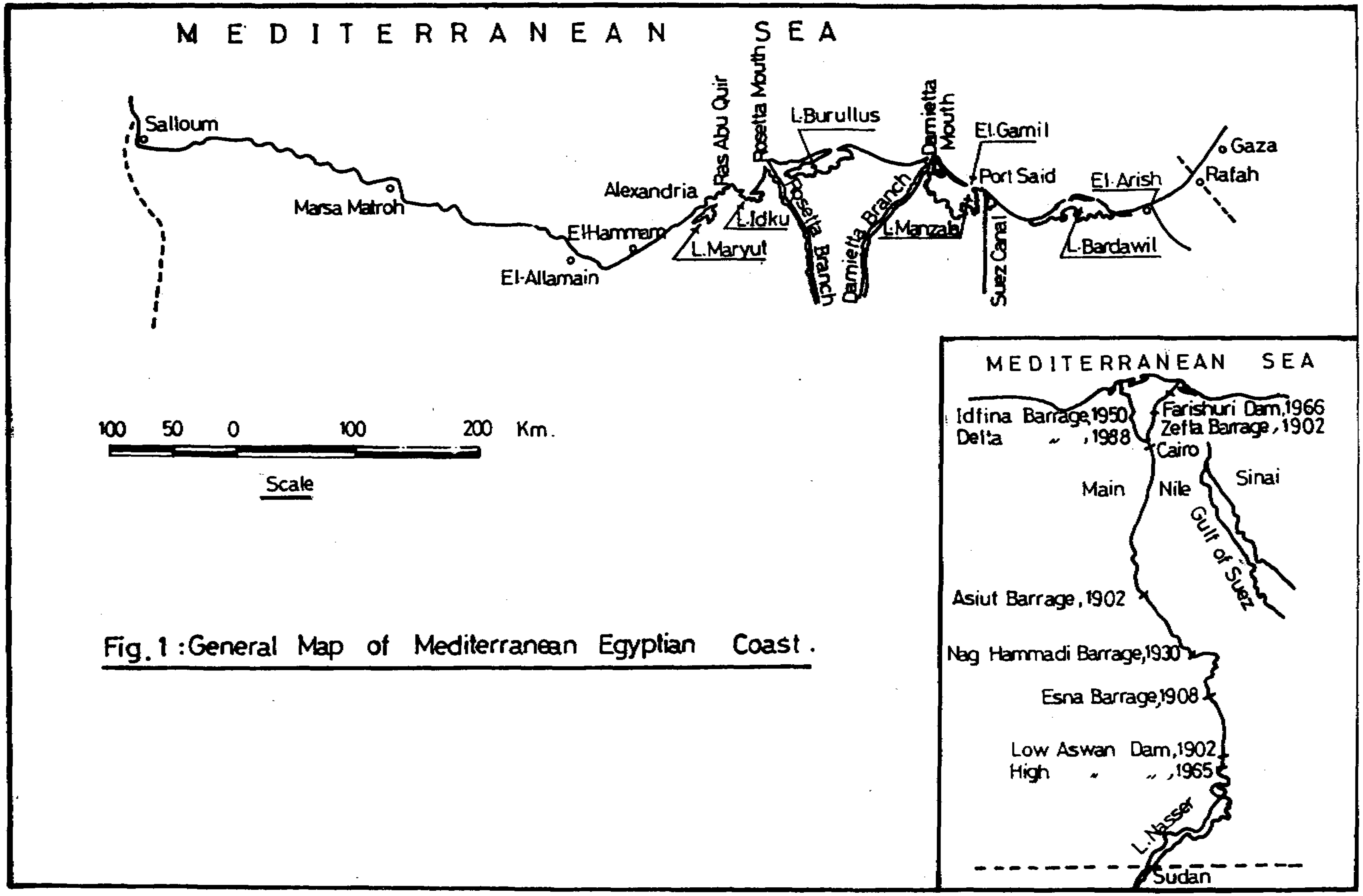

Fig. 1 : General Map of Mediterranean Egyptian Coast.

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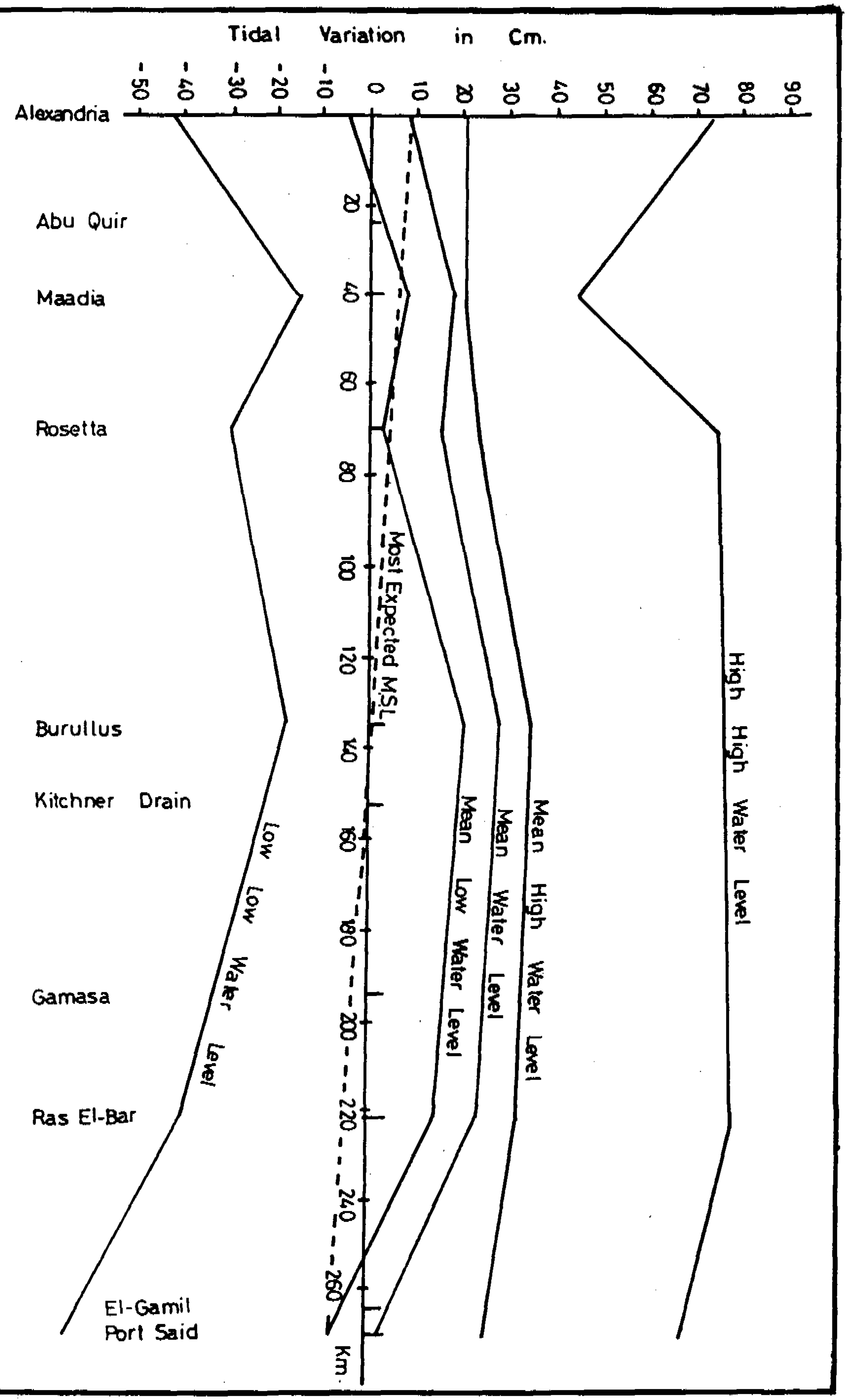

Fig. 2 : Tidal Variations along the Coast.

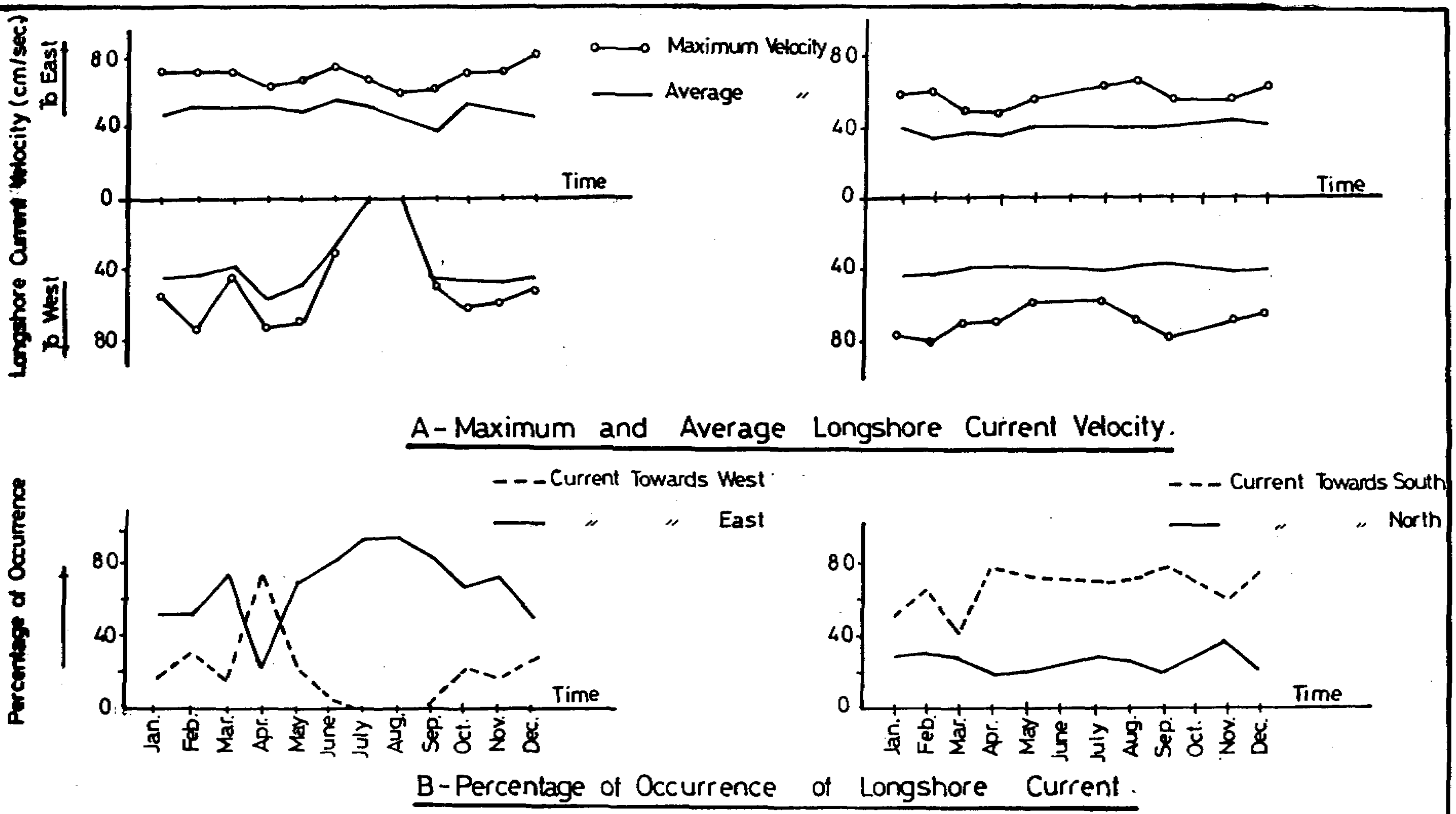

Fig. 3a: Variation of Current Velocity and Percentage of Occurrence at Burullus Area for the Year 1988.

Fig. 3b: Variation of Current Velocity and Percentage of Occurrence West Rosetta Promontory for Year 1988.

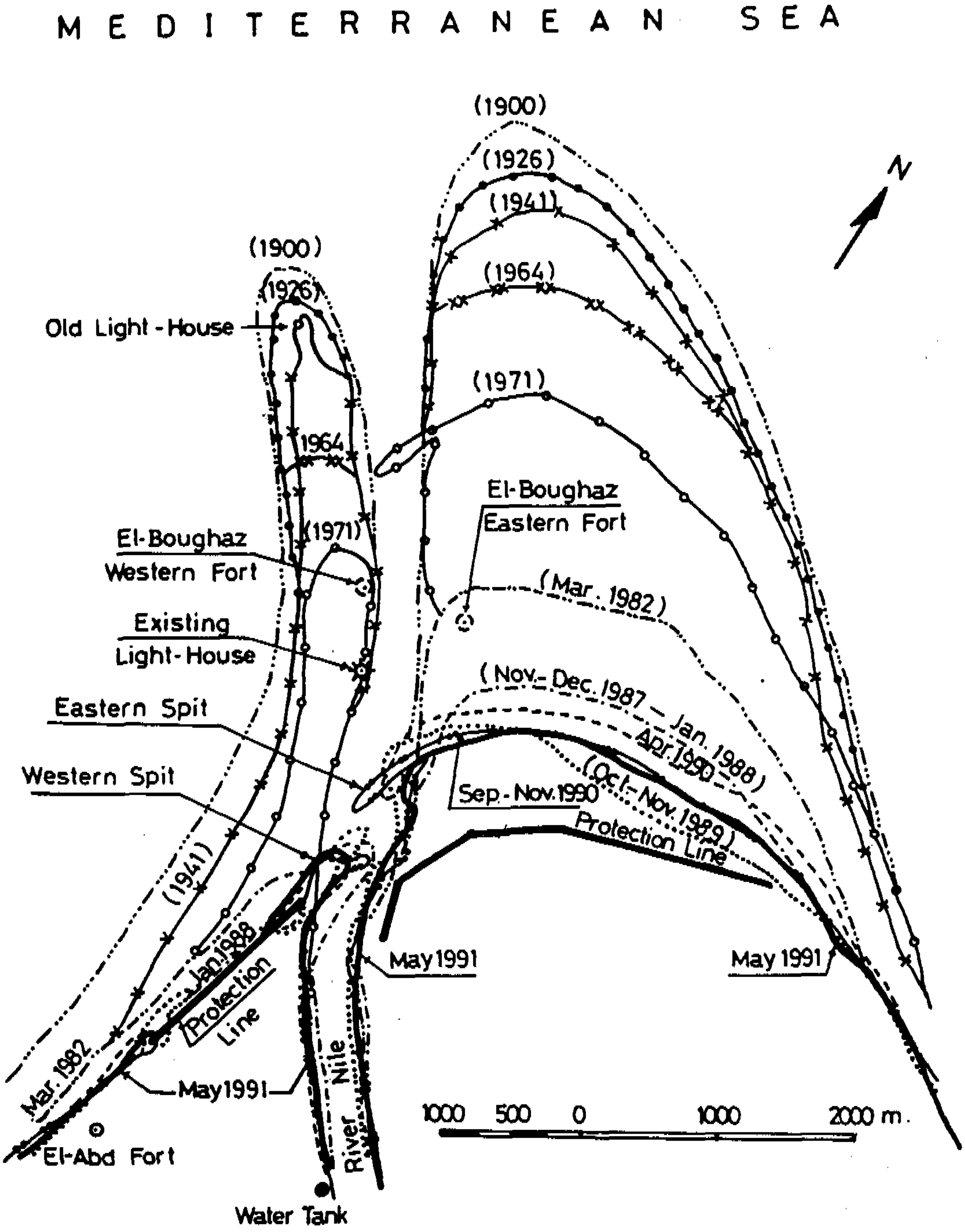

Fig. 4 : Retreat of Rosetta Promontory During the Period from 1900 to 1991.

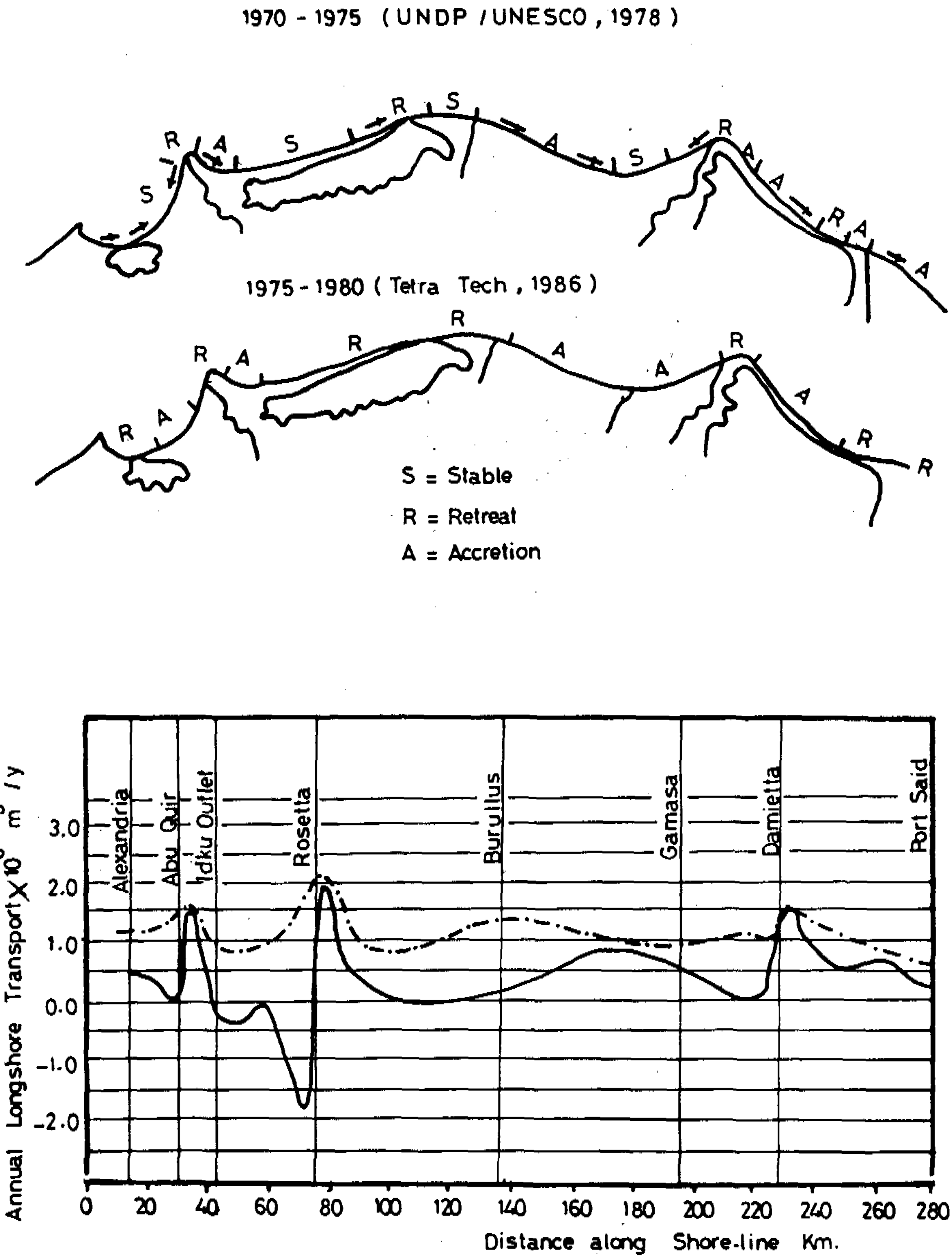

Fig.5a : Accretion , Erosion and Longshore Transport (UNDP/UNESCO, 1978 and Tetra Tech, 1986)

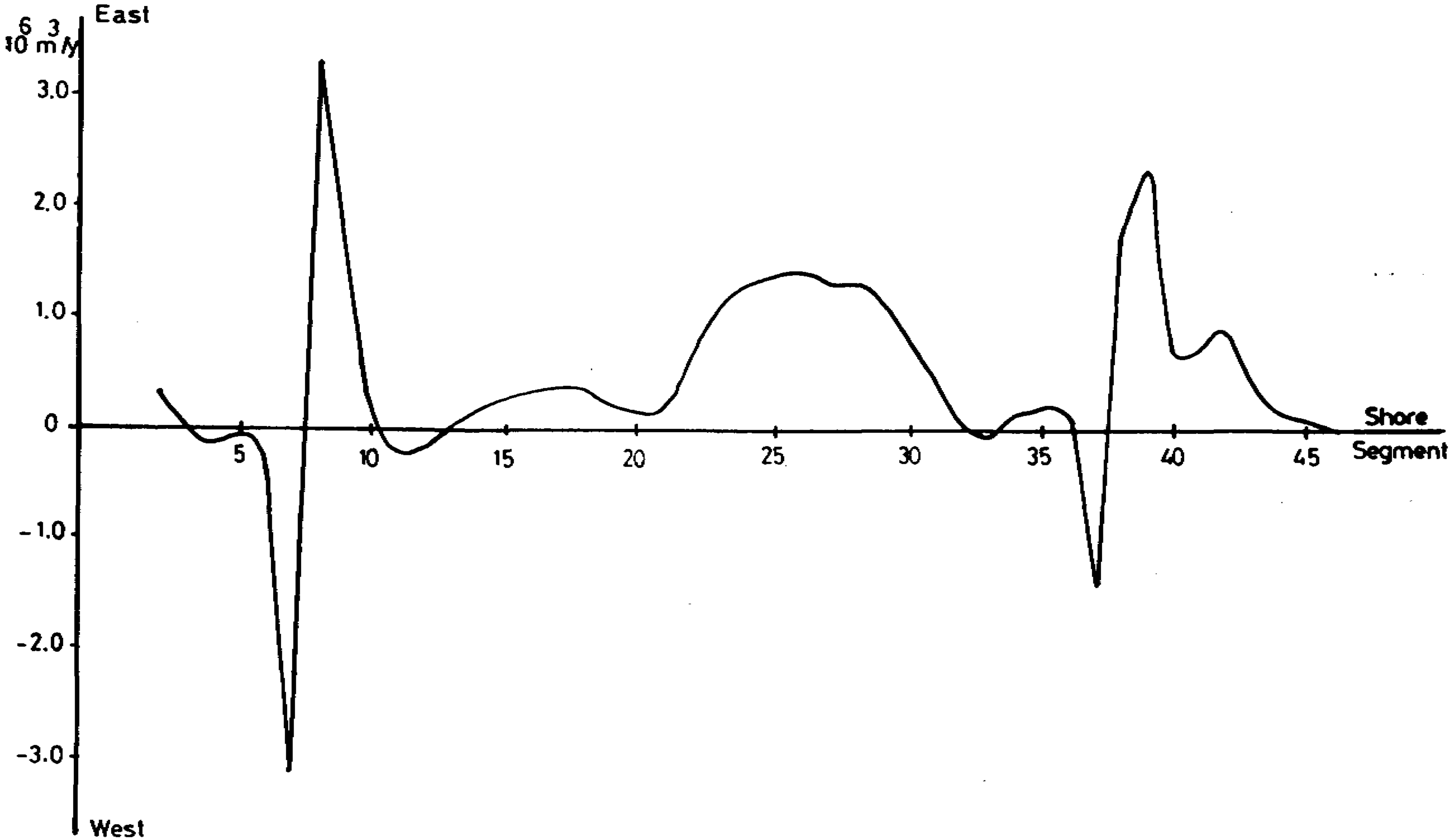

Fig. 5b : Potential Erosion , Accretion and Longshore Transport Rates (UNDP / UNESCO , 1978)

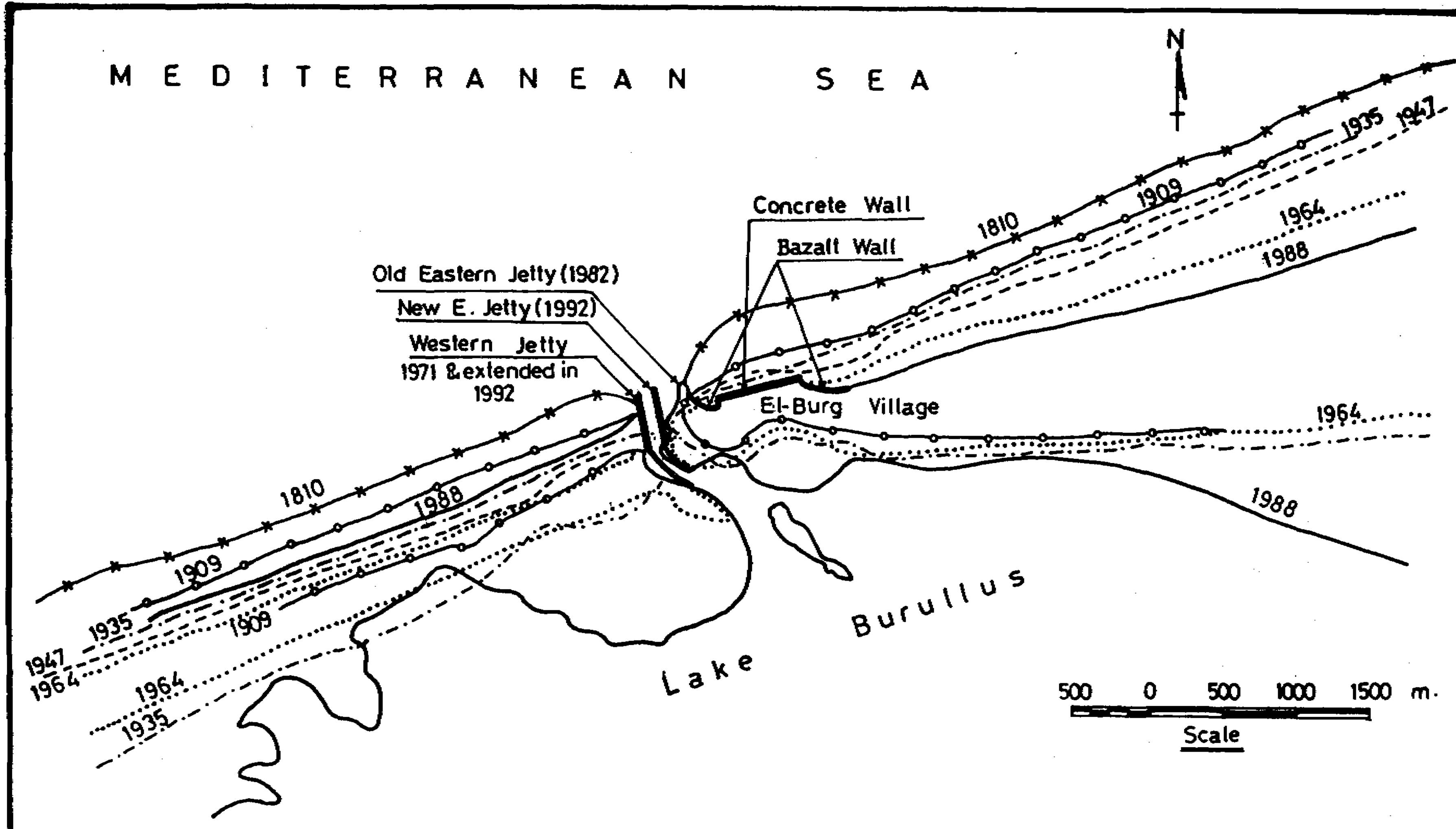

Fig. 6 : Shore-line Changes at Burullus Headland from 1810 to 1988.

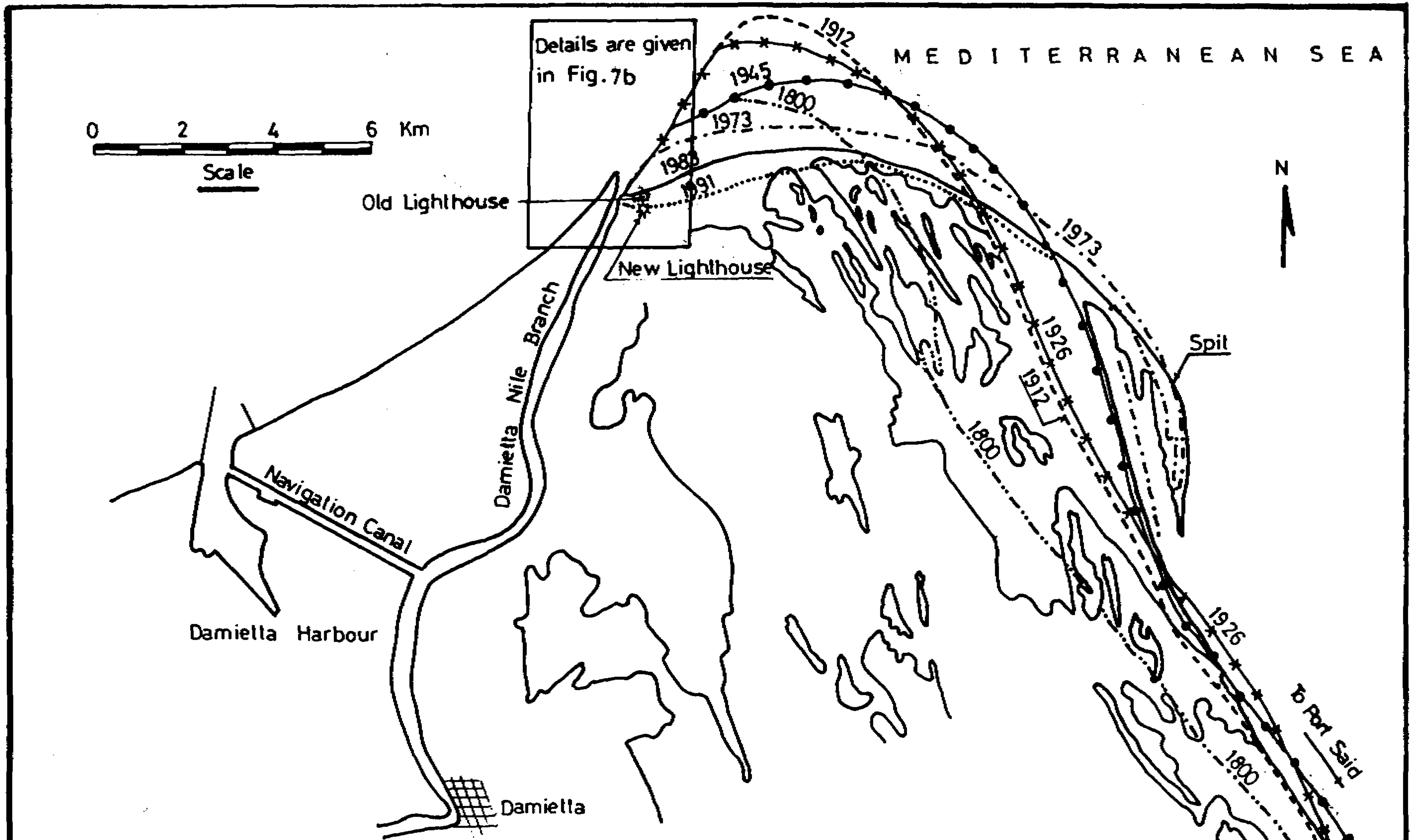

Fig.7a. Evolution of the Shoreline and Spit Formation on the Eastern Side of Damietta Promontory.

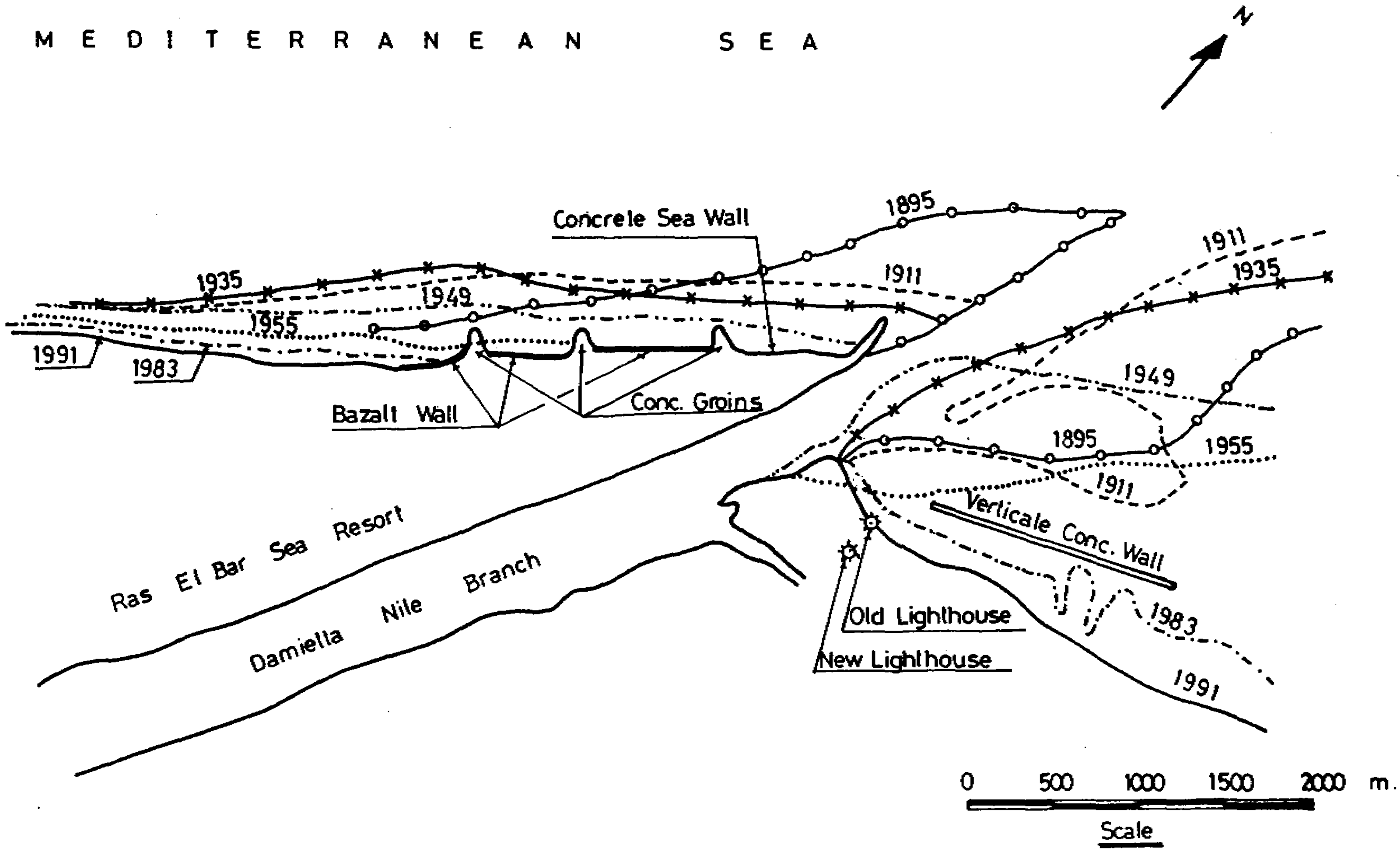

Fig.7b. Shoreline Changes (1895 - 1991) at Damietta Promontory . (Long Term)

POTENTIAL CLIMATE CHANGE IMPACTS ON NILE BASIN

Dr. Magdy Saleh[1], Dr. K. Strzepek[2] and D. Yates[3]

ABSTRACT

The Nile Basin among other four main river basins: Le Plata, Mekong, Indus and Zambezi were the focus of recent research project "Complex River Basin Management" in which basins were studied to evaluate the climate change impacts. The main goals in each basin's analysis were to: 1. assess the physical and social elements that are sensitive to climate change in each basin and evaluate its variation over time; 2. simulate the impacts of climate change scenarios on the water resources of the studied basins; 3. assess and when possible, quantitatively simulate the water related resource impacts of changes in basin water supply; 4. identify potential adjustments to climate change through empirical studies and interactions with basin decision makers; and 5. evaluate potential adjustments in basin management and planning.

The above objectives were the main targets of the climate change study on the Nile basin. Climate changes analysis showed mixed results in terms of future flow yields. Two GCMs showed reductions in flow whereas another GCM showed 30% increase in yield at Aswan. After obtaining the initial results of the Nile basin climate impacts assessment, an extension study was initiated in which Egypt was selected as a model for an integrated study for evaluating the climate change impacts on sea level rise, global agriculture and human health.

1. GREENHOUSE PHONOMENA

The temperature of the earth is a balance of the short wave radiation coming from the sun, its loss by longwave radiation from the earth, the atmospheric absorption of the some of the longitudinal radiation and finally radiation a fraction of the gained back to the earth . Carbon Dioxide (Co_2) allows the penetration of sun radiation but absorbs the longwave radiation in a way similar to the glass in a greenhouse. Therefore, Co_2 has been considered responsible for "greenhouse effect" because of trapping the solar heat inside. Human activities in burning fossil fuel are the major causes for Co_2 production. Oceans dissolve half of the produced Co_2 and the rest added to the atmosphere, causing an increase in the Co_2 level. Since the beginning of the industrial revolution Co_2 is in continuous increase; it reached 316 parts per million by volume (ppmv) in 1959 with a present level of 350 ppmv. In addition to Carbon Dioxide, Methane and Nitrons Oxide contribute to the greenhouse effect but with a smaller percentage. Climatologists have agreed that a doubling of Co_2 levels is expected by year 2060, which will eventually raise the global temperature 2 to 5 °C causing a global warming.

Global warming may also cause a sea level rise rangeing between 30 to 130 cm in the next century. The impact of global warming on water resources will be directly transferred to the

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[2] Prof. of Civil Engineering, University of Colorado at Boulder, USA

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agriculture sector. The change in moisture, heat or wind will affect the crop yields. the change in crop yield will govern the farm income, food supply and the whole economy. In general, the agriculture production is dependent on three types of resources other than climate: natural resources (soil, topography, water resources); capital resources (fertilizers, animal and machinery), and human resources (labor, market and management).

2. MODELING BASELINE SCENARIO

In order to predict the Nile Basin waters under climate change scenarios, the present conditions should be modeled and calibrated. Then such a model can be applied to estimate the Nile flow yield under new projected precipitation and temperature climate conditions. Therefore, the Nile Basin was modeled by dividing it into its major basins: the Equatorial Lakes basin, the Sudd basin, the White Nile Basin, the Blue Nile basin, and the Atbara basin. The Equatorial Basin is divided into four catchment areas and three lakes, each modeled separately. In addition, the Sudd basin is a simplified representation of the entire White Nile catchment from Mongalla to Malakal, including the Sobat River. All the swamps are represented as one and modeled via the water balance method described by Suttcliffe and Park (1987).

All of the catchments are modeled in a lumped, one-dimensional water balance model with spatially-weighted parameters. Precipitation and temperature surfaces were obtained from GRASS (Geographic Resources Assessment System, US Army Corp. of Engineers) GIS. to determine precipitation and temperature surfaces of monthly average values on a 25 x 25 km grid for the entire basin. Catchment boundaries were delimited on these surfaces and the weighted average monthly value of precipitation and temperature was calculated for each of the four major catchment areas.

The average monthly precipitation values were used directly in the model, but temperature was used to derive average monthly PET using the Thornwaite method (Shaw, 1987). Thornwaite was chosen because Oliver (1948) successfully used the Thornwaite approach to study PET in the Nile basin.

The soil moisture and groundwater are modeled in study area by separate water balance models with exchanges between them. Input to soil moisture is the balance of water remaining after interception losses and direct surface runoff. Direct surface runoff is a linear function of the soil moisture. The groundwater component of runoff is modeled as a non-linear function of storage in the groundwater zone.

With precipitation and PET determined, the model was calibrated by fitting four parameters: surface runoff coefficient, interception factor, and the coefficients of the non-linear groundwater runoff equation. For most basins, these parameters are constant over the year. For two of the basins, wet season and dry season parameters were needed.

The Equatorial Lakes were modeled using a monthly mass-balance approach with catchment inflow, direct lake precipitation and lake evaporation equal to PET. The model used the lake's elevation-area-storage-curves and non-linear outflow storage curves (WMO, 1970). No calibration was needed for the lakes.

The swamps of the Sudd are modeled using the mass-balance and non-linear reservoir approach of Suttcliffe and Park (1987). Inflow to the swamps was the catchment runoff plus the spill from the Bahr el Jabel. Contribution to the White Nile flow at Malakal from the Sudd was the discharge from the swamps.

The model results compared with the naturalized historical flow is presented in Table 1. The modeled results are considered the reference points which provide the BASE scenario in the climate change analyses.

Table 1. Comparison Between the Naturalized Historical Flow (MCM) and Model results At Aswan

Month	Historical Flow	Modeled Flow
JAN	3.63	4.75
FEB	2.61	4.26
MAR	2.01	3.4
APR	1.69	2.95
MAY	1.75	2.72
JUN	2.33	2.67
JUL	6.26	6.38
AUG	17.53	16.96
SEP	20.47	18.02
OCT	14.07	11.27
NOV	7.57	7.39
DEC	4.8	5.27
Annual	**84.72**	**86.03**

3. CLIMATE CHANGE SCENARIOS

3.1 General Circulation Models (GCMs)

Climate forecasting and generating climate change scenarios are approached by one of two means: empirically or analytically. In an empirical method, climate data are collected to analyze past climate change or to provide information about the present warming conditions. In an analytical method, simulation models are applied to generate climate scenarios according to given set of input parameters.

In simulation models, the climate system components, (atmosphere, cryosphere, oceans, and land and biosphere) are represented by the mathematical formulas of their natural behavior. These formulas are applied to the globe after dividing it into grid cells of few kilometers width and length; where as the atmosphere is divided into several layers. Super fast computers are required to solve the atmosphere formulas. The integration of the formulas represent what is called general circulation modes.

In the Nile basin climate study; three general circulation models are applied : Goddard Institute for Space Studies (GISS); Geophysical Fluid Dynamics Laboratory (GFDL); and United Kingdom Meteorological Office (UKMO).

3.2 Climate Change Modeling Results

According to the USEPA the following guidelines were defined for all country studies research team: 1. Use the years 1951 through 1980 as baseline conditions or as much data as available during the same period; 2. Use GCMs for doubled Co_2 and transient scenarios; and 3. Use arbitrary scenarios to test sensitivities. It is recommended to use 2 °C and 4 °C warming with no change in precipitation and 20% increases and decreases in precipitation, applied with the base period.

According to the above guidelines, the climate change of the Nile basin is emulated by the GFDL, UKMO and GISS GCM scenarios. To assess climate change effects, the GCM grids are overlaid on the historic monthly temperature and precipitation surfaces in the GIS. Monthly precipitation and temperature changes between the one and two times CO_2 scenarios for each grid cell provide new surfaces. These new precipitation and temperature surfaces are considered the input conditions for the developed Nile Basin model. Table 2. presents the base and GCMs obtained temperature and flow.

New catchment-weighted average climate parameters were calculated from the new temperature and precipitation surfaces. For the sensitivity analysis, spatially-homogeneous changes in temperature (2 and 4 °C) and precipitation (20%) were applied to the absence climate parameters.

Table 2. Nile Basin Determined Temperature and Flow

Scenario	Temperature (C)	Flow (milliard m^3)	% of Base
Base	0	86	100
GFDL	3.15	20	23
UKMO	4.73	76	88
GISS	3.45	112	130

Table 3. Nile River Flows Under Sensitivity Analysis

Preciptation *	-20	20	0	0	-20	-20	20	20
Temperature **	0	0	2	4	2	4	2	4
Flow (MCM)	32	147	39	8	10	2	87	27
% of Base	37	171	46	10	12	2	101	32

* Basin-wide average change as percentage of Base
** Basin-wide average delta T degrees Celsius over Base

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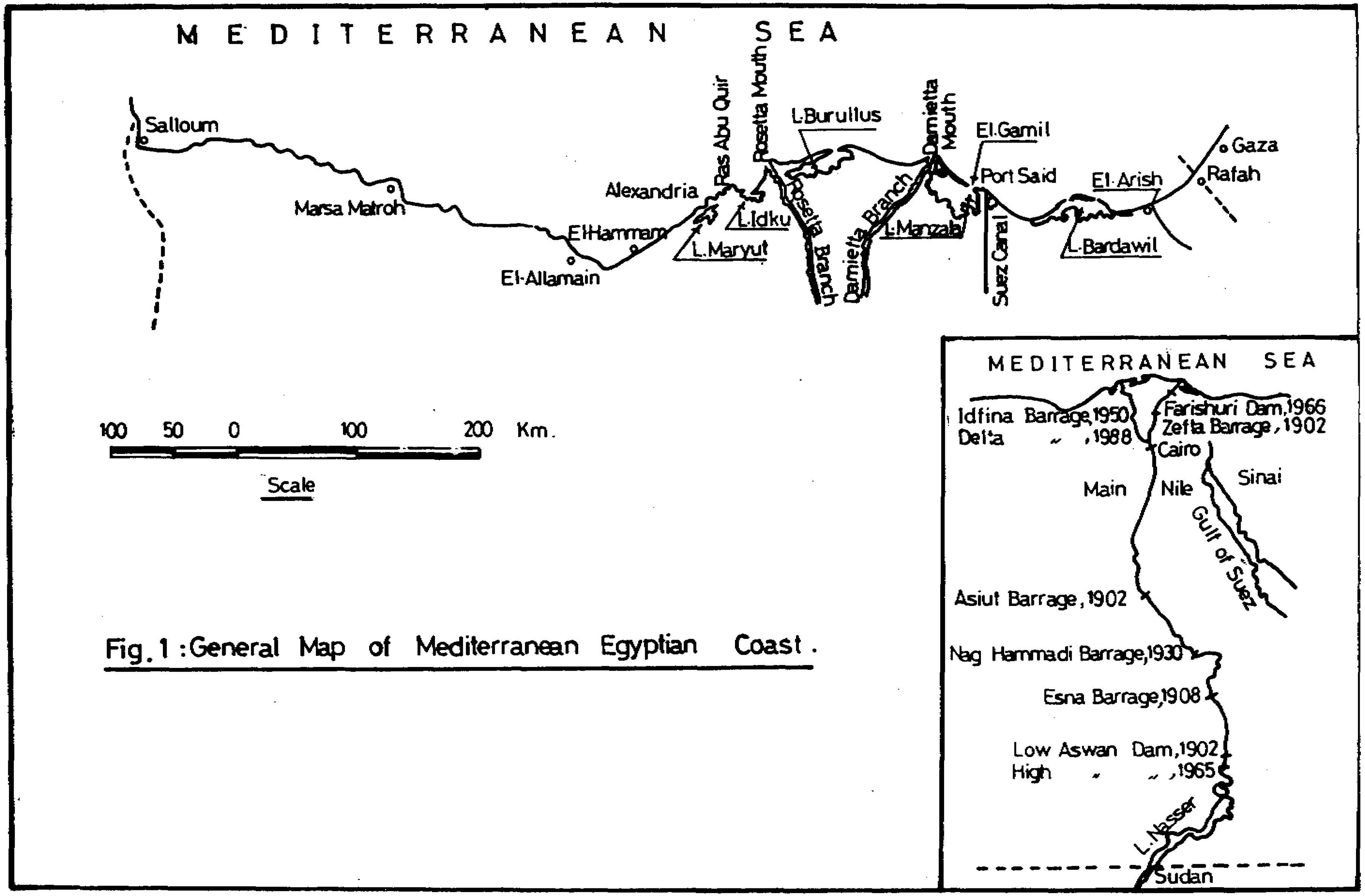

Fig. 1 : General Map of Mediterranean Egyptian Coast.

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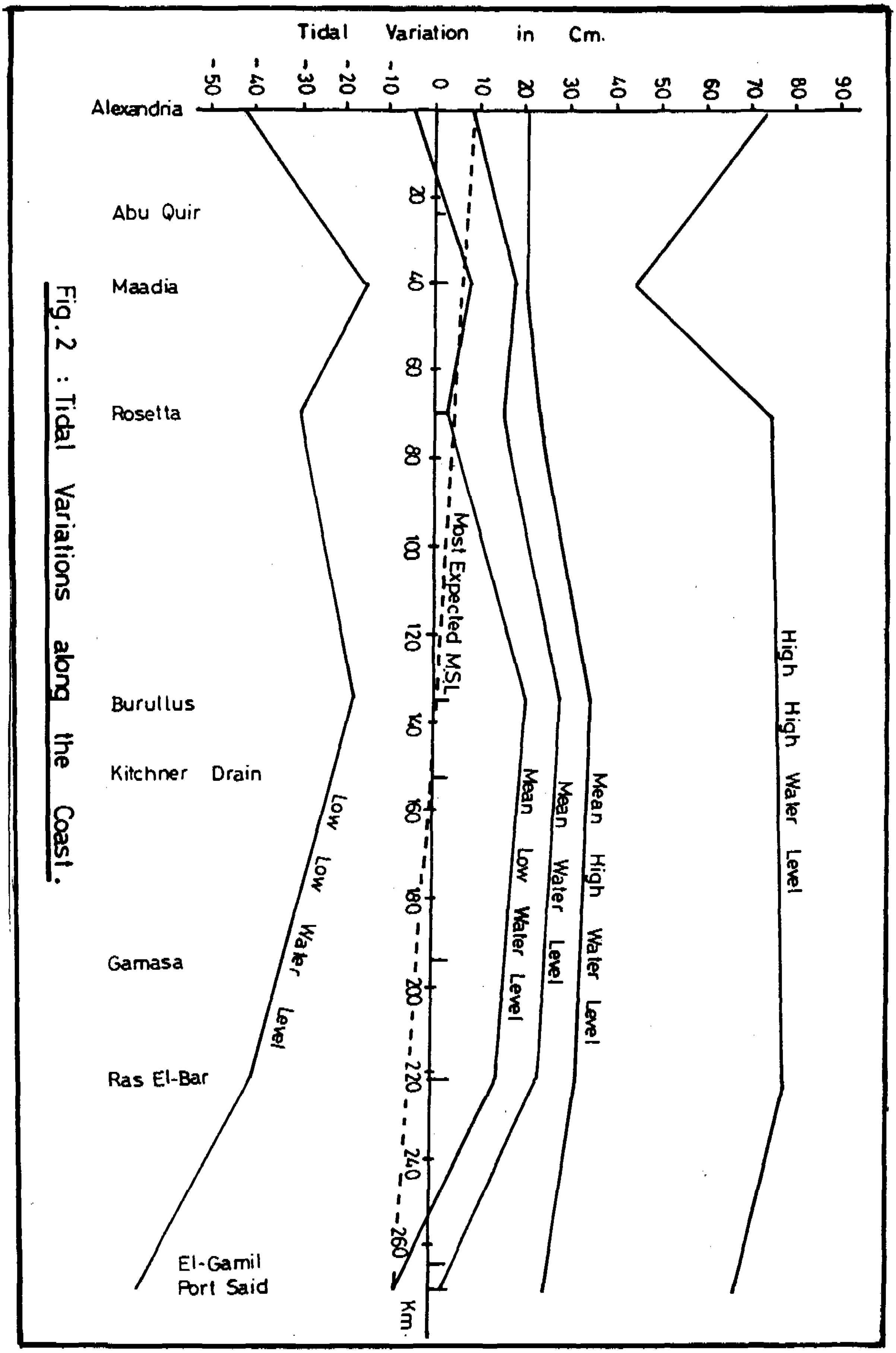
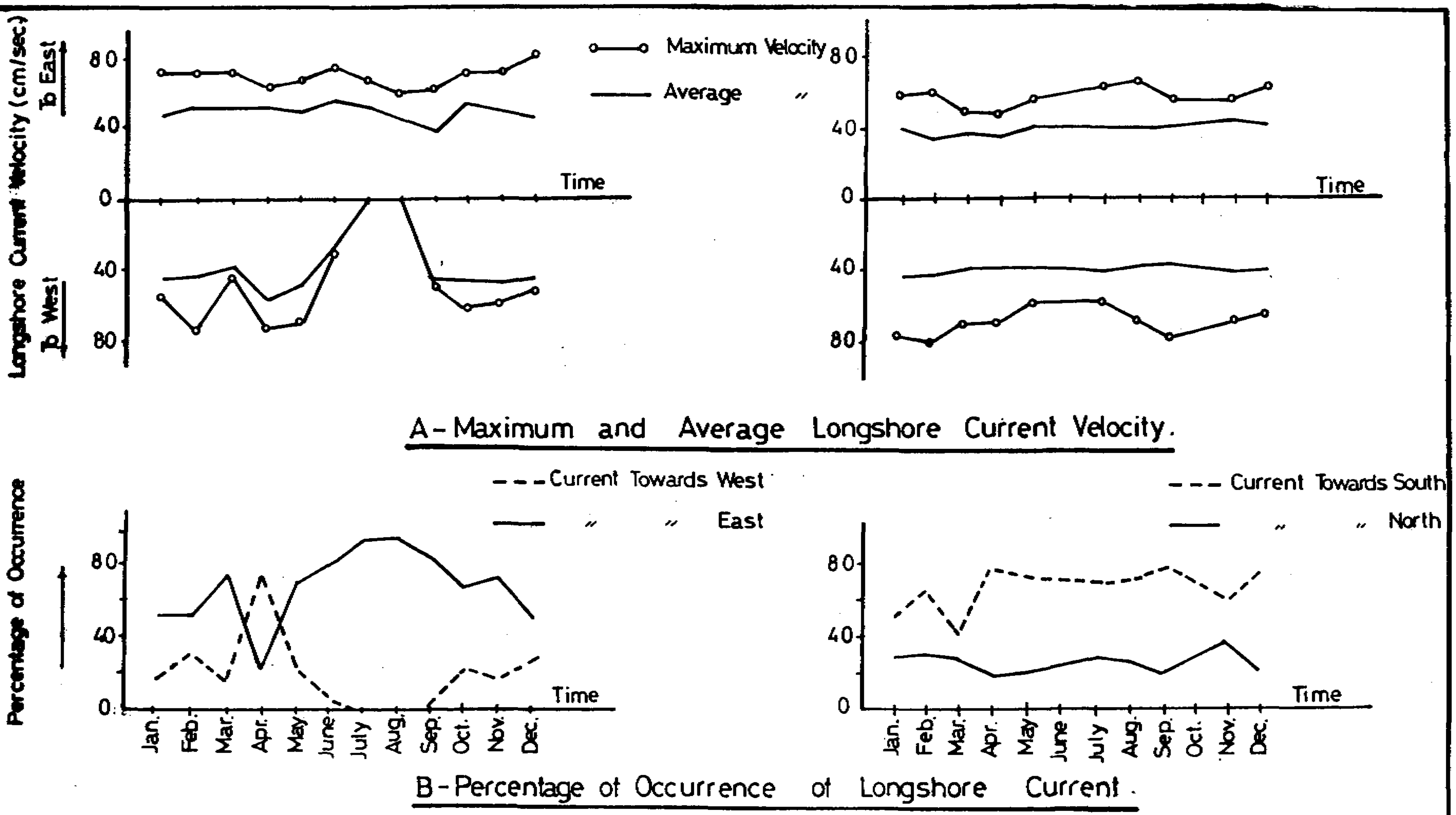


Fig.2 : Tidal Variations along the Coast.



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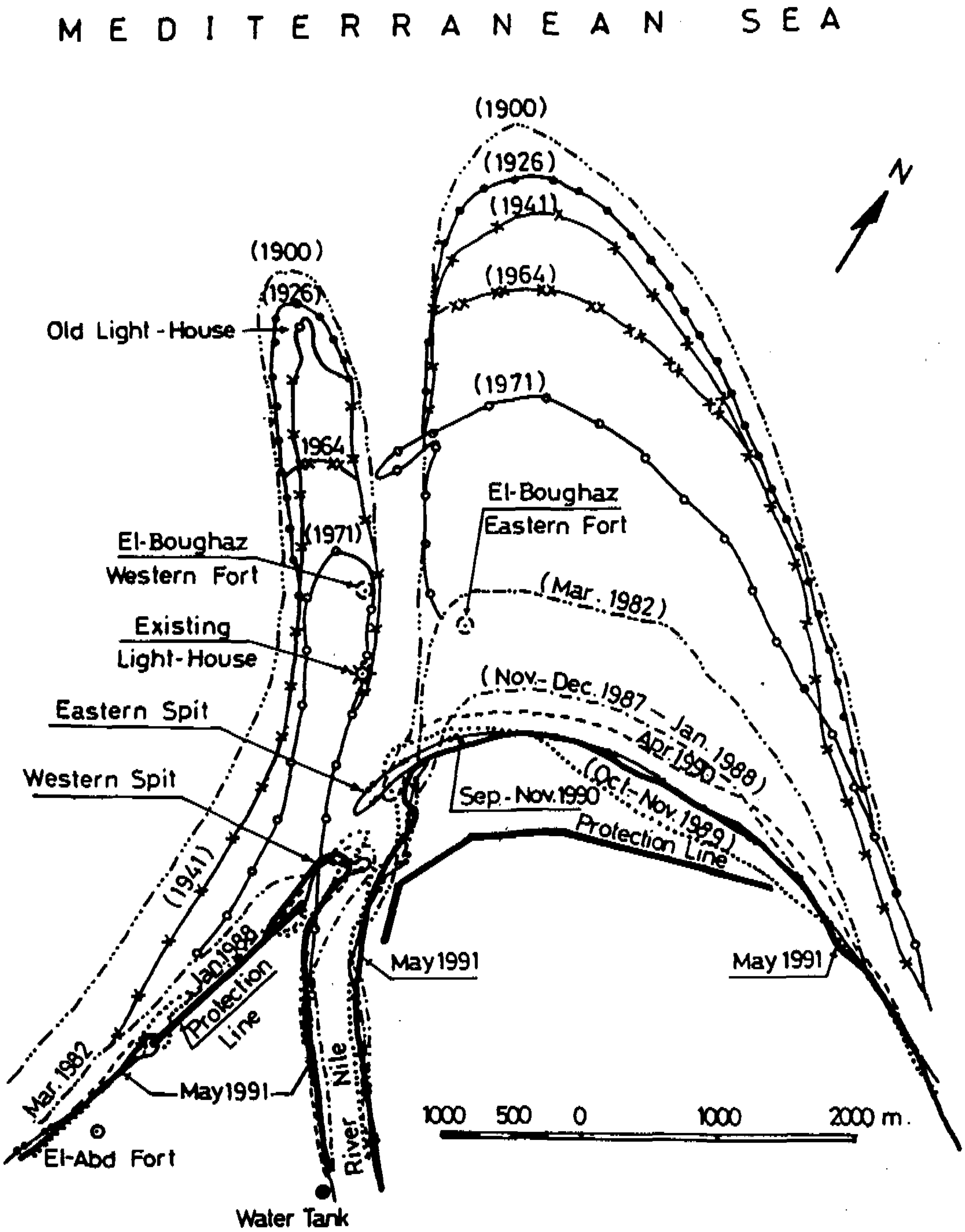

Fig. 4 : Retreat of Rosetta Promontory During the Period from 1900 to 1991.

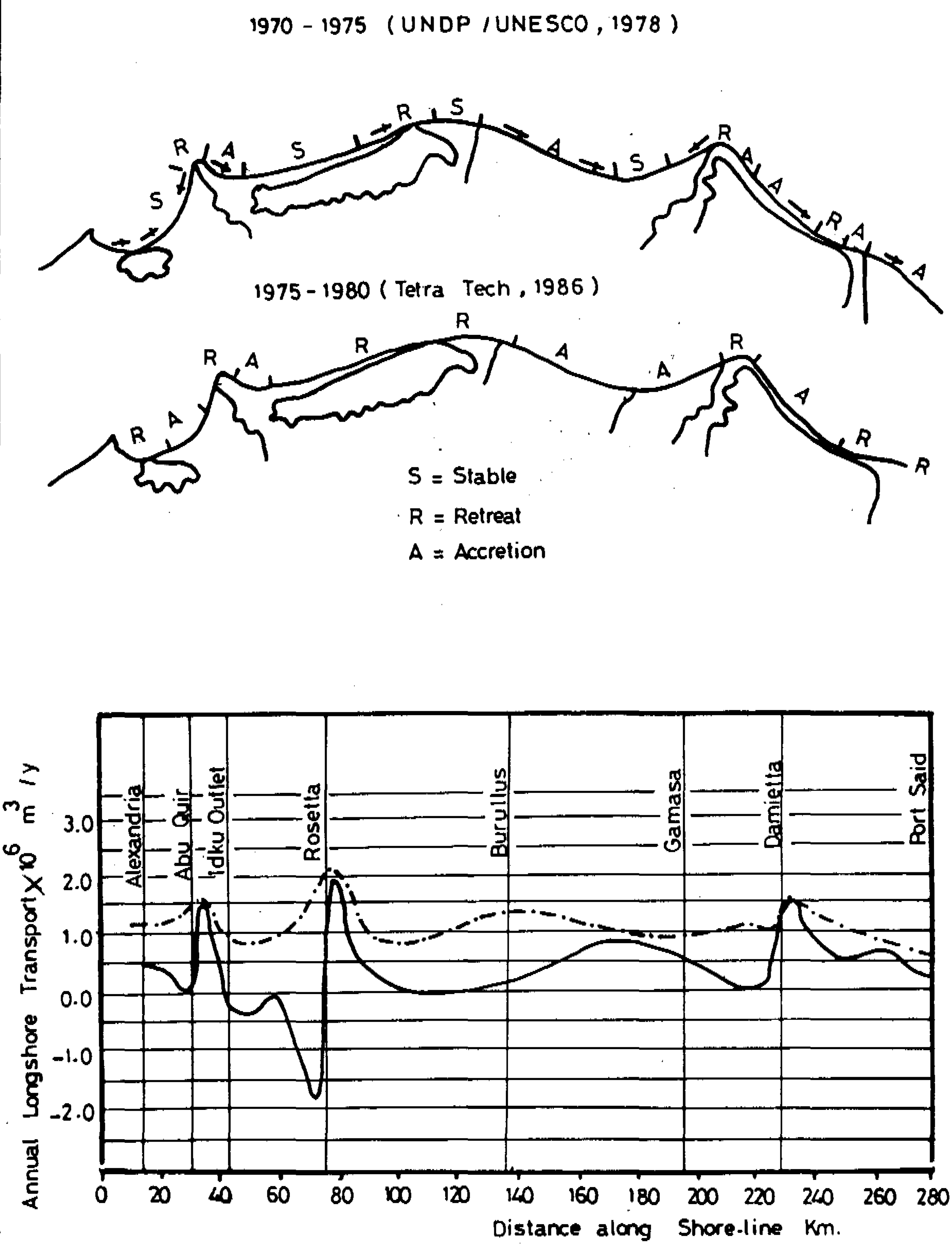

Fig.5a : Accretion , Erosion and Longshore Transport (UNDP/UNESCO, 1978 and Tetra Tech, 1986)

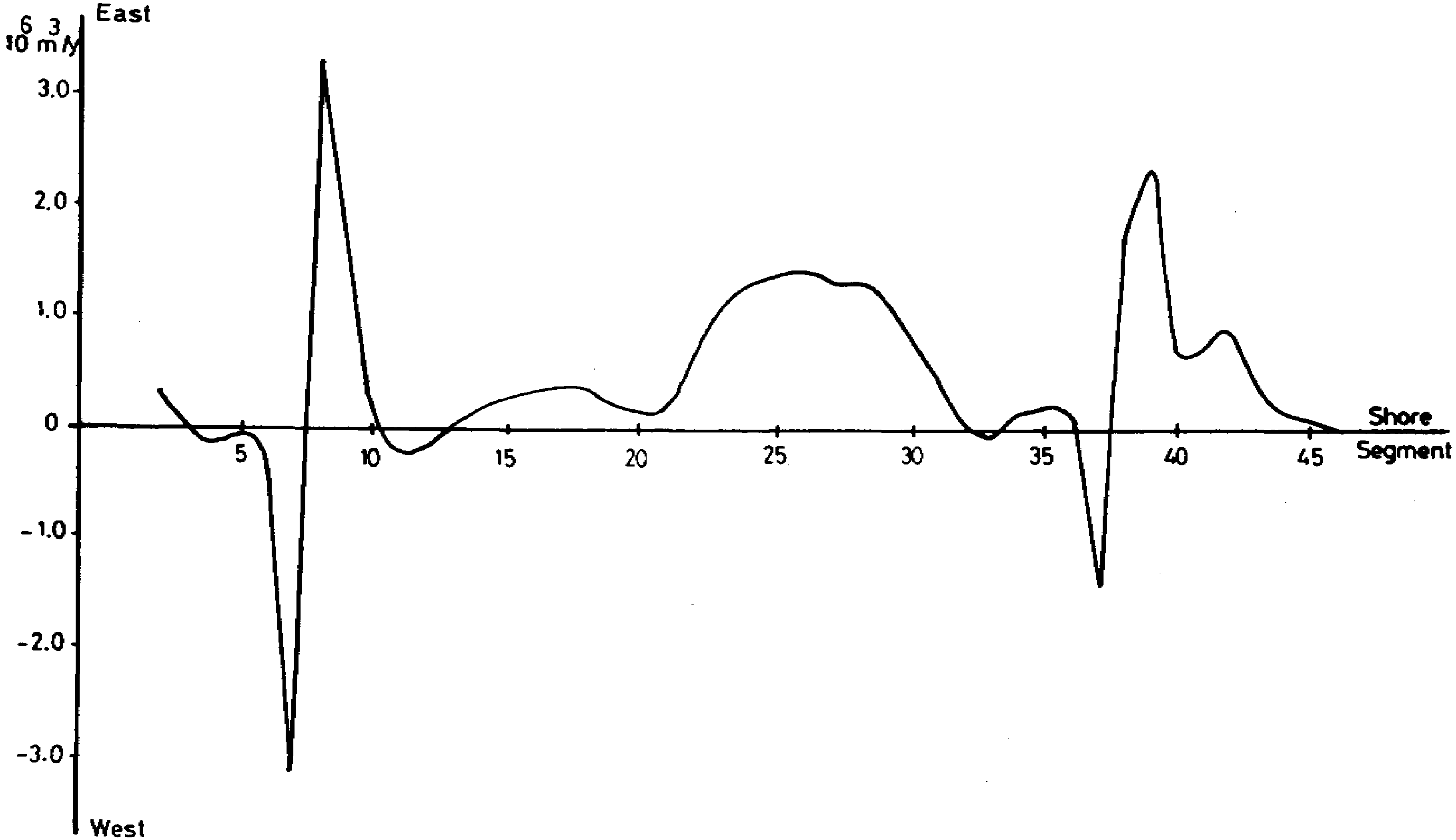

Fig. 5b : Potential Erosion, Accretion and Longshore Transport Rates

(UNDP / UNESCO, 1978)

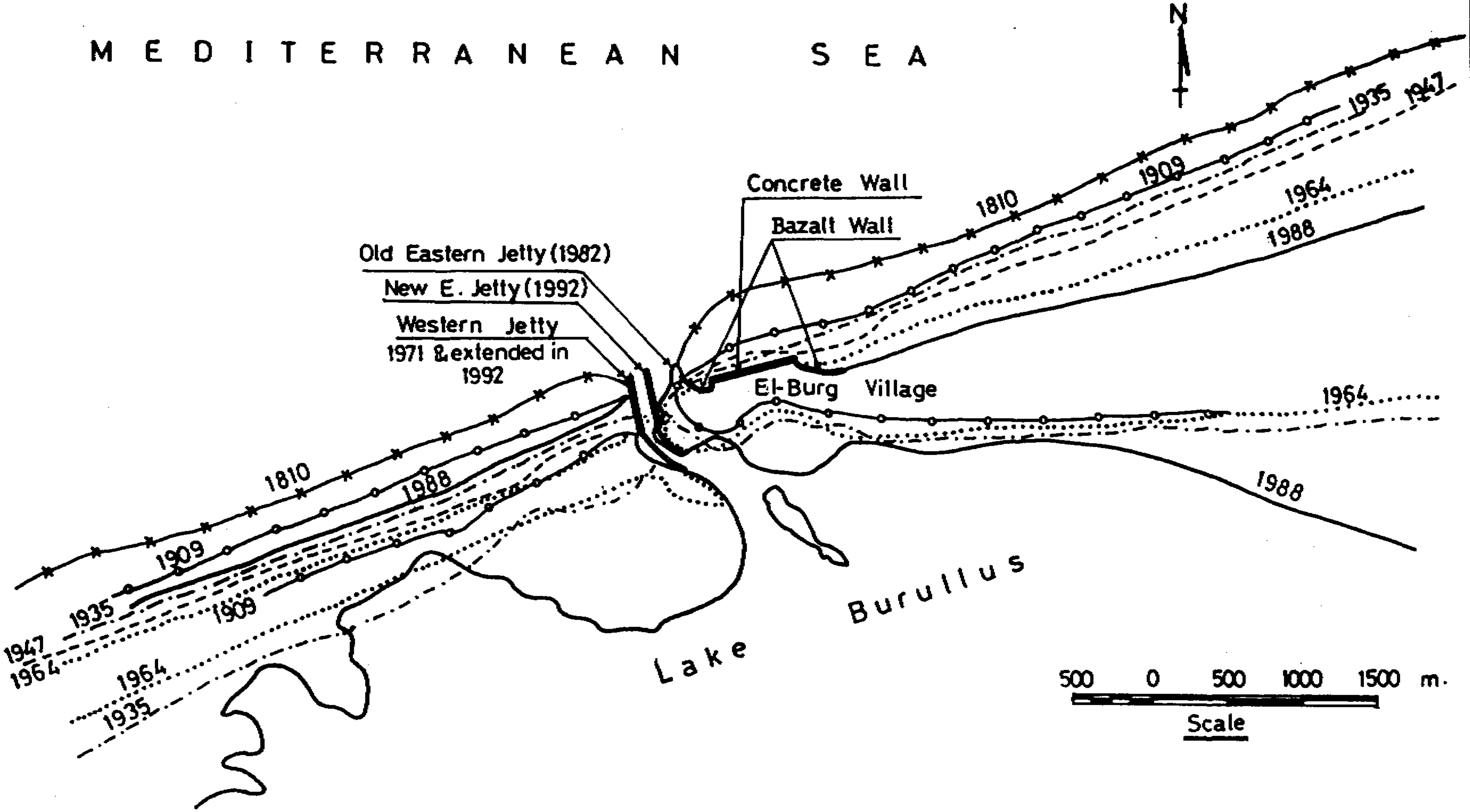

Fig. 6 : Shore-line Changes at Burullus Headland from 1810 to 1988.

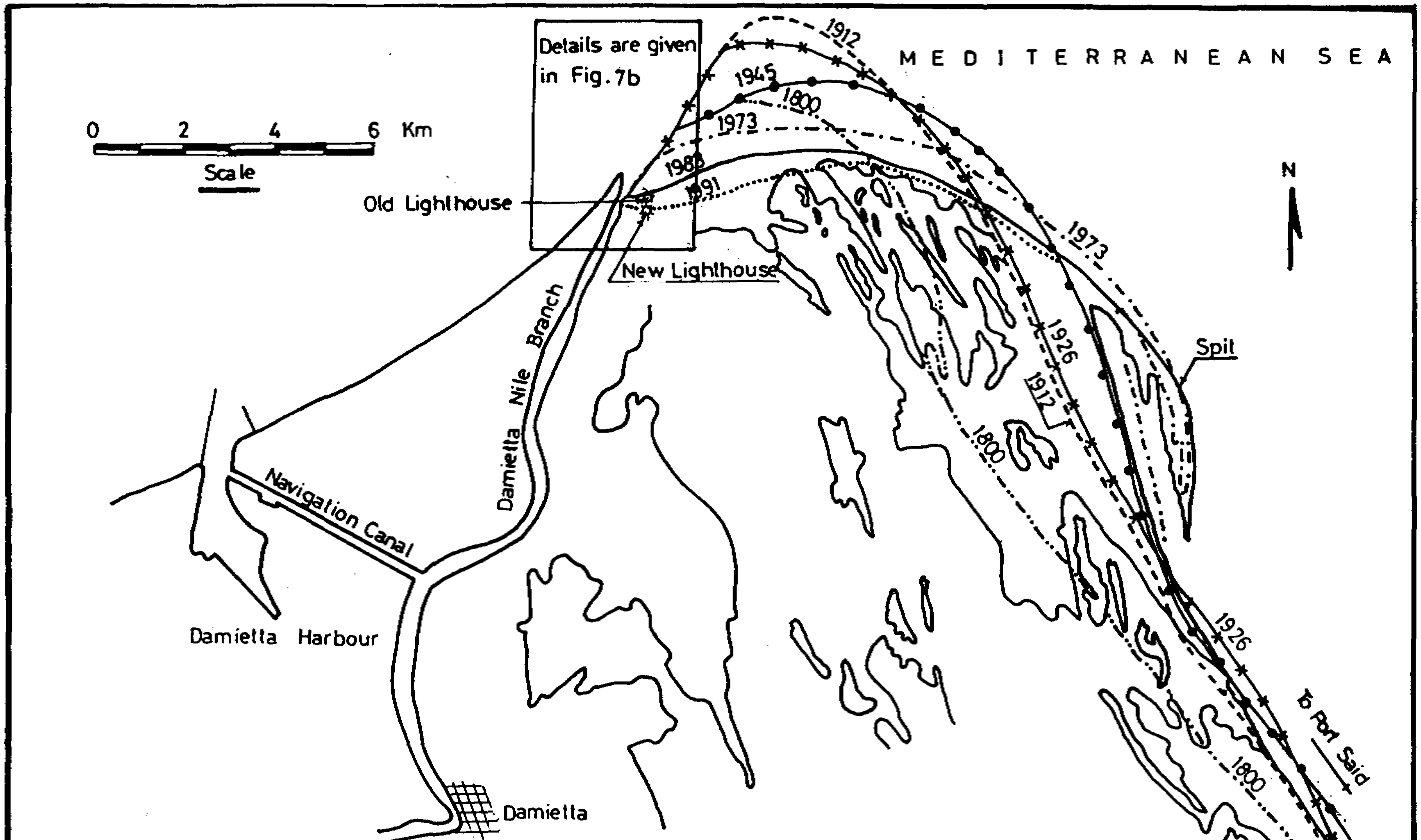

Fig.7a. Evolution of the Shoreline and Spit Formation on the Eastern Side of Damietta Promontory.

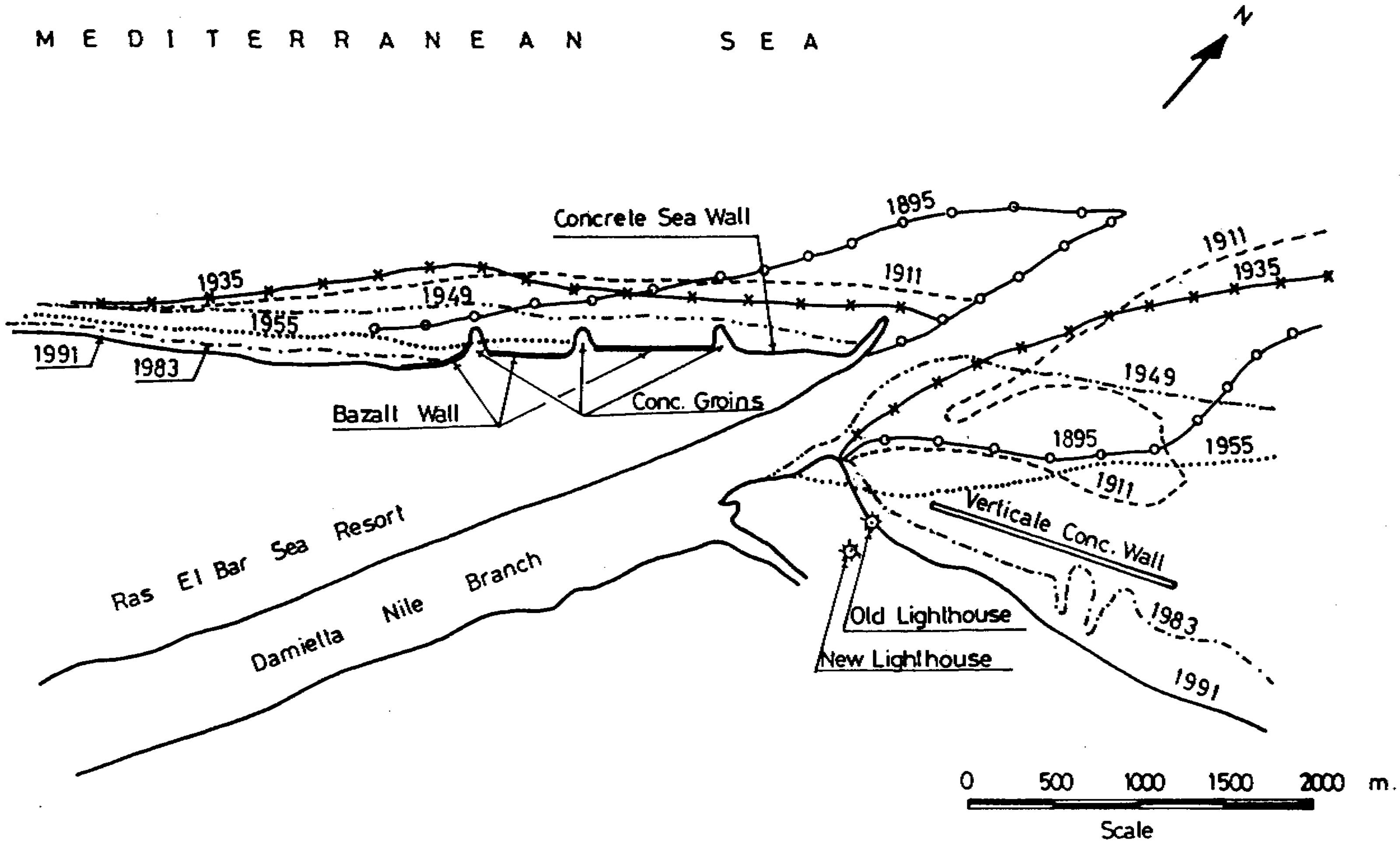

Fig.7b. Shoreline Changes (1895 – 1991) at Damietta Promontory . (Long Term)

POTENTIAL CLIMATE CHANGE IMPACTS ON NILE BASIN

Dr. Magdy Saleh[1], Dr. K. Strzepek[2] and D. Yates[3]

ABSTRACT

The Nile Basin among other four main river basins: Le Plata, Mekong, Indus and Zambezi were the focus of recent research project "Complex River Basin Management" in which basins were studied to evaluate the climate change impacts. The main goals in each basin's analysis were to: 1. assess the physical and social elements that are sensitive to climate change in each basin and evaluate its variation over time; 2. simulate the impacts of climate change scenarios on the water resources of the studied basins; 3. assess and when possible, quantitatively simulate the water related resource impacts of changes in basin water supply; 4. identify potential adjustments to climate change through empirical studies and interactions with basin decision makers; and 5. evaluate potential adjustments in basin management and planning.

The above objectives were the main targets of the climate change study on the Nile basin. Climate changes analysis showed mixed results in terms of future flow yields. Two GCMs showed reductions in flow whereas another GCM showed 30% increase in yield at Aswan. After obtaining the initial results of the Nile basin climate impacts assessment, an extension study was initiated in which Egypt was selected as a model for an integrated study for evaluating the climate change impacts on sea level rise, global agriculture and human health.

1. GREENHOUSE PHONOMENA

The temperature of the earth is a balance of the short wave radiation coming from the sun, its loss by longwave radiation from the earth, the atmospheric absorption of the some of the longitudinal radiation and finally radiation a fraction of the gained back to the earth . Carbon Dioxide (Co_2) allows the penetration of sun radiation but absorbs the longwave radiation in a way similar to the glass in a greenhouse. Therefore, Co_2 has been considered responsible for "greenhouse effect" because of trapping the solar heat inside. Human activities in burning fossil fuel are the major causes for Co_2 production. Oceans dissolve half of the produced Co_2 and the rest added to the atmosphere, causing an increase in the Co_2 level. Since the beginning of the industrial revolution Co_2 is in continuous increase; it reached 316 parts per million by volume (ppmv) in 1959 with a present level of 350 ppmv. In addition to Carbon Dioxide, Methane and Nitrons Oxide contribute to the greenhouse effect but with a smaller percentage. Climatologists have agreed that a doubling of Co_2 levels is expected by year 2060, which will eventually raise the global temperature 2 to 5 °C causing a global warming.

Global warming may also cause a sea level rise rangeing between 30 to 130 cm in the next century. The impact of global warming on water resources will be directly transferred to the

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agriculture sector. The change in moisture, heat or wind will affect the crop yields. the change in crop yield will govern the farm income, food supply and the whole economy. In general, the agriculture production is dependent on three types of resources other than climate: natural resources (soil, topography, water resources); capital resources (fertilizers, animal and machinery), and human resources (labor, market and management).

2. MODELING BASELINE SCENARIO

In order to predict the Nile Basin waters under climate change scenarios, the present conditions should be modeled and calibrated. Then such a model can be applied to estimate the Nile flow yield under new projected precipitation and temperature climate conditions. Therefore, the Nile Basin was modeled by dividing it into its major basins: the Equatorial Lakes basin, the Sudd basin, the White Nile Basin, the Blue Nile basin, and the Atbara basin. The Equatorial Basin is divided into four catchment areas and three lakes, each modeled separately. In addition, the Sudd basin is a simplified representation of the entire White Nile catchment from Mongalla to Malakal, including the Sobat River. All the swamps are represented as one and modeled via the water balance method described by Suttcliffe and Park (1987).

All of the catchments are modeled in a lumped, one-dimensional water balance model with spatially-weighted parameters. Precipitation and temperature surfaces were obtained from GRASS (Geographic Resources Assessment System, US Army Corp. of Engineers) GIS. to determine precipitation and temperature surfaces of monthly average values on a 25 x 25 km grid for the entire basin. Catchment boundaries were delimited on these surfaces and the weighted average monthly value of precipitation and temperature was calculated for each of the four major catchment areas.

The average monthly precipitation values were used directly in the model, but temperature was used to derive average monthly PET using the Thornwaite method (Shaw, 1987). Thornwaite was chosen because Oliver (1948) successfully used the Thornwaite approach to study PET in the Nile basin.

The soil moisture and groundwater are modeled in study area by separate water balance models with exchanges between them. Input to soil moisture is the balance of water remaining after interception losses and direct surface runoff. Direct surface runoff is a linear function of the soil moisture. The groundwater component of runoff is modeled as a non-linear function of storage in the groundwater zone.

With precipitation and PET determined, the model was calibrated by fitting four parameters: surface runoff coefficient, interception factor, and the coefficients of the non-linear groundwater runoff equation. For most basins, these parameters are constant over the year. For two of the basins, wet season and dry season parameters were needed.

The Equatorial Lakes were modeled using a monthly mass-balance approach with catchment inflow, direct lake precipitation and lake evaporation equal to PET. The model used the lake's elevation-area-storage-curves and non-linear outflow storage curves (WMO, 1970). No calibration was needed for the lakes.

The swamps of the Sudd are modeled using the mass-balance and non-linear reservoir approach of Suttcliffe and Park (1987). Inflow to the swamps was the catchment runoff plus the spill from the Bahr el Jabel. Contribution to the White Nile flow at Malakal from the Sudd was the discharge from the swamps.

The model results compared with the naturalized historical flow is presented in Table 1. The modeled results are considered the reference points which provide the BASE scenario in the climate change analyses.

Table 1. Comparison Between the Naturalized Historical Flow (MCM) and Model results At Aswan

Month	Historical Flow	Modeled Flow
JAN	3.63	4.75
FEB	2.61	4.26
MAR	2.01	3.4
APR	1.69	2.95
MAY	1.75	2.72
JUN	2.33	2.67
JUL	6.26	6.38
AUG	17.53	16.96
SEP	20.47	18.02
OCT	14.07	11.27
NOV	7.57	7.39
DEC	4.8	5.27
Annual	**84.72**	**86.03**

3. CLIMATE CHANGE SCENARIOS

3.1 General Circulation Models (GCMs)

Climate forecasting and generating climate change scenarios are approached by one of two means: empirically or analytically. In an empirical method, climate data are collected to analyze past climate change or to provide information about the present warming conditions. In an analytical method, simulation models are applied to generate climate scenarios according to given set of input parameters.

In simulation models, the climate system components, (atmosphere, cryosphere, oceans, and land and biosphere) are represented by the mathematical formulas of their natural behavior. These formulas are applied to the globe after dividing it into grid cells of few kilometers width and length; where as the atmosphere is divided into several layers. Super fast computers are required to solve the atmosphere formulas. The integration of the formulas represent what is called general circulation modes.

In the Nile basin climate study; three general circulation models are applied : Goddard Institute for Space Studies (GISS); Geophysical Fluid Dynamics Laboratory (GFDL); and United Kingdom Meteorological Office (UKMO).

3.2 Climate Change Modeling Results

According to the USEPA the following guidelines were defined for all country studies research team: 1. Use the years 1951 through 1980 as baseline conditions or as much data as available during the same period; 2. Use GCMs for doubled Co_2 and transient scenarios; and 3. Use arbitrary scenarios to test sensitivities. It is recommended to use 2 °C and 4 °C warming with no change in precipitation and 20% increases and decreases in precipitation, applied with the base period.

According to the above guidelines, the climate change of the Nile basin is emulated by the GFDL, UKMO and GISS GCM scenarios. To assess climate change effects, the GCM grids are overlaid on the historic monthly temperature and precipitation surfaces in the GIS. Monthly precipitation and temperature changes between the one and two times CO_2 scenarios for each grid cell provide new surfaces. These new precipitation and temperature surfaces are considered the input conditions for the developed Nile Basin model. Table 2. presents the base and GCMs obtained temperature and flow.

New catchment-weighted average climate parameters were calculated from the new temperature and precipitation surfaces. For the sensitivity analysis, spatially-homogeneous changes in temperature (2 and 4 °C) and precipitation (20%) were applied to the absence climate parameters.

Table 2. Nile Basin Determined Temperature and Flow

Scenario	Temperature (C)	Flow (milliard m^3)	% of Base
Base	0	86	100
GFDL	3.15	20	23
UKMO	4.73	76	88
GISS	3.45	112	130

Table 3. Nile River Flows Under Sensitivity Analysis

Preciptation *	-20	20	0	0	-20	-20	20	20
Temperature **	0	0	2	4	2	4	2	4
Flow (MCM)	32	147	39	8	10	2	87	27
% of Base	37	171	46	10	12	2	101	32

* Basin-wide average change as percentage of Base
** Basin-wide average delta T degrees Celsius over Base

The sensitivity analyses indicate that the Nile basin is extremely sensitive to any change in climate, with some especially remarkable outcomes, e.g.: Nile flow decreases 98% with 4 degree C warming and 20% decreased precipitation. This represents, of course, a disastrous reduction in water supply. The other sensitivity runs indicate that response of the basin to precipitation change is not linear, but is symmetric for both increased and decreased precipitation.

The GCM scenarios and the detailed sensitivity analysis provide mixed results for the Nile basin. Several conclusions are obtained from the climate analysis. The Equatorial Lakes have a very delicate water balance, and even a slight increase in temperature or slight decrease in precipitation in the Lakes sub-basin forces its contribution to the Nile flow to zero. The Sudd, currently responsible for large water loss, is made an even more efficient evapotranspirer due to increases in temperature. In addition, with less spillage from the Equatorial Lakes, the Sudd is able to evapotranspire more of the runoff from the Sudd catchment.

The Ethiopian Highlands are the key to Nile flows under historic climate as well as possible climate change. Under the UKMO scenario, with the White Nile contributing no flow, total Nile flow is only reduced by 12 percent. Similar conditions prevail under the GISS scenario, with 35 and 48 percent increases in precipitation for the Blue and Atbara basins, but annual temperature increases of only 3.2 degrees in both basins. This results in a 69 percent yield increase in the Blue Basin and a 125 percent yield increase in the Atbara basin.

Finally, the GFDL projection of a 76 percent decrease of flow at Aswan occurs due to the fact even though the Blue and Atbara Basin have approximately the same the temperature increases as the GISS scenario, the precipitation in both basins is 96 percent of historic, resulting in a 40 percent difference for the Blue between GISS and GFDL, and 52 percent difference for the Atbara basin. This change in precipitation results in 98 MCM difference in yield from the basins or 153 percent of historic yield of the basins.

It is clear that the sub-basin modeling effort has uncovered some remarkable climate change sensitivities in the Nile basin. The challenge of dealing with these changes falls to the management system. Gleick (1990) found similar results in a study of the hydrologic sensitivity of the Nile Basin.

3.3 Potential Adjustment To Climate Change

A wide range of potential adjustments were discussed at two workshops held in Cairo in 1991 and 1992, attended by Egyptian Government officials and water managers, academics, scientists and some international experts. Several issues related to water allocations, management in Egypt and Sudan, and infrastructural changes in upper and lower basins. Generally, the managers felt that Egypt could adapt quite easily to a 10 to 15 percent reduction in Nile flows. Reduction of 20 percent or greater was deemed disastrous and would result in major social and economic impacts. In addition, calculation of climate change impact on the Nile is complicated by assumptions about intricate water allocation and institutional arrangements, mainly between Sudan and Egypt. Sudan is assumed in the base scenario analyses to be taking its full legal 18.5 MCM allocation which is currently take only 60% of its share.

4. CONCLUSION

This study has shown that Nile River flows throughout the basin are extremely sensitive to temperature and precipitation changes. GCM scenarios for 2XCO2 provide widely diverging pictures of possible future river flows, from a 30 percent increase to a 78 percent decrease. Faced with such diverse possible scenarios, it is difficult to for current water managers in the basins to adopt specific guided rules. Futher integrated studies and analyses will be needed to improve the awareness of the uncertain impacts of climate change on the water resources, agriculture and national economics

ACKNOWLEDGMENT

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FERTILIZER ABUSE AS A POSSIBLE THREAT TO WATER QUALITY IN EGYPT

M. Abdel Monem[1], M.A. Abdel Khalek[2], M.B. Abdel Ghani[2]

ABSTRACT

With increasing the poverty of Egyptian soils in nutrients, application of chemical fertilizers became essential for maintaining soil fertility and increasing crop production. Egypt now is known as heavy consumer of fertilizers, because of its intensive agricultural farming system. High percentage of the applied N fertilizers is lost due to poor management in form of ammonia volatilized, or nitrate leached. High nitrate concentration was detected in groundwater and drainage water throughout different crop rotations. Also nitrate concentration in groundwater drinking well in Sharkia governorate was found to be higher than the Egyptian and international limit. Although studies on adverse health impact of high nitrate concentration are limited in Egypt, researches carried out in different countries show that high nitrate concentration in drinking water could be of serious threat to health. Better fertilizer management is needed in Egypt. Applying N fertilizer at the suitable time and using the proper method, and using soil test and plant tissue analysis as a base for fertilizer recommendation would be important in increasing fertilizer efficiency and decreasing losses in addition to the potential utilization of bio-fertilizers as partial substitute for chemical fertilizers.

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1. INTRODUCTION

Soils of the Nile Valley and Delta of Egypt had been originated from Holocene alluvial deposits which consists mainly of dark grayish brown Nile suspended matter. Soil classification according to USDA soil taxonomy system, show that order Vertisol dominates the soils of the Valley and Delta and Entisols and Aridisols are found in scattered areas along Rosetta and Damietta branches and areas adjacent to desert (SWRI, 1990). The suspended matter which was carried by the river from its courses and contains clay fraction, organic matter and soluble salts were substantially decreased after the construction of the High Dam, 1964 (Abu el Atta, 1982). Several studies have definitely established the poverty of most Egyptian soils in organic matter and nitrogen content.

Results of soil fertility survey study conducted by the Soil and Water Research Institute, where 5670 soil samples representing eleven governorates were collected, indicated that the tested samples contain an adequate concentration of potassium, 36% were poor in phosphorus and 75% were poor in nitrogen. Discontinuity of the precipitation of the Nile mud over the Egyptian soils after the High Dam, may need to replenish the soil with plant nutrients applied as chemical fertilizers to maintain the soil fertility and ensure crop production.

2. FERTILIZER CONSUMPTION

Egypt is known to be a heavy user of chemical fertilizers which have been used in the Egyptian agriculture since the turn of the century. Comparative use of chemical fertilizers is illustrated in Figure (1).

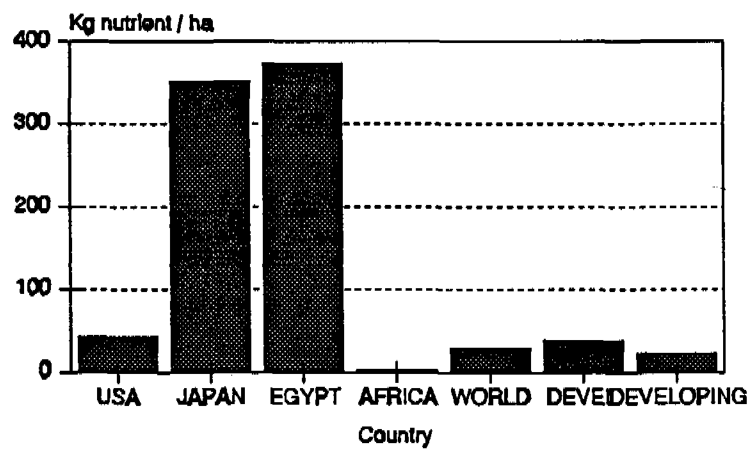


Fig (1) : Consumption of fertilizer per hectar of the cultivated area in 1994
Source : Badiane et. al. (1994)

It shows that Egypt consumption is more than 10 times as much of all nutrient per hectare as does the average of the whole world. In fact there is gradual increase in fertilizer consumption in Egypt. Data illustrated in Figure (2), indicate that nitrogen fertilizer consumption was approximately doubled in 1993 as compared with 1980, while phosphorus consumption was increased 70% for the same period. There are several reasons for the increase in nutrient consumption including the intensive agricultural farming system, where the crop rotation consists of 2 or 3 crops, also the gradual increase in the recommended fertilizer rate for various crops. Rate of nitrogen fertilization was more than doubled for wheat, rice and maize in 1991 as compared with 1970 (Figure 3), which is due to release of high yielding varieties, and continuous decrease in soil fertility (Hamissa and El Mowelhi 1989). They also reported that, adding newly reclaimed land to the cultivated area, contribute to the increase in fertilizer consumption.

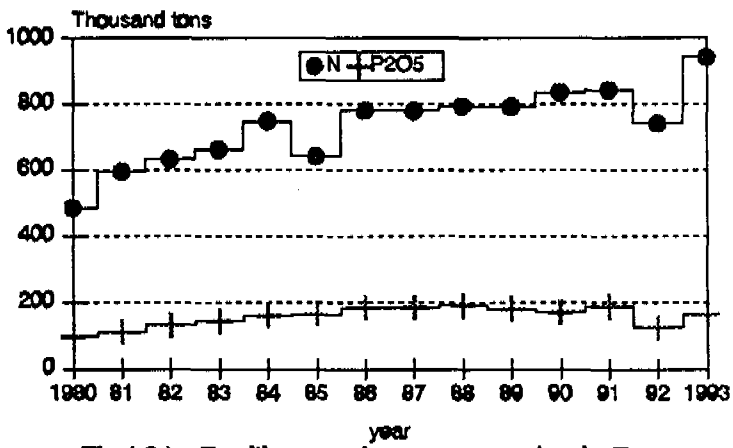


Fig (2) : Fertilizer nutrient consumption in Egypt
(Source: IFDC 1993)

3. LOW RECOVERY AND HIGH N-LOSSES

Recovery of the applied nitrogen fertilizers by various crops in Egypt is poor. Nitrogen recovery by wheat was reported to be 38% and 35% as N-15 labelled urea and ammonium nitrate were used as fertilizers. Less recovery was obtained as fertilizers applied to sandy soils. Abdel Monem et. al. (1994) reported 28% recovery by wheat in light texture soils in Sharkia governorate. Eid et. al. (1975) indicated an average of 38% of the applied N as ammonium sulfate was recovered by maize. Under the flooded conditions, Hamissa et. al. (1986) reported that nitrogen recovery by rice could be as low as 10% if nitrogen fertilizer was applied to the water before levelling, while it reached 39%, when fertilizer was applied at 10 cm deep. Abdel Monem et. al. (1993), indicated low recovery by rice form applied labelled urea (22%) as added to wet soil, and higher (41%), as added to dry soil. The major cause for poor recovery is the extensive losses of the applied N fertilizers. Losses was estimated to be as high as 49% when fertilizers were added to sandy soils (Soliman et. al. 1993), and to 62% as urea broadcasted to rice under the flooded system (Abdel Monem et. al. 1993). In addition to ammonia volatilization and denitrification, nitrate leaching is considered one of the main important mechanisms for the nitrogen fertilizers losses. Nitrate leached from the root zone into the surface and groundwater causes great concern mainly form health and environmental aspects.

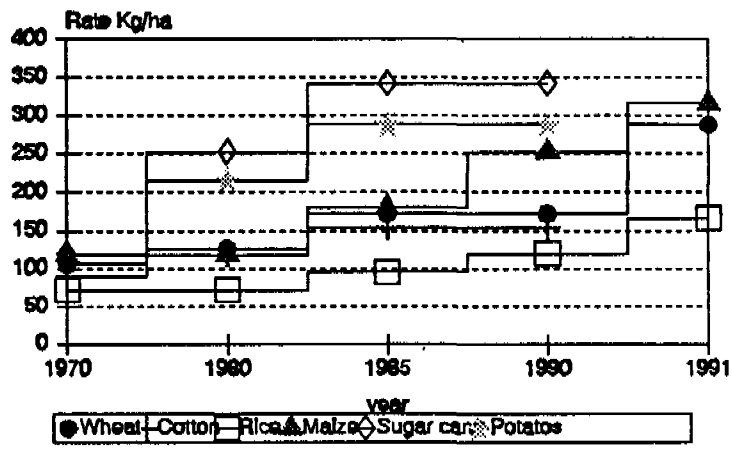


Fig (3) : Gradual Increase In N fertilizer rate for various crops
(Source : Hamissa et. al 1991 and IFDC 1993)

4. NITRATES IN WATER RESOURCES

4.1 River Nile

Several water quality surveys of the River Nile (from Aswan to the Mediterranean sea) were undertaken between 1976 and 1986. The main objective of these surveys was to evaluate Nile water quality and the potential effect of some pollutants with respect to the different water use. One of the recent studies was carried out by El Sherbini et. al. (1993) showed that the concentrations of NO_3 along the river were very low and below the standard limit value of 45 mg/L. It fluctuated between 0.87 mg/L and 3.0 mg/L at some locations. Similarly the concentration of NH_3 were below the standard value (0.5 mg/L).

In another water quality monitoring program for Rosetta Branch of the River Nile, El Sherbini et. al. (1993) indicated that the compounds of nitrogen concentration found upstream of the Delta Barrage remained within the stream standard. However, ammonia and organic nitrogen concentration increased downstream of El Rahawy drain, and gradually decreased to reach downstream of Kafr El Zayat area and on to Edfina barrage. Nitrate concentration remained between 2-7 mg/L for most of locations and increase to about 12 mg/L at Kafr el Zayat due to industrial pollution at this location.

4.2 Drainage Water in Main Drainage System

The drainage water monitoring program established since 1980 at Drainage Research Institute (DRI) reported by El Guindy (1989), show that highly concentration of nitrate between 11 mg/L to 49 mg/L were found. The main source of these highly concentration value may be due to fertilization of agricultural lands and the sewage system drains of the public main drain. Table (1) shows concentration of NH_3 and NO_3 in drainage water in Delta.

Table (1): Ammonia and Nitrate concentration in drainage water (mg/L)

Location	NH_3	NO_3
Eastern Delta		
Belbeis Drain	3.9	45
Wadi P.S	3.9	49
Bahr Bagar	3.7	46.5
Nizam P.S	2.6	31.0
Middle Delta		
Segaia P.S	1.2	13
Sematay P.S	3	30
P.S No.5	2.7	29
Hamoul P.S	1.2	11.8
Bridge Drain	1.2	13
Western Delta		
Khairy P.S	1.6	22
Tabia P.S	2.6	32
Dushudi P.S	1.2	11.8
Max P.S	2.4	28

4.3 Drainage Water in Field Scale

Abdel Dayem and Abdel Ghani (1992) monitored nitrate concentration in irrigation, drainage and ground water in a pilot area provided with tile drainage system in Sharkia governorate (Figure 4 and 5).

The time scale (horizontal axis) refers to time of collecting water samples after the sowing date of each crop. They found that the nitrates concentration in irrigation water (Fig 4) do not exceed 50 ppm except in July where it reaches maximum value 85.6 ppm. This could be attributed to using of irrigation canal for surface drainage purposes during rice cultivation. Data illustrated in Fig (5) show that there is clear impact of crop rotation and the existing farming system on nitrate concentration in groundwater and drainage water. While NO_3-N concentration was found to be very low during the winter season, it exceeded 250 ppm during the summer season.

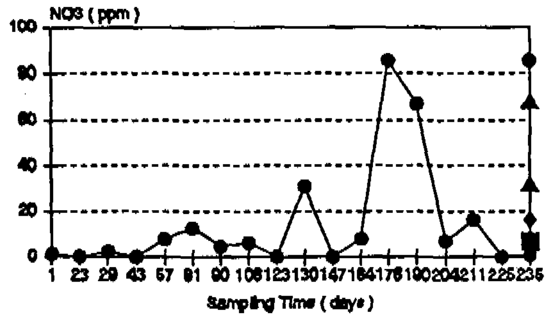
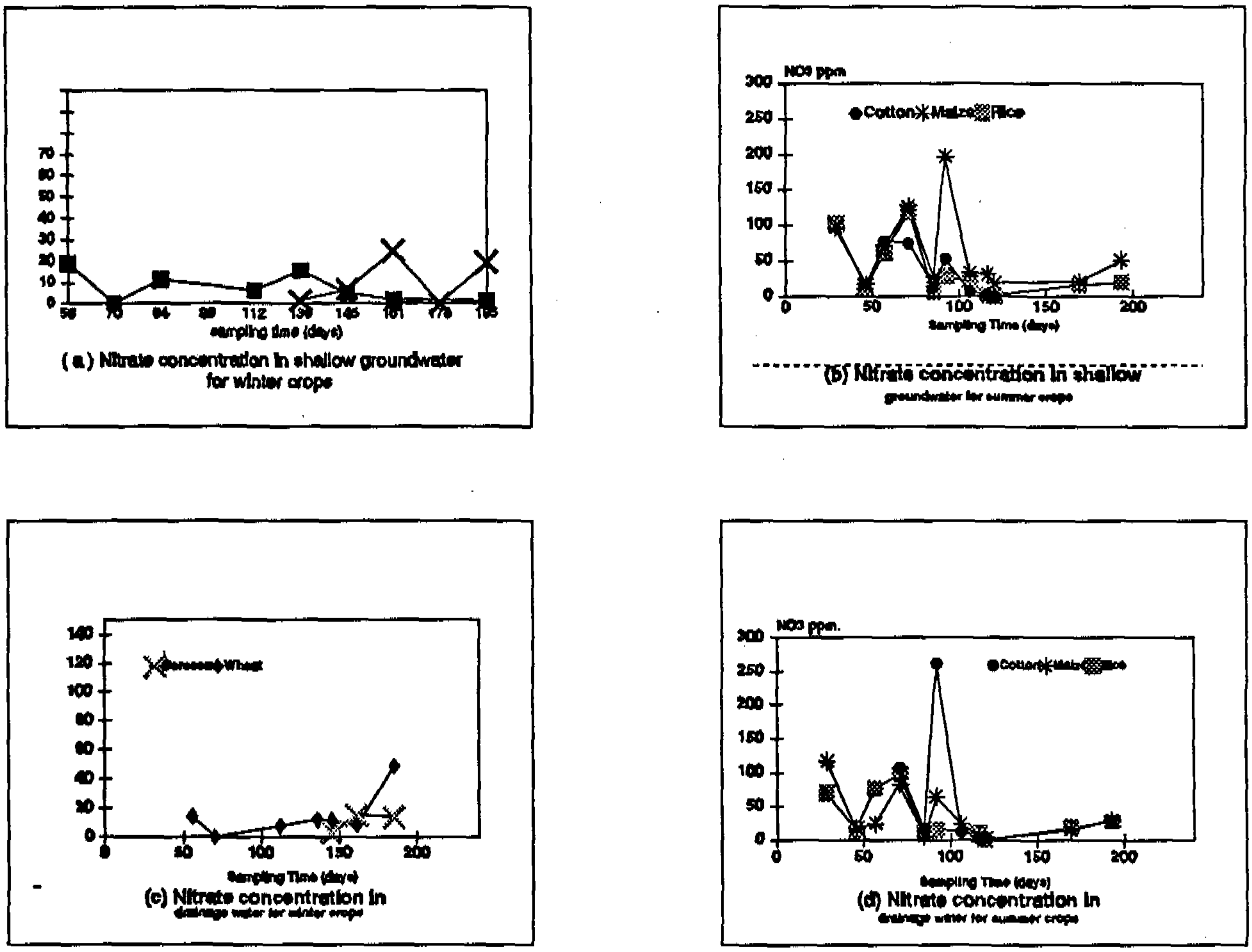


Fig. (4) Nitrate concentration in Irrigation water



(a) Nitrate concentration in shallow groundwater for winter crops

(b) Nitrate concentration in shallow groundwater for summer crops

(c) Nitrate concentration in drainage water for winter crops

(d) Nitrate concentration in drainage water for summer crops

Fig (5): Nitrate concentration in shallow groundwater and drainage water during winter and summer seasons

They attributed this to the fact that berseem (clover) is not fertilized in winter season while higher doses of N-fertilizers usually applied to corn, cotton, and rice during summer season. However, continuous flooded crops produce lower concentration than intermittently irrigated crops probably due to dilution and denitrification (Bouwer, 1987).

Nitrates concentration in drinking water from a groundwater well (1 pipe penetrating the clay cap to the sandy aquifer at abut 10.0 m deep) is shown in Figure (6). The maximum concentration in winter was 35.5 ppm. It occurred in February following application of urea for wheat. In summer, a higher concentration of 234.4 ppm occurred in July which associated with application of ammonium sulphate for rice and calcium nitrate for cotton and maize. These concentrations are critical and calls for better water management to control the groundwater pollution with nitrates. The current Egyptian water quality standards require that the concentration of nitrates discharged into surface fresh water bodies or groundwater aquifers not to exceed 45 mg NO_3 - NL^{-1} (El Sherbini et. al. 1993). The drinking well in this farm is too shallow and it might be more safe to adhere to the common practices of drilling deep wells for drinking purposes.

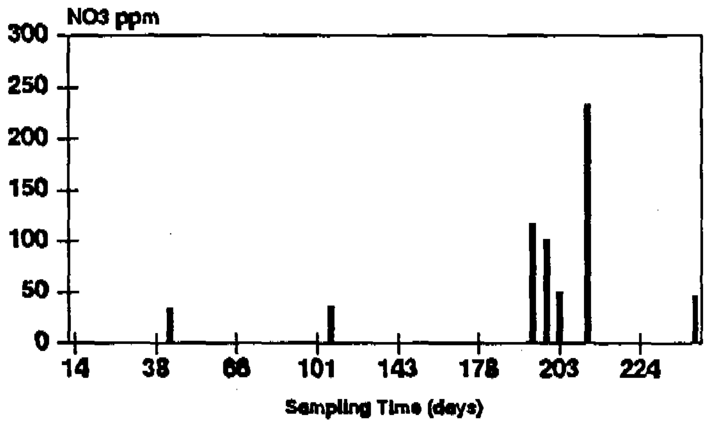


Fig (6) Nitrate concentration in groundwater (drinking well)

5. ENVIRONMENTAL AND HEALTH ASPECTS OF NITRATE

High nitrate levels in the surface water brings about many undesirable changes including proliferation of algae, in the dissolved oxygen depletion in the bottom water and decrease in water clarity. Nelson (1984) reported that high amount of nitrate present in soil solution is the major factor influencing its high concentration in the plant. He pointed out the adverse health impact of excess accumulation of nitrate (or nitrite) in plant parts consumed by humans or animals. High nitrate concentration in the drinking water could be of serious threat to the health.

Nitrate is rapidly absorbed into blood where it oxidizes Fe of hemoglobin to the ferric state forming methemoglobin which cannot function in oxygen transport. Possible links were reported between birth defect and heart diseases and nitrate concentration (Black, 1989). With increasing the public concern, standards for nitrate concentration have been set at 10 mg NO_3-NL^{-1} in USA (Follet and Walker, 1989), and at 50 mg NO_3-NL^{-1} by the EEC (Newbould, 1989). In Egypt, the standard value for NO_3-N concentration was reported as 45 mg NO_3-NL^{-1} (El Sherbini et. al. 1993).

6. BETTER FERTILIZER MANAGEMENT FOR REDUCING NO_3 LOSSES

Increasing efficiency of applied N fertilizer will lead to high recovery by plant and less N-losses. Applying fertilizer at the most suitable time and using the proper method increases the relative effectiveness of N-fertilizers. Hamissa et. al. (1974) reported 11% increase in N-uptake by corn, as the applied rate of fertilizer was split into three equal doses comparing with two equal doses. Split application of urea or ammonium nitrate increased N-uptake by wheat planted in sandy soils, and the fertilizer use efficiency, as compared with single application at planting (Soliman et. al. 1993). Method of N-fertilizer application for rice could be of great importance with respect to nitrogen losses. Soliman and Abdel Monem (1994) reported decrease in N-losses from applied urea to rice from 64% down to 12%, as urea was applied as deep placement.

Utilization of bio-fertilizers as N-fixing bacteria, Azolla and blue green algae could be used as a possible partial substitute for using chemical nitrogen fertilizers. N-fixation through legume/Rhizobim association was well established through several studies conducted to evaluate the ability of winter and summer food legume, as well as forage legume for N-fixation. Hamissa et. al. (1988) estimated N-fixed to be in range between 90 and 145 kg N/ha for faba bean, and 14 to 28 kg N/ha for chickpea, and 53 to 83 kg N/ha for lentils. Inoculating cereal crops with a symbiotic fixers such as Azotobacter and Azosprilla proved to be effective in reducing the applied N-fertilizers (Ishac et. al. 1982). Azolla Anabaena and blue green algae have the potential to be used as bio-fertilizers for rice. Abdel Monem et. al. (1994) reported that, in addition to its ability to fix N_2 and be used as green manure, Azolla also has an important role in reducing losses form applied chemical fertilizers.

Although the idea of using soil test as an indication for predicting fertilizer requirement in Egypt was realized ling time ago (Mahmoud, 1934), application of major nutrients is recommended generally based upon number of field trials distributed throughout the country (Hamissa, 1993). Specific recommendation for N fertilizers taking into account soil test values and plant tissue analysis in needed. The idea of fertilization of rotation rather than fertilization of single crop should be applied for development of environmentally sustainable and economically viable fertilizer recommendation.

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ENVIRONMENTAL IMPACT OF DRAINAGE SYSTEM ON LAKE QARUN IN FAYOUM

H. El-Atfy[1] and M. Eissa[2]

ABSTRACT

Fayoum Depression (178,900 ha) which is located 90 km south of Cairo, is characterized as a closed basin with an arid climate, high evaporative demands, very low rainfall, and considerable land slope. Irrigation has been practiced in the Fayoum depression as basin flooding during the Nile floods for thousand years. Since 1900, it was switched for perennial irrigation with multi-crop rotation. Irrigation water is supplied from the Nile at Lahun. Lake Qarun (240 km^2) is situated in the lowest part in the northern boundary of the Fayoum depression. The average annual lake water level is -43.73 (m.MSL) with seasonal fluctuation ranges up to 0.8 m. The natural drainage water of the basin which originates from irrigation losses and excess water supply, discharges into Lake Qarun through the two main drains; Batts and Wadi. After introducing of an intensive cropping pattern and the related increase in water supply to the Fayoum, the water level of Lake Qarun started to rise resulting in waterlogging of the neighboring agricultural lands, changing the salt balance of the lake and hampering fish life, tourist activities and natural habitat. A monitoring network to provide basic data on water quantity and quality at several selected locations in main canals and drains was established in 1983. It is a vital for Fayoum, Governorate to maintain the water level and salt balance of the Lake Qarun. Fayoum Irrigation Department has carried out several efforts to overcome this problem. Diverting part of the drainage flow from Wadi drain towards Wadi El Rayan depression and implementing a policy of reuse of drainage water played an effective role in reduction of the drainage water flow to the lake. Moreover, an improved water management was executed through the Fayoum Water Management and Drainage Improvement project (phase I) resulted in reducing the average water level of Lake Qarun by approx. 0.25 m in one year.

RÉSUMÉ

La dépression du Fayoum (178,900 ha) située à 90 km au Sad du Caire est un bassin fèrmé, avant un climat arid. La demande évaporative est grande, très faible pluie et le terrain est en pente considérable. L'irrigation a élé pratrqué à l'aide de bassins naturels pendant la crue du Nil pour milliers d'années. Depuis 1900, cette manière d'irrigation a été remplacée par l'irrigation permanente et donc une rotation à plusieur récolte. L'eau qui sert à l'irrigation est fournie du Nil á Lahun. Le Lac Qaroun (240 km^2) est situé dans le creux de la limite nord de la dépression de Fayoum. Le niveau d'eau moyen est -43.73 m (en haut du niveau moyen de la mer); flottant dúrant la saison à une étandue de 80 cm. L'eau du drainage agricol naturel du bassin est dechargée dans le Lac Quaroun par deux canaux de drainage "Batts et Wadi". L'introduction dun model de re'colte intensif et l'augmentation de l'approvisenment en eau pour Fayoum sont résultés en un accroissement au niveau d'eau du lac et en problèmes de drainage des terrains agricoles au voisinage. Comme un autre résultat, l'équilibre salain du lac est changé affectant aussi les poissons, l'habitat naturel et les activitées touristiques. Un réseau moniteur a été installé en 1983, en vue de fournir des données initiales sur la quantitée et la qualitée de l'eau prélevée à des points de repaires selectionnés dans les principaux cannaux et point de vidange. Il est vital pour le Governorat de Fayoum de maintenir le niveau d'eau et l'equilibre salain du Lac Quaroun. Le Departement de l' irrigation de Fayoum a éxécuté plusieurs efforts pour surmonter ce problème. Une portion de l'eau du drainage est diverti vers Wadi El Rayan; et l'eau drainage est utilizeé pour irrigation. Ces actions ont diminue's les quantitiées d'eau disposées dans le Lac. D'autre part, une meilleure gestion de l'eau a été éxécuté par le project "L'amélioration de la géstion en eau et en drainage de Fayoum" qui est résultée en réduire le neveau moyen de l'eau dans le Lac Quaroan par 25 cm par au.

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1. BACKGROUND

The Fayoum depression is situated in the western desert at about 90 Km south of Cairo and 30 km west of the River Nile. The area of the depression is 426,000 feddan* ($1789\ km^2$) of which about 364,000 fed ($1530\ km^2$) are served by irrigation system. The depression slopes from + 27 m. MSL at Lahun south east to - 44 m. MSL at the south shore of Lake Qarun at 35 km N-E from Lahun (Fig 1). Soils of Fayoum are Neonile sediments, where heavy textured clay in the middle, medium textured soils in the fringes. Some rock outcrops occur in the south west and north west of the area. Wind blown deposits occur around Lake Qarun (FWSB tech. note 1984).

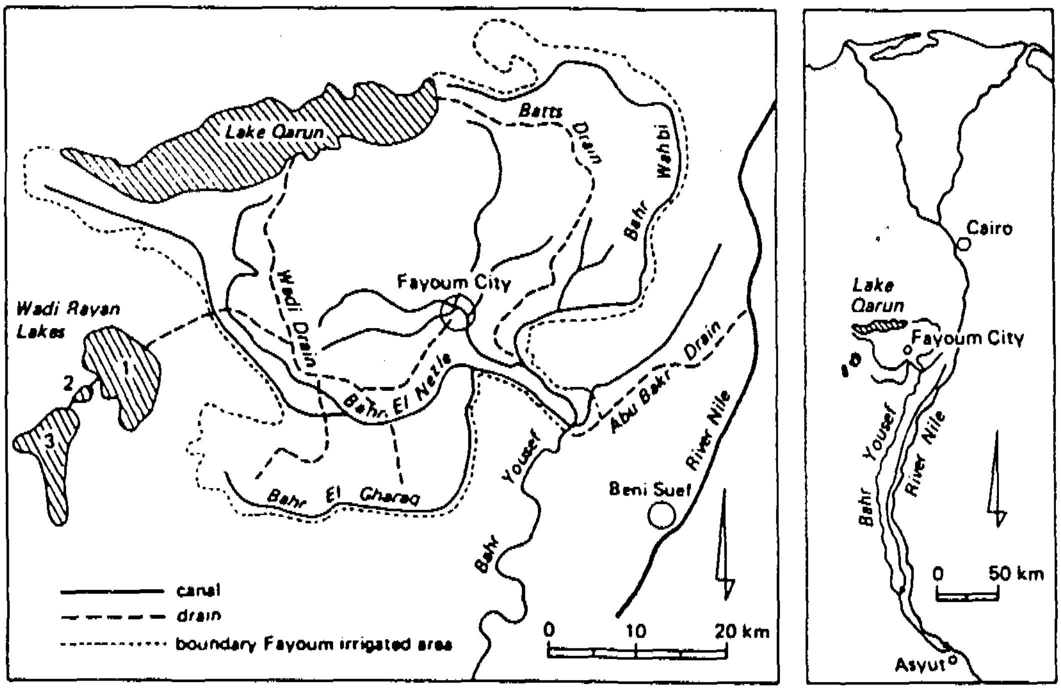

Figure 1. Fayoum Depression

The Fayoum has an arid climate which characterized by a high evaporation rate (1,980 & 2,090 mm / year) and very low rainfall (9.2 & 13.7 mm / year) at the shore of Lake Qarun and Fayoum town respectively (Amer,1992).

2. IRRIGATION SYSTEM

Due to the conditions of Fayoum, the Nile water entering the depression at Lahun Barrages is the unique source of irrigation water for the cultivation lands of Fayoum. Two main canals carrying this water (Bahr Yousef & Bahr Hasan Wassef) to be conveyed to the fields via the secondary and tertiary canals. The supply of irrigation water is continuous up to the rotational units, of some 80 - 200 fed. The presence of a considerable land slope enables the irrigation water to be distributed by gravity and proportionally to the areas

* feddan = 0.42 ha

** MSL is Mean Sea Level

being served by the distribution system named " Nasbah" which is a group of special type of broad crested weirs known as the " Fayoum Standard Weir". In practice, water distribution over the different subareas was far from proportional as designed (Amer and de Ridder, 1989).

The nununiformity of water distribution was mainly due to the enlarging of the dimensions of the weirs and providing them with large diameter pipes under their crests which enabled the farmers of the upstream reaches of the irrigation canals to use more water than their requirements. Consequently, the excess water at these areas was flowing directly to the drainage system. In the other hand, there was a poor match between the supplied discharges over the months of the year and the related water requirements releasing more excess water to the drainage system and subsequently to Lake Qarun (Amer, 1992).

Also, during the last thirty years, the total irrigation water entered Fayoum (Fig 2) showed an increasing trend after 1973 (after completion of the diversion drain to Wadi el Rayan). It resulted in a high annual average of 2,323 * 10^6 m^3 instead of 2,036 * 10^6 m^3 which affected the water level of Lake Qarun (FWSB, 1984).

Amer (1992) indicated that the average salinity of irrigation water enters Fayoum is 0.45 ds/m (288 ppm) to result about 664,000 tons of salts transported to Fayoum yearly. This amount as well as the additional excess salts from the used fertilizers, are flushed through the drainage water to the drainage reservoirs (Lake Qarun & Wadi el Rayan Lake)

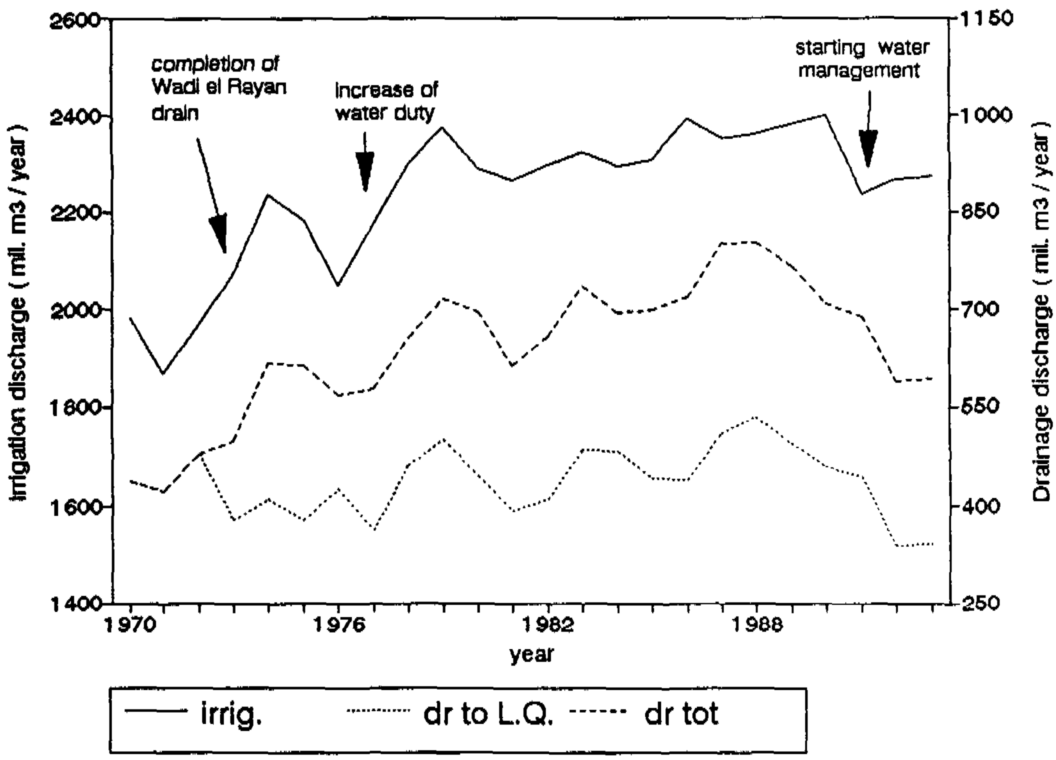

Figure 2. Irrigation and drainage discharges of Fayoum

3. DRAINAGE SYSTEM

The drainage water flows by gravity to Lake Qarun, the deepest point of the depression, due to the existing natural slope. The main drains are the Batts drain (in the eastern part) and the Wadi drain (in the western part) of the Fayoum. Between these two water courses, several minor drains discharge directly into Lake Qarun.

Since 1973, Wadi el Rayan drain diverted about 2/3 of the flow of Wadi drain to Wadi el Rayan Depressions through a tunnel in the Limestone ridge between these depressions (Fig.1).

In general, about 67% (440 * 10^6 m^3/year) of the total drainage water of Fayoum with an average salinity of 1.57 ds/m (1004 ppm) flows to Lake Qarun (FaWMDI, 1990). The drainage water in the Fayoum Basin originates from irrigation losses and excess water supply as mentioned previously, especially in November through January. Over the last 25 years, the total drainage discharges have gradually increased, consequently, water level of Lake Qarun was getting higher. However, the diversion of part of the drainage water to Wadi el Rayan Depression relieved, for the first five years after completion, the pressure on the Lake (see Fig. 2).

4. LAKE QARUN

Lake Qarun is the lowest part of Fayoum depression. The Lake is the remanent of an ancient pre-historic Lake which covered a greater part of the oasis. In historic times the Lake was converted into an artificially controlled body of water, the Lake Moris, which was used as a regulator for the excessively high and low Nile floods. Around year 1800, the function of the Lake ceased, consequently, the surface area of the lake gradually reduced to its present dimensions at the north west fringe of the depression. The lake level was changing only in accordance to the changing in the discharges of supplied irrigation water to Fayoum and in the drainage inflow into the lake. The trend of water level change of Lake Qarun over the last century is shown in Fig. 3 (FWSB, 1984).

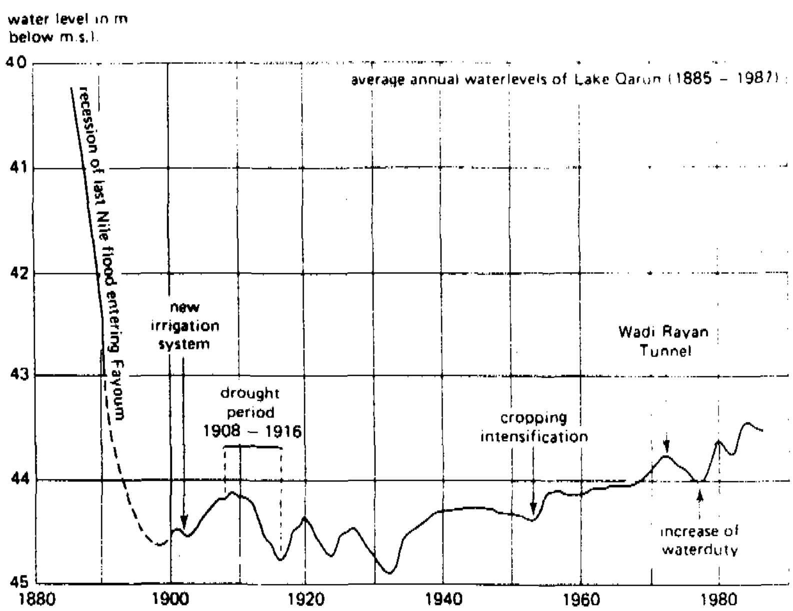

Figure 3. Water levels of Lake Qarun during the period (1880-1987)

Lake Qarun is not only a reservoir for the drainage water of Fayoum, but also a one of the most important sources of fish with its particular species. It is also considered the nearest recreation place for Cairo people with its long beach and nice motels and hotels. Besides, it plays a good role in the tourism activities in the Fayuom provence.

The lake covers an average area of about 240 Km^2, at the level of -43.73 m.MSL, which changes according to the water level. The average depth of the lake is 4.5 m, while the maximum depth reaches to 9 m. The volume of the lake at the same level is $1100 * 10^6$ m^3. However, this volume is slightly changed due to the wind blown deposits of sand from the northern shore and the sediments from the drainage water.

Amer (1989) indicated that the mean average evaporation rate from the lake water is 1762 mm ($423 * 10^6 m^3$) with high daily rates in Summer, about 7 mm, decreases to about 2 mm in Winter days (see Fig. 4).

Seepage flow into the lake either from the Nile Valley or from Wadi el Rayan Lake is considered not significant. Also, seepage from the lake is not likely (FWSB, 1984).

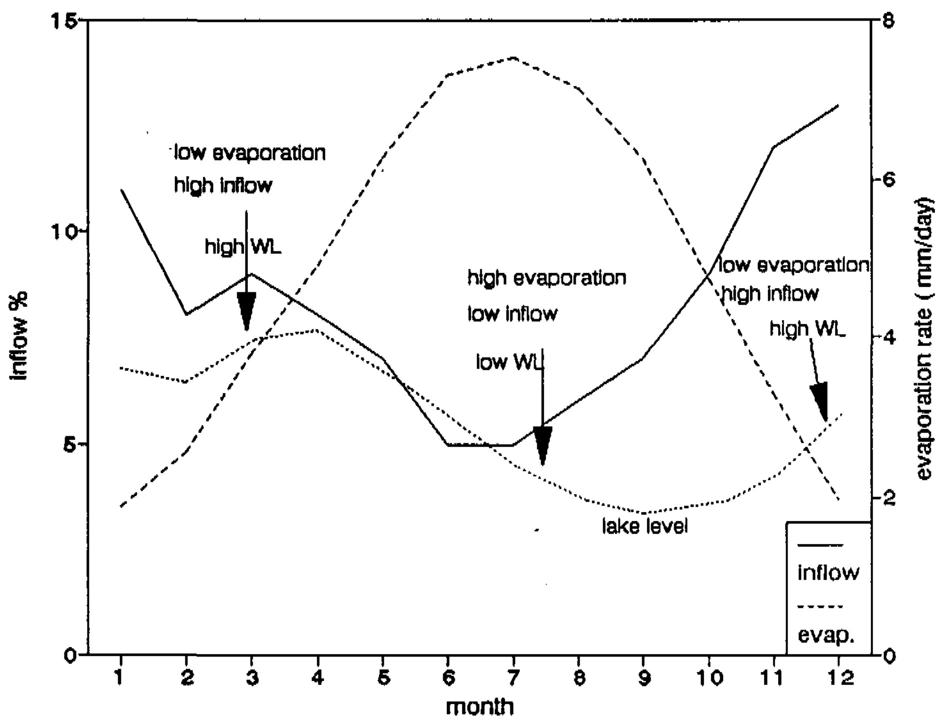

Figure 4. Effect of drainage inflow and evaporation on lake water level

5. ENVIRONMENTAL IMPACTS OF LAKE QARUN

5.1. Lake Level

The lake level is changing as a result of drainage water flow and the evaporation from the lake surface. Where in summer months and due to the shortage in irrigation water, the field and percolation losses are very low (low inflow), while the evaporation losses from the lake is the maximum. Therefore, it reaches the lowest lake level. During the closing period, irrigation canals are emptied for maintenance which result in a very high tail escape losses (very high inflow) contemporary with very low evaporation rate. Consequently, the lake level rises to the highest level. During Spring and Autumn, surplus water is available for leaching the fields with high percolation losses, whereas the evaporation rate is low result in a high lake level (Fig. 4). These conditions create a fluctuation of about 0.80 m around the annual average level.

When the average annual lake level rises to higher than the safety level (-43.73 m.MSL), the neighboring areas will be flooded with the lake water, especially during the high peak. The affected areas differs according to the related water levels as presented in table (1). Not only the flooded areas which will be affected, but also other neighboring agricultural areas will be water logged and subsequently suffer from salinization. Also, flooding damages the coastal road (the dike), the lake beach and affects the tourism activities.

Table 1. Submerged areas related to the different water levels of Lake Qarun.

Year	Lake level	Lake area	Submerged area	Remarks
	m.MSL	Km^2	feddan	
Avg.	-43.73	240.0	0	Present safety level.
1972	-43.75	239.5	-105	Just before starting Wadi el Rayan.
1979	-44.00	234.0	-1414	4 years after diverting to W.R.
1989	-43.33	248.7	2095	After the increase of water duties, crop
1990	-43.19	251.8	2829	intensities, and water supply.
1991	-42.92	257.1	4086	Just before the water management policy.
1992	-43.15	252.7	3038	One year after.
1993	-43.33	248.7	2095	Two years after.
1994	-43.55	243.9	943	Three years after (expected level).

5.2. Salinity Of The Lake Water

The average salinity of the drainage water flowing into Lake Qarun is 1.69 ds/m (1079 ppm). Over the last ten years, the salt load of the inflow water ranged between $422 * 10^6 - 500 * 10^6$ Kg/year. Therefore, an annual increase of 0.4 g/l is occurred where the average salinity of the last year (1993) reached to 39 g/l.

Like the lake level, salinity is affected by the drainage inflow into the lake and evaporation rate. During the summer months, the salinity is about 6 % above the average. While during the spring, it is 6 % below. As no salt leaves the lake, the salinity is increasing continuously. The present rate of salinization is 0.4 g/l per year. Fig. 5 shows the gradual increase in salinity from 1906, after the complete recession of last Nile flood entering Fayoum, to 1992.

The continuous increasing in Lake water salinity has a serious negative impacts on the activities depending on the Lake such as fishering, recreation, tourism. Also, it causes rapid salinization for the affected soils when flood may occur and subsequently the need for more efforts for leaching processes.

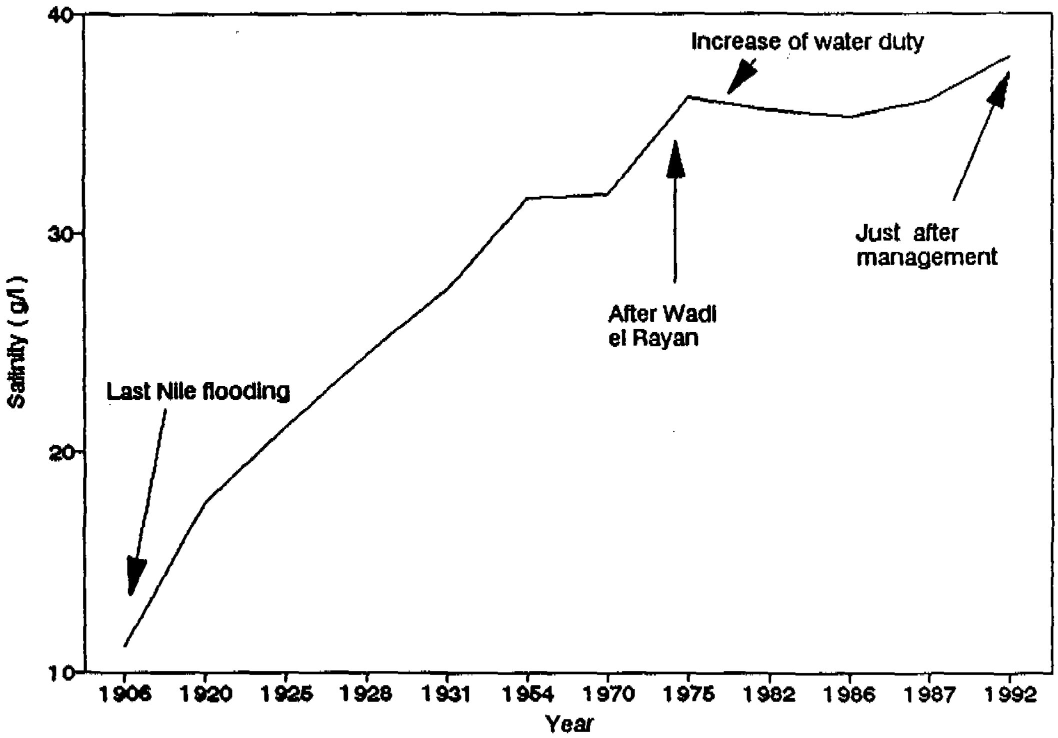

Figure 5. Average salinity of Lake Qarun during the period (1906 - 1992)

From the previous discussion, it is clear that to achieve the safety water level and salinity balance of Lake Qarun, an annual drainage water inflow to the lake should be maintained at 420 * 10^6 m^3.

6. CONTROL OF WATER LEVEL AND SALT BALANCE OF LAKE QARUN

To over come the problems of lake level rise and salinity increase, many efforts were carried out during the last three decades. Fayoum Irrigation Department assisted by different local and foreign research agencies has implemented some remedial projects. They aim to control the lake water level, maintain its salinity, provide protection to the adjacent affected lands, and improve water use efficiency and environment.

6.1. Controlling The Lake Water Level

Direct and indirect efforts were carried out to lower and control the Lake level. They are summarized as follow:

- Diversion an amount of 220* 10^6 m^3/year, to the western depression of Wadi el Rayan started from 1973, which equals about 33 % of the total amount of the drainage water discharge into Lake Qarun. This lead to decrease the annual average discharges that flow into Lake Qarun. However, continuous irrigation supply resulted in an increase of the overall Fayoum drainage water. (Fig. 6)

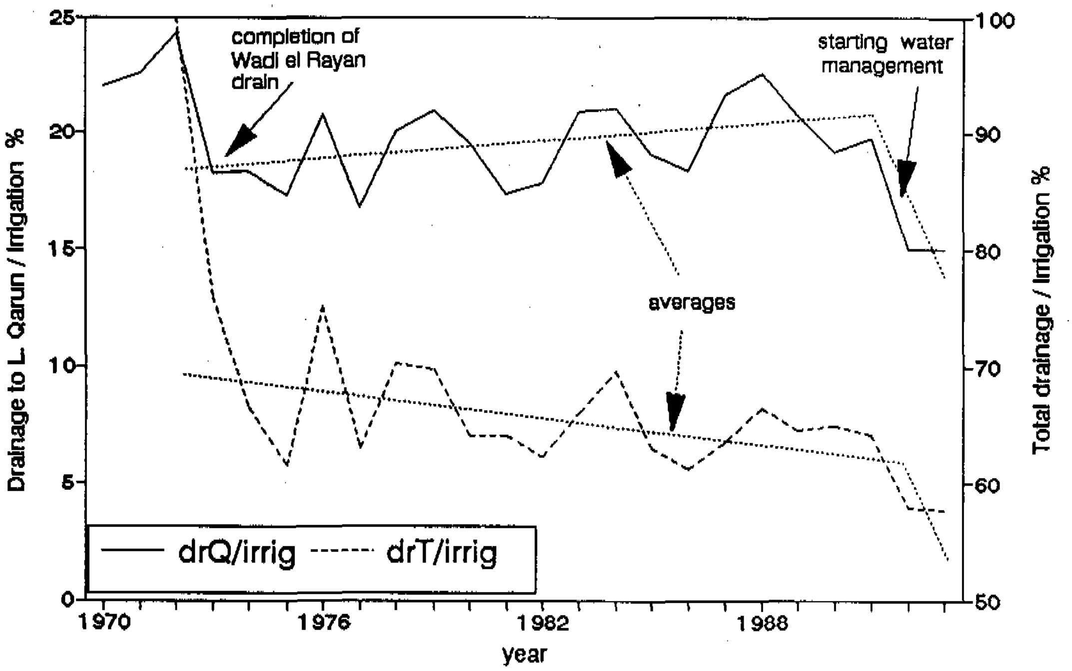

Figure 6. Changes of the Drainage / Irrigation Ratio

- Remodeling the hydraulic structures (weirs, gates regulators, offtakes,...etc) over the main and distributional canals. Accordingly, the proportional distribution of the available irrigation supplies throughout the different areas in Fayoum was improved. The remodeling programme (started by the end of 1991) decreased the excess water released from the upstream command areas of the irrigation canals which flows again to the lake and eliminated the problem of the shortage of water in tailends. Percentage of the reduction improvement of the lake level reaches to 25 % per year with reference to the safety water level of the lake as shown in Fig. 7.

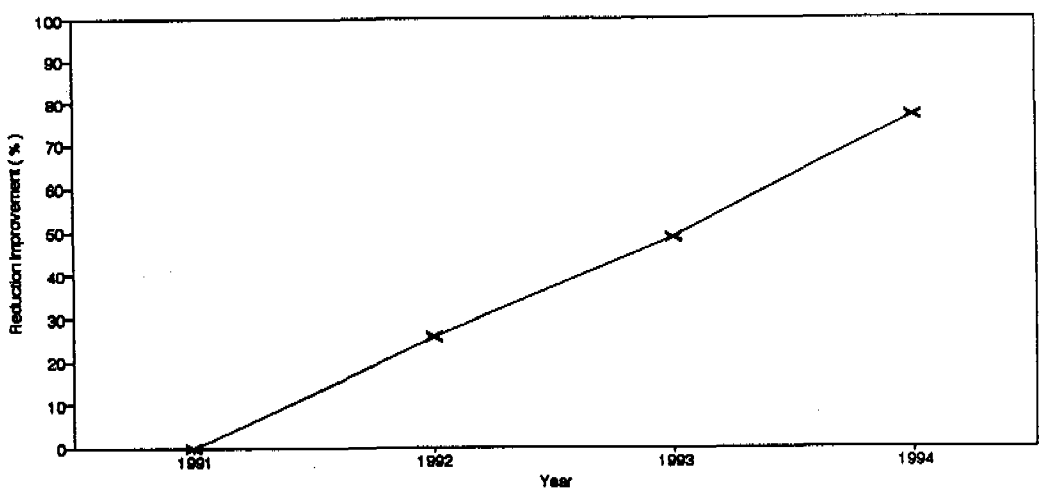

Figure 7. Reduction improvement of lake level after management policy

- Re-use of drainage water for irrigation. It includes the mixing pumping station from Batts drain at Tamia district (4,5 m^3/sec) to Bahr Wahby canal, and some other smaller capacity pumps on secondary drains. Also, there is almost a similar amount of drainage water is diverted by gravity to the irrigation system mainly in the middle part of Fayoum depression. It resulted in a reduction of about 160 * 10^6 m^3/year of the net drainage flow, into Lake Qarun (about 38 %). The water level in Lake Qarun was considerably lowered after the starting of pumping the drainage water of Batts drain to Bahr Wahby at the end of 1993.

Fig (8) shows the overall effect of the water management policies and remodeling programmes that were carried out to lower the Lake level during the last few years.

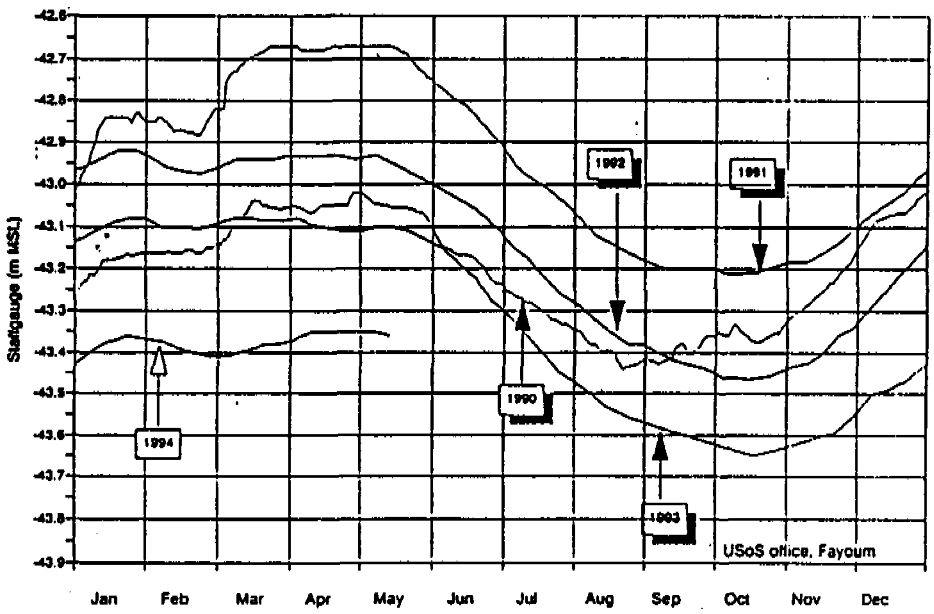

Figure 8. Monthly water levels of Lake Qarun (1990-1994)

6.2. Protecting The Adjacent Lands

The adjacent cultivated areas at the eastern and middle parts of the southern coast of the lake have a slight high elevation more than the normal fluctuated level of the lake. They were always suffering when the lake level getting higher.

To over come this problem the following efforts were carried out to face this problem.

- Construction of a dike along the coast of the lake as well as a protection wall at the village areas.

- Deepening the interceptor drains along the lake coast and lifting the collected water by using pumping stations, wherever it is needed .

- Implementation of a surface drainage system for the affected areas to maintain a sufficient deep water table and to flush the accumulated salts in the soil profile.

6.3. Maintaining The Salinity Of The Lake

Lake Qarun has a salinity of 38 g/l which is higher than of the sea , with an annual increase of o.4 mg / l. Consequently, it may after about 50 years, become a dead-life lake. Therefor, it was necessary to stop or to maintain the salt balance of the lake. A salt extraction plant was constructed nearby. It extracts, recently, about 180,000 ton/year, and planned to be increased to more than 300,000 ton/ year in the future.

7. Conclusions

- Lake Qarun plays an important role for Fayoum water management, besides, the recreation, tourism, fishering, and salt extraction activities.

- Rise of lake water to a level higher than the safety average level of (-43.73 m. MSL) causes many environmental problems.

- The monthly distribution of the supplied irrigation water is not either uniformly distributed or timely matching with the requirements. Excess water during the months of low demands still flows into Lake Qarun via the drainage system.

- Diversion a part of drainage water to Wadi el Rayan Depression reduced the inflow to Lake Qarun for few years. However in the other hand, it created the concept of increasing the crop water duty and expanding of the reclamation areas. This lead to an increase of the irrigation supply and consequently the drainage water flow.

- Following better water management policy resulted in maintaining, to a great deal (about 75 %), the lake level and prevented most of the negative impacts of the lake level rise.

8. Recommendations

To improve the present policy of water management and control of lake environmental aspects, the following recommendations might be helpful :

- Maintaining of Abu Bakr spillway at Lahun where the excess water during the months of low demands and closing period could be discharged.

- Investigating intensively the criteria, plan and strategy of reuse of drainage water in irrigation. It has to be interrelated to the water management programme to prevent its negative effects on soil and crop yield in Fayoum.

- Improving the irrigation distribution and water use efficiency on farm level.

- Keeping an annual inflow of about $420 * 10^6$ m^3 into Lake Qarun is essential to maintain the level and salinity at reasonable values.

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MATCHING EVOLVING WATER QUALITY MANAGEMENT STRATEGIES TO MONITORING SYSTEM DESIGN

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ABSTRACT

Good world water resources management under current conditions is becoming, more or less, a surviving issue. Water pollution and related water quality problems add a new dimension to the process of the overall water resources management. Previous experiences in the field of water quality management showed that such practices have cost a huge sum of money to achieve some how an acceptable level of environmental control. Unfortunately, developing countries cannot afford for similar procedures. However, a procedure to design and implement a monitoring system that can evolve with time as the required resources (human and financial) become available is recommended in this regard. A water quality monitoring system design strategy that depends mainly on the flow of information has been developed. In this dynamic design consideration has been given to the limited resources of developing countries, and the proposed design strategy produces only that information necessary to support the chosen management level. Management/information relationships have been used to develop three phases of an implementation strategy for the proposed water quality monitoring system. The first one starts the monitoring activities by testing the system through a *Stream Standard Based Management*, that is checking the water bodies in the design country against any pollution that influences the beneficial uses of the water. The second phase, moves towards more control with a permit system, called *Permit Augmented Management*, which subjects effluents from many industries or firms to routine monitoring. The last phase, called *Incentive Assisted Management*, seeks the proper methods to help polluters comply with the rules and regulations by offering technical and financial assistance. Non-point sources of pollution have also been discussed, so that information about these sources and their impact help the authorities to take the desired management actions for control.

SOMMAIRE

La bonne gestion des ressources mondiales d'eau potable en condions normales, est devenue, plus ou moins, une question de survie. La pollution de l'eau et les problèmes de qualité de l'eau qui en résultent, ont ajouté une nouvelle dimension au processus global de gestion des ressources en eau.

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Des expériences préalables dans le domaine de la gestion de la qualité de l'eau ont montré que de telles pratiques ont couté une somme d'argent exorbitante pour arriver à un contrôle approximativement acceptable de l'envirronnement. Malheureusement, les pays en voie de développement ne peuvent se permettre des procédures similaires. Néanmoins, une procedure visant à concevoir et mettre en place un systéme de contrôle évolutif dans le temps à mesure que les ressources nécessaires (humaines et financiéres) seront disponibles est recommandé à cet égard. Une stratégie conceptuelle de systéme de contrôle de la qualité de l'eau qui dépend principalement sur la diffusion de l'information a été développée. Dans ce concept dynamique, les ressources limitées des pays en voie de développement ont été prises en compte, et la stratégie de concept proposée ne requiert que l'information la plus nécessaire pour soutenir le degré de gestion choisi. Les relations entre la gestion et l'information ont été utilisées pour développer trois phases de la stratégie de mise en place du système propose de contrôle de la qualité de l'eau. La premiére phase demarre les activités de contrôle en testant le systéme à travers une *Gestion Basée sur le Courant Normal*, ce qui consiste à vérifier la masse d eau dans le pays test contre toute pollution qui influence l'usage bénéfique de l'eau. La seconde phase tend à plus de contrôle grâce à un systéme de permis, appelé "*Gestion de l'Augmentation de Permis*" qui suppose l'avale de nombreuses industries et compagnie pour un contrôle routinier. La dernière phase appelée "*Gestion Stimulante Assistée*", cherche les méthodes les plus appropriées pour aider les pollueurs à accomplir les régles et devoirs en offrant une aide technique et financiére. Des sources de pollution ignorèes ont également été abordées afin que l'information concernant ces sources et leurs impacts aide les authorités à prendre les actions de gestion desirées pour le contrôle.

1. INTRODUCTION

Water quality management, as a means by which countries maintain or improve the quality of their nation's waters, has evolved rather rapidly over the past 25 years. And it is still rapidly evolving! In developed countries today, the evolution concerns itself with trying to go beyond human needs for clean water and address the water quality needs of a healthy ecosystem. In developing countries, the evolution concerns itself with protecting human health and meeting the needs of a growing economy, as well as ecosystem sustainability. In both cases, water quality management is changing.

As a water quality management effort matures within a country, it passes through stages. As the management effort matures, its need for information about water quality changes. Very early water quality management efforts often need data only where there is an obvious water quality problem. As laws are passed to address recurring problems, water quality management is often required to establish water quality criteria and standards that protect currently acceptable uses of water (ecosystems, health, industry, or agriculture). Now the information needed by the growing water quality management effort must relate to given water quality variables and levels of those variables deemed acceptable. As the standard violations become numerous, laws are passed to provide penalties for those causing the violations. Now the information obtained about water quality must be able to enforce, often in a court of law, what actually happened in the stream. As those causing the violations are increasingly fined for polluting the water, the government is asked to provide financial assistance in building facilities to treat the polluted water. The water quality management agency, which is still growing in staff, now must rate the seriousness of water quality problems for purposes of determining which community receives government assistance first. And so on!

This progression of evolving water management and related information needs has a profound impact on the design and operation of the water quality monitoring system that is to supply the needed management information. The purpose of this paper is to examine the steps in this management evolution and attempt to relate that evolution to corresponding monitoring systems. The goal is to have the approach and level of management matched with an appropriate monitoring system - one designed to support such management. It is hoped that such thinking will be useful to those who are designing and implementing water quality management efforts in developing countries.

Too often, the design of water quality monitoring systems is treated independently of the chosen strategy for management. This can result in management efforts that are not provided with information it needs to function effectively and efficiently. There is a need to examine the relationship between management strategies and monitoring system designs in a more formal manner than has existed in the past.

2. LEVELS OF WATER QUALITY MANAGEMENT

In examining the history of water quality management, Soliman (1992) has identified five levels through which many countries have evolved since World War II. These levels are not necessarily linear. They can, and are, mixed in a number of different ways, but they are listed here as levels for purposes of developing a discussion of the information needed to support different management efforts. The levels are defined as follows:

1. Crisis Management: A small management structure is established to respond to water quality problems as they arise. There is very little proactive management (ie regulation). This level corresponds to the "nuisance" based efforts to deal with water pollution problems that was used in many countries prior to the 1950s.

2. Stream Standard Based Management: As the frequency of nuisances begin to negatively inhibit development of a healthy economy, a more proactive approach to water quality management was required. The first step toward a more proactive level of management involved defining how society used water and making sure these uses were protected. In general the uses protected were related to human health, economic health and recreation (ie swimming and fishing). The impact of poor water quality on these uses was quantified, via establishment of water quality criteria (such as the classic McKee and Wolf, 1963). The management goal, under this level of management, was to try to insure that society's uses of water were protected. The means to actually control water quality within these criteria, and

related standards, was weak (eg enforcement conferences were used in the United States when this level of management was employed in the 1960s).

3. Permit Augmented Management: Simply establishing stream standards does not provide a means to control water quality. Extraction and discharge permits have been added to management efforts to provide a means of actually controlling stream water quality within the limits set by the stream standards. This level of management was initiated in the United States in 1972 and included the legal means to insure that permit conditions were met. A major task of management was to define the discharge limits that would insure that the stream standards were met.

4. Incentive Assisted Management: Many water quality management efforts include incentives, generally financial, to assist dischargers in reducing their pollution load on the environment. The nature and extent of the incentive generally depends upon the local economy, severity of the problems, or public perception of the severity. Grants and/or loans to public bodies to construct wastewater treatment plants represent the most common incentive. In the United States incentives have been a part of the Federal legislation, and many state laws, since the early days of formal water quality management efforts. However, the heyday of such incentives was in the 1970s after passage of the Federal Water Pollution Control Act Amendments of 1972.

5. Holistic Management: As water quality management becomes increasingly sophisticated in its efforts to control water quality within acceptable bounds and balance the trade offs between the competing uses, as well as cope with the expanding concept of uses (eg sustaining an ecosystem), there is a constant need to enhance the understanding of the integrated physical, biological and chemical processes involved and incorporate this understanding into management decision making. In particular, as management achieves adequate control of point sources of pollution, focus often shifts to controlling the more difficult non-point sources of pollution. These sources often are generated by the life styles of individual citizens and achieving control over these sources requires both a good understanding of the exact causes and educating the public about their role in the problem. It is at this level of management that a more holist management approach is being initiated. The debate surrounding reauthorization of the Clean Water Act in the United States currently is addressing many of these issues.

Again, it needs to be pointed out that there are many other ways that water quality management could be categorized. This particular categorization is undertaken in order to relate management to monitoring support.

3. MONITORING AS A DYNAMIC PROCESS

Water quality monitoring is not a static process. As the management evolution, summarized and categorized above, clearly illustrates, management is dynamic. The monitoring utilized to support such management must, likewise, be flexible and dynamic.

Water quality monitoring, in general, can be defined as consisting of six linear activities (Ward et al, 1990): (1) sampling the water; (2) analyzing the sample in the field or laboratory; (3) storing and retrieving the data; (4) analyzing the data via plots, statistics and/or models; (5) preparing reports that present the findings; and (6) having the generated information readily understood and incorporated into water quality management decision making. As one attempts to match the information needs of management to the design of the supporting monitoring effort, the monitoring system designer must have a clear and complete view of these six components and their linear connections.

The "design" of a water quality monitoring system can be approached from many different levels (as can management). Furthermore, the actual implementation of a design can be approached from a number of different levels. In other words, the design and implementation of a water quality monitoring system can be viewed separately. It may be desirable for a country to develop a long term vision for its approach to water quality management, and its corresponding monitoring system design, with the realization that both will be implemented in stages over time, as the economic well being of the country permits or as the public demands. The hope in such an approach is that an appropriate water quality management program is being utilized at all times thus assuring that such management is occurring in an efficient and effective manner.

The creation of a water quality management vision and strategy, as outlined above, that can be implemented in stages, is designed to fit with the realization that achieving effective water quality management in developing countries lies not in the realm of technology nor even in the availability of funds, but rather in the development of local plans and programs that can be sustained with local human and financial resources (Okun and Lauria, 1992). In many cases it is highly desirable that a long term vision, with implementation stages, be used to guide the evolution of a water quality management program in a developing country.

Also, there is the possibility that different regions of a country will be implementing different levels of water quality management (and corresponding monitoring) due to differences in water quality problems and availability of human and financial resources. Having an overall vision of how the different levels will eventually merge into one coherent management system, can assure all involved that each region's efforts do contribute to the country's water quality well being in a coordinated manner.

Further, there is the possibility that not all six steps in the total water quality monitoring system will be implemented at the same time. Obviously, the first three steps are highly dependent on each other. For example, no sampling is meaningful unless samples are analyzed, either in the field or laboratory. Also, if the results are not recorded and stored in an easily retrievable and understandable manner, the results will not be readily available for future data analysis. However, the final data analysis, reporting and use for decision making could occur at that point in time when the management level is up graded to where it needs the information. An overall plan helps assure that when management needs information, it will be available. Thus, if financial resources are limited, but it is desired to begin some management/monitoring efforts in a region of a country, only half the monitoring/information system may be implemented.

This last point deserves more comment. Water quality management is often implemented at the exact same time, or even ahead of, its corresponding monitoring system. The monitoring system generally requires time to produce the information, particularly regarding the time scale, needed for management decision making. Thus, there is often frustration on the part of management, initially, with the results generated by its monitoring system. Thus, by planning ahead, it will be possible to implement the monitoring system ahead of the beginning of the management effort, thus insuring that when management decisions need to be made, information from the monitoring system will be available.

To further illustrate the concepts being discussed above, three of the management levels (stream standard based, permit augmented, and incentive assisted) will now be discussed in relationship to their need for information from a monitoring system. Crisis management, generally, does not require routine inputs of water quality information. The exact nature of, and need for information to support, holistic management is beyond the scope of this paper. It is readily apparent, however, that such integrated management will require an extremely sophisticated environmental monitoring system in which water quality will be only one component.

4. MATCHING MONITORING TO MANAGEMENT

The following discussions of information needs for various levels of management are being approached in a connected fashion. In other words, the stream standard based level of management is being viewed as a possible first phase in a country's efforts to establish on organized approach to water quality management. A second phase is adding permits to the management "tools" available to those responsible for managing water quality. A third phase is developing incentives to assist polluters in meeting their discharge limits.

The monitoring system design is being viewed as having closely connected phases of evolution - phases that could be anticipated, and even planned for, over a given time horizon. Furthermore, the discussion is restricted to the interactions of management levels and implementation of a monitoring system design. In other words, a design methodology is not presented as it is beyond the scope of this paper. Readers interested in how to approach the design of water quality monitoring systems are referred to Ward et al (1990), Adkins (1993), Loftis et al (1991), and Ellis (1989).

Thus, the connectivity between management information needs and the actual monitoring taking place in the field is the focus of the following discussion. The goal would be to have the level of management and its corresponding information needs being planned in a well coordinated fashion so that they both "grow" together, particularly in a developing country where human and financial resources may be particularly limiting.

4.1 Stream Standard Based Management

In approaching water quality management planning, from an overall perspective, this is the first level of management that requires an organized approach to routine acquisition of water quality information. If water quality standards have been developed for the rivers and streams of a country, how is the water quality information system to provide decision making information? It has been generally recognized that ambient water quality monitoring (samples collected at regular intervals over time and space) will not detect very many short lived violations of stream standards (General Accounting Office, 1981; Loftis and Ward, 1981; and van Belle and Hughes, 1983). Such monitoring, rather, informs the managers of the general status of water quality conditions and gives indications of tendencies of standards to be violated in a particular reach of a river or stream. A key factor in designing such monitoring programs is to consider how represent sampling points are in order to obtain indications of water quality conditions that relate to critical decision points in the hydrologic/ecologic system.

It should also be pointed out that there are a number of monitoring strategies that have been used to obtain water quality information for management purposes. It is being assumed, in this case, that an ambient monitoring system is being considered as the backbone of the information system supporting management. Intensive studies are definitely a part of any water quality information system, but it is the ambient monitoring that most often needs to be very carefully designed to insure relevance to the particular management level being utilized by a country.

Assuming that a monitoring system design has been prepared that insures representative samples at critical points in the system, it remains to be determined exactly how this design will be implemented in support of this level of management, especially given the evolving nature of management and the limited human and financial resources. The key point, as noted above, is that design and implementation do not have to occur together.

The concept of implementing only a portion of the monitoring system design, to better mesh with the human and financial resources available, has two dimensions: (1) initiate sampling at a small percentage of the sites identified in the design; and (2) sample at all the sites but do not initiate the latter half of the monitoring system design beyond the bare basic data summaries.

To illustrate, consider the watershed shown in Figure 1. The region has eleven stream segments and each can be placed into one of three categories of importance based upon uses of the water within each segment (see Table 1). Categories could be included in the implementation of the monitoring plan, depending upon the funding available.

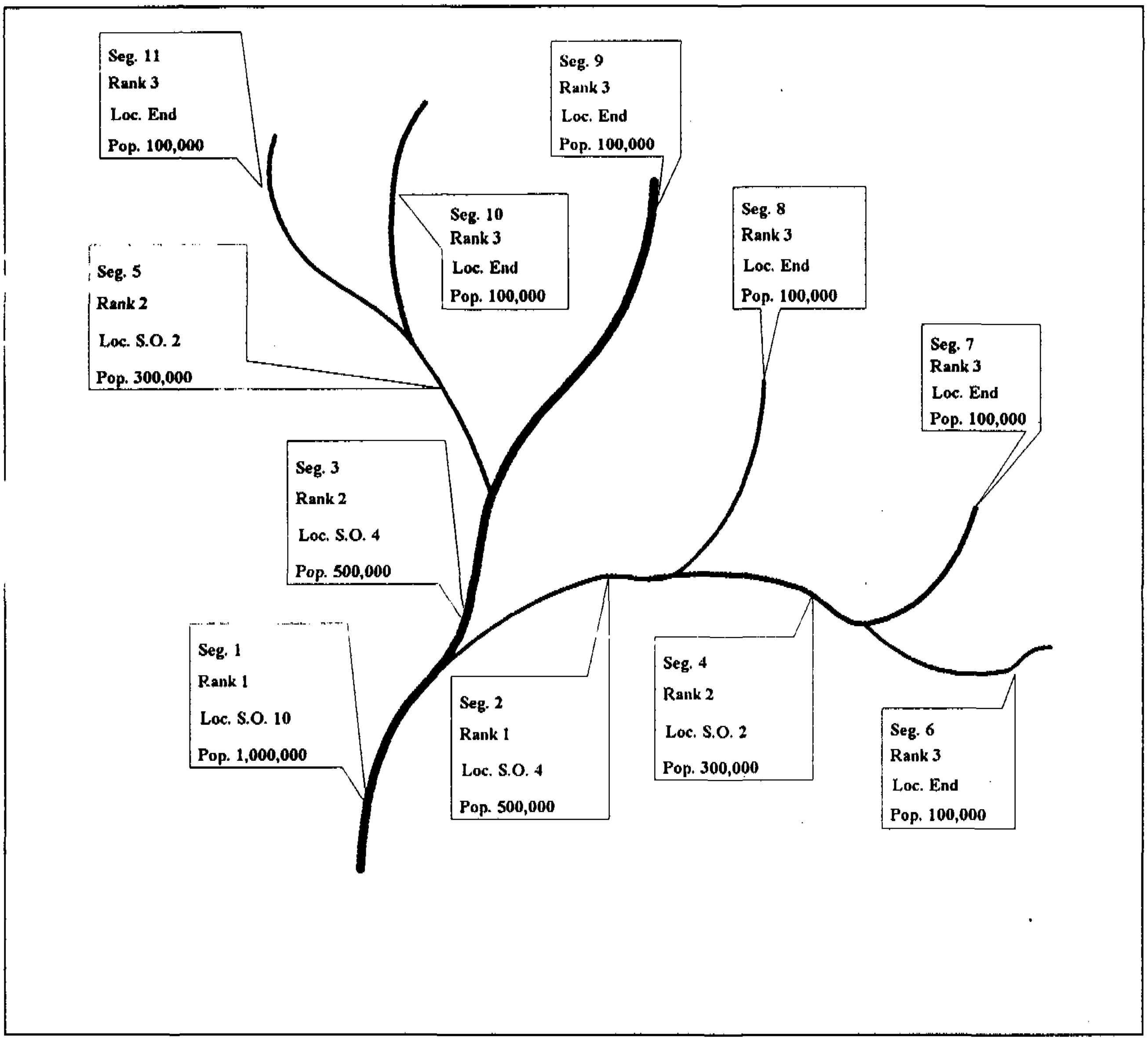

Figure 1: Example of Stream Rank in a Particular Region.

All the sampling points in Figure 1 could be sampled, samples could be analyzed, and the resulting data stored. The follow on data analysis, reporting and utilization of the information within management could be delayed until additional resources, both human and financial, are available. Great care must be taken to assure that the collection of data does not simply become an end in itself in this case.

Table 1: Example of a Stream Rank for the Stream Segments in a Particular Region.

Stream No.	Rank	Location	Accumulated Population
1	1	Source of 10	1,000,000
2	1	Source of 4	500,000
3	2	Source of 4	500,000
4	2	Source of 2	300,000
5	2	Source of 2	300,000
6	2	End	100,000
7	3	End	100,000
8	3	End	100,000
9	3	End	100,000
10	3	End	100,000
11	3	End	100,000

In general, the monitoring occurring within the stream standard based management level cn result in two basic types of reports or "information products". These are: (1) regular reports describing the general status and trends in water quality relative to the applicable standards; and (2) periodic reports that describe need for immediate management action. The information contained in the latter report eventually gets presented and analyzed in the regular status and trends reports. It is critical that the reports and the information contained therein be published in a manner that gets the information to those funding the monitoring operation.

4.2 Permit Augmented Management

In a developing country, there is little need to move to this level of management if the stream standards are not being violated. If, however, status and trends reports from the stream standard management level indicate that standard violations are occurring regularly, it will be necessary to move toward some means of controlling discharge quality. In those areas where the violations are most frequent and of largest magnitude, water quality management can begin to issue some form of discharge permit.

The impact on water quality monitoring with this more proactive level of management is great. Effluents must now be monitored, more intensive measurements must be made in those streams receiving the discharges (to determine permit limits), and improvements (or lack thereof) to stream quality, as a result of permits, needs to be assessed and documented.

Effluent monitoring can take on many forms. The two most common are requiring the discharger to measure the quality of the discharge and report the results to the management agency (similar to that used in the United States) or the discharger can be charged for the measurement that is conducted by the management agency (similar to that used in Egypt). In the former case, the management agency normally performs some form of random sampling of effluents to confirm self monitoring data.

Reporting and information utilization is similar to that in the previous management level. Regular reports on the status and trends in effluent quality and its general impact on surface water quality is needed, as well as reports on violations and related specific impacts and clean up, where required.

At this point, the water quality monitoring supporting the management agency is producing information on stream conditions and effluent conditions.

4.3 Incentive Assisted Management

At some point in the evolution of a water quality management program, incentives, in the form of technical assistance, training, and/or financial loans or grants are often provided. This assistance does not come without costs; thus, there is a desire to allocate the limited resources to those areas in most need or capable of best utilizing the assistance. The ramifications to monitoring tend to revolve around the need to identify where the water quality can best benefit by assistance and then to determine if the assistance has had a positive impact.

This level of management tends to be regional or problem specific, within the larger framework of setting standards and issuing permits. In other words, assistance is provided and once the situation is under control, this form of management is withdrawn in order to assist another community or solve another problem elsewhere. At the country level, however, the assistance is in the form of an ongoing program moving its focus around the country as needed.

It is particularly important that water quality information be obtained to justify the assistance. Reports should be produced documenting the water quality impact of a construction grant, availability of training, or use of technical advise. These will require monitoring of a special study nature - designed to document improvement in water quality due to a specific management activity. One report, at the end of an assistance effort, would present the impact and evaluate whether it was successful or not. And, if not, what should be done the next time to improve the water quality impact of the assistance.

4.4 Holistic Management

Beyond point source control, there is the need to address non-point source problems and improve the relationship between water quality and the surrounding ecosystem. In many ways, this type of approach may be the basic approach of the future, but at this point in time, it tends to be the most sophisticated and information intense form of water quality management. Developing countries need to be very aware of the information demands of this level of management and plan accordingly.

Special, rather intense, studies are needed to quantify non-point sources of pollution and define their relationship to land use, air quality and the general health of the ecosystem. In the U.S., the Geological Survey's National Water Quality Assessment (NAWQA) Program is producing information that has the potential to quantify such relationships. This monitoring effort is extensive and costly, but something like it is needed at this level of management.

Water quality information at this level of management begins to take on a public information role that must occur if the public is to agree to modify their life styles that are negatively affecting land and air quality and, eventually, water quality.

It must be pointed out here that many aspects of the information needed to support this level of water quality management are still being explored. How can water quality information be made interesting and informative for citizens of a country? How do we measure the health of an ecosystem? What organisms are representative of the ecosystem? What means are available to assist individuals in adapting to lifestyle changes necessary to protect the environment?

There are examples of programs that assist citizens in adapting to lifestyle changes, but they might be considered only a drop in the bucket. For example, well-head protection programs insure that wells are installed in a manner that does not lead to groundwater pollution via the casing of the well itself.

5. SUMMARY AND CONCLUSIONS

Many developing countries are moving toward establishing some formal approaches to water quality management. In this paper, the need to consider a larger context for such planning and implementation, especially as such planning relates to water quality monitoring, has been discussed.

While there are considerable limitations under which many countries approach the design and establishment of water quality management, it has been pointed out here that the overall plan, or design, of a water quality management/monitoring program can be separated from its implementation. Implementation can occur in stages that better matches the human and financial resources of the country. Such an approach permits a country to match its level of management with a monitoring system that is appropriate. As resources become available, the up grading of management, and its related monitoring, becomes much more obvious to the decision makers - a "road map", if you will, is available to guide the evolution of water quality management in an effective and efficient manner.

Finally, it is realized that not all countries will use the approaches to water quality management briefly summarized herein. There is a need to carefully explore various approaches that best match the social, economic, and environmental characteristics of a country. Hopefully, what this paper has indicated is that it is best to think beyond the immediate implementation possibilities and lay out a longer range plan that incorporates an evolving management approach with a corresponding evolving monitoring system design.

For a country to attempt to move straight to a complex, holist form of water quality management, without permitting itself to evolve through the means of supporting such management, particularly with respect to obtaining the needed information, may set the stage for inefficient use of monitoring and management resources. While it is realized that time may be working against such an evolutionary approach, it may take more time to establish an effective water quality management program if the approach used ignores the need to integrate acquisition of water quality information into the management process and day-to-day operations.

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DEALING WITH WATER DEMAND MARGINS

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Abstract:
For a long time the demand for water in the Netherlands has played a rather insignificant role. Since the last few decades there have been an increase of so many functions which relate to the discharge and storage of water that during the dry period of the year the water systems of the Netherlands experience a water shortage.

The shortage of fresh water results in narrow margins in the dry season. It is therefore important to set priorities to and optimize the use of water. These priorities depend on the economic, social and ecological values determined by decision makers.

This leads to two important conclusions:

a) A good set of instruments is needed to determine the consequences of the projects.

b) An integrated approach concerning the disciplinary board, of the watersystem projects is necessary, also in the case of relatively small project areas.

Résumé:
La question pour l'eau était presqu'inconnu en Pays-Bas déjà longtemps. Dans les dernières décades il a arrive plus en plus des functions pour l'eau en rélation avec sa décharge et sa stockage, ci-que il a arrive l'expérience de défaut de l'eau dans les périodes le plus séche chaque année.

Ce défaut de l'eau frais a résulte en margins exigues durant le saison séche. Pour ce raison il est important pour faire des priorités en trouvant l'optimalisation dans l'usage de l'eau. Ces priorités dépendent des valeurs économiques, sociales et écologiques comme il sont developper par celles qui prend les décisions politiques.

Deux conclusions importantes sont réconnues:

a) Il faut besoin un set des instrument de model pour calculer les conséquences des plans.

b) Une chiffre approché integrates, concernant les disciplines differentes, des plan des systèmes de l'eau sera nécessaire, aussi en cas des plans d'une aire assez petite.

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1. INTRODUCTION

For a long time the demand for water in the Netherlands has played a rather insignificant role. Only the surplus of water was and still is an important topic. Floodings due to heavy rainfall in combination with the melting snow of the Alps have caused problems to the safety of the people who lived along the rivers and they destroyed the crops.
Today not only the surplus of water but more so the shortage of water during dry summers causes problems for the various users of water. Furthermore the different types of water use lead to complex decisions for the Water Boards about who is allowed to use the available water during dry periods.
The water authority therefore needs adequate instruments to make the right decisions. These instruments consist of hydrological models to forecast the discharge, and models to calculate any possible damage according to the decisions for a particular use of the available water.
As a result of the intensive use of water, especially during periods of low discharge, the margins in water demand and availability are narrow and therefore important. Data should be available in time; alternatives should be regarded before a final decision can be taken; the different types of damage which do not always compare, should be regarded, and last but not least the organisation should be equipped to give immediate answers to make the right decisions.

This paper shows the problems of the small water demand margins in the Netherlands and gives an overview of the development of instruments dealing with these narrow margins.

2. FRESH WATER SUPPLY

The river Rhine is by far the most important supplier of fresh water in the Netherlands. Approximately 65 per cent of the fresh water surface comes from the Rhine, 8 per cent from the Meuse and the remainder from rainfall (24 per cent) and a number of cross-frontier rivers. Figure 1 gives an overvieuw of the main rivers in the Netherlands.Most of the rainfall ends also in the Dutch part of the Rhine basin.
The river discharge mainly consists of surface run-off and partly of base flow. During dry periods base flow is the main source of fresh water. It is formed by the limited run-off of groundwater from the catchment area supplemented by melting water from the glaciers in the Alps.

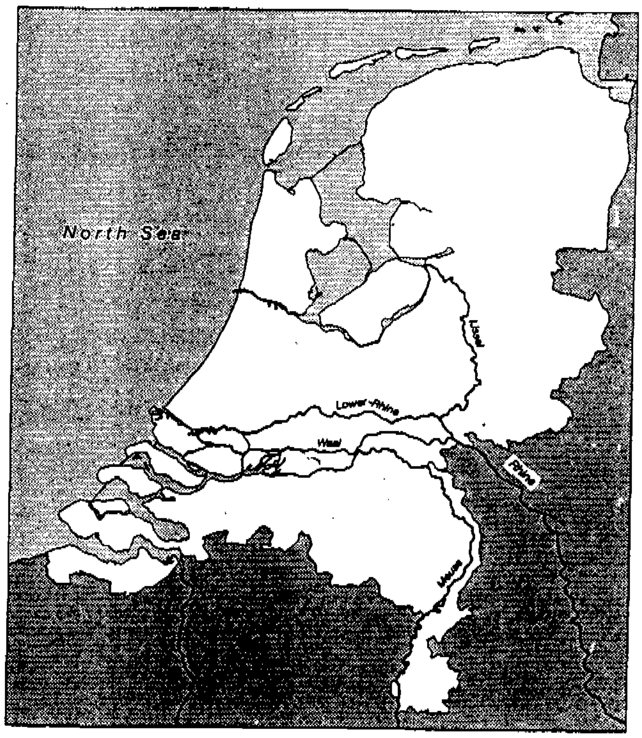

Figure 1. Main Dutch rivers

Figure 2 gives an overview of the discharge data of the last 7 years at the Lobith measuring point, which is the point where the river Rhine flows from Germany into the Netherlands.

Year	Annual Mean	Minimum (daily mean)	Maximum (daily mean)
1987	2861	1368	7642
1988	2823	1175	10274
1989	1821	855	4531
1990	1856	901	7028
1991	1753	794	6712
1992	2011	865	4933
1993	2015	1203	11039

Figure 2. Characteristic discharge figures at Lobith (m3/s).

Figure 3 gives an overview of the 10, 50 and 90 per centile discharges over the period 1901-1980 (in decade averages).

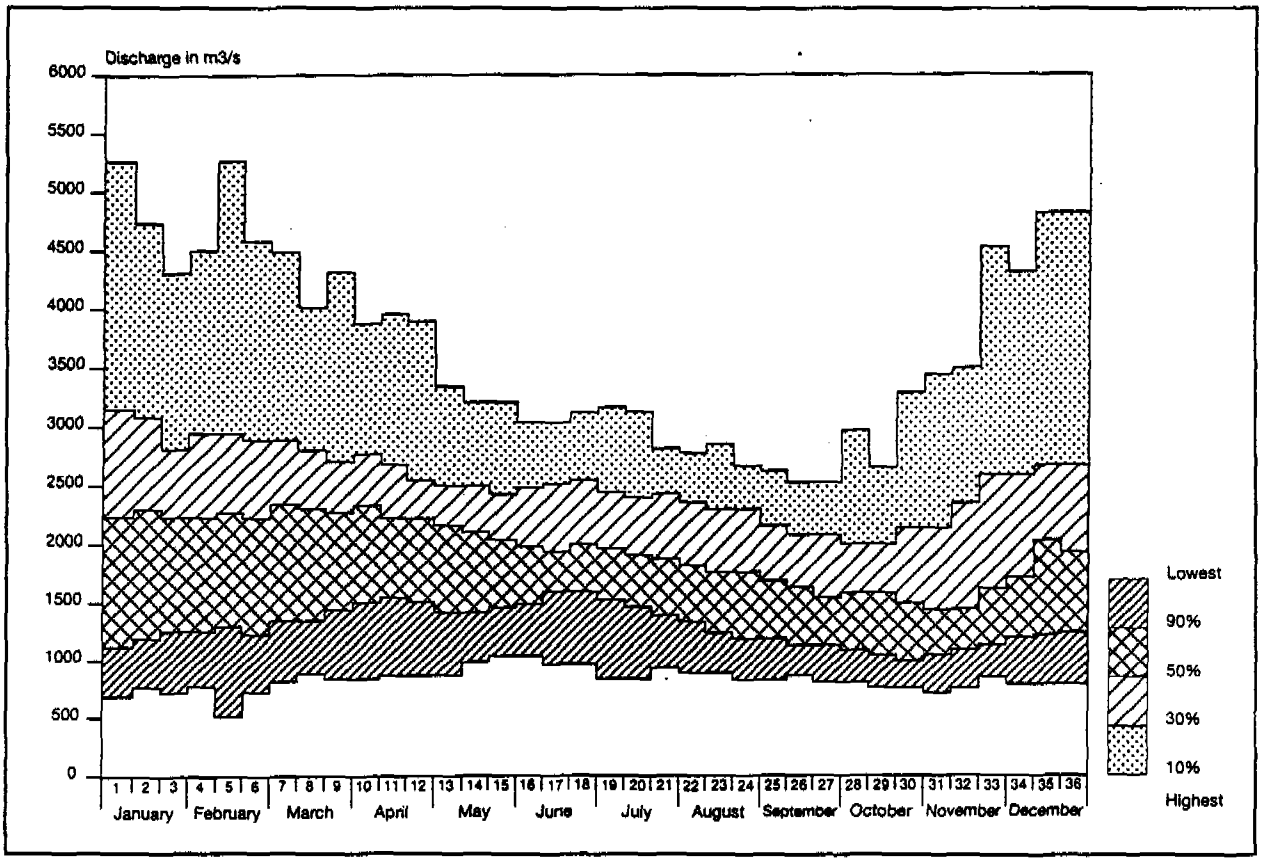

Figure 3. Hydrographs of the Rhine at Lobith (m3/s).

Despite a relatively constant discharge there are also relatively high and low discharges in the Netherlands part of the Rhine. The peak flow flood waves are caused by heavy rainfall as a result of Atlantic depressions, sometimes in combination with sudden thaw upstream in the catchment area.
The low discharges are caused by continuous drought in the catchment area, in periods that the contribution of melting water is already limited (in the summer and in the autumn). The low water levels are amplified, because the constant drop of the river bottom, as a result of erosion, makes the low water levels even lower.

In the Netherlands, the delta area of the Rhine, the Rhine splits up in three river branches 25 km downstream from Lobith. The river IJssel, which flows towards the north, is the main supplier of a large lake (IJsselmeer), which is an important fresh water basin. Of the two branches which flow westward the most northern is dammed up by relatively low discharges, both as regards shipping and the supplier of water to the IJsselmeer. The southern branch, the river Waal, flows freely to the sea and has a significant function in the water supply towards the western part of the country.

There have hardly been any problems with high discharges in the past decades. Most river dikes have a design height based on a flooding expectation of 1:12,000 years.
However, the low discharges have caused problems, be it that they are of a different nature than those of the high discharges.

3. SOME HISTORY

In the Netherlands the Rhine is a typical alluvial river. The last Ice Age left a system of twisting rivers with many shallow river beds. This network of water discharges alternatively deposited very fine to very coarse sediments. Clay particles were deposited further away from the main stream. The thus resulting sandy levees rose quicker than the clayey basins and became higher. However, these levees burst again in times of high discharges.
A more moderate climate changed the discharge regime and the twisting river system was slowly replaced by the meandering type. The continuing sand deposits which sometimes fell dry during long periods, led to the development of river dunes. It was in these river dunes and on other high lands that the first people settled in the Netherlands. Traces of habitation have already been found during the period from 1800 to 1000 B.C.
Around 1000 A.D. people started to protect themselves against high river discharges. They did this first by building their houses on artificial mounds. Later dikes were built around the occupied areas, thus creating the first polders. Around 1450 growing dike construction had resulted in a closed system of main dikes along the rivers. Between these dikes the water flowed freely. These dikes, however, burst frequently. This was caused on the one hand by high discharges, on the other as a result of ice banks and drift ice in severe winters.
To protect themselves against these dike bursts, around 1850 people began to construct normalization works in the river. This included the construction of groynes, the removal of sand banks and the cutting off of river bends with the objective to realise a better water and ice discharge and to prevent dikes from bursting.

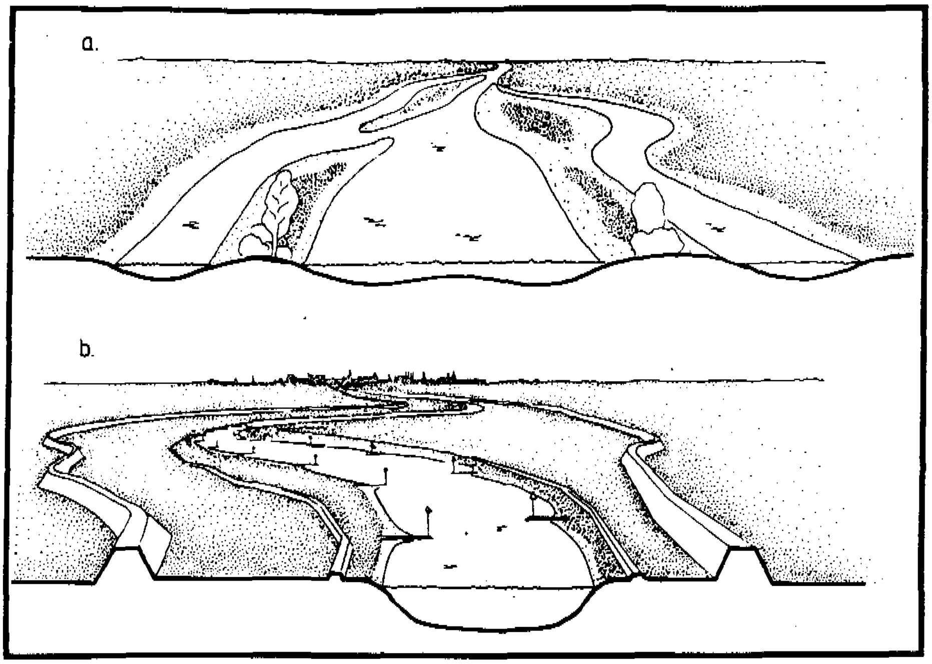

Figure 4. River Normalisation Works

At the start of the 20th century the number of dike bursts had been drastically reduced. It was reasonably safe to live along the river, cultivate the land and rear cattle. The most important user functions of the river had thus been optimised.

4. THE DEVELOPMENT OF THE USER FUNCTIONS OF THE RIVER

Chapter 3 shows that throughout the ages the number of user functions of the river Rhine had been rather limited. The river was a popular place to settle along, because of the water supply for man, animal and agriculture. Fishing developed as a source of food. The river also provided an excellent means of transport for shipping. The normalisation works built by the end of last century, for the easy discharge of water and ice, also had a positive effect on shipping, because the fairways had become deeper and more permanent.
The availability of water during periods of low discharges played a minor role: there was always sufficient water to meet the requirements, and the navigable depth was accepted by the shipping trade.

Since the last 2 centuries man has increased his use of the river. In other words, the number of user functions has slowly risen. This has in fact begun with the intensification of the original user functions. The wish to settle along the river, safeguarded against flooding, increased. The function of the river as a reliable transport route of water, ice and sediment became more and more important. Closely connected, the function of the river as the supplier of drinking water for man and animal, water for agriculture and a source of food through fishing grew.
Shipping also continued to develop, in particular when, in the middle of the 19th century, canals were constructed and river works carried out to create better accessibility for shipping.
The river was also used for sand and clay dredging for the brickworks and for civil engineering projects. During the second part of this century industry developed very fast.

Particularly Rotterdam became the location of all kinds of industry as a result of increased seaport activities. The harbour area and the river around Rotterdam were not only used for shipping but also for the disposal of cooling water from the petrochemical industries and power stations, and for the disposal of communal and industrial sewage, resulting in an enormous deterioration of the water quality.
In addition to the shipping routes and the industrial areas, recreation started to boom. Cruising, angling and other forms of water recreation became more and more popular.

This intensive use of the rivers and the lakes was not very good for the water systems. The water quality deteriorated, which had a negative influence on the production of drinking-water and on recreation; the water temperature increased hereby decreasing its cooling functions, and it increased fish mortality; the edibility of fish and shellfish decreased; the variety of organisms went down etc.

The waters became less suitable to fulfil their functions. This was particularly obvious during times of low discharge, hereby introducing the for the Netherlands unknown phenomenon of water scarcity. The intensification of the water functions during the past decades made this slowly a problem. The discharge was not every year so low that problems arose. By now there have been enough problems to quantify the boundary conditions which functions set to a particular availability of water and to translate these into economic variables.

5. WATER NEED

5.1 Introduction

This chapter gives a few examples of economic loss as a result of water shortage in the Netherlands. It also shows that these losses have only started to occur the use of the river functions increases and also that there is a reciprocal function influence.

5.2 Shipping

The transport sector is of great significance for the Netherlands. Inland shipping, in particular the international transport of goods, has been of great importance throughout the ages. In 1988 the river Rhine was used to transport 139 million tons of goods. The Waal, as the most important branch of the Rhine, is the busiest river of Western Europe and forms the connection between the seaport Rotterdam en the German hinterland. The degree of loading of the inland vessels is approximately 50 per cent. This means that the total carrying capacity of the vessels is twice the total transported load. One of the most important reasons for this is the limited unloading depth at low water level. Presently the aim for a given very low water level in the river is a fairway of at least 150 m. wide and 2.5 m. deep. It has been established that every extra decimeter water depth at a particular low river discharge provides annually an economic profit of about US$ 10.000.000 in transport costs. In other words the extraction of water which causes a drop in navigable depth, even if this is a matter of centimetres, will result in an economic loss for the shipping transport.

5.3 Salt Water Control

The Rhine flows as an open river into the sea. This means that the tidal influence is noticeable far upstream. And with the tidal influence sea water intrusion. The first 30 to 40 kilometres of river water are unsuitable for agricultural and horticultural purposes, which is exactly the region with great economically important horticultural areas. The water extraction points for these areas along the river have, as a result of increasing water use upstream, been replaced further upstream. However, these extraction points are still confronted with salt water during periods of low water discharge. This problem has become worse not only as a result of increasing water extraction but also because of the deepening of the Rotterdam harbour, because of which the sea water reaches far further inland. In particularly during periods with little fresh water to control salt water. To protect the extraction points against sea water intrusion, at least 600 m3/s of water needs to flow down via the Rotterdam waterway. During periods of low river discharges this quantity is not reached, resulting in agricultural losses.

5.4 Hydro-electric Power

One of the branches of the Rhine has a hydro-electric power station, which generates energy via the river discharge. In the Netherlands the head-loss at the hydro-electric power station is limited (approx. 3 m.). The discharge is therefore of real importance for the output of the power station. In case of small discharges (< 50 m3/s) the power station must be shut down, because the flow rate is then too low to keep the power station in action. During periods of low discharge every extraction from water upstream from the power station can be harmful.

5.5 Ecological Recovery

The increasing intensification of the use of water systems has not only led to a drastic deterioration of the water quality, but also to a continuous adaptation of the physical design. Dikes have been built and rivers regulated, fixing channels and fairways and making them suitable for use at low discharges. Constructions have been built for the infrastructure, shipping and harbour activities etc.

These operations as to the structure of the water systems have cut the hydrological dynamism, typical of natural water systems, drastically. With the limitation of this dynamism the diversity of the ecosystem has also been reduced. The abundance of varieties has dwindled, the quantity of organisms has been reduced and with them the basis of the water system for various purposes. To stop this deterioration and to realise an improvement in the development of the varieties, plans have been made for the ecological rehabilitation of the water systems. An important means is the return to a greater dynamism.

The previous chapters show that it is exactly the increase in dynamism which will produce great economic damage to the other purposes.

6. WATER DEMAND BY ECOLOGICAL REHABILITATION

6.1 Introduction

Despite the costs, the choice which has been made in the Netherlands is the one which aims at more dynamic water systems in favour of one aiming at sustainable functioning.
It is therefore of great importance to quantify the relation between an increased dynamism, the development of the abundance of varieties and the (economic) consequences for other purposes.
To reach ecological rehabilitation of the water systems a two-track policy is used. On the one hand there are extra efforts to protect the water systems against contamination through discharges and diffuse inflow. On the other the design of the water systems is adapted such, that the dynamism increases and physical barriers, particularly for fauna, are evened out, in consideration with the other functions.
In particular the latter policy to reach ecological rehabilitation, the design measures can influence the availability of water for other interests.
A few examples will be mentioned in which this influence on the water quantity, in particular during periods of low river discharge, plays a role.

6.2 Fish Ladders

In the past decade fish ladders have been constructed in those parts of the canalized river branches where hydro-electric power stations are situated. Part of the ecological rehabilitation of the river is to make the weirs free from obstacles to create opportunities for the migration of fish to upstream spawning grounds. However, a fish ladder requires a fresh water flow to guide the fish to the passage. This fresh water flow means a lower flow rate for a hydro-electric power station, when situated near this weir. This shows the user costs of the application of a fish ladder at somewhat lower discharges.

6.3 Side Channels

A measure to reach a greater species diversity for flora and fauna, is the construction of side channels along the canalised rivers. Side channels are: down flowing, relatively shallow tributaries of the main channel with rather low dikes.

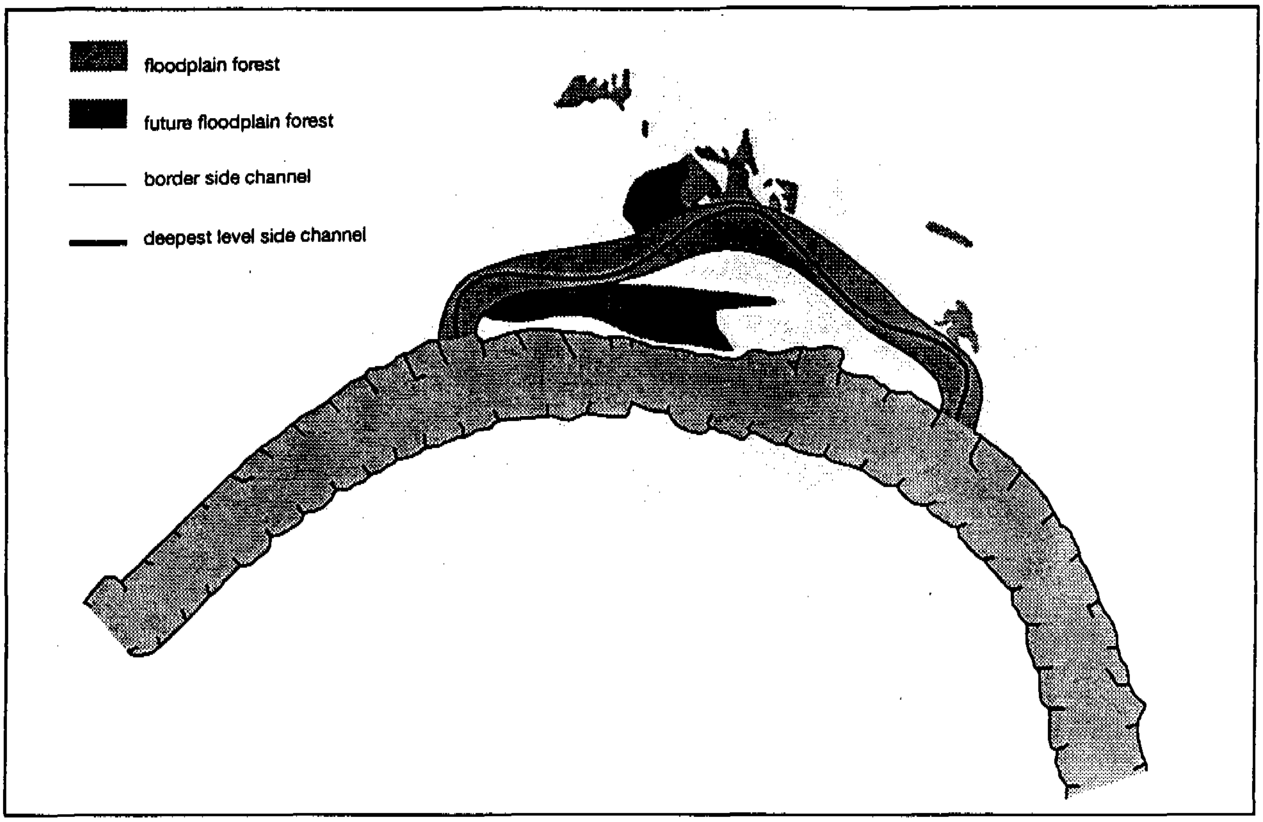

Figure 5. Example of a side channel

Low flow velocity, no shipping and the fact that the water discharge function is not important, make it possible for flora and fauna not present elsewhere to develop, simply because there are no abiotic circumstances. In earlier times side channels were an ordinary phenomenon along rivers. This means the return of organisms, which used to occur here, can be expected: and thus ecological rehabilitation.

Side channels, however extract water from the main channel and consequently some of the sand and sediment transport. This has direct consequences for the available navigable depth in the main channel during periods of low discharge. It has already been mentioned that a systematic change of the navigable depth may have immediate economic consequences for shipping transport costs. The construction of side channels, as a part of ecological rehabilitation, requires in the planning stage accurate calculation of the consequences for other functions. The enormous economic interests which play a role, make the margins of the water availability very important.

6.4 Construction Of Lakes And Gulleys In Floodplains

Another possibility for the return of dynamism along rivers is the intervention locally in the morphology of the floodplains.

In the Netherlands floodplains are characterised by mainly low areas where, when they are not flooded, cattle and crop farming takes place. The presence of minor flood dikes lowers the flooding frequency. The following figure gives an schematic overall picture.

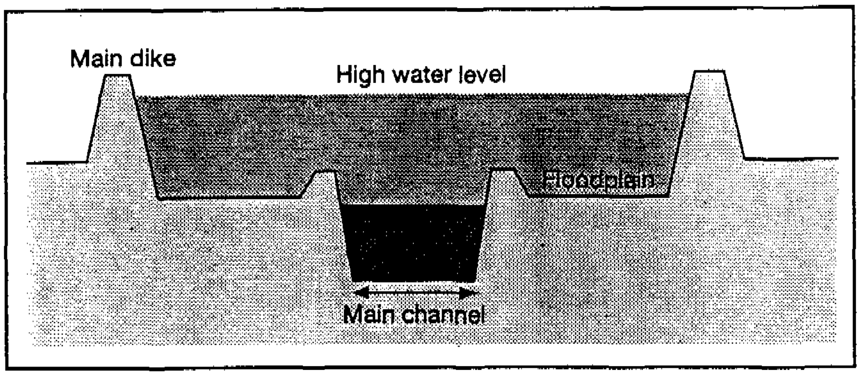

Figure 6. Floodplains in the Netherlands

Extra dynamism, both in the hydrology and the ecotope of the floodplain, is obtained by the increase of the flooding frequency in combination with the construction of channels or lakes. Flooding and renewal of water in the lakes of the floodplain is to occur frequently, resulting in the development of the accompanying characteristic organisms.
However, a lower river discharge will result in an extra rapid drop in the groundwater level of the floodplain because of the presence of open water. This effect, an extra rapid downward seepage of the groundwater, not only occurs in the floodplain but also in the surrounding agricultural land, and sometimes even in the area inside the dike. Most often this will mean damage. The harmful consequences of low water levels also feature here, whereby the duration also plays a role.

6.5 Water Demand Margins

As has been shown in the preceding chapters, the availability of water plays a fundamental role in the hydraulic design projects for the ecological rehabilitation of the water systems. This becomes most clear when choices must be made between the realisation of a particular design variant for ecological rehabilitation in relation to the acceptation of particular damage elsewhere.
It may be concluded that reorganisation for ecological rehabilitation often goes hand in hand with extra water demand. During periods of low river discharge this extra need for water leads to extra water demand in another field. This is particularly true for water systems where the allocation of water at low discharges has already been greatly optimised.
In view of the great economic and ecological interests which occur in periods of water scarcity, it is of great importance to accurately predict the consequences during the planning of the reorganisation projects for water availability for the various functions. This requires advanced hydraulic, hydrological and ecological models.

7. PROBLEMS AROUND WATER DEMAND MARGINS

As chapter 5 has already indicated, the increasing utilisation of the water systems has resulted in 2 effects:

1. We now have periods with a water shortage with consequences for the various user functions. Before low water periods were never regarded as periods with a water shortage.
2. Because the various user functions of the water are linked to economic and ecological interests, the water quantity margins have become essential. These margins can be linked to substantial economic interests.
   This has led to a number of developments.

Because the margins have become more important, the collection of data has become more intensive , accurate and frequent. In addition the requirements which the model simulation has to comply with have been extended. The wish for more accuracy leads to the development of ever more advanced software. This in turn leads to more accurate data collection, and to the start of processes which had so far been neglected for reasons of second priority effects. This all leads to a spiral in which more and more process effects need to be included in the margin-calculations. At the same time it can be said that this influences the development of the management expenses of the models.
This is illustrated in figure 7.

Another development which became in fact necessary is the integrated approach of the various interests: integral water management.
This may seem simple, but it is not. There are two reasons: a technical and an organisational one. The different interests/functions are often linked to different disciplines. Know-how and model instruments are developed within these disciplines. Integration of these instruments is often impossible, because the processes have been taken from different angles. Or the relation between these processes have not been studied. Or model simulation takes place with different variables or from other abstraction levels etc.

Moreover the disciplines are often the responsibility of different organisational institutes (Ministries, local authorities, other departments etc.). When weighing the various interests, this may lead to communication problems as a result of: variables of different interest groups which are difficult to compare, totally different approach of problems by experts, a complex of interests, conflicting political views etc.)

It may be concluded that for the optimal utilisation of the water demand margins, an integral approach must be chosen for the functions involved in the planning stage. This goes for the technical instruments as well as the organisation set-up of the various disciplines.

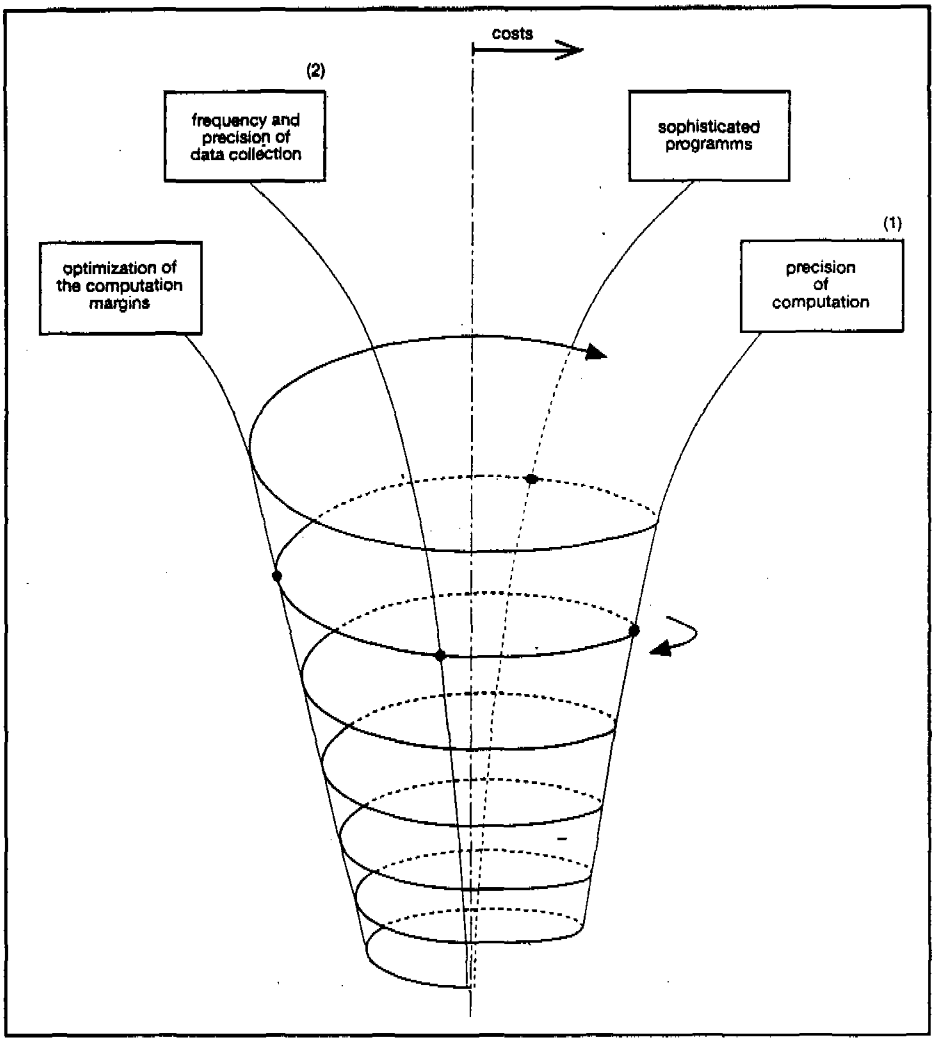

Figure 7. Development spiral

8. INTEGRATED APPROACH OF TECHNICAL INSTRUMENTS

8.1 Models

Model development for water systems has been introduced long ago. The first models concerned the flow of water, as the oldest function of the rivers used to be the safe and quick discharge of water and ice. Flooding of the surrounding land was so avoided. Shipping interests had also the hydraulic function of the rivers at heart, at which flow velocities on the one hand and navigable depth on the other, and consequently sedimentation and erosion problems, were at stake.

The model approach began with hydraulic simulation, imitating flow through discharge, tides and wind.

The growing model areas, the increase in hydraulic complexity and the wish to simulate more and more situations, stimulated the development of analogous and later numerical mathematical models. This was cost-saving and the number of variables was greatly extended compared to physical models.

The hydraulic models were succeeded by the development of the morphological models; later the water quality models and finally the ecological models. It needs to be said, however, that the development of the software of the earlier mentioned model types has also progressed.

The enormous development of software and hardware has led to the following two problems which are still relevant today: a) the simulations result in an enormous amount of output data and b) output data of one model must often serve as input data for the following model, because many effects have a mutual influence. It is sometimes so that this mutual influence is so characteristic, that even after a particular period in one process, a particular period of the other process must be simulated, to return then to the first process (on-line model simulation).
On-line calculation can also be necessary with more than 2 processes and therefore models.

The situation of the model instruments of some years ago can be represented as follows.

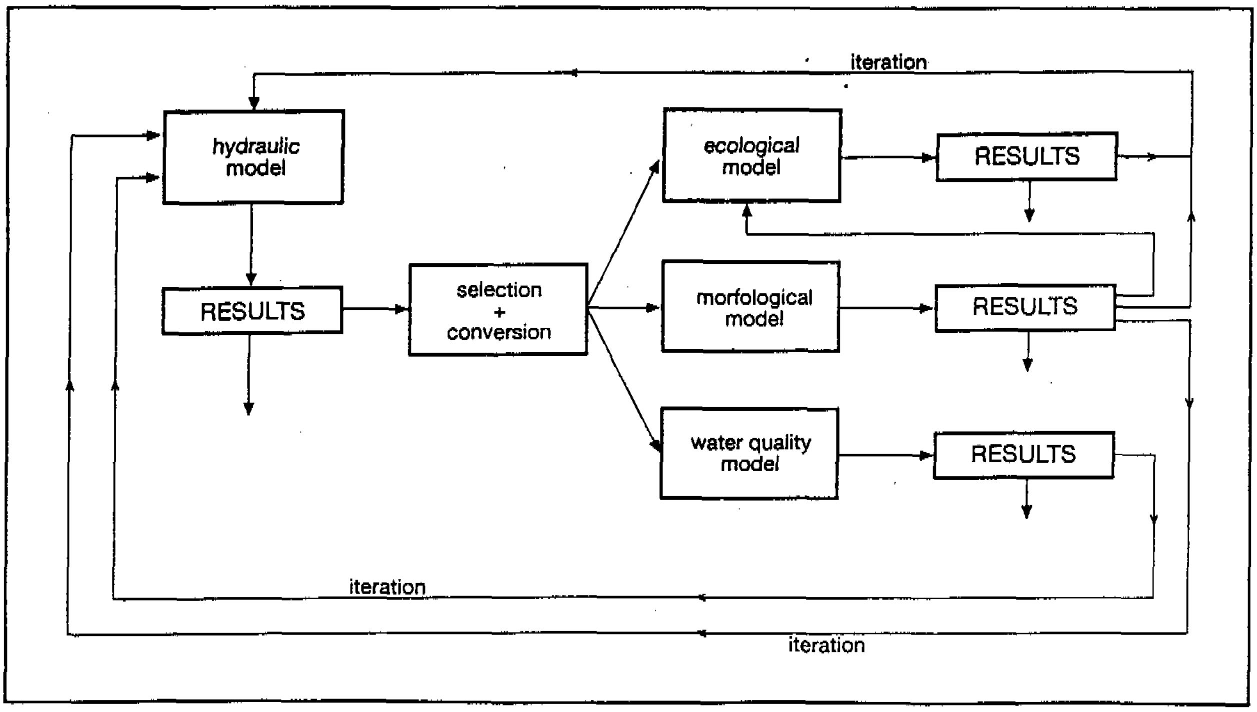

Figure 8. Diagram of the conventional model instruments

8.2 Integrated Model System (ISM)

As has been said the need has arisen to use output data of one model efficiently as input data for another. This efficiency must be reached with standards for the consistent input and output of data. This must result in the simultaneous use of all relevant models, both on-line and off-line. This approach particularly uses the margins of calculation outcomes which cannot be approximated accurately with the conventional model instruments.

This requires a central database in which all input and output data for models are stored. This includes the nature of the data, the location and the time to which the data applies and the density of the data series as regards time and location.

The projects around the design and use of water systems always play an important geographical role. It is therefore natural that a Geographical Information System (GIS) is used as a central database for models. This means that a particular model uses the necessary input data from the GIS, makes its calculations, which are then stored again in the GIS. Depending on the model, the data from the GIS will first need to be selected and processed before the model is able to start its calculations. The output data will also first be processed (for the correct format) before it can be returned to the GIS. Both processing operations, the withdrawal and return of data from and to the GIS, will have to be model bound. Because more than one model will use the same database (GIS), there need to be strict requirements as to the data storage in the GIS.

Figure 9 gives a schematic representation of what model instruments should look like, in order to use the margins of the availability of water efficiently, and considering the various interests involved. This results in the possibility of the related calculation of a number of chosen variables. Thus, in a technical sense, realising an integrated approach of the functions.

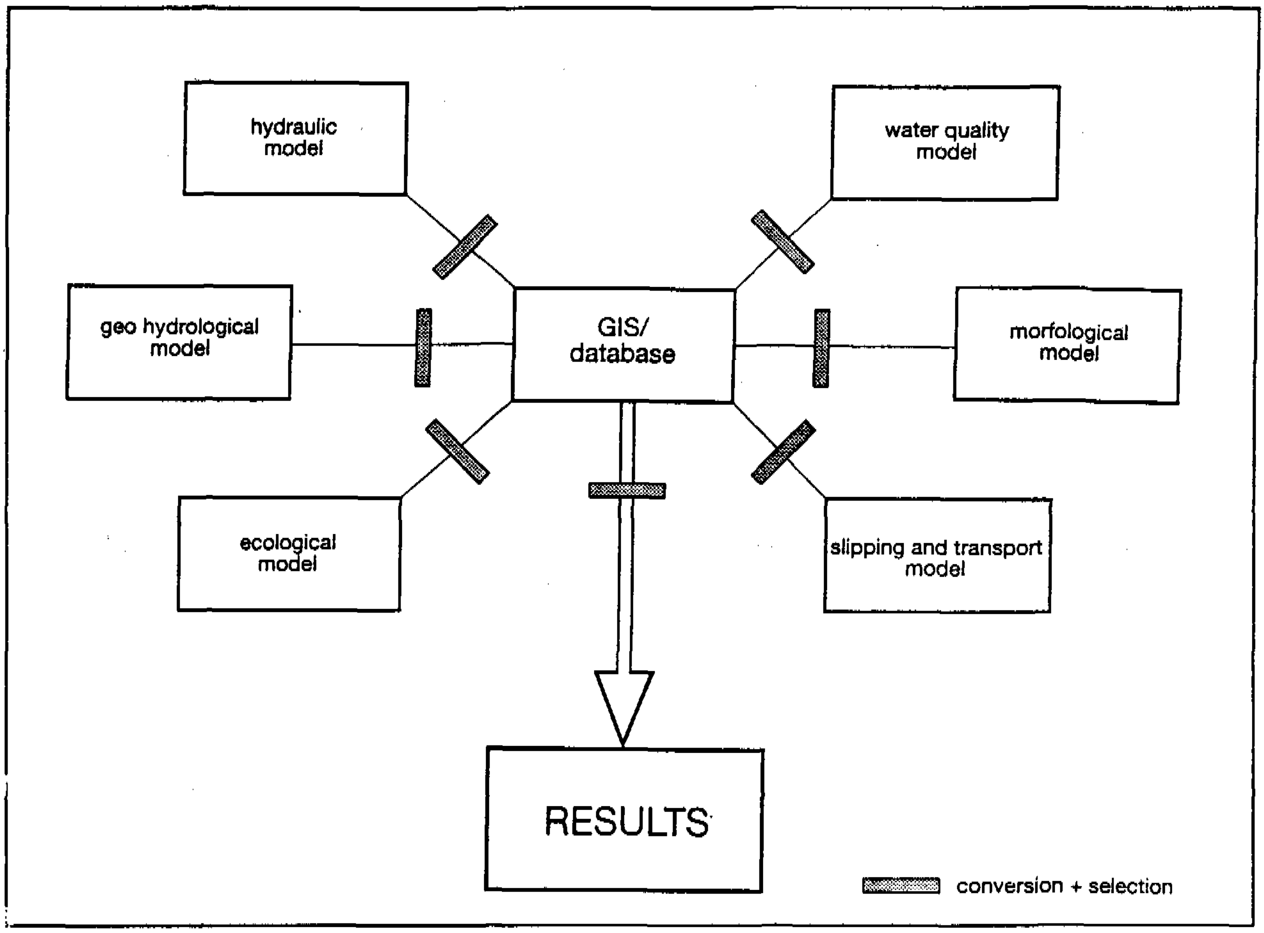

Figure 9. Diagram of an Integrated Model System (ISM)

9. INTEGRATED APPROACH IN THE ORGANISATION

Apart from an integrated approach of the technical instruments, the organisation must also be geared to an integral approach in water system design projects, particularly to optimally utilise the earlier mentioned margins.

To make optimal use of an IMS with a GIS as a database, it is essential that the most important disciplines are brought together in a project team. This not only applies to the knowledge development stage, but also to the planning stage directed to a concrete project.

The knowledge development of the disciplines should, as far as it is directed to the process description of models, result in accessible models. Taking into account all wishes and requirements of the other disciplines. This means for researchers among other things: to acquire a basic knowledge of the other disciplines, the joint establishment of knowledge development projects, aiming at the implementation in the GIS for the results, and close consultations to come together in a wide range of knowledge.

The same is true for the planning stage. It is important that all disciplines involved are represented in one team with the same objectives. For a number of disciplines it means that a special know-how must be present for the use and the structure of the GIS. The structure really means the format in which data is written out for mutual use.

In order to reach this, it is necessary that the disciplinary units are thus organised, that the boundary conditions are optimal for intensive cooperation. This means: no organisational barriers as a result of spreading over different departments or divisions even. A central steering of both the development of knowledge and the planning on a level which makes practical steering still possible.

To use an IMS it is important to have all the relevant disciplines together in making the different alternatives and carrying out the assessment. This becomes more and more important when the margins are narrow. This is not only true for physical margins, but also for small policy or managing margins. The situation in the Netherlands is that because of the relatively large water demand, the physical margins are narrow, and because of the important economic and ecological consequences the social and political margins are narrow.

It is our experience that the need for an integrated approach is highly advisable in plans involving many water system functions. This is relevant in land reorganisation plans, nature rehabilitation plans, wetland development plans etc. A team of civil engineers, ecologists, soil experts, GIS and model experts, socio-economists a.o. may work together in finding the users wishes, the alternatives as well as the possible solutions for the decision makers.

The narrow technical and social margins in the assignment of water demand leads to an integrated approach of water management plans. The results of this set up of research and project design are positive. It leads to a more efficient use of water, sometimes to unexpected solutions, to a clear understanding of the all the relevant consequences and it makes it easier for decision makers to choose responsible solutions. Last but not least, it can also avoid wrong decisions. If certain consequences are not fully considered in the design, in the long term the results can cause damage to one or more functions. In the case of nature, it may be too late for rehabilitation.

10. CONCLUSIONS

1. Water scarcity is a relative concept. After its primary use as drinking water there are secondary interests, which can be so important that we can speak of periods of water scarcity.
2. The increase of user functions of water systems in the Netherlands has led to a situation in which, during periods of low river discharges, a choice must be made as to its allocation.
3. The economic interests at the use of surface water have, with the development of prosperity, become so great that when the discharges are low, the available margins need to be optimally utilised.

4. The utilisation of these margins can only then take place when:
a. the model instruments are linked via a database, so that the various models can calculate interactively and,
b. the disciplines involved cooperate in a project team, such that a careful policy analysis could be established as to the solution variants.

5. As to the design projects, usually aimed at the ecological rehabilitation of the water systems, it seems logical to define a GIS as the central database of the model instruments.

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ENVIRONMENTAL POLLUTION OF GROUND WATERS AND SOILS DUE TO TEXTILE INDUSTRIAL EFFLUENTS IN THAR DESERT

I.C. Gupta[1] and B.L. Jain[2]

ABSTRACT

The large volume (25960 m^3d^{-1}) of effluents arising from about 760 hand processing textile units in Pali, a city situated in Thar desert of Rajasthan, is characterised with abnormal pH (10.0-11.5), high salinity (8.5-14.0 dSm^{-1}), BOD (400-800 mgL^{-1}), and COD (900-1500 mgL^{-1}); excessive concentration of sodium (70-125 $mmolL^{-1}$) and carbonates (4.0-16.0 $mmolL^{-1}$) followed by conspicuous absence of calcium. Very high values of SAR (60-100 $mmolL^{-1}$) and RSC (30-45 $mmolL^{-1}$) disqualify these effluents for discharge into inland surface water or direct use for irrigation. Conventional treatment of the effluents consisting of filteration, equalisation, acid (H_2SO_4) treatment, sedimentation and aeration although lower BOD, COD and pH to a safe level but the values of SAR and RSC which are more relevant from irrigation point of view, remain high i.e. 55 $(mmolL^{-1})^{1/2}$ and 21 $mmolL^{-1}$, respectively. Laboratory experiments were conducted to examine the efficacy of gypsum in the further reduction of SAR and RSC to safe level. Gypsum @ 3 tonnes per million litre reduced SAR to 18 $(mmolL^{-1})^{1/2}$ and RSC to zero. It is implied therefore that effluents should be treated simultaneously with gypsum after treatment with sulphuric acid to enable their re-use for irrigation and prevent environmental pollution.

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1. INTRODUCTION

Due to inequitable distribution of water and present rate of consumption, the water resource world over has been fast dwindling. In 1975, 19 countries were classified as having less than 500 cubic metres of renewable water per person per year. By 2000, ten more countries will fall in this category and the number will grow upto 40 a few years later, if the present trend continued. About 70% of the total surface water in India is polluted and the magnitude, is growing day by day. The Gangetic basic alongwith an area of more than one billion km^2, a largest delta in the world, acquires a total pollution load of 500 million litres per day on its course from Gomukh to Calcutta. The net result is the slow shrinking of the delta area and environmental degradation due to destruction of forests and agriculture. One of the main sources of water pollution is industrial effluents arising from more than 4000 large and medium industries.

In Thar desert of western Rajasthan, where the water resources are highly limited and environment is fragile, a discharge of 25960 m^3d^{-1} of effluents from about 760 hand processing textile units (small industries) in Pali city has been responsible to bring dubious distinction to the city as being second most polluted in India. In addition to Pali, about 328 industrial units in Jodhpur and 395 industrial units in Balotra (Barmer) are also discharging 9300 m^3d^{-1} and 3900 m^3d^{-1} of effluents, respectively. The effluents without appropriate treatment are directed to flow in local nearby seasonal rivers viz. Bandi (Pali), Jojri (Jodhpur) and Luni (Balotra). These rivers remain practically dry for about ten months after monsoon season but for the flow of industrial effluents, thus causing serious geoenvironmental pollution and anthropogenic hazards. The soil, surface and ground waters are getting highly polluted thereby intensifying the process of desertification in Thar desert. The environmental pollution has acquired serious dimensions, as about 500 riverine wells and 2000 ha of otherwise most productive irrigated lands have been doomed. Industrialists seem interested in the money spinning enterprises as the growth of textile units continues unabated but there is no concern about the deteriorating environment. There is urgent need to pull the part of Thar desert encompassing Pali, Jodhpur and Balotra (Barmer) out of the cruel prospect of an ecological disaster. For the sake of brevity, the problem studied herein deals only with Pali city where situation has become most alarming and serious.

2. MATERIAL AND METHODS

Pali city (73°4' - 25°7') situated in Thar desert of western Rajasthan is characterised with low annual rainfall (400 mm), high evaporation (2500 mm per year) and lack of surface water resources. The ground waters are commonly saline and soils are sandy loam to sandy clay loam in texture and are classified as Calciorthids. Bandi river, a tributory of Luni river, passes by the periphery of the city. About 25 per cent area in Pali district and 60 per cent area in Thar desert is covered by wastelands.

Bandi river which was seasonal has become perennial and effluents flow linearly upto 40-50 km till these disappear through percolation and evaporation. Due to the downward and lateral movement of water through hydrological cycle linked up with the ground water recharging, the well waters upto a horizontal distance of 500 m from the river have been polluted due to effluents.

3. RESULTS AND DISCUSSION

3.1 Characteristics of Effluents

The chemical composition and other properties of effluents vis-a-vis tolerance limits for effluents to be discharged into inland surface water and on land for irrigation, according to Bureau of Indian Standards (1981) are presented in Table 1. The effluents have abnormal pH and contain excessive concentration of soluble salts. BOD and COD values are also very high. Oil and grease, and sulphides are present in slightly higher concentrations compared to tolerance limits but total chromium and phenolic compounds occur within safe limits (Anonymous 1992 b). The colour is reddish brown/green and odour is obnoxious. The percentage of sodium among cations is 90. Sodium Adsorption Ratio (SAR) is 82 $(mmolL^{-1})^{1/2}$ and Residual Sodium Carbonate is 42 $mmolL^{-1}$ (Gupta and Jain, 1992).

There are no limits prescribed for sodium percentage, SAR or RSC for effluents to be discharged into inland surface water and therefore there is no legislation by which industries may be asked to treat the effluents to lower the values of sodium percentage, SAR or RSC before these are directed to flow in local nearby seasonal rivers in which recharge due to rainfall or runoff is far less than the total load of effluents around the year. In fact these seasonal rivers which otherwise remain dry for ten months of the year can not be considered as inland surface water as perennial rivers. It is here that a distinction has to be drawn between seasonal rivers and perennial rivers and standards have to be set accordingly by Bureau of Indian Standards.

It would be appropriate, however, if the tolerance limits for effluents to be discharged, into seasonal rivers are, accepted as the same as that of the on land for irrigation. Interestingly, no limits have been set even for SAR for effluents to be discharged on land for irrigation although it is very important parameter to evaluate the suitability for irrigation. The parameter of sodium percentage for which limit of 60, has been set, is however a obsolets criteria and quality of irrigation water is no more evaluated on this basis (Gupta, 1990).

Although the limit of SAR has been set ideally as 10 for waters highly suitable for irrigation but this limit has been relaxed upto 20 under most favourable situations where soils are of light texture, rainfall is good and salt tolerant crops are raised. Likewise, a water free of RSC has been recognised as highly suitable for irrigation but this limit been relaxed upto 5 under favourable situations.

Table 1 : Characteristics of industrial effluents before & after treatment & BIS standards

Parameters	Characteristics of raw effluents	Tolerance limits for effluents to be discharged		Characteristics of effluents after treatment
		into inland surface water	on land for irrigation	
pH	10.0-11.5	5.5-9.0	5.5-9.0	8.5
TSS (mgL^{-1})	300-500	100	200	nil
TDS (mgL^{-1})	600-7000	2100	2100	6000-6700
BOD (mgL^{-1})	400-800	30	100	30
COD (mgL^{-1})	900-1500	250	-	180
Oil and (mgL^{-1}) grease	20-25	10	10	nd
Total Cr (mgL^{-1})	0.18	2	-	nd
Sulphides (mgL^{-1})	3.64	2	-	nd
Phenolic- (mgL^{-1}) compounds	0.24	1	-	nd
Colour/odour	reddish brown/ green	Colourless and odour-less as far as possible	-	*
Sodium(Percentage	90	-	60	90
SAR ($mmolL^{-1})^{1/2}$	82	-	-	55
RSC ($mmolL^{-1}$)	42	-	5	21

* intensity of colour and odour is reduced.

It may be relevant to mention here that the composition of effluents does not remain constant. Not only it varies from season to season but also from hour to hour. In rainy season the effluents are highly diluted and pollution effect is minimised. Hourly variations even take place due to differences in the timing of different processes in the industries.

The concentration of bicarbonates is high and that of carbonates is excessively high. Whereas both these ions are known to precipitate divalent cations viz. magnesium and calcium, the carbonates in excessively high concentration cause toxic effect to the properties of soil and plant growth. Due to very high concentration of bicarbonates and carbonates, the solubility of magnesium and calcium is highly reduced and as a result the total concentration of divalent cations is less than 2 $mmolL^{-1}$, calcium being present in traces only. Calcium is a vital element responsible for the maintenance of cell viability of the plants. Although no limits have been set directly for calcium concentration and indirectly it has been considered in SAR and RSC, it is felt that the presence of absolute concentration of calcium ions varying from 2 to 5 $mmolL^{-1}$ should be considered as necessary as far as the quality of water is to be evaluated for irrigation.

Studies conducted at CAZRI have revealed that the effluents are free of heavy metals and toxic elements (Agarwal and Kumar, 1990). The presence of dyes and colour etc. is not so far significant from irrigation point of view.

Considering the values of three important conventional parameters viz, TDS, SAR and RSC vis-a-vis tolerance limits, it is obvious that the effluents as such do not qualify for direct use for irrigation or discharge into seasonal rivers. Although pH is not the basis to evaluate the quality of natural waters for irrigation because they seldom have abnormal pH but this also becomes important parameter in case of polluted waters.

3.2 Pollution of Ground Waters

Prior to the advent of industrialisation, before about 20 years from now, the analysis of 84 ground water samples collected from all over Pali block showed EC from 0.9 to 26.0 dSm^{-1} (average 10 dSm^{-1}), SAR from 2.2 to 49.6 $mmolL^{-1}$ (average 21.6 $mmolL^{-1})^{1/2}$ and RSC from 0 to 26 $mmolL^{-1}$ (average 2.1 $mmolL^{-1}$). But 20 per cent of water samples, mostly representing riverine wells, had EC lesser than 5 dSm^{-1} and SAR less than 18 (Jain, 1979). Compared to past, EC of riverine well waters has now increased from 5 to 10 dSm^{-1}, SAR from 20 more than 40 $mmolL^{-1}$ and RSC from 0 to more than 10 $mmolL^{-1}$, justifying abandonment of the wells. Riverine wells have been more adversely affected than wells away from river (Table 2). Studies conducted by Ground Water Department have also revealed higher values of EC, SAR and RSC in case of riverine wells compared to wells away from the river (Anonymous, 1992).

3.3 Pollution of Soils

The productivity of soil depends on the physical, chemical and biological properties. Biological properties include organic matter, content of micro-organism and their activity. The soils irrigated with polluted ground waters were examined for populations of micro-organisms, actinomycetes, free living N-fixers and nitrifiers and were compared with adjacent soils irrigated with unpolluted waters (Table 3). The populations of bacteria and fungi were very low in polluted soils viz. 14.67 x 10^{5-1} and 1.00 x $10^{3}g^{-1}$ compared to unpolluted soils (72.33 x $10^{5}g^{-1}$ and 20.67). Likewise, actinomycetes, free living N-fixers and nitrifiers were reduced drastically in polluted soils. Similarly, activities of various enzymes were unduly low. A sample of river bed soil impregnated with saturated solution of effluent revealed the activities of enzymes at 0-15 cm depth to be insignificant and at 15-30 cm to be zero (Rao et al., 1993). These observations justify the abandonment of irrigated soils and indicate that prolonged use of untreated effluents would make the soils completely sterile and lead to ecological disaster.

Table 2 : Chemical analysis of industrial effluents, polluted & unpolluted riverine wells (December, 1991)

Parameters	Raw effluents	Polluted wells (Near river)	Unpolluted wells (Away from river)
EC (dSm^{-1})	8.5 - 13.9	5.2 - 12.5	2.4 - 7.4
<u>Ions (meq/L)</u>			
Sodium	73.0 - 124.0	38.0 - 112.0	12.0 - 47.0
Calcium + Magnesium	0.5 - 2.0	0.3 - 1.2	4.8 - 17.0
Carbonate	4.0 - 16.0	2.0 - 6.0	0
Bicarbonate	14.0 - 40.0	28.0 - 38.0	4.0 - 16.5
Sulphate	9.0 - 15.0	9.8 - 15.4	2.6 - 16.5
Chloride	75 - 112	40 - 90	20 - 60
SAR ($(mmolL^{-1})^{1/2}$)	60 - 100	39.7 - 200	4.2 - 23.9
RSC ($mmolL^{-1}$)	30 - 43	8 - 47.7	0

3.4 Conventional Treatment of Effluents

The conventional treatment of effluents consists of five processes viz. filteration, equalisation, acid treatment, sedimentation and aeration. After treatment, pH of the effluent reduces from 11.5 to 8.5, TSS from 500 mgL^{-1} to zero, COD from 1500 to 180 mgL^{-1} and BOD from 800 to 30 mgL^{-1} (Anonymous, 1992 b). Whereas acid treatment and other processes are remarkably efficacious in reducing pH, TSS, BOD and COD etc., SAR and RSC values still remain very high and content of TDS remains almost the same. SAR is reduced from 82 to 55 $mmolL^{-1}$ and RSC decreases from 42 to 21 $mmolL^{-1}$. The reduction of TDS is not possible. Therefore, these treated effluents can not be re-used for irrigation and obviously the treatment does not serve much useful purpose. However, if the values of SAR and RSC are lowered further, these effluents could be re-used for irrigation, TDS remaining almost the same, for raising salt and alkali tolerant crops, grasses and trees etc.

Table 3 : Populations of micro-organisms & enzyme activities of polluted & unpolluted soils

Property	Unpolluted soil	Polluted soil (Abandoned)	Effluent soaked river bed soil
Bacteria (x10^5 g^{-1})	72.33	14.67	
Fungi (x10^3 g^{-1})	20.67	1.00	
Actinomycetes (x10^4 g^{-1})	19.67	3.00	
Free living N fixers (x10^2 g^{-1})	7.00	1.10	
Nitrifiers (x10^2 g^{-1})	92	4.5	
Dehydrogenase (PKat g^{-1}) soil hr^{-1})			
0-15 cm	11.62	3.15	1.42
15-30 cm	2.87	1.85	0
Acid phosphatase (PKat at 100 g^{-1} soil)			
0-15 cm	4.09	0.83	0.24
15-30 cm	2.87	0.25	0
Alkaline phosphatase (nKat at 100 g^{-1} soil)			
0-15 cm	6.62	1.03	0.28
15-30 cm	3.97	0.41	0

3.5 Additional Treatment of Effluents

A laboratory experiment was conducted wherein the conven- tionally treated effluents were further treated with sypsum to ameliorate and make them useable for irrigation. The use of gypsum in reduction of SAR and RSC of natural waters and soils is quite well known (Gupta and Chandra, 1972; Gupta, 1980; Jain and Gupta, 1992). The changes taking place due to gypsum treatment at the rate increasing from 1 to 5 tonnes per million litres revealed progressive decrease SAR and RSC. The application rate of gypsum at 3 tonnes per million litre reduced SAR from 55 to 18 mmolL^{-1} and RSC from 21 to zero mmolL^{-1}. However, EC increased from 8.5 to 9.5 dSm^{-1}. The increase in EC is obviously due to increase in the concentration of calcium ions but waters having EC of about 10 dSm^{-1} and SAR upto 20 can be used for raising salt and alkali resistant crops, grasses and trees etc. (Gupta, 1990). It may be pointed out here that absolute treatment either with sulphuric acid or gypsum can not be useful and therfore treatment first with sulphuric acid to reduce pH and then with gypsum to reduce SAR and RSC is necessary because solubility of gypsum is very low at very high pH.

4. SUMMARY AND CONCLUSIONS

Due to inequitable distribution of water and present rate of consumption, the water resource world over has beenfast dwindling. In 1975, 19 countries were classified as having less than 500 cubic metres of renewable water per person per year. By 2000, ten more countries will fall in this category and the number will grow upto 40 a few years later, if the present trend continued. About 70% of the total surface water in India is polluted and the magnitude is growing day by day. One of the main sources of water pollution is industrial effluents arising from more than 4000 large and medium industries. In Thar desert of Western Rajasthan, where the water resources are highly scarce, about 25960 m^3 of effluents per day, arising from about 750 hand processing textile units (small industries) in Pali, a largest centre of its kind in Asia, have been responsible to bring dubicious distinction to the city as being second most polluted in India. The large quantity of effluents is being discharged in the local seasonal river causing serious geo- environmental pollution and anthropogenic hazards. The ground waters, otherwise suitable for irrigation are getting highly polluted and irrigated agriculture has been doomed in 2000 ha thereby contributing to the intensification of desertification.

Studies were concentrated on the composition of effluents, their pollution effect on ground waters and fertility of irrigated soils which have been abandoned for long. The efficacy of conventional treatment plant of the effluents was also evaluated. The textile industrial effluents are characterised with abnormal pH (10.0-11.5); high salinity (8.5-14.0 dSm^{-1}), BOD (400-800 mg/L) and COD (900-1500 mg/L); excessive concentration of sodium (70-125 $mmolL^{-1}$) and carbonate ions (4.0-16.0 me/L); and conspicuous absence of calcium ions. Very high values of SAR (60-100 $mmolL^{-1}$) and RSC (30-45 $mmolL^{-1}$) disqualify these effluents for discharge into inland surface water or direct use for irrigation. Conventional treatment of the effluents involving use of sulphuric acid although lowers the pH, BOD and COD etc. but the values of SAR and RSC which have more relevance from irrigation point of view, remain high i.e. 55 and 21 $mmolL^{-1}$ respectively. To reduce SAR and RSC to safe level and raise the concentration of calcium ions, a vital element responsible for the maintenance of cell viability of plants, it has been concluded that effluents after conventional treatment with sulphuric acid should be simultaneously treated with gypsum. This will not only prevent ground water pollution, restore health of doomed irrigated soils but also conserve a huge resource of water which could be reused for irrigation of another 2000 ha existing waste lands to raise salt tolerant crops, grasses and fuel wood plantations thereby checking environmental degradation and preventing ecological disaster.

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LIMITS TO HYDROPOWER DEVELOPMENT IN THE HIMALAYAN RIVERS OF NEPAL

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ABSTRACT

A small country Nepal is endowed with a rich hydropower potential. Theoretically, over 83,000 MW of power can be developed from its' Himalayan rivers. Unfortunately, such an enormous potential is practically unexploited.

Development of hydropower projects imparts several adverse impacts to its environment. In Nepal, however, the Himalayan rivers also possesses a continuous threat to the hydropower projects. The Himalayan environment characterized by fragile and vulnerable geophysical conditions, extreme hydro-meteorological distributions and unmanaged human interventions can ingenerate typical adverse consequences which have the potential to influence tomorrow's decisions on hydropower development in the country. On the basis of the past evidences, some of those important phenomena are highlighted to underscore the need for a better understanding of the Himalayan rivers, which, otherwise, would inhibit the successful utilization of the country's single important natural endowment.

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1. INTRODUCTION

Nepal, with an area of just 147,181 sq.km, is predominantly a mountainous country. Located in the mid of the mighty Himalayas, occupying about one-third of its' 2500 km long range, the country is potentially rich in hydro resources. Although, Nepal constitutes only 13.5 percent of the entire Ganges Basin, the average annual surface run-off from Nepal (excluding water from rivers originating from Tibet) is 174.2 billion cubic meters (Shrestha, 1993), that is about 40 percent of total yield of the Basin. The abundance of the resource is substantiated by the fact that the average annual surface run-off per square kilometre of land area in Nepal is about 4.4 times higher than the world average. The potential of this resource is further enhanced as there are more than 6000 rivers and rivulets in Nepal, many of which originate at an elevation as high as 8000 m in the Himalayas and flow down to the southern plains at an elevation of just 100 m within a distance of merely 100 to 200 km. Such being the profile of Himalayan rivers in general, combined with prevailing high discharge, it is said that Nepal is endowed with an excellent potential of hydropower, estimated at 83,000 MW (excluding the potential of those watersheds having area less than 300 sq.km).

At present, the traditional sources like fuelwood, agricultural residue and animal dung account about 95 percent of total energy consumed in the country, of which 78 percent is met by fuelwood alone. Among commercial sources, which constitute 5 percent of total energy consumed, electricity accounts only 15 percent and remaining 85 percent is supplied through imported hydrocarbon based fuels. As such, over 1980s, 35 percent of the country's total export earning was spent on importing petroleum products alone. To date, Nepal has developed less than one percent of the total economically exploitable hydropower potential, which is estimated to be about 42,000 MW. Current generating capacity of hydropower plants connected to Integrated Nepal Power System (INPS) is only 218 MW, and another 6 MW generating capacity is available through isolated small hydropower plants.

Clearly, the path Nepal has been following to meet its energy demands is an erroneous one, which if not rectified, could jeopardize its' vulnerable economies as well as encourage environmental destructions in a long run. The apparent failure to utilize its' enormous hydro potential and to minimize over-dependency on unsustainable means like fuelwood and imported hydrocarbons, therefore, deserves a scrutiny.

2. HYDROPOWER DEVELOPMENT IN NEPAL: AN OVERVIEW

Nepal has long been exploiting its' hydropower potential through traditional water mills ("Ghattas") for agro-processing. These water mills, made entirely of local materials, are still widely used in the villages scattered throughout the mountainous regions of the country. It was only in 1911 that hydroelectricity was produced for the first time in Nepal through a 500 kW turbine at Pharping to supply electricity to Kathmandu. Although, another plant of 640 kW was installed again in 1934, there seems to have little incentive to develop more hydropower plants until 1960s. By 1970 the total installed capacity was raised to 25 MW, which included Trisuli run-of-river plant (21 MW), the first project to produce bulk electrical energy in Nepal. Another breakthrough in the history of hydropower development was achieved in May 1982 when the Kulekhani, a high dam storage project with 60 MW installed capacity, was commissioned.

Since the development of Trisuli hydropower project in 1967, there is a dramatic increase in the electricity consumption rate. Within the last twenty-five years (1969-93), the peak demand and the annual energy sales have grown respectively from 10 to 214 MW and 21 to 674 GWh. The load forecast shows that in another 10 years the peak demand will exceed 600 MW, which means the necessity to add another 400 MW in the present system. It is worth noting that at present a mere 10 percent of the total population of the country have access to electricity.

The hydropower development planning in Nepal has never been a systematic affair and lacked sincerity. The approach in the past has been too ambitious. Illusioned by the fact that the immense hydro potential in Nepal could be marketed to India has caused Nepalese planner to pay little concern for the long term development planning of small and medium scale projects for domestic needs. As and when the government feels pressure for additional capacity, a project is just hand-picked and developed under the external technical and financial assistants (grants and loans). Such donor driven projects, albeit being inferior and expensive, were accepted for implementation as there was no long term planning and only a few projects were in the stack to chose from for a detailed study which is required prior to the execution. Kulekhani I and II (total 92 kW) and Marsyangdi (69 kW) projects are the examples in this case.

Even after the reinstatement of the democracy in 1991, the government, so far, largely remained indifferent towards the formulation of a plan for rational utilization of its' rich hydro resources. At present the country is facing an energy crisis which has prompted long hours of load shedding, over 14 hours during winter when all run-of-river projects are unable to generate at their full capacity. However, apparently, the same psyche of the past has continued to invade, and the government is running after a single project, Arun III (201 MW), which will take 10 years to complete and cost US$ 3800 per kW.

3. HIMALAYAN RIVERS AND ITS ENVIRONMENT

The Himalayas, a region of extreme and complex geophysical, hydro-meteorological, ecological and socio-economic diversity, are the highest but the youngest mountain system on earth. According to Bahadur (1992), the Himalayas contain about 50 percent of all glaciers outside polar regions, and therefore are the source of vast potential for water resources development. Nepal, being located in the centre of the Himalayan belt, in fact, exhibits all the characteristics of the Himalayan environment. Out of 6000 rivers in Nepal, 1000 are more than 11 km long and about 100 of them are longer than 160 km (Shanker, 1991). The unique run-off characteristics of these rivers are the consequences of numerous interacting elements that constituted the Himalayan environment. The Himalayan rivers of Nepal, which drain south towards Ganges Basin can be distinguished into three groups according to their origin: the Trans-Himalayan rivers, High Himalayan rivers and Monsoonal Mountain rivers. Within the third category, some of the rivers originating in the Siwalik (the foot-hills of the Himalayas) are virtually ephemeral in nature, and therefore, are of little value as far as water resources development is concern. All the three major river system of Nepal, the Karnali, the Gandaki and the Kosi are the complex representation of the three prominent physiographic regions, namely, the Trans-Himalayas, the High Himalayas and the Middle Mountains.

3.1 Geophysical Environment

As it comes to the issue of water resources development in the Himalayan rivers, the inherent geophysical environment stands out to be the foremost element that deserves a thorough examination. The major river system in Nepal are believed to be antecedent or concomitant to the uplift which has produced the Great Himalayan Range (Chyurlia, 1984). A recent study by Arita and Ganzawa (1994) revealed that the Nepalese Himalayas underwent rapid and accelerating uplift and erosion over the past 2.2 million years due to the continuing convergence of the Indian and the Eurasian continental plates. They estimated the average erosion rates range from 3.4 to 6.8 mm per year for the interval from last Pliocene to the present time while the apparent uplift (upheaval of the land surface) rates for the same period range between 0.9 to 2.9 mm per year. Being one of the tectonically most active mountain ranges on the earth, the entire region is fraught with many potentially dangerous discontinuities. On-going tectonic activities, presence of fragile geological formations, high relief and steep topography are some of the major factors which strongly influence any water development project in the Himalayan rivers.

3.2 Hydro-meteorological Environment

The monsoon system originating from Indian ocean is the principal source of water in Nepal. precipitation is unevenly distributed throughout the country, temporally as well as spatially. Within a short period of less than four months from mid-June to end of September, the summer monsoon which comes from south-east brings in about 70 to 90 percent of the total annual precipitation. During winter, from January through March, precipitation is mainly related to the western disturbances which influence mainly in the western region of the country and progressively decrease towards east. During this same period, the snowfall in the higher altitude (approximately above 3000 m in the north facing slopes and above 3600 m in the south facing slopes) is at its' maximum.

The total annual precipitation varies greatly depending on altitude and local topographic features, and range from less than 250 mm on the north of the main Himalayas Range to about 5000 mm on the southern slopes of the Himalayas. The average annual precipitation for Nepal is estimated to be about 1700 mm, out of which 18 percent falls as snow, 72 percent is available as direct run-off and 10 percent percolates to form subsurface storage (Sharma, 1991). In general, snowmelt contributes to run-off from March to July and accounts about 10 percent of the average annual streamflow.

As a consequence of extreme variations in the precipitation distribution, the annual streamflow pattern exhibits a pronounced seasonality. In fact, it is very difficult to distinguish the hydrological characteristics of the Trans-Himalayan and High Himalayan rivers on the basis of currently available data. As both the types of rivers receive snowmelt contribution during dry season, the annual hydrographs for these rivers have more or less similar variations. In these rivers, the discharge is at its' low during February to March and reaches maximum during mid-July to mid-September. The ratio of average annual maximum to average annual minimum discharges in these rivers (at the upper reaches) normally do not exceed about 60. However, for those rivers purely dependent on monsoonal rain (with some contribution from subsurface flow), this value is quite high. In this latter category of rivers, the dry season falls during March to May.

The Arun is the only river that belongs purely to the first category as it originates from the Tibetan plateau. Other rivers like Sun Kosi, Bhote Kosi, Trisuli, Budhi Gandaki, Marsyangdi, Kali Gandaki and Karnali which originate from the Inner Himalayan valleys (rain-shadow zones) resembling to the Tibetan plateau are hydrologically similar to the Trans-Himalayan rivers. The Arun river whose basin area lies predominantly in the Tibetan plateau has the lowest annual water yield (0.015 $m^3/s/km^2$). In general, the rivers in the far-western region of the country also have low annual water yield. The Seti river (Pokhara) has the highest annual water yield (0.090 $m^3/s/km^2$) among the Nepalese rivers. From the standpoint of water resources development, the Monsoonal Mountain rivers are less attractive and can be utilized only through the expensive high dam storage projects. On the other hand, the High Himalayan and Trans-Himalayan rivers which possess steep gradient and relatively more sustained flow can best be utilized by developing simple run-of-river type projects.

3.3 Ecological Environment

A small country Nepal is the habitat for wide variety of flora and fauna, ranging from the dense tropical monsoon forests of the Himalayan foot-hills, to deciduous and coniferous forests of the subtropical and temperate regions, and finally to the sub-alpine and alpine pastures and snow-covered Himalayan peaks. The abundance of this biological diversity is attributed to the fact that the extreme physiographic conditions that inherit the country is virtually remained unspoiled. It is estimated that within different ecosystems in Nepal, there are over 6500 species of flowering plants, over 1500 species of fungi and over 350 species of lichens (EPC, 1993). About 370 species of flowering plants are considered endemic to Nepal and around 700 species are known to possess medicinal properties. The fauna of Nepal include about 175 species of mammals, 850 species of birds and 180 species of dragonflies. Among these, many terrestrial and aquatic plants and animal species are believed to be rare and endangered. Currently, 26 mammals, nine birds and three reptiles have been legally classified as endangered. Water resources development projects affects these terrestrial and aquatic ecosystems in one way or other during construction and operation stages. The extent of impacts would depend on the size and type of the development and the location.

3.4 Socio-Economic Environment

Agriculture plays a dominant role in the Nepalese economy. It provides employment to over 80 percent of the labour force, contributes more than half of the total GDP, and is a major supplier of raw materials to industries (MoF, 1993). Being overwhelmingly a mountainous country, the available land is extremely limited. The average area of cultivated land per capita is just 0.15 hectare. Due to the ever increasing population pressure, all the river valleys which are supposed to be the best sites for high dam projects are heavily populated with extensive cultivation. Even the marginal lands on the mountain slopes are gradually being encroached for subsistence farming and livestock grazing. The evolving pressure on mountain watershed by human activities has also encouraged the natural erosion process to become rapid and has been the major factor behind the widespread mass wasting in the middle mountain belt during wet season. Under these circumstances, hydropower development in the middle mountain region would prove expensive for several reasons.

4. Hydropower Projects and Environmental Implications

The exploitation of water resources is inevitably accompanied by a disturbance of the natural balance. The extent, magnitude and duration of the impacts of a project on the environment depend on the scale of changes in the water regime and the size of the project's components and the infrastructural facilities that would be constructed in the area. In Nepal Himalayas, however, the environment also possesses a continuous threat to the hydropower projects. Past experience has, now, compelled to realize that, in the Himalayan watershed, the latter aspect could exert overriding influence in the development of hydropower projets. The environmental problems associated with the construction and operation of hydropower projects are documented in a large number of literature, and therefore, are not discussed in this paper.

The Himalayan environment characterized by fragile and vulnerable geophysical conditions, extreme hydro-meteorological distributions, and unmanaged human interventions ingenerate some typical phenomena which are gaining wishful attention due to the recent progresses in the utilization of the Himalayan rivers for hydropower and other purposes.

4.1 Glacial Lake Outburst Flood (GLOF)

The catastrophic discharge of large volumes of water is characteristic of many mountain rivers, especially originating from glaciated areas. As about 18 percent of the country constitutes snow and ice covered area, which serves as the headwaters for most of the river systems, understanding of such events is crucial for the development of the country's water resources.

Glaciers are continuously changing in their size and shape under the influence of climatic variations. In Nepal, glacier lakes are normally formed either between the thinning receding ice front (retreating glacier) and the end moraines, which is known as moraine-dammed lake or between the main advancing glacier and the tributary, which is called ice-dammed lake. The latter type of glacier are believed to exist very few in Nepal, and unlike former type of lakes, they are less hazardous as their bursting normally do not release catastrophic discharges. Moraine-dammed glacier lakes which is common in this region, contain very rich debris and dammed by relatively thick and large volume of lateral and end moraines. Over the years, such glacier lakes have the tendency to grow very large. The Imja glacier lake, the headwaters of the Dudh Kosi river, to the south of Mt. Everest, which looked like just a couple of small ponds during 1955-63, has grown so large that in the last thirty years the lake has assumed a depth of about 100 m and the surface area of 0.60 sq.km. At present this lake contains approximately 28 million cubic meters of water (Yamada, 1993). So far, similar other seven potentially hazardous glacier lakes have been noted in Nepal (Mool, 1993).

As the lake evolves over the years, it reaches a stage at which the lake becomes more prone to breach. In fact, lakes dammed by ice or by a mix of ice and moraine always remain unstable (Yamada, 1993). The bursting of the moraine-dammed lake can take place by progressive erosion of the dam material or by the sudden removal of a portion of dam material. The erosion of the dam material can be caused by overtopping of dam due to progressive rising of lake levels or by the creation of surface wave either by landslide, rockfall and icefall, or by wind action. Breaching can also be caused due to piping through the dam formed by moraines and ice. Earthquake may also trigger the dam to break.

GLOF is characterized by exceptionally high concentration of sediment and a sharp rise in peak discharge. In the case of bursting of moraine-dammed lake, peak discharge is attained within several minutes or couple of hours. The destructive power of the surge created by GLOF down a river system depends on the size of the lake, the magnitude of initial surge, river slope, channel roughness and shape of channel. Large quantities of materials are eroded from terraces, valley walls, river banks and previous fluvial deposits. The vertical and lateral erosion of the stream channel has the potential to destabilise talus slopes, former debris flows and landslides and to initiate new ones. These processes leave an extensive series of unstable zones which are subject to intermittent movement and become sources of river sediment over several years following the GLOF event. During the Dig Tsho GLOF of 4 August 1985 in Dudh Kosi, it was estimated that a volume of 6 to 10 million cubic meters of water drained from the lake within four hours with peak discharge exceeding 2000 cubic meters per second (Vuichard and Zimmerman, 1987). This event resulted in massive changes in the river channel as well as river bed over most of the sections between Dig Tsho and the Sun Kosi confluence (about 90 km) with extensive degradation and aggradation. Namche Small Hydropower plant nearly completed was washed away by the flood, besides extensive damages to other properties in the downstream reaches.

The most active glaciers of Nepal and adjoining Tibet in China are located in the eastern part of the country. The records revealed that at least thirteen GLOF events had occurred in Nepal in the past thirty years, seven of them only in the Arun river. GLOF of 1964 in this river was caused by bursting of Gelhaipuco lake (in Tibet) which had released 23.36 million cubic meters of water with heavy concentration of sediment, resembling a debris flow whose bulk density was estimated at about 1.45 ton per cubic meter (LIGG/WECS/NEA, 1988).

Apparently, GLOF possesses three clearly distinguishable hazards as far as hydropower development in the Himalayan rivers is concerned. Firstly, GLOF can be potentially destructive which can impart hydropower projects located in close proximity to the source of GLOF total destruction or heavy damage. Secondly, the relatively high peak discharge associated with GLOF necessitates any hydraulic structures across the river to be designed with a higher factor of safety to pass safely the anticipated floods. And finally, the most important implication of GLOf is that, especially where large and expensive intakes or reservoirs have been constructed, there is danger of damage, clogging and far more rapid siltation than design specification indicate (Ives, 1986).

4.2 Seismicity

The evolution of the Himalayas is associated with a process that involve the collision of the Indian plate with that of the Eurasian plate causing vertical movements, and the consequent upheaval. The plate movements remain active till today, giving rise to accumulation and release of tremendous amount of strain. As such, the entire Nepal which falls in the mid of Himalayan arc is considered to be one of the most seismically active regions on the Earth. It is believed that the seismicity in the region is probably caused by the activities in the thrust faults (main central thrust, main boundary thrust and Himalayan frontal fault) running parallel along the Himalayan range as well as the transverse faults below the Indo-Gangatic alluvium, which supposed to have extended to Nepal Himalayas.

Within the last 100 years four great earthquakes of magnitudes exceeding 8 on the Richter scale have occurred along the Himalayan arc: they are 1897 Western Assam, 1905 Kangra, 1934 Bihar-Nepal, and 1950 Eastern Assam earthquakes. Prior to 1897 there were three such great earthquakes, 1885 in Kashmir, 1833 in Western Bihar and 1803 in Utter Pradesh. The instrumental seismic data suggest that the Mountain Boundary Thrust (MBT) is the major source of seismic activity of the region. Field observations in western Nepal of distinct pressure ridges, over 100 km length of the surface trace of the MBT, and outcrops of Lesser Himalayan rocks thrust southward over young, unconsolidated alluvium deposits confirms that the MBT has been, and most probably, will be a source of very large earthquakes (HPC, 1989). It is considered that the MBT is capable of generating a maximum credible earthquake of magnitude exceeding 8.

Unfortunately, the MBT runs along the middle mountain belt of the country, which holds most of the potentially best sites for high dam storage projects in Nepal. As the prediction of earthquake events and their magnitude is beyond the reach of present day science, any hydropower projects proposed in this region should be planned with full provisions of safety measures to brace the maximum credible earthquakes. Definitely, this will significantly push up the capital investment required for hydropower development in Nepal. Besides cost factor, the psychological threat of dam break will continue to hunt the minds of general populace, which will be very difficult to remove. It is very much likely that the public outcry on such issue will outweigh any good proposal for large hydropower projects in the vicinity of the seismically active belt in the Himalayas.

4.3 Extreme Precipitation

Apart from the prevailing characteristic of monsoonal precipitation, there are instances of exceptionally high precipitation occurring over one place or other in this region, once in few years. Often termed as "cloud burst", such events generate higher intensity and shorter duration rainfall over a relatively smaller area, leading to debris torrents and flooding down the river system.

During summer, the low pressure zone, known as "monsoon trough" which normally hovers over the Ganges plain just below the country's southern border with India, occasionally shifts towards the foot-hills of the Himalayas. The phenomenon commonly referred to as a "break" in the monsoon (Ramaswamy, 1962) is often associated with western disturbances and other similar influences (e.g. strong low pressure zones from south china sea moving towards the Himalayas). Under these circumstances, the most unstable atmospheric condition is developed, and produces an event like cloud burst.

Although, it is not very clear whether all the extreme precipitation events occurred in the past can be considered as cloud burst, eventually such events have assumed the primary role of triggering widespread devastations and flooding in the middle mountain regions of the Himalayas. The recorded history of precipitation in Nepal in the past 35 years implied that there are over a dozen of events with 24 hours precipitation exceeding 400 mm. The latest in the series was the event of 20 July 1993 in the central Nepal, during which 24 hours precipitation reached 540 mm, prompting a disaster of unprecedented magnitude in the recent times (Shrestha, 1994). Nation's two important water projects, Kulekhani Hydropower system (92

MW) and Bagmati Irrigation Project, were severely damaged as a result of this particular outbreak. During the event, the Kulekhani reservoir which receives water from a catchment of 126 sq.km experienced a peak inflow of 1450 cu.m/sec (MoWR, 1993) and the reservoir water level was up by 20 m within 8 hours, filling about 61 percent of live storage volume. A similar event in 1987 badly damaged Sun Kosi Hydropower Project (10 MW), disrupting its' operation for about 5 months.

4.4 Mass Movements and Sedimentation

The geologically young Himalayas are constantly under the influence of uplift, weathering and erosion. The variations in the tectonic movements, parent material, altitude and climate result in variations in the extent of slope instability in time and space. Bruijnzeel and Bremmer (1989), following an extensive review of the literature on the subject, noted that steep dip-slopes, unstable nature of rocks due to their structural disposition (e.g. degree of fracturing), depth and degree of weathering, high seismicity, and oversteepening of slopes through undercutting by rivers ranked among the most important geological factors that instigate mass wasting in Nepal Himalayas. As mentioned earlier, the natural events like GLOF, cloud burst and seismic activities also play a significant role. Besides these natural factors, the population pressure and subsequent expansion of development activities, especially in the middle mountain and the foot-hills of the Himalayas, have recently started to show some interrelation with the mass movements. However, such man-accelerated mass wasting processes are believed to be active at local levels only and entails less impact than the natural factors (Carson, 1985; Hamilton 1987). Euphrat (1987) in his study of a middle mountain catchment east of Kathmandu estimated that about 80 percent of the slides could be classified as "occurring naturally".

The high incidence of mass movements in the Himalayan watershed induces several adverse conditions which directly affect the extent with which the water resources potential of Nepalese rivers can be utilized successfully. Although, the complexity of the process do not allow one to make a "good" estimate of the quantity of the material moved and predict their likely occurrences, the recent evidences suggest that the mass movements and the resulting sediment yield in these rivers could play a crucial role in the development of water resources projects.

In July 1993, the country's only storage hydropower project, Kulekahni reservoir, was subject to heavy sedimentation as a result of widespread mass wasting activated by intense rainfall in its' watershed. Following the event, the rise in the reservoir bed level was surveyed employing echo-sounding technique (Sthapit, 1994). The result revealed that 66 percent of the dead storage has been filled by sedimentation during the last 12 years of its' operation and the single incident of the last year alone accounted about 76 percent (7.71 million cu.m) of the total sedimentation since May 1982. This calculates, on the average, removal of about 61 mm of material from the entire watershed of 126 sq.km during the particular event which lasted for about 30 hours. In an another estimate by Pokharel (1994) for Bagmati basin, which is relatively a larger catchment (2720 sq.km), showed that the same July event had brought down about 95.8 million cubic meters of sediment into the river system downstream, which is equivalent to removal of 35.4 mm on the average from the entire basin. These figures imply that the earlier estimates like one compiled by Galay (1987) for rivers in Nepal are highly underestimated.

The mass movement processes have become the matter of great concern not only because of its' contribution to high rate of sedimentation in the Himalayan rivers, but they also possess other types of hazards like temporary damming of river course and sudden outburst releasing destructive floods like GLOF, threat to project components like headwork, power house, access roads and other surface structures, develop instability of the reservoir rim, and intrusion of sediments into the power canal (or tunnel) and ultimately to the turbine. All these consequences necessitate heavy operation costs as well as shorten the life of the project, both of which are detrimental to the project's economy.

The implications of the Himalayan environment, indeed, have become a matter of great concern, especially when it comes to the development of hydropower projects. Because of the presence of potentially damaging hazards in the Himalayan environment, as illustrated above, it is possible that a large number of prospective sites for hydropower development either would become totally unattractive, or turn out to be very expensive to construct and operate. At least, the adverse impacts resulting from GLOF, extreme precipitation and mass movements are already visible. These processes have severely affected the existing hydropower projects which were not foreseen during the planning stage. Seismicity is a real threat which ought not to be ignored in the planning stage.

5. SUMMARY AND CONCLUSIONS

Despite having a large number of potentially attractive sites for hydropower development in Nepal, a host of natural problems abound. This paper has attempted to highlight some of these important aspects which deserve a thorough understanding for the successful utilization of water resources in this country. Water resource projects interacting with the Himalayan environment are constantly under the threat of natural hazards. In order to minimize destructive consequences due to extreme natural events and not to jeopardize the beneficial uses for which the projects are developed, it is invariably required to improve the present state of understanding and the information available on different factors mentioned above.

Undoubtedly, the provision of elaborate engineering preventive and mitigative measures in the design are bound to be expensive. On the other hand, hydropower projects being capital intensive propositions, a least developed country like Nepal cannot absorb higher risk posed by extreme events prevalent in the Himalayan environment. This dichotomy of cost and risk would continue to hinder tomorrow's hydropower development decisions in Nepal, even if other equally influencing constraints like geopolitics, capital scarcity and technological illiteracy (or incapability) are resolved.

It is definitely not the intention of this paper to advocate that the water resources development in Nepalese river should be limited. What has been emphasized here is the need to improve the present state of knowledge-base and information on the extreme natural events which are specific to the Himalayan environment, and to pay due attention while developing water resources projects in the country. In fact, any deferral in the utilization of this single important natural resources would push Nepal further back from the present state of desperate poverty.

There are indeed three scenarios under which Nepal can benefit from its' immense water resources potential.

The first scenario, and perhaps the most attractive and dependable one, is to promote extensive development of small projects which can be constructed and operated by mobilizing local resources alone (both money and manpower). As the local capability builds on, the gradual switching from small- to medium-scale projects would become attractive in the subsequent years. At the same time it is also essential to explore opportunities for developing large-scale multipurpose projects which are attractive for export. However, the development of this latter category of projects would require comprehension of several other issues, resolution of which are beyond the mere engineering challenge.

The second scenario, which is dependent much on the interests and the needs of lower riparian countries, is to push for a sound regional consensus on hydropolitics for the mutual benefits. A congenial solution on the subject would be possible only if this is taken together with other regional issues which will open an avenue to establish a workable mechanism for "giving and receiving" among the participating countries. For this India, being a regional power, should come forward with some magnanimity by breaking its' strong affinity to bilateralism, particularly on the water resources agenda, and by upholding the objectives of the South Asian Association for Regional Cooperation (SAARC).

The third scenario, a little more optimistic one, is the technological breakthrough in the existing transmission and distribution systems. Unlike oil, for all practical purposes, electricity lack mobility. This has created a situation of monopoly at the receiving end. However, now, some rays of hope have been offered by the recent developments in the "global rural electrification" concept (Glaser, 1991; Leonard, 1991). The concept is based the principle that a satellite in geosynchronous Earth orbit, 35,900 km above the equator, can transmit electrical energy (by converting it into microwave energy) to earth-based receiving antennas at desired locations. Studies are underway to assess the feasibility of beaming power from a generating plant on Earth to a reflector in geosynchronous orbit and back to a receiving site at a great distance from the generation source. Provided that such a technology becomes commercially viable, the current affair of having only a single market for the export of electricity generated in Nepal, which she has to accept purely due to her unfavourable geopolitical positioning would be totally eliminated.

Nepal has been experiencing difficulties in utilizing its' only rich natural resources, hydropower, for various reasons. Given that either of the scenarios described above becomes a reality, a successful development and management of hydropower projects would still remain a challenging task in the days to come unless a complete understanding of the inherent physical environment of the Himalayan rivers is made.

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IMPROVING THE HYDROLOGIC CYCLE AND WATER ENVIRONMENT IN RIVER BASINS UNDERGOING URBANISATION

Wataru TAKAHASHI[1] & Ken KAMITAKAHARA[2]

ABSTRACT

As natural river basins undergo development, major alterations are observed in the water environment in them. Urban development in particular brings about such changes as increased demand on the water resources, pollution of the water in rivers passing through the urban areas, reduction of the discharge during periods of no rainfall and intensification of flood disasters. All these are issues that are of major concern to the residents and, at the same time, are issues that cannot be solved by individuals.

The first step in the conservation of the river and water environment in urbanised areas is the study of the past and present conditions of the hydrologic cycle in each river basin, on the basis of which conservation and improvement plans are drawn up. These plans are then expanded to cover whole regions instead of single river basins. Through the implementation of such measures, one can expect to achieve satisfactory water environments in the urban areas as a whole.

With these points in view, a study was conducted on the conditions along the Ebi River, which flows through Funabashi City in the eastern part of the Tokyo Metropolitan Region. The basin of the Ebi River presented an area appropriate for such a study in terms of its size, while Funabashi City is an area that has seen rapid urbanisation during the recent decades.

In the present paper, discussions are first made on the outline conditions of the river basin and the changes in the population and land use conditions brought about by the urban development, followed by calculations on the various components of the hydrologic cycle. Observations are then made on the changes in the hydrologic cycle through a comparison of the conditions at present, as deduced from the above calculations, and the conditions in 1955, immediately before rapid development began in the area. Finally, it is pointed out that underground infiltration systems will be an effective means of making improvements in the hydrologic cycles in urban areas undergoing development, and a note is made of the plans for future investigations in the study area.

RÉSUMÉ

Les bassins naturels des rivières étant soumis à des évolutions, des modifications majeures ont été observées dans leur environnement hydrologique. Le développement urbain en particulier apporte des changements drastiques tels que l'augmentation de la demande vis-à-vis des ressources en eau, la pollution des cours d'eau passant dans les zones urbaines, la réduction des débits pendant les périodes sans précipitations et l'intensification des inondations. Tous ces problèmes sont des sujets d'inquiétude pour les résidents et, simultanément, ne peuvent être résolus individuellement.

La première étape de la préservation de l'environnement des rivières et de l'eau dans les zones urbanisées passe par l'étude des conditions passsées et présentes du cycle hydrologique dans chaque bassin de rivière. Des plans de conservation et d'amélioration sont ensuite établis

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sur la base de l'étude effectuée. Ces plans sont alors étendus à l'ensemble d'une région, sans se cantonner aux seuls bassins des rivières. Par la mise en oeuvre des mesures préconisées par ces plans, un environnement sain pour les cours d'eau peut être obtenu dans les zones urbaines dans leur ensemble.

Une étude sur les conditions le long de la rivière Ebi, traversant la ville de Funabashi, à l'est de la sphère métropolitaine de Tokyo, a été réalisée à partir de ce point de vue. Le bassin de la rivière Ebi a été considéré comme zone appropriée pour la conduite d'une telle étude en termes de dimensions et en raison de l'urbanisation rapide dont la ville de Funabashi a fait l'objet lors des dernières décades.

Dans le présent document, des discussions ont tout d'abord été entreprises sur les conditions d'ensemble du bassin de la rivière, sur les évolutions au niveau de la population ainsi que sur les conditions d'utilisation des terrains dues au développement urbain. Ces discussions sont suivies par des calculs sur les différents composants du cycle hydrologique. Des observations sont ensuite effectuées sur les évolutions du cycle hydrologique par le biais d'une comparaison entre les conditions actuelles, déduites à partir des calculs précédents, et les conditions en 1955, immédiatement avant le développement de la région. En dernier lieu, on remarque que les système d'infiltration souterrains constitueront un moyen effectif d'apporter des améliorations aux cycles hydrologiques dans les régions urbaines en cours de croissance et une note indique les plans pour les futures investigations prévues dans la région étudiée.

1. STUDY AREA

The Ebi River Basin, which has been selected as the study area, comprises a suburban area situated at the western end of Chiba Prefecture, approximately 23 km to the east of central Tokyo.

The Ebi River has a catchment area of 26.52 km^2, 99% of which is contained within the municipal boundaries of Funabashi City. With a well-developed network of above-ground and underground railways and trunk roads connecting it to Tokyo, this municipality has undergone rapid development as a commuter town.

1.1 Principal Components of River Basin

The principal rivers making up the Ebi River System are listed in Table 1. The main channel of the Ebi River originates at an elevation of around 30 m and empties out into Tokyo Bay. This main channel is joined by the seven tributaries, namely, the Nagatsu, Maehara, Hazama, Miyamae, Takane, Nenda and Kitayatsu.

There are no mountainous areas in the river basin, which is made up of a plateau at elevations of 20 to 30 m and a low-lying plain at elevations of below 10 m, both of which occupy about the same area.

In geological terms, the whole basin is covered by dark brown organic soil, below which there is a 5 m stratum of Kanto loam. This Kanto loam is reddish brown soil formed from the volcanic ash produced by the eruptions between 30,000 and 10,000 years ago of volcanoes, including Mt. Fuji and the Hakone Volcanoes. The surface organic soil consists of humus deposited during the past 10,000 years or so.

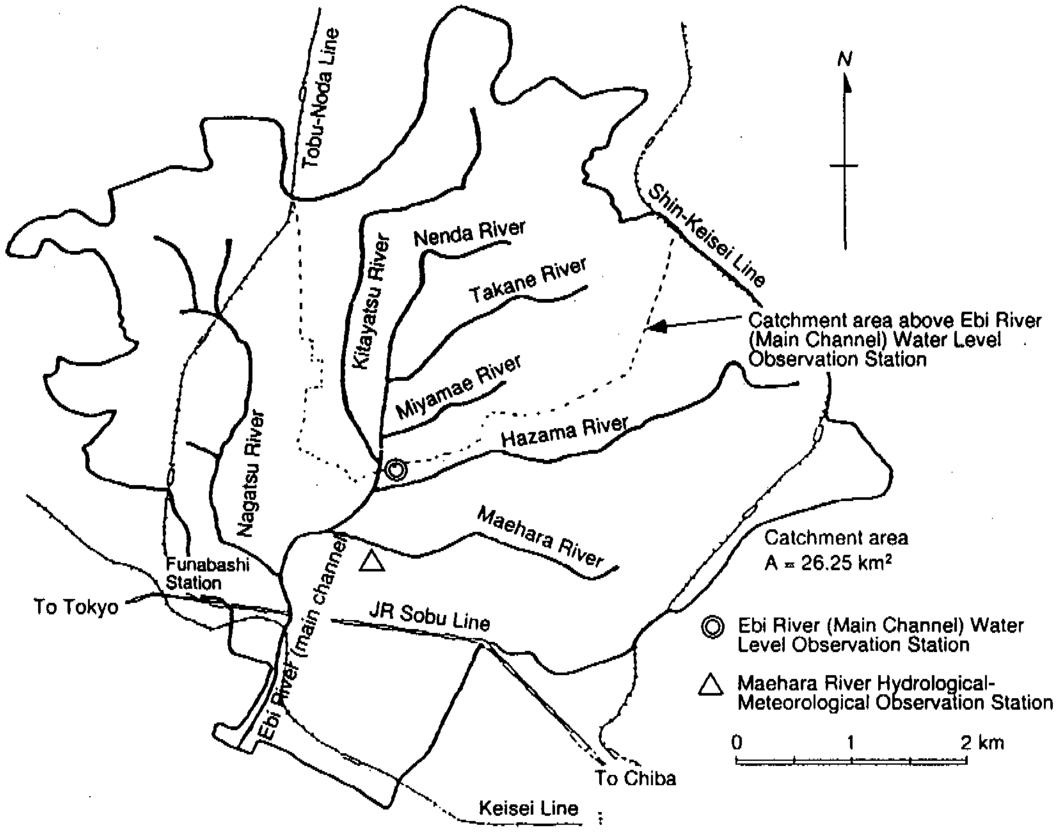

Figure 1. Ebi River Basin

Table 1. Data on Ebi River System

Item	
Catchment area	26.52 km^2 (source: Chiba Institute of Technology)
Length (Catchment area)	
Ebi River (main channel)	2.67 km (3.42 km^2)
Kitayatsu River	4.00 km (3.85 km^2)
Takane River	2.80 km (1.61 km^2)
Miyamae River	1.50 km (0.78 km^2)
Hazama River	4.50 km (5.32 km^2)
Maehara River	2.34 km (3.79 km^2)
Nagatsu River	2.99 km (5.88 km^2)
Nenda River	3.00 km (1.87 km^2)
Trunk channel length	8.00 km
Land gradient	(Ebi River) 1/1000 ~ 1/1300
Geology	Kanto loam and Narita formation
Vegetation	Cultivated land and planted forests (coniferous)
Watershed elevation	TP. 30 m
Municipalities	Funabashi City (26.25 km^2) and Kamagaya City (0.27 km^2)

1.2 Changes in Population and Land Use Conditions

The population in the river basin, which began to increase gradually after the Second World War in the early 1950's, started to increase more rapidly in the years around 1955. This is attributable to the concentration of the population in Tokyo and the resulting housing shortage and rise in land price, whose effects began to percolate into the neighbouring areas around this time. The population of the river basin doubled from 89,000 in 1960 to 160,000 in 1975, and has since continued to increase at a steady rate. In the 1930's most of the low-lying areas in the river basins were being used as paddy fields and the plateau areas as forests and dry fields. Besides the township on a slight rise in the ground near the river mouth, housing was to be found only in clusters of houses dotted along the edge of the plateau and along main roads.

Around 1955, housing began to spread out from the township into the neighbouring plateau areas. With the gradual acceleration of this expansion, paddy fields began being converted into housing in the 1960's, and with a further acceleration of the population increase, the residential area began to extend into the plateau areas along the middle and upper reaches of the Ebi River. The residential area exceeded 50% of the river basin in 1985 and has since continued to show a gradual increase.

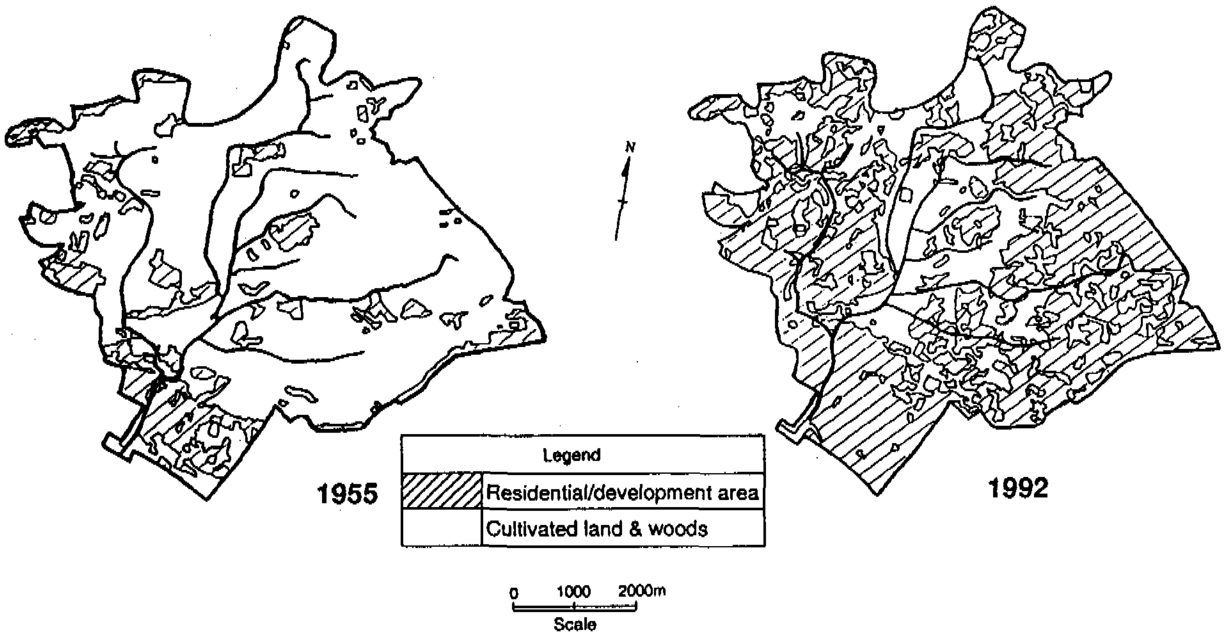

Figure 2. Urbanisation of Ebi River Basin

Table 2. Urbanisation of Ebi River Basin

Year	Residential area (km^2)	Residential area (%)	Population in river basin (x 1,000)	Population density (per km^2)
1955	4.22	15.91	53.3	1.965
1965	8.63	32.53	89.3	3.293
1975	14.11	53.19	160.3	5.911
1985	16.40	61.84	191.4	7.217
1992	16.85	63.35	202.4	7.632

2. COMPONENTS OF HYDROLOGIC CYCLE

In the water cycle in an urban area, one needs to consider such factors as the transfer of water from other river basins and the presence of drainage facilities and impermeable surfaces in addition to the natural factors. In an urban area, therefore, the infiltration is smaller and the surface runoff, on the other hand, is greater than in a non-urban area. The decrease in the infiltration into the ground and the pumping of water through wells result in a decrease in the groundwater and consequently in the volume of water seeping out from the ground on to river channels and other ground surface areas. At the same time, there is the leakage from the waterworks and this is considered a factor contributing to the recharge of groundwater in urban areas.

The water balance in an urban area may be expressed by the following equation.

$$P + W = E + \Delta S + (R_S + R_G + R_1 + R_2)$$ [1)]

- P : precipitation
- R_S : surface runoff
- E : evapotranspiration
- ΔS : change in volume of water stored in ground
- R_G : groundwater outflow
- R_1 : rainwater drainage
- R_2 : sewer drainage
- W : water transferred from other areas

The above equation was applied to the Ebi River Basin for calculation of the water balance in terms of rainfall equivalents (mm), obtained by dividing the relevant water volumes by the area of the river basin. The values for each component in the equation were obtained as follows.

The study year was 1992. The component values given below are annual values.

2.1 Precipitation

There are nine rainfall observation stations in and around the Ebi River Basin, including the Maehara River Hydrological-Meteorological Observation Station, established for the purpose of this study at the end of 1991. While the measurement values taken on the rainfall gauge at Maehara Station are used for 1992, measurements taken at other stations in the vicinity are used for the years prior to 1992.

Precipitation in 1992 = 1,472 mm

2.2 Inflow into River Basin Other than Precipitation

Discussions are made below on the volumes of water other than precipitation, which enter the river basin from other areas and influence the hydrologic cycle.

2.2.1 Potable water

The whole of the river basin is covered by Chiba Prefecture Bureau of Waterworks. Most of the water supplied through this network comes from the dams on the upper reaches of the Tone River, outside the Ebi River Basin. The following figures were obtained through a study.

Water supplied = 22,965,000 m^3 (rainfall equivalent = 866 mm)
Leakage 1,837,000 m^3 (rainfall equivalent = 69 mm)

2.2.2 Industrial water

Industrial water in this area is supplied by the Chiba Prefecture Bureau of Public Enterprises. The source of this water is the same as for potable water. Large factories, however, are found only in the western part of the river basin, along the Nagatsu River, and the industrial water network covers only a part of the river basin.

Water used = 2,473,000 m^3 (rainfall equivalent = 93 mm) leakage = 0

2.2.3 Pumping of groundwater for domestic use

Despite the spread of the potable water network, there are over 4,600 households also using groundwater, electrically pumped in all cases from wells. The amount of water supplied thus was estimated by multiplying the population using it by the unit volume for utilisation of waterworks in Funabashi City.

Domestic groundwater use = 1,289,000 m^3 (rainfall equivalent = 47 mm)

2.2.4 Pumping of groundwater for agricultural use

For the irrigation of the paddy fields in the Ebi River Basin, one is dependent mainly on the water pumped up from the deep, confined aquifers, rather than on surface water. Its use is concentrated in the April-September rice-growing season and especially between May and August.

Agricultural groundwater use = 2,266,000 m^3 (rainfall equivalent = 85 mm)

2.3 Movement of Precipitation according to Land Use Conditions

The movement of water, once it has reached the ground surface in urban areas, may take the form of evapotranspiration, infiltration or runoff, and the values for each of these categories vary greatly according to the land use conditions.

In the study here, the river basin was classified into the permeable and impermeable zones and the zone with rainwater infiltration facilities as shown below, and calculations were made on the movement of water in each zone.

Permeable zone:	paddy fields, dry fields, forests, vacant land, water surface, housing land (50%), others (50%), schools (65%)
Impermeable zone:	housing land (50%), others (50%), car parks, roads, railways, schools (35%)
Infiltration facilities zone:	leaching wells, infiltration trenches, U-shaped infiltration gutters - Their catchment areas are included in the impermeable zone.

The areas of the permeable and impermeable zones were estimated through investigations using aerial photographs and urban planning maps and through field surveys. The results are given in Table 3.

Table 3. Land use in Ebi River Basin

Land use classification	Area (km^2)	Ratio (%)	Permeable zone (km^2)	Impermeable zone (km^2)	Permeable zone (%)	Impermeable zone (%)
Housing land	2.26	22.93	1.13	1.13	11.46	11.46
Hard structures	0.62	6.31	0.00	0.62	0.00	6.31
School premises	0.46	4.65	0.30	0.16	3.02	1.63
Vacant land	0.75	7.62	0.38	0.38	3.81	3.81
Water zone	0.08	0.83	0.08	0.00	0.83	0.00
Cultivated land (dry)	2.39	24.26	2.39	0.00	2.39	0.00
Paddy fields	0.54	5.52	0.54	0.00	5.52	0.00
Forests	0.58	5.87	0.58	0.00	5.87	0.00
Car parks	0.12	1.26	0.00	0.12	0.00	1.26
Railways	0.01	0.12	0.00	0.01	0.00	0.12
Roads	1.79	18.19	0.00	1.79	0.00	18.19
Others	0.24	2.46	0.12	0.12	1.23	1.23
Total	9.87	100.00	5.53	4.34	56.00	44.00

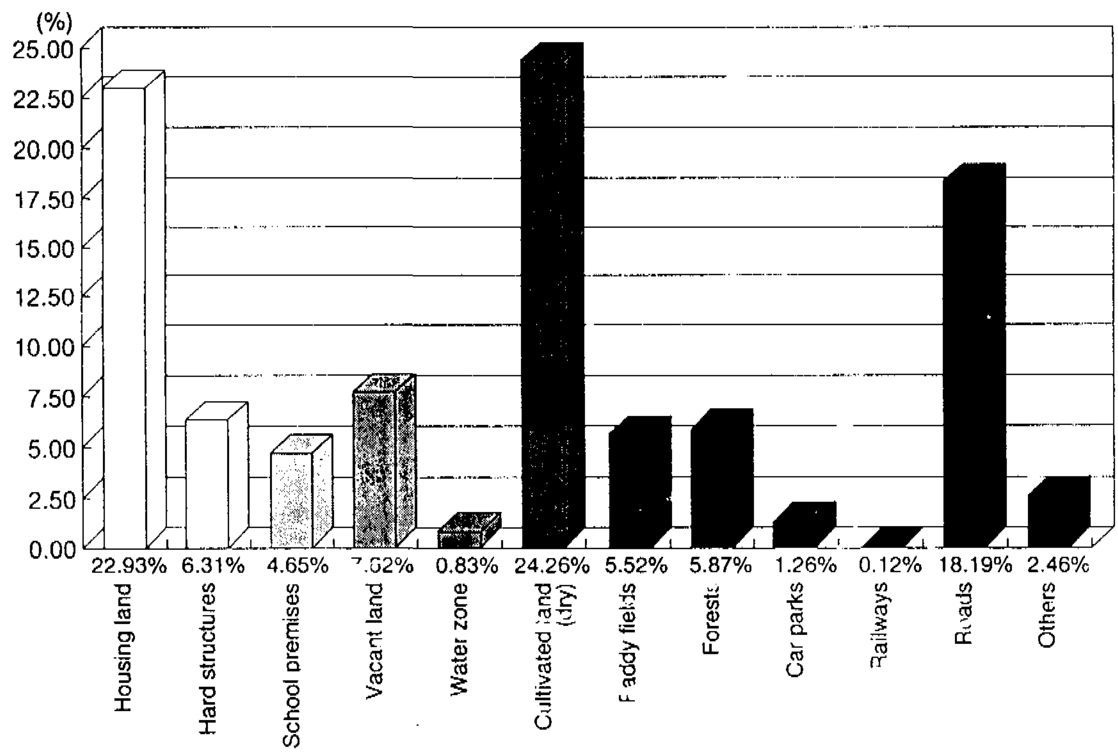

Figure 3. Land use in Ebi River Basin

2.3.1 Evapotranspiration

The amount of evapotranspiration varies according to the duration and amount of rainfall and according to regions and seasons. For the estimation of the evapotranspiration in the permeable zone here, use was made of such data as the estimations made in the past on the ten-day evapotranspirations in western parts of Chiba Prefecture[2] and measurements taken on paddy fields in the Kazusa and Shimousa areas of Chiba Prefecture during both the irrigation and non-irrigation seasons.[3] For the impermeable zone (including the infiltration facilities zone), an evapotranspiration of 2 mm per spell of rainfall was assumed.

Permeable zone:	309 mm
Impermeable zone:	106 mm
Infiltration facilities zone:	1.5 mm

2.3.2 Surface runoff

A part of the precipitation is converted into surface runoff. Runoff rates were established for each land use category and the runoff was calculated, as a basic rule, using the following equation.

$$R_S = (P-E) \times f$$

f : runoff coefficient

The runoff coefficients used were as follows.

Permeable zone:	paddy fields:	0.1	dry fields:	0.1
	forests:	0.1	vacant land:	0.1
	water zone:	0.2	housing land:	0.2
	others:	0.2	school premises:	0.2
Impermeable zone:	housing land:	0.8	others:	0.8
	car parks:	1.0	roads:	1.0
	railways:	1.0	school premises:	0.8

"Others" here include such areas as parks and precincts of Shinto shrines.

For the infiltration facilities, the rainfall in excess of their capacities was considered as the overflow runoff.

Separate calculations were made for the irrigation and non-irrigation seasons for the paddy fields.

The results obtained were as follows.

Permeable zone:	97 mm
Impermeable zone:	570 mm
Infiltration facilities zone:	0.1 mm
Total:	668 mm

2.3.3 Infiltration

The infiltration was calculated with the following equation.

$$I = P - (E + R_S)$$

I : infiltration

The calculation results were as follows.

Permeable zone:	418 mm
Impermeable zone:	72 mm
Infiltration facilities zone:	11 mm

2.3.4 Sewers

Combined systems are used on the public sewers in the Ebi River Basin. These sewers serve only the downstream coastal areas close to Tokyo Bay and cover only 9.1% of the river basin. The precipitation in excess of the capacity of these sewers flows directly into the sea (Tokyo Bay) as overflow.

The amount of surface runoff flowing into the sewers was calculated with the following equation.

$$R_{ssw} = R_s \times r_{psw}$$

R_{ssw} : inflow of rainwater surface runoff into sewers
r_{psw} : proportion of sewered area in river basin

The drainage from homes and industrial facilities into sewers was calculated with the following equation.

$$RD_{sw} = \{(W_{all} - W_l) + D_f\} \times r_{asw}$$

RD_{sw} : drainage from homes and industrial facilities into sewers
W_{all} : total potable water supply in river basin
W_l : leakage from potable waterworks
D_f : groundwater pumped for domestic use
r_{asw} : proportion of sewered population in river basin

The following values were obtained by applying the hydrological quantities observed in the Ebi River Basin to these equations.

Inflow of surface runoff into sewers = 67 mm
Drainage from homes and industrial facilities into sewers = 87 mm

The inflow of groundwater into the sewers, assumed to equal the difference between the amount of water handled at the drainage pump stations and the discharge on the sewers, was estimated at 49 mm.

3. CHANGES IN HYDROLOGIC CYCLE DUE TO URBANISATION

The discharge on urban rivers may be classified into two types. One is the "rainfall discharge," derived mainly from the surface runoff at times of rainfall, which flows directly into the rivers and often causes floods. The other is the relatively stable "non-rainfall discharge" observed during periods free from rainfall, which is derived from the groundwater produced by the infiltration of previous rainfall into the ground and leakage from waterworks and drains into the ground. The non-rainfall discharge, in turn, may be classified into groundwater outflow, consisting mainly of groundwater, and artificial drainage, derived from water supplied from sources outside the river basin as potable and industrial water and discharged either via sewers or without treatment into the rivers and the sea.

The values obtained for these components of the discharge were as follows.

3.1 Rainfall Runoff

This consists of the rainfall surface runoff minus the evapotranspiration and infiltration, and its amount varies greatly with the land use conditions. The following equation is used.

$$R_{fl} = R_s - R_{ssw}$$

R_{fl} : amount of precipitation flowing into rivers as surface runoff

A value of $R_{fl} = 601$ mm was obtained for the Ebi River Basin, using the values of $R_s = 668$ mm for the surface runoff obtained in Section 2.3.2 and $R_{ssw} = 67$ mm for the inflow into sewers obtained in Section 2.3.4.

3.2 Groundwater Inflow into Rivers

This is the inflow into rivers of the shallow groundwater produced by the infiltration from the ground surface and leakage from waterworks and drains. The following equation is used.

$$R_G = I + I_a + W_l - D_f - O_{sw}$$

I_a : infiltration from rainwater infiltration facilities
W_l : leakage from waterworks
O_{sw} : leakage from sewage networks

The groundwater pumped up for agricultural use, since it is taken from the deep underground, was assumed not to affect the water cycle in the river basin as groundwater inflow.

The values for the above items in the Ebi River Basin were as follows.

$I = 490$ mm (Section 2.3.3)
$I_a = 11$ mm (Section 2.3.3)
$W_l = 69$ mm (Section 2.2.1)
$D_f = 47$ mm (Section 2.2.3)
$O_{sw} = 49$ mm (Section 2.3.4)

From these, a value of $R_G = 474$ mm was obtained.

3.3 Artificial Drainage

This is the water transferred from other river basins as potable and industrial water and discharged into the rivers after use, and is derived from "artificial" sources as opposed to natural sources such as rainfall. The following equation is used.

$$R_d = (W_{all} - W_l) + W_{id} - D_f - RD_{sw}$$

R_d : artificial drainage discharged into rivers from homes and industrial facilities

W_{id} : industrial water used

RD_{sw} : drainage from homes and industrial facilities into sewers

The values for the above items in the Ebi River Basin were as follows.

$W_{id} = 93$ mm (Section 2.2.2)

$D_f = 47$ mm (Section 2.2.3)

$RD_{sw} = 87$ mm (Section 2.3.4)

By applying these figures, a value of $R_d = 756$ mm was obtained.

3.4 Hydrologic Cycle in Ebi River Basin

Calculations have been made above for the various components of the hydrologic cycle in the Ebi River Basin. These are summarised in Figure 4.

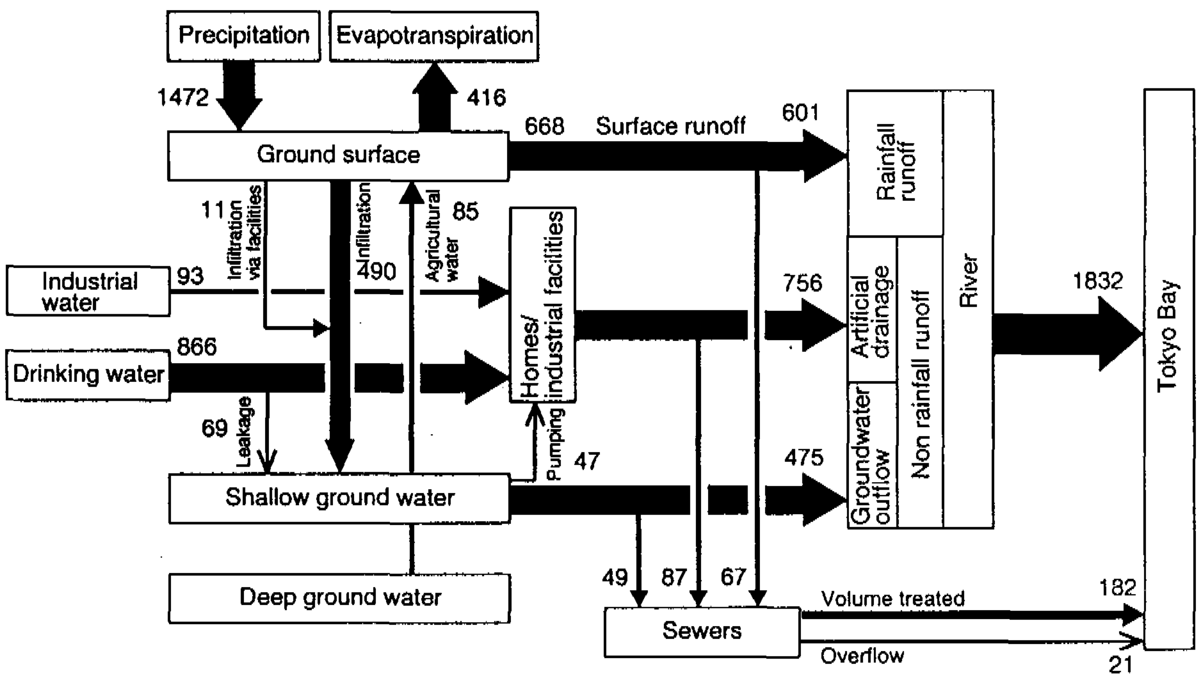

Figure 4. Hydrological cycle in Ebi River Basin (1992) [unit: mm/year]

4. COMPARISON OF PRE-URBANISATION AND RECENT HYDROLGIC CYCLES

Figures have been given above for the urbanised area immediately prior to the commencement of rapid urbanisation in 1955. A procedure similar to that used in the preceding sections for the estimation of the hydrologic cycle in 1992 was applied to estimations on the hydrologic cycle in 1955, which is shown in Figure 5. The data for 1955 and 1992 are compared in Table 4.

The above table shows that the groundwater outflow was greater in 1955, prior to urbanisation, despite the relatively low annual rainfall that year. Similarly, one may presume that the infiltration after rainfall would have been greater and the surface runoff considerably smaller.

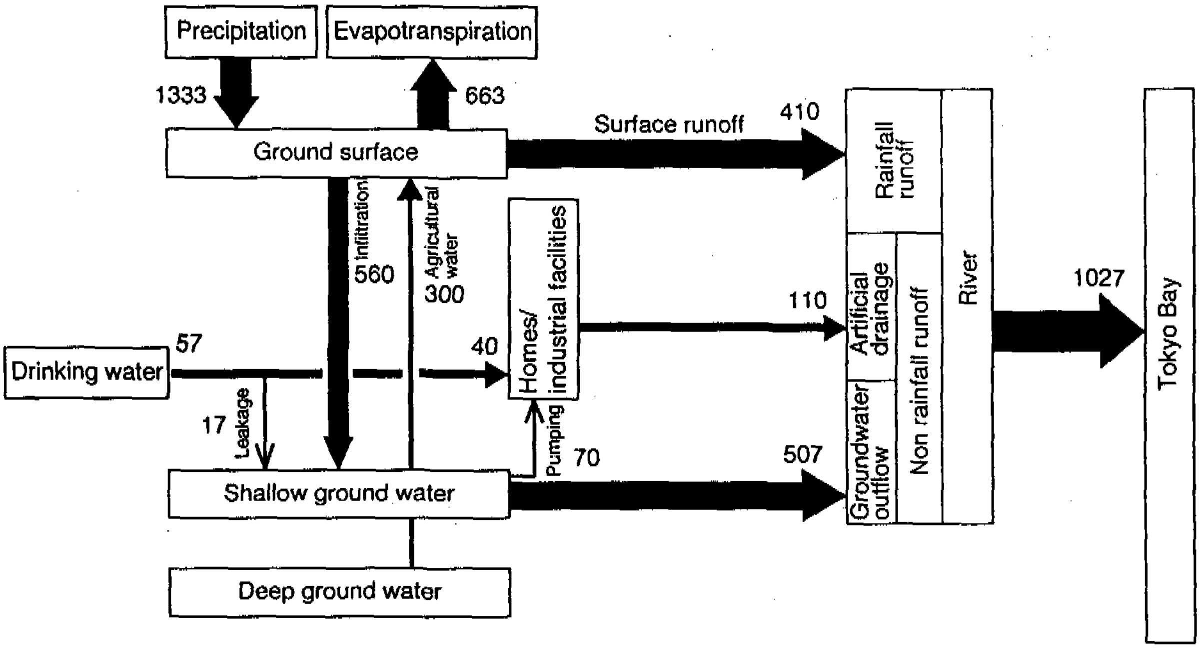

Figure 5. Hydrological cycle in Ebi River Basin (1955) [unit: mm/year]

Table 4. Changes in hydrologic cycle in Ebi River Basin due to urbanisation

Item/Year	1955	1992	1992/1955
Population of river basin	53,000	202,000	3.8
Population density: per km^2	1,965	7,617	3.9
Housing land ratio: %	12	22.9	1.9
Paddy field ratio: %	20	5.5	0.28
Dry field ratio: %	45	24.2	0.54
Forest ratio: %	16	5.9	0.37
Permeable zone: km^2 (%)	3.16 (11.9)	13.48 (50.8)	4.27 (area ratio)
Impermeable zone: km^2 (%)	23.36 (88.1)	13.04 (49.2)	0.56 (area ratio)
Precipitation: mm	1,333	1,472	(1.10)
Population served by waterworks	23,951	202,014	8.43
Public sewers	None	Some areas	—
Pumping for agricultural use: mm	300	85	0.28
Rainfall runoff: mm	410	601	1.47
Artificial drainage: mm	110	765	6.95
Groundwater outflow: mm	507	474	0.93

5. OBSERVATIONS AND CONCLUSIONS

5.1 Observations

5.1.1 Rainfall runoff

A rapid increase has been observed in the surface runoff with the expansion of the impermeable zone. This runoff occurs only during periods of rainfall, and descends through urban areas as flood water. The result is that a two-year probability rainfall of 25 mm/hr. is sufficient today to cause inundation in the urban areas along the Ebi River. The floods in recent years have, in fact, necessitated the implementation of improvement works on the river channels. The first phase of this project is now under way, aiming at the provision of facilities capable of withstanding an 8-year probability rainfall of 50 mm/hr., with plans for construction of facilities able to withstand a 50-year probability rainfall of 70 mm/hr. in the second phase.

5.1.2 Non rainfall runoff

The "non rainfall discharge" on a river is the discharge produced after a period of several days without rainfall. This discharge consists of the water transferred from other rivers and drained into the river and the groundwater flowing out into the river.

The water transferred from other river basins through artificial conduits and disposed of after use will be discharged into the river until sewerage systems are completed. The amount of water discharged in this way into the Ebi River has been gradually increasing and has been a cause of water pollution. Industrial areas are found only along the lowermost reaches of the Ebi River, and the records taken at the hydrological observation stations, located at points unaffected by industrial water, give a clear indication of the variation due to the changes in the volumes of domestic wastewater.

The outflow into the Ebi River of groundwater derived from infiltration and leakage water has been on the decrease with the reduction of the permeable zone. The observation records indicate an extremely stable pattern for this outflow.

5.2 Sumary and Conclusions

5.2.1 Summary

The years since the 1960's have seen a rapid concentration of the population in urban areas throughout Japan, which has produced an exponential growth in the demand for water. While measures have been taken to procure the water required from other areas with excess water resources in the Tokyo Metropolitan Region, the progress of urbanisation has produced effects other than the increase in water demand. The ground has been rendered impermeable in much of the high-density residential areas, and this has resulted, on one hand, in an increase in the runoff into the rivers during rainfall, causing an increase in flood disasters, and in a decrease in the river runoff, on the other hand, at times of no rain, accelerating the deterioration of the water quality in the rivers due to the discharge of domestic wastewater from the residential areas.

A major factor behind these phenomena is the conversion of the natural forests and hills through development into urban areas. With a view to elucidating the mechanism involved here, a study was conducted on the Ebi River, which flows through Funabashi City in the eastern part of the Tokyo Metropolitan Region. A report has been made above on the studies conducted on the hydrological characteristics of the river basin through observations on the river, and on the changes brought about by urban development in the hydrologic cycle through a comparison of the conditions in 1955, immediately before the commencement of rapid urbanisation, and the conditions today in 1992. There follows below a discussion of the future policies, including the suggestion that the use of underground infiltration systems will be effective in making improvements.

5.2.2 Conclusions

The observations made above indicate that a reduction of the surface runoff after rainfall and an increase of the infiltration into the ground would be effective in improving the hydrologic cycle.

At the same time, the completion in future of large-scale sewerage systems, which will absorb all the water transferred from other river basins and discharged after use, will reduce the inflow of water from this source to zero. The only source of the non rainfall discharge will then be the outflow of groundwater. While this will mean an improvement of the water quality due to the elimination of the pollutant load in the artificial drainage, it will also mean a major reduction of the non rainfall discharge, which will create new environmental problems.

Under these circumstances, it is proposed that a use should be made of the "infiltration via facilities" given in the drawing of the hydrologic cycle (Figure 4). An extensive use should be made of the facilities mentioned in Section 2.3, such as leach pits, infiltration trenches and U-shaped infiltration gutters, which are installed in the impermeable zones in river basins. This will result in the conversion of the impermeable zones into permeable zones, leading to a reduction of the surface runoff and an increase in the infiltration.

Studies will be conducted in future on the quantities of the infiltration that can be expected through these facilities with a view to raising the feasibility of such a plan. As a further recommendation, the authors would like to suggest that, rather than disposing of all the artificial drainage through large-scale sewerage systems, some of this drainage should be discharged into the rivers after treatment at decentralised purification plants. Studies will have to be conducted on the water quality in the rivers for this purpose. At present, the authors are conducting hydrological surveys, including surveys on the water quality, on the Ebi River and one of its tributaries, the Maehara River.

ACKNOWLEDGEMENT

The report presented here forms a part of the study being conducted in the Ebi River Basin, which was begun three years ago and which will continue in the future. The authors would like to take this opportunity to express their gratitude to Prof. Katsumi Mushiake of the University of Tokyo, who is conducting this study jointly with Takahashi, to the staff at Prof. Mushiake and Takahashi's offices, to the River Environment Foundation and the Urban Rivers Section of the Chiba Prefectural Government for their cooperation and to other relevant agencies for the provision of information used in the study.

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GROUNDWATER MANAGEMENT WITH DIFFERENT IRRIGATION DEMAND ALTERNATIVES

Abdallah E. Dabbagh [1] and Walid A. Abderrahman [2]

ABSTRACT

With Government encouragement and support, the total irrigated areas in Saudi Arabia have increased from about 0.5 million ha in 1975 to about 1.35 million ha in 1990, to contribute to the food security. The Kingdom managed to develop a successful model in converting large areas of the desert lands into highly productive farms. Modern and advanced technologies have been utilized in farming and irrigation practices. The country managed to achieve self sufficiency in five agricultural commodities; wheat, date palm, eggs, poultry and dairy products. In 1990, the irrigation water demands was about 19.685 billion m3 or 92% of the national water demands in the country. Groundwater resources is the main water source for about 94% of the total demands. Improvement of groundwater management in the Kingdom and irrigation demand reduction are essential for maintaining the long-term productivity and quality of the aquifers. The recent modification on the Government's price support to wheat has several positive goals such as: diversification of the agricultural production to other types of crops needed, adjustment of the wheat production to the level of the annual national consumption and reduction of the irrigation water consumption in heavy pumping areas especially in wheat producing regions. The groundwater conditions in terms of quality and levels will be improved especially in heavy pumping areas such as Qasseem, Kharj, Wadi Ad-Dawasir and Al-Hassa. Different cultivation scenarios, discussed in this paper indicate that expanding the areas of other crops in addition to the remaining wheat areas will still result in saving considerable amounts of water, and in increasing the production of other required types of crops.

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INTRODUCTION

To meet the growing food demands in the world, the irrigated area has increased from about 170 million ha in 1970 to about 240 million ha in 1990, (Pallas, 1993). As a result, the irrigation water demands has increased drastically. In most of developing countries such as the arid countries in the Middle East where the available water resources are limited, the agricultural demands represents more than 80% of the total water demands (Hennessy, 1993). Improvement of irrigation management is becoming critical to increase the efficiency of irrigation water use and to reduce irrigation demands.

Saudi Arabia extends mostly in arid and severely arid regions where the average annual rainfall is less than 150 mm/year. During the last two decades, the Kingdom has experienced comprehensive developments in agricultural, industrial, social, and construction sectors. The Government has supported and encouraged farmers to contribute in securing the Kingdom's food supply. The total irrigated area has increased from about 0.5 million ha in 1975 to about 1.35 million ha in 1990 (MAW, 1990). Self sufficiency in several strategic crops such as wheat has been achieved. The price support for crops especially for wheat has helped greatly in developing the infrastructure of farms. In 1990, the total wheat area was 744,421 ha or 55% of the total agricultural area in the Kingdom (MAW 1990). The wheat production was about 3.5 million tons, while the predicted national wheat demand was 1.175 million tons. This trend does not satisfy the national goal to diversify the agricultural production to meet the growing demands for other types of crops such as vegetables and fruits (MOP, 1990).

Irrigation water demands in the Kingdom has increased drastically due to the large increase in the agricultural area (MOP, 1990). In 1990, irrigation water consumption was about 92% of the national water use; and the nonrenewable groundwater resources was the source of about 94% of the national irrigation water consumption. This paper describes the history of the irrigated agriculture areas; and investigates the regional and national irrigation water demands for each crop group, the available aquifer and groundwater resources and the potential management problems of irrigation water. It also examines the impact of the modifications in government's price support to wheat on the irrigation demand reduction and groundwater management with different cropping scenarios. It further suggests recommendations for improving the groundwater management.

HISTORY OF IRRIGATED AREAS IN THE KINGDOM

Major developments and progress have been achieved in the agricultural sector. The government's support to farmers has been instrumental to satisfy growing national needs for basic food items. Efforts from government and farmers have been employed to reclaim the desert lands into highly productive farms. Modern and advanced technologies in agriculture and irrigation were utilized. Large areas of desert lands were converted to highly productive farms. The agricultural achievements of the Kingdom are well recognized on regional and international levels. Advanced technologies were developed and/or transferred in the agricultural and irrigation practices to farm the desert lands. The Kingdom is divided into eleven agricultural regions (Figure 1)(MAW, 1990). The cultivated areas in the Kingdom has expanded from less than 400,000 ha in 1971 to 1.341 million ha in 1990 (MAW, 1990). The threshold increase in the agricultural areas has started after 1979 (Figure 2). In 1990, the area of cereals was 969,780 ha or 72% of the total cultivated areas in the Kingdom (Table 1),(MAW,1990). The total wheat area was 744,421 ha or 55% of the total cultivated areas in the Kingdom; while, the areas of fodder crops, vegetables and fruits were 13%, 8% and 6.5% of the total agricultural areas re-

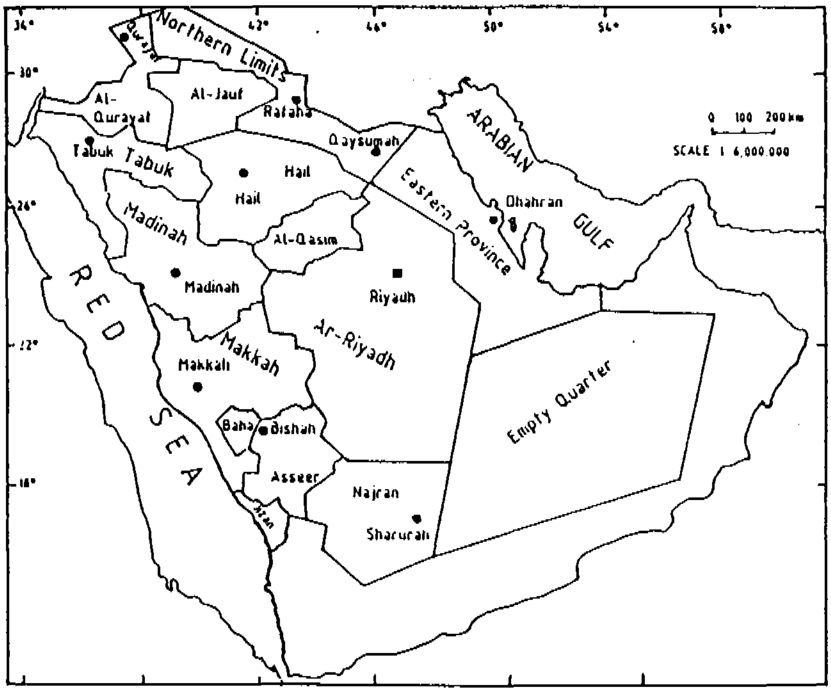

Figure 1 The agricultural regions in Saudi Arabia.

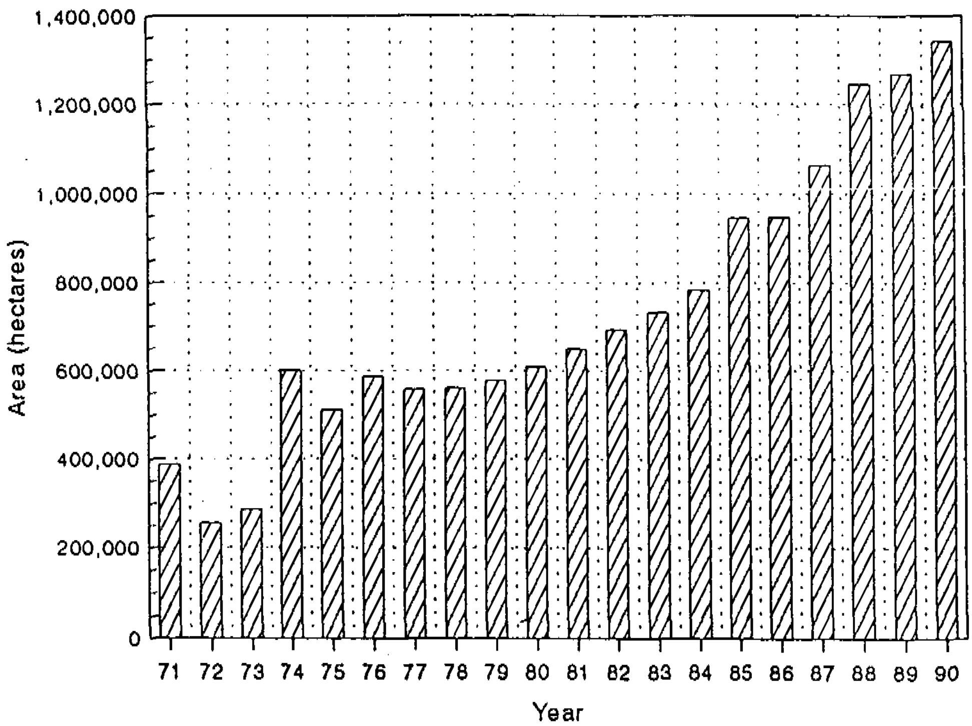

Figure 2 The total agricultural areas in Saudi Arabia between 1997-1990

Table 1. The cropped areas in the agricultural regions of Saudi Arabia during 1990 (hectares)

REGIONS	CEREALS			VEGE-TABLES	FODDER CROPS			FRUITS			TOTAL
	Wheat	Others	Total		Alfalfa	Others	Total	Dates	Others	Total	
Eastern Regn.	26,283	7,112	33,395	8,252	2,257	5,338	7,587	9,891	589	10,480	59,722
Riyadh	341,171	25,838	367,009	29,963	24,990	13,208	38,198	21,057	3,099	24,156	459,326
Qaseem	248,820	7,743	256,563	16,142	12,187	5,705	17,892	6,958	2,380	9,338	299,935
Hail	69,009	147,777	78,768	1,677	4,034	2,622	6,656	7,026	529	7,555	94,656
Northern Regn.*	45,812	3,318	49,130	5,799	2,637	2,528	5,165	3,323	3,103	6,426	66,520
Medina	3,869	351	4,220	1,892	1,561	254	1,815	6,774	1,259	8,033	15,960
Makkah	1,031	20,623	21,654	22,578	263	21,274	21,537	4,893	1,684	6,577	72,346
Aseer	5,604	15,528	21,132	3,099	3,554	9,091	12,645	6,106	2,986	9,092	45,968
Al-Baha	1,153	2,690	3,843	470	140	3,214	3,354	557	317	874	8,541
Jizan	0	131,473	131,473	10,529	50	61,853	61,903	23	2,195	2,218	206,123
Najran	1,669	924	2,593	4,086	1,294	2,445	3,739	1,236	726	1,962	12,380
Kingdom	744,421	225,359	969,780	104,487	52,967	127,532	180,499	67,844	18,867	86,711	**1,341,477**

* Northern region includes Tabuk, Al-Jauf, and AL-Qurayat

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spectively (Figure 3). The wheat production of 3.5 million tons in 1990 has far exceeded the predicted national demands of 1.175 million tons (MOP, 1990). This trend in wheat cultivation does not satisfy the planned national goals to diversify the agricultural production to meet the growing demands of basic food crops (MOP, 1990).

The distribution of agricultural areas indicate that 79% of the cultivated areas are located in four regions namely: Riyadh (from Al-Kharj to Wadi Ad-Dawsir), Qasseem, Jizan and Hail. The percentage of the agricultural areas in Riyadh, Qasseem, Najran and Hail were 34%, 22%, 15% and 7% of the total agricultural areas respectively (Figure 4). This is due to the availability of suitable soils, climate, groundwater and manpower. The distribution of the areas of crops varies between the regions. About 46%, 33% and 9% of the wheat areas were in Riyadh, Qasseem and Hail respectively; about 34%, 21% and 12% of the fodder crop areas were in Jizan, Riyadh and Makkah respectively; about 30%, 23%, 16%, 10%, 8% and 6% of the vegetable areas were in Riyadh, Makkah, Qasseem, Jizan, Eastern Region and Northern Region respectively; and about 31%, 15%, 10%, 10%, 10% and 9% of date palm areas were in Riyadh, Eastern Region, Hail, Qasseem, Medina, and Aseer regions respectively.

WATER RESOURCES FOR IRRIGATION IN SAUDI ARABIA

Surface Water

The low rainfall quantities in most of the Kingdom is expected to create limited surface runoff. The quantities of the annual runoff in the Kingdom is estimated to be about 2,230 million m^3 of which 1,450 million m^3 is produced in the western coastal parts of the Kingdom (Authman, 1983). The storage capacity of 187 constructed dams of different shapes and sizes is 475 million m^3. These dams were constructed for groundwater recharge and flood control purposes.

Groundwater

Geological and Hydrogeological studies showed that groundwater are stored in more than 20 layered principal and secondary aquifers of different geological ages (MAW, 1984). The Arabian Shelf includes the deep sedimentary aquifers which are formed mostly of limestone and sandstone that overlay the basement rock formation known as the Arabian Shield, and covers about two third of Saudi Arabia or 1.485 million km^2 (MAW, 1984). These aquifers crop out in the western parts of the Shelf and extend towards the eastern parts of the Kingdom with varying total thickness between few hundred to more than 5,000 meters (MAW, 1984). The major aquifers are: Saq, Wajid, Tabuk, Minjur, Dhruma, Biyadh, Wasia, Dammam, Umm Er Radhuma and Neogene. The secondary aquifers are: Al-Jauf, Al-Khuff, Al-Jilh, the upper Jurassic, Sakaka, the lower Cretaceous, Aruma, Basalts and Wadi Sediments. Apart from the last two, the groundwater resources stored in these aquifers are non-renewable. The groundwater quality varies between sites and among aquifers (Table 2). The isotopic analyses showed that the fossil groundwater in the above aquifers is 10,000-32,000 thousand years old (MAW, 1984). Large volumes of groundwater are stored in the sedimentary aquifers (KFUPM/RI, 1987). The estimated groundwater reserves to a depth of 300 meters below ground surface is about 1919 billion m^3 with a total annual recharge of 2,762 million m^3 based on several hydrogeological studies as given in Abdulrazzak, 1992, (Table 2). The renewable groundwater resources are stored mainly in the shallow alluvial aquifers and within Basalts which extends mostly in the southwestern parts of Saudi Arabia with varying thickness and width (MAW, 1990). These aquifers store about 84 billion m^3 with an average annual recharge of 1,196 million m^3 (BAAC, 1980).

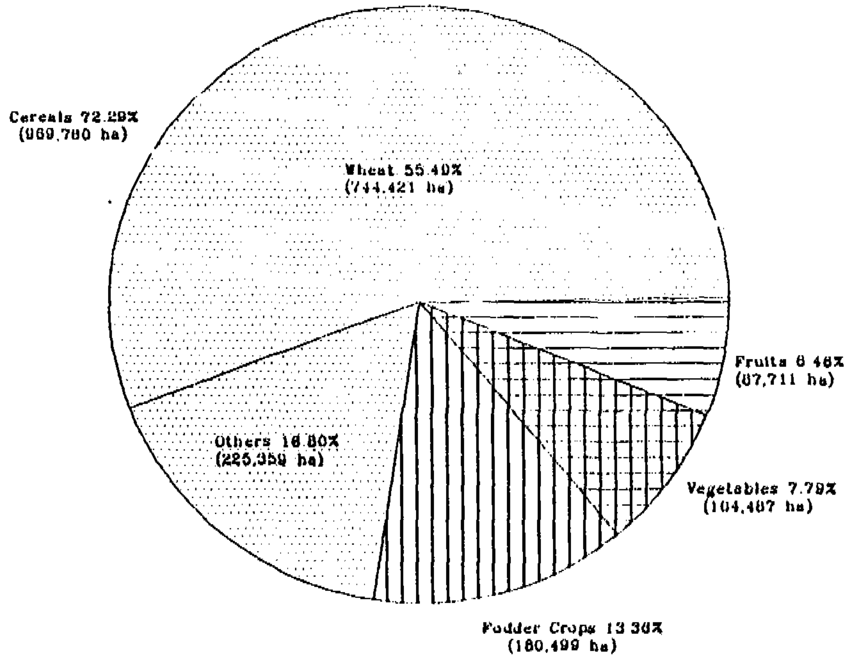

Figure 3   The areas of cultivated crops in different regions of Saudi Arabia in 1990.

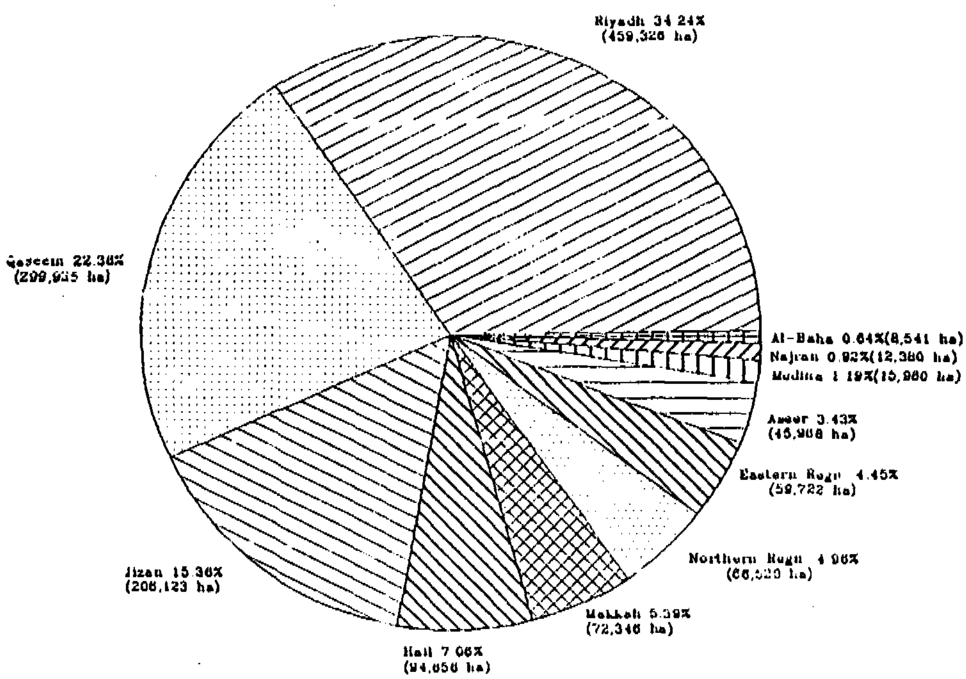

Figure 4   The agricultural areas in different regions of Saudi Arabia in 1990.

Table 2: The estimated groundwater reserves in Saudi Arabia to a depth of 300 meters below Ground level in million m^3.

Aquifer	Reserve (mm^3)	Recharge (mm^3)	Water quality ppm
Saq	277,000	310	300-3000
Tabuk	205,000	455	250-2500
Wajid	180.000	104	500-1200
Minjur-Dhruma	177.000	80	1100-20,000
Wasia-Biyadh	490,000	480	900-10,000
Um Er Radhuma	131,000	406	2000-5000
Dammam	25.000	200	2600-6000
Khuff & Tuwal	30,000	132	3800-6000
Aruma	71,000	80	1600-3000
Jauf & Sakaka	100,000	95	400-5000
Jilh	113,000	60	3800-500
Neogene	120,000	360	2400-4000
Total	1,919,000	2,762	

The total national groundwater reserves in the shallow and deep aquifers to a depth of 300m below ground surface is about 2003 billion m3. These volumes of renewable and nonrenewable groundwater resources represent a sustainable source for irrigation water in the Kingdom if properly managed.

IRRIGATION WATER DEMANDS

With the exception of the southwestern region, the Kingdom has arid and severely arid climates. The average annual rainfall ranges from 25 mm to 100 mm. The average annual evaporation range from 2500 mm to about 4500mm. With low precipitation and very high evaporation the irrigation water is required to satisfy more than 90% of the crop irrigation requirements (MAW, 1984). the rainfed agriculture represents about 70% of the total agricultural areas of Aseer and Al-Baha (personal experience estimation). Since the calculated irrigation requirements for different crops in the Kingdom ranges from about 700 to more than 2000 mm, and the average rainfall in the agricultural regions (with the exception of southwestern region) ranges from 25 to less than 150 mm, the rainfall contribution to the irrigation requirement of crops can be given a conservative average value of 5%.

The irrigation water demands for different types of crops were calculated for each region for the year 1990. This was based on the following parameters: a) the irrigation requirements per hectare of each cultivated crop type for each irrigation method in each region using irrigation water with an average salinity of 2,000 mg/l; and b) the area of each cultivated crop and the related irrigation method in each region.

The total irrigation requirements were highest for Riyadh, followed by Jizan and Qasseem, with values of 5.86, 3.73 and 3.23 billion m^3 respectively (Figure 5). The irrigation demands were highest for cereals followed by fodder crops and fruits, with values of 10.53, 5.20 and 2.71 billion m^3 respectively. The irrigation demands of wheat was 6.20 billion m^3 or 31% of the total national irrigation water requirements; and about 50% of irrigation water consumption by wheat was in Riyadh, and 40% was in Qasseem and Hail.

The distribution pattern of the agricultural areas in the Kingdom has resulted in concentrating the groundwater pumping in limited areas. It was observed that hundreds or thousands of production wells are clustered in small agricultural areas such as Al-Hassa, Al-Kharj and Al-Qaseem and Wadi Ad-Dawsir (Al-Kaltham and Al-Tokhais, 1986, BRGM, 1986; KFUPM, 1987; KFUPM, 1990; Al-Tokhais, 1992). The spatial distribution of these wells, and the pumping quantities and policies do not suit the hydraulic properties and the productivity of the local aquifers. The total number of drilled wells has increased from about 26,000 in 1982 to about 52,500 in 1990 (Al-Tokhais, 1992). The number of wells in Qasseem and Hail was about 15,000 in 1990. Excessive quantities of irrigation water was used in some farms, (Kamand, 1986; KFUPM, 1993; KFUPM/RI, 1989; KFUPM/RI, 1987; A-Muqrin, 1992; MOP, 1985, Badr, 1986; and Abdulaziz et. al., 1986).

In spite of the existence of large quantities of stored groundwater, the above improper practices of water use have caused large cones of depressions to develop, and led to unacceptable decline in groundwater levels and lower water quality in several areas (Abderrahman, 1990; BRGM, 1985; and KFUPM/RI, 1990). Table (3) shows the quantities of irrigation water consumption and the source aquifers in different regions of the Kingdom. The agricultural area in the Arabian Shelf is about 1.1 million hectares or 81% of the total cultivated areas in the Kingdom , and the rest is extended in the Arabian Shield. The irrigation water demands represent 92% of the total water demands in the Kingdom. Groundwater resources from the deep aquifers in the Shelf produce about 12.996 billion m^3 or about 70% of the irrigation demands, and 5.591 billion m^3 or 30% is supplied from shallow aquifers in the Arabian Shield. Given the reserve values of Table (2), and the water consumption values of Table (3), it is suggested that the Eastern and Northern regions do not anticipate significant regional declines in groundwater conditions except in some local areas of over pumping due to clustering of large number of wells in small areas such as Al-Hassa, and Tabuk. While, areas such as Jizan, Makkah, Qasseem and Hail will suffer from deterioration in groundwater conditions if the management of groundwater is not improved and the irrigation consumption is not reduced. In Riyadh area, groundwater problems will increase in local areas such as Al-Kharj and Wadi Ad-Dwasir if the present pumping rates are not lowered and Water utilization policies are not adjusted.

Tables (4) and (5) indicate that groundwater resources represent the major and potential water source in Saudi Arabia. About 94% of the irrigation demands are satisfied

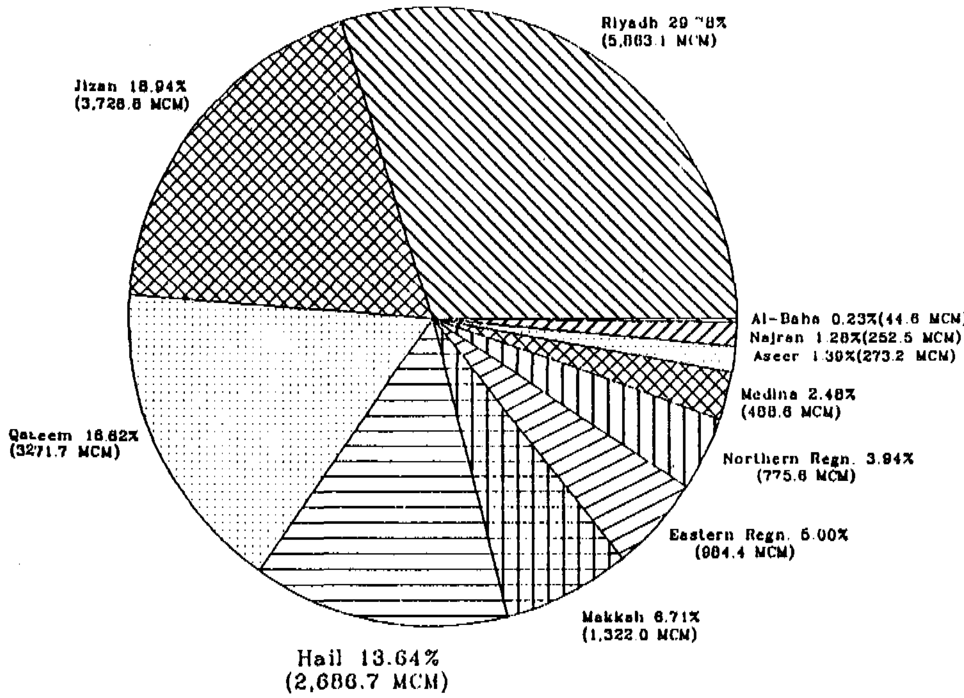

Figure 5 Water consumption of crops in different regions of Saudi Arabia in 1990 in million cubic meters (MCM).

Table 3. Source aquifers and irrigation water consumption in different agricultural regions of Saudi Arabia

Regions	Aquifers	Water Consumption. (MCM)
Eastern Regn.	UER, Dammam, Neogene	984.4
Riyadh	Biyadh, Wasia, Minjur, Dhruma, Wajid Upper Jursassic - Middle Cretaceous	5,863.1
Qaseem + Hail	Saq, Tabuk Shallow Alluvial aquifers, Jilh, Khuf	5,958.4
Noerthern Regn.	Saq, Tabuk Basaltic aquifers, Al-Jauf, Aruma, Sakaka	775.6
Madinah	Basaltic aquifers, Shallow Alluvial aquifers	488.6
Makkah	Shallow Alluvial aquifers, Basaltic aquifers	1,322.0
Aseer	Shallow Alluvial aquifers	273.2
Al-Baha	Shallow Alluvial aquifers	44.6
Jizan	Shallow Alluvial aquifers	3,728.8
Najran	Wajid Shallow Alluvial aquifers	252.5

from non-renewable groundwater resources from shallow and deep aquifers in the Arabian Shield and Arabian Shelf respectively. Consequently, Improvement of groundwater management in the Kingdom is essential for maintaining the long-term productivity and quality of the aquifers. This includes the adoption of effective approaches for irrigation demand reduction, and modification of the groundwater pumping policies in terms of timings and quantities to minimize the drawdowns and change in quality of groundwater in various regions of the Kingdom. Reduction of irrigation demands can be achieved by improving the irrigation efficiency especially the surface irrigation from the present average of 0.54 to 0.65, utilizing effective irrigation methods, and by the implementation of proper irrigation schedules for each type of crop according to the actual requirements. Improving the surface irrigation efficiency to 0.65 will result in saving 1.46 billion cubic meters or 7.4% of the total irrigation water consumption. But, it is important to recognize that it will be difficult to reduce the irrigation demands to 11.2 billion m^3 in the year 2000 as planned by Ministry of planning (MOP, 1990); (Table 6.) even with the implementation of all above measures.

Table 4: Water Resources in Saudi Arabia (million m^3)

surface water	2,230
groundwater resources	2,003,000(84,000 in Sh.Aq.)
groundwater recharge	3,860(1,196 to Sh.Aq.)
Desalination	795
Treated wastewater	217

Table 5: Water supply in Saudi Arabia (MOP, 1990) (in million m^3/yr)

water source	1990
treated wastewater effluents	110
desalination water	540
surface water & Shallow aquifers(Renewable water)	2100
groundwater nonrenewable	*18,591
total	21,341

* Authors' estimation

Table 6: The Growth of Water Demand in Saudi Arabia in Million m^3

Year	Domestic and Industrial	Agricultural	Total
1980	502*	1850*	2,352*
1990	1650*	19,691**	21,341*
2000	2900*	11,200*	14,100*

* MOP estimation
** Authors' estimation

THE IMPACT OF THE RECENT MODIFICATION OF PRICE SUPPORT TO WHEAT

In 1990, the total wheat area of 744,421 ha or 55% of the total agricultural area in the Kingdom, produced about 3.5 million tons. while the predicted national wheat demand was 1.175 million tons. This trend was pushing the country to be a producer of a single agricultural crop. It also does not meet the national objectives for diversification of the agricultural production to satisfy the growing demands for additional basic food items such as vegetables and fruits (MOP, 1990). Moreover, the irrigation water consumption of wheat was about 31% of the national irrigation water use; and most of that pumping was concentrated in Riyadh, Qasseem and Hail regions.

The recent modifications on the Government's price support to one quarter of the previous wheat production from the farmers has several positive and important goals. The first goal is to reduce the wheat production to the level of the annual consumption. The second goal is to encourage farmers to diversify their production to other needed types of crops for the Kingdom such as vegetables, fodder and fruits. The third important goal is to reduce the irrigation demands in heavy pumping areas, in order to conserve the long-term productivity and quality of groundwater resources in the aquifer systems in different regions of the Kingdom.

Assuming different scenarios for future cropping pattern in the Kingdom reveals several irrigation demand alternatives (Table 7). If 25% of the wheat area is cropped and the rest is left without cultivation, then the national irrigation demands will be reduced by 4.64 billion m3/year or 24%. Assuming that the cultivated area of vegetables (104,487 hectares) is doubled and cultivated using sprinkler irrigation, in addition to the 25% of the original wheat area, the additional water demands for vegetables will be 0.994 billion m3/year and the water savings will be 3.684 billion m3/year or 19% of the total irrigation water. If the alfalfa area (52,967 hectares) is doubled and cultivated in addition to the 25% of the original wheat area, the additional water demands for alfalfa will be 2.069 billion m3/year; and the water saving will be 2.573 billion m3/ year or 13%. If the Barley area (56,907 hectares) is doubled and cultivated in addition to the 25% of the original wheat area, the additional water demands will be 0.398 billion m3/year; and the water saving will be 4.244 billion m3/ year or 21.5%. If the alfalfa, vegetables and barley areas are doubled and cultivated in addition to the 25% of the original wheat area, the additional water

Table 7. National irrigation demands under different cultivation scenarios

scenarios	new area of wheat	additional cultivation area	additional water demand billion m^3/yr	irrigation demand saving billion m^3/yr	percentage saving (%)
I	25% of original wheat area	-	-	4.642	24
II	25% of original wheat area	double vegetables area	0.994	3.648	19
III	25% of original wheat area	double alfalfa area	2.069	2,573	13
IV	25% of original wheat area	double barley area	0.398	4.244	21.5
V	25% of original wheat area	double vegetables, alfalfa, and barley areas	3.461	1.181	6
VI	25% of original wheat area	50% increase of vegetables, alfalfa, and barley areas	1.731	2.912	15

demands will be 3.461 billion m3/year; and the water saving will be 1.181 billion m3/ year or 6%. If the areas of alfalfa, vegetables and barley are increased by 50%, and cultivated in addition to the 25% of the original wheat area, the additional water demands will be 1.594 billion m3/year; and the water saving will be 2.917 billion m3/ year or 15%.

The above scenarios indicate clearly that the reduction of the wheat area by 75% even with expansion of vegetable , barley, and alfalfa areas will result in saving significant volumes of the water consumption for irrigation. The impact of this reduction will be positive on the groundwater levels and quality in different wheat areas in the Kingdom especially in heavy pumping areas such as Qasseem, Kharj, and Wadi Ad-Dawasir. For example, the field measurements of groundwater levels in deep observation wells in a large irrigation scheme in the Eastern province have shown a recovery of about 20 to 30% of the recorded drawdowns in previous years after reduction of wheat area. But, this impact will be minimal in regions dominated by other crops such as Jizan which is dominated by fooder crops.

The above scenarios illustrate that modification of government's price support to wheat has far reaching consequences on the utilization of water resources and agricultural production in the Kingdom. These scenarios as well as many other scenarios should be analyzed in great detail. They further illustrate that there is a great need for a national agricultural plan to define the optimal selection of the types of crops and their related areas to be grown in each region of the Kingdom. The plan should consider all factors related to the availability and productivity of groundwater and its quality, soil type, climate, local agricultural practices, national needs, economic conditions and social impacts. To make the implementation of the plan beneficial to the management of groundwater, adoption of proper irrigation scheduling and effective irrigation methods are required. The water pumping policies from wells and the spacings between wells should be defined according to the hydraulic properties of the aquifers in each region. All above and other related information should be transmitted to the farmers through water extension offices in the agricultural regions especially in regions dominated by wheat.

SUMMARY AND CONCLUSIONS

The Kingdom of Saudi Arabia has managed, through government initiated programs, during less than fifteen years to convert large areas of desert lands into highly productive farms. With the government's price support policy to agricultural production, the infrastructure of modern irrigated agriculture was established, and selfsufficiency in production of strategic food crop such as wheat has been accomplished. The increase in cultivated areas, clustering of large number of wells in small areas and the excessive groundwater pumping for irrigation in these areas has resulted in unacceptable impacts on the groundwater conditions. Improvement of groundwater management and the adoption of effective measures for lowering the irrigation demands are critical for conserving the long-term productivity and quality of aquifer systems in the Kingdom. The new modification in the price support will help in reducing the wheat area, diversifying the agricultural production, and reducing the irrigation water consumption and groundwater conservation.

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MIDDLE EAST COOPERATION TO RIVER BASIN PLANS: AN EXAMPLE OF THE JORDAN AND YARMUK RIVERS

Peter J. Reynolds[1] and Abdullah M. Mohorjy[2]

ABSTRACT

The Current basic framework for allocation of Jordan river water is enshrined in the "Main Plan: 1953" and the "Johnston Plan: 1955" which were negotiated with the United Nations but never formally endorsed by the Governments concerned. After Israeli occupation of Palestine in 1967, no multi-national water projects on the Jordan river system could be promoted owing to political constraints with inter-state riparian questions. Israel has heavy dependence on the recharge areas in the Arab catchment which include the extensive aquifers underlying the West Bank. Thus, without resolution of these inter-state water resources problems, it is difficult without a compromise to achieve a peace settlement.

SOMMAIRE

Le cadre général actuel de l'attribution des eaux du fleuve Jourdain a été consacré par le "Plan général de 1953" et le "Plan Johnston de 1955", négociés dans le cadre des Nations Unies mais jamais formellement approuvés par les gouvernements intéressés. Suite à l'occupation de la Palestine par Israël en 1967, aucun projet hydraulique multinational sur le bassin du Jourdain n'a pu être envisagé du fait des contraintes politiques entre les états riverains. Israël dépend fortement de zones d'alimentation situées dans l'aire de captage arabe qui comprend les importantes nappes aquifères su-dessous de la rive ouest. En conséquence, faute d'une résolution de ces problèmes de ressources en eau, il est difficile d'aboutir à un accord de paix sans un compromis à ce sujet.

INTRODUCTION

Countries usually consider water as a national resource at their sovereign disposal. Yet, the sources of water, the catchment area, river basin boundaries and river channels, often transcend political borders. In the Middle East, as in similar arid or semi-arid areas where rainfall is sparse and water the mainstay for survival, disputes over water have repeatedly become a serious focus of political and military struggles. Although relatively small, the Jordan River Basin epitomizes many of the problems of water resource management which occur in other parts of the world on a broader but equally complex scale. The constraints of a highly intensive water management system, and the necessity for an optimal utilization of all natural resources, are

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compounded in the Jordan River Basin by the particular geo-political structure of the region to which Israel is bound by the heritage of its past and by recent history.

Current professional literature offers ample descriptive and analytical texts on the subject of the Jordan River. The main technical and developmental aspects which confronted the planners until the mid sixties were described by Stevens, and Garbell. The political dynamics of the region, which accompanied and often swamped the water issue, were reviewed by Ionides, Doherty, Laqueur, Hammond and Alexander, Kedouri, Udovitch, Pold, and others. Specific development themes were discussed by Wiener, and several other writers.

Earlier studies abound on the geo- and hydro-graphical nature of the Jordan Valley and many a visionary and planner was intrigued by the inherent potential for its development. Among the first to convey these ideas into tangible engineering concepts, was Lowdermilk who realized the opportunity to apply the recently acquired experience of the Tennessee Valley Authority to the Jordan Valley. His inspiring work was followed by detailed proposals by Hays and technical reports and projects drawn up the Chas. T. Main Inc., J.S. Cotton, and Tahal, Israel's National Water Planning Organization.

The shifting of national borders and truce lines following the 1967 war relegated the water issue to second place, even though the political situation remains precarious. On the other hand it has become possible, for the first time after decades of turbulence, to evaluate certain aspects of the region's water resources by looking at them within the natural limits of the catchment area, regardless of jurisdictional divisions.

This paper examines the issues of water resource management in the Northern Jordan Valley with a view to obtain a better understanding of the problems which were stirred up by the initiatives for the comprehensive development of that region.

The argument put forward is, that the existing water resources -- if rationally exploited and managed -- are adequate for meeting the bulk of current demand for irrigation, industry and domestic uses of all co-riparian states in the catchment area. Matters of major concern, however, are the imminent environmental and ecological issues which may compromise the operation of any intensive multi-purpose water system.

THE PHYSICAL SETTING

The Jordan-Kinneret Basin is an elongated valley, 100 km in length, and between 20 to 40 km in width, situated between Latitude 32°48 - 33°29 North and Longitude 35°35 -35°53 East. It covers an area of 2730 km^2 and drains the Northern Jordan Rift Valley.

Its general outline is determined by the tectonic features of the Rift which are geologically young; one of the last phases of which caused the formation of Lake Kinneret (also known as

Lake Tiberias or the Sea of Galilee) some 18000 years ago. Elevations range from 2814 m at the Mount Hermon summit to minus 210 m at lake level.

The natural system of the Jordan River and of Lake Kinneret, which acts as an intermediate lake, drains toward the Dead Sea at 298 m below sea level. Physiographically the basin is characterized at the North and on both flanks by mountainous ranges, and a central part covered by alluvial plains. The mean annual precipitation for the Lake Kinneret watershed is 790 mm, varying from 1600 mm in the upper area, to 400 mm in the South over the lake area.

The Jordan River supplies an average of 650 million cubic meters of water per year, or about 40% of Israel's total water budget. Its main sources are the Hermon karstic springs and the flow is continuous throughout the year, averaging from 18 million cubic metes in August to 75 million cubic meters in February. Stormflows occur as a result of heavy precipitation in the northern part of the catchment area and the Hula Valley. Flooding takes place when precipitation reaches an intensity of 50 mm per day in the Hula Valley. The mean annual water flow entering Lake Kinneret is 521 million cubic meters for the 22 year period 1959/60-1980/81. This figure is the net flow, after deducting an estimated quantity of 110 million cubic meters consumes in the upper basin.

REGIONAL WATER DEVELOPMENT SCHEMES

The reclamation project proposed by Lowdermilk was probably one of the first comprehensive river basin development schemes on a regional and multi-national basis. Patterned along the lines of the Tennessee Valley Authority, it was tentatively entitled "The Jordan Authority" and, similar to the TVA, it encompassed the development of the agriculture, power and manufacturing for the socio-economic progress of the people living in the region.

Lowdermilk envisaged the diversion of sweet water from the Upper Jordan and the Yarmuk River -- a major tributary entering the Jordan River south of Lake Kinneret -- into open canals or closed conduits running around the slopes of the Jordan Valley. He also pointed out the difference in altitudes between the Jordan Valley and the Mediterranean Sea which offered a splendid opportunity for a combined power and irrigation scheme (Fig. 1).

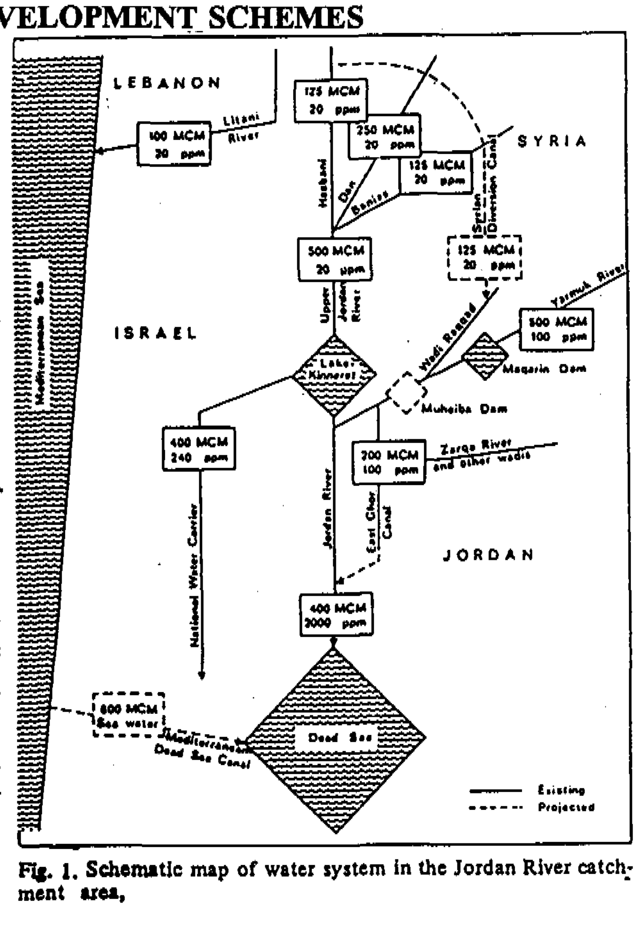

Fig. 1. Schematic map of water system in the Jordan River catchment area,

Several of Lowdermilk's ideas were later incorporated into a detailed technical report prepared by the Commission on Palestine Surveys, which foresaw the utilization of water resources on a regional scale, including the use of groundwater, interception of storm run-offs, drainage of the Hula Lake and swamps, and irrigation of the lower Jordan Valley. The commission suggested that all head-streams of the Jordan River be collected by a countrywide water carrier and diverted close to their sources, thus enabling flow by gravitation with a minimum amount of pumping. Headwaters from the Litani River -- which flows in Lebanon, north of the Jordan River -- was to be fed into the Hula Valley, thereby augmenting the quantity of water for irrigation and hydroelectric power. The Yarmuk River was to be diverted to Lake Kinneret. Ultimately a seawater canal from the Mediterranean to the Dead Sea was to be built in order to replace the flow of the Jordan River and for generating additional hydroelectric power. These proposals, as well as other projects embodying similar concepts, were the forerunners of a unified plan for the integrated development of water resources in the Jordan Valley prepared in 1953 at the request of the United Nations. This plan, also known as the Johnston Plan, became the basis for extensive negotiations conducted between several Arab states and Israel by E.A. Johnston who came to the Middle East as a special envoy from President Eisenhower.

Various components of the original scheme such as the use of water from the Litani River, or the Mediterranean-Dead Sea hydroelectric project, were subsequently discarded for reasons of feasibility or due to opposition from the Arab States. The final plan regarded Israel, Jordan and Syria as co-riparian states to the Jordan and Yarmuk Rivers, while Lebanon was recognized as a riparian to the Jordan Basin. The Johnston Plan took into account the development schemes prepared separately by Israel and Jordan, and made provisions for supplying as far as possible the full quota of water stipulated by the governments for the irrigation of their farmlands. Nevertheless, although the Johnston Plan was endorsed by experts of both sides as a logical and equitable approach to the development of the joint river system, it was rejected by the Arab League Council on political grounds.

Israel and Jordan proceeded thereupon to work individually on their modified water development schemes: namely, the Israeli National Water Carrier Project, and the Jordanian Great Yarmuk Project: the latter in cooperation with Syria. Both projects were basically in line with the Johnston Plan and were financially supported by the USA. The main features of the Israeli and Jordanian schemes can be described as follows:

Israel: The National Water Carrier Project:

The National Water Carrier extends from the Upper Jordan Basin through nearly the full length of the country, interconnecting with existing branch networks and local drainage, storage and irrigation systems. Its design derives from the marked difference in rainfall between the northern and southern parts of the country, seasonal variations, and regional drought situations. The Water Carrier was planned to draw 320 million cubic meters of water annually from Lake Kinneret and export it out of the Jordan watershed to the southwestern part of Israel. This amount represents about 60% of the long-term inflow into Lake Kinneret, with the balance destined to meet the demand around the lake and in the Lower Jordan and Beth Shean Valley.

and to cover evaporation losses from the lake surface. A special characteristic of the system is the need to raise the water from Lake Kinneret -- lying at 210 m below sea level -- to lands at elevations above sea level.

In order to overcome these shortcomings and to coordinate the water supply with other existing systems, a 200 km-long trunk line was built to carry water from the Upper Jordan Basin to the South. The carrier comprises a complex of canals, pipelines, and tunnels, with a capacity conforming to the water allocation of the Johnston Unified Water Plan.

Water abstraction from Lake Kinneret has risen steadily from 195 million cubic meters in 1965 -- the first year of full operation -- to an average of about 450 million cubic meters for the period 1980-1990. Hydrological studies have indicated the need for hold-over storage capacity of some 500 million cubic meters, excluding the local consumption of 130 million cubic meters. Such live storage amounts to one eighth of the lake water volume and can be obtained by operating between a maximum of 208.9 m and a minimum of 211.8 m below sea level. A recession of shore structures and might draw opposition from shore inhabitants and diverse users of the lake.

Originally the National Water Carrier was planned to withdraw water directly from the Jordan River at Benot Yaakov Bridge, situated between Lake Hula and Lake Kinneret. This location above sea level would have enabled gravitational flow and the descent of excess winter flows to Lake Kinneret for storage and generation of electric power. In 1953, however, Benot Yaakov was within the demilitarized zone between Israel and Syria, and when construction on the intake structures began, Syria protested to the United Nations. As a result work was suspended pending the outcome of deliberations in the Security Council. Israel embarked consequently on building, at Eshed Kinrot on Lake Kinneret, an alternate intake which is now in operation.

Jordan: The Great Yarmuk Project:

The Jordanian project was planned to provide in its ultimate phase about 700 million cubic meters of water a year for irrigation and hydroelectric power, mainly from the Yarmuk River and partly from the Lower Jordan River Basin and several small tributaries. The Muzeirib phase was designed to withdraw 70 million cubic meters of the Yarmuk headwaters for the irrigation of an arid farming region in southern Syria. The main part of the project was the construction of the East Ghor Canal for the irrigation of traditional farming areas and formerly undeveloped arable lands in the Jordan Valley between the Yarmuk and Zarqa Rivers. A 900 meter-long tunnel was built to conduct the water from the Yarmuk headstream to the 70 km-long East Ghor Canal running down to the south, roughly parallel to the Jordan River. The amounts of water carried by this canal were augmented by the damming of several small wadis (side streams) in the area. The completion of this part of the Yarmuk Project coincided with the inauguration of Israel's National Water Carrier in 1964. By 1979 the East Ghor Canal had already reached a length of 100 km and a further extension was planned that would bring the canal near to the Dead Sea.

In order to impound the winter flows of the Yarmuk Basin, two dams were projected: the Maqarin Dam, about 35 km east of the Yarmuk-Jordan confluence, and the Haled Dam, some 20 km east of the same confluence. Neither location, however, suited Arab plans for diverting part of the Jordan River headwaters to the Yarmuk River (see below). An alternate downstream location was therefore chosen at Muheiba, near Hamat Gader, about 10 km east of the Yarmuk-Jordan confluence. Construction of this dam was started in 1966 but interrupted by the 1967 war. It was later continued at the Maqarin site and renamed Al Wuheda in 1957, then abandoned.

THE ARAB DIVERSION PLANS

Although the Johnston Plan was rejected by the Arab States, it was adopted in practice by Israel and Jordan. Both countries acquiesced, though not formally, with the water allotment laid down in the Johnston Plan. Israel proceeded with the building of the National Water Carrier with some modifications, while Jordan carried out its own irrigation development program of the East Ghor Canal.

In January 1964, shortly before Israel started to pump water from Lake Kinneret into the National Carrier System, the Arab League decided to divert part of the Jordan River headwaters, so as to prevent their flowing into Israeli territory. (There is a certain parallel her with the US/Canada negotiations over the Columbia River, particularly the negotiations and developments of the late 1950s and early 1960s which led up to the 1964 Treaty. At one point British Columbia actually threatened to divert the upper Columbia into the Fraser. The plan purported to divert the Hasbani River in Lebanon to the Litani River by way of a tunnel and to conduct the flow of the Wazani and Banias springs to the Yarmuk River by means of a 70 km-long canal which would dump the water into the Raqqad River, a tributary of the Yarmuk (Fig. 1). The Banias-Yarmuk canal was to be constructed against the rising slopes of the Golan Heights at an elevation of 350 to 300 m above sea level, in some places within a short distance of the Israeli border.

The planned carrying capacity of the canal was to be 17 million cubic meters per month, but since such flows occur only between December and April, the annual quantity of diverted water would be around 125 million cubic meters, including the Hasbani waters destined for use in Lebanon and Syria. When fully operative the diversion canal would abstract a quantity of water equal to about one-third of the installed capacity of Israel's Water Carrier. Furthermore, the partial removal of saltless headwaters would increase the salinity of Lake Kinneret by about 60 parts per million.

An appraisal of the potential applications of the diverted water in the three Arab countries involved in the scheme indicated only marginal returns. Moreover, the execution of the plan appeared highly unrealistic from either the economical or engineering point of view, mainly because of the rugged terrain along the canal's trajectory.

The intensification of the Arab-Israeli conflict which led to a gradual escalation of border incidents and erupted into full-scale war in 1967 put an end to the diversion project. The consequent changes in the geo-political space containing the region's water resources neutralized for the time being the Jordan headwaters as a central subject of dispute.

ISRAELI WATER DEVELOPMENT SCHEMES IN THE JORDAN BASIN

In the aftermath of the 1967 war, development was continued in two areas: the Hula Valley and the Golan Heights. In the Hula Valley drainage and canalization work (formerly contested by Syria) could be carried out and was concluded in 1971. The main purpose was to reduce flooding in the Hula Valley by lowering the water level of the Jordan River to enable faster drainage of storm run-off. Since the completion of this work no flooding has been recorded in the Hula Valley.

In the Golan Heights a large-scale agricultural development program was initiated, envisaging the irrigation of 9000 hectares of crops by means of a yearly water allocation of 54 million cubic meters. Before 1967 there was hardly any irrigated land in this area, as can be deduced from the markedly low water consumption -- about 1 to 2 million cubic meters per year -- for livestock rearing and domestic use. By 1980 already about 22 million cubic meters of water were provided for the irrigation of some 6500 hectares, in the Golan Heights.

The manifold increase in water supply to the Golan Heights was made possible by developing local resources and by drawing water from Lake Kinneret. The development of local water resources comprised the construction of dams for impounding winter storm run-off and drilling for groundwater. Sixteen dams with a total storage capacity of 10 million cubic meters were planned and in part are already in operation. Tapped groundwater and local springs further increased the water supply by several million cubic meters a year. In the southern Golan -- an area devoid of water resources, but with the major concentration of arable land -- water is pumped from Lake Kinneret.

Most of the water available on the Golan Heights -- except minor quantities in the eastern part which would normally drain into the Yarmuk basin -- are actually part of the Jordan-Kinneret watershed. In other words, the agricultural development of the Golan Heights draws mainly on the water resources of the Upper Jordan. Yet, in spite of the substantial amounts of water withdrawn from the country's main supply, the efficiency of the system has not been impaired. Even the future utilization of 6 to 7 percent of the Jordan basin's total water yield is not expected to cause major problems or shortages.

To date Israel's Water System has been able to accommodate, within bounds, most national requirements for agriculture, industry, and domestic needs and is expected to be capable of absorbing fluctuations resulting from an erratic climate and a growing economy. Much of this has been achieved through rationalization, particularly in agriculture, with the introduction of new technologies such as drip and trickle irrigation. Planners are confident that current reserves and seasonal replenishment are adequate for meeting the bulk of the demand for which the system was designed. Notwithstanding, future population growth and the expansion of farming may require the development of new or non-conventional sources of water in the 1990s.

ECOLOGICAL AND ENVIRONMENTAL CONSIDERATIONS

The operation of an integrated and centrally-controlled water system has so far afforded considerable flexibility and regulative capacity for meeting fluctuating demands and varying situations. However, when used to the limits of its capacity, such a system (functioning practically as a closed system) must depend increasingly on a delicate balance in terms of quantity and quality.

Salinity has probably been the most complex problem encountered during the various stages of the project. Since the Yarmuk River was diverted (contrary to earlier plans) directly to the East Ghor Canal instead of first flowing into Lake Kinneret, its possible diluting effect was lost.

At present the salinity of Lake Kinneret is approximately 240 parts per million, compared with 20 parts per million at the Jordan point of entrance to the lake. Although a salinity of 240 parts per million can be tolerated for some agricultural uses, it is considered high for the irrigation of citrus groves which produce one of the country's major export crops. The diversion of saline springs from the shores of Lake Kinneret and abundant rains in the year 1970's, and 80'0 have helped to lower the chlorine content of the stored water which is expected to continue stable at present levels. On the other hand, a gradual deterioration of water quality has been noted in recent years along the Upper Jordan River, expressed mainly in the form of increased pollution.

Also, as a result of the draining of the Hula Valley and the growing use of fertilizers, more nutrients, especially phosphates and nitrates, are reaching Lake Kinneret. Persistent pesticides flushed into the Lake constitute another health hazard, either directly when used as drinking water, or indirectly through the contamination of fishlife.

The growing urbanization in the catchment area and around the distribution network of the National Water Carrier is particularly critical. The Carrier was planned to conduct water of potable quality in order to obviate the need for an additional distribution network. But, due to the geographical compactness of the watershed, some quantities of untreated sewage from uncontrolled sources may occasionally reach the lake without any natural clearing processes. Not all localities in the catchment area possess effective sewage treatment and disposal facilities which usually entail substantial outlays for plants and installations. Even so, treatment plants are subject to disruptions for repair or maintenance, as already proved in the past, and latent health risks may consequently become critical when contaminated water is pumped into the Carrier's distribution network.

Another problem is the rapidly expanding role of the Upper Jordan Basin and Lake Kinneret as an inland recreation area. The Israeli withdrawal from Siani following the Peace Treaty with Egypt and evacuation of numerous beach resorts and recreational facilities along the Red Sea cost has already begun to attract large numbers of vacationers to the northern riverine region and lake shores. The environmental impact of recreational activities is expected to compound the problems of water quality produced by agricultural and urban effluents. As the system approaches the physical limits of water supply, it becomes even more difficult to alleviate pollution by means of dilution. Appropriate devices and planning measures must be elaborated, therefore, to enhance the existing system in harmony with the environment. Such measures will require among other things the cultivating of administrative capacity and improved management techniques.

Until now the two main water systems in the catchment area, that of Israel and of Jordan, have operated as separate entities. However, mounting challenges of environmental and ecological problems, the need to preserve natural and historical landscapes, and the emergence of non-conventional approaches and new development projects, may dictate an increasing degree of coordination among the riparian states of the Jordan River in the foreseeable future.

SUMMARY AND CONCLUSIONS

While water continues as a vital commodity in the Jordan River Basin, the argument of water scarcity as grounds for all-out conflict is refuted by the fact that it was possible to withdraw substantial quantities from the Kinneret reservoir for irrigation in the Golan Heights without impairing the functioning of the system or creating major shortages. In its general lines the Johnston Plan proved to be workable solution and in practice was adhered to by the Israeli National Water Carrier and the Jordanian-Syrian Yarmuk Project.

In the long run, population growth and agricultural development may require new and non-conventional sources of water for the region. At the same time it seems that quality rather than quantity will remain the overriding criterion in the region's water resource management.

The implications of a closed and intensively-used water system can already be noticed in several areas. Beside salinity -- still one of the major concerns -- there is the problem of a gradual deterioration of water quality, expressed in higher rates of pollution along the Upper Jordan River. Since the National Water Carrier was planned to conduct potable water, health hazards penetrating the system may become critical forthwith. The draining of the Hula Valley has also increased the flow of nutrients to Lake Kinneret, while the flushing of persistent pesticides into the system's main reservoir constitutes another health risk through the contamination of drinking water and fishlife.

From an environmental standpoint the growing urbanization in the catchment area and the addition of untreated sewage from uncontrolled sources is a particularly critical issue. The growing importance of the Upper Jordan Basin and Lake Kinneret as inland recreation areas, following the Israeli withdrawal from Sinai with its numerous Red Sea beach resorts, adds yet another facet to the pollution problems already caused by agricultural and urban effluents. Last but not least are the changes wrought by the retention of water which may affect both the natural and historical landscapes for which the Jordan River is famous. Although pollution can be alleviated by dilution, it is clear that within the given limits of the Jordan River Basin sheer quantity cannot replace the need for rationalization and meticulous planning for meeting future demands. Evidently the conflict over water in the Jordan Basin stems to a considerable extent from man's interference with Nature's delicate ecological equilibrium. Further demographic growth and economic development in the region, and the attendant intensification of water uses, will warrant a growing degree of coordination among the co-riparian states in the not too distant future.

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NON-CONVENTIONAL WATER RESOURCES DEVELOPMENT ALTERNATIVES
To Satisfy the Water Demand in the 21st Century

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ABSTRACT

Many countries in the Middle East will over commit or deplete virtually all of their renewable sources of fresh water by the end of this century, if current patterns of consumption are not quickly or radically altered. In these circumstances, Israel, PLO/Palestine and Jordan unquestionably hold the greatest potential for either conflict or compromise.

Political feasibility as well as technical and economic feasibility of the hydro-powered seawater reverse osmosis (RO) desalination, including two hybrid pumped-storage type co-generation schemes in the Dead Sea and Aqaba regional development plans are examined in this study, taking into account the water politics and unlimited source of seawater which has not yet been taped except in the oil rich Gulf states. Owing to substantial reduction in the operating cost as energy consumption to retrieve off-peak electricity, the unit water cost of the hybrid co-generation scheme is preliminarily estimated to be US\$0.68/m^3, which is less than 50% compared with US\$1.6/m^3 of the traditional RO.

Of course, water conservation is an essential issue of water management, while non-conventional alternatives including desalination and reuse of the treated waste water with membrane separation technology are increasingly important to supply fresh water in the arid regions in a framework of water for peace.

SOMMAIRE

Un bon nombre de pays en Moyen-Orient exploiteront excessivement et épuiseront pratiquement toutes leurs ressources renouvelables en eau fraîche à la fin de ce siècle, si les modes de consommation actuels ne sont pas modifiés rapidement et d'une façon radicale. Dans ces circonstances, il existe sans doute un grand potentiel de conflit ou de compromis entre l'Israël, la Palestine/OLP et la Jordanie.

La viabilité du dessalement de l'eau de mer par la méthode d'osmose inverse (OI) au moyen de l'hydroélectricité, ainsi que les deux usines de co-production hybride par pompage installées dans le cadre des projets de développement régional de la Mer Morte et d'Aqaba, sont examinées sur le plan politique aussi bien que sur le plan technique et économique dans cette étude. L'étude tient compte aussi de la politique de l'eau et la source inépuisable de l'eau de mer qui reste encore non exploitée, sauf dans les états riches en pétrole du Golfe. Grâce à la réduction remarquable des frais d'exploitation, qui résulte de la consommation d'électricité hors pointe, le prix unitaire de l'eau produite par les usines de co-production hybride est évalué préliminairement à 0,68 \$EU par m^3, ce qui représente moins de 50% du prix de 1,6 \$EU par m^3 d'eau produite par la méthode d'OI traditionnelle.

Naturellement, la conservation de l'eau est un élément essentiel à prendre en considération dans la gestion de l'eau alors que les méthodes non conventionnelles de dessalement et de réutilisation des eaux usées, traitées par la technique de séparation par membrane, sont devenues de plus en plus nécessaires à l'alimentation en eau fraîche des régions arides, dans le cadre de "l'eau pour la paix".

1. INTRODUCTION

Limitations on water, one of scarcest resources in arid region, are likely to have a significant impact on the economic development of all countries of the Middle East. Middle East water resources issues in the aftermath of the Persian Gulf war are also likely to have a significant impact on the future political framework. The scarcity and the high cost of its development have long been recognized in arid regions, especially in the Arabian Gulf countries where neither surface water nor renewable fresh groundwater are available. The demand for water, however, to serve expanding third world populations continues to increase, while fresh water supplies are finite, and it is becoming more and more difficult to develop them on a renewable basis. Almost all fresh and renewable waters such as river streams, lake water, and groundwater, which are termed "conventional water " or "traditional water", have already been exploited or are going to be fully developed in the countries of Middle East and North Africa by the end of this century.

Desalination is a key application of non-conventional water resources development. The ocean holds $1{,}338 \times 10^6 km^3$ of seawater, which accounts for 96.5 % of the total water reserves of the earth of $1{,}386 \times 10^6 km^3$ has not been tapped except minor use in the oil rich Gulf states. Not only the desalination of saline water but also the reclamation of treated waste water by using the membrane separation technology, will play important role in the water resources planning to satisfy the water demand and environment management in the next decade as 21st century.

This study attempt to evaluate some new non-conventional approaches to water resources planning which need to be taken into account in building the new peace of the Middle East. These new approach offer the opportunity to introduce new applications of well-tried technology to solve long-standing water problems which are at the center of many of the potential source of conflict.

As water shortages occur and full utilization is reached, policies tend to be framed more and more in zero-sum terms, adding to the probability of discord and it would seem to be unavoidable that the severity of Middle Eastern water problems will continue to increase significantly. By the end of the 1990s, Israel, Jordan and the West Bank or Palestine will have lost virtually all of their renewable sources of fresh water if current patterns of consumption are not quickly and radically altered. In these circumstances, the Jordan River system, which includes the Al-Wuheda dam scheme on a major tributary of the Yarmouk river, unquestionably holds the greatest potential for conflict. (see Figure 1)

Techno-political water resources development alternatives and their feasibility are examined to evaluate the priority in those proposed water resources and energy development projects in Israel , Palestine, and Jordan, taking into account the recent Middle East peace settlement in the September 1993 (Israel/PLO 1993).

Sustainable yield of renewable fresh waters in Israel is $1{,}500 \times 10^6 m^3$ per annum. Israel had already exceeded this level by the early 1970s, and had to cut 29% in its national water supply from $1{,}987 \times 10^6 m^3$ in 1987 to $1{,}420 \times 10^6 m^3$ in 1991 without loosing net agricultural product and economic growth. Water savings in the agricultural sector have been 40% from $1434 \times 10^6 m^3$ in 1986 to $875 \times 10^6 m^3$ in 1991(ICBS1992).

Apart from heavy financial and political investment in the new settlements on the West Bank, Israel is being dependent on the West Bank for some $430 \times 10^6 m^3$ per annum of its water supply out of a total $1{,}420 \times 10^6 m^3$, which accounts for 30% of the annual water potential. Israeli heavy dependence on the fresh renewable water resources in the occupied Golan Heights also amounts to $305 \times 10^6 m^3$ per annum, which accounts for 90% of the total potential yield of $330 \times 10^6 m^3$ (Zarour 1993).

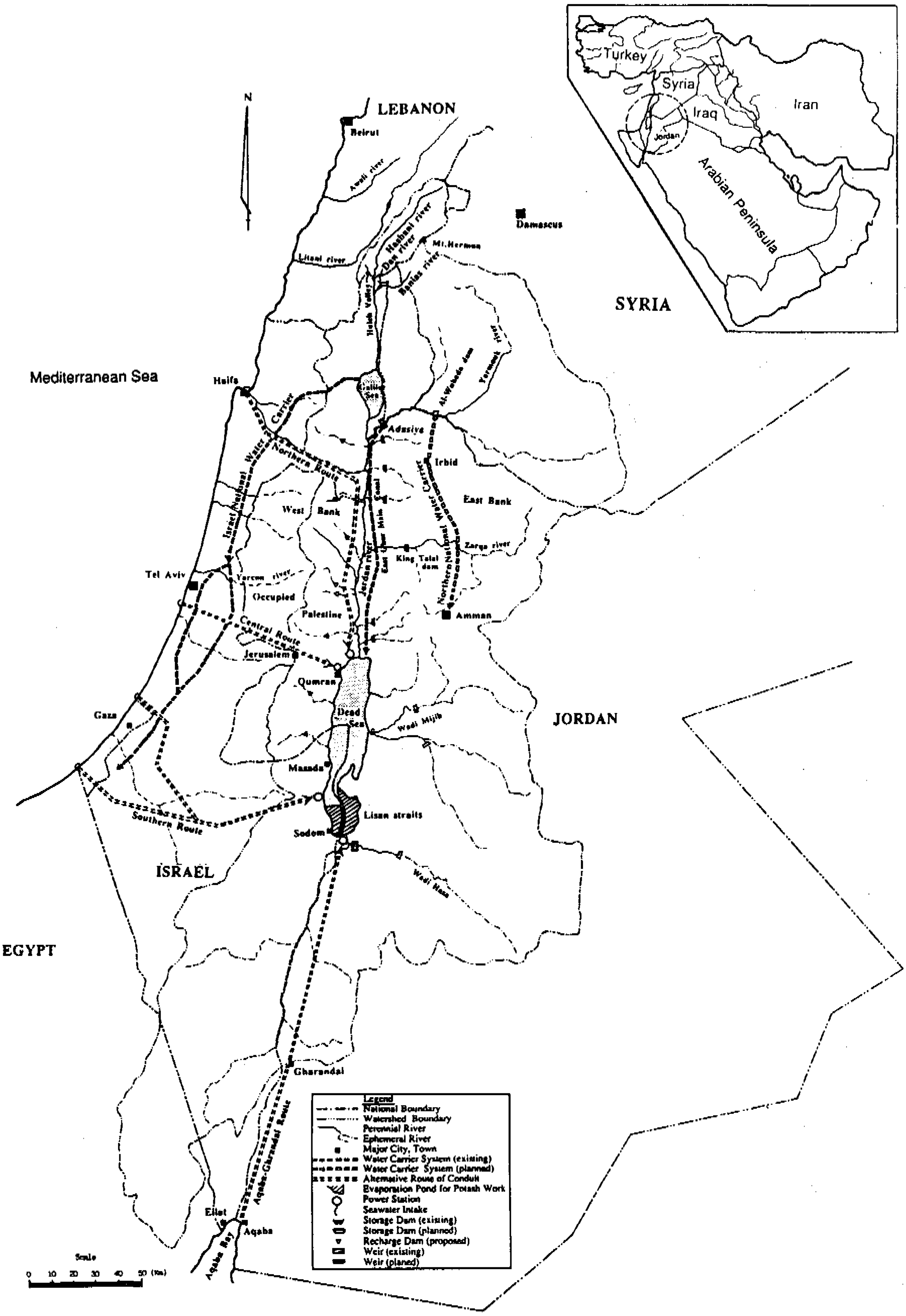

Figure 1. Water resources development project in the Jordan river system

Groundwater is the main source of water supply in the West Bank, of which the potential is estimated to be $600x10^6m^3$ per annum (Benvenist 1988). Israel withdraws $430x10^6m^3$ of fresh groundwater, which accounts for 73.5% of the total pumping of $585x10^6m^3$ in the West Bank. While, the Gaza strip consumes only $105x10^6m^3$, of which the source of groundwater has been seriously contaminated by seawater intrusion owing to heavy pumping exceeding the sustainable yield (Zarour 1993)..

Thus, Israeli dependence on the water source in the occupied Palestine including Golan Heights and West Bank amounts to $735x10^6m^3$, which accounts for 52 % of the total water consumption of $1,420x10^6m^3$ in 1991. This would be less critical if Israel was not already over-exploiting its renewable water potential. Since 1982 Israel's national water company MEKOROT has been integrating the West Bank and Gaza supplies into the Israeli network. It seems clear that control of these sources will not be surrendered until alternative resources have been served or cutting supply by water conservation. The water resources of the West Bank being diverted into Israel, account for 73.5 % of the West Bank's water resources.

Jordan will also have exhausted its renewable fresh water resources very soon, except for river flow of $78x10^6m^3$ ($37x10^6m^3$ of flood flows and $41x10^6m^3$ base flow) in wadi Mujib and flood flows of $168x10^6m^3$ in the Yarmouk river (World Bank 1988). These two are only major tributaries of the Jordan river system which have not been fully developed. The Wadi Mujib, which is the third largest tributary flowing into the Dead Sea in Jordan, has no inter-state riparian complications such as the Yarmouk. The current question on sustainable water development in Jordan is whether it can afford to continue to develop fossil groundwater in the deep sandstone aquifers such as Disi, and if so then "for what" ? and "for ever"? or "how long"?.

Energy issues like water are critical matters in the development of non-oil producing countries like Israel, Palestine and Jordan. These countries are the major riparians of the Jordan river system, and all have increasing demand for desalination and the reuse of treated waste water which will consume substantial quantity of energy or electricity.

The current energy source of in the region is heavily dependent on crude oil , gas and coal to generate electricity. Many countries such as Israel and Egypt are planning to introduce nuclear power plant to replace the old steam power plant. A significant deficit in peak power supply has been a long standing problems, while substantial off-peak electricity is being wasted in many developing countries. Although international networking of the electric supply is being discussed between adjoining states, no alternatives have been suggested other than building a new pumped-storage unit and/or gas turbine generating units.

The energy supply is closely related to desalination and reuse of treated waste water which consumes substantial electricity for treatment. Taking into account the recent advances in desalination, planning to introduce large scale seawater desalination by the year 2000. Although this is likely to be dependent on low energy types of reverse osmosis, the energy cost will still be 50-60% of the total (Murakami 1991). Consequently the potential use of the off-peak electricity will be a key element in minimizing the cost of water management and operation.

2. TECHNO-POLITICAL DEVELOPMENT ALTERNATIVES

After exploiting all of the renewable fresh water resources within their national boundaries, Israel, Palestine and Jordan have no choice except to develop transboundary waters and/or non-conventional waters. Water conservation is an important and essential issue in the water management, but development of non-conventional water alternatives is becoming imperative to supply fresh portable water to the growing population in the Middle East and within the framework of a water master plan for peace.

2.1 Project Feasibility and Techno-political Priority in the Middle East Water Perspectives

Any water project whether conventional or non-conventional in the Middle East will have to be reviewed for;

1) Technical and environmental feasibility
2) Economic and financial feasibility
3) Social and political feasibility

Project priority among the techno-political alternatives will be evaluated by taking into account the project time schedule priorities such as 1) short-term or emergency, 2) mid-term, and 3) long-term as shown below;

Year	*1995 2000 2005 2010 2015*
Short-term	---== == ===+++++++
Mid-term (1)	---------------------=======
Mid-term (2)	------------------=======+++++++
Long-term	----------------------------------== =============+++

where, a) -: study, political negotiation and development, b) =: project implementation , and c) +: supplemental implementation, if any.

Following priorities are proposed on the assumption that equal weight will be given to each feasibility element. Location of the proposed projects are shown in the map of Figures 1 and 2.

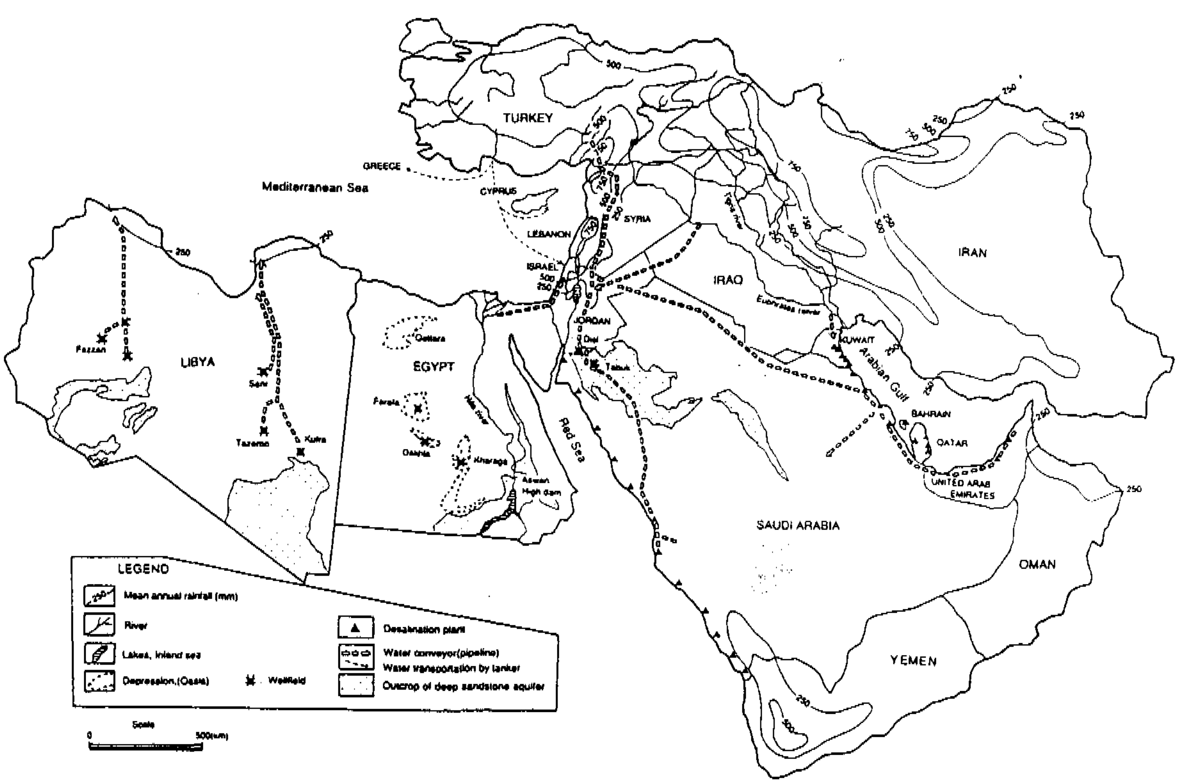

Figure 2. Water resources development project in the Middle East

(1). Short-term relief : highest priority and urgent countermeasure in water development and management - no political constraints.
- *Water conservation and water management*
- *Reuse of treated waste water (for supplemental tree-crop irrigation)*
- *Desalination (for potable water supply mainly by reverse osmosis)*

(2). Mid-term relief (1) : high priority in the water-energy development - included in a strategic peace agreement between Israeli, Palestine and Jordan which may facilitate peace negotiations, with benefits for multi-lateral regional economic development opportunities in the Dead Sea region and the Aqaba region.
- *Mediterranean (Gaza) -Dead Sea (MDS) conduit scheme with hydro-powered RO desalination for co-generation*
- *Aqaba seawater pumped-storage scheme with hydro-powered RO desalination for co-generation*
- *Red-Dead Sea (RDS) or MDS canal hydro-electric scheme*
- *Dead Sea pumped-storage scheme*

(3). Mid-term relief (2) : medium priority in the water supply alternatives with some bi-lateral negotiations with water rich countries such as Turkey, Albania, Iran, and south-east Asian countries
- *Inter-state water transportation by tankers or tags and bags,*

(4). Long-term relief: medium to low priority (but it does not mean any less important) - with complicated multi-national riparian negotiations and/or technical-economical-financial complexity.
- *Inter-state water transportation by pipeline, canal, and others , including;*
  Nile-Gaza/Israel water pipeline,
  - *Iraq-Jordan water pipeline,*
  - *Litany (Lebanon-Israel) basin water transfer,*
  - *Iraq-Kuwait water pipeline,*
  - *Mini-peace pipeline (Seyhan-Ceyhan-Jordan river system),*
  - *Peace pipeline or canal,*
  - *Peace canal,*
  - *Iran-Qatar submarine water pipeline,*
  - *Turkey-Israel submarine water pipeline,*
  - *Megawatershed (Rift Valley groundwater development),*

After exploiting renewable water resources up to the limits of the sustainable yield, 1) water conservation will be essential to manage the water resources development and supply, 2) water politics and negotiations will be priority issues in any transboundary water development project, and 3) environmentally sound innovative technology development with reasonable cost reduction will be the key issue in non-conventional water development.

2.2 Perspectives of the Con-conventional Water Development Alternatives

Conventional alternatives, which include stream water and groundwater development, has the highest priority in water resources planning, where there are still renewable fresh waters to be developed without creating any inter-state riparian questions. This ideal situation does not exist in most countries of the Middle East apart from Turkey, Syria and Lebanon.

Non-conventional alternatives, which comprise desalination, reuse of treated waste water, and water transportation by tanker or bag, will be key issues to sustain water development in the 21st century, when no renewable fresh water will be able to be developed exceeding the sustainable yield, while the general characteristics of non-conventional water resources will be that they are generally more complex in development and operation than conventional sources, and are almost always more expensive. The great advantage of desalination and reuse of treated waste water is that there would be no political constraints in their development. The unlimited supply of seawater is another advantage for desalination, especially since 70% of the Arab and Israeli populations live along the sea coast. This situation favors Israel and the Gaza strip, but not the West Bank and Jordan except for Aqaba coastal plain.

Fossil groundwater by contrast is far too valuable an asset for use except for as a strategic reserve which can be used for a short time relief during extreme drought or emergencies.

2.3 Techno-political Alternatives in Water-Energy Developments in Israel, Palestine and Jordan Perspectives

The current energy source of in the region is heavily dependent on crude oil (2.5 million tons of oil equivalent) and coal (2.3 million tons of oil equivalent) for generation of electricity. The annual production of electricity amounted to 20.9 billion kWh at an installed capacity of 5,835 MW in 1991 (ICBS 1993). Israel is planning to replace its steam power generating system with nuclear by steps in the 21st century. A significant deficit in peak power supply has been a long standing problems, while substantial off-peak electricity is being wasted. Although international networking of the electric supply is being discussed between adjoining states including the Egypt, no alternatives have been suggested other than building a new pumped-storage unit and/or gas turbine generating units. The energy supply is closely related to Israeli water supply which consumes substantial electricity for water pumping. The pumping demand amounted to 1,528 kVA in 1991, of which the cost accounts for 30 % of total expenditure on water supply by MEKOROT. Israel situation in the water and energy perspective is not exceptional case, of which the experience would be refereed in many non-oil producing countries including Jordan and Palestine.

The priority in the techno-political alternatives differ in each state such as Israel, Palestine and Jordan, depending on her nature of resources and development level of water resources. Following is a list of techno-political priority in the major riparians of the lower Jordan system and Aqaba bay.

Israel
- Water conservation
- Desalination including both brackish water and seawater
- Reuse of treated waste water for tree-crop irrigation
- Reclamation of irrigation return by RO
- Retention of wadi flush water including groundwater recharge
- MDS conduit scheme for co-generation
- Medusa water bag project from Turkey
- Water management of the Jordan Valley including desalination of brackish springs and waste saline water from Tiberias lake and drainage network
- Dead Sea pumped-storage for peak-power supply
- Inter-state water transfer and importation by tankers of bags including pipeline options from Nile and Turkey (mini-peace pipeline)
- Dead Sea solar-pond scheme and/or Aqaba ocean heat-energy conversion scheme (future technology)

Palestine (West Bank)
- Water conservation
- Groundwater management of mountain aquifer
- Retention of wadi flush water including groundwater recharge
- Sanitation of waste water including reuse for tree-crop irrigation
- Water management of the Jordan Valley including desalination of brackish springs and waste saline water from drainage network
- Inter-state water transfer such as mini-peace pipeline from Turkey

Palestine (Gaza)
- Water conservation

- Groundwater management of coastal aquifer
- Retention of flush water including groundwater recharge
- Sanitation of waste water including reuse for tree-crop irrigation
- Desalination of brackish groundwater and seawater
- Inter-state water transfer and importation by tankers or bags, including water pipeline option from Nile

Jordan

- Water conservation
- Conventional river development in her territory including storage dams on the Wadi Mujib, Wadi Hasa and other small tributaries
- Interstate river development including storage dam on the Yarmouk (Al-Wuheda dam), taking into account the coupling of the MDS canal project
- Retention of wadi flush water including groundwater recharge
- Sanitation of waste water including reuse for tree-crop irrigation
- Reclamation of irrigation return by RO
- Water resources management of fossil groundwater in Disi sandstone aquifer
- Water management of the Azraq and Jordan Valley including desalination of brackish springs and waste saline water from drainage network
- Desalination of brackish water in Azraq, Jordan Valley including Aqaba-Disi hydro-powered reverse osmosis desalination for co-generation
- Desalination of seawater in Aqaba region including hybrid pumped-storage scheme with hydro-powered reverse osmosis desalination
- Red-Dead Sea canal hydro-electric scheme or Dead Sea pumped-storage scheme for peak-power supply
- Aqaba deep seawater heat-energy conversion scheme (future technology)
- Other inter-state water transfer and importation options

Two non-conventional applications of co-generation scheme such as "MDS conduit scheme" and "Aqaba hybrid seawater pumped-storage scheme" are selected from the above alternatives to develop ideas of inter-state regional economic cooperation which may include a shadow benefit of adding some incentives for settling the new peace of the regions.

3. HYBRID CO-GENERATION ALTERNATIVES IN THE INTER-STATE REGIONAL DEVELOPMENT PLANNING

The inter-state regional economic development plan for peace will have to cover two strategic regions such as Dead Sea (Israel/Palestine/Jordan) and Aqaba (Egypt /Israel /Jordan /Saudi Arabia). These two regions will be gateway to initiate peace cooperation program between the countries of the Middle East. Owing to the geopolitical uniqueness of the Dead Sea, joint regional development plan has a prominent place in the September 1993 Peace Agreement between Israel and PLO (Israel/PLO 1993). Geopolitically, the Aqaba region is shared by four states - Jordan, Israel, Egypt, and Saudi Arabia. The Aqaba bay region has great potential for development of international tourism, commerce and industry if some of the principal infrastructure can be shared, and in the short term could be even more important. Owing to a hyper-arid climate of the region, however, water supply will be the main constraints to development.

3.1 Scenarios of the Hybrid Co-generation Development

Water and energy will be the key elements in any regional development which will also include tourism/resorts, industry and commerce. This study suggests two core projects for co-generation of water and electric power ; the Mediterranean-Dead Sea conduit scheme and the Aqaba seawater pumped-storage scheme as shown below. These would take into account the following possible scenarios to share the resources and benefits;

1) An inter-state electricity grid or network including Egypt, Israel, Palestine, Jordan, Saudi Arabia, Syria and Lebanon, to provide cheap off-peak electricity to pumped-storage schemes, will be incorporated in the plan to provide peak energy and balance the grid.

2) Techno-political project priority given to (a) MDS co-generating conduit scheme in the Dead Sea region development plan and (b) Aqaba co-generation pumped-storage scheme in the Aqaba regional development plan

3) An inter-state water pipeline, to connect the three states along the Aqaba coastline, to share the fresh portable water from the hydro-powered reverse osmosis desalination plant in an enlarged Aqaba co-generating pumped-storage scheme.

4) An inter-state sanitation and environmental management program including waste water recovery for tree irrigation and sustaining the clean water environment of Aqaba bay.

Aqaba region was outside the scope of the bi-lateral peace negotiation between Israel and PLO in 1993, in which the Dead Sea regional economic development and MDS conduit scheme had a strategic priority in terms of geopolitics. In a broader context, Aqaba regional development and hybrid seawater pumped-storage with hydro-powered reverse osmosis (RO) desalination is possibly of even greater importance for economic development of the whole region. Aqaba hybrid pumped-storage scheme for co-generation will be even more competitive when compared with a single purpose hydro-power scheme such as Dead Sea pumped-storage or Red-Dead Sea canal.

3.2 Techno-political Review of the Mediterranean/Red Sea Canal Projects

The Mediterranean or Red-Dead Sea canal hydro-power project was proposed in the early 1980s, which would exploit the 400 m elevation difference between the Mediterranean /Red Sea (zero meters) and the Dead Sea (-400 meters) by linking the two seas.

Discussion of the Mediterranean-Dead Sea (MDS) canal has been including the five main alternative canal routes such as *a) Northern Route* , *b) Southern Route (1)* , *c) Southern Route (2)* , *d) Central Route* , *e) Aqaba Route* , as shown in Figure 1. The "Central Route" canal would have been 72 km long, including a 15 km section of open canal and a 57 km tunnel 5 m in diameter (WPDC 1980). The first 30 km section would have crossed Israeli territory, and the second 42 km section would traverse the West Bank (occupied Palestine). The minimum distance route option was, however, put-aside for fear of possible saline (seawater) water leakage through the tunnel which would contaminate fresh groundwater aquifers underlying the Judaea mountain range.

After considering 27 alternative conduit routes to connect the two seas, the "Gaza - Ein Bokek" route with 80 km tunnel length was selected to minimize the capital cost in 1982. The selected route, however, would cross the occupied Gaza Strip as shown in Figure 1 . For political reasons, an alternative route was considered which would move the entrance of the canal northwards into Israeli territory. This would have added 60 million US. dollars to the cost, and 20 km to the planned 100 km-length (WPDC 1980). However, even if political problems in Gaza Strip are avoided, they would be certainly have been encountered in Jordan which shares the Dead Sea with Israel and also extracts minerals such as potassium from it .

The Israeli MDS solar-hydro development project would have generated 800MW electricity with annual generated electricity of $1.4\text{-}1.85 \times 10^9$ kWh by assuming a gross water head of 444-472 m and maximum discharge of 200 m^3/sec with annual average flow intake of $1.23\text{-}1.67 \times 10^9 m^3$(Tahal 1982). The total project cost was estimated to be US\$ 1.89×10^9 (at 1990 prices). The planned effect of the canal was to raise the level of the Dead Sea by 17 m from -402 to -385 m below sea level. This would have meant that the mineral processing plants in both countries would have to be moved and potash production could fallen by 15 per-cent (WPDC 1980).

Jordan viewed with Israel over the canal power scheme in 1981, by proposing to bring seawater from Aqaba bay to the Dead Sea. This scheme would also have exploited the 400 m drop between the Gulf of Aqaba and the Dead Sea to generate electricity. Seawater would have been pumped into 215 m elevation, and then put into a series of canals and reservoirs to Safi, 200 km further north (see Figure 1). The Red-Dead Sea canal hydroelectric project would generate 334MW (975GWh per annum) for 8 hours a day for the peak power demand (WPDC 1980, JVA 1981). The pumped-storage scheme includes two pumping stations with installed capacity at 70MW including power requirement of 615GWh per annum of electricity. The estimated total construction cost is about JD224 million at 1981 price.

The flow of water from the Jordanian carrier would have forced Israel to cut back its own influx of water into the Dead Sea, or the level would have risen so high as to flood the potash works (of both Israel and Jordan) and the surrounding hotels on the Israeli side. Israeli interest then turned to seawater pumped-storage from the Dead Sea (WPDC 1989) It should be noted that a United Nations mission found that the maximum level to have been reached by the Dead Sea would have been -390.5 m which would not have flooded any religious or archaeological remains, nor would it have triggered earthquakes as this level was comparable with previous equilibrium levels, and would not increase reflectivity.

3.3 MDS Conduit Scheme for Hybrid Co-generation

The co-generation scheme was first conceived to provide both hydro-electricity and fresh water from reverse osmosis seawater desalination plant in the early 1980s (Glueckstern 1982). The use of a part of hydro potential to make the reverse osmosis desalination cost-effective was put-aside, however, owing to a poor understanding for the membrane technologies and the cost at the time of early 1980s.

Discussion of the MDS in the early 1980s may have overlooked concept of shared resources and the benefits of joint development. Indeed up to now 1994 there has still been no attempt to conceive comprehensive development of the Jordan river system including linkage of MDS and Al-Wuheda dam on the Yarmouk tributary. The new co-generation approach to the MDS scheme thus takes into account; i) recent innovative developments in membrane technology for the reverse osmosis (RO) desalination which aim to save energy and to make reverse osmosis (RO) desalination more cost-effective, and ii) recent changes in the Middle East political situation following the Gulf War that may make comprehensive basin development not only technically and financially feasible, but politically desirable and urgent.

3.3.1 Hydro-powered seawater reverse osmosis desalination for co-generation

The new co-generation scheme would exploit the elevation difference of 400 m between the Mediterranean Sea and Dead Sea (see Figure 3). The Dead Sea water level will be maintained at a steady-state level with some seasonal fluctuations of about 2 meters to sustain the sea water level between 402 m and 390 m below mean sea level, during which inflow into the Dead Sea should balance evaporation.

The bi-lateral development plan of Israel/Jordan Mediterranean-Dead Sea conduit scheme, hereinafter referred to as IJMDS, is a co-generation alternative which would combine solar-hydro scheme with hydro-powered seawater reverse osmosis (RO) desalination plant as illustrated in Figure 3. The IJMDS scheme would have six major structural components, including;

1)An upstream reservoir (the Mediterranean) at zero sea level, with essentially an ultimate amount of water,
2) An seawater carrier in tunnel , canal and pipeline, with booster pumping potion
3) an upper reservoir and surge shaft at the outlet of the seawater carrier to allow or

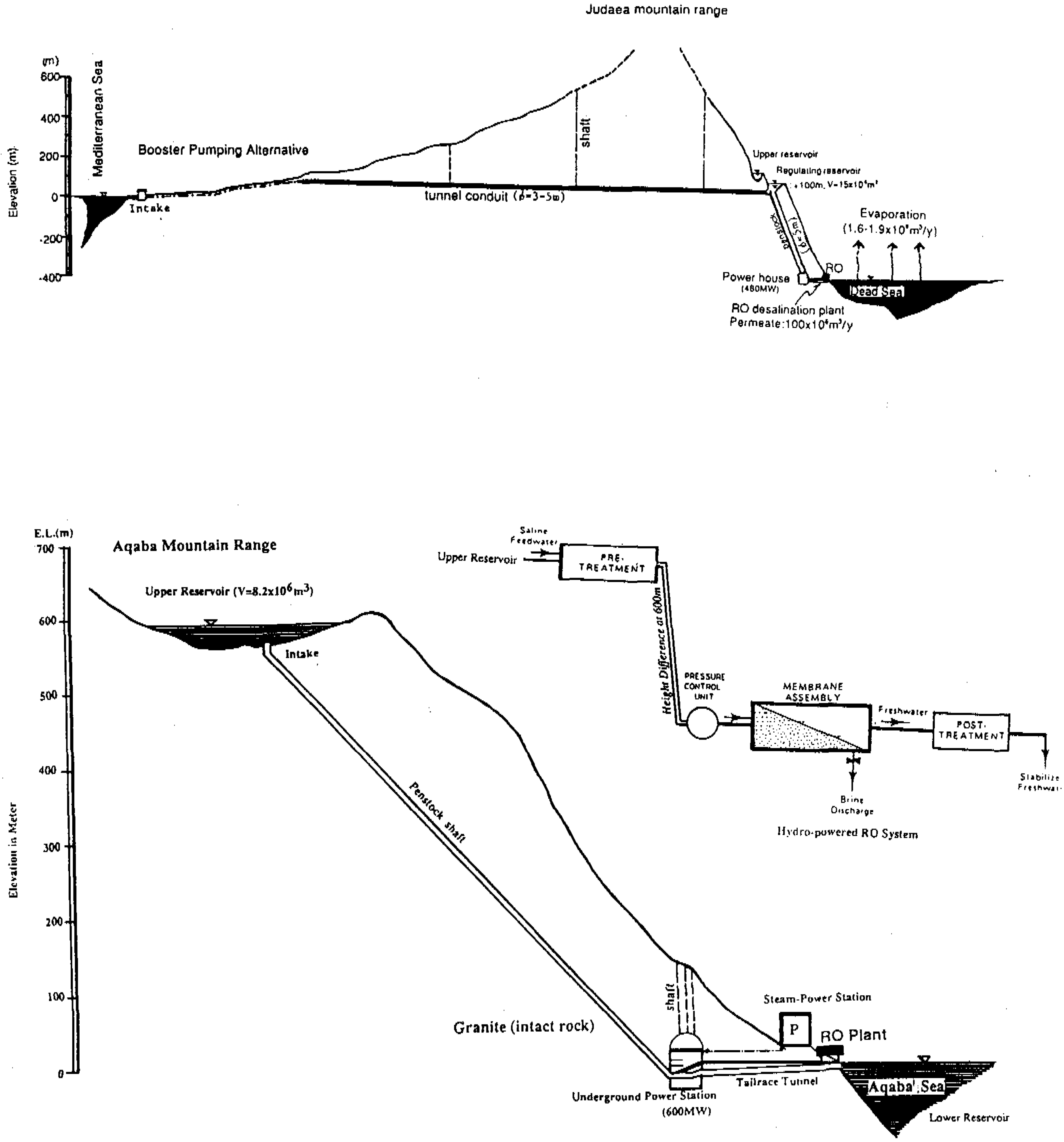

Figure 3. Schematics of hydro-powered reverse osmosis (RO) desalination

regulating the water flow,

4) *An storage type hydroelectric unit capable of reverse operation to allow the system to also work as a pumped-storage unit, if required,*

5) *A downstream reservoir (the Dead Sea,) at a present surface elevation of approximately 400m below sea level,*

6) *a hydro-powered reverse osmosis (RO) desalination plant, including pa re-treatment unit, a pressure converter unit, the RO unit, an energy recovery unit, a post-treatment unit, and regulating reservoirs for distribution.*

3.3.2 Estimates of hydro-power potential

The theoretical hydro-potential to exploit the head difference between the Mediterranean Sea (=0 m) and Dead Sea (=-400 m) by diverting 56.7 m^3/s (=$1.6x10^9 m^3$ per annum) of seawater is estimated to be 194 MW. The hydro-power plant produces $1.3x10^9$kWh per annum of electricity with installed capacity at 495MW assuming the peak-power operation. These figures are coincide with the Tahal's plan in 1981 (Tahal 1982).

These estimates of the hydro-potential are based on the conventional equations as shown below;

Pth = 9.8*Ws*Q*He (1)
P = Pth*Ef (2)
Pp = P*(24/8) (3)
Wp = 365*24*Gf*P (4)

where, Pth : Theoretical hydro-potential (kw)
Ws : Specific weight of seawater (=1.03)
Q : Flow discharge (m^3/sec.)
He : Effective difference head of water (m)
P : Installed capacity (kw)
Ef : Synthesized efficiency (=0.85)
Wp : Installed capacity for 8 hours a day of peak operation (kw)
Wp : Potential power generation (output) per annum (kWh)]
Gf : Generating efficiency (=0.85)
* : Multiply

3.3.3 Methods of co-generation for the MDS

The booster pumping alternative is applied to make an effective head difference of 500m, taking into account the operating water pressure at 50kg/cm^2 and cheap electricity during off-peak time. The seawater diversion capacity is estimated to be 50 m^3/s, including 39m^3/s of intake water for hydro-power unit and 11m^3/s of feed water for desalination unit.

The hydro-power unit has a theoretical hydro-potential of 160 MW, and it generates $1.2x10^9$ kWh per annum of electricity for the installed capacity at 480MW with the peak-power operation for 8 hours a day . The installed capacity of the RO plant to produce $100x10^6 m^3$ per annum of permeate is estimated to be 322,300 m^3/d with a load factor of 85 %. (Murakami 1991)

Marginal operation of the RO system is designed to use the hydro-potential energy in a tunnel conduit (penstock) with 481.5 m of effective head of water for 16 hours a day during the off-peak time. The feed water requirements to produce $100x10^6 m^3$ per annum of permeate with 1,000 mg/l of the total dissolved solids (TDS) are estimated to be $333x10^6 m^3$ per annum assuming 30 % recovery ratio. The brine reject of $233x10^6 m^3$ per annum, of which the salinity is 57,000 mg/l of TDS, is then wasted into the Dead Sea. (Murakami 1991).

The energy recovery potential from the brine reject is estimated to be 28,280 kW, assuming 20% of friction loss in RO circuit. .

Energy recovery = $9.8 \times 1.03 \times (233 \times 10^6/365/86400) \times (587 \times 0.95 \times 0.8) \times 0.85$

Annual product of the electricity from the RO brine is estimated to be 168×10^6 kWh with a load factor of 68 %. The recovered energy (electricity) will be used to supply electricity for the post-treatment process or other purposes to save the electricity from the national grid.

3.3.4 Cost estimates of hydro-powered reverse osmosis (RO) desalination plant

The project cost of the proposed RO unit is preliminary estimated to be US$ 389,355,000 of the capital and US$44,387,000 per annum of O&M. The cost estimates are based on 1990 prices assuming that *1) plant life of 20 years, 2) membrane life (replacement) of 3 years, 3) 8 % interest during three years construction, 4) excluding cost benefit from energy recovery and 5) excluding costs for source water and pipeline/distribution* .

The unit water cost of the hydro-powered seawater reverse osmosis desalination for the annual product water of $100 \times 10^6 m^3$ is estimated to be US$ 0.68/m^3, which may be reasonable when compared with international water tariffs and the estimated unit water tariff of US$0.85-1.07/$m^3$ in the "Peace Pipeline" project (David 1991). Estimated unit water cost of desalination is shown in Table 1.

Table 1. Unit water cost of desalination and treated sewage

Method of desalination and treatment	Feedwater	Product water	Unit water cost
	TDS/ppm	TDS/ppm	US$/m3
Seawater desalination by MSF	40,000	50	2.7
Seawater desalination by RO	40,000	500-1,000	1.6
Seawater desalination by hydro-powered RO	40,000	500-1,000	0.68
Brackish water desalination by RO	3,000	300-500	0.46
Tertiary treatment with loose RO	1,000	300-500	0.17

Remarks; MSF (Multi-stage Flush), RO (Reverse Osmosis)
; Plant scale is assumed to be 27,000m3/day

The investment cost of the co-generation scheme is preliminary estimated to be US$$2.3 \times 10^9$, including US$$1.9 \times 10^9$ of the hydro-power unit and US$$0.4 \times 10^9$ of the reverse osmosis (RO) desalination plant (Murakami 1991).

4. INTEGRATION OF HYBRID CO-GENERATION SCHEMES IN THE INTER-STATE REGIONAL ECONOMIC DEVELOPMENT PLAN

Middle East water perspectives include many discussions and strategic scenarios with alternatives. Techno-political water resources devilment alternatives and their feasibility are examined to evaluate the priority in those proposed water resources development projects in Israel, Palestine and Jordan which are the major riparians of the Jordan river, Dead Sea and Aqaba bay, taking into account the recent Middle East peace settlement and political changes after 1991-93.

Two non-conventional water-energy development schemes are proposed, including "MDS conduit with hydro-powered seawater reverse osmosis desalination" and "Aqaba hybrid seawater pumped-storage with hydro-powered reverse osmosis desalination" to provide the idea of sharing resources and benefits among the riparian states.

4.1 Dead Sea Scheme

The Dead Sea surface, which is the source of evaporation for the MDS solar-hydro scheme, is the joint heritage of riparian states including Israel (300 km^2 ; 30%) and Jordan (700 km^2 : 70%). While the conduit route would pass through the Palestine (Gaza, 10 km : 10%) and Israel (90 km : 90%). Actual evaporation rate after impounding seawater from the Mediterranean has been estimated to be 1,908mm per annum at an equilibrium water level before 1948 (Calder 1984). The water budget of the Dead Sea for the co-generation scheme to generate $1.2x10^9$kWh per annum of electricity and $100x10^6m^3$ per annum of fresh water is shown as below (Murakami 1991, Biswas 1994);

- *Evaporation after impounding seawater from the Mediterranean*:-$1,900x10^6m^3$
- *Tailrace water from MDS hydro-power station* :+$1,220x10^6m^3$
- *Brine reject water from RO plant* : +$233x10^6m^3$
- *Inflow from catchments* : +$447x10^6m^3$

From a water budget study of the Dead Sea, the decrease in the inflow from the catchment would result in increasing the hydro-potential energy so as to introduce more seawater from the Mediterranean. There are four major alternatives to cut the flows including;

1) Al-Wuheda storage dam on the Yarmouk river : $200x10^6m^3$
2) Storage dam schemes on the riftside-wadis in the East Bank, including wadi Mujib, wadi Hasa and etc : $100x10^6m^3$
3) Flood retention - groundwater recharge dam schemes on the side-wadis on the West Bank (Occupied Palestine) where limestone geology is predominant.: $100x10^6m^3$
4) Brackish water delineation by RO for irrigation return and saline springs flowing into the lower Jordan river : $100x10^6m^3$

Among them, the Al-Wuheda dam scheme with an effective storage of $195x10^6m^3$, is Jordan's last major river development that is urgently needed for the national water supply grid to add $155x10^6m^3$ per annum of the renewable fresh water. This will also reduce substantial amount of winter run-off flowing into the Dead Sea to add 20MW of hydro-potential and/or $120x10^6$kWh per annum of electricity (Murakami 1993c).

The lower Jordan river brackish water desalination plant is proposed to salvage $100x10^6m^3$ per annum saline streams flowing into the Dead Sea. This will also add 10MW of hydro-potential and/or $60x10^6$kwh per annum of electricity. Unit water cost to produce *$100x10^6m^3$* per annum of fresh portable water from brackish water with 3,000-6,000 ppm of TDS has been estimated to be US\$0.4-0.5/m^3, which would be piped to municipal water supply including Jerico (Murakami 1991, 1994). The waste water with amount of 80-90% of the municipal water supply would also be intensively treated to reuse it for tree-crop irrigation. Another membrane separation technology including micro-filter (MF), ultra-filter (UF), and loose RO would improve not only the sanitary environment but also the strategic reuse of treated waste waters for a part of municipal water supply.
The product water of $100x10^6m^3$ per annum from MDS desalination plant could be split fifty and fifty between Israel and Palestine as PLO and Jordan, which would be mainly used for M&I with aim of supplying fresh portable water exclusively in the hot and arid low land of the Central Ghor, taking into account the reasonable unit water cost of US\$0.68/m^3 (Murakami 1991).

4.2 Aqaba Scheme

Construction of any new thermal or nuclear power stations in the region will benefit from a pumped-storage scheme for efficient energy use during off-peak time. Hybrid water-energy co-generation system is an application of reverse osmosis (RO) desalination annexed to a seawater pumped-storage scheme (Murakami 1993b). The Aqaba scheme would use seawater which would be pumped directly to an upper reservoir on the top of an escarpment at 600-800m above sea level, and from there into a penstock to yield a water pressure of 60kg/cm^2 to generate 600MW electricity as potential base energy and 100x10^{6}m^3 of fresh portable water. Off-peak electricity to boost the water to 600m elevation would be supplied from either a steam power plant at Aqaba or from the most economical alternatives source whether nuclear power plants in Egypt or Israel, or from other electricity grids in the region including Saudi Arabia.

A schematic profile of hybrid seawater pumped-storage scheme for co-generation is shown in Figure 3. The specification for the hydro-powered seawater reverse osmosis desalination unit would be similar to that developed for the MDS conduit scheme for co-generation. The design discharge is preliminary estimated to be 116m^3/s, assuming a specific weight of seawater of 1.03 and synthesized efficiency of 0.85.

The pumped-storage scheme would be designed to generate peak power for 4-8 hours a day. The marginal operation of the RO system could make use of the hydro-potential energy in the penstock pipeline with 600m of head difference for 16-20 hours a day during off-peak time.

The feed water requirements to produce 100x10^{6}m^3 per annum of permeate with 500-1,000 mg/l of TDS are estimated to be 333x10^{6}m^3 per annum by assuming 30 % of recovery ratio (70 % for brine reject). The installed capacity of the RO unit is estimated to be 322,300 m^3/d with a load factor of 85 %.

The energy recovery potential from the brine reject is estimated to be 28,900 kW by assuming 20% of friction loss in RO, and it is shown as below;

Energy recovery = 9.8x1.03x(233x10^6/365/86400)x(600x0.95x0.8)x0.85

The annual production of electricity from the RO brine reject is estimated to be an annual production of 172x10^6 kWh with a load factor of 68 %. The recovered energy would be used to supply electricity for the post-treatment or other pumps to save electricity from the national grid.

The total investment cost of the proposed hydro-powered seawater reverse osmosis (RO) desalination unit is preliminarily estimated to be US$ 389,355,000 (see Table 2).

Table 2. Capital cost of Aqaba hydro-powered seawater RO desalination

A. Major capital cost element	US$	Remarks
A-1 Pre-treatment	44,195,000	
A-2 Desalination plant	70,414,000	
A-3 RO membrane/equipment	84,835,000	
A-4 Control and operating system	5,952,000	
A-5 Appurtenant works	27,013,000	
A-6 Powerline and substation	11,427,000	
A-7 Energy recovery/turbine	2,999,000	sum(A1-A7)=245,835,000
A-8 Design and construction management	62,250,000	
A-9 Financial expenditure	80,270,000	assuming 8% discount rate
Sub-total	389,355,000	1990 price, 15-20 years plant life

The annual cost is estimated to be US$ 18,568,000 in financing costs and US$ 44,387,000 in operation and maintenance (O&M) costs as shown in Table 3. The unit water cost of desalination to produce $100x10^6m^3$ per annum of fresh water is preliminarily estimated to be US$ $0.68/m^3$, by assuming the same design criteria as for the MDS hydro-powered seawater reverse osmosis desalination plant.

Table 3. Operation and maintenance cost of Aqaba hydro-powered RO desalination

B. Major O&M cost element	US$ per annum	
B-1 Labour	3,718,000	
B-2 Material supply	1,860,000	
B-3 Chemicals	7,440,000	
B-4 Power to boost feedwater	3,100,000	using off-peak electricity
B-5 Membrane replacement	28,269,000	each 3 year
Sub-total	44,387,000	1990 price

The fresh portable water of $100x10^6m^3$ per annum from Aqaba hydro-powered reverse osmosis (RO) desalination plant in the pumped-storage scheme could be shared among Jordan (Aqaba), Israel (Eilat), Egypt (Taba) and Saudi Arabia (Haql) in accordance with agreement on the inter-state regional economic development program. The non-oil producing state of Jordan, of which the national economy is not so strong as the neighbors such as Israel and Saudi Arabia will have exclusive chance to export $100x10^6m^3$ per annum of fresh portable water and valuable peak electricity to import cheap off-peak electricity from Israel, Egypt and Saudi Arabia. Aqaba hydro-powered seawater desalination will also save $17.5x10^6m^3$ of fossil groundwater from Disi which is being piped to Aqaba municipal water supply. Schematic of the method of sharing water and energy of the Aqaba hybrid seawater pumped storage scheme with hydro-powered reverse osmosis (RO) desalination is illustrated in Figure 4.

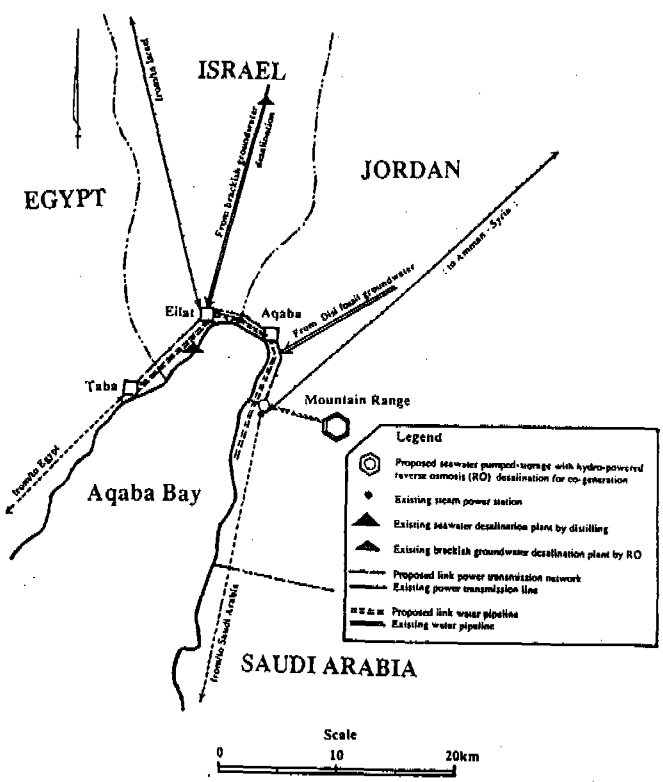

Figure 4. Inter-state joint economic development plan with co-generation scheme

4.3 Water for Peace Project in the Heart of the Middle East

The historic peace accord between Israel and the Palestine Liberation (PLO) in Oslo on 13th September 1993, produced a Declaration of Principles which included proposal for an inter-state regional economic development plan (Israel/PLO, 1993). Regional economic development was conceived as a key element to sustain the peace process in the region. The protocol on Israel-PLO relations suggests that priority be given to certain projects including development of the Dead Sea Region and the Mediterranean Sea (Gaza) - Dead Sea Canal (see Figure 1). The weak point of the bi-lateral peace agreement was that it did not at that stage include Jordan which is a major riparian state of the Dead Sea and Jordan river.

It is now necessary to re-examine the techno-political non-conventional water-energy development alternatives in two inter-state regions such as Dead Sea and Aqaba in the context of sharing resources and benefits, taking into account the next possible multi-lateral peace agreement among Israel, Palestine as PLO and Jordan. It has also to be remembered that riparian of Syria, Lebanon, Egypt and Saudi Arabia are contiguous and could share resources and benefits from the schemes for peace settlement.

5. SUMMARY AND CONCLUSIONS

Project feasibility and techno-political priority in the Middle East water perspectives are evaluated to satisfy the water demand in the next decade as 21st century in a framework of water for peace, taking into account the 1) technical-environmental feasibility, 2) economic-financial feasibility, and 3) social-political feasibility.

After exploiting almost all the renewable fresh water resources, there is no alternatives to satisfy the increasing water demand except for water conservation and/or non-conventional water resources development.

Non-conventional water resources development alternatives including desalination of saline water and reuse of treated waste water with membrane separation technology are the priority alternative, taking into account that there is few constraint in terms of the international politics for peace.

Hybrid co-generation alternatives in water and energy development are elaborated in Israel, Palestine as PLO and Jordan including two strategic inter-state economic development regions such as Dead Sea and Aqaba Bay.

The hydro-powered seawater reverse osmosis (RO) desalination in the MDS conduit scheme and the Aqaba hybrid pumped-storage scheme would achieve substantial cost to retrieve off-peak electricity from the steam power plant, which has long been a major constraint in the seawater desalination practice. The unit water cost of hydro-powered seawater RO desalination is preliminarily estimated to be US$0.68/m^3, which is 50% less cost to compare with US$1.6/m^3 of the traditional RO.

This study attempts to evaluate some new non-conventional approaches to water resources that need to taken into account in building the new peace of the Middle East. The Dead Sea hydro-solar development for co-generation should be discussed in the context of a basin water master plan for sustainable development and management with sharing of resources concept, and providing the basis for peace collaboration between Israel and its neighbors. Aqaba hybrid pumped-storage scheme for co-generation would also be elaborated in the context of an inter-state regional economic cooperation plan among the Jordan, Israel, Egypt and Saudi Arabia. These new approaches offer the opportunity to introduce new applications of well-tried technology to solve long-standing water and energy problems that are at the center of many of the potential source of conflict.

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SATELLITE BASED DISTRIBUTED OPERATIONAL HYDROMETEOROLOGICAL FORECAST SYSTEM FOR THE NILE RIVER

Dr. Bayoumi Attia[1], Mihailo Andjelic[2] and Curtis B. Barrett[3]

ABSTRACT

The U.S. Agency for International Development (AID) is funding a project to establish a Monitoring, Forecasting and Simulation system for the Nile river. The project is being executed by the Food and Agriculture Organization (FAO). The National Oceanic and Atmospheric Administration (NOAA) is the prime subcontractor to the project. The primary purpose of the project is to provide decision makers with long range accurate river forecast information for the Nile river at the High Aswan Dam.

Phase I of the project (September 1990-September 1993) involved initial development of a Nile Forecasting System (NFS) for the Blue Nile River. Over 80 percent of the runoff of the Nile originates from the Blue Nile System. Phase I was completed with the installation of the latest version of the NFS in July 1993. Underway now is Phase II (September 1993-September 1995) which involves significant improvement of the accuracy and simulation of the NFS for the Blue Nile as well as expansion of the system to include the White Nile River System. Version 2.1 of the NFS was installed in Cairo in June 1994. It contains enhanced satellite calibration coefficients, a hydrologic calibration system, enhanced reservoir routing system for the Blue Nile river, improved precipitation/state variable assimilator and improved graphics outputs. Future planned improvements include the addition of Quantitative Precipitation Forecast (QPF), establishment of a Data Base Management System, calibration of hydrologic models & the Nile satellite precipitation hybrid technique for the White Nile basin and addition of a "swamp" hydrologic simulation model.

Besides improvements in the Nile Forecast System, training of Egyptian meteorologists and engineers continues as the sophistication and complexity of the system increases. Training involves Hydrologic models & systems, Satellite Precipitation Estimation, Geographical Information Systems, short term and long term QPF, Precipitation analysis and computer systems/Graphical User Interface.

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1. INTRODUCTION

A project to Monitor, Forecast and Simulate (MFS) flows along the Nile river was initiated three years ago by the U.S. Agency for International Development (AID). The executing agency to the project is the United Nations Food and Agriculture Organization (FAO). The prime contractor in the project is the National Oceanic and Atmospheric Administration National Weather Service. the Primary purpose of the MFS project is to develop a hydrometeorological forecast system for the Nile River flows into the High Aswan Dam. Forecasts should project as far into the future with lead times of three to five months if possible. Operation of the Nile irrigation delivery system in Egypt, including its many water control structures and strategies of water use, requires a real-time forecasting system. An additional goal is to regionalize forecast capability so that many of the nine Nilotic countries within the Nile Basin could benefit from use of the Nile River forecasts.

Phase I of the project (September 1990-September 1993) involved development of a Nile Forecasting System (NFS) for the Blue Nile River. Over 80 percent of the runoff of the Nile originates from the Blue Nile System. Phase II of the project now underway (September 1993-September 1995) involves improving the accuracy and simulation of the NFS for the Blue Nile as well as expansion of the system to include the White Nile River System.

NOAA's role is involved in the training of Egyptian engineers to operate the Nile Forecast Center (NFC) in Cairo, Egypt and the development of the Nile Forecast System. The Nile Forecast Center became operational in July 1993 concurrently with the installation of the first complete version of the Nile Forecast System. NOAA has trained six Egyptian engineers who operate the Nile Forecast Center in Cairo. The engineers were trained in hydrology, meteorology, geographical information systems, hydrologic forecasting, computer software, and the UNIX operating system. Currently a Meteorologist is being trained in Silver Spring, Maryland on utilization of Satellite Estimation Techniques while a hydrologist is being trained on hydrologic model/technique updates.

The latest Version of the NFS was installed in Cairo in June, 1994. It contained critical enhancements in reservoir routing, satellite precipitation estimation & precipitation analysis as well as improvements in performance of the forecast system on the scientific work station computers.

Currently NOAA NWS is developing a Quantitative Precipitation Forecast technique, a data base management system, a hydrologic model to simulate/forecast flows through the SUDD swamp region and a major calibration effort is underway to calibrate satellite estimation coefficients and hydrologic model parameters for the White Nile basin and its tributaries. This version is expected to be installed at the NFC in Cairo in June,1995.

2. THE NILE FORECASTING SYSTEM STRUCTURE

The Nile Forecasting System consists of two sub-systems. The Primary Data User System (PDUS) provides the continuous input of METEOSAT Satellite data to the NFC. The Nile Forecasting System resides on IBM RISC 6000 Workstations and contains the hydrologic models and software required to produce river and flow forecasts along the Nile River system.

Real-time METEOSAT satellite imagery data is received every 30 minutes by the PDUS. The PDUS consists of a satellite dish antenna, a receiver, and four Personal Computers. Imagery data are automatically transferred by Ethernet to the RISC Workstations. The Nile Forecasting System then processes the imagery data with the final output being flow hydrographs at designated locations along the Blue Nile River.

The Nile Forecast System consists of a Hydroclimate data base system, a preprocessor component, a forecast component, a user interface, and a GIS. The computation of data and forecasts is based on the METEOSAT Grid system which is a quasi-rectangular 5.5 Km grid scale. There are 11,000 grid cells in the Blue Nile Basin each having an area of about 30 square kilometers.

Once a day the automatic pipeline processes all real-time data, executes all the program runs, dates forecast information, and produces up to date flow simulations for seven locations along the Blue Nile.

3. HYDROCLIMATE DATA COMPONENT

The Hydroclimate component consists of an observed precipitation time series data base, a climate data base, observed flow and stage data, reservoir data, potential evapotranspiration data, monthly gridded precipitation files for more than 50 years, and a METEOSAT raw imagery data base.

Observed precipitation data is automatically input into the NFS via the Meteorological Data Distribution System (MDD) installed at the NFC. In addition, river stage, flow, and reservoir data is manually entered into the system daily.

Monthly and daily climate rainfall statistics for every grid cell have been calculated and stored in the data base for the Blue Nile system.

Seasonal & monthly evapotranspiration have been entered for the entire Blue Nile Basin.

4. THE PREPROCESSOR COMPONENT

The principle job of the preprocessor component of the NFS is to convert incoming hydrometeorological raw source data into precipitation estimates required by hydrologic models to produce simulations and forecasts.

The latest (Version 2.1) preprocessor contains five processors.

Figure 1 shows a schematic of the Version 2.1 system. METEOSAT imagery data are

NFS VERSION 2.1 PIPELINE

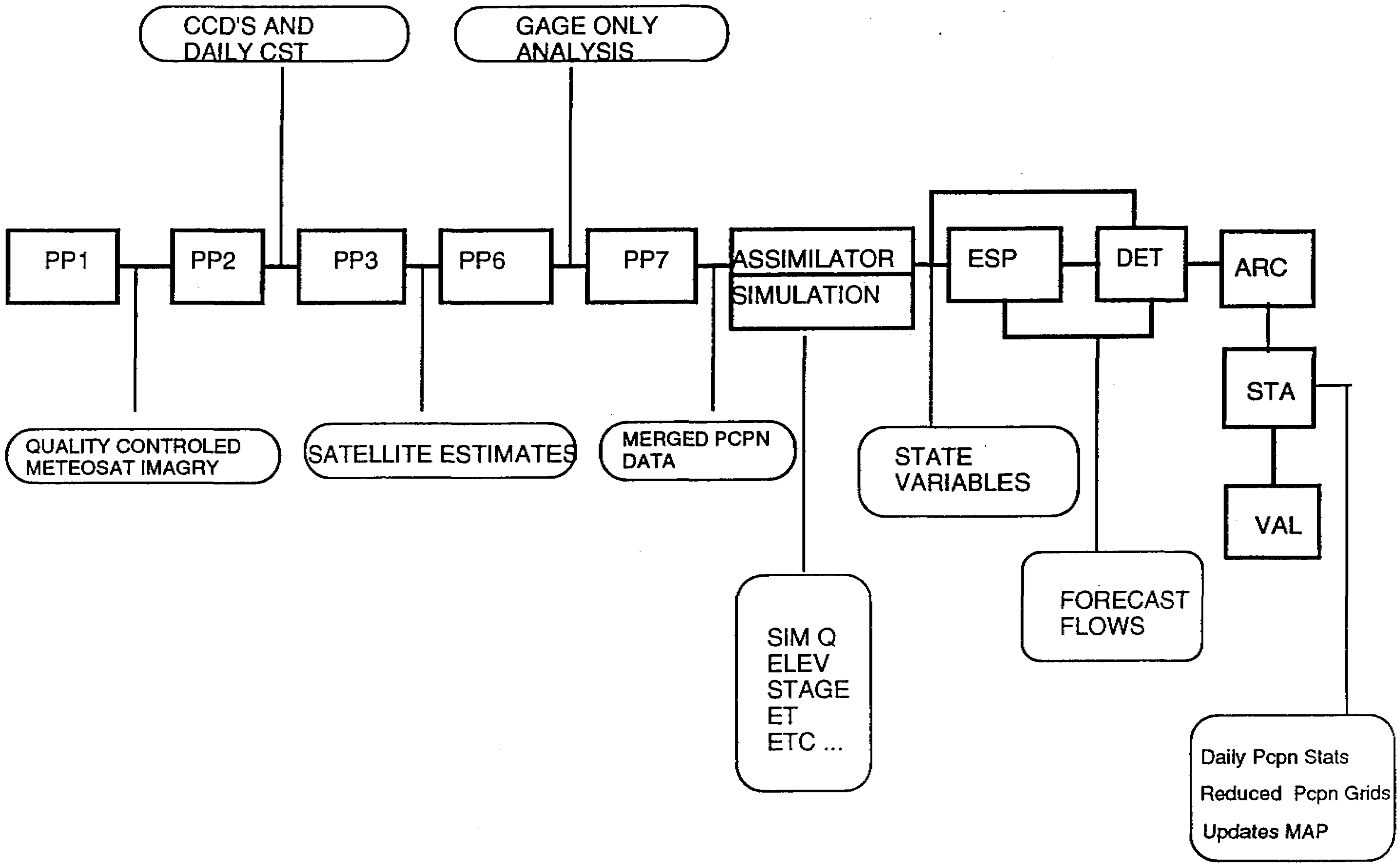

FIGURE 1- NILE FORECASTING SYSTEM VERSION 2.1

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automatically entered into a designated directory on the workstation via Ethernet from software supplied by the vendor. An automatic sequencing of all the processors occurs once a day in the evening. Processors 1 to 7 are automatically run (based on the clock) to produce daily estimates of rainfall.The Nile Forecast System is unique because very little observed precipitation data are available in the Nile Basin. Therefore, a major source of precipitation data becomes satellite estimates of precipitation at the METEOSAT grid resolution. The five preprocessors quality control imagery data, convert imagery data to estimates of rainfall using the Nile Climatological Satellite Precipitation Technique, filters high frequency noise from the precipitation estimate, merges the satellite estimate data with observed precipitation data, and uses climate statistic data to estimate the best spatial and temporal distribution of precipitation in grid form (Barrett, 1992).

Initially, the project investigated the use of existing satellite estimation techniques developed by Reading University/U.K., Bristol University/U.K., GOES Precipitation Index (GPI) developed by Arkin, the Progressive Refinement Technique as well as the Convective Stratiform Technique (CST) (Newby, 1992). By early 1993 a unique Hybrid Nile NFS Climatological Technique was developed (Schaake and Newby 1993). This technique was integrated into the NFS this summer by establishing a preliminary theta merge factor which merges satellite estimates with objective analysis of the operational precipitation (Schaake,1993).

The computation of the gridded merged rainfall estimates are written to the data base that will be used by the forecast component to compute runoff. A mean areal precipitation time series is computed for pre-selected subareas.

5. THE FORECAST COMPONENT

The Forecast Component consists of distributed hydrologic models and software to produce flow and stage hydrographs based on precipitation inputs supplied by the preprocessor (Koren,Schaake,Barrett,1992). There are a number of hydrologic operations in Version 2.1. These operations consist of: a sub-watershed model to compute surface runoff at grid points and sub-areas, a hillslope routing model to route flow from pixel to a stream, a channel routing model to route flow from pixel to pixel and from sub basin to sub basin, a reservoir routing model, a Stochastic hydrologic model for the White Nile Basin, an Assimilator to filter rainfall inputs and state variables, and a technique to use climatological information to predict long term flow forecasts & uncertainty (The NWS Extended Streamflow Prediction ESP model) and a hydrologic calibration system.

The runoff simulation model operates in the Blue Nile and Atbara river basins and is a grid point model with the sub basin represented as connected grid points with each grid cell being a METEOSAT pixel. The runoff simulation model has three parts: a water balance model developed by Koren and Schaake (1992) which produces surface runoff; a single, non-linear storage equation to route surface runoff within the cell to the stream; and a single, nonlinear storage equation for moving water from grid cell to grid cell (i.e. the sub basin stream channel network).

The runoff grid cell model has fourteen parameters and four state variables. In the water balance model there are the state variables of soil moisture storage, surface moisture storage, overland flow

flow storage, and channel storage (Koren, 1992). Various utility and application programs are also available to provide support functions to the operational models (Schaake, 1990). These functions such as conversion of grid spacing and time interval values are used on an off-line basis.

The water balance simulation model has five parameters for water balance including maximum values for moisture deficits (dm), maximum groundwater flow (qmax), bottom layer component which produces subsurface flow (ksm), upper layer deficit proportion (kd), and Kdt which is the time scale factor in days (Koren and Schaake, 1992).

The hillslope routing model has three parameters and one state variable while the channel routing model has six parameters and one state variable. The hillslope routing model has three parameters. The parameters are hillslope friction slope (SLOPE), the roughness coefficient (ROUGH), and the hillslope length (LENGTH).

The channel routing component has six parameters. The parameters are: 1) the effective channel length (LENGTH), 4) the Channel slope (SLOPE); ROUGH which is the channel roughness coefficient; and the two parameters of channel cross-section (a and b).

Connectivity of the grid points was determined by the GIS based stream network definition and by elevations. From the connected METEOSAT grid, average channel length and slope was determined.

In addition to the three hydrologic operations described above, the forecast component consists of carryover files that contain state variables, parameter files, gridded output files of flow values, and hydrographs in time series format for designated subarea locations. Each subarea location has been selected based on the hydrologic characteristics or availability of real-time hydrologic gage data. For each subarea location, mean areal precipitation, mean areal PE, mean soil moisture deficit, and runoff are computed.

There are two reservoirs in the Blue Nile Basin where reservoir routing techniques are applied. These reservoirs are Sennar and Roseires. They are in Sudan, located along the lower Blue Nile River and operate according to fixed rules or phases of operation. In general, the reservoirs will fill storage during the occurrence of the annual summer flood, and spill during the winter months.

The Extended Streamflow Prediction (ESP) model produces long term forecast hydrographs based on past climatological conditions and current soil moisture states in the watershed. During an ESP run, the current soil moisture states are used as the starting point to generate 50 years of hydrologic traces based on previous monthly evapotranspiration and precipitation inputs for the historical record. The resultant projections represent the range of past climatic conditions which are equally likely in the future. ESP then fits the 50 traces to a probability distribution. In version 2.1, displays are available to show excedance probabilities of 90%, 75%,50%, 25% and 10%.

The Assimilator technique in the NFS is used to adjust precipitation and state variable inputs based on error properties. Discrepancies between observed flows and simulated flows are primarily due to errors in precipitation estimation, water balance state variable estimates and channel routing states. The assimilator recognizes these input errors and adjusts daily values (once a week) to minimize the difference between observed and simulated flows. The NFS assimilator algorithm is based on a non-linear programming technique (Koren,1994).

A first order Markov stochastic Model (Koren,1994) is used to simulate flows for the White Nile River at Malakal. This model is included to provide the capability of NFS to predict total volume inflow into the High Aswan Dam. The model simulates monthly flows which are transformed into daily discharges by the use of a simple linear reservoir. This model is executed in the pipeline daily.

There are two basic types of outputs from the forecast component. The outputs are 1) gridded runoff and streamflow and 2) time series of streamflow and water balance components for select "forecast locations".

The forecast component has two modes of operation. These two modes are 1) the standard run and 2) run scenarios in work space areas. The standard run is triggered automatically each day by the clock. Once all the precipitation data has been received and processed, the model system is executed for all grid point locations for all present and historical time steps. State variables, runoff and carryover files are updated and new time series created for the forecast points.

The non-standard work space run option is available if the forecaster wants to create or run scenarios that are necessary for hydrologic analysis but does not update the NFS carryover or state variable files. An example of the run scenario is if the forecaster wants to run "what if" conditions based on a variable future precipitation. A series of runs could be made by comparing zero future precipitation to average future precipitation to above average precipitation scenarios.

6. THE USER INTERFACE

The User Interface displays satellite imagery data, gridded data, and time series data; it also serves as the interface between the forecaster and the NFS Version 2.1 software and models. The NFC forecaster can run hydrologic forecast runs as well as control the parameterization, re-execution, and backtracking of the standard automatic pipeline run. The User Interface is driven by a menu system that is linked to actions through configuration files in the workstation (Bellerby, 1992). Figure 2 shows a typical ESP projection display.

7. THE GEOGRAPHICAL INFORMATION SYSTEM

The GIS was included in the NFS to create a map background for display purposes as well as to perform analysis to estimate hydrologic model parameter type information including gridded flow path connectivity, drainage basin area definition for forecast locations, and physical variables such as elevation, slope and length. Primary considerations for the GIS were the ability to interface with the grid-point models, real-time response rates, cost, and capability to produce the specific hydrologic parameters. Because of this, customized GIS software was written for the project (VanBlargan, 1992a).

The GIS utilizes vector and gridded raster file formats. The raw data files were manually digitized from 1:2,000,000 scale topographic maps produced by the U.S. Defense Mapping Agency.

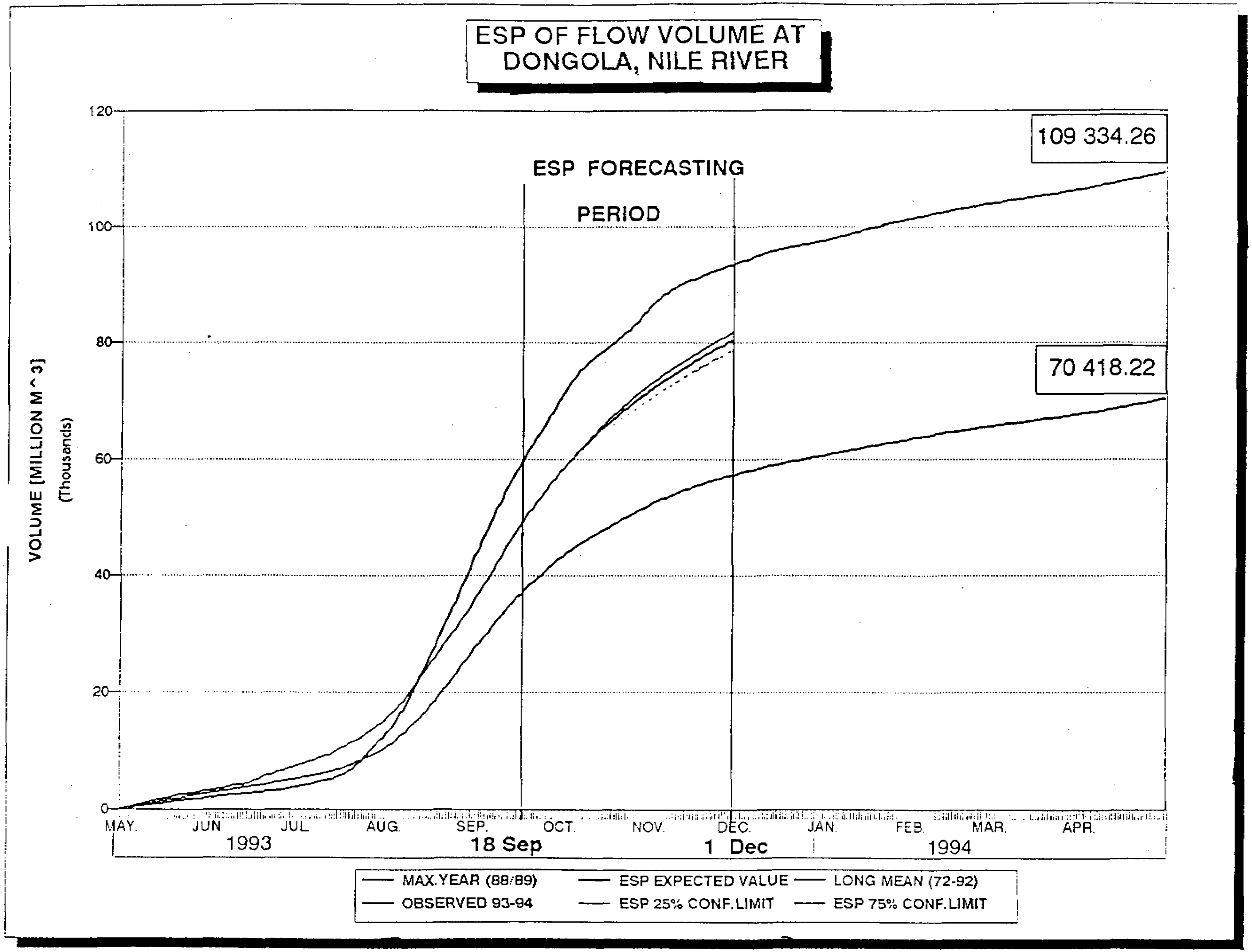

FIGURE 2 NFS VERSION 2. ESP PROJECTIONS

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A high resolution 30 arc second terrain data set will be added to the NFS Version 3.0 (June,1995) for the Blue Nile Basin only.

A commercial GIS program (ARC/INFO), was used to digitize the basic GIS data sets which included streams, elevation contours, political boundaries, city names, and basin boundaries. The customized GIS developed for the project addresses important issues such as methods of combining raster and vector, integrating hydrologic models with hydrometeorological and geographic data, and estimating hydrologic parameters with digital geographic data (VanBlargan, 1992b).

8. DEVELOPMENT OF AN ENHANCED NILE FORECASTING SYSTEM

NOAA is currently developing an enhanced Nile Forecasting System (Version 3.0) as per the Phase II Workplan. This enhanced version of the Nile Forecasting System is scheduled to be installed in June, 1995. The principle enhancement of the system will be the ability to simulate and forecast flows along the White Nile Basin. A more robust set of hydrologic models using observed & satellite based rainfall will be calibrated to available hydrometeorological data. A Swamp model will be added to the suite of models to simulate SUDD swamp conditions. An Aswan Dam Simulation, routing and control model will be linked to the NFS to produce a more integrated Water Forecast & Management system.

NFS Version 3.0 will include a Quantitative Precipitation Forecast Technique which will link short term 5-Day QPF product input obtained from the ECMWF QPF and will also link longer term (multi-month precipitation predictions) based on statistical correlations with El Nino/Southern Oscillation index data obtained from the NWS *Climate Analysis* Center.

Further planned improvements in the NFS include addition of Data Base Management System capabilities as well as conversion of the system graphics library to a commercial graphical library linked with X-windows .

9. SUMMARY

The initial operational river forecast system for the Blue Nile River was installed in 1992 in Cairo, Egypt. Since then, various enhanced or improved versions have been installed with the latest system installed in June 1994. The first operational forecast for the Nile was issued in July, 1993. The forecast predicted 17 percent above normal volume inflow into the High Aswan Dam for the period July-November, 1993. This forecast assumed near normal precipitation conditions during the forecast months. The forecast was accurate as observed runoff into the dam during 1993 approached 17 percent above normal. Continued planned improvements to the NFS include integration of an Aswan Dam Decision Making/Control model with the forecasting system which will provide the basis for optimal use & distribution of inflow to agriculture & hydropower users.

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STUDY OF THE HYDROLOGICAL SITUATION
IN GAZA STRIP

Yousef Abu-Mailah[1]

ABSTRACT

The ground water is the only water resource in the Gaza Strip, the replenishment of ground water is estimated at about 40 mcm /year and 10 - 15 mcm / year from rainwater and underground eastern flows respectively . The water crises in the Gaza Strip are created by intensive exploitation for domestic and agricultural purposes, where the water situation has reached an alarming condition, that needs an immediate intention . The study indicates that,(1) the future water supply faces a serious threat in terms of quality and quantity, due to the rapid deterioration, over consumption by Israeli settlers and sea water intrusion, (2) the main characteristic features of the Gaza Strips aquifer are negative water level decrease of about 10 - 20 cm / yr., annual water deficit of about 60 mcm / yr., high chloride concentration (except at the north part) (10 ppm /yr., concentration increment) and high nitrate concentration (1ppm / yr., concentration increment) . Also the study indicates that the hydrological and ecological situation of the ground water aquifers in the Gaza Strip is facing a real threat and there should be a real and practical solution for this crisis .

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1. INTRODUCTION

There are number of hydrological studies about the coastal aquifer of Gaza Strip since the beginning of the seventies pointed out an increase of the intensive exploitation and overpumping , between 50 - 60 mcm / year . Also a hydrological indications through the period 1980 up to 93 declared a destruction in the watery situation of the Strip; for example:-

1- High chloride concentration, more than 1000 ppm, near the sea shore , in different areas in the center and in the eastern regions in the south of the Strip.

2- An increase in the nitrate concentration than the required drinking water standard in most of the areas in the Strip . This indicates a deterioration in the ecological quality of the aquifer. In spite of the ground water levels in the wells did not decrease and still lower than the desired one . Also in some regions a change in the natural direction of the ground water noticed .

Due to the increase of water demand in a number of wells the domestic water in the aquifer decreases . Therefore, an urgent solutions are needed to overcome the increase in the drinking and agricultural water demand and to improve the environmental quality in the Strip to end the ground water pollution .

2. THE STUDY AREA

For this study, Gaza Strip is divided into areas and hydrological cells, every zone a result of connection and addition of hydrological section (from section 100 north up to section 81 south) and every section divided into cells ; beach cell, eastern reservoir cell and western reservoir cell, part of the eastern reservoir in the study is extended outside the Gaza Strip border , (Fig. 1) .

3. THE STUDY ZONES

3.1 Gaza Zone

It is the area laying extreme north of Gaza Strip , with an area of 100 km^2, and consist of 95 - 100 sections . This area considered as the highest rainy parts of Gaza Strip and have the square zero of the beach cell and the squares 3 and 4 of the eastern cell .

3.2 Gaza Vally (Mogragah) Zone

Consist of 92 - 94 sections with an area of 35 km2 . In this zone the down stream of Gaza valley, the square zero of the beach cell, the squares 1 and 2 of the western reservoir cell and the square 3 of the eastern reservoir cell are present .

3.3 Der El - Balah And Middle Zone

Consist of 87 - 91 sections with an area of 90 km2 and pass through salcka valley . This zone laying on the square zero of beach cell . The squares 1 and 2 of the western reservoir and the squares 3 and 4 of the eastern cell are in the zone .

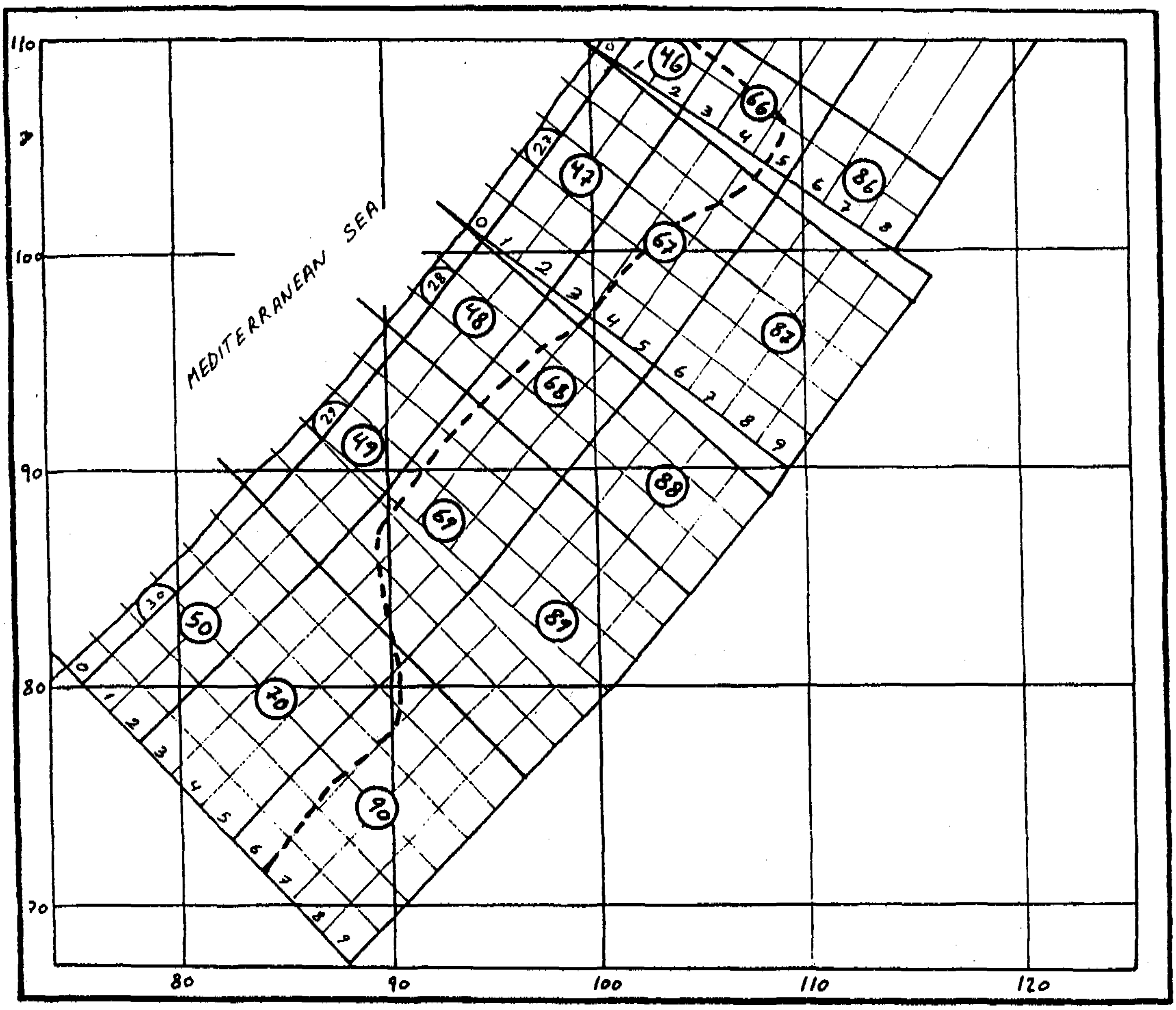

Fig. (1) : Hydrological Cells and Zones of Gaza Strip . .

3.4 Khan - Younis And Rafah (Southern Zone)

Consist of 81 - 86 sections with an area of 140 km2 . It is lying in the eastern south of Gaza Strip and has the squares zero of the beach cell, 1 and 2 of the western reservoir cell and 3 , 4 and 5 of the eastern reservoir cell .

4. AIM OF THE DTUDY

The main purpose of the study is to give a picture about the hydrological position of Gaza Strip for the period between 1970 and 93 , through the data's available about the wells of every cell area of Gaza Strip zones (Fig. 1) . Also this study aim is to evaluate the situation and the changes in the Strip, fined the reasons for water shortage and destruction of hydrological position in the last decade and put the recommendations and suggestions for the aquifer improvement .

5. GEOGRAPHICAL BACKGROUND

5.1 Location

The Gaza Strip is located on the southeastern shores of the Mediterranean area , between Israel and Egypt (Fig. 2) . The total area of the Strip is 360 km2 , its length along the coast is about 40 km and its width ranges from 8 - 12 km .

5.2 Topography

The Gaza Strip forms the western part of the wider southern coastal plain of Palestine . The gently rolling terrain rises from sea level up to an elevation of about 80 - 100 meters on the eastern border .

A line of coastal sand dunes with elevations up to 40 meters above sea level extends from the shore to a distance of 4 - 5 km inland . The line of dunes , which is almost continuous throughout the Strip , is wider to the north and south than in the center ..Inland of the dunes (the soil) are mainly sandy or sandy silty .

The possible hydrologic feature of the Strip is wade Gaza, which runs SE - NW for a length of about 8 km , in the south of the Gaza city, discharging into the Mediterranean. The catchment areas of the wade extends widely to the East, up to the limestone mountains of Palestine ; it has a total area of about 3000 km2 .

5.3 Climate And Rainfall

Laying along the eastern shore of a sea , and at the junction of four geographic zones , Gaza Strip has a semi - arid Mediterranean climate , with mean temperatures varying from 10 - 17 oc in January and 22 - 29 oc in August (Melloul and Bibas, 1992 a). Rainfall occurs only in the winter months, from October to April and the average values of about 400 mm / yr. in the north part to 250mm / yr. in the south of Gaza Strip. Variations in climate, particularly rainfall, do not end with season and location, even greater variations occur from year toyear, with the region lunching from successive year of drought or near - drought condition to other years of rainy condition (more than 400 mm / yr.) . Therefore, for either short - term or long - term water planning, it is very important to have a good understanding of the spatial, seasonal and annual variations in rainfall than of annual or national averages .

The average annual rainfall in the Gaza Strip based on a 30 years' record (1951 -80), indicate an increase from 200 mm / yr. in the south to about 400 mm / yr. in the north of the Gaza Strip. The average monthly and rainfall amount within the period 1931-60, are presented in table (1) .

The evaporation figures for Gaza have been calculated from data published by Ashbel (1970). The latter evaporation data, based on the Piche Method , were multiplied by a factor of 0.70564 to get a yearly total of about 1300 mm (Atlas of Israel, 1985), which is the average annual evaporation of the Gaza Strip in an open water surface. The potential evapo-transpiration (Doorenbos and Pruitt, 1984) in the Gaza Strip is approximately 1300 0.8 = 1040 mm / yr.

Table 1. Rainfall and other Climatic Data of Gaza Strip .

		Temperature (°C)	Evaporation (mm)	Gaza Town Average Rainfall (mm)	Khan Younis Average Rainfall (mm)
1.	January .	13.6	63.4	83.3	56.7
2.	February .	14.0	73.1	55.3	39.2
3.	March .	15.8	94.1	41.2	29.7
4.	April .	18.0	116.4	8.9	6.4
5.	May .	21.3	133.4	3.7	4.4
6.	June .	23.8	135.5	0	0
7.	July .	25.7	137.8	0	0
8.	August .	26.7	137.8	0	0
9.	September.	25.2	124.9	0.7	0.5
10.	October .	22.9	113.7	15.6	9.3
11.	November .	19.8	91.0	70.9	48.5
12.	December .	15.4	78.7	91.8	63.2
	Annual	20.1	1299.8	371.0	258.0

Other climatic data concerning the Gaza Strip :

1- Mean annual rainfall . 200 - 400 mm.
2- Variation in annual rainfall . 95 - 100 mm.
3- Mean annual evaporation from open water surface . 1200 - 1400 mm.
4- Mean daily relative humidity . 70 - 75 % .
5- Mean annual cloudiness . 30 - 35 %.
6- Mean annual temperature . 19 - 21 °C.
7- Mean annual of cloudiest month (January) . 12 - 14 °C.
8- Mean annual oh hottest month (August) . 26 - 28 °C.
9- Mean annual solar radiation (incident on horizontal surface). 189 - 195 Kg cal/cm^3/yr.

Source : Israel Meteorological Service; Atlas of Israel, 1985 .

5.4 Hydrological Condition

Geographic, climatic and hydrological conditions simply provide the backdrop on which the structure of human use of water is presented . In some parts of the world, these conditions allow for sample water availability, but in arid and semi - arid regions, such as that of Gaza Strip , they are ultimately limiting .

The hydrological position of the ground water reservoir of Gaza Strip is an extension of the coastal layer extended from the Ashkelowne area north to Rafah area south of Gaza Strip and from the sea shore west to the Jews settlements; Neram, Nereem, Nahal oz and Kesofeem etc., east (Fig. 2) .

The figures 3, 4 and 5 clears a hydrological layer carrying the water aquifer at the Gaza Strip sea shore, prepared in 1992 by an Israeli experts working in Israel and Gaza . The aquifers consist of a layer of sand, continental clay with some sand, and marine clay with some sand, and in the base consist of marine clay from Niojeen age . The Gaza Strip aquifers consist of a number of sub aquifers composed mainly of sand, sandstone (kurkar), and pebbles of pleistocenian age. In some places the sub aquifers overlain each other and separated by imoervious and semipervious clay layers usually continental deposits and paleosols (Fig. 6) .The upper most sub aquifer (designated A in Fig. 6) lies mainly under the sea bed and extended only a few hundred meters in land, up to 2 km from the shoreline . Sub aquifers B and C is situated below A near the coast line , but rise in an eastward direction according to the natural slope of the geological layers . The lower the sub aquifer, the farther it extends inland from the coast, where the lowest one (C) extends up to 5 km inland . The total thickness of the aquifer layers varies from 10 meters on the eastern boundary to 120 meters near the coast (Melloul and Bibas , 1992 b) .

The eastern end of the aquifer complex extends beyond the boundary of the Gaza Strip. In this region however, the aquifers are thin and saline . The center is underlaid by clayey marine deposits of the Saqiya Formation (Melloul and Bibas , 1992 b). The base of the coastal aquifer system is formed by a series of blue - black shale's of Neogene age, several hundred meters thick. Below the shale's it seems that there is a confined cenomanian limestone aquifer , which contain a very saline water . The top of the aquifer consists of recent dune sands in the western part of the Gaza Strip and of finer continental deposits (sand and loess) in the eastern part beyond, interbedded with paleosols (Melloul, 1977).

6. GROUND WATER

6.1 Ground Water Recharge

The total amount of rainfall on the Gaza Strip (360 km2) is about 110 mcm / yr. (Abu-Maylah; 1990) . Part of this water evapotranspirates from the agricultural farms or is lost by surface runoff and its evaporation . The remainder infiltrates through the soil and recharges the ground water. The infiltration rate (or natural recharge) depends on many factors such as climate, topography and soil type . Sand dunes, as in the western part of the Gaza Strip , have a high infiltration capacity and are a suitable recharge areas . Recharge rates in semi-arid regions are generally low due to the higher potential

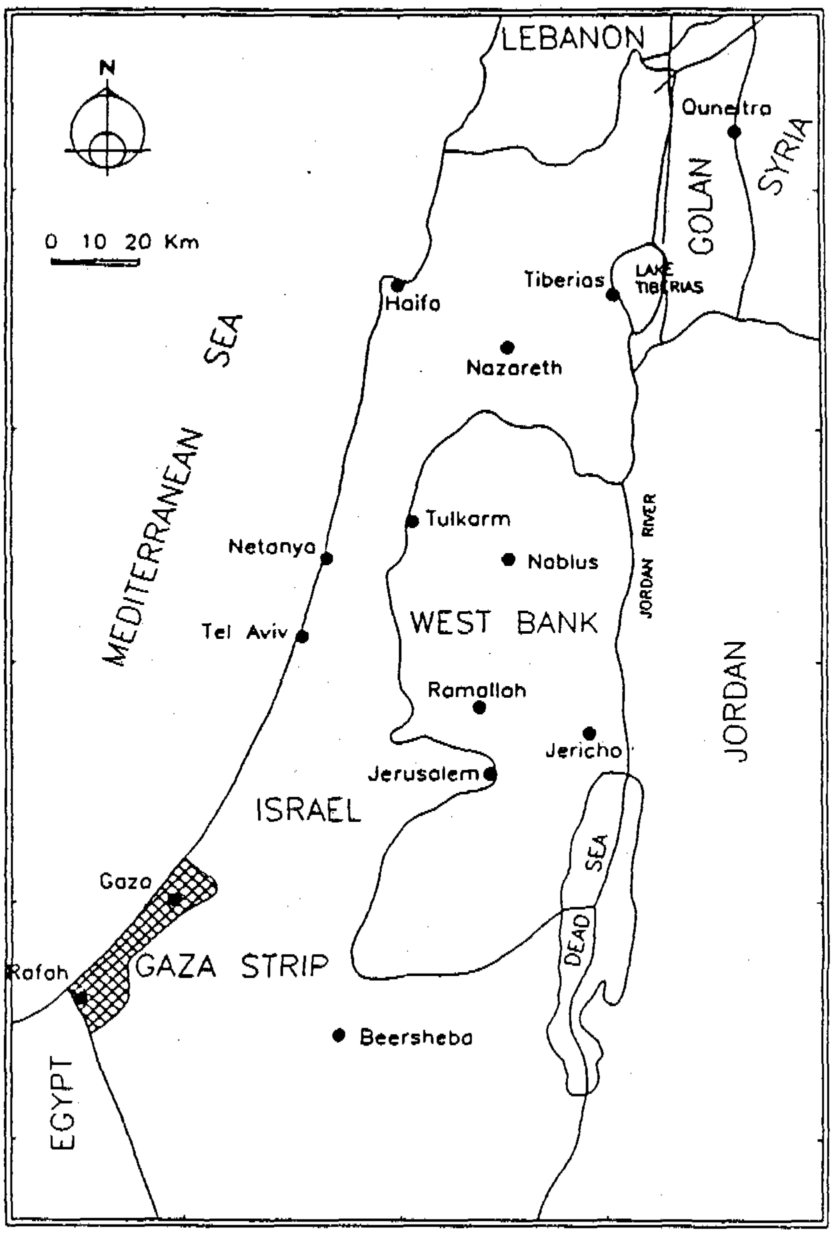

Fig. (2) : Location Map of Gaza Strip .

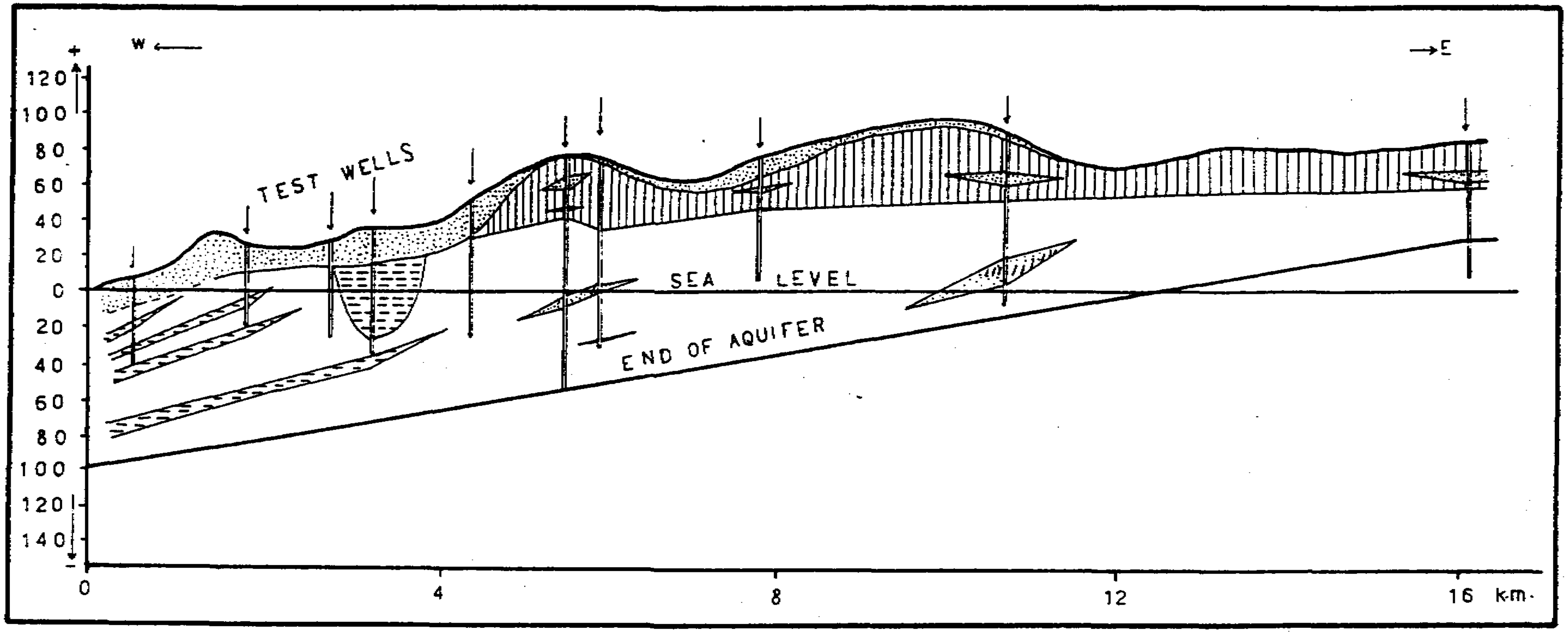

Fig. (3) : Hydrological Cross Section in South of Gaza Strip .

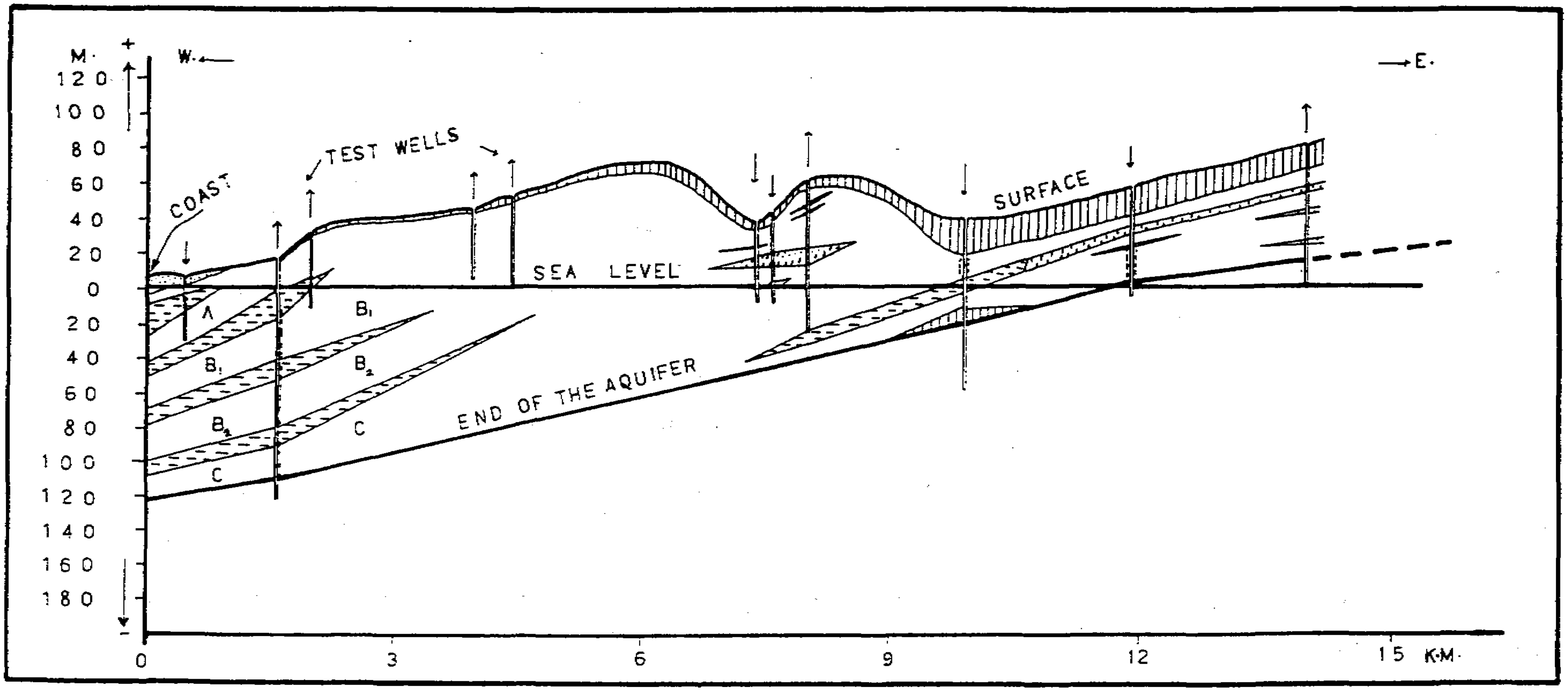

Fig. (4) : Hydrological Cross Section in Center of Gaza Strip .

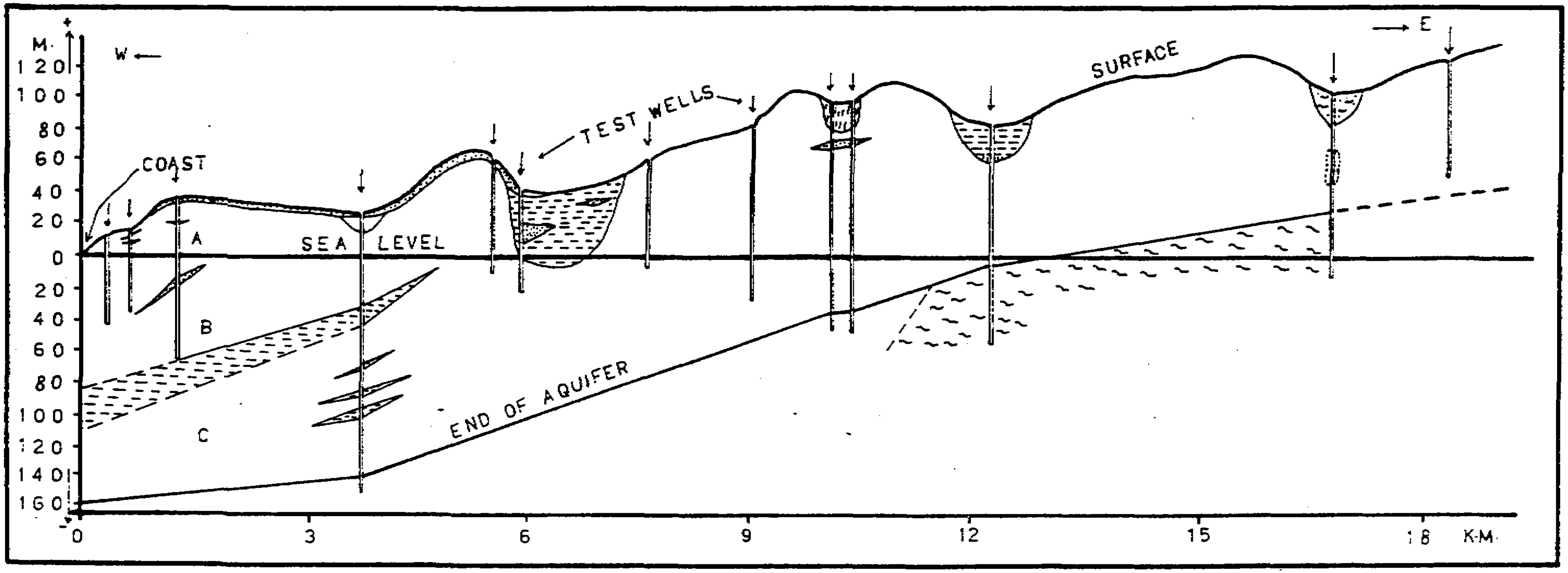

Fig. (5) : Hydrological Cross Section in North of Gaza Strip .

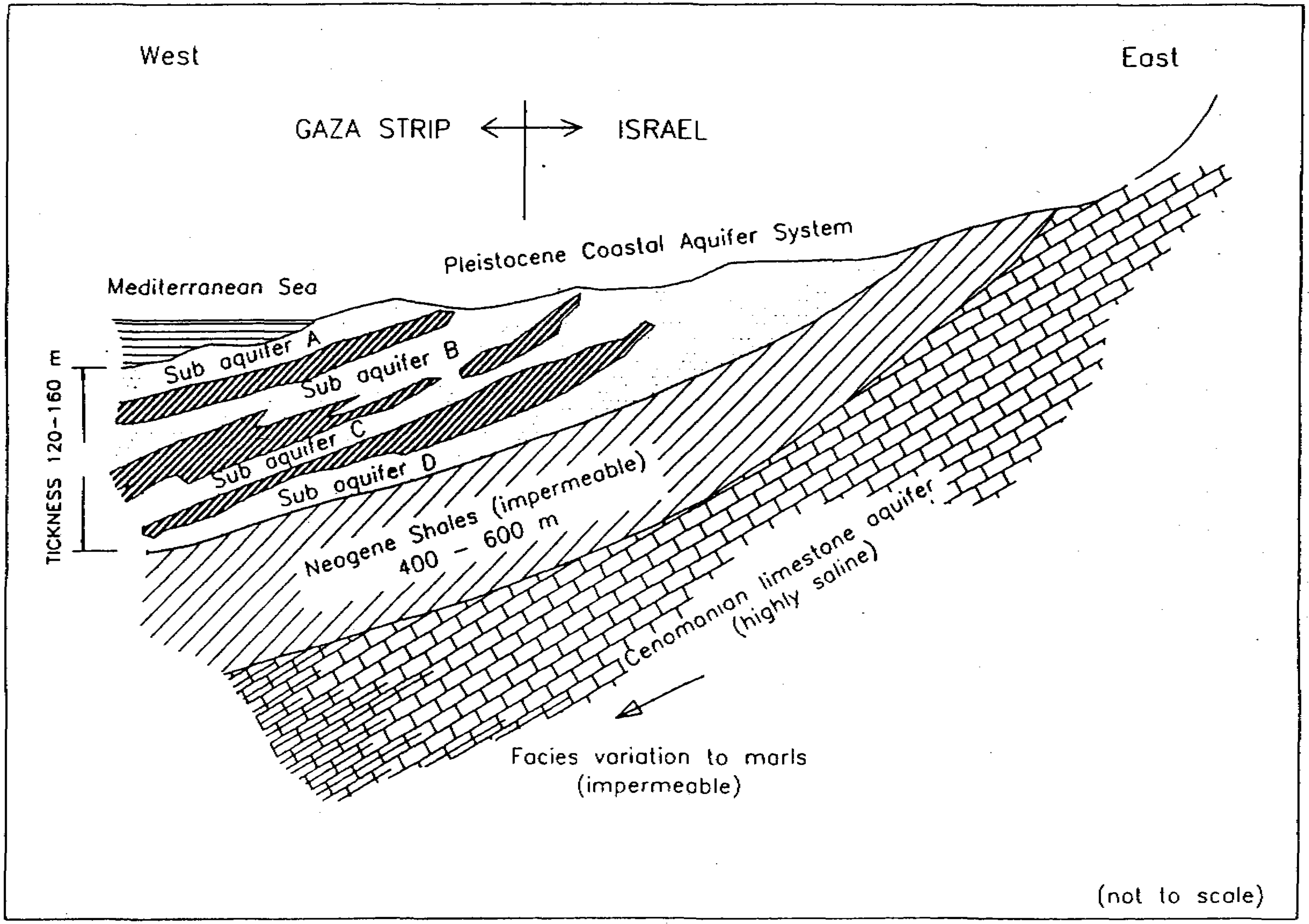

Fig. (6) : **Simplified hydrological Section across Gaza Strip** .

evaporation. The ground water recharge in Gaza therefore is expected not to exceed 25 % of the rainfall (25 mcm / yr.).

Data sources (Schwarz, 1982 ; Coordinator of government operations, 1986 ; Kahan, 1987 and Benvenisiti and Khyat, 1988) indicated a natural replenishment ranging from 40 - 80mcm /yr., but did not clear any background of the figures, these estimations may include ground water inflow from outside the Gaza Strip . According to Schwarz (1982), the present over - exploitation of ground water in the Gaza Strip estimated to be about 30 - 60 mcm / yr. and the ground water declining as a result, (for example) by 0.5 - 2.5 meters during the period 1977 - 82 . Schwarz estimation based on current tends of water use and demographic projections, where there will be a water deficit of 200 - 400 mcm / yr. in the Gaza Strip toward the end of the 1990's.

6.2 Movement And Evaluation Of Ground Water

The most recent pizometric contour map of the coastal aquifer shown in figure (7) refers to spring 1992 . This shows that, in general, the ground water movement from the eastern boundary, where its elevation is around 3 - 7 meters above sea level westwards, to the sea or to large coastal depressions, originated by heavy pumping , where the water level is found about 1 to 2 meters below sea level (The Israeli Government Information) . These depressions act as round water collectors and fervor sea water intrusion, as well as the inflow of saline water (about 600 - 2000 ppm chlorides) that exist in the eastern part of the Gaza Strip and beyond it .

A water level monitoring network established in the area indicates that during the last ten years (1984 - 93), there is a continuous drop in the ground water level throughout the Strip. The general trend is in the region of 5 - 30 mm / yr. and the total being more than 2 mete, as shown in Figure (7), (The Israeli Government Information) .

6.3 Ground Water Extraction

A total of about 2100 wells existing in Gaza Strip are drilled wells with a total depth ranging from 20 to 60 meters, while 400 wells are hand-dug wells, only few meters deep. The present ground water extraction is estimated to be about 120 mcm / yr.

6.3.1 <u>The planned Extraction according to zones</u>

Equations (1) and (2) are the hydrological balance equations; give the permitted withdrawal; where ideally suggested that the aquifer is a homogeneous, unilayer and of same properties .

$$QSP + PP = QE + NR \; B \, PP + S \qquad \text{...}(1)$$

then from equation (1), we get :

$$PP = (- QSP + NR + S) / (1 - B) \qquad \text{..}(2)$$

where :

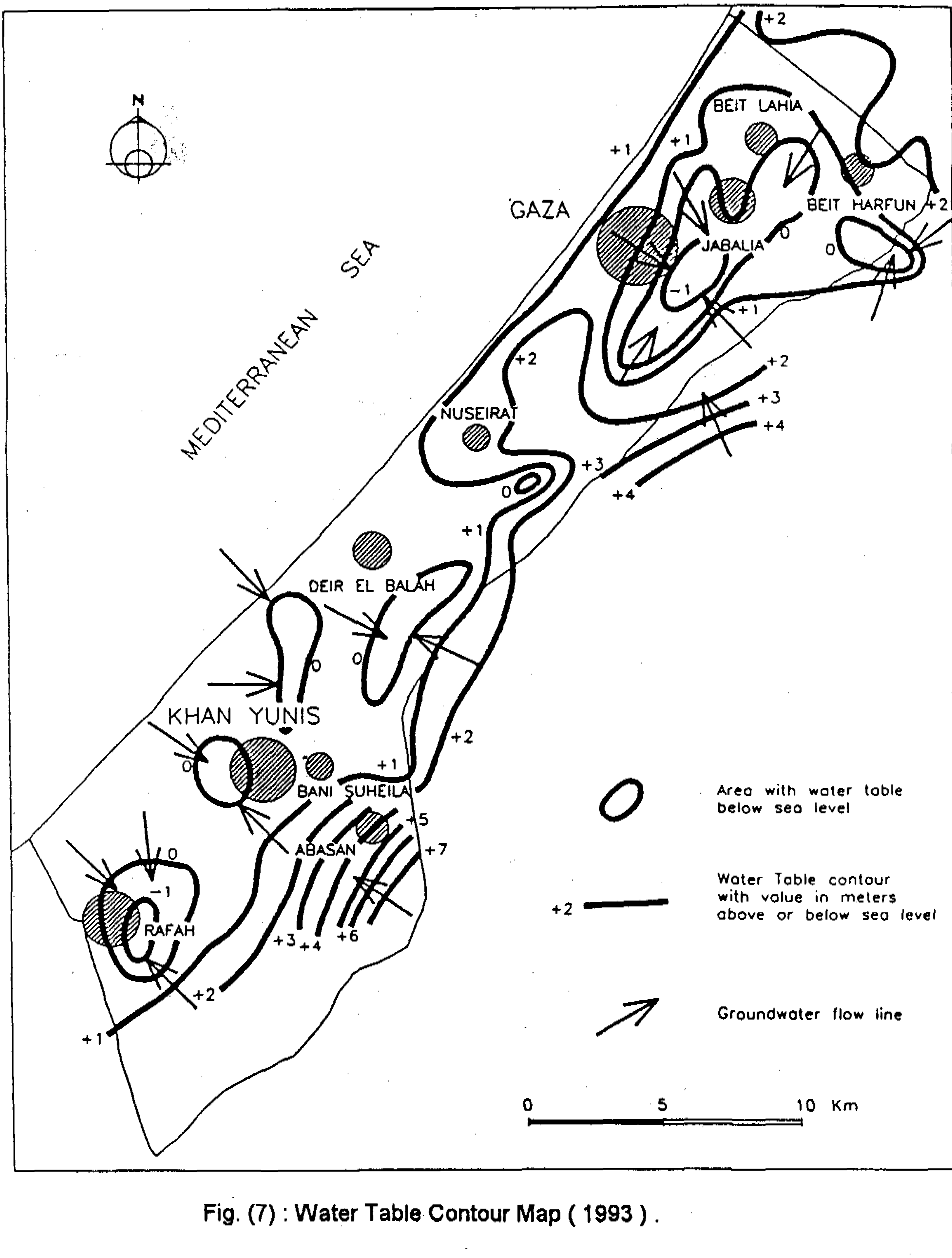

Fig. (7) : Water Table Contour Map (1993) .

QSP	=	planned water quantity moved from the aquifer where these quantities should be extracted from the aquifer .
PP	=	the permitted extract .
QE	=	amounts of water enter the aquifer from the eastern border of the Strip .
NR	=	natural recharge for the aquifer from rainwater (NR = R A X), where ,
R	=	is the average yearly rainfall; A is the natural recharge open area and X is a coefficient .
B	=	coefficient (return recharge by sewage or septic tanks and irrigation water where it is estimated according to coastal situation .
S	=	average water quantity pass to the aquifer from the vallies basin (Bet - Hanoun, Gaza and Salka vallies) .

After applying the data's for every zone of the Gaza Strip in equation (2), we got an average permitted withdrawal value of about 55 mm / hr. ; +- 5 mm / hr. Table (2) shows the permitted withdrawal calculated for various areas of Gaza Strip, where the calculation based on the average recharge quantity for every square .So to stop and prevent the sea water intrusion, the permitted withdrawal should be equal to the recharge for the hydrological balance .

For the evaluation of ground water potential, the recharge of the coastal aquifer systems in Gaza Strip occurs principally by direct infiltration of rain water, return to the aquifer from irrigation and waste water and ground water inflow from the eastern part of the aquifer .

Discharge from the system occurs essentially via pumping wells and, to smaller extent by seaward outflow . According to Netherlands Hydrology Study (1991), the annual ground water recharge is in the order of about 25 - 50 mcm / yr., it constitutes the only renewable source of fresh water and should be the basis for exploitation of the ground water reservoir .

According to a recent water balance prepared by Israeli authorities (Israeli Government Information), the total annual inflow are 80 - 90 mcm / yr. consisting of about 47 mcm /yr. rainfall infiltration (corresponding to about 130 mm / yr. of precipitation over the whole area), 14 - 25 mcm / yr. return from irrigation and waste water and 20 mcm / yr. the average eastern ground water inflow .

However, due to the eastern sub-aquifer inflow being reduced to about 10 - 20mcm /yr., due to pumping of recently drilled wells in Israeli territory . Moreover, the surface runoff of flood water in wade Gaza, that used to contribute largely to the recharge of the coastal aquifer, have been greatly reduced by the construction of diversion weirs in the up stream of the wade .

6.3.2 Over pumping

Table (2) show the permitted, actual and increased withdrawal quantities for various areas of Gaza Strip in the year 1992 / 93. The increased withdrawal is the difference between the actual and permitted quantities and it is considered as the deficit. This study indicates that the actual withdrawal is more than the ermitted value through the year 1992 / 93 in all the areas of the Strip and due to it the yearly deficit increases . Also it indicates that the increased withdrawal of Gaza (north), Der-El Balah (middle) and Khan - Younis and Rafah (south) are approximately of a nearby values because these areas are the highest populated places of the Strip .

For Gaza Strip the total average withdrawal is about 120 mcm /yr., the permitted withdrawal is 60 mcm / yr. and the aquifer is highly inclined from east to west, toward the sea, and slightly inclined from south to north . So most of the water consumption in the coastal area are in he cells (1 & 2) and the cells (zero & 4) of figure (1) .

It is expected that due to the increase of population of Gaza Strip, the water demand increases, where the water deficit and water level in the aquifer decreases. This leads to a reduction in water quality and it will not be suitable, neither for domestic nor agricultural use.

Table 2. The Withdrawal Situation in Gaza Strip, 1992 / 93 .

Area from North - South.	Permitted withdrawal, mcm .	Actual withdrawal, mcm.	Increased withdrawal, mcm.
1. Gaza & north .	26.0	50	24.0
2. Gaza, wade .	5.5	12	6.5
3. Der El- Balah .	8.5	23	14.5
4. Khan-Younes & Rafah.	13.0	35	22.0
Total	53.0	120	67.0

6.3.3 Water level in Gaza Strip

The water level in the year 1993 and its changes are shown in Figure (8), where there are changes in the water levels and hydrological gapes in the areas; Gaza, Der - El Balah and Khan Younis and Rafah . Also the water moves as a radial rays in the gaps away from the sea direction .

In general view to the map of figure (8), we find that there is an unstabilization in the water level with comparing with last 10-15 years situation (Abu - Maylah, 1991) .

7. GROUND WATER QUALITY IN GAZA STRIP

7.1 Salinity (Chliride)

Figure (9) show a statistical picture for the ground water salinity according to zones and locations for the year 1993, and of a 395 locations . The results indicate that around 49 % of the locations have a chloride concentration more than 600 ppm (not suitable for domestic use) and 37 % of a chloride concentration less than 400 ppm (suitable for domestic use). From the figure we find that the good water quality (less than 250 ppm

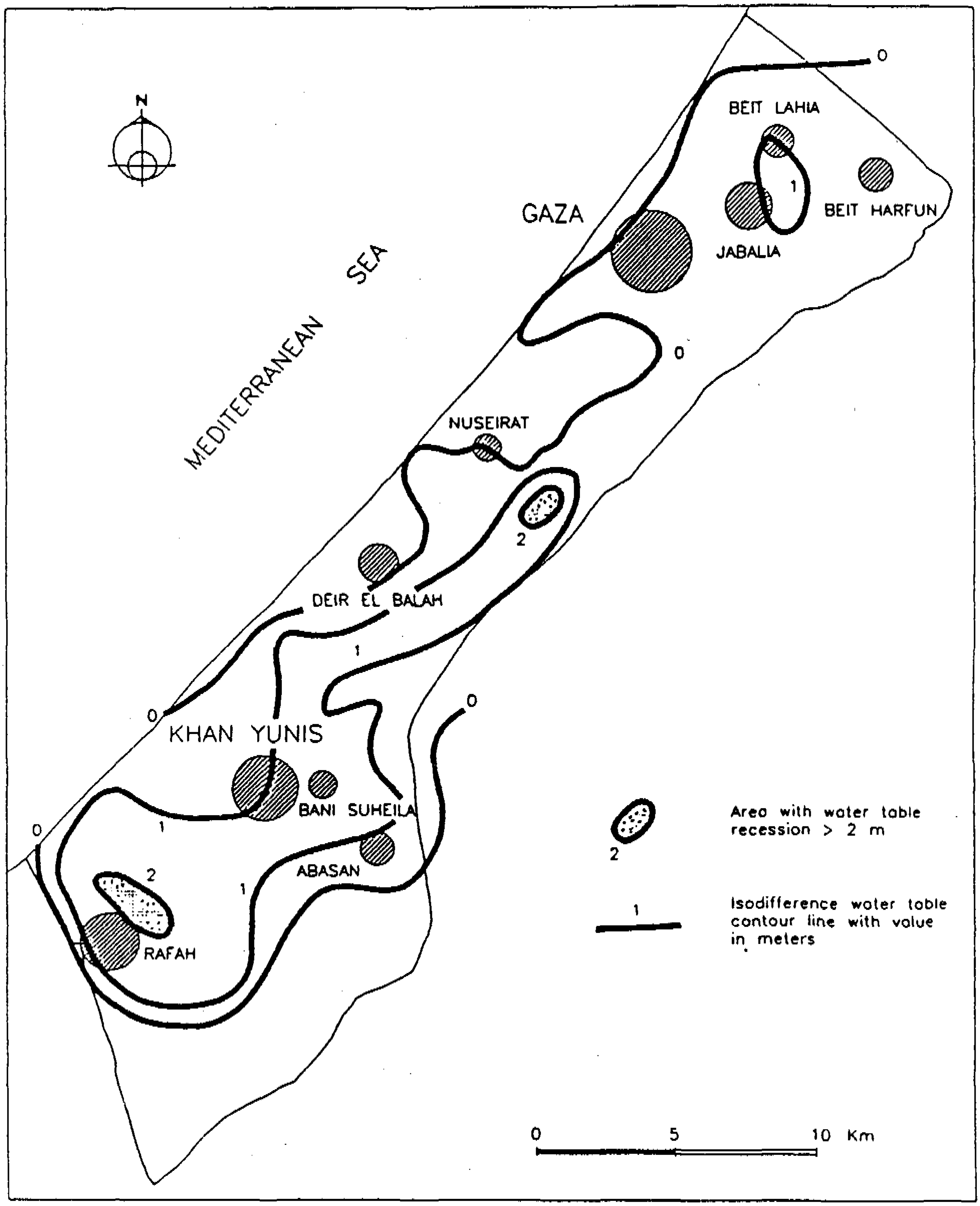

Fig. (8) : Water Table Recession Map (1993).

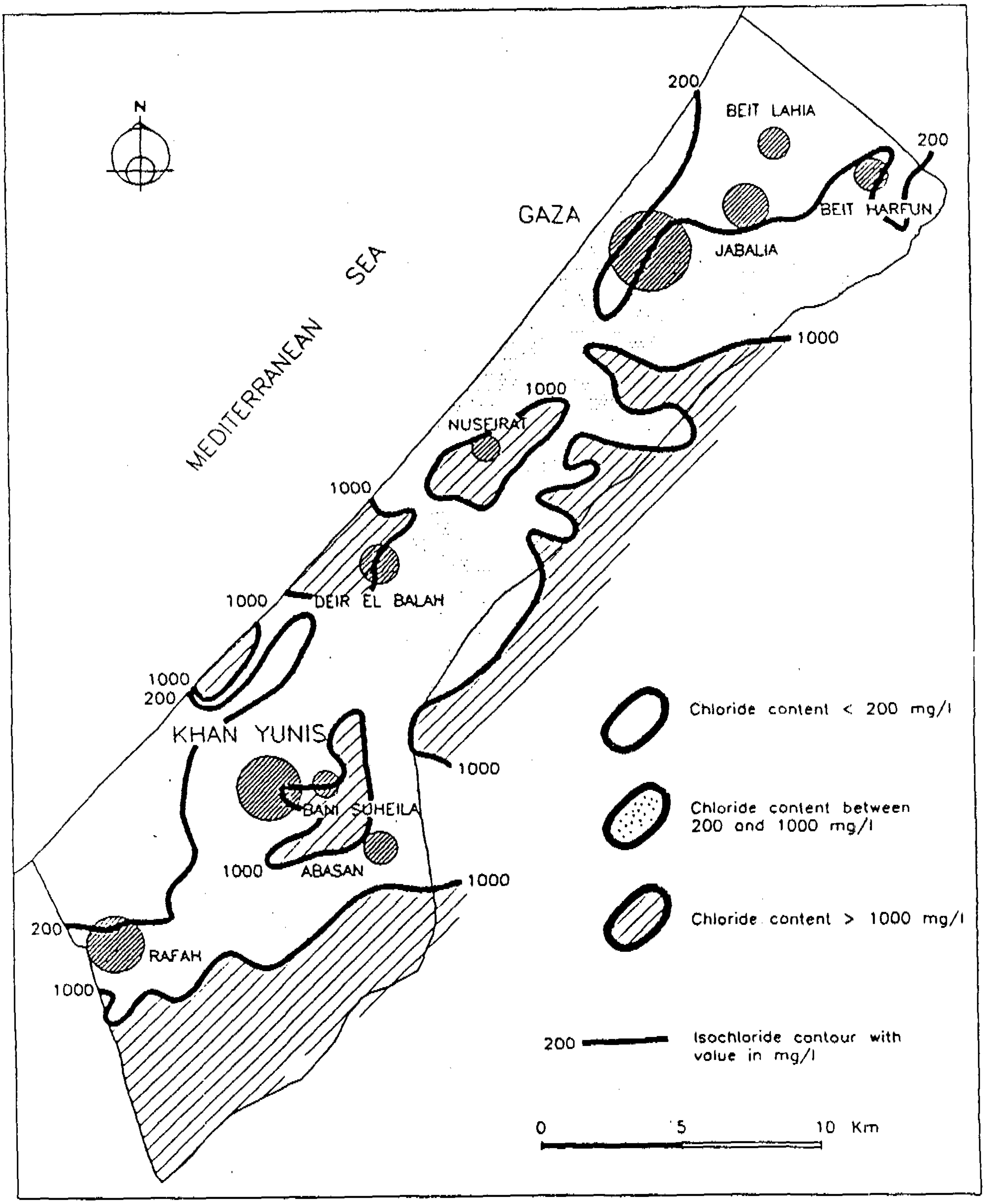

Fig. (9) : Chloride Concentration Map (1993) .

chloride concentration), present in the squares number 100 and 99 north,squares number 84 and 81 west and the parts of wade Gaza and Der El - Balah . But in the eastern and southern areas of the Strip the ground water chloride concentration is very high and is not suitable neither for domestic nor for agricultural use. Table (3) shows the chloride average concentration of about 625ppm, the chloride concentration between a range of 34 - 1522 ppm (in the coastal aquifer) and a standard deviation of 397 ppm .

Table 3. The Hydrological Situation for the year 1992 / 93 .

	Concentration, ppm .		Water level,	Total pumping.	Permitted pumping	Over - pumping
	NO_3^-	Cl^-	meters .	mcm	mcm	mcm
Mean .	102	625	0.37	120	53	67
Min.	25	34	2.47 -			
Max.	383	1522	9.43			
St. Dev.	59	397	1.52			

Therefore, the chemical quality of the ground water of Gaza Strip coastal aquifers varies widely , both laterally and vertically. The uppermost sub-aquifer, especially under the sand dunes, contains good to fair quality water, with chloride concentration ranging from 50 to 200 ppm . However, the quality deteriorates to the east and the chloride concentration increases up to 1000 - 1500 ppm. Some samples of a chloride concentration more than 1000ppm are also encountered in some places near the sea shore. Lower aquifers usually contain very poor quality water of a high chloride concentration increases with depth from 10000 - 20000 and up to 60000 ppm (more three times that for sea water), recorded in exploratory wells completed in the lowermost sub-aquifer, at a depths of 80 and 160 meters above sea level.

The origin of this salty water in the lower sub aquifer and in the eastern part of the area seems to be geological . It was probably the result of natural water existing in the uppermost sub aquifers near the coast and it may be due to the sea water intrusion.

From Figure (9), it would appear that only two relatively small areas in the northern and southern parts of Gaza Strip (coinciding with the two larger patches of sand dunes), of a chloride concentration less than 200 ppm . In most of the areas the chloride concentration is between 200 and 1000 ppm, in the whole eastern part it always exceeds 1000 ppm and a number of the wells near the sea have been deteriorated and out of use where during the last ten years the sea water intrusion reached a distance of about 200 to 2000 meters .

The periodic measurements over the last 10 years (1984 - 93) indicate a steady decline of ground water quality, with a constant increase in chloride concentration at an average rate of 10 - 15 ppm / yr., through, in some extreme cases it was as much as 30 ppm / yr. (Abu-Mailah, 1990) .

The sources of salinity (chloride) are essentially due to the following :

1- Inflow of ground water from the east, which has a chloride concentration of 600 - 2000 ppm .
2- Sea water intrusion from the west .
3- Up-flow of deep aquifer, high salinity underground water .
4- Progressive salivation of the soil due to over irrigation and land surface pollution
5- The mismanagement of ground water use .

These salivation progress have a long term impact as they can be considered irreversible to large extant . If the over pumping is stopped today, it will take many years fore the salinity of the ground water to reach its original level .

The efficiency of the up mentioned reasons increases with the consumption increase . Since the aquifers are connected (or open) to the sea direction, it is expected that there is sea water intrusion into the aquifers . But if the aquifers are not connected to the sea, the salinity source may be due to the saline water basins. Then the intrusion of deep saline water into the aquifers of Gaza Strip means the reduction of the reservoirs sweet water where most of the wells near the salinity source have been affected .

The chloride concentration variations for three areas in the eastern part of the Strip for the period from 1972 - 93 are shown in Figures 10 , 11 and 12 .

The saline water intrusion estimated only for the portion of the aquifers (A, B1 and B2 of Figures 3, 4 and 5), because most of the wells are not very deep and beyond that layers. In the layers A and B1 of the northern part of the Strip (sections 95 and 100) the intrusion reached a distance of about 300 meters and the maximum intrusion is 2000 meters in the middle parts of the Strip (sections 86 and 94) . But in sections 81 and 85, the intrusion is the minimum and about 500 meters . The intrusion in the southern parts of the Strip measured through the wells there and the chloride concentration was about 50 ppm in seventies (Melloul and Azmon, 1990) and 100 ppm nowadays .

It appeared that there is a chloride concentration of about 60000ppm or more in the C layer . This is due to the presence of avery high saline water reservoir under the ground water aquifers and this saline water moves up with the increase of the withdrawn water from the upper aquifers . So if the ground water withdrawals from the upper aquifers continue as it is now for the domestic and agricultural needs, the salinity concentration increases by the previous up mentioned reasons (Abu-Mailah, 1991).

7.2 Nitrate Concentration

Nitrates are considered to be a good indicator for ground water pollution . The nitrate levels for 350 wells sampled for this study are shown in Figure (13) and table (3) . Table (3) indicate that the nitrate concentration is high of the range between 25 and 382 ppm, with an average of about 102 ppm and a standard deviation of 59 ppm . For further information, only 44 % of the analyzed ground water wells have a nitrate concentration more than 95 ppm and 13 % of the samples have a concentration less than 45 ppm with a constant increase of an average rate of 1.5 ppm .

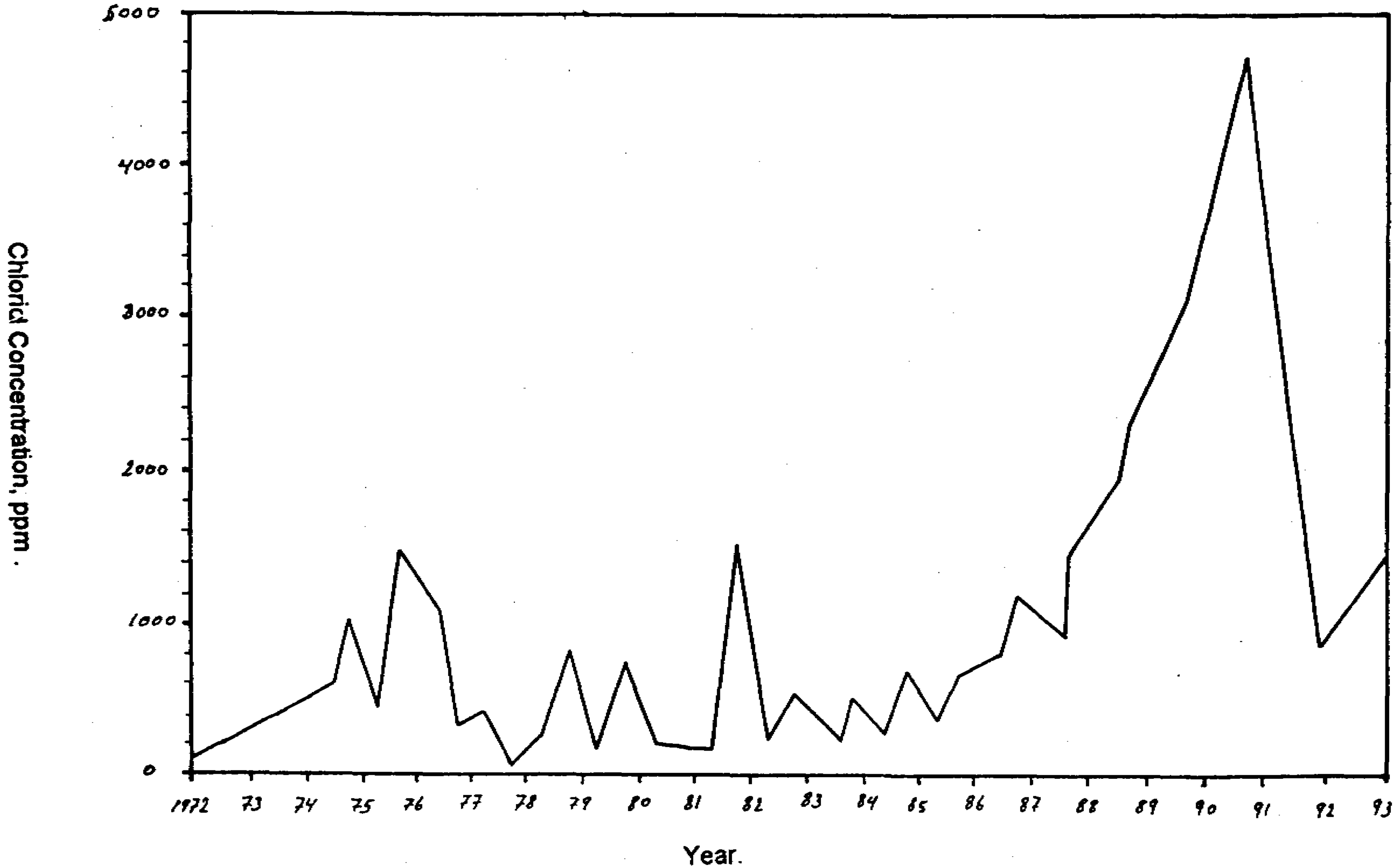

Fig. (10) : Chlor-graph in Section no. (86). see map of fig. (1) .

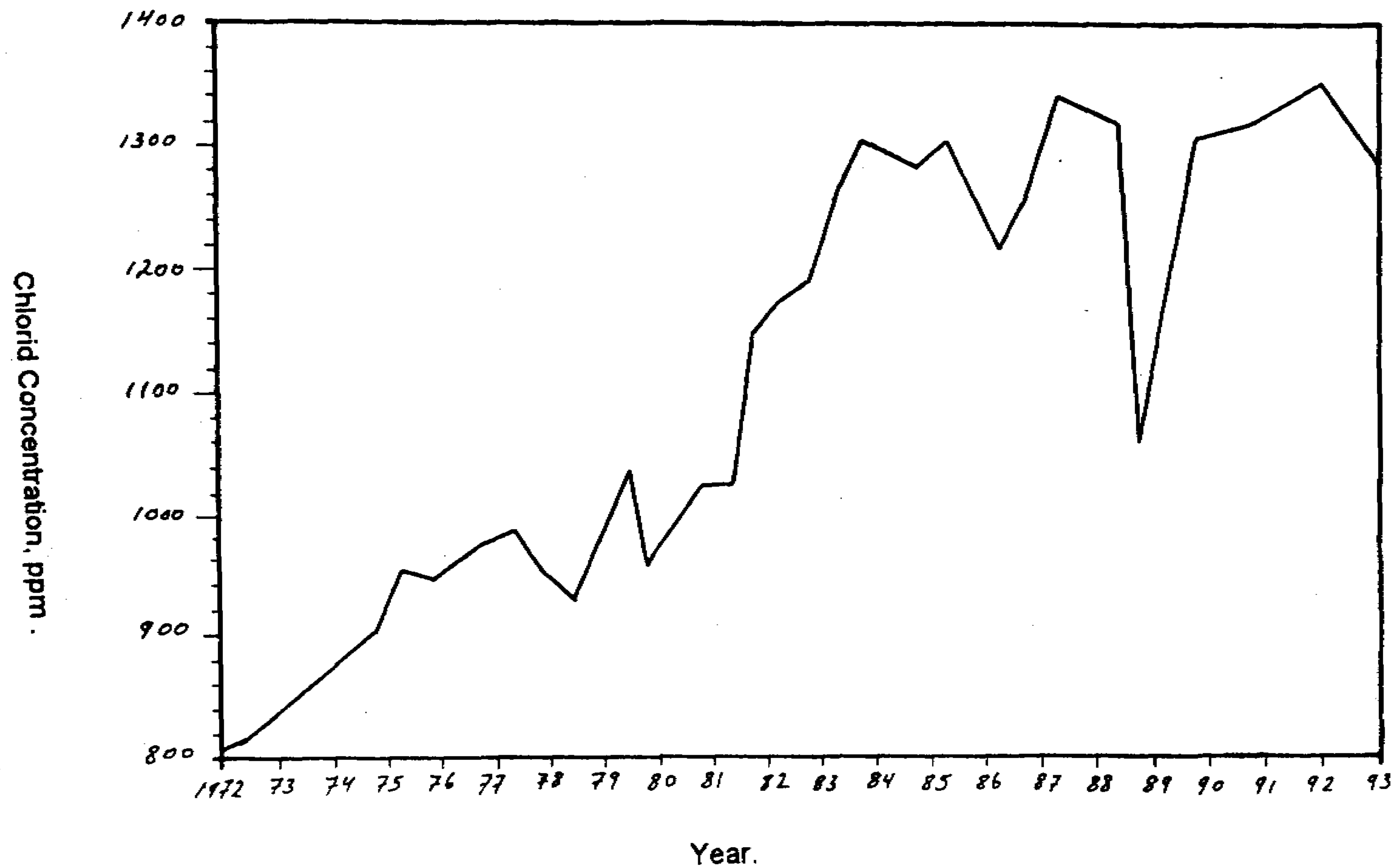

Fig. (11) : Chlor-graph in Section no. (92), see map of fig. (1) .

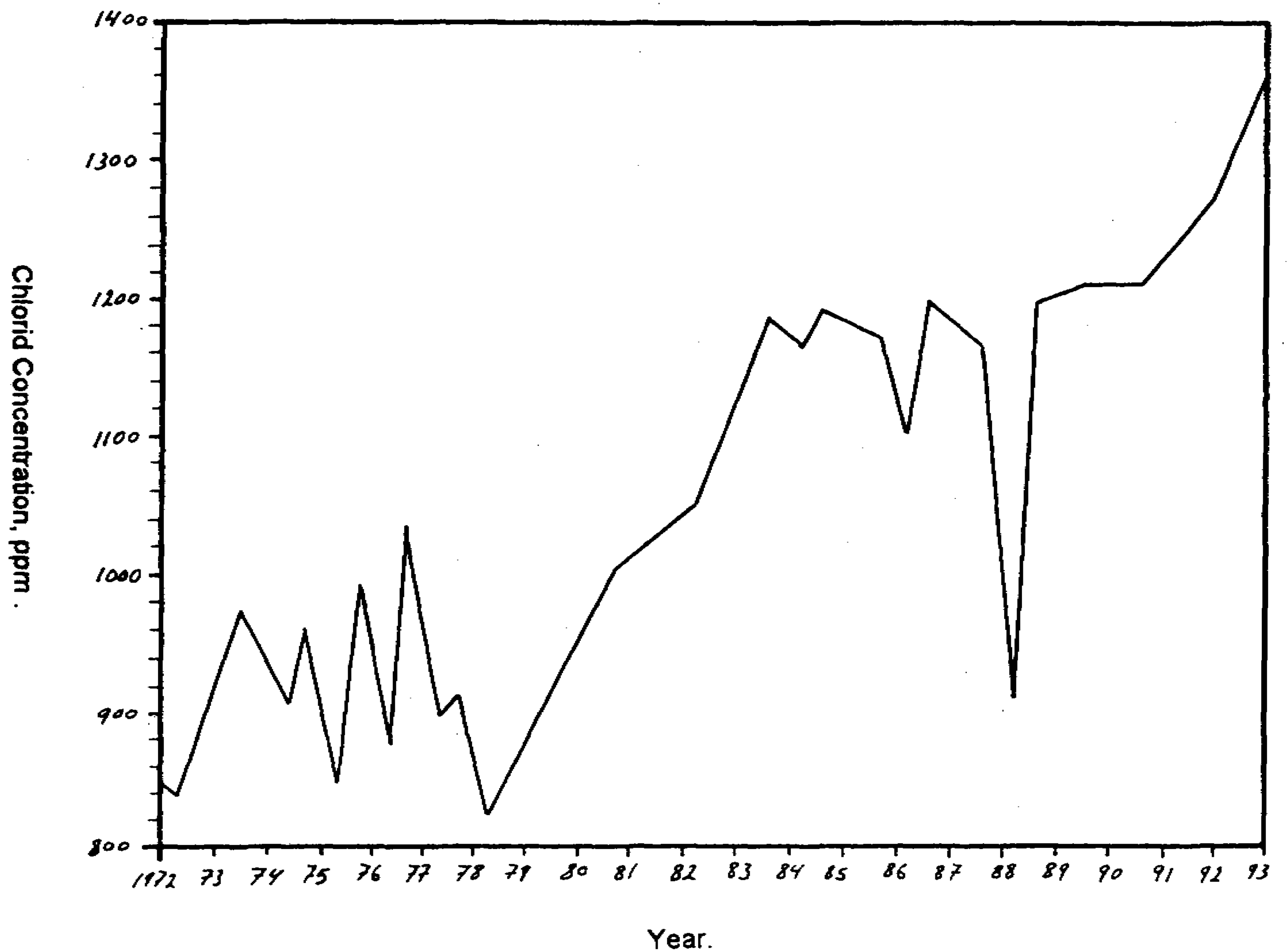

Fig. (12) : Chlor-graph in Section no. (100). see map of fig. (1) .

(T5-S1) 4.22

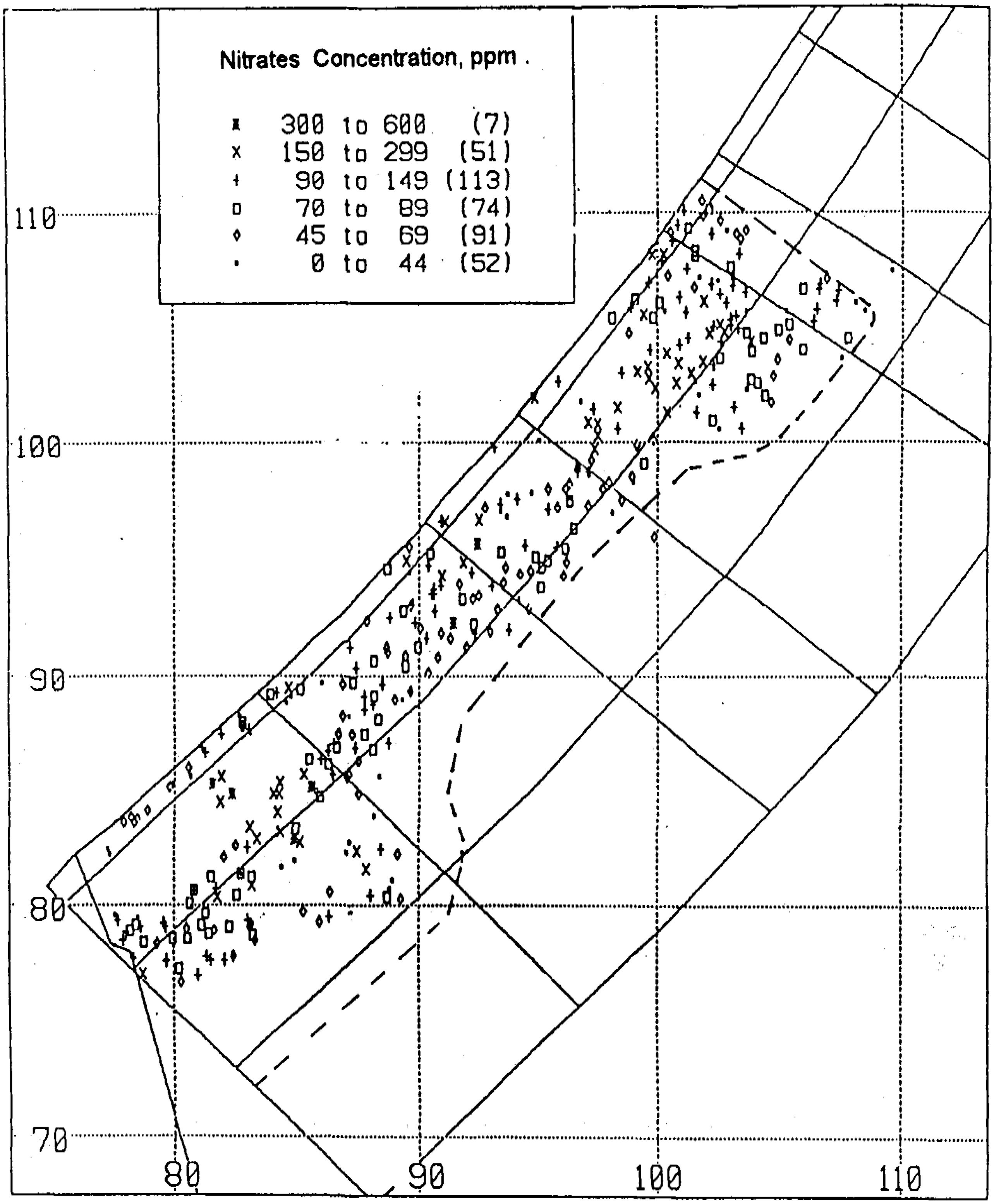

Fig. (13) : Nitrates Concentration Map (1993) .

The high nitrate concentrations throughout the Gaza Strip are probably a result of nitrogenous fertilizer's contamination and infiltration of waste water . Higher values up to 150 ppm nitrate concentration are found in wells located at the refugee camps (highest populated areas in the Strip) and near the agricultural fields .

8. RUNOFF WATER

There are no permanent surface water resources in Gaza strip, like rivers or lakes, but temporary flow of surface runoff due to rainfall is the only source of ephemeral surface water, which may be used through rain water harvesting techniques .

The storm runoff is a function of intensity and duration coupled with the ability of the soil to adsorb the water at a rate sufficient to prevent collection of water on the surface, therefore the type of soil is an important aspect to assess the runoff generating capacity of a certain area . A soil map of Gaza Strip (Figure 14) complied by Ravikovitch (1953) and Dan et.al.(1971) is present .

The sand dunes in the western part of Gaza Strip probably will not yield any surface run-off (soil type 1 of Figure 14), but the soil in the eastern part of the Strip is less sandy, whilst the silt and clay content increases from south to north . Loessial sands at Rafah area generally changes into sandy loess in Der El-Balah area, gradually into loess at west of wade Gaza and north of Gaza city . Clayey loess soil present northeastward Gaza city.

Based on the soil map, it is roughly estimated that one third of Gaza will yield surface run-off and 10 % of the rain water might be " harvested " as run-off .

The only dry river - course traversing the area is wade Gaza, which drains a large part of the northern Negav (3500 km2). However, these wade only carry water 10 - 15 days per year . Due to the construction of dams upstream of the wade (outside the Gaza Strip border), where the flood water are now used in Negav Desert by Israelis, and the water do not reach Gaza Strip, it comes only in cases of excessive rainfall, as occurred in the spring of 1991 . Also there are a number of small wades and vallies within the area that may concentrate runoff water .

9. EVALUATION FOR THE HYDROLOGICAL SITUATION FOR THE YEAR 1993.

To get the final picture about the hydrological situation for the ground water in Gaza Strip, table (3) is established . From the figures of the table we noticed :

1- For nitrate concentration; the average value is about 100ppm, the maximum and minimum values are 380 and 25 ppm respectively and 59 ppm the standard deviation .

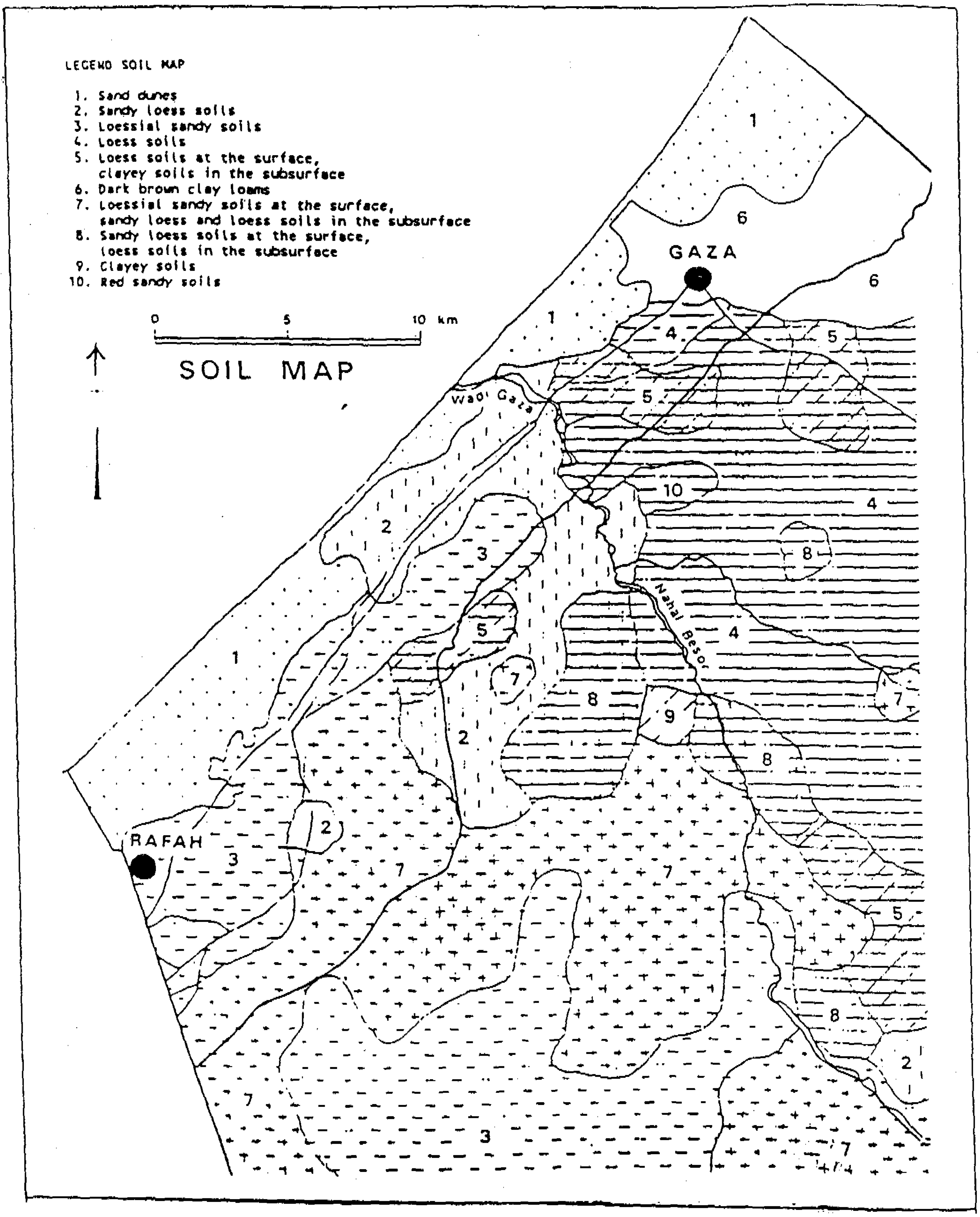

Fig. (14) : Soil Map (compiled from Revikovitch, 1953 and Dam, 1991) .

2- For chloride concentration; the average value is about 625ppm, the minimum and maximum values are 34 and 1520 ppm respectively and the standard deviation value is about 397 ppm .

3- The average water level indicates that the level is low. The average, minimum, maximum and standard deviation values are 0.37, 2.5, 9.5 and 1.5 meters respectively .

4- The withdrawal value during the year 1993 was about 120 mcm, where the increment about 67 mcm .

5- From the previous discussions we conclude :
   a. The average number of wells are not of a good water quality
   b. The good drinking water quality of nitrate and chloride concentrations less than 95 and 270 ppm are present at west Khan Younes, Rafah and limited areas of north Gaza Strip .

10. CONCLUSION

From the previous discussions about the hydrological position in Gaza Strip, the good water quality, ether for domestic or agricultural use, is present only in a limited places of the Strip . The danger starts with the salinity increase to a concentration more than 600 ppm, nitrate concentration increase to more than 95 ppm and the water level less than the required value . This situation is present in the meddle and east of the Strip .

The average water level reduction in Gaza Strip is between 5 - 19cm / yr. This indicate that every year the saturated zone of the aquifers in Gaza Strip reduces by a value of 5 - 10 cm . This reduction affects the water consumption in the east of the Strip, where the saturated zone reduces very fast and the eastern part will be more deteriorated. The saturation zone level reductions near the sea, negatively destroy the aquifers . In the areas where connected to the sea water, like the meddle of Gaza Strip, the reduction of the ground water level lead to the movement of saline water from the deep aquifers . In the first months of the year 1992 and after the heavy rainfall on the area, about 900 mm / yr., it is expected that there will be an increase in the ground water level .

Nowadays there are many areas have a chloride concentration between 400 and 500 ppm . This indicate that after a year, the ground water will not be even suitable for ordinary agricultural purposes . So for the ground water withdrawal fro the aquifer, the following salinity sources should be considered :

1- South Gaza Strip, near the eastern border, there are wells of a very high salinity and the water is not suitable for domestic use and sometimes for agricultural use.
2- Salinity is very quickly and continually increases near the sea.
3- In the inner areas of the Strip, where a high ground water withdrawal; like Gaza, Der El-Balah, Khan younes and Rafah, the salinity concentration increment is not normal and a polluted water reaches the aquifers .

For further information, a complete waste water collection systems are not present in various cities and villages of Gaza strip and there is no any central center for waste water collection and treatment, but there are thousands of percolation pits and septic tanks for the waste water. In the last years there were an extensive use of the chemical fertilizers like phosphorus compounds . Where parts of these compounds passes to the ground water and pollute it and this passage is high because the ground layers are heterogeneous .

After studying the nitrate concentration, clearly 45 % of the ground water are not suitable for the domestic use and the concentration increases by 1.5 ppm / yr. This situation needs more study and attention to find the exact sources for this pollutant and the solution .

In general, the present study summarize a clear picture about the situation of the ground water up to the year 1993 in Gaza Strip. It gave an idea about the ground water quantity, methods of identification of its presence, reasons for the water quality reduction and methods for improvement and stopping the ground water deterioration .

11. SUGGESTIONS AND RECOMMENDATIONS

1- The water awareness by various information systems for the domestic and agricultural uses .
2- In the critical areas where the ground water level and quality decreases, it is better to reduce the water consumption .
3- Improving the irrigation methods and use of modern methods, like land drip irrigation .
4- Reduction in the use of good quality water for irrigation and uses water of less quality .
5- Improve the water management systems of the municipalities .
6- Building up an underground dams against the sea water intrusion.
7- The artificial recharge to the aquifers by the treated waste water and reuses of the recharged water for irrigation . The recharge may be in the areas, where the sand duns . By this method, about 60 % of the domestic water (30 mcm / yr.) wil be reused .
8- Better use for the surface water runoff of wade Gaza and the small vallies, Beet Hanoun and Salqa, by constructing a small dams at some locations of the vallies, where the collected water will be recharged to the ground water to improve its quality.
9- Improve the water balance in a short period by :
   a. Importing water from West Bank, where there are an excess water , this depends upon the political situation .
   b. Sea water desalination, but this method is rejected by the Palestinians because of economical and political reasons .
   c. Closing the wells at the eastern side of the Gaza Strip border, that drilled by the Israelis, where these wells are very deep and withdraw water from the Gaza Strip's aquifers.
   d. Removal of the dams, that constructed at the upstream of the wade Gaza valley in the Israeli side, to allow the storm water pass to the Strip .
   e. There should be a solution and removal for the Jews settlements of Gaza

Strip, because these settlements increase the water consumption of Gaza Strip . where the settlers consume a high quantity of a high quality ground water.

ACKNOWLEDGMENT

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