AFRO-ASIAN CONFERENCE

3-6 December, 1987, Bombay. India.

Integrated Water Management In Urban Areas

3.7 : A.B. Maduskar - Commercial Approach in Water Utilities.

3.8 : C.G. Chandler - Lessons from Urban Water Supply Projects in South Asia.

12.30 p.m. to 1.30 p.m. : **LUNCH**

1.30 p.m. to 3.30 p.m. : **Session 7 - Water for Industry**

Chairman : T.R. Krishnarao, Managing Director, Hindustan Dorr-Oliver Ltd.

4.1 : A.A. Kakkar - Reuse of Wastewater

4.2 : R.S. Ekbote - Wastewater Utilization in Factory Premises.

4.3 : R.G. Deshpande - Control of Industrial Water Demand by Quota System.

4.4 : F.W. Crowley - Recycling of Treatment Plant Waste.

4.5 : R.S. Chauhan, N. Balaji & G.L. Mishra - Seawater as a Source of Augmenting Water Supply.

4.6 : V. Venugopalan & S.R. Shukla - Public Health Engineering : Training Needs in Water Supply and Sanitation Needs.

3.30 p.m. to 4.00 p.m. : **TEA**

4.00 p.m. to 5.00 p.m. : **VALEDICTORY FUNCTION**

Address by : S.S. Tinaikar, Municipal Commissioner, Municipal Corporation of Greater Bombay.

6.00 p.m. to 7.00 p.m. : Programme at Nehru Planetarium

SUNDAY, DECEMBER 6, 1987

Technical Tour — Meeting Place : Khodadad Circle, Dadar, Bombay 400 014.

Departure Time - 7.30 a.m.
Expected Return - 6.00 p.m.

Visit to Maharashtra Industrial Development Corporation's MIDC. BARVI Head Works and Water Treatment Plant at Jambul.

(Tea & Lunch arragements have been made Courtsey : Maharashtra Industrial Development Corporation, MIDC).

AFRO-ASIAN CONFERENCE

3-6 DECEMBER, 1987

NEHRU CENTRE, BOMBAY, INDIA

Organised By :

INDIAN WATER WORKS ASSOCIATION

BOMBAY CENTRE AND INTERNATIONAL DIVISION

PROGRAMME

THURSDAY, DECEMBER 3, 1987

Venue : Shanmukhananda Hall, 292, Flank Road, King's Circle, Bombay 400 022.

2.00 p.m. to 4.15 p.m. : REGISTRATION

4.30 p.m. to 6.00 p.m. : INAUGURATION

6.00 p.m. to 6.40 p.m. : REFRESHMENTS

6.40 p.m. to 8.00 p.m. : CULTURAL PROGRAMME

Dance performance 'NRITYA-GANGA' by Ms. Sucheta Bhide - Chapekar

FRIDAY, DECEMBER 4, 1987

Venue : Nehru Centre, Dr. Annie Besant Road, Worli, Bombay 400 025.

TECHNICAL SESSIONS

9.00 a.m. to 10.30 a.m.: **Session 1 - Water Resources Development - 1**

Chairman : M.A. Chitle, Chairman, Central Water Commission, Govt. of India.

1.1 : U.J. Bhat & J.A. Taraporevala - Tapping of Ground Water from River Beds for large Water Supplies.

1.2 : K.R. Rushton - Conjunctive Use of Surface & Ground Water for Urban Water Supply.

1.3 : J.C. Nardeu - Estuary Reservoirs.

1.4 : F.W. Law & A. Kumar - Bombay Water Supply, Resources System. Simultaneous Hydrologic & Hydraulic Modelling under realistic condition.

1.5 : R.S. Dhaneswar - Protection of Water Intake.

10.30 a.m. to 11.00 a.m.: **TEA**

11.00 a.m. to 12.30 p.m. : **Session 2 - Water Resources Development-2**

Chairman : Dr. Satish Chandra, President, Institution of Engineers (India), Director, National Institute of Hydrology, Roorkee.

1.6 : S.A. Bhanagay - Strategies for Managing Urban Water Supplies.

1.7 : D.K. Dutt - Aquifer Management in Urban Environment.

1.8 : T. Damodar Rao - Exploitation of Sea Coast Aquifier in India.

1.9 : Dr. K.M. Subrahmanyam & V.K. Raju — Integrated Approach to Drinking Water Problem : Case Study of Hyderabad Metro Water Supply.

12.30 p.m. to 1.30 p.m. : **LUNCH**

1.30 p.m. to 3.00 p.m. : **Session 3 - Water Conservation-1**

Chairman : B.V. Rotkar, Member Secretary, Maharashtra Water Supply and Sewerage Board.

2.1 : D.N. Young - Rehabilitation of Water Distribution System in N.W. England.

2.2 : Satish Chandra - Water Conservation for Urban Areas.

2.3 : P.P. Alma Jose - Water Wastage Control - Phillipine Experience.

2.4 : P.T. Gurnani & S.M. Master Reconditioning of the old 900 mm. dia. Kilokri Cast Iron Main in Delhi.

3.00 p.m. to 3.30 p.m. : **TEA**

3.30 p.m. to 5.00 p.m. : **Session 4 - Water Conservation-2**

Chairman : R.A. Khanna, Special Secretary, P.H.E. Department, Govt. of Madhya Pradesh.

2.5 : J. Pickford - Low Cost Water Supply and Sanitation with Special Reference to Urban Areas.

2.6 : S.S. Uluatam - A Simple Cost Optimization Model for Water Distribution System.

2.7 : B.V. Rao & M. Dixit - Simple Method for Design of Water Distribution Network.

2.8 : D.B. Field & H.E. Jordans - The Integrated Approach to Upgrading and Managing Water Supply System.

7.30 p.m. **BANQUET**

Venue : Hotel Sun-n-Sand, Juhu, Santacruz (West), Bombay 400 049.

SATURDAY, DECEMBER 5, 1987

Venue : Nehru Centre, Dr. Annie Besant Road, Worli, Bombay 400 025.

9.00 a.m. to 10.30 a.m.: **Session 5 - Financial Management-1**

Chairman : Dr. Madhav Godbole, Secretary, Finance Department, Govt. of Maharashtra

3.1 : Asian Development Bank - Funding of Development Projects in the Water Supply and Sanitation Sector : The Asian Development Bank Approach.

3.2 : E.O. Okeke - Funding of Urban Water Supply Development Projects in Nigeria

3.3 : M. Seager - Revenue Generation for Water Supply to Low Income Urban Areas : A Need for Innovation.

3.4 : T. Hall - Experiences in the apprisal of Water Supply and Sanitation Projects

10.30 a.m. to 11.00 a.m.: **TEA**

11.00 a.m. to 12.30 p.m.: **Session 6 - Financial Management-2**

Chairman :

3.5 : C.D. Khoche - Multipurpose Project Sharing of Costs.

3.6 : J. B. D'Souza - Cost Recovery in Low Cost Sanitation in Urban Areas.

PREFACE

We are happy to note that this Conference has attracted papers from various parts of the world and the response has indeed been overwhelming. The Technical Papers Committee has had a difficult time choosing papers for presentation at the conference.

The 31 papers which find their place in this publication cover various facets of the subject of the conference and it is hoped that they will prove useful to the delegates attending the Conference as well as to the large number of members of the Indian Water Works Association and others who for one reason or another could not attend on this occassion.

We would like to extend our sincere thanks, firstly, to all the persons who submitted papers for review and to those of our colleagues who participated in the planning, review and printing of the papers. Special thanks are due to the President of the Indian Water Works Association and to the Chairman and Secretary of the Organising Committee for their unstinted support in our endeavours.

MR. YD PENDSE

MR. C NATARAJAN

PROF. CES RAO

MR. V KHANNA

MR V VENUGOPALAN

DR. AD PATWARDHAN

MR SR KSHIRSAGAR

MR AD BHATE

MR PK CHARANKAR

PROF. SJ ARCEIVALA (CHAIRMAN)

OCTOBER, 1987.

TECHNICAL PAPERS

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Section 1 : Water Resoruce Development:

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Sr.No.	Author	Description
2.4	PT Gurmani & SM Master	Reconditioning of old 900mm dia. Kilokri Cast Iron Main in Delhi.
2.5	John Pickford	Low Cost Water Supply and Sanitation with Special Reference to Urban Areas.
2.6	SS Uluatam	A Simple Cost Optimization Model for Water Distribution System.
2.7	BV Rao & M Dixit	Simple Mehtod for Design of Water Distribution Networks.
2.8	DB Field & HE Jordans	The Integrated Approach to to Upgrading and Managing Water Supply System.
Section 3 : Financial Management:		
3.1	SV Juneja	Funding of Development Projects in the Water Supply & Sanitation Sector: The Asian Development Bank Approach.
3.2	EO Okeke	Funding of Urban Water Supply Development Projects in Nigeria.
3.3	M Seager	Revenue Generation for Water Supply to Low Income Urban Areas: A Need for Innovation.
3.4	T Hall	Experiences in the Appraisal of Water Supply & Sanitation Projects.
3.5	CD Khoche	Multipurpose Project - Sharing of Costs.
3.6	JB D'Souza	Cost Recovery in Low Cost Sanitation in Urban Areas.
3.7	AB Maduskar	Commercial Approach in Water Utilities.
3.8	CG Chandler	Lessons from Urban Water Supply Sewerage Projects in South Asia: The Need for Institutional Development .

Sr.No.	Author	Description
Section 4 : Water for Industry:		
4.1.	AA Kakkar	Reuse of Wastewater.
4.2	RS Ekbote	Wastewater Utilisation in Factory Premises.
4.3.	RG Deshpande	Control of Industrial Water Demand by Quota System.
4.4.	FW Crowley	Recyling of Treatment Plant Waste
4.5.	RS Chauvan, N Balaji & GC Mishra	Seawater as Source for Augmenting Water supply.
4.6	V Venugopalan & SR Shukla	Public Health Engineering Training Needs in Water Supply and Sanitation Sector.

SECTION 1

WATER RESOURCE DEVELOPMENT

TAPPING GROUND WATER FROM RIVER BEDS FOR LARGE WATER SUPPLIES

Prof. JA Taraporevala
B.Sc. (Bom & Edin)
Principal (Retired)
Poona Engineering College &
Director of Techn.Edn.
Bombay (Retd).

UJ Bhatt
B.E., S.M.(M.I.T)
Retd. Chif Engineer of
Gujarat & Bombay State
Retd. Chief Engineer,
Gujarat Refinery, *Baroda.*

SYNOPSIS

While utilising usual sources of reservoirs and surface river waters for community water supplies & large industires, reliable ground water confined in phreatic aquifers remained unutilised till 1964. The authors share their experience of tapping this ground water by system of radial collector wells installed in the last 23 years: 37 wells completed, 11 under construtction and 12 investigated. They attach a list of Projects and their costs, and compare, from the case studies for these works if alternative, of conventional sophisticated water treatment plants were adopted. The saving in the cost is considerable for a poor country like India and request that this system may be explored and adopted as appropriate technology by other developing countries. The chief merit is quick realisation of large water supplies (45 to 225 Mld realised in one working season of 8 months). The quality of water remains conformed to the accepted standards (WHO) in all cases.

After independence, India has been able to implement large projects in many sectors such as hydro-electric power generation, irrigation, steel, cements, fertilizers, petrochemicals, electronics and atomic energy, to name only a few. It is a prerequisite for all these projects to have large quantities of water as one of their most important infrastructures. For most of these plants, India has tapped water supply from storage reservoirs or rivers and used it after sophisticated water treatment to bring the waters to the quality standard required. Also for community water supplies and industries, leading Corporations like Delhi, Bombay, Bangalore, Hyderabad and Calcutta have installed latest water treatment plants to conform to the potable water standards prescribed by the Ministry of Health. In the changing world many countries have attined independence in the last 50 years, and the technocrats are as a result concerned with the rapid development of their economy. The engineers and technicians all over the world are now trying to think on the lines of developing "appropriate technology" alongwith the conventional systems suitable for their environments, and using as far as possible indigenous materials available to them and simple in operation. In India, we have harnessed our water resources from the magnificient river system coming from Himalayas like Bhakhranangal, Hirakund (Mahanadi), Damodar Valley etc. and also in the South from River Kaveri, Tungabhadra, Krishna and Godavari. There is also a proposal by our late, eminent engineer, Dr.K L Rao, for developing a water grid, connecting Northern rivers like Ganga with Southern rivers to Narmada in the centre and Kaveri in the South. This is technically feasible and must be exploited. We also welcome the National Water Policy so that development is not hampered by artificial geographical boundary of the States and regions. But, we have not been able to put our mind seriously to another important source that of ground water. That is why the second author, as Engineering-in-chief of the Gujarat Refinery, for the first time in 1964 adopted the system of Radial Collector Wells in India, for large supply of 90 Mld (20Million Gallons per day) for the requirement of Gujarat Refinery and Gujarat State Fertilizers Co. Ltd., near Baroda. Since then, it is gratifying to note that this system has proved attractive all over the counrty as would be seen from the Table attached (Appendix - A) showing locations and costs of Radial Collector Wells constructed where large water supply schemes have been carried out in India. Encouraged and inspired by the successive operation of more than 37 such water supply schemes, operating since last 23 years without any trouble and eleven wells under construction, the authors are glad to share their experience with the profession.

There is nothing new about the system of Radial Collector Well, as it is the improved and modified form of Ranney well system, and is also an evolution of the collector galleries in the phreatic aquifer and has been practised in India in the South for many years. However, its application for large scale industries and large cities for community water supply, was first introduced in 1964, for the water supply of Gujarat Refinery. This system is also applicable for the rural water supply for drought-prone areas, as we have designed for the North Gujarat Water supply from river Banas.

From the list we may enumerate the main works categorywise.

1. Community Water supply for -
   (a) Delhi Water & Sewerage Board
   (b) Ahmedabad Municipal Corporation
   (c) Baroda Municipal Corporation
   (d) Surat Municipal Corporation
2. Large Scale Industries Like -
   (a) Gujarat Refinery
   (b) Gujarat State Fertilizers Co Ltd
   (c) Gujarat Electricity Board
   (d) U P State Electricity Board
   (e) Texmaco - Yerraguntla South
   (f) Ballarpur Paper Mills - Maharashtra.
   (g) Scheme for supplying drought-prone areas of important part of Saurashtra and Gujarat by 5 Radial Collector Wells equivalent to 50 MGD from the Narmada basin, below the proposed Sardar Sagar Reservoir.

It will be seen that India offers grand potentialities for abstraction of large quantities of water for community water supplies for cities, groups of villages and large industrial undertakings. According to the last census (1981) there were more than 150 cities with population between 100,000 and 20,00,000. India is also fortunate to have number of large rivers in alluvium soil like the Indo-Gangetic plain, covering the States of Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal; Brahmputra basin in Assam, Mahanadi basin in Orrisa, Coastal Andhra Pradesh with river basins of Krishna, Godavari; Tamil Nadu with Nyveli Tamraparni etc., Kerala, Maharashtra particularly Vidarbha portion, Gujarat with basins of Tapi, Narmada, Mahisagar, Sabarmati and Banas and parts of Rajasthan.

The authors had shared their experiences with the engineering profession by their paper contributed to World Congress International Water Resources Association in 1975. It was conveyed that the first large water supply of 90 Mld (20 M.G.D.) by radial collector well in 1963 in Gujarat was adopted not only because it was economically the best, almost being half of the cost of the surface water supply from the river Mahisagar with conventional water treatment, but primarily because this system was the only method affording realisation in a short period. Compared to the other methods scheduled for 30 months, this water supply was achieved within 11months! The first well in 6 months and the second well in the next 5 months. This helped the Gujarat Refinery to fulfil its Time Table for the completion of whole project.

After completion of Gujarat Refinery the authors formed Consultancy organization concentrating on designing of water supplies, on similar lines elsewhere promoting economy and expediency. It is no small gratification for the authors that in the period of 21 years, the system has been adopted all over the country and by now, more than 36 large water supplies have been achieved throughout the country.

Every year, large parts of the country are affected by floods and equally large parts in other areas suffer from drought, as it is evident from last year and also this year's experience. While U.P., Bihar and part of Bengal experienced unprecedented floods, Orisa, Maharashtra, Rajasthan and parts of M.P. and whole of Gujarat are expepriencing severe drought. As Engineers, we all would like to see blue prins ready for emergency water supplies and the permanent solution for the recurring drought, particularly as regards drinking water supplies. To quote from our own experience, one of the worst ever draught affected Ahmedabad in 1972. The water supply crisis was averted just in time by the construction of first radial collector well in th river Sabarmati, when most of other sources had dried up. That year Sabarmati river was dry on the surface from the month of March when the sub-soil water level was 1.5 mts. below river bed. As the Municipal corportion decided to supply water on water on war footing, the radial collector well was started in November and water supply was available in good time, and successfully averted the crisis, at the peak of hot weather by May. The Corporation authorities saw the merit. They were convinced by three year's experience by saving of Chemicals for water treatment etc., the entire cost of the well was recovered in a short period of 3 years. The Corporation, as a result, decided to install radial collector wells for the further replenishment of city's water supply and it will be of interest to know that the Corporation has constructed four more wells, each of 45 million litres per day (10 MGD) capacity. Taking a cue from this, the Ahmedabad Electricity Co for their Thermal Power Station also constructed radial collector well for their expansion programme. The Gujarat Electricity Board for their Thermal Power Station at Gandhinagar, 25 kms. north of Ahmedabad, installed two radial collector wells in river Sabarmati and have just started a third well for their expansion after satisfactory performance of the present water supply.

In Mahisagar river, near Baroda, convinced by the performance of two wells of the Gujarat Refinery the Municipal Corporation installed the first well in 1969. Satisfied by its functioning they constructed another well of 10 MGD capacity in 1979. They are thinking of third well now to avert crisis of recurring draughts. Gujarat State Fertilizers also situated near Baroda, and the Gujarat Refinery, added one more well of this type each for their expansion programme and the Gujarat Refinery have just now launched on the project of the fourth well. The Indian Petrochemicals Corporation Ltd., a large Public Undertaking, also near Baroda, had achieved two such wells in 1973. They are planning to install an additional well now. However, another most significant fact is that, Delhi Water Supply & Sewerage Board had launched the project of six wells in 1965, and after satisifcatory performance by this system, have since then added ten more wells, bringing the total to 16 wells, in the Yamuna basin. The Water supply replenishment in Delhi which had to be done expeditiously for the 'ASIAD GAMES', was also fulfilled by construction of radial collector wells in good time.

The U.P. State Electricity Board have done two wells for their Thermal Power Project at Tanda from the Ghagra (Ganga basin). They have launched on two more wells for further replenishment.

The State of Gujarat has utilised the alluvium strata of all the main rivers, starting from Mahisagar going to Sabarmati, Tapi and now Banas. The present water supply of Surat city is being replenished by construction of two radial collector wells in river Tapi each of 9.0 MGD capacity. One well is under completion and another will be ready in 'December 1987. The Krishak Bharati Co-operative Ltd., for Hajira Fertilizers Complex have also received Feasibility Report for two wells each of 10 MGD and third of 5 MGD, a total of 25 MGD from river Tapi.

This system of radial collector well would also be applicable with profit to the Rural Water Supply for scarcity areas and 'No-Source Villages'. Gujarat Water Supply & Sewerage Board are contemplating to adopt this system for their 'No-Source Villages' in Radhanpur in North and chain of villages in Bhal near Vallabhipur. We are looking into the problem of other 'No-Source Villages' of Gujarat by this quick and reliable system of water supply. The other states can with profit keep blue prints ready for the chronic drought areas, if rivers with suitable alluvium are available in the the vicinity. The investigations have established the feasibility of water supply for such areas near Agra, in Utter Pradesh.

The West Bengal Govenment have constructed two wells and are looking for more locations in the Damodar basin. Assam, of course, is full of alluvium suitable in the Brahmaputra basin and yet this remains to be tapped.

Both Tamil Nadu and Andhra Pradesh are full of water bearing strata and have potentialities. We have constructed one well at Yerraguntala in Andhra Pradesh. Perhaps, it is not known that Tamil Nadu in historical times have had large number of water supplies from infiltration galleries. The galleries are the predecessors of radial collector wells. The Neveylli basin, the Tamraparni basin, and areas in North of Madras would prove good sources and yet, Madras, the capital city with a population of five million suffered severe drought in regard to drinking water, twice in the last decade. It is gratifying to know that the solution of sharing Krishna water, is now a reality. This is bound to take time in realisation. Certain intermediate solutions could help. From the exploration, about 20 Kms. to the North, there is good alluvium which can be profitably harnessed for such interim purposes.

As regards Haryana, Punjab, there are excellent sites available and we might look with confidence to satisfactory solution of water supply for the proposed capital of Haryana State by installation of radial collector wells.

Similarly, excellent sites are available in river Tavi for Jammu, the winter capital of the State of Jammu and Kashmir.

The investigation necessary and other hydraulic features of the scheme are outlined in a joint paper by the authors[1]. This may please be referred to for details. A schemetic diagram is attached of Radial Collector well Appendix C. The authors would like to emphasize the main advantages of the system which has proved economical and is the most expedient, as it affords large water supplies of 10 to 121/2 mgd, in one working season of 8 months. The other advantages are -

1. The quality of water abstracted by this system remains the same as the water comes filtered through a deep natural bed of sand and gravel. Public Health Engineers know that the quality of water treated is best obtained by slow sand filtration.
2. There is a natural filter simulated around the horizontal slotted radial pipes which ensures removal of both turbidity and inorganic impurities and also organic impurities. This has been established by test of water carried out daily by reliable laboratories of the Gujarat Refinery, Indian Petrochemicals and at Municipal Corporation of Baroda, Ahmedabad and Delhi. The quantity also remains unchanged. It will not be out of place to mention that the quality and quantity both deplete and deteriorate, in case of tubewells, as experienced in the State of Gujarat in Mahasana District and Baroda over last 50 years.
3. The radial collector well taps water hitherto neglected in our country from the sub-surface of river alluvium which would otherwise flow eventually into sea. This would be precious addition to our utilisable water resources.
4. Compared to tubewell water supply, it is feasible by this system to obtain large quantities of water from a central spot.
5. It works out, thereofre, far more economical in the first cost and running expenditure due to centraliseed maintenance, eliminating long line of electrification and connection of numerours tubewells separated by long distance requiring separate houses for maintenance staff, land acquisition etc.
6. The pumping costs are reduced as the lift in the case of Radial Collector wells is no more than about 15-20 mts. In a majority of cases for Tubewells, it is 30 m. if not much more.
7. We have made case studies for several water supply schemes where we have installed radial collector wells and as a sample we give the latest case study for water supply from river Tapi for Surat (Appendix B1 & B2). From the table Appendix 'A' attached, it will be seen that compared to the other system utilising sophisticated water treatment the cost is reduced by atleast twice or more, sometime thrice. The actual total cost of water supply by Radial Collector Wells is Rs.1883 lacs. Other alternatives would cost Rs.4832 lacs (i.e. 2.70 times the cost of Radial Collector Wells).
8. The operation of the system is simple and trouble-free. There have been no complaints regarding the functioning of this schme from any of the clients so far.

It is hardly necessary to point out that engineers are aware that the total cost of a project should comprise of the first cost plus capitalising of amortisation, operating and running and interest costs. It becomes evident, therefore, that where the conditions are favourable, such as suitable composition of aquifier and where there is sufficient water in the river basin, the experience of 23 years with 37 projects, has proved that there is no method of water supply that can compete in economy and expediency with this system. Would it, therefore, not be incumbent on professional engineers to consider this system along with other alternatives, while designing new water supply projects?

In conclusion, the authors would like to emphasize that the system is a glorious example and demonstration of apropriate technology suitable for Indian and other developing countries for large water supplies because it can be achieved hundrd percent indigenously at least overall cost and in the shortest possible time.

REFERENCES

1. *Prof. JA Taraporevala and UJ Bhatt "Source of Water supply from Sub-surface of Rivers in India" Proceedings Second World Congress International Water Resources Association in December 1975. Volume III Page (267-275).*

2. *UJ Bhatt "Presidential Address". The Indian Water Works Association Annual Convention, Bombay 1973.*

3. *JA Taraporevala and UJ Bhatt Ground Water and with Special reference to Radial Collector Wells, Journal of Indian Water Works Association - January - March, 1974.*

4. *L Huisman."Ground Water Recovery" The Macmillan Press, London, 1972.*

APPENDIX 'A'

List of Projects completed and under construction showing cost of water supply by Radial Collector Wells Vs Cost of the same by Conventional Water Treatment if adopted.

Sr. No.	Name of the Project	Client	No.of wells completed	No.of wells under const.	Cost of wells completed in lacs.	Likely cost if alternative sophisticated treatment of water is adopted Rs. in lacs.	Region	Year of construction
1	2	3	4	5	6	7	8	9
1.	Water Supply Replenish -ment 10 MGD from river Mahisâgar a well, bridge, pipeline & pumping stn.	Baroda Mun. Corpn.	2	-	140	350	BARODA GUJARAT STATE	(i) 1968 (ii) 1981
2.	Gujarat Refinery	Govt.of India	3	1	126	346	BARODA GUJARAT STATE	(i) 2 1963-64 (ii) 3rd 1978
3.	Replenishment of Water 8 MGD from river Sabarmati including a well, bridge and pipeline.	Ahmedabad Mun. Corpn.	3	1	145	350	AHMEDABAD GUJARAT STATE	(i)1 1973 (ii)2 1980 (iii)2 1983
4.	Augmentation of water supply of 20 MGD from river Jamuna basin by Radial Collector Well.	Delhi Muni. Corpn.	13	3	374	900	DELHI DELHI STATE	(i) 6 1966 v 1 1978 (ii) 2 1972 vi1 1984 (iii)2 1974 vii2 1985 (iv) 2 1976
5.	Water Supply 20-25 MGD by two Radial Collector Wells including bridges, pipeline & Pump House from river Mahisagar.	Indian Petro-chemicals Corpn. Ltd.	2	-	102	226	BARODA GUJARAT STATE	(i) 1978
6.	Water Supply 16-18 MGD from river Sabarmati at Gandhinagar for Thermal Power Station. 2 Radial Collector Wells including bridge & pipeline.	Gujarat Elec. Board	2	1	112	300	GANDHINAGAR	2 1980
7.	Water Supply 10 MGD from river Tapi for expansion of Thermal Power Station	Guj. Elec. Baord	-	1	-	-	SURAT GUJARAT STATE	
8.	Water Supply - Dalla - 2.5 MGD from river Sone including Well & Pump House	U.P. State Cement Corporation Ltd.	1	-	8.2	20	UTTER PRADESH STATE	

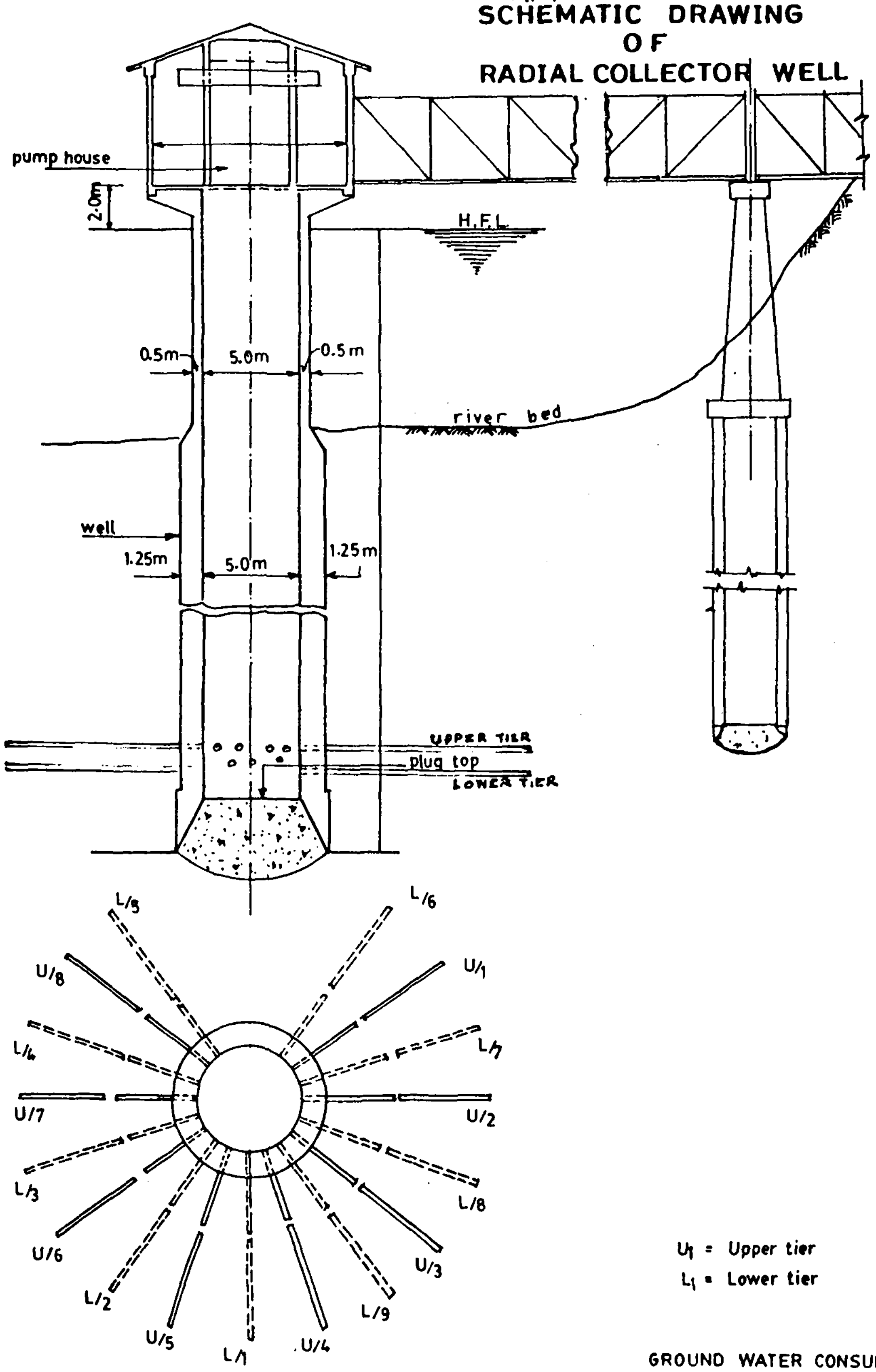
1	2	3	4	5	6	7	8	9
9.	Water Supply for Behrampur	Govt. of Orrisa	3	-	58.46	188	BEHRAMPUR (i) ORRISSA STATE (ii)	1980 1985
10.	Water Supply for Burdwan	Govt.of West Bengal	1	-	55	170	BURDWAN WEST BANGAL STATE	1983
11.	Water Supply for Asansol	-do-	1	-	62	190	ASANSOL WEST BENGAL	1983
12.	10 MGD Water Supply Scheme	Guj.State Fert.Co.Ltd.	1	-	45	153	BARODA GUJARAT STATE	1978
13.	Surat Municipality Water Supply 20 MGD	Surat Mun.		2	200	429	SURAT (i) GUJARAT STATE (ii)	1983 1986
14.	Hajira Fertilizer Project Krishak Bharati Co-op.Ltd.	Jt. Sector with Farmers Coop.	-	3*	-	-	SURAT GUJARAT STATE	
15.	Gujarat Water Supply & Sewerage Board, Gandhinagar	Govt. of Guj.	1	2*	79	200	GUJARAT STATE	1984
16.	Ahmedabad Elec. Co.Ltd.		1	-	60	150	AHMEDABAD GUJARAT STATE	1984
17.	U.P.State Electricity Board - Thermal Powr Stn.		2	3	170	450	UTTER PRADESH STATE	1983
18.	Texmaco - Yerraguntala	Andhra Pradesh	1	-	22	60	ANDHRA PRADESH STATE	1984
19.	Ballarpur Paper Mills Maharashtra		-	1	125	350	MAHARASHTRA STATE	1985
		TOTAL	37	18	1883.66	4832		
B.	Narmada-Saurashtra Water Supply Scheme, Gujarat Water Supply & Sewerage Board (50 MGD with pipeline 433 Kms)	Govt.of Gujarat	5 wells Proposed at source	Feasibility Report submitted.	500	1300	GUJARAT STATE	1986

* Our Feasibility Reports have been accepted for these Projects.

AFRO-ASIAN CONFERENCE

APPENDIX 'C'

SCHEMATIC DRAWING OF RADIAL COLLECTOR WELL



GROUND WATER CONSULTANTS.
BOMBAY- BARODA.

From: **Surat Municipal Corporation, Surat.**

APPENDIX B2

Case Study: 20 M.G.D. Water Supply Running

Expenditure including operation and Maintenance for Proposals in Appendix B1

1.	a) Alum: 2000/Kg/day @ Rs.2.30/kg.	Rs. 4,600
	b) Lime: 25 Kg/day @ Rs.1.50/Kg Rs.37.50 i.e. Rs.38/-	38
2.	Energy Consumption for treatment Plant about 1200 KWH/day @ Rs.0.80/unit	960
3.	Extra energy consumption due to two stage pumping involved in this alternative as against one stage pumping 300 KWH/day @ Rs.0.71 unit.	200
4.	Operational cost of water treatment plant	400
5.	Operational cost for raw water intake and jackwell	325
6.	Operational Cost for clear water pump house.	500
	Total per day	Rs. 7,023
	∴ Total for 265 days	25,63,395
	Cost of making diversions of water to flow into well during summer.	1,00,000
	Total Cost Rs.	26,63,395
	When capitalised on the basis of 9 per cent interest this works out to.	Rs. 295,93,278

APPENDIX B1

SURAT
MUNICIPAL CORPORATION, SURAT

Proposal for 20 MGD Water Supply from Tapi River Surface intake and treatment by sedimentation and rapid gravity filtration.

A.	Raw Water intake well with strainer type intake arrangement and pipe line leading to jackwell.	Rs. 4,00,000
B.	Jack Well and pumping station.	8,25,000
C.	Pumping installation and electrification in the Jackwell as above.	11,00,000
D.	20 MGD Treatment plant including Chemical storage, handling, dosing, mixing, flow mesurement clari-flocculararators, rapid sand gravity filters, etc. complete with 5 lakhs gallons capacity clear water reservoir-cum-sump and pump house.	80,00,000
E.	Pumping installations and electrification in the pump house for clear water.	30,00,000
		1,33,25,000
	Add: Capitalised cost as per Appendix B2	295,93,278
		429,18,278
		Say, Rs.429/- Lacs

CONJUNCTIVE USE OF SURFACE AND GROUND WATER FOR URBAN WATER SUPPLY

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SYNOPSIS

This paper indicates how surface water and groundwater can be used conjunctively for urban water supply. Two aspects of conjunctive use are considered; the physical inter-action between groundwater and surface water as well as the combined use of surface and groundwater storage to meet urban demands. Case studies for various surface water supplies combined with differing types of aquifer are presented and the advantages of conjunctive use are highlighted.

INTRODUCTION

The phrase 'conjunctive use of surface water and groundwater' usually refers to the technique of the combined use of these alternative sources for the efficient and economical supply of water. There is, however, a second important implication that groundwater and surface water are physically inter-related such that water which is lost from the beds of rivers or reservoirs to the aquifers can subsequently be abstracted from wells. It is important to consider both of these aspects of conjunctive use when discussing urban water supplies.

When both surface water and groundwater are used for urban water supply, there is a greater flexibility to even out the hydrologic variations. However, there are many examples in Asia and Africa which demonstrate that there has been a stready decline in the yields of such schemes due to over-exploitation of the resources. This paper considers a number of case studies which illustrate both the advantages and disadvantages of conjunctive use for urban water supply.

The examples are chosen to illustrate the following features:

- groundwater can be used to provide a back-up when the surface water is not adequate or is diminishing.

- groundwater abstraction can induce recharge from surface water sources, thereby augmenting the groundwater potential and decreasing the run-off losses.

- far more than the annual replenishment can be drawn from a groundwater reservoir during years of drought whereas a surface reservoir cannot be over-drawn.

- the cost of developing groundwater sources is often less than that of surface sources, but when account is taken of the frequent over-exploitation of aquifers, the costs for continuous yields are generally similar.

- groundwater generally needs little treatment as compared to surface water sources

- if the salinity of the groundwater is increasing it can be mixed with surface water of lower salinity to produce an acceptable water for industrial or domestic purposes.

RELATIVE MAGNITUDES OF QUANTITIES IN RESOURCE ALLOCATION

Before considering individual case studies it is important to quantify various demands on water resources. The following calculations contain many simplifications, but they do highlight the quantities of water involved in urban supply. Calculations are based on a per capita basis; if there is a substantial industrial development, the figures quoted below should be increased by as much as 50%.

As a first estimate it can be assumed that the quantity of water released from source to meet the per capita domestic demand is 166.7 litres per day. This is equivalent to the statement that 1 m^3/d can supply the domestic needs of 6 people.

When compared to the irrigation demand, domestic needs are small. For example, it is often necessary to provide 8 mm/d of irrigation water to a paddy field for successful crop growth. Thus 1 m^3/d of water can irrigate an area of 125 m^2.

Combining these two calculations, 1 km^2 of irrigated agriculture requires as much water as 48,000 people.

Similar simplified calculations can be performed related to the volumes of water required to supply water for domestic requirements. For one person, a years supply of water is equivalent to more than 60 m^3. Considering first surface water storage; if a reservoir has an average depth of 10m and 40% of the stored water is lost by evaporation and seepage, the plan area of reservoir required per capita is $10m^2$. Consequently a reservoir with an area of 1 km^2 can store the annual requirements for 100,000 people. Note that this calculation assumes that the reservoir will be refilled each year.

Similar calculations can be performed for aquifers. If the saturated depth of an aquifer is 30m and the specific yield (drainable porosity) is 0.2, the same plan areas apply as for a surface reservoir. Since aquifers often cover much larger areas than surface reservoirs; it would appear that aquifers are potentially a more reliable source of water.

The danger of these simple assumptions about storage becomes apparent when account is taken of the replenishment of the storage. In semi-arid and arid areas the partial or total failure of the rains results in surface reservoirs which fail to fill during many of the years. Then, when above average rainfall occurs the reservoirs overflow. With aquifers the situation is often different. The potential recharge to an aquifer depends on the intensity and distribution of rainfall and the nature of the run-off, but often this potential recharge is unable to pass through the unsaturated zone to reach the aquifer[1]. Taking a typical rainfall recharge figure of 100 mm/year, the area of aquifer which has a recharge equivalent to the per capita annual requirement of 60 m^3 is 600 m^2. This means that a square kilometer of aquifer can supply less than 1700 people if the aquifer is not to be over-exploited. A city of 1,000,000 people requires an aquifer area of 600 km^2 to meet the domestic requirements on the assumption that no over-exploitation occurs and that no water is taken out for agricultural or other purposes.

This section has highlighted the contrasting demands of urban areas and agriculture. Secondly it has shown that the per capita annual requirement of water is about 60 m^3. Finally, it has emphasised that the use of groundwater requires far more aquifer area than that of surface water sources to meet a given demand. Groundwater storage appears to be attractive, but once the rate of replenishment of an aquifer is considered, the dangers of over-exploitation become apparent.

PHYSICAL INTERACTION OF GROUNDWATER AND SURFACE WATER

Sources of Recharge

Often surface water and groundwater are considered as though they are unrelated yet losses from surface water by percolation become recharge to an aquifer. Canal irrigation schemes typically have an efficiency of less than 50%, where the efficiency is defined as the quantity of water used by the crop divided by the water released from the reservoir. Although some of this loss of water is due to evaporation and evapotranspiration, by far the greatest proportion is a seepage loss to the aquifer. When fertilisers are used there is a likelihood that the recharge water will contain a significant concentration of nitrates

In urban areas there is another significant loss which occurs by **water leaking out from water pipes and by wastage**, most of this loss becomes recharge to an aquifer. Although the loss from water supply pipes is a welcome source of recharge, leaking sewers or other effluent losses provide a poor quality recharge which can lead to severe problems in an aquifer. Another unwelcome source of recharge is the inflow of saline water. This may be caused by pumped wells which are too close to the coast or alternatively the saline water may be old trapped poor quality water.

Actual Recharge

The estimation of the quantity of water which actually reaches an aquifer requires careful consideration of the physical mechanisms. Although it is possible to estimate the **potential recharge** which leaves the soil zone, the conditions in the unsaturated zone may limit the amount of water actually reaching the water table. Typical examples include:

a) the presence of **low permeability zones** which restrict the vertical flow, Fig.1(a). This low permeability zone only allows water to pass at a lower velocity than the rate at which water drains from the soil zone. This causes ponding of water above the low permeability zone. The limiting effect of these low permeability zones can be illustrated by the aquifer response to the heavy rainfall in Madras in November 1985 when almost one metre of rain fell in 4 days. Yet there was hardly any long term rise in groundwater head indicating that the water was not transmitted to the main aquifers.

b) the potential recharge may not be able to enter the aquifer because the **aquifer is full.** This is often the case in hard rock aquifers. In the aquifers of the basement complex of Nigeria, the aquifers fill within a few days after the onset of the heavy rains; much of the potential recharge which cannot enter the aquifer becomes run-off, Fig.1(b). Similar behaviour is observed in Central India.

Recharge from Rivers

Aquifers can be recharged by rivers; when the rivers flow continuously a steady transfer of water may result. However, the estimation of the flow of an aquifer from an intermittent river is far more difficult. More progress is required in identifying the flow process but at present a reasonable approximation can be obtained by considering two factors:

i) the ability of the aquifer to accept water and

ii) the quantity of water available in the river.

In effect a river valley aquifer is 'looking' for water and once there is water in the overlying river it will draw water downwards due to the vertical hydraulic gradient. The rate at which the water can flow vertically into the aquifer is limited, Fig.1(c), and therefore much of the flow in the river does not infiltrate but continues downstream. Layers of lower permeability overlying the main aquifer can improve the overall recharge to the aquifer by collecting water above the low permeability zone whilst the river is flowing; this water subsequently moves slowly through the low permeability zone into the main aquifer, Fig.1(d).

Outflows from Aquifers

Significant natual outflows can occur from aquifers to springs, rivers and the sea. Before acquifers were exploited, all the outflows occured by natural means. Even when exploitation of the aquifer commences, a significant proportion of the recharge can leave the aquifer especially when the water table is high. These losses are often difficult to quantify; but in areas with moderate topographical gradients as much as 50% of the recharge may leave the aquifer through natural outlets. These natural outlets often provide the baseflow for rivers during the non-rainy season and therefore the exploitation of such aquifers can have a serious effect on the baseflows.

EXAMPLES OF CONJUNCTIVE USE

There are many examples of the conjunctive use of surface and groundwater for urban water supply. Surface water supplies can be taken from rivers, reservoirs, springs etc. whilst groundwater supplies can be withdrawn from deep wells in alluvial, sedimentary or hard rock aquifers or from shallow wells. Four typical combinations are considered below.

Surface Reservoir and Alluvial Aquifers

A number of major cities in Africa and Asia have a surface water supply and also take significant quantities of water from alluvial aquifers. The water may be drawn from the aquifers by shallow hand dug wells or deep tubewells.

Conjunctive Use in Madras

Madras in South India is a typical example where most of the water is supplied by surface reservoirs, but in addition there are deep tubewells and numerous shallow domestic wells. The various sources of supply and their approximate capacities and yields are as follows; reference should be made to Fig.2 for the location of the sources:

Main Reservoirs:

Poondi reservoir	(capacity 75 mcm)
Cholavaram tank	(capacity 15 mcm)
Red Hills lake	(capacity 30 mcm)

these three reservoirs are interconnected.

Major Well Fields :
(alluvial aquifer 30-60m thick)

Minjur well field	(yield 45 Ml/d)
Panjetty well field	(yield 34 Ml/d)
Tamaraipakkam well field	(yield 21 Ml/d)

these major well fields supply mainly to industry

Agricultural wells are found throughout these alluvial aquifers; their yield approaches ten times that of the major well fields during the main irrigation season.

Small Sources and Domestic Wells:

There are a number of small reservoirs Shallow wells for public supply are found near the coast.
Domestic wells are common, there are more than 100,000

Even with the wide variety of sources, Madras frequently faces crisis conditions due to an inadequate supply of water. The reservoirs completely fill for about half of the years and therefore during the remaining years the aquifers become a vital source of supply.

Major Well Fields

Extensive exploitation at the major well fields commenced in the late 1960's. Initially wells are constructed to tap water in the main aquifer with the slotted sections of the casing positioned a few meters below the first clay layers; generally the wells did not penetrate the full depth of the alluvial aquifer. Due to the increasing total abstraction, water table levels fell with the result that many farmers who had been using shallow wells were forced to convert their wells to dug-cum-bore wells. Subsequently a number of tubewells were drilled by the farmers.

This heavy abstraction led to a gradual decline in regional groundwater heads together with a significant fall in pumped levels. The close proximity of neighbouring wells drilled by farmers has caused many of the original public supply wells to become inefficient with the pumped water levels below the uppermost slots. Consequently new wells had to be drilled. Wells drilled close to the original wells proved to be satisfactory for a few years but further falls in the pumped levels have required further new wells with the slotted casing still lower. As many as four wells have been drilled at the same site.

In the vicinity of the main well fields, the groundwater heads have fallen so far that there is difficulty in maintaining the yield. Even though there have been a number of wet years, the actual recharge to the deeper aquifers has been restricted due to the limited flow through the clay layers as indicated in the previous section and discussed in more detail by Krishnasamy and Sakthivadivel[2]. This large alluvial aquifer is a very valuable resource, but unless the abstraction by the farmers is severely restricted so that the groundwater heads recover substantially, the aquifer will not be able to provide large quantities of water at times of heavy demand during drought periods.

One further disadvantage is that this aquifer is in contact with the sea. As abstraction has increased there has been a steady deterioration of conditions close to the coast. Ramalingham[3] has reported measurements of the changing conditions in the vicinity of the coast. He suggests that the conditions can be represented by the classical Ghyben-Herzberg theory but, as indicated by Rushton[4], the measured response tends to reflect the fact that an open borehole obeys the laws yf hydrostatics even though conditions in the aquifer are different. Nevertheless, the heavy pumping in the alluvial aquifer is tending to draw in substantial quantities of saline water.

Domestic Wells

The distribution network for public supply in Madras is generally good. However, during drought periods such as 1983 there was insufficient water in the water mains and therefore recourse was made to domestic dug wells. Substantial quantities of water were taken from these wells resulting in drawdowns of several metres. A number of the wells became saline due to the influence of modern sea water or older trapped formation water.

Since 1983 the quantity of water taken from the domestic wells has decreased but water levels have not fully recovered. During the present drought of 1987, the domestic wells are again being used and the yield is often less than that of 1983.

Achieving Reliable Supplies in Madras

At present the combined urban and agricultural demand in Madras exceeds the rate of replenishment. Although small improvements can be made by constructing new well fields, the only reliable solution is to reduce the demands. This can only be achieved by restricting the agricultural abstraction. As explained previously the agricultural demand is high compared to the domestic demand.

If there is a significant reduction in agricultural demand for a period of about ten years, water levels would recover sufficiently for the management of the aquifer to become a realistic option. Once it is known how much water is available in the reservoirs following the monsoons; an allocation can be made for urban nand for agricultural requirements. In dry years more water can be taken from the aquifer provided that the withdrawal is reduced in other years. Unless such a management strategy is introduced, Madras is likely to remain in a crisis condition every time that the rains are significantly below average. Management of the whole system can be greatly assisted by mathematical models of the whole aquifer. Of particular importance is a model of the regional groundwater flow which can represent the complex interaction of the various features.

River Supply and Alluvial Aquifers

There are a number of examples of cities which obtain water from both major rivers and deep alluvial aquifers. Lahore in Pakistan and Ahmedabad in India are two examples. For each of these conurbations there has been extensive developments of deep tubewells with the result that shallow dug wells have dried up, pumped water levels in the tubewells have declined, more power is used to withdraw the water from greater depths and it is often necessary to drill new, deeper tubewells. Again the main problem is that the aquifer is over-exploited.

There is an interesting method in Ahmedabad in utilising the surface water resources. Water is released from a large reservoir to flow down the Sabarmati River to flow towards Ahmedabad. Rather than diverting water from the river, large wells with horizontal addits have been constructed in and near to the river bed. These wells draw the water into the aquifer with the result that there is little flow in the river on the downstream side of the wells during the dry season. This method of induced recharge can be used provided that the permeability of the river bed is sufficiently high. Increasing the induced recharge utilising artificual recharge techniques have also been explored[5].

Surface Supply and Hard Rock Aquifers

The basement complex covers extensive areas of Africa and Asia. These areas are usually ideal for the construction of reservoirs since the leakage from the reservoirs is small. On the other hand the aquifers of the basement complex tend to have poor yields and poor storage.

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Hyderabad in Central India will be taken as a typical example; many similar situations can be identified elsewhere. Hyderabad does have a number of surface reservoirs but when the rains fail there is insufficient water to meet the urban demands. It is then that intensive exploitation of the aquifer occurs. Existing shallow wells which are dug into the weathered zone are exploited and they often run dry because the water is unable to move through the weathered zone at a sufficient velocity to replenish the wells. One alternative is to dig further shallow wells but these shallow wells only provide a small yield since each shallow well is typically able to draw water from distance of only 100 to 200 metres, Fig.3(a).

An alternative approach is to drill tubewells through the weathered zone into the fractured zone. If productive fractures are intersected during the drilling, there can be a tenfold increase in yield compared to the shallow wells. Furthermore, it is usually assumed that an alternative source of water has been tapped by these tube wells so that they will not interfere with the shallow wells in the weathered zone.

Unfortunately this assertion is not correct. Detailed studies by Rushton and Weller[6] have shown that the fractured zone draws groundwater horizontally towards the well but this water originates from the overlying weathered zone, Fig.3(b). A well drilled into the fractured zone is more efficient at collecting water but it only collects water from the weathered zone for distances of up to 500m from the well. There are exceptions to this rule such as when a well taps a major fissure which is continuous over large distances; but most hard rock wells conform to the mechanisms as described above.

This mechanism of the fractured zone drawing water from the weathered zone has an important effect on the yield of tubewells in a city such as Hyderabad. For the first few years of operation the tubewells do provide a satisfactory yield, but as the weathered zone is gradually dewatered, the yield falls off and many wells require several years of rest before an adequate reliable yield can be achieved. The situation can be summarised by saying that as the population and hence the demand increases, the withdrawal from the aquifer, particularly in drought years, has to increase significantly. In certain cases this increased demand has been met without difficulty for a number of years but then a sudden decrease in yield of the tubewells occurs.

FLOOD PLAIN AND HARD ROCK STORAGE

Nyala in Western Sudan is a town that developed because of a plentiful supply of water from a wadi aquifer. There are extensive deposits of sands and sandy clays in the bed of the wadi in the vicinity of Nyala and these fill with water each time the wadi is in flood. Wells with a good yield have been constructed in these deposits.

As the population increased, the demand for water also increased and there is now considerable difficulty in meeting the demands at times when the water levels in the aquifer are low. Alternative supplies can be obtained from large diameter wells in the surrounding hard rock aquifers but yields of the wells are poor compared to the wells in the wadi deposits.

Additional sources of supply are urgently required. Surface water reservoirs appear to be an alternative, but it is unrealistic to construct a major dam in the wadis. The surrounding hard rock areas are suitable for a number of small reservoirs. If small reservoirs are constructed it is essential that they should be used conjunctively with the wells in the wadi aquifer. This would involve using the surface storage first to minimise the losses due to evaporation and only using the wadi aquifers when the surface storage is depleted. However, because it is much easier and more convenient to take water from the wadi aquifer, it would be difficult to obtain agreement to use surface storage first.

DISCUSSION AND CONCLUSIONS

The advantages of the conjunctive use of surface water and groundwater have been illustrated by a number of examples. Yet, successful conjunctive use requires imaginative management. There will always be a number of inter-related issues. For example, the mixing of groundwater and surface water can be of value in providing water of an acceptable quality, especially if the salinity of the groundwater is high, this requires the **simultaneous use** of groundwater and surface water. On the other hand, resource considerations suggest that the **surface water** should be used **first** with groundwater reserved for times of scarcity. When capital and running costs are considered, groundwater is usually cheaper and therefore this indicates that **groundwater** should be used **first.** Each of these three objectives suggests different strategies.

In deciding which of these three strategies to follow note must be taken of the particular features of the area. Nevertheless, if there is a risk of scarcity during drought periods, groundwater must be considered as the valuable reserve which is used cautiously so that it is available in times of greatest need.

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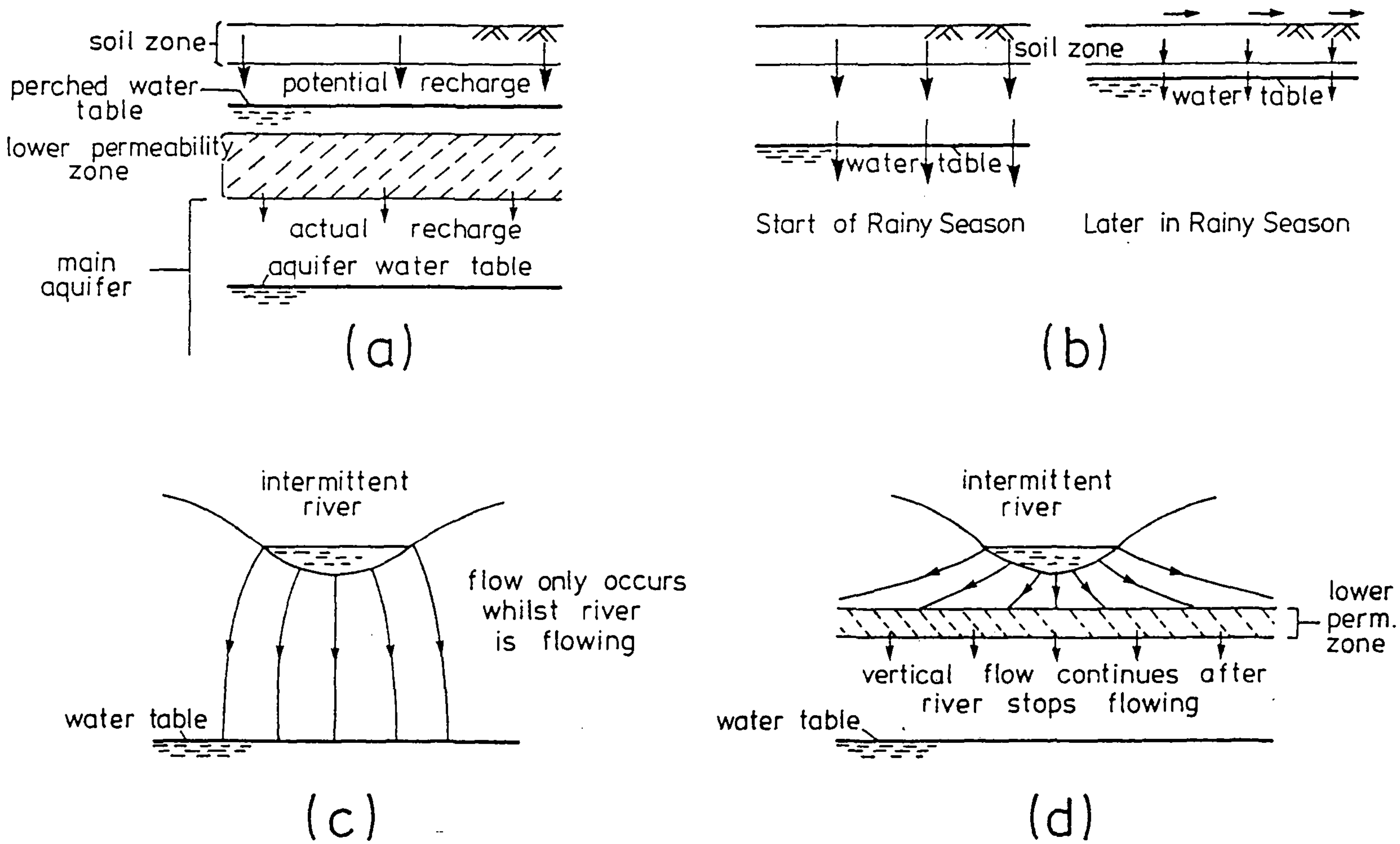

Fig: 1. Difference between potential and actual recharge (a) effect of layer of lower permeability, (b) effect of rising water table, (c) inflow from a river, (d) influence of low permeability zone on flow from a river.

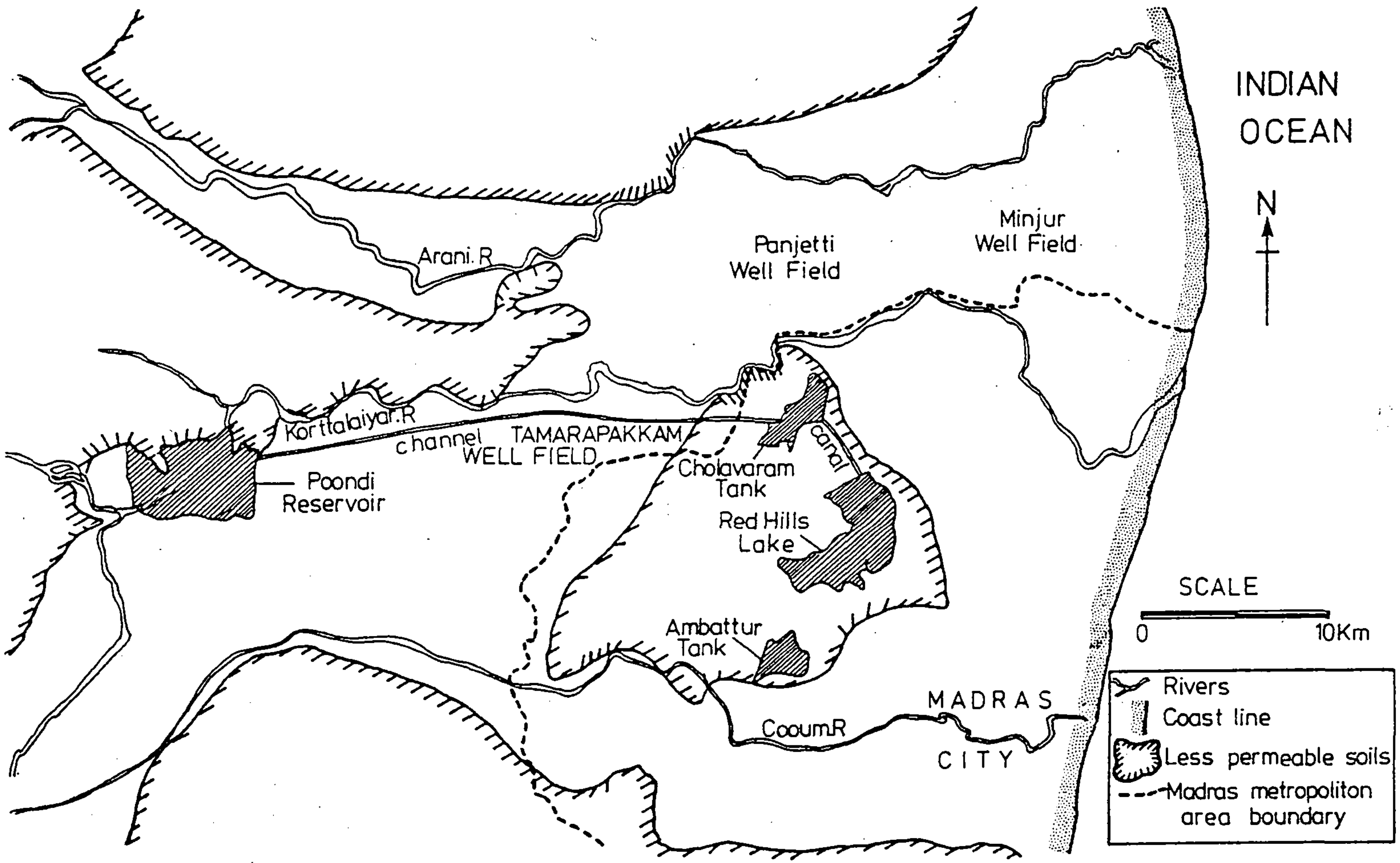

Fig: 2. Surface and groundwater sources for Madras

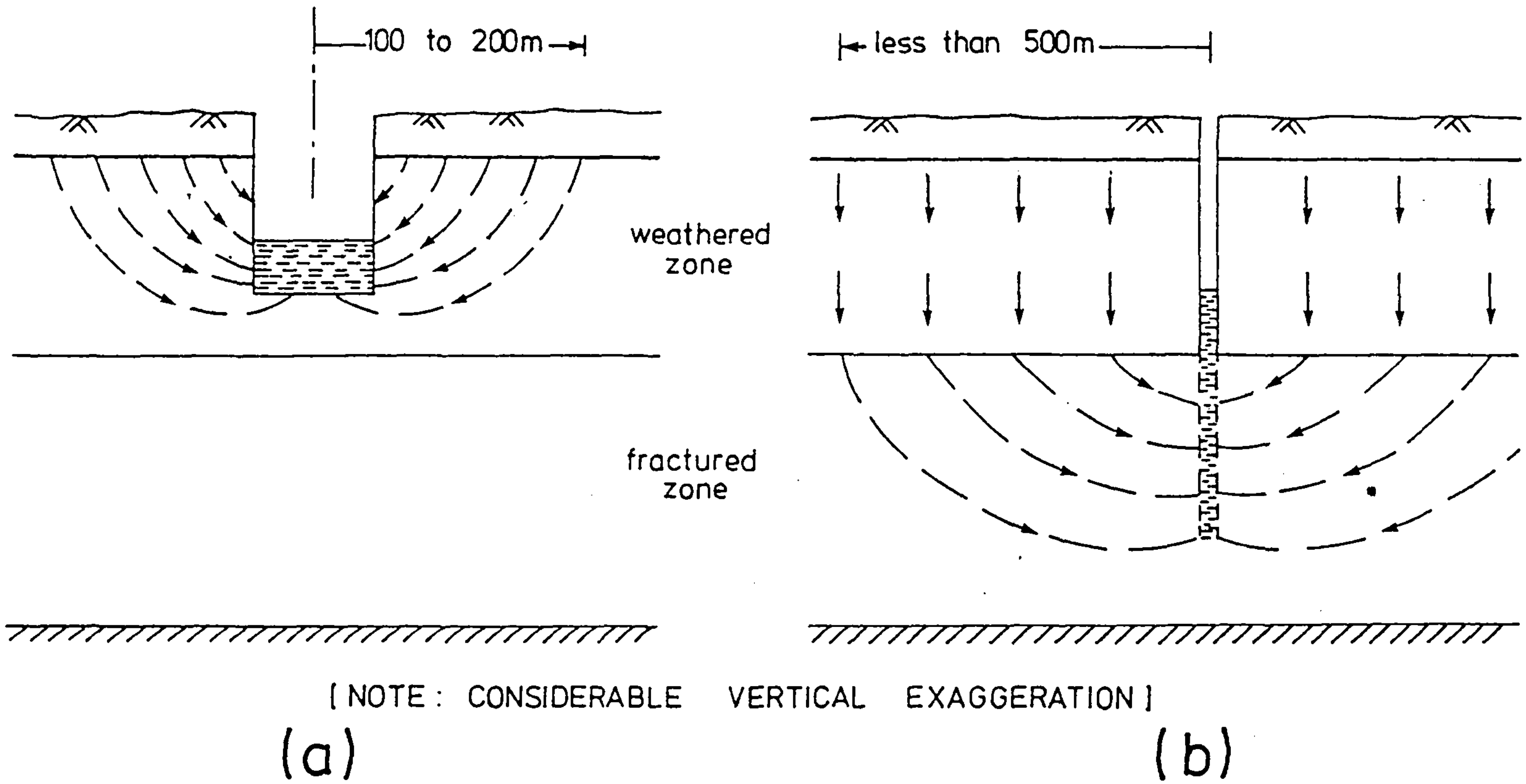

Fig: 3. Exploitation of weathered fractured aquifers, (a) shallow dug wells, (b) tubewells into fractured zone.

ESTUARY RESERVOIRS

JEAN CLAUDE NARDEAU
SAFEGE, Paris.

SYNOPSIS

Most of the main cities in S.E. Asia are located in flat, deltaic areas where the rivers are tidal. Periodical sea water intrusion (either seasonal during dry weather, or daily during spring tides) may occur very far upstream of the rivers. This obliges to locate raw water intakes for public water supply, sometimes very far away from the cities.

Sea water intrusion may become more and more severe when the dry weather flows are further depleted by upstream water abstraction from the rivers, in particular for irrigation.

Since all these cities have a booming rate of increase in demand for water due to increase of population, increase of standard of living and other economic factors (in particular industrial developments), the conventional design of developing additional raw water sources suitable for domestic and industrial uses have become more and more expensive, both in terms of capital investments and running expenses. Conventional designs normally involve various precautionary measures to face sea water intrusion : either location of raw water intake very far upstream of the cities, with associated long raw water pipelines and high pumping costs or construction of tidal barrages with expensive flood control structures.

The engineers of SAFEGE have participated since around 15 years in studies of unconventional designs to work out more effective and cheapest alternative solution : some solutions (estuary reservoirs) have been already implemented in S.E. Asia (Singapore, Malaysia) and their operation has been fully successful since more than 10 years; some other solutions (creation of an air bubble curtain against sea water intrusion, by compressed air injection through a perforated ramp located on the ground of the river bed) have been successfully implemented in Europe and studies are on the way to check under which conditions such air bubble curtains can be developed in Indonesia. The present note concentrates only on estuary reservoirs.

BASIC PRINCIPLE

1. Most of the time, sea water intrusions are only intermittent, either seasonal (during dry weather flows) or daily (during spring tides). These periodical sea water intrusions prevent continuous raw water pumping. Nevertheless, there are generally long periods of time, in particular during the rainy season, when the water is fresh and suitable for domestic and industrial consumption.

   But discontinuous pumping requires the development of buffer storage reservoirs to face the periods of time when the water becomes brakish.

2. In the delta areas, there are generally wide mangrove or mudflat areas, whose economic values are low and where, under adequate design, fresh water storage reservoirs may be developed to store water when the water is fresh in the river and to restitute fresh water to the system when the river water becomes brakish.

This has proved feasible, in spite of the unfavourable initial conditions : saltish or brakish ground, presence of organic matters, sulphides,.... with a risk of high chloride content, high acidity and high iron and manganese content, if the design is not adequate.

At present around 30% of the population and industries of Singapore are supplied with water stored in estuary reservoirs developed in former mangrove and/or mud flat areas. The supplied treated water strictly complies to the WHO standards.

TYPES OF ESTUARY RESERVOIRS

Depending upon the local conditions (topography, tidal effects, hydrology, ground conditions.....) several types of estuary reservoirs may be considered:

- **Elevated diversion reservoir :**

  The reservoir is built in mangrove or mudflat area by constructing a 6 to 8 m high surrounding dyke. The bottom of the reservoir is not dredged it is only cleared from vegetation. As an example, the PANDAN reservoir in Singapore has been formed by a 6200 m long dyke, 7 m high over a surface area of 10 m^2. The storage capacity is 6.0 x 10 m^3; the construction cost was US$ 2.6 million in 1976. This reservoir shall be filled by pumping selected fresh water from the river.

- **Dredged diversion reservoir :**

  The reservoir is built by dredging (cutter suction dredger) down to 5 to 8 m below the main sea level. Surrounding dykes, 1 to 2 m high, are built around the reservoir to allow deposit of liquid dredged materials. After drying (one or two years), the area reclaimed by the dredged materials may be suitable for non-polluant activities. In Singapore, the Tengeh reservoir is of this type; the surrounding reclaimed area is now developed as a golf ground. This type of reservoir is filled by gravity.

- If topography allows it, estuary reservoirs may also be developed by damming the river (or a tributary) itself, either with a low dyke (Poyon reservoir in Singapore or Lower Layang reservoir in Malaysia) or by a conventional dam equipped with flood control structures; in such a case the dam may be well above the mean sea level (MURI reservoir in Singapore, Plover Cove reservoir in Hong Kong) or below the mean sea level if the river is deep (the Kranji dam in Singapore is around 20 m high below the main sea level).

SOCIO-ECONOMIC ADVANTAGES OF ESTUARY RESERVOIRS

The economic advantages, as compared with conventional design, originate from various components :

- shorter distance of pumping, if any pumping is required.

- easier operation of the system because the raw water intake may be located close to the treatment plant.

- siltation of the reservoir may be controlled at the raw water intake by natural sedimentation or by artificial flocculation, (Aluminium Sulphate) within a sedimentation basin.

- optimum use of natural water resources, because the water stored in estuary reservoirs is abstracted from the downstream end of the river where there is no more competition with other users. The fresh water is lost to the sea.

If, within the conventional design, an upstream reservoir is planned, the socio-economic advantages of the estuary reservoir alternative may be considerable because the alternative will imply only limited funds for land/acquisition (low economic value of the mangrove forest) and limited problems of human resettlements.

As an indication, SAFEGE has recently conducted a study for the water resources development of PULAU BULAN (Indonesia) for U.I.C. CULINDO LIVERSTOCK PTE LTD for the water supply to a big farm project.

Pulan Bulan is located nearby Pulan Batam. Based on information obtained from the Industrial Development Authority of Pulan Batam, we have compared the overall cost of conventional reservoirs (NONGSA, LADI, MUKAKUNING) and of estuary reservoirs. For the same guaranteed yield, the latter was around 2 to 3 times cheaper than a conventional design.

BOMBAY WATER SUPPLY RESOURCES SYSTEM SIMULTANEOUS HYDROLOGIC AND HYDRAULIC MODELLING UNDER REALISTIC OPERATING RULES

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SYNOPSIS

This paper presents a case study for Bombay's resource system. Dimensionless profiles for monsoon inflows have been developed with the available 66 years' data. The yield of various sources has been assessed using probability analysis. Control curves for various reservoirs have been drawn to enable optimal utilisation of the assessed yield. The hydraulics of transmission system has also been simulated. A combined model has been developed. The yield has been optimised considering realistic operating rules.

INTRODUCTION

Bombay gets its supply of water from the lakes and rivers. The major lakes are Upper Vaitarna, Vaitarna and Tansa. Their capacity is about 652 billion litres. The daily normal withdrawal is about 1400 million litres. They are all situated about 100 to 120 Kms from the city. The major river which supplies water to Bombay, the Bhatsai river, has on it a multipurpose reservoir and the allocation to Bombay's Water Supply is about 1365 Mld. The Bhatsai project is being developed in phases. The first phase has been completed, the second phase is about to be completed and the third phase has just been started. In addition, water is drawn from two small lakes Vihar & Tulsi and also from Ulhas river. The total supply from these smaller sources is about 200 Mld.

The existing treatment plant at Bhandup has a normal capacity of about 1900 Mld and has an overload capacity of 10%. Another treatment plant at Panjrapur is being constructed in phases and shall finally treat all the water from Bhatsai source. It will have an excess hydraulic capacity of 20%. Thereafter Bhandup will treat largely the Tansa and Vaitarna Water.

Presently water from the major lakes and the Bhatsai river is being treated at Bhandup and conveyed to the city. The scheme is presented in Exhibit-1.

HYDROLOGY

Seasonal runoff data in case of Tansa lake was available for 66 years. Daily inflows and monthly inflows for all other lakes were available only for a few years.

Daily or monthly inflow data could be used to draw some 'real' monsoon profiles. However, if a dimensionless profile could be drawn from the historic data it could be applied at sites with more limited information to form a 'conceivable' record of flows. For the analysis weekly time periods were convenient; they could be plotted on arithmetic calendar paper together with the means of monthly volumes. For Bombay, evidence of an early maximum inflow volume per unit time lying between the second and fourth weeks in July was strong;

some years also showed a much smaller, later peak between late August and mid September. Four trial standard profiles were tried, the criteria used in selecting the profile finally adopted being.

i) Coincidence (in calendar weeks) with the week of maximum inflow in 1975, 1976 and 1978 (all three years' peaks coincided); and

ii) Close agreement with the 1969-78 monthly mean volumes.

The adopted dimensionless profile was truncated slightly to correspond to the average monsoon duration. The histogram used is shown in Exhibit-2.

Although the profile is based on scanty data, and it implies that monsoon profiles are independent of whether the monsoon arrives early or late, it nevertheless represents a valid attempt to improve on the use of seasonal volumes alone by adding the data for seasonal start and finish.

PROBABILITY ANALYSIS

The series of weekly volumes produced with the aid of the dimensionless profile were ranked (rank 1 = driest) at independent events of given duration and with free starting dates for durations from 38 upto 180 consecutive weeks, to cover all the critical period (single dry to four dry seasons and three monsoons).

Inflow probability analysis takes into account the Monsoon start and end dates and daily inflows.

The seasonal inflow data is converted to monsoon profiles based on daily or weekly inflow data available. Based on the data the best profile as explained in the previous paras have been adopted as a 'Standard dimensionless monsoon profile'. This curve is used for plotting positions of the exponential distribution.

The standard histogram aids in calculating the % inflow volume for the number of wet days in a particular wet season. For a particular plot, the set of % inflow volume could be found out by knowing the wet season length and the no. of wet days for the required plot. The set of % inflows thus could be arranged or ranked in an ascending order and the return period could be calculated by using any of the return period formulae.

The ranks were expressed as return periods using the formula for plotting positions of the exponential distribution. The family of lines in Exhibit-3 enables cumulative inflow volumes for given durations & return periods to be estimated. The choice of return period for water supply yield 'failure' is a matter of judgement; shorter return periods give higher yields but more frequent shortages, and vice-versa selection of a short return period for the latter will decrease the opportunities for overdrawing above a relatively higher yield, and increase the frequency with which cutbacks must be applied.

INFLOWS USED FOR SIMULATION STUDIES

Drought Runs

Drought Simulation Studies usd a combination of 95% inflows and 92% dry season lengths (20 year and 12.5 year return period respectively). In the case of Bombay region the probability of future yield is dependent on two factors viz., monsoon inflow and lengths of dry weather and wet weather periods.

The chief objective is to determine the 95% reliable yield of the Bombay Source System as a whole under present and future conditions. In present and future conditions. In order to test the system rigorously against 95% reliable runoffs it was necessary to re-order the sequence of dry and monsoon seasons, starting with the wettest of these monsoons and ending with the driest followed by the longest dry season. This ensures that each critical period (D, DMD etc.) contains the 95% inflow but lies as close as possible to the end of the next longest critical period. For example Lower Vaitarna is normally single dry season critical i.e. its 95% reliable yield is related to a 42 week dry season. On the other hand, Upper Vaitarna's critical period is 3 dry seasons plus 2 monsoons (DMDMD). By placing Lower Vaitarna's critical D at the end of Upper Vaitarna's critical DMDMD, both are emptied simultaneously at the end of the last dry season when Upper Vaitarna has already been hit by a progressively worsening set of inflows.

The drought sequence used is as follows:

Dry (D)/ Monsoon (M)	Volume 1000 Ml	Sequence duration weeks
D1	---	---
M1	229	16
D2	---	35
M2	167	18
D3	---	31
M3	125	16
D4	---	42

The above volumes are for Tansa Catchment; inflows to the other sites were found using the transposition factors. The runoff Transposition factor for Vaitarana, Upper Vaitarana, Bhatsai Dam site & Pise with respect to Tansa runoff were found to be 2.19, 1.2, 3.30 abd 7.9 respectively. These represent the estimated ratio of mean annual flows based on mean rainfall maps and an annual catchment loss of 690 mm.

Historic Runs

A main frame computer program was written specifically to describe the complete resource system. From the outset it was designed to embody all significiant operating constraints and realistic oprating decisions. Historic runs were made with the objective of finding the frequency and severity of cutbacks and modifying operating rules and control curves, as necessary to reduce those cutbacks and raise delivered supplies. Program features included;

- Drawoff aqueduct hydraulics based on local pipe roughness measurements.

- Pump type curve interaction.

- Year by year growth of demand.

- Works augmentations introducd in correct time sequence.

Inflow data for Tansa, Bhatsai and Vaitarna were available for 66 years, for 10 years (1967-76) and for 3 years (1974, 1977 and 1978) respectively. Tansa inflow data was used as a base and were ranked by dividing into 10 classes. All the inflow data for other catchments were ranked. Inflow at Tansa belonged to a clss of known rank and could then be coupled with an identically ranked inflow at Bhatsai. Seasons lengths and dates were taken s identical to those at Tansa for all reservoirs with the exceptions of some years between 1969 and 1978 when, at Bhatsai the flow records for those years suggested somewhat larger recessions than at Tansa. Weekly inflows were found using the standard profile. The inflows were found using the standard profile. The inflows at Vaitarna and Upper Vaitarna for all other years was found by using transposition factor. After scanning the historic record the decade

1924-33 was chosen for the bulk of test runs as its average inflow coincides with the 66 years' average inflow and it contains a reprentative seasonal range.

RESERVOIR CONTROL CURVE

a control curve may be described as a continuous line (with a suitable time axis as base) each point on which is the minimum storage needed on that date in order that the stated yield may be safely drawn from the reservoir during all future drought inflows of specified severity. A control curve also leaves enough storage to provide adequate protection against floods at the end of the monsoon. Control curves provide a strategy for dealing with events wetter or drier than the design drought.

The control curve is designed to anticipate a spectrum of design droughts within a chosen range of probable runoff volumes; an historic record of inflows may be used to modify the shape of the curve to account for the variation of timing of occurence of those probable drought flows. If ensuing inflows are greater than those used to construct the curve, storage rises above the curve and drawoffs in excess of the yield may be made temporarily, subject to hydraulic constraints such as treatment works' capacities, drawoff and transmission system etc. If a drought of rarer than the specified probability is experienced, storages willfall below the control curve. In this event, emergency strategies may eventually become necessary. A single control curve normally relates to a given yield of specified reliability. If desired, a family of curves for different reliabilities and drawoff rates can be produced although more complex they can formalise the emergency strategies.

METHOD OF DERIVING CONTROL CURVES

Time interval and data

The time period choice could be any convenient interval varying between a day and a month but a week is a practically convenient interval in terms of water works operations. Inflows for curve construction can come from an historic record directly or from a probability analysis of that record. The latter is much to be preferred as a consistent known risk is then produced.

With the known inflow data and the duration of critical dry length and wet seasons, a control curve for any reservoir can be drawn. An example for Vaitarna reservoir is illustrated. Inflow data (extended from Tansa) was available and the data was analysed by a method which permitted probability estimates for any number of weeks to be obtained. No assumption was made about the starting date of either the wet or dry seasons. A twenty year return period was adopted, the level of reliability previously used in Bombay Water Supply work. Drought timing came from historically extreme early and late start dates to dry periods when constructing control surves. Ranking lists were available for droughts of all durations over 66 years.

By giving most weight to the data of third ranked event it was possible to estimate the approximate timing of a 20 year drought e.g.

Ranking for low flow volumes of duration 142 weeks:

Rank No.	Run off Volume 1000 Ml	Return period (Years)
1	269.2	65.7
2	300.9	32.9
3	301.0	21.9
4	332.1	16.4

CONTROL CURVE CONSTRUCTION

Each point on the curve represents the minimum storage required in the reservoir when drawing the yield for which the control curve is drwan; this point on the control curve can be calculated as the maximum of the values of S_{iw}, the storage required at the beginning of calender week iw, calculated for all possible periods, p, where

$$S_{iw} = \sum_{i = iw}^{i = iw+p-1} (D_i + E_i + L_i - Q_i)$$

D_i = Drawoff to supply

E_i = Evaporation losses

L_i = Leakage losses

Q_i = Inflow volume with 95% probability of exceedance.

Inflow volumes have to be checked and this was done from the 1896 mansoon to 1978 dry season. Inflow durations around the critical drawdon period for the reservoir were then inspected. For any duration of interest historical events were noted which were of roughly similar inflow to the 95% case for the same duration, but with starting dates which were especially early or late. The significance of these events is that to cover a repetition of the years in which they occured (or began), large volumes of storage would be necessary both early and late and therefore they are definitive for the control curve.

If the storage requirements to just survive an ensuing drought with 95% inflows are calculated and plotted against the historical range of starting dates, a control curve based on 95% drought inflows is formed from the upper envelope of all the cases examined i.e. protection is ensured against once in 20 years low monsoon occuring on any date, however awkward, that has been experienced in the past.

Live storages required for the critical conditions are found and plotted. The final stage is the conversion of live storage to lake levels, s the simulation program uses levels for making operation decisions. This also provides the opportunity of choosing where, within the gross storage available, the required live storage band is to be located. It is usually lifted so the highest point is at normal top water level in order to give the largest margin of safety. However if the control curve is for the full potential yield of the source the curve will take up all of the live storage. Just occasionally the control curve may be lowered so tht the bottom point coincides with the lowest level at which the cut back yield will be apable of gravity drawoff. This gives the maximum potential pa for for using any surplus storage above the control curve to balance but floods and give non firm additional supplies to reduce pumping costs elsewhere.

Exhibit - 4 shows the storage required and control curve for Vaitarna lake.

TRANSMISSION SYSTEM

Water from major lakes is transmitted to Bhandup Treatment plant (TP) via Yewai. Water from Bhatsai is injected into the system at Yewai. Flow of water from Vaitarna system is by gravity while that from Pise to Yewai via Panjrapur is by pumping. Three stages of development of the Pise pumping were considered.

Pumping stations are represented as families of characteristic curves.

Head and flow of the Vaitarna and Bhatsai systems balance at the Yewai injection point before flowing to Bhandup TP. Just upstream of Yewai is th Agra road Value complex which is used to reduce heads in the Vaitarna mains before the injection point is reached, for balance of flows.

Bhandup TP capacity was used as a constraint and priorities for the various sources were allocated in order to make for straightforward operational decision making and to draw water available purely by gravity in preference to pumped water. The prioriy list adopted after exploratory study and a knowledge of current practice was:

1. Tansa

2. Vaitarna system (i.e. Upper & Lower Vaitarna)

3. Bhatsai via Pise injected into Vaitarna mains at Yewai.

4. Bhatsai via Pise treated at Panjrapur treatment works (when available) and supplied separately to the city.

Chart - 1 indicates the iterative procedure used for flow balancing and to assess flows from different sources. **Chart - 2** indicates the sequence of simulation and allocation of priorities.

TIME SCALE OF SIMULATION

The works programme forming an input to the simulation covered ten years, nominally 1980-1989. A typical example is shown in Table -1. The works programme may be varied at will. The chief intention is to simulate the supply growth over the coming decade as the various planned works are commissioned and to examine the optimum phasing of those works. This provides a much more real simulation than the steady demand state runs that have often been adopted in such studies.

COMPUTER RUNS

Different works programme were tested for 95% drought inflows and historic inflows.

The results of the runs indicate that improvement in yield is feasible with improvement in hydraulic capacity of the mains. They also indicate that it is feasibile to reduce spills. By taking a large number of runs for various conditions it has been demonstrated that the maximum capacity of treatment plant could be continually utilised with high degree of confidence.

OPTIMUM OPERATION

Any water supply system involves many different operating decisions. The decision becomes more complex when simultaneous operations of different sources/reservoirs is involved as in Bombay. Different objectives may be chosen at different times and no one quantity or performance index will summarise the system's efficiency. It was therefore decided to review simulation rsults in a uniform manner by three indices, in the order in which BMC priorities lie:

1. A supply reliability index
2. A maximum yield index
3. An economic performance index

They have been produced directly from the computer simulation annual summaries in identical units (100 M1/year) and can thus be added to produce the Overall Efficiency Index.

Each index takes in those factors which are of obvious concern.

Supply Reliability Index:

TABLE 1

TYPICAL WORKS PROGRAMME

	YEAR 1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Bhandup T.W Capacity,ML/D	1841	1841	1841	1841	1841	2023	2023	2023	2023	2023
*Panjrapur T.W Capacity,ML/D	0	0	0	0	0	0	0	1000	1000	1000
Tansa Mains C-Value Week 13	75	75	70	75	81	90	120	120	120	120
Week 14-39	75	75	82	90	102	120	120	120	120	120
Week 40	75	66	71	76	83	120	120	120	120	120
Tansa Mains Diameter, M	2.300	2.300	2.300	2.368	2.364	2.360	2.360	2.360	2.360	2.360
Yevai-Bhandup Vaitarna Mains dia. M	3.380	3.380	3.380	3.380	3.525	3.525	3.525	3.525	3.525	3.525
Bhatsai capacity, 1000 ML	150	225	338	508	730	920	920	920	920	920
Bhatsai full supply level M MSL	98	105	113	123	134	142	142	142	142	142
*BMC Allocation from Bhatsai, ML/D	455	455	455	455	455	455	660	1364	1364	1364
*Pise Stage Number	1	1	1	1	1	1	2	3	3	3
*No of Pise Pumps, Stage 1	6	6	6	6	6	6	6	6	6	6
Stage 2	0	0	0	0	0	0	6	6	6	6
Stage 3	0	0	0	0	0	0	0	6	6	6
Mohili Hump Invert Level M THD	111.9	111.9	111.9	111.9	111.9	111.9	111.9	107.0	107.0	107.0
Tansa Pumped Drawoff (1=Available)	0	0	0	0	0	1	1	1	1	1
VT-Tansa Duct Connection (1=Available)	1	1	1	0	0	0	0	0	0	0
*Bhatsai Irrigation Duty, 1000ML	0.0	0.0	19.3	51.0	98.7	162.6	226.3	308.8	308.8	308.8
*Bhatsai BMC Cutback Level, M MSL	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0

* Asterisk denotes values which apply until the end of the monsoon in current year.
Tansa mains C-Value increases linearly from week 40 of current year to week 13 of following year (inclusive) during annual relining operation.
'Constant works' runs only: (1) Tansa C-Value for weeks 14-39 taken for whole year,
(2) Asterisked works following monsoon apply (EG 1981 Bhatsai Irrigation Duty, 1000 ML = 19.3).

= Bhandup + Panjrapur T.W. throughput (Excluding Ulhas) for the lowest fortnight of the year (expressed as 52000 Ml x number of weeks with outage due to reservoir emptying).

Less: Any upper Vaitarna Hydro-power shortfall (expressed as 52000 Ml x number of weeks with outage due to reservoir empying)

Maximum Yield Index =

= Bhandup + Panjrapur T.W. throughput (excluding Ulhas) in the year

Plus: Minimum unused storage during the year x 0.365

Less Total spills of lower Vaitarna and Tansa.

Economic performance Index:

= Upper Vaitarna annual generation flow.

Less Pise total annual pumping

Less Tansa total annual pumping of bottom water (i.e. any pumped drawoff between 500Mld and maximum pump capacity).

These indices were calculated for a run covering the period 1980 to 1989 in the typical weather range of 1924 to 1933. The overall index has shown a distinct improvement on original values before rules were improved. Whereas originally in the forth year of the 95% design drought, it would lie near to 900, a figure of 1500 is now reached. This index now has an absolute range from just under 400 for the failure year 1900 up to about 1700 or 1800 in years like 1899 and 1974 which have low spills and good outputs.

CONCLUSION:

The simultaneous modelling of hydrology and hydraulics of the system provides a good insight into the modifications required in the system for optimum operation and also provides a good base for operating procedures.

ACKNOWLEDGEMENT

The authors thank the MCGB for giving an opportunity for carrying out the studies and for the co-operation rceived from the concerned officers. We would like to thank Mr. MK Gokhale, Chief Engineer (WSP) in particular for making useful suggestions for improvement of the paper.

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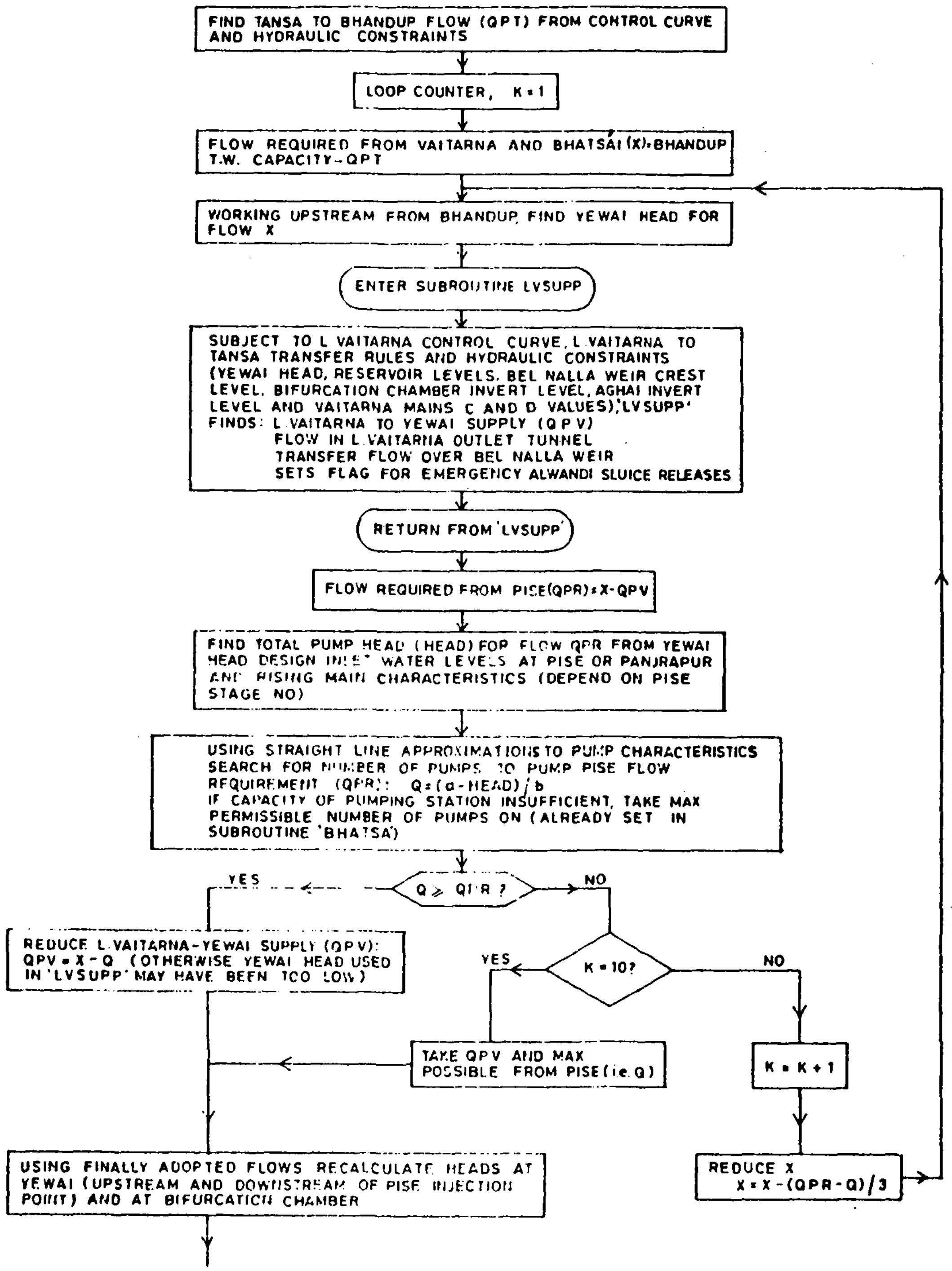
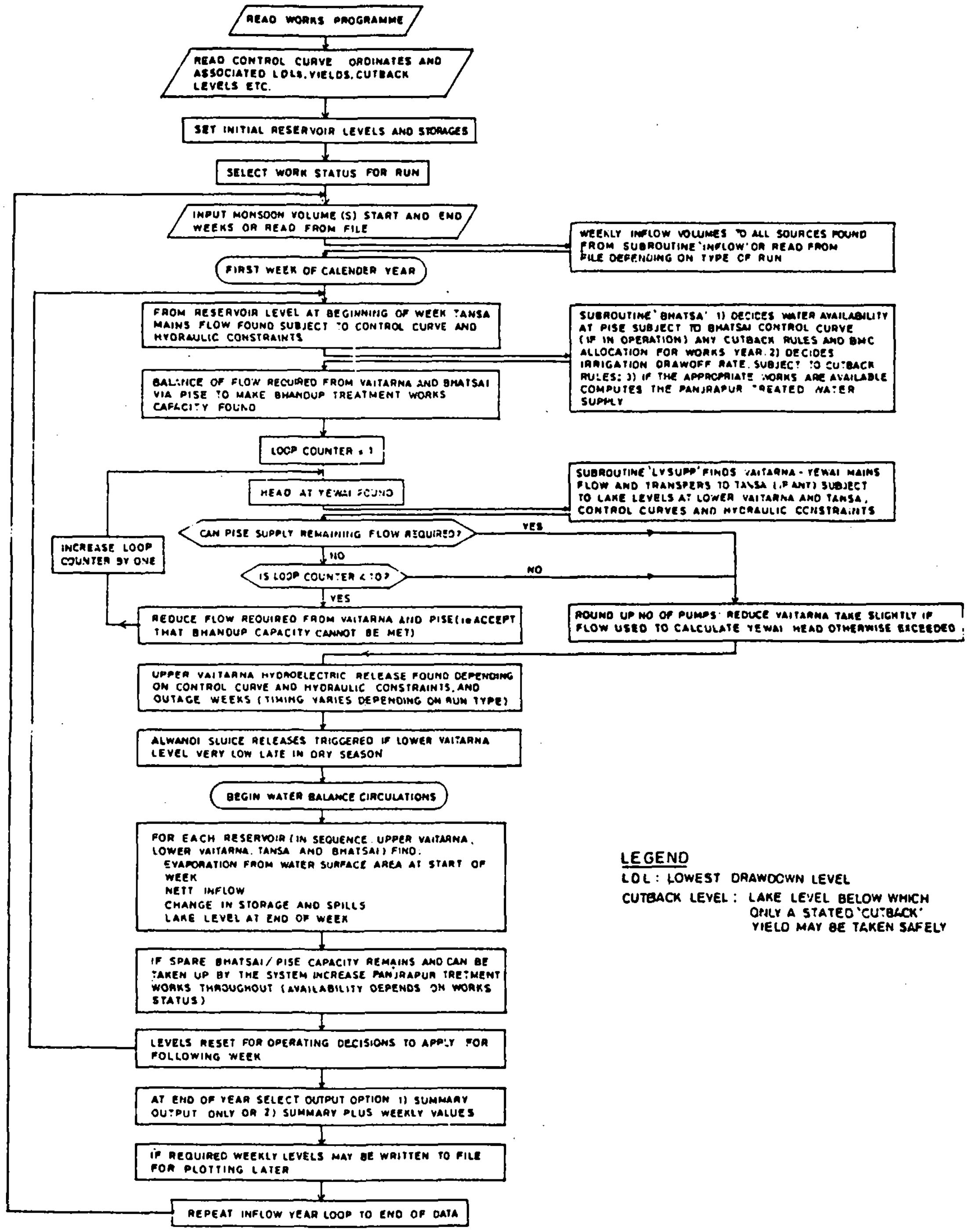


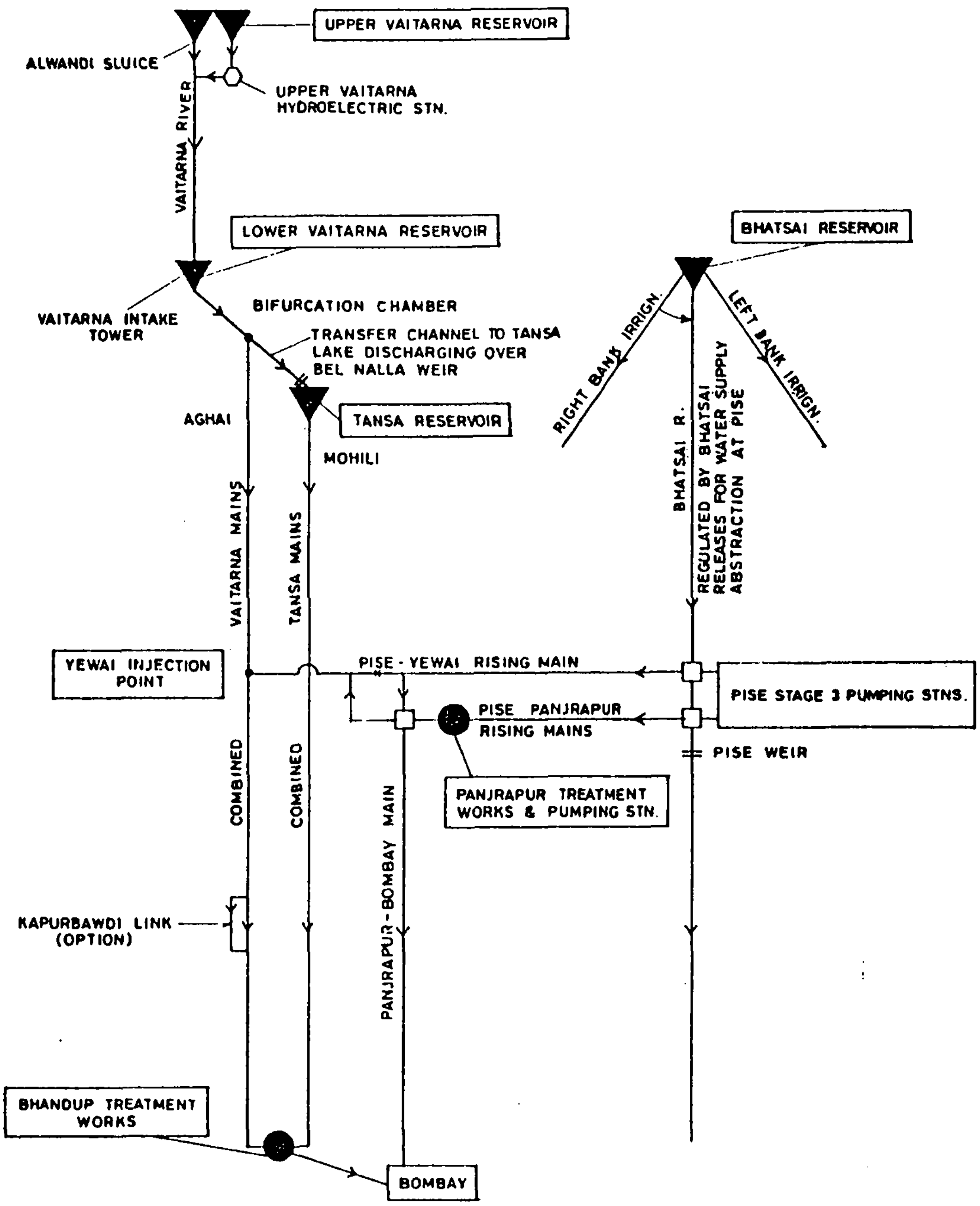
FLOW CHART SHOWING BALANCE OF HEADS AND FLOWS AT YEWAI

CHART 1



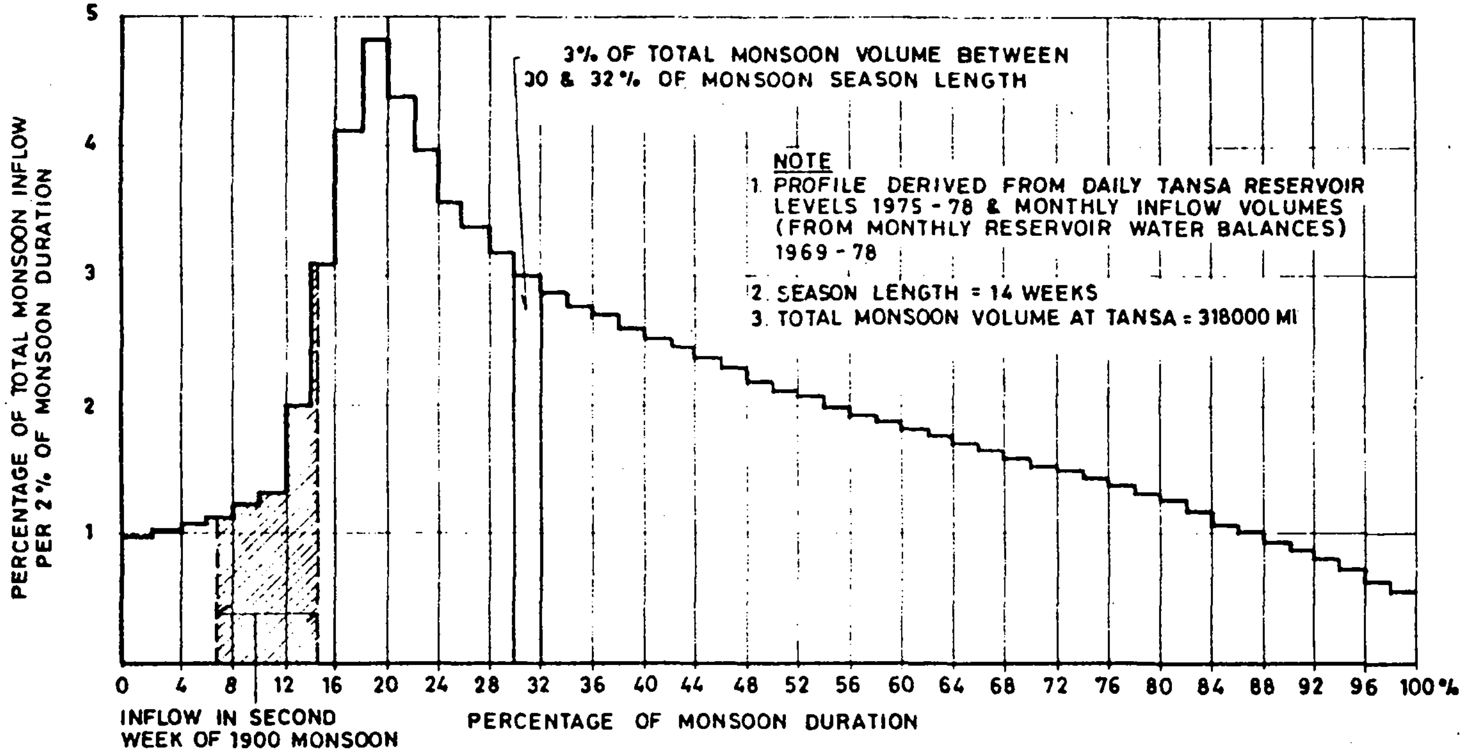
BOMBAY SOURCE SYSTEM SIMULATION PROGRAM
OUTLINE FLOW CHART

CHART 2



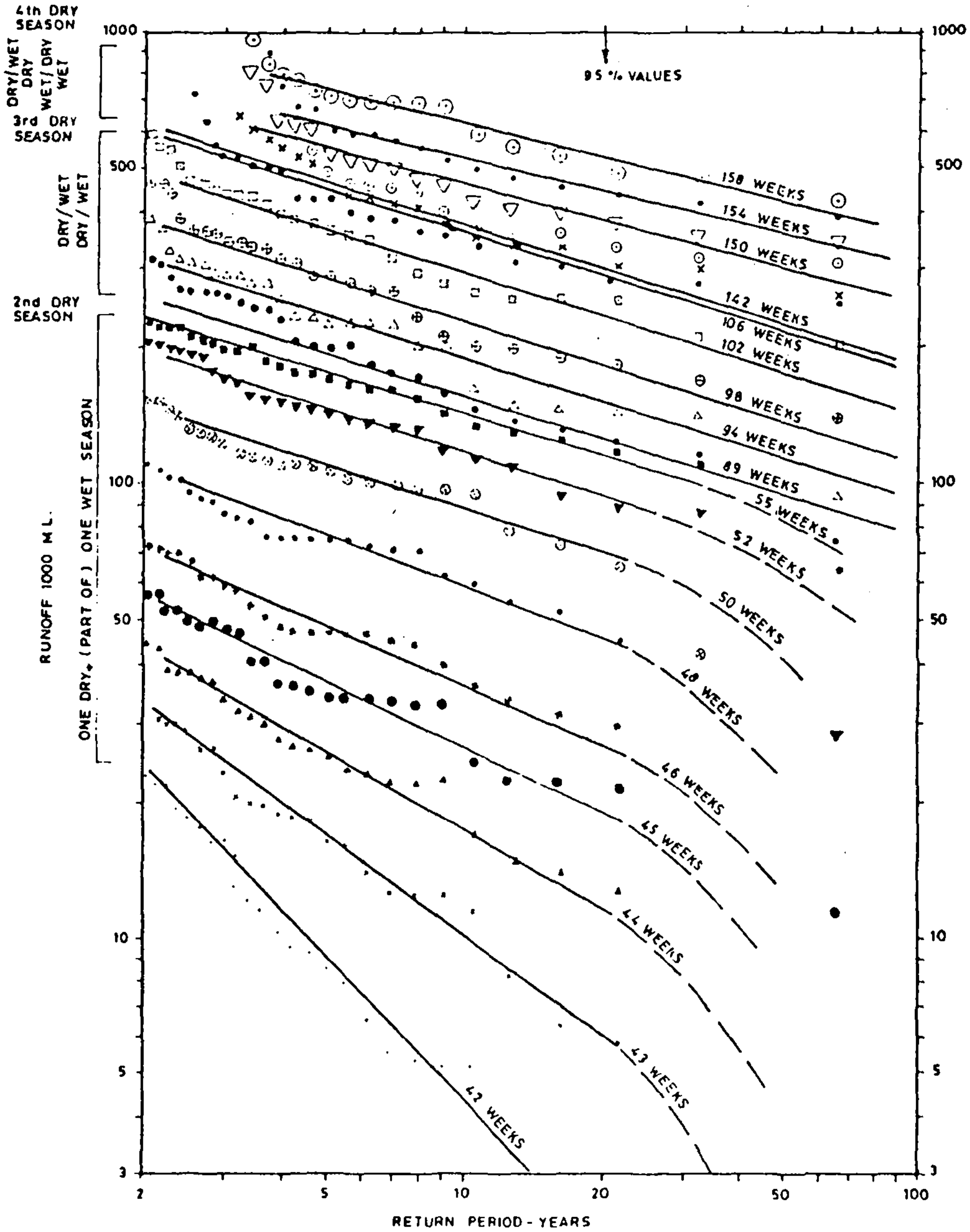
SCHEMATIC DIAGRAM OF BOMBAY WATER SUPPLY SOURCES

EXHIBIT 1



HISTOGRAM OF DIMENSIONLESS MONSOON INFLOW PROFILE

EXHIBIT 2



PROBABILITY ANALYSIS OF TANSA RUNOFFS (INDEPENDENT EVENTS)

EXHIBIT 3

NOTES

1. DATA COMPRISE TANSA MONSOON START AND END DATES AND SEASONAL INFLOW VOLUMES FOR 1896 - 1953, 1969-70 1972-80 (66 YEARS), CONVERTED TO WEEKLY VOLUMES USING STANDARD INFLOW PROFILE.
2. FOR THE SAKE OF CLARITY, NOT ALL WEEKLY DURATIONS IN RANGE 42 - 158 WEEKS SHOWN
3. RETURN PERIODS FOUND FROM PLOTTING POSITION FORMULA FOR EXPONENTIAL DISTRIBUTION
   E.G. FOR RANK 2 EVENT AND N = 66
   RETURN PERIOD = $\left(\frac{1}{66} + \frac{1}{65}\right)^{-1}$
   = 32.7 YEARS
4. RUNOFFS < 3000 ML NOT PLOTTED

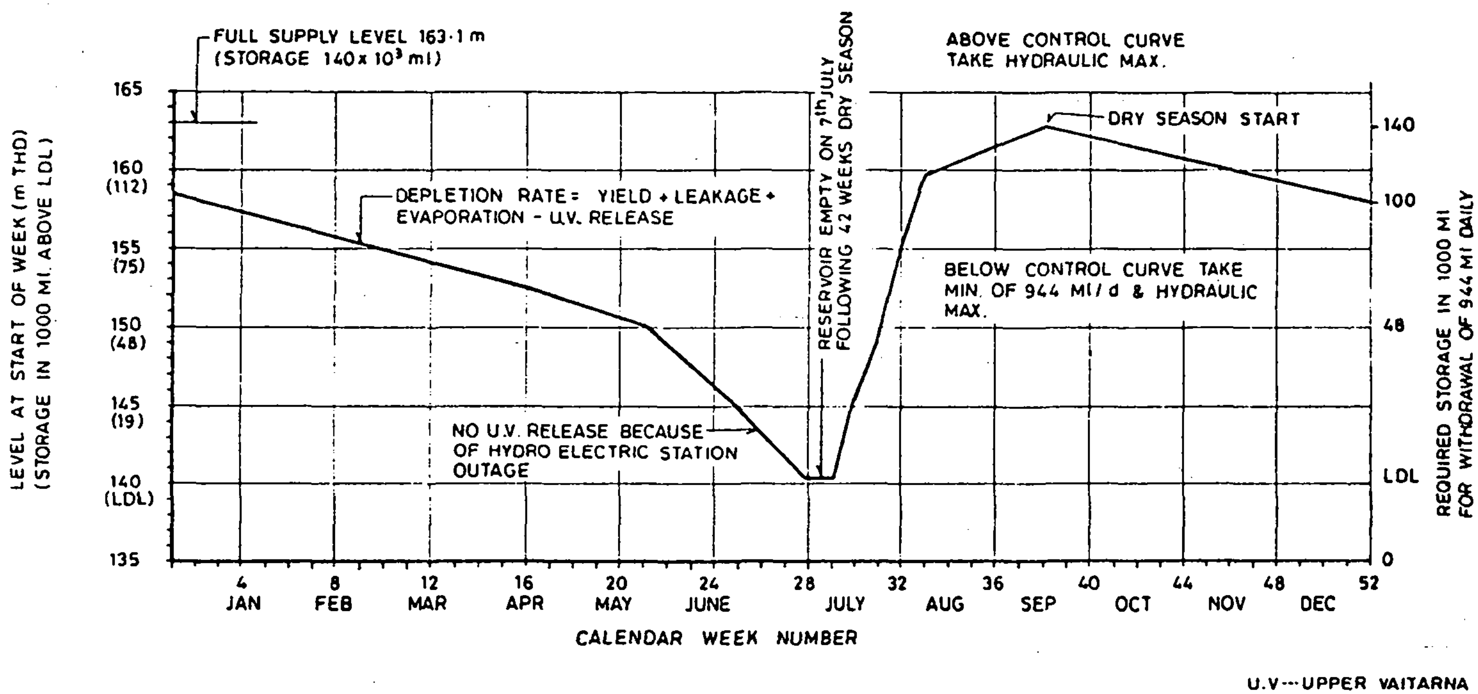


EXHIBIT SHOWING CONSTRUCTION OF CONTROL CURVE FOR LOWER VAITARNA RESERVOIR

EXHIBIT 4

PROTECT WATER INTAKES

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SYNOPSIS

Water resources in India are adversely affected by increased wastewater discharges, resulting in depletion in quality and reduction in usable quantity. The causes are illustrated as, less upstream flow and more downstream flow resulting in backflow, as witnessed at Delhi and Kanpur, polluting conditions of the open canals carrying raw water to the Water Works as observed at Pune and Kanpur, prevailing polluting conditions at Kanpur and Agra, discharge of shock loads upstream of intakes as found at Monghyr and Lucknow, location of intakes in Hooghly estuary, influence of industrial wastewaters to intakes and abstraction of water of Damodar river in Asansol-Durgapur region. Corrective measures such as, piped raw water to intakes, restricted entries to public at the intake points and effective guarding of sudden wastewater discharges are based on the existing conditions. For long-term measures, a proper authority and its powers are to be identified for protection of water resources; for this, successful operation of River Authorities in Western Countries can be taken as providing guidelines for effective implementation. Modifications of these guidelines to suit Indian conditions will, of course, be necessary.

INTRODUCTION

The Government of India has given due importance to the water resources by setting up a separate Ministry and are actively engaged in the implementation of programmes. It is obvious that when there is a rise in population and standard of living, the demand of water increases considerably and more so in urban locations, where there is excessive concentrated load on the natural resources. These urban centres withdraw huge volumes ofwater and return about 80-90% in the form of wastewaters. An excessive quantity of surface water from reservoirs, open channels, irrigated farms, is consumed for irrigation and in addition to this, evaporation losses are high during summer months. It is estimated that basins with scarce resources exhibit per capita availability of water between 1000 to 2000 m^3 and rivers covering these categories are Ganga, Yamuna, Southern tributaries, Krishna, Mahi and Tapi (1). It is imperative that the entire water resource system is required to be handled effectively for the survival and sustenance of economic growth.

Cleaning operation of the river Ganga over a stretch of 2525 km is in progress over a period of 5 years with the proposed cleaning of river Yamuna from Delhi onwards. With changed circumstances and general awareness in environmental protection as a whole and surface waters in particular, the author, based on his observations and field studies, would like to share his views to express his anxiety in the protection of water intakes on a long-term basis.

PROBLEMS AT THE SELECTED WATER INTAKES

While emphasising the points on the protection of water intakes, the author desires to put forth certain incidences to justify the actions subsequently proposed, or solutions called for.

BACKFLOW OF WASTEWATERS TO INTAKES

In this case, following examples are cited :

Delhi : The jaundice epidemic caused by suction of untreated domestic wastewater from Nazafgarh nullah flowing downstream of Wazirabad Water Intake during 1956. After this episode a barrage was constructed so that water intake is well protected. During the fifties, Wazirabad area of Delhi was thinly populated. Because of expansion of the city from all sides, the thinly populated area has rapidly developed in recent years. Once upon a time river Yamuna was free from any contamination before it entered the outskirts of the city, but now there exists no safe intake in the vicinity of the city.

Kanpur : It is reported that during one of the rainy days in the past, there was heavy downpour, which had resulted in inundation of a few areas of the Thermal Power Station located downstream of Water Intake at Bhaironghat. Power plant authorities released accumulated rain water, which got mixed up with major city drain wastewater of the Sisamau nullah and the level of water at this point suddenly increased, which resulted in the backflow of this mixed polluted water to the upstream intake point but there was no epidemic reported. However, gastric ailments are prevalent in the city. There are occasional instances when downstream wastewater had back-flowed and was pumped to Kanpur Water Works when dredging of the channel - which brings Ganga water from a distance of about 7 km - remains inadequate.

SUPPLY OF WATER THROUGH CANALS

Pune : Canal water from Khadakwasla dam to the city of Pune is fed to the newly built water works for the city and another abstraction in the Cantonment, to its Water Works. The entire length of this canal has hutment dwellers on either bank. The water is used and abused by them when they consume canal water for domestic needs. The population is gradually increasing along the canal in recent years.

Kanpur : In addition to the supply of Ganga water from Bhaironghat pumping station, canal water is also fed to Water Works. The canal emerges at one end from Lower Circular Canal, carrying Ganga water and ends at the Benajhaber Water Works with a length of 3-4 km. All along its length on either side people are residing with their buffaloes. The inhabitants use canal water for varied purposes and dump wastes in liquid and solid forms into the canal water. Open defecation is observed all along the canal during morning hours. It needs no further elaboration that the canal water is getting polluted at number of places.

As the river Ganga enters Kanpur at Bithour, it changes its course towards Unnao, instead of Kanpur. Because of carriage of heavy silt from Himalayas, the river which was once flowing near Kanpur about 40 years ago, is now flowing at a distance of about 7 km from Kanpur.

To keep the supply of river water to water intake at Bhaironghat and river side Thermal Power Station, Ganga water is brought through dredged channel towards Kanpur. Water Works spend about Rs.20 lakhs per year for dredging operation. During summer months the open land along the course of dredged channel on both sides is occupied by many cultivators and they grow seasonal vegetables and fruits. Number of people are engaged and considerable quantity of fertilizers are used for cultivation. In addition to this condition, the intake point continues to receive wastewaters through nullah from Nawabganj and Ranighat at the upstream point at a distance of about 100 m from intake. There is a subsequent thrust of pollution caused by the number of washermen washing clothes during day time. Number of buffaloes are washed in the dredged channel. All these operations are going on upstream of the intake point. During morning hours, number of people use the open land in close proximity to intake for defecation. Hence the intake point at Bhaironghat continues to be severely exposed to heavy pollution.

RIVER CONDITIONS AT THE INTAKES

Kanpur : It is observed that major flow of river Ganga at Hardwar is diverted to Upper Ganga Canal for irrigation and the remaining flow, which reaches Aligarh, is further diverted to Lower Ganga Canal for irrigation. When the river reaches Kanouj, the quantity of flow, especially during summer months, is further reduced, till it reaches Kanpur, where at Bithoor, it takes a turn to the opposite bank towards Unnao. It is reported that the average annual flow in Ganga at Kanpur is about 1200 m^3/sec while during April-May, it is reduced to about 90 m^3/sec (2).

Agra : River Yamuna receives all the wastewaters through outfalls originating from the city of Delhi and when it reaches Okhla, it is diverted by a barrage to Agra Canal which supplies water for irrigation. The river water quality, downstream of the barrage is further influenced by the wastewaters originating from Vrindaban and Mathura. Before the river Yamuna reaches Agra intake point, it receives fresh wastewater discharges from the city of Agra. The author has witnessed the deteriorated condition of the river at the intake point during one of the visits when the river water looked virtually like a slurry and full of freenish algae. The conditions of the river changes every day. Generally the condition of river Yamuna at the water intake is the worst as compared to any intake point in Uttar Pradesh and hence the water works authorities face constant problem of poor river water quality, which in turn create serious difficulties in treating the water.

DISCHARGE OF SHOCK LOADS TO THE RIVER

Monghyr : During the sixties, newspaper headlines had drawn attention to the news that Ganga caught fire, which was due to heavy discharge of oil refinery wastewater into river Ganga and due to friction the surface caught fire, resulting in fish kill in Ganga water at the intake point of Monghyr town. The town was deprived of water from the intake for 3 days till the pollution was washed away.

Lucknow : Recently Lucknow water works intake experienced pollution due to heavy discharge of wastewater from a sugar mill located about 100 km upstream at Sitapur. There was immediate depletion in dissolved oxygen, resulting in fish mortality.

Dead fish were floating on the waters of river Gomati at Lucknow. The water works authorities had to curtail the water supply till the pollution was cleared.

LOCATION OF INTAKES IN ESTUARINE REGION

The river Ganga, as it enters West Bengal, is termed as Bhagirathi river and then Hooghly estuary. The stretch of 100 km of Hooghly estuary covers Calcutta Metropolitan Development (CMD) area, of which the stretch of 35 km from Palta-Serampore to Garden Reach-Howrah accommodates 6 Water Works Intakes. This stretch is covered with thickly populated area of CMDA. The stretch is influenced by two ebb and two flood tides in a 24-hour cycle. The intake points located at Palta, Serampore, Kamarhati, Uttarpara, Garden Reach and Howrah, are influenced by the wastewater discharges located at upstream and downstream points and are related to tidal changes. Even if more water is made available at Farakka, the tidal conditions will prevail and the influence of wastewaters will also continue. As per NEERI report, all the abovesaid intake points showed deteriorated water quality from the point of view of bacteriological examination (3).

INFLUENCE OF INDUSTRIAL WASTE-WATER ON INTAKES

During Environmental Impact Studies conducted by NEERI in Asansol-Durgapur region in West Bengal (4,5), it was observed that the intake point of a paper mill in Raniganj was located downstream of point of discharge of a part of the untreated paper mill waste and was creating nuisance to the mill itself as the discharge remained unnoticed by the Mill Authorities. Similarly, the Iron and Steel Mill at Burupur, located in Asansol, discharged spent liquor into river Damodar in an untreated condition when the water intake point was located downstream of the discharge point. The Water Works personnel of the mill were complaining about the problems in the distribution system. The causes were not known on account of unawareness of the nuisance created by the mill itself.

ABSTRACTION OF RIVER WATER

It is reported by the Central Board for the Prevention and Control of Water Pollution that most of the rivers in India surveyed by the Board are polluted and obviously the intakes located on these rivers are continuously influenced by the polluted wastewaters. Although dilution of pollution solves the problem for a short term to certain extent, it is universally recognised that dilution is not to be considered as solution to pollution. If the river receives pollution exceeding its limit to assimilate it, the river gradually turns into an open drain. Damodar river is considered as the life-line of Asansol-Durgapur region, where its water is abstracted by 33 agencies and our old estimates revealed that when the maximum limit of 50% drawal of water from a river was exceeded, it was feared that after 1974, there would not be any fresh water in the stretch of 50 km from Panchet dam to Durgapur barrage. Damodar river, once known as the river of sorrow, on account of flooding of the low lying areas during monsoon and before Damodar Valley Corporation (DVC) was established, the same river has continued to remain the river of sorrow, but now because of heavy pollution. During surveys conducted by NEERI in 1966-68, Damodar river was considered as the most polluted river in India.

CORRECTIVE MEASURES ENVISAGED

Following measures are proposed for the protection of the intakes :

1. It is known that the Water Works at Bangalore receive raw water through a pipeline (1.2 m diameter) from Halli river water source, located at a distance of about 80 km. This might have been considered an adequate and reliable supply and a safe water resource, free from nearby pollution. For a city like Kanpur, it is strongly felt that Ganga water should be brought to the city from upstream location at Bithoor at a distance of about 15 km from Bhaironghat intake point. Although the flow of river at Bithoor is meagre during dry weather periods, the quality undoubtedly remains satisfactory. It is proposed to bring river water from Bithoor through pipe to Bhaironghat intake by the side of the old bank of Kanpur, so that digging operations are minimised and the existing unabated pollution from the surrounding region at Bhaironghat can be stopped. The intake well is to be well protected from the surrounding polluted sources. Inspite of repeated attempts made to impress upon the various agencies, political leaders, ministers and press, the need for piped raw water supply, and the prevailing conditions were highlighted, they have failed all these years and will continue to fail in future too. There seems to be no other workable alternative than to bring piped water from a location which remains free from pollution. There needs to be a guarantee from the Development Authorities that they will not extend wings of development in that region. This is equally applicable to other intakes located elsewhere.

2. Canal waters at Kanpur and Pune are extensively exploited by the inhabitants in the regions. It is not possible to stop this pollution unless the canal is closed, which is not feasible. The Water Works Authorities of Pune city and Pune Cantonment area should bring piped water from Khadakwasla dam instead of drawing from the nearby canal which is contaminated.

   It is revealed that the baseline studies conducted by NEERI that since the 35 km stretch, encompassing the 6 water intakes in Calcutta exhibited poor bacteriological quality, alternate location is required to be thought of. It was observed that the point upstream of Kalyani-Tribeni location is usually free from any source of pollution and can maintain good quality. Hence raw water through pipeline all along the bank be brought from this location to Palta-Serampore area, a distance of about 20-25 km and farthest point of Garden Reach-Howrah at a distance of 40-50 km.

3. Water works intakes are notified protected areas but it is always observed that access to the intake point by outsiders either from the water works premises or from river side is a common site and that washing operations - utensils, clothes and bodies - are carried out very near to the intake. This is undesirable and it is absolutely necessary to guard the intake closely and entries for unauthorised persons must be restricted. This rule continues to be violated and most of the intakes are even without any guard.

4. Industries located on the bank of a river should not discharge wastewaters in bulk quantities and in an untreated condition, causing nuisance to water intakes of their establishments or to downstream consumers. Central and State Pollution Control Boards are armed with legal powers in protecting surface and ground water sources but sudden discharges of huge quantities of waste materials continue to occur and there needs effective policing of the water resources.

5. Because of the deteriorated quality of Yamuna river water at Agra Water Works intake, influenced by the pollution loads discharged at Delhi, Vrindaban, Mathura and Agra City, the fresh impact of pollution load from Agra City drains can be eliminated by shifting intake point at a safer location upstream, where no city wastes are discharged. While selecting the intakes, quantity and quality considerations be given priority and there should not be any development programmes adjoining the intake.

EFFECTIVE ACTIONS FOR LONG-TERM GOALS

The abovesaid examples elucidate different causes of pollution, but no effective corrective measures are seen to be successfully implemented in most of these places. It is a question that remains unanswered: who should protect the water intakes? Is it the Water Works Authorities? But then how are they answerable to the nuisance created upstream and rarely downstream of the intake and what authority have they got to stop it? Is it necessary to set up River Authorities who are made responsible? But then how do they execute the duties for which they are created? It is observed that there are some river authorities in western countries having long, successful records. To quote a few, are the Tennessee Valley Authority in the United States, the Thames River Authority in U.K. etc. How do we look at these successes under Indian perspective for implementation? If the people in the region are causing nuisance instead of an industry, then how do they succeed in operation and maintenance of a system? Peoples' participation is universally recognised as an important factor for effective execution of the scheme meant for them. Under Indian conditions are there any examples where such schemes are found effective, so that similar attempts be made elsewhere? Damodar Valley Corporation could not succeed in protecting the water quality of river Damodar.

Under the Ganga Action Plan, the wastewaters discharged from 27 urban locations will be intercepted and discharged on land after due treatment. The river is expected to be pollution-free by 1990, but once the target is reached, what programmes are envisaged to protect the river beyond 1990? The Irrigation Commission (1972), The National Agricultural Commission (1974) and the Rashtriya Barh Ayog (1980) have repeatedly stressed the need for providing River Commissions for integrated management of the water resources but todate such commissions are non-existent.

The questions raised above are pertinent to the existing state of affairs and need practical solutions for the management system to be perpetual and compatible with existing private and governmental entities. The solutions must be cost-effective, provide multi-disciplined staff and services, necessary for effective operation, and above all, be capable of achieving and maintaining fiscal stability.

Can we achieve the protected water intakes on long term basis?

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STRATEGIES OF
MANAGING URBAN WATER SUPPLY SYSTEMS

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SYNOPSIS

There has been phenomenal growth of urban centres in our country. The urbanisation places excessive concentrated load on the natural water resources system necessiating constructoin of large storage reservoirs to meet the demands of water supply for these urban areas exclusively or in conjuntion with the demands for the other purposes like irrigation, industry, etc. The purpose of this paper is to draw attention of planners and engineers to the problems encountered in urban water supply management of large cities through multi-purpose storage reservoirs duly illustrated by a case study on Dharoi reservoir in the state of Gujarat. The projected scenarios of the simulation studies analysed with shortages due to inadequate water availability from the Dharoi reservoir and the strategies of managing water supply requirements and reservoir have been discussed. The results of the studies and discussions may be useful to analyse and plan action for reservoir management with similar problem

INTRODUCTION

The growth of cities in India has been assuming alarming proportions due to several reasons. The flow of rural population to urban centres due to lack of employment opportunities and increased emphasis on industrialisation in the urban areas requiring large labour force drawn mostly from villages are the main reasons. Urban growth requires increased per capita demand for water. The urbanization places excessive concentrated load on the natural water resources system in the river basin as they make large point withdrawals of water. This necessiates creation of large reservoirs to meet the demands of water supply for the urban centres exclusively or in conjunction with irrigation and industrial water supply. Even though the total use of water for the urban and industrial requirements may not be in large as compared to aggregate needs of agriculture in the basin, large consumption in small areas leads to considerable strain on water resources systems. In the initial stages of planning, number of projects were planned and constructed with inadequate hydrologic and other data which has lead to considerable gap between expected performance and achieved performance of the reservoirs in meeting the targetted demand with stipulated reliability in respect of urban water supply, irrigation etc. The purpose of this paper is to illustrate this problem with a case study of Dharoi reservoir which supplies water to Gandhi Nagar capital city and to the adjoining industrial city of Ahmedabad of Gujarat State. Some strategies of management have also been suggested.

THE DHAROI RESERVOIR

The Dharoi reservoir is the largest reservoir in Sabarmati basin with a live storage of 829 Mm . It intercepts a total catchment of 5476 Km out of which 3217 Km is the free catchment. It is contemplated to meet mainly the drinking water supplies to the cities of Ahmedabad and

Gandhinagar from Vasna Barrage downstream of the reservoir. The demand for drinking water is expected to be of the order of 188 Mm and was envisaged to be met at a reliability of 98%. In addition, the reservoir is to provide 218 Mm of water at a reliability of 75% for irrigating areas in Mehsana and Sabarkantha districts mostly located in adjoining Lune basin. The Dharoi reservoir has been in operation since 1977 but there have been difficulties in meeting targetted demands. Studies were, therefore, carried out by CWC to review the water availability from the reservoir to meet the envisaged demands and to evolve suitable reservoir operation policy.

Surface and Ground Water Development in Sabarmati Basin

Surface Water Development

The Sabarmati basin is extensively developed. Upstream of Dharoi dam, there are two dams-Wakal (under construction) and Sei (existing) in the state of Rajasthan and Harnov I and Harnov II existing dams in t the state of Gujarat supplying water to their individual irrigation commands. Below Dharoi reservoir, Hatmati and Guhai dams have been constructed in the state of Gujarat to meet the irrigation requirements of their individual commands. Below the confluence of Hatmati river, there is Vasna barrage which supplies drinking water to cities of Ahmedabad and Gandhi Nagar. Downstream to the cities, exists an irrigation command area called Fatewadi Command which is in existence prior to Dharoi dam. Fig.1 shows the existing surface water developments in the Dharoi command and Fig.2. illustrates the Sabarmati System through a flow diagram.

Ground Water Development

The Dharoi command area is situated in seven talukas of Sabarkantha and Mehsana districts of North Gujarat. Idar and Himatnagar Talukas are situated in the command within the Sabarmati basin and portions of Mehsana district, namely Visnagar, Vijapur, Khulari and Dishpur lie in the Luni river basin. Thus the major portions of command areas do not contribute to the recharge in the Sabarmati basin. Out of a planned command of Dharoi of 117,705, ha, about 20,280 ha. lies in Sabarmati basin. Besides, the Dharoi command area, potential recharging areas exist in the commands of Guhai and Hatmati dams and Hatmati barrage.

Based on the various studies carried out by Central Ground Water Board, it is seen that

i) the cities of Ahmedabad and Gandhinagar use ground water extensively for industrial purposes.

   In Sabarkantha district, six of the ten talukas are over exploited in ground water development viz. Idar, Modasa, Himatnagar Bhidola and Boyod. In the remaining four talukas, namely Khedbrahma, Prantij, Vijaynagar and Malpur also the exploitation is more than 50%. Combining the relevant areas it has been preliminarily estimated that in Ahmedabad and Sabarkantha districts, 97% of ground water is confined aquifers has been expoited.

ii) as regards the unconfined aquifers, the ground water potential is reported to be comparatively less developed in Ahmedabad and Sabarkantha districts. A preliminary estimate being 23% and 45% respectively for Ahmedabad and Sabarkantha[3]

PERFORMANCE ANALYSIS AND SUPPLY CAPABILITIES OF DHAROI RESERVOIR

A single reservoir simulation model "Central Water Commission Modified Tauxhal" - (CWCMTH)[4, 5] was used to analyse the performance and to evaluate supply capabilities of Dharoi reservoir to meet the demand of water supply to Ahmedabad-Gandhinagar twin cities and irrigation at stipulated reliabilities. The model computes the firm irrigation yield and mandatory yield by the usual simulation technique for each period of time series. The term yield as used in the model implies the total amount of water available at stipulated reliability. The optimization algorithm used for the estimation of firm yield for irrigation and mandatory requirement is a binary search technique in which arbitrary upper and lower limits are pre-assigned and a trial level of yield taken as the mid-point of the two values. After each mass balance for the entire sequence, for any selected level of requirement, that requirement will either be met (success) or not (failure), thus defining either a new lower bound or a new upper bound. The new estimate of trial yield is taken as mid way between previous limits. This trial search technique continues till the difference between the upper and lower limits converge to a pre-assigned convergence limit. The model computes firm yield for irrigation as well as mandatory releases upto a point when one extra failure is just encountered. The stipulated reliabilities considered in meeting the mandatory releases for urban water supplies to Ahmedabad-Gandhinagar alongwith irrigation supplies were 95%/98% for mandatory releases and 75% for irrigation.

The model requires long-term data, irrigation demands, releases for municipal and industrial uses and evaporation for the adopted simulation period with reservoir characteristics.

For Dharoi Reservoir studies, 14 simulation periods comprising of June (One period), 12 ten daily periods from July to October and one single period for November to May were considered.

The following assumptions are implicit in CWCMTH model :

i) There is no change in evaporation rate from year to year.

ii) The pattern of demands remain unchanged.

iii) The mandatory requirements have a priority over the irrigation requirements.

The output of the model gives the mandatory releases made for each simulation period which makes it possible to analyse as to how much demand can be met with what reliability.

At the project formulation stage, the hydrologic data from 1951-65 had been used to develop rainfall-runoff relationship[5] which was used to extend data from 1868 onwards. In view of the availability of data after 1965 and due to the wide scatter in the rainfall-runoff plot of data from 1951-65, it was considered desirable to recast the estimated inflows into Dharoi reservoir.

The broad steps used in hydrological analysis included (i) Infilling missing period rainfall data, (ii) Monthly rainfall-runoff regression with random component, (iii) Disaggregation of monthly series into ten daily periods for use in simulation model.

Three inflow series were used in the CWCMTH model as mentioned below:

a) A hydrologic series of 35 years

for the period (1951-85) has been considered. Of this, data pertaining to (1951-76) is observed one using current meter. The remaining data (1977-85) comprises of estimated inflow into the reservoir. The entire data supplied by the State Govt. was available in 10 daily form.

b) In addition to the above 35 years data, the data for 16 years i.e. (1935-1950) was used in the analysis. However, the data for this period was in the monthly form and the same was disaggragated into 10 daily flows (from July to October). Thus a total of 51 years was considered.

c) In addition to 51 years of historic data (1935-85), pseudohistoric series for (1901-34) has been developed. This series was merged with the 51 years data resulting in a long series of 85 years.

From the revised hydrological analysis it was seen that the annual average surface runoff at Dharoi Reservoir may be varying between 500 to 575 Mm3 The provided storage of 829 Mm3, therefore, appears to be high because of high evaporation expected at higher elevations. Table 1 below gives the characteristics of the historic and developed pseudohistoric series used in simulation studies on Dharoi reservoir. The runoff generating potential of Dharoi catchment in Gujarat can be seen on a period wise basis through this Table.

Table 1

Charateristics of three inflow series considered in the study

	June	July	Aug.	Sept.	Oct.	Non-monsoon Nov. to May	Remarks
1951-76							
Mean	13.31	87.10	138.17	202.97	29.17	25.40	Observed data by satisfactory method of obser-vation
Std.Dev.	19.29	61.24	135.65	269.23	30.95	24.69	
1953-85							
Mean	20.03	142.80	157.32	164.37	22.13	20.77	Observed data including the observations by f float & estimated flows.
Std.Dev.	34.71	180.81	139.34	230.75	25.52	20.02	
1901-85							
Mean	26.40	121.83	156.04	162.57	25.97	24.21	Pseudohistoric series
Std.Dev.	34.86	145.74	133.67	211.01	26.77	18.70	

RESULTS OF THE STUDY

Two types of strategies for management of urban water supply system can be identified. Firstly less quantity of water can be made available at more reliability. Alternatively, more quantity of water can be made available at less reliability. In the latter case, it becomes unavoidable to have severe shortages during lean season which might defeat the very purpose of constructing the reservoir.

From the various trials of simulation made for the purpose, broadly the following were the inferences (5).

i) Dharoi reservoir envisaged to provide 188 Mm3 of mandatory releases at an annual reliability (Probability) of 98% and about 218 Mm3 for irrigation supplies at an annual reliability (Probability) of 75%. As the runoff generating potential at the site is far less as compared to the one assessed at project formulation stage, with very limited data, it does not seem to be possible to meet even the water supply demand at stipulated reliability of 98%. A reduction in irrigation supplies, therefore, appear inevitable. The mandatory demands of urban water supply have been attempted at a lower reliability of 95%. This means that shortages in water supply to urban areas may be acceptable for 5% of the time instead of 2% of the time. Again, the adopted strategy is to consider periodwise failures instead of annual failure in releases which gives more flexibility to the planner.

ii) If full mandatory demand of 188 Mm^3 for the supply to urban areas is attempted from the reservoir, then extent of shortage expected in the various periods would be as under for about 5% - 10% of time (Table 2).

Table 2

Shortages in meeting the Urban Water Requirements

Period		Extent of shortages in meeting the Urban Water Requirements 10% of time	5% of time
June	(1-10)	34%	73%
July	(1-10)	---	50%
	(11-20)	---	32%
	(21-31)	---	---
Aug.	(1-10)	---	---
	(11-20)(	---	---
	(21-31)	---	---
Sept.	(1-10)	---	---
	(11-20)	---	---
	(21-30)	---	---
Oct.	(1-10)	---	---
	(11-20)	---	---
	(21-31)	---	---
Nov. - May		---	76%

iii) As the command areas for irrigation have already been developed, it may be necessary to give some irrigation supplies. However, if 100% of the required water for mandatory demand is released, it will be possible to support only 11% of the irrigation area with a reliability of 75%. Reduced mandatory releases for 70% of demand and 50% of demand were also considered in the study. With this it was possible to irrigate 43% and 71% of the area for 75% of the time.

STRATEGIES FOR WATER SUPPLY MANAGEMENT

It can be seen from Table 2 that period of expected shortfall in water supply for the cities of Ahmedabad and Gandhinagar starts from Nov. and continue till July 21. The extent of shortage will reduce with a decrease in the target of firm water supply but without being fully eliminated. However, the critical period will remain the same under both alternatives.

In so far as supplies for Nov.-May period are concerned, in the event of falling short of target level in the reservoir, rationing could start and continued till the May. But the period from June 1 to July 21 may pose problem. During this period there may or may not be adequate rainfall to build up the reservoir for a proper release decision. The study shows that month of june is a more critical period with expected shortages varying between (34-73)% between 90-100% of the time. Best release decisions may be possible with accurate rainfall prediction model coupled with a conceptual hydrologic model for upstream catchment of Dharoi reservoir. Considerable work has been done on the conceptual hydrologic models but not on the quantitative rainfall prediction models. With the availability of more information on monsoon behaviour through satellite imageries and use of proposed super computers, it would be possible to develop such prediction models. The task force required for this purpose could be a multi-disciplinary one, comprising of mathematicians, meteorologists, physicists, engineers, specialists in remote sensing, hydrologists etc. In the present context of country wide drought, such models would have been very useful to plan the strategies of management.

To reduce the shortages in the system, particularly for irrigation supplies, recycling of return flows from the municipal supplies to the cities of Ahmedabad and Gandhinagar can be considered. For example, irrigation commands downstream of Vasna barrage can be easily met after recycling.

Reduction in reservoir losses could be another strategy. In reservoirs with carry-over capacities evaporation losses are significant. In Dharoi reservoir, these losses could be upto 30%. Some experimental studies with use of chemical spread over surfaces in small reservoirs in Gujarat, Rajasthan and Karnataka have indicated a noticeable reduction in evaporation losses at a cost of 45-60 paise per kilo litre of water saved (See Chandra & Sikka). With more research on this aspect perhaps it would be possible to develop such chemicals which could withstand high wind velocities on commercial basis to economise on the manufacturing cost.

In order to reduce the conveyance losses to the minimum, closed conduit systems for water supply to cities would be desirable. For Ahmedabad, & Gandhinagar, the water supplies are through open canal. The losses through these canals may be of the order of (7-18%)[6] in various parts of Sabarmati basin due to seepage etc. The evaporation losses from open canals also could be significant.

The canal waters are susceptible to pilferage also. If these could be reduced by providing conduit distribution system, the required release for urban water supplies at the head of reservoir may further reduce by about 20 Mm3. Thus if irrigation supplies downstream of Vasna could be made after recycling and conduit distribution system is provided there can be a reduction in demand of about 50 Mm3 at the head of Dharoi reservoir.

Based upon the studies conducted by Central Ground Water Board, it is estimated that only 23% of unconfined aquifers have been used in the basin. The studies by Physical Research Laboratory (PRL), Ahmedabad further indicate that annual recharge in Sabarmati basin will be of the order of 1200 Mm3 (6). If Ranney wells have been successfully used to tap the recharged water in Sabarmati basin, it may be necessary to take up detailed studies of unconfined aquifers. The conjunctive use of ground and surface water on rational basis may be possible after these studies and assessment. The water quality of the ground water availability also needs to be checked regarding its suitability for drinking and irrigation use. Ground water modelling, however, is an essential prerequisite before such a study is attempted. The ground water modelling should include the quality aspect as well to adjudge suitability of water for irrigation and for drinking.

CONCLUSIONS

The purpose of this paper is mainly :-

a) to draw attention of the planners and engineers to the problems encountered in urban water supply management of large cities through multipurpose storage reservoirs illustrated by a case study.

b) to project and examine with reference to case study the possible remedial measures like efficient reservoir management, control of evaporation, use of closed conduit system for water carrying, use of alternative sources of water supply like ground water and measures like recycling of used water etc.

c) to identify the weak links in dealing with analytical part of the problem. It has been suggested to evolve accurate models for rainfall prediction. It has also been suggested to form multi-disciplinary task force for this purpose, as this is a very complicated problem. Any sophisticated reservoir management strategy would not be effective enough without such a model, in real time operation. The other weak link is the cheaper varieties of evaporation control chemicals.

d) It has been brought out that the problem of water supply can be better tackled as a multi-purpose - multi reservoir system including ground water sub-system. Ground water modelling for establishing sizes of such reservoir and recharges has been suggested.

Finally, it needs to be mentioned that case of Dharoi reservoir may be one among many reservoirs where adequate studies have not been carried out at the project formulation stage and which may have fallen short of targets. Such cases should be reviewed considering the availability of more data, new methods and modelling techniques with the concerned river basins as rational planning units if workable solutions are to be found to water related resource problems.

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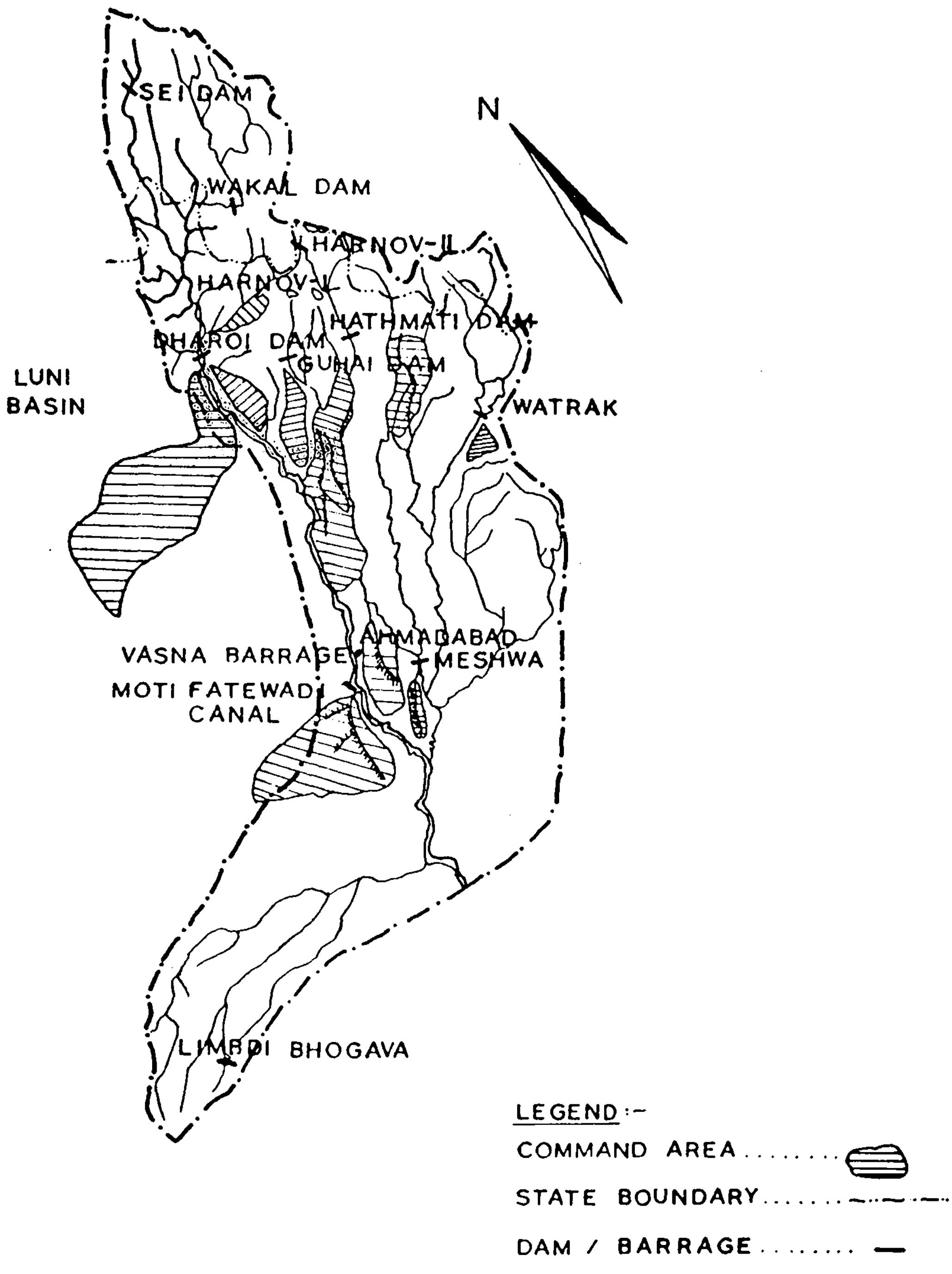

FIG. 1 .MAP SHOWING WATER RESOURCES PROJECT SITES, CANAL NET WORKS & COMMAND AREAS.

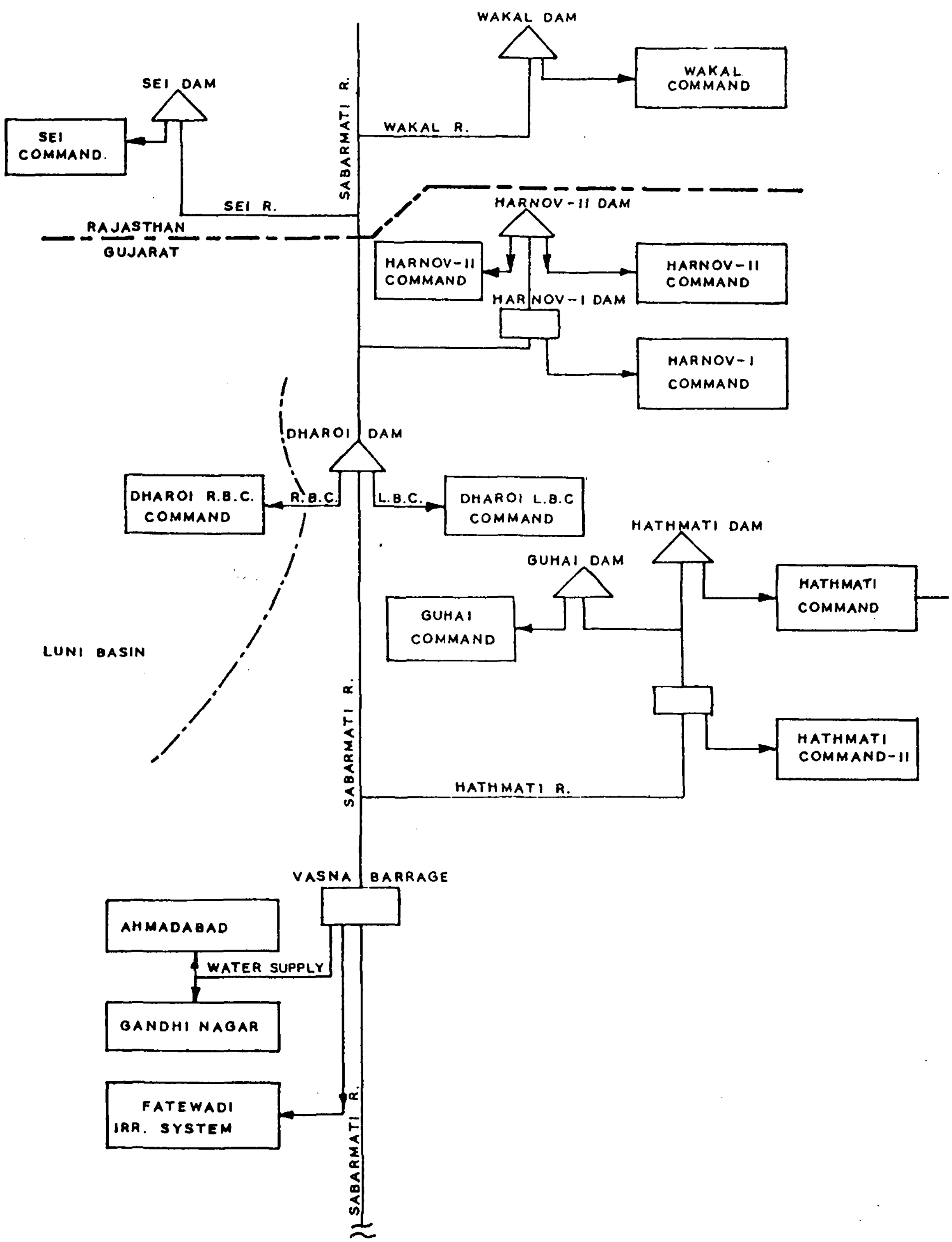

FIG. 2 SABARMATI RIVER SYSTEM

AQUIFER MANAGEMENT IN URBAN ENVIRONMENT

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SYNOPSIS

The expected massive urban growth in next few decades suggests that the present problems of water availablity in quantity and of desired quality for ever increasing urban water demands shall be alarmingly compounded. The aquifers that provide the safest water under natural conditions for a myriad of urban uses are in a state of stress as a result of ad hoc developmental strategies. These are required to be managed in a broader perspective, taking into account all the interlinked factors with systems analysis technique as a tool to evolve an optimal development strategy. A much more broadly composed and skilled planning team than before is needed to solve the problems.

INTRODUCTION

Groundwater, generally a renewable resource, is a critical one particularly in semi-arid and arid parts of the world. Precipitation continually replenishes aquifers which feed ground water into wells, natural springs and effluent streams. In nature, a dynamic equilibrium usually exists between precipitation, runoff and infiltration into the ground. Over years, the water table fluctuates about a mean. It recedes during drought and rises when it rains. However, in the process of development of an aquifer, the state of dynamic equilibrium is disturbed. The disturbance is most poignant in urban environments where the impact of man is more per unit area.

The construction of impermeable barriers on the surface such as roads and buildings reduces the rate of ground water replenishment. On a local scale, the intensive concentration of large number of people in urban areas is charaterized by water demands exceeding the yields of the parts of catchments in the immediate vicinity. The larger an urban complex, the greater the hydrological region that may be affected in the acquisition of its water supply.

The urban aquifer system (stressed in a myriad of complex ways) needs to be managed in a manner specific to the region concerned so as not to affect the environment adversely. The paper discusses these management problems in context of Chandigarh city.

IMPACT OF URBANIZATION ON AQUIFERS

Among the hydrological problems associated with urbanization are the continually increasing demands for water for various uses, changes in the physical environment that alter the natural water balance and the disposal of wastes that may contaminate groundwater. Of considerable hydrological importance, however, is the relative location of an urban centre in the river basin of which it is a part, as well as the degree and charater of its hydrological overlap with other centres and their distance from a large water body or sea/ocean. Studies have indicated that by the year 2000 A.D., half of the world's population will be urban and the rate of urbanization between 1975-2000 will be three times that of the period 1950-1975[1]. The large concentration of people in a relatively small portion of the land area shall have a significant influence on environmental process. The resultant water withdrawals for domestic and industrial uses shall climb so dramatically over future decades that the present problems may be regarded as merely a prologue of what is to come.

The effects of urban development on the underlying aquifer systems include:

a) Reduced infiltration and consequently less ground water recharge as a result of increase in impervious surfaces.

b) Lowering of water table due to extensive use of ground water. This adversely affects the agriculture and forestry, diminishes the base flow of streams and aggravates the pollution problem.

c) Domestic and industrial wastes disposed on ground or to the underlying aquifer may lead to ground water quality degradation.

d) Heavy groundwater withdrawal under weak geological strata may lead to land subsidence.

e) Induced saline intrusion in coastal cities as a result of heavy ground water pumping.

Figure 1 presents the pre and post urban state of ground water components of the hydrological system. Figure 1(b) illustrates the local water balance changes brought about in the ground water regime as a consequence to urbanization. The water quality aspect is not included as it would lead to complicated presentation.

URBAN AQUIFER MANAGEMENT OPTIONS

In spite of technological advances and general environmental concerns, growing urban areas cause almost insurmountable problems for planners and decision-makers both on local and regional scales since the area of influence of urban development is confined not only to the city concerned but transcends its borders. The management concerns are basically two : (i) to hold the ground water to an optimal level such that the hydrological environment is not unduly stressed and city needs of ground water are also satisfied to a desirable extent, and (ii) to maintain the ground water quality to a safe level.

The classical management of ground water system uses safe yield as the criterion for permissible withdrawal. The natural safe yield of the aquifer that lies within the forewalls of city boundary is grossly inadquate to meet the myriads of urban water requirements. It has indeed collapsed in view of growing ground water withdrawal that significiantly outweighs the so called safe yield limit. There is thus need to replace this concept by more rational approaches for better management of urban aquifer.

As is indicated in fig.1 (b) the urban ground water system is interlinked with a number of sub-systems. Any simplification to develop the ground water as is the safe yield concept, without considering the interacting sub-systems shall result in sub-optimal development of the resource. Systems analysis techniques that use systems model building and optimization offer a more rational alternative to evolve an optimal development and management strategy for the complex urban aquifer system. This may also call for system simulation on a scale larger than the physical boundary of the city area. Sometimes, it may mean consideration of the whole river basin for an optimal solution.

Having settled that the urban aquifer management problem may have to be solved in a bigger context, may be in a river basin perspective with systems analysis technique as tool to solve the vexing problems, it remains to identify how such a process could possibly be approached. Identification of system elements and their inter-linkages would perhaps be the first step. This should include all the essential factors that interact with the major aquifer system of which the urban aquifer may be a part. Aquifer simulation and appropriate optimization models may be thought of as the next step. The models may include the quality aspects also if a situation so warrants; although economic evaluation of the benefits and costs involved in ground water pollution may be difficult to evaluate.

With the development of a systems approach, the efficacy of various structural measures like artificial recharge, watershed management, recycling of waste water, sewage and waste water treatment, import of surface water, induced recharge from river bed, sub-surface dykes etc. for a balanced ground water utilization in conjunction with the surface water availability may be studied and an optimal scheme evolved for the specific situation in hand.

REAL LIFE URBAN AQUIFER MANAGEMENT - A CASE STUDY

General

The concepts outlined earlier were employed in the aquifer management issues of Union Territory (UT) of Chandigarh. The city came into being after independence and presently serves as the joint capital of the States of Punjab and Haryana. The UT extends in an area of 114 km^2 that comprises the capital city and the rural area. The city has been conceived as residential with only administration of the States and related infrastructure. Growth of industries particularly the heavy ones that affect the urban environment has been restricted. The population of the city is 6.25 lakhs. Fig.2 presents the general features of the Union Territory of Chandigarh.

Water Problems of the City.

There is no perennial surface water source in the vicinity of Chandigarh. The sustained flow of Ghaggar river located 3km east of UT boundary is not adequate (0.16-1.81m^3/sec). Feasibility of a surfce water source for city water supply by damming Ghaggar river near Chandimandir was investigated in midfifties but the project was shelved when existence of potential aquifers within capital project area was established. At all promising locations, tubewells in the depth range of 50-100 m were installed in the western and Central parts between Patiali Rao and Liesure valley. Further investigations revealed the existence of highly promising aquifers in Sukhna Choe area. By 1963 about 60 tubewells with a cumulative yield of 54,480 m^3/d (12 mgd) operated in Chandigarh. Subsequently 30 more tubewells were added enhancing the total yield to 1,00,000 m^3/d (22 mgd). By 1986 the number of tubewells increased to 160. The ground water draft that stood at 20 MCM/year in 1963, went up to 53 MCM in 1981 in view of the phenomenal population growth of the city. However it has decresed progressively from 1981 onwards to 37.03 MCM in 1986. A study conducted by Kidwai[3] however indicated a safe yield of the UT aquifer as 7.3 MCM/year or 20,000 m^3/d (4.4

mgd) which was subsequently estimated s 30 MCM/Year (82,000 m^3/d or 18 mdg) by Jindal and Jaganathan[4].

The water requirement as estimated by the Chandigarh Administration for a population of 6.25 lakh and other ancillary uses is of the order of 3,90,000 m^3/d (86.65 mgd) of 143 MCM/year (vide Table 1).

To meet the huge deficit in demand and availability, ground water draft of 53 MCM (1,45,200 m /d) recorded in 1981 has stressed the aquifer with resultant declining trend in the water levels and consequent reduction in well yields. The decline is observed to be about 1.0 to 1.5 m/yr in different parts. The persistence in decline in view of the tremendous gap between safe yield and actual withdrawal is indicative of ground water mining. Figure 3 presents the water table profile along a typical section over different time horizons and describes the influence of urbanization on the ground water environment.

PHYSIOGRAPHIC FEATURES

The UT is located at the foothill of the Siwalik ranges. With two major ephemeral draining streams - Sukhna choe in the east and Patiali Rao in the west (Fig.2). The Central part of the capital is a water divide of the two streams and seems to have formed by their coalescing alluvial fans. The catchment area of Sukhna choe and Patiali Rao before they enter the Union Territory are 36 Km^2 and 40 Km^2 respectively.

The Sukhna choe is dammed North east of Sector 6 to create a perennial artifical lake with water spread of 1.62 Km^2. All the surface runoff generated in its catchment is arrested by this dam and almost no flow is allowed downstream except during highly wet monsoon year. Al the flows downstream of the dam are from minor tributaries joining it in the downreaches. A large part of the original one kilometer wide flood plain of the choe has been reclaimed for other uses by raising embank-

Table 1

Esimated Water Requirement of Chandigarh

Purpose		Rate	Requirement	Quantity
i)	Domestic	204 lpcd (45 gpcd)	6.25 lakh persons	0.1275 MCM/d
ii)	Public stand Posts	70 lpcd (15 gpcd)	2.00 lakh persons	0.0140 MCM/d (3.0 mgd)
iii)	Irrigation Public (Parks)	60.62 m^3/ha/d (13340 g/ha/d)	2672 ha.	0.1628 MCM/d (35.64 mgd)
iv)	Irrigation Private (Lawns)	44.9 m^3/ha/d (9800 g/ha/d)	1234 ha.	0.0553 MCM/d (12.19 mgd)
v)	Industrial & Commercial	44.90 m^3/ha/d (9880 g/ha//d)	779 ha.	0.0349 MCM/d (7.69 mgd)
			Total	0.3935 MCM/d (86.65 mgd).

ments and restricting the choe course to 60-80 m width. Similarly, the Patiali Rao is also channelised in a narrow course and beyond Dadu Majra, its dischrarge is diverted to Jainti Devika Rao - a stream further west of the area.

In addition to these, there are two minor streams draining the central part of the UnionTerritory and another stream originates in the Siwalik hills in north-eastern part close to Mansa Devi Temple flows along the south-estern border from Manimajra to Makhanmajra before joining Sukhna choe just beyond the U.T.area.

The water holding capacity of Sukhna lake was 5 million cubic metres (MCM) when its bed level was 343.2 m. Its capacity reduced substantially due to 6.73 m silting that raised the bed level to 349.9 m. To maintain a minimum depth of water in the lake, desilting operations are carried out periodically. The Central Soil Reserarch Institute, Chandigarh developed the catchment of the lake by adopting soil conservation practices and reduced the inflow of silt content to 5 ham from the original 55 ham per annum. These practices also decresed water flow into the lake from original 6.78 MCM to present 3.70 MCM. Reduction in surface flow may also augment seepage to the ground water reservoir from the catchment area.

HYDROLOGICAL SET-UP

The two distinct geological units - The Quarternary and the Teritary are exposed in the Union Territory of Chandigarh. There is wide variation in sub-surface lithology over the area; more arenaceous towards Sukhna choe as compared to Patiali Rao and Central parts where it is more argillaceous. Further, the aquifer material is very coarse in Sukhna choe area where it is composed of sand, boulder and pebbles against fine to medium sand in Patiali Rao and central parts.

Sukhna Choe Area: The lithological cross section along Sukhna choe (Fig.4) shows that there are 3 aquifer groups ranging in thickness from 10 to 30 m separated by 5.20 m thick extensive clay beds within 100 m depth. The clay beds occur at (i) 20-40 m, (ii) 50-60 m and (iii) below 75 m. Thick clay beds occur close to land surface also but are generaly not extensive except towards Manimajra and railway station.

Potential aquifer zones at 112-140 m, 160-189 m, 214-336 m, 253-270 m.depth were established through an exploratory borehole upto 465 m depth in the centre of sector 28 by the Central Ground Water Board. Six aquifer zones exist below 300 m depth but their potential is not tested.

The cumulative thickness of aquifer zone upto 100 m bgl varies. from 23 to 59 m - the average being 36 m.

These are unconfined to semi-confined and are locally confined at deeper levels. Average transmissivity values in the Sukhna choe area are 330 m^2/d in the norther part and 195 m^2/d in the southern parts. For the deeper aquifers (100-300m) the transmissivity values in norther parts are 850m^2/d and in the southern parts only 91 m^2/d. The storativity values of the order of 10^{-4} determined through pumping tests suggest these acquifers to occur under confined conditions. These aquifers (upto 100m) are capable of sustaining discharges of the order of 100-300 m /hr per well with reasonable drawdowns of 6 to 10m. The deep well (112-279 m) in Sector 28 sustained 180 m^3/hr pumping with 7m drawdown. The deep tubewell (130-220 m) in sector 33 sustained 113 m^3/hr. discharge for a drawdown of 10m.

Patiali Rao and Central Parts : The lithology of the sub-surface formation in the Central and Patiali Rao area indicated no defined grouping of aquifer zones, though there appears predominance of clays down to 100-120m depth. The cumulative thickness of 3-6 aquifers zones ranged between 13m and 36m with an average of 27m. The transmissivity values are between 330 and 460 m^2/d. The storativity values of the order of 10^{-4} suggest confined conditions for these aquifer zones.

The Central Ground Water Board exploratory borehole down to 450m encountered 9 aquifer zones of cumulative thickness equal to 64m. between 130 and 450m. The aquifer material is fine to medium sand. These aquifer zones could sustain a discharge of 50 m /hr for 12.5m. drawdown. In the northern part of sector 10, six aquifer zones with a cumulative thickness of 65m. exist between 120 and 340m. depth. The potential of these zones has not been determined.

QUALITY: The Chemical quality of Chandigarh groundwater, but for its high temporary hardness, is well within the acceptable limits prescribed by WHO, ISI and the ICMR. First detailed ground water quality study of dugwell and tubewell zone was made by Kochhar, B.D.[5] Kidwai[3] (3)and Jindal & Jaganathan[4]

The chemical quality data showed a decrease in TDS and total hardness in 1969 as compared to 1963 but the situation seems to have reversed by 1974 when the TDS and total hardness again were comparable to 1963. Thus, it can be concluded that the chemical quality of ground water with heavy pumpage over 3 decades induced no significant change.

The analytical data of 1969 and 1975 do not contain iodine and fluoride information, though the 1963 data shows iodine deficiency. As against 1 microgram/lit present in Chandigarh water, the desirable requirement is 5 microgram/lit to avoid giotre syndrome. Accordingly Chandigarh Administration has made it mandatory to sell iodised salt in the capital city. (This salt contains 5 mg. of potassium iodide per kg. of pure salt).

CHANDIGARH AREA GROUNDWATER MATHEMATICAL MODEL

General

The Chandigarh water supply problem was studied by Central Ground Water Board through UNDP assisted special groundwater balance Project. A mathematical model was developed for the groundwater system to evaluate the Chandigarh water supply potential and alternative schemes which may be implemented to increase the available supply.

Salient Features of the Model

The model is based on finite difference approximation of the two dimensional parabolic partial differential equation of groundwater flow derived from the Darcey and continuity laws. The differencing scheme uses space centred central difference and time centred Crank-Nicholson Schemes. The solution of the resulting set of finite difference equations is based on the technique developed by Halepaska and Hartman[6] Basically, the method employs a head extrapolation technique using the Del-Squared Aitken relation prior to each time step. The system of linear equations forms a tridagonal matrix which is then solved for head using the Thomas algorithm. The computed values of head are then compared to the extrapolated values. If the difference is greater than some chosen epsilon the computed value is resubstituted and the linear equations solved again. This iterative procedure continues until two successive iterates fall below epsilon. The method has been found to be unconditionally stable with respect to time and space and provides fast and accurate solutions requiring a minimum of computer processor time. For details 'Ghaggar

River Basin Ground Water Mathematical Model Report No. DP/UN/IND-74-009/2' may be referred to.

Model Results

Two operational runs of the model were conducted. In the first run, 1977 pumping conditions (less than 1981 pumping level) were imposed and the effect of this fixed stress was studied for 23 years (1977-2000). Fig.5 shows the water level elevations generated by the model for the year 2000. It is seen that in the heavy pumping areas, 25-30 metres drawdowns are observed with the lowest water level elevation occurring in the heart of the Sukhna choe well field. Analysis of the results show that a steady water level decline is predicted.

The second operational run of the model was made to evaluate the efficacy of inducing recharge in aquifer along the Ghaggar River during monsoon to counterbalance the effect of heavy pumping in chandigarh well fields. The average rate of seepage flux of 350 lit/sec per grid was obtained during the monsoon period. 5 wells of 60 lit/sec per grid were made to operate near Ghaggar to cause lowering of the water level below the invert of the river bed. The 5 year regional water level elevation can be seen in Fig.6. The effect of the induced recharge is apparent in the deflection of the contours in the vicinity of the recharge sites. The results indicate that the present water supply to the city of Chandigarh could be immediately enhanced by a high density well field in the Fatehpur area.

MANAGEMENT OPTIONS FOR CHANDIGARH WATER SUPPLY

The natural yield capability of the aquifer is inadequate to meet the present and growing water requirement of the city.

There is no noticeable water quality deterioration with urbanisation.

The present water supply to the city is 1,76,200 m^3/d (38.83 mgd) against a total demand of 3,90,000 m^3/d. The supply has therefore to be immediately increased more than double to meet the present requirement. With steady increase in urban population, the demand shall continue to increase aggrevating the existing critical situation. The water demand for the year 1991 is estimated at 4,19,400 m^3/d.

The present supply of 1,76,200 m^3/d is maintained through tubewells and canals. The tubewells supply 1,01,300 m^3/d and the canals 74,900 m^3/d. Schemes to infuse additional water into city water supply system are already under way through sewerage water purification and supply from Bhakra system; the former to provide 68,100 m^3/d and the latter 90,800 m^3/d. when added to the Chandigarh water system, the availability shall rise to 3,24,600 m^3/d (71.50 mgd) a part going waste. This will leave a deficit of only 94,800 m^3/d by the year 1991.

If zero deficit is to be achieved by the year 1991, there is need to explore additional avenues to add 94,800 m^3/d to the city water supply system. This deficit and additional requirements beyond 1991 could be planned through:

i) diversion of additional water from Bhakra system, purify and bring it to the urban water supply system. This will depend on availability of adequate water from Bhakra system throughout the year as per demand.

ii) diversion of additional water from Bhakra system during high releases from the reservoir and to store it in ground water reservoir through appropriate artificial recharge projects.

iii) Induce recharge to the ground water system from the local ephemeral streams during monsoon period.

iv) Watershed management practices in the catchment areas of Sukhna Choe and Patiali Rao to augment ground water recharge.

v) A combination of the above options.

Studies indicate technical feasibility of all the options, their adoption, however, is a subject of detailed economic analysis. No relative economic study appears to have been carried out to suggest the best sources of action for the present problem. An optimization model alongwith the system model discussed earlier shall alone suggest the optimal solution to the Chandigarh Water Supply problem.

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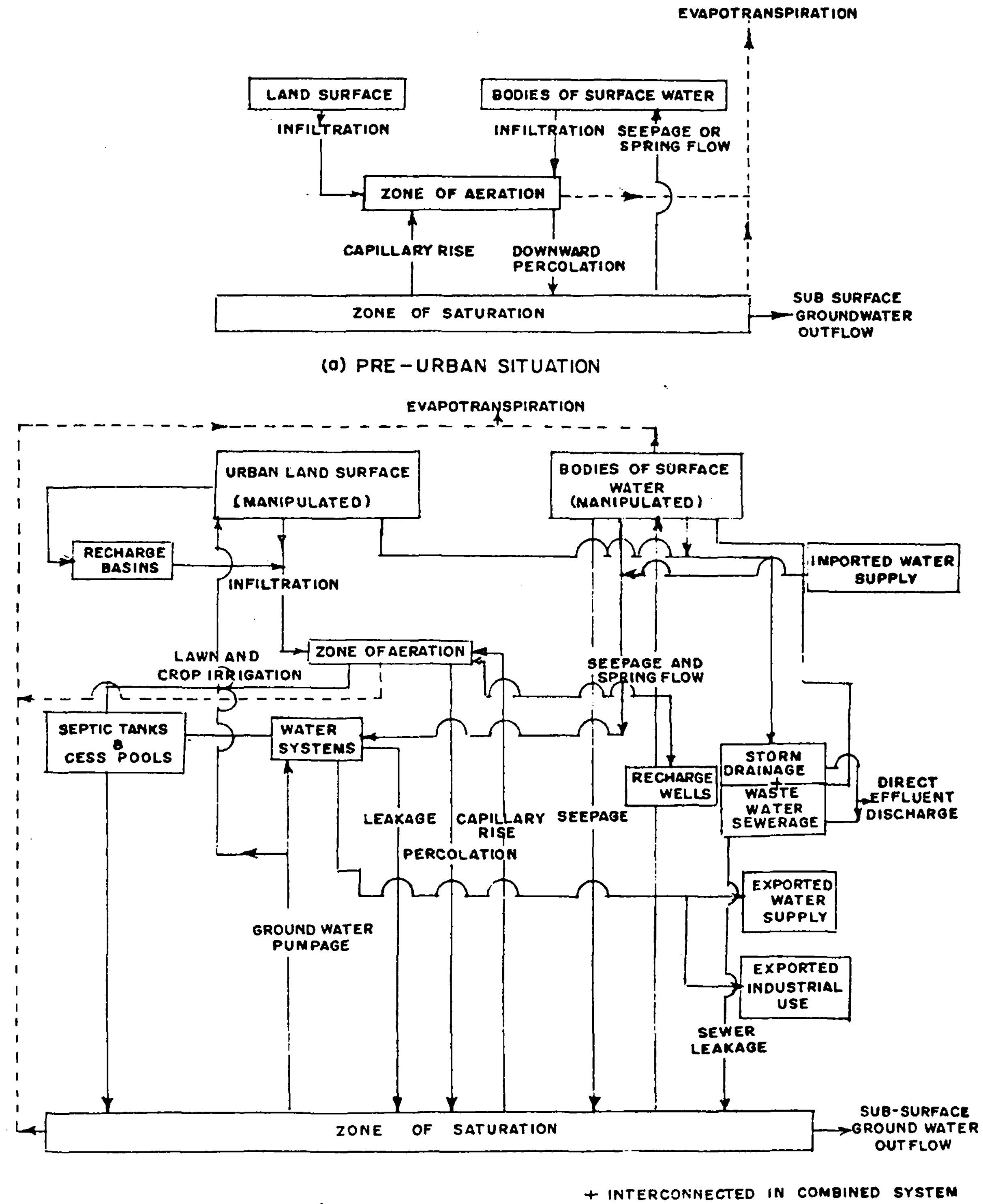


(b) POST—URBAN SITUATION

Fig.1.

STATE OF GROUNDWATER COMPONENT OF THE HYDROLOGICAL SYSTEM
(Adapted from Mc. Pherson, 1974)

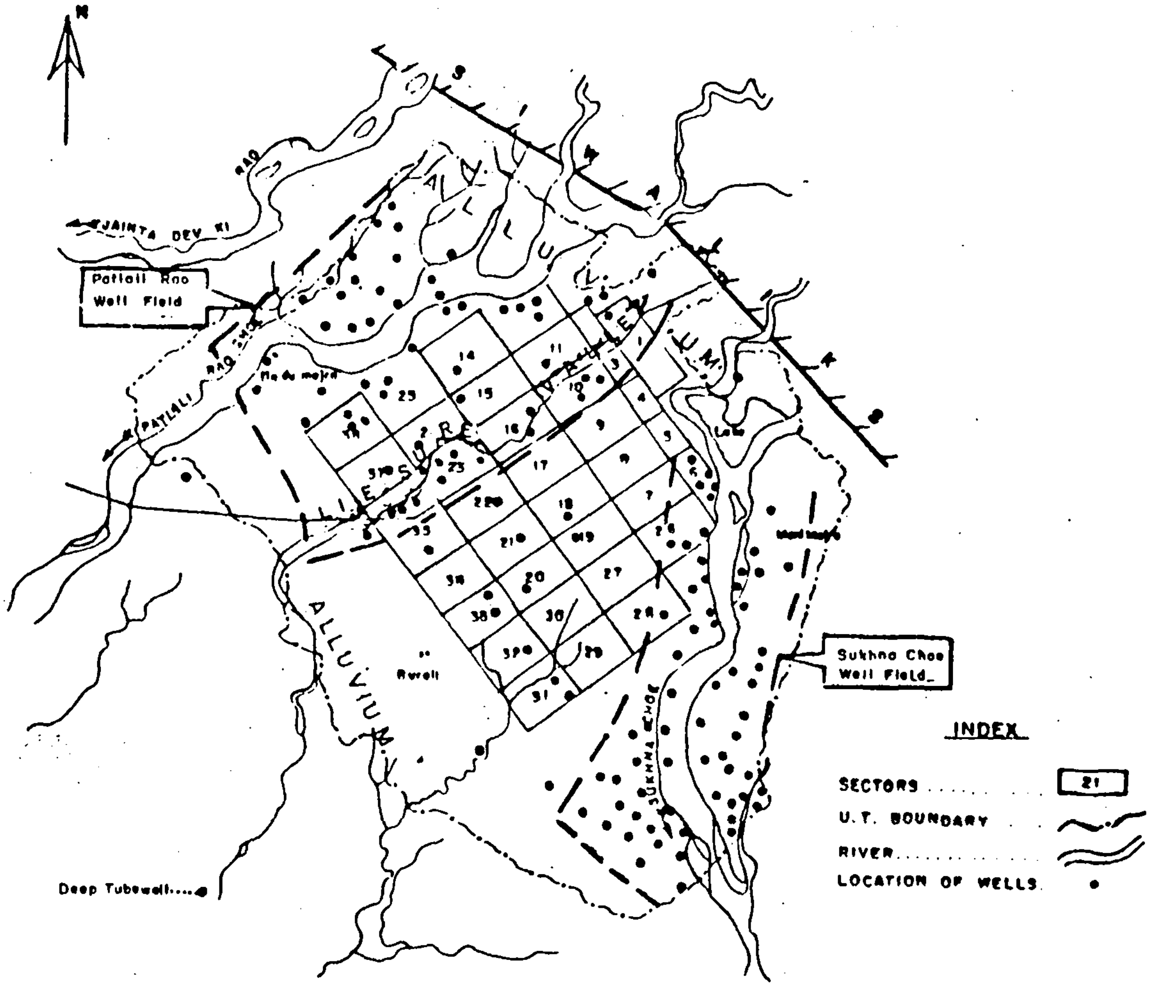
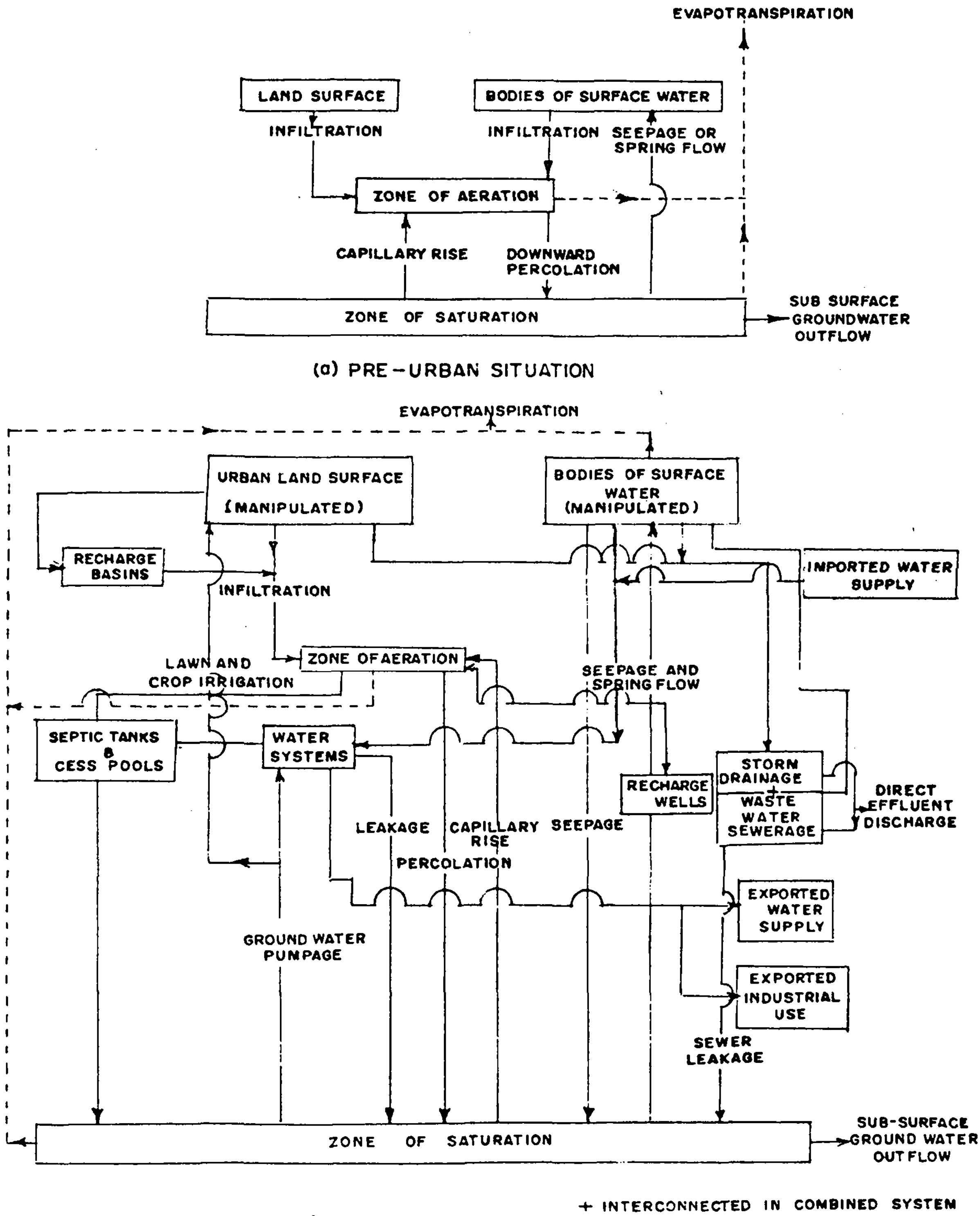


Fig.2. GENERAL FEATURES & LOCATION OF WELL FIELDS



(b) POST-URBAN SITUATION

Fig.1.
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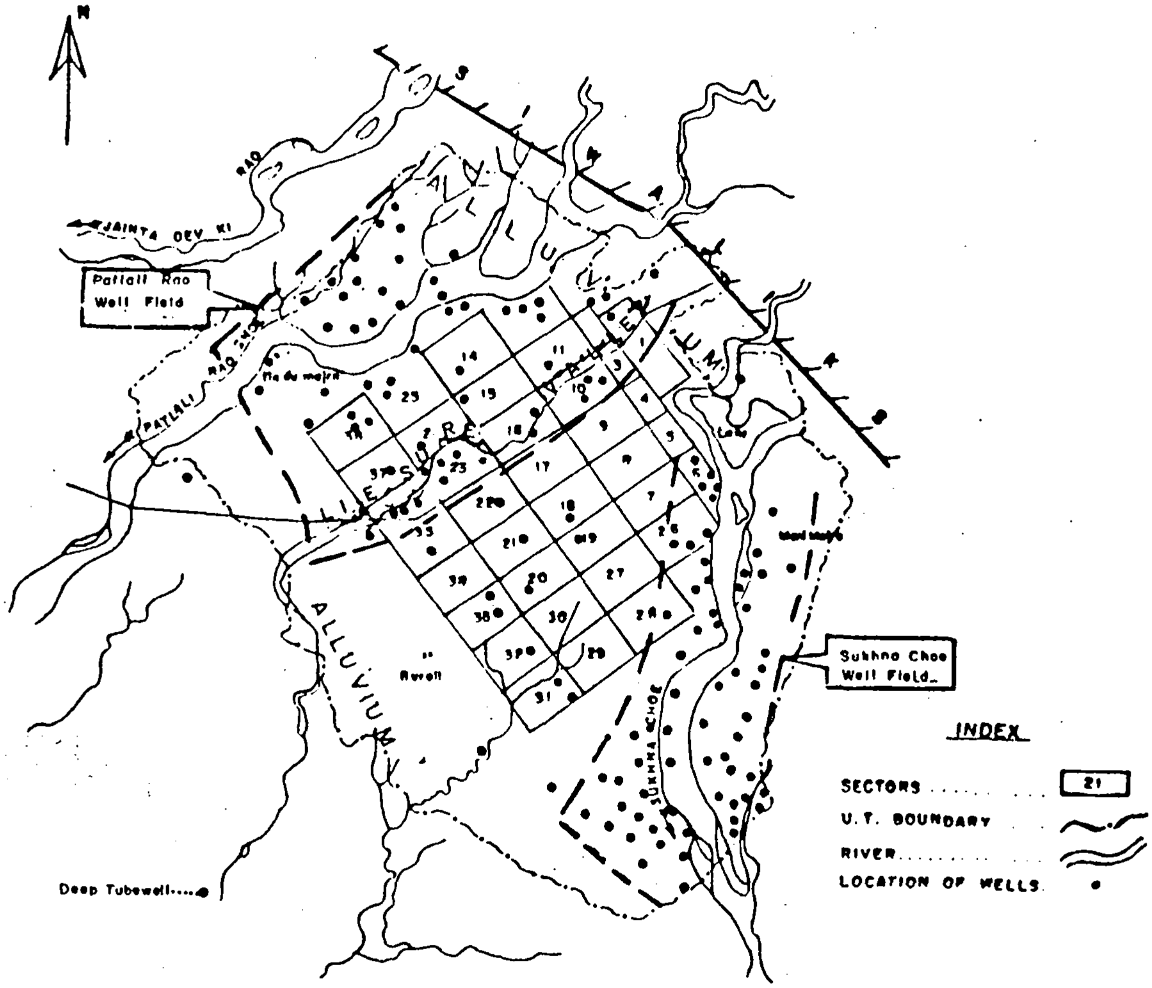


Fig.2. GENERAL FEATURES & LOCATION OF WELL FIELDS

Fig.3. WATER TABLE PROFILE OF CHANDIGARH AQUIFER

SECTION A-A'
Scale:- 1:63,000

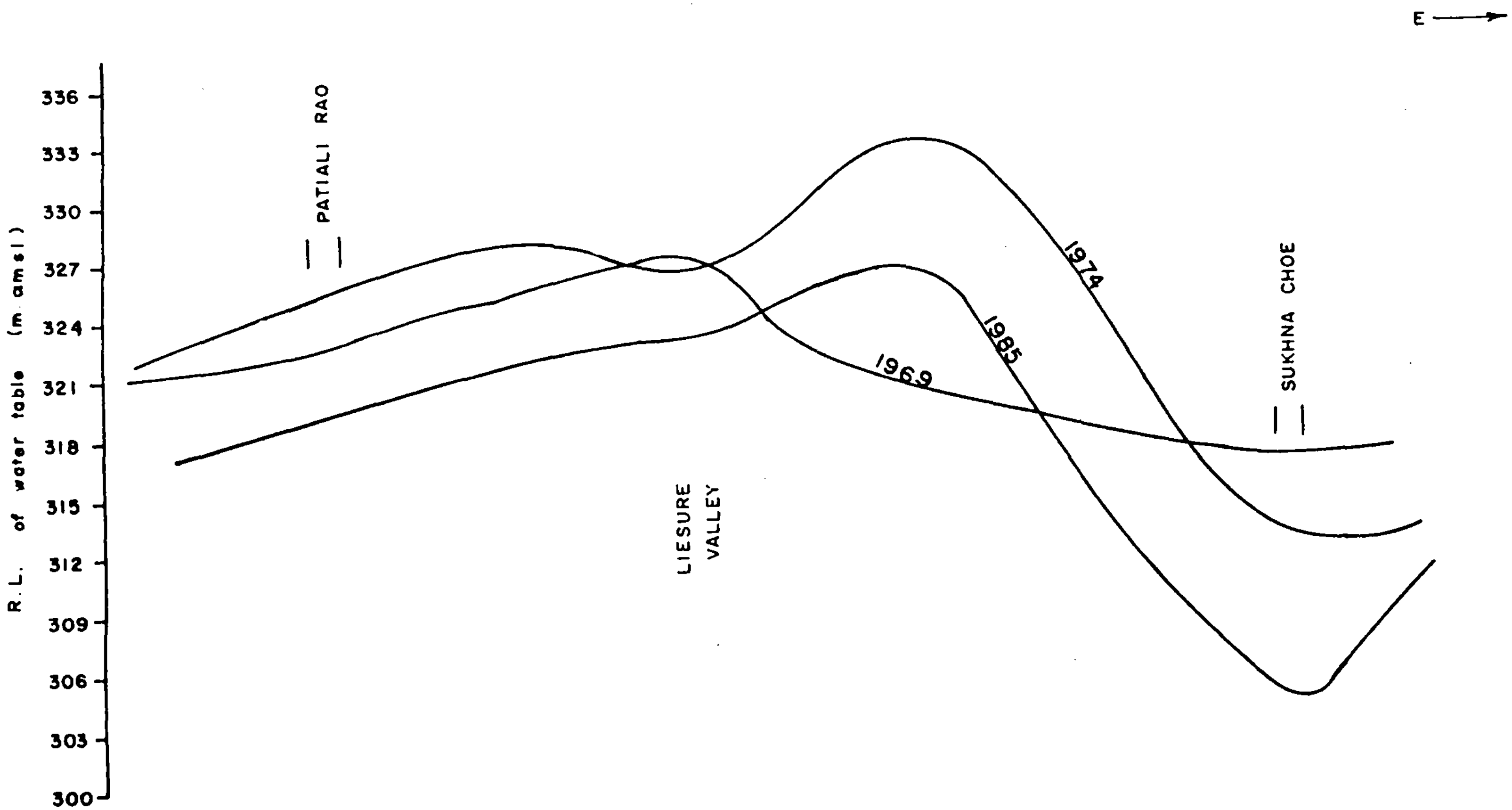


Fig.4. GEOLOGICAL CROSS SECTION ALONG SUKHNA CHOE

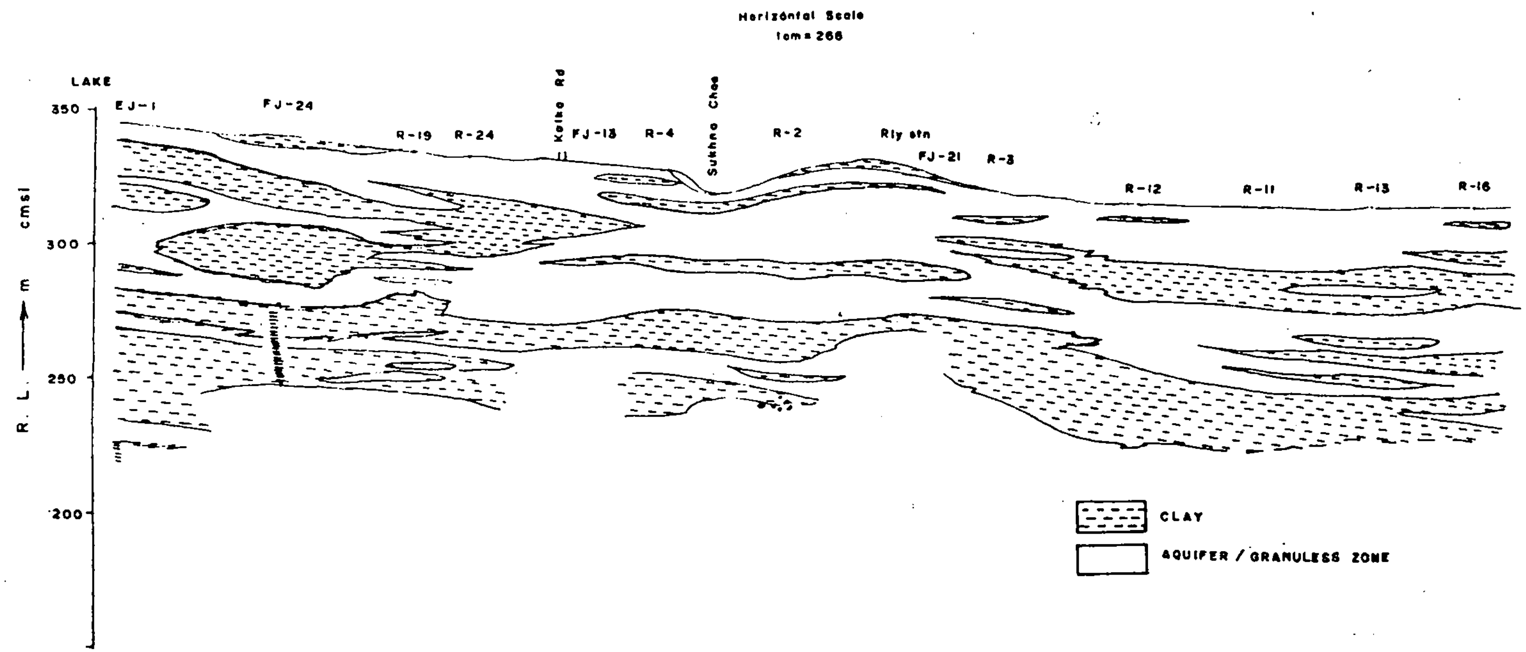
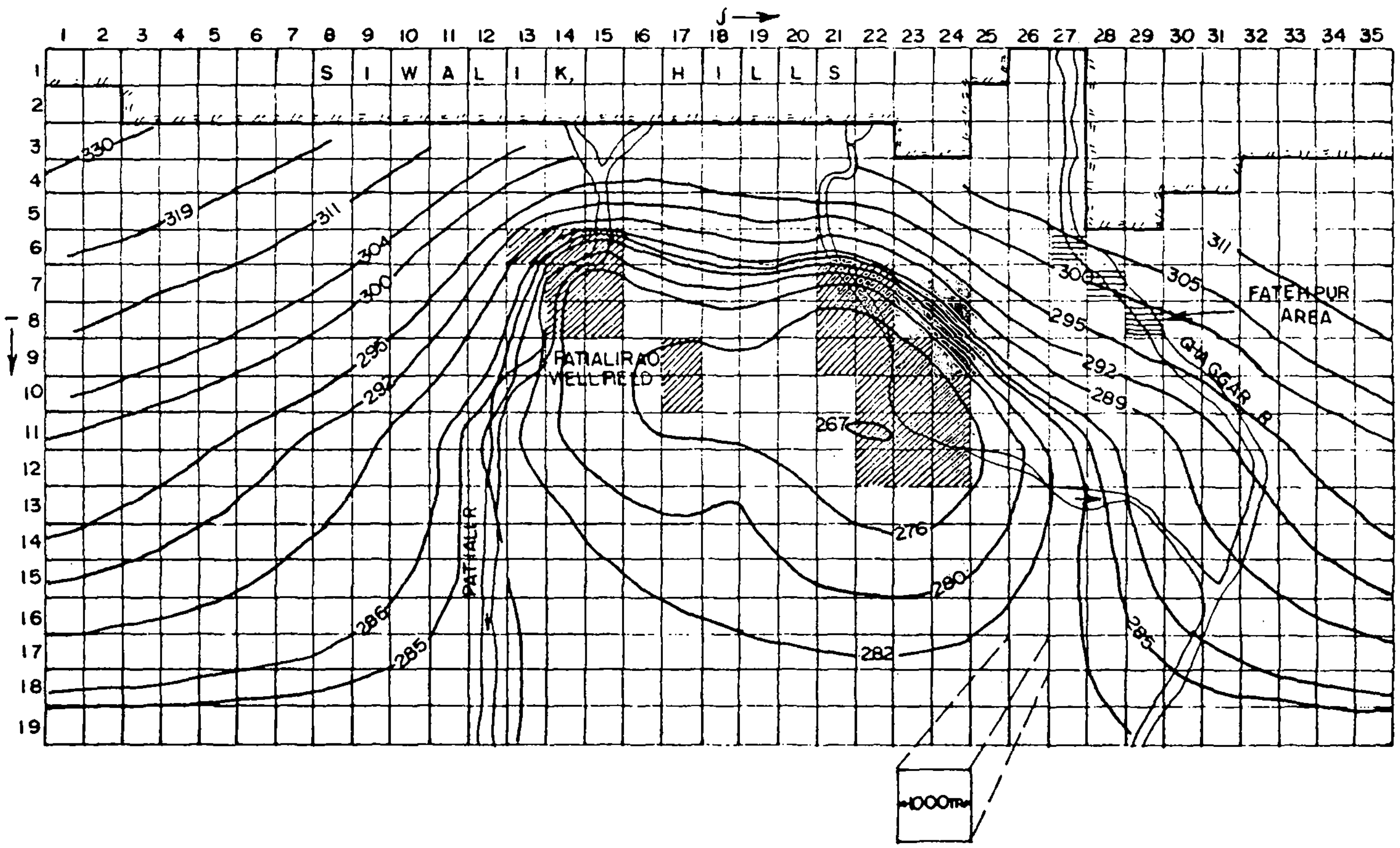
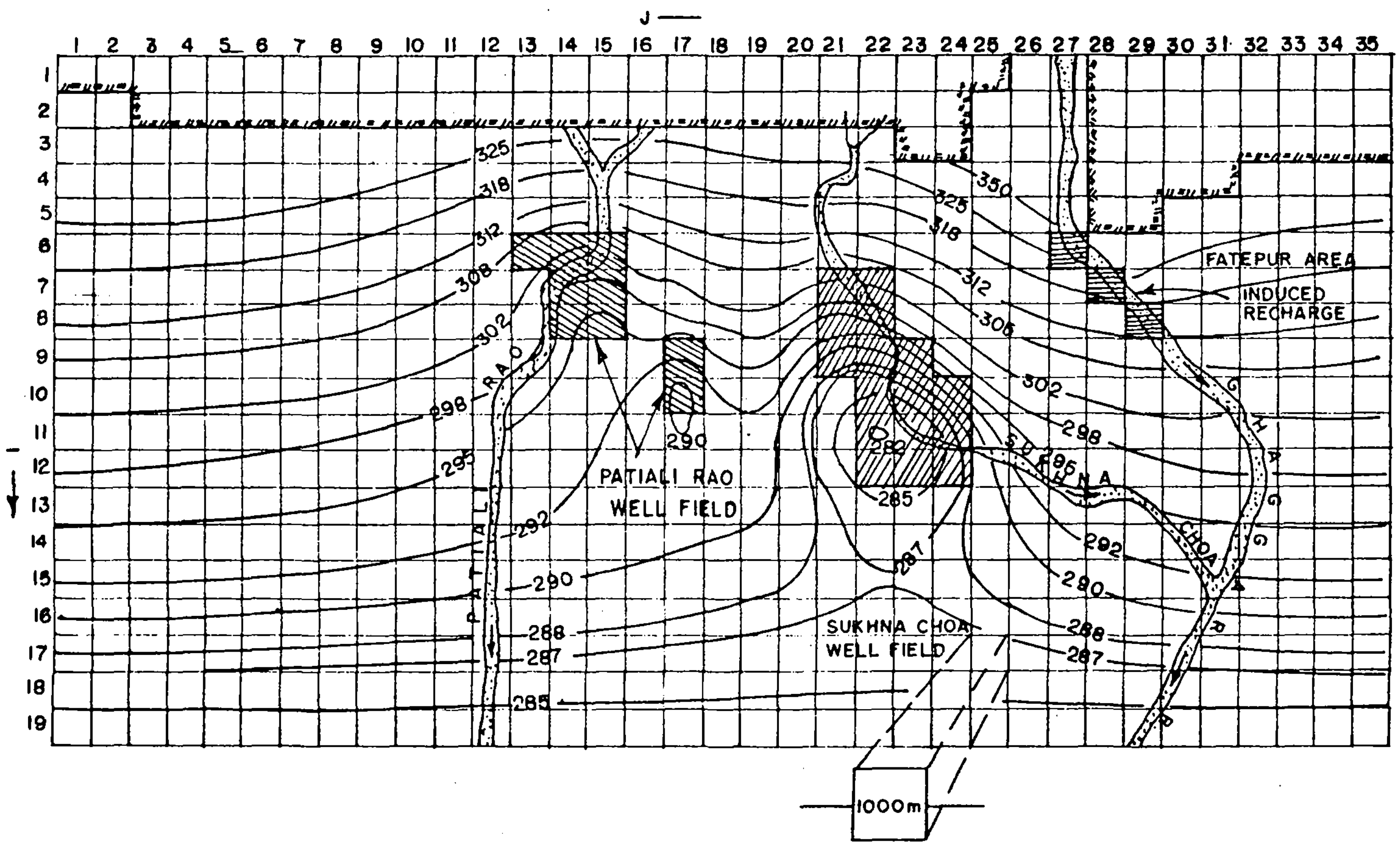


Fig.5. WATER LEVEL ELEVATION IN 2000 PREDICTED BY CHANDIGARH AREA GROUND WATER MODEL



(After:- Report of GHAGGAR River Basin Ground Water Mathematical Model)

Fig.6. WATER LEVEL ELEVATION WITH INDUCED RECHARGE IN CHANDIGARH I



(AFTER: REPORT OF GHAGGAR RIVER BASIN
GROUND WATER MATHEMATICAL MODEL.

EXPLOITATION OF SEA COAST AQUIFER IN INDIA

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SYNOPSIS

India is having a long sea coast. Tamil Nadu in particular is blessed with a sandy coast line which extends all along from north of Madras city to Kanyakumari. Rainfall in this area and the inland seepage give rise to a tenueus water balance with saline water on the seaward side and fresh rain water and inland seepage on the land ward side. This equilibrium is easily upset if over exploitation is practiced. A method to extract fresh water from this region is examined in this papaer.

INTRODUCTION

It is estimated that an average rainfall of 100cm is realised as an average amount over the 3.2 million square kilometre area on the Indian subcontinent. This represents a volume of 3200 billion cubic metres. Another estimates places the total utilisation and run-off figures at 1600 billion cubic metres. Hence, the remaining 1600 billion cubic metres has to reach the sea by the subsurface route India is blessed with a long sea coastline. Hence, it is to be assumed the sub-surface flow meeting the sea is substantial along the sea coast. This appears to be a promising source when the quantities involved are examined. Further, sea coast has also wind blowing for a substantial part of the day which can be harnessed for extracting water. An installation of such a unit at Marakkanam in South Arcot District in Tamilnadu is being discussed in this paper.

THE SEA COAST FRESH WATER:

A peculiar condition exists on the sea coast. The fresh water derived from rain and seeping down from the land sloping towards the sea follows an underground path. This flow creates an interface with sea water and establishes and interface with sea water and is in equilibrium with the saline layer. In actual practice, sea water may intrude inland below the fresh water layer and exist below the fresh water layer. Thus we get two layers, the top layer of fresh water with a sea water layer below it with a density of 1.03 (3% by weight assumed as salt in sea water). For example, when the sand in a sea coast is say 10m deep, the fresh water may be found 1m below the ground level and may extend to a depth of 9mm. The sand layer from 9m to 10m may contain sea water.

EXPLOITATION OF SEA COAST AQUIFER:

People living on the sea coast use the fresh water aquifer in a limited way. Every where on the seacoast even in a rain shadow region it is possible to extract this fresh water. In Tuticorin area in Tamil Nadu coconut shells with long handles were used to scoop up a small amount of water seeping into a conical bottom of a pit dug on the sea shore. This limited the drawl of water so that saline intrusion was avoided. Over - exploitation of this aquifer invariably spoils the aquifer by intrusion, of saline water that is existing below the fresh water zone. Where a thicker layer of fresh water zone is available, wells can be used to supply water of acceptabvle quality. Natural formation with clay barriers to prevent saline intrusion can yield more quantity. One well with laterals in Muttukadu near Madras city is in operation since 1975 and is yielding about 600 to 700 lpm.

THE SEAWATER - FRESH WATER EQUILIBRIUM:

The equilibrium condition for a specific unit draw-down can be worked out mathematically. We may assume in a sandy aquifer on the sea coast, the fresh water table is AB as in Fig.1. The top of saline layer is represents the well which is to extract the water. On extraction, there is a drawn down with the level in well as CD. The distance between AB and CD is dh, the drawn down. The thickness offresh water aquifer is H. After the draw down, the thicknes of aquifer is h.

The lowering of water table by say 1 unit will result in an upswelling of the saline layer by nearly 33 units from hydraulic consideration as below:

The upswelling $S = \frac{dh}{1.03 - 1.0}$ where dh is the draw down in the well, the density of sea water is 1.03 and density of fresh water is 1.0. In other words, a draw down of 1' will result in a saline intrusion of $\frac{1}{1.03 - 1.0} = 33'$. This will turn the entire water well saline. This has been observed and the people in habiting the costal area are very careful to extract only very small amounts of water in their shallow wells. By such means, they keep salinity out and obtain their water needs.

A NOVEL METHOD TO EXTRACT FRESHWATER ON THE SEA COAST.

The equilibrium condition for a draw down dh in a well with isotropic, unconfined aquifer is given as $Q = 1.36 \frac{K(H^2 - h^2)}{\log \frac{r}{r_w}}$ where Q is the quanity of water extracted, K is the coefficient of permeability of the aquifer, H is the depth of aquifer before pumping, h is the depth of aquifer while pumping r is the radius of cone of influence and r_w is the radius of well. The draw down in the well dh = H-h.

The radius of well has an important effect on draw down for the same yield. For the same yield, a larger diameter will give a smaller draw down which is also brone out in experience. Since it is very important to keep the draw down to a low value, a large diameter well will result in less saline instrusion for an equal extraction of water when compared to a small diameter well.

To construct a large diameter well is costly. One method to reduce this cost is to construct well with laterals radiating from it to a suitable length into the aquifer. Collector wells extracting large quantities of water have come into existence. In the context of sea coast aquifer, the emphasis is not on the quantity but on keeping the draw down to a minimum. Since draw down is to be kept low, the laterals need be only slightly submerged in the aquifer. In practice 1 to 2 feet below the low water level is sufficient.

PREVIOUS EXPERIENCE IN PROVIDING LATERALS WITH PERMEABLE CAPSULES:

As mentioned earlier, a 4 ft. diameter well with 4 laterals each 20 ft. long is in use in Madras. Another well is Arangamkuppam and a third well at Arangam in Gummidipoondi area showed substantial increase in yield of potable water on the sea coast after providing laterals fitted with permeable capsules. Wells at Industrial Estate in Tada on the Tamilnadu-Andhra border has also yielded water of satisfactory quality in sufficient amount. An existing well in Sulurpet Space Department Campus was provided with laterals to improve the yield.

In view of these experiences, it was decided to attempt such an installation on the sea coast for drawl of the floating fresh water.

INSTALLATION OF A LATERAL WELL ON THESEA COAST A CASE STUDY.

A village Chettinagar on the sea coast about 120 kms. South of Madras City in Tamilnadu was chosen for installation of a lateral well. In this village, suitable spot was selected and a 165mm OD PVC casing pipe was used to install a tube well 6m deep. The water table was 2.5m deep. Open excavation was done to expose the strata upto the water table. This excavation had a diameter 18 metres wide. The tubewell area was excavated 1.2m deeper so that the water depth in the region was 1.2m. The tubewell was cut at this level and a special fabricated PVC Central piece was fixed to the cut tubewell. The central piece had 6 ports to accommodate a 63mm OD PVC pipe in each port.

Trenches were dug with wooden plank support to a depth of 1.2m and 63mm OD PVC laterals were laid in these trenches each to a length of 9m. The laterals were made up of 75cm long PVC pipess each of which had provision to accommodate a permeable capsule. This article is made of inert particles bonded to each other with an adhesive and having a very permeable structure. This article keeps out the sand and permits entry to water. Shrouding with sieved coarse and was done to avoid choking of the pores by fine sand. The six laterals extend over the area of drawl of water. Further, each lateral can draw water only through the permeable capsule ensuring the entire area covered was exploited uniformly.

The central piece was fitted with 165mm PVC pipe for the cut portion and the tube well completed. The filling up of the excavated area resulted in an installation with only a 165mm PVC pipe showing up but with 6 laterals each 9 metre long and each provided with 12 points of water drawl. The water drawn into the well now comes from the 72 permeable capsules. Pumping tests indicate that a continuous drawl of about 40 lpm does not result in any saline intrusion. In areas, where the fresh water layer is thin, the drawl can be restricted suitably to minimise the saline intrusion from the saline layer below the fresh water layer. Where more fresh water flows into the sea, it may be possible to pump out substantial quantities. Also, in rainy season, it may be possible to do this pumping more intensely.

INSTALLING WIND MILL PUMPS FOR THE SEA COAST AREA:

The recent interest is renewable energey has made available windmills that can be used profitably on the seacoast. If such installations can be installed in conjunction with the lateral well, we may obtain a self sufficient system. It is estimated that wind with sufficient velocity will be available for resonably long duration on the sea coast. A 2m diameter wind mill with a mast of 15m height may pump about 2000 litres/ hour for about 10 hours a day. A 40 litres per capita per day, 500 persons may be served by one such unit. An overhead tank of 10,000 litres capacity and a distribution system with 4 stand posts may ensure dependability of the system.

Some special precautions seem warranted. The atmospher will have spray of salt laden droplets and may hasten corroission in R.C. concrete structures. So the 10,000 litre OHT may be of HDPE. The supporting structure may be of galvanised steel members. Sufficient strength for the structure should be provided to stand Cyclonic condition that may occur during monsson.

A rough cost estimate is given below. This canbe refined to the actual site condition in each case.

1.	Cost of the lateral well with 6 laterals each 9m long and with 12 permeable capsules.	Rs. 25,000/-
2.	Cost of overhead tank of 10,000 litres capaicty made of HDPE and with galvanised steel member pedestal 3m high.	Rs. 60,000/-
3.	Cost of Windmill with self-lubricating system & galvanised steel mast 15m high.	Rs. 40,000/-
4.	Cost of distribution system.	Rs. 15,000/-
5.	Incidential expenditure	Rs. 10,000/-
	Total	Rs.1,50,000/-

This would work out to Rs.300/- per capita. Maintenance charges at about Rs.1000/- may be sufficient, use of PVC or HDPE pipes all through would avoid corroission to a large extent.

CONCLUSIONS:

1. It is possible to explit the fresh layer found floating over saline layer on the sea coast.
2. An arrangement of laterals with permeable capsule radiating from a tubewell or an existing well can draw the fresh water for the habitations.
3. The sea coast wind can be used for water extraction through use of windmills.
4. The cost of the installation is reasonably low.
5. The technology for installing such a unit is indigenously available.

ACKNOWLEDGEMENT:

The author acknowledges the assistance extended by the authorities of Tamil Nadu Water Supply and Drainage Board for trying out this project at Chettinagar in Marakkanam Block of South Arcot District in Tamil Nadu.

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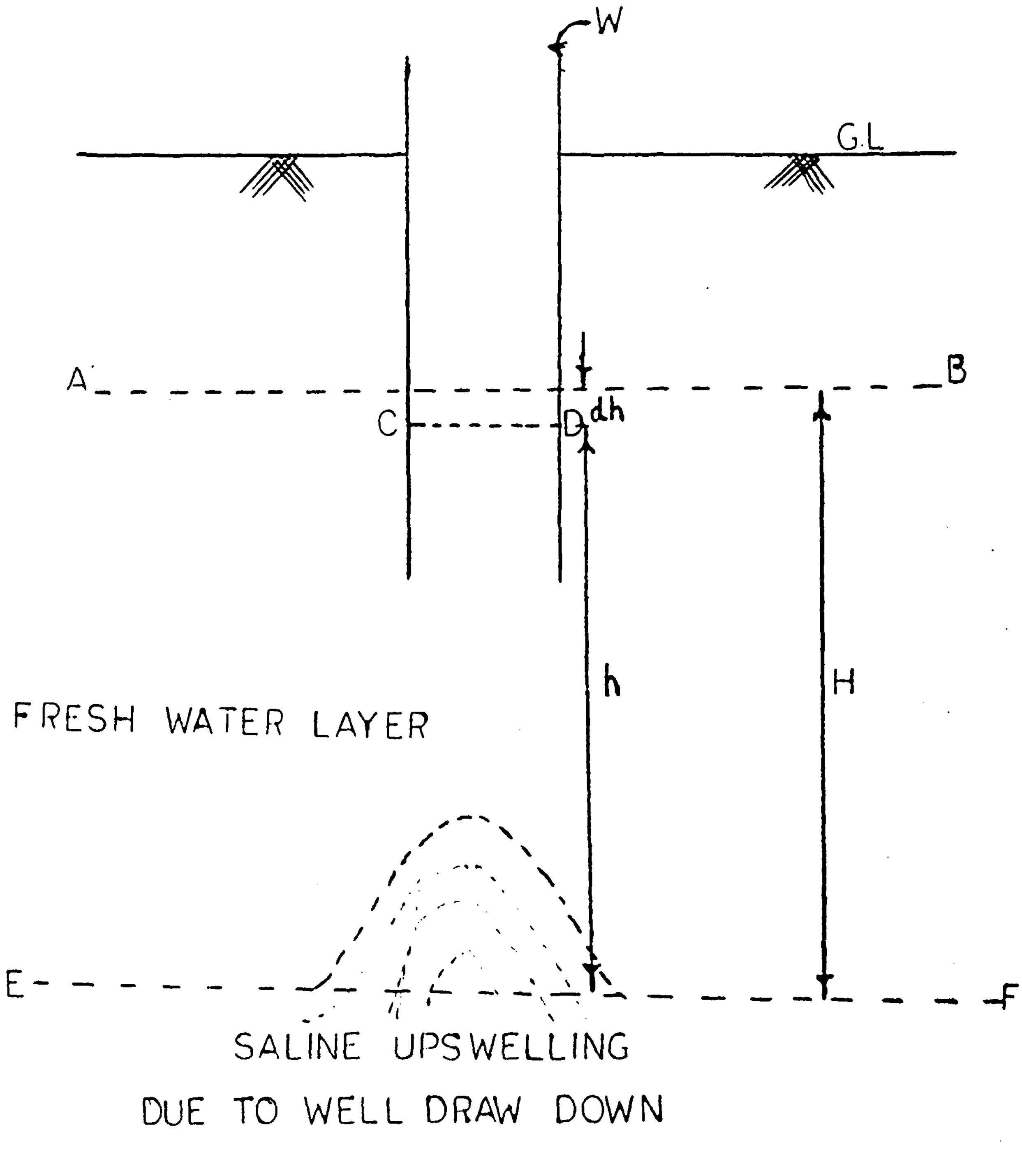
W
G.L
A
B
C
D
dh
h
H
FRESH WATER LAYER
E
F
SALINE UPSWELLING
DUE TO WELL DRAW DOWN

Fig.1.

INTEGRATED APPROACH TO DRINKING WATER PROBLEM CASE STUDY OF HYDERBAD METRO WATER SUPPLY

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SYNOPSIS

Continued drought for the last four years and the increased population and industrialisation has depleted the main sources of drinking water in the twin cities of Hyderabad and Secunderabad and water supply has been cut-down to few hours on alternative days. In order to overcome the crisis of water supply, large seale exploitation of groundwater is restored to. The integrated use of ground and surface water for the drinking water supply has helped tide over an explosive situation and gave enough time for the planners and administrators to think of alternative measures like diversion of Krishna or Godavari river waters.

INTRODUCTION:

Hyderabad - Secunderabad twin cities have a population of over 25 lakhs. The total requirement of water both for drinking and industrial use is of the order of 380 MLD (million litres per day) 100 MGD (million gallons per day). But the total quantity that is received from Osmansagar, Himayatsagar reservoirs and the Manjira dam is about 342 MLD (90 MGD). Because of the reduced inflows into these lakes and also due to evaporation losses, this year only 125 MLD (33MGD) is being supplied from the surface reservoirs. To meet the remaining quantity of water supply, it is decided to go in for groundwater on large scale. The State Government Water Department being the apex body for evaluation, monitoring and exploitation of ground water resources, was asked to assess the potential available in and around the metro area and exploit the ground water resources on emergency basis. The studies carried out and the results obtained for tackling the drinking water problem of Hyderabad Metro and presented in this paper.

HYDROGEOLOGY OF HYDERABAD METRO AREA:

The twin cities of Hyderabad nd Secunderabad are underlain by grey and pink granites and granite gneisses group of rocks of the Arechean age and are intruded at places by dolorites, basalts, peg matites, quartz reefs and veins. Due to the characteristic resistance to weathering the dolarites in the field apper as boulder strewn ridges.

Granites and the granite gneisses are generally refered to as hard rocks which are devoid of primary porsity. Secondary porosity is introduced into these rocks by chemical and mechanical changes in the granular fabric giving rise to weathered zone. The storage, movement of groundwater and its occurence in the well depends on the extent to which the secondary porosity has dedveloped. Thus the weathered zone is the important groundwater reservoir in the granite rocks and the fissures and fractures in the rocks beyond the weathered zone are also favourble for groundwater development in the granitie terrain.

RAINFALL, PHYSIOGRAPHY OF THE METRO AREA:

Hyderabad Metro area is located at

an average elevation of +500.00M. above MSL with a mountain range surrounding at +600.00M. The maximum temperature in summer is 42°C and minimum temperature in winter is 9°C. The relative humudity is 69% at 08.30 hours and 48% at 17.30 hours.

The normal annual rainfall of Hyderabad is 773 mm. the annual rainfall at Begumpet Raingauge Station from 1966 to 1986 is shown in figure 1.

GROUNDWATER POTENTIAL OF THE METRO AREA

The depth of existing dugwells ranges from 6 to 12 metres, while the depth of borewells range upto 40 meters. The yields of bore wells range from 5,000 litres per hour to 30,000 litres per hour. The hydrography of observation well at Prasanthinagar, Amberpet at Hyderabad is given in figure 2.

The Ground Water Department has carried out systematic hydrogeological and geophysical surveys in the metro area. Aerial photo interpretation was used to decipher the lineaments, structural features indicating potential areas available for groundwater exploitation. The Department has carried out integrated surveys for selection of well/bore well sites for various agencies both Government and Industrial undertakings for exploitation of groundwater resources. A list of Agencies to which groundwater surveys have been carried out in the metro area is given in Annexure-I.

The groundwater potential of the Hyderabad metro area is estimated on the basis of the presently accepted norms i.e., Rainfall recharge method and water table fluetuation method. Due to rapid urbanisation, the ground water assessment in the area requires considerable alteration. The hydrogeological characteristcs in urban areas are altered due to laying of smooth roads and concentration of urban dwellings. These developments increase the impervious surface area, thus reducing infiltration and increase surface runoff. During heavy storms, this rapid increment in surface runoff reduces the recharge to the groundwater body which in effect decrease base flow contribution in the area. Further, the storm ater sewers drain the direct runoff without any water to percolate the goundwater body.

Taking all these limitation into consideration, the groundwater potential of the Hyderabad Metro has been estimated and found to be feasible for construction of about 6,000 borewells which can withstand about 16 hours or pumpoing at an average rate of 4000 lph including 2000 public bore wells already existing in different localities of the metro within a radius of 15 kms. This is apart from already existing private borewells whose number is not yet known. Annexure-II gives areas hich are highly potential from ground water point of view.

SCHEME OF EXPLOITATION OF GROUND WATER FOR METRO WATER SUPPLY:

During the recent crisis 300 borewells were drilled (high capacity wells with yields more than 4000 lph(1000 gph) of 150 em.dia. in various parts of the twin cities. The location of some high capacity borewells alongwith depth drilled and yield in litre/hour is given in Annexure -III. These wells are used in the following ways.

1. If the borewell is located by the side of the supply main, the water is dirctly pumped into the main. At some places, the mains are initially filled with borewell water thus pumped.

2. If the borewell is located away from the supply main, the water is loaded into the tanker lorry and despatched to the needy

areas. There are about 300 tankers both public and private tranporting water to the various colonies.

3. Where the yield is less than 500 gph, the borewells are fitted with hand pumps.

4. The quality of groundwater is tested for each borewell and then only the water is let out into the supply main. If the water is not of standard quality a board on the borewell is put as "water for non-drinking purpose only".

5. A part from the wells drilled by Ground Water Department the Hyderabad Metro Water Supply also has drilled several borewells and by and large water supply to theresidents of thetwin cities has been kept up once in two days without creating any hindrance.

6. Water from Vijayawada wheich is about 300 Km. and which is on the banks of river Krishna is is being trnsported through tanker wagons by Railways.

QUALITY OF GROUNDWATER IN HYDERABAD METRO AREA:

The quality of groundwater in the metro area is generally very good in its natural environment and is fit for domestic and agricultural use. The water is fit for drinking purpose. The chemical quality of ground water of the metro area are given in Annexure - IV.

The wide range of electrical conductivity can be due to urban pollution getting percolated into the groundwater which is a local porblem specific to the area. Most of the Industrial Estates are situated out side the metro limits. But a dozen Industries are concentrated in the Azamabad, Vidyanagar and Sanathnagar area. Industries located up stream of Hussainsagar lake in the heart of the area dispose their effluents into the lake and hence the water is dark, turbid and foul smelling. An area of 15 to 20 sq.km. between Kukatpally and Begumpet is identified as highly polluted.

CONCLUSION:

As can be seen from the above water is a scaree commodity. Safe drinking water has to be provided for urban areas. With the on slaught of droughts and drying up of surface water reservoirs many of the cities which depend on them for water supply face severe strain to cope up with this problem. In such circumstances, ground water should be scientifically evaluated and exploited. The planning for use of groundwater has to be integrated with the surface water in all urban areas and groundwater cannot be left out as a separate entity while planning for water supply schemes. Similarly unrestricted growth of urban areas shall have an effect on the hydrological cycle in as much as it may prevent the rainfall to perecolate to the groundwater body. There is need to prevent groundwater getting polluted in the urban areas by dispersing industries. Provision of green belts in and around the metro areas help preserve the environment safe and allow water resources clean and fit for human consumption.

ANNEXURE - 1

LIST OF AGENCIES/DEPARTMENTS TO WHICH GROUNDWATER SURVEYS HAVE BEEN CARRIED OUT BY GROUND WATER DEPARTMENT FOR SELECTION OF SITES FOR BORE-WELLS.

1. Bharat Heavy Electricals Limited Ramachandrapuram.

2. Electronic Corporation of India Limited, Moula Ali.

3. Nuclear Fuel Complex.

4. IDL. Chemicals Limited

5. Andhra Pradesh Housing Board Kukatpally Housing Colony.

6. Defence Metallurgical Research Laboratory.

7 Administrative Staff College of India.

8 Osmania University Campus.

9. Director of Medical and Health Services.

10. Central University of Hyderabad.

11. Andhra Pradesh Agricultrual University.

12. Water and Land Management Training and Research Institute.

13. Jawaharlal Nehru Technological University.

14. Contonment Board, Secunderabad.

15. Ordinance Factory.

16. Kamala Nehru Polytechnic for Women.

17. Lalbahadur Stadium, Sports Complex.

18. Hyderabad Urban Development Authority Colony, Vasanthalipuram.

ANNEXURE - II

STATEMENT SHOWING AREAS SUITABILE FOR GROUNDWATER DEVELOPMENT IN HYDERABAD METRO.

I. Areas within a radius of 5 to 15 Km. from Metro:

1. Areas around Amberpet and Uppal.

2. Areas around Boinpally and Picket.

3. Areas around Kukatpally, Miyapur and Ramachandrapuram.

4. Areas around Shaikpet.

5. Areas around Gaganpahad and Shamshabad.

6. Areas around Alwal, Malkajigiri.

II. Areas within Twin Cities:

1. Ares in the Vicinity of Masab tank (viz.) Vijayanagar Colony, Mallepalli, Bazarghat, Goshamahad etc.,

2. Areas in the vicinity of Hussainsagar . (Viz.) Domalguda, Gandhinagar, State Bank of India Colony, Kavadiguda, Musheerabad, Chkkadpally etc.,

3. Areas in the vicinity of Ameerpet and Begumpet.

4. Areas such as Khairaatabad and Somajiguda.

5. Area around Osmania University Campus.

6. Lalapet, Regimental Bazar, Maredpalli, Airport Road, Boggulakunta and Alwal.

ANNEXURE - III

LIST OF BOREWELLS DRILLED BY GROUND WATER DEPARTMENT
(150 Cm.Dia, yielding more than 3800 LPH)

Sl. No.	Location	Depth in m.	Yield in LPH
1.	Exhibition Grounds	36.55	25,000
2.	Secretariat	27.43	30,000
3.	R.T.C., Nacharam	32.00	26,000
4.	Kundanbagh	21.21	7,200
5.	Ziaguda, Sanjainagar	45.60	6,000
6.	King Koti Hospital	40.00	4,200
7.	Ameerpet - 1	37.18	6,400
8.	Ameerpet - 2	37.18	6,400
9.	Begumpet - 1	30.60	32,000
10.	Begumpet - 2	21.65	8,000
11.	Khairtabad	37.10	16,000
12	Nehrunagar	46.00	8,000
13.	Begumpet - 3	37.13	20,000
14.	Begumpet - 4	41.75	4,000
15.	M.G. Nagar	56.47	10,000
16.	Kulasompura	32.30	6,000
17.	Vanasthalipuram	37.12	4,000
18.	Dilshuknagr	41.70	4,000
19.	Sarathi Studios	42.00	16,000
20.	Old Alwal	43.58	6,800

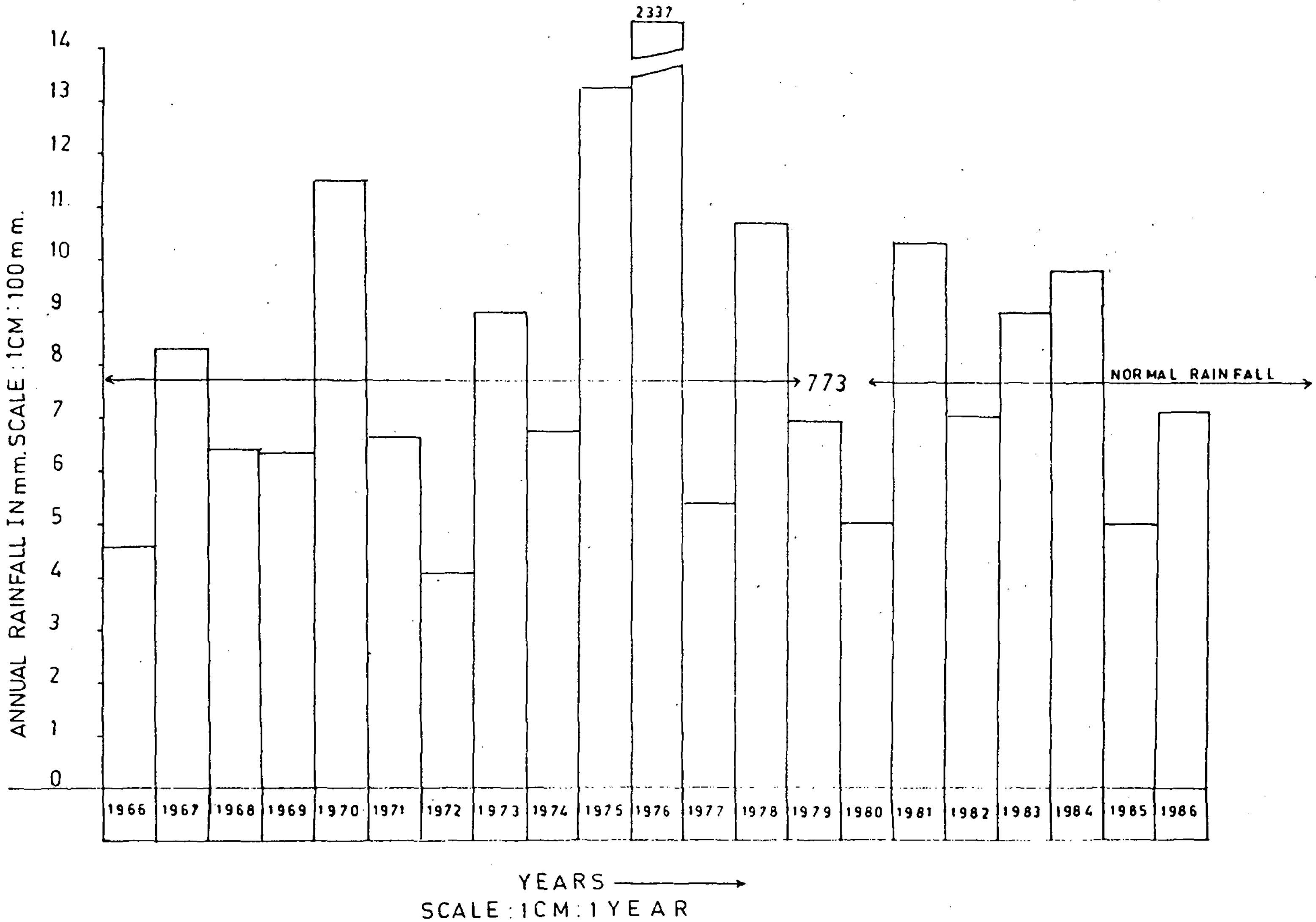
ANNEXURE - IV

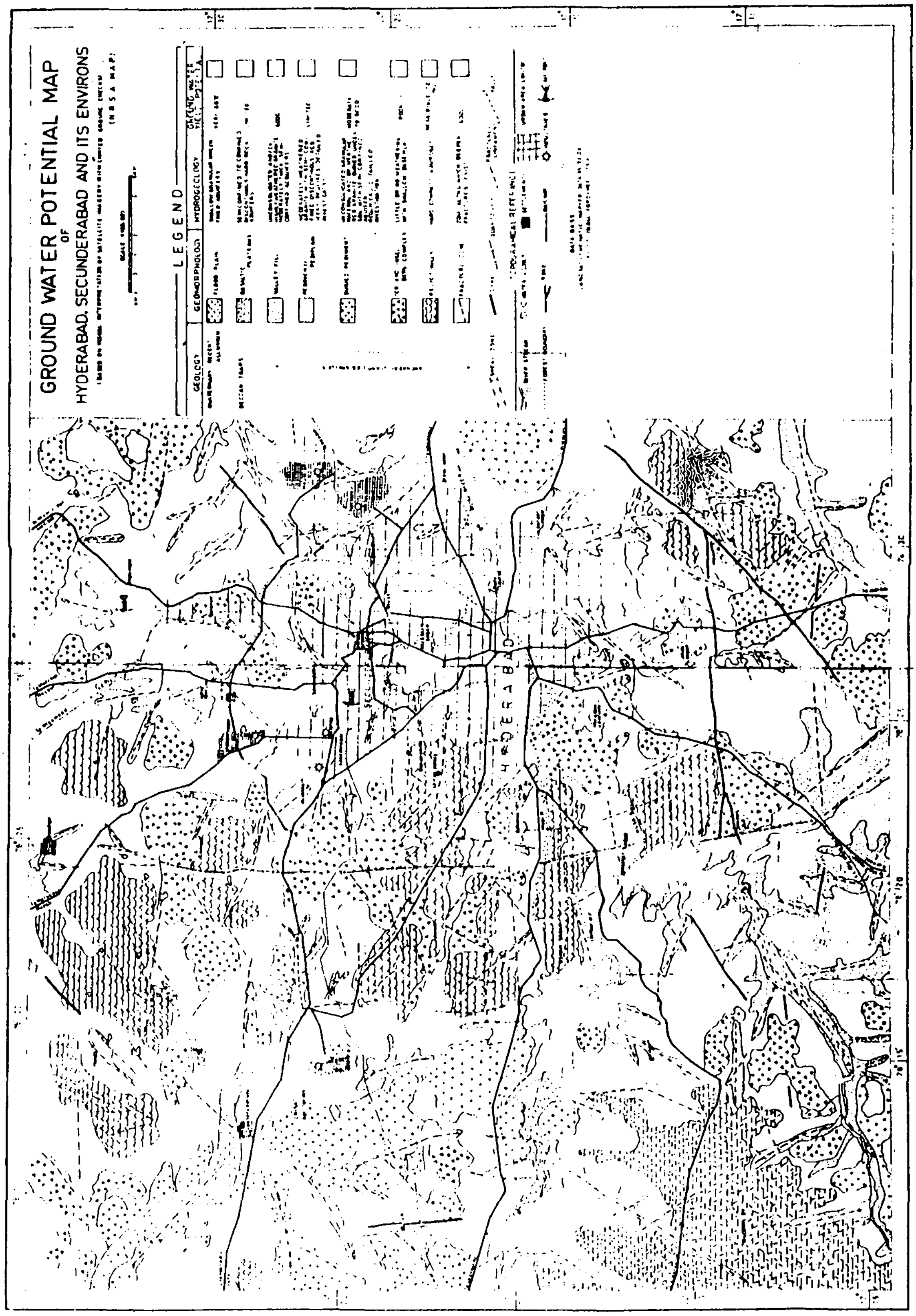
QUALITY OF GROUNDWATER IN HYDERABAD METRO AREA

Location	p^H	EC Micro Moh./Cm.@ 25°C	Total hardness as Ca CO_3 PPM	Na PPM	Cl PPM	F PPM
Sanathnagar	7.60	1850	372	-	280.00	1.25
Golconda	7.95	1090	210	-	120.60	0.18
Uppal	7.80	676	300	20.00	39.00	1.60
Tirumalgiri	7.35	1465	473	107.00	199.00	0.95
Chandra yangutta	7.70	645	248	42.60	56.70	0.88
Nacharam	7.15	708	258	17.00	44.00	1.68

FIG. 1

ANNUAL RAINFALL AT BEGUMPET RAINGAUGE STATION FROM 1966 TO 1986




GROUND WATER POTENTIAL MAP
OF
HYDERABAD, SECUNDERABAD AND ITS ENVIRONS
LEGEND
GEOLOGY
GEOMORPHOLOGY
HYDROGEOLOGY
HYDERABAD

SECTION 2

WATER CONSERVATION

THE REHABILIATION OF WATER DISTRIBUTION AND SEWERAGE SYSTEMS IN NORTH WEST ENGLAND

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SYNOPSIS

The paper describes North West Water together with the development of water services in the North West of England from the time of the industrial revolution which started on a worldwide basis in this region. A futuristic view is taken of the management of water services and an integrated system approach is developed for longer term planning horizons. Implementation of the approach is described together with regional distribution and sewerage surveys. Computerised information collection, handling and management systems are described and how they interface and integrate into computerised modelling systems, telemetry and ultimately fully automated control. Pipeline renovation systems for both sewerage and water mains are outlined and special attention is paid to the need to integrate leakage control into long term rehabilitation planning strategies. The importance of training staff as well as the manual workforce is emphasised particularly in a changing technological and economic scene. A brief description is made of training concepts, needs and facilities. The paper concludes by suggesting that many of the building blocks presently available could with suitable adaptation for local circumstances be transferred to other water utilities, as part of their long term rehabilitation programme.

BACKGROUND

North West Water is one of the largest of ten regional water authorities controlling all aspects of the water cycle in England. It was formed in 1974 when the 250 water undertakings throughout the region, often municipally controlled, were consolidated into one organisation. These have now been unified into an integrated and comprehensive management system at river basin level covering the whole of the water cycle. The Authority deals with water resource provision, water distribution, sewerage system, sewage treatment, together with the control of river water quality, fisheries management, flood protection, sea defence, recreation, amenity and conservation.

The region covers 14000 square kilometres with 7 million people and over 2.5 million homes. It is one of contrasts - beautiful areas with clean rivers, small communities and few industries and also densely populated areas where industry is concentrated and pollution is severe.

We supply an average of 2500 Ml of water each day. The supply and distribution system includes 213 major reservoirs, 240 boreholes and springs, 50 river intakes, 628 service reservoirs, 500 km of supply aqueduct and a total length of water main of 38,350 km. The sewerage and sewage treatment facilities comprise 30,000 km of sewer and 635 sewage treatment works. To carry out these functions we employ 8500 people. Our annual turnover is £400m of which approximately half is operating cost and half capital spending on rehabilitation and improvement. Figure 1 shows the location of NWW in the UK together with a schematic of our integrated water supply system.

DEVELOPMENT OF WATER SERVICES IN NORTH WEST ENGLAND

Sewerage

The migration of people from the land to form the industrial societies gained momentum towards the end of the 18th century. It was then that new towns were developed particularly in the north of England and as a pre-requisite the first 'modern' water services were provided.

Prior to 1850, before machine made clay pipes were available, the forms of sewer construction were many and varied, but in todays terms would be considered poor, although many are still functioning. It was not common to construct ovoid sewers in single ring brickword with no mortar. Clayware proved to be the best material for use in the manufacture of small diameter pipes and has been extensively used since 1848, initially without 'joints' which allowed the water to enter and leave at will. Later improvements utilised collar joints and it is only in the last twenty years or so that flexible water tight joints have been provided.

As towns expanded more sewers were connected to the earlier systems and these in turn became hydraulically overloaded having twc main effects. Firstly flooding which lead to a proliferation of storm overflows and pollution of rivers and secondly the removal of non-cohesive ground by continuous hydraulic surcharge, which causes the sewer to collapse. In this region some 4500 km of sewer built before 1887 are still in use today.

Water Supply

Up to the middle of the 19th century most of the new towns in the region drew their water from nearby wells, springs and rivers, which rapidly became polluted from the overloaded and piecemeal sewerage systems. By the 1840s the major industrial conurbations of Greater Manchester and Liverpool were looking beyond their local boundaries for unpolluted sources of water supply. The obvious resources were the undeveloped moorlands on the adjacent Pennine hills and by 1850 an extensive series of upland catchment reservoirs was established. The conveying aqueducts terminated in storage reservoirs, which in turn fed an extensive series of distribution mains. Most of these mains were constructed of cast iron, with caulked lead joints, and still remain as the backbone of present day water supply networks. Because of the soft peaty nature of the water, which reacts with the old pipes, problems are caused by encrustation of iron oxides coupled with undersizing, which causes poor and widely fluctuating pressures, dirty water at the tap and numerous bursts. On top of this is the almost insurmountable problem of leakage which in parts of the region approaches 50% of water supplied.[1]

The Future

A science fiction view of the management of water services in the 21st Century would probably include the control by a satellite in a stationary orbit in space over a region. No people would be involved. Data from sensors measuring pressure, flow, network condition etc. would be transmitted to the satellite where a powerful computer would interpret this information and investigate such action necessary to automatically control the water and sewer networks. This would be no utopian society since bills would still arrive with alarming frequency, save that in this case payment would be taken straight from your bank account before you even realised it! Here then we describe a fully integrated water service. The question to be raised is whether or not this is science fiction or, if we want it, whether or not it is achievable. In technological terms it is and many of the component parts are already available. On the premise that we want to take the technical benefits, how do we move from today's outworn system to tomorrow's updated situation?

PLANNING THE WAY AHEAD

Water and sewage treatment facilities have one outstanding advantage over distribution and sewerage. They can be seen. As a consequence management of these assets is more readily planned since data on condition, performance and needs is more readily identifiable.

Underground systems suffer from the fact that they are out of sight and data is difficult to obtain. The advent of modern technology however has changed this situation and it is now possible to look to some longer term asset management plan.

Planning the integrated system approach

The first requirement of any approach to an asset management plan is for a better knowledge of the system to be operated. Physical records need to be updated and it is at this very first step that the use of computers to store information needs to be considered. Paperwork systems provided in the past, often to very high standards, rapidly become outdated and history has shown that they quickly fall into disrepute. Computer based information systems are more readily updated and manipulated and should in the long term prove invaluable.

A second information requirement is on system performance and it is necessary to obtain details of pipe conditions, burst frequency and location, leakage levels, pressure and water quality. Pressure, reliability, interruption and water quality problems need detailed investigation so that the full extent of problems to be faced in rehabilitation can be determined.

Networks then need breaking down into zonal areas for management purposes in operational, metering and leakage terms. Networks models need to be built at both strategic and detailed levels so that the causes of problems can be understood and solutions developed.

The advantages of this approach is that it allows the integrated planning of complex and conflicting requirements but, at the same time, allows the Authority to identify its long term spending and business needs. Included in these are the maintenance and improvement of service standards, the establishment of operating and capital funding requirements, as well as the optimisation of staff and other resource requirements.

Priorities in rehabilitation for zones can be applied and phased programmes implemented. An orgnisation can be developed to achieve specific tasks and targets and the needs for training for technical staff and operatives can be established. Furthermore latest technologies can be applied to the maximum effect. The description above has been couched in terms of water distribution but the experienced observer will quickly see that the requirements for sewerage are parallel, with much of the information needs being identical.

IMPLEMENTING THE INTEGRATED APPROACH

In conjunction with the Water Research Centre the Authority has embarked on a major review of both the sewerage and water distribution networks. The cost of these surveys is some £6m. The sewerage review, which started first is now completed and final results from the distribution survey are expected shortly.

Sewerage

The objectives of the sewerage review are in line with the foundations set out in the Water Authorities Association/Water Research Centre Sewerage Rehabilitation Council.(2) The broad philosophy of the approach is that it is both unnecessary and uneconomic to replace all sewerage systems and that as much of the existing pipework will be retained. Furthermore the bulk of expenditure will in future be spent on the core of the system which will have most impact on service. Survey, analysis and planning costs will go up, but are more than offset by capital cost savings and there are valuable spin-offs in improved measures of service levels and operation.

The comprehensive nature of this review is unique and it is the author's belief that no similar survey had been undertaken elsewhere. Other surveys have been undertaken in one aspect of performance - flooding, structural condition, pollution, however in this case all three aspects have been considered at the same time.

The region has been divided into 90 units serving population ranges of 30,000-1,20,000. These were then placed into groups of strata based on the likely rehabilitation costs. Seventeen units were selected for the review. Checks were made to demonstrate that no statistical bias had been introduced and that the statistical integrity of the review had not been prejudiced.

The stages of survey, information gathering, the preparation of an information database, network modelling of verified WASSP-SIM models, was completed for all 17 units. Water quality issues have been addressed through an interim procedure which is part of a long term research programme being funded principally by NWW and WRc. This is a new approach and the sewerage engineer can present information to the river scientist in terms the latter can relate to. The river is divided into reaches and the pollutant loading rate curves can be constructed. From these the river scientist can advise on any reductions required.

This information is then correlated before rehabilitation proposals with a 25 year planning horizon are drawn up and costed for each of the seventeen units.

The review has provided an opportunity to refind current methodologies. It has highlighted further areas of research, particularly the need for a more quantitative water quality impact assessment method, and has demonstrated the sensitivity of costs to flooding performance criteria. This supports the recommendation by some experienced analysts that WASSP-SIM needs to be adapted to model surface run off and the entry of flows to the sewerage systems more realistically under extreme flood conditions[3].

Water Distribution

The concept of the water distribution review is similar to that described for sewerage and is expanded in the WRc Water Distribution Rehabilitation Manual[4]. The region has been broke down into 90 zones and 19 of these have been chosen as study units, with an average population of 80,000. The factors selected in determining the stratification of units have been the service factors of water quality, pressure, continuity of supply, together with cost factors of energy and leakage (direct costs, damage, deferred resource development). Surveys have been carried out, again in conjunction with Water Research Centre, and the information is being collcted and analysed with a view to preparing rehabilitation options, costs and solutions for each study unit. Interim results are available and the final report will be completed in 1988.

INFORMATION SYSTEMS

In order to be able to successfully manage both the long term planning requirements and the day to day operational needs of a large and complex business such as the management of water services, it is necessary to set up data gathering, analysis and presentation systems to present management with the information it needs to monitor and control its operation and investment strategies. It is theoretically possible to define these information requirements and then design an integrated corporate data system, to gather, analyse and present this information. This is not practical and information would be required within the time span needed to develop the system. Whilst the popular complaint of lack of information is widely heard within water services, in reality there is often masses of information which unfortunately is not readily accessible or capable of being manipulated. Within NWW scattered information can be found, in some cases of events during the last century. Comprehensive and structured data has been kept since the Authority was established in 1974. The recent review of the water distribution and sewerage networks have drawn to light masses of information which needs to be managed.

For these reasons there has been a need to develop both manual and small computerised data collection and analysis systems in association with the analysis and development of the full 'corporate' system. The following series of developments should be viewed as some of the building blocks already available which ultimately will form part of the overall integrated system.

Consumer Services System

This computerised system logs every enquiry by a customer related to water distribution and sewerage. It also records all complaints of bursts, poor supply, dirty water, together with new service connections, repairs etc. Immediate information can be given to enquiries from a street index which is displayed on the screen. The system automatically generates and monitors all activities associated with inspectors, the work gangs and liaison with other utilities and highway authorities. Management reports can be taken from the data base on network as well as manpower performance.

Asset Condition Monitoring

Hand held computerised data capture devices pre-programmed so that they can be readily used by inspectors and junior technical staff are being used to collect information on the

the location and physical characteristics of mains and sewers on site. On return to the office the inspector down loads the information onto small personal computers for later analysis. These PCs can then be networked into a mainframe, where a general database is available.

Network Analysis

Network analysis packages are available on both mainframe and PCs to help analyse the existing and projected networks to ensure cost effective rehabilitation and improvement.

Loggers

Solid state loggers are being used extensively to collect field data on pressure and flow to assist in monitoring the performance of the network, monitor the effectiveness of leakage control policies and provide data to calibrate models. They are also used for continuous meter reading in association with leakage control and for instantaneous readings for charging purposes.

Work Planning

Project planning packages are being used on PCs to ensure the effective use of resources, particularly on leakage control. Similar planning packages, based on querying theories, which were first used to handle the embarkation and loading operation of aircraft at Heathrow Airport, London, are being developed to manage the operation of repairs, rehabilitation and extension to the networks, as well as network management. This work is now being examined by other utilities who face similar problems of relating incoming work to a limited manpower resource.

Record Drawing and Asset Database

The Authority has embarked on a systematic review of record drawings of sewers, water mains and supply and treatment facilities. In respect of sewerage and distribution this will involve redrafting existing plans onto an overlay system, as well as taking off an asset inventory. The use of digital mapping systems have already been investigated and a start has been made on digitizing records. Inventories are now computer based and a digital mapping system based on one of the authorities fourteen management units should be working within a few months time.

Telemetry

The Authority is currently investigating £17m on a regional telemetry scheme which will ultimately provide on line data capture of many activities including sewerage and distribution. This system will provide real time pressures and flows in the network to improve control and optimisation. It will also report on pumping station state, performance and efficiency. The first stage is mostly complete and is linked by land lines, UHF or microwave systems to management computer systems where information can be archieved, displayed for action or passed on for further interrogation. In some cases limited control is available but the second stage of this development - fully automated control - for which planning is well underway, awaits a decision to proceed.

Support Systems

Mainstream management accounting together with financial systems are provided by mainframe computers. Linked into these systems are those for the management of stores, vehicles and plant, payments and purchasing, together with personnel information.

PIPELINE REHABILITATION

The costs associated with the rehabilitation of pipelines can be considered in three groups. Firstly the physical cost of replacement or renovation. Secondly the cost arising from the disruptive nature of the engineering works to install or maintain those networks and thirdly those associated with the system performance, be it flooding, poor pressure, pollution or other inadequacies. Any possible way of reducing the time and cost elements of the first two and at the same time solving the third will lead towards efficiency. This course leads us wherever possible to renovate the existing system rather than replace it. In any event we will have to follow this course since, not only is it sensible, the alternative of complete replacement is not affordable even to the richest of nations.

North West Water has therefore taken the lead in many of the new renovation techniques, some of which are described below and form part of the £65m spent this year on sewerage rehabilitation.

SEWER RENOVATION TECHNIQUES

The principal techniques for sewer renovation fall into three basic categories: stabilisation; lining (pipe and segmental); coatings; and could show savings of up to 50% of physical replacement costs.

Stabilisation

These methods include hand and pressure pointing of brick sewers which are then drilled and pressure grouted between the outside wall and surrounding ground. This system has limited application and should only be used where the original structure still has integrity. Similar techniques are available for small diameter pipelines where machines have been developed to seal off leaking joints by impregnation with chemical grouts.

Lining (pipe)

For small diameter pipelines, where men cannot enter, remote lining systems have been developed. These include inserting into the existing sewer medium density polyethylene pipe lines (MDPE) which are pre-weld on the surface into long lengths. The new pipe is lead into the old down a short ramp excavated from the surface. A winch wire is attached at a nose cone fitted to one end of the pipe string and the whole is pulled into the old sewer. Hundreds of metres can be inserted in one pull thereby reducing surface excavation, disturbance and cost. The annulus is then grouted, connections remotely made and the loss in diameter is often compensated by better carrying characteristics. Similar systems have been developed in glass reinforced plastic and screw jointed polypropylene pipes which are cut into short lengths so that they can be taken down manholes. This saves any surface excavation, although the pipework and installation may be more expensive.

An alternative to these methods is the 'insitu form' process whereby a polyester impregnated sock is introduced into the sewer by water pressure. The water is heated and the resins set. This system has the advantage that it will adapt to any shape of sewer and deal comfortably with irregularities. Its drawback is low structural capability, together with the need for careful quality control on site.

Lining (segmental)

Where men can enter a pipeline

the system can be renovated by carrying-in preformed segmental panels. These are then erected in place before the annulus between the segments and the old sewer is grouted. If necessary the composite structure can then be drilled and pressure grouted. Great structural strength can be provided in these systems and any loss of carrying capacity can usually be catered for at minimum cost by careful study of the network and the provision of least cost options for hydraulic improvement. Linings of this type have been built in glass reinforced cements and plastics, resin concrete and preformed gunite. High structural strength is provided by reinforcement.

On-line replacement

Where a sewer has marginal spare hydraulic capacity and relining would exacerbate the situation, then other techniques need to be considered. Machines, driven by hydraulic power and/or compressed air have been developed, which when fed into a pipeline, propel themselves along the line and at the same time crush out the old pipe. Attached to the back of the machine is a fully welded long length of MDPE. This is pulled along behind the machine as it progresses effectively producing a size for size replacement. NWW has led the way in the development of these systems which are now extensively used for water distribution as well.

WATER DISTRIBUTION RENOVATION TECHNIQUES

Expenditure on water distribution will account for some £25m this year. The following short notes describe some of the renovation systems in use, which again should show savings of up to 50% of replacement costs. Others are being developed.

Scraping and Lining with Cement Mortar

80% of the existing distribution system is constructed in unlined iron pipes. The remaining 20% comprises asbestos cement, uPVC, and modern polyethylenes. The problem therefore is dealing with encrusted iron pipes. Since 1920 a method has been available in North West England to overcome this problem. Mains are taken out of service and two short lengths of pipe are removed, at approximately 80 metre centre to centre. A steel wire is 'floated' through the main and attached to two winches. A steel scraping device is then pulled along the main until it is clean. In extreme cases boring equipment is used. Residue deposits are then removed. A spinning head is introduced into the main and fed with cement mortar. This effectively sprays a coating onto the pipe wall. The thickness of the coating is determined by the speed the spinning head is pulled through the main. Make up pieces are then provided to the cut sections and the pipeline is recommissioned, usually with 24 hours. Extensive use of this technique has been made over the past 5 years and some £10m per annum is spent on this work.

Epoxy Cement Lining

A similar system has been developed using an alternative mortar. Epoxy has the advantage of being used in thinner sections, and mains of 100 mm diameter can be lined without loss of carrying capacity. The purpose of all water distribution lining systems is to prevent the water attacking the iron. In no way does this type of lining provide any structural capability. The linings do however provide a limited amount of 'sealing' to joints and go someway towards leakage control. Epoxy cements have the advantage of setting quicker than cement and mains can be returned to service quicker. In addition the system is cheaper in the small diameters.

Sliplining

This system is similar to that described for sewerage in so far that MDPE is slipped in long lengths into an existing main. The pipe is designed to be self sufficient and does not rely on any characteristics of the old main. In consequence it can be used where an existing main has failed structurally by graphitisation or other reason.

Size for size replacement

This relatively new technique, first developed by the gas industry, is now extensively used for water services. The system is as described for sewerage but is more extensively used in water distribution. The advantages are enormous insofar that the same or increased sized mains can be provided. NWW are also using the system for the provision of new mains in unmade ground where the system is described as moling and, in addition, for the replacement of service pipes.

New materials in water distribution

The present trend away from the traditionl short length iron based pipe system increases. New MDPE pipelines which can be heat welded into continuous lengths and colour coded for ease of recognition and safety are increasing in use. They have the long term advantage of being relatively jointless, and hence leakage should be minimized.

LEAKAGE

Lekage, which is an integral part of the rehabilitation process, deserves special attention not only in this paper but probably in most water undertakings throughout the world.

Unaccounted for water in NWW has been growing at an average rate of 2.1% per annum since 1974 when the authority was formed. The existing regional level of over 35% is totally unacceptable both in economic and political terms. If it had continued to grow at its historic rate a new regional resource would have been required within ten years. This too would be both economically, politically and environmentally unacceptable.

The causes of UFW are well known and include overflowing reservoirs, trunk main and aqueduct leakage, high pressures which exacerbate the problem of leakage, unauthorised use, which requires organisation control and monitoring, under registration of meters, distribution systems and service pipes in poor condition, as well as other facets.

In 1981, following the publication of Report No.26 Leakage Control Policy and Practice(5), NWW developed a ten year plan to bring the regional average of 35% UFW down to levels around an average of 20% UFW. Our objectives were to reduce net night lines from 17 to 11 l/p/hr. Teams were set up with the latest technical equipment and reductions were achieved within 5 years down to 13 l/p/hr.

However, limitations in the apprach taken soon became obvious, since savings achieved were difficult to sustain and other issues were suffering at the expense of leakage.

There is nothing basically wrong with the principle set out by WRc in Report 26 although modern technology calls for an updating of the report. However an undertaking cannot just set out to look for leakage in an unplanned crash programme. Short term savings may be achieved; they will not be sustained as we know to our cost.

Leakage is not a separate issue, it is part of other considerations and needs to be built into the broad rehabilitation strategy and into system management. In this way the costs and volumes of leakage can be established for each zone alongside rehabilitation strategies. It may well be that the latter will solve the former but the reserve will never be the case. We have identified areas within our region where acceptable leakage levels will never be achieved in economic terms until the system is rehabilitated. Obviously facts such as these clarify priorities and ensure sound and lasting investment.

TRAINING

Concepts

Radical changes in technology and business approach, such as those now being made in water distribution and sewerage, call for changes in attitudes of personnel involved, together with changes in their skills. NWW starts its training process for both its staff and manual workforces with a structured system known as Individual Training Profile (ITP). This system identifies the training needs for each individual and begins with the most senior management, cascading through the organisation. Once an individual has an agreed training profile, suitable courses, or on the job training will be provided to meet the need.

Training needs

Needs have been identified over the full range of activities undertaken by personnel in water distribution and sewerage, from the initial contact with the customer through to high technological training of scientists and engineers. Training packages are provided under three broad headings: management, professional and technical. The first two broad categories are easily recognizable but over the past few years more attention has been given to management training and skill based training for manual staff.

Training resources

Training centres, together with appropriate staff, have been built up on two locations. One concentrates on management and professional and the other on technical skills, particularly those in the practical field. These centres are supplemented locally by on the job training with the trainers moving from their centre to any location within the region. This feature is an essential part of the service, particularly for water distribution and sewerage personnel who are located throughout the region. External resources are also used but increasingly specially tailored programmes are developed to meet the ITP needs. Many of these externally developed courses are then run in NWW training centres or on the job.

CONCLUSION

The rehabilitation of distribution and sewerage systems calls for long term planning objectives if results are to be achieved within a recognised timescale and an acceptable financial target. A fully integrated system should be technically achievable if careful planning is followed. The needs and aspirations outlined in this paper are not the sole preserve of the richer 'technological' utilities but those of most water undertakings throughout the world. The speed of implementation will however be limited by finance coupled with retraining of staff and manual work-forces. The paper has identified many of the component parts which have now been developed and built, and which one day will be fully, rather than partially, integrated. There is no reason why these component parts could not be adapted to suit local circumstances and be used by other water utilities.

We started off with a futuristic look to water services in the twenty first century. It is in fact only thirteen years away and further research and development is still required. Perhaps it is now time to ask whether anyone here today has a good satellite and rocket?

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WATER CONSERVSTION FOR URBAN AREAS

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SYNOPSIS

The increasing costs of development, treatment, delivery, the physical scarcity of water and the competing urban water demands, specially during the period of droughts have been resulting in increasing interest in the water conservation in urban areas. The water conservation measures may be supply or demand oriented measures, permanent or short term measures including reactive measures adopted during periods of drought or low flow. Some important water conservation measures for residential or municipal uses with greater emphasis on evaportion reduction mesures and reactive measures have been discussed in the paper. The percentage saving of evaporation reduction from reservoirs has been found to be in the range of 10 to 35 percent at a cost of Rs.0.40 to 0.60 per thousand litres of water saved.

INTRODUCTION

Water is a limited natural resource and used in various sectors including municipal, industry and agriculture. The requirment of water by 2000 A.D. for the urban and rural water supply is expected to be 1.3 million ha.m and 1.11 million ha.m respectively. It has been evidenced by last 2-3 years of drought in the country that how availability of water in urban areas gets adversely affected during the periods of drought. The loss of water through evaporation, leakages, neglect and misuse put a heavy drag on the existing water supplies and make them further less available for urban dwellers. Annual evaporation losses from surface water storages alone are of the order of 30 to 50 percent depending upon the type of terrain & climatic conditions. According to an estimate made by National Commission on Agriculture (1976), about 6 million ha.m of water evaporates from reservoir surfaces every year.

Water conservation historically has not been a planned effort but instead initiated in the face of emergency in response to the situation of critical water shortages. Even a small percentage of reduction in water use on a long term basis i.e. both during normal and scarcity years could provide a substantial saving in water and carryover storage for further use on a continued basis. The efforts have been made in this paper to present the possible ways and means of conserving water for urban areas with major stress on evaporation reduction as a water supply conservation measure.

WATER CONSERVATION

Water conservation practices are a specific subset of natural resources management. While the immediate purpose of water conservation practices is to better utilise existing water supplies, the ultimate effect is to alter substantially water supply planning and use practices to increase future water availability in urban areas. There are broadly two kinds of water conservation. The first kind, is the attempt to achieve permanent changes in the handling and using of water.

The second kind, is the contingency programme for periods of drought or low flow. Entirely different decision criteria is required for both of these kinds. The first and second kinds of conservation could also be classified as the conservation during normal and drought year. The water conservation measures may be supply oriented or demand oriented measures.

The supply oriented measures aim at increasing the water supply through water conservation practices which basically reduce losses through evaporation, leakages, conveyance and distribution.

The demand oriented or water use oriented conservation measures augment the existing water supply through the practices which reduce water usage, wastages, misuse and neglect.

WATER SUPPLY CONSERVATION MEASURES

These masures include conservation mesures at source like evaportion reduction and planned water allocation and distribution mesures.

Water Conservation through Evaporation Reduction.

Availability of water for domestic uses in urban areas could be increased by reduction of evaporation losses from reservoirs, tanks for water supply. It has been observed that evaporation losses from shallow tanks or reservoirs during January to June are about 50% of the capacity of the tank. The National Chemical Laboratory (NCL). Pune, in a study reported that 2000 sq. km water spread area is available for adopting evaporation reduction measures.

It has been found in the country and elsewhere that the monomolecular films of long chain fatty alcohols such as cetyl and Stearyl alcohols and other type of alcohols are effective in reducing evaporation losses by forming a mono-molecular thin film over the water surface. NCL found in their laboratory studies that pure ethylene oxide monocondensates with cetyl and stearyl alcohols gave higher rates of evaporation reduction. The use of commercially available water evaporation retardant chemicals (WERCs) has been demonstrated by various state government and research organisations in the country. The NCL, National Environmental Engineering Ressearch Institute (NEERI), Central Soils & Materials Research Station (CSMRS), Karnataka Engineering Research Station (KERS), Directorate of Irrigation Research & Development (Maharashtra), Gujarat Irrigation Department, UP Jal Nigam, Rajasthan PHED, Hyderabad Metro Water Works etc. have conducted series of field trials on the use of these commercially available WERCs on several tanks, lakes and reservoirs meant for water supply and irrigation.

The chemicals are available for use in powder and paste forms and both are of fatty alcohol group. The WERC available in the powder form is pulverised and sprayed or dusted over the water surface to form a thin film. Recent practice had been of using WERC available in paste form. The diluted paste kept in drums is carried on floats and allowed to trickle down drop by drop from the drum on water surface.

The details of few such field experiments with percentage savings in evaporation reduction are given in Table 1[3,4,5&6]. It can be seen from the table that when WERCs are sprayed during the periods from January/February to May/June, a considerable amount of water in the order of 10 to 35 percent can be conserved against evaporation losses. The percentage saving of water through use of WERCs will depend on the geophysical conditions, climate, location of the lakes their depth and water spread area, and wind velocities. The percentage saving decreases with increase in wind velocity. If wind velocity is well below 15 km/hr. the saving is likely to be more (i.e. of the order of 25-30%) and at higher wind velocities around 20-25 km/hr or so the saving is likely to be reduced to about less than 10% due to breaking up of films by waves.

The reservoirs in Saurashtra region during 1985-86 drought were sprayed with the WERCs to reduce the evaporation from rservoirs in order to save water for maintaining municipal water supply to the cities. The total water saved against evaporation loss within a period of about 5 months (January - May) was of the order of 2.56 mcm (90.38 m.cft) and the average saving in evaporation was about 11 percent as given in Table 1.- The cost of evaporation reduction by WERCs of various projects is given in Table 2. The latest cost figures range from Rs.0.30 - 0.60 per 1000 litres of water saved. The cost of saving 2.56 mcm of water in Saurashtra region was Rs.12.20 lakhs which comes to about Rs.0.58 per thousand litres of water saved. This cost of saving water to povide additional water supply for domestic uses can be compared favourably with the alternative means of transporting water by Rail or Road for drinking water supply.

One of the effective ways to reduce the effect of high winds on increased evaporation losses is to have tree belts around the water bodies. This would moderate the effect of descicating winds blowing towards the water body and further reduce evaporation losses since films of WERCs will then be less prone to disturbance due to reduced wind velocity over the lake/reservoir. This would also improve the environment of the area. The work of establishing tree belts can as well be taken under the social forestry programme launched by the Government. The compartmented reservoir is another method of reducing evaporation loss in areas having a releatively flat terrain by reducing the exposed water spread area. In this system, the surface area to depth ratio is reduced by keeping the water concentrated. The increase in average depth reduces the amount of solar energy input into the reservoir as well as the exposure to the atmosphere thus reducing evaporation loss and conserving more water.

Forcasting Runoff for Water Use Planning.

How efficiently the monsoon runoff can be predicted as on July Ist, August 1st, September 1st and October 1st is of prime importance for water use planning in water scarcity areas where surface water reservoirs supply water for urban areas. Knowing the status of water availablity by month of September/October, the decisions to allocate water from reservoirs to various uses can be accordingly planned. In irrigation reservoirs, depending upon the water availability status, drinking water use should be allocated top priority during water stress condition. In water supply reservoirs, depending upon the future water availability forecasts suitable adjustments in distribution of water will have to be planned in advance to take care of future scarcity condition.. National Institute of Hydrology has developed a method of forecasting monsoon runoff using simple correlation technique to correlate monsoon runoff with the total runoff upto the end of June, July, August and September.

Leakage Reduction

It is a water distribution oriented conservation measure. It is difficult to determine actual amount of system leakage. The commonly observed types

TABLE - 1

Percentage Saving in Evaporation Losses Achieved in Different Reservoirs/Tanks in India for Drinking Water Supplies.

Sl. No.	Name of reservoir/ project	Location	Period of Study	Average wind Velocity km/hr	Average % saving in evaporation reduction
1	2	3	4	5	6
1.	Kukkarhalli Lake	Mysore	Jan.59-May 59 (5 months) Fen.61-Apr.61 (3 months)	-	14.4 11.7
2.	Welwhan Lake	Lonavala	Feb.16-May 61 (4 months)	-	9.6
3.	Aji Lake[a]	Rajkot	Apr.68-June 68 (3 months)	23	16.5
4.	Indira[b]	Pune	1977-78 1978-79	15 -do-	38.19 35.20
5.	Kedaipur PT[b]	Nagpur	1977-78 1978-79 1979-80	- do- - do- -do-	34.78 16.01 15.87
6.	Ramgarh Lake[c]	Jaipur	Apr.85-July 85 (4 months)	14	23.4
7.	Foy Sagar[c]	Ajmer	Jan.86-June 86 (6 months)	8	35.0
8.	Maja dam[c]	Bhilwara	Jan.86-July 86 (7 months)	10	30.0
9.	Osman Sagar[c]	Hyderabad	Apr.86-June 86 (3 months)	14	33.0
10.	Nyari-I dam[c]	Rajkot Div.	Dec.85-May 86 (6 months)	12	16.5
11.	Aji-I[a]	Rajkot Div.	Dec.85-May 86 (6 months)	11	20.0
12.	Bhadar[a]	Rajkot Div.	Dec.85-May 86 (6 months)	11	16.0
13.	Ten Reservoirs[a & c] (Average)	Rajkot Irrig. Circle	Dec.85-May 86 (6 months)	-	11.08

(a) : Cetyl-Stearyl alcohol (Powder form)
(b) : Linoxyd CS - 40 (Paste form)
(c) : Ceto - Stearyl alcohol (Paste form)(ACILOL - TA - 1618 WER)

TABLE - 2

Cost of Evaporation Reduction by WERCs*

Sl. No.	Name of reservoir	Location	Year of study and duration.	Cost of water saved/ cu.m (1000 litres)	Average % saving in evaporation reduction.
1.	Aji lake	Rajkot	1968 (3 months)	0.04	16.5
2.	Indira PT	Pune	1976-77 1977-78 1978-79	0.27 0.30 0.40	35.00 38.19 35.20
3.	Kedarpur PT	Nagpur	1977-78 1978-79 1979-80	0.34 0.59 0.56	34.78 16.01 15.87
4.	Ramgarh Lake	Jaipur	1986 (first 15 days only)	0.30	23.4
5.	Ten Reservoirs of Saurashtra	Rajkot Irrigation Circle	1985-86 (5-6 months)	0.58	11.08

* Cost of applying water evaporation retardant chemical including cost of materials, labour & equipment usage.

of leaks are from broken main and joint leaks, leaks between main and customer's meter, hydrants and toilets and faucets.

Leakage detection and repair is a viable supply oriented method of conserving water. It needs a regular monitoring and maintenance of the system in the municipal areas. Howe reported on the basis of a survey in USA that the water savings could approach 9 percent of total water production, if all economically feasible leaks were repaired.

WATER USE CONSERVATION MEASURES

These measures include the practices of water saving between and beyond drought, basically reducing the water demand.

Metering residential and industrial water use is one of the structural measures to accomplish water conservation. In the absence of proper metering, economic control is very difficult as the quantities supplied cannot be accounted for and often lead to its misappropriation. And misuse of water during lean periods is harmful. The effects of metering on residential water usage has been a subject of much debate. This is due to the difficulty of quantification of the usage reductions of universal metering. The success of almost all non-structural reactive measures to be adopted would depend primarily on efficient metering facilities. The metering would also induce a feeling in the public to go for installation of water saving devices in the homes attached to existing water fixtures.

Changes in Water Pricing Structures

The use of pricing policy is an effective tool for achieving water conservation. Pricing is a proper economic inducement whenever feasible, either by an increase of water price during times of reduced water supplies or by a decrease of price incase of an abundant water supply. The following quotation by Samulson aptly describes the human tendency.

"Whenever water is very dear, I demand only enough of it to drink. Then when the price drops I buy some to wash with. At still lower prices, I resort to still other uses; finally, when it is really cheap, I water flowers and use it lavishly for any possible purposes".

The appropriate water rates which reflect cost and availability of water may prove to be more effective in making people conscious of judicious water use and induce them to adopt water conservation. Increasing block rates means charging a higher price per gallon if customer uses more than a certain amount of water, specially in drought prone areas could be a better policy of water conservation in urban areas.

Changes in Water Use Patterns

The imposition of water use changes or restrictions is essentialy a short term method of reducing demand to conserve water during water scarcity or on-going drought periods. These reactive measures include the practices of changing water oriented life styles, habits and out-side the house uses. Some of these to mention are taking short showers, reduce bathing frequency, fewer toilet flushings reuse of residential waste water i.e. from bathroom, laundry etc. for scrubbing floors and similar non-potable domestic uses and for watering of plants etc., check leaving of tap open when not required, restricting use of water for lawns and gardens, using drip or sprinkler for applying water for lawns and gardens, reuse of waste water in industries etc. The amount of water savings that can result from such restrictions is not precisely known but it effects in substantial saving of water may be in the order of 10 to 30 percent of total usage.

Rationing of municipal water is resorted to when the demand outstrips the supply even after taking all preventive steps. There are two main methods of doing this i.e. rota cuts and stand pipe. Rota cuts method consists of shutting off the supply to an area for fixed periods of the day. In stand pipe method, supplies into houses are made to collect water from specially installed outlets called stand pipes. The latter method is adopted during condtions of extrme scarcity when the Rota cuts method totally fails. During situations with relatively lesser severity of water scarcity, the rota cuts offer much more flexibility and efficiency than the supply by stand pipes which causes considerable hardship to the consumer.

Recycling

Recycling of residential waste water can reduce the demand for treated raw water to an urban utility. At present the waste water is some times used for irrigation or in certain industries. Residential waste water recycling can be effected by segregating black and gray waters and using the gray water for some indoor non-potable uses before discharging the same to the sewer system. Waste water from toilets etc. containing high concentrations of organic matter are called black water while that from bathrooms, laundry etc. polluted primarily with soap-related wastes are termed grey water. Generally these two are combined and discharged into the sewer system. In a typical residential recycling system, gray water can be reused for cleaning or scrubbing the floors, watering lawns, flushing toilts etc., with or without filteration before discharging it to sewer system. This practice may involve some construction and special plumbing expenses.

WATER CONSERVATION EDUCATION AND INFORMATION

Water conservation education and information to convince the water user about the seriousness of water scarcity or shortage are the backbone and vital components of any water conservation programme. In order to do so water managers should also be given sufficient back ground and training in water conservation programme. In order to do so water managers should also be given sufficient back ground and training in water conservation at various levels. There is a need to include such education system at different levels in schools and colleges so that students are made aware of water conservation practices and educated to learn to live with water scarcity. An understanding of water supply and its use for development of a conservation ethic in urban areas is essential for successful water conservation. It would also need to develop a public information system for water conservation in urban areas. There is every possibility of success of water conservation mesures through water consciousness campaigns to create awareness in the users.

CONCLUSION

Water conservation is essentially one of the important means in the managment of water resources in urban areas so as to augment the existing water supply and to avert critical water shortages. The field trails on evaporation reduction through chemicals in the country have shown a substantial saving in evaporation reduction of about 10 to 35 percent. The cost of saving evaporation is found to vary from Rs.0.4 to 0.6 per thousand litres of water which is cheaper than other alternative modes of providing drinking water by rail and road transport. In addition, tree belt must be encouraged around water bodies to achieve more saving through reducing the descicating effect of wind and its velocity towards water body and improve environment also.

In addition to long term permanent mesures of water conservation, adoption of suitable reactive measures like rationing, changing water use practices be also attempted. Residential waste water recycling is another area in which much remains to be done. The water conservation education and information system for water conservation campaigning is also vital as a part of water conservation programme in urban areas.

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WATER WASTAGE CONTROL : PHILLIPINE EXPERIENCE

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SYNOPSIS

Water wastage and its control is increasingly becoming a great concern in the water supply industry. Uncontrolled wastage may drain huge amounts of capital and operating expenses to meet the water utility's expansion and operating requirements. Eventually, if uncorrected at an early stage, it can cause the downfall of that water utility.

This paper shares the findings of the Local Water Utilities Administration in the Phillipine setting which were arrived at after the launching of their Operation and Maintenance Assistance Program to control water wastage in their water supply projects. The paper tries to identify the different causes of high unaccounted water in the various water systems of the country and also brings forth recommendations to correct the situation. Analysis of the problem starts from the planning stage of the project until its operational stage. While many of the recommendations are still to be implemented, it is sincerely hoped that this paper gives the different participants of the Conference and other readers some insights and ideas on how the problem of high unaccounted water may be faced.

INTRODUCTION

Proper operation and maintenance of facilities is often overlooked. All too often, maintenance has been considered as unglamorous job compared to other technical jobs like planning, design, construction. This problem is common in most parts of the world, both developing and developed countries.

In the field of water supply, the IBRD and the ADB have been very much concerned with the proper maintenance of water systems. In the Asian region, several Technical Proceedings and Workshops have been conducted for the purpose of gaining expertise in the proper maintenance of water systems through the sharing of experience.

With the same concern, the Local Water Utilities Administration (LWUA), a national agency charged with the responsibility of developing urban water systems all over the country, conducted a survey of Water Districts in 1984, whose water systems have been improved/expanded. The survey was prompted by feedbacks that many of our completed projects are not providing better water service in terms of better pressures and adequate supply and the expected increase in revenue was not commensurate with the increase in operating cost due to the expanded service area.

RESULTS OF THE SURVEY

Figure 1 shows that of the fifteen Water districts surveyed, their unaccounted water varied from 38% to 78% with majority of them falling in the range of 45% to 65%.

A. High Unaccounted Water (UAW) is due to :

i) Large percentage of old pipeline/service connection being retained in the newly installed improvement.

Most if not all of the old pipes were retained with little investigation on the need to rehabilitate or replace the defective portions. The percentage of old pipes to the total length of pipe in the system varied from 40% to 77%.

(The survey considered leaks as the only major cause of unaccounted water but additional causes were discovered during the implementation of OMAP).

ii) Water Districts had no funds for leak repair.

More often than not, leak repair work has been underestimated. With the extensive work to be done, the water districts usually do not have the funds to undertake it. If a district is to borrow funds to correct leakages after the construction phase, it is very often that their capacity to pay would have been exceeded. These conditions made leak repair after construction very difficult to pursue.

iii) Water Districts lack the capability to control wastage.

To be able to conduct leak detection and repair, Water District personnel need to have training and equipment. The districts needed training to analyse operating data and synthesize what to expect when some variables are changed.

B. High Unaccounted Water Led to :

i) High cost of production.

Assuming that they would be able to reduce the unaccounted water to a maximum of 25%, the value of monthly losses ranged from P21,000 in the small districts to P2M in the large ones. These equivalent amounts could pay for loans ranging from P1.7M to P180M payable in 20 years at 14% interest rate (refer to Figure 2). If the losses can be controlled and recovered, the districts can afford to borrow funds to make their operation more efficient.

Although their unit production cost is less than their average selling price, their effective unit production cost (unit production cost divided by the volume of water sold) is greater than the average selling price (Figure 4). The high effective cost of production is due to the high water losses.

ii) Undue need to tap additional sources at an early stage.

Many of the water districts surveyed had an artificial shortage of supply because of the high unaccounted water. In the early stages of project development, the Water Districts had to develop additional sources not only for the additional demand but also due to the water losses. The strategy of development was more geared on the extending the service area rather than replacing or repairing the old system. The assumption was that after construction, the leaks in the old system would crop up due to higher pressures. It was thought that locating and repairing leaks would not be a problem. This expectation, however, did not happen. If some cropped up, the discovered leaks cannot explain the huge water losses.

It appears that the Districts have had two huge expenses due to this strategy. Firstly, they had to spend capital to develop additional supply. Secondly, operating cost became higher without its corresponding revenue because of the higher volume of losses.

THE OPERATION AND MAINTENANCE ASSISTANCE PROGRAM

As a result of the 1984 survey, the Operation and Maintenance Assistance Program (OMAP) was conceived to assist the Water Districts in correcting operational inefficiencies of their water systems in terms of :

A. Reduction of Unaccounted Water

Initially, the survey indicated that leakage is the major contributor to the high unaccounted water. In the pilot studies conducted in 1985, it came out that there are other factors which effects have been initially underestimated like losses due to inoperational water meter and stealing of water.

B. Reduction of Production Cost

1. Improved schedule of pump operation. There have been cases where there were pumps with high unit cost of operation which were operated even during periods of minimum demand.

2. Proper maintenance. Poor maintenance practices led to reduction in volume of water sales due to frequent breakdown of production facilities and the cost of repair or replacement became a burden.

3. Training of Operating Personnel. The operating personnel of the district have to be trained on the practical knowledge of using equipment and analysing gathered data to come up with corrective measures. It is expected that the operating personnel of the district will continue these activities.

FINDINGS OF THE OMAP

A. Leaks

About eighty to ninety percent of the leaks occur in service lines. A great majority of these lines are old and corroded GI pipes which are temporarily patched up with rubber strips. These are long GI service pipes laid parallel to each other along open canals spanning two or more blocks. Some of the leaks are abandoned connections plugged with wood which have decayed and gave way. Service connection leaks also occur on relatively new lines. Identified causes are mainly the following :

1. exposed or insufficient depth (less than 0.46M) of laid plastic tubing with unselected backfill materials.

2. galvanic corrosion of GI service

taps welded on steel pipes.

3. use of sub-standard plastic fittings in place of the brass fittings.

4. injury of the plastic tubing at the end of the compression type fitting or improper flaring methods when flare type connections are used.

5. injury of the plastic tubing in road crossing when the tubing has to be pulled through sleeve pipes.

It was also observed that the poor workmanship was due to lack of supervision of the installation/repair works and lack of training of plumbers in the proper methods of service connection installation. We feel that without proper training of plumbers, the present level of workmanship would not be improved.

B. Production Monitoring/Zone Metering

1. Production metering. Almost all the old production facilities, and even some new ones, are without production meters to measure the production. Many production reports were estimated using pump rating that were valid some years ago. Some were just estimated and adjusted to come up with reasonable level of unaccounted water.

2. Zone metering. Valves were frequently found insufficient to isolate a manageable section of the water system and a number of those already existing were found to be inoperable. Preparation for zone isolation and metering took some time before leak detection/repair could be started. Nightflows have been used to indicate the extent of losses in an isolated section. However, there have been limitations to this indicator. Most of the consumers with non-continuous supply have their faucets or storage tanks constantly open to store water anytime it becomes available.

C. Consumption Metering

i) All of the projects under study claim to have policy that all meter connections are sealed. Actual field conditions indicate that this policy is not enforced and penalty is not imposed when the seal has been tampered. Because of the lax enforcement of the policy, cases of tampering of the meter internals have been numerous. Various methods have been used like the trimming of the vanes, inserting objects to slow down the rotation of the vanes, or even inverting the meters.

ii) Tampering of water meters. Various methods have been employed by the consumers in tampering like the use of magnets to deter the rotation of the magnetic drive, insertion of wires or other objects to slow down the vane's rotation, removal or inversion of the water meter. Aside from the non-enforcement of the policy on meter sealing, location of the meters inside the premises of the consumers make tampering of water meter easy as it is away from public view.

iii) "Averaging" of consumption. Of all the meter related water losses, the practice of "averaging" of consumption is found to be contributing most. This is a practice of taking the average consumption of a consumer for the last three months if the water meter of that consumer has been found defective (stuck up, grossly under-registering, with blurred lens). It is at this condition that the consumer tends to waste water and consume more than what is billed. It has been found that the actual consumption could react up to two and a half times the "averaged" consumption. Studies conducted to determine the usual cause of meters getting stuck up indicate silt/sand particles as the main cause. If the accumulated silt does not clog the strainer, they would accumulate on top of the magnet of the vane wheel hindering attraction between the driver and driven magnets.

iv) Location of water meters. A good number of water meters are still in old locations where they are now inaccessible, e.g., beside creeks back of the house, or inside bathrooms. The meter reader is tempted to just estimate the consumption from previous readings. This situation presents another source of losses to the district.

v) Flat rate connections. Existence of unmetered connections does not appear to be a problem as almost all of the projects are 100% metered. In the Buyog sub-system in Baguio City, the water billing for the area increased by 27% after the defective meters were replaced and the flat rate consumers were metered. This indicates the tremendous effect of a good metering program.

vi) Inaccuracy of meters. Though it affects the whole meter population, inaccuracies has minimal effect (about 3-5%) to the total losses when compared to those due to defective and tampered meters and flat rate connections. It was observed, however, that under-registration in meters of commercial and industrial connections could contribute largely to the water district's losses in terms of revenue. The water district should be more concerned in looking out for defective water meters in residential connection and concentrate accuracy testing on meters of large commercial and industrial connections.

B. Analysis/Breakdown of Unaccounted Water

Even with an improved monitoring system it will be difficult to accurately quantify the distribution of water losses. However, based on the experience gained in the projects under OMAP, it is possible to make a reasonable breakdown of water losses in percentage of the total production. (Please refer Table 1.)

It appears that illegal water use and leaks are the main contributors to the unaccounted water. In some cases, water loss due to illegal connections is more than that due to leaks. It was known that illegal connections were common in many water districts but it was completely underestimated. Illegal water use is usually in the magnitude of 20% but documented cases in test areas reaches 60% of the inflow to that area. House to house campaign to track down illegal users, although it brings in revenue to the district in terms of penalties and payment for estimated water use, has not been so successful in terms of reducing the unaccounted water. Going on a house to house campaign is not possible in all cases, especially in areas where the peace and order situation is uncertain. Tact and boldness on the part of the OMAP team members is a must in carrying out this kind of campaign. There have been cases where illegal water users were pinpointed but the water district showed reluctance to rectify the situation for whatever reasons. Such behaviour does not only lower the morale of teams but may endanger the success of the OMAP.

E. Equipment Maintenance

OMAP activities covered mainly the rehabilitation and rewiring of electrical installations in pump stations, procurement of basic hand tools while instructions were given to O&M staff both in the field and in the shop to improve operating and maintenance practice.

Since the installation of motor protection relays in Metro Cebu's production facilities, like over/under voltage and single phasing protections, the number of electrical breakdown has been reduced drastically. (Please refer to Table 2.) It would appear that the quality of power supply from the electric cooperative has a great effect on the service life of the motors. There is an interplay of reduction of production due to the tripping of the protection relays during high/low voltage conditions and the possibility of running the pump to maintain production with the danger of burning the motors and probably incurring longer periods of shutdown.

Table 2 further indicates that for the period 1984 to 1986, the main contributor to downtime of production units is power interruptions while electrical problems which is a function of the quality of available power supply is next.

Many of the activities on planned maintenance cannot be undertaken because of the lack of a workshop. Funding of Metro Cebu's workshop has been included in the OMAP loan of the water district to allow the district to conduct preventive and corrective maintenance activities themselves in view of the 48 pump stations they have.

F. Implementation Scheme

When the OMAP was planned, we had foreseen that costs to implement it would be confined only to professional services and cost of flow meters, valves, fittings and repair materials for pipeline and service connection leaks.

As the program proceeded, it became more evident that most of the projects have deficiencies in their physical plants that have to be corrected to bring the operating conditions and efficiencies to acceptable levels.

It was observed in sub-systems of two projects, Metro Cebu and Baguio Water districts, that the unaccounted water after some time goes back to the original level before the implementation of the OMAP. The unaccounted water of the Buyog sub-system of Baguio was reduced from 76 to 53%, or in terms of volume, from 20,000 to 7,200 cubic metres per month, after leaks have been repaired and defective meters have been replaced. Although the reduction was not very impressive, the operation greatly improved with the use of only one pump simultaneously serving the three areas which previously served at different times by rationing using two pumps. Three months after the OMAP and the unaccounted water has been reduced to 51%, the unaccounted water went back to almost its original level of 61% or an increase in losses by 1,000 to 8,300 cubic metres per month.

In Cebu, the nightflow of the Mananga area was reduced from 99.7 to 43.7 litres per second in August 1985. The nightflow was re-monitored in July 1986 and the nightflow has increased to 90.9 litres per second, almost to its original level.

The experience in Cebu and Baguio indicate that the effects of repair works done by the OMAP teams are temporary in nature due to the occurrence of new leaks in other portions brought about by the increased pressure. It now appears that the efforts being exerted under the OMAP would be rendered useless and objectives would be barely achieved if these deficiencies are not corrected in a more comprehensive way of replacing old and leaky pipes and service lines.

RECOMMENDATIONS

A. Reduction of Unaccounted Water

i) Leakage Control/Repair.

(a) Investment Requirement. At least 80% of the leaks occur and recur on service connections. It is also the experience that after a period from the completion of leak detection/repair in an area, the unaccounted water goes back to its pre-OMAP levels. This indicates that repairing leaks on old and dilapidated pipes is just a temporary solution. There is an immediate need to replace/rehabilitate service connections and service laterals. This activity by itself requires a lot of planning, designing and considerable capital which could run into millions of pesos. Based on studies in service connection rehabilitation in Cebu, the average cost of rehabilitating service connections (including the proper laterals to eliminate the "spaghetti" connections) would vary from P3,500 to P8,000 per connection depending on the street cover. LWUA is now considering this item in the preparation of its capital budget to improve the chances of Water Districts becoming viable. The pilot aim in Colon St. of Metro Cebu which is being prepared for this kind of work will give a lot of information in planning LWUA's activities in this area of activity.

(b) Technical Standards for Service Connections: A review of existing standards for the installation of service connections is necessary to eliminate the problems on poor installation methods.

(c) Training/Supervision. Training should be given to plumbers in the proper use of plumbing tools/ materials and proper installation procedures and techniques. Getting them informed with the standards is a great step in attaining a leak-free service line. In addition, close supervision on the proper installation/repair of service connections is equally important.

ii) Illegal Usage.

(a) Illegal connection. Many of the existing illegal or unregistered connections have been inherited when the water system was turned over to the district by the local government which was originally operating the system. The district may devise methods to locate illegal connections through a house to house campaign, or pay for information leading to location of such or in areas where the practice is rampant, the water district could re-excavate distribution lines and disconnect unregistered connections. The last method is one of the methods being investigated in a pilot area in Cebu city which was identified to have excessive losses due to illegal usage. In all cases the necessary penalties and charging of estimated consumption should be applied. These methods, however, has their own limitations and may not bring remarkable results. We recognise the difficulty of ferreting out illegal connections and the period of eradicating it would depend on the method and also the determination of the water district to implement it. The point is, once the district goes into this program, there should be a sustained effort in going after illegal connectors. Failure to sustain the program will give out a signal that the district does not mean business.

(b) Meter tampering. Meter tampering is done to reduce the registered consumption. In effect, this practice was tolerated by the non-implementation and non-enforcement of the policy of sealing the meter connection. We have observed in some water districts where the water meter is installed nearest the tapping point and outside the premises of the consumer, there was little chance for the consumer to tamper with the water meter and service line as they are exposed to public view. The fear of the water meter getting lost when it is installed outside the consumer's premises is unfounded since this does not happen in districts where the meters are outside the consumers' premises.

iii) Unregistered consumption.

(a) Defective/inaccurate meters. Compared to the losses due to leaks and illegal connections, water loss due to meter inaccuracy is minimal (3-5%). However, losses due to non-functioning water meters, if not immediately replaced, contribute significantly to the total unaccounted water. Water districts should exert more effort in immediately replacing these meters. There should be a close co-ordination between the Commercial Division and the Maintenance Division. The meter readers of the Commercial Division shall report all defective meters and all connections with abrupt changes in consumption. These reports shall be forwarded to the Maintenance Division for them to pull out and replace the defective meters. The water districts should be more concerned about non-functioning water meters in residential connections and conduct annual accuracy testing on meters of large commercial and industrial connections.

(b) Regular Maintenance of Water Meters. Due to the absence of meter service records, it was very difficult to establish the relation of years of service of a water meter with the degradation of its accuracy or its chances to become defective. We feel, however, that five years of operation would be reasonable. Many of the water meters in the projects under study have been operating for five years and the overall under-registration is only 3-5% of the production.

B. Project Evaluation

i) Cost of rehabilitating the existing system: It is imperative that the project feasibility study should determine the need to rehabilitate/replace existing pipelines before considering extension of service. The cost of rehabilitation should be included in the total project cost estimate to determine the "true" project cost to make the system operate as designed. Some projects have been considered feasible by considering only the expansion project cost but later turned out requiring additional capital to rehabilitate the old portions of the distribution system. The additional capital usually makes the project unfeasible. The said part is that this is known only after LWUA has sunk substantial investment into the project and later discovered that the project cannot be operated as designed.

ii) Maintenance Equipment and Facilities. Project study should also consider putting up support facilities/equipment/spares for maintaining equipment. The project study should include such cost in the project study to come up with a more realistic project since most of the water districts do not have the funds to put up such facilities and materials. Without these items the project will soon meet operational difficulties because of the absence of maintenance.

iv) Capability of Water District to Operate and Maintain. The project study should also assess the readiness and training needs of the District's personnel starting from the supervisors to the plumbers/operators. Preparing the Water District for the new/expanded facilities should be done while the construction is still going on. Preventive maintenance activities and schedules should be prepared by the design engineers together with the contractor/equipment supplier. Operation manual should be prepared by the design engineers with experience in operation and maintenance. Training of personnel prior to the turnover of facilities should include operating and preventive maintenance instructions. Hands-on training shall be done during the start-up.

C. On Water District Policies and Operation

i) Policy on sealing of water meters. Water districts should enforce the policy on sealing of water meters and the application of penalties on illegal water users. This is a deterrent to any move to tamper the water meter. Repeated breaking of the seal is no longer accidental and investigations should be made to see if there have been attempts to tamper the meter. The districts should be more firm on the enforcement of this policy.

ii) Relocation of water meters. Meters that are hidden from public view could be very tempting for tampering to some people. Likewise, inaccessible water meters are purposely or inadvertently not read by the water meter reader. Relocation of the water meters nearest the tapping point and outside the consumers' premises will deter meter tamperers and decrease the chance of it being unread. If necessary, the meters may be housed to protect it.

iii) Proper installation methods. District personnel should place more concern on proper installation of service lines since these is the major cause of leakage. Construction supervisors should closely supervise this kind of work.

D. Review and Revision of the LWUA Technical Standards

i) System zoning. System design shall consider the ease of dividing the system into manageable zones and the possibility of isolating and metering zones for easier measurement and control of water losses.

ii) Technical Standards. Due to the poor quality of power supply from electric cooperatives it is necessary to use other protective relays aside from thermal overload relays to protect the motor from voltage fluctuations and single phasing. Such should be specified in the Standards.

iii) Production metering should become standard in all sources, whether existing or proposed water sources.

iv) On steel pipes. The use of cement coated and lined steel pipes as distribution laterals should be discontinued. This pipe material should be used only for transmission lines where it is not tapped to avoid exposing the steel pipe and start oxidation corrosion or galvanic corrosion between the steel and brass service line fittings.

TABLE - 1

OPERATING CONDITIONS METRO CEBU WD

LOST PRODUCTION PERIOD

YEAR	NO.OF BREAKDOWNS		PUMP DAYS LOST DUE TO		BROWNOUTS (Hours)	AVE. PROD'N RATE	
	Elect' 1	Mech' 1	Elect' 1	Mech' 1		CUMD	CUM/HR
1874	12	14	501	38	7,311	1,165	50
1985	15	6	89	39	11,202	1,160	50
1986	4	-	39	-	3,578	1,765	73

TABLE - 2

LOSSES DUE TO SHUTDOWNS

YEAR	LOST PRODUCTION, CUM		
	Elect'1	Mech' 1	Power Interrupt
1984	583,665	44,270	365,550
1985	103,240	45,240	560,100
1986	68,835	0	261,194
TOTAL	755,740	89,510	1,186,844
%	37%	4%	58%

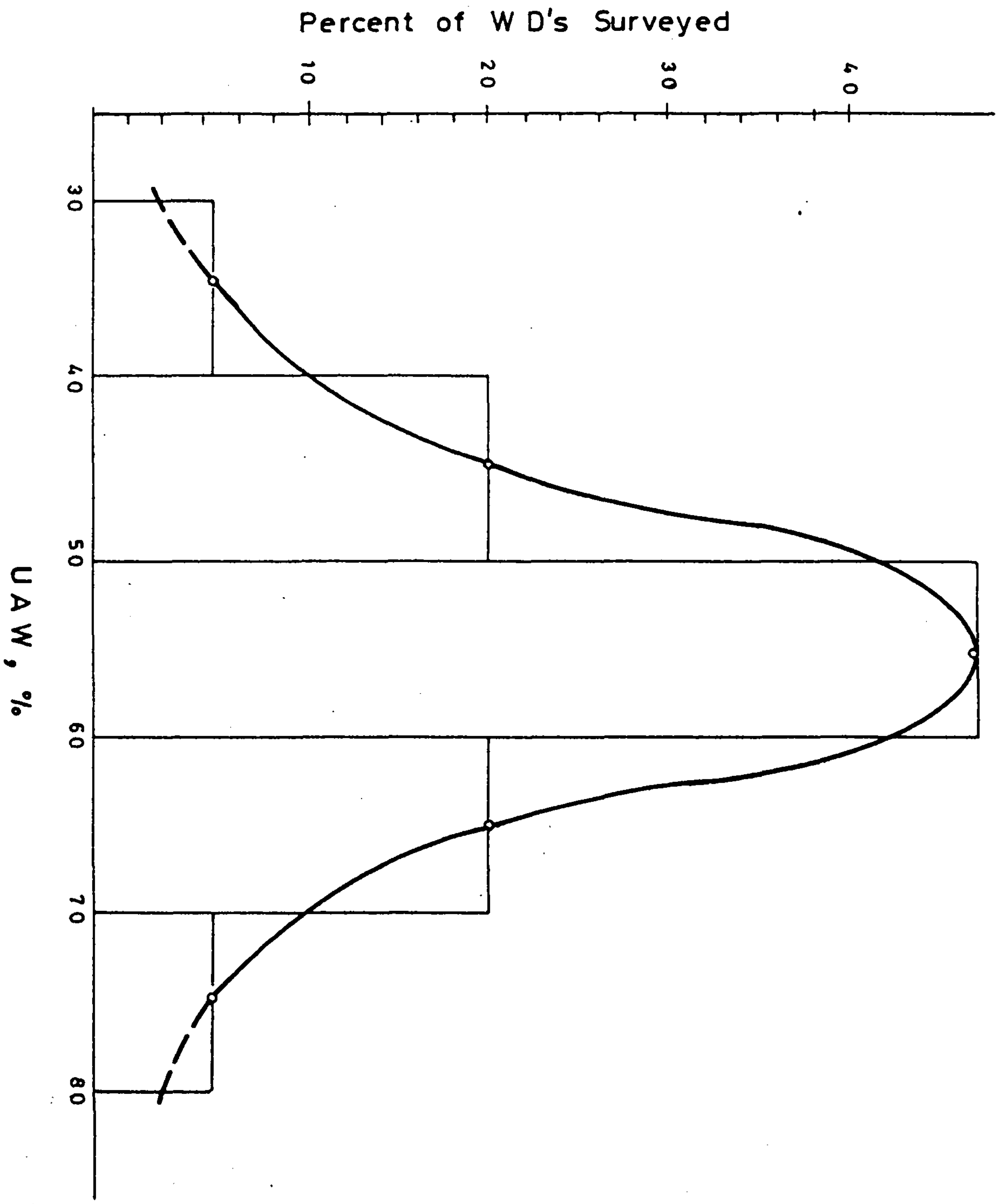
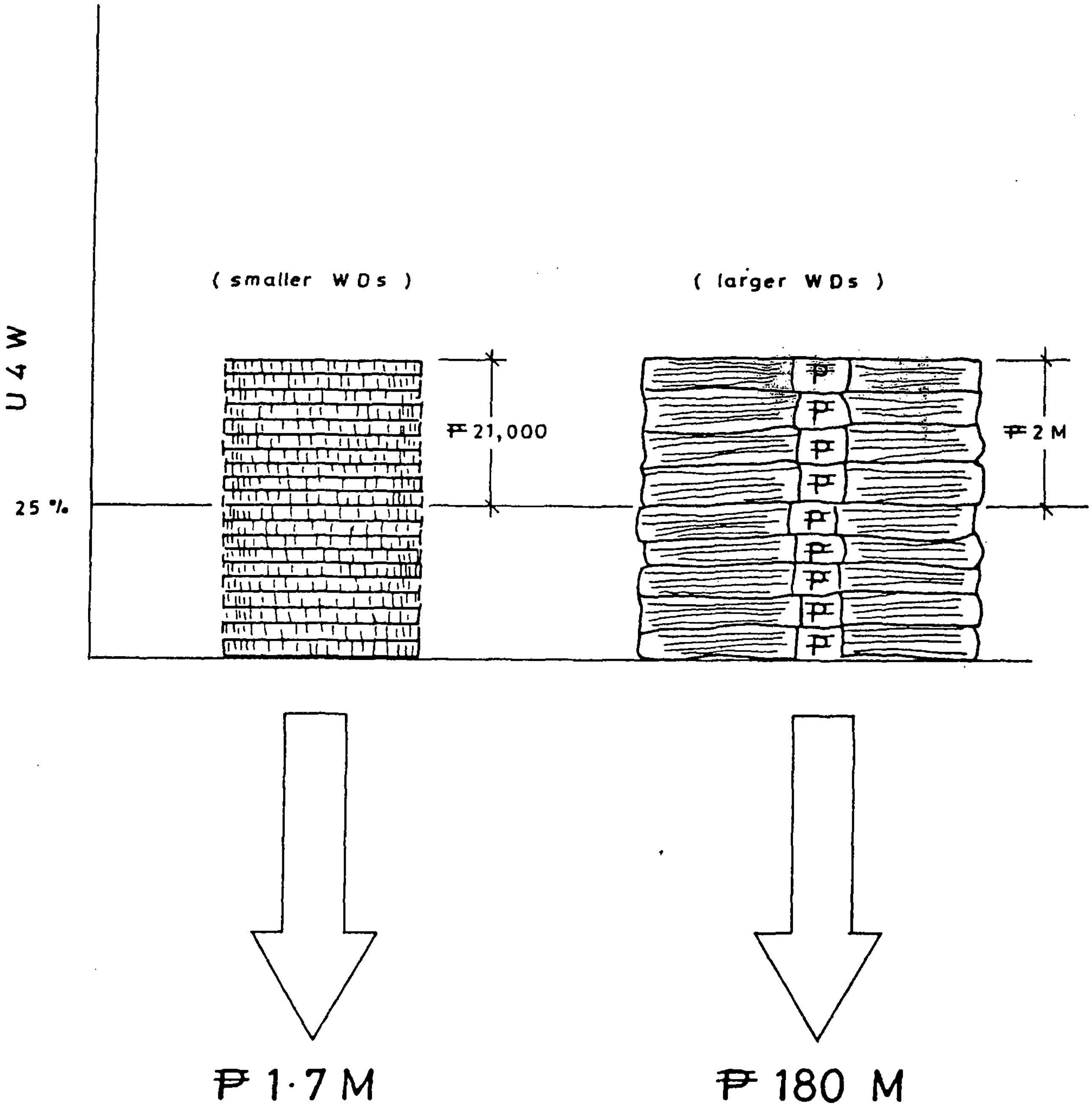


Fig.1. SURVEY UNACCOUNTED WATER OF 15 WD's

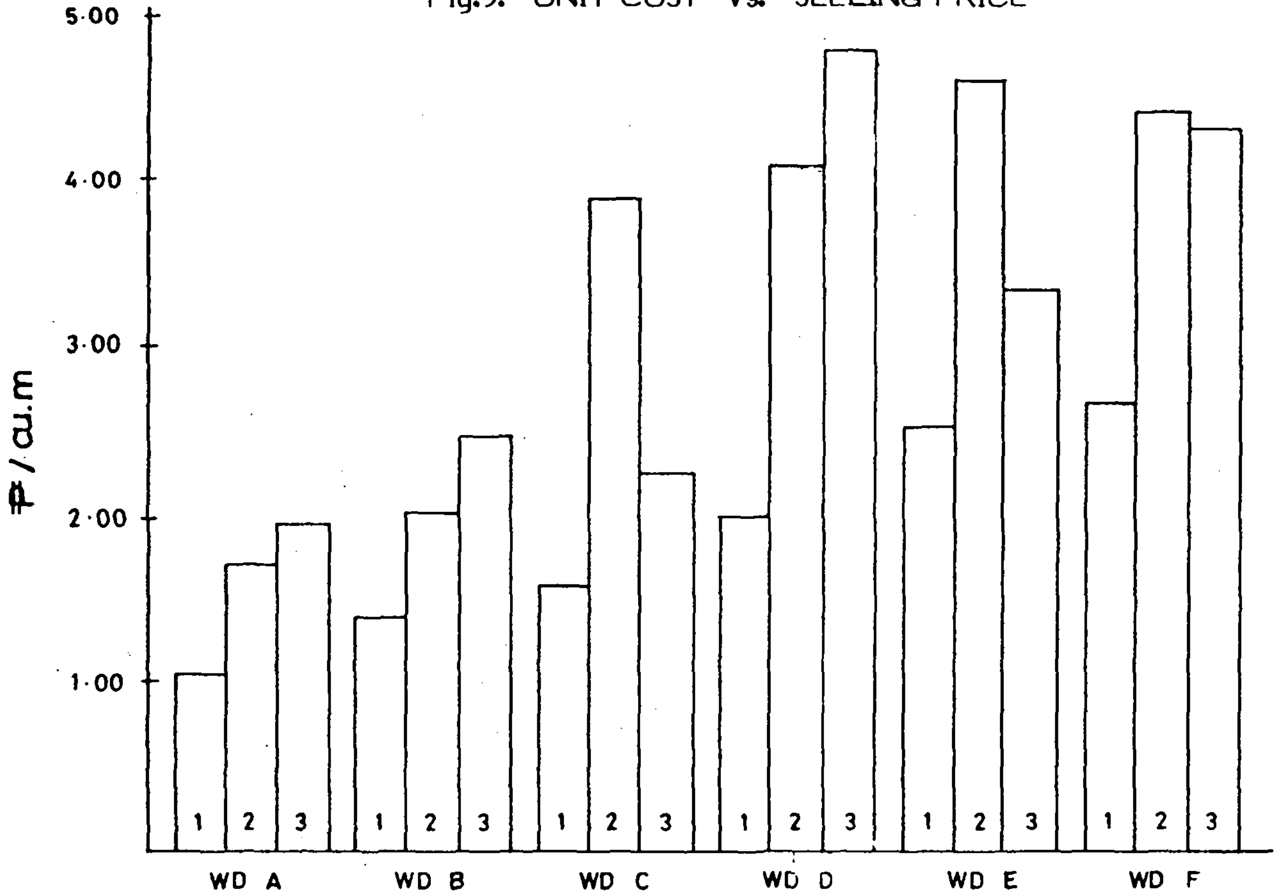
Value of Lost Water / Month
(after 25 % UAW)



Value of Equivalent Loan
(20 years, 14 %)

Fig.2. DRAIN OF RESOURCES/INCOME

Fig.3. UNIT COST Vs. SELLING PRICE



Legend:
1. Unit Production Cost (including loan servicing)
2. Unit Effective Production Cost (including loan servicing)
3. Unit Average Selling Price

RECONDITIONING OF THE OLD 900mm (36) DIA. KILOKRI CAST IRON MAIN IN DELHI

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After Independence in India there has been a phenomenal growth in the size and population of the city of Delhi. As a result, the city has grown in all directions. Water works are mostly located in North, North West & North East of Delhi. The treated water has to be carried for long distances to Western and Southern parts of the City. With the result, the areas at the tail end of the Transmission System are facing shortage of water supply. Since the sources of water supply are also limited, a need was felt to distribute available water in a more equitable manner.

For rationalising the distribution of water, a detailed study of various Transmission Mains and the Distribution System was carried out by DWS & SD Undertaking. While checking the carrying capacity of various Transmission Mains, it was observed that the 900mm dia. Cast Iron Kilokri Main supplying water from Wazirabad Water Works to southern parts of Delhi was carrying only 45 MLD against the capacity of about 65 MLD. By using Pitot Metres, the carrying capacity coefficient ('C' value in Hazen Williams formulae) was determined which worked out 75 which is appreciably lower than the 'C' value of 100 usually considered for design purposes for Cast Iron pipes. It was observed that the drop in the 'C' value was essentially due to the following reasons :

1) The low carrying capacity coefficient due to tuberculation in the pipes.

2) The leakages in the joints of the Cast Iron Mains.

For improving the carrying capacity in the Main, it was decided to get the Main cleaned, scraped and internally lined with cement mortar. This is the first time that an old Cast Iron main has been taken up for reconditioning by this process. This paper covers a case study regarding the process involved and the results so achieved.

The KILOKRI MAIN was laid in the year 1963-1969, for a length of about 20 kms, and supplies water essentially to South Delhi but enroute it also supplies water to various other areas through direct Tappings. The Main is also inter-connected with other Transmission Mains running parallel to it. In all, there are 18 Tappings and Interconnections as shown in Figure 1.

In order to ensure minimum dislocation of water supply, the work was carried out in 2 phases i.e .during the winter of 1985 and 1986. In the first phase, the section from Wazirabad to Rajghat (total length of about $9^1/2$ kms) was isolated and the existing Tappings of this portion of the Main were transferred to the parallel duplicate Main. All the Sluice Valves on the Interconnections and Tappings were closed and additional sluice valves were provided where these were not water tight. Since the method of cleaning the Main was by Hydraulic Scraping, to avoid damage to the on-line sluice valves, the same were removed and replaced by Cast Iron pipe pieces of adequate length. The Main was then successfully isolated on trial basis.

CLEANING OF THE MAIN

The TWO main alternatives of cleaning the Main are -

1) Hydraulic Scraping (Figure II showing the Scraper inside the pipe)

2) Mechanical Scraping

The option of Manual Scraping can be taken wherever the Main could not be cleaned otherwise.

In the instant case, since water with adequate pressure was available, it was decided to go in for Hydraulic Scraping with Manual Cleaning at certain places. The initial short reach of 1200 (48") diameter Cast Iron pipe from Wazirabad (length of about 850 metres) was cleaned manually.

Prior to the start of Hydraulic Scraping, following activities were completed.

a) Cutting of the Pipes at Wazirabad as well as at Rajghat ends.

b) Introducing the Hydraulic Scraper into the cut portion of the Pipe at Wazirabad end.

c) Providing an end catch box at Rajghat and where there was 'T' connection.

d) Providing 12" dia Scour Valve alongwith necessary piping for discharging the Waste near Rajghat and suitably blank flanged, since it was at this location the scraped material and waste water could be discharged to nearby disposal point.

e) One pressure gauge was installed at the starting point just ahead of location where the Scraper is introduced and the other pressure gauge was installed near the scour valve.

f) The Scraper was articulated into 2 halves, both halves coupled with flexible joints and it succeeded in negotiating the 45° bends. All the pipes were then joined suitably.

HYDRAULIC SCRAPING PROCESS

It was ensured that sounding rods, portable wireless sets, mobile wireless set mounted on vehicle were available during the Scraping process. The line was slowly charged over a period of 12 hours from the reverse direction to prevent any movement of the Scraper. The water main was pressurised and the same was maintained at about 1 kg per cm^2. During the Charging process, all the air was dispelled from the pipeline and humps through the air release valves, so as to ensure that no AIR POCKETS remained within the Main.

The actual scraping was taken up during late night hours when the traffic noise was at a bare minimum. The supervisory personnel were spread out along the Main and provided with sounding rods for picking up the sound of movement of the Scraper. Certain personnel were provided with portable wireless sets to facilitate quick communication with regards to monitoring water pressure, actual position of the Scraper, etc. The pressure was then slowly increased in the direction of flow (i.e. in the direction of the movement of the Scraper) by giving continuous instructions to the Valve Operator at the Pumping Station at Wazirabad. When the pressure reached about 2 kg/cm^2, the Scraper started moving. The rumbling sound of the Scraper was picked up with the help of the Sounding Rods. The Scour Valve was gradually regulated so that the speed of the Scraper was regulated at the rate of 1Km per hour.

In this operation, the Scraper did not travel upto the full $9^1/2$ kms length but got stuck up after travelling about 4 kms. The Scraper then had to be located and the pipe was cut to facilitate the removal of same. On entering the Pipe to locate the exact position of the Scraper. it was found that a large quantity of stones and boulders were heaped in front of the scraper alongwith the scraped material. The Scraper encountered hard encrustation build-up around stones and boulders in the Main and nearly all the Scraper Blades were damaged due to same, with the result that the last $2^1/2$ km stretch of the 4 kms movement of the Scraper in the Main was not scraped properly. In view of the unsatisfactory performance, the Scraper was removed and rebuilt with new blades once again using a different hardness. The Scraper was reinserted at Chandrawal Water Works II (at about 2 kms downstream at Wazirabad Water Works). The Scraping process was repeated but the Scraper encountered the same kind of problem after travelling 2.8 kms downstream and stopped after travelling only about 800 metres beyond the point where it first got stuck up. Three hydraulic scrapings were carried out in this entire reach. However, the last 300 metres had to be cleaned manually. With the result now 9.1/2 kms of the Main was ready for mortar lining.

CEMENT MORTAR LINING PROCESS

Various materials required for lining process are as under :

a) **Portland Cement**

Fresh OP Cement conforming to IS. 269-1976

b) **Sand**

Consisted of inert granular material. The grain being strong, durable and uncoated was suitably graded to pass No.16 Mesh Screen with not more than 5% passing through No.100 sieve. Sand should be clean and free from silt, clay, lumps, shale, etc. and other deleterious substances. The total weight of such substances should not exceed 3% of the combined weight of the sand.

The approximate proportion of the sand and cement for the mortar is 1 part of Portland Cement to 1 part of sand by weight. Amount of water added is such that it produces a workable Mix making an allowance for moisture collecting on the internal surfaces of the pipeline. The water/cement ratio used was 0.35 approx.

Since the Main was laid in 1965-1966, to get the Main ready for Lining, we had to dewater the Main wherever necessary by plungers attached to winches (Figure III). After the pipe inner surface became dry, all joints were hand finished with cement mortar mix to facilitate smooth travel of the Lining Equipment within the Pipe. This was also done with a view to ensure proper and uniform surface finish of cement mortar lining.

The access openings were planned about 500 metres apart wherever possible and at shorter distances where there were bends or troughs in the main. One cast iron pipe length of about $3^1/2$ metres was removed and the Bridge Plate was inserted to facilitate insertion of cement mortar lining Equipment inside the Pipe.

LINING EQUIPMENT

The Lining Equipment (electrically operated) consisted of a Mixer near the Access opening which worked continually to obtain maximum plasticity of cement mortar. A Lining Machine which actually does the Lining, and Intermediate Loader which pumps mortar into the Lining Machine for spraying the same within the Pipe with centrifugal force and the Power Loader which collects Cement Mortar from the Mixer and travels into the Pipe to discharge the same into the Intermediate Loader on a continuous basis. (Sequence & position of Equipment shown in Figure IV).

The Lining Machine with Intermediate Loader was than taken to the starting position of the Pipe and the first load was carried by the Power Loader to the Intermediate Loader. As soon as the Intermediate Loader and the Lining Machine started working, the Lining Machine operator, with the help of gauge, adjusted the travel speed of the Lining Machine to ensure Lining thickness of 7mm. The trowelling arrangement of the Lining machine was also suitably adjusted such that cement mortar applied to the Pipe would be uniform and produce a Lining of uniform thickness with good surface finish.

Once the Lining of one section was completed, the openings were closed with plastic sheets. After cement mortar lining had initially set, hand finishing was done by masons wherever required and then water was introduced for curing. Plastic sheets prevented any through air draft. After curing, the access openings were closed with cast iron pipes and collars.

After completion of the lining in the first phase till Rajghat (a length of about $9^1/2$ kms) all access openings were closed, excavations refilled and dressed up, valves reinstated, etc. The Main was flushed for 24 hours, and samples of water were sent to the Municipal Laboratory for testing till satisfactory test result was achieved. The 'C' valve was then carried out and the average 'C' value for this section on test indicated a figure of 128.

During the winter of 1986, the balance section was taken on hand and the above process was repeated. During hydraulic scrapings, the same problem as faced in the first phase was encountered. This was causing a lot of delay and as such the major portion of the Main had to be hand scraped and cleaned and after cement mortar lining, the 'C' value test was done and the test result indicated average value of 125-130.

CONCLUSIONS

The following are the BENEFITS we expect to realise after having reconditioned the KILOKRI MAIN by internal cleaning and cement mortar lining.

1) **Corrosion Protection** - Cement mortar lining would have created a chemical shield against corrosion. Because of its high compressive strength and arch action, cement mortar lining is not dependant on bonding to the interior pipe wall unlike other types of inner linings which depend entirely upon their bond or adhesive strength to hold them in place. Unlike bituminous and thin film linings which protect only by sealing the water away from the metal, internal cement mortar lining would achieve superior protection through creation of a zone of alkalinity on the pipe surface, thereby, eliminating corrosion, tuberculation and discoloured

water from the lined pipe.

2) Leakages through joints would be minimised since cement mortar lined pipe is a pipe within pipe and all defective sluice valves were repaired/replaced during the reconditioning of the Main. Ingress of contaminated water through leaky joints would be eliminated thereby minimising the incidence of water borne disease like Cholera, Jaundice, Typhoid, Gastroentiritis, Diarrohea, etc.

3) The 'C' value, i.e. the flow and carrying capacity of the Pipe was increased and this increased flow carrying capacity would be maintained for over 50 years, thereby extending the life of the pipe by a further 50 years or more. The above would also result in reducing the Pumping Cost and Conservation of vital energy resources.

4) The additional sluice valves and scour valves were introduced to enable future isolation and flushing of various sections, if so required.

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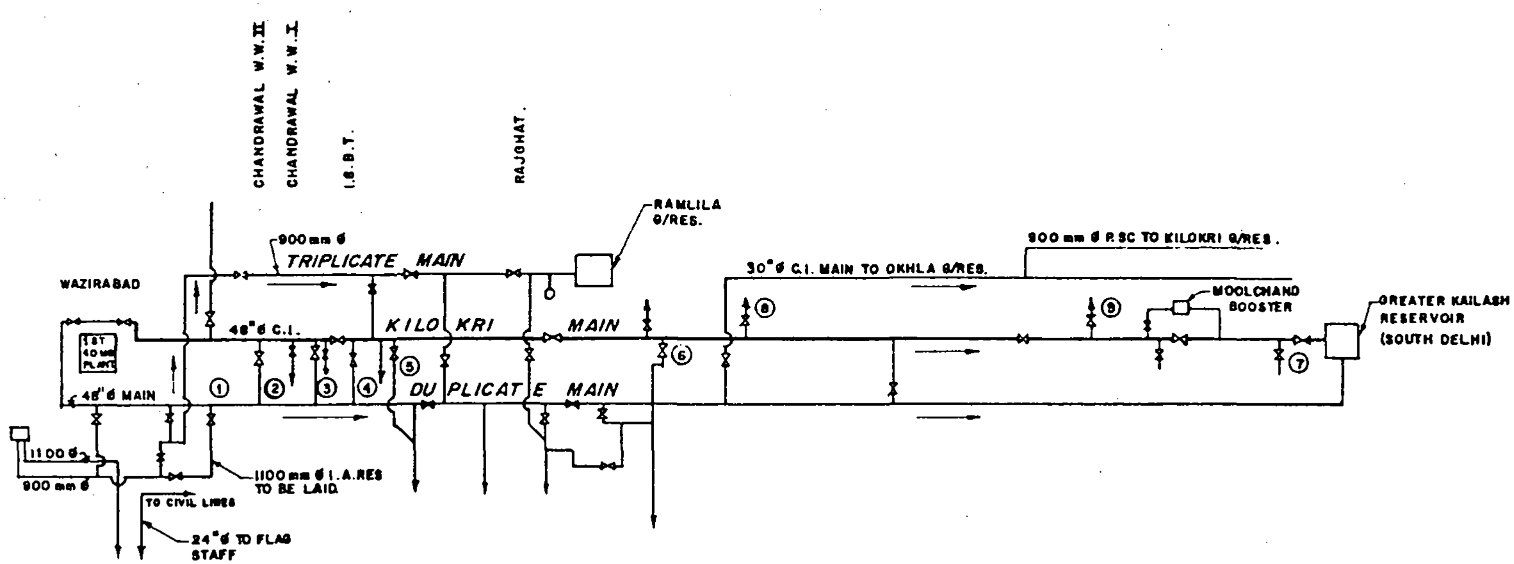
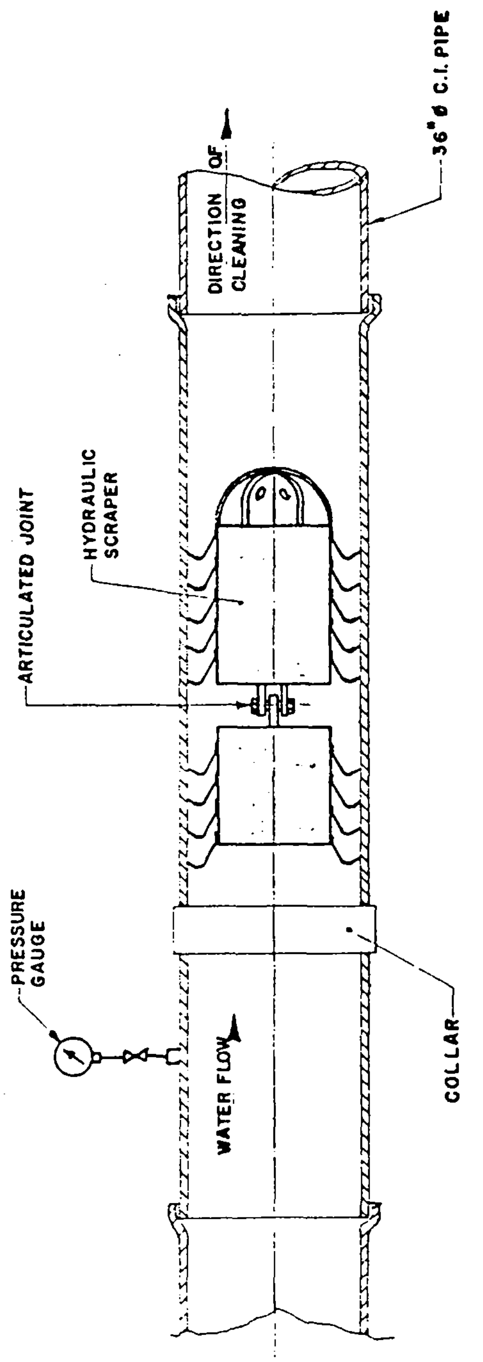


FIG. I

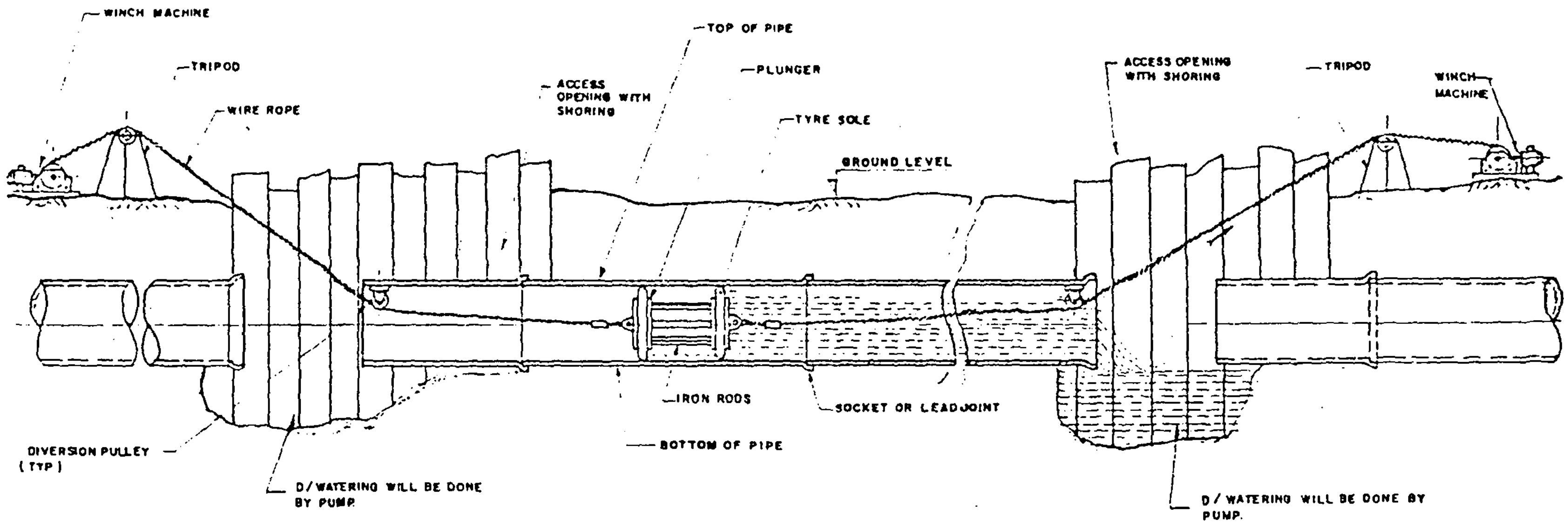
C.I. KILOKRI MAIN

SR.No.	DESCRIPTIONS
1	24" ø TAPPING TO SHAHADARA
2	30" ø TAPPING TO I.A.R.
3	36" ø TAPPING TO CHANDRAWAL W.W.II.
4	30" ø TAPPING TO CHANDRAWAL W.W.I.
5	12" ø TAPPING TO G.P.O.
6	24" ø TAPPING TO PRESS AREA.
7	12" ø TAPPING TO SADIQ NAGAR.
8	18" ø TAPPING TO EXHIBITION GROUNDS.
9	12" ø TAPPING TO JANGPURA.
	SLUICE VALVE.



SCRAPER FOR CLEANING OF PIPE LINE

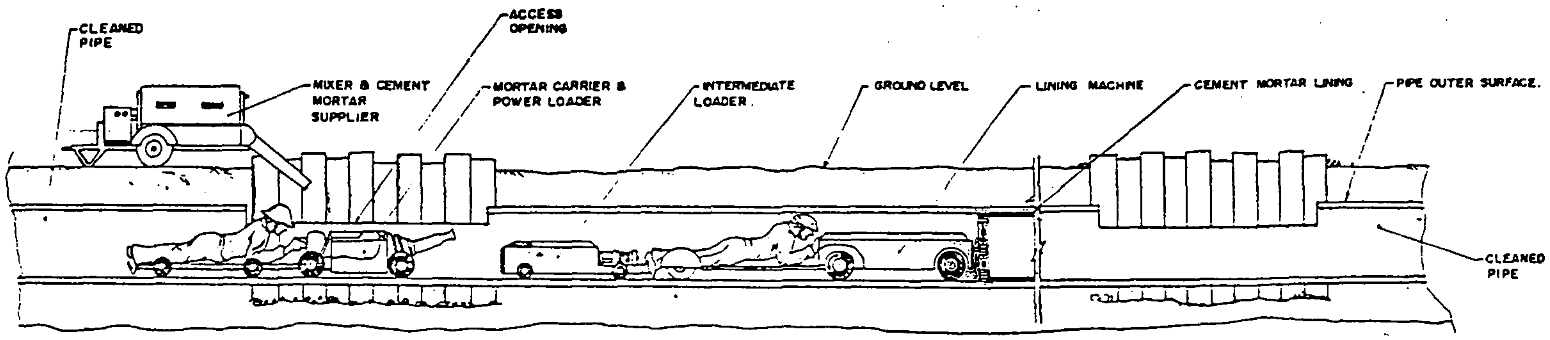
FIG. II



PLUNGING WATER FROM PIPE

FIG. III

FIG. IV



ARRANGEMENTS FOR CEMENT MORTAR LINING IN-SITU

LOW-COST WATER AND SANITATION WITH SPECIAL REFERENCE TO URBAN AREAS

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In many large cities in Africa and Asia the water supply is as good as in industrial countries. Certainly the quantity available is ample. For domestic supplies alone, it is not unusual for the volume supplied per person to be based on a design figure of two or three hundred litres per day, compared with a UK average of 120 litres per person per day[1]. However, this copious delivery may be reserved for the most fortunate - for the elite, for those with regular salaries, for the rich.

Less privileged people make do with water in meagre quantities, often drawn from polluted shallow wells, tanks, ponds and nullahs. Many of these people live in the slums of the city centres, in squatter settlements and in the urban fringes. Many are poor. Some are very poor.

Health aspects

Disease and death inevitably result from inadequate quantities of poor quality water and from lack of proper sanitation. The incidence of diarrhoeas and worm infestation is invariably higher amongst the poor than the rich. Different standards of nutrition, housing and access to health care all have their effects, but bad water and sanitation are major factors in the spread of disease. An epidemic of cholera amongst the poor may so alarm neighbouring rich people that they become willing to contribute to the cost of good water for the poor. However, the continuous risk of diarrhoeas and worms has less influence on the good will of wealthy groups.

Paying for conventional water supplies

Conventional piped water supplies are costly, drawing raw water from surface or underground sources well beyond the limits of the urban area. Then it is stored, transmitted, pumped, treated, stored again, disinfected and distributed. So capital costs are high. To ensure that safe water is delivered continuously, operation and maintenance costs recur month after month.

A widely accepted economic theory that receives the support of important bodies such as the World Bank lays down that the users of public services should pay for those services. At least the users should cover the expenditure involved in operation and maintenance. If possible they should pay for the interest and repayments for loans raised for capital works. The money should come from the 'disposable income' of beneficiaries.

But the poor have little disposable income; some have virtually no income at all. Certainly they cannot afford the comparative luxury of large quantities of treated piped water. So low-cost water is needed. But how can the cost be lowered?

Reducing waste

One way of minimizing the unit cost of delivered water is to cut down waste. Reducing unaccounted water is in fashion. In some towns lost water amounts to more than half of what comes from the sources. The emphasis given to this topic at many Conferences is a clear indication of its current importance. By eliminating illegal connections and by detection and control of leaks a higher proportion of the available supply can be made available for authorised outlets at little cost. Perhaps it would not be unreasonable for this extra water to be given to poor people for a charge equivalent to the cost of reducing the unaccounted water.

Utilisation of unaccounted water is only a one-off process. Once the distribution losses have been reduced to 20% or so the cost of further reduction of losses may exceed the value of the extra water.

Low-cost rural supplies

Since the beginning of the International Drinking Water Supply and Sanitation Decade much has been said and written about low-cost water supplies. However, nearly all of it refers specifically to rural supplies. Attention has been given to spring boxes, to bamboo pipes for gravity supplies, to small scale slow sand filters, to natural coagulants, to hand-dug wells, to handpumps and to much else. There has been a vast international research effort to devise new and better handpumps and test existing types of handpumps. The objective is to find a cheap, long-lasting handpump that is capable of local manufacture and village level operation and maintenance (VLOM). Sometimes it seems that this objective will never be achieved. Yet still there are dozens of field workers, amateur inventors, research laboratories and university departments involved in devising new designs.

All of these low-cost rural methods may be appropriate for urban fringe areas with scattered dwellings. However, as towns grow the fringes become absorbed. Surface waters soon become so polluted as to be unsuitable for safe supplies and community-centred projects become more difficult as village-size groups become merged into the total urban conglomeration.

GROUNDWATER UTILISATION

The use of groundwater from aquifers beneath built-up areas is a subject of considerable debate. Depending on the groundwater depth and availability it may be abstracted by shallow wells, by handpumps used by small neighbourhood groups or from deep boreholes which serve larger but still local communities. Whichever method of abstraction is used, the cost is likely to be much less than obtaining water from the conventional piped water supply.

Pollution of groundwater

Controversity on the suitability of underlying groundwater centres on the likelihood of pollution. The degree of pollution is of course influenced by the sanitation system. As will be discussed later, for low-income communities the most appropriate disposal of excreta usually results in infiltration of polluted liquid into the soil through pits or drainfields. Unsafe water is inevitable if it is taken from shallow groundwater very near to pits or drainfields which go down to the groundwater.

Pollution of water by excreta consists of microorganisms that have a limited life and chemical substances that persist. The microorganisms may be pathogenic and be the cause of disease and death on a large scale.

They transmit the diarrhoeas and worms that result in the debility and reduced life expectancy that are common against low-income people in Africa and Asia. A thorough study of the literature by Lewis and others[2] indicates that providing there is a metre or so of soil between the bottom of the pit or drainfield and the highest level of the groundwater, there is little danger of transmission of microorganisms. Where the groundwater table is penetrated the crucial factor is the time taken for microorganisms to travel to the place where water is abstracted. Travel time exceeding about ten days renders the water safe from the point of view of microorganisms. In some soils with slow-moving groundwater the "safe distance" between a pit or drainfield and the point of abstraction may be only a few metres. The common 15-metre rule for separation of latrines and wells is then more sufficient. On the other hand, liquid infiltrated into fissured or broken rock may travel several hundred metres within ten days.

Nitrate concentration

While microorganisms are removed or inactivated, salts in solution may be unaffected by passage through soil. Consequently they may accumulate in groundwater beneath human habitations. High concentrations of nitrates are not uncommon in groundwater drawn from localities with a large number of pit latrines or septic tanks. The water may then be deemed as unsuitable for human consumption. Four reasons are given for this rejection.

(a) The concentration exceeds guidelines laid down by the World Health Organisation and other bodies;

(b) Nitrates are evidence of pollution.

(c) High nitrates cause methaemoglobinaemia (blue baby disease).

(d) High nitrates lead to stomach cancers.

Use of guidelines

Most international standards and guidelines have been devised by groups of experts with considerable experience. There are obvious advantages in relying on them, whether they refer to the amount of steel reinforcement in concrete or levels of trace substances in air or water. However, it is not unreasonable to compare the consequences of adhering to them strictly as against disregarding them. In the case of low-cost water supplies the choice may be between ample water that fails to satisfy standards and not providing improved water at all. Put another way, the choice may be between quantity and quality.

Feachem[3] has listed fourteen Decade-related infections and their control. For only one is water quality more important than other interventions. This is a guinea worm, whose control is comparatively easy. So in terms of health benefits providing an ample supply of any quality water is better than bothering too much about quality alone.

Indicator of pollution

Analysing water to find whether nitrates are present is a useful way of discovering whether the water may have been polluted. The absence of nitrates in groundwater under built-up land shows that the catchment area is outside the area served by on-site sanitation. The presence of high concentration of nitrate merely indicates that the water has probably been polluted by excreta. This would be a reasonable deduction from the site without the analysis. The crucial consideration is whether the groundwater still contains viable microorganisms which may include pathogens.

Blue baby disease

Methaemoglobinaemia is a disease that occasionally proves fatal. It may affect young babies fed with artificial milk made up with high-nitrate water. Ways to avoid this potential hazard are encouragement of breast-feeding and giving bottled water from another source to babies who cannot be fed naturally. The cost of such bottled milk is infinitely less than providing the whole community with low-nitrate water[4].

Cancers

High-nitrate water has been "implicated in the causation of gastric cancer"[5] but the evidence is far from convincing. Studies in England and elsewhere indicate that low nitrate concentration may be just as harmdful[6,7]. In any case, a very small possibility of a risk of cancer is a poor argument against using a potentially beneficial aquifer.

PROVIDING A MINIMUM ACCEPTABLE QUANTITY

Although groundwater has been considered at some length the normal method of providing water to low-income people is by extension of the supply that serves more fortunate sections of the community. The problem is how to provide this water at low cost.

Most systems are designed with an eye to keeping cost to the minimum and consequently there are no easy ways to reduce the cost per litre of water delivered. The heart of the problem of providing low-cost water is this: increased quantities of water can reduce the incidence of water-related diseases, but the greater the quantity the greater the cost. There is also a limit to the health benefit derived from increased quantities of water. There appears to be no clearly defined threshold between inadequate and adequate supply. Figures between 10 and 60 litres per person per day (lpd) have been suggested. Probably something near the lower of these is sufficient for personal and household hygiene.

We have already considered the savings that can result from reduction of water losses in the distribution system. Wastage of water at outlets in houses with individual connections can also be reduced. One way to do this is to ensure that leaking taps (or faucets) are speedily put right. Another way is to charge for metered water by a system that subsidises minimum quantities by higher rates for excessive use. Neither of these have enough effect on the unit cost to enable water to be supplied at really low cost to low-income people.

Standpipe supplies

Substantial savings in the capital cost of distribution systems are possible by eliminating individual house connections. The length of pipelines is reduced and the need for individual household meters is avoided if piped water is delivered through public standpipes.[8] A further saving is effected in the disposal of wastewater.

Of course, there are quite serious disadvantages to standpipes compared with house connections. It is obviously less convenient to have to go to a standpipe rather than turning on a tap at home. There is danger of pollution of the water after it has been drawn from a standpipe, particularly if open-top vessels are used for carrying the water.

Then there is the question of charging for the water. With metered household connections the authority has the opportunity of obtaining an income to cover its expenditure. It must be admitted that many authorities in Africa and Asia fail to collect the money due because of faulty meters, poor meter-reading service or administrative inefficiency. Nevertheless, in theory the system of collecting revenue is straighforward. Not so with standpipes. A community levy may be charged on all properties within the area served by the standpipes and may take the form of a poll tax or a house tax. Charging at the standpipe often requires the services of an attendant, whose wages may cost a substantial part of the revenue. The Provincial Waterworks Authority in Thailand is trying out coin-operated standpipes. It will be interesting to learn during discussion of this paper whether other authorities have experience of these devices.

Other points for discussion

(a) To what extent should better-off *people subsidise their poor neighbours?*

(b) Is groundwater which does not satisfy international standards acceptable if it provides affordable water?

(c) Are public standpipes a satisfactory low-cost alternative to individual house connections?

LOW COST SANITATION

In the early 1970s the author began advocating pit latrines as the most appropriate form of sanitation for low-income people. At that time this idea was rejected by many engineers, health officials and civil servants. In the years that followed there has been a remarkable change of attitude and now it is generally accepted that on-site sanitation is often the only affordable means of excreta disposal for large sections of the urban population.

Pit latrines can provide all the health benefits of conventional sewerage and sewage treatment for about one tenth of the cost. They have the advantage that they can be constructed by householders, applying the D.I.Y. idea that has become popular in industrialised countries. They require no regular work for operation, unlike sewage treatment which requires constant attention for satisfactory performance.

Although there are variations in detail, two types of pit latrine shown in figures 1 and 2 are now accepted as almost standard practice. Where people used water for anal cleaning some form of pourflush water seal is incorporated, with the pit often offset from the latrine superstructure[9]. Where solid material is used for anal cleaning the ventilated improved pit (VIP) latrine has proved most satisfactory[10]. When well constructed and kept clean both types of latrine have no nuisance from flies or smell. Large deep pits last for well over twenty years. A variation is two small lined pits with capacity for about two years accumulation of faecal solids. The decomposed solids are free from pathogens and can be manually removed from the shallow pits. The main disadvantage of pit latrines is their inability to deal with large quantities of sullage, even in soils which are permeable.

Compost latrines have been successfully used in Vietnam, but when tried elsewhere have not been satisfactory and are more suitable for rural than urban areas. The conservancy system with buckets or dry latrines was formerly widely used in Africa and Asia, but is now rejected on health, nuisance and social grounds.

Sewerage

The cost of individual household WCs connected to a conventional sewerage system is too great for the method to be considered as low-cost. In addition, for satisfactory operation WCs and sewers require a reliable piped water supply of about 75 lpd, which is seldom available in low-income areas. Where poor people live in sewered areas, low-cost sanitation can be provided by communal latrines connected to the sewer. A problem with all communal latrines is maintaining them in a clean condition; many become so fouled that they are unfit for use. This problem has been solved in some places where users pay a small fee to an attendant whose responsibilities include keeping the latrine clean.

Proposals for reduced-cost sewers have received a great deal of publicity. Systems known as "aquaprivy sewerage" were introduced in several Zambian towns around 1960[11], and reports indicate that some are still functioning well. The principle is incorporated in the small-bore sewer system advocated by the World Bank in several publications. Suspended solids are settled in chambers or pits and the effluent passes to sewers which can have small diameters and flatter gradients than conventional sewers. Another system which is claimed to result in substantial savings in high-density housing sites has shallow sewers laid within householders' plots - again the diameter and gradient are less than customary. There is need for thorough investigations into the cost and long-term performance of these systems under a variety of local conditions.

Points for discussion

(a) In many countries legislation now prohibits the conservancy system; has this helped low-income people to adopt improved sanitation practices?

(b) How willing are householders to empty their own double pit latrines, whether VIP or pour-flush?

(c) Is there evidence of successful long-term use of reduced cost sewerage system?

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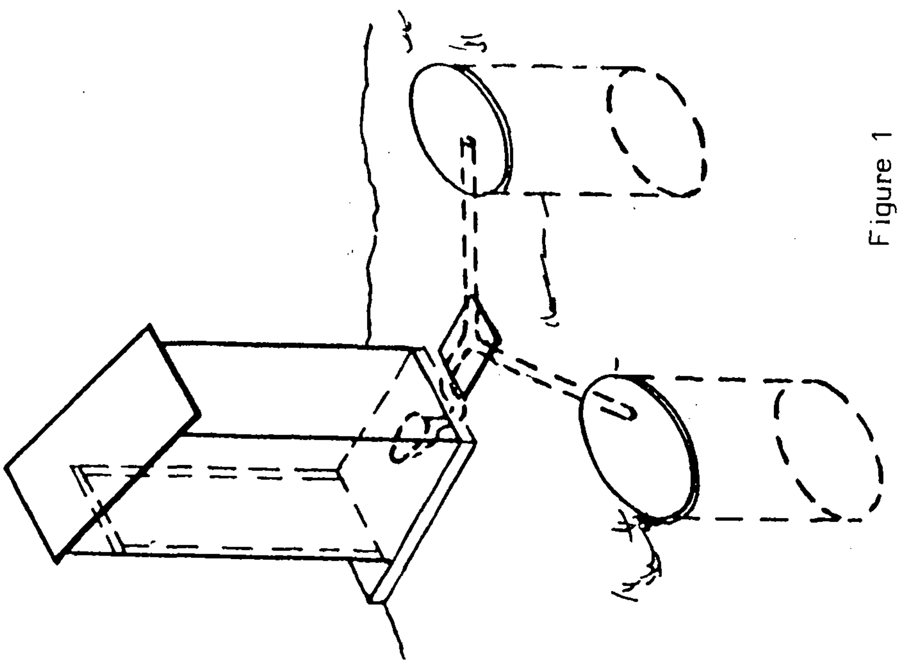

Figure 1

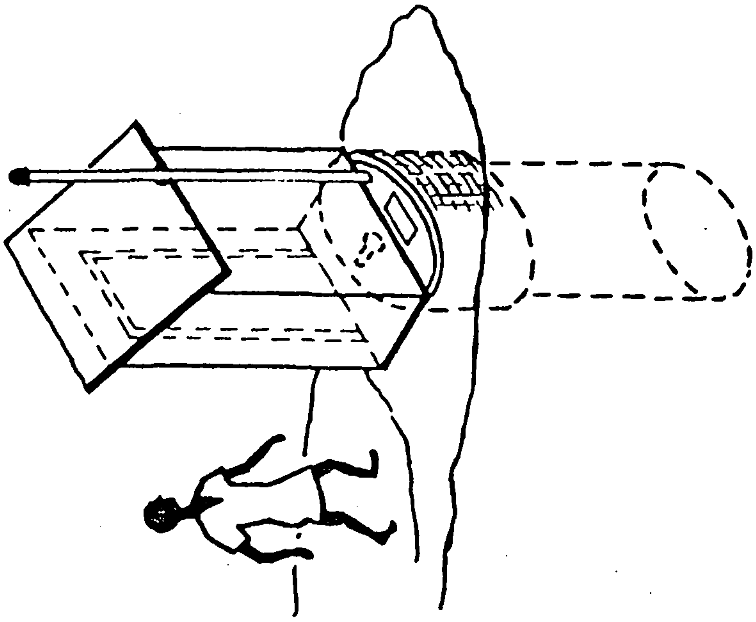

Figure 2

A SIMPLE COST OPTIMIZATION MODEL FOR WATER DISTRIBUTION SYSTEMS

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SYNOPSIS

The optimal design of multi-source looped and gravity distribution systems involving a single loading pattern has been considered. The model used is based on the transportation and linear programming (LP) method, which produces locally optimal solutions. The unit transmission costs from sources to demand nodes are determined. Then design distribution graph is obtained by means of both the modified-column minimum (MODI) and LP methods. After allocation of flows the optimization of the network is carried out by applying the diameter (D) and flow (Q) specified LP techniques.

INTRODUCTION

The water distribution system serves to convey the water drawn from source or treatment plant, to the point where it is delivered to the users. Branched system and looped water network system are the main types of distribution networks. In general, branched systems are only used for small capacity community supplies delivering the water mostly through public standpipes and having few house connections, if any. For larger distribution systems looped network grids are more common[5].

Branches systems have the advantage that their design is straightforward. The direction of the flow in all pipes and the flow rate can be readily determined. This is not so easy in the looped distribution network where each secondary pipe can be fed from two sides.

The network design and optimization techniques can be classified into two categories :

a - check design and optimization
b - direct design and optimization

There is no method for optimal design of looped distribution system that is completely satisfactory.

In network design, Tong, A.L. (1961) presented a method of solution in which equivalent lengths of pipes in a loop are balanced and proper sizes of pipes are obtained from pressure surfaces. Cros, H. (1961), developed a systematic method of solution provided that the pipe sizes are preselected. A non-linear programming method with continuous variables was developed by Jacoby (1968)[6]. Lai, D., and Schaake, J. (1969) used linear programming (LP) formulation with prespecified head at every node in the system while planning a major addition to the New York city water supply system. The least cost solution of a given network of known inflow, outflow and nodal head values was devised by Sarker, A.K. (1971) and Rath, P.C. (1970) and called equivalent diameter method. Barlow, J.F. and Markland, E. (1972) presented a method of economic solution of pipe networks using the concept of cost-effectiveness to judge alternative designs. A method to evaluate the global minimum of the nonconvex capital cost function of a hydraulic network based upon a deterministic single load pattern and continuous diameters was developed by Cem,browicz, R.G., and Harrington, J.J. (1972)[4]. Kally, E. (1972)[8].

has studied a method in which the design for the least cost distribution network meeting all the requirements. A methodology for the optimal design and operation of a water distribution system using a modified Newton-Raphson method was developed by Shamir, U. (1974)[11]. Rasmusen, H.J.(1985)[10] has presented a heuristic procedure for optimization of water supply networks. A valuable contribution to the problem of optimal distribution system design have made by Alperovitz and Shamir (1977)[1].

A theory of optimization of gravity-fed water distribution system was developed by Bhave, P.R. (1982)[2]. The method for the optimal design of multi-source, looped and gravity fed distribution systems is illustrated by Kalayci, A. (1986)[7] with computer aided direct optimization through a case study.

METHODS

Transportation model is used to be able to allocate the limited amount of water from several sources to numerical demand nodes at minimum cost[12]. The optimal design of multi-source, looped-water distribution systems subjected to a single loading pattern is carried out as solution for a transportation problem by employing LP optimization and MODI methods. MODI method is a streamlined version of the simplex method that takes advantage of the special mathematical structure of the transportation problem and used to minimize the model[13]. In looped network, the link discharges can not be computed a priori and therefore LP techniques can not be applied directly[9]. So the looped network is converted to branching one by using the transportation problem principles for the application of LP techniques. Optimization of this branching distribution system is carried out after obtaining the design distribution graph for the network. Design distribution graph is the design paths to all demand nodes and gives various distribution trees[2].

CASE STUDY

The network is selected as a case study is shown in Fig.1. Design and node data is given in Table 1 and 2.

This looped network is converted to transportation model by defining the unit transmission cost values.

Unit transmission costs

Prior to optimization of selected design paths, the unit transmission cost is compared with the following assumptions:

-- transmission cost varies linearly with the discharge from source to node,

-- the topographical layout of the network, the node demands and the minimum required hydraulic gradient level (HGL) values are known and fixed,

-- the capital cost per unit length of a pipe varies non-linearly with the diameter[4,7]

Transmission cost equation is derived as

$$C'_{mn} = L_{mn}^{1+y/r} (H_{Sm} - H_{Dn}^{min})^{-y/r}$$

where

L_{mn} = the path length from source node Sm to demand node Dn,

H_{Sm} = the HGL at source node Sm,,

H_{Dn} = the minimum required elevation at demand node Dn.

y,r = coefficients - values are 1.41 and 4.87 respectively based

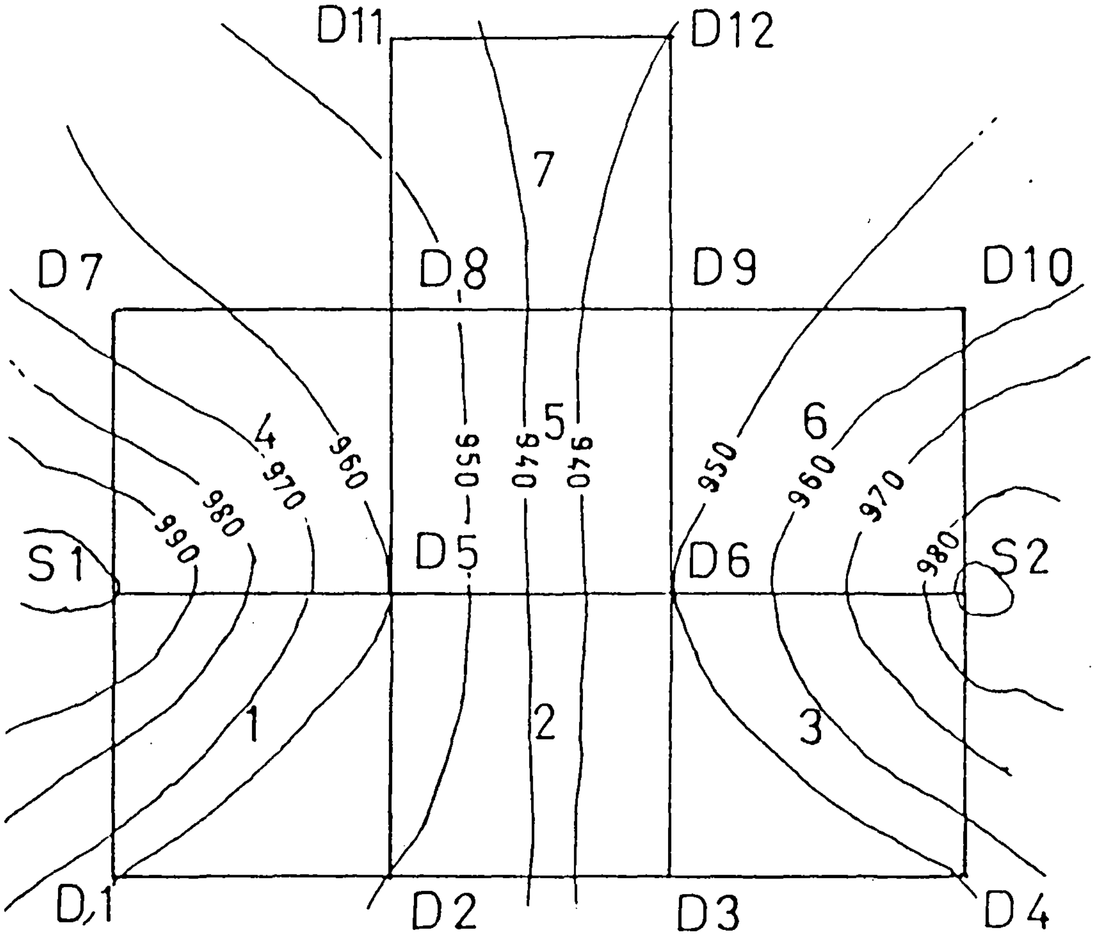

Figure 1

The example network D and S indicates demand and source nodes respectively

Table 1

Basic Data for the Network

	Value
Number of Sources	2
Number of Nodes	14
Number of Free Loops	7
Number of Links	20
Number of Links, meter	1000
Capacity of Source, SI, lt/sec	425
Capacity of Source, S2, lt/sec	275

Table 2

Node Data for the Network

Node	Ground Elevation (meter)	Min. Allowed Pressure, (meter)	Min. Required Elevation, (meter)	Demand (lt/sec)
S1	1000.0	0	1000.0	50.0
S2	990.0	0	990.0	50.0
D1	960.0	30	990.0	50.0
D2	950.0	30	980.0	50.0
D3	945.0	30	975.0	50.0
D4	950.0	30	980.0	50.0
D5	960.0	30	990.0	50.0
D6	950.0	30	980.0	50.0
D7	965.0	30	995.0	50.0
D8	955.0	30	985.0	50.0
D9	945.0	30	975.0	50.0
D10	950.0	30	980.0	50.0
D11	945.0	30	975.0	50.0
D12	940.0	30	970.0	50.0

on 1986 unit prices of construction regulations of Turkey[7].

The compared unit transmission cost values are given in Table 3.

Allocation of Network

After determining the unit transmission cost values from sources S1 and S2 to all demand nodes, LP model is used to obtain the design distribution graph. The objective function is formulated for minimization of transportation cost to be able to meet the discharge requirements at all demand nodes by selecting the discharge requirements as decision variables. Allocation of the network by MODI model is also carried out by unit transmission cost values, source capacities and node demands. The design distribution graphs obtained by LP and MODI Methods are identical (See Fig.2 and 3)[7].

Network cost minimization

The distribution system is optimized by applying LP techniques after the design distribution graph is selected. The separate LP optimization models are formulated to deal with the either D-specified condition in which the secondary pipes are of some minimum or specified diameter, or the Q-specified condition in which the secondary pipes carry some minimum or specified discharge.

The pipe types depending on the pipe diameters in both D-specified and Q-specified conditions are :

Ø65 = Ø P.V.C. pipe
Ø125 = Ø Asbestos cement pipe.

In both conditions, for the calculations of head-losses, Ludin formula has been used for asbestos cement pipes and Colebrook formula for PVC pipes.

i) Ludin head-loss equation for asbestos cement pipes. (Eternit Catalog)

The velocity equation can be expressed as follows;

$$V = 0.279 \times C \times D^{2.65} \times J^{0.54}$$

in which;

C: Roughness coefficient
V: Velocity of flow (m/sec)
D: Diameter of pipe (m)
J: Hydraulic gradient of flow.

The velocity equation for asbestos cement pipe can be written as;

$$V = 39.381 \times D^{2.65} \times J^{0.54}$$

ii) Colebrook head-loss equation for P.V.C. pipes (PIMAS Catalog)

The head-loss equation can be expressed as follows;

$$1/\sqrt{\lambda} = -2 \log (2.153/Re /\sqrt{\lambda} + K_s/3.71xD), \text{ and,}$$

$$J = \lambda x V^2/2xgxD$$

in which;

λ: Friction coefficient
Re: Reynolds number
K_s: Roughness coefficient which can be taken as 0.007 for PVC pipes.

The velocities for all pipe diameters are taken between the minimum and maximum limits of 0.5 m/sec and 1.5 m/sec[5].

In D-specified condition, firstly, the critical paths and the critical sub-paths are determined to obtain the H_{Dn} values for all demand nodes.

The paty having the minimum available average friction slope equal to the critical slope is termed critical path; and the node, at the end of critical

Table 3

The Unit Transmission Cost Values (C'_{mn})

Node	L_{mn} From S1 (m)	L_{mn} From S2 (m)	H_D^{min} (m)	C'_{mn} From S1 (TL)	C'_{mn} From S2 (TL)
S1	-	3.000	1.000	-	-
S2	3.000	-	990	-	-
D1	1.000	4.000	990	3.802	-
D2	2.000	3.000	980	7.404	15,685
D3	3.000	2.000	975	12.025	8.265
D4	4.000	1.000	980	18.593	3.802
D5	1.000	2.000	990	3.802	-
D6	2.000	1.000	980	7.404	3.802
D7	1.000	4.000	995	4.648	-
D8	2.000	3.000	985	8.265	19.177
D9	3.000	2.000	975	12.025	8.265
D10	4.000	1.000	980	18.593	3.802
D11	3.000	4.000	975	12.025	20.211
D12	4.000	3.000	970	16.531	12.829

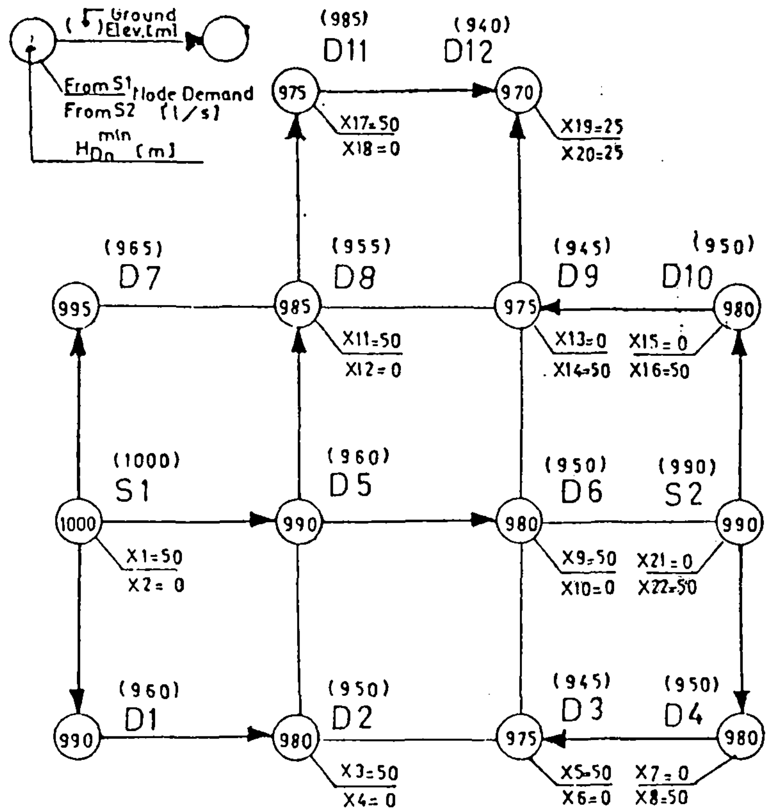

Figure 2
Design Distribution Graph by LP Solution

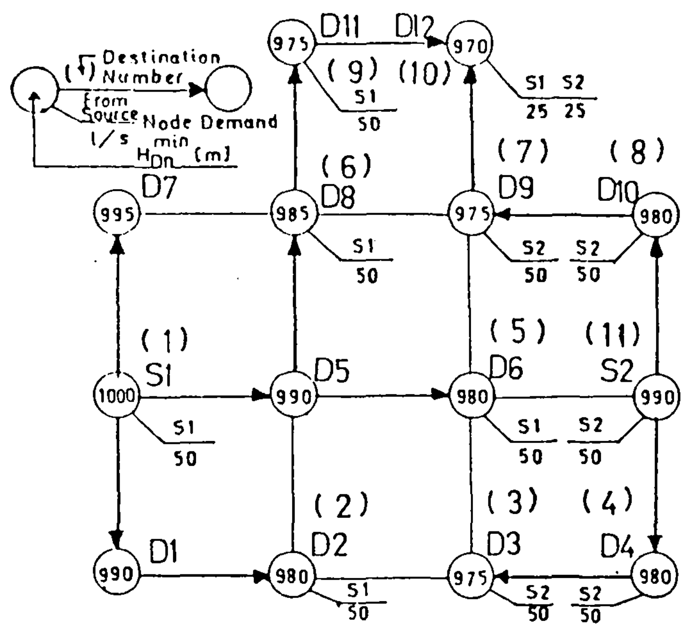

Figure 3
Design Distribution Graph by MODI Method Solution

path is termed critical node. The procedure for D-specified condition computations are given in Appendix.

A minimum diameter of 100 mm. is taken for all secondary pipes. Then the discharges in the secondary pipes are determined by using the Colebrook head-loss formula since the friction slopes and the diameters are known. Using the flow continuity constraints, the discharges in the primary pipes are computed.

As seen in Fig.4, at the end of iteration VII;

i) the discharge allocation is nearly the same as iteration VI, so, the optimal solution is reached and the iteration VII gives the best solution for D-specified condition.

ii) the pipe, D11D12, carries a very small discharge of 2,65 lt/sec, therefore, it is considered the pipe, D11D12, to have a diameter of 65mm (the minimum diameter for secondary pipes).

iii) the head-loss differences for all loops are seen to be zero.

The optimal value of the objective function is only consist of the primary pipes since the secondary pipes do not enter the LP model formulation. The total cost of the example network is determined by considering also the seven secondary pipes. So, the optimal value of the objective function including all pipes is calculated as $C_D = 120, 18 \times 10^6$ TL with 1986 unit prices.

In the Q-specified optimization, a minimum discharge of 4.0 lt/sec is taken for all secondary pipes assumed to have the minimum diameter of 100mm and the minimum flow velocity of 0.5 m/sec.

The discharges in all primary pipes are found by satisfying the node flow continuity constraints. The discharge allocation and the computed results can be seen in Fig.5. In Appendix the procedure of the method is given.

In Q-specified condition, the secondary pipe discharges are constant, so, only one LP iteration is sufficient to find the optimal solution. The optimal value of the objective function including all primary and secondary pipes is 138.67×10^6 TL for Q-specified condition.

RESULTS

The following points may be noted for the suggested methodology. For the D-specified condition, the diameters of the secondary pipes are fixed in advance and, therefore, these pipes do not directly enter into the LP model. This restricts the size of LP model of primary pipes only and thus, the size of LP model is reduced. However, as the discharges in the secondary pipes change during each LP iteration, the LP model must be revised and resolved several times before the final optimal solution is obtained.

For the Q-specified condition, the discharges in all the pipes remain constant and therefore only one iteration is sufficient. However, all the secondary pipes must be included in the LP model. This increases the number of the decision variables, pipe length constraints, and als othe path head-loss constraints. Further, the loop head-loss constraints must also be considered. This, therefore, increases the size of the LP model.

The initial H_{Dn} values are obtained by the critical path concept. This helps in fixing the flow directions in the secondary pipes. Furthjer, as these H_{Dn} values are usually close

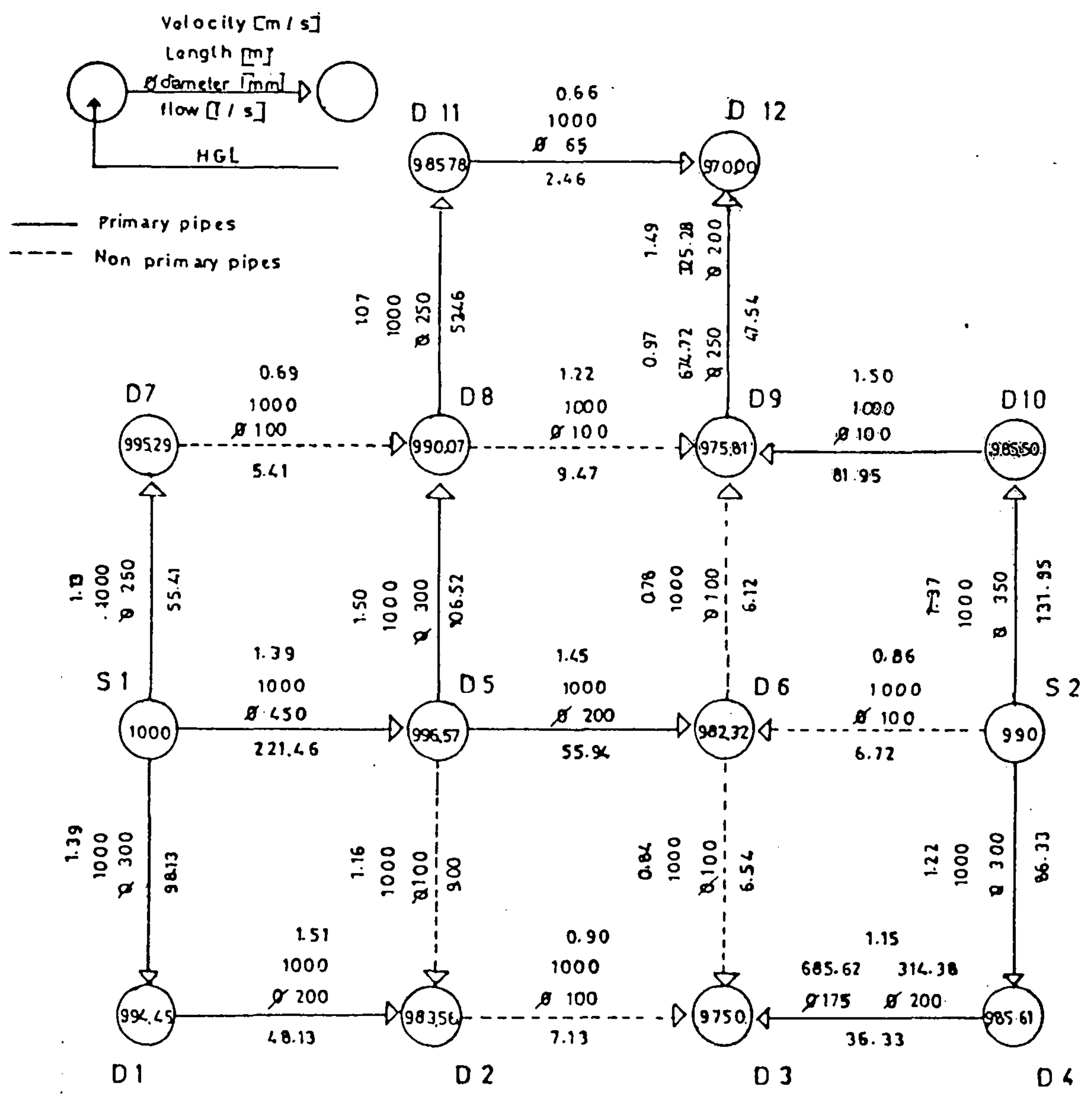

Figure 4

Best Solution of the Network for D-Specified Condition

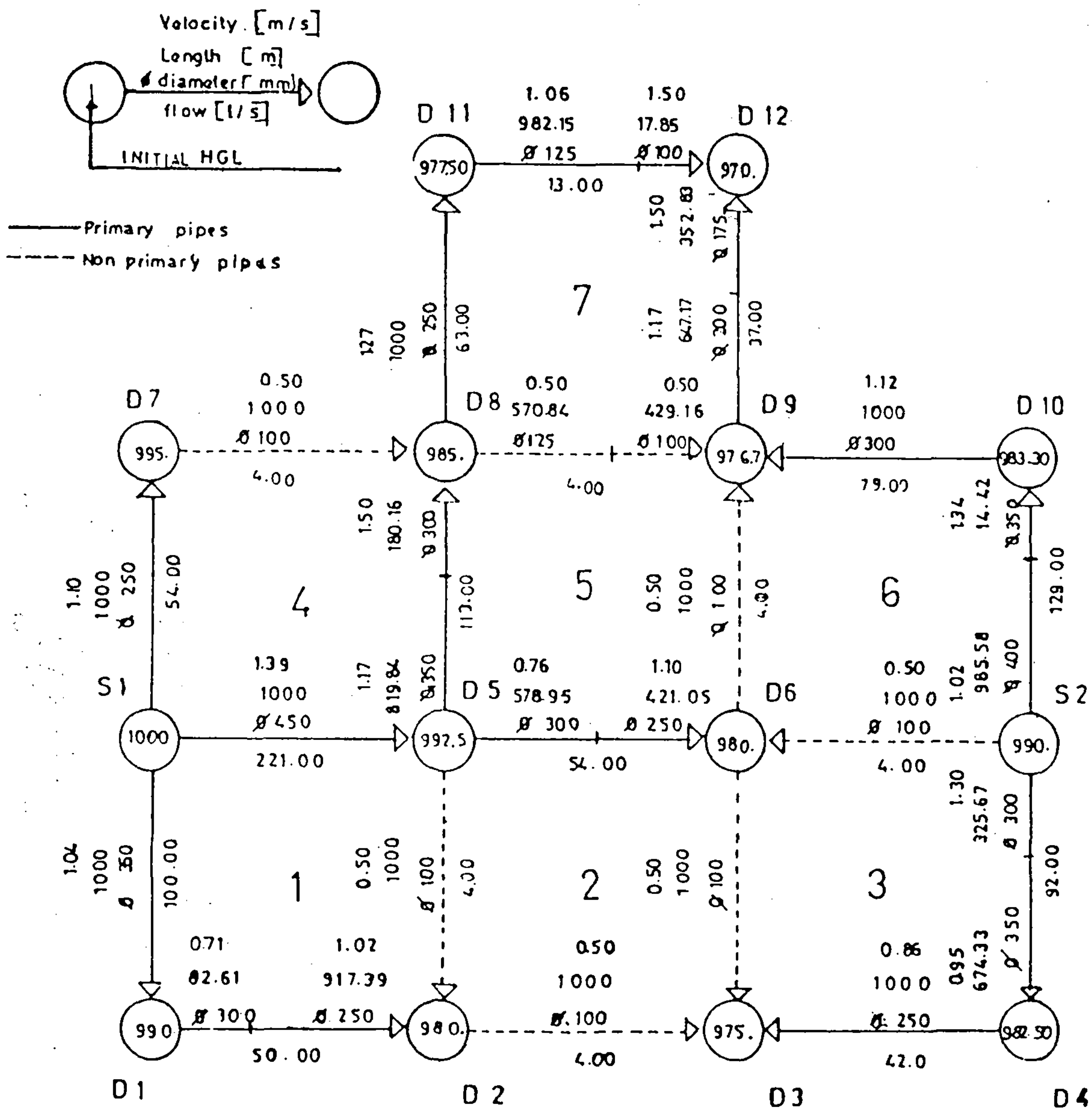

Figure 5

Network Details for Q-Specified Condition to the optimal H_{Dn} values, the discharges in the secondary pipes are also close to their optimal values and, therefore, the number of iterations for the D-specified condition is reduced.

The critical path concept also helps in selecting each pipe sizes for each pipe. This restricts the size of LP model. However, four or more pipe sizes may be selected for each pipe for certainly of optimum solution. This would increase the size of LP model. In practice, two pipe sizes by the critical path concept would serve the purpose.

For D-specified condition, the pipe sizes in secondary pipes need not necessarily be of same minimum size. Similarly for Q-specified condition, also the different discharges can be provided in secondary pipes. However, in the D-specified condition, the convergence may be slightly delayed and therefore the number of iterations may increase. Further, though the reliability of distribution increases, the cost of the network also slightly increases.

CONCLUSION

This investigation showed that the transportation models can be applied to looped network multi-source water supply systems to obtain the design distribution graph by allocating node demands. Optimization of the branched distribution system is carried out by LP and MODI methods for diameter and flow specified conditions. The advantages of MODI method against LP method are observed during the solution of transportation problem (13).

The methodology as developed here is applicabel to gravity fed distribution systems subject to a single loading pattern and the procedure yields a locally optimal solution. This, however, is the limitation in all the presently available methods as none of them guarantee the solution to be the globally optimal one (3). When the secondary pipes are of some minimum or specified diameter, the optimal cost of the hypothetical network is found as 120.18×10^6 TL at end of seventh iteration. Since the discharges remain constant in Q-specified condition, only one iteration gave the optimal solution as 138.67×60^6 TL. (7). The cost values are not very much different from each other for this hypothetical network. However, for the actual networks a distinct deviation is expected.

Finally, it can be concluded that this simple cost optimization model for the design of multi-source looped gravity fed water supply systems of small urban or suburban areas, industrial districts is a very convenient and promising solution especially under very limited financial conditions.

APPENDIX

D-Specified Condition

The several steps should be followed in this method can be listed such as :

1) Select the design distribution graph and identify all the distribution trees and the primary and secondary pipes.

2) Calculate the H_{Dn} values for all the demand nodes according to the critical path concept.

3) Take the minimum or the specified diameters for all the secondary pipes (1).

4) Calculate the discharges in the secondary pipes for the assumed H_{Dn} values.

5) Considering the discharges in the secondary pipes and satisfying the node flow conti-

nuity constraints, obtain the discharges in the primary pipes.

6) Optimize the cost of the distribution network by applying LP model

Minimize Cost = $_{i\;j}\, C_j L_{ij} + C_{np}$

in which;

i: Primary pipe number,
j: Pipe diameter,
C_j: Cost per unit length of pipe with diametert j,
L_{ij}: Length of pipe with diameter j in pipe i,
C_{np}: Cost of secondary pipe

Subject to :

i) Length constraints

$_{j}\, L_{ij} = L_i$, for all primary pipes

in which;

L_i: Length of pipe i.

ii) Pressure contraints

$_{mn\;j}\, S_{ij} L_{ij} \quad H_{Sm} - H_{Dn}^{min}$ for all paths

in which;

mn: all pipes in the path from source node S_m to demand node D_n

S_{ij}: Friction slope (hydraulic gradient) of pipe with diameter J in link i.

iii) Non-negativity constraints

$L_{ij} \quad 0$, for all i and j.

7) Calculate the head-loss in each pipe using the obtained L_{ij} and corresponding S_{ij} values; then, calculate the H_{Dn} values for all the demand nodes.

8) Repeat steps (4) to (7) until the discharges in the secondary pipes are found nearly the same on successive iterations.

The procedure should be followed in determining the critical paths can be listed such as :

1) List the paths to all demand nodes for which H_{Dn}^{min} values are specified, and determine their maximum available friction slopes.

2) Determine the critical slope and the critical path.

3) Estimate the H_{Dn} values for the demand nodes on the critical path by the following formula;

$H_{Dn} = H_{Sm} - S_c \times L_{mn}$ where;

S_c: The critical slope (the minimum of all the slopes on the critical path)

4) Continue the procedure until proposed friction slopes for all the pipes are estimated.

Q-Specified Condition

The several steps should be followed in this method can be listed such as;

1) Obtain the design distribution graph, identify all the primary and secondary pipes.

2) Considering the assumed H_{Dn} values calculated according to the critical path concept, determine the flow direction in the secondary pipes (if the assumed H_{Dn} values happen to be the same both the nodes of a secondary pipe, assume the flow direction from a node nearer to a source to the farther node).

3) Take the minimum or the specified discharges for all the secondary pipes.

4) Satisfying the node flow continuity constraints for all the nodes, calculate the discharges in all the primary pipes.

5) Detach each secondary pipe at its downstream node so that the network is temporarily converted to a branching one.

6) Optimize the cost of the distribution network by applying LP model:

Minimize Cost = $_{i}\ _{j}\ C_j L_{ij}$

Subject to:

i) Length constraints

$_{j}\ L_{ij} = L_i$, for all pipes i

ii) Pressure contraints

min $_{j}\ S_{ij} L_{ij} = H_{Sm} - H_{Dn}^{min}$, for all paths mn

iii) Loop constraints

$_{i}\ _{j}\ S_{ij} L_{ij} = 0$, for all loops

iv) Non-negativity constraints

L_{ij} = o, for all i and j.

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A SIMPLE METHOD IN THE DESIGN OF WATER DISTRIBUTION NETWORKS

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SYNOPSIS

This paper deals with a simple method for the optimal design of water distribution systems. The results obtained by this method were compared with those obtained from other standard mathematical programming methods like Steepest Descent, Davidon - Fletcher - Powell method and Nelder - Mead method. The Results indicate that the simple method is fast coverging and less time consuming. This method can take into account the discrete nature of thecommercially available pipe diameters compared to the other methods wherein the variation of the pipe diameter is continuous in nature.

KEY WORDS

Design of water supply networks, Finite Element methods, simple method steepest descent method, Davidon - Fletcher - Powell method, Nelder - Mead method.

INTRODUCTION

The present coverage of drinking water supply for urban population is about 80% and for rural population is about 30%. In order to achieve 100% coverage of water supply for both urban and rural population, investments of the order of hundred billion rupees are to be made in India. As the distribution part of thewater supply system accounts for about 70% of the total project cost, any improvements in the design of these heavy investment oriented projects will lead to substantial savings in total costs.

In the design of water distribution systems, mathematical programming techniques such as linear programming[6] nonlinear programming[1,2,3,4] and Dynamic programming[7] techniques have been used. The computer storage requirements to solve a nonlinear network problem by linear programming (LP) and dynamic programming (DP) techniques is substantially higher leading to increased compoutational costs. The nonlinear programming techniques consider the pipe diameters as continuous varibale, which ultimatly have to be rounded off to the nearest available market sizes. The simple method was tested on several existing networks and the results were compared with those obtained by other standard techniques like steepest descent (SG), Davidon - Fletcher - Powell method (DFP), Nelder Mead (NM) method.

DESIGN OF DISTRIBUTION NETWORK

The design of networks is based on the principle of minimization of total cost of the system. Here the total cost is assumed to consist of (i) pipe costs including its laying and right of way costs, (ii) pumping costs. In the case of gravity systems pumping costs are absent. The pipe and pumping costs mainly depend upon the pipe diameter.

The design of a distribution system can be treated as a series of analysis problems for different sets of pipe diameters and selecting the best set of pipe diameters giving the minimum cost satifying a set of constraints. It may be noted that for a network of M pipe, there are factorial M pipe set combinations to be examined for design. Obviously, analysing the network for all these pipe set combinations to pick up the best set is a difficult task. Each design procedure has its own way of selecting the next best set of pipe diameters. The number of trials needed to move to the optimal solution indicates the efficiency of the algorithm.

FORMULATION OF THE PROBLEM

For a network N nodes and M pipes, the total cost can be written as

$$F = \sum_{i=1}^{M} UC_i(D).L_i + \sum_{i=1}^{M} K_l \; (\gamma q_i \, h_{fi}) + \text{fixed costs} \qquad ....(1)$$

Where

$UC_i(D)$ is the unit cost of pipe as a junction of pipe diameters for the i^{th} pipe

L_i Length of the i^{th} pipe.

K_l A coefficient which will take care of present worth of pumping cost, hours of pumping, efficiency of pumping, unit cost of energy etc.

$$K_l \cong 0.365 \frac{a_1 \; a_2}{\eta} (SPWF)$$

where

a_l is the number of hours of pumping per day (10 hr/day)

a_2 is the unit cost of energy in Rupees per Kilowatt hour (Re.0.256/Kwh is the efficiency of the pump.

SPWF is the Series Present Worth Factor

$=[(1 + r)^{NY} - 1]/[r(1 + r)^{NY}]$

r is the discount rate used.

NY is the number of years of project life

γ is the specific weight of water

q_i is the discharge in the i^{th} pipe

h_{fi} is the pressure head loss in the i^{th} pipe

The cost of installation of pumps can be included in fixed costs. Using the pressure head loss versus the discharge relationship in the form of Darcy Weisbach formula,

$$h_f \; \frac{fL}{12.1} \quad \frac{q^2}{D^5} \qquad ....(2)$$

the pumping costs or the second term in equation (1) now bcomes

$$C_{pumping} = K \sum_{i=1}^{M} (fL\ q_i^{3}/D_i^{5}) \qquad ....(3)$$

where

$$K = \frac{0.365\ a_1 a_2}{12.1} \left[\frac{(1+r)^{NY} - 1}{r\ (1+r)^{NY}} \right] \qquad ....(4)$$

In the above formulation all the units must be in SI units. If the Hazen Williams formula is used with FPS units, the expression for cost of pumping is

$$C_{pumping} = \frac{a_1\ \ a_2\ (62.4)}{\eta} \quad \frac{q}{7.2 \times 60} \quad h_f (0.746) \qquad ....(5)$$

where q is in US gallons/minute

h_f is the head loss in ft

$$h_f = \frac{3.5587\ L}{C_{Hw}^{1.85}} \quad \frac{q^{1.85}}{D^{4.87}} \qquad ....(6)$$

where q is in US gpm

D is in inches

L is the length in ft

C_{HW} is the Hazen - Williams coefficient.

Now the objective in the design procedure is to minimize the total cost subject to a set of given constraints.

$$\text{Min} \quad F = \sum_{i=1}^{M} UC_i(D)L_i + K \sum_{i=1}^{M} \frac{f_i\ L_i\ q_i^{3}}{D_i^{5}} \qquad ....(7)$$

subject to

(i) $D_{min} \leq D_i \leq D_{max}$ ....(8)

(ii) $D_i \in \{ D_{comm} \}$ ....(9)

(iii) $H_j - Z_j \geq (P_{min} / \gamma) = h_{min}$ ....(10)

(iv) $\sum_{\substack{j=1 \\ j \neq k}}^{N} q_{jk} + C_j = 0; K = 1 \text{ to } N$ ....(11)

where q_{jk} is the flow in the pipe connection j^{th} and k^{th} node C_j is the demand at node j in appropriate units

$$\text{(v)} \quad \sum_{\substack{i \in k^{th} \text{ loop} \\ k=1}}^{NL} (hf)_{ik} = 0 \qquad \text{....(12)}$$

There are several methods available to solve the problem specified by equations (7) to (12). Sequential unconstrained minimization techniques which involve the incorporation of constraints into the objective function would make the problem,- unwieldy. However, when network solver is coupled with any ptimization procedure it will reduce the size of the problem. Constraint equations (11) and (12) will be satified by thenetwork solver. Constraintequations (8), (9) and (10) will be taken care of at the optimization stage which varies the pipe diameters in such a way that the objective function is minimized.

NETWORK SOLVER

The analysis pipe networks is based on the laws analogous to Krichoff's voltage law (KVL) applicable to electrical networks. These laws are (i) the algebraic sum of the flows around any ujunction should bezero, (ii) the algebraaaic sum of the pressure head drops around any closed loop should be zero, (iii) the specific pressure head loss versus the discharge relationship should be maintained for each pipe in the network. Since the pressure head drop versus the flow relationship is nonlinear an iterative scheme is to be adopted to solve for the discharges in pipe and pressure heads at the nodes. The different methods available for the analysis of pipe networks re (i) Hardy Cross method, (ii) Newton - Raphson method and (iii) Finite Element method (FEM). When these methods were applied to analyse different networks, the Finite Element method[9] scored well over the other methods interms of convergence and time of computation and simplicity in the preparation of input data. In the present study, the FEM has been used, coupled with the compact storage schemes for sparse matrices in the analysis part of the design procedure. The detailed discussion on the Finite Element method applicable to networks was given by B.V. Rao[9] It was found in the course of present iinvestigations that FEM yielded results iin case of some networks where the other two methods failed. Thé linkage between the network solver and design for pipe diameter is an follows:

1. Read the initial diameters, system configuration, loading (demands) and other necessary data.
2. Call network solver
3. Using the flows and pressures from network solver, adjust the pipe diameters as per the chosen strategy (by either SD, or DFP or NM or Simple method).
4. Are the constraint conditions satisfied? If no, go to step 2.
5. Is the objective function minimum. If yes go to step 7.
6. Go to step 2
7. Print results and stop

The final solution will be in terms of a set of pipe diameters for a given loading condition or the demands at different nodes in the network and given pressure heads at specified nodes.

SOLUTION PROCEDURE

Some of the stndard methods used in the optimization procedure are

(i) Steepest descent method (SD)

(ii) Davidon - Fletcher - Powell method (DFP)

(iii) Nelder - Mead method (NM)

Apart from these, a method which is being referred to as

(iv) Simple method.

has also been used which was developed bythe authors. In all the four methods used here, thedecision variables are the pipe diameters, the continuity and loop condition given by equations (11) and (12) were satified during the analysis part of the program. nodal pressure were checked during the design stage and the pipe diameters were allowed to take values in between D_{min} and D_{max} during design stage of the prgram.

a) Steepest Descent Method[4]

The steepesest descent method (SD) method can be described as follows:

1. Read the starting diameter values D_i, i = I to M. Find the value of the obj. function $f_I = F(D_I)$
2. Call the Network solver routine to satisfy the nodal continuity equations.
3. Find the step length λ to minimize $F\left\{ D_I - \lambda \nabla F(D_i) \right\}$ to move to the optimal point.

   $f_2 = \text{Min}\ F\left\{D_i - \lambda \nabla(D_i)\right\}$
4. If abs $\left[\dfrac{f_2 - f_1}{f_1}\right] \leq 10^{-5}$ goto 6
5. $f_1 = f_2$ and

   $D_i = D_i - \lambda \nabla (D_i)$ for i = I to M

   go to step 2
6. Print results and slop

b) Davidon - Fletcher - Powell Method, DFP [4]:

This method can be briefly described as follows:

1. Read the starting diameter values $\{D\}$ for all pipes. Set [H] = Identity matrix. Set Counter K = 0
2. Find the gradient vector $\{\nabla F\}$, Direction vector $\{d\}_k = -[H]\{\nabla F\}$

3. Put K = K + 1. Call the NETWORK SOLVER. Find λ to minimize $F(D_i + \lambda d_i)$
4. The minimum value of λ is $\lambda_{min.}$

   Update the diameter values.

   $$\{D\}_{K+1} = \{D\}_K + \lambda_{min}\{d\}_{kj}\ v = \lambda_{min}\{d_k\}$$

   If $D_i < D_{min}$, then $D_i = D_{min}$

   If $D_i > D_{max}$, then $D_i = D_{max}$
5. Find $\{\nabla\}F_{K+1}$; $u = \{\nabla F\}_{K+1} - \{\nabla F\}_k$
6. If $\{\nabla\}F_{k+1} \leq 10^{-5}$ go step 8
7. Update [H] matrix

   $$[H]_{k+1} = [H]_k + \frac{V \quad V^T}{V^T \quad u} - \frac{H_k \quad u \quad u^T H}{u^T \quad H \quad u}$$

   goto step 2
8. Print result and stop.

c). Nelder - Mead Method [4]

In this method a set of N + I mutually equidistant points in N dimesnstional space, Known as rgular simplex is chosen. In two dimensions, the simplex is an equilateral triangle and in three dimensions it is a rgular tetrahedron. This method compares the values of the function at the (N + I) vertices of the simplex and moves the simplex towards the optimum point during the iterative process. The movement of the simplex is achieved by the application of three basic operations - reflection, expansion and constraction. The details about this method can be found in any standard reference text book on optimization [4] The decision parameter is the diameter of pipe. As the number of pipe elements increase, the storage requirment increase. The network is to be solved in between iterations to make sure to at the nodal continuity equations are satisfied. The number of function evaluations becomes excessively large in this case with the increase in the number of pipe elements. The memory requirement and time of computation is large compared to the other methods as can be seen from table No.4 & 5.

d) Simple Method

From equation (7), the total cost for a single pipe is given as:

$$F_1 = UC(D).L + \frac{KfLq^3}{D^5}$$

Choosing Diameter D as the decision variable, for minimum of F_1, $\partial f_1/\partial D$ should be zero. Hence

$$\frac{\partial F_1}{\partial D} = L\frac{\partial}{\partial D}\left\{UC\ (D)\right\} - 5\,K\,F\,L\,\frac{q^3}{D^6} = 0 \qquad \text{....(14)}$$

or

$$DUC = \frac{\partial}{\partial D}\left\{UC\ (D)\right\} = \frac{5\,K\,f\,q^3}{D^6} \qquad \text{....(15)}$$

at optimum point. For a given discharge q, optimum diameter is

$$D_{opt} = [5\ K\ f\ q^3/\ DUC]^{1/6} \qquad \text{....(16)}$$

or for a given diameter D, the optimum discharge Q_{opt} is

$$Q_{opt} = D^2\ [DUC/(5\ k\ f)]^{1/3} \qquad \text{....(17)}$$

When FPS system of units and Hazen - Williams formula were used, the expression for Q_{opt} is

$$Q_{opt} = \left[\frac{(DUC)(C_{HW})^{1.85}\ D^{5.87}}{4.87\ K}\right]^{1/2.85} \qquad \text{....(17a)}$$

Where C_{HW} is the Hazen - William's coefficient

Q_{opt} is the discharge in U.S. gallons per minute

D is the diameter of pipe in inches

UC(D) is the unit cost of pipe of diameter D in Rs/ft.

For a given set of commercially available pipes $\{D_{comm}\}$ the optimal discharges $\{Q_{opt}\}$ can be evaluated and stored. In other words, it can be interpreted that if the discharge $(Q_{opt})_J$ is maintained in a pipe of diameter (Dcomm)j j = I to NAPD, then the total cost is minimum,

Now the strategy for varying the pipe diameter in the design procedure is as follows. If the discharge q_i in any pipe, is such that

$$(Q_{opt})_j \leq \text{abs}\ q_i \lesssim (Q_{opt})_{j+1}$$

then the diameter of the pipe chosen should be in such a way that

$$(D_{comm})_j \leq D_i \leq (D_{comm})_{j+1} \qquad \text{....(18)}$$

While chossing the pipe diameter D_i, two possible alternatives arise. The first alternative is:

(i) If $(Q_{opt})_j \leq$ abs (q_i) $1/2[(Q_{opt})_j + (Q_{opt})_{j+1}]$

then $D_i = (D_{comm})_j$

and If $1/2\,[(Q_{opt})_j + (Q_{opt})_{j+1}] \leq \text{abs}\,(q_i) \leq (Q_{opt})_{j+1}$ ....(19)

then $D_i = (D_{comm})_{J+1}$ j = 1 to NAPD

(ii) The second alternative is

If $(Q_{opt}) \leq \text{abs}\,(q_i) \leqslant (Q_{opt})_{j+1}$ ....(20)

The second alternative as given by expression (20 gave better results as can be seen in Table No 3

The solution procedure in the case of simple method is as follows:

1. Read the network configuration, starting values of pipe diameters and other relevent data.
2. Call network solver to calculate flows and pressure heads.
3. Adjust the pipe diameters as per the strategy given by expression (20).
4. Count the number of diameter changes in each iteration. If there is no change in pipe diameters print results and stop. Else go to step 2.

Case Study:

all these methos were tested on a network shown in Fig.1 consisting of 43 nodes and 59 pipes with one balansing reservoir. This is small segment of BMC water distribution system. The data regarding pipe lengths, starting diameters, pipe connecting nodes is as shown in Table No.1. All the units are in FPS units because they represent acutal network.

The consumptions at different nodes is gpm (US gallons) starting from node 1 are:

[- 3730, 40, 121, 55, 121, 156, 116, 56, 198, 145, 120, 19, 82, 53, 89, 74, 155, 276, 85, 83, 65, 123, 70, 89,. 23, 73, 60, 74, 110, 121, 84, 98, 35, 28, 109, 119, 122, 34, 80, 47, 25, 34, 63.]

The negative sign - indicates input at the node.

The data regarding the commercially available pipe sizes and then unit costs are as shown in Table No.2

The computations were carried out using a micro-computer of ESPL make 512 KB RAM with a Motorola 68000 microprocessor. The time of computation for each run was also noted and given in table.

Discussion of Results:

The variation of total cost with the mode of pipe diameter selection in simple method is as shown in Table No.3 in table No.3. Adjustment of pipe diameter as per condition no.3 in table no.3 gave optimal results. Hence the same strategy has been used in further studies in the case of simple method when Comparison of the results were made with the other methods.

The results obtained by four different methods are as shown in Table No.4. It can be seen from Table No.4 that for different starting points, simple method coverged to more or less the same value compared to the other method. In all these cases, the loading on the network or demand pattern was kept the same throughout. The time needed for convergence in simple method is more or less the same where as in other methods the time of computation is different for different starting points. The steepest descent method and DFP method failed to pick up the minimum value. The convergance beyond the values shown in Table 4 is extremely slow especially in the case of steepest descent, DFP and Nelder-Mead methods.

Table No.5 shows the results obtained by applying all the methods to different networks when full pumping is involved. Each network is identified by the number of nodes and number of links. The starting value of diameters is same for each of the network and for all the methods. The starting value being the existing pipe diameters. The results show that the simple method gives the least value.

Gravity System:

In the case of gravity system no pumping is involved, water reaches the consumers purely by gravity. Hence the objective function in this case is

$$\text{Min } F_2 = F_2(D) = \sum_{i=1}^{M} UC_i\,(D)\,L_i \qquad ....(21)$$

Subject to the constraints given by eqns. (10) to (13).

The objective function given by equation (20) is either increasing or decreasing with diameter D, hence care should be taken while applying methods like steepest descent DFP and Nelder Mead. In these methods constraint equations (10) and (11) may restrict the variation of pipe diameters in the design procedure. However, in simple method, this variation can be taken care of easily.

Some changes have to be incorporated into the design procedures of gravity systems which using simple method, as the equation (17) is not applicable here. The optimal discharges $Q_{opt}g$ in the case of gravity system for commercially availabve pipe diameters may be derived as follows:

The main constraint in the system is that the pressure heads at all the nodes should be above a specified minimum, say h_{min}. If the difference between the pressure heads at source H_s and at farthest point H_{fp} is above h_{min}, then,

$$(H_s \text{ - head loss due to friction}) \not< H_{fp} \qquad ....(22)$$

$$\text{or} \quad \left(\frac{P_s}{\gamma} + Z_s\right) - (HG.L_s)_{fp} \geq \left(Z_{fp} + \frac{P_{min}}{\gamma}\right) \qquad ....(23)$$

where P_s is the pressure at source

Z_{fp} is elevation of farthest point

HG is the hydraulic gradient

$L_{s,fp}$ distance between the soruce and farthest point

$$\frac{H_s - H_{min}}{L_{s,fp}} \times \frac{h_f}{L_{s,fp}} = \frac{f\ Q^2}{12.1D^5}$$

$$Q_{opt}{}^{g} = \left[\frac{12.1D^5 \quad (H\ G)}{f}\right]^{1/2} \qquad \text{....(24)}$$

$Q_{opt}g$ is the optimum discharge for a given diameter D in the case of gravity system. HG should be specified when $\{Q_{opt}{}^{g}\}$ values for all the commercially available pipe diameters $\{D_{comm}\}$ are calculated, which can be used in the design procedure. The rest of the procedure is same as before.

This method has been applied to several networks of BMC and the results are as shown in Table No.6 and 7.

Table No.6 shows the results obtained by applying all the methods for a single network of 43 nodes and 59 pipes with serveral starting points. Irrespective of the starting point, the simple method converged to the same value where as the other methods failed to produce the minimum point.

Five different full gravity networks have been studied by all these methods and the results are as shown in Table No.7. Each ntwork is identified by the number of nodes and links. The starting value of diameters is same for all the methods studied for a given network, the starting value being the existing pipe diameters. It can be seen that the simple method produces the least value.

Table No.8 shows the lengths of the programs being used in these studies. This is only for give some idea baout the length of each program used.

Conclusions:

1. Though no mention has been made in this paper for want of space about the analysis of the networks, it was found during the course of present investigations that the Finite lement method of network analysis is superior tothe conventional methods like Hardy-Cross method and Newton Raphson method.

2. The simple method applied to both pumped and gravity system gave consistently good results compared to the steepest descent, Davidon - Fletcher- Powell, Nelder-Mead methods.

3. The convergence is independent of the starting point in the case of simple

method.

4. The program length and memory requirement is less in the case of simple method compared to other methods.

Notation

a_i	Number of hours of pumping per day
a_2	Unit cost of energy in Rs/KWH
C_{HW}	Hazen - Williams coefficient
C_j	Consumption at node j
$C_{pumping}$	Cost of pumping
D_{comm}	Set of commercially available pipes
D_{min} & D_{max}	Minimum and Maximum of pipe diameters

$$DUC = \frac{\partial}{\partial D}\left\{UC\ (D)\right\}$$

DFP	Davidon - Fletcher - Powell method
f	Darcy - Weisbach friction factor
F	Objective function, or total cost
g	Acceleration due to gravity
h_j	Pressure head at node j
h_{min}	Minimum pressure head at nodes
h_{fi}	Head loss due to friction at node i
[H]	Hessian matrix or matrix used in DFP method
H_j	Total pressure head at node j = $h_j + Z_j$
H_s	Total pressure head at the source point in gravity system
H G	Hydraulic gradient in gravity system
K	Coefficient used in the cost function
L_i	Length of pipe i
$L_{s'fp}$	Shortest distance between the sourcve point and farthest point in the case of gravity system
M	Total number of pipes in the network
N	Total number of nodes in the network
NAPD	Number of available pipe diameters in the market
NL	Number of loops in the network, NL = M - N + 1
NY	Life of the project in no. of years
P_{min}	Minimum pressure at the nodes

q_i	Discharge in the pipe i
Q_{opt}	Optimium discharge allowed in the case of pumped system
$Q_{opt}g$	Optimum discharge allowed in the case of gravity system
r	Is the discount rate used
S D	Steepest descent method
SPWF	Series present worth Factor
UC(D)	Unit cost of pipe as function of pipe diameter
Z_j	Datum level for node j
Z_s	Datum level for source point in the case of grvity system.

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Table No.1

Data for Network Shown in Fig.1

Pipe No.	Connecting nodes From	To	Length in ft.	Diameter in inches	Hazen Williams coeff.
1	2	3	4	5	6
1	2	1	300	12	80
2	2	1	300	12	80
3	2	3	500	16	80
4	3	5	1400	16	80
5	5	7	1375	6	70
6	7	6	700	6	80
7	4	6	800	6	80
8	2	4	500	6	80
9	3	41	1000	6	80
10	5	41	1500	6	80
11	10	6	750	6	80
12	9	10	1100	12	80
13	8	9	825	16	80
14	4	8	350	16	80
15	17	18	550	12	80
16	16	17	200	12	80
17	11	16	400	12	80
18	9	1	1250	12	80
19	18	23	900	12	80
20	18	23	900	12	80
21	11	22	2300	6	80
22	14	7	300	6	80
23	13	14	300	6	80
24	12	13	400	12	80
25	10	12	700	12	80
26	12	25	600	6	80
27	24	25	600	6	80
28	24	23	750	12	80
29	5	15	300	15	70
30	15	43	1350	9	70
31	43	20	700	6	80
32	20	26	350	12	80
33	26	19	525	12	80
34	13	19	250	12	80
35	19	33	475	6	80
36	32	33	475	6	80
37	32	24	600	12	80
38	31	32	425	12	80
39	31	30	1000	6	80
40	30	29	400	6	80
41	26	34	200	6	80
42	31	34	200	6	80
43	15	21	825	15	70

TABLE No.1 (Continued)

Pipe No.	Connecting nodes From	To	Length in ft.	Diameters in inches	Hazen Williams coeff.
44.	21	43	300	9	70
45	21	28	1100	15	80
46	28	27	500	12	80
47	27	20	300	12	80
48	27	38	200	6	80
49	37	38	200	6	80
50	37	31	625	12	80
51	36	37	1100	12	80
52	36	35	650	6	80
53	35	30	750	6	80
54	28	40	450	15	70
55	40	39	750	15	80
56	39	36	400	16	80
57	22	29	1250	6	80
58	10	42	575	6	80
59	18	42	575	6	80

Table No.2

Unit cost of commercially available pipe sizes in Bombay
(as per the data supplied by BMC in 1980)

Pipe dia in mm	Unit cost in Rs/met	pipe dia in mm	Unit cost in Rs/met
50	214	450	1315
80	275	500	1510
100	346	550	1740
125	390	600	2000
150	429	650	2200
200	530	700	2400
250	632	750	2605
300	813	800	2800
350	945	850-	3000
400	1104	900	3214

Table No.3

Variation in total cost of network as per the mode of pipe diameter selection by using simple method.

Net work studied : BMC network (43 nodes, 59 pipes) with full pumping.

Sr. No.	Condition to be satisified $[q_i = abs (q_i)]$	Pipe diameter selected	Total cost in 10^6 Rs.
1.	If $(Q_{opt})_j \leq q_i \leq (Q_{opt})_{j+1}$ then	$D_i = (D_{comm})_j$	7.15
2.	If $(Q_{opt})_j \leq q_i \leq \frac{1}{2} [(Q_{opt})_j \quad (Q_{opt})_j + 1]$	then $D_i = (D_{comm})$	6.63
	If $\frac{1}{2} [(Q_{opt})_j + (Q_{opt})_j + 1] \leq q_i \leq (Q_{opt})_j + 1$	the $D_i = (D_{comm})_j + 1$	
3.	If $(Q_{opt})_j \leq q_i \leq (Q_{opt})_j + 1$ then	$D_i = (D_{comm})_j + 1$	6.35
4.	If $(Q_{opt})_j \leq q_i \leq (Q_{opt})_j + 1$ then	$D_i = (D_{comm})_j + 2$	6.52

Note: All other parameters are kept same for the purposes of comparison.

Table No.4

BMC Network (Vikhroli) 43 nodes, 59 pipes involves pumping ' Hazen - Williams formula used)

S. No.	Initial Diameters assumed		Steepest descent (SG)		DFP		Nelder - Mead		Simple		Remarks
	Dia	cost in 10^7 Rs	Time sec	Cost in 10^7 (Rs)	Time (sec)	Cost in 10^7 (Rs)	Time (Sec.)	Cost in 10^7 (Rs)	Time (Sec.)	Cost in 10^7 (Rs)	
1	Random	0.832	61.6	0.751	84.2	0.975	390.9	0.902	105.5	0.635	Simple method converges to the same value irrespect of the starting point.
2	15 " for all pipes	1.29	283.3	0.967	147.8	1.296	792.9	1.438	106.9	0.632	
3	25 " for all pipes	2.5	47.6	2.618	221.4	1.931	333.7	2.619	111.3	0.636	
4	35 " for all pipes	3.57	48.9	3.569	73.5	3.825	335.7	3.57	114.9	0.636	

Table No.5

Result obtained by using different methods to various networks of BMC, full pumping is involved FPS units with Hazen - Williams formula have been used.

Sr. No.	Network (Nodes, links)	Initial Cost in 10^7 (Rs)	Simple Method		Steepest Descent		DFP Method		Nelder - Mead	
			Time (Sec)	Cost in 10^7 (Rs)	Time (Sec.)	Cost in 10^7 (Rs)	Time (sec)	Cost in 10^7 (Rs)	Time (Sec.)	Cost in 10^7 (Rs)
1.	(32, 45) Zone 1	0.961	45.6	0.507	39.8	0.696	55.7	0.815	162.2	0.736
2.	(40, 65) Zone 2	1.799	89.1	1.674	78.4	1.985	93.8	2.184	808.8	2.041
3.	(43, 59) Vikhroli East	0.832	105.5	0.635	61.6	0.751	84.2	0.975	390.9	0.902
4.	(86, 133) Zone 3	8.56	232.4	6.122	183.4	7.703	1043.1	7.161	2192.6	7.421
5.	(148, 158)	1.26	179.1	0.844	146.3	2.814	2784.97	2.55	3050.7	2.654

with existing pipe diameters as starting point and one balancing reservoir for each network.

Table No.6

BMC network (Vikhroli East) 43 nodes, 59 pipes involves no pumping (full gravity system), Hazen - Williams formulla used. Cost is only due to pipe cost.

Sr. No.	Initial dia assumed		Steepest descent (SG)		DFP		Nelder-Mead		Simple method		Remarks
		Cost in 10^7 (Rs)	Time (Sec.)	Cost in 10^7 (Rs)	Time (Sec.)	Cost in 10^7 (Rs)	Time (Sec.)	Cost in 10^7 (Rs)	Time (Sec.)	Cost in 10^7 (Rs)	
1	Random (1)	0.8495	124.3	1.011	142.6	1.011	725.7	0.909	134.6	0.69	Simple method converges to the same value whatever may be the starting point.
2	15 " for all pipes	1.124	144.7	1.43	52.4	1.431	311.2	1.431	92.4	0.682	
3	25 " for all pipes	2.838	41.1	2.618	57.3	1.89	266.2	2.618	95.5	0.68	
4	Random (2)	0.798	103.9	0.947	113.2	0.947	688.6	0.887	123.3	0.692	
5	35 " for all pipes	3.56	33.9	3.82	227.2	2.1	264.7	3.57	81.5	0.68	

Table No.7

Full Gravity (BMC networks), FPS units, Hazen - Williams formulla

Sr. No.	Network (nodes, links)	Initial Cost in 10^7 (Rs)	Simple Method		Steepest descent		DFP Method		Nelder Mead	
			Time (Sec.)	Cost in 10^7 (Rs)	Time in	Cost in 10^7 (Rs)	Time (Sec.)	Cose in 10^7 Rs	Time (Sec.)	Cost in 10^7 (Rs)
1	(32, 45) Zone I	0.927	36.4	0.55	22.1	0.76	38.8	0.76	123.5	0.723
2	(40, 65) Zone 2	1.73	108.0	1.703	424.6	2.00	70.7	2.00	694.6	1.907
3	(43, 59) Vikhroli (E)	0.798	123.3	0.691	03.9	0.947	113.2	0.947	688.6	0.886
4	(86, 133) Zone 3	4.39	150.1	4.33	329.7	5.05	195.7	5.05	1815.8	4.97
5	(148, 158) Zone	1.267	160.4	0.228	628.9	0.286	3335.0	0.712	2496.5	0.256

With existing pipe diameters as starting point and one balancing reservoir for each work

Table No.8

Program length for each method on ESPL computer 16 - bit machine

Sr. No.	Method	Full pumping			Full gravity		
		No.of prog. statements	Prog.length of fortran file in bytes	Prog. length of obj. code in bytes	No. of prog. statement	Prog. length of fortran file in bytes	Prog. length of obj. code in bytes
1	Steepest descent	723	19245	39424	674	18154	37388
2	Davidon Fletcher Powell	763	19840	36352	727	18690	35328
3	Nelder Mead	724	19275	40448	724	19243	39936
4	Simple	572	15018	35840	499	12478	34816

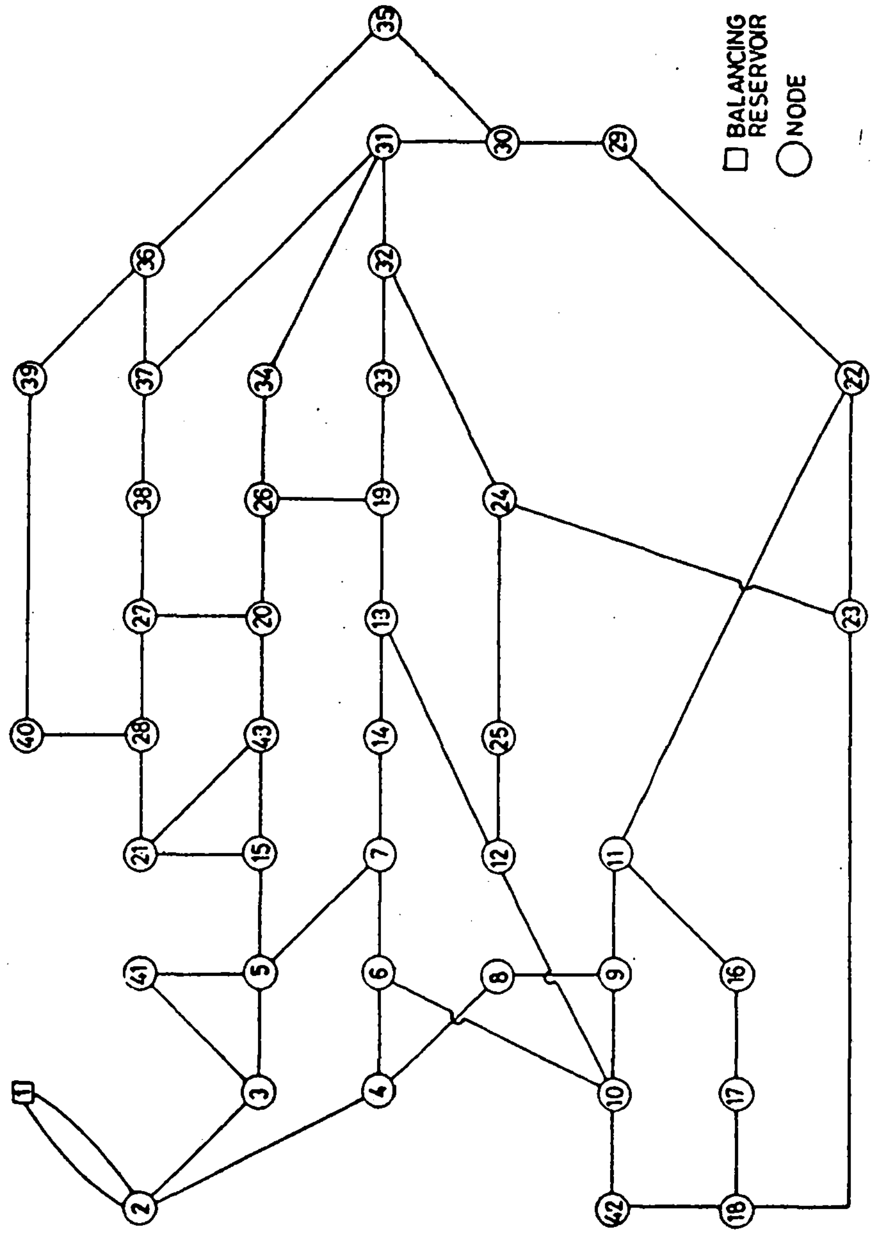

FIG.1. BMC NETWORK (43NODES, 59PIPES)

THE INTEGRATED APPROACH TO UPGRADING AND MANAGING WATER SUPPLY SYSTEM

DB FIELD
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SYNOPSIS

There is a requirement worldwide to make existing water supply systems more efficient.

Modern technology and new procedures have a large part to play in meeting this requirement but they must be applied as part of an integrated strategy if their full benefits are to be achieved.

Each separate technology can be regarded as a module in the strategy with one or more of the following attributes:

It will make improvements in a particular supply function; e.g. reduce leakage.

It willmaximise or increase the economic life of existing plant.

It will reduce operating costs.

It will enable management to plan future investment with .greater accuracy.

The integrated strategy must be based upon complete knowledge of present condition and performance together with realistic and practical targets for the future.

INTRODUCTION

Water supply engineers and managers are today faced with the increasing problem of how to manage assets, improve levels of service, reduce operating costs and meet future demand; all within limited and budgets.

Assets, made up of pipes, valves, pumps, meeters and reservoirs represent a large investment whose condition is usually unknown and for which crisis management may be the only form of maintenance undertaken.

Levels of service mesured in terms of quality, continuity and pressure may well fall below those recommended or are attainable in practice in the existing system. Also operating costs may be high and revenue low due to system or management problems.

Modern technology has an important part to play in helping the engineer and manger to correct the situation and bring about improvements in all areas. Many authorities have already undertaken a programme of improvements by the application of one or more of the currently available technologies in order to remedy the more immediate problems.

However, the use of technology in this way will not give the maximum benefits which are potentially available nor will it give the best possible return on its investment.

This can only be attained if the system and its management are looked at as a whole and an integrated appraoch taken to upgrading the complete operation. This can only come about if engineers and managers have a complete and accurate picture of the current state and performance of the system as it stands and a realistic appraisal of what it needs to achieve in the future.

With this, a strategy can be constructed which, the modular and planned implementation of modern technology will ensure improvements at all levels, maximise the life of the system and meet the needs of the future.

This in essence, is the **Integrated Approach to Upgrading and Managing Water Supply Systems.** The following chapters describe some of the modules which would be used in any strategy, their individual benefits and how they relate to other modules in an integrated system.

All these have been developed by the Water Research Centre and have been implemented in the UK, a great deal of it in the North West Water Region where the first stages of an integrated system are already in progress as a joint programme between the Authority and WRc. They are, individually, being implemented, in other parts of the world and will ultimately form the foundations for integrated systems in those areas.

THE NEED FOR INFORMATION

No reliable strategy can be constructed without accurate and complete information about the current state and performance of the existing system. In many cases, this is just not available or it is unreliable as a basis for making good decisions. Where records are deficient, a comprehensive manual survey over a period of time could provide the information required. However, a modern computer based data acquisition system would provide a far more accurate and reliable way to build a data base. This would use modern equipment to record pressures, flows, pump and valve status, fault data, energy used and storage patterns.

Such a system would form part of a comprehensive, system wide management information and remote control system at some future date in the application of the integrated strategy and must be designed with this in mind. This has already been done in many parts of the UK and in the Fat East using procedures developed by WRc.

ASSESSING THE PRESENT SITUATION

The need for information has already been stressed as a pre-requisite to having a full understanding of the present system. This is only part, albeit a major part of building a model of the system as a whole. There is the additional need to augment this with performance data that can only be obtained in the field and by building computer models to simulate actual against design performance. This includes such data as:

Levels of leakage

Burst repetition rate

Discoloured water

Supply pressure

Updating records - mapping

Performance simulation

Measuring levels of leakage has been made more accurate and meaningful by the development of new procedures and equipment at the Water Research Centre. The use of magnetic flow insertion meters, data loggers and the recently introduced **Nightliner** greatly simplify the procedure and enable the engineer to carry out this task cost effectively and accurately.

The tracing and recording of discoloured water problem can now be undertaken using the Automatic Liquid Filtration Instrument (ALFI) originally specified by WRc. It also has a role in monitoring the effectiveness of rehabilitation procedures or chemical dosing.

The updating and maintenance of accurate records can be greatly assisted by the use of digital mapping. Here, a computer, 'holds' the standard version of street maps overlaid with pipes, valves, meter position and other equipment. These are being used extensively by Water Authorities in the UK with great advantages to both operations and planning. This asset record can then be linked to performance related issues such as complaints, bursts, and leakage levels to provide part of a comprehensive management system fcr the assets.

One of the more powerful tools available to the engineer in gaining an understanding of the system is network modeling. The latest version, WATNET III, is the result of progressive development and with its interactive colour graphics display, enable the engineer to simulate system performance under a variety of demand conditions.

The correct application of these procedures and tools enable an engineer to build up a thorough knowledge of the current status and performance of the system - which builds towards and integrated strategy.

PLANNING THE FUTURE

With complete and accurate knowledge of the present system decisions can be made about the future, desired, system and the part the various technology modules play in achieving it.

Here a word of warning must be given, technologies are not fixed -they are dynamic with some moving ahead much faster than others. Decisions made today must reflect this and allow for the later incorporating of new developments cannot take place without recognising their need to fit into existing system and practices.

The area where the most significant development are taking place is that of computer based management and control systems. Developments are taking place is that of computer based management and control systems. Developments iin software and hardware will allow the engineer and manager in the future to optimise the system under all conditions of demand and status. More importantly they allow him to be more accurate in forecasting future demand and capital expenditure.

Already, certain techniques based upon computer science are being made available from the Water Research Centre. Among these are:

Pump scheduling to reduce energy and maintenance costs.

Real time simulation of supply and distribution network operation.

Short term demand prediction.

Automatic leakage detection.

Automatic pressure control.

These incorporated in the future system provide the first steps toward the fully automated systems.

To these will be added Contingency Planning; where the responses to fault conditions are pre-planned and the potential benefits of Expert Systems.

With all this in mind, the future system can be agreed and the path laid for its achievement. This path is the INTEGRATED STRATEGY.

THE APPLICATION OF TECHNOLOGY

The application of technology into an integrated strategy requires a fundamental understanding of its opration and place 'in the scheme of things'. What must be particularly understood is its relation to other technologies, each of which can be regarded s a module in the integrated strategy. The following are considered as major modules in the strategy, each contributing to overall improvements:

Watermains Rehabilitation - In the past, most enovation schems have been based upon condition analysis. Today, rehabilitation is based upon performance analysis e.g. water quality, pressures, interruptions, consequences of failure of a component part. Therefore its success will depend upon a thorough knowledge of the systems performance entailing the use of network analysis and data aquisition. This guides the engineer to those parts of the system where investment of resources and money will have the most beneficial effect. Developments in rehabilitation include

> In-situ lining with epoxy resin giving excellent friction characteristics and avoids water quality problems.
>
> Cement mortar linings with less effect on water pH.
>
> Replacement moling which bursts the existing pipe and allows one of a larger capacity to be inserted.
>
> Pipe insertion techniques which prevent leakage.
>
> Fully structural linings.

Leakage Control - This is now a well established technology and has been successfully implemented in many countries, many using the procedure developed by WRc. Its immediate benefits are the reduction in costs and, in some areas, making more water available for consumption. The success of any leakage control scheme will depend upon an accurate assessment of the marginal cost of leakage which in turn requires:

> Accurate measurement of leakage levels.
>
> Realistic costing of water lost.

This will guide the engineer to which of five possible methods of leakage control will give the best return in the investment and running costs.

Again, the need for information and knowledge is emphasised and this, therefore, relates to data aquisition, which can be used for more rapid and less labour intensive meter readings needed in most leakage control schemes. It also relates of network analysis which provids the model for installation of meters or operation of valves.

Leakage control in itself is a symptomatic cure and does not remove or minimise the casue of leakage. This will onlybe overcome by the use of rehabilitation technology previously described.

Detecting leaks is another area where great advances has been made, particularly with the introduction of the Mark III Correlator which reduces the numbner of 'dry holes' significantly.

Recent develolpments in meters have also contributed to more accurate leakage control with one meter doing the job previously done by separate district and waste meters.

Monitoring and Control - The benefit of data aquisition in the earlier stages of an integrated strategy have already been mentioned.

The integration of the management function across the whole operation and its optimisation can only be realised by the implementation of comprehensive control and monitoring systems coupled with applicable software tools to analyse and present information.

It has relevance not only to the day to day operation of the system but also to long term planning and the effective use of capital in the future.

Until recently, most monitoring and control systems were based upon conventional telemetry and were centraly directed, centrally controlled. The availability of smaller and more powerful micro-computers has provided the means to move to centrally directed but locally controlled schemes and a management by exception philisophy.

Local microprocessors, communicating over conventional telephone lines (PSTN network) or radio to a central computer, can carry a days or weeks pre-programmed instructions and only communicate back if a fault occurs. In addition, the micro-computer can store data over a long period and pass this up to the central computer at a convenient time. The near future will see the incorporation of both network simulation and digital mapping providing a comprehensive, real time management system with facilities to optimise all operations across the supply system.

Equipment - Any integrated strategy must take into account new development in equipment which can contribute to the efficiency of the system.

Data loggers, Nightliners and electromagnetic insertion meters have already been mentioned but need to be explained further.

The Spectrascan data logger was designed in conjunction with WRc to meet the need of the industry for a tough, reliable low power unit which could recorded flow and pressure over a long period of time and be installed in a flooded meter chamber. It is used in leakage control schemes and for proving network models.

The Nightliner fulfills the need for a simple unit to provide easily accessible information on total flow and minimum night flow at a glance giving enhancements to meter based leakage control schemes.

The electromagnetic insertion flowmeter was developed by WRc from the earlier range of turbine insertion flowmeter. It has improved accuracy and repeatability and required a smaller tapping for insertion into a supply or distribution pipeline.

Top-Tap - This was a joint development by the WRc and Thames Water Authority and answers the need to minimise excavation in crowded urban areas when installing insertion meters.

WHERE TO BEGIN

Equipment, technology and procedures cannot in themselves, form the integrated system. Such things as training, funding and unique local factors have to be incorporated into the strategy.

Initial and continuous training of technicians, engineers and managers must be planned so that as each step is taken, the authorities staff are already in a position to participate in the planning and implementation process.

Obtaining the capital to carry out the strategy will be made easier if each step, and the whole integrated system, can be shown to be self-funding. That is, each improvement will generate sufficient revenue to service the capital required for its implementation. It is therefore essential that realistic economic models of the system at each stage of the strategy be constructed.

Local factors can play an important part in the decision making process. For example, in areas where periodic droughts lead to water shortages it will be necessary to look at the financial and social consequences and weigh this against technical and economic factors.

Thus, the beginning of the approach to the integrated system has no single point. It starts with a full understanding of where you are and where you want to go, a full appreciation of the cost of getting there what are the immediate priorities for implementation and the effects of and on local conditions.

CONCLUSIONS

Water supply system can be successfully upgraded using modern technology but the maximum benefits will only be obtained if each is regarded as part of an integrated strategy.

Each department in a water utility will have differing priorities but the ultimate corporate goal will always be the same: to ensure that a stragtegy is developed that allows separate areas to be integrated into the total, future water supply system.

A central component in any strategy will be concerned with the role of information technology, computers and microprocessors. Particularly in its provision, data storage and processing and presentation of information to users. This is truly the shared resource having impact upon daily operations and long term plnning in all departments.

Compatibility of equipment and computer software is essential in achieving the Integrated system. If it is not compatible additonal expenditure will be incurred in later years when replcement or upgrading is required.

The need for training and changes to operational procedures must be adequately addressed within the integrated approach if complete success and cost effectiveness is to be obtained.

SECTION 3

FINANCIAL MANAGEMENT

FUNDING OF DEVELOPMENT PROJECTS IN THE WATER SUPPLY AND SANITATION SECTOR : THE ASIAN DEVELOPMENT BANK APPROACH*

SYNOPSIS

The Asian Development Bank is an international development finance institution owned by its 32 regional and 15 non-regional member governments. The Bank was established in 1966 mainly for the purpose of lending funds and providing technical assistance to developing member countries (DMCs).

The Bank's lending activities are divided into two major categories - "conventional" loans from Ordinary Capital Resources (OCR), and "concessional" loans from the Asian Development Fund (ADF). Both types of loans are intended principally to cover the foreign exchange requirements of specific projects. A DMC's access to ADF is determined on the basis of the country's debt repayment economic situation. Along with per capita GNP, a country's debt repayment capacity is also taken into account in determining its eligibility for concessional loans.

The Bank, so far, approved a total of $19,570.4 million for 827 loans. Of these, 453 loans were conventional and 374 were concessional. The loans were made to finance 749 projects in 28 DMCs. In addition, the Bank has financed 1,849 1/ technical assistance projects, amounting to $215.1 million, assisting 27 DMCs.

The Bank's operations provide principally for the financing of specific projects in such fields as agriculture and agro-industry; energy, industry and non-fuel minerals; development banks; transport and communications; water supply and sanitation; urban development; education; and health.

The improvement of water supply and sanitation facilities is of critical importance to the health and socio-economic progress of Asia. It has been estimated that in developing countries, 80 per cent of all illness is related to contaminated drinking water and the lack of sanitation. Even in the most-advanced of the Bank's DMCs, it is rare for more than one half of rural populations and three quarters of urban populations to have a piped water supply system. In the least-developed DMCs, only about 10 per cent of rural populations and one half of urban population have such systems.

THE SECTOR

The Bank's financing in this sector in the past has been in expanding water supply and sanitation facilities, mainly in the urban areas. These projects have principally served domestic consumers, but institutional, commercial and industrial users have also benefitted significantly. However, Bank financing in the sector is shifting from major urban projects towards smaller provincial urban areas and rural areas. Bank-financed irrigation and rural development projects also include the provision of drinking water in project areas, but this usually is only a small component of any project. Total Bank lending for water supply and sanitation projects has, so far, amounted to more than $1,441.0 million (or 7.4 per cent of the Bank's total

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* This paper has been extracted from a study entitled "Water Supply and Sanitation Sector Strategy Review" prepared by the ADB in April of 1986.

1/ Projects with project preparation and advisory and operational components are counted as one.

lending program), covering 57 projects in 17 countries. These 57 projects are helping increase water supply capacity by more than 12.6 million cubic meters per day and sewage treatment capacity by 2.3 million cubic meters per day. More than 60 million people have been benefitted.

The Bank's decision in 1980 to provide sector loans 1/ is of considerable importance for water supply and sanitation programs in rural areas. This type of lending has made it feasible to finance large numbers of small systems characteristic of rural water supply and sanitation development. In such loans, the sectoral needs are identified in terms of (i) capital investment required; (ii) strengthening of technical and managerial capabilities; and (iii) improving supporting financial and sectoral policies. Accordingly, when a loan is made to a DMC, the primary responsibility for the proper utilisation of the loan proceeds for sub-projects in the sector is delegated to the borrower or the Executing Agency.

In financing water supply and sewerage projects, the Bank pays special attention to the financial position and capability of the responsible entity/authority. Such entities should be in a position to operate and maintain their systems efficiently and, where practicable, to finance a reasonable portion of future expansion out of internally generated funds. Revenues for these purposes are sought through appropriate tariff levels, but in determining these levels, consumers' ability to pay is a vital factor. Where some beneficiaries/consumers cannot afford rate levels consistent with the broad financial objectives mentioned above, alternative means for achieving financial viability are sought, such as cross-subsidization among consumers, government subsidies, and adjustment of project scope.

Based on experience and current trends, the Bank's future activities seem likely to be characterised by the following: (i) preparation of sector profiles; (ii) further assistance in rural areas; (iii) increased sector lending; and (iv) greater involvement in environmental aspects.

The assistance for development of water supply and sanitation facilities in rural areas is likely to be increased and relatively fewer loans provided for expansion of water supply and sanitation systems in urban areas because of :

- greater emphasis in many DMCs on financing projects in rural areas, where the proportion of people having access to potable water is relatively low; and
- the capability of some urban entities to finance expansion through internally generated funds.

Preparation of country sector profiles in selected DMCs are required in order to identify the need, scope and timing of the Bank's assistance. These profiles, which will be prepared on the basis of in-depth reviews of the sector, will examine such aspects as the adequacy of and constraints present in government programs, institutional and manpower capability, and existing or new training

1/ The scope and components of a sector loan depend on the characteristics and needs of the sector concerned. The Bank may finance the capital investments needs of a sector in a specified geographical area (area slice) or may support them over a specified period of time (time slice), or both.

programs. Some of the major constraints are likely to be :

- institutional, particularly in rural areas, where at present few institutions with financial and technical capability in the water supply/ sanitation sector exist;

- shortage of manpower, particularly engineers, accountants and technicians, who are needed for project planning and implementation and, perhaps more important, operation and maintenance of such systems; and

- shortage of local currency because of the large amounts involved.

In order to provide increased assistance for development of water supply in rural areas, sector lending will be used more extensively. Advisory and operational technical assistance will be needed to strengthen institutional capability, particularly with respect to operation and maintenance and management of more efficient accounting systems, with such assistance incorporated within the sector loans.

For those DMCs whose economies continue to grow rapidly, particularly in the industrial sector, there will be a need for the Bank to consider greater involvement in environmental improvement, through safe solid waste disposal and air and water pollution control.

THE PROJECT CYCLE

General

Bank loans, whether project or sector, and whether provided from OCR or ADF, follow a sequence of activities making up a project cycle or the project management cycle (see Figure 1).

The key and essential steps in Bank's project management cycle are as follows: (i) identification; (ii) preparation; (iii) appraisal; (iv) loan negotiation and approval; (v) implementation and supervision; and (vi) post-evaluation.

Project Identification

Priority of the project must be established not only in the sector but also in the overall development strategy of the country. An economic analysis of the sector will provide an understanding of the development potential and provide a framework for evaluating national and sectoral policies and problems.

An important activity in project identification is programming missions, which are carried out annually by the Bank. These Bank missions identify suitable projects on a three-year rolling cycle for the Bank's consideration.

Project Preparation

Project formulation and preparation is primarily the responsibility of the executing agency. A reconnaissance mission from the Bank discusses the status of project preparation and the institutional and financial aspects. A project profile thereby emerges, indicating the project objectives, principal issues and a timetable for its further processing.

Most water supply and sanitation projects are financed on the basis of feasibility studies, normally carried out by consultants but sometimes by the public entity's own staff. If necessary, the Bank provides the responsible executing agency with technical assistance for project preparation. Such a study examines the technical, institutional, economic and financial aspects of a proposed project.

Project Appraisal

Following the Bank's reconnaissance, mission and when additional studies and data gathering are completed and a project prepared, a fact-finding mission is mounted. An issue paper is prepared thereafter, to form the basis for seeking advice and direction from Bank management 1/ on the position with respect to the issues and the approach to be adopted to resolve same. If further work is required to complete project preparation and resolve issues before proceeding to the next stage, such work is then commissioned and a pre-appraisal mission mounted. Otherwise an appraisal mission is mounted. The four major aspects examined and appraised are technical, institutional, economic, and financial.

TECHNICAL

The technical appraisal is concerned with evaluation of alternative questions of the recommended scheme, its physical scale, layout, and location of physical facilities. It also examines the technology to be used, types of equipment or processes, technical standards to be adopted, procurement arrangements, and the implementation schedule and arrangements.

In a water supply and sanitation project, technical appraisal will be concerned with existing set up, the projected demand, level of service, arrangements for proper operation and maintenance, and whether all alternatives have been considered. A critical part of this technical appraisal is a review of the engineering data and the alternatives considered to determine that the most cost effective solution has been selected. In finalising project costs, adequate allowances for physical contingencies and expected price increases during implementation area considered. Proposed procurement arrangements are reviewed to make sure that the Bank's requirements are met. In addition, technical appraisal is concerned with reviewing the costs and cost recovery arrangements for operating and maintaining project facilities. The impact of the project on the environment during implementation and thereafter is also examined, to ensure that adequate measures are taken to eliminate or mitigate any adverse effects.

1/ The President and Vice-Presidents.

INSTITUTIONAL

The institutional appraisal involves an examination of the borrowing entity itself, its organisation, management, staffing, policies and procedures. It further includes an appraisal of government policies that condition the environment in which the institution operates.

Institutional appraisal should address many questions, e.g., whether the entity is properly organised and its management adequate, whether local capabilities are being used effectively, and whether policy or institutional changes are required. It is difficult enough to develop institutions that will economically implement, operate and maintain urban water supply and sanitation facilities. In rural areas, the approach formulated must take into account social attitudes and patterns of behaviour if any success is to be achieved. Programs must be introduced to educate the potential rural consumers as to the benefits and cost of the services and the cost of wastage/misuse. If payment is not made for the service, in kind or in cash, it has been found that the service will soon cease to function. The

Bank recognises the need for a continuing re-examination of institutional arrangements and will adopt a long-term approach.

ECONOMIC ANALYSIS

In the economic analysis of the project, a cost-benefit analysis of the project is undertaken. Both macro as well as micro aspects and impacts are examined. The economic appraisal studies the project in its sectoral and country setting, the investment program for the sector, and key government policies are all examined.

In the majority of water supply and sanitation projects, it is possible to assess alternative solutions having the same benefits and select the least-cost solution. Whether qualitative or quantitative, the economic analysis always aims at assessing the contribution of the project to the development of the country.

FINANCIAL

Financial analysis done primarily to ensure that there are sufficient funds to cover the cost of implementation of the project. The Bank typically finances the foreign exchange cost and expects the borrower or the government to meet some or all of the local costs. An important aspects of the appraisal is to ensure that there is a financing plan that will make funds available to implement the project.

Financial appraisal is also concerned with project financial viability. The Bank examines closely whether the water supply and sewerage entity will be able to meet all its financial obligations, including debt service payments, and whether it will be able to generate sufficient funds from operation to provide adequate working capital, to earn a reasonable return on its fixed assets, and to make a satisfactory contribution to its future capital requirements.

The finances of the entity are closely reviewed through projections of the balance sheet, income statement, and cash flow statements. Where financial accounts are inadequate, 1/ a new accounting system must usually be established, often with technical assistance financed out of the loan.

Financial appraisal is also concerned with whether or not the project can recover investment and operating costs from project beneficiaries. Subject to affordability, the Bank normally expects that the beneficiaries will pay all the operating and maintenance costs, and, over the life of the project, the capital cost via the inclusion of depreciation of capital investments in operating costs.

In cases in which beneficiaries cannot afford the project, the Bank would require that alternatives such as reducing the level of service, cross-subsidisation by other consumers, or government subsidies be examined before agreeing to proceed with the proposed project. In each case, actual cost recovery takes account of the income position of the beneficiaries. The policies of the Bank try to strike a balance among the need to use scarce resources efficiently, considerations of equity, and the need to generate additional funds to expand the project.

1/ A change from a cash system of accounting to a commercial system of accounting using accrual method is required in order to record revenues and expenditures on the day the services are provided or received, thereby reflecting true operating results rather than the cash flow in the profit and loss statement.

The financial review often highlights the need to adjust the level and structure of tariffs changed. Some governments wish to subsidise services as a matter of policy and therefore may be reluctant to approve tariff increases necessary to ensure the viability of the entity. The establishment of tariffs to reflect the true economic cost of the service provided, subject to checks on affordability to each of the various consumer groups, is one of the major objectives of lending by the Bank. Especially in rural water supply and sanitation projects, the Bank often has to set its sight on a long term goal, recognising that it will take time to bring about what may be far-reaching changes in financial policy.

Loan Negotiation and Approval

On return from the field, Bank staff prepare an appraisal report that sets forth findings and makes recommendations to Management with regard to the appropriate terms and conditions of the loan.

The appraisal report is reviewed at a number of levels before it is finally cleared for Management consideration by the Staff Review Committee (SRC). 1/ Once the project is cleared by Management, discussions and negotiations are held with the Borrower based on the loan/project documents, which tie up the objectives and scope of the project and the commitments/responsibilities of the Borrower and the Bank for project implementation, operation and maintenance. These agreements are known as the loan documents/agreements. The project is then presented to the Board of the Bank for approval. After approval, the loan agreement is signed. The project can then move on to the implementation stage.

1/ Chaired by the director of the relevant project department and attended by all other departments.

Implementation and Supervision

The borrower is responsible for the implementation of the project. Project funds are disbursed by the Bank on application from the borrower, for financing procurement and the services of consultants required to assist in the implementation of the project.

All projects face implementation problems, some of which cannot be identified in advance. Therefore, the Bank stresses that supervision should be the first priority in the assignment of project staff. With the increase in the number of water supply and sanitation projects covering a large number of rural communities, there is a need to increase the resources of the Bank devoted to supervision of this type of project due to the inherent complexity, often incorporating institutional changes, as well as training, and health education programs.

Recruitment of consultants under a loan for a project is the responsibility of the Borrower. As in the case of procurement of goods and serviced, the Bank has guidelines for recruitment also incorporated into the loan agreement. The Bank supervises the implementation, through progress reports from the Borrower and periodic field visits by Bank staff to review progress.

Post Evaluation

This last stage of the project cycle follows the final disbursements ofthe Bank funds for the project. An independent department of the Bank, the Post Evaluation Office, reviews the project completion report of the Bank's project staff and prepares its own audit of the project, often by reviewing materials at the headquarters, and through field visits where necessary.

Each audit and project completion report for water supply and sanitation projects reviews projections made at the time of appraisal and actual results with regard to number of beneficiaries, water demand, physical completion and cost estimates. The financial internal rate of return 1/ is re-estimated on the basis of actual implementation cost and updated information one expected costs and revenues. The evaluation system provides valuable feedback, and is taken into account in subsequent project identification, preparation and appraisal work.

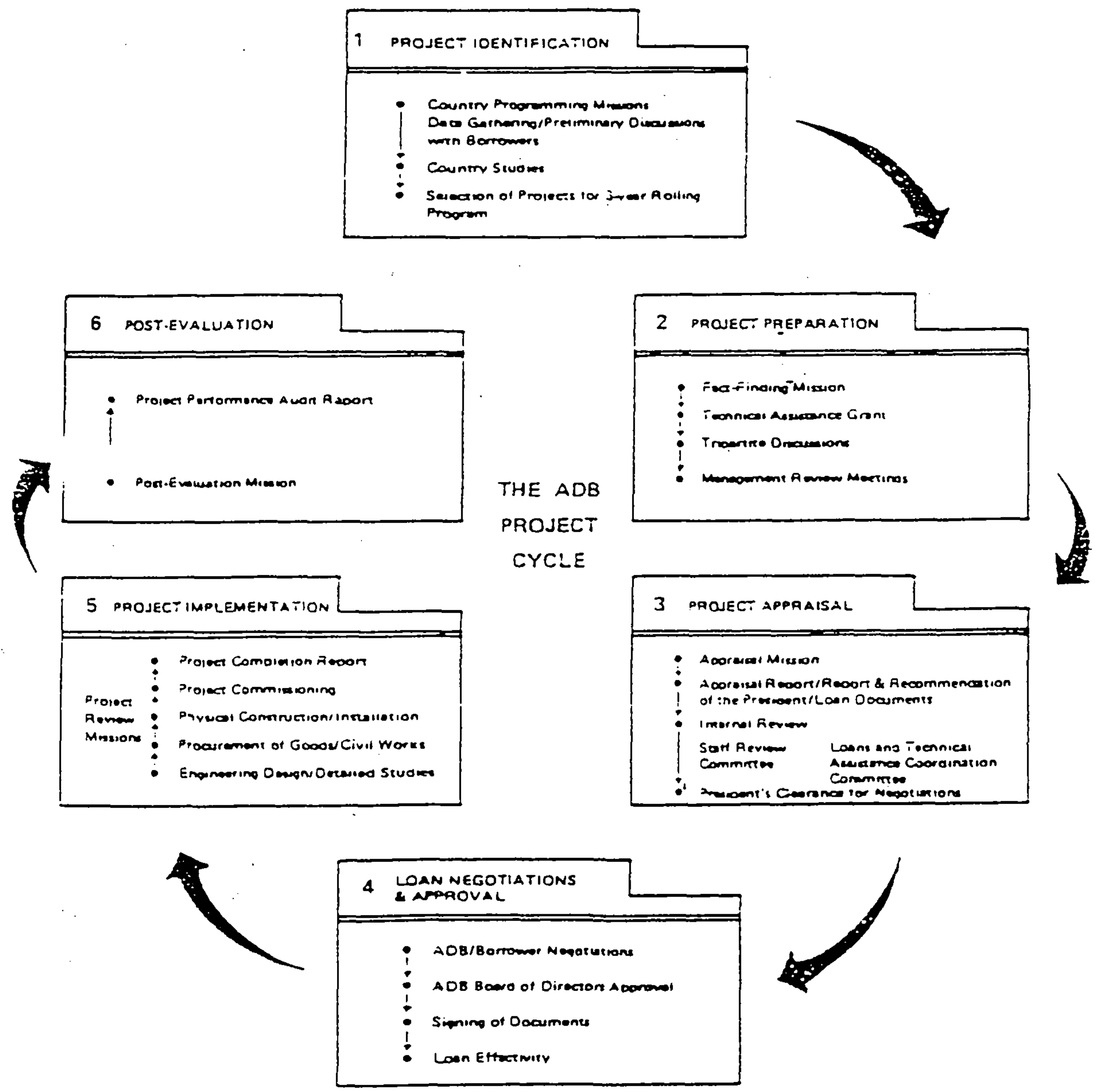
CONCLUSION

The improvement of water supply and sanitation facilities is of critical importance to the health and socio-economic progress of the Philippines and Asia. It has been estimated that at any given time there are about 150 million Asians suffering from gastroenteritis, and that if all persons had access to safe drinking water and sanitation, infant mortality would be reduced by 50 per cent. In the past, the Bank has made a contribution to the improvement and expansion of water supplies in major urban centres and to reducing the problems caused by inadequate and overloaded sewerage systems, which particularly affect the urban poor. In recent years, the Bank's role has been enlarged with financing being directed increasingly to projects in provincial and rural areas. This trend will continue and future Bank activities will show a balanced spread between major urban water and sewerage systems and relatively simple village water and sanitation systems. The Bank has also recently become involved in comprehensive studies of air, water and solid waste pollution in order to determine the most cost-effective approach to environmental protection.

The objective of this brief paper has been to give a general overview of the Bank's lending operations, its basic policies, and the programs and techniques it uses in its efforts to contribute to water supply and sanitation development in the DMCs of asia and the South Pacific. However, the Bank is only one source of financing available to the sector. For example, the World Bank (IBRD) offers financing which follow the same basic methodology as the ADB while organisations such as UNDP and UNICEF offer valuable assistance in financing feasibility studies and small pilot schemes. On a bilateral basis many countries offer developmental assistance on a grant basis to the sector through organisations such as the Australian Development Assistance Bureau, Japanese International Cooperation agency, and United States Agency for International Development to mention only a few.

1/ FIRR - the financial rate of return on an asset investment is the discount rate that equates the present value of future net revenue streams (over the economic life of the asset) to the cost of the investment.

PROJECT MANAGEMENT CYCLE



FUNDING OF URBAN WATER SUPPLY DEVELOPMENT PROJECTS IN NIGERIA

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General

Nigeria which has a land mass area of about 924,000 km^2 is located on the West Coast of Africa with a shoreline that extends for about 800 km. The country is situated between latitudes 4°10' and 13°50 North and between longitudes 2°15' and 14°45'E. In the North she is bounded by Niger Republic, in the West by Benin Republic, in the East by Cameroum Republic, and in the South opens directly into the Atlantic through the Bight of Benin.

Climate

The Climate in Nigeria is predominantly tropical with a mean maximum temperature varying between 30.6°C in the coastal belt and 38.4°C in the North. The mean minimum temperature over most of the Southern area is about 22.0°C and about 18.9°C in the North while cooler temperature exist in the Jos and Mambila Plateaux.

Two seasonal climatic conditions dominate in the country. The rainy season (March - September) with a short drought in July-August, and the Dry season (October-February). A microclimatic condition called. the harmattan exists in the dry season. The harmattan is more severe in the North and of long duration. It occurs mostly between October-January in the North and January-February in the South.

The mean annual rainfall throughout the country varies from over 3000mm in the Niger Delta to less than 500mm in the extreme North-east and North-west. Jos Plateau has a mean annual rainfall of about 1500mm.

Geology

Nigeria is underlain by two broad geological units :

(i) The cyrstalline rocks of the Basement complex

(ii) The sedimentary Deposits.

The Crystalline Rocks of the Basement Complex

This underlies an area of about 524,900 km^2 or approximately 50% of the surface area of the country. These rocks are exposed in three main blocks geographically separated by younger overlying sedimentary rocks namely the North Central, Eastern and the Western blocks. See Figure 2.

Resources availability in the basement depends partly on the degree of the presence of secondary and tertiary porosities and partly on the depth of the overburden lying directly on the basement. Groundwater occurrence here is predominantly confined to water table aquifers that are found in buried channels, weathered mantle and shear zones and jointed or faulted traces. Geophysical studies are therefore usually employed to explore the thickness of the overburden and intersection of the fractured zones where water availability are known to be very promising, producing high yielding aquifers. The experience so far is that a lot of water abound (for domestic water supply) in the basement rocks.

Sedimentary Deposits

The major aquifers in Nigeria are located in the sedimentary basins which cover about 50% of the whole country. Sedimentation began in early cretaceous through Tertiary to Recent times. Lithology is varied depending on environment of deposition marine, continental, lacustrine, fluviatile or deltaic. In terms of Water Resources, some members of the sedimentary formation hold vast quantities of water while others have quantities which are not dependable.

There are six broad units of the sedimentary deposits namely :

(i) Sokoto Basin

(ii) Chad Basin

(iii) Benue Valley or Trough

(iv) Middle Niger Basin

(v) Southwest - Southwest sedimentary low land

(vi) Anambra and Cross River Basin.

SOURCES AND TREATMENT OF WATER SUPPLIES

Nigeria is one of the countries of the World with abundant water resources in the form of adequate rainfall, rivers, streams, lakes and large underground water. The total potential amount of water assessed for the Country is roughly 220 billion cubic meters with the major drainage basins being :

- The Niger Basin drainage system
- Anambra River/Cross River Drainage system
- Ogun-Oshun River Drainage system
- Komadogou-Yobe Drainage System

However, the most prominent feature of the natural waters is the presence of two major rivers : the River Niger which enters the country through the Northwestern Border from Niger Republic and the Benue River which enters from the Northeast border through the Republic of Camerouns. The entire drainage network which is denorithic is via these two major rivers. Please see Figure 3. Both rivers with their watersheds extending outside the borders of the country have a confluence at Lokoja from where they empty into the Atlantic Ocean through an extensive deltaic network system. The major contributing tributaries to this network system are the Sokoto Rima and Kaduna with their water sheds at the Northern uplands which drain into River Niger through the northeastern section. River Gongola drains into Benue from the northeastern section while Lake Chad at the extreme northeast forms an outlet for Hadejia Jama'are with its water shed originating from Jos Plateau. Rivers Ngada and Yedseram which have their water shed extending from the Cameroun Mountains also drain into Lake Chad.

Of noteworthy is the contributing discharges of the tributaries in the South into the two major rivers. In the Southwest, Rivers Oyan and Oyi drain into River Niger while Rivers Ogun, Oshun, Owena, Ogbesse, Benin and Yelwa flow directly into the Atlantic Ocean through numerous coastal creeks.

The principal rivers. contributing into Benue River from southeast are Rivers Taraba, Katsina-Ala and Donga which take their origin from Cameroun Mountains. Anambra River down south drains directly into River Niger.

Imo river which takes its sources from Enugu-Nsukka Plateau and Cross River which also originate from neighbouring Cameroun Mountain discharges directly into the Atlantic Ocean through the coastal creeks. It is important to note that the highest discharges of these rivers are recorded in the months of June October with the peak period in August-September. The annual discharge of river Niger through its deltaic system is estimated 220,000 million m^3, while estimated cumulative annual discharge for the perennial rivers and streams is given as 200,000 million m^3.

NATIONAL DEVELOPMENT AND WATER SUPPLY

The place and role of water supply in Nigeria's National Development is that of high priority. This is perhaps in keeping with the popular definition that absolute poverty means lack of basic necessities of life including clean water.

Prior to the sixties, Nigerian economy was virtually wholly agricultural and export oriented. Since water supply is a primary input to the agricultural and other socio-economic sectors of the economy, one would have expected an aggressive and protective national policy concerning water resources development. The records however do not reflect such attitudes of policy.

The turning point in water resources development in our country came as a result of the severe drought that ravished and decimated the Sahell Region from the late sixties to the mid-seventies.

The Northern half of Nigeria was severely attached and there was acute water supply problems. Agricultural harvests are very lean, thousands of livestock and people perished because of hunger and starvation. These in turn led to massive migration not only from the Northern part of Nigeria but also from the neighbouring countries on the Northern border. The missing and socio-economic consequences was frustrating and these led Government to realise that in order to ensure that such catastrophy does not repeat itself in the future, all necessary steps must be taken to set up and implement realistic and effective water resources/ water supply development programmes. Such programmes would require feasibility studies as to the desirability and/or viability of harnessing water sources where development is called for to ensure uninterrupted water supply. These crystallised in the formulation and preparation of a National Water Supply and Sanitation Master Plan that is tailored to meet the aspirations of Nigeria's national development objectives by ensuring that there is clean and adequate water supply inputs to the socio economic programme. This Master Plan is presently being given the finishing touches as part and parcel of a National Water Resources Master Plan which is under preparation.

SOURCE AND TREATMENT OF URBAN WATER SUPPLY PROJECTS

Urban water supply projects in Nigeria are based on the extraction of water from both surface and underground water sources. These involve the construction of dams (sometimes for multipurpose uses) and other forms of impoundments and the

Federal Government alone has completed the construction of the following large dams for water supply to some urban cities and for other purposes :

- Bakolori Dam : Supply of water to Sokoto Metropolis
- Oyan Dam : Supply of water to Abeokuta and Lagos Metropolis.
- Goronyo Dam : Supply of Water to Goronyo and parts of Sokoto.
- Dadin Kowa Dam : Supply of water to Gombe metropolis; and
- Tiga Dam : Supply of Water to Kano metropolis.

The cost of construction of these dams alone and the reservoirs are quite enormous and are in hundreds of U.S. Dollars. Some of the State Governments have also constructed some medium to large dams for their own water supply schemes. In addition to surface water extraction deep boreholes are drilled in some major cities to support urban water supplies at enormous cost.

Water, water everywhere, but not a drop to drink is often a cliche associated with developing countries. This means that the waters from the impoundments and the boreholes must be treated and made wholesome before they are delivered to the homes. These water treatment plants and processing associated with our major urban water supply schemes are other components of urban water supply funding in Nigeria.

INSTITUTIONAL ARRANGEMENT FOR WATER SUPPLY DEVELOPMENT AND MANAGEMENT

Nigeria operates a three-tier government system namely Federal, State and Local Governments. The Federal Government administration is at the centre, followed by the nineteen State Governments, a Federal Capital Territory which has the powers of a State Government and the 304 Local Government Authorities.

FEDERAL

The Federal Ministry of Agriculture, Water Resources and Rural Development (FMAWR & RD) through the Federal Department of Water Resources (FDWR) is the Federal Ministry responsible for water resources development. The functions of this ministry under water resources development are amongst others.

(1) Quantitative and qualitative water resources assessment and evaluation by the collection of hydrological, hydrogeological, water supply and irrigation data.

(2) Advice and Water Resources Policy Formulation for the Federal Government

(3) Monitoring the activities of the Basin Authorities in water Resources development.

The Divisions of the Federal Department of Water Resources are :

(a) Hydrology and Hydrogeology

(b) Water Supply and Quality Control

(c) Irrigation and Drainage

(d) Planning

The Federal Department of Water Resources from the above therefore, is responsible for policy advice, data collection and collation,monitoring and co-ordination of water supply matters in the country.

There are also eleven River Basin Development Authorities (RBDAs) covering the entire country, these are the implementing arms of Federal Department of Water Resources and are responsible for bulk water supply through dams and boreholes.

A Directorate of Food, Roads and Rural Infrastructures (DFRAI) directly under the office of the President was created in February 1986 to make major interventions in the rural areas. Rural Water Supply and Sanitation provision is one of their major assignments. The highest policy making body for Water Resources is called the National Council on Water Resources (NCWR) which was created on March 30th 1981.

The FMAWRRD, RBDAs, DFRAI, State Water Boards, some Universities Federal Ministries of Health, Meterology, and Electricity and Nigeria Society of Engineers are members of the NCMR.

The National Council on Water Resources is serviced by the National Technical Committee on Water Resources with five sub-committees namely

- Water Supply and Sanitation Sub-committee
- Irrigation and Drainage - Sub-committee
- Manpower development Sub-committee
- Hydrological and Hydrogeological Sub-Committee
- Sub-committee on Dams.

STATES

The provision of water supply to the Nigerian populace is the responsibility of the state government through their water supply agencies known as State Water Boards/Corporations or Ministries of Punlic Utilities (with a water supply division) See figures 4 and 5. The State Water Boards/Corporation are semi-autonomous and are headed by General Managers while the Public Utilities are run as Ministries with electricity, water supply etc. forming the divisions. The management of water supply therefore, within a Water Board/Corporation is more efficient as the typical beaureaucratic red tapism associated with Ministries is avoided.

NIGERIA'S URBAN WATER SUPPLY REQUIREMENTS

As attempt at exhaustive discussion of funds for Urban Water Supply in Nigeria will necessarily require an assessment of the urban water supply requirements based on population forcast and projected life span of water supply schemes.

Nigeria's population is presently estimated at about 100 million with about 28% (28 million) inhabitants in the urban areas. A 2.5% growth rare is usually assumed. Less than 50% of urban inhabitants have access to potable water supply with the per capita consumption based the socio economic level of the area and the climate conditions, varing from 75-300 litres/day. Also in addition to the urban areas, there is water demands for industry, commercial houses, fire fighting, street washing, public fountains, agricultural, livestock and pipe losses through leakages and pipe bursts. A usual practice may be to estimate these at 50% of the per capital since accurate figures may not exist.

The life span of water supplies schemes is usually limited to 20-30 years after which most of the mechanical and electrical components, pumps chemical dozers, air blowers etc. may seize to function very properly. The dams and reservoirs are usually designed for longer years-upwards of 50 years. All the above indicate the enormous need for funding water supply projects for Nigeria's urban population.

FUNDING

The funding of urban water supply projects have been through grants (internal & external), subventions, loans from commercial banks (national & international).

MATCHING GRANTS

In 1975, the Federal Government, on observing that the amount of money needed for providing adequate potable water supply was collossal, intervened by providing what was called "matching grants". The idea was for every capital project proposed by the States, once the project was approved by Federal Department of Water Resources, the Federal Government would provide 50% of the total capital cost.

This was however stopped in 1978 because the states objected to the FDWR vetting and therefore requested that the money should be sent directly to them; as the oil boom was gradually dwindling down the Federal Government discontinued practice.

STATE SUBVENTIONS

The State Water Supply agencies because of their non-commercial management (for political reasons the people had often been given the impression that the provision of water supply was a social duty) usually carry out their duties through the utilisation of State Government subventions.

At the begining of each financial year the water supply agencies (WSA) normally prepare yearly budgets which are then approved after vetting by the individual state Governments. However, it is common knowledge that at the end of the year less than 10% of the approved bugetted amount is released by most of the State Governments. Table 1 shows the review of capital projects.

The table 1 is shown on page 7.

The Water Supply Agencies (WSA) if they would be allowed to operate economic tariffication would probably be able to use the meagre state subventions for capital projects and salaries, while using the money collected from consumers for operation and maintenance. The above is however not the case, resulting in the majority of the WSAs being economically non-viable.

However, there is an exception to the above, as those States (Kaduna Anambra, Borno and Lagos) which have borrowed money from the World Bank are made to charge economic rates.

The usual tarrifs charged by the States are averagely :

WATER RATES

Unmetered households =₦2.00 to 15.00 per month

Metered households =₦0.11 to 0.55 per cubic metre(M^3)

Industries & Commercial Premises =₦0.22 to 1.5 per cubic metre(M^3)

TABLE 1

FIVE YEAR STATISTICAL REVIEW OF CAPITAL PROJECTS

No.	Year	Budget Allocation ₦	Actual Receipt ₦	Receipt Allocation %
1.	1979-March 1980	14,500,000.00	1,148,381.40	7.9
2.	April-Dec. 1980	11,870,160.00	1,183,941.46	10.0
3.	1981	13,556,000.00	4,819,178.65	3.3%
4.	1982	50,206,000.00	2,887,178.65	9.6
5.	1983	105,823,400.00	2,887,178.65	2.7
6.	1984	78,840,000.00	1,814,029.41	2.3
	Total...	374,795,560.00	15,520,986.52	4.14

EXTERNAL GRANTS

Occassional grants are received from the various UN Agencies and from some friendly countries.

UNDP

The UNDP is involved in assisting States meet their water supply needs. The first of such projects which had an estimated UNDP input of US $ 460,000.00 was for Benue State for provision of technical assistance, some equipment including a drilling rig and some spare parts. to enable the State drill boreholes.

Another programme UNDP is assisting Nigeria on is the provision of materials (screens, casings etc) and technical assistance to the tune of US $ 50,000.00 to Chand Basin Development Authority for the drilling of boreholes. This programme is for the drought affected areas of Borno State of Nigeria for the provision of water through boreholes.

The UNDP however has just embarked on a new programme for five States namely Bauchi, Benue, Borno, Plateau and Ahuja. Under this programme the UNDP would contribute US $ 2.5 million for 3 years and the States 2.5 million Naira for the same period. The UNDP contribution will be in the way of technical assistance and provision of spareparts.

Also UNDP provided a grant of US $ 0.5 million for the Lagos State Water Supply Project.

UNICEF

UNICEF's assistance is more directed towards the rural areas but the technical workshops and manpower developed by UNICEF within their programmes assist greatly in developing urban water supply.

Other organisations/friendly countries that have intervened in urban water supply in Nigeria are Canada through CIDA (see case study on Lagos State Water Supply Project.)

COMMERCIAL BANKS

Nigerian Based Banks

In a manner of cases Federal parastatals (River Basin Authorities) and State Governments have borrowed money from commercial banks to finance construction of new dams or water works. A good example of this is the ₦16m Nigerian Merchant Bank Ltd. financed Alau Dam in Borno State; the dam is being constructed by Chad Basin Development Authority and will supply water to Maiduguri town for the Borno State Water Supply Project which is World Bank financed to the tune of US $72 million.

Non-Nigerian Based Banks

A number of projects are equally financed using loans from overseas banks. In some cases, contractors have provided the financing, and some of such arrangements have turned out disastrous especially when out of desperation to get the much needed loan the contract had been made turnkey.

A good example is the ₦99 million (US $ 184.5 million) turnkey fixed price 3 years "49 towns Project" which was awarded to Biwater shellabear in 1980. The project was for the design, construction and commissioning of water supplies for 48 towns and villages throughout Niger State. The contractor assisted in arranging for a loan for 85% (US $ 141.1 million) of the foreign exchange component. By December 1983, when due to unsettled claims by the contractor resulting from variations to the original proposal after the commencement of the project and delays in payments by Niger State Water Board the contractor suspended the project. Strangely enough, at this juncture, the contractor had already been paid 93% of the original contract price with only 64% of the work completed.

A major component of this project was the Biwater tower. The Biwater Tower comprises a treated water reservoir top a steel cylinder which contains a package treatment plant (under pressure) and into storage in a single pumping operation. The Biwater Tower was conceived by Biwater and researched in the U.K. for two years. Apart from this, at the time of signing of the contract there was no operational experience for this combination treatment plant and storage tank.

The above funding shows how poor developing countries out of desperation to fund essential projects are driven into taking suicidal decisions which at times are not technically based for e.g. the standard design concept advanced by the contractor is for both surface and groundwater to be treated by coagulation/sedimentation and filteration, and as half of the schemes are to use groundwater which would not require sedimentation and possibly not filtration, it thus means that the treatment plants installed at these sources would be redundant and therefore a complete waste of funds.

All these exploitation would have been avoided had the Niger State Water Board refused the turnkey offer, thereby having the project properly designed by another body who would also inspect the contractor during construction.

NON COMMERCIAL BANKS

African Development Bank (ADB)

The ADB, based in Cote D'Ivoire is a new comer in the financing of urban water supply projects in Nigeria. The first loan from this organisation is US $ 31.8 million for the execution of Ibadan Water Supply Emergency Rehabilitation Project in Oyo State. The loan has a 5 year moratarium at 8.3% interest rate payable over a period of 15 years.

European Investment Bank (EIB)

The EIB based in Luxumbourg is also a new comer in the funding of water supply projects in Nigeria. The first involvement is in the Lagos State Water Supply project discussed as a case study.

World Bank (IBRD)

The World Bank is extensively involved in the funding of urban Water Supply projects in Nigeria. Its involvement is in the provision of loans for individual state Governments namely :

Kaduna State Water Supply Project [1979] - US $ 92.00m

Anambra State Water Supply Sanitation Project [1981] US $ 67m

Borno State Water Supply Project [1983] - US $ 72 and

Lagos State Water Supply Project US $ 173.2 (See case Study)

These loans are normally guarranteed by the Federal Government who is designated the borrower.

The World Bank is also to provide funds for the "Nationwide Water Supply Rehabilitation Project" which is a Federal government intervention for a nationwide urban water works rehabilitation. This project is being handled by the Federal Department of Water Resources and has these components.

(a) Substantial technical assistance (project preparation; manpower training and accounting systems),

(b) preparation of projects by the states for external funding

(c) special studies (such as for rural water supply)

(d) assisting the states meet their rehabilitation needs

The initial estimate (1984) for the totality of the above project was US $ 84 million. The project has just commenced with the "Rehabilitation Needs Study" which will be completed by the end of 1987.

EDUCATION RESEARCH AND DEVELOPMENTS

I have tried to show that the supply of fresh potable water to the Urban Cities in Nigeria, and infact rural areas too is essentially a public sector affairs, with Governments or their Agents getting directly involved. The point is evident that water therefore is a highly politicised natural resource. On one hand, its development is constrained by lack of capital, manpower and power politics while on the other hand, Government has inadvertently created the impression to the people that water supply is a great social service and therefore the Government cannot effect realistic cost-recovery strategies to make water supply schemes self sustaining. Here lies the dilema.

The solution of the dilema will be the evolution of low cost and appropriate technology and the acquisition of skills for water industries in developing countries including Nigeria. These no doubt will reduce the level of funding by reducing to the barest minimum the cost components of foreign technology, expertise and franchise.

Because of these reasons, education, acquisition of skills and research will continue for sometime to constitute a significant percentage of funds allocated to the water supply sub-sector of our economy. In the recent past, Nigeria has had twinning programmes with some West European

Countries in the development of her water supply personnels. These are aimed at improving our manpower base for these industries. Presently too, Nigeria's Research Scientists and Water Supplyl Professionals have started looking inwards in the research, design and fabrication of simple water supply equipment that are appropriate to our needs using available technologies. We are also studying the possibilities of manufacture of water supply treatment chemicals and solvents. We have made tremendous progress in these fields.

LAGOS STATE WATER SUPPLY PROJECT

A Case Study

Lagos State is the smallest State of the country with a growth rate of 9% (from 1950 - 1980) and with a population of over 7 million it is the most densely populated state in Nigeria.

The Lagos State Water Corporation (see figs. 6 - 8) is the institution responsible for the provision of water supply in the State.

Before January 1986 the Lagos State Water Corporation (LSWC) had run its activities through subventions from the Lagos State Government (LASG) and negotiated revenues from government authorities. These funds amounted to less than one third of the revenues needed for the Corporation to finanace its operation and maintenance activities as well as expanding the water works and distribution systems which already had a 25 year backlog in the development of primary mains networks and a 15-20 years backlog of investments in water works and in the secondary and tertiary mains.

With the above situation where the LSWC depended entirely on government subventions without being allowed to have direct consumer tarrifs (therefore not commercially viable) it was not surprising therefore that the average level of service was 351cd (8gcd) in 1980 as against a targetted 1141cd (25gcd) in 1978.

Lagos State depends on both surface and underground sources for its drinking water supply. Ogun and Owo Rivers are the two principle sources, with 204,570m^3 per day (45 mgd) of raw water being drawn from the Ogun River and its tributary the Iju River at Iju water works and about 18,180m^3 per day (4mgd) from Owo at Ishashi water-works. With the newly (1983) completed Oyan Dam (and the almost completed Ikere Gorge Dam) by Ogun Oshun River Basin Development Authority, an additional release of at least 640,000m^3/day would be guaranted constantly under all normal natural conditions. The groundwater yield is however limited, and by 1977 the yield in the Lagos area was estimated at 477,300m^3 (80 mgd) per day of which industry abstracts 363,680m^3/day (80 mgd) and the rest goes for domestic consumption through ten mini waterworks (120,800 m^3/day i.e. 25.4 mgd) of which seven mini waterworks are within Metropolitan Lagos and produce 81,830m^3/day (18 mgd).

The commercial viability of the LSWC is worsened by the fact that the Iju and Ishashi waterworks are producing less than their rated capacities coupled with the fact that there are no reliable data on leakages or unaccounted for water. The present level of service is therefore very uncertain.

In the light of the above, the LASG invited the World Bank to provide a loan which would help rectify the inefficiencies while also improving the level of service; so, under the proposed project the population having access to public water supplies will increase from 2.9 million in 1985 (i.e. 47%) to 6.5 million in 1995 (i.e. 65%) without the project however the proportion would fall to 30% in 1995. Direct domestic connections would increase from 75,300 to about 179,700 (43% access) and public standposts from 2,800 to 3,200 (28% access) while industrial and commercial connections would increase from about 8,000 to 15,000 by 1995 and about 65,000 meters would be installed as part of the project with an additional 10,000 meters being procured. The project which is the first of a 3-phased 15 year expansion programme and which is expected to be completed by September 30th 1984 and to close March 31, 1995 has these components.

- increased production capacity of 318,220m^3 per day (70 mgd). This would be achieved by expanding the water supply facilities by the construction of an intake structure on the Ogun River at Akute, construction of a raw water pumping station and 8.2 km and 1600 mm diameter raw water main to a 318,220m^3 per day treatment plant at Adiyan for floculation, clarification, aeration, rapid sand filteration, disinfection, treated water pumping, transmission and storage at Oke-Aro reservoir (10,000m^3) and standby generators (see fig.7)
- Laying of addtional 80 km of of primary mains;
- providing and laying 280 km of secondary mains 877 km of tertiary distribution mains and about 112,000 consumer connections;
- rehabilitation of existing water supply facilities;
- provision of additional vehicles, mobile plant, equipment and tools;
- provision of office, workshop and depot accommodation and provision of consultant and technical support personnel to essist with institutional development of LSWC including training and studies.

The projects also addresses the tarrification issue squarely as yearly increases are to be expected with the present tarrifs.

So in January 1986, the level of charge had increased by 80% and 40% for domestic and industrial/commercial consumers, but marginally for Government and its institutions. For the first time direct charges were introduced for water sold at public standposts.

The project because of its enormous size, costing approximately a total of ₦1.7 billion is being con-financed by various institutions.

	US $
- IBRD (World Bank)	173.2 million
- Loan from a consortium of French Banks (to be guaranteed by COFACE)	137.5 million
- Loan from European Investment Bank(EIB Loan)	47.7 million

-	Grant from Canadian International Development Agency (CIDA)	3.2 million
-	Grant from United Nations Development Programme (UNDP)	0.5 million
		363.10 million
-	Funds to be provided by Lagos State (State contribution	60.8 million
-	Funds to be provided by LSWC ("Own funds")	52.8 million
		475.07 million

WORLD BANK LOAN

The loan of US $ 173.2 million which was negotiated in Washington in November 1986 is to be repaid within twenty years with five years marataruim at the variable interest rate of 7-8%.

The Federal Government of Nigeria (FGN) is expected to guarrantee the loan by borrowing and on-landing the full amount to Lagos State Government on the same terms as the Bank loan. Lagos State Water Corporation will however bear all the foreign exchange risks.

EUROPEAN INVESTMENT BANK LOAN

The European Investment Bank loan US $ 47.7 was negotiated in Luxumborg in January 1987 and the FGN was also the borrower. The loan has a variable interest rate of about 7.1/2 (5% min. and 8% max.), with 5 years moratarium and thirteen years repayment period.

The Lagos State Water Supply project is a very ambitious project with will drastically change the LSWC from an organisation constantly depending on State Government's subvention to a commercially oriented financially viable water utility.

The project has depicted the various forms of funding vis-a-vis subventions (counterpact funds) from State Governments, funds generated through application of economic tarrifs, loans from commercial banks, softer loans from reconstruction oriented banks (i.e. EIB and World Bank) and grants from friendly countries (CIDA) and NGOs (non governmental organisations) like the UNDP.

CONCLUSION

In the last few pages I have focussed on the funding of urban water supply development projects in Nigeria; however, the above should not be treated in isolation; at the back of our minds we should bear in mind the rural water supply angle.

Even though the majority of Nigerians live in the rural areas the amount of money so far invested has only scratched the top of the problem, a lot more investment still has to be made.

So, when both urban and rural water supply are considered, it becomes obvious that the problems are enormous and cannot be solved within the limited resources available to the country.

It is a huge task, and a concerted effort has to be made. So the help of NGOs and friendly countries is needed. Gone are the days when donor organisations had systematically concentrated on the other African Countries, and when confronted on why Nigeria was missed out, always answered that Nigeria is rich and therefore does not require the aid.

We all here are aware of the drastic drop the price of oil had gone through, and Nigeria's economy being very dependent on this sector for its operations fell in the same proportion. This resulted in our currency which in the good old days was at par with the pound sterling, being devalued drastically to 7₦ to the £ as against ₦1 to the £.

The above shows the extreme pressure we are under.

I wish to sieze this opportunity therefore to appeal to all the donor organisations to please consider Nigeria for thier grant-in-aid.

The decade goals have to be achieved if not in 1990, a few years later, in order to pull Nigeria out of the circle of countries having one of the highest rate of infant mortality.

FOOT NOTE

All the costs (except that of 1.7 Billion Naira for Lagos State Water Supply Project) mentioned in this report were got when the value of the Naira (N), the Nigerian currency was equivalent to 1.5 US $. If translated in the present day exchange rate of 1N to 3.9 US $. The prices would have been excessively astronomical and highly distorted as the projects were conceived some years ago.

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Figure 1

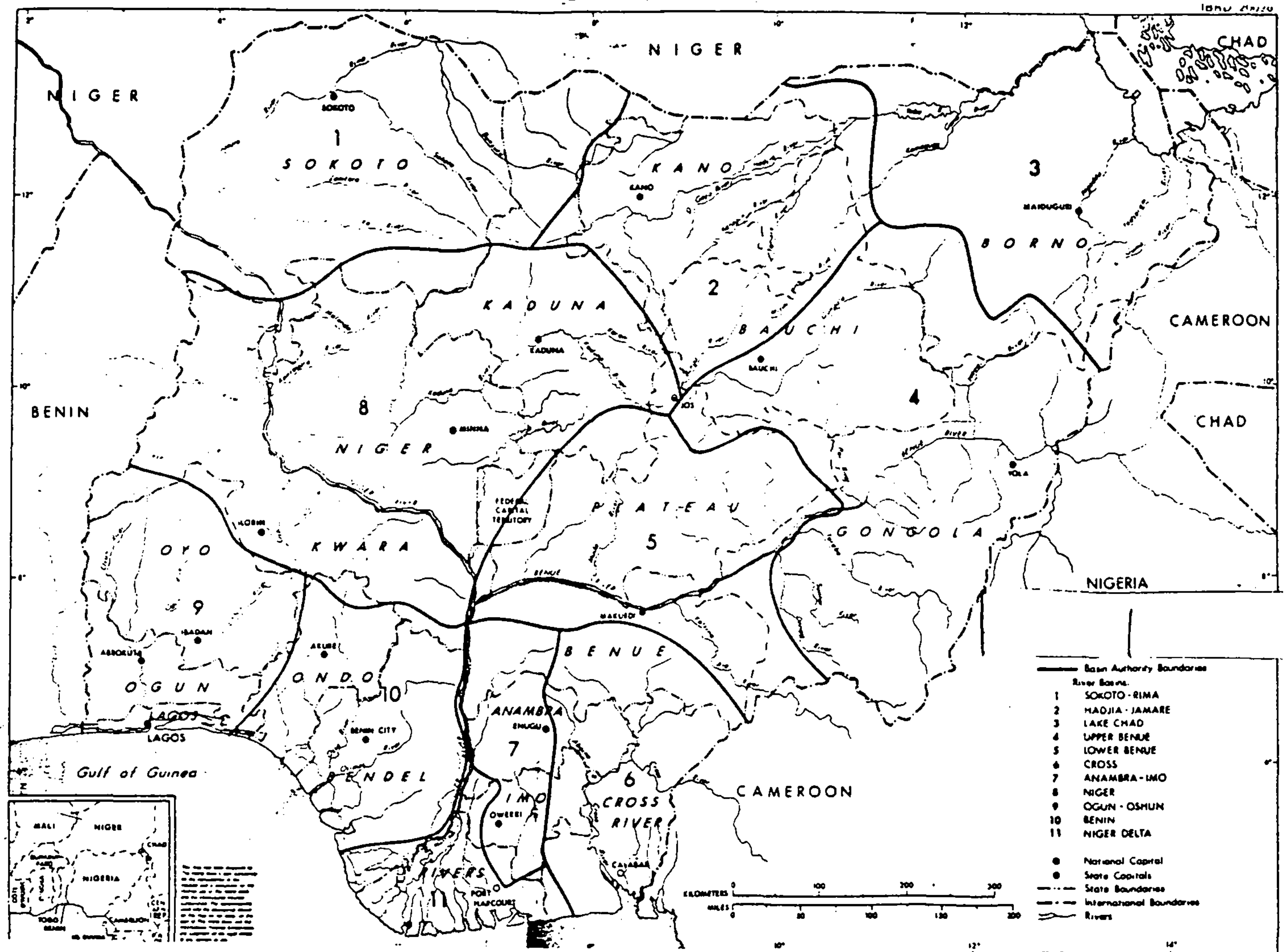
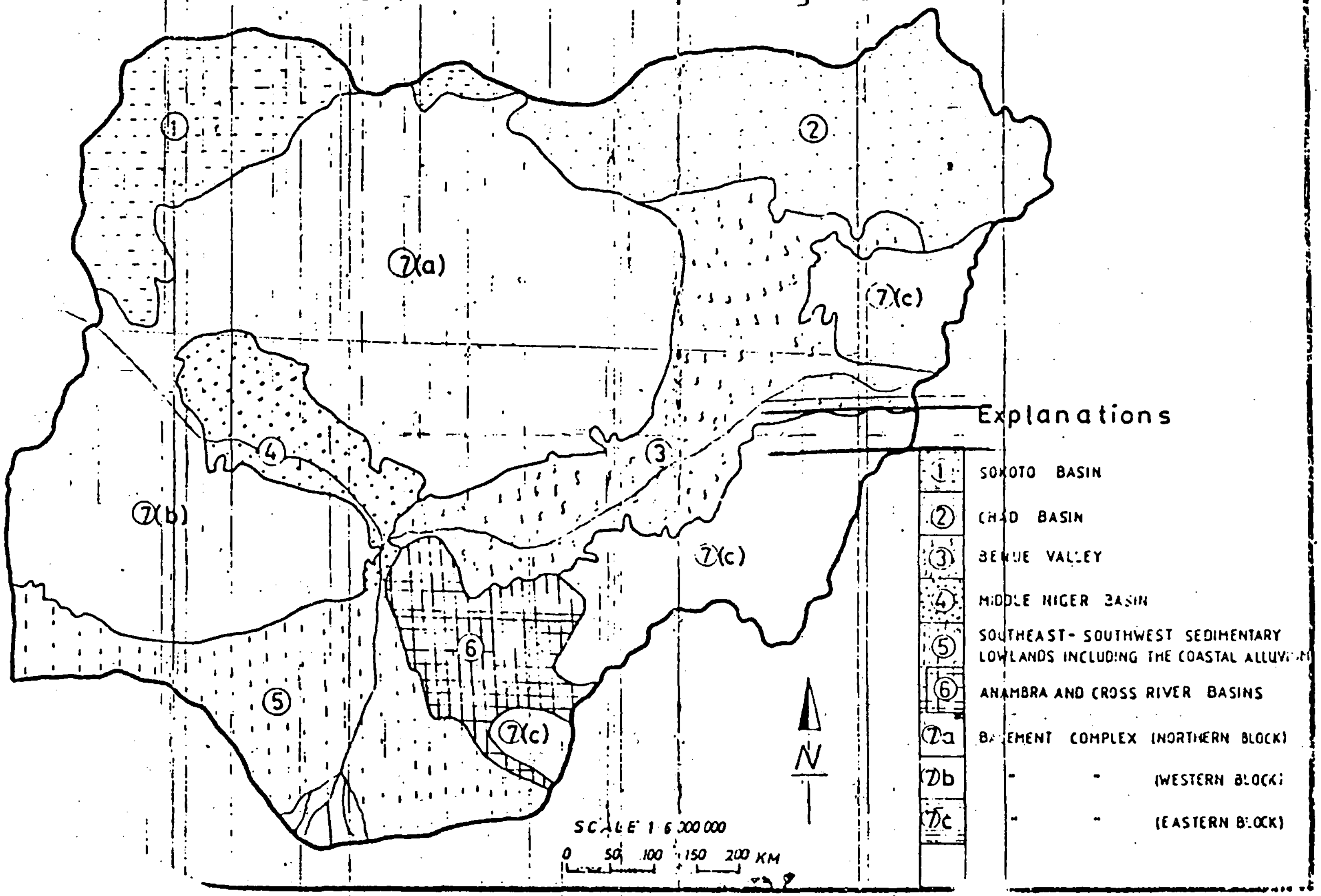

NIGER
NIGER
CHAD
1
SOKOTO
KANO
3
BORNO
2
KADUNA
BAUCHI
CAMEROON
BENIN
8
NIGER
4
CHAD
OYO
9
KWARA
PLATEAU
5
GONGOLA
NIGERIA
OGUN
ONDO
10
BENUE
ANAMBRA
7
LAGOS
Gulf of Guinea
BENDEL
IMO
6
CROSS RIVER
CAMEROON
RIVERS
Basin Authority Boundaries
River Basins.
1 SOKOTO - RIMA
2 HADJIA - JAMARE
3 LAKE CHAD
4 UPPER BENUE
5 LOWER BENUE
6 CROSS
7 ANAMBRA - IMO
8 NIGER
9 OGUN - OSHUN
10 BENIN
11 NIGER DELTA
National Capital
State Capitals
State Boundaries
International Boundaries
Rivers

Figure 2

Groundwater Map of Nigeria



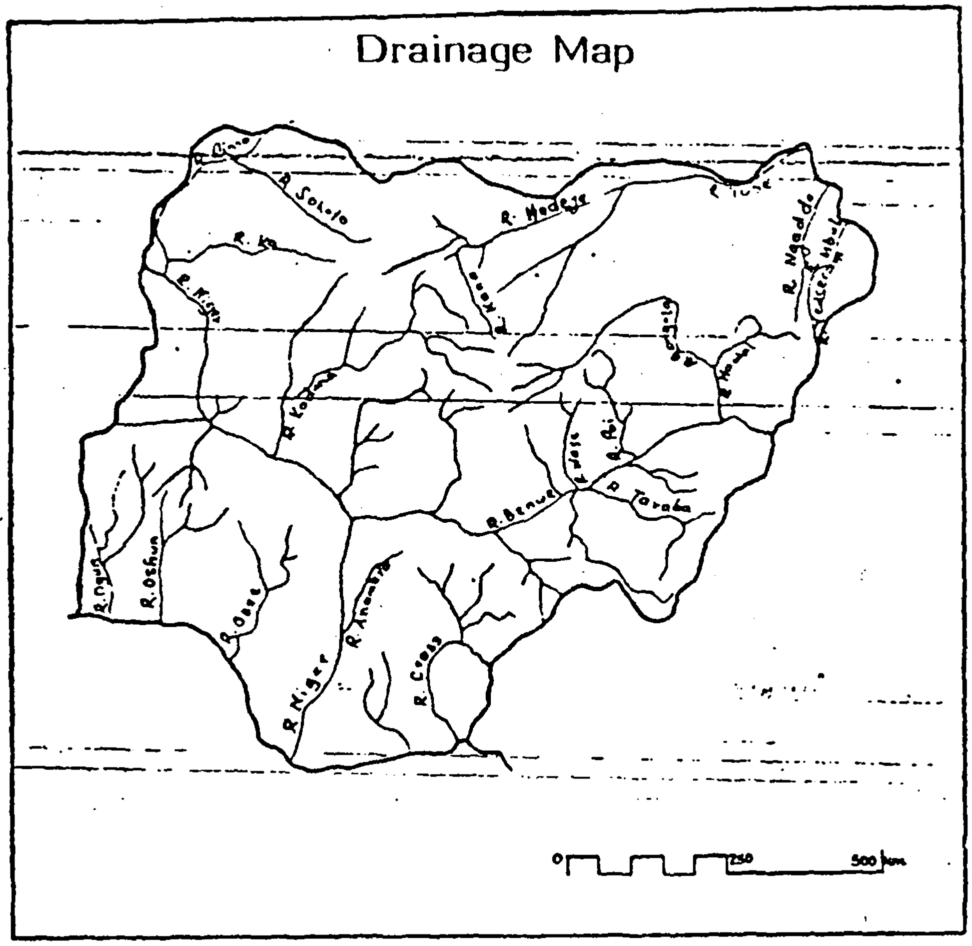
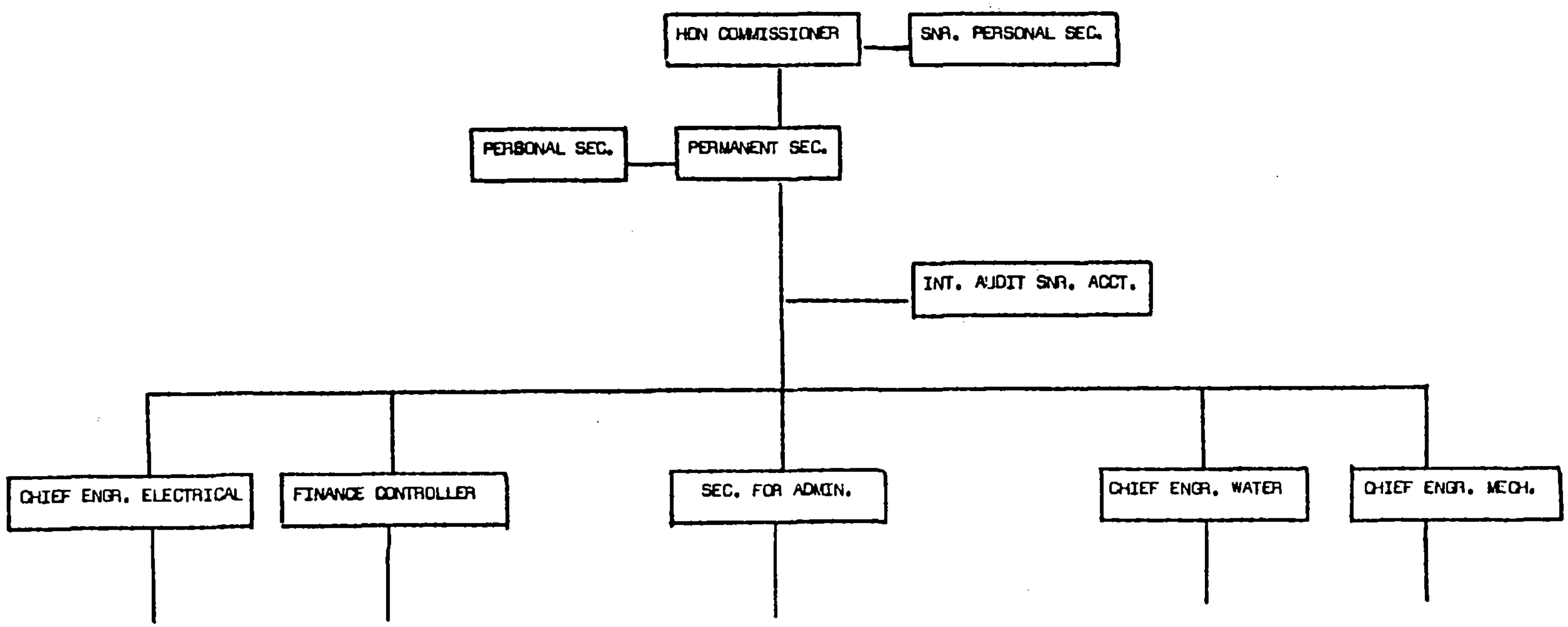

Drainage Map
R. Sokoto
R. Hadeje
R. Ka
R. Niger
R. Kaduna
R. Benue
R. Taraba
R. Ogun
R. Oshun
R. Osse
R. Niger
R. Anambra
R. Cross
R. Ngadda
0
250
500 km

Figure 3

ORGANISATION CHART FOR MINISTRY OF PUBLIC UTILITIES OWERRI, IMO STATE OF NIGERIA

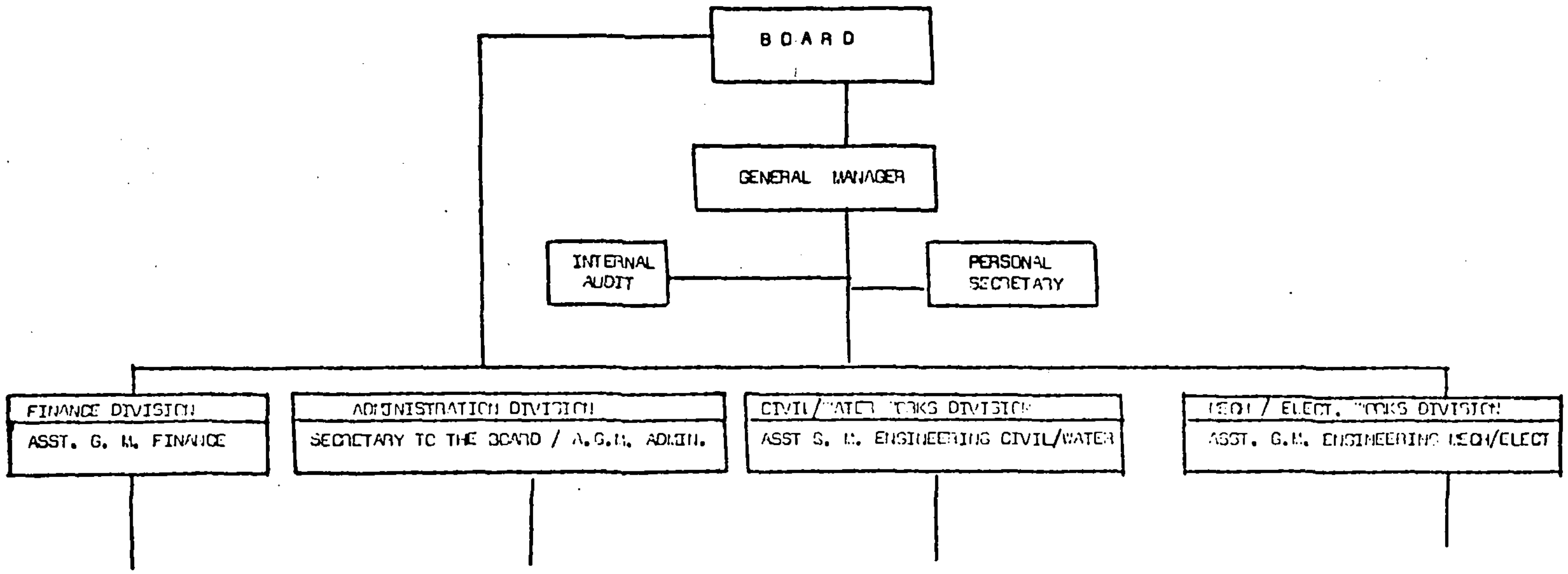


NOTE

Under this set-up, the beareaucratic red-tapism involved slowed down the activities of the Water Supply Department making it less effective.

Figure 4

ORGANISATION CHART FOR IMO STATE WATER BOARD, OWERRI

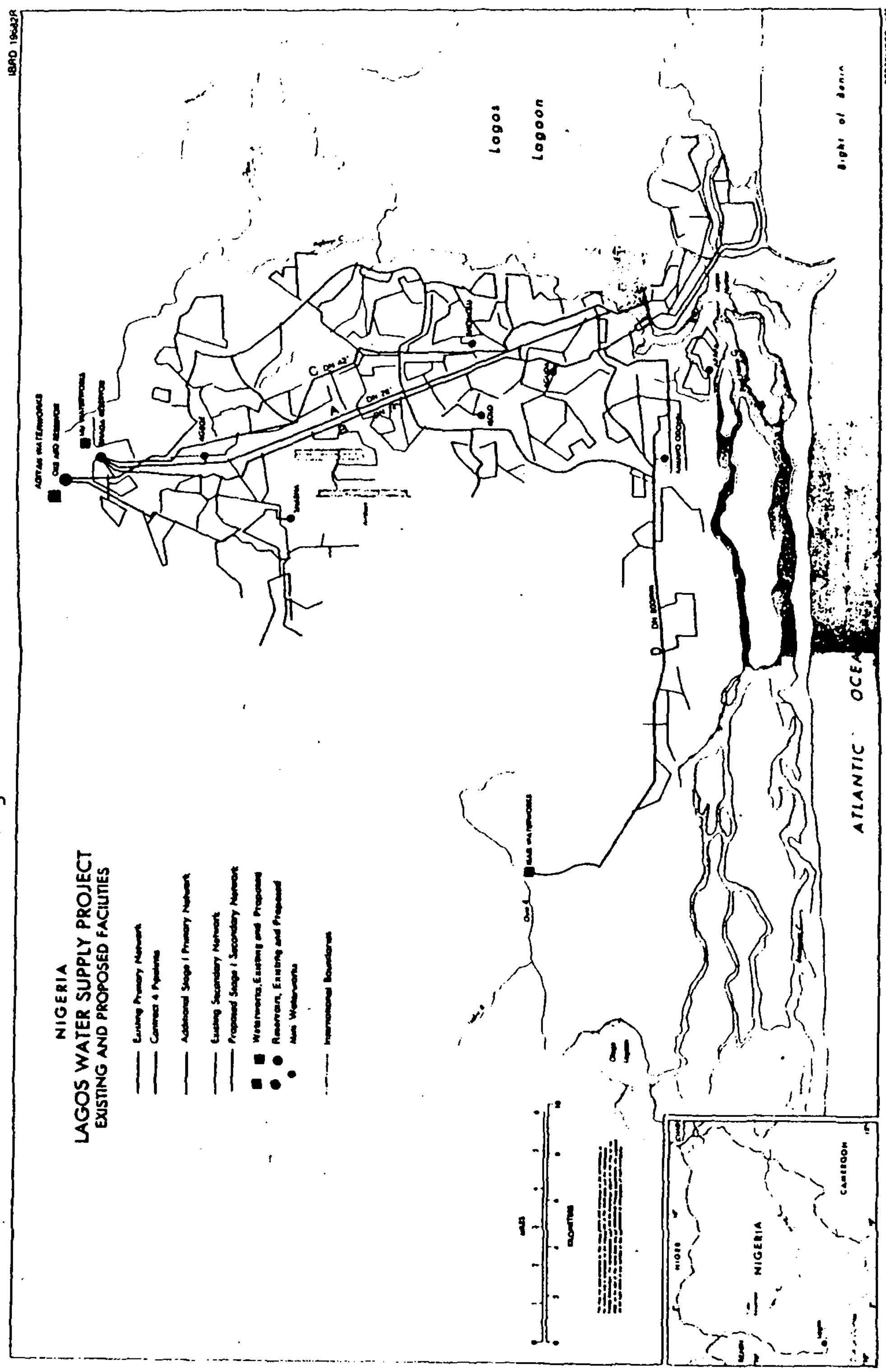


NOTE

With the above set-up, the Water Agency reports directly to a Board and has a certain level of autonomy. Its operations are therefore more efficient.

Figure 5

Figure 6


NIGERIA
LAGOS WATER SUPPLY PROJECT
EXISTING AND PROPOSED FACILITIES
Lagos
Lagoon
ATLANTIC OCEA
Bight of Benin
NIGERIA
CAMEROON

NIGERIA

LAGOS STATE WATER CORPORATION

ORGANISATIONAL CHART (OCTOBER 1985)

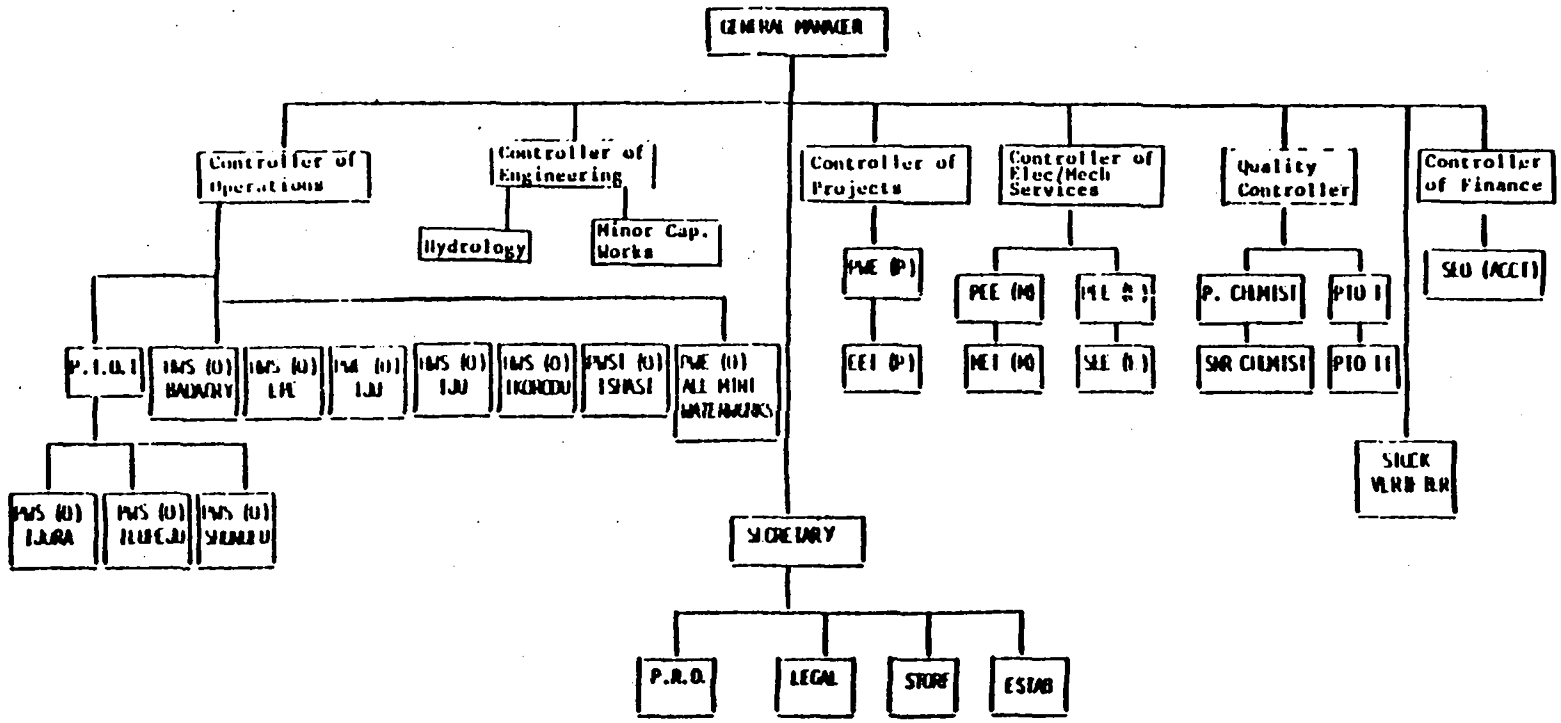


Figure 7

NIGERIA

LAGOS STATE WATER CORPORATION

PROPOSED NEW ORGANIZATION CHART

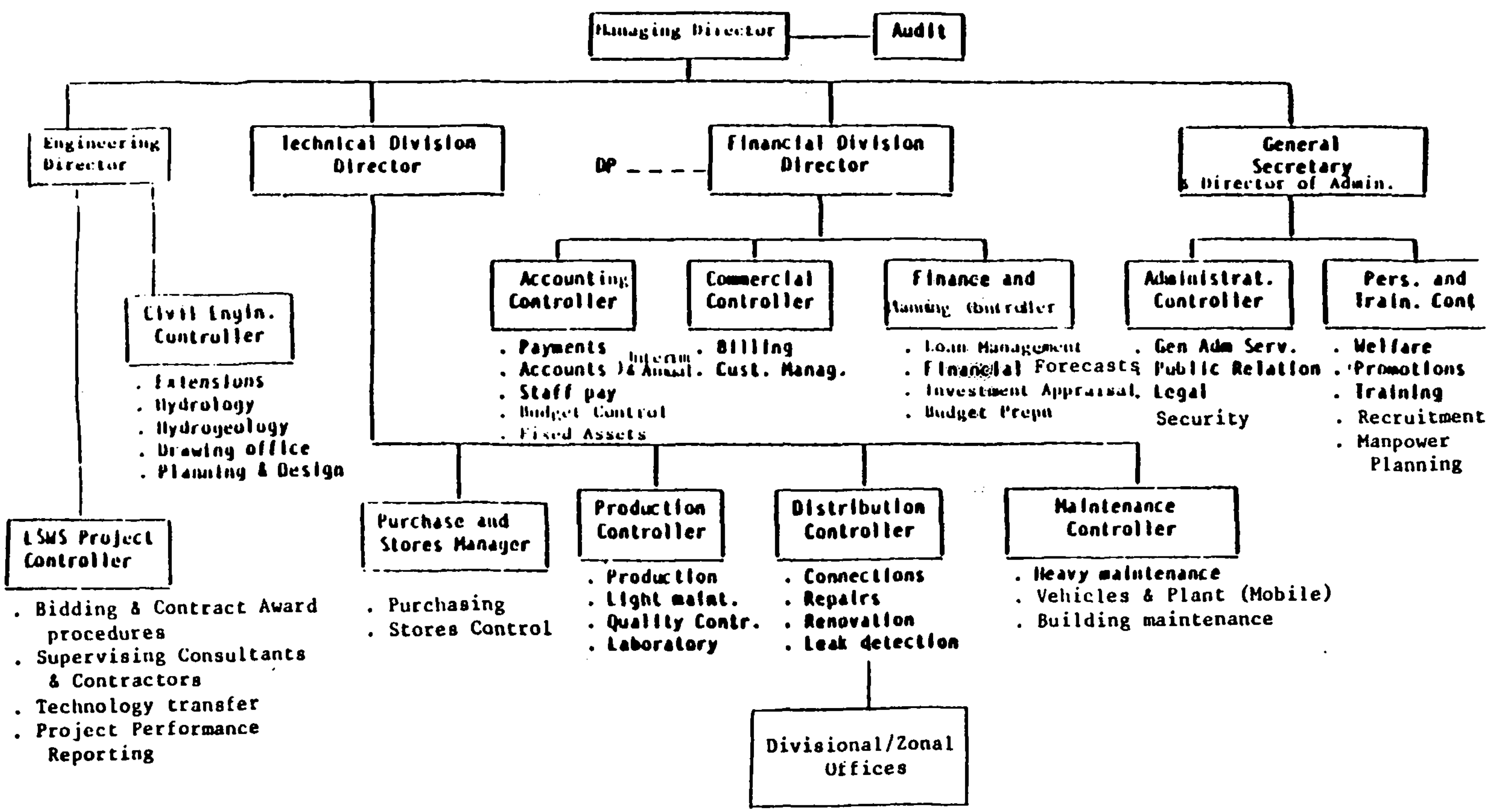


Figure 8

REVENUE GENERATION FOR WATER SUPPLY TO LOW-INCOME URBAN AREAS : A NEED FOR INNOVATION

MICHAEL SEAGER
International Reference Centre for Community Water Supply and Sanitation, Hague, Netherlands.

SYNOPSIS

It is widely acknowledged that both the water supply and sanitation and the economic conditions of the low-income poor of urban areas in Africa and Asia vary significantly from city to city and district to district. It is difficult therefore to make generalisations. One factor that is common to most cities however is a growing fear that serving the burgeoning urban poor with water and sanitation in coming years will impose an impossible financial burden on municipalities and city authorities[1] (1).

Against this background the paper will suggest that, providing parallel issues such as early and continuing user-participation, appropriate choice of service levels and maintenance provisions are attended to, the financial burden can be sizeably reduced by thoughtful introduction of appropriate revenue generation methods. Secondly it will propose that the adoption of an innovative and flexible approach in selecting, designing and adapting revenue systems to meet the needs and potential of diverse user groups is likely to be the most important ingredient of success.

INTRODUCTION

The reality of explosive urban growth in the developing world is hard to encompass. By the year 2,000, 44% of the population in developing regions will be in urban agglomerations and of these, half, or over 450 million people, will be struggling for survival in slums and shanty towns[2] Providing these vast new urban populations with basic services, including water supply and access to medical and educational facilities seems an insurmountable problem. Nor is it sufficient to argue that providing services to low-income urban areas merely exacerbates the problem by encouraging further migration from rural areas; it is estimated that natural increase in existing urban populations will in any case account for over 60% of the anticipated growth[2]

So how, as far as water and sanitation is concerned, can the challenge be met? Assuming in the first place that the political will exists to provide services to low-income, often illegal and temporary dwellers, the fundamental obstacle is usually one of money. Whilst large scale external investment funds are sometimes available to meet pressing low-income urban needs, most donors will increasingly want to be reassured about recovery of a significant part of the recurrent costs, including money for operation and maintenance. Programmes for low-income areas will not escape the discipline now being increasingly imposed on rural schemes. And yet, whilst appropriate technologies often exist and there is growing experience of working in partnership with the users, the problem of revenue generation continues to be put aside, in low-income urban as well as rural supplies.

Nevertheless promising experiences

now coming in from several regions of the world indicate low-income urban areas can be successfully served and financed, and without inevitably placing a financial burden on other consumers, or diverting funds from other, equally needy, development sectors. But the message seems to be, as in the rural sector, that there is no one answer to revenue generation. Innovation in finding and adapting appropriate financial solutions and flexibility in changing and improving them with time seem to be the ways to success. The rest of the paper will emphasise this, showing the degree to which low-income urban groups may vary, why conventional revenue policies do not meet the needs, and finally selectively illustrating the wide range of revenue-yielding solutions that could be considered. Three examples will be given of how success has been achieved in practice, sometimes under most difficult circumstances, through innovation.

SOME VARYING CHARACTERISTICS OF LOW-INCOME URBAN POPULATIONS

Low-income urban peoples are no more uniform than many of their rural cousins. The varying characteristics of each group to be served will therefore greatly affect the type of revenue generation system that is likely to prove successful. These characteristics need careful assessment in conjunction with users, to determine what is or is not feasible in a particular case.

But though necessary, assessment is not always straightforward. As an example, suppose that a revenue system is being planned that requires a significant degree of organisational input and responsibilities from the user-group as a whole. Is the community sufficiently unified to sustain such a system?

There is at first sight an obvious difference between the cohesiveness to be expected from large new squatter areas, impersonal and insecure, compared with older and smaller slum areas (barrios or wards), with an established and strong local identity and tradition. And yet the squatter-area dwellers may in fact be better unified through sharing the insecurity of having no legal rights to the land, and through having arrived in the city together. On the other hand the slum dwellers, through being more secure, may be more individually independent and may have arrived from different rural areas over a longer period of time or be long established urban dwellers.[3,4]

The example shows then how carefully the different factors need to be balanced, before deciding what might be the most appropriate revenue systems for further discussion with the users. Characteristics*, some knowledge of which might help agencies and users design appropriate revenue generating systems, include:

- degree of homogeneity within the community in terms of income, water use, shared interest, origin, age distribution, initiative and potential for working together;

- whether the population is transient (and average length of stay), settled, or a mixture of both;

- size, (generally within groups less than about 500 persons or so, most members are known to each other on a face-to-face basis);

- local identity and scale, (e.g. smaller groups of poorer house-

* after ref. (3)

holds established as enclaves within other areas may be more unified);

- relative awareness of social rights and needs and ways to achieve these, together with level of awareness of the potential health benefits, as well as the more obvious convenience benefits, that improved services and environment can bring;

- extent, strength and integrity of leadership (how active, whether better educated, whether representative of all users or only the better-off);

- degree of existing community relationships and organisation (often stronger in distinct districts, isolated areas, or where a common threat or insecurity is shared);

- nature and degree of security of housing tenure (squatters? tenants? owners?) and income (e.g. seasonable employment?);

- evidence of other community or individual enterprise, particularly those requiring continuing recurrent cash contributions;

- degree of existing commercial awareness and experience, (whether there is commercial exchange outside the immediate community);

- opportunity to use or potential for training communal or voluntary skills (fund raising, collecting, book-keeping).

As a general starting point, interest in water and environmental sanitation will usually be high amongst low-income urban dwellers. This can be a strong factor in helping people appreciate that improving such services is worth a reasonable personal outlay in terms of money and other commitments. Reasons for this interest include the obvious immediate impact of water shortages, flooding and insanitary conditions, but may also include factors such as time-saving potential, privacy and safety of women and the possible secondary economic interest in water for beer-making or commercial clothes - washing for example.[4]

Whether this interest is an individual interest or a shared, community interest depends on the history and demography of the people in the area. A shared status or ethnic origin may bond a particular community but will also mean communities can be expected to vary from area to area within the city, demanding possibly different and locally appropriate solutions.[4]

Urban life often means more impersonal behaviour, with weakened community bonds. Nonetheless in a low-income urban environment common problems may become more visible due to close proximity, and generate new feelings of community spirit and self-reliance[4] A common problem in involving users in revenue generation remains however a general lack of confidence, both within an urban community in dealing with financial matters and of the agency in allowing them to. In part this is due to suspicion amongst relative strangers in newly-formed community groups, and to there being few sanctions to apply against defaulters anyway[3] Often there is equal mistrust on the part of the users for agency capability and fairness in handling water revenues.

As far as new arrivals from the countryside are concerned there is a useful potentially positive factor to build on when exploring options for water service and accompanying revenue generation. This is the reservoir of practical initiative, clearly evidenced by their migration to the city in the first place. This still holds true in part even if migration was forced on the people by rural poverty or encouraged by an idealised vision of city life. The initiative and willingness to adapt, already displayed by the new arrivals, could well be positive factors in generating input and responsibilities towards water supply at user level.

And there are many other such factors and characteristics, many unique to particular cities and districts. Such factors will each have a direct or indirect bearing on the relative sense of identity and solidarity of the community, its ability to manage and sustain a particular revenue generating system, and conversely the level of agency responsibility and support required to balance this.

THE FAILURE OF THE CONVENTIONAL APPROACH

In the past, where the decision has been taken to offer some form of water supply to low-income urban users, it has too often been on the basis of :

- lowest and cheapest possible service levels (often shared public taps, widely spaced along main access roads). The choice between a free standpost, inconveniently sited and which people do not want, and an expensive house-connection, which they cannot afford, is, in reality, no choice at all;

- acceptance of a policy of free water, subsidised by other consumers, or a short-lived attempt at the introduction of an inappropriate revenue generation system;

- concentration on physical coverage rather than use, impact and financial and operational viability throughout the working life of the system;

- little if any discussion with users on their preferences, needs and ability to contribute (financially and in terms of assisting operation and maintenance);

- half-hearted commitment to providing a service from the outset, leading to a ready acceptance of 'insoluble' difficulties and a low priority for repair/ problem solving.

The negative experiences that have come from such approaches has meant a general pessimism that solutions to serving low-income areas, particularly financial solutions, can ever be found. Nonetheless, there is increasing evidence that providing the characteristics of the users are carefully assessed and appropriate systems designed and introduced, revenue generation can be successfully achieved in sustaining services to low-income areas.

But this demands pragmatism as well as innovation. It is no good promoting a financial management system based on community participation for ideological or other reasons in an area whose residents have no sense of, or potential for developing, community cohesion. Similarly, where such cohesion does exist and there is an opportunity to work together, not to use it to help internally manage and control revenue generation would be to waste a valuable asset.

In the following section, three examples are given to illustrate the range of possible revenue generation and management solutions, each solution involving a greater or lesser degree of user participation. Each has proved successful in practice because it was appropriate to the particular user characteristics, needs and capabilities at the time.

AN ALTERNATIVE FRAMEWORK FOR PLANNING REVENUE GENERATION

Assessing Characteristics and Selecting Options

It has already been suggested how important it is to assess and recognise the characteristics of a user group, so that innovative and appropriate revenue-generating systems can be formulated and discussed with the users. This growing knowledge about the user group and its needs and capabilities should be kept in mind :

- when choosing or designing one or two potential revenue systems which might work in a particular area for onward discussion;

- in planning how to present, discuss, amend and agree a suitable system with the users;

- in introducing, supporting and managing a particular system and adapting and improving it in service in greater or lesser partnership with the users.

But how can this assessment and updating of user characteristics be done? Opportunities for learning may arise in a number of ways, including :

- carrying out limited and appropriate base line studies;

- sounding out local knowledge and experience from ordinary people as well as leaders;

- learning about the experiences of other projects and interventions in the area.

However it is built up, once sufficient information is available one or two possible ways of generating revenue can be formulated, for onward discussion and development with the users. There is naturally a wide range of solutions but three examples, each requiring different degrees of user participation and responsibility, are now put forward for illustration.

Providing Services to the Users (no direct community participation, limited responsibility)

Providing direct services at cost to the users may well be most appropriate solution in many cases where the users are known to be temporary dwellers. An example would be an area housing migrant or seasonal workers. Such users have some money and an immediate need for services. On the other hand, trying to introduce longer-term community-based approaches here, in a user group that is essentially in transit and with little community spirit, could be counter-productive. Instead a solution based on water kiosks or centralised sanitation, water, laundry and bathing facilities, where specific services are provided at a uniform charge, may be the most appropriate solution.

An example is the Sulabh Shouchalaya Sansthan experience in Patna, India[5]. Here a non-governmental orgnisation has constructed and maintains a large number of attended sanitary facilities near public places and low-income slum areas. For a fixed fee (free for children and destitutes), anyone can use the latrines, bathing and laundry facilities or collect water.

The service is cost-covering and serves the real needs of a floating population, such as rickshaw pullers and others. Although poor, such people have small sums of money available for sanitary and water facilities, but no normal access to them.

Providing Services with the Users
(partial community participation, and shared responsibility)

This would be an appropriate basis for a revenue generation system where a significant degree of community cohesion and potential had been identified but where external stimulation and support was needed. A partnership would be set-up between the user group and the agency*, whereby each had its specific responsibilities and obligations. One of the obligations of the users would be to contribute to or cover recurrent costs via an agreed revenue generation system, and perhaps to directly contribute towards maintenance as well.

A good example of this balanced responsibility comes from Malawi. Here, within the Urban Communal Water Point programme, low-income user groups in satellite communities around urban district centres are brought into the water supply system via neighbourhood standposts. Water to each standpost is metered. User groups are responsible for monitoring individual use and agreeing and collecting monies to cover the monthly billing. Whilst communities take a high level of responsibility for operation and revenue generation, maintenance responsibility remains in the hands of the agency operator, whose costs are covered by the rates charged for the water[6]

* 'agency' could here be governmental agencies at state or local level, non-governmental agencies or private promoters with an official mandate.

Providing Services by and through the Users
(full community participation and responsibility)

The provision and management of the water service by the users themselves under the aegis of the agency is in many senses the ideal. The agency authorises and monitors the water source, or sells water in bulk to the user area. There are thus few financial risks for the agency and responsibility for distribution, equitable charging and collection of revenue remains with the community. Whilst low-income urban communities that are both able to take on and are given such organisational responsibilities are not common, where communities have been able to take up the initiative they have often been extremely successful.

An example is the shanty-town 'favela' Vila 31 de Macro in Brazil[7] Here earlier conflict with the authorities about the establishment of the favela had led to a feeling of community solidarity and the establishment of a legally constituted co-operative.

This rapidly initiated a number of self-help activities, beginning with a school and a pharmacy and quickly progressed, with the agreement of the authorities, to the establishment of the community's own, internally financed and operated, piped water supply.

INNOVATION, FEASIBILITY, PROGRESSIVE DEVELOPMENT

In putting forward these three levels of community participation and responsibility the intention is not to over-simplify. Rather it is to give three examples of how different approaches to providing services, and recovering revenue for them, must be chosen depending on the specific characteristics of the low-income urban group being served. There are naturally many stages in between these three solutions, ranging from full agency responsibility for water supplies and point-sale at cost at one extreme, to full 'sub-contracting' of services and cost recovery to the users themselves at the other. Each will have its particular merits and de-merits in particular circumstances.

And should different solutions be applied in different areas of the same city? The answer is probably yes, provided there is broad equity and an equal opportunity for user groups to progress to more independent systems when ready to do so.

So to innovation in selecting options and flexibility in refining them in discussion with the users we should perhaps add the need for progressive development with time. Water supply in urban areas never stands still for long but in low-income areas, with rapidly changing numbers, composition and income capacity, the need to keep the basis of supply, and the revenue system that goes with it, under constant review and development is even more important.

Revenue generation in low-income urban areas can be made to work then, but it needs innovation, flexibility and a commitment to progressive development. Inherent in this is an acknowledgement that if people get what they need, they will usually pay a fair price for it; that they are more likely to pay if they are involved from the beginning in the planning, design, implementation and management of the revenue generating system, (as in other linked aspects of water supply such as maintenance); and that the responsibility on the agency to perform by providing a fair service in return is just as crucial as that of the users in keeping their side of the agreed partnership.

A recent IRC Occasional Paper "What Price Water"[8] looks in more detail at revenue generation options, the social and organisation frameworks within which they could be applied, and the vital links with other aspects of project activity. A companion literature review on revenue generation will also be available soon[9].

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EXPERIENCES IN THE APPRAISAL OF WATER SUPPLY AND SANITATION PROJECTS

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SYNOPSIS

India has declared massive water supply and sanitation objectives to provide safe water supplies to 100 percent of urban and rural population and sanitation service coverage to 80 percent of urban and 25 percent of rural population by 1990. This will cost about Rs.25,000 crores (US $ 19 billion) to the country. The timely completion of projects is therefore in the interest of all agencies as this would reduce the overall costs. The whole project preparation and completion phase should be carefully studied and streamlined. Delays have occured in the past due to variety of reasons such as late procurements, redesigning, increased implementation costs, increased financial burden, loss of momentum etc. Theauthor discusses the possible remedies to avoid such delays which can be: a good project monitoring information, detailed engineering of the project, streamlining of tender procedures, prequalification of contractors, early administrative action etc.

INTRODUCTION

PROJECT CYCLE

The Sector Background

The countrywide development and implementation of new projects in the sector is essential if we are to property address India's declared Decadal Water supply and sanitation objectives to provide safe water supplies to 100 percent of urban and rural population by 1990 and sanitation service coverage to 80 percent of urban and 25% of rural population. This is a massive objective implying providing water to about 410 million people and sanitation services to some 210 million. This program may possibly costs upwards of Rs.25,000 crores (US $ 19 billion) and the implementation of a very large number of individual projects if the target is to be properly addressed.

Project Cycle Components

The importance of the project cycle in this context cannot therefore be over emphasised and it may be useful to look briefly at project preparation activities in relation to the whole project cycle which may be considered as follows in relation to Bank funded operations:

- Identification
- Preparation
- Appraisal, Negotiation and Lending Operations
- Legal Agreements and Effectiveness
- Implementation and Commissionning
- Completion

It may be appreciated that the whole project cycle implies an overall time frame 10 - 15 years. Typically world

Bank supported sector projects in India have historically required a period of 7 - 9 years only for implementation after the finalisation of the legal agreements. All current water and sanitation lending operations are predicated on this time cycle. This does not imply, of course, that agencies cannot execute projects in a shorten period if they so wish. In fact, they are encouraged to do so and it is in their best interest since this would reduce overall costs by saving on price contingencies.

PROJECT PREPARATION

The importance of the identification and preparation phases of the project should be properly understood in relation to the whole process. Typical time fromes for these activities in India have extended through 3 - 4 years for a variety of reasons which we will address in the following sections. However, it is readily apparent and well recognised tht the whole project preparation phase must be very much streamlined if thedecadal objectives are tobe properly addressed. There is therefore urgent need to improve the institutional capability of executing agencies to square up to these needs.

In order to improve the efficiency of this process it may be helpful to give some appreciation of the outputs necessary in order that the World Bank, or any other lending agency, can properly appraise a project to see if it is suitable for lending operations. The output should include the following major components:

i) Properly justified technical proposal based on factual field data and observations, and including appropriate sector background;

ii) identification of project components in sufficient detail to present reliable cost estimates based on detailed engineering analysis to the maximum extent;

iii) Financing plan in relation to overall agency financial operations and analysis of historical and projected operations;

iv) institutional arrangements; capability, administrative capacity, staffing, training;

v) economic justification, social and health benefits; and

vi) impact of project on operation and maintenance, revenues, tariffs and property taxes considerations.

The excuting agencies should be encouraged to establish "Project Cells", which should be staffed up with experienced multi disciplined, professionals, at the start of the preparation activities. It will be appreciated from the foregoing outputs that the project preparation activity comprises much more than a basic engineering study and needs an all round professional team including management, financial and economic analysts apart from the technical and engineering inputs. This aspect is very critical to the successful and timely achievement of project preparation objectives and needs to be stressed in this gathering because, in the past, a major cause of delayed project preparation stems from the fact that many project presented for World Bank review did not even address financial considerations and were simply enginering studies. In future, project reports must properly address operationa nd maintenance, institutional financial and economic implications, otherwise delays will occur while donot agencies seek to review these aspects.

However, in the light of increasing awareness of these needs, it is pleasing to record that serveral sector agencies in India are now developing a sound capability totake a much more positive role in the whole preparation activity. The capability has been built up with the active support of the local consulting sector (which is itself also going through a learning exercise in the process). This expertise now needs to be replicated on a broad scale countrywide so that new and less experienced agencies may also begin to benefit from this experience. The overall objective must be cut down the processing time for projects to the maximum extent and ultimately encourage the aaagencies to effectively appraise their own projects.

Elsewhere in the region we have been able to substantially reduce the preparation time frame by adopting a number of interrelated initiatives including:

- Identifying and addressing institutional shortcomings at an early stage;
- timebound plans of action for agency activities;
- frequent intervention by World Bank staff;
- setting up project cells staffed up by agency/consultant personnel;
- encouraging interactions between engineering and financial desiplines; and
- trainging workshops to improve data management and technical operational efficiency (e.g. computer network analysis and financial management)

These initiatives are commended to your attention. However in striving to improve efficiency and save time we must notlose sight of the need for adequate detailed analysis so that the agency and the workd Bank maymove ahead confidencly into the later stages of the project lending and implementation. In the next sections, major causes for delay will be discussed inmore detail and possible lessons and remedies will be suggested.

DELAYS AND REMEDIES

Delays

For too often in the past, projects have been appraised on the basis of inadequate feasibility information and budget estimates for reasons with which we are all only too familiar. In many cases this practice has resulted in delays during the project implementation due to:

i) delays in setting up project calls

ii) procurement delays

iii) restructuring and redesign of project components

iv) vastly increased implementation costs.

v) time and cost over runs

vi) inability of agency to meet financial covenants

vii) very slow disbursement of loans and consequent cancellations

viii) increased financial bruden on executing agencies.

ix) Operation andmaintenance not properly appreciated.

It is therefore important to balance the necessary level of detailed preparation with the need to proceed expeditiously. It may be that an extra 6 - 12 month in preparation will pay off in the implementation phase. It is also very important to maintain the momentum of the project. Loss of momentum between phase of project is primary cause of delay. This can arise due to:

i) signing of Agreement;

ii) institutional arrangements

iii) agreement on tender packages

iv) preparation of tender documents

v) tendering procedures etc etc

vi) appointment of technical assistance

Remedies

Suggested remedies include the followings:

Project Monitoring:

Project monitoring information is essential for management decision making and we would particularly commend the Project Preparation and Control Cell (PPCC) activity which has been established by Bombay Municipal Corporation (MBC) in connection with ongoing water and sanitation projects. This PPCC operation provides an excellent model for replication within the South Asia region (and elsewhere). It has been developed by BMC with local consultancy assitance and could be replicated widely with great benefit (Your Chairman may wish to give his comments on this PPCC activity since he is a primary beneficiary!)

Detailed Engineering:

Engineering should be detailed to the maximum extent during project preparation within the time frame established by the agency so that the cost estimates can be accepted with confidence.

Major Contracts:

All major contracts should be identified as soon as possible (preferably before the World Bank appraises the project).

Tender Procedures:

Tendering procedures, whether International as Local bidding, should be agreed so that this activity is clearly defined at the start of the project.

Prequalification of Contractors

It is strongly recommended that agencies prequality contractors for major contracts, this activity should be properly planned to avoid delaying tender invitations (PPCC has important contribution in this respect)

Administrative Actions:

Necessary administrative actions should be addressed expeditiously with the objective of avoiding delays e.g. if improved revenues are required within the financial constrants of the project, the necessary procedures should be initiated in due time. Delays inevitably mean that project momentum is lost.

Agency Responsibility:

It should be clearly established at the start that the project identification and preparation is an agency responsibility so that a pride of ownership is developed. This is a very important concept of a 'bottom up' approach to project development which has been success fully adopted in recent funded projects. This applies particularly in the case of projects involving a number of executing agencies each with several components.

CONCLUDING REMARKS

It is hoped that the foregoing presentation will have served to provoke same throughts which may lead ultimately to a substantial cut back inthe 'lead in' time required for agenciesto prepare projects ready for appraisal by external donors. The examples and suggestions have been drawn from recent experiences in the preparation of sector projects in the South Asia region for World Bank assistance. However, many of the issues are of a general nature and could be usefully applied in other lending situations.

It is apparent that there in an 'in country' capability to improve this particular activity in the project cycle. Some agencies have made substantial efforts and develcped good capability. This effort needs to be diseminated and replicated on a wide scale in the besdt national interest.

It is also recommended that an 'operational guideline' and covering all aspects of project preparation could be iin national interest. This would provide a manual for excuting agencies to use in the same way that the design manuals are followed.

MULTI-PURPOSE PROJECT-SHARING OF COST

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SYNOPSIS

Apportionment of cost of multi-purpose project amongst the various uses/ users is an important aspect to be decided in the overall planning of the water resources development projects. The paper deals with the various methods in vogue at present for allocation of cost of the multi-purpose projects. No single method can, however, be recommended for adoption for allocation of cost. The various methods discussed in the paper may have to be considered by the various users and a method for which there is an overall agreement could be adopted. Union Ministry of Water Resources have recently advised that all new irrigation projects should, at the very planning stage itself, include a component of drinking water supply to meet the drinking water requirement of rural areas, if such a possibility exists, in consultation with the concerned local State Government bodies. This recommendation may, in many cases, involve apportionment of cost for domestic water supply component also. It is, therefore, felt that a review of various methods available for cost apportionment will be useful in this context also.

INTRODUCTION

Storage reservoirs are now-a-days generally planned and developed as multi-purpose schemes by providing multi-purpose benefits like irrigation, flood control, water supply to meet municipal and industrial requirements, hydro power, navigation etc. with a view to achieving an optimal use of the available limited water resources. The allocation of cost for these multi-purpose projects which serve two or more than two purposes, amongst various uses and the users is, therefore, important for projects planning and determining the techno-economic viability of the project.

Apportionment of cost for multi-purpose project is an important aspect which needs to be decided before the project is taken up for implementation. This needs to be handled judiciously and decided amicably to avoid disputes and consequently delayed development of a region and economic loss to the country as a whole.

The question of apportionment of cost and allotment of reservoir storage space for different purposes in a multi-purpose project was examined in great detail by a Committee constituted by the erstwhile Ministry of Irrigation and Power and subsequently by a Sub-Committee of the 7th Irrigation and Power Seminar held at Bangalore in September 1960. The Sub-Committee had recommended allocation of cost to only three main purposes (i) Irrigation (ii) Power and (iii) Flood control. They had also suggested that other purposes should not be tagged with any of these three main purposes, unless the cost of such a subsidiary function exceeds 10% of the total cost of the project.

ALLOCATION OF COSTS

Erstwhile Union Ministry of Irrigation has issued guidelines[1] for preparation of detailed project reports for multi-purpose projects. It recommends that the allocation of cost for each component of the multi-purpose project be worked out as per IS: 7560 - 1974 which indicates that the cost of other components like water supply, road/railway bridges over the head works be shared by the concerned departments on mutually agreed basis.

The apportionment of joint cost may have to be made along different users or among different States/U.T. Govts. who are sharing benefits of the joint project. The main objective of allocation is to distribute the cost on equitable basis amongst various purposes. This is somewhat complicated and it must be accepted at the outset that no universal agreement has yet been reached between the views of the various committees and other authorities who have studied it. No two cases are alike and each must be considered on its merit.

BASIC PRINCIPLES FOR ALLOCATION OF COST

The Indian Standard[2] (IS: 7560-1974) gives following guidelines[1] for allocation of cost among different purposes of river valley projects. The use of one structure to provide more than one service makes possible the provision of services at less than the total cost of separate structures for each service. This being so, the basic principle for cost allocation is that the savings derived through the use of the combined structure for numerous purposes should be shared equitably by these purposes. Cost allocation is, therefore, the process of apportioning the cost of a multi-purpose project equitably among the several purposes served and includes the specific or separable cost of individual features which serve only a single purpose and joint cost of the features which serve several purposes. The central problem is the division of joint cost for all structures which produce several kinds of services. The difficulty involved in this problem can be minimised by arriving at the smallest possible figure of the joint cost.

The basic principle, therefore, to ensure equitable allocation to the various purposes is that the cost allocated to a purpose should be :

(a) not more than the benefits to be achieved by that purpose,

(b) not more than the cost of an alternative project built for that purpose alone, and

(c) not less than the cost of the items meant for the specific (exclusive) use of that purpose.

Besides the above three basic principles, due consideration has also to be given to the national priority or urgency of any purpose over others at the time of formulation of the project or its subsequent review.

Common Allocation Procedures : The different methods for cost allocation generally have a common procedure followed in four steps, namely: (a) to determine specific costs which serve each of the purpose, (b) to assign such specific costs to various purposes from the capital cost and to find out the remaining joint cost, (c) to distribute joint cost equitably to various purposes, and (d) to sum up, for each purpose, the specific cost and the share of joint cost chargeable to that purpose.

METHODS FOR COST ALLOCATION

Following are some of the methods currently in use for cost allocation :

(a) Alternative cost method,
(b) Alternative justifiable cost method

(AJC method)
(c) Bearability concept
(d) Benefits method
(e) Ceiling allocation method
(f) Equal apportionment method
(g) Separable costs - Remaining benefit method (SCRB method)
(h) Use of facilities method
(i) Vendibility method

The methods are briefly described below.

Alternative Cost Method :

In this method, the alternative cost of a new single purpose project is split up into two parts, namely, the specific cost equal to that in the multi-purpose project, and the balance. The joint cost of the multi-purpose project is then distributed in the ratio of the balance. The allocated joint cost is then added to the respective specific cost to arrive at the total cost allocated to each purpose. The alternative cost for each purpose may be defined as the lowest cost of achieving the same or equivalent benefits in single purpose. Structure that will accrue to each purpose in the multi-purpose structure. The alternative should be real in the sense that it can be built and if built would produce equivalent benefits. The specific cost is the cost of that portion of the project which is built for exclusive use of a purpose. Joint costs are the costs of identifiable physical facilities which serve more than one purpose. They are the residual costs representing the difference between the cost of the multi-purpose project as a whole and the total of the specific cost for all project purposes.

Alternative Justifiable Cost Method :

This method is similar to the alternative cost method, the only difference being that the specific cost is subtracted from the justifiable cost. The joint cost is then distributed in the ratio of the balance as in the alternative cost method and the cost allocated to each purpose/function is worked out by adding the respective specific cost to the allocated joint cost. The justifiable cost is the benefit accruing to a particular purpose or the cost of an alternative project whichever is less.

Bearability Concept :

This concept suggests that the net revenue from the minor advantage (gross revenue minus the operation, maintenance and depreciation on both the specific cost and share of the joint cost of the minor advantage) shall be equal to interest charges on the capital investment on the minor advantage both specific cost and share of joint cost chargeable to the minor advantage.

Benefits Methods :

In this method, the cost is allocated to each purpose by its specific cost plus a share of the joint cost in direct proportion to the estimated net benefits accruing to that function.

Ceiling Allocation (or Priority of Use) Method :

In a multi-purpose project the various purposes to some extent compete with each other for the use of the water or storage space. The functions have different timing for the periods for optimum storage and release of water and thus all of them cannot be served in an optimum manner.

If some of the functions are served proportionately more than others, the priority of use method will give special consideration to such priorities.

The priority of use method assigns the specific cost entirely to the individual purpose and assigns the remaining joint costs to project purposes in a descending order of priority. Thus, the top priority purpose is charged with joint costs equal to the lesser of two amounts, namely :

(a) the benefits minus specific costs assigned to that purpose, or

(b) the cost of the most economical alternative minus specific costs assigned to that purpose.

The remaining joint costs are then allocated in the same manner to the other functions in order of priority. In this way, the higher priority functions are assigned the maximum allocation represented by alternative joint cost for these purposes, thereby relieving the lower priorities from sharing the joint costs.

Equal Apportionment Method :

In this method, the joint cost is distributed equally among the different purposes served by multi-purpose project. It is based on an arbitrary assumption that an equal portion of the joint cost is reasonably chargeable to each of the purposes.

Separable Cost - Remaining Benefits Method (SCRB Method) :

The basic principle of distribution in this method is the same as in the alternative justifiable cost method. It may, however, be said to be a refined form of that method in so far as the concept of scientific cost for each purpose is replaced by the concept of separable cost. Separable cost for each purpose is subtracted from the justifiable cost and the remainder which is really the 'remaining alternative cost' is termed, in this method, as the 'remaining benefits' for the purpose. The joint cost (which in this case is the difference between entire project cost and the sum of separable cost) is, then distributed in the ratio of remaining benefits for each purpose/function. When separable cost for all purposes/functions consists of specific cost only the separable cost remaining benefits methods is identical to the alternative justifiable cost method in computation and results.

Use of Facilities Method :

This method is based on the premises that the joint cost should be proportioned along the various functions according to their amount of use of the joint facilities. There are usually two approaches for assessing the use for each purpose. They are the 'capacity approach' and the 'water-released approach'.

In the 'capacity approach' the joint cost is distributed in the ratio of storage assigned to different purposes, whether or not those storages are actually used. Two or more purposes may make use of the same reservoir capacity alternately or simultaneously. For instance, a part of flood waters as stored may be used for irrigation purposes. This storage, would then be included both for flood control and irrigation. Similarly, power storage may be utilised for irrigation, after the water has passed through the power house. In the 'water released approach', the joint cost is distributed in the ratio of total quantity of water released for each purpose. For instance, a part of flood waters as stored may be utilised for irrigation or to maintain the minimum depth for navigation or to produce secondary power. The total quantity of water in a flood season may be greater than the capacity of the storage space for the purpose. Thus, an estimate has to be made of the total quantity of water that may have to be held back in order to ensure flood protection to damage centres downstream keeping in view the average flow conditions downstream of the reservoir. Similarly, a portion of water released from the power house may be utilised for irrigation, in addition to that for exclusive storage for irrigation. The total quantity of water likely to be released in the interest of each purpose has, therefore, to be estimated. The joint cost is that distributed in proportion to the total quantity of water released for each purpose.

Vendibility Method :

The vendibility (the value in the market of the services rendered by a project purpose expressed as an annuity) theory assumes that the products of a multi-purpose project are sold in an entirely free competitive market. The method assumes that the revenues from all benefits of multi-purpose project shall at least be equal to the total cost of the project. The revenues of each benefit should be sufficient to cover the specific costs and in addition should contribute towards the joint cost in such a manner as to render the entire project remunerative with revenues realised from each of the benefits at competitive prices. In this method, a particular purpose, the revenues from whose benefits are not sufficient to meet its cost are subsidised by other purposes the benefits from which are produced at more competitive price.

The method of dividing joint cost is as follows :

(a) The specific cost is subtracted from the estimated revenues for that purpose.

(b) The remainder is capitalised at the prevailing rate of interest, and

(c) The remainder is the share of the joint cost or is the upper limit of the share of the joint cost for this particular purpose.

SUITABILITY OF THE VARIOUS METHODS

The use of any one of these methods is not strictly governed by a set of conditions under which each method is applicable. Actually, the selection is governed by the fact whether a particular method satisfies the broad and basic principles detailed above and whether it ensures the most equitable allocation of cost of various purposes/functions of a multi-purpose project. The set of conditions under which each method has been generally found suitable has been described in the following paras for the guidance of the user.

Alternative Cost Method gives no consideration as to whether the single-purpose project is itself economical or not and may be used when this consideration is not of significance.

Alternative Justifiable Cost Method meets the shortcomings of both, the benefits method and the alternative cost method by utilising the lesser of the two values. The method satisfies all the three basic conditions.

Bearability Concept takes into consideration the fact that the cost allocation of the project should also be so oriented that the major part of the cost goes to that function of the project which may pay it back without undue strain.

Benefits Method requires that the benefits be measured on a comparable basis. However, monetary benefits are not always a reliable measure of the relative importance of various purposes and the determination of what constitutes usable benefits is often subject to controversy. This method satisfies the conditions (a) and (c) but does not fulfil the requirements of condition (b).

Ceiling Allocation Method has the advantage of taking cognisance of gaps in urgency of the participating purposes, thus the less urgent purpose gets the advantage of having to share a lesser part of the joint cost. The method, however, suffers from the deficiency that the purpose with secondary urgency does not necessarily, in all cases, get a proportionately smaller share of the total or joint cost.

Equal Apportionment Method is largely a working rule for the sake of simplicity and ease of calculations. This method should be avoided unless none other logical methods may be applied. This method may be applied when the cost of alternative single purposes projects, the benefits and savings according to each of the purposes are almost equal. This procedure does not satisfy any of the conditions except (c).

Separable Costs - Remaining Benefit Method (SCRB Method) results in a more equitable distribution of project cost. It introduces a refinement in reducing the amount of joint cost that is to be distributed by utilising values of separable costs instead of specific costs, the joint cost is reduced, thereby correspondingly reducing chances of dispute of error in the ultimate distribution of cost. This method, however, is laborious in that, the separable costs for all the participating purposes are to be separately assessed. In this method all the three basic conditions are satisfied.

Use of Facilities Method has merit of attempting to allocate the joint cost on the basis of use of the waters for each purpose of the project. However, it suffers from the deficiency that there is no upper limit to allocation in relation to either benefits or an alternative justifiable cost. Although the two common measures of use are the storage capacity and the quantity of water released, at one extreme flood control is directly related to the capacity of reservoir to store water and at the other extreme, the irrigation is primarily dependent on the volume of water released. The water release approach is not an entirely satisfactory method if the water is released for more than one use. If the 'capacity approach' is used, it neglects the dynamic variations and so may fail to measure the reasonable use by the function of the project. If the two approaches could be satisfactorily reconciled in one single method, the use of facilities method would be of far greater value. It satisfies all the three basic conditions mentioned earlier. It is however, useful in making sub-allocation on the simple basis of a proportionate use of a given facility as measure in physical terms, such as the division of the cost of canal between municipal water and irrigation water.

Vendibility Method is not usually applied to public works, the benefits from which are generally not offered for sale in the open market, as in the case of private business under conditions of perfect competition. The method does not satisfy any of the conditions except (b). Use of facilities method is generally adopted for allocation of costs of multi-purpose projects. Erstwhile Union Ministry of Irrigation also advocated this method for cost allocation.

CASE STUDIES

Some typical examples wherein cost apportionment has been done for various uses are given under :

The Bhatsa Irrigation Project, Maharashtra[3] which envisaged construction of a storage dam across Bhatsa river is essentially for augmentinq water supply to the Bombay Metropolitan City as well as for providing irrigation facilities. The first stage of the project (the dam is proposed to be constructed in two stages) aims to provide a storage capacity so as to meet the domestic water supply to Bombay Metropolitan City as well as to meet irrigation requirements of 5906 Ha. The gross capacity of 265.92 MCuM comprises of 180.74 MCuM for domestic water supply and 85.18 MCuM for irrigation. Sharing of cost for head works costing Rs.812.12 lacs has been done accordingly in the ratio of 180.74 HaM and 85.18 HaM between domestic water supply and irrigation. The share cost of domestic water supply and irrigation components works out to Rs.653.79 lacs and 158.33 lacs. The method obviously followed for apportionment is facility use method.

The Singur Project[6] envisages construction of a dam across Manjira river, a tributary of Godavari river in Medak district of Andhra Pradesh for storing 84930 HaM of water to meet the additional water supply requirements to the tune of 11324 HaM of the twin cities of Hyderabad and Secundrabad. Total domestic supply from the project is planned to the extent of 27121 HaM and for irrigation 48410 HaM. The cost has accordingly been apportioned in the ratio of 27121 HaM for domestic water supply (Rs.15.20 crores) and 48410 HaM for irrigation (Rs.27.14 crores). Here again the facility use method has been followed. Generally while allocating the cost of the canal system, the apportionment is made in the ratio of cusecs-mile for each State.

The Sabarmati Reservoir Project[4] at Dharoi-Gujarat envisages construction of composite dam on river Sabarmati near village Dharoi in Mehsana district of Gujarat. The storage capacity of the project including the carry over provision of 0.307 lakh HaM is 0.908 L HaM. The storage provision for water requirement has been worked out as 0.374 L HaM including direct irrigation demand 0.176 L HaM and fair weather requirement of water supply as 0.197 L HaM. The total cost of the project is Rs.1758.56 lakh out of which 1089.34 lakh has been charged for irrigation and Rs.669.22 lakh allocated to water supply component. The method followed for apportionment of cost is facility use method.

North Koel Reservoir Project[5] envisages construction of a dam on North Koel river in Daltonganj district of Bihar. The live storage of the dam is 0.756 L HaM out of which 0.0437 L HaM will be reserved for industrial and domestic purposes and 0.844 L HaM for irrigation purposes. The cost of dam has accordingly been apportioned in the ratio of the quantity earmarked for the domestic and industrial use vis-a-vis the live storage. The cost for industrial and domestic water supply works out Rs.195.26 lakh and for irrigation Rs.11,354.32 lakh out of total cost of Rs.11,550 lakh for the project as a whole.

The Polavaram Project[7] proposed across river Godavari about 42 km upstream of Godavari barrage in Andhra Pradesh is a multi-purpose project conferring irrigation benefits for upland areas, water supply for industries in Vishakhapatnam township and steel plant, generation of hydel power, affording navigation facilities and development of pisciculture and providing recreation benefits. It also diverts 80 TMC of water to Krishna river to augment the supplies of Krishna Basin. This project is at present under appraisal in Central

Water Commission.

The main components of the project are, (i) left canal and right bank canals for irrigation, (ii) power generation, (iii) water supply to Vishakhapatnam city, Vizag steel plant and other industries, (iv) navigation, and (v) diversion of 80 TMC of water to Krishna river.

The allocation of cost of this project to the different component is worked out based on the guidelines given in IS 7560 - 1974 by adopting the 'Water releases approach' under the use of facilities method, as this method was found to be most suitable for allocation of cost of the project. The joint cost of the dam is apportioned among irrigation and water supply components only. The power component is omitted as the storage facilities created by the dam is not directly utilised for power generation. In actual practice, power generation is envisaged to be done by utilising the flood waters of the running river and the waters released for irrigation for the existing ayacut in the Godavari delta and by pumped storage method from the point available on the downstream of the dam due to the construction of Godavari barrage.

One more purpose which is served by this project is diversion of 80 TMC of Godavari waters to Krishna river. This is the unique feature and precedents are not available for apportioning the cost of such component to the cost of dam. In the calculations given in the project report for cost allocation, the cost of dam has not been apportioned for this purpose.

The total estimated cost of Rs.88,417 lakhs has been apportioned as follows:

(a) Irrigation - Rs.58,638 lakhs (Rs.41,700 lakhs for left canal and Rs.16,938 lakhs for right canal)

(b) Navigation	-	Rs.2,177 lakhs
(c) Water supply	-	Rs.7,662 lakhs
(d) Power	-	Nil
(e) Flood control	-	Nil
Total		Rs.88,417 lakhs

The navigation component has since been excluded from the project by the State Government. The apportionment of cost, as given in the project report is however yet to be finalised.

SUMMING UP

Recently, the Union Ministry of Water Resources have desired that all irrigation projects at their initial planning stage should provide for domestic water supply component, if such a possibility exists. The cost allocation would be necessary if the drinking water supply cost exceeds 10% of the total cost of the project. It is therefore, necessary that planners of the multi-purpose irrigation or river valley projects are aware of these methods so that after careful considerations and discussions amongst participating States/Organisations an amicable agreement is reached for cost allocation amongst various uses, before project is taken up for implementation. Allocation of cost which may be fair to all purposes concerned at a particular time will perhaps be manifestly unfair to some with the passage of time. All cost apportionment should therefore be subject to periodic review to enable appropriate adjustments to be made in the light of changed circumstances.

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COST RECOVERY IN URBAN LOW-COST SANITATION

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SYNOPSIS

This paper presents a case against direct cost recovery in low-cost urban sanitation projects, arguing that the property tax system offers a better prospect for the recovery of full financial costs with due regard to considerations of affordability. Adoption of LCS is consequently likely to be far more widespread than under a system of direct recovery of loans, so that the health impact of LCS projects is better promoted; ignoring affordability will result in spotty application and frustration of the health potential.

Nothing that the efficiency price of LCS is well below financial costs, the paper recognizes the constraints on governmental resources that make full financial cost recovery necessary. It examines several factors germane to recovery, e.g. affordability, already mentioned; the kinds of sanctions available; the insensitivity of loan repayments to inflation. All these reinforce the argument for basing cost recovery arrangements in municipal towns on the property tax system.

INTRODUCTION

It is increasingly recognised that the quest for good health depends for success much more on the quality of drinking water and on sanitation than on the advances in modern medicine; also that the former route to health is many times as cost-effective as the latter. Yet the costs of providing sanitation can themselves be prohibitive if relicance is placed only on modern sewerage systems; in fact, there is not the slightest possibility that all urban homes in India will be sewered before the Prime Minister takes us into the 21st Century.

So there is today a growing emphasis on cheaper sanitation. This can take a number of forms. One system, perhaps most appropriate to most Indian towns and even to the fringe areas of our large cities, is a provision of pour-flush latrines with twin cylindrical pits. The pits are about 3 feet in diameter and lined with bricks in a 'honey comb' pattern, which lets out the liquid waste into the surrounding soil but retains the solids. These solids settle, and evolve into a harmless "humus" a year or so after use of the pit ceases. The latrine is connected to one of the pits till it is full; it then switches to the other. The filled pit is emptied a year after the switch, and its contents can be useful in agriculture. Latrine-flushing needs very little water.

The UNDP has been coaxing various governments in this country to adopt this low cost sanitation system (LCS) in some of India's smaller towns.

This paper relates to the recovery of the costs of urban investments by governments whether at the national or local level, or at levels in between from the beneficiaries of these projects. The recovery may be either individual or collective. Beneficiaries may or may not be actual users; landlords, for example, may benefit by appreciation in value of homes occupied by tenants and improved by provision of sanitary latrines.

Cost may be recovered in several ways. Three of the common modes are (a) the pricing of output (in projects concerned with production or services); (b) the repayment of loans advanced to beneficiaries; (c) taxes, rates or user charges imposed on beneficiaries.

Why Recover Costs

If a project is genuinely productive, beneficiaries should be able to pay for the costs of goods and services it provides and still increase their real incomes. To the maximum extent feasible, therefore, costs of such projects should be recovered. Important issues are involved when projects fail to pay themselves:-

- Resources will be strained, and repetition of the project elsewhere will become less and less possible.

- The project beneficiaries will be receiving an income subsidy, not enjoyed by others.

- Materials and services received free or at prices below their true cost may be wasted or used inefficiently.

The second and third of these factors call for some comment, in relation to sanitation. In much of the Third World, and particularly in India, adquate sanitation is not an ardently felt need, particularly at the lower educational and income levels, where fields, open spaces and alley-ways are generally used for defecation, to the extent that separate spaces are earmarked by convention for men and women, and the morning toilet trip is often a social occasion. In this respect the provision of safe water (and consequently of sewerage) is markedly different, and its supply free of cost is likely to lessen its value in the eyes of its users and to encourage waste; this in turn would require earlier augmentation of the supply and resource to more distant, costlier sources. No so with low-cost sanitation; in fact, the difficulty here, except in the relatively rare social groups that really value privacy (the connection with health is seldon recognised), is to persuade people to pay for a facility they have hitherto regarded as available free.

The second factor listed above tends to overlook the social value of sanitation, in which respect sanitation is in a class apart from transportation, power, irrigation, etc. Providing a householder with a latrine has a health impact on the community in which he lives, including those who already have sanitary latrines, as well as those who live outside the community but have close enough contact with it to share its health problems. While it may be true, thereofore, that he gets an undue benefit if this latrine is provided free, it is also true that if he pays its full cost he is conferring a benefit on the community. It may make good sense, therefore, to exempt sanitation beneficiaries from direct recovery of total cost1/ and to share the cost in some measure with the City's/country's population in general.

What Costs to Recover

Like irrigation schemes, water and sanittion projects generally concern themselves with the recovery of the financial costs of these projects. What are these, in relation to LCS ? First, of course, the capital costs: chiefly items such as pit preparation, pans, traps (vents where applicable), and latrine superstructures. Next, the administrative costs: municipal supervision, accounting, tax or loan recovery. Third, the recurring cost: mainly pit emptying. 2/ This recurring cost is generally low, and may be equalled or exceeded by the manurial value of the pit contents and the sale proceeds thereof. If it is not, or if sale is difficult, the recovery of emptying costs may make beneficiaries uncomfortable because these costs are "lumpy"; were recovery spread out evenly on a quarterly or monthly basis it would be much less burdensome.

In their anxiety for replication, project promoters often suffer from an obsession with **financial costs,** and emphasize the need to recover them in full (although in practice they tend to accept partial or long-deferred recovery arrangements). There is less concern with economic costs, or questions of efficiency. The World Bank's guidelines have this to say:

> "A convenient starting point for *judgements on cost recovery* is price policy: What should be the level and structure of prices of the output from the project.......... One traditional objectives of pricing policies in the private sector has been to set prices so as to maximize the economic benefits from the projects without taking into account ...... the different income classes that (the beneficiaries) may belong tom,to or the extent to which the project changes the resources at the disposal of the government. Since these prices are designed to create maximum economic benefits, in this sense, any departures from them will entail sacrifices in economic benefits..... Significant departures from efficiency prices should only be made after due consideration of the losses that may accrue to the economy as a consequence."
>
> "Broadly speaking, the efficiency price of a product should be equal to the current **economic** cost of producing the last unit sold plus any mark up that may be necessary to clear the market".

It is not easy to estimate the marginal economic cost of a VIP or PF latrine, nor is it possible to use the familiar sourrogate, willingness to pay, for a reason explained in para above. Yet, since LCS involves practically no lumpy investments 3/ of the kind that characterize power, or transportation, or even large water supply schemes, one would expect marginal economic cost to be nearly equal to the average financial cost of a single latrine; it is in fact considerably less in most undeveloped countries. This is because the cost of a latrine includes certain sales taxes on materials, which do not enter the calculation of economic costs, plus a large component (possibly one-fifth) of expense on unskilled labour, which needs to be shadow-priced well below the price reckoned for the project, in view of the high level of unemployment /underemployment prevalent in these economies. These factors are not likely to be substantially offset by the under-pricing of capital that characterizes most governmental projects. There is also another reason for a reduction of the "efficiency" price from the financial level, although precise calculation is even less possible in this respect than in regard to the shadow-pricing just mentioned. This has to do with the health impact on the community of an individual householder's decision to install a latrine. Just as in a highway project the price to be charged for use should be the cost of an additional vehicle trip, i.e. the wear and tear cost, **Plus** the additional congestion cost imposed on others, **plus** the cost of additional pollution and noise, so in LCS the efficiency price should contain a **negative** adjustment to reflect the health benefits to others than the beneficiary. The fact that health benefits cannot be quantified should not prevent us from recognising cost recovery arrangements that ignore them as at least to some extent extrotionate.

Not quite as difficult to estimate is the value of water saved. Pour-flush and VIP latrines require less than a fifth of the amount of water commonly used for flushing latrines connected to sewers. It is tempting to count this as a further negative adjustment of the efficiency price in LCS projects, but one has to remember that the proper comparison to make is not between LCS and sewerage but between LC sanitation and no sanitation at all - the cost of which in water-use in negligible.

Modes of Recovery

What does appear from the foregoing paragraphs is that from the strictly economic point of view, the appropriate costs (efficiency price) to recover in LCS projects are likely to be appreciably lower than the financial investment costs, although precise estimation of the former is elusive. But there are other factors that affect the issue, notably (1) the government's resource problems, which might make repetition of a set of project difficult if investment costs were not recovered, (2) the pattern of income distribution among the beneficiaries. The first of these tends to take the case back to its emphasis of financial costs and towards their full recovery, eclipsing efficiency considerations; the second raises possibilities of cross-subsidies within a scheme.

The eclipse of efficiency pricing, despite the sacrifice of economic benefits which it entails is truly remarkable, and may indeed have to take the blame for the tardy spread of LCS in developing countries. Very few projects even notice the departure from efficiency pricing, much less do they try to estimate the extent of the sacrifice. The emphasis on replicability is generally equated with the need to recover **directly** as great a part of a project's financial costs as possible (even though indirect recoveries can make a project just as replicable).

Let us now look at some of the recovery possibilities available to a municipal body in LCS project planning. These are -

1) Full cash payment by beneficiary;

2) Full deferred payment by beneficiary against loan from municipality;

3) Part loan from municipality to beneficiary, the rest being contributed by beneficiary in cash or kind (e.g., in the form of labour);

4) Part loan from municipality, part grant 4/ (in cash or in the form of materials needed pans, traps, cement, etc.)

5) Full grant, followd (or even proceded) by taxation, usually a cess or surcharge on property tax; sometimes, a specific user charge or a surcharge on the water rate (or even a non-specific tax).

Of these several possibilities the first, and possibly the second, have to be ruled out, except for the relatively few affluent households in an LDC community, unless the loan is subsidised for poor people, i.e. longer durations or lower interest rates are applied than generally prevail in the market. The third alternative is difficult to operate uniformly in a town; it works harshly against household that do not have able-bodied male members. It is nevertheless worth while to attempt it because it reduces the loan burden. Perhaps it could be usefully combined with the fourth course (e.g., by matching with a grant any contribution by a beneficiary), but this raises awkward adminstrative problems if contributions vary, as they will. Obviously, any grant element reduces recoveries, and ought therefore to be restricted to the poorer households in a community. On the other hand, loans suffer from the danger of providing negative real returns in times of serious inflation.

They have other drawbacks too, described later in this note.

The fifth alternative is seldom favoured in relation to services that are installed within private premises, at least to the extent that they are so installed. Individual connections in water supply schemes, sewerage schemes or power supply schemes generally entail payment by beneficiaries for those parts of the connections that fall outside the public domain. And yet sewerage schemes involve outlays by the public authority that, calculated on a per-individual-household-basis, far exceed the grant that an LCS installation would require. Moreover, this (5th) option offers the advantage of full financial cost recovery. If it is based on the property tax, it adjusts itself to the income pattern of the community because it varies in proportion to property values 5/ and therefore at least approximately to householder's economic condition. There is, further, the possibility of true recovery **in real terms** in inflationary conditions; loan repayment schedules are not generally susceptible of such adjustment to changes in money value, where tax assessments and tax rates can be raised.

A tax surcharge also permits the (Gradual) recovery of money spent on biennial (or less frequent) pit clearance and on community latrines, the latter of which otherwise escapes collection except through an administratively awkward and perhaps discouragingly expensive user charge.

Furthermore, it tends to encourage citizens to install sanitary latrines (as noted earlier, an incentive is needed), since they would have to pay the tax anyway. The loan alternative leaves householders free to take it or leave it; leaving it exposes the community to health hazards of which the reluctant householder bears no part of the cost. On the other hand, there is a danger that the landlord of a rented house may reap an undue benefit from a sanitation improvement effected and paid for by the municipality, an improvement which enables him to increase disproportionately the rent payable by his low-income tenant.

In smaller towns the tax option may present another problem. Property values tends to be low in such towns, so a sanitation surcharge on the property tax would have to be levied at a relatively high rate if it is to ensure cost recovery, and may take the tax to a level beyond the limits prescribed iin the municipal law.I am not aware whether this is a real problem in more than a few marginal cases. In most of the smaller towns I have observed, municipal councils keep tax levels well below the maxima prescribed by law, and there is plenty of room for enhancement.

LCS projects are generally the result of a policy approval by national governments of low-cost sanitation as an alternative cheaper than sewerage or even septic tanks. For their implementation national or state government tend to rely on municipalities or village councils, to which they transfer money, either as loans or outright grants. The administration of the LCS program, then, remains generally in the hands of local bodies, which carry out the physical installation of latrines either themselves, through contractors, or through householder's own effort. The costs, total or partial, are generally converted into loans to individual beneficiaries. The process of recovery of these loans is often visualized as simple because local authorities are already engaged in the process of tax recovery, so that very little extra work is involved. This is of course, fallacious: tax accounting is much less complex than loan accounting, which entails interest calculations, with which municipal accounts clerks are quite unfamiliar, because few municipalities are even legally empowered to land. Even the **tax** recovery process in many municipalities tends to be seriously incompetent. In a group of 15 municipal towns for which statistics were recently collected, tax recovery performance varied from 25 to 89 per cent, not reaching even 50% in 76 cases. There is little reason to expect that LCS coasts will be more assiduously recovered in most towns than these figures suggest - quite the contrary, in facts, if the system is to depend on loan repayments. Apart from the accounting difficulties earlier mentioned, the usual sanctions for default in loan repayments may not work: mortgage foreclosures are unlikely to be enforceable for latrine loan defaults, almost certainly not when occupancies change. This is a characteristic which LCS shares with slum upgrading programs. Due tend to be far more recoverable when the only penalties for default are not too drastic: the more drastic a penalty, the less likely it is to be used. A **range** of coercive processes that begin with quite light penalities is generally a more useful instrument of recovery than a simple sanction like eviction. Most tax laws equip an adminstration more fully than mortgage deeds, which visualise foreclosure and dispossession as the only remedy available, and easily attract obstructive political intervention.

Distribution Aspects

While the Tax system offers a better prospect of recovery than a loan system, it also has the advantage of being roughly adjustable to the income pattern. Attempts in some project feasibility studies prepared by a UNDP unit in India to adjust loan: grant arrangements to the income pattern have not been convincing. They tried to treat access to amenities (water supply, power, bucket latrines) as a surrogate of income or affluence, and to vary the loan: grant proportion accordingly. Those with no amenities would quality for a 75% grant; those with one, a 50% grant; those with two, a 25% grant; and to those with three amenities the entire outlay would be a loan 6/. But the very first town listed in one of the feasibility studies displayed these characteristics:

Assuming that the income data are not too inaccurate, the figures show that 734 poor families (and 25 indigent ones) would get a much rawer deal than 1,120Ø (1,022+98) relatively well-off ones. Were the figures I have just chosen small in relation to the total number of households, 7,798, the anomaly they reveal could have been ignored as marginal. It is true, of course, that amenity access has been chosen as the basis of discrimination because it is a more practical option than a differentation based on income data, which would be unreliable. Yet, the unfairness built into the system needs serious re-thinking. Is a nearer approximation to actual economic conditon discernible, and would discrimination more closely related to that condition be administrtively feasible? I suggest that a property tax surcharge offers such an alternative (See Annex). At any rate it is not likely to be blatantly regressive, to the extent demonstrated by the table above.

CONCLUSION

The proceding pages present an argument for reliance on indirect methods of cost rcovery in LCS programs. That LCS is not unique in this respect is beginning to be recognized. Here is an extract from a World Bank Report on Urban Operations, with which it is appropriate to close this paper:

Household Income p.m. (Rs.)	Number of households with No Amenities	One Amenity	Two Amenities	Total
0 - 200	29	38	25	92
200 - 500	1,064	1,523	734	3321
500 - 900	1,022	1,655	1,200	3877
900 -	98	207	203	508
Total	2,213	3,423	2,162	7798

"Cost recovery as a means of generating resources to ensure financial replicability of project investments still remains a major concern of most projects. Constraints to achieving this objective are not justy found in the urban sector, however. In most countries, effective cost recovery is difficult in many sectors: water, power, irrigation, rural credit, and small scale enterprise projects. The need for effective cost recovery has become more pressing in the midst of th difficult macro-economic circumstances of the 1980s. The range of direct cost recovery... varies from 15 percent in Liberia to 90 percent in Ecuador. In countries where direct cost recovery has been traditionally quite difficult alternative means of charging for services have had to be implemented. In Liberia, for example, approximately 85 percent of project cost is expected to be recovered indirectly through city-wide property tax charges. This has been done quite effectively in the past in Mali".

1/ The term **direct** cost recovery is used here to mean direct payment by beneficiaries for services or goods provided in the project. Plot charges, house loan repayments, utility charges are examples of direct payment. Indirect cost recovery refers to recovery through general governmental or municipal revenues.

2/ In a full analysis of technology section, cost recovery and affordability, the cost of the additional water needed to make certain systems operate needs also to be taken into account. However, cost-recovery policies for water supply services are best considered separatly, and are not covered here.

3/ Except for those required for establishing capacity for materials manufacture (pans, traps, cement, steel, bricks). These materials represent perhaps a third of the total cost, but if manufacturing capacity already exists in the country marginal and average costs may not be too far apart.

4/ The word "grant" is used hereto include an arrangement under which a local body spends the relevant amount to have the latrine installed for the beneficiary, but does not **directly** recover it as it would recover a loan. The local body may itself get the money for such grant as a loan or a grant from a higher level government.

5/ While it is true that property tax assessments are unreliable, especially in smaller municipal towns, it remains likely that the error is one of general under-valuation and therefore general under-assessment, not of inequitable discrimination between one income group and another.

6/ Implicit in these provisions is a subsidy, and to that extent a departure from the target of full financial cost recovery. This approximates 50% of cost, and may be partially or fully justified by consideration set out in the discussion on economic costs. See also annex.

ANNEX

Recoveries graded to Income Levels

The belief that the capital or annual letting value of housing and therefore the property tax level vary roughtly in proportion to the income level of the occupant appears to be a reasonable one. Given this assumption, it is easy to show that tax recoveries which approximate 11/2to 2% of occupat income are sufficient to meet full recovery requirements for a sanitation facility that costs about Rs.1000, if the interest rate applied is between 5 and 10% and recovery is expected over a span of 20 years. (A 5% rate appears to be low, but a housing finance institution in India has been offering loans for LCS for certain income groups on these terms.)

The pattern of income distribution iin a group of 15 towns in Maharashtra State in 1980 is shown in the table below.

The total income of of 100 representative households would thus be about Rs.47650 monthly; the cost of 100 LCS facilities would be Rs.100,000. A 5%

Monthly Faimly Income Rs.	Percentage of Households
0 - 200	13
200 - 500	53
500 - 900	26
Over 900	8
	100

interest rate will require recoveries at 1.37% of income to recoup the capital outlay with interest in 20 years; a 10% rate will require 2.01%. These percentage rise very slightly if the periodical costs of pit emptying are added on.

However, in the visibly better-off town mentioned earlier, recoveries at only 1.67% of income would suffice to recoup the outlay in 20 years at an interedst rate of 10%. At the Rs.200 monthly income level this would mean a payment of Rs.39.98 **per year.** Contrast this with the scheme proposed, under which (a) the 2213 families with no amenities (98 of them in the highest income group) would each have to pay Rs.29.37 per year, (b) the 2162 families with two amenities (25 of them in the income group below Rs.200 p.m.) would each paid Rs.85.95 per year, **and yet (c) the total recovery after 20 years would be less than half of the total outlay,since there would be an overall grant exceeding 50%, there being no familis with 3 amenities (see 6/)**

COMMERCIAL APPROACH IN THE WATER UTILITIES

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SYNOPSIS

Normally a Cash Accounting System (CAS) is used by Water Works Organisations. The commercial accounting system which is infact an accrual accounting system is quite different and from Cash Accounting System. Switching over to Commercial Accounting System is not an end in itself. The objective should be to achieve overall improvement for which this system should be used as one of the tools.

Better planning, objective decision making and judgements based on proper and better perspective of the entire situation are the things needed. This could be done only by having motivated managers at various levels.

Many a times, the commercial accounting system is considered as a panacea for problems related to financial management, particularly in the public sector. During my visits to various places in other parts of the State/ Country, as well as while delivering the lectures on the subject in the classes, I observe this feeling. This feeling is further strengthened on account of conditions laid down by the institutions like, IBRD/IDA while sanctioning loan/credit that the institution will adopt the commercial accounting system. Many authorities, it appears also laid much emphasis on this commercial accounting system than on the objectives for which the system is required to be operated.

The present accounting system followed in the Government and Semi-Government organisations like the Municipal Corporations, is Cash Accounting System, which is nothing but the accounting system based on the receipts and payments. This is particularly because there is a system of grants/ budget provisions and the notion that the amount is required to be spent in a particular year, when the budget grant is provided for the same. Its is from this point 'of view, many times, we observe that there is unusual rush on the Government treasuries in the month of March and particularly in the last week of financial year. No doubt, this Cash Accounting System suffers from number of drawbacks and yet it came to stay in the Government and Semi-Government organisations/departments for a long.

As against this, the commercial accounting system is distinct from the cash accounting system in a sense that it is an accrual accounting system. It produces the financial statements as the income and expenditure account as against receipt and payments account. Remaining all other things unchanged. the income and expenditure account co-relates with the activites during the period say a year (of course in monetary terms). The outstanding liabilities relate to the expenditure actually incurred in the year but not paid for. In the cash accounting system (Government accounting system), this expenditure though, incurred is never reflected in the same period but will be reflected only when payment is made towards the expenditure. Similar is the case in respect of accounts receivables wherein the income is earned (the service rendered or the goods sold) but the amount not received then the same will not be reflected in the cash accounting system (Government Accounting System) but will be reflected in the commercial accounting system. The Balance Sheet as at the end of the year will reflect this outstanding liabilities and accounts receivables in the commercial accounting system but will not be the case in respect of Government accounting system. In a nut-shell, the commercial accounting system is the scientific accounting system which reflects the correct position related to the transactin during a particular period (say a year) through the income and expenditure account and the balance sheet also reflects the correct state of affairs of the organisation as at the end of the year.

This is the basic different between the two accounting systems. The question, naturally asked is, what would we achieve through this commercial accounting system? I it merely because that we get the more accurate picture of the financial transactions of the organisation? Is it also argued that over a period of time, even as per the cash accounting system the picture presented is more or less the same and should we take troubles to switch over to the new system?

These are no doubt pertinent questions but they are basically raised because the objectives are considered to be just fulfilling the conditions laid down by the institutions like IDA/IBRD rather than the purpose behind laying down such conditions. Similarly it is also a mere assumption that once the commercial accounting system or the accrual accounting system is followed, it will solve the problems related to financial management.

The prime objective of any organisation ultimately should be to control the various resources which are used as input in the system and ensure maximum utilisation or optimum utilisation of these resources. The value of a ratio O/I(output upon input) should be the maximum. No doubt while dealing in the public sector, the targets are not short term but the entire action is initiated from the long term point of view and where we are concerned more with the social benefits and social costs. Commercial accounting system is only one of the tools in the hands of the management to get correct financial information for the purpose of ultimate control. Budgetary control or ensuring the expenditure within the budget grant is the measure adopted in the Government or Semi-Government organisations irrespective of what system of accounts is followed in the organisation. If the cannons of financial property are followed/observed in such organisation in true sense, I think half the problems will get solved. However, in Government of Semi-Government organisation, a tendency to play safe is predominant and more emphasis is laid on the procedural aspect rather than the performance aspect, which in turn is guided by the complicated procedures and rules and the auditor's guidelines. What is more important is to lay emphasis on the performance or management audit rather than procedural audit. I am reminded of a short story by A.G. Gardener "All about a Dog". I read this story in our text-book in school days,I think (author) gives us a message which should be universally accepted and in a way is really a guideline for anybody working in the public sector. Procedural audit no doubt plays an important role but this itself is not enough. If such audit is contrary to the main objective, it will only defeat the purpose of audit. This would perhaps result in compliance of the requirements of the procedural audit, without the delivery of the goods. In fact, many of the frauds in the public sector are committed without violating the procedure and sanctions. The purpose of the management audit on the contrary would be result oriented and in the process perhaps may not strictly adhere to the requirements of the procedural audit. The second one is definitely preferable to the first one. No doubt, the ideal solution would be to comply with all the requirements in respect of procedural audit and still deliver the goods in the best possible manner. This can be achieved by better planning, objective decisions, and judgements based on the broader and better perspective of the entire situation. This broad and better perspective of the entire situation can be visualised only by motivated managers at various levels, which always had been a plus point in private sector.

In this context ultimately, we will come to the same conclusion that even by adopting commercial accounting system, the problem is not going to be solved.

According to me therefore, even though the system plays a very crucial role in the large organisations which are impersonal in nature, that alone would not be sufficient, unless there is a change in the outlook and the approach.

This outlook and the approach which I would call a commercial or business-like approach, could be a common factor for both the private and public sector, though, the objectives in both the cases would be quite different. Maximisation of the profit could be a dominant factor in the private sector, while maximisation of the services should be the predominant factor in the public sector. Here, of course is a great difference in the sense there are various options for alternative plans for investments in private sector, as the objective is only towards the maximisation of the profit which could be achieved either by way of more turnover rolling by way of more margin of profit. In fact, in developing/underdeveloped countries, considering the scarcities of the commodities and peculiar situation of scarcity of resources, it is always a seller's market. The public sector really speaking being in a monopolistic situation, theoretically could be in the best bargaining situation, but for the pressures from the common man and their representatives, who directly or indirectly would not allow exploitation of the consumers at the hands of the public sector responsible in delivering the goods or rendering the services. Similarly, the options for alternative plans for investments are not many or in fact are already limited in the context of sectorwise or areawise priorities at National/State/Local levels. So, on the one hand there are constraints about these options while on the other hand the price policy/tariff policy could not be easily modified as is the case inthe private sector. There is less flexibility and therefore, what is left out is only better utilisation of the available resources under the given circumstances. The entire situation becomes complex on account of multi-disciplinary aspect for decision making as well as for execution and so on.

It is from this point of view, of better utilisation of the available resources, that the businesslike approach would be more helpful in achieving these objectives.

Accounting is considered as the appropriate recording, compiling, analysing, interpreting etc. etc. of the transactions and the objective of the accounting system does not end with a scientific system, but it is really a means to an end viz. the better management - the management for decision, execution and control.

The better accounting system thus becomes an obvious logical corollary for the better management.

The accounting system earlier followed in the MCGB was on the lines of Government accounting system and even the chart of accounts or budget heads were not flexible enough to accommodate new changes so easily: similarly for drawing various inferences and for various permutations and combinations, such a system would not have been adequate. The new accounting system introduced in the water supply and sewerage department in the MCGB not only adopted the principles of commercial accounting system, i.e. not only it started managing the accounts on accrual basis but a new system of responsibility code and a new chart of accounts were introduced by which on the one hand compilation through cmputer is possible while on the other hand information in various permutations and combinations can be available. It is further developed in such a manner that it is useful for responsibility accounting system which normally is coupled with performance budgeting aspect. It is also possible fr any manager at any level to draw specific inferences from the accounts maintained under this system which provides important necessary data for arriving at his own conclusions and take decisions. The decision could be in respect of e.g. recovery procedures and controls, percentages, figures of return on investments (ROI), decision in respect of replacement, future expansion, decision regarding repairs vs. replacements, preventive maintenance, purchasing policy and so on and so forth. In fact, the improvement has not to be and it could not be from one angle but unless it is a total improvement, it is difficult to get the desired results.

Simultaneously, therefore, various sub-systems of accounting were considered for the purpose of improvement, which inter alia cover general accounting, pay-roll and provident fund accounting, stores accounting, inventory control, reverse accounting and costing system for the purposes of transport transactions and processes at filtration plant.

This of course, could not have been achieved overnight despite relatively better situation prevailing in Mumbai (Bombay), as compared to any other city in India. In the initial stages, development of the manpower through systematic orientation and training was the important task which always is a pre-requisite for development and implementation of any new thing. Getting everybody conceptually very clear is the key to the success in this respect. Our experience had been that if concepts in these respects are clear, normally there are less problems in implementation. Many of the problems are due to non-clarity of the concepts, similarly instead of waiting for fully deveoped system the things were implemented and were improved on continuous basis. Even now the process of improvement is not complete. Presentation of the exact state of affairs or facts is the most important thing and the accounting system must achieve this. It could be said that in respect the results are fairly good so far the objectives in this respect are concerned. This is particularly so in respect of the general accounting system, pay roll and provident fund accounting system, stores accounting and inventory control system, but lot more is to be achieved particularly in respect of outstandings accounting, so far bills receivables are concerned but here also in near future the organisations expects to mke a dent and improve upon the present position.

The problems in most of the cases are personal problems in the sense, it is always on account of the reaction of any person in the organisation, whether he is from the Accounts Department or from Executive Department.

In the initial period, therefore, special orientation courses were designed and conducted for some of the employees from executive departments like engineering departments - both technical and non-technical staff from these departments. Even when computerisation was introduced some time back, training was given to the staff working in user departments, before there was a switching over. This was definitely consistent with the totality approach, in the sense that the managers viewed it from the entire organisation's point of view and keeping the results before him. It did not, therefore, remain an exercise as a ritual, but an exercise with full involvement of all concerned. This definitely had an impact on various branches related to budgeting and accounting, auditing on the one hand and executive wing on the other hand. Appreciating the role to be played by each one in the organisation, there still remains a sort of cohesion in the entire department which alone will be helpful in achieving the desired results.

Normally it is taken by the engineers or the executive wings that accounting or auditing aspect is to be looked after only by the accounts departments forgetting the fact that he himself is accountable for certain things, i.e. he really is accountable for each rupee spent by him and naturally answerable to the public. Gainful utilisation of each rupee spent by anybody on behalf of the organisation, is the real commercial or businesslike approach though it is always to be judged in the context of the objectives of the organisation which is service oriented and put to the test of benefit-cost ratio - social benefit - social cost and here the concept of the organisation is, that it is not only going concern but growing concern. The large investments therefore, are to be viewed in this context and not from the short term point of view. The results of the investments for filtration of Bombay's water are seen for the last 5 years. The change in the outlook of the auditors and accountants from this point of view is most important thing. Seeing the things from the eyes of other persons seems to be simple but is a very difficult thing. The habits and the prejudices die hard. The dynamic approach of every manager whether he is placed horizontally or vertically in the hierarchy of the organisation, according to me is the key to the success of the organisation.

The motivated manager with imperfect system would give better results than the totally non-motivated manager even though equipped with the best systems. The ultimate objective would be perfect systems in the hands of the dynamic and motivated managers at all levels.

As distinct from the manager in the private sector the role here is a different one. The manager here, is more like a Trustee or as per the concept in the Hindu Philosophy - Ancient Hindu Philosophy "A Selfless King" who will see to it that everything goes perfectly well and everything is dynamic, though he himself will not have any interest - personal interest in the same. In short, there should be a full involvement without any attachment.

Here it is a combination of the two tendencies commonly seen in the private and public sector. In the private sector, there is likely to be total involvement but with specific interested motives which are subjective and therefore, many a times even decisions are subjective. In the public sector on the other hand the decisions are supposed to be objective, but then the experience, many a times shows that there is less involvement and therefore the results are far from satisfactory. What is needed is the perfection of objectivity with full dynamism by the people with a detached approach.

The accounting and financial systems in the improved forms provide necessary data for this objectivity and dynamism but it depends ultimately on individuals.

The implementation and faithful implementation is more important. Whether it is commercial accounting system or otherwise, it will not make any change unless first we achieve the faithful implementation of any prescribed system. It will be seen that in the general analysis the discrepancies are more on account of non-compliance and non-implementation in toto of given system, rather than the basic lacuna in the system, whether it is engineering system, accounting system or auditing system.

The businessman though more particular about his profit is also very meticulous about the reasons for these discrepancies and also about utilisation of the resources - the resources like manpower, material, money, machinery and motor (vehicle and power). This better utilisation he wants to achieve through better controlling systems which is possible through the simple but effective reporting system naturally even being meticulous in number of things. The successful executives at the macro level are not interested in the details at the micro levels, as the same are required to be linked at the levels of managers, at the macro levels and managers at the micro levels are fully conscious that if they do not report faithfully, it will not remain secret from the top executive for a long. The top executives or businessmen thus are interested in 'A' Grade items or things from the respective managers for the purpose of control.

In the Water Utilities, what is needed is this TOTALITY approach and businesslike approach where a good reporting system is also developed which will reveal number of deviations as well as the causes for these variances. No doubt, in the present complexities and the changing economic conditions it would be first needed to lay down definite physical norms or parameters, which process itself will take quite a long before they are set and operated. Normally it is expected that in the Tender Document they are reflected and they are prepared by engineering expertise in the field. Thorough survey of the site conditions, perfect detailed designs and fairly good cost estimates are the pre-requisites for deciding these physical norms. Though, this is mainly true in respect of expansion and construction activities, it is equally true in respect of repairs and maintenance.

Despite various efforts in this direction, the experience had been that the project costs have gone up tremendously with number of projects in this sector in India. It would be interesting to have a better analysis of the whole situation. This of course, being the result of number of factors, particularly three important elements, Time Factor, Price Factor, Physical Variances Factor. Unless it is possible to segregate these three important elements, it would not be possible to pin-point the exct disease and find remedial measures. While the delays and the cost escalations beyond what was expected, were the major contributing factors, physical variances was also not less important factor, in few of the sub-projects. This should be an EYE-OPENER to everybody working in the Water & Sanitation sector in this WATER DECADE. As yet the accounting system automatically could not aggregate these factors, though, with a fairly good accounting system, it was possible to indicate this with some exercise.

To sum up the entire logic, I may conclude that it is not the system alone which will automatically remedy the situation, though the perfect system is a 'MUST' for the purpose. What is needed is an appropriate approach on the part of the manager or the persons responsible for delivering the goods in the Water Supply and Sanitation Sector which is essential in Public Sector.

LESSON FROM URBAN WATER SUPPLY AND SEWERAGE PROJECTS IN SOUTH ASIA: THE NEED FOR INSTITUTIONAL DEVELOPMENT

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SYNOPSIS

A review of experience with World Bank/IDA-financed urban water supply and sewerage projects in South Asia indicates, in hindsight, that project designers have frequently underestimated the time required for project completion. In addition, implementing agencies have often become preoccupied with hardware features (particularly construction activities), while at the same time ignoring software activities (particularly institutional development). The author suggests that additional funds be designated for well designed software-related activities in order to enhance institutional development. Successful institutional development should also have the effect of reducing future cost overruns and delays in projects, and improve the financial and operational performance of implementing agencies.

INTRODUCTION

A review of experience with World Bank/IDA-financed urban water supply and sewerage projects in South Asia yields, in hindsight, a lesson which may be of interest to others presently involved in similar projects, or who may expect to be in the future.

In the past, project designers have frequently underestimated project costs and underestimated the time required for project completion. Project cost overruns of 20-60% have not been uncommon in the period 1977-1987, even though project scope has often been reduced during implementation in order to stay within available funding. Project delays have also been common; from start to finish, water supply and sewerage projects have been averaging about eight to ten years, as compared to the typical estimate of four years assumed before project initiation.

Certain factors have contributed to these problems. The level of experience of an implementing agency in designing and implementing large projects has been an important factor in determining the speed and efficiency of implementation. Agencies undertaking their first large project with World Bank or IDA financing have generally taken longer than agencies with extensive experience in large-scale urban projects. Of course, project delays and cost overruns are interrelated, as prices for delayed components increase over time in relation to worldwide and local inflationary pressures. Cost overruns have also been attributed to the use of preliminary rather than detailed engineering designs. As a result of these past experiences, the World Bank and its affiliates are beginning to use a 9 year period for the implementation of new projects and insisting that project cost estimates be derived from detailed design studies.

In addition to delays and cost overruns, other notable problems have been seen in urban water supply projects. When supervising project activities, implementing agencies often become preoccupied with the construction activities (or hardware features) designed to increase the amount of water available, while at the same time often ignoring necessary accompanying measures designed to reduce the amount of unaccounted for water, water supplied to the system but not billed to consumer for various reasons.

It can generally be assumed that unaccounted-for water losses are 40% or greater in systems which : (1) lack organized and intensive efforts to reduce system leakage and unauthorized connections, (2) do not have effective consumer and bulk meter maintenance and repair programs, and (3) lack efficient procedures for retail billing and collection. These problems are particularly evident in South Asia, where most water systems supply water intermittently to consumers, usually for not more than a few hours per day, and accurate measurement of unaccounted-for water losses is difficult. Many implementing agencies need to do more to accurately measure and to reduce the percentage of unaccounted-for water. High percentages of unaccounted for water indicate that significant amounts of potential revenue are not being collected, a deficiency for which all consumers must bear the cost through higher water tariffs.

In water supply projects designed so that the implementing agency is to be a bulk supplier to nearby municipal authorities, problems have often developed in deciding institutional responsibility for operation and maintenance, leak detection and repair, consumer billing and collection, and accounting within the municipal systems. In addition, there has often been delay by bulk consumers (usually municipalities) in the payment of bills for water received; it has not been uncommon for some municipalities to delay payment by several months (or even years in the case of a serious dispute), thus contributing to the financial problems of the implementing agency. More time spent in project design, in order to work out the institutional responsibilities of the bulk supplier and the local municipalities can lead to concensus on the major issues prior to project initiation.

Turning to sanitation in South Asia, improvements are lagging behind those in water supply. Sewers generally exist only in the core areas of certain large towns, and the costs for installing conventional sewers and treatment facilities continue to rise. Even where they have been installed, it has often been difficult to get householders to connect to the sewers, because of the high costs involved. Better success has been found in projects where the costs of connecting households to the street sewers are financed by the implementing agency, then recovered gradually through tariff charges.

As mentioned earlier, hardware features often hold predominant interest in water supply and sanitation projects for the staff of implementing agencies. Yet software features are also generally called for in project documents, including, institutional development activities such as staff training, improvements in accounting practices, meter inspection and maintenance, leak detection and repair, and improvements in billing and collection. While civil works components are often pursued vigorously and completed with a high degree of success by most implement software objectives to the same degree. Yet it is often found that the same agencies which pursue construction activities with great enthusiasm also have existing facilities which are not in good repair due to lack of adequate maintenance or proper management, among other factors.

On the financial front, some sector institutions are not generating sufficient revenues to meet the operating costs of their water and sewer services not to mention debt service, maintenance, and depreciation. Because of increasing demands for water and sewer services in urban areas, governments can no longer afford to heavily subsidize water supply and sewerage activities. Heavy subsidization only gives validity to the idea among consumers that water supply service should be "free", as many rural-based cultures have long believed. Sector agencies need to inform consumers that while the water itself may be free, the expenses for collection, transmission, treatment storage, and distribution of the water are costs that must be borne by the consumer if service levels are to be improved in the face of rising population pressures in fast growing urban areas. Similar arguments can be made regarding the need for adequate sewerage fees, where applicable.

Although sector agencies have been often organized along commercial lines and given broad powers to provide water and sewerage service, the task of rasing tariffs to levels sufficient to meet revenue generation needs has frequently met with difficulty in the political arena. Some agencies have achieved limited success in depoliticizing tariff increases by obtaining blanket authority from government to raise tariffs as necessary to remain abreast with increases in power and chemical costs.

A general lesson evident from this review of urban water supply and sewerage projects, is that the time for institutional development is now. It is no longer sufficient to talk about the need for institutional improvements; it is time to begin implementing them. The general areas of operation and maintenance, training, billing and collection, meter inspection and repair, and unaccounted-for water are subjects of concern, and areas where software improvements are frequently necessary.

Sector institutions need to be transformed from primarily construction oriented agencies, to institutions which also carry out activities for operation and maintenance efficiently, and strive to serve consumers well at the retail level. Thus far only negligible amounts of funds have been set aside to carry out institutional development tasks. If approximately 6-10% of World Bank/IDA project funding were allocated for well designed software-related activities (compared to the 0-2% often allocated), a good start could be made toward upgrading existing institutions. Successful institutional development should reduce future cost overruns and delays in project implementation, and improve the financial and operational performance of implementing agencies. If water supply and sewer agencies are to survive and remain financially viable until the end of this century, the time for institutional development is now.

SECTION 4

WATER FOR INDUSTRY

WASTE WATER REUSE

AK Kakar
M I E (I)

"Alles ist aus dem wasser entsprungen
Alles wird durch des wasser erhalten."

"All things are sprung from water
all things are sustained by water"

Faust by Goethe Pt-II Act 2.

"You never know the worth of water till the well runs dry".

-- **Benjamin Franklin**

SYNOPSIS

Rapid growth of population, faster rate of urbanisation, industrial growth have increased water demand for various purposes. Depletion of water sources has been causing scarcity. With advancement, socio-cultural aspects have been gaining importance and people and government are getting conscious about healthy environment. This has given rise to pollution control mesures. Renovation and reuse of wastewater takes care of both the aspects of scarcity and pollution control.

INTRODUCTION

Reuse of waste water has multiple significance due to the environmental, conservationist and socio-economic considerations. There is a growing understanding throughout the world of the urgent need to conserve, recyle and reuse our limited water resources. The science, technology and practice of water renovation and reuse have gone through a number of phases in the past one hundred years. The initial phase was motivated by two quite different thrusts, one based on conservations' concept that society's wastes should be conserved and utilised to preserve the fertility of the soil while the other, more pragmatic approach, was directed towards eliminating water pollution.

Substantial experience has been gained in this field and reuse-technology has become a major area of interest to engineers, biologists, chemists, agronomists, public health engineers and water sources authorities throughtout the world. Despite the high cost involved, developing countries are also engaged in this area with renewed zeal and interest.

WASTEWATER SOURCES & QUALITY

Wastewater is the spent water, about 70% of the water supplied, alongwith such groundwater and surface run off and industrial wastes as may enter, or be admitted, to the collecting system. The wastewater may find its course in open nallas and rivers where no drainage system exists, where there is a systematic sewerage system, the waste water finds its way to such sewers. In the former case the wastewater of one community is utilised as a source of drinking water for the areas downstream of it.

Since it is essential to know the nature of wastewaters for designing optimum treatment and disposal facilities, detailed investigations regarding their quality are needed. Sampling & test procedures have

TABLE - 1 : Typical Compsosition of Domestic Wastewater

Constituents.	Concentration mg/l		
	Strong	Medium	Weak
Total solids	1200	720	350
Total dissolved solids	850	500	250
Fixed solids	525	300	145
Volatile solids	325	200	105
BOD (5 day 20°C)	400	220	110
COD	1000	500	250
Nitrogen (total as N)	85	40	20
Free Ammonia	50	25	12
Nitrites	0	0	0
Nitrates	0	0	0
Phosphorous (total as P)	15	8	4
Alkalinity (as $CaCo_3$)	200	100	50

been laid down. Typical composition of domestic wasteater is given in table 1.

Variation in flows causes variation in concentrations of wastewater constituents and needs to be taken care of while designing the system. The principal factors that are responsible for loading variations are:-

A. The established habits of residents which cause short term variations.

B. Seasonal conditions which cause longer term variations.

C. Industrial activities which cause both, long and short term variations.

These factors are to be taken account of while planning wastewater utilisation.

WASTEWATER RENOVATION AND REUSE.

It is generally impossible to reuse the wastewater completely and indefinitely. Reuse of treated effluent by direct or indirect means is a method of disposal that complements the other disposal methods. The amount of effluent reused is affected by the availability and cost of fresh water, transportion and treatment costs, water quality standards and the reclamation potential of the waste-water.

Reuse of wastewater can be classified according to its utility in the following catagories.

a) Municipal

b) Industrial

c) Agricultural

d) Recreational

e) Ground water recharge

Conservation and reuse of water in arid areas has obvions significance. Due to ever increasing demands for more and more water, plants for water renovation and reuse are spreading to many areas of the world not normally considered arid. Such programmes have broadened to industries, to recreational, municipal reuse and even to the well established forms of reuse in agriculture. Another aspect is to reduce river and lake pollution.

Thus reuse can be classified as direct and indirect. In the latter form comes the water drawn from river source for drinking purposes, which contain wastewaters of upstream towns.
In 1977 it was estimated that 100 million people throughout the world are being supplied with drinking water by this method of indirect reuse. Present figures are not available but it is presumed that they are sufficiently large. Table 2 gives an idea potential for direct and indirect reuse.

Water has always been used and reused by man. The natural water cycle viz. evaporation and precipitation is one form of recycle.

The location of wastewater renovation plant need not always be at the same place as the municipal wastewater disposal plant. Treatment processes work most efficiently and economically when dealing with a steady flow of waste water rather than with the irregular flow

TABLE - 2

Potential uses of renovated water

Use	Direct	Indirect
Municipal	Park or golf course watering Lawn watering with separate distribution system, potential source for municipal water supply.	Groundwater recharge to reduce aquifier overdrafts.
Industrial	Cooling tower water, boiler feed water, process water.	Replenish groundwater supply for industrial use.
Agricultural	Irrigation to certain agricultural lands, crops, orchards, pastures and forests, leaching of soils.	Replenish groundwater supply for agricultrual overdrafts.
Recreational	Forming artificial lakes for boating, swimming etc, swimming pools.	Develop fish and water fowl areas.
Others	Groundwater recharge to control saltwater intrusion, salt balance control in groundwater, as a wetting agent, for solid waste compaction.	Ground water recharge to control land subsidence problems, oil well repressurizing, soil compaction.

(Ref. G. Tchobanoglous, R Eliassen-The indirect cycle of water reuse Vol.6 No.2, 1969).

as in urban areas. Obviously an irregular flow will affect the capacity of the plant. Therefore the location should be so adjusted that regular, uniform withdraweal of waste water is possible as depicted in Fig.1.

Wastage or losses of wastewater during renovation vary according to the climatic conditions of the area. It has been roughly found that this loss is 20% in humid areas and about 60% in arid areas in the United States.

COMPOSITION OF WASTEWATER

Use of water by a city adds a variety of materials such as grit, dirt, oil, bacteria, fertilizer, pesticides miscellaneous organic matter from streets or land erosion, human waste (organic matter, bacteria, viruses, salts) laundry waste (inorganic salts, phosphates, salts, surfactants), industrial waste (heat, inorganic salts, colour, metals, organic toxic materials, oil and the product itself). Even with so many materials in the wastewater, municipal wastes are 99.9% water.

Because of these many materials in waste water at very low concentrations it is impracticable to measure all of them. Only the classes of contaminants are generally measured, eg. BOD. COD, TOC. BOD measures the oxygen required by organisms to stablize organic matter under aerobic conditions, COD measures oxygen required to chemically oxidize the organic compounds. The microbiological characteristics principally depend upon measuring the concentration of coliform group of bacteria.

SPECIFIED CONSIDERATIONS OF REUSE

For the treatment to be provided to wastewater various considerations of reuse are taken into account. Quantity of water to be reused is is important, whether it is to be recycled several times or only once. In case of former, the treatment would require demineralisation. Character of waste-water entering the renovation plant, specially if this contains some industrial pollutants. A survey of sewerage system would determine how much of the available wastewater could be reused.

Distribution of renovated water to various users is possible only if reuse is of similar nature. The multiplicity of piping system containing different qualities of renovated water is impractical. Therefore, for the purpose of economy the user of wastewater has to be big enough to make the distribution process simple. An idea of variety of purposes for which treated waster can be used in a planned way can be had from the study of literature referred to herein.

TREATMENT PROCESS

In the past, the treatment of waste water was confined to conventional, biological, primary plus secondary treatment. This process helps to remove suspended solids, biodegradable organics, micro-organisms. Recently newer, more effective treatment systems are in use. Fig.2 gives an outline of biogical treatment system.

ADVANCED TREATMENT PROCESSES

Advanced treatment technology for wastewater is needed to meet the problems arising out of indirect or convert reuse, as conventional treatment is not sufficient to remove many harmful oranic and inorganic pollutants. Viruses are clearly resistant to these forms of treatment.

Recently studies and research have enabled treatment of wastewater to meet stringent pollution control requirements and to provide high quality water for many reuses. Health protection is of paramount importance in all wastewater reuse applications. The advanced processes are sometimes coupled with the conventional ones or may be used in a tertiary manner after conventional treatment. Principal processes are: chemical treatment, adsorption with activated carbon, filtration, reverse osmosis, electro-dialysis, microscreening, ion exchange, chlorination and ozonation. The details of these process are not discussed here.

A rough idea of performance of conventional secondary treatment can be had from Table-3.

TABLE - 3

Typical performance of Conventional Secondary Treatment.

Pollutants	Effluent (mg/1)	% removal
S.S.	20 - 30	80 - 90
BOD	15 - 25	80 - 90
COD	30 - 60	70 - 80
Ammonia-N	15 - 25	0 - 10
Phosphorous - P	6 - 10	0 - 40
Coliform	1/ml.	99.99

Table -4, gives an idea of water quality obtained after different treatment stages.

TABLE - 4

The Range of Changes in Water Quality as Fresh Water Becomes Wastewater and Is Gradually Renovated for Reuse in Industry and Tall Buildings in Bombay (Arceivala, 1967, 1969)

		Water quality at different treatment steps.				
Item	**Fesh municipal water**	**Raw domestic sewage from the area**	**After extended aeration and settling**	**After Coagulation and filtration**	**After softening and chlorination.**	**After demineralization**
(1)	(2)	(3)	(4)	(5)	(6)	(7)
pH	7.6 - 7.8	7.15 - 7.65	7.2 - 7.8	7.1 - 7.3	7.1 - 7.2	8.75
Total hardness (mg/lit. as $CaCO_3$)	35 - 40	120 - 160	120 - 160	120 - 170	4.0[a]	NIL
M.O. Alkalinity (mg/lit. as $CaCo_3$)	40 - 45	125 - 200	125 - 200	110 - 180	110 - 180[b]	5.0
Chlorides, mg/lit. as Cl.	15 - 20	60 - 130	60 - 130	60 - 130	60 - 130	NIL
Sulphates, mg/lit. as SO_4	1.5 - 2.5	10 - 25	10 - 15	15 - 25	15 - 25	NIL
Phosphates, mg/lit. as PO_4	Traces-0.1	6 - 16	3 - 5	0.2 - 0.5	0.2 - 0.5	NIL
Nitrates mg/lit. as NO_3	1.0 - 2.0	1.0 - 3.0	13 - 19	13 - 19	13 - 19	NIL

Table 4 Contd.

Silica, mg/lit. SiO_2	8 - 24	10 - 14	10 - 24	10 - 20	10 - 20	NIL
Total solids, mg/lit.	80 - 90	500 - 800	300 - 500	300 - 450	320 - 480	5.0
Suspended solids, mg/lit.	5 - 10	150 - 250	15 - 30	NIL	NIL	NIL
Turbidity, SiO_2 units	5 - 10	Turbid	10 - 20	2.0 - 3.0	2.0 - 3.0	0.2.
BOD_5 20°C, mg/lit.	0.5 - 1.5	200 - 250	6 - 10	1.0 - 2.0	1.0 - 1.5	NIL
COD, mg/lit	1.0 - 2.0	250 - 350	16 - 40	4- 6	3.5 - 5.0	NIL
Bacteriological quality (as per coliform standards)	Safe	Unsafe	Unsafe	Safe	Safe	-
Special conductance	-	-	-	-	-	10 micromhos

[a] Softened water is blended with unsoftened water to give a final hardness of 40 mg/lit. as in fresh municipal water.

[b] Alkalinity is reduced by acid treatment just prior to use in cooling towers. This increases sulphate content somewhat, since H_2SO_4 is used.

As discussed earlier, health aspects have a tremendous influence on modern reuse applications. The WHO proposed health criteria for wastewater reuse and has suggested treatment processes for various reuses and these are discussed briefly in following paras:-

A-IRRIGATION REUSE

This is the oldest and largest reuse. Here advanced treatment is not always required.

B-RECREATIONAL REUSE

It is becoming increasingly popular in arid areas of the world. California state is said to have written standards that can be used for ensuring the quality of reuse water. The treatment units deployed are primary treatment, activated sludge, biological nitrification two stage lime treatment, dual media filtration and chlorination. This would give turbidity not more than 10 units.

C-INDUSTRIAL REUSE

It too is gaining importance in the modern context. The treatment is cheap when compared with cost of recreational use. The units are primary, activated sludge, chemical clarification, dual media filtration, chlorination.

D-DOMESTIC REUSE OF NONPOTABLE WATER

It is useful where dual distribution system is in operation. Here the renovated water is supplied to communities through spearate piping system and this water is utilised for flushing, washing, cleaning etc. The treatment involves conventional biological treatment followed by filtration and chlorination.

E-DOMESTIC REUSE OF NEAR POTABLE WATER

Here tertiary treatment is needed and the water available conforms to stringent standards. Units involved are; primary treatment, activated sludge, biological nitrification, two stage lime treatment, dual media filtration, granular carbon treatment, Ion exchange and chlorination.

A comparative study of capital cost of a 38 mld plant and operational cost on 1974 rates has been extracted from the book by Shuval and is abstracted in Table No.5.

TABLE - 5

Cost of 38 mld treatment system to produce reusable water

Type of reuse	Capital cost Dollars/mgd.	Operating Cost (Cents/ 1000 gall.)
A- Irrigation	NIL	NIL
B- Recreational	9.641	40.7
C- Industrial	8.237	35.6
D- Non potable domestic	-	25.0
E- Near potable domestic	13.181	62.10

STATUS OF WASTEWATER REUSE IN DIFFERENT COUNTRIES

As already mentioned wastewater reuse has been gaining a lot of attention round the world. The achievements in these countries have been reported by a number of authors in the USA, Federal Republic of Germany, India, Israel, Japan, South Africa, U.K. etc. In the Indian context lot of work has been done by S.J. Arceivala. A brief description of reuse in California in U.S.A. has been shown below to give an idea of the status as in 1974, as it is not possible to furnish informations of every country in this article.

In India reuse was limited to agricultural reuse wherein the treatment needed is insignificant. Since sewerage system is existent in towns and big cities only, wastewater reuse is confined to these places like Bombay, Madras. In Bombay reuse is practised in industries and tall buildings where cooling towers are using it. The sewage of same building is recycled for cooling tower of tall buildings. S.J. Arceivala has a number of studies to his credit in this field. According to him the cost of 200m^3 per day capacity tertiary plant was U.S.dollars 50,000 (1970 prices) while its running cost per 1000 litres was dollars 0.04 as compared to fresh water figure of 0.058.

In the Indian context wastewater is being utilised (after sludge digestion) for uses like bio gas generation, sludge cakes as manure and effluent for irrigation. The bio gas which is rich in methane is used for cooking lighting and fuel for engines. Pilot plant studies were conducted by U.P. Jal Nigam Engineers under the guidance of former Managing Director Shri B.P. Verma and a few such treatment works are in existence. The auther too was involved in the construction of one such plant at Dehradun. The main content of Bio gas, thus generated, is 65-70% methane. This has sufficient calorific value (4713 Kcal per cum. of gas as compared to 9122 Kcal per litre of Kerosene oil) so as to be used as fuel for cooking etc. Sluge of digester after drying is rich in manurial values. Its fertilizer values are:-

1- Status of wastewater	850 community sewerage system population - 19.4 million	
	Discharge - 2.5. million gallons/day	
2- Reuses	A - Irrigation of crops	90%
	B - Parks, golf courses etc. Industrial cooling	5%
	C - Recreation	2%
	D - Other, like ground water recharge, ornamental lakes, wild life habitat	3%
3- Reliability of treatment works	56% had serious equipment outages 30-60% had serious failures.	
4- Public attitude	Opposed to use where high contact of reused water desired. People needed to be educated about the utility of reuse.	
5- Statutory regulations.	Exist	
6- Future expansions.	Enthusiastic.	

N	1.517%
O and P_2O_5	0.04%
K as K_2O	1.30%

From the above discussions it would be obvious that reuse of waste water could go a long way in solving the water crisis of the world and every environmental engineer has to exert in this direction to mitigate the sufferings of the future generations.

REFERENCE

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2. *Wastewater Engineering, Treatment Disposal Reuse - Metcalf & Eddy Inc. 1979.*
3. *Wastewater Renovation & Reuse Hillel I. Shuval 1977.*
4. *Pilot Plant Studies by B.P. Verma, Former M.D, U.P. Jal Nigam, Lucknow.*
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FIG-1

REGULAR WITHDRAWAL OF WASTEWATER

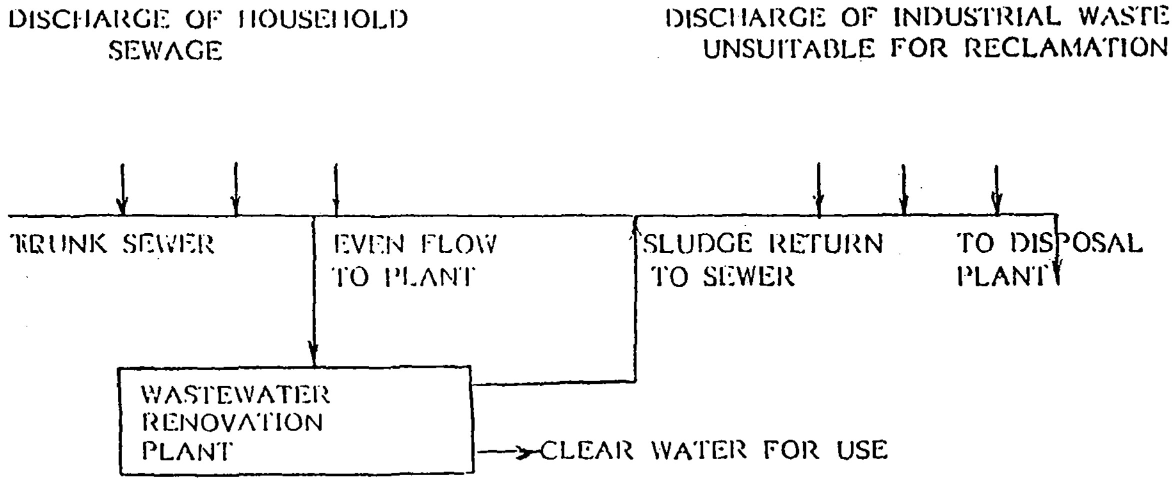
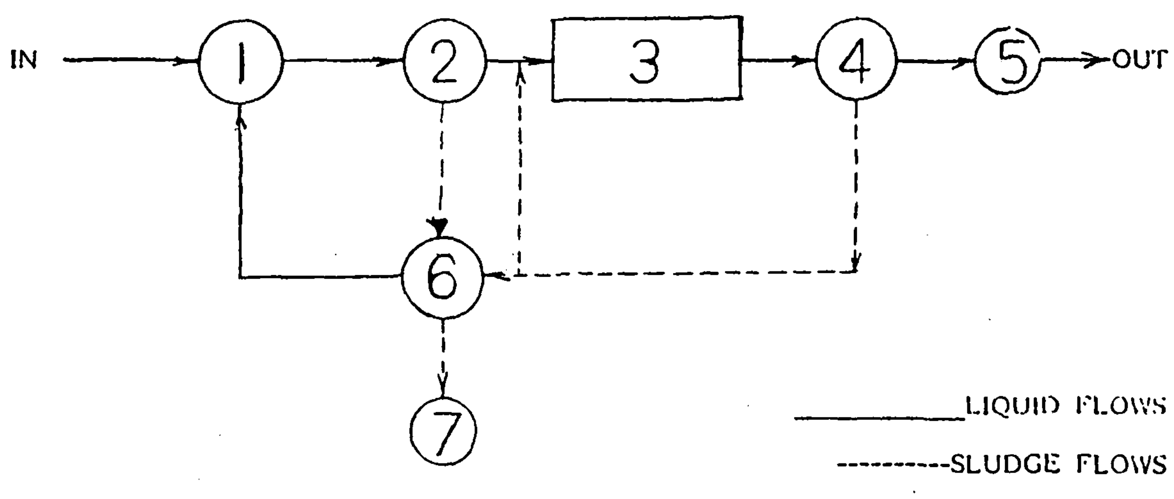


FIG-2

BIOLOGICAL TREATMENT SYSTEM



1. PRELIMINARY TREATMENT.
2. PRIMARY SEDIMENTATION.
3. BIOLOGICAL OXIDATION.
4. SECONDARY SEDIMENTATION.
5. DISINFECTION.
6. SLUDGE DEWATERING.
7. ULTIMATE SLUDGE DISPOSAL.

WASTE WATER UTILISATION IN FACTORY PREMISES

By

Mr. RS Ekbote
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F.M.S.P.I

SYNOPSIS

The utilisation of waste water is very much essential. One of the ways of utilisation is that of plantation and lawns in factory premises. This requires proper study of all aspects of waste water generation, segregation tratment to standards, study of soil required for horticultural purposes, plantation layouts and waste water distribution system. If all these activities areproperly implemented, it will reduce the pollution hazard of surrounding ares and restore the ecological balance. The paper discusses the actual uses of waste water at the factory of M/s. Bajaj Auto Limited, Aurangabad, one of the world leaders in the manufacturing of Scooters and autoriskshas.

INTRODUCTION

Ajantha and Ellora, situated in Maharashtra state near Aurangabad city, are world famous for cave paintings and rock-cut Kailash Temple respectively. About a hundred years ago, when the explorer unearthed the caves of Ajantha, theentire surrounding area was thick with vegetation and greenery. A few centuries ago, during Ramayana and Mahabharata periods (about 3000 B.C.) this part of Maharashtra was called as "Dakshina Desha". The area was full of jungles and wild animals. Naturally the artists who have carved the caves and done painting work have very aptly depicted jungles, wild animals in the carvings of Ellora's Kailash Temple and beautiful paintings of Ajantha.

Slowly due to pressure of population, paucity of natural fuel for cooking and as means of livelyhood and survival, the jungles and trees were recklessly cut making the areas barren. No efforts were made to replant the trees and make good the loss of vegetation. Atharva Veda says about mother earth, "What of tree I dig out,let that quickly grow over, let me not hit they vitals or they heart". Meaning thereby one can take from the earth and theatmosphere only so much as one puts back into them. Man has completely ignored this message resulting in loss of flora and fauna and desertation of the land.

For the progress and survival mankind industrialisation is very much essential. During the process, the natural settings are disturbed. The trees are uprooted and the area becomes barren. Hence the only course left to restore ecological balance in the industrial surrounding is to plant trees, nurseries and gardens. This not only purfies the surrounding of the industry but prevents dust from entering sophisticated machines. It refreshes the workers and gives natural serenity and purity to the environment.

The industrialist gets bogged down with mire thought of planting trees and spending considerable amount for water required for watering the trees. He has to fight in the market for remaining competitive for his product cost. He will mot mind paying for water which he requires for production. He has no alternative but to treat water before letting out from his premises. If this waste water is utilised economically for plantation and lawns for his factory, he may be encouraged to do so.

The basic factors to be considered prior to setting up of the factories are:

1) Quanity of waste water generated from shops.
2) Proper segregation and discharging into treatment unit.
3) Proper designing of the effluent treatment plant.
4) Proper designing for the requirment of soil type in each area of the factory.
5) Proper decisions about trees to be planted, nursery and lawns to be grown etc.
6) Proper assessment of requirment of water of each para for the plantation.
7) Keeping proper and sufficient ares for plantation around the shops, canteen etc.
8) Proper designing of treated waste water distribution system.
9) Proper execution schedule of construction of factory, construction of treatment plant, construction of return waste water lines and proper plantation of trees.

If all these factors are well studied and implemented, it will trun into a beaautiful lush green factory surrounding along with production activities. Then we will be proud of honouring the pious stanzas like "Atharva Vedas" as stated above. Real justice only will be given, when so called management technique of PERT/CPM takes care of horticultural activities as essential activities of project management.

M/s. Bajaj Auto Limited, a leader in the manufacturing of scooters and auto-rikshas. have set up plant in the backward areas of Maharashtra near Aurangabad city about 25 KM from world famous Kailash Temple of Ellora Caves. The area of about 360 hectares alloted to the company is totally barren. The Maharashtra Industrial Development Corporation has laid a 25 KM long water pipe line from Jikwadi dam reservoir for supplying water to industrial area in which this factory is situated. The supply rate of water is about Rs.2-00 per CuM. While taking the challange of setting up the industrial complex in a record time, utmost importance hs been given to proper treatment of waste water and its utilisation for gardening activities.

While designing the industrial complex, deep study has been done for proper layout of the plants, waste water lines, plantation, lawns, trees, nurseries etc. The chemical effluent has been segregated from industrial and domestic effluents. Separate drainage lines are laid for chemical, industrial, domestic water and for storm water. Chemical effluents are treated separately and disposed of. The industrial and domestic effluents are collected and treated in propertly designed effluent treatment plant to the standards laid down by the State Pollution Control-Board.

In case of horticultural purposes, the black cotton soil is very much useful. However, for construction of buildings and machinry foundations, black cotton soil is undersirable. Hence after proper study of requirement of soil thickness required, the black cotton soil has been very carefully removed from the fctory premises as a part of construction activity and deposited in the predetermined areas of nurseries, lawns gardens. It will be interesting to note that about 4 lakhs CuM of

B. C. soil has been removed costing about Rs.1 crore, and given free of cost for horticultural purposes. If not properly planned, the entire B.C. soil might have been dumped on adhoc basis and wasted. This is one of the factors making the horticultural operation very economical.

The second important factor for horticultural operation is ample water. This is taken care of by treating the waste water in effluent treatment plant and supplying it for plantation. The discharge of effluent has been properly assessed and treatment plant consisting ofscreen chamber, wet well, pump house, aeration tank, clarifiers, sludge sump, sludge drying beds, contact-cum-storage tank for treated effluent, pump house for return waste water. The estimated generation of effluent is about 3,200 CuM/day for which effluent treatment plant has been constructed at the capital investment of Rs.50 lakhs. The cost of treated water is only Rs.1.00/CuM, if the cost of manure which is obtained from sludge drying bed is considered and used for tree plantation. If this waste water had not ben utilised, it would be mere waste and an expenditure to the product cost. However, this water is now available for horticultural purposes almost free of cost making horticultural operation very economical.

The layout of shops, effluent treatment plant and plantation plan indicate return pipe lines and plantation. Chart No.1 indicates the type of trees planted and water requirement. The Chart No.2 indicates the quality of effluent before treatment and after treatment indicating that all parameters are well within limits specified.

From the data of water requirment, it has been estimated that 3,200 CuM of treated water will take care of about 120 acres of land which is about 15% of the total area. This means that the treatment plant is in a position to supply entire water required for total area of the factory premises and thus waste water can be used very economically.

As attempt has been made as above to indicate that waste water, if treated properly and utilised for factory premises, will be a boon to the industry. It will reduce the pollution, of the surrounding area and restore ecological balance.

CHART No.1

PLANNING OF PLANTATIONS

Sr. No.	Particulars	Species Planted	Nos.
01.	Flowering tree planted along the road side for Avenues, Around buildings, shops, Canteen building, Dispensary etc.	Gulmohar, Peltophorum, Spathodia, Jacaranda, Millingotonia, Pangara, Casia Sp, Rain Trees, Amaltas,Palash, Persian Lilac, Parkia,. Etc.	8,000
0.2.	Flowering trees, foliage trees planted around DG set, Diesel tank, New Central Bank area, Cement Godown, South of road No.2, Petrol Pump area Administration Office etc.	Gulmohar, Peltophroum Bauhinia, Acacia, Casuarina, Ficus, Species, Neam Bougain Villeas, Jacarandas and mixed shrubs of flowering &' foliage plants	6,500
0.3	Flowering and foliage shrubs planted in the road dividers, along the shops, buildings, canteen area and along the main roads, etc.	Plumbago, Lantana red, Blue, White & yellow, Malpihia, Calliandra, Tecoma Stans, Bougainvilleas, Royal palms , Periwinkle (Barmasis) Ixoradwarf Chinese etc.	12,000
0.4	Decorative foliage trees planted in clusters, rows along the roads, open plots, shops, petrol pump, along the boundary of the two wheeler watchmen's quarters etc.	Eucalyptus, Casuarina(Saru), Acacia auriculiformis, silver oak, green Bamboos, Ficus species, Alstonia Scholaris, Subabul etc.	10,000
0.5	Nursery Plantations in 5 acreas plot flowing trees, foliage trees, Bamboo grooes, for wind break, few furit plants, flowering and foliage shrubs, creepers etc.	Bakan, Pongamia glabra, sisum, green bamboos, subabal for wind brak, few fruit plants like mango, chikoo, awala, Pomegranate, cirrus, varieties, coconut etc. Casuarina (Saru)	12,0000
0.6	Tree plantation done near effluent treatment plant for afforestation.	Eucalyptus, Casuarina(Sarus), green bamboos, Pangara, Subabul etc.	1,000
07.	Plantation done at the Housing complex along the boundary flowering and foliage trees, creepers etc.	Neem, Peltophorum, Bakan Neem, Casuarina (Saru), Acacia auriculiformis, Bougaincilleas in assorted colurs etc/.	5,000
		Total	54,500

Water Requirement for 300 acres of factory area :

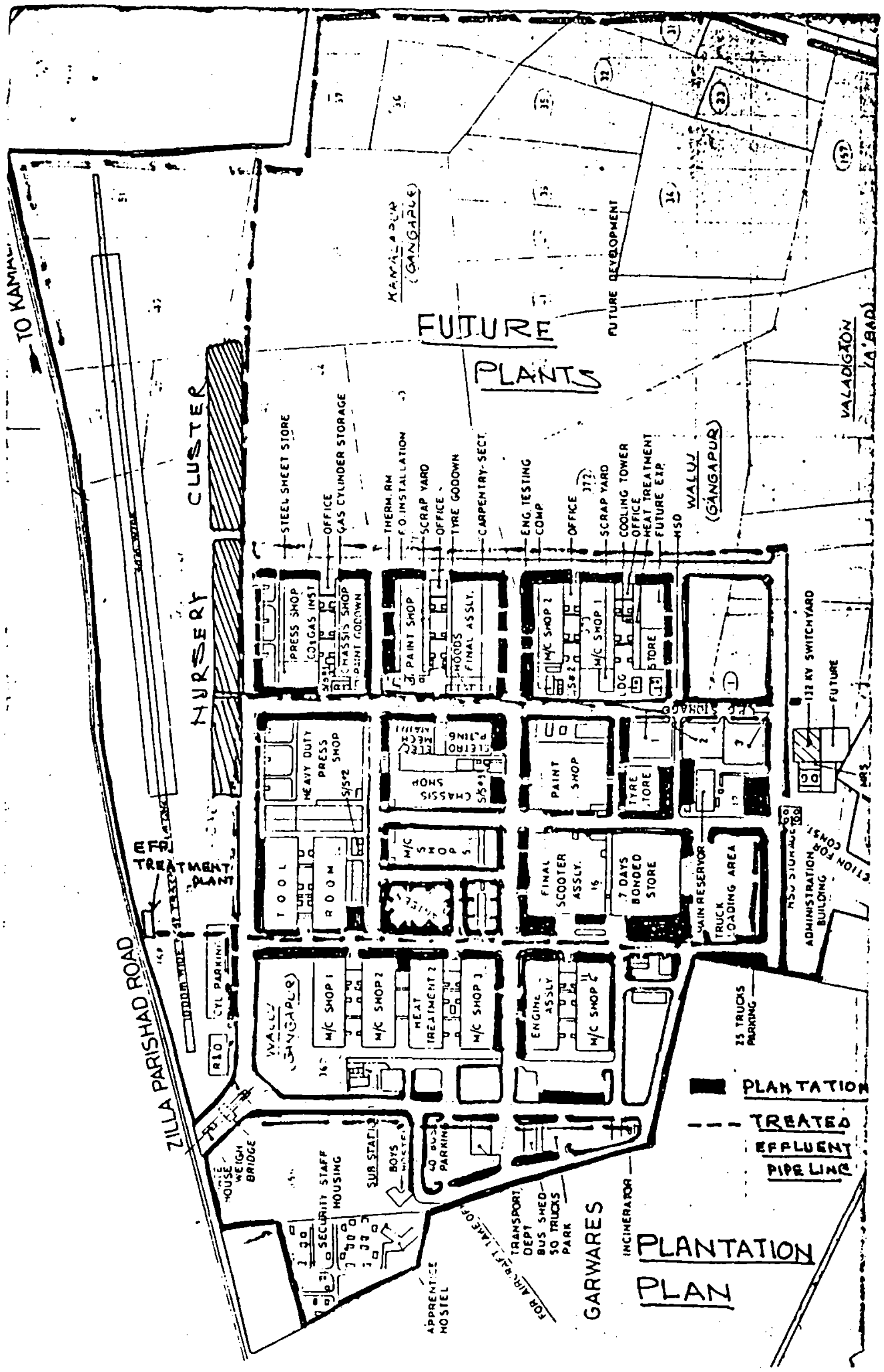
Trees 54,000 Nos	: 220 CuM.
Lawns and Nursery	: 680 CuM.
Total	: 900 CuM.

Total for 900Acres = $2700M^3$

CHART NO.2

RESULT OF WASTE WATER ANALYSIS

Sr. No.	Parameters	Required		Before Treatment	After Treatment
01.	pH	6 to 8		6.80	7.60
02.	SUSPENDED SOLIDS	NOT TO EXCEED	30 mg/ltr	232.00	24.00
03.	B.O.D. -5 DAYS 20^{C}	-do-	30 mg/ltr	220.00	18.00
04.	C.O.D.	-do-	250 mg/ltr	466.00	89.00
05.	COPPER	-do-	3 mg/ltr	0.03	0.02
06.	SINC	-do-	5 mg/ltr	0.25	0.10
07.	NICKEL	-do-	3 mg/ltr	0.03	0.02
08.	CYNIDE	-do-	0.1 mg/ltr	Nil	NIL
09.	CHROMIUM (Cr^{+}	-do-	0.05 mg/ltr	Nil	NIL
10.	DISOLVED OXYGEN	NOT LESS THAN	5 mg/ltr	1.80	5.20
11.	OIL & GREESE	-do-	10 mg/ltr	5.80	NIL
12.	BIO-ASSAY TEST	90% SURVIVAL IN 96 HRS.		-	O.K.


FUTURE PLANTS
CLUSTER NURSERY
ZILLA PARISHAD ROAD
EFF. TREATMENT PLANT
WALUJ (GANGAPUR)
VALADGAON (A'BAD)
FUTURE DEVELOPMENT
STEEL SHEET STORE
GAS CYLINDER STORAGE
SCRAP YARD
TYRE GODOWN
CARPENTRY SECT.
ENG. TESTING
COOLING TOWER
HEAT TREATMENT
PRESS SHOP
PAINT SHOP
FINAL ASSLY.
M/C SHOP 1
M/C SHOP 2
HEAVY DUTY PRESS SHOP
CHASSIS SHOP
TYRE STORE
TOOL ROOM
FINAL SCOOTER ASSLY.
7 DAYS BONDED STORE
MAIN RESERVOIR
TRUCK LOADING AREA
132 KV SWITCHYARD
ADMINISTRATION BUILDING
HEAT TREATMENT 2
M/C SHOP 3
ENGINE ASSLY
25 TRUCKS PARKING
WEIGH BRIDGE
SECURITY STAFF HOUSING
SUB STATION
40 BUS PARKING
APPRENTICE HOSTEL
TRANSPORT DEPT BUS SHED 50 TRUCKS PARK
GARWARES
INCINERATOR
PLANTATION
TREATED EFFLUENT PIPE LINE
PLANTATION PLAN

CONTROL OF INDUSTRIAL WATER DEMAND BY QUOTA SYSTEM

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Dy. Municipal Commissioner
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SYNOPSIS

Rapid urbanisation leading continuous widening of the gap in the supply and demand of water presents serious problems for the Water Works Authorities. The situation assumes critically during a drought year when the Water Works Authorities invariably attempt to curb industrial demand of water. Under such circumstances, a quota system for Industrial water demand was enforced in Bombay. The author describes the evaluation of the quota system in Bombay and examines its efficacy.

INTRODUCTION

Bombay City though only a State Capital of the Maharashtra State, is an economic capital of the country. It is second largest populated city in country and ranks amongst the first ten large cities of the world. It supports many economic activities, lead by industry and followed by trade and commerce. These economic activities or state job potentials leading to phenomenal rate of increase of population mainly by influx of job seeking populace. The rate of increase of population in the City has dittered all the classical methods of forecasting population over the last 4 decades which is evident from the Table No.1 showing population growth, and availability of water for the past 8 decades.

CRITICAL YEAR

Bombay WWA, in a normal year, overdraws from the sources in an attempt to at least marginally narrow down the gap between the supply and demand of water. However such overdrawal adds to the critically during a drought year. In the year 1965 the rainfall was scanty resulting in unsatisfactory impounding at the sources whereas the monsoon set in abnormally late in the year 1966, giving rise to very grave situation in summer of 1966. The sources recorded their lowest levels, and there was talk of even evacuating the city which was mercifully not required to be effected. However, this close shave focussed the attention on urgent necessity of augmentation of city's water supply on one hand and of curbing the water demand of the City on the other.

WATER QUOTA FOR INDUSTRIES

As is the normal experience, WWAs give a higher priority to the domestic demand and attempt to curb/curtail the industrial supply. Coincidentally it was at about the same time, Govt. of Maharashtra, in an indirect attempt to curb the growth of population in the city, had made an important decision of not allowing any new industry to be started in the city as also not allowing any expansion of the existing industries in the City except in very special cases. The decision logically led to a conclusion of pegging the total industrial water demand in the City and thus a 'quota system' was born.

OBJECTIVES OF THE QUOTA SYSTEM

The objectives of the quota system were --

Table 1

Population and Water Supply in Bombay

Year	Population in millions	Water Supply (mld)
1901	0.93	145.0
1911	1.15	145.0
1921	1.38	227.0
1931	1.40	295.0
1941	1.80	295.0
1951	2.99	428.0
1961	4.15	918.0
1971	5.97	990.0
1981	8.24	2048.0

1. To peg the consumption of water for industrial use to a level obtaining in the year 1967.

2. To promote awareness of the acute shortage of the resource-namely water - amongst the industrial consumers.

3. To encourage the industries to use the available quantity of water judiciously by avoiding wastage, adopting recycling of water etc.

CONTROL MEASURES

The Govt. of Maharashtra empowered by Municipal Commissioner to adopt any or all of the measures mentioned below to enforce the quota system.

1. To charge industrial cosnumer for whom a quota has been fixed at 20 times the normal industrial rate for the quantity by which his consumption exceeds the quota.

2. To throttle the connections to as much extent and for as much period as was necessary to restrict the supply within the quota.

3. To discontinue the supply for as much period as was necessary to restrict the supply.

INITIATION OF QUOTA SYSTEM

Initially the water drawn and consumed by each industry during a reference period of continuous twelve calendar months was evaluated from the meter readings and an average monthly consumption for every industry was established. A quota equal to 90% of such average monthly consumption was fixed for each month requiring industries to limit their water consumption to the quota figure.

Apart from fixing the quota, MCGB employed the services of Consultants to study 40 industries and to suggest means of reducing the demand of water without affecting the quality and the quantity of their product. A majority of these were textile industries. The recommendations of the consultants were made available to the industries free of charge.

EVALUATION OF QUOTA RULES

Initially the quota rules were made applicable to industries consuming more than 1,50,000 lts. per month. This limit was subsequently raised to 3,00,000 lts/month and was recently further raised to 5,00,000 lts/month as an A.B.C. analysis indicated that better results can be achieved by closely monitoring a lesser amount of industries having larger consumption.

A number of industries represented that since their consumption varied as per their production schedules which were governed by many factors beyond their control. In view of these genuine difficulties, the penal actions were decided to be initiated only if the quota was exceeded in a period of one quarter - 3 months.

Although the Municipal Commissioner had powers to charge 20 times the normal charge, it was decided to charge twice the normal charge for first infringement and thrice the normal charges on the second infringement during the financial year.

A number of cases where industries were drawing much less than the quota for long periods and since such industries were blocking the quota quantity, the rules for charging a minimum of 90% of the quota irrespective of actual lesser consumption were introduced and at the same time an exces of 10% above the quota was exempted from penal action. These limits were later revised to ±20%.

Various rules and procedures were evolved to deal with cases of industries which were unable to draw minimum quantities either due to strikes or lockouts or due to general deterioration of water supply in the zone.

SUCCESS OF QUOTA SYSTEM

Did the quota system succeed in achieving its objectives ? The answer to this question is "Yes and No" in as much as it did retard the rate of increase in industrial demand in the last 20 years or so on one hand but on the other hand, it hardly promoted any industry to come forward to examine its own demand more critically and to adopt means such as wastage, prevention or recycling of water.

REASONS FOR PARTIAL SUCCESS

Some of the reasons for partial success are --

1. Absence of data or unreliable data recorded by water meters gave rise to disputes thus impending the adoption of penal measures.

2. Since penal actions involved large sums of penalty it was suspected that the water meters were tampered with and hence no control was possible.

3. Administrative staff often ignored the basic objective of pegging industrial consumption and looked upon penalties as revenue of the organisation and thus deferred action for throttling or disconnecting the supply.

4. Vagaries of market conditions, uncertain labour relation and uncertain availability of raw materials coupled with involved procedure of reducing and subsequently restoring quota, promoted some industries to draw their quota irrespective of their need.

5. Perhaps the cost of water being comparatively very small, the penalty charges failed to affect the production cost. Also perhaps

"Seller's Market" conditions the increased cost could be conveniently passed on to the consumer thus eliminating the need for the industry to take any corrective action.

CONCLUSION

Although the quota system does achieve some success in controlling the increase in the industrial demand, it is felt that efforts involved in administering the quota rules are not commensurate with successes gained.

RECYCLING OF TREATMENT PLANT WASTE

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SYNOPSIS

The most significant waste product from a conventional water treatment plant is a thin sludge containing aluminium hydroxide together with organic and inorganic matter derived from the raw water. Methods are available for the treatment of this sludge, to yield water, which may be recycled through the plant, and a thicker sludge which may be disposed of. Alternatively the thickened sludge may be treated with sulphuric acid to yield a solution of aluminium sulphate suitable for re-use in the treatment process.

Guidelines are given of the processes used in two full-scale plants - one in Bombay and one in Scotland.

INTRODUCTION

The treatment of water, like many other industrial operations, yields a number of waste products. Clearly the nature and amount of these waste products depends on factors such as the composition of the raw water, the degree of purification to be achieved, and the processes to be employed.

At works employing coagulation followed by sand filtration, large volumes of waste water are produced intermittently as sludge from sedimentation tanks and during back washing of the filters. The sludge is often unsuitable for recycling but the filter washwater may be recycled to the raw water intake, usually after balancing and sedimentation. If this is not done and the washwater is discharged to waste the water so lost is to be regarded as a waste product having a value related to the cost of finished water. This value must be compared with the cost of providing and operating the plant required for recovery of the water content of washwater. The economics of recovery of washwater are discussed in subsequent sections.

Among the other waste products which have been identified at treatment works [1] the following are probably the more important :

(i) Sludges from pre-sedimentation stages.

(ii) Precipitates from iron and manganese removal processes.

(iii) Calcium carbonate sludges from lime softening plants.

(iv) Spent regenerants and washwaters from ion-exchange processes.

The constituents of these wastes are usually of little value and since also they are relatively innocuous they are often disposed of with minimal treatment. Commonly used disposal routes are :

Discharges to land or to local water courses,

Discharge to local sewers,

Lagooning, and

Drying on sand beds.

Where such direct routes of disposal are not available waste sludges may be dewatered by thickening and reduced to solid form in filter presses or in centrifuges. Such solids may then be transported for disposal as a solid waste at local landfill sites.

A major item in the running costs of a works employing chemical coagulation is the cost of the coagulant itself (usually alum) which is converted almost quantitatively into alumiunium hydroxide in the hydroxide sludge and in the washwater suspended solids. Many attempts have been made to recover this aluminium for reuse but few full scale plants are now believed to be in operation. The reasons for the failure of this procedure to gain general acceptance are discussed in a subsequent section.

Of the other waste products mentioned above only the calcium carbonate sludge offers any prospect of the recovery of a valuable product - in this case lime. In principle all that is needed is to thicken the sludge to increase its solids content followed by calcining in a suitable kiln. The process was employed for many years at the Southend water works in the United Kingdom where a very hard water was softened and disinfected by the "excess lime" process; this has since been discontinued on grounds of cost. There are also problems associated with the presence in the sludge of impurities such as magnesium hydroxide and clay. However chalk is still being recovered for use in the cosmetics industry at a treatment works operated by the East Surrey Water Company.

In recent years the statistical association between hardness of water and cardiovascular disease has led to a lessening of interest in softening of municipal supplies and the subject of recovery of lime will not be discussed further in this paper.

We are left therefore with two waste products of potential value which can be recovered from wastes at a water treatment works, namely water from filter washwater and alum from coagulant sludges. These are discussed in more detail in the following sections.

RECOVERY OF WATER FROM FILTER WASHWATERS

The intermittent washing of sand filters following coagulation stages yields large volumes of water containing a few hundred mg/l of suspended solids. Washing may take place at intervals of about 24 hours and the volume of water used may be 2 or 3% of the volume of finished water. Recovery of this water by return to the inlet works requires pumping plant and ancillaries; there may also be an increase in the amounts of alum and chlorine required to treat this part of the input since it differs in quality from the bulk of the raw water at the intake. In view of the intermittent nature of the discharge, balancing tanks will be needed in order to match the steady rate of return of water with its intermittent production. The cost of power required for pumping must also be taken into account.

In considering the economics in more detail it may be helpful to give some results of a recent study carried out by Binnie & Partners on behalf of the Municipal Corporation of Greater Bombay for the Panjrapur Works.

At the present maximum works flow of 545Mld (120Mgd) (corresponding to about 40% of the ultimate output) 18 filters are in service and could use for each wash a maximum of 600 m^3 (132000 gallons) including draindown and cross-wash water. The total usage of water is therefore 10800 m^3 per day (2.4 million gallons) assuming a 24-hour length of filter run.

On the basis of a water charge of Rs.10 per 10000 litres the loss of revenue is Rs.10800 per day or Rs.38.9 lakhs per annum.

This loss of revenue may be prevented by recovery of washwater; to achieve this the following capital expenditure is required :

	Rs. lakhs
Inlet pipework	25
Pumping plant and accessories	34
Structures	36
Delivery pipework to works inlet	5
	100
Contingencies	10
	110

Additional running costs will include electrical power, additional chlorine and additional alum; the latter is a provision for the "worst case situation" as it is thought unlikely that the alum dose rate would in fact need to be increased.

Taking into account also the costs of maintenance and spares the net present values for 3 discount rates and 3 estimates of plant life are as follows :

	Net Present Value (Rs. Lakhs) at discount rate shown		
	5%	10%	15%
Option (a) - No washwater recovery			
over 20 years	776	489	332
over 25 years	886	526	344
over 30 years	972	548	351
Option (b) Washwater recovery plant			
20 year life	374	266	205
25 year life	413	279	209
30 year life	443	287	211

These figures show that the provision of washwater recovery is in real terms more economical than direct discharge taking into account the loss of revenue. The results are insensitive to discount rate and plant life and lead us to believe that consideration should be given to the inclusion of a washwater recovery system at this works; the client has been advised accordingly.

RECOVERY OF ALUM

The basic process for the recovery of alum from alum sludge at a water works is shown in Figure 1. Sulphuric acid is mixed with thickened sludge converting precipitated aluminium hydroxide to a solution of aluminium sulphate. The remaining insoluble material is thickened, separated and dewatered for disposal. The acid supernatant is returned to the inlet of the works and supplemented with new alum to make up the required alum dose.

The amount of acid required may be greater than that stoichiometrically required to react with the aluminium hydroxide because of the presence of other substances in the sludge - e.g. calcium carbonate(2). In practice it is not usual to attempt to extract all the aluminium as the low pH necessary would tend to extract organic colouring matter and heavy metals. Some of the recovered aluminium will remain in solution in the underflow from the acid sludge thickener; depending on subsequent processes this may or may not be recovered. Since it is necessary to purchase sulphuric acid in order to recover alum a major consideration in the economic assessment is the cost of sulphuric acid in relation to the cost of new alum.

Thickening of the coagulation sludge is essential in order to ensure that the concentration of the recovered alum is greater than the minimum required for effective coagulation (0.15% as aluminium in solution corresponding to 0.17% as aluminium in the thickened sludge).

Some of these points may be illustrated by reference to a recent study carried out by Binnie & Partners in connection with the Karkh Scheme in Iraq. This work has an average summer monthly output of 800 Mld (176 Mgd) and uses alum as the coagulant for clarification of the water, the alum being added prior to both the presettlement and clarification stages of treatment. The estimated average dose rate of alum at each of these dosing points is 50 mg/l as aluminium sulphate hydrate. On the basis of this through put and alum dose rates the daily requirement of alum is very large (80 tonnes per day) and quite costly. Obviously methods for reducing the consumption and hence the cost of alum are worth considering and one of these would be to recover alum from the waste sludge which would otherwise be discharged to waste and to use this to replace fresh alum.

In laboratory tests using sludges similar to those likely to be produced at the works the pH values were lowered to various values using sulphuric acid and it was found that up to 54% of the aluminium content could be extracted by a acidification to pH 2.1, stirring for 30 minutes and settling. If the resulting sludge were to be further dewatered, e.g. by centrifuging, recovery of up to about 75% of the alum could be expected. The amounts of sulphuric acid were used however greatly in excess of that theoretically required to extract all the aluminium and this was attributed to the presence of calcium carbonate in the coagulation sludge.

The organic quality of the recovered alum was reasonable and this was expected since the natural colour and organic content of the raw water are low. The recovered alum proved to be more effective than new alum in jar tests possibly because of the effect of acid in the recovered alum in lowering the pH value in the coagulation stage.

Simple costing shows that because of the higher consumption of acid the process was not likely to prove economically acceptable at Karkh unless the ratio of cost of acid to alum fell to about 0.55 compared with its present value of about 1.1. This was thought unlikely to occur.

An uneconomic process for the recovery of alum might prove acceptable under some conditions e.g. where the resulting reduction in the volume of sludge facilitated disposal in an area where disposal would otherwise prove difficult. There are however no difficulties in disposal of sludge at Karkh and it was therefore decided that recovery of alum at this works was not likely to prove an acceptable proposal.

A modified process developed in the UK by Paterson Candy International attempts to reduce capital costs by omitting the thickening stage and the final pressing stage, any suspended materials being returned with the alum solution to the works inlet. Pilot plant trials are usually necessary to determine if this can be done. To limit the build-up of suspended material and other unwanted chemical parameters, only a proportion of the total sludge from the clarifiers is recycled.

The process was costed in 1980 for the Panjrapur works of the MCGB. For treating sludge produced by a 454 Mld (100 Mgd) treatment works, a contractor's estimated cost was about Rs.108 lakhs and the estimated chemical running cost about Rs.11.6 lakhs per annum. Power costs were reckoned to be small in comparison.

The above chemical running costs were based on the chemical prices as given below :

Aluminium sulphate Rs.900/- per tonne delivered site.

Sulphuric acid Rs.925/- per tonne delivered site.

The costs also allow for a non-monsoon alum dose of 10 mg/l and a monsoon dose of 20 mg/l and assume that 75% of the alum is recycled to the works inlet and that 25% new alum is used.

By comparison the annual cost of alum at Panjrapur (without a recovery system) was about Rs.20 lakhs.

A revised economic comparison between the provision of an alum recovery plant and the annual cost of alum at Panjrapur (without a recovery system) was carried out. Civil, power and labour costs and taxes were neglected in calculating discounted costs for the alum recovery plant. Taxes were included in chemical costs in both options considered.

The results, taking into account capital cost, maintenance and spares costs at 5% per annum, and chemical operating costs, are tabulated below :

		Net Present Value (Rs. lakhs) at discount rate shown		
		5%	10%	15%
(a)	Option 1 - Alum Recovery Plant			
	over 20 years	526	310	240
	over 25 years	507	302	237
	over 30 years	494	298	235
(b)	Option 2 - No Alum Recovery	412	216	150

These comparisons show that this method of alum recovery would not be economic at this works, the conclusion being insensitive to discount rate and plant life.

Alum recovery has been used successfully at many large scale plants - 17 in Japan, 1 in UK, 1 in France and 2 in the United States. It is believed however that the process has now been distributed at most if not all of these plants.

The plant in the UK at Daer in Scotland (3, 4) operated successfully for some 15 years and in addition to the use of acid treatment to recover alum employed the interesting process of freezing to dewater the sludge. The layout of the works is shown diagrammatically in Figure 2.

In 1971 the works was treating 118 Mld (26 Mgd) using a dosage of 20 mg/l of alum and 4 mg/l of activated silica. The sludge from sedimentation tanks (later including washwater sludge) was mixed by recirculation in holding tanks giving a steady solids content of about 0.5%. Each day sludge was pumped from the holding tanks and acidified to pH 2.1 by injection of sulphuric acid. The pH value was said to be critical and represented a compromise between efficient recovery of alum and extraction of undesired organic matter. After a period of contact and sedimentation of about 20 hours supernatant liquor containing alum was decanted and thickened sludge discharged for further thickening in a separate vessel; an additional quantity of alum was recovered at this stage.

The remaining sludge was frozen and then thawed; by this means the sludge is converted to a stable grannular form and a further quantity of alum solution was recovered.

About 50-70% of the alum was recovered for reuse. The operation was considered satisfactory though the recovered alum was thought to have some adverse effect on the operation of the sludge blanket; colour was not a major problem at this works. Though the alum recovery has now been discontinued pending reconstruction of plant at the works there remains the possibility that it may be reintroduced in the future. The use of the freezing process is considered satisfactory since it produces a grannular sludge of low volume and high density which may be disposed of within the area of the works.

CONCLUSION

An attempt has been made in this paper to illustrate some practical aspects of the recovery of two potentially valuable products from the waste streams of conventional water treatment plants. The products discussed are water and alum, and the case studies given are intended to illustrate the relevance of recovery processes to local conditions.

The primary motivation for employment of recovery processes is usually economic - the nett present value of the recovery process is less than that of the alternatives.

It is implicit in such calculations that the balance of economic benefit will be different at different times and in different places. Thus if, as seems likely, the cost of energy, materials and manpower continue to increase, the opportunities for employing recovery processes may well become more abundant.

The other motivation for making use of recovery processes is to minimise the environmental impact of a water treatment plant either by reducing its demands on local water resources or by facilitating the disposal of its waste products without causing local pollution. Water treatment plants are not often regarded as source of pollution, but present tendencies towards construction of larger units, together with increasing public awareness of the need to protect the environment, may also create opportunities for recycling of waste products, provided always that this represents an economic solution to the pollution problem.

Whether therefore the motivation is the rather narrow concept of on-site economics, or takes into account also the wider concepts of environmental impact, it seems likely that opportunities for making use of the waste products of water treatment plants will tend to increase.

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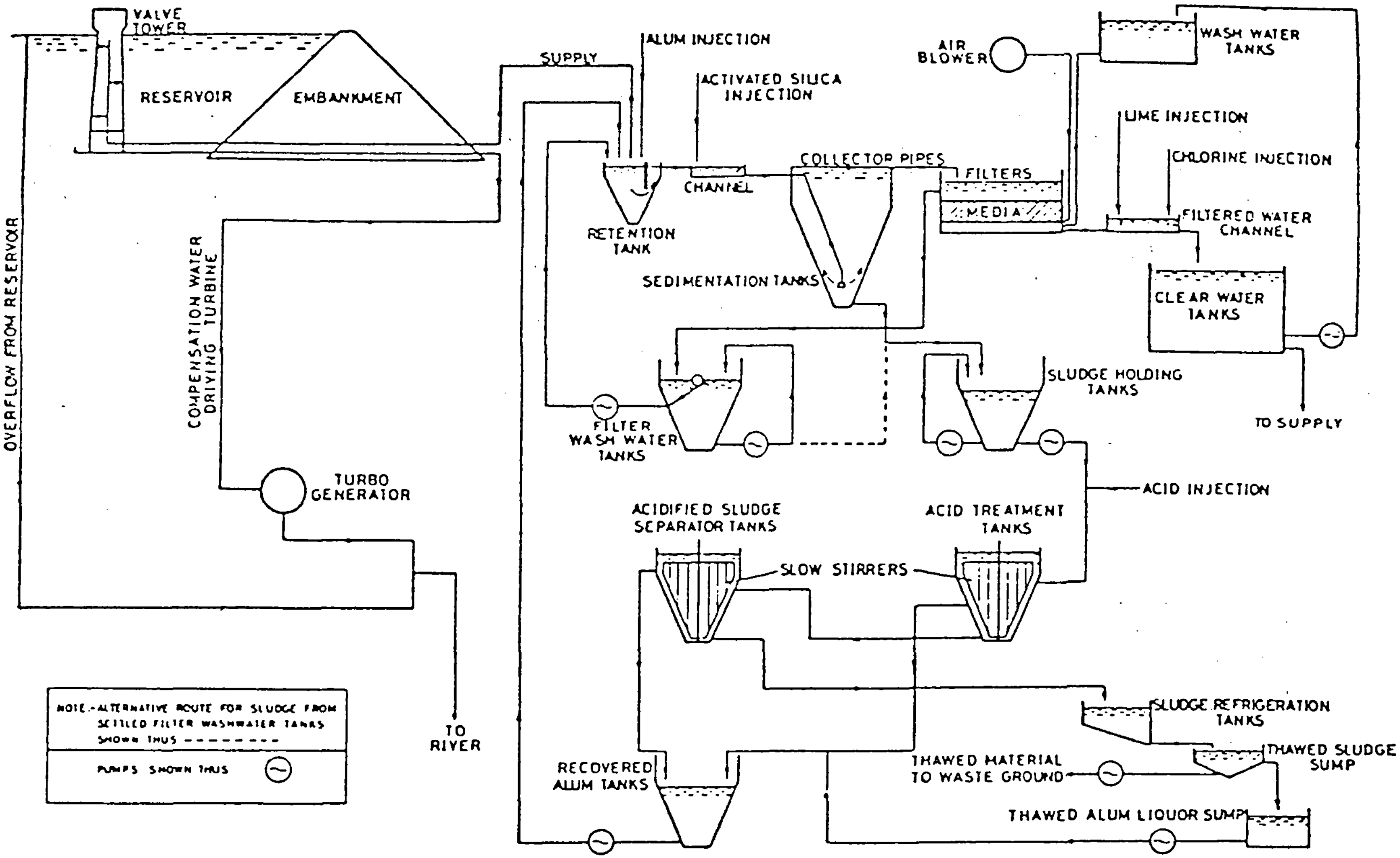


Fig. 2. *Diagrammatic Layout of Daer Waterworks.* (4)

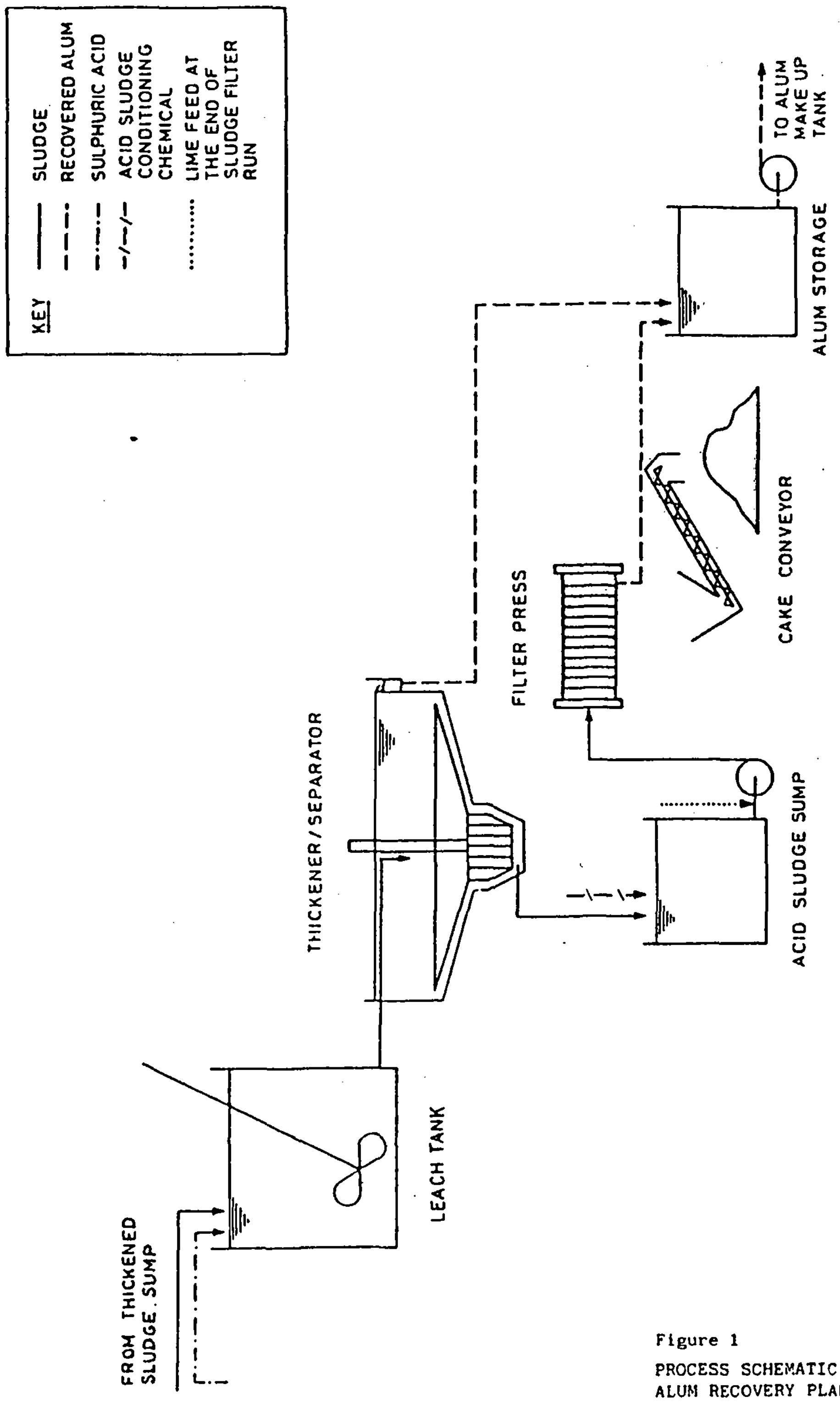


Figure 1

PROCESS SCHEMATIC OF AN ALUM RECOVERY PLANT - WITH UNDERFLOW RECOVERY

SEA WATER AS SOURCE FOR AUGMENTING URBAN WATER SUPPLY

RS CHAUHAN N BALAJI GC MISHRA

SYNOPSIS

Fresh water resources of our Coastal cities are being increasingly strained due to increase in population, industrialisation and change in people's life-styles. In places where additional fresh water is not available or can not be spared due to competing use, such as for agriculture, urban water supply may be augmented by using sea water after desalination.

Among the known desalination process, three, namely distillation, electrodialysis and reverse osmosis (RO) are commercially proven. Of these, reverse osmosis (RO) is used for both sea water as well as brackish water desalination.

RO is a membrane separation processes. A semipermeable membrane separates sea water and pure water and high presure is applied to thesea water causing pure water to pass through the membrane while salts remaains in the reject water. The pressure applied depends on the salt concentration and varies from 400 psig for brackish waster to 1000 psig for sea water.

The incoming water is subject to pre-treatment for the control of suspended mattrer, organic fouling, p^H, corrosion, residual chlorine etc. The water is then passed through a train of RO modules which separate pure water and reject concentrated brine. Finally the desalinated water is stabilised by pH control and degassification and then the final product is sent to the distribution network. The capital cost of RO Plant for handling sea water ranges from \$ 1000 to \$ 1850 per m3/d capacity. For brackish water the capital cost ranges from \$ 220/m3/d to \$ 320/m3/d. The oerating cost depends on the cost of energy, chemicals, cartridge filters, membrances, labour etc. and various from place of place. But generally the cost would be \$ 1.54/m3 to \$ 2.39/m3 for sea water and \$0 0.29/m3 to \$ 0.40/m3 for brackish water. In an Indian plant using brackish water, operating cost works out to Rs.3.60/m3.

In the recent past water has been transported from Vijayavada to Madras and Hyderabad by rail, to augment water supply of these cities. The cost of trnsport alone in case of Madras was Rs.58.00/m3 and that for Hyderabad wasRs.50.00/m3. Compared to this, the cost of water from RO plant is very small and a 1 MGD RO plant at Madras or Hyderabad will have a payback period of a month only. Therefore, use of sea water to augment urban water supply in scarcity areas is economially viable.

INTRODUCTION

With the increase in world population and also due to improved standard to living, the use of fresh water and its requirement has increased drastically. In some cases this has severely strained available fresh water supplies. Shortage of freshwater hs adversely affected development and peoples quality of life.

In India also unplanned urbanisation has adversely affected the potable water supply of the urban areas. Added to this, rains have also played hide and seek or truant for the last two or three years in succession. Some metrapolitan cities like Madras, Jaipur are facing actual shortage of water. It is high time for planners to think of alternative source of water for such cities. So acute was the scarcity of drinking water in Madras three/four years back that it had to be transported by rail tankers from Vijayawada. Drinking water shortage has been reported in the States of Gujarat and Rajasthan also.

With ever incresing population of our country there will be, by turn of the century, more areas, where people will suffer due to shortage of this basic aminity unless appropriate mesures are planned now and implemented gradually.

In the past, brackion water and sea water were not considered developable resources for potable and agricultural uses. The High levels of salts in these waters made it unpalatable for drinking and unsuitable for normal agricultrual purposes without desalination. Flash evaporation and few other processes were initially developed tomake saline water suitable for industrial and human usage but these were used only in limited way, mostly in coastal areas of Middle East countries, since the economics of these processes is not favourable. However, the development of desalination technology has now made these water resources available for use of mankind.

Five major desalination processes have been used; Ion-exchange, distillation, freezing, reverse osmosis and electro-dialysis. Of the three commercially proven processes namely distillation, electrodialysis and reverse osmosis there is no one process which could be universally suited to all applications. Suitable one has to be selected for a particular application. Generally distillation and reverse osmosis are used for sea water desalting whereas reverse osmosis and electrodialysis are used for brakish water desalination.

In this paper Reverse Osmosis system hs been discussed in detail, highlighting the technology and cost analysis. Also given in this paper, as a case study in the cost analysis for transporting water from Vijawada to Madras by Rail tankers as was resorted to 3/4 years back when Madras was facing a grave water crisis. The position even today is no better.

An attempt has been made in this paper to putforth some guideliness to the concerned authorities which may enable them to carryout schemes for tapping sea water/brackish water.

THEOREY OF REVERSE OSMOSIS

Desalination by Reverse Osmosis is a membrane separation process. It is based on the natural process of "Osmosis" which is basically a biological process. When a semi-permeable membrane such as living cell wall separates two solutions with differing concentrations of dissolved solids, pure waster flows from the solution containing the lower concentration of solute through the membrane into the solution containing the higher concentration of the solute till the equilibrium is attained. If pressure is applied grdually to the more concentrated solution, the normal osmotic flow gets retarded until a stage is reached when there is no flow at all. This pressure is known as 'osmotic pressure'. A pressure in excess of the osmotic pressure results in reverseing the flow of water i.e pure water passing frommore concentrated solution. This process of seperation the pure water from the concentrated solution is termed as "Reverse Osmosis". The theory is clearly illustrated in Fig.1&2.

SCHEME FOR REVERSE OMOSIS SYSTEM

A reverse osmosis system consists

of four major units as shown in Fig.3; (1) pre-treatment (2) high pressure pump (3) membranes battery (4) post treatment unit.

The incoming feed water is pre-treated so that quality is competible with the requirements for optimum performance and life of the membranes. The treatment usually consists of chlorination, removal of suspended matter, pH control, addition of scale inhibitor and removal of excess chlorine.

These pre-treatment facilities are a must before the water can be fed to the membrane. The desired quality can be achieved by clarification, pressure filter and cartridge filter for removal of suspended matter upto 1 microne size, chlorination for removal of bacteria and dechlorinnation to remove excess of free chlorine as certain membranes are attacked by free chlorine.An elaborate chlorination and sodium sulphite dosing system are pvovided.

Automtic pH control for feed water is done and sulphuric acid is preferred for the same. The control of scale is done by dosing Hexa meta phosphate.

The dosing system normally consists of tanks and dosing pumps and for chlorination either chlorine cylinder with chlorinator or hypochlorite solution with dosing pumps are provided.

HIGH PRESSURE PUMPS

The pump delivers the pre-treated water at high pressure appropriate for the membrane depending on the feed water being used. To have an idea ordinary brackish water with total dissolved solids (TDS) content of 1,500 mg/1 will have an osmotic pressure of 15 psig while sea water with a TDS of 35,000 mg/1 hs an osmotic pressure of 350 psi. The external pressure applied to salt solution must exceed the osmotic pressure of the solution for Reverse Osmosis to occur.

For brackish water the pressure should be 400 - 600 psig and sea water 800 - 1000 psig.

MEMBRANE ASSEMBLY

The semi-permeable membrane inhibits the passage of dissolved salts while permitting almost salt free water to pass through. Feed water sent to the membrane is thus split into water product stream and concerntrated brine reject. No membrane gives cent percent rejection of dissolved salts, so a small percentage of salt does move through the membrane and appears in the product. It may not be out of place to mention that the leading expert in this field is an Indian called Dr. Sourirajan.

STABILIZATION

The product water from the membrane assembly requires pH adjustment and degasification before being transferred to the distribution systems for potable use.

ECONOMICS OF REVERSE OSMOSIS PLANT

Brackish and sea water have been considered here to have an idea of the economics of RO plants. RO is used for other purposes also but the above costs may not apply for such cases. The comparative cost of the other processes has also been indicated to enable the reader to compare capital investment for each process.

CAPITAL COST

The capital cost on RO system depends on the system capacity, degree of pretreatment, feed water salinity, temperature and overall scope of the project. System costs vary with the type of water being treated i.e.sea water or brackish water and the size of the system. Large facilities can achieve an economy of size and minimize the per unit cost of product.

In general the total capital cost for sea water plants may range from $ 1,000 to $ 1,850 per m/d^3. for plant size upto 3,800 m3/d plant and beyond 3,800 m3/d capital cost may drop below $ 1,000 per m^3/d

These costs are based on:-

Feed TDS	35,000 mg/l
Feed temp	21°C
Conversion	30%
Plant load factor	85%

No energy recovery

Capital cost for brakish water plants range from $ 220/m3/d for 94,000 m3/d plant to $ 320/m3/d for 3800 m/d plant. The costs are based on;

Feed TDS	2000-5000 mg/l
Conversion	80%
Plant load factor	75%

OPERATING COST

Operating costs for RO system vary greatly from place to place. Variables affecting these costs include energy, chemicals, filter, cartridge, labour and membrane replacement. For seawater plant without energy recovery total water cost ranges from $ 1,54/m3 to $ 2.39/m3. If energy recovery were used the totral water cost would be reduced by 17%. In brackish water plant the total water cost ranges from $ 0.29/m3 to $ 0.40/m3. In an Indian plant the cost would be Rs.3.60/m3.

Some of the operating parameters are given in Table -2.

Table - 2

Summary of operating conditions and operating cost for Cape Coral Reverse Osmosis Plant :-

Total water produced-product Plus blend.	423Mm^3.
Average daily production	6930m3/d
Average raw water blend	1.510m3/d
potential water production at 17,000 m3/d	9.21Mm3
Overallplant utilization	46%
Feed pH range	5.8 to 6.0
Sulphuric acid dosage	125mg/1
SHMP dosage	3.4 mg/l
Caustic dosage	21 mg/l
Chlorine dosage	4.4 mg/l
Free chlorine residual	1.5 to 2.0 mg/l
Feed water pressure range	295 to 315 psig
Membrane cleaning	Nil
Cartridge filter replacement	One
Operating Cost	Cents/m^3
Chemicals	1.5
Electrical	7.7
Labour	3.1
Membrane replacement	3.3
Equipment maintenance	1.1
Total Operating cost	16.7
Amartized capital	14.6
	31.3

Table - 3

Summary of design data, operating factors and operating cost of a water treatment plant at Kind Khaled Airport.

	Design	Actual
Plant capacity m3/d	11745	12303
High purity industrial rate m3	4305	4562
Potable water rate m3/d	7440	7441
High purity industrial water TDS	100	51
Plant recovery rate %	85	79
Acid consumption kg/m3	0.1676	0.1852
Inhibitor consumption kg/m3	0.0156	0.0058
Power consumption Kwh/m3	1.52	1.62
Operating pressure kPa	2.979	2.099

Operating cost	Saudi Riyal 1.21/m^3 r

Table - 4

Summary of design data operating factors and operating cost of a water treatment plant in India.

Plant capacity		2x60m^3/h
Feed water temperature		31°C
pH		6.2
Pressure;		
RO Feed		19.5 kg/cm2
RO brine		15.0 kg/cm2
RO Product		1.05 kg/cm2
Flow		
RO Product		60 m3/h
RO Reject (Brine)		20 m3/h
Conductivity		
RO Feed		950 Us/cm
RO Product		73 Us/cm
Salt reject		97.7%
Cost of plant	Rs.	2.194 crores
Operating cost	Rs.	3.02/m3

OPERATING PROBLEMS IN REVERSE OSMOSIS SYSTEM

Most failure in Reverse Osmosis plants occur due to deposition of matter particles on the membrane surfaces or in the membrane structure. Other problems occur due to mechanical failures. The major problems are;

1/Fouling

Fouling is the deposition of materials within the plant resulting in reduced performance of the system. These deposits are from four major sources.

- precipitates
- colloids
- particulates
- Mircro organisms

Precipitates;

During the reverse osmosis process the salts remaining in the water on the feed side of the membrane get concentrated as water passes through the membrane. The concentation can be two times or more thn that of the feed water. These concentrations often exceed the solubility limites.

Colloids

Colloids are particles less than one mircon in diameter. The major colloids of concern for reverse osmosis are organic compounds, heavy metal colloids and silica.

Particulates

Undissolved solids such as sand, rust particles, plant material, algae etc. clog feed water passage and membrane

Mircro organism

Most bacteria are 1 to 3 microns in size and can enter a pressure vessel but cannot pass through a reasonably perfect membrance. These bacteria cause foulding and degradation of certain types of membranes like cellouseacetate.

2/mechanical failures:

Due to high pressure needed for RO system operation, piping joints, valves develop problems though not frequently.

3/Corrosion

Corrosion of materials is a significant factor in reverse osmosis facilities. The feed, brine and product streams are all corrosive.

4/Poor operation badly damage the best of RO units.

STEPS TO OVER COME THE OPERATING PROBLEMS

The above problems are serious in nature and must be taken care of during designing the Reverse Osmosis system. Most of the above problems are such that they can be taken care of during designing stage itself.

Precipitates: The raw water analysis should be properly studied and proper pre-treatment, like softening etc. if needed should be provided so that the concentration of Ca and Mg can be kept well within the solubility limit.

Colloids and particulates: These can be taken care of providing Dual Media filter as well cartridge filter to remove particulates and colloids.

Micro Organism: These are removed in the system by proper dosage of chlorine. Regular testing for bacteria should be carried out and the chlorine (free) should be kept at an optimium level by dechlorinating.

Corrosion: Corrosion is controlled by providing SHMP dosing and also by proper selection of material at the engineering stage itself.

Selection of trained personnel/giving proper traing to them and following the instructions given in the manual are very important factors. Also by providing automation of the plant for critical requiremnts, it will be possible to keep off the problems due to human errors.

A typical process and instrument diagram for a RO plant is shown in Fig.4

Emergy Recovery: The high pressure (54.4 - 68 atm) involved in the sea water reverse osmosis has prompted to use the brine reject stream for the recovery of energey. The stream is usually discharged at 1.4 atm less than the fed water stream to the membranes.

The potential for energy recovery is high and recoveries upto 2.6 kWh/m3 of product water may be possible. A variety of energy recovery devices such as impluse (pelton) turbines and reverse running pumps have been used for other application.

In a recent study (Mr. Singh and Cabibbo in 1980) the available power was estimated for both sea water and brackish water using energy recovery. Some of these data are given below in Table -5.

COST OF TRANSPORTING WATER BY RAILWAY TANKERS FROM VIJAYAWADA TO MADRAS/HYDERBAD.

3/4 years back when Madras City was facing water crisis as it is facing now, water was taken to Madras in Rail tankers from Vijayawada. Recently, Krishna water was tranported from Vijayawada to Hyderabad in Railway tankers to overcome water shortage in the city. Cost of transporting water from Vijayawada to Hyderabad is Rs.50.00 per m3 and that to Madras is Rs.68/- per m3. If we compare this cost with the cost of approx. Rs.4/- per m3 for treating sea water by RO process for augmenting water supply to Madras City, then we find that a 1 MGD RO Plant will pay back its cost in just 29 days. Therefore use of sea water to augment urban water supply is economically viable in areas of water scarcity area in costal towns.

CONCLUSION:

Fresh water resources of our coastal cities are being increasingly strained due to increase in population, industrialisation and change in people's life styles. In places where additional fresh water is not available or can not be spared due to competing use, such as for agriculture, urban water supply may be augmented by using sea water after desalination. The new RO technically has made desalination both technically and economically viable.

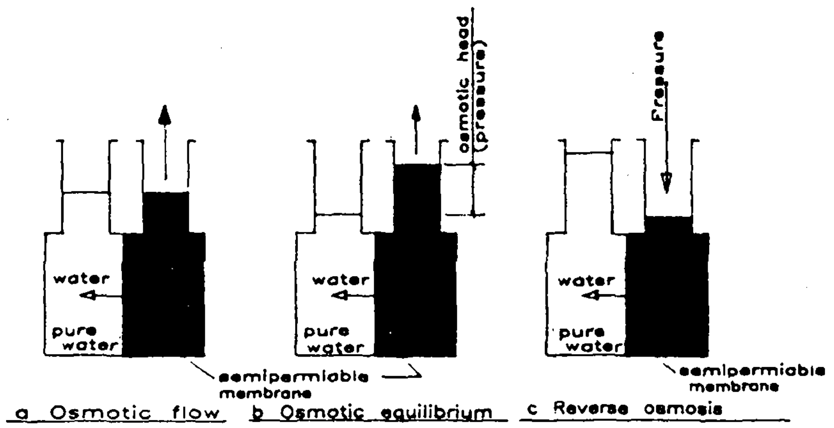
* Reference USAID desalination Manual

TABLE - 5

Energy recovery from reverse osmosis systems

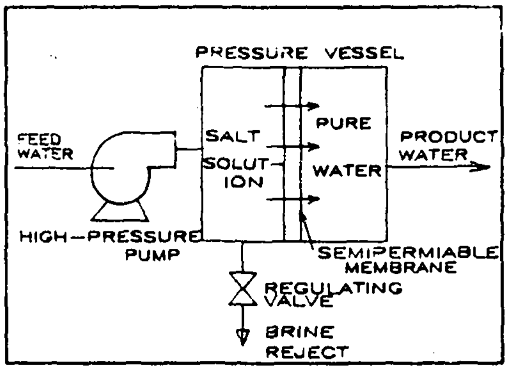
Plant size MGD	Product water recovery %	Brine flow gpm	Available pressure	Available power KW (a)		
				Ideal Power(b)	Shaft (c)	Equivalent electric motor
1	2	3	4	5	6	7
Brackish water (d)						
1	50	694	360	109	91	101
	70	298	350	46	40	42
	80	174	335	26	23	24
5	50	3,470	360	545	480	505
	70	1,490	350	230	200	210
	80	870	335	130	130	120
Sea water(e)						
1 gpm	20	2,780	850	1.027	900	950
	25	2,080	850	770	675	710
	30	1,620	840	590	520	550
5	20	13,900	850	5,133	4,500	4,750
	25	10,400	850	3,840	3,375	3,550
	30	8,100	840	2,950	2,600	2,750

a/ Recoverable
b/ Ideal power at 100% efficiency
c/ Shaft power at 88% efficiency
d/ Feed water pressure 400 psi
e/ Feed water pressure 900 psi
TDS 35000mg/l
Temp 25°C



Chemical potential of water in salt solution
is raised, osmotic flow is reversed

Fig. 1



semipermiable membrane

fig-2

PRINCIPAL OF REVERSE OSMOSIS IS USED
TO OBTAIN PURIFIED WATER FROM A SALT SOLUTION

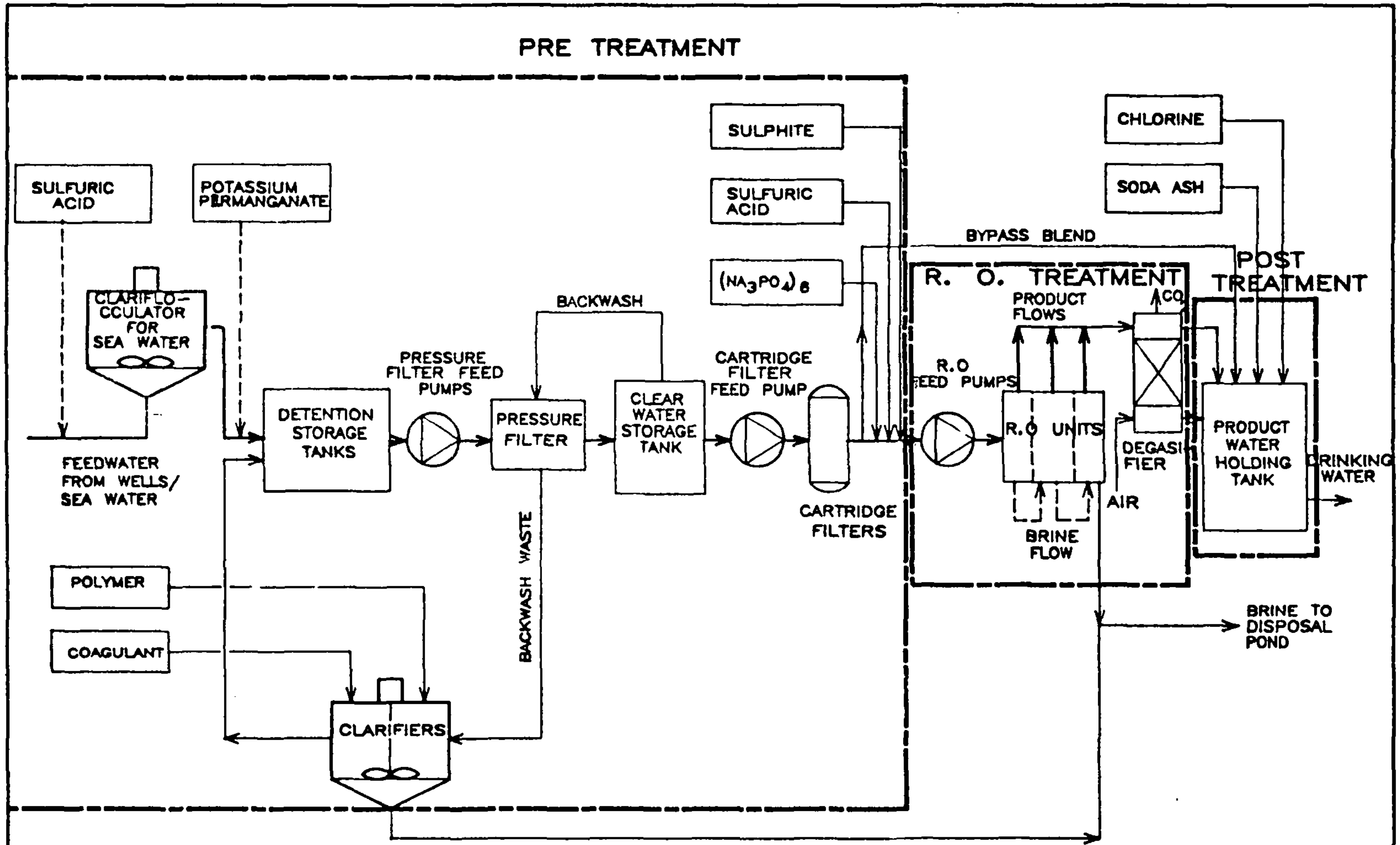


FIG.3 REVERSE OSMOSIS SYSTEM FOR DRINKING WATER

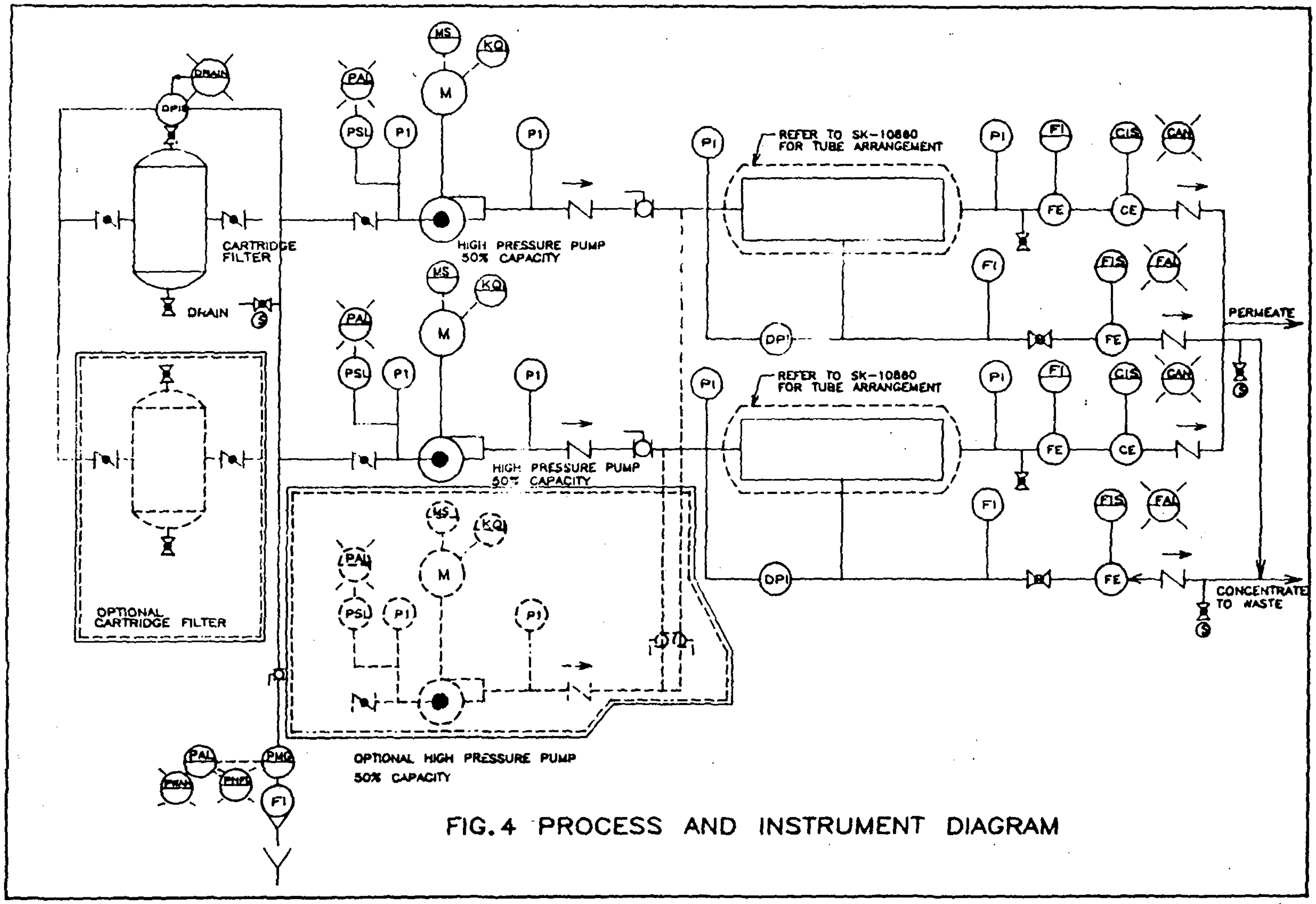


FIG. 4 PROCESS AND INSTRUMENT DIAGRAM

PUBLIC HEALTH ENGINEERING TRAINING NEEDS IN WATER SUPPLY AND SANITATION SECTOR

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SYNOPSIS

Manpower development and training is one of the key element to success or failure of the Decade vis-a-vis the sector objectives. In developing countries, there is a desperate shortage of qualified manpower; not only to carry out the Decade Plan but also to operation & properly maintain the completed schemes. Where a manpower plan has already been made, it should be compared with the projected Decade requirements; if non-existant, the planner might want to recommend that one be drawn up as part of the Planning Process. Training being expensive & complex, component of human resources development, its cost and programme structure should be clearly identified with the purpose of funding suitable sponsors & concessionary funding.

INTRODUCTION

Someone said that education and training provokes thought, heigtens awareness and raises consciousness. Public Health Engineering education is no exception. The Central Public Health & Environmental Engineering Organisation (CPHEEO) in the Ministry of Urban Development has attempted to achieve these objectives through the PHE training programme. The programme was started as a part' of Health Plan in the year 1956 and has continued with increasing tempo over the years. Now that the International Drinking Water Supply & Sanitation Decade is on, and skilled manpower would be required in a larger measure than before, it will be our charge to meet this challenge by increasing tempo of the programme. The training will also have to cater to all categories of personnel to ensure that the training reaches greater number and effects a qualitative improvement to enable them to face variegated tasks set before them.

In retrospect, the CPHEEO can with pardonable pride claim that the performance has been good, though there could be room for greater efforts in this direction and have partially met the needs of personnel of State Public Health Engineering Departments and Boards. But this is not the time for complacency and there must be growing realisation that the efforts that have to be put in this direction in future years have to be several fold if the training needs have to keep pace with the likely increase in manpower. While the CPHEEO is fully conscious, that it has to play a role in the National Manpower training in Public Health Engineering, there is equally an urgent need on the part of State PHE Departments/ Boards to participate more effectively and realise that the programme can be crowned with success only when the States maximally utilise all the training facilities so that the courses do not languish for want of representation.

The training programme had catered in the past to three categories of personnel in the PH Engineering field viz (a) Graduate engineers being given training in Post Graduate courses; (b) Subordinate engineers holding diplomas being oriented in Public Health Engineering through shorterm courses and (c) Refresher courses tailored to the needs of the senior, middle and junior level engineers and other para engineering personnel. The details of the Post-Graduate course duration and intake capacities in the Institute Sponsored by the Min. of Urban Dev. is shown in Annexure-I. The minimum qualification for admission to the PG Course (PHE) in respect of Govt. sponsored trainees is given in Annexure-II The number of candidates trained in various courses sponsored by this Ministry is indicated in Annexure-III.

SHORTCOMINGS IN TRAINING PROGRAMME FOR MANPOWER DEVELOPMENT

In many countries the greatest single obstacle to successful construction and subsequent management of water supply and sanitation systems is the shortage of skilled and experienced personnel. If a countrywide programme is to be prepared it is as essential to forecast the requirement of manpower as it is of funds. Finance may be forthcoming from various sources including external sources, but for personnel, reliance must be placed on local recruitment (with the possible exception of the temporary employment of a few foreign specialists) and, while funds can be used immediately they are received and allocated, personnel have to be trained in advance.

The cost of training is itself an investment, recoverable (with interest, it is hoped) when the trainee becomes an asset rather than a liability to the programme as a whole. There are several ways in which this investment may be wasted, e.g.

- by selecting the wrong type of candidate, or one without the necessary background knowledge to benefit from training.
- by failing to have a sufficiently attractive staff structure, with salary and promotion prospects, to retain the skilled men after training.
- by an unbalanced training programme, leading to the misuse of trained men in carrying out subordinate work (e.g. qualified engineers having to perform draughtsman's surveyor's or clerk's duties owing to lack of supporting staff)
- by failing to anticipate training needs, so that staff are not ready to take over their duties when required.

It is therefore important to plan recruitment, training and personnel requirements together and in advance, and also to ensure that the needs of government, local authority and private employees are all taken into account, otherwise there may come a time when all these sectors are competing for an insufficient number of qualified personnel.

Training should be considered as a continuing rather than as a once-for-all-time activity. The best men in any grade should be encouraged and given the opportunity of qualifying for duties with a higher responsibility their subordinate should be preparing to step into their positions when this happens. In-service training may be effected by a number of methods; e.g. fellowships and short university courses for professional staff; seminars and travelling lectures for professionals and sub-professionals;

summer schools, trawelling instructors and demonstrations for craftsman and artisans. Arrangements whereby operators from small installations work for a time in larger plants, and similar devices suitable to the conditions within the country, are inexpensive but effective ways of raising standards of the water supply and sanitation services.

TRAINING REQUIRED PERSONNEL

Many national water supply & sanitation programmes experience severe constraints due to shortage of personnel required for management, planning, construction, operation, maintenance, evaluation and training.

The task of training professional and technical personnel needed to meet the Decade's goal - from policy makers, surveyors and economists to sociologist, engineers and mechanics- is enormous. Training should be truly relevant to actual needs. Past training content has neglected planning, management, evaluation, methodology and the relationship between water supply, sanitation, health and socioeconomic development. Specialist training has not had a rural focus and there has been a lack of sensitivity to different cultures and social patterns. There will thus be an increased multidiciplinary emphasis, incorporating existing materials and solutions which have worked well.

Special focus will have to be placed on training personnel at local level, since many failure in water/sanitation projects can be traced to lack of skilled local-level personnel.

TRAINING PROGRAMME DESIGN

The manpower development and training strategy of a country will reflect the aims of the Decade vis-a-vis the sector objectives. The following activities deserve particular attention in the design of a support programme for manpower development and training.

- the elaboration of national manpower development schemes as part of the overall plan;

- the expansion of existing and establishment of new national and regional vocational/technical training institutions to cater for middle- and lower level personnel for water supply and sanitation.

- the special promotion of training for multipurpose front-line workers (community health workers);

- the development of teaching/learning materials, including manuals, guidelines and visual aids;

- the establishment of crash training programmes to meet urgent needs;

- pressure for inclusion of training schemes in the institutions-building component of coverage of project.

VARIOUS ASPECTS OF PUBLIC HEALTH ENGINEERING TRAINING PROGRAMME

There are many aspects of public health engineering training programme under which the training can be imparted. Few of the topics are listed as below :

(i) Project Planning Cycle

(ii) Pre-investment Planning Activities

(iii) Technical Analysis of Projects

(iv) Financial Evaluation through discounting and other engineering economical tools

(v) Economic Evaluation

(vi) Accounting & Financial Planning

(vii) Water Tariffs Setting

(viii) Organisation & Management of Water Supply & Sanitation Services

(ix) Project Management

(x) Special Topics

In addition to the above theory aspects it is always preferred that the trainee should be given an exposure to the practical aspects in the field which could be arranged by field visits.

CONCLUSION

Public Health Engineering Training is essential for design, management, operation and maintenance of water supply & sanitation facilities if programmes are to meet the criteria of cost-effectiveness and efficient operation, maintenance & repair. Greatly expanded training efforts are clearly critical to all aspects of water supply & waste-disposal development, in both urban and rural areas. The field benefits of investments already made and the continuing realisation of such benefits are dependant on systems that function 24 hours a day.

There is a general agreement that the principal constraint is not the lack of availability of such training facilities but are failure to utilise it by the concerned organisation as it receives a low priority. The importance of public health engineering training should be realized by the Heads of the concerned departments responsible for providing water supply and sanitation facilities to the people and adequate steps should be taken in order to provide suitable training at different levels of personnel involved in the programme, from time to time.

ANNEXURE - I

STATEMENT SHOWING DETAILS OF POST GRADUATE COURSE DURATION AND INTAKE CAPACITIES IN THE INSTITUTES SUPPORTED BY MINISTRY OF URBAN DEVELOPMENT

Sl. No.	INSTITUTE	Period for which stipends are extended (Months)	Total duration of the course including project work (Months)	INTAKE CAPACITY		Year from which the course has been supported by Min. of U.D.	REMARKS
				Total	Reserved for Min. of U.D.		
1.	All India Institute of Hygiene & Public Health, Calcutta.	10	16*	30	30	1956	*The Academic term is of 10 months duration
2.	V.J.T.I., Bombay	16	16	17	10	1956	
3.	Anna University, Madras	18	18	15	9	1956	
4.	Roorkee University, Roorkee	18	18	15	5	1956	
5.	Visvesaraya Regional Collee of Engineering, Nagpur	18	18	13	7	1986	
6.	Birla Vishvakarma Mahavidyalaya, Vallabh Vidya Nagar	18	18	15	15	1984	
7.	Sri Jayachamarajendra College of Engineering, Mysore	18	18	15	10	1986	
8.	Motilal Nehru Regional Engineering College, Allahabad	18	18	13	5	1986	

Note : *In some institutions, the project work could be based on the work in the Department itself after the trainee rejoins his post.*

ANNEXURE - II

MINIMUM QUALIFICATION FOR ADMISSION TO POST GRADUATE COURSES (PHE) IN RESPECT OF GOVT. SPONSORED TRAINEES

1.	All India Institute of Hyginene & Public Health, Calcutta	-	B.E. (Civil)
2.	V.J.T.I., Bombay	-	B.E. (Civil) AMIE (With GATE)
3.	Visvesaraya Regional College of Engineering Nagpur	-	B.E. (Civil) with 50% marks
4.	Anna University, Madras	- -	B.E. (Civil) B.E. (Chemical) B.E. (Mechanical or Electrical) with 3 years experience.
5.	Roorkee University, Roorkee	- -	B.E. (Civil) with 60% marks AMIE (with entrance test)
6.	Birla Vishvakarma Mahavidyalaya, Vallabh Vidya Nagar	-	B.E. (Civil) with 55% marks
7.	Sri Jayachamarajendra College of Engineering	- -	B.E. (Civil) with 50% marks AMIE (with entrance test)
8.	Motilal Nehru Regional Engineering College, Allahabad	-	B.E. Civil, Mechanical, Chemical, Agricultural and Architect.

ANNEXURE - III

NO. OF CANDIDATES TRAINED IN COURSES

Sl. No.	Name of Course	Upto 31.3.1986	During 1986-87	Total	Remarks
1.	P.G. Course in Public Health Engineering	1135	74	1209	
2.	Short-term Course in Public Health Engineering	1609	51	1660	
3.	Refresher Courses	3279	308	3587	Information from 2 courses awaited
4.	Water Works Supervisors' Course	1540	201	1741	
5.	Sewage Works Supervisors	88	28	116	
6.	Improved Design techniques using micro-computer	13	54	67*	* This includes 3 candidates from Nepal.

AFRO-ASIAN CONFERENCE - INTEGRATED WATER MANAGEMENT IN URBAN AREAS - BOMBAY, 3-6 DECEMBER 1987

STUDY OF NON-REVENUE WATER CONTROL IN CHONBURI, THAILAND

by John Richardson

ABSTRACT

This paper describes a modern, systematic but simple approach to investigation of losses from an urban water supply system and the formulation of a cost-effective policy for their control. It explains that leakage is only one component of loss and that non-physical losses can and should also be addressed. Field tests and investigations to quantify losses are described, as well as an analytical approach to selecting a method of control. Since losses are shown as not confined to older systems, the paper stresses that design, materials selection and construction standards must not be sacrificed to achieve rapid growth.

STUDY OF NON-REVENUE WATER CONTROL IN CHONBURI, THAILAND

by

John Richardson, [a] BSc, CEng, FICE, MIWEM

INTRODUCTION

Non-revenue water (NRW) may be defined as that amount of treated water entering a distribution system which does not earn revenue for the water supply utility. NRW comprises physical losses, or leakage, and non-physical losses arising from authorised and unauthorised free use, meter under-registration and under billing. NRW is nowadays considered a more accurate description than unaccounted-for water, since some losses may be accounted-for but not produce revenue.

This paper describes a 1986 Study of the causes and magnitude of NRW in Chonburi, a provincial town in Thailand, and formulation of a policy for its control. The Study was funded by the Overseas Development Administration of the British Government and undertaken by the Water Research Centre (WRc) of UK in association with Watson Hawksley Asia.[1]

BACKGROUND AND OBJECTIVES

The Provincial Waterworks Authority (PWA) of Thailand, established in 1979, is responsible for 190 urban and 600 piped rural systems outside Metropolitan Bangkok. About 3.5 million people are provided with direct service out of about 6 million in all service areas.

PWA inherited a range of technical, institutional and financial problems. It embarked on an ambitious Water Decade programme of upgrading and capacity expansion in over half of its systems, and streamlining administrative and financial management, and operation and maintenance (O&M) programs. Owing to funding constraints, PWA concentrated where possible on cost-effective investment for performance improvement of existing assets, to reduce funds required for entirely new facilities. One area of potentially high return on investment was identified as the reduction of NRW, which PWA estimated ranged from 30-50 per cent of production in the majority of its systems.

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[a] The author is a Partner of the Watson Hawksley group of consulting engineers and a Resident Partner of Watson Hawksley Asia, Singapore

The direct cost of NRW is equal to the marginal cost of its abstraction, treatment and distribution. NRW reduction could therefore save money by reducing the throughput of a system by an equal amount. However, suppressed demand exists in most of the PWA urban systems and water saved through NRW reduction could be sold to existing consumers, generating increased revenues exceeding the marginal cost. Based on the present average tariff of US$0.28 per cu m, each 10 per cent reduction in country-wide NRW would generate an additional revenue of about US$8.3 million per annum.

PWA selected Chonburi, (see Fig. 1), one of its largest systems, for a detailed study. The system covers the coastal towns of Chonburi, Bang Saen, Ang Sila, Bang Phra and Sriracha with a total population of 185,000. Service is presently provided to 21,000 metered consumers (140,000 population). A surface water treatment plant provides a maximum of 55,000 cmd for pumped distribution. Pipe material is predominantly asbestos cement (AC). About half of the consumers are directly connected to the pumped system, and the remainder receive gravity supply from 9 ground level or elevated tanks. In 1985, NRW was estimated at over 40 per cent.

The Study objectives were; to assess the physical and non-physical components of NRW; to determine the most appropriate and cost-effective leakage control policy; and, to recommend methods to reduce the non-physical component of NRW.

APPROACH

The Study involved three distinct but complementary investigatory approaches over a 3-month period;

(i) determination of leakage levels by field tests in sample areas of the system;

(ii) review of local policies and practices which affect leakage; materials selection; design and construction standards; and, O&M programs;

(iii) assessment of non-physical losses by field and desk studies of consumer records, billing and accounting practice and metering policy.

From (i) and (iii), present NRW and its components were determined. Analysis of the cost of leakage in (i) was then made and compared with the cost of alternative leakage detection and control strategies. From (ii), recommendations were made for improvements to minimise occurrence of new leakage and, from (iii), suggestions were made for amendments to some policies and practices to reduce non-physical NRW.

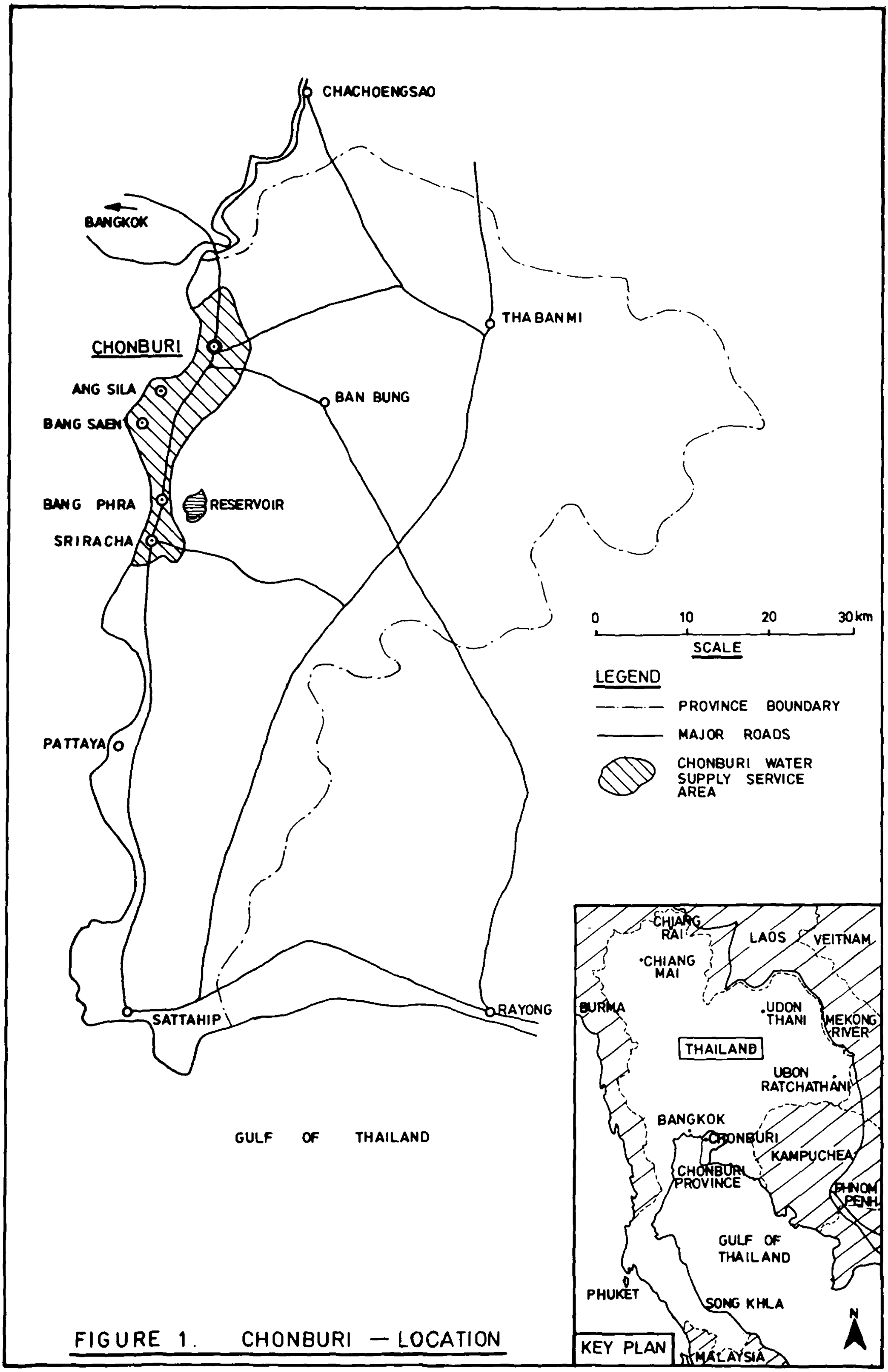

FIGURE 1. CHONBURI — LOCATION

The field leakage tests were carried out in accordance with procedures outlined in WRc Report No 26 [2/] the result of a major programme of field experiments in the UK in the 1970s to standardize the approach to leakage investigations and methods of control. In Chonburi, the field tests comprised the following:

1. <u>Pressure Survey</u>

Pressure transducers with data loggers were connected to fire hydrants at 72 locations for an average of 3 days per location, to record system fluctuations in pressure. The purposes were to (a) examine the scope for pressure reduction which would reduce leakage, and (b) relate leakage levels measured during night-time field tests to those which would occur during full day operation.

2. <u>Leakage Measurements</u>

Leakage was measured in (a) reservoirs, (b) trunk mains and (c) distribution system.

(a) <u>Reservoirs</u> - night-time drop tests were carried out on 3 reservoirs over about 6 hours, with the outlet valves securely closed and themselves checked for leakage. Level transducers were connected to data loggers.

(b) <u>Trunk Mains</u> - the Chonburi system has about 60 km of trunk mains, 23 km of which have no direct consumer connections, thus permitting easy testing. One length of 14 km was tested by inserting turbine meters at either end and recording the difference in measured flow over a 12-hour period (see Figure 2). To eliminate meter inaccuracy, the meters were exchanged and the test repeated. A second length of 2 km was tested using a 40 mm dia. revenue meter on a bypass, with pulse outlet connected to a data logger.

(c) <u>Distribution System</u> - three areas were selected, two in Chonburi town and one in Sriracha. They contained 8,730, 2,032 and 5,141 consumers respectively and, together, represented 75 per cent of the total system. Several days were spent ensuring that the areas could be fully isolated, inserting new valves where necessary. Consumers with large night-time flows were identified. Tests were conducted between 11.00 pm and 4.00 am. The two Chonburi test areas were gravity fed from reservoirs whose inlet valves were closed and themselves checked for leaks. The quantity entering each test area was measured from the drop in reservoir level, large consumers had their meters (previously checked for accuracy) read at the beginning and end of the test and an allowance was made for night-time consumption by normal domestic consumers as measured by the calibrated meters in the revenue meter accuracy test (see below). The remaining quantity was leakage.

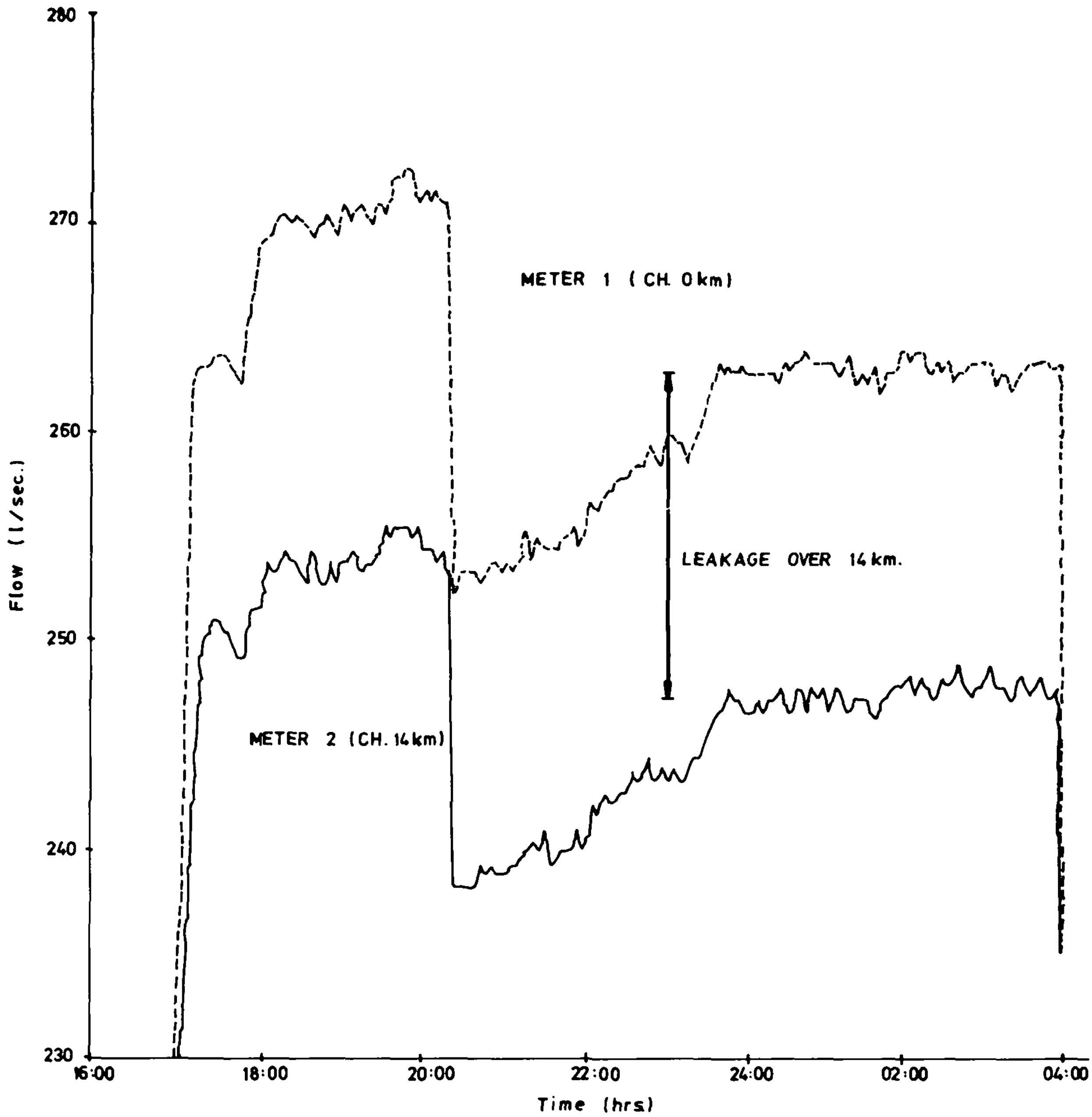

FIGURE 2. TYPICAL TRUNK MAIN LEAKAGE TEST

The Sriracha test area was pump-fed and the inflow was measured by pre-calibrated insertion meter, otherwise the procedure was the same.

3. Pilot Leakage Reduction

A pilot demonstration of leakage detection methods and reduction techniques was carried out. This also provided information on the cost of the basic elements of alternative leakage control methods. A pilot zone with 734 consumer connections was identified within one of the field test areas which showed the highest leakage. By installation of extra boundary valves, supply to the pilot zone was confined to one main and measured by a pre-calibrated Helix 3000 meter, selected for its accuracy over the range of flows and head losses expected. The pilot zone was sub-divided into 13 discrete sub-zones by installation of further (step) valves. Preparatory monitoring for one week ensured that all valves were drop tight, all flow entered only through the metered main and pressures and supplies could be adequately maintained. The length of mains in each sub-zone was measured. The costs of all materials and labour in setting up the pilot zone were recorded.

Three step tests were then carried out. The 13 step valves were closed one by one, thus gradually reducing the area served. The flow reduction as each valve was closed was recorded by data logger attached to the Helix meter (see Figure 3). Steps with large drops in flow in proportion to the length of mains showed that leakage was highest in those sub-zones. These sub-zones were then inspected for visible leaks which were repaired. A Microcorr Leak Noise correlator was used to locate non-visible leaks; several were found and repaired. The cost of the work was recorded.

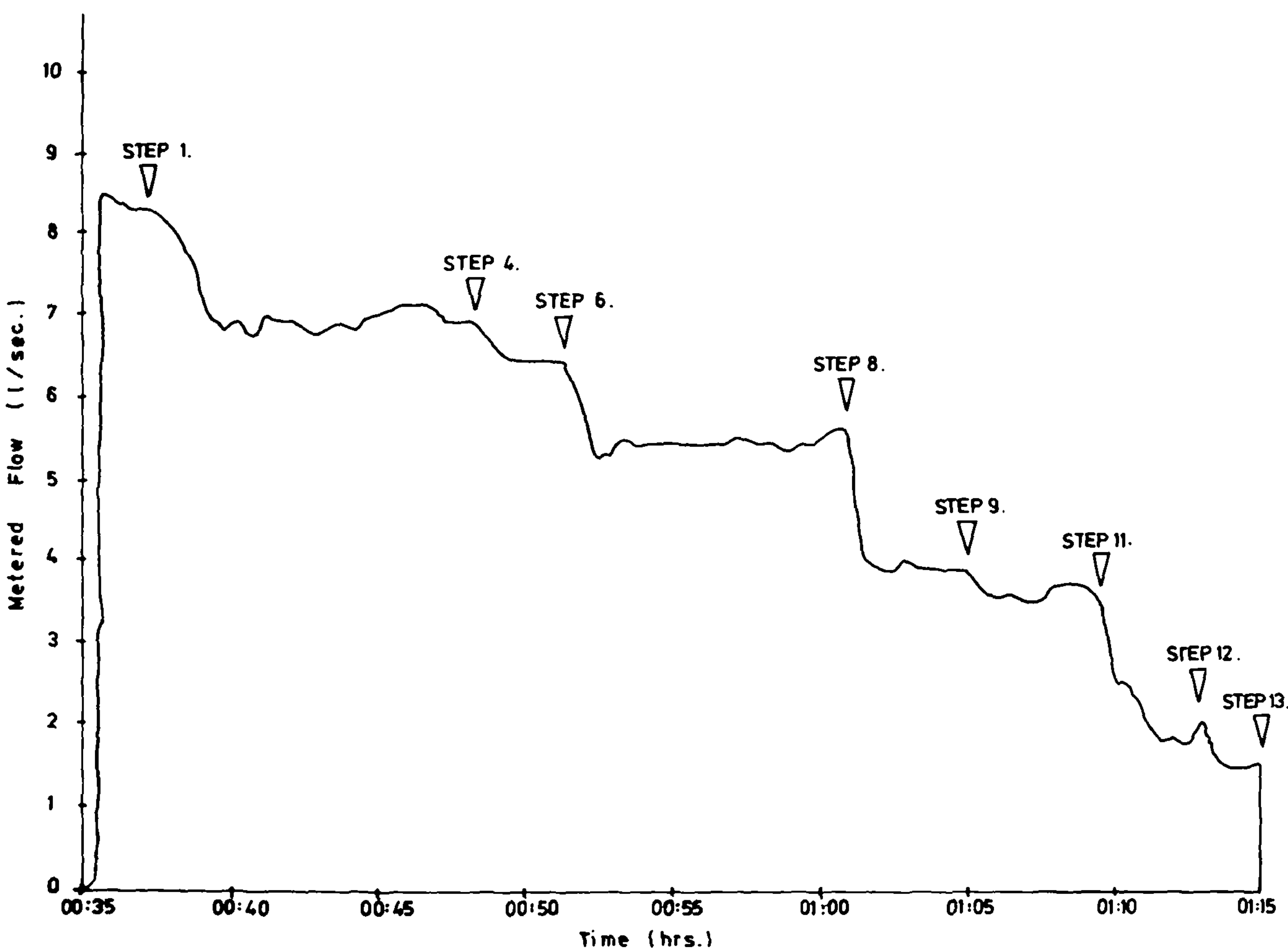

FIGURE 3. TYPICAL STEP TEST

Factors affecting leakage were investigated by reviewing design practice, materials used, standards of construction and O&M programs. Time was spent observing pipe transportation, mains laying, installation of service connections and meters and making of tappings on mains.

Non-physical losses were investigated by:

- field tests of revenue meter accuracy by parallel insertion of a calibrated meter;

- field observations of the possible existence of illegal connections;

- establishment of the quantity of authorised free use;

- determination of the probable extent of meter under-registration and underbilling by analysis of the records of 8,000 consumers, analysis of operation of the meter repair workshop and observation of meter reading, recording, billing and revenue collection procedures.

RESULTS OF INVESTIGATIONS

Distribution system (not end-of-line residual) pressures varied from 16-43m head at night to 0-17m in daytime, with average zone pressures of 6-30m head. Supply is intermittent in several areas and pressures are too low to achieve leakage reduction by pressure control.

Reservoir leakage was 5.5 cu m/hour in one reservoir but negligible in the others. Trunk main leakage averaged 2.6 cu m/km/hour, or 2 per cent of water produced. Distribution system leakage corrected for pressure, averaged 36 l/consumer/hour, or 34 per cent of water produced, by far the largest system component of NRW. Proposed expansion of treatment capacity will raise minimum distribution pressures to 10m head and increase potential leakage to 60 l/consumer/hour, or more than 50 per cent of water produced, unless leakage control measures are initiated. Leakage was greatest in Chonburi town where 82 per cent of the distribution system is less than 18 years old and least in Sriracha where 75 per cent is over 25 years old, denying the frequent assumption that leakage is higher in older systems.

The pilot leakage reduction work reduced leakage by a third in a 6-week period, based on measured minimum night flows at beginning and end of the period. Several further leaks, pinpointed for PWA repair in the post-Study period, were expected to lead to a similar quantum of reduction.

Considerable scope was found for improvement in materials selection, pipe handling, mains laying techniques, installation of service connections, tapping of mains and general supervision of contractors. Study findings pointed to a deterioration in standards as rapid expansion of the system was made to attempt to keep up with high urban growth rates. The danger of leakage becoming a chronic problem was all too apparent.

Of the elements of non-physical losses, authorised free supply for firefighting, mains flushing, concessions to PWA employees, war veterans and a temple school was insignificant. Theft was not apparently widespread, at 1.7 per cent of water produced. Underbilling, caused principally by low estimated consumptions during the average of about 4 months between identification of a malfunctioning meter and its repair or replacement, was just under 2 per cent. Meter under-registration was the largest element, at nearly 6 per cent of water produced. Meters were often over-sized for the range of flows passed, not properly recalibrated after repair and often experienced a gradual deterioration of accuracy. One large consumer meter tested for accuracy was under-registering by 25 per cent, or 70 cu m/hour, over the test period, showing the importance of regularly checking principal consumers.

The quantified components of NRW derived during the Study are summarised below:

Table 1. NRW Components

Component/Element	Losses	
	Unit	% of Water Produced
<u>Physical (Leakage)</u>		
Reservoirs	(negligible)	-
Trunk Mains	2.5-5.2 cu m/km/hour	2
Distribution System	670-1230 l/cons/day	34
Sub-Total	-	36
<u>Non-Physical</u>		
Authorised free use	90 cmd	0.2
Theft	940 cmd	1.7
Meter under-registration	3,140 cmd	5.7
Under-billing	940 cmd	1.7
Sub-Total	-	9.3
Total NRW		45.3

CONCLUSIONS AND RECOMMENDATIONS

Physical Losses

Present leakage control in Chonburi is passive, that is, investigation and repair only when leaks are noticed and reported. The measured level of leakage shows potential financial benefit from an active leakage control policy. With suppressed demand in Chonburi, this benefit should be the excess of extra revenue over the cost of the leakage control policy. The uncertainties of suppressed demand are avoided by calculating the unit cost of leakage and deducting the unit costs of the leakage control policy and the residual level of leakage.

The unit cost of leakage is equal to unit savings from reduced operating costs (mainly energy and chemicals) and deferred or scaled-down capital investment in system expansion. Unit operating costs can be calculated directly. Unit capital costs can be calculated from the formula:

$$\text{Unit capital cost} = \frac{\text{total discounted capital cost} \times r^2}{(1 + r) \times 3.65 \times d}$$

where r = the discount rate
d = annual charge in demand (cmd)

(ref: WRc Report No. 26)

For Chonburi, the unit operating cost was calculated at US$0.04/cu m and the unit capital cost at US$0.13/cu m, giving a unit cost of leakage of US$0.17/cu m, equal to US$155/consumer/year at present consumption rates.

The four active methods of leakage control considered are:

<u>Regular sounding</u> - systematic use of sounding sticks to listen for the characteristic noise of leaking water.

<u>District metering</u> - continuous metering of flows entering zones with typically, 2,000 - 5,000 consumers, comparison with expected consumption and monitoring for inexplicable increases. High meter readings are followed by investigation for leakage.

<u>Waste metering</u> - regular, say quarterly, metering of minimum night flows entering sub-zones of 500 - 2,000 consumers, comparison with expected night flows and investigation for leakage in the case of higher-than-expected readings.

<u>Combined metering</u> - combined district and waste metering so that when district metering shows high readings, the waste meter readings will direct investigation more quickly to the sub-zones with leakage.

The costs of these four methods applied in Chonburi were calculated from the recorded costs of the pilot work done in this Study. Research and experience elsewhere has enabled prediction of reduced leakage levels achievable with each method, permitting the cost of residual leakage to be calculated.

Table 2 summarises the above analysis:

Table 2. Leakage Control Costs

Leakage Control Method	Average Leakage Now l/consumer/hr	Cost of Leakage Now $/consumer/yr	Reduced Level of Leakage Achievable l/consumer/hr	Cost of Leakage Control Method $/consumer/yr	Cost of Residual Leakage $/consumer/yr	Total Cost of Leakage Control $/consumer/yr
Regular Sounding	36	155	22	0.7	32.5	33.2
District Metering	36	155	16	1.1	23.6	24.7
Waste Metering	36	155	12	1.8	17.7	19.5
Combined Metering	36	155	12	1.8	17.7	19.5

Waste metering and combined metering were shown to be equally cost effective. Combined metering permits quicker identification and location of leaks and was therefore recommended for Chonburi.

<u>Non-Physical Losses</u>

Total non-physical losses of 9.3 per cent could be reduced to about 3 per cent through the following:

- a comprehensive revenue meter testing and recalibration program,
- rapid repair or replacement of unserviceable revenue meters and more realistic estimated readings in the meantime;

- recalibration of all new and repaired meters on a purpose-made test rig; and

- continued diligence in locating unauthorised connections.

Improvement in several policies and practices were recommended to support leakage control;

- discontinuation of the use of galvanised iron piping for consumer connections, in favour of non-corroding materials;

- use of under-pressure tapping machines and corrosion-resistant fittings for mains tappings;

- greater care in the transportation, handling and laying of pipes, particularly AC pipe, including even bedding in dry trenches, restriction of angle deviation of pipe joints, correct installation of thrust blocks at bends, pressure testing of pipelines and careful inspection of all valves, fittings and tappings for leakage before commissioning;

- avoidance of oversized revenue meters;

- use of semi-positive displacement meters in preference to inferential meters;

- training to assist meter readers in identifying faulty meters; and

- orientation training for construction supervisors in the importance of strict adherence to specifications to minimize long term NRW problems.

If these recommendations, estimated to cost about US$1,000,000 over two years, are fully and consistently implemented, it is estimated that NRW in Chonburi could be reduced to about 15 per cent, generating an additional annual revenue of about US$1.6 million.

SUMMARY

NRW is a major problem in urban areas of developing countries.[3/] The Study is an example of a systematic approach to investigation of NRW using modern but relatively simple techniques. Leakage proved to be the major loss in Chonburi but the importance of addressing and reducing non-physical losses is also demonstrated. A well planned and consistently implemented NRW control policy can result in rapid recovery of cost outlay. Newer distribution systems sometimes leak more than older systems, and strict standards must be maintained during periods of rapid system expansion, to prevent NRW becoming a chronic problem.

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