MANAGEMENT OF THE ENVIRONMENTAL IMPACT OF WATER RESOURCES DEVELOPMENT PROJECTS

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MANAGEMENT OF THE ENVIRONMENTAL IMPACT OF WATER RESOURCES DEVELOPMENT PROJECTS

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WATER RESOURCES DEVELOPMENT IN THE ESCAP REGION AND ITS ENVIRONMENTAL EFFECTS

Prepared by the secretariat of United Nations Economic and Social Commission for Asia and the Pacific (ESCAP)

INTRODUCTION

Over the past years ESCAP has given increasing attention to the problem of the integrated relationship between development and environment. Sound water resources development is particularly essential for ensuring sustainable economic and social progress in many developing countries of the region. Water resources development projects produce, in one way or another, environmental changes, some beneficial and few not. In the past, decisions on such projects were dictated by technical and economic factors, but nowadays environmental considerations are also playing an increasing role in the process of making decisions and formulating policies on water resources development activities.

Since the understanding of potential environmental effects associated with water resources development is quite important for formulating the environmental management policy, this paper is intended to show the scope of the water resources development activities in the region, bringing to the attention of the participants some of the major environmental impacts of these projects and suggesting ways to avoid or reduce the adverse effects.

I. Dams and reservoirs

Since the 1950s, the rate of construction of dams and associated reservoirs, designed mainly for generating electricity, supplying water for irrigation, domestic and industrial needs, and for flood control in the region, has been very impressive. In 1950, there were 1,717 dams over 15m height in service in the ESCAP region, of which 394 were located in the developing countries. In 1982, as many as 23,210 dams were listed, including 20,623 in the developing countries (see table 1).

Table 1. Number of dams over 15m in the ESCAP countries, by period of completion

Country or area	Number of dams			
	Until 1950	1951-1977	1978-1982	Total
Afghanistan	-	2	-	2
Australia	122	198	54	374
Bangladesh	-	1	-	1
Bhutan	-	-	-	-
Brunei Darussalam	-	1	-	1
Burma	1	1	-	2
China	8	16 492	2 095	18 595
Fiji	-	-	2	2
Hong Kong	13	24	-	37
India	202	797	86	1 085
Indonesia	14	12	7	33
Iran (Islamic Republic of)	-	17	4	21
Japan	1 173	833	136	2 142
Lao People's Democratic Republic	-	1	-	1
Malaysia	1	10	1	12
Maldives*	-	-	-	-
Mongolia	-	-	-	-
Nepal	-	-	1	1
New Zealand	28	38	6	72
Pupua New Guinea	-	3	-	3
Pakistan	3	30	5	38
Philippines	1	5	3	9
Republic of Korea	116	433	69	628
Samoa	-	-	-	-
Singapore	-	2	1	3
Sri Lanka	23	41	5	69
Taiwan (a province of the People's Republic of China)	12	23	2	37
Thailand	-	22	19	41
Viet Nam	-	1	-	1
Total	1 717	18 997	2 496	23 210

Source: International Committee on Large Dams, World Register of Dams, (1984).

The environmental effects of dams and reservoirs are felt far beyond the sites of the projects because such large engineering structures change to a large extent the overall hydrological regimes of the rivers on which they are constructed. The nature, importance and magnitude of impacts will vary considerably from one reservoir to another owing to the influence of a number of variables: size, shape, and depth of reservoir; inflow and outflow rates; range of fluctuations in water level; climate and weather; geology and geomorphology; and soils in the watershed, along the reservoir shores, and in affected downstream areas; tectonic characteristics of the reservoir site; vegetative cover in the reservoir site; distance of the reservoir from the sea; riverine flora and fauna which may be affected by the impoundment; importance and value of resources and features to be flooded; and type and extent of human and animal diseases associated with the aquatic system. Some of the major impacts typical for countries of the region are described below.

1. Sedimentation

Depletion of storage capacity is the most significant upstream effect of reservoir sedimentation. The silt that accumulates behind a dam may cause considerable ecological and engineering problems and prevent the reservoir from performing its intended functions, such as water supply, flood control, hydropower generation, navigation and recreation. For example, in China, 178 reservoirs in the Huggang District of Hubei Province lose 6 million m^3 of storage capacity each year owing to silting. Many small reservoirs had to be abandoned after just two or three years of operation and some larger hydroelectric stations had to be taken partially out of operation. The survey of 33 large- and medium-sized reservoirs in the Chiang Jiang river basin revealed that 16 are already more than half filled with silt, and the average useful life will not exceed 13 years.[1]

Clearly, the rate at which a reservoir silts up depends on the amount of sediments carried by the river which feeds it, and that, in turn, depends on the rate of soil erosion in the river's catchment area. The rate of soil erosion increases dramatically in areas with excessive deforestation rates since, for example, high-intensity rains can quickly wash away the soils of the tropics. Highly erodible soils, like loess, in arid and semi-arid zones with inappropriate cultivation practices and inadequate vegetation cover, are also prone to intensive soil erosion.

On the other hand, as a result of siltation in the reservoir, clear water flowing downstream causes channel degradation and bank erosion. The deposition of silt in the reservoir also results in some loss of natural nutrients downstream and thus may decrease the productivity of the flood plains downstream of the dam. Another effect of reservoir sedimentation is possible erosion of the river delta.

Since reservoir sedimentation influences all parts of a river basin and leads to several adverse effects, a detailed study of alterations in erosion and sedimentation processes has to be carried out on any proposed dam project.

2. Inundation

The creation of reservoirs often leads to the inundation of large areas of land. In many cases the flooded area contains thousands of hectares of valuable agricultural land. In India, for example, more than 40,000 ha of farmland were submerged by the Srisailam hydroelectric scheme; that land had provided a livelihood for about 100,000 local villagers. In Sri Lanka about 3,000 ha of land cultivated with various crops will have been flooded owing to the construction of the Victoria dam.[2]

The flooding of a reservoir without clearing the area beforehand is a common practice. The inundated land is often covered with forest having not only commercial value but also great ecological importance, particularly in tropical and subtropical zones. Thus, in Malaysia, the Temenggor dam project has resulted in flooding of valuable forest area, threatening the survival of 100 species of mammals and 300 species of birds.[3] In India, one of the main considerations taken into account in shelving the proposed dam project in the Silent Valley was the threat to the tropical forest and its unique wildlife. Several more water resources development projects have been abandoned in the region in view of possible adverse effects on the environment. In Malaysia, for instance, the Tembeling hydropower project has been cancelled[4] on the grounds that, if it had been implemented, 130 km^2 of tropical rain forest, which serve as the habitat for a number of rare species, would have been inundated.

Some of the most important and serious problems of dam construction are connected with evacuation and resettlement of the people whose homeland is flooded by the waters of man-made reservoirs. Approximate data on the number of persons resettled owing to creation of several selected water reservoirs in the region are given in table 3. Moreover, there are some large projects the construction of which will trigger the veritable exodus of hundreds of thousands of affected dwellers. In China, the gigantic Three Gorges multi-purpose scheme is estimated to displace 1.4 million people; in the Philippines, the construction of 40 proposed new large dams could affect more than 1.5 million people.[5]

3. Seismic effects

It is assumed that the weight of impounded water imposes new stresses on the earth's crust which, in turn, may generate seismic activity owing to the existence of layers having varying compressibility. Such seismic activities have been recorded for a number of dams and associated reservoirs in the ESCAP region. For example, major earthquakes believed to be connected with dam construction, occurred at Hsinfengkiang in China in 1962 (magnitude 6.1 on the Richter scale) and at Koyna in India in 1967 (6.5 on the Richter scale).[6]

Table 2. Resettlement of people owing to the construction of some dams and reservoirs in the ESCAP region

Name of project and date of complet[illegible]	Country	Number of people relocated
Bhakra, 1963	India	36 000
Damodar (4 projects, 1959)	India	93 000
Gandhi Sagar	India	52 000
Lam Pao	Thailand	30 000
11 projects 1963-1971	Thailand	130 000
Nam Ngum, 1971	Lao People's Democratic Republic	3 000
Nam Pong, 1963	Thailand	25 000-30 000
Nanela, 1967	Pakistan	90 000
Pa Mong (projected)	Thailand/Lao People's	310 000-480 000
Tarbela, 1974	Pakistan	86 000
Upper Pampanga, 1973	Philippines	14 000

Source: A.K. Biswas, "Impacts of hydroelectric development on the environment", Energy Policy December 1982, p. 349.

Other dams and reservoirs in the countries of the region suspected of triggering off minor earthquakes are Benmore in New Zealand (1966), Kurobe in Japan (1961), Talbingo in Australia (1972)[7] and Danjiangkan in China,[8] where more than 100 minor earthquakes have been experienced.

Dams can be designed to resist collapse during earthquakes, and sites where large dams and reservoirs are to be constructed have to be investigated thoroughly for potential earthquake hazards. The need for caution is especially great in areas that are known to be seismically active.

4. Microclimate changes

Local changes in the microclimate, favourable or not, are caused by man-made water reservoirs. The area affected depends mainly on a climatic zone, local meteorological conditions and dimensions of the reservoir, and extends, as a rule, over the territory adjacent to the water body. The major microclimatic effect is increased atmospheric moisture.[9]

It has been observed that the microclimate becomes less continental in the vicinity of reservoirs located in temperate or semi--arid zones. In China, for example, meteorological studies carried out near the Danjiangkan reservoir have revealed a moderating effect of the reservoir on the climate. The mean summer temperature around the reservoir has decreased by about 1°C and the average winter temperature has increased by about the same amount.[10]

II. Irrigation

Irrigation plays a crucial role in promoting agricultural development in the ESCAP region, where 60 per cent of the world's irrigated land is located. Since the early 1960's the total irrigated area in the region has increased by 42 per cent, from 94.4 million to 134.2 million ha in 1985 (table 4), and it covers 29.3 per cent of the arable land in the region.

The introduction of irrigation to an area leads to significant ecological changes. There is no doubt that an irrigation project has a favourable effect on the microclimate after the area is irrigated: relative humidity is increased, evaporation rates are lower, and in certain cases temperatures are also modified favourably. However, many irrigation schemes in the region have resulted in degradation of cropland and water quality, and in the spread of water-related

Table 4. Cultivated land and irrigated area in the ESCAP region (Thousands of hectares)

Country or area	Cultivated land, 1985	Irrigated area 1961-1965	1970	1980	1985	Irrigated area/ Cultiated land (%)
Afghanistan	8 054	2 208	2 340	2 650	2 660	33.0
Australia	48 600	1 115	1 476	1 500	1 620	3.3
Bangladesh	9 135	501	1 058	1 569	2 073	22.7
Bhutan	102	-	-	-	-	-
Brunei Darussalam	7	-	-	1	1	14.3
Burma	10 067	681	839	999	1 085	10.8
China	100 883	35 500	38 123	45 317	44 461	44.1
Democratic People's Republic of Korea	2 362	500	500	1 050	1 070	45.3
Fiji	240	1	1	1	1	0.4
India	168 950	25 523	30 440	38 478	40 100	23.7
Indonesia	20 880	4 100	4 370	5 418	7 059	33.8
Iran (Islamic Republic of)	14 830	4 800	5 200	4 948	5 740	38.7
Japan	4 758	3 350	3 415	3 055	2 931	61.6
Lao People's Democratic Republic	900	13	17	115	119	13.2
Malaysia	4 370	233	262	320	334	7.6
Mongolia	1 354	3	10	35	42	3.1
Nepal	2 319	77	117	520	650	28.0
New Zealand	501	82	111	183	250	49.9
Papua New Guinea	383	-	-	-	-	-
Pakistan	20 500	11 139	12 950	14 680	15 440	75.3
Philippines	7 900	710	826	1 219	1 430	18.1
Republic of Korea	2 144	830	1 000	1 150	1 220	56.9
Samoa	122	-	-	-	-	-
Sri Lanka	2 205	361	465	525	583	26.4
Thailand	19 620	1 729	1 960	3 015	3 600	18.3
Viet Nam	6 795	992	980	1 542	1 770	26.0
Total:	457 981	94 448	106 450	128 290	134 239	29.3

Source: FAO Production Yearbook, 1979, 1986

A dash (-) indicates that the amount is negligible.

Over the past years, Pakistan has spent large sums on its On-Farm Water Project with the aim of reducing the seeping of water from the 63.100 km canal network and thus preventing waterlogging. In addition, nearly 200.000 tube-wells have been installed to exploit ground-water and lower the water table.

diseases. Since the impact of irrigation on the environment tends to be cumulative, the results can best be seen in those regions where irrigation has been practised intensively for a relatively long time. But, it should also be recognized that the same practices may have a much more rapid and severe effect when introduced into the fragile and delicately balanced ecosystems of some of the developing countries of the region.

1. Waterlogging and salinization

Irrigation water is generally brought to crops through unlined canals and ditches that allow vast quantities of water to percolate. Flood irrigation methods widely practised in the region also contribute to the infiltration of water. Where drainage is inadequate, the ground-water level gradually rises, eventually entering the crop's root zone and waterlogging the soil. In arid and semi-arid zones, waterlogging may be accompanied by salinization affecting crop yields by interfering with the capacity of plants to take up moisture and oxygen.

The problem of waterlogging and salinization is particularly urgent, as these processes are continuing at a rapid pace in China, India, the Islamic Republic of Iran and Pakistan. Thus, in the Indus Valley in Pakistan, there is one of the largest irrigation systems in the world. With the fast extension of irrigation there, started about 40 years ago, ground-water levels have risen from an average depth of 25 m up to near the soil surface.[11] In the country as a whole, more than 10 million ha out of 14.7 million under irrigation are now estimated to suffer from salinity and waterlogging.[12]

Owing to soil salinization and waterlogging, large areas of irrigated land in the region have been abandoned, thus contributing to the spread of desertification, the expansion of which is estimated at one million ha per annum in Asia.[13]

2. Spread of water-borne diseases

In tropical and subtropical areas, the introduction of perennial irrigation schemes appears to enhance the favourable conditions for the incidence and spread of water-related diseases, such as malaria and schistosomiasis. Relatively few studies have been undertaken to compare the distribution and intensity of these diseases in areas before and after irrigation development, but those that have been carried out point to surface irrigation practices as a significant factor in the increase in the prevalance of malaria, schistosomiasis and other water-borne diseases.[14]

3. Degradation of water quality

Degradation of both ground- and surface-water quality owing to irrigation development has become a serious problem in some areas of the region. Various pollutants, such as nitrogen compounds and pesticides, which are used widely in irrigated agriculture, may be washed out by filtrating water into ground-water. Owing to the growing use of fertilizers, nitrate contamination is increasing rapidly in areas under perennial irrigation. Salty water from irrigation systems is generally returned to the nearest river, inevitably increasing the river's salt content. For down-stream agriculture, it poses the problem of irrigation with increasingly saline water.

The potential effects of irrigation and proposed remedies for their alleviation are summarized in table 5. It may be noted that there are a number of measures which can be taken to prevent the extensive environmental damage that might have been caused by irrigation. Even waterlogging and salinization are not inevitable consequences of irrigation development and can be alleviated by sound design and construction of irrigation and drainage systems and efficient water management, especially by reduction of seepage losses from irrigation networks and by better farm water management.

III. Ground-water exploitation

Ground-water is used extensively in some parts of the region for drinking water supply as this source is usually of high quality and in most cases not contaminated, and is free of mud and sediment. With the increased availability of pumping equipment, ground-water is also becoming the preferred source of supply for irrigation, especially in the alluvial plains where ground-water is nearer the surface. In the northern provinces of China, for example, nearly one million wells have been sunk since the middle of the 1950s. During the 1960s and 1970s, 1.6 million tube-wells were installed in India resulting in an increase in the area irrigated by ground-water from 29 per cent in the early 1950s to 40 per cent in the mid.-1970s.[15]

Table 5. Impacts of irrigation development

Causal activity	Possible impact	Possible remedies
Surface irrigation	1. Waterlogging 2. Soil salinization 3. Increase of diseases 4. Degradation of water quality	1. Increased irrigation efficiency 2. Construction of drainage systems 3. Disease control measures 4. Control of irrigation water quality
Sewage irrigation	1. Contamination of food crops 2. Direct contamination of humans 3. Dispersion in air 4. Contamination of grazing animals	1. Regulatory control 2. Tertiary treatment and sterilization of sewage
Use of fertilizers	1. Pollution of ground water, especially with nitrates 2. Pollution of surface flow	1. Controlled use of fertilizers 2. Increased irrigation efficiency
Use of pesticides	1. Pollution of surface flow 2. Destruction of fish	1. Limited use of pesticides 2. Co-ordination with schedule of irrigation
Irrigation with high silt load	1. Clogging of canals 2. Raising of level of fields 3. Harmful sediment deposits on fields and crops	1. Avoiding use of flow with high silt load 2. Soil conservation measures on upstream watershed
High velocity surface flow	1. Erosion of earth canals 2. Furrow erosion 3. Surface erosion	1. Proper design of canals 2. Proper design of furrows 3. Land levelling 4. Correctly built and maintained terraces
Intensive sprinkling on sloping land	1. Soil erosion	1. Correctly designed and operated system

Source: Adapted from UNEP "Draft guidelines on the environmental impacts of irrigation in arid and semi-arid regions", 1979.

1. Depletion of ground-water

Ground-water reserves are recharged by the natural infiltration of surface water. However, ground-water is often pumped at rates that exceed replenishment, resulting in the depletion of the resource, the lowering of ground-water levels or decreased pressure in the aquifers. Excessive ground-water exploitation and subsequent lowering of ground-water tables appear to be increasingly common in the region. Thus, in Thailand, in the Bangkok metropolitan area, it has been estimated that in 1982 1.3 million m^3/day were pumped from public and private wells, while studies undertaken by various experts have recommended that the safe yield in the area should be around 600,000 m^3/day, taking into account reasonable aquifer recharge.[17] This extremely high rate of extraction exceeding twice the recommended safe yield has caused a rapid decline in the ground-water level by about 2.5 m per annum. In the North China Plain, where irrigated crop farming is impossible without ground-water, and major cities in this zone, including Beijing, are critically dependent on ground-water pumping for basic domestic and industrial supply, ground-water overdrafts have led to rapid ground-water level drops amounting to 4.4 m a year in the Baimiao district of Tianjin Province. In Tamil Nadu State in southern India, water tables fell by 25-30 m over the 1970s owing to overpumping of ground-water for irrigation.[17] Large parts of Bangladesh also suffer from overpumping and subsequent decline in the water table by as much as one metre per year. In many cases, ground-water cannot be further pumped by the widely used No. 6 hand pump, designed to lift water from depths reaching 7 m and utilized throughout the country in 65,000 villages.

2. Land subsidence

The ground-water withdrawals accompanied by the decline of its level often cause land subsidence or land surface settling. Subsidence rates can range from 1 cm to 50 cm per 10 m drop in ground-water level, depending on the thickness and compressibility of the water-bearing formations. Surface sinking owing to ground-water withdrawals has been observed in several parts of the region. Impressive cases of land subsidence have been reported in China. In Shangnai city, a cumulative amount of subsidence equal to 2.63 m was recorded over the period from 1921 to 1965.[18] As a result of this phenomenon the city suffered great damage as water overflowed the Chiang Jiang river banks flooding the depression, and industrial, commercial and social developments were severely affected.[19] However, because the city is not critically dependent on ground-water supplies, extraction rates were lowered and since 1963 the aquifers have been replenished with 17 million m^3 of surface water a year, and the problem is now basically under control.[20]

3. Salt-water intrusion

In coastal areas, excessive exploitation of ground-water inevitably leads to salinization of coastal fresh-water aquifers owing to intrusion of salt water from the sea. Salt-water intrusion threatens to contaminate the drinking water supplies of many coastal cities and towns in the region. The situation is especially severe in those areas where ground-water tables have been lowered far below sea level, and induced salt-water intrusion has caused deterioration of the water quality. Thus, the shallow aquifers, which once supplied fresh water to consumers, have become contaminated with salt water in Manila and Jakarta, where the ground-water levels have declined to as much as 150 m and 30 m below sea level respectively.[21] Intrusion of salt water is also a major problem impeding municipal water supply development in Bangkok.

Intrusion of sea water, with considerable detrimental effects on soil and vegetation, has been reported in the coastal zones of Australia, Bangladesh, China, India, Thailand, Viet Nam and the South Pacific islands, where excessive extraction of ground-water is widely practised. In small islands and atolls of the Pacific, the inhabitants of which depend to a large extent on ground-water for their domestic supplies, ground-water reserves and freshwater lenses floating on sea water are highly vulnerable to salt-water intrusion, owing to the low surface elevation and small size of the islands and atolls.[22]

A number of measures can be taken to avoid the adverse implications of ground-water exploitation. First of all, to prevent depletion of ground-water reserves, safe yields of aquifers have to be determined and should not be exceeded by extraction. In order to decrease and stop subsidence, demand for ground-water may be reduced by using alternative sources and, in some cases, ground-water extraction has to be fully stopped and replaced with other sources of water. Artificial replenishment of ground-water reserves by the infiltration of surface water can be successfully applied if the quality of water injected is satisfactory.

IV. Flood control works

Floods represent a serious problem in many river basins throughout the region, particularly in the areas affected by typhoons. Flood plains occupy up to 20 per cent of the territory in several countries of the region. The percentage is much higher in Bangladesh, where about two thirds of the territory lies in the flood plains of the Ganges and Brahmaputra rivers. In the ESCAP countries, the cost of damage caused by floods was estimated at more than $US 5 billion in 1981 and has been steadily increasing in most of the countries affected by floods.

To mitigate floods or their effects and thereby reduce the damage, engineering works, often referred to as structural measures, are traditionally and widely used in the countries prone to this natural disaster. Structural measures include construction of dams, reservoirs, levees and floodwalls, channel modifications and floodways. Dams and reservoirs are constructed upstream of the area they are intended to protect.

One of the main methods used for controlling floods is the construction of levees along the river in order to confine flood waters to the part of the flood plain where its passage causes little or no damage. The total length of the levees in 10 selected countries of the region exceeds 240,000 km (see table 6).

Levees occupy relatively small areas on flood plains, but can produce catastrophic results if they are breached or overtopped. The problems of drainage congestion can also be created behind the embankments. This impact has been observed in India, where the levees were constructed along some sections of the Brahmaputra and Kosi rivers.[23] To avoid this problem, it is recommended that drainage outlets be provided so that drainage of valleys is not impeded. The environmental impacts of levee construction might include alteration of the riverside benthic fauna and flora, which perhaps causes changes in the trophic chain, fish stocks could also be affected by the elimination of spawning grounds.

Improving flow conditions by channel modifications may enable flood water to be passed at a lower level than would have occurred naturally. In general, modification of natural stream channels by clearing, dredging and straightening is more appropriate to small streams, but may also result in minor improvements in the passage of flood flows in large watercourses. The environmental effects of flood-control channel modifications can be quite severe in some ca-

Table 6. Length of flood-control levees in selected ESCAP countries (1986)

Country	Length of levees km	Country	Length of levees km
Bangladesh	4 963[a]	Malaysia	2 152
China	185 000	New Zealand	3 000
India	11 868[a]	Pakistan	4 150[b]
Japan	9 962	Philippines	572[c]
Republic of Korea	18 457	Thailand	445[c]

Source: Based on information provided to the ESCAP secretariat by the countries of the region.

a) For 1980.

b) For 1981.

c) For 1984.

ses. Although these effects vary considerably, those observed include water quality degradation and loss of terrestrial and aquatic habitat. Probably the most considerable effects are caused by dredging activities. Dredging a waterway, of course, destroys local benthic life; and in an estuary, increasing the depth can induce penetration of salt water further upstream.

V. Interbasin water transfer

In some countries of the region, interbasin water transfer is becoming an attractive option in redistributing the available water resources in conformity with the demand for water. Mass water transfer over long distances from a water-surplus region to a water-deficient area to promote the agricultural and industrial development of that area could be achieved by diverting the course of water or by constructing a large canal.

Australia, India, Japan, Malaysia and Pakistan have constructed some projects varying in scope to divert water from one basin to another. In addition, Japan, India, the Islamic Republic of Iran, Nepal and Thailand are seriously considering the feasibility of other such projects, and China has recently taken a decision to start diverting the water from the Chiang Jiang River to the North China Plain.

Mass water transfer schemes undoubtedly have not only important economic effects but also significant environmental consequences, which need to be carefully analysed and assessed. The environmental impacts of a largescale water-transfer scheme could best be evaluated in three groups separately for (a) the exporting basin, (b) the route of conveyance, and (c) the importing basin.[24] For each group it is recommended to consider the impacts on physical system, water quantity, water quality, land, atmosphere, and biological system.

The impacts to be anticipated in the exporting basins include changes in the flow, sediment load and channel configuration resulting from decreased discharge of the river. The decrease in discharge also has important implications for salinity conditions and the ecology in the estuary. These potential impacts depend mainly on the regime of diversion from the river. Concerning the impacts of conveyance on ground- and surface-water systems along the route, the routes are to be carefully selected considering the possibility of seepage from transfer canals. In areas of delivery, the possibility of increasing salinity in agricultural areas receiving the additional irrigation water is to be assessed first. In addition, throughout the transfer scheme under consideration, the effects on water quality, health and climate are to be looked into as well.

VI. Prospects for co-operation

There is a need for intensified regional co-operation in the field of environmental management in water resources development. Some countries have accumulated essential experience and knowledge in environmentally-sound development of their water resources. This experience and knowledge could be very useful for those countries starting to plan and carry out large water resources development programmes, in helping them to avoid repeating the mistakes made by the other countries in the past. Further regional co-operation should be aimed at the exchange of information and experience on identification of the potential implications of water resources development projects, application of methods and techniques for their evaluation, and legal and institutional aspects of incorporating environmental considerations into water resources development planning.

In particular, collaboration in elaboration and application of appropriate methods and procedures, adapted to local conditions, for studying, assessing and predicting the environmental implications of water-related development activities could be very fruitful, as interest in this subject has recently become widespread in the region. Co-operation in the field of environmentally sound management of water resources could also include exchange of relevant environmental data and information, notification and consultation on planned activities in water sector with potentially significant environmental effects on territories of other countries, joint monitoring of the environment, collaborative preparation of assessment documentation, implementation of mutually agreed mitigation measures for projects affecting neighbouring countries.

Besides, it is essential to promote regional co-operation in education, training and research related to environmental aspects of water resources development in order to strengthen the ability of the countries concerned to identify the potentially adverse impact of water resources development projects on the environment, effectively take them into account and minimize any eventual damage. The co-operation in this field can be supported through the ESCAP Regional Network for Training in Water Resources Development.

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ENVIRONMENTAL PROBLEMS ASSOCIATED WITH WATER RESOURCES DEVELOPMENT IN THE LOWER MEKONG BASIN

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1. The river and its basin

One of the great rivers of Asia and, indeed, ranking as number twelve in the list of the world's longest rivers, the Mekong rises at an elevation of some 16,400 feet (5,000 metres) close to the Dzanag La pass in the Tanghla Shan mountain ranges on the northeastern rim of the great Tibetan plateau in southwestern China. Along its course, the Mekong flows through or along the borders of six countries, China, Burma, Laos, Thailand, Kambodia and Viet Nam before joining the South China Sea southwest of Ho Chi Minh City. In volume of water discharged into the sea, the Mekong, with an annual average discharge of approximately 475 x $10^9 m^3$, moves up to be the sixth largest river in the world.

Its total drainage basin, including some 160,000 km^2 in China, is about 783,000 km^2. The river enters its lower basin at the common Burma-Lao PDR - Thailand boundary point and the distance from there to the ocean is some 2,380 km. It is this stretch of the river that is the subject of the United Nations sponsored water and related resources development programme, The Mekong Project. This paper concentrates on the lower Mekong river and its basin (Fig. 1).

The lower Mekong basin covers an area of some 611,00 km^2, or about 77 per cent of the total area of the river basin. It includes nearly the whole of the Lao PDR (202,400 km^2), the northern tip and the northeast area of Thailand (180,240 km^2), ninetenths of the State of Kambodia (154,000km^2) and the western flank and southern tip of Viet Nam (65,200 km^2).

2. Environmental determinants of development

The distinct environment, geology, and climate in the basin together dictate resource use patterns and potential for development. The complex geological history of the basin has provided five physiographic units: the Northern Highlands, The Annamite Chain, the Southern Uplands, the Korat Plateau and the Mekong Plain[1] (Fig. 1).

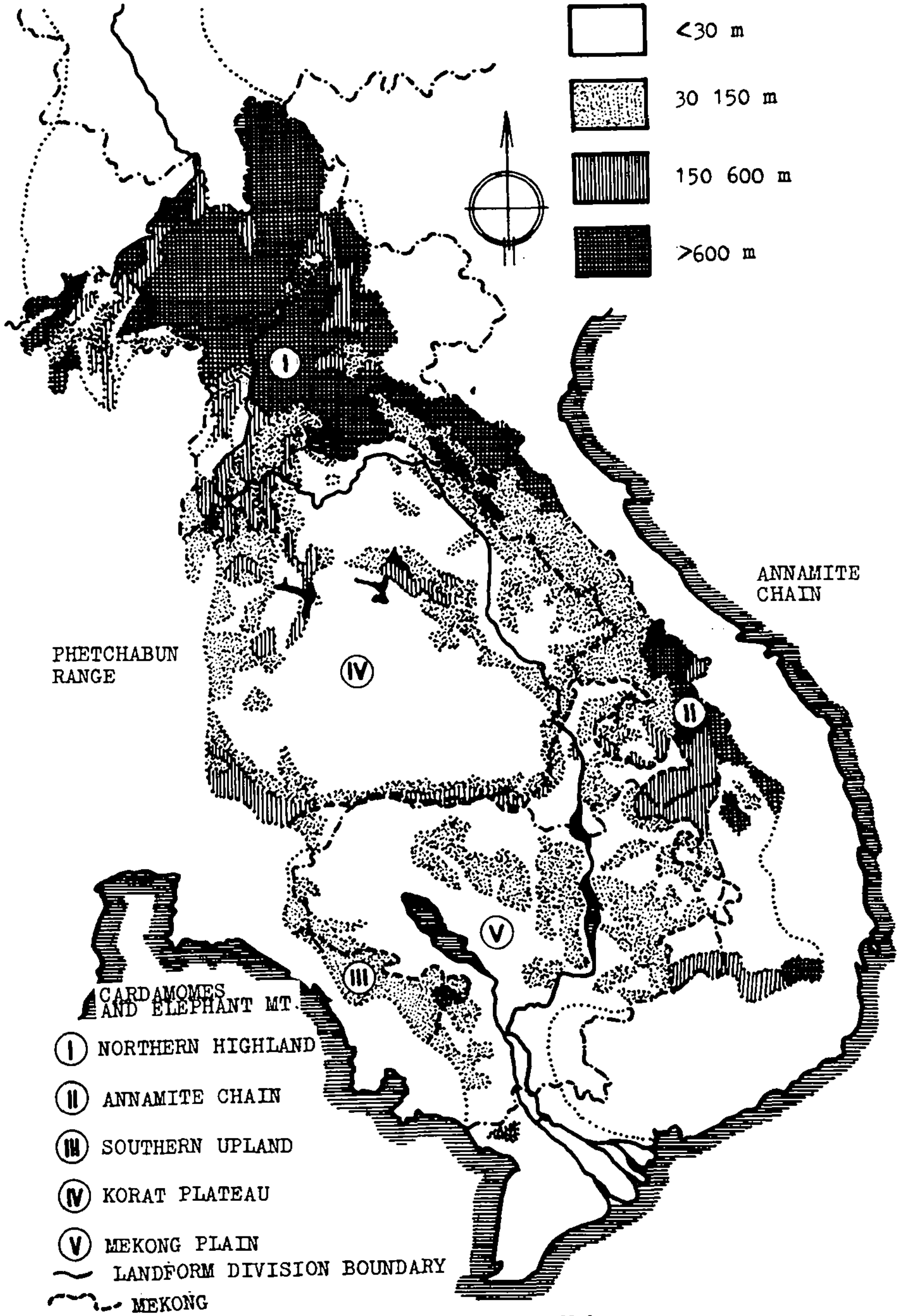

Fig. 1 The Lower Mekong River Basin.

The Northern Highlands, covering northern Lao PDR with only the western rim in Thailand a strongly folded mountainous area where the processes of erosion have carved a highly complex and dissected relief. There are a few relatively large upland plains, such as the plain of jars on the Xieng Khouang Plateau (Lao PDR). The river valleys in the Lao PDR usually have small quarternary alluvial terraces. North Thailand, in Chiang Rai province, however has extensive plains with C.2200 km^2 of wet rice fields.

Rainfall is high - 1,200 to 2,000 mm a^{-1}. Temperature is generally high. Occasionally, however, cold air from Siberia and China penetrates, lowering air temperatures to near zero.

Human population is sparce averaging 5-14 km^2 except on the valley floors as in Chieng Rai (Thailand) where numbers average 57.9 km^2. However, population density is reportedly increasing.

All the factors described above have significant influence on resource use. Wet rice cultivation is possible only in the deltas of tributaries. In the uplands slash and burn cultivation practiced by hill-tribes has contributed to considerable loss of natural forest cover and to erosion which is having significant negative influence on water resource developments in the plains. The potential for hydro-electric power development is substantial.

The Annamite Chain, located mainly in the Lao PDR, is 800 km long and has a steep and mountainous terrain in the north and central parts, but forms dissected hills and rolling-to-hilly plateau in the south. The chain extends into Viet Nam and Kambodia. Of interest is the hilly Karstic limestone area - the Khammouane plateau, which is the single most extensive limestone deposit in the basin. This 50 to 300 km wide and 500-2,500 m high mountain chain, divides the western Mekong drainage from eastern South China Sea drainage.

Rainfall is heavy on the south and west flanks, which receive the brunt of the south-west monsoon; some inner valleys, however, are drier, with deciduous forests. Once, areas which receive $> 2{,}000$ mm a^{-1} were completely covered by dense rainforest, but many have been cleared for swidden agriculture. As a result, forests have been completely depleted particularly in the southern most region. Swidden agriculture still dominates, with $< 1\%$ of the land under wet rice. Populations are sparse ($< 4 km^{-2}$, N; 5-40km^{-2}, S), but highly diverse hill-tribe cultures occur.

The potential of the area for agricultural development is limited. Although the Mekong tributaries have a more gentle profile than the streams draining into South China Sea, they are still broken by many falls and rapids in the Northern sector and are suitable for hydro-electric power development. The less accented southern sector provides limited irrigation potential in tributary valleys. Vast areas of the chain which are now barren and covered only with grasses with a savannah type of character can be developed for live stock grazing.

Southern Uplands consist of the Elephant and Cardamomes Mountains, separating the Mekong Plain in Kambodia from the Gulf of Thailand, and continuing into Thailand. To the east are continous mountains, while the west comprises rolling, dissected plains, which yield orchard fruit and field crops. The Uplands are 500 - 1,700 m altitude and except for some steep escarpments, slopes are moderate in the north and steep and eroded in the South.

Rainfall is very high - up to 5,000 mm a^{-1} in places - with dense, tropical rainforest and very low human population densities (< 4 km^{-2}). Hill-tribes are a negligible portion of the population, and even swidden agriculture is very limited (though more common on the drier North side). There is little scope for agricultural development.

The Korat plateau comprises northeast Thailand and adjacent parts of Lao PDR. It is a large (250,000km^{-2}) saucer-shaped inter--mountain basin tilted towards the south east. The altitude of the floor is 100-200 m with surrounding mountains reaching 1,400 m. Greater part of the plateau consists of relatively flat lands and is underlain by thick cretaceous salt deposits. Due to rain shadow effect of surrounding mountains, the area is dry.

Rainfall is erratic and fluctuates between 1,000 to 1,250 mm. Recurrent floods and droughts afflict the plateau much of which is now covered with unproductive scrub or grassland vegetation, although it was originally forested. Extensive deforestation has contributed to erosional problems. Several major tributaries of the Mekong in the Lao PDR, the Nam Theun, Se Bag Fai, Se Bang Hieng and Se Done have alluvial valleys in the plateau. In Northeast Thailand, more than half the plateau is drained by the Mun and Chi rivers, which have experienced some of the earliest development of rice agriculture in the basin and, judging from archaeological sites, supported fairly dense prehistoric and early historic human populations. Later populations were thinner, but recent agricultural advances have allowed the population to rise again and much of the plateau now supports between 80-150 people km^{-2}.

A number of reservoir sites have been developed mainly for hydro-electric power generation and irrigated agriculture. Fisheries are an unforeseen ancillary benefit in the reservoirs. From a purely physiographic point of view, the plateau would appear to offer substantial scope for further agricultural development by means of flood control, drainage and irrigation of the more productive soils.

Mekong plain is a vast low-lying area, a relatively small portion of which actually consists of fluviatile deposits of the young Mekong. It comprises most of lowland Kambodia, the Mekong Delta of Viet Nam, and small sections of south Lao PDR and east Thailand. Most of it lies below 100 m, with a few higher outcrops scattered throughout the plain, while much of North Kambodia comprises rolling and dissected plains between 100-200 m high. The Mekong Plain is the result of erosion and sedimentation; the sediments vary in depth, from at least 500 m near the mouth to only 30 m. At the "nine mouths" of the Bassac and Mekong, the combined action of river deposition and the sea has produced a coastal belt of slightly higher elevation. Deposition in the delta continues to extend the Ca Mau Peninsula south and west at a rate of 150 $m\ a^{-1}$ in some places.

The plain is the most densely populated part of the basin with >450 people km^{-2} in the rice-growing regions of the delta (rice is grown on 50% of the land). The richest rice-growing areas of the State of Kambodia are also densely populated, especially south of Tonle Sap and on the Battambang Plain. The north and east savannah, however, are very sparsely populated (<4 people km^{-2}). The lowlands, particularly the areas of Holocene alluvium, have historically been the most densely populated and productive agricultural parts of the Lower Mekong Basin, with apparent agricultural and water resource development potential.

3. Water resources

The Mekong discharges annually more than $475 \times 10^9\ m^3$ of water into the South China Sea. The sources of this surface water are disparate. About 20% of the annual flow comes from the upper basin (i.e. above the Burma - Lao PDR - Thai boundary). Some 70% of the flow is contributed by the Thai - Lao PDR section. The remaining 10% comes from Kambodia - Viet Nam sector excluding the delta[2].

While snow-melt produces a more or less uniform flow in the upper Mekong, the lower Mekong exhibits pronounced seasonal variations reflecting rainfall patterns. The river rises following the onset of monsoon in May or June, and attains a maximum level in August or September in the upper section of the lower Basin and in September and October in the lower Section. It then falls off rapidly in December and slowly thereafter to reach its lowest level in April. There are no mainstream storage structures and those on the tributaries do not have a significant effect on the mainstream flow. Only the Great Lake in the State of Kambodia significantly affects mainstream flow, largely in the delta.

There are distinct alternating dry and wet seasons in the basin area as a result of influence of the monsoons. While during dry season there is shortage of water, large areas are flooded during the wet season. The flooding behavior of tributaries also varies from one part of the basin to another. Tributary basins in Thailand (e.g. Mun and Chi) have relatively small channels but have extensive flood plains ranging from 10 to many kilometres wide. These basins located as they are on the lee side of mountain ranges receive low rainfall. They usually remain dry for several years, filling irregularly. Highest rainfalls occur along the windward slopes of Annamite mountains and in the Lao PDR and the State of Kambodia, thus floods of a different magnitude develop in these areas. Stream courses here are generally well defined and accommodate floods which are fairly uniform from year to year.

Resource development constraints. The main foci of water resource development in the Mekong basin are the production of the staple food, which is rice, the principle source of protein-fish, hydro-electric power for domestic, industrial and agricultural purposes and navigation in the river. Initial estimates place the theoretical potential of hydro-electric power resources of the lower Mekong basin at 58,000 MW installed capacity and 505,000 GWh for annual energy production. The estimated potential of the basin for year-round irrigation with the help of storage and flood plain reservoir is of the order of 6.4×10^6 ha. Development of the resources is sought to be achieved mainly through dam construction and irrigated agriculture development. Due to physiographic limitations rice cultivation in the basin is possible only in the delta, the Mekong plain, the Korat plateau, the tributary deltas in the Annamite Chain and valley floors in Northern Highlands.

In the natural state, development of rice cultivation is beset with problems of shortage of water in the dry season and flooding of vast areas in the wet season, particularly in the delta and the Korat plateau. Even in the wet season irregular rainfall which causes either dry spells or over-abundance of water affects plant growth. Furthermore in the delta inadequate discharge in the Mekong for irrigation withdrawal during the low flow period and intrusion of salt water from the sea present additional constraints.

Dams and other water control and regulatory measures would appear, on the surface, to be the logical answer to overcome the above constraints. However, soil conditions in the Korat plateau, and in the delta present formidable problems under water management and irrigation development. About 1.8 x 10^6 ha in the delta are covered by acid sulfate soils and another 2 million hectares in the Korat plateau are influenced by underlying geologic salt deposits. Water control drainage and irrigation acidify the potentially acidic soils and exacerbate the acid in developed acid sulfate soils. Irrigation of lands underlain with salt deposits results in salinization of top soils and render them unfit for cultivation. Furthermore, salinity control in the delta will affect the important fishery resources which depend on the salinity intrusion for breeding, nursery and forage in the delta wetlands. These problems are described in some detail in the following section.

4. Environmental problems

Environmental problems or issues that have direct relevance to water resources development in the basin are:

- Watershed degradation erosion and sedimentation;
- Acidification of soils in the delta;
- Soil salinization in Korat plateau;
- Problem soils - danger of desertification as a result of improper exploitation;
- Inundation control-effects on fisheries;
- Toxic bio-cidal levels in edible organisms;
- Waterborne diseases; and
- Potable rural water supply in problem (saline and acid) areas.

<u>Watershed degradation</u>. Degradation of Mekong watershed conditions has become one of the main concerns in recent years. Millions of hectares of valuable forests have been degraded to inferior scrub, grasslands or savannah, or have been encroached by subsistence agriculture. As a result, soil conditions have deteriorated, with increased water run off and erosion. It is estimated that between 1970 and 1985 alone some 13 x 10^6 ha of closed forest disappeared in the lower Mekong basin (Table 1) through encroachments of forest (both legal and illegal), shifting cultivation and agriculture development projects.

Table 1. Changes in closed forest cover between 1970-1985 in the lower Mekong basin

Country	Closed forest 10^6 ha		Annual deforestation	Deforestation
	1970	1985	10^3 ha	%
State of Kambodia	11.00	7.42	239	32.5
Lao PDR	13.00	7.91	339	39.2
Northeast Thailand	5.31	2.33	199	56.1
Southern part of Viet Nam	3.60	2.67	62	25.8
Total in lower Mekong Basin	32.91	20.33	839	38.2

A major problem is forest degradation by fire, often started intentionally for reclaiming forest land for shifting cultivation. Forest fires combined with short fallow periods in between lead to soil exhaustion. Grasses such as Imperata cylindrica and Themeda triandra then take over, changing the forest ecosystem from savannah wood land into unproductive grassland. Approximately 8.5 x 10^6 people are said to depend on shifting cultivation affecting an area of some 17.5 x 10^6 ha in the lower basin. While slash and burn cultivation, practiced in the traditional way with short cropping and long fallow periods in between, may be a sound land-use measure, with population increases and the current intensive ways, it has severely depleted the soil. Population increases in the basin and the consequent increase in demand for fuel-wood or charcoal have further increased inroads into forests. Except perhaps in the Lao PDR and the State of Kambodia, there is an acute scarcity of fuel-wood in the basin. In term of this it is expected that the pressures on remaining forest resources will be extremely high. However the lion's share in deforestation goes to illegal logging, and effective control to stem this destructive practice seems almost impossible for various reasons. Important are lack of adequately staffed and effective technical organizations, lack of coordination among various agencies, shortage of funds and, at places, insecure political conditions.

Erosion. The main areas of concern in relation to erosion are the hilly areas mainly in the Lao PDR. By 1972, more than 10×10^6 ha of forest were reported to have been destroyed[3]. The annual rate of deforestation for shifting cultivation and through forest fires in Lao PDR alone is estimated to be 300,000 ha. Generally, in the basin, excessive deforestation is attributed to enormous increase in population densities in the basin from 16.3 persons per km^2 some 70 years ago to 66 persons per km^2 in 1988. As a result, people living in plains have encroached on forested hill areas and are reclaiming them for agriculture at an ever increasing rate. In fact the problem of erosion induced sedimentation reservoirs is so serious that power production at two dams, Selabam and Nam Dong, has been adversely affected. It is also apprehended that the rate of silting in the Nam Ngum reservoir has reached alarming proportions. Elsewhere in the basin however, despite the rather drastic changes in forest cover their erosional effects are not manifest at least in the main Mekong. Sediment yields in the river and tributaries are rather low compared to other Asian rivers[1].

Acidification of soils in the delta. An estimated 1.8 million hectares, or approximately 45 per cent of the Mekong delta in Viet Nam is covered by acid sulfate soils and is not readily and easily amenable to agricultural development. These soils are characterized by pyrite deposits at relatively shallow depth which react to oxygen intrusion with pyrite oxidation and development of sulfuric acid. Soil pH in acid sulfate areas may drop to values below pH2 and, under these conditions, toxic polyvalent cations (metals) are dissolved from the soil minerals. Secondary reactions relate to immobilization of phosphate, inhibition of the nitrogen cycle and potassium deficiency due to leaching. Although farmers in the delta have developed through trial and error ingenious water and soil management strategies to overcome these constraints and obtain yields form such soils, large parts of the most severely affected areas lie fallow in spite of the obvious need to reclaim all available land to increase food production in the country. Reclamation of these areas is fraught with difficulties, as inappropriate strategies may lead to enhancement of acidification and even successful strategies may cause damage in other areas, if they result in production of acidic and toxic drainage waters. Such drainage waters and also flood waters which have overflown acid sulfate soils are not only unsuitable for all water uses but also cause acidification of adjacent lands and surface water bodies with often catastrophic effects on agricultural crops and fisheries.

In earlier days, vast areas of acid soils were covered with Melaleuca forest. However, population pressures have lead to reclamation of these lands for irrigated agriculture. Furthermore, defoliation of the Melaleuca forest during the recent war was followed by harvest of the wood and cultivation of the lands for paddy. Lands so converted could only be used for one or two seasons. Thereafter they had to be abandoned because of developed acidity. Even raised bed cultivation, a method used successfully by farmers, has resulted in acidification of surface waters affecting crops and fish in the entire area.

Soil salinization in Korat plateau. Covering the whole of northeastern Thailand and parts of Vientiane plain in the Lao PDR, the recent alluvium is underlain by a typical formation, the Mahasarakam formation. Different strata of this formation are more or less salt-bearing with a lower "rock salt" structure, comprising several strata from "basal salt to upper salt inclusive", and an "upper clastic layer"[4]. The occurrence of salt-affected soils in the plateau "coincides with the area of Mahasarakam formation and saline ground-water. The Korat plateau, as other parts of the basin, is interspersed with wetlands of various dimensions. In recent years water resource development activities, including dam construction and "flood plain development" for irrigated agriculture have resulted in the draining of the wetlands and their conversion into irrigated agricultural lands.

Prior to the "development activities", agriculture was mostly rain-fed and seasonal, yielding modest returns of 1.5 tons/ha/yr of rice. At that time, periodic flooding of the fields by rivers used to wash out the surface salts, besides providing fish harvests of 10-25 kg/ha for the flood duration. Embankment, dam construction and drainage of wetlands and the subsequent development of irrigation in these areas resulted in the elevation of saline ground-water levels, either due to hydrostatic pressure, caused by water storage in the dams, or due to downward seepage from the irrigated fields. This, coupled with capillary rise, has resulted in salinization of surface soils in irrigated areas. This type of secondary salinization in irrigation areas has been reported from many areas. Examples are "the Nong Wai irrigation project area in Khon Kaen, Kampuwapi south of Udorn, the Lam Pao irrigation scheme at Kalasin and Nam Oon irrigation area in Sakhon Nakhon"[5]. The increase of surface soil salinization in the irrigated areas is estimated at 10% over a period of 10 years. The areas thus salinized have become unsuitable for any productive use.

<u>Problem soils - danger of desertification as a result of improper exploitation</u>. Problem soils are defined as those which present inherent constraints to productive utilization. Besides the acid and saline soils mentioned above, there are various other problem soils in the basin such as shallow skeletal soil and sandy surface soils in Thailand and Lao PDR, and peats, and exhausted grey soils in Viet Nam.

Skeletal soils in this context are defined as soils containing 35 per cent of lateritic concretions or gravel of more than 2 mm in diameter in a given volume of soil. Physical constraints to plant growth are coarse texture and shallow depth, which restrict root growth. Also, the capacity of such soils to retain water and nutrients is generally low.

Peat soils contain at least 20-30 per cent of organic matter in the upper 80 m of the profile. The main growth limiting factors are low bearing capacity, shrinkage, irreversible drying, deficiencies of micro and macro nutrients and fungal diseases associated with them. Only peat sols of less than 1 m depth can be brought under cultivation.

Grey soil in the basin remain to be classified and characterized in detail. Its main constraint seems to be low fertility because of nutrient deficiencies.

As in the case of acid and saline soils, ever increasing population pressure in the basin (with the exception of the Lao PDR) and the vast areas the problem soils cover have rendered their reclamation imperative. Therefore, water resource development activities in the basin have to reckon with the problem of utilizing productively the problem soil areas. Unplanned and inappropriate use of these lands has already rendered vast areas irreversibly unproductive. This explains the urgency of addressing this problem in the basin.

Inundation control and its effects on fisheries. Historically, the most productive of all Mekong basin fisheries are those dependent on seasonal flooding; but these fisheries are unusually vulnerable to proposed schemes for the elimination of floods. The floodwater fisheries of the basin hinge on seasonal rains caused by warm humid monsoons from the southwest, which usually begin in May and extend through September, depending on latitude. Along with and following the monsoon rains, waters of the mainstream and tributaries begin to rise. The timing and effects of this rise differ by river sector but generally floodwaters may cover almost the entire low gradient drainage basin of the Mekong and its tributaries, all the way to the estuarine zone in Viet Nam. The natural, long-time evolution of the reproductive cycle of most freshwater fishes of the basin has synchronized ripening of the gonads with the onset of the rainy season and flooding, and has led to extensive migrations of these fishes into the zones of inundation. These zones not only afford a rich variety of spawning habitats, but also, while inundated, provide nutrient-rich nursery grounds. As the flood water begins to subside following onset of the dry, cool northeast monsoons (usually beginning in October), the young and the adults return to the river and tributaries and provide a rich fishery there: some of the young remain in the wetlands in the flood plains and contribute to year round fish harvests there.

The natural system of high productive potential combined with the opportunity for efficient harvest makes the Mekong floodwater fishery, like those of the other great river-flood inundation zones of the world, one of high value and catch. The seasonal fallowing and drying that follows annual inundation is the key to nutrient release from inundated land for cycling into aquatic production. These events accelerate the breakdown of organic materials, such as plant remains, for rapid transfer via food chains into fish and other aquatic crops during the next flood.

Exceeding in magnitude the fisheries of the freshwater zone are the fisheries of the brackish waters in the Mekong estuary proper and in the adjacent waters of the South China Sea. In these estuarine and coastal waters, shellfish are more prominent than in the inland parts of the basin. Marine organisms predominate, as there is a progressive downstream change from freshwater to marine habitat. Like all estuaries, that of the Mekong is potentially among the most efficient of all aquatic systems for the transfer of solar energy into fishery production. This efficiency here is reinforced by the shallowness of the waters and the relative nutrient richness of the ecosystem which receives the nutrient rich silt washed down seasonally during floods, the estuary being situated at the downstream end of the vast drainage basin.

The Mekong inundation zone and estuarial ecosystems sustain delicately tuned interactions between the physical environment and the biota. These interactions are highly vulnerable to the alterations in quantity and timing of annual inundation and mainstream discharge implicit in the installation of engineering works and operation of water management systems upstream and in poldering of flood plains. These alterations will impinge upon the life cycles, distribution, and abundance of the freshwater zone, estuarine, and coastal fishery organisms. Of particular concern may be dispersion of commercially exploitable concentrations of valuable fishes that seasonally occur in the river and off the river mouths.

The fishery yield and value from these ecosystems - the Mekong freshwater zone, estuary and waters of the South China Sea under direct Mekong influence, - have never been precisely quantified in spite of substantial size and great local economic and nutritional significance. Extrapolations of existing records and statements by experienced government officials indicate that the annual production of these waters from all types of fisheries (commercial, artisanal, and subsistence fishing and from aquaculture) may approximate 500,000 metric tons, currently valued at US$ 225 million.

Toxic bio-cidal levels in edible organisms. One of the objectives of water resources development in the basin is raising agricultural production from the present 12.7 million metric tons to 37 million metric tons per year. This has required among other measures the intensive use of pesticides and herbicides; all the more so because monoculture enhances vulnerability to attack from plant and animal pests. Intensive use of herbicides and pesticides, as is well known, can render the aquasystems unproductive and even harmful to human populations. In order to avoid these impacts agricultural development should be made compatible with aquasystem development. The problem of toxic biocides at present is not widespread, though acute in certain locations, particularly in Northeast Thailand.

Waterborne diseases. Experiences in different parts of the world have shown that water resource development projects such as those implemented or contemplated in the lower Mekong basin, may result in serious, adverse health consequences. Especially in tropical and subtropical areas, where water - and vectorborne diseases such as malaria, Schistosomiasis and Filariasis affect the lives of millions of people, ecological changes induced by water resource projects may directly contribute to the spread, propagation or introduction of such diseases by creating favourable habitats for vectors and intermediate hosts. The incidence of Schistosomiasis, for instance, rose dramatically in many arid and semi-arid countries in Africa and the Middle East after man-made irrigation supported the propagation of snail intermediate hosts. In a southern province of Egypt for example, the prevalence of Schistosomiasis reportedly grew from 3% to 42% within 20 years.

Water resource development projects do not only affect habitats of vectors and intermediate hosts but also contribute to the spread and introduction of pathogenic agents by attracting people representing a variety of epidemiological situations, such as migrant labourers during construction work and settlers after its completion.

Waterborne diseases in the lower Mekong basin could be classified into the following three types:

- Waterborne diseases sensu stricto or water transmitted diseases. In this category man or animal is the source, and the main reservoir, of infection. The agent is discharged to the water with human or animal feces or urine. Water is a vehicle for infective agents: bacteria, viruses or parasites. Examples are a variety of diarrheal diseases, enterotoxic, Escherichia coli infections, shigellosis, salmonelloses, cholera, virus infections, typhoid and paratyphoid, virus hepatitis A, amoebic disentery, giardiasis, leptospirosis, etc.

- Water transmitted helminthic diseases with involment of an intermediate host or hosts living in the water. Examples are Schistomoasis, opisthorchiasis and paragonimiasis. Snails are the first intermediate host for parasite development and fishes, crabs and plants the second intermediate host for certain parasites. Humans get infected through direct water contact (schistosomiasis) or by consuming uncooked intermediate hosts.

- Vectorborne diseases. Water constitutes the breeding place for the vectors. Examples are Malaria, filariasis and Japanese B encephalitis.

Of the variety of diseases, schistosomiasis (blood fluke disease) is a primary focus of attention of the Mekong committee. The first human case of schistosomiasis originating from the Mekong basin was reported in 1957 in a Laotian living in Paris. Intensive studies showed that schistosomiasis in this area is caused by a then, unknown parasite, now called Schistosoma mekongi. This parasite resembles closely Schistosoma japonicum, but its intermediate host is an planorbid freshwater snail, Tricula aperta, living in certain parts of the Mekong river. The snail is also abundant in the Mun river, a tributary running through Ubol Province, Thailand where a major project, the Pak Mun dam, is planned. So far, two foci of human Schistosomiasis are known in the lower Mekong basin, one at Khong Island in the southern tip of Laos, the second one at Kratie, Kambodia. No proven case has ever been diagnosed in Thailand, except from refugees from Laos and Kambodia.

The liver fluke Opisthorchis viverrini is considered as another important potential health problem because of the high prevalence in the population of the Northeastern part of Thailand (34.6%) and Laos (46.5% in Vientiane and 39.7% in Khong island). Infection is acquired by the habit of eating raw cyprinoid fish that serve as the second intermediate host for the parasite. Other waterborne helminthic infections such as paragonimiasis, angiostrongylosis and fasciolopsiasis and intestinal flukes, of which detailed data are only available from Thailand, appear relatively less important.

Among vectorborne disease, malaria constitutes clearly the most serious health problem in areas of the Mekong basin. Considering the enormous obstacle of drug resistant strains of Plasmodium falciparum rapidly spreading over Southeast Asia, it is of upmost importance to prevent creating new breeding habitats for the vectors. Quite a number of primary vectors are known in the Mekong basin which require different types of breeding sites for efficient propagation, such as slow running, vegetated streams (An. minimus, An. maculatus), paddy fields (An. nivipes), stagnant water in forests (An. dirus), brackish water (An. sundaicus). Other vectorborne diseases in the Mekong basin include dengue haemorrhacic fever transmitted by Aedes mosquitoes and Japanese B encephalitis transmitted by Culex mosquitoes. Unlike malaria which is endemic in the area, these two diseases usually manifest themselves as epidemics. In the Mekong delta dengue haemorrhagic fever was one of the leading causes of morbidity during the years 1976-1983. Japanese B encephalitis is usually associated with pig breeding as these animals serve a reservoir for the virus.

As stated above diarrheal diseases are worldwide and are one of the biggest killers of children below five years of age. This group of diseases is very common in all three riparian countries and rank high in prevalence and incidence in all age groups especially in densely populated Mekong delta where the sanitary standards are low. In water, fecal micro-organism indicators reach medium to high levels in 100% of surface water of the Mekong river as well as in its branches, canals and ponds. The surveys showed further that 98.5% of the dug well water samples were contaminated.

Rural potable water supply in problem areas. In the lower Mekong basin - as in most developing regions of the world - domestic water supply from central water treatment plants is only available for cities and major settlements. Villages and individual households in rural areas are not connected to such facilities. This means that more than 80% of the population have no access to treated water but depend directly on surface water bodies for domestic supply, including drinking water and preparation of food. Thus, public health and hygiene depend to a large extent on the quality of these water bodies - their contamination with pathogenic organisms or toxic chemicals. With increasing population densities and intensification of agricultural land use, increasing amounts of domestic waste waters and agricultural chemicals (fertilizers, pesticides) have reached the surface water bodies. At present tributaries in Northeastern Thailand show signs of eutrophication and in the Mekong delta - where population density is highest - even the main river distributaries show levels of bacterial contamination which render them unsuitable as sources of drinking water. Consequently, there is a high prevalence of diarrhoea type diseases and intestinal parasites in these densely populated parts of the basin.

In addition to these anthropogenic problems, resulting from short-circuit between waste disposal and domestic water supply, natural problems of two areas, namely salt contamination and acid waters, impinge on quality and potability of water sources. These natural problems do not only affect surface waters but also the groundwater which could otherwise be regarded as a comparatively safe alternate source to domestic water supply. Thus, in large areas of the basin rain water is the only water source of adequate quality for domestic consumption, but rainwater is available only during a part of the year, and safe storage facilities are required to keep a sufficient quantity for the dry season without risking secondary contamination. Taking 201/person day as the absolute baseline for the demand of good quality water, a storage tank of about 20 m^3 would be required to last a family of 6 persons over the 5 to 6 mounths of the dry season. Most families in rural areas are too poor to purchase such a tank, and the smaller tanks which are in use are often open and exposed to secondary pollution. When stored drinking water has been consumed, either water has to be bought and in some instances - transported over several kilometers - or low quality water has to be used which of course has impacts on public health. In many households of the delta simple filtering techniques are used to make surface waste more suitable for domestic purposes. While these techniques can improve the quality they cannot be regarded as safe. From the above it can be seen that supply of potable water to rural households in problem areas is at present rather urgent.

5. Programme of action to solve the problems

The underlying philosophy of the Mekong Committee's environmental programme is to cement the environmental dimension into Mekong development projects with a view to ensuring that productivity of primary natural resources - terrestrial, aquatic and human - does not deteriorate as a result of development activities in the basin and that maximum socio-economic benefits can be achieved. Therefore, a comprehensive environmental programme pervades all the Committee's development activities and includes steps to anticipate, as far as possible, both the undesirable side effects and unaccounted benefits resulting from development activities, and to demonstrate measures to maximize benefits and alleviate adverse effects through effective management. The most important elements of the programme are briefly summarized below.

a) STUDIES leading to environmental assessment, including identification of problems; and

b) PILOT MANAGEMENT, REHABILITATION AND AMELIORATORY ACTIVITIES to demonstrate measures to enhance benefits and to offset adverse effects of water resource development projects, on the environment.

Table 2 illustrates projects under implementation with a view either to study in depth or to formulate and demonstrate measures to alleviate the problems described above.

Table 2. Mekong environmental programme

STEP 1	Data/information collection and identification of problems	1.3.01 1.3.04 1.3.06 1.3.13 1.3.17 (Phase II)
STEP 2	Problem investigation and solving	1.3.15
	- Watershed management	1.3.03 1.3.12
	- Acidification of soils	1.3.05 1.3.08
	- Salinization of soils	1.3.02
	- Waterborne diseases	1.3.06 (Phase II)
	- Inundation control	1.3.11
	- Toxic biocidal levels	1.3.17
	- Potable rural water supply	to be formulated
	- Problem soils	1.3.14
STEP 3	Pilot projects to demonstrate problem solution	
	- Development of acid soils	1.3.05 1.3.02
	- Fishery protection and production	3.6.01,02,03,04 3.6.05,06,07,08
STEP 4	Environmental assessment	3.1.01 3.5.03 3.4.02
	- Environmental planning - Rational resource use allocation	1.3.01,10

List of projects represented by the above numbers

1.3.01	Co-ordination of environmental planning (basin-wide)
1.3.02	Assessment of potential and application of reforestation and agro-forestry to soil management (Lao PDR and Thailand)
1.3.03	Control of soil erosion, sedimentation and flash flood hazards (basin-wide)
1.3.04	Establishment of a water quality monitoring network (basin-wide)
1.3.05	Ecologically sound development of water and land resources in Mekong delta (Viet Nam)
1.3.06	Study of water-borne diseases, Phase II (basin-wide)
1.3.08	Management of acid sulfate soils (Viet Nam)
1.3.10	Integration of environmental management aspects in Mekong resource development projects (basin-wide)
1.3.11	Assessment of impacts of water management on fishery resources in the basin (basin-wide)
1.3.12	Mekong watershed assessment for elaboration of a management programme (basin-wide)
1.3.13	Study to formulate plans for the management of the wetlands in the lower Mekong basin
1.3.14	Studies and pilots projects for the productive use of problem soils (basin-wide)
1.3.15	Environmental study of the Xeset hydropower project (Lao PDR)
1.3.17	Water quality monitoring network in the lower Mekong basin, Phase II (basin-wide)
3.4.02	Construction of flood protection and reclamation of swamp and marshland in the Vientiane plain (Lao PDR)
3.5.03	Integrated planning study of the Quan Lo/Phung Hiep agriculture water control project (Viet Nam)
3.6.01	Fishery development in the Nam Souang reservoir (Lao PDR)
3.6.02	Development and management of reservoir fisheries (Thailand)
3.6.03	Development of fishermen communities in Nam Ngum basin (Lao PDR)
3.6.04	Construction of the Lam Dom Noi fish seed production centre (Thailand)

3.6.05 Management of the Tha Ngone pilot fish farm (Lao PDR)

3.6.06 Construction of the giant freshwater prawn hatchery, Vung Tau, Phase I (Viet Nam)

3.6.07 Expansion of the prawn hatchery, Vung Tau Phase II (Viet Nam)

3.6.08 Establishment of a fish seed production centre at Cai Be (Viet Nam)

6. Conclusion

It is now universally acknowledged that investigations of ecological consequences and broadly defined environmental impacts should be central to planning and design of development projects. Often, quite minor alterations in plans and additional costs in construction phase, can prevent major environmental, economic and social costs.

In international river basin planning, such as that of the Mekong in particular, environmental parameters assume especial importance as off-site impacts of development actions in one riparian state could manifest themselves in another. For instance, injudicious watershed management in an upper riparian country could have undesirable effects on water use or viable life of impoundments in a lower riparian state. Unregulated withdrawals of water in upper sections of rivers may influence adversely agriculture and fisheries downstream. Impoundments upstream could alter downstream ecology to such a degree as to seriously affect various facets of river productivity. Recognizing, in particular the trans-national nature of impacts or river basin development, the Mekong Committee has been bestowing the due attention to environmental parameters in development.

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APPROACHES TO INTEGRATION OF ENVIRONMENTAL ASPECTS INTO WATER RESOURCE DEVELOPMENT PLANNING

Dr. V.R. Pantulu

1. Introduction

Historically, the efforts of the Interim Mekong Committee have centered on water resource management for hydroelectric power generation and irrigated agriculture, with lesser emphasis on fisheries and aquaculture, upland or rain-fed agriculture, navigation, and industrial development - all for socio-economic improvement. Increasingly, in its life-time, the Committee has intensified its concern over environmental implications of development. While so doing it has continually refined its interdisciplinary and multidisciplinary approaches to project planning and design.

Within the foregoing context, over the years, innumerable development needs and opportunities have been identified; many carefully studied for feasibility, and some implemented as projects. A few of these projects have been successful in a large measure in all of their dimensions (social, environmental and economic) but others have failed to achieve their stated objectives. In consequence, it could be argued that water resource management has been overemphasized and management of environmental and human resources neglected, although implicitly and explicitly these are central to the overall development scheme.

In the last decade or so, world-wide recognition has been given to ecological problems associated with large-scale development schemes. Nevertheless, very few serious critics have opposed technological development altogether. If developing societies are to provide satisfactory living conditions for all their members, they have to modify the environment. What is needed, however, is an improvement in approaches to technological development. Instead of employing ecologically "careless" technologies, a way needs to be found of selecting technologies which incorporate broad environmental and human concerns. The process of evaluating and selecting such technologies provides an ideal opportunity for the consideration of human values, which cannot always enter into standard economic analyses with their emphasis on efficiency and uniform social objectives. Therefore, it is now acknowledged, that central to planning and design of any development project, should be investigations of their ecological consequences. As a result of such investigations, sometimes quite minor alterations in plans and additional costs in the construction phase can prevent major environmental, economic and social costs after completion.

Sustainable success of development activities depends on various factors such as: a) the inherent capacity and limitations of the resource(s) to be developed, b) environmental factors and linkages which further or hinder the realization of this capacity, and c) the influence of related resources. Development targets and strategies, therefore, have to be chosen taking into consideration significantly related factors, in order to allow full use of resources without over exploitation, or development of one resource at the expense of another. Usually, the resource base to be developed and the purpose for which it is to be developed are predetermined without due consideration of alternative resource uses and the ecological context in which the development will take place. Under these conditions, side effects of development cannot be anticipated and, therefore, inadvertencies in planning lead to under-optimal resource use or - in the worst case - to total environmental degradation.

Since the commencement of implementation of the Mekong project some 30 years ago, the situation in the lower Mekong basin has undergone major changes, mainly resulting from haphazard, unplanned resource reclamation not only by the ever-increasing population but in some instances also as a direct result of development activities in which environmental implications were not adequately considered. The environmental programme of the Committee with its limited resources has not been able to keep pace with planned and unplanned developments in the basin. While on the one hand, the background knowledge on certain mechanisms leading to environmental problems has increased significantly as a result of surveys, investigations and post audits, on the other hand, other problems have surfaced and expanded. For instance, the basin has lost a major portion of its forest cover during the last 20 years and increasing erosion and siltation problems are already threatening the viability of reservoirs constructed for hydropower generation and irrigation in some countries. Water quality monitoring activities - which were initiated in the expectation that they would allow timely detection of problems arising eventually - revealed that quality problems of natural origin already exist in the basin and that in some cases remedial measures are urgently needed. While pilot management programmes to enhance benefits from reservoir fisheries and to offset downstream fishery losses were implemented, the need for institution of similar programmes in areas under irrigation development and flood control have became more urgent. Salinization of soils as a direct result of irrigation has increased in some parts of the basin posing the threat of desertification, if adequate measures are not implemented immediately. Elsewhere acidification of soils has presented a formidable impediment to development of agriculture.

Thus, it may be concluded that at the present stage the incorporation of environmental aspects into the Committee's development programme is more, and not less, important than at the time of inception of the environment unit in 1975.

2. The environment - our perception

Perceptions and perspectives relating to environment differ from person to person and from country to country. The term "environment" is often misconstrued to mean preservation of status quo or protection of one or the other resource - forests, fish, or wild life or in other words a conservationist approach. These issues taken in isolation cannot be identified as environment, they are issues for interest groups competing with one another for one or the other natural products or ecosystem uses.

A purely conservationist or protectionist approach may be appropriate in the developed world where most of the natural resources have been exploited to a considerable degree, where the majority of the population is enjoying the fruits of development and development backlash is beginning to be felt. However in a developing country situation where the status quo has not served the people well, where neglect or improper development is destroying the very resource base, ecologically sound development is a necessity, and conservation of usage of resources rather than conservation of one or the other components of the ecosystem in isolation is the imperative. Here, environment has to be modified, albeit in an ecologically sound manner, to meet the basic needs and aspirations of the people. In developing societies people live close to nature. They exploit all the goods and services provided by natural or semi-natural ecosystems. In such a situation, sectoral development of one or the other resource - say hydropower or irrigation - disregarding the other products and uses of the ecosystem is bound to cause environmental and socio-economic disruption. Therefore, it is important to aim at a balanced development of all important natural goods and services to the extent possible or to provide for mitigation of losses through supplementary development efforts. In short, according to our perception "environment" is another name for integrated development of all resources likely to be involved or influenced in the development process in such a manner as to preserve the productivity of the resource base, and to derive optimum benefit from it.

3. The strategy

There are two elements in our environmental policy a) reactive, b) preventive. The reactive element comprises rebuilding or protecting ecosystems or resources destroyed or threatened as a result of development projects while the preventive element represents environment cum economic development planning where environmental parameters are considered integral to development planning.

The Mekong environmental programme was initially focussed on sectoral investigations and surveys to ascertain the status of some water-related resources and to assess the observed or anticipated effects of water resource development activities on them. These sectoral studies are followed by pilot environment enhancement or development projects to demonstrate measures to rebuild, revive, ameliorate or protect natural products or services or ecosystems adversely affected or endangered by the Committee's development projects. This approach was necessary initially because in the Mekong countries - as indeed elsewhere in developing countries - environmental programmes were considered as obstructive to development. Examples of environment enhancement projects are: a) aquaculture in non-arable lands in irrigation service areas of dams, b) fishery management projects in hydroelectric reservoirs to offset adverse effects of dams on fisheries, c) prawn hatchery to offset adverse effects on the migratory giant freshwater prawn of water resource development projects, d) reforestation by fruit tree plantation to stem erosion on mountain slopes and to provide economically attractive alternatives to detrimental land use in watersheds and e) a pilot project for ecologically sound development of acid sulfate soils. These projects have served to focus on tangible benefits of giving due consideration to environmental aspects.

Simultaneously with the sectoral investigations mentioned above, a detailed data collection effort was launched for specific areas in connection with development planning and feasibility studies of dams. On the basis of information derived from the data, environmental problems in the basin were identified. Thereafter, detailed problem investigation to study the mechanisms of problem development followed. On the basis of these investigations, measures to alleviate the problem were formulated and later demonstrated through pilot projects. On successful conclusion of the pilot projects the measures are expected to be applied basin-wide in situations when similar problems are observed or anticipated. Details of the environmental problems are described in the author's another paper presented at this session.

Besides problem identification and amelioration, environmental impact assessments (EIA's) of selected projects [1) 2) 3)] and environmental post audits of certain completed projects also form parts of the environmental programme. While impact assessments aim at assessing environmental and socio-economic impacts of proposed projects, post audits are focussed on measuring the success of completed projects in achieving their objectives and to assess the environmental impacts that have resulted from project implementation.

Our experience has shown that while EIA's may be appropriate for pre-determined economic development projects and have limited usefulness in assessing some impacts, they are not necessarily instruments of ecologically sound development. EIA implies pre-determination of project location and implementation procedures. Environmental parameters come into the picture at a later stage only to ascertain the nature of the effects of the project. But, important issues relating to interactions and dynamic relationships between, physical, biological and human components of the environment are completely overlooked. As long as the view that environment and development are discrete entities is maintained, EIA's alone are inadequate as effective tools of environmental planning and if environment and development are considered as two sides of the same coin and the term "environmentally sound development" is accepted as synonymous with "integrated development", EIA's become superfluous because environmental aspects are considered and incorporated in the planning stage of the project itself, and not just added as an appendage after project plans are finalized. Therefore the accent in the Mekong environmental programme is gradually shifting to regional economic cum environmental planning which is styled environmental planning.

An example of "environmental post audit" is the Nam Pong Environmental management study [4] [5]. The study is an attempt at systems approach to resource management in one of the sub-basins of the Mekong river namely the Nam Pong river basin in northeast Thailand, in which a dam was constructed some 15 years ago. Results of this attempt are elaborated in two reports entitled "Environmental management and water resource development in the Nam Pong basin of northeastern Thailand" (Phase II) and "Nam Pong environmental management research project" (Phase III). The former relates to a sectoral and the latter to a systems approach in resource management. In the Phase II studies a wide array of sectoral resource management issues such as land use and land capability, fisheries, farm management, reservoir regulation, and socio-economic and health conditions that stem from resource exploitation were examined. It was found that while this study did give limited insights to some critical interrelationships which appear to affect behaviour and output of the basin system, some less obvious, but none-the-less equally important, issues that derive from interactions among components of socio-economic and bio-physical sub-systems were not evident. Furthermore, issues concerning management by public agencies, such as questions regarding the nature and sequence of interventions, the viability of such interventions in terms of Government policy and so on, further confounded an already complex situation. Therefore in the Phase III, the question of interactions among components of the sub-systems, and reactions of the system components to management alternatives were addressed through a mathematical simulation model of the system[5]. This was admittedly an experimental effort with the object of achieving environmentally sound resource management, based on a clear understanding of the dynamic ecological relationships between physical, biological and human components of the river basin system[6]. The process of constructing an integrated simulation model has served, as much as the final product, to make users of the project (managers and affected population) aware of the environmental interdependencies of their actions.

The model itself provided a decision making tool, producing quantitative predictions of the ecosystem's response to management actions. Its particular strengths are that it can be used to illustrate likely consequences and trade-offs of a range of possible management actions. Also, it conveys the implication of random events which must be considered by managers and it presents cohesive indicators of outcomes, which people from a wide variety of disciplines can comprehend (e.g. income trends). Decisions are not formulated by the model. Rather, the model serves as an assessment tool.

4. Environmental planning

The component steps in environmental planning are the following:

1. Assessment
2. Planning
3. Management
4. Monitoring

Activities comprising the above steps are outlined in Table 1 and described below, briefly.

Environmental assessment begins with collection of bio-physical and socio-economic information (Environmental data collection) for the region in which development projects are to be planned. The data provide general background information on all bio-physical and socio-economic parameters necessary for determining appropriate locations, development, strategies and alternate scenarios for development.

Bio-physical and socio-economic data collection of a region (e.g., a tributary river basin) - which can be identified as a system - in which a development programme or programmes are proposed to be undertaken is the first step in environmental planning. In this context, the Mekong Committee has initiated a detailed environmental data collection programme for the entire lower basin. The data base is currently being established at the headquarters of the International Mekong Committee at Bangkok. The environmental data base is a major tool for Environmental Planning. The purpose of the data base is to assemble, in one place, currently scattered information on land and water resources in the basin, so that it will be readily available for planning and development in a form most useful for the process. The following are examples of functions that the data base can serve:

1. inventory of land and water resources in the basin;

2. documentation of past and present resource use;

3. matching resource use to resource capabilities:

4. assessment of the environmental effects of the Committee's development projects;

5. evaluation of existing and potential conflicts and compatibilities among land and water resource uses; and

6. clarification of interrelationships among environmental and socio-economic factors.

A software (ARC/INFO) developed by Environmental Systems Research Institute is being used to operate the data base on micro-computers.

The second step is ecosystem evaluation of the area in which a project is to be located. This evaluation will include a) examination of development possibilities, b) identification of natural goods and services available from regional ecosystems which are liable to be affected by the project, c) assessing potential conflicts in the use of these goods and services, and d) formulating strategies to resolve conflicts in the light of the socio-economic conditions and policies in force in the region.

The third step is resource use allocations, based on the above evaluation, by matching resource use with resource capability. This will result in formulation of several alternative development scenarios. The different scenarios include an analysis of respective economic, social, and environmental benefits and desbenefits. From these scenarios, one, which on balance, is considered most beneficial by users and decision makers is selected. Besides benefits of development, any strategy, however good, is bound to have some adverse effects on some of the resources. Therefore, after selecting the optimum strategy, the next step would be formulation and incorporation of measures to offset adverse effects on other conflicting resources and resource uses in project planning.

The fourth step, which comes after project implementation is environmental monitoring of project performance vis-a-vis the biophysical and social economic setting of the region in order to verify the actual against the predicted impacts of the project. This should not merely be a passive monitoring but an active one geared to correction of unforeseen events and problems adversely affecting project, which might surface from time to time.

As a case study in environmental planning, a project for ecologically sound development of an area called Quan Lo/Phung Hiep in the Ca Mau peninsula of Viet Nam was taken up. This is an interesting case where proposed development of an area for irrigated agriculture is likely to bring about adverse environmental impacts that are likely to negate the very purpose of the development. At present, agricultural development in Quan Lo/Phung Hiep area is hampered by severe salt water intrusion, lack of freshwater during the dry season, flooding during the wet season and the presence of saline or saline acid soils. It is argued that drainage and irrigation measures can create a more favourable situation and salinity intrusion may be reduced by control structures. However, these measures, particularly the prevention of salt water intrusion, are likely to cause substantial negative impacts on the productive and valuable fisheries in the area in which farmers currently earn 20 times more income from shrimp farming than by rice farming on the same land. Shrimp farming depends entirely on ingress of young shrimp during ebb tides in certain seasons. Also, drainage may provoke acidification of the potentially acid soils and exacerbate the problems caused by acutely acid soils in the area. Besides these, water level regulation in the canal network is likely to have negative impacts on navigation which is the most important, if not the only, means of transportation in the area. Therefore, it is necessary to adopt an integrated resource development approach, taking into account ecological, economic and productivity aspects of the ecosystem and taking care not to trigger negative impacts. Therefore, development of this area has been taken as a pilot exercise for ecologically sound development through environmental planning.

Following this experience other sensitive areas in the basin will be taken up for economic cum environmental development planning.

5. Conclusion

There is a lot written and spoken about eco-development, sustainable development and environmental planning, but unfortunately, to our knowledge, few practical applications of these ideas exist. We realize that there may be many institutional economic and other constraints to application of the type of planning proposed herein. Therefore, what has been stated here may appear to be an oversimplification of a complex situation. Nevertheless, our experience so far has indicated that given the will and proper understanding on the part of decision makers and adequate communication between different disciplines involved in the development process, it should not be difficult to achieve the objectives of ecologically sound development.

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Table 1.

ASSESSMENT: analysis and evaluation of natural and socio economic conditions	Steps: - data collection - systems analysis (i.e. definition of system components, their interactions and functions) - diagnosis (i.e. identification of constraints, conflicts and problems)
PLANNING: identification/ selection of a course of action that will lead to sustainable development	Steps: - resource use allocation, according to resource capabilities - formulation of alternate development scenarios - selection of the most desirable scenario, in consultation with decision makers/users
MANAGEMENT: implementation of the most desirable course of action	Steps: - implementation of pilot projects for demonstration of suitable strategies - propagation of suitable strategies through extension services and training programmes
MONITORING: long term observation of trends and developments, including performance of development projects	Steps: - establishment and maintenance of monitoring networks - corrective measures for unforeseen affects - regular updating of resource and resource use inventories

ECOLOGICAL PROBLEMS ASSOCIATED WITH RESERVOIRS

Prof. L.A. Sirenko

The nature and scale of the ecological problems arising from the creation of reservoirs are determined by numerous factors. Among them of prime importance are those of natural and geographical conditions, geological and physico-chemical features of landscapes, soils, and water bodies constituting the basis for reservoirs' construction. On the other hand, the area, depth and volume of water in them also are of importance.

While estimating the damage caused by negative ecological aftereffects of reservoirs' construction, of primary importance are the natural, economic, and social factors.

In the world anually, from 300 to 500 new reservoirs are commissioned. Many large world rivers such as the Volga, Angara, Missouri, Colorado, Parana, Dnieper and others have been turned into cascades of reservoirs. Since the human activities require more and more fresh water, the same will happen to the majority of world rivers in 30-50 years (1, 3, 4).

Water storage and its use Preconditions for the construction of reservoirs

The rivers of Asia possess tremendous hydroelectric resources. According to various data (1, 4), their economic hydroelectric potential constitutes 1/4 to 1/3 of the world one. The complete volume of runoff of Asiatic rivers exceeds 10 thousand cubic kilometers which is a considerable share of the whole volume of hydro-speare which is defined today as 1340 million cubic kilometers of water.

The share of fresh water constitutes only 3 percent of water reserves or about 31 million cubic kilometers. The scientists believe (5) that about 96 percent of fresh water are stored in glaciers, polar snows icebergs, and only 0.6-1.0 percent of fresh water is in a fluid state suitable for direct use.

The greater part of runoff in Asia is known to be flowing in large river systems, second only to the Amazon and Congo Rivers. The rivers Hwang Ho, Yangtze, Mekong discharge their waters into the Pacific; the rivers Salween, Brahmaputra, Ganges, Indus, Shatt-al-Arab (formed by the Tigris and the Euphrates Rivers) discharge their waters into the Indian Ocean.

On the continent there are also the areas of inner discharge and what is very important, there are some areas in the Arabia and Asia (Takla-Makan, Gobi, some areas of Tibet) which have no perennial flow.

The precipitations in this region are distributed very unevenly: the differences in the volume of annual precipitations on the territory of Asia reach 100 times (from 5.000 to 50 mm). The seaside and on windward slopes in the south and east Asia receive 8000 to 12000 mm a^{-1}. In India (Cherapunji, Assam State) was registered "the world record" in the annual amount of precipitation - 22.900 mm, i.e. the layer of precipitation constituted almost 23 meters. But in many other areas of Asia the evaporations surpass the amount of precipitation.

Hence, such unevenness in spatial distribution of precipitations can be regarded as the first premise for the construction of reservoirs in the region.

Considerable temporal fluctuations of hydrological regime of rivers, especially in the monsoon areas, are also of no less importance for problems of supplying the region with waters. Here, 80 percent of annual discharged occur in two months and its layer fluctuates from several to thousands of millimeters. This factor is considered as the second premise.

Today in Asia are living over 50 percent of the world population. By 1980, about 130-140 mln hectares of lands had been irrigated in Asia, and according to the predictions (1, 3) their area would amount to 270-280 mln hectares in 2000.

Especially large irrigation systems (300-500 and more thousand hectares) have been created on the basis of water resources of reservoirs in India, China, Iraq, Syria, Pakistan. The need in water fcr irrigation can be considered as the most important premise for construction of reservoirs.

Power engineering also demands much water. The use of water by power engineering can also be considered as important premise. Reservoirs also help in prevention of floods. Scores of millions of hectares of tillable land are flooded every year and damages caused by inundations cost billions of dollars (1, 3, 4).

The rates of construction of reservoirs are cited in Tables I and 2.

By the 1980s, about 550 reservoirs with capacity over 100 mln cubic meters each had been constructed in Asia. Their total volume reaches 900 cubic kilometers. In general there are at least 15.000 reservoirs in the continent though this figure is not exact (1).

The total usable storage of reservoirs is about 400 cubic kilometers. Only 3-4% of reservoirs have storage 100 mln. cu. m or more, but their share in the total storage amounts to 90%.

The distribution reservoirs in the area is uneven. In general they are located in eastern areas adjacent to the Sea of Japan, the Yellow Sea, the South China Sea, in Indo-China and Hindustan, peripheral districts of Arabia. Almost 70 percent of the number and total storage capacity of reservoirs are confined to moderate and subtropical natural and climatic zones.

33 reservoirs, including those under construction, are very large reservoirs (with the total storage capacity over 10 cubic kilometers), 83 are large reservoirs (1-10 cubic kilometers capacity), 432 medium size reservoirs (0.1-1.0 cubic kilometers capacity).

The total area of the reservoirs of 100 square kilometers each constitutes 20 thou. sq. km. The total area of reservoirs in Asia is 45-50 thou. sq. km. (0.16% of the territory).

India and China are leading in numbers and capacities of reservoirs. They are followed by Iraq, Turkey, Thailand, then by Pakistan, Iran, Syria, Vietnam, Japan. These are the largest "water reservoir" countries in Asia.

The major part of reservoirs in the region is characterized by seasonable regulation of the discharge. The reservoirs with carryover storage have been created on the rivers, not relatively abundant in water, located in the arid areas of Western Asia.

<u>Positive aspects of the construction of reservoirs</u>

1. The construction of the reservoirs ensured the increase of firm flow in Asia by 20% on the average with some fluctuations with respect to individual countries from 5 to 30%. The reservoirs help solve the problem of supplying industrial centers, cities and settlements with water even if these localities are situated far from reservoirs.

2. The reservoirs improve conditions for water intakes, reduce SS, colour odour, oxidability and bacterial pollution of water which facilitate trentment of water, reduces the consumption of coagulant and chlorine. However, in some Asiatic countries outside the USSR

the reservoirs are not regularly used for water supply because of the lack or insufficient development of the water treatment systems corresponding to technological and hygienic requirements of modern industrial and potable standards.

3. The reservoirs smooth seasonal fluctuations of the quality and temperature of river waters which makes it possible for the water supply plants to operate more regularly within a year.

4. The availability of reservoirs completely or partially prevents the disasters caused by floods. In India, for example, this kind of damage amounts to 1.5 billion rupees.

5. Reservoirs enhance the recreation factor and esthetics of the landscape. Sometimes they turn are the centre of formation of these landscapes though in the Asiatic countries outside the USSR the coefficient of the recreation usage of reservoirs is rather negligible.

6. Reservoirs store a necessary volume of water for irrigation. For example, there are over 300 mln hectares of irrigated lands in the world. Of them more than 160 mln hectares were irrigated during the last 25 years. About 60% of all irrigated lands are in China, India, the USA and the USSR.

7. It is not possible to solve the problem of energy supply without reservoirs. The share of hydroelectric power in the power balance of Asia (with exclusion of the USSR) varies from 10% (Afghanistan) to 50% (India).

8. The cost of shipping cargoes through the reservoirs as compared to rivers in the USSR, for example, is 1.5-5 times lower and the capital investments in the river transport are 1.2-3 times lower.

9. Reservoirs play an essential role in fishefarming. It concerns the USSR, India, China, Sri Lanka, Vietnam, Kambodia, Laos and other countries. Small-scale irrigation reservoirs are the most productive. Each hectare of them provides tens and sometimes hundreds of kilos of fish annually. In some countries of Indochina and Hindustan fishery in reservoirs proved to be so profitable that many forms gave up agriculture.

As has been mentioned above, the ecological effects of the creation of reservoirs depend to a large extent on their morphometry and the landscale of location. From this viewpoint it is worth noting the pecularities of the reservoirs built in river basins of flat countries. They possess the following features:

- considerable area of the surface and of the area of flooded lands per unit of cubic capacity and pressure head;
- small maximum (just over 25 m) and medium depth (usually 5-9 m);
- small depth of lowering of the level (within 2-7 m);
- large-scale change of the surface area with level fluctuations;
- intensity of transformation of shores and of flooding of lands.

Ecological aftereffects of reservoirs on the state of adjacent territories

1. Creation of reservoirs and the regulation of the discharge influence the nature on vast territories. The changes in the environment manifest themselves practically in all parts of the geosphere - lithosphere, hydrosphere, atmosphere, biosphere and influence their elements - geodynamics (seismology, relief, hydrology), hydrological, climatic conditions, soils, flora and fauna. In the long ran it results not only in the transformation of aquatic and land nature components of ecosystems, but also in the change of conditions of life of the population.

2. The degree of influence of reservoirs of different dimensions has its own features. The influence of large especially of the largest reservoirs (Table 3) is often felt tens and thousands of kilometers up and downstream from a water engineering system causing continuous changes in fluvial conditions, the nature of discharge and in the process of formation of deltas and offings. The construction of such reservoirs radically transforms the aquatic and land nature complexes within the relatively wide range of territories. The main reservoirs of hydroelectric power stations constructed on the Volga, Angara, Yenisei, Dnieper and other rivers are referred to the categories of large of largest ones, i.e. to those which render the greatest influence on the environment. The Vadi-Tartar reservoir in Iraq is considered to be one of largest in Asia; there are 33 very large reservoirs, 83 large reservoirs, i.e.: their influence is becoming rather noticeable.

Small reservoirs' influence on the surrounding environment is, as a rule, limited by the zone of influence of occuring natural processes (high waters, inundations, etc.), therefore they do not cause essential changes in nature.

It is important to note that the directional effect and the range of influence of reservoirs on the environment are greatly dependent on the nature and scope of programs carried out during their design, construction and maintenance. Therefore, special attention should be paid to ecological expediency and the quality of work carried out in this direction. Firstly, it can be performed on the basis of synthesis and generalization of world experience in construction and exploitation of reservoirs in various regions of the world. Secondly, physical and simulation modelling should be an obligatory stage in optimization of reservoirs' principal parameters. The models are to be used for examining the major hydrotechnological and operational problems of reservoirs, optimization of ecological aftereffects. It is necessary not only to preserve the environment in its original state but rationally use the natural potential in ecologically sound way.

3. Construction of reservoirs breaks the set patterns of geodynamic processes not only in the area occupied by the reservoir, but around to it too.

Reservoirs lead in some extent to change of seismicity of the territory. For example, during the ten years that had passed after filling of the reservoir mead on the Colorado River (its area is 8.000 sq. km.) 6.000 local shocks were registered. After filling of the reservoir on the Achelous River in Greece there were 740 shocks registered during a year on the area of 100 x 100 km.

Great intensification of seismicity was observed on the reservoir Shivanjisagar in India: before filling of the reservoir having the capacity of 2.78 cubic km there was no sign of seismic activity in this area. With filling of the reservoir there were observed here moderate shocks, their intensivity gradually increased, leading to 1967 earthquake with great damage effect with magnitude from 5.9 to 7.

In the Soviet Union large reservoirs were built in seismically safe areas.

The increase of seismicity has been also observed in the areas where relatively small-size reservoirs had been built. In Bulgaria, for example, the number of local earthquakes especially in the areas of breaks considerably increased in the basin of the Arda River after construction of the cascade of three reservoirs - Studen Kladenets, Kyrdjali and Ivailovgrad.

4. Geological activities of reservoirs manifest themselves in

abrasion of banks (in erosion in upper parts of the reservoir), transportation of drifts and their accumulation.

As a result of deposition of silt in reservoirs of China, India, the Indochina countries the degradation of river-beds in lower reaches of water developments is rather active.

5. In the course of operation the reservoirs silting up results in lessening of their cubic capacity and shortening of the operation period. For large reservoirs in flat countries this ratio is 1:3, and the operation period lasts 500-1000 years.

Big and small rivers of Asia especially in its east and south carry a lot of drifts which causes the intensive silting of reservoirs especially small ones, characteristic for India and China. The annual rate silting is 0.05 to 1.4% of useful capacity of reservoirs. As a rule, it diminishes with the increase of water-collecting area. This regularity is characteristic for other regions of the world as well.

The Sanmynsia (the Hwang Ho River) reservoir registered a particular "world record" in silting up. During 6 years it lost 30% of its useful capacity (from 9.6 to 5.9 cubic kilometers) which resulted in reduction of electric power generation since 1964 by more than 70%. In its middle flow the Hwang Ho carries up to 38 kg of drifts per 1 cubic meter of water.

The predictions as to the rate of silting up for many reservoirs of Asia proved to be underestimated by 1.5-2 times. This resulted from inadequate account of the inflow of products due to banks damage and transformation and which make up to 50% of solid particles during the first years of operation.

6. Reservoirs change temperature conditions in the water body. For example, during the construction of the Bhakra reservoir the temperature of water surface layers increased as compared to the river by 6-8°C in cold seasons, and by 1-2°C in warm seasons. At the same time evaporation and hence the losses of water were enhanced.

7. Reservoirs cause changes in microclimate. The degree of their influence decreases as the distance from the water edge increases. There are shipts in the air temperature, its humidity, speed and direction of wind, cloudiness, precipitation (it increases at the bank and decreases on the water area), the conditions of log formation. The reccurence of fogs especially increases in winter.

8. Reservoirs change the conditions and sometimes general direction of movement of ground waters. In lithological masses which

were dry before damming up there appear new water-bearing strata. The seepage process is the most intensive in the first years after the filling of reservoirs (4).

9. The underflood caused by the elevation of ground waters is the most serious aftereffect of construction of flat country reservoirs. The underflooding starts from the moment of filling reservoir when the level of ground water rises by 1.0-1.5 m (up to 2.0-3.0 m in arid zones) and higher to the surface. The banks of many reservoirs bear the negative traces of flooding, bogging is one of them. During the vegetative period the signs of bogging round the reservoirs with slight level fluctuations appear in the second or third year, while the shifts in meadow vegetation are observed in the fourth or fifth year of operation of reservoir.

10. Reservoirs influence the soil and vegetative conditions in the surrounding landscapes. The water regimen in the soils adjacent to reservoir also change. Principal changes of soils in the flooding zone are characterized by considerable excess of moisture, certain increase in trophics accumulation of readily soluble salts in arid zones. Reservoirs cause wetlanding and gleying of lower horizons of soils, formation of meadows, and bogging.

11. Flooding of soils changes the nature of vegetation. In forest and forest-steppe zones the restructure of meadow phytocoenosis takes place when ground water level rises up to 0.6-0.8 m and 0.8-1.0 m from the surface accordingly. When ground waters rise to 0.3-0.5 m (the subzone of intensive flooding) the number of former sorts of vegetation lessens 2-3 times already in the 1st or 2nd year of operation of reservoirs.

12. Reservoirs essentially influence the fauna of the adjacent territories. This influence has many aspects and may be both of direct nature (perish of animals in the process of hydroconstruction operations, filling of reservoirs, cutting of migration, routes, etc.) and indirect (changes of hydrological and hydrochemical conditions, climate, soils, vegetation, etc.). Reservoirs make shifts in transmigration of birds and are an essential barrier on the way of migration of animals.

The influence of reservoirs on formation of water quality and bioproductivity of basins

Construction of reservoirs render essential influence on formation of the quality of water and bioproductivity of the rivers which serve as the basis when creating reservoirs.

Reservoirs lead to basins of a new kind. They differ from the rivers used as the basis for reservoirs and from the lakes. These basins approach the lakes with respect to some features. Under the influence of hydrological, meteorological, physicogeographical, biological factors the chemical composition of water in reservoirs is being formed anew. In the period of filling and during the first years of operation the quality of water and sanitary and biological conditions of reservoirs considerably deteriorate. In this period the hygienic and sanitary conditions in reservoir may deteriorate especially when the sanitary measures were not carried out during the construction period (7, 10).

"Biological pollution" and overgrowing with aquatic generation are an inevitable consequence of the construction of reservoirs. The biological pollution is caused by mass-scale development of the blue-green algoe, so called algal bloom. The algal bloom and ensuing deterioration of the quality of water have been registered in all reservoirs of the Soviet hydroelectric power stations in all regions.

The decrease of content of SS (because of sedimentation) and considerable increase of water transparancy in reservoirs (if there is no algal bloom) with accumulation of biogenics intensified the overgrowing of irrigation canals with aquatic plants where the clarified water rich in biogenics is inflowing. Earlier, due to the high degree of water turbidity the vegetation did not progress in irrigation canals. The overgrowing of canals with aquatic plants considerably decreases their throughput manual, or mechanical clearing proved to be inefficient and for ecological reasons the weed-killers could not be used either. The annual drying-up of canals for several days proved to be the most effective means (the water intake canals from the Bhakra reservoir in India, for example their total length is almost three thousand km.). This process prevented intensive growing of the plants.

So, to achieve the desired results, it is necessary:

1. To carry out comprehensive analysis of negative ecological aftereffects caused by the construction of reservoirs in the main regions of the country, taking into account dimensions, scales, morphometry, particular features of physical and geographical conditions, nature of operation and economic use of water and biological resources.

2. On the obtained results to work out the physical and simulation models to get maximal optimization of parameters of the reservoir not only from the viewpoint of water engineering construction and operation to generate electric power and carry out irrigation, but also to minimize the negative ecological aftereffects.

3. Construction of a reservoir should be carried out after comprehensive examination of the design and feasibility study of both positive and negative ecological aftereffects and the programs to minimize the damage caused by reservoirs.

4. A complex of preliminary works prior to the construction of reservoirs should be considerably improved. The complex includes: sanitary arrangements on the territory subjected to flooding and on the water-collecting area, creation of waterprotective zones of forest-bush and meadow vegetation; cessation of discharge of sulphur compounds into the air.

5. It is necessary to revise, the agricultural practices, use of mineral fertilizers in the water-collecting area, etc.

6. The reservoir operation service must be provided with equipment for oil collection, algae removal, benthal deposits removal, etc.

7. Each reservoir or a cascade should be provided with instructions on their complex use and reconstruction aimed at of creation of the conditions for their filling and operation with maximal observation of ecological requirements.

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Table I.

Tentative indices of some principal reservoirs of states in Asia and the Pacific in which full cubic capacity exceeds 5 cubic kilometers and the surface area exceeds 250 sq.km.

State & the name of reservoir	River, lake	Year of filling of reservoir	Damming of water level at dam	Capacity of reservoir, cub. km.		Area of surface sq. km.		Length of reservoir	Kind of use
				full	useful	total	lakes prior to pondage		
India									
Gandisagar	Chambal	1960	60	8.4	6.9	650	-	70	IH
Gobindsagar (Bhakra)	Satledge	1963-1967	200	9.9	7.4	176	-	85	IHSNR
Nagarjunasagar	Krishna	1974	120	11.5	6.9	285	-	40	HSI
Rihand	Rihand	1962	90	10.6	-	465	-	65	IH
Tungabhadra	Tungabhadra	1957	45	-	-	380	80	-	HI
Ukai	Tapi	1972	65	8.5	7.1	520	-	110	IHPR
India, Pakistan									
Tarbela	Indus	1976	130	13.7	6.0	260	-	80	HSI
Pakistan									
Mangla	Jelam	1967	116	7.2	6.6	260	-	75	HI
China									
Dantsziankou	Han-yang	1974	90	20.9	-	-	-	100	HI
Liutssiasia	Hwang Ho	1968	140	5.7	4.1	130	-	200	HAI
Sanminsia	Hwang Ho	1960-1962	90	35.4	-	2350	-	300	HISK
Sinan-yang	Sinan-yang	1960	100	21.6	8.8	580	-	-	HA
Sinphin-yang	Sinphin-yang	1961	100	13.9	0.9	390	-	-	HA
Phinmang	Sungari	1937-1955	90	10.8	5.6	550	-	170	HIA
The Korean People's Democratic Republic, China									
Suphunko	Yalutsziang	1940	90	12.0	7.5	230	-	120	H
Malaysia									
Keniir	Treshtanu	underway	140	13.6	-	-	-	-	H
Lao PDR									
Namigum	Ngum	1970-1971	65	7.0	4.7	370	-	50	HI
Vietnam									
Haobin	Da	underway	120	9.4	-	-	-	200	HI
Thak-ba	Tiay	1963	15	3550	2160	35	-	-	IHS
Afghanistan									
Kajakay	Hilmend	1953	80	2680	-	50	-	-	IH
Sangar (Hong Kong)									
Gaodao	Filling	1979	-	272	-	-	-	-	W
Indonesia									
Jatiluhur	Chatarum	1967	82	3000	2120	83	-	-	IHW
State of Kambodia									
Prektkhnot	Prektkhnot	1974	25	1120	-	-	-	-	IHW
The Korean People's Democratic Republic									
Nampho	Tedongan	underway	25	3000	-	-	-	-	I
Republic of Korea									
Soyanhanho	Soyangan	1973	-	2900	-	-	-	-	IHW
Sri Lanka									
Senanayaka	Gal	1951	40	950	-	77	-	-	IH
Japan									
Okutadami	Tadami	1961	140	600	460	10	-	-	H
Nepal									
Kulekhani	Kulekhani	1976	-	70	-	-	-	-	H
Thailand									
Khaolaem	Khuenoi	1983	80	7.6	5.0	-	-	-	HI
Namphong (Ubonratna)	Phong	1965	35	2.6	-	410	-	65	HI
Sirikit	Mae Nan	1972	100	10.5	9.8	250	-	130	HIA

NOTE: Deciphoring of letters according to the kinds of use of reservoirs

- A - accumulation (preservation) of the stock of water for various purposes;
- W - water supply (for public and industrial services and cooling);
- I - irrigation;
- T - timber floating;
- S - prevention of inundations;
- R - recreation;
- F - fishery;
- N - navigation;
- H - hydraulic power.

Table 2.

Indices of the reservoirs of the USSR in which full cubic capacity exceeds 5 cubic kilometers and the surface area exceeds 250 sq.km.

The name of reservoir	River, lake	Year of filling of reservoir	Damming of water level at dam	Capacity of reservoir, cub. km.		Area of surface sq. km.		Length of reservoir km	Kind of use
				full	useful	total	lakes prior to pondage		
Baikalskoye (Irkutskoye)	Angara, Lake Baikal	1956-1959	30	47.6	46.6	32.965	31.500	700	HNTWFR
Boguchanskoye	Angara	underway	70	58.2	2.3	2.325	-	375	HNT
Bratskoye	Angara	1961-1967	106	169.3	48.2	5.470	-	565	HNTWFR
Bureiskoye	Bureya	underway	124	22.5	11.5	800	-	150	HS
Bukhtarminskoye	Irtish	1960-1967	67	49.6	30.8	5.490	1.783	350	HFNRS
Verkhnetulomskoye	Tuloma	1963-1964	63	11.5	3.9	745	80	120	HTF
Viliuiskoye	Viliui	1965-1972	68	35.9	17.8	2.170	-	470	HWN
Vodlozerskoye	lake Vodlozero, r. Vodla	1934	4	0.8	0.6	370	320	35	T
Volgogradskoye	Volga	1958-1960	27	31.4	8.2	3.115	-	540	HNIFWR
Votkinskoye	Kama	1961-1964	23	9.4	3.7	1.120	-	360	HNTWFR
Vigozerskoye	Nizhniy Vig	1932-1933	6	6.4	1.1	1.250	560	85	AF
Gorkovskoye	Volga	1955-1957	17	8.8	2.8	1.390	-	430	HNTWFR
Dneprodzershinskoye	Dnieper	1963-1965	15	2.4	0.3	565	-	115	HNWIR
Zaporozhskoye (Dneprovskoye)	Dnieper	1932-1933 1947-reconstructed	39	3.3	0.8	410	-	130	HNWR
Zeiskoye	Zeya	1974	98	68.4	32.1	2.420	-	225	SHNTF
Ivankovskoye	Volga	1937	14	1.1	0.1	325	-	120	WNHFR
Ilmenskoye (Volkhovskoye)	Volkhov, lake Ilmen	1926-1929	13	10.2	10.1	2.180	982	210	HNFWR
Imandrovskoye	Niva	1936	13	11.2	2.3	875	810	120	HRTW
Iovskoye	Iova (Kovda)	1960-1961	36	2.1	0.6	295	95	60	HT
Inari	Paatsoyoki (Paz)	1942	8	4.9	2.4	1.100	1.050	150	H
Kairakkumskoye	Syr Darya	1956-1959	24	4.2	2.6	510	-	55	IHWR
Kamskoye (Permskoye)	Kama	1954-1956	21	12.2	9.2	1.915	-	270	HNTWFR
Kanevskoye	Dnieper	1972-1976	11	2.6	0.3	675	-	130	HNWR
Kapchagaiskoye	Ili	1970	41	28.1	6.6	1.845	-	170	HINFR
Kakhovskoye	Dnieper	1955-1958	16	18.2	6.8	2.155	-	230	IHNFWR
Kievskoye	Dnieper	1964-1966	12	3.7	1.2	920	-	110	HWRNF
Kovdozerskoye (Kniazhegubskoye)	Kovda lake Kovdozero	1955-1957	20	3.4	1.9	610	295	60	HTF
Kolimskoye	Kolima	1983	117	14.6	6.5	440	-	150	H
Krapivinskoye	Tom	underway	46	11.6	6.7	670	-	160	WHANR
Krasnodarskoye	Kuban	1973-1975	25	2.4	2.2	420	45	45	ISNWFR
Krasnoyarskoye	Yenisei	1967	100	73.3	30.4	2.000	-	390	HNTWSFR
Kremenchugskoye	Dnieper	1959-1961	17	13.5	9.1	2.250	-	185	HNWIFR
Kubenskoye	Sukhona, lake Kubenskoye	1828-1917	4	1.7	1.4	650	380	60	NTF
Kuibishevskoye	Volga	1955-1957	29	58.0	34.6	5.900	-	650	HNWIFR
Kumskoye	Kuma, lakes Piaozero, Topozero	1962-1966	33	13.4	8.7	1.910	1.690	150	HTFW
Kureiskoye	Kureika	1979	72	13.4	10.1	750	50	100	H
Lovozerskoye (Serebrianskoye)	Voronia	1970-1972	65	3.0	1.7	555	235	160	H
Mingechaurskoye	Kura	1953-1959	65	16.1	7.4	605	-	70	IHSNFWR
Nizhnekamskoye	Kama	1981	15	12.9	4.4	2.580	-	270	HNTWFR
Novosibirskoye	Ob	1957-1959	20	8.8	4.4	1.070	-	200	HNFWR
Nurekskoye	Vashs	1972	300	10.5	4.5	100	-	70	HNRI
Onezhskoye (Verkhnesvirskoye)	Svir, l. Onezhskoye	1951-1952	17	13.8	13.1	9.930	9.700	350	HNFTR
Saratovskoye	Volga	1967-1968	15	12.4	1.8	1.830	-	350	HNIFWR
Sayanskoye	Yenisei	1980-1987	220	29.1	14.7	633	-	290	HINTWR
Segozerskoye	Segezha	1957	5	4.7	4.0	815	750	50	HTN
Toktogulskoye	Narin	1973	180	19.5	14.0	285	-	65	HINA
Tiuya-Muyunskoye	Amu Darya	1984	13	7.3	5.0	780	-	80	IHNF
Ust-Ilimskoye	Angara	1974-1977	88	59.4	2.8	1.870	-	300	HNTFW
Khantaiskoye	Khantaika, l.Khantaiskoye	1970-1975	50	23.5	17.3	1.560	880	160	HF
Tsimlianskoye	Don	1952-1953	26	23.9	11.5	2.700	-	360	NIHFWR
Chardarinskoye	Syr Darya	1967-1968	24	5.7	4.7	900	-	70	ISHNF
Cheboksarskoye	Volga	1982-1985	15	13.8	5.7	2.190	-	330	HNTFWR
Shekaninskoye (Cherepovetskoye)	Sheksna, l. Beloye	1963-1964	15	6.5	1.8	1.670	1.130	160	NHTFR
Yushkozerskoye	Kem, lake Yushkozero	1980	10	3.8	1.6	695	430	-	HTF

Table 3. Grading of reservoirs according to their dimensions and depths (1)

Grading of reservoirs	Full capacity, cubic meters	Square of water surface, sq.km.	Ratio with respect to overall number of reservoirs, %
The largest	upwards of 50	upwards of 5000	less than 0.1
Very large	50 - 10	5000 - 500	1
Large	10 - 1	500 - 100	5
Medium	1 - 0.1	100 - 20	15
Not very big	0.1 - 0.01	20 - 2	35
Small	less than 0.01	less than 2	44

According to depth

Grading	Maximum depth, m	Medium depth, m
Extremely deep	over 200	over 60
Very deep	100 - 200	30 - 60
Deep	50 - 99	15 - 29
Medium depth	20 - 49	7 - 14
Not deep	10 - 19	3 - 6
Shallow	less than 10	less than 3

ENVIRONMENTAL IMPACT ASSESSMENT OF WATER RESOURCES DEVELOPMENT PROJECTS IN THE ESCAP REGION

Dr. K. Suzuki

1. Introduction

Water resources development is one of the most significant activities in the developing countries of the ESCAP region. It is, however, recognized that water resources development, besides having many beneficial effects, may also have adverse environmental impacts, either directly or indirectly, on a short or long-term basis.

Throughout the region, there is also growing recognition that incorporation of environmental considerations into the planning stage of such development projects could avoid costly delays and economic misinvestment. For that purpose, many countries of the region have adopted environmental impact assessment (EIA) procedures, as effective planning tool for the projects which may have potentially significant environmental impacts. The purpose of this paper is to briefly present such EIA systems adopted in the region, and review their implementation in selected countries.

With the advent of EIA, various terminologies have been developed. Some of them have almost same meanings with each other, such as "initial environmental examination", "initial environmental evaluation" and "preliminary environmental assessment". To avoid confusion by those terminologies, a glossary is attached as Annex I.

2. Environmental impact assessment systems in selected countries of the ESCAP region

Overview of EIA requirements in the region

EIA was first introduced in the United States through the enforcement of the National Environmental Policy Act in 1970. In the ESCAP region, it has been adopted since late 1970s. The current status of EIA systems in the region, based on the information available in ESCAP, is presented in Table 1 where three distinct, broad categories can be identified.

Table 1. Status of EIA requirements in the ESCAP region

Country or area	Status of EIA requirements		
	I	II	III
Australia	x		
Bangladesh			x
Burma			x
China		x	
Hong Kong			x
India			x
Indonesia		x	
Islamic Republic of Iran		x	
Japan			x
Republic of Korea		x	
Malaysia		x	
Nepal			x
New Zealand		x	
Pakistan		x	
Papua New Guinea	x		
Philippines	x		
Sri Lanka		x	
Thailand		x	

I: Specific laws/acts on EIA

II: No specific laws/acts on EIA but having general environmental legislation which empowers a government agency to require EIA for particular projects

III: No formal requirements for EIA but through administrative measures requiring EIA for specific types of projects

a) Countries with specific laws/acts on EIA (Australia, Philippines and Papua New Guinea)

b) Countries having no specific laws/acts on EIA but having general environmental legislation which empowers a government agency to require EIA for particular projects (China, Indonesia, Islamic Republic of Iran, Malaysia, New Zealand, Pakistan, Republic of Korea, Sri Lanka and Thailand)

c) Countries and areas having no formal requirements for EIA but through administrative measures requiring EIA for specific types of projects (Bangladesh, Burma, Hong Kong, India, Japan and Nepal)

After the adoption of legislative/administrative measures, some countries needed certain preparatory periods for the enforcement of EIA procedures. For instance, Thailand incorporated EIA provision in December 1978, through amendment of its environmental legislation. This provision has been enforced since July 1981, when the first notification was issued. In Indonesia, the act was promulgated in 1982, while the EIA regulation was issued in July 1986 and came into force since July 1987. EIA guidelines and directives are still under preparation. Similarly, Pakistan enacted its environmental ordinance in 1983, however, it was only recently that EIA provisions became effective. Still now it is applied only to public sector industries.

On the other hand, some other countries enforced EIA immediately after their promulgations. India has applied EIA procedure since 1978, and Sri Lanka introduced/enforced EIA in January 1984.

Recently, significant progresses have been observed concerning EIA systems within the region. In Malaysia, EIA procedure and guidelines have been developed in line with the government policy statement contained in the Third Malaysia Plan 1976-1980. In 1985, the government amended its environmental act to include EIA provision. The EIA order was issued and guidelines were revised in November 1987 and came into force since April 1988.

As mentioned earlier, Indonesia initiated actions for enforcement of EIA requirements. Pakistan took necessary action for EIA implementation, and as an initial step, public sector industries have become subjected to EIA. EIA guidelines for industries has also been prepared.

Papua New Guinea issued in 1985 the revised "General Guidelines for the Preparation and Content of Environmental Plans" to strengthen its EIA act. In Sri Lanka, EIA guidelines were established in March 1987. In China, EIA guideline (Management Guideline on Environmental Protection of Construction Projects of the People's Republic of China) was issued in March 1986.

It can be said that the countries of the region, either based on explicit requirement or on an ad hoc basis, are trying to improve or upgrade their EIA systems, based on their several years of experiences of EIA implementation.

Projects requiring EIA

There are several approaches to identify the projects requiring EIA. The process, which is called "screening", include:

a) Positive lists and negative lists;
b) Project threshold approach;
c) Environmental sensitivity criteria; and
d) Initial environmental examination (IEE).

In many cases, these approaches are used together. For instance, project threshold approaches are usually used with positive lists. Similarly, after screening by project threshold approach, IEE are frequently applied.

In the ESCAP region, some countries conducting EIA on an ad hoc basis (e.g., Bangladesh, Burma, Nepal) do not seem to have specific screening procedures. China, Indonesia, Islamic Republic of Iran, Papua New Guinea and Sri Lanka may have such procedures, however, information is not available.

In India, specific types of development projects are subjected to EIA, for which general criteria are applied for further screening. For instance, among industrial projects, the followings are required to conduct EIA:

a) Those which can significantly alter the landscape, land use pattern and lead to concentration of working and service population;

b) Those which need upstream development activity like assured mineral and forest products supply or downstream industrial process development;

c) Those involving manufacture, handling and use of hazardous materials;

d) Those which are sited near ecologically sensitive area, urban centres, hill resorts, places of scientific and religious importance; and

e) Industrial estates with constituent units of various types which could cumulatively cause significant environmental damage.

Japan, Malaysia, Republic of Korea and Thailand have adopted threshold approaches with positive lists. Philippines uses both positive list and environmentally sensitivity criteria.

Types of the projects subjected to EIA in selected countries of the region are summarized in Table 2. More detailed information concerning types and scales of water resources development projects are presented in Table 3. Environmental sensitivity criteria in Philippines are also attached as Table 4.

Table 2. Projects subjected to EIA

	India	Japan	Malaysia	Philippines	Korea	Thailand
Agriculture (Land clearing)		x	x		x	
Drainage/irrigation	x	x	x			x
Forestry			x	x		
Fishery			x	x		
Mining/Quarrying	x		x	x	x	x
Dams/Reservoirs	x	x	x	x	x	x
Power generation						
Hydropower	x	(x)	x	x	x	
Thermal power	x	(x)	x	x	x	
Nuclear power		(x)	x	x	x	x
Land reclamation		x	x	x	x	
Road transport		x	x	x	x	x
Railways		x	x		x	x
Airport		x	x		x	x
Ports/Harbours	x	(x)	x		x	x
Urban development		x	x		x	
Tourism/Resort development			x		x	x
Industrial estates	x	x	x		x	x
Industries	x		x		x	x
Others						
Waste treatment			x		x	
Water supply			x			
Coastal zone	x					

Table 3. Types of Water Resources Development Projects Requiring EIA

Country	Types of the Projects
Bangladesh	Regulations under discussion. Currently on an ad hoc basis.
Burma	On an ad hoc basis.
China	All the projects that will cause environmental impacts (not clearly identified).
India	River valley projects (not clearly identified). (Major hydroelectric, irrigation projects are subject to EIA since 1978).
Indonesia	Regulations under discussion.
Japan	Construction of dams with surface areas of 200 hectares or more on rivers prescribed in the River Law. Lake development projects and river waterworks with alteration areas of 100 hectares or more * The hydroelectric projects with 30.000 KW or more, and being considered environmental considerations are particularly necessary, are subject to EIA based on the Decision of the Ministry of International Trade and Industries.
Malaysia	Drainage and irrigation. a) Construction of dams and man-made lakes and artificial enlargement of lakes with surface areas of 200 hectares or more b) Drainage of wetland, wildlife habitat or of virgin forest, covering an area of 100 hectares or more c) Irrigation schemes covering an area of 5.000 hectares or more Power generation and transmission a) Dams and hydroelectric power schemes with either or both of the followings: (i) dams over 15 meters high and ancillary structures covering a total area in excess of 400 hectares (ii) reservoirs with a surface area in excess of 400 hectares Water supply a) Construction of dams, impounding reservoirs with a surface area of 200 hectares or more b) Ground-water development for industrial, agricultural or urban water supply of greater than 4,500 cubic meters per day
Nepal	Regulations under discussion. Currently on an ad hoc basis.
Pakistan	Regulations under discussion. Currently on an ad hoc basis.
Philippines	a) Major dams b) Major power plants (including hydroelectric) * Projects within environmentally critical areas are also subject to EIA
Republic of Korea	River projects within an urban planning area with a population of 500,000 or more, prescribed in the River Management Law as ranges over a midstream length of 10 kilometers or more Construction of a dam or river mouth weir set forth in the River Law.
Sri Lanka	All development projects. (Guidelines are established in March 1987, but relevant information is not available in ESCAP)
Thailand	Dam or reservoir: storage volume greater than 100 million cubic meters or storage surface area greater than 15 square kilometers Irrigation: irrigated area greater than 80,000 rais (12,800 hectares)

Table 4. Environmental sensitivity criteria for environmental impact assessment in the Philippines

(1)	All areas described by law as national parks, watershed reservoirs, wildlife preserves and sanctuaries;
(2)	Areas set aside as aesthetic potential tourist spots;
(3)	Areas which constitute the habitat for any endangered or threatened species of indigenous Philippine wildlife (flora and fauna);
(4)	Areas of unique historic, archaeological or scientific interest;
(5)	Areas which are traditionally occupied by cultural communities or tribes;
(6)	Areas frequently visited and/or hard-hit by natural calamities (geologic hasards, floods, typhoons, volcanic activity, etc.);
(7)	Areas with critical slopes;
(8)	Areas classified as prime agricultural land;
(9)	Recharge areas of aquifers;
(10)	Water bodies characterized by one or any combination of the following conditions: a) Tapped for domestic purposes; b) Within the controlled and/or protected areas declared by appropriate authorities; c) Which support wildlife and fishery activities.
(11)	Mangrove areas characterized by one or any combination of the following conditions: a) With primary pristine and dense young growth; b) Adjoining mouth of major river systems; c) Near or adjacent to traditional productive fry or fishing grounds; d) Which act as natural buffers against shore erosion, strong winds and storm floods; e) On which people are dependent for their livelihood.
(12)	Coral reef characterized by one or any combination of the following conditions: a) With 50 per cent and above live coral line cover; b) Spawning and nursery grounds for fish; c) Which act as natural breakwater of coastlines.

Source: Proclamation Nº 2146 of the Philippines, proclaming certain areas and types of projects as environmentally critical and within the scope of the environmental impact statement system established under Presidential Decree nº 1586.

EIA procedures in selected countries of the region

In general, EIA process consists of the following steps:

a) Identification of projects requiring EIA

The process is generally called a screening. Various methods employed for screening are mentioned above.

b) Identification of major environmental impacts

The process is generally called as scoping. Scoping can be conducted through determination of Terms of Reference of EIA study. IEE has also function of scoping.

c) EIA study and preparation of EIA report

There are two types of EIA, namely IEE and detailed EIA. IEE is a preliminary assessment of environmental impacts, to determine the need for detailed studies and if so, to identify the crucial topics to be covered in detailed studies.

d) Evaluation of EIA report

Evaluation can be conducted by the project proponent, line agency and environmental agency. Review committees may also be created either permanently or on an ad hoc basis, to make adequate evaluation and recommendations.

e) Reflection of recommendations contained in EIA report

If EIA report is approved and the project is endorsed, then the recommendations in the report for mitigation measures/ environmental enhancement measures are incorporated in the project design and implementation.

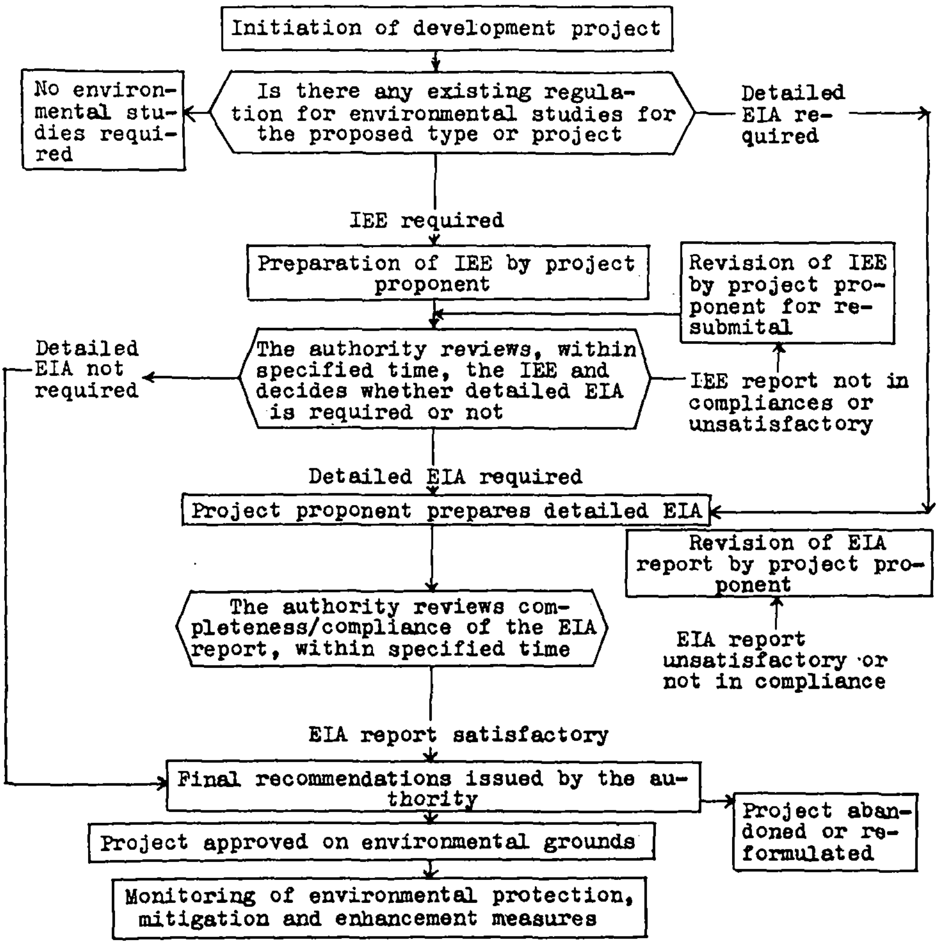
f) Monitoring and other follow-up activities

During the construction and operation stages, environmental monitoring are conducted and furhter mitigation measures/ environmental enhancement measures are taken, if considered necessary.

Sequential action of EIA procedure typically observed in the ESCAP region is shown in Figure 1. IEE is employed in various countries of the region with functions of screening and scoping.

Comparative analysis of EIA procedures in selected countries of the region is presented in Table 5. Most countries have adopted or have under preparation lists of project types requiring EIA. The definitions used are rather general,, such as major industrial projects or major dams/reservoirs. In many cases, however, further screening procedures other than IEE are not clearly prescribed. Only a few countries employ such screening procedures using general criteria.

Figure 1. Sequential action of EIA



Source: ESCAP. Environmental Impact Assessment: Guidelines for Planners and Decision Makers (Bangkok, 1985), (ST/ESCAP/351).

Notes: EIA - environmental impact assessment;

IEE - initial environmental examination.

Table 5. EIA procedures in Asian countries

	Type of project requiring EIA	Procedures for project screening	Initial environmental examination	Procedures for scoping	Institution for evaluation of EIA	Institution for final decision on EIA acceptance	Regulations for mitigation	Procedures for control of mitigation
Bangladesh	Regulations in drafting stage	No specific procedures	No specific regulations	No specific procedures	Department of Environment Pollution Control	Department of Environmental Pollution Control	No specific regulations	No procedures
China	Specified types of development projects	No specific procedures	No specific regulations	No specific procedures	Environmental Protection agency	Environmental rotection agency	No specific regulations	No procedures
India	Specified types of large development projects	Screening procedures by DOE in preparation	IEE based on a questionnaire	No specific procedures	Environmental Appraisal Committees	Department of Environment	Integral part of TOR and questionnaires	No procedures
Indonesia	Development projects with significant environmental impacts	No specific procedure	Preliminary environmental information report	TOR based on project information	Authorized government agency through review commission	Authorized gouvernment agency	Environmental management plan and environmental monitoring plan required	Envisaged
Malaysia	Specified types of development projects	No specific procedures	Preliminary assessment by application of a matrix	TOR based on preliminary assessment	Review Panel; support through Expert Panel possible	Approving authority on recommendation of the review panel	No specific regulations	Envisaged
Nepal	Regulations in drafting stage	No specific procedures	No specific regulations	No specific procedures	Not yet determined	National Planning Commission	No specific regulations	No procedures
Philippines	- Major development projects according to technical specifications - Projects in environmentally critical areas	No specific procedures	Project description based on a formalized outline	No specific procedures	Review Committee public hearing possible	EMB on recommendation of Review Committee	No specific regulations	No procedures
Sri Lanka	All development projects	Screening procedure in preparation	IEE based on a questionnaire	Scoping meeting Scoping document	Review by interested parties and agencies	CEA	Environmental action plan required	No procedures
Thailand	Major development projects according to technical specification	Project proponent screens projects using ONEB criteria	(EE based on ONEB guidelines)	TOR for EIA prepared by ONEB and project proponent	ONEB	ONEB	No specific regulations	No procedures but frequently carried out

Scoping procedure is considered to be adopted in several countries through the determination of Terms of Reference of EIA study. IEE is also conducted in many countries, with function of either screening, scoping or both. Relationship between screening, scoping and IEE is rather complex. In general, screening procedures are rarely required if IEE is needed. On the other hand, many countries adopt TOR based scoping even when they require IEE.

Some countries adopt IEE and detailed EIA, while others use only detailed EIA (or no specific provision for IEE). In general, IEE approach is prevalent in the region, however, countries such as China, Hong Kong, Japan and Republic of Korea do not utilize IEE. In all countries, EIA study is conducted and EIA report is prepared by the project proponent. In most countries EIA report should cover the following items:

- description of the project, identifying possible sources of environmental impacts,
- description of existing environmental situation prior to the project,
- identification and prediction of environmental impacts resulting from the project,
- comparative analysis of the environmental condition with and without the project (including alternatives),
- evaluation of the impacts,
- outlining of mitigation measures to be taken, and environmental monitoring programmes during/after the project.

In most countries (e.g. India, Malaysia, Thailand), the institutions responsible for evaluation of EIA are environmental agencies. In Indonesia, authorized government agencies, that is, respective line agencies, with assistance of review committees, are responsible for evaluation. Several countries (India, Indonesia, Malaysia and Philippines) have created review committees, which are responsible for (i) evaluation and review of IEE and detailed EIA; (ii) recommendations of mitigation measures; and (iii) recommendations on the issuance of project clearance.

Only a few countries have provisions of environmental management plan/environmental action plan for mitigation measures and follow-up activities of EIA. In many countries, however, through guidelines or other means, mitigation measures and environmental monitorings are required to be described in EIA report.

No existing EIA procedure reviewed has addressed or solved the problem of how mitigation measures could be implemented when they are under the responsibility of other institutions. This is particularly relevant to water resources development projects, since various indirect impacts of the projects seem to be very significant. Typical effects of such kinds may include deforestation and agricultural encroachment, resulting in destruction of productive ecosystems, soil erosion, siltation and increased flood risk.

In conclusion, EIA procedures in the region have significant diversities. Some of them seem to be too general and feasible for further improvements.

3. Experiences on EIA of water resources development projects

In the ESCAP region, huge numbers of EIA have been undertaken concerning water resources development projects. For instance, in India, 498 river valley projects have been submitted to the Department of Environment, out of which 255 have been approved, 217 rejected and 26 are pending now. In Thailand, Electricity Generating Authority of Thailand has conducted 19 EIA study concerning hydroelectric power projects since 1972, of which 6 have fallen into the legal EIA requirement.

Based on these experiences, and on various case studies on environmental impacts of water resources development projects, undertaken in the region, the Environmental Co-ordinating Unit of ESCAP has developed draft EIA guidelines for water resources development.

The primary purpose of the guidelines is to assist government agencies in the planning and carrying out of EIA for water resources development projects. The draft guidelines cover (i) fundamental approach for EIA, (ii) environmental impact and management requirements of water resources development projects, (iii) general assessment methodologies, and (iv) resource requirement for EIA. Practical aspects of EIA have been emphasized in order to assist planners and engineers who are actually engaged in the EIA work.

These guidelines will be finalized after the Expert Group Meeting of EIA of development projects, scheduled from 15 to 19 August 1988 at Bangkok, in which government officials from 13 developing countries as well as experts from several developed countries are expected to participate. The draft guidelines are attached as Annex I, for the review and comments of experts.

One of the problems regarding EIA of water resources development projects is that there are few studies to examine the effectiveness and accuracy of EIA through comparative analysis of environmental impacts predicted at the EIA stage and those actually examined at the post-implementation stage. In this regard, the Electricity Generating Authority of Thailand has recently undertaken a post-construction environmental study of Srinagarind Dam Project, EIAs of which were conducted in 1970s. ESCAP has undertaken a case study (comparative analysis) of this project, summary of which is attached as Annex II.

4. Conclusions

Many countries of the ESCAP region have introduced EIA systems as a planning tool for integration of environment into development planning. Their systems are being improved and upgraded.

Various types of projects are subjected to EIA in the countries of the region. In most countries which have EIA systems, water resources development projects require EIA. However, definition and scale of the projects requiring EIA differ from country to country, depending on the country situation.

EIA procedures adopted in the region have significant diversities. Generally speaking, screening and scoping procedures seem to be more emphasized and strengthened. Mitigation measures and environmental monitoring also require appropriate provision in the EIA procedures.

Co-ordination mechanisms with other institutions when mitigation measures are not under responsibility of the project proponent, are not addressed in any EIA procedure in the region. This is considered particularly relevant to water resources development projects, since those projects require broader perspective such as comprehensive watershed management approach.

With regard to EIA of water resources development projects, various experiences have been accumulated in the region. Since such experiences are scattered, attempt has been made to compile them in the guidelines for the sector.

GLOSSARY

With the advent of EIA as a tool for incorporating environmental consideration in developmental activities over the last 15 years, various terminologies have been developed and some of them are listed and described below.

- Environmental baseline study (EIS)
- Environmental setting (ES)
- Environmental inventory (EI)
- Environmental identification (EI)
- Ecological reconnaissance
- Initial environmental examination (IEE)
- Environmental impact investigation (EII)
- Partial environmental impact assessment (PEIA)
- Environmental impact assessment (EIA)
- Environmental appraisal (EA)
- Environmental assessment (EA)
- Environmental impact evaluation (EIE)
- Environmental impact statements (EIS)
- 102 statements (used in USA)

Although various aforementioned terminologies have been employed, most of them are used interchangeably. The commonly used terms in Asia are "environmental inventory", "initial environmental examination", "environmental impact assessment" and "environmental impact statements".

"Environmental inventory" is a complete description of the environment as it exists in an area where a particular proposed action is being considered. This serves as a basis of evaluating the potential impacts on the environment, both beneficial and adverse, of a proposed action. The term "environmental baseline study", "environmental setting" or "environmental identification" could be considered as similar in scope to the "environmental inventory".

"Initial environmental examination" is a preliminary assessment of environmental impacts of a project and indicates those aspects which deserve in-depth study. It provides only a cursory review of principal impacts and therefore of more limited depth than an environmental impact study. The terms "ecological reconnaissance", "environmental impact investigation", "partial EIA", "preliminary EIA" could be placed under the same category as the "initial environmental examination".

"Environmental impact assessment" basically embodies the steps of prediction, scaling and significance interpretation, although many terms may be used to describe these particular steps. Thus, most often, the terms "environmental assessment", "environmental appraisal" and "environmental impact evaluation" have been interchangeably used with "environmental impact assessment".

Finally, the "environmental impact statement" is a document written in specified format following specific agency's guidelines. The EIS represents a summary of the environmental assessment. EIS has also been referred to as "environmental statements", "impact statements", "environmental impact reports" or "102 statements" in the United States.

There are a number of terms that are widely used in the field of environmental protection and impact assessment and a knowledge of their precise meaning would be of great utility. Some of them are listed below:

1. Environment: The surrounding zone (the specific zone to be affected by the project), all natural resources (physical and biological) and human resources (people, economic development, and quality of life values).

2. Ecology: Study of inter-relationships of organisms to their environment and the interrelationships between organisms.

3. Environmental resource or value: An aspect of the environment which is of benefit to man (including all ecological resources and values).

4. Ecosystem: A community and its environment (living and non-living considered collectively: this may range in extent from very samll units to very large).

5. Environmental effect or impact: Effects of actions which alter the environment (as measured by physical, chemical and biological parameters) including natural and man-made actions.

6. Environmental planning: Planning activities with the objective of preserving or enhancing environmental values of resources.

7. Rapid environmental assessment: Term used by the World Health Organization for a preliminary assessment similar to an initial environmental examination.

CASE STUDY OF ENVIRONMENTAL IMPACT ASSESSMENT OF SRINAGARIND DAM PROJECT

I. Introduction

In Thailand, environmental impact assessment (EIA) procedure has been introduced in 1981, when a promulgation on EIA was first issued. However, EIA of water resources development projects had been undertaken even before the promulgation, on an ad-hoc basis. The Electricity Generating Authority of Thailand (EGAT) is among major conductors of such EIAs for multi-purpose dam/reservoir projects. The record of EIA for EGAT's hydro-power projects are attached as Appendix I.

Since EIA has been newly introduced in the region, there are few projects which have both EIA studies and post-construction environmental evaluation. As one of such projects, EGAT has recently completed a post-construction environmental evaluation report of Srinagarind Dam Project. In order to evaluate the accuracy and effectiveness of EIA studies, ESCAP has adopted this project for case study on environmental impacts predicted at EIA study and after completion of the project. This paper is a summary of the case study report.

II. Srinagarind dam project (SND)

Quai Yai River Basin (QYRB) and Water Resources Development Plan

The QYR originates from the Thanon Thongchai mountain ranges which form part of the western border between Thailand and Burma. The River flows pass high mountains and dense tropical forest for about 380 km. before it joins with the Quai Noi River (QNR) to form the Mae Kong River (MKR) just below Kanchanaburi. The QNR has an annual runoff of about 4,600 MCM from its 14,800 sq.km. With its average gradient of about 1:900, the River is quite suitable for development into source of electrical power production and water for irrigation. As far as the QYRB is concerned the development comprised the following:

SND Project. The project is located at Ban Chao Nen, Amphoe Srisawat, Kanchanaburi Province. SD is a Rock filled dam 140 m. high, with 15 m. wide and 610 m. long dam crest. The dam itself has a volume of 12.3 MCM. The capacity of the reservoir is 17.744 MCM. The capable electric power installation is 720 MW and the annual electric energy production of 1,200 MKWh.

The Lower Quai Yai Project or the Tha Thung Na Dam (TND) Project. The project is located at Ban Tha Thung Na, Amphoe Muang, Kanchanaburi Province, some 28 km. downstream of the SND. This project would enhance the electric power production of the SND greatly. The TND is a concrete gravity dam of 350,000 CM. The storage capacity of the reservoir and its surface area are 56.3 MCM and 8.35 sq.km. at 59.70 m MSL respectively. The installed capacity is 38 MW, and the annual energy production is 126 MKWh.

These two projects have already been completed and commissioned. The other two projects to be described below were shelved on environmental ground, after being strongly protested by the public. The projects are as follows:

Nam Choan Dam Project, (NCD). This project is to be located some 135 km. of SND at Huai Nam Choan. The dam is a rock filled type 185 m. in height. The anticipated installed capacity would be 580 MW capable of delivering electrical energy at 1,108 MKWh.

The volume of the dam would be about 12.2 MCM. The reservoir capacity and the water surface would be 5,950 MCM and 137 sq.km. at 370 m. MSL respectively.

Huai Khlong Ngu Dam Project (HKD). The project is to be located about 40 km. north of SND. It would comprise an upper regulating pond resulted from damming the Huai Khlong Ngu. The SND would then act as the lower pond. Electricity generators to be installed would be of the reverse pump - turbine type capable of producing 1,000MKWh. annually.

The Srinagarind Multi-purpose Project (SMP) in the National Water Source and Energy Development Context

The SMP consists of two dams, namely the SND and the TND located some 60 km. and 32 km. from the confluence between QYR and QNR respectively. Apart from hydropower generation, SMP is envisaged to perform another important functions of irrigation and flood control. Yet other secondary purposes include fisheries, tourism, navigation, salinity and water pollution control. A summary of important project features for both dams is given below:

Project Description	SND	TND
Dam Type	rock-filled	rock filled/concrete
Dam Height, m.	140	30
Av.an.inflow, MCM	4,600	4,400
Normal hwl, m. MSL	+180.00	+59.70
Min.w.l., m. MSL	+ 86.00	+55.50
River bottom elv., m.MS	+ 45.00	+32.00
Active storage, MCM	17,511	28.8
Max.pow.gen.cap. MW	7,200(540 as of 1987)	38.0
Av.an.pow.prod MKWh	1,235	170

The SMP in the Context of the Mae Klong River Basin Water Resource Development

The RTG initiated MKRB development since 1903 by constructing irrigation canals and flood protection dike along some parts of the low lying banks of the MKR followed by hydropower development study. The RID also initiated pumping irrigation project at Tha Lor Irrigation at Amphoes Tha Muang and Panomthuan in 1955. The RID prepared a master plan for the MKRB Development which comprises 4 stages of activities.

Stage I. This comprises the construction of Vajiralongkorn Deversion Dam at Amphoe Tha Muang, Kanchanaburi Province, and a distribution system covering an irrigated area of 191,056 ha.

Stage II. This stage comprises the construction of the SND on the QYR and the extension of the irrigation system to cover another area of 275,000 ha. on both banks of the River.

Stage III. This stage includes the construction of the Khao Laem Storage Dam (KLD) on the Quai Noi River and the expansion of the irrigation system to include Lum Pachee. At present there appears to be no definite plan being laid down yet.

Stage IV. This is to be the last stage of the development which includes the construction of the Nam Chon Storage Dam (NCD) in the upper reaches of the GYR.

The chronology of the development is as follows: The construction of Vajiralongkorn Deversion Dam was completed in 1970. The Greater Mae Klong Irrigation Project which comprises Stage I, Stage II - Right Bank were completed in 1977, and 1984 respectively. Stage II-left Bank and the drainage project are to be completed by

1993 and 1989 respectively. These are the works to be carried out by the RID. The EGAT had completed the construction of the SND, the TND and the KLD since 1980, 1981 and 1985 respectively. Stage IV development was shelved by the RTG in March 1988 because of the strong public protest on the ground of the environment although economically the scheme was viable.

III. The environmental impacts of the project

For the SMP which includes both SND and TND, three environmental and ecological studies had been carried out directly concerning the project and two other studies, also on dam construction in the MKRB which had some relevant information.

The first study was carried out by AIT in 1972 on "The Ecological Reconnaissance of the Quae Yai Hydroelectric Scheme", and it was followed by another also carried out by AIT in 1974 on "Selected Ecological Surveys of the Quae Yai Hydroelectric Scheme". In 1977, the EGAT awarded a study contract to the Southeast Asia Technology Co., Ltd. (SEATEC) on "Environmental and Ecological Investigation of Lower Quae Yai Project". The first two studies are directly concerned with the SND, and the last one with the TND.

Another project was awarded to the then Applied Scientific Research Co-operation of Thailand (ASRCT, now named Thailand Institute of Scientific and Technological Research, TISTR) by EGAT in 1975 to conduct a "Preliminary Environmental Study of Upper Khwae Noi Basin" which would contribute toward the construction of the Khao Laem Dam (KLD). Later in 1979, the Team Consulting Engineers Co., Ltd. was retained by the EGAT to conduct another study on "Environmental and Ecological Investigation of Upper Quae Yai Project". This is the study concerning with the Nam Choan Dam (NCD).

Environmental Impact Assessment Reports

a) The Ecological Reconnaissance of the Quae Yai Hydroelectric Scheme

This is the study carried out by the Asian Institute of Technology (AIT) with collaboration of several other agencies. The AIT handled water and agricultural Engineering sector and led the Study Team. Other sectoral studies included aquatic plants, archaeology, fisheries, forestry, social science and tropical medicine. The reconnaissance was conducted with the objectives of identifying potential problems which might be caused by the construction and operation of the SMP and of recommending remedial actions. The project started on August 1972 and completed the field study in October of the same year. One month later in November, the study report was submitted to EGAT.

The methodology employed in the reconnaissance included literature reviews, aquisition and analysis of secondary data, field investigation, laboratory and field analysis, and interviews with relevant and key officials both in Bangkok and local areas. It was pointed out that the reconnaissance was not an in-depth study but rather a general review of potential ecological consequences.

b) The Selected Ecological Surveys of the Quae Yai Hydroelectric Scheme

Arising from the work on the ecological reconnaissance mentioned above which was carried out during the wet season from August to November of 1972, it was believed desirable to extend it to cover a dry season period, and to remedy some of the limitation experienced during the work. EGAT thus awarded AIT another contract to conduct "Selected Ecological Surveys of the Quae Yai Hydroelectric Scheme" to be implemented during April and December 1973. Within the scope of this work, studies of the existence of causative agents and vectors of Schistosomiasis, Opistorchiasis, Paragonimiasis, Gnathostomiasis and Angiostrongyliasis were made. The survey covered some areas which had not been covered before.

c) The Environmental and Ecological Investigation of Lower Quae Yai Project

This project could be considered as an environmental impact assessment project carried out voluntarily by EGAT since there was no legal requirement for EIA reports at that time. The study project was awarded to SEATEC in 1977. The duration of the project was to be eight months from December 21, 1977 to August 21, 1978. The main objectives included the investigation of the existing environmental and ecological conditions of the project area with particular reference to socio-economic, and issues of compensation and resettlement, the evaluation of the probable effects of the project on the environment and vice versa; and the recommendation for corrective measures and monitoring programmes to mitigate adverse effects and to enhance the beneficial effects.

d) Other Environmental Impact Assessment Studies

The work on "Preliminary Environmental Study of Upper Khwae Noi Basin" by ASRCT was intended to provide some background information on the related ecological, sociological and cultural aspects of the project. This was to complement another report entitled "Interim Feasibility Report on the Khao Laem Project" prepared by the Snowy Mountains Engineering Corporation (SMEC) who were giving technical assistance to EGAT. The period of the ASRCT study was from March 7 to May 15, 1975, involving a study team of about 40 persons from universities and government agencies. The study approach was similar to other studies already mentioned.

The work on "Upper Quae Yai Project: Environmental and Ecological Investigation" carried out by the Team Consulting Engineers Co., Ltd. could be considered to come quite close to the full scale EIA which was later required by law in 1981. The administration and organization of the study team as well as the study methodologies employed were again similar to the Lower Quae Yai study carried out by SEATEC.

Major Predicted Impacts

Hydrology and related problems

The Ecological Reconnaissance (ER) anticipated that free travel by boat in the QYR would be impeded at the proposed SND, but the large body of water impounded by the dam would open new navigation possibilities to upstream areas. This would result in a net benefit to communications along the river, although downstream navigation and water transport would be at a disadvantage.

The diurnal peak waves created by the power plant operation would result in scouring of the river bank immediately downstream. There would also be bed scour, bank erosion and degradation below the impoundment. The study on the LQY revealed the fact that the TND would re-regulate the rapid diurnal fluctuations of river stages caused by the operation of the SND, and the effect of the TND on erosion should be more beneficial than harmful. The total annual sediment load of the TND was estimated to be about 161,000 cum.

The present day 5 and 50 year return floods would become 15 and 1,000 year return floods with SND causing the floods to be 3,100 and 6,100 ha at Tha Muang respectively. An area of about 20,000 ha. would be inundated. Some of the soils of the area had been found to have poor drainage characteristics which might lead to rising water table, and a ground water table within the root zone is harmful to most crops with the exception of rice. A surface drainage would be necessary.

Salt contained in the irrigation water and salt rising from deeper soil layers into the root zone through an elevated ground water level were both harmful. This implied the utmost precaution in drainage design and construction. If soil layers containing iron pyrites were brought into contact with air through drainage facilities without sufficient neutralizing substances, the pyrites might be oxidized and sulphuric acid produced would cause very acid soil.

For the pollution abatement and salinity intrusion control to be effective, efforts should be made to resolve the problem with collaboration of all concerned. Monitoring should be carried out on a continuous basis, and a reservoir operating rule should be established.

Heavy Metals and Mining

Lead and zinc levels in the QYR were observed to be higher than background levels, especially in the vicinity of a mine, but were below the drinking water quality limits suggested by WHO. Adequate treatment facilities of wastewaters from mines and mineral dressing plants should be provided. Monitoring programme should also be established.

Forest and Wildlife

The impoundment of the TND would have much lesser effects on forest and wildlife than the resettlement site development due to the small size and low forest value in the reservoir area. The wildlife study revealed that wild fauna were not abundant. The TND would cause a loss of about 20 sq.km. of forest area. No rare species were reported to be in existence.

It was expected that wildlife fauna would be forced by impoundment to migrate to the nearby national park and wildlife sanctuary, and some would be lost. If the reservoir filling rate was not too rapid, the majority of the animals was expected to be able to escape safely. Clearing of sites for resettlement would also drive the animals out of their usual habitat, but the neighbouring national park and wildlife sanctuary were expected to provide alternative refuge so that the overall effects would not be too great.

The study recommended measures to control excessive erosion and loss of topsoil due to logging and forest clearing as well as cultivation. Forest extension programme should be implemented together with intensifying efforts to protect the forest and wildlife from illegal logging and animal poaching.

Fisheries

During the first year of filling, the oxygen in the water would be consumed largely by biochemical processes resulting in decrease of DO content. There had been no envidence of sudden fish kill in the reservoir. With time, the water would become more productive in natural basic foods which were suitable for limnophillic fish species such as carps, labyrinthici, and miscellaneous groups which were observed in substantial numbers in the reservoir.

Downstream fisheries were not fully exploited, and would be adversely affected by the SND because of the diurnal fluctuations in the river flow, and the dam would also be drawing deoxygenated water from a depth of between 40 and 28 m. below free water surface. High sulphide concentrations would cause fish migration and death downstream.

Aquatic Weed Infestation

ER considered aquatic plant infestation of man made reservoir in tropical countries to be a very important problem, drawing from the experience with the BPD where approximately 80 sq.km. had been reported to be covered with Eichhornia crassipes, the water hyacinth.

It was recommended that a hydrobiological study of the impounded water and monitoring of infestation of aquatic weed be carried out regularly. Physical and chemical methods should be used for the control.

Resettlement Pattern and Administration

There were 58 named villages situated in the catchment area, but the total population to be relocated would be around 9 to 10 thousand. The villagers on the whole were not happy about the SND and the necessity for them to be relocated elsewhere. They felt very insecure about compensation and the real government intentions. Reservations were expressed about relocation sites concerning mainly soil fertility and the size of the plots to be alloted.

As for the resettlement scheme for the TND, shortage of water supply and endemic diseases were the two major problems in the area together with the need for irrigation water.

About 50% of those interviewed understood the beneficial effects of the SND, but 42% expressed negative views toward the resettlement scheme, while 53% had known nothing about it. Only about 40% agreed to be relocated, but 53.5% wanted to obtain sufficient compensation for purchasing land somewhere else. Some of the recommendations included detailed surveys of potential sites and preference of the population to be relocated concerning the size of the plot and the required infrastructures. A compensation and resettlement committee should be set up at both project and village levels, with representatives from the villagers.

Health

The general level of sanitation was poor. Drinking water was obtained from both the river and from rain water. The nearest physicians and hospital were located in Kanchanaburi. Malaria was the most significant disease in the area.

Included among several recommendation was the need to provide adequate water supply, and environmental sanitation together with the provision of adequate public health personnel and facilities.

Archaeological Sites

ER examined the known patterns of prehistoric ecological adaption in an attempt to construct a model of the prehistoric man-land relationships along the QYR. A Hypothesis was made concerning the subsistence and settlement patterns along the QYR some 20,000 years ago.

It was recommended that investigation of archaeological and historical sites be carried out both for the project area and the surroundings which might be further developed.

Tourism

ER Identified a number of tourist attractions. The potential of the SND and reservoir as another tourist attraction was also discussed. Increase in tourism would create demand for community development, including food and services. Any unplanned development could create problems of water supply, sanitation and pollution. Laws should be enforced strictly to control these and other related problems such as traffic and crime.

Post-construction Environmental Evaluation

The SND was commissioned in 1980 and has been in operation ever since. In the meantime EGAT has continuously monitored its impacts on the environment. EGAT also started a series of post-construction environmental evaluation of some of its projects, such as the BPD and the Bang Lang Dam. The Srinagarind Dam Project (SND) is now under Post-construction Environmental Evaluation (PEE). The Study was conducted during April 25, 1986 to December 25, 1987 with a total budget of 2.0 million Baht.

Concerning the MKRB, the proposed construction of another dam in UQY area, the Nam Choan Dam, has created a great deal of controversies which resulted in the RTG's decision to delay the implementation of the project indefinitely. Information, data and opinion generated from the studies concerning above controversies were heavily utilized in assessing what actually or appears to happen since the SND was completed and has been in operation.

Physical Resources

Analysis of rainfall data in the PEE revealed that there was no significant change in the rainfalls. The data obtained during the 1976-1985 period for Kanchanaburi indicated significant trends to higher humidity, lower evaporation, lower ambient temperature, lower atmospheric pressure, more cloudiness, and greater visibility.

PEE found that there was no significant change in the rainfall-runoff relationship in the basin area. However, the flow downstream of the SND at VDD was reduced during wet seasons. Dry season flows could be maintained at above critical levels for the control of salinity intrusion and pollution for most of the time.

As far as ground water was concerned, PEE found the levels of water in deep wells sunk in the upstream areas and in areas adjacent to the reservoir fluctuated with the reservoir levels as predicted. However, no effect of the SND could be found in the Lower Quae Yai area nor in the area of the lower MKRB which was irrigated under the Great Mae Klong Irrigation Project. A decreasing trend of ground water level had been observed. This might be due to the improvement of drainage capacity of the area as a result of the GMKRBI Project.

PEE found that the water quality of the QYR upstream of SND met NEB's class I standard even though the upstream area had attracted development activities such as mining, new resettlements, tourists floating huts etc. The PEE and the investigation carried out during NCD controversy found that the level of Fe, Cd, Pb, Cr and Hg were lower in 1986-1987 than in 1980.

The water quality in lower reaches were found deteriorated and it was contaminated with domestic and industrial wastes as expected. The dilution and pushing effects of higher flow in the MKR as a result of the SND and TND operations evidently helped to maintain the water quality in the MKR on a satisfactory level, corresponding to Class III of the NEB's standard.

Analysis of annual sediment yield of the upper basin of QYR demonstrated an increase by about 10% since the implementation of the SND. Reservoir and river banks erosion and slides were observed at several locations as anticipated during the ER and the LQY studies. SND decreased the sediment supply to the downstream areas and estuary, which had both beneficial and detrimental effects. Mining activities in the upper basin area increased as predicted.

Ecological Resources

PEE found that species diversity of fish in SN reservoir was less than it is in the upstream QYR at present. It was found also that during the pre-impoundment period there were more species of fish in the QYR than at present. This was contrary to the prediction which was based upon the Ubol Ratana reservoir.

Concerning aquatic weed infestation which had been predicted earlier, observations revealed that the problem was not so serious as anticipated. PEE found forest characteristics varying with topographic reliefs, soil types, climatic conditions and human activities. Data revealed by PEE appeared to indicate that SND was not the main agent that induced deforestation which went on even without development activities.

Economic Values

Since SND was commissioned, flooding took place only once in 1982, and at a much reduced flood peak. It was estimated that if there were no SND, there could have been flooding in 1978, 1981, 1982, and 1983.

With SND the higher flow downstream of the VDD helped keeping the water quality in a better situation, but efforts should be made to keep the flow not greater than 80-100 cms. during dry season so that the water in the estuary area would not become too fresh for marine shrimp and oyster farming.

With the SND and TND river transport and boat navigation along the QYR downstream of its dams became unpracticable and lost a great deal of the business to road transportation. However, with the SND, the reservoir had created an all year round possibility for water transport deep into the upstream areas.

Quality of Life Values

a) Public Health. Although number of health centres and other health facilities became much higher PEE found that they were still inefficient. The situation with regard to malaria had been improved, but was still a problem in the project area. Influenza became the most prevalent disease among the population in the two resettlement areas while malaria dropped to the second place. Although environmental sanitation had been considerably improved, it was still far from adequate except in the resettlement areas.

b) Resettlement and Compensation. Since the construction of the SND and the TND, two resettlement areas was developed by EGAT at the respective dam sites. About 1,000 families in 65 villages were evacuated and resettled during 1975-1978. About 52 million Baht was allocated by EGAT for land aquisition to be turned into resettlement villages. Each family was provided with an area of 18 rai for cultivation and 2 rai for residence. Some necessary infrastructures were also provided by EGAT. Each resettlement village was also provided with water in the forms of deep wells, storage tanks, weirs, and farm ponds. Water supply distribution systems were also constructed. EGAT founded the Ban Chao Nen Co-operative Ltd. and provided it with 10 million Baht as a long-term loan with 10 years grace period. In addition, several other government agencies also provided occupational training in farming, fishing, etc. to the villagers. A total sum of about 147.80 million Baht was invested.

Some socio-economic problems emerged since the resettlement. These include the need to adjust to the new life style and to live in the market economy system instead of subsistence living conditions that most villagers were used to. Soil fertility and the size of land holding were among major concerns of the villagers, some of whom claimed that they were not properly compensated due to improper survey and due to their lack of necessary documents to support their claims. Relocation management was another factor contributed toward the negative attitudes of some villagers also. This includes inadequate preparation of lands, and delays.

About 75% of the resettlers believed they would be better off without the SND and the TND. This negative attitude could be communicated to others and would probably make it more difficult for the RTG to implement another similar scheme especially in the same area. This was reflected by the fact that 74% of the resettlers were also negative toward the construction of a new dam in the vicinity.

The chronic problems which had been with the resettlement since the beginning were water supply and irrigation water, plot sizes and soil quality, and health. The higher income group had negative attitude towards the project, but of lesse intensity.

c) Tourism and Recreation. The SND no doubt contributed some beneficial effects upon tourism and recreation. PEE estimated that the SND played an important role in generating at least 30 million Baht for raft tourism and about 40 million Baht for visit to the dam.

IV. Conclusions

Major Impacts

Several positive and negative impacts had been identified. They could be classified into two groups, namely the impacts on human and the impact upon natural resources. Out of the two broad groups, it appeared that socially, economically and psychologically the impacts upon the displaced population were the greatest, but this was not always recognized when the impacts were analyzed on the basis of economic principle of cost-benefit analysis of quantifiable values in monetary terms. For the second group, the impacts were greatest on the ecological system of the watershed area.

In order to rank the importance of impacts, a criteria must first be established. But to establish a criteria, one has to decide first on the goals and objectives of the development activities and the policies and strategies one would like to employ. Development activities would inevitably disturb the environment. As in the case of the SND, some parts of the forests would have to be inundated and cleared for resettlement. A trade-off would have to be made. One could never be able to develop while keeping the environment intact in its prestine conditions.

If we were to make the first scenario based upon the watershed area upstream of the dam, the greatest impacts on the social aspects would be on the displaced people and on ecological aspect of the watershed ecological system. Both of them were adverse impacts. If we now make the second scenario based upon the MKRB downstream of the dam, the greatest impacts would be on the socio-economic conditions of the people. These impacts were positive but we could hardly say on the ecological aspects whether the impacts would be positive or negative.

The following summarize major impacts according to intensity of their significance:

	Positive	Negative
<u>Upstream Areas</u>:		
Resettlement		x
Watershed Area		
Forest & Wildlife		x
Erosion & Sedimentation		x
Fisheries		x
Inadequate Data for assessment- (certain benefits in economic term indicated)		
Archaeological & Historical Values		x
<u>Downstream Areas</u>:		
Socio-Economic Aspects		
Economic Growth	x	
Human Use Values	x	
Quality of Life Values	x	
Ecological Aspects		
Inadequate data for assessment		

Relationship between EIA Requirements and Findings

For the case of the SND, the situation was complex. Less emphasis could be on ground water hydrology, water supply, navigation, highways/railways and the transport system in general. Nutrition, recreation and aesthetics could also be reduced in emphasis, as well as the study on market for power, power production alternatives, rural electrification and transmission lines which were usually covered in feasibility studies.

On the other hand, it was thought very useful to focus upon mitigation measures and monitoring programme, not so much on the methodologies, but on the cost and practicability. In this respect assessment of the institutional and legislative aspects might be incorporated.

Risk assessment was one of the item that appeared to have been neglected. For the case of the SND, this particular aspect was believed to be extremely important.

It was believed that the river/lake basin or watershed may be considered as a management unit for planning since "It is an ecological unit; linkages based on physical resources make it work (Hamilton 1985 quoted by Hufschmidt and Ma Cauley). The use of watershed as the unit for planning would give systematic perspective which embraces the entire complex of biophysical, social, economic and institutional factors whose interactions have direct impacts upon long-term, "sustainable", development programme while, at the same time, alleviate problems inherent in the case by case basis assessment which are now confronting us.

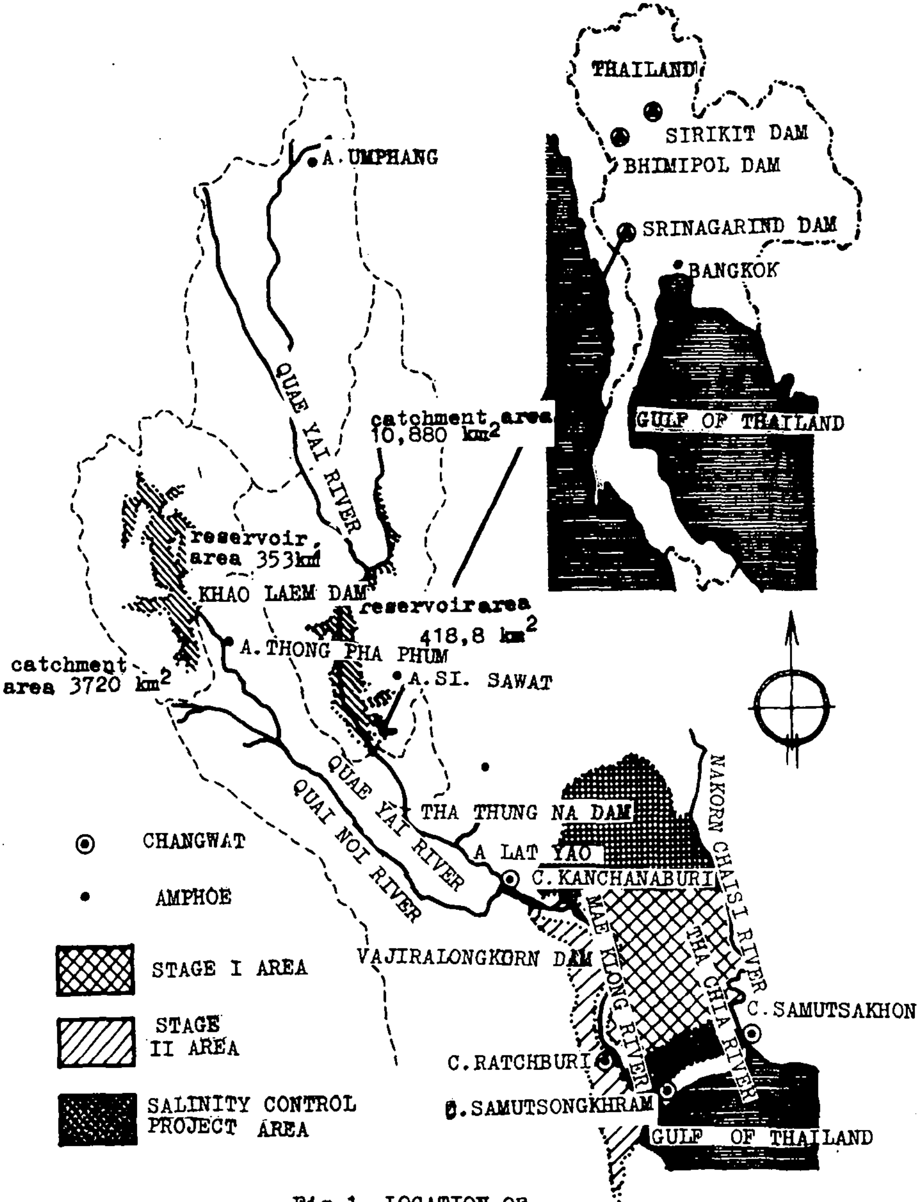


Fig.1 LOCATION OF SRINAGARIND DAM

THE USE OF REMOTE SENSING METHODS TO MONITOR ATMOSPHERIC POLLUTION OF WATERS

Dr. G.Ya. Krasovsky

Precipitation is a significant factor contributing to the pollution of water bodies situated in industrial areas or in regions susceptible to the effect of air masses migrating from those areas. This factor becomes particularly important during the spring snow melt, as the snow cover for a long time accumulates pollutants entering the atmosphere from various sources. An extensive literature is available on the problem of space survey data interpretation with a view to studying the snow cover and its parameters. A fairly complete review of the literature is given in (I). The sources cited there essentially deal with determination of parameters of global snow cover distribution, based on space survey data, such as thickness and extent, boundaries, moisture, water equivalent as well as identification of seasonal types of snow. These parameters are important for establishing stable patterns and factors of current climatic changes and of runoff forecasts.

This report gives a number of practical recommendations on the use of space images in analysing the processes of water body pollution with substances of technogenic origin, accumulated in the snow cover.

1. Visual Interpretation of Polluted Snow Cover on the Water Body

Visual interpretation of space images obtained in the visible and in the IR range allows qualitative evaluation of the snow cover pollution scale. It also allows to establish their nature and to compare, in a relative scale, the extent of pollution: pollutants, whose composition depends on the types of production dominating in major industrial centres, build up in the snow cover, thereby reducing its albedo 2 to 3 times. On the negatives, polluted snow cover is represented by lighter shades, on the prints - by darker shades. In practice, when using such signs of snow cover pollution, one must remember that generally the brightness of snow cover is determined by a multitude of factors. Among these are snow thickness, age, moisture, type, condition of surface that is liable to change due to daily freese-thaw cycles, etc. For this reason, the mapping of snow cover pollution should be confined to areas where the effect of above changes is almost the same. In particular, in the case of water bodies proper, this last requirement is observed in most cases. Highly informative, in relation to the mapping of spatial distribution of snow-cover man-induced pollution, are space images of high spatial resolution and large scale obtained on the basis of space surveys in different spectral zones.

To provide an illustration (Fig. 1), we have made use of space pictures obtained with MCY-C scanner in January through April, 1987. With the aid of visual treatment of these pictures boundaries were established for the zone of stable man-induced pollution of snow cover in the Leningrad area, its outlines being in full conformity with the data of (2). The scanner ensures survey in the ranges of 0.5-0.7 and 0.7-1.1 u. Its scanning width is 1.300 km, surface resolution in nadir - 250 m. Periodicity of repeated area scanning is 7-8 days. Because of cloudiness, it is virtually impossible to gather statistical data on repeated space pictures of individual regions. However, even materials of repeated irregular surveys undertaken during snow cover formation and melting make it possible to obtain sufficiently reliable evaluations of the regularities of water body pollution caused by the effect of air masses originating in major industrial areas. Fig. 2 shows focal points of air basin pollution with technogenic substances on the European territory of the Soviet Union. The pollutants were identified by interpreting the snow cover pollution from the space pictures obtained with the aid of MCY-C during January through April, 1987.

2. Retracing Spatial Distribution of Pollutants in the Snow Cover of Water Bodies

Quantification of the mass of pollutants accumulated in the snow cover of separate segments of water bodies is of practical interest for planning and decision-making relating to prevention of water basin pollution of specific regions involving technogenic substances, entering the water bodies with precipitation, including transborder migration. The composition of chemical elements and compounds in the snow depends on the types of production at the sources of pollution, while spatial distribution is determined by the dis-

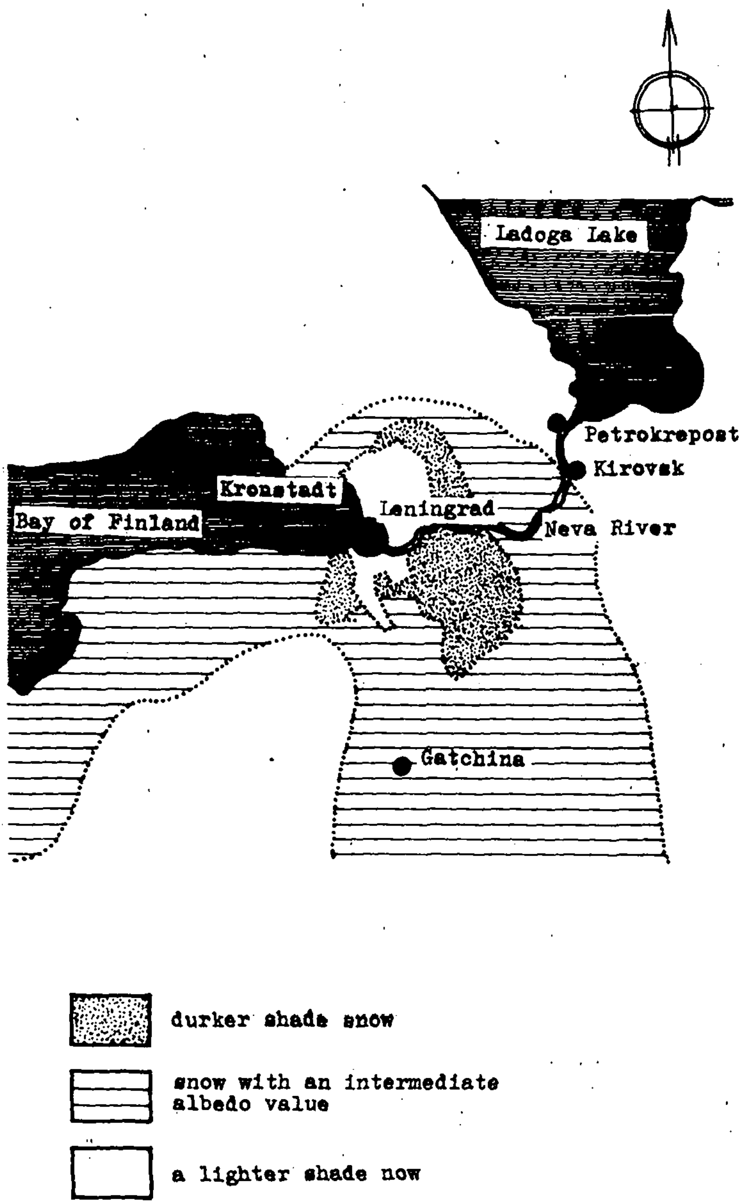


Fig. 1. Zone of Stable Industrial Pollution of Snow Cover around Leningrad, Based on MCY-C Scanner Images Obtained in 1987

Fig.2 Focal Points of Air Basin Pollution by Industrial Centres

tance between these sources and the water body, the dispersion and phase composition of releases, dominating directions of the wind, its mean velocity in the transfer layer within the period under consideration. It is for this reason that in the case of large water bodies a considerable variability in the content of pollutants can be observed at different points, the degree of variability declining as the water body surface area decreases. For example, at Onega Lake, which is used in this paper as a test object, the observed differences in the content of various pollutants are shown in Table 1.

Table 1. Extreme Concentrations of Pollutants in Snow Samples Collected from Onega Lake Water Surface

Parameter	1985(n=14)		1986(n=32)		1987(n=34)	
	max	min	max	min	max	min
Sulfates, mg/l	13.1	3.3	6.0	1.7	10.9	2.5
Nitrites, mg/l	0.011	0.003	0.028	0.001	0.025	0.005
Ammonia nitrogen, N/l	0.28	0.09	0.31	0.08	0.52	0.17
Bichromatic oxidizability, mg/O/l	21.7	2.7	13.9	1.0	10.5	1.0
Hydrocarbons, mg/l	2.0	0.0	0.3	0.1	-	-
pH	6.6	4.0	6.6	3.9	7.1	3.9
Suspanded solids, mg/l	24.2	0.4	-	-	-	-
Cu, solid phase CnC - 10^5 mg/l	-	-	8.8	1.8	-	-

If there are local sources polluting the snow cover of water bodies, the change in the concentration of some pollutants in the snow as the distance to the source increases can be approximated by the following function:

$$C_l^{(a)} = C_o^{(a)} l^{-f} \quad (1)$$

where $C_l^{(a)}$ - concentration of pollutants "a" in the snow at a distance "l" from the source; $C_o^{(a)}$ - mean concentration at the boundary of the pollution zone in the immediate vicinity of the source (10 to 20 stacks of medium height); l - distance; -f- parameter, describing the condition for pollutant transfer in the atmosphere. This parameter may be different for different elements and compounds,

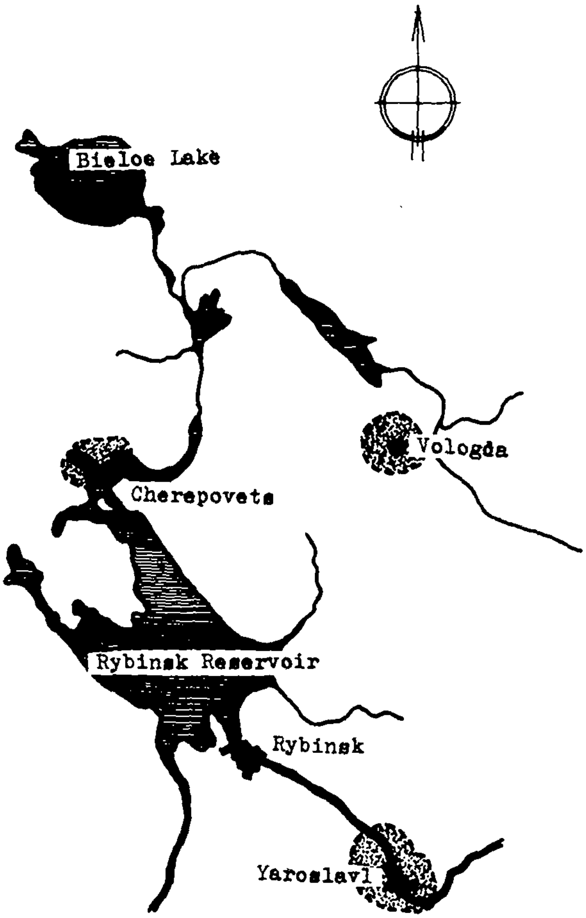


Fig 3 Rybinsk Reservoir Snow Cover Pollution Zones

or for the same element in releases of different industries. Its numerical value can be determined for each direction from the results of pollutant concentration measurement in two points. The total mass of a pollutant over a certain area of the water body is determined by area integration of equation (1). It should be remembered that products of releases into the atmosphere may be sorbed or dissolved by precipitation. This may considerably distort the spatial distribution of the snow cover pollution, retraced with the aid of mathematical models of atmospheric transfer of pollutants.

The main regularities of spatial distribution over the lake area of chemical elements and compounds, including those given in Table 1, can be established by snow sampling at a predetermined network of stations, followed by chemical analysis.

Fig. 4 shows a diagram of sampling stations location at Onega Lake. Snow samples were taken by KA-26 helicopter, while the snow gauging survey was on. Analysis of the table data makes it possible to identify those areas of the lake that are subjected to notable effect of local industrial releases. In fact, the stations at Petrozavodsk and Kondopoga invariably record high concentration of all pollutants. Yet, the data thus obtained are definitely insufficient for calculating the mass of pollutants accumulated in the water body snow cover. Naturally, expanding the network of sampling stations takes much time and is costly.

The task may be solved using modern algorithmic and program means of correlation and regression analysis. To achieve this, it is necessary to have sufficient observation statistics regarding the brightness of snow covered areas characterized by similar indicators of the degree of pollution. By processing the statistics, the following functional relationships are obtained:

$$C^{(a)} = f(U_1, \ldots U_n) \qquad (2)$$

where $U_1, \ldots U_n$ - brightnesses of particular areas of the water body in n-spectral intervals. On this basis, it is possible to determine mean concentration of a pollutant "a" in the snow cover in any point of the water body. By computing water body areas, delineated by isolines, it is easy to calculate the mass of a pollutant accumulated in the snow cover of test-object. It may be assumed that equations of the type (2) obtained using the data for Onega Lake will apply to all water bodies of the north-western part of the USSR European territory, including lakes like Ladoga, Bieloye, Choudskoye, Ilmen',

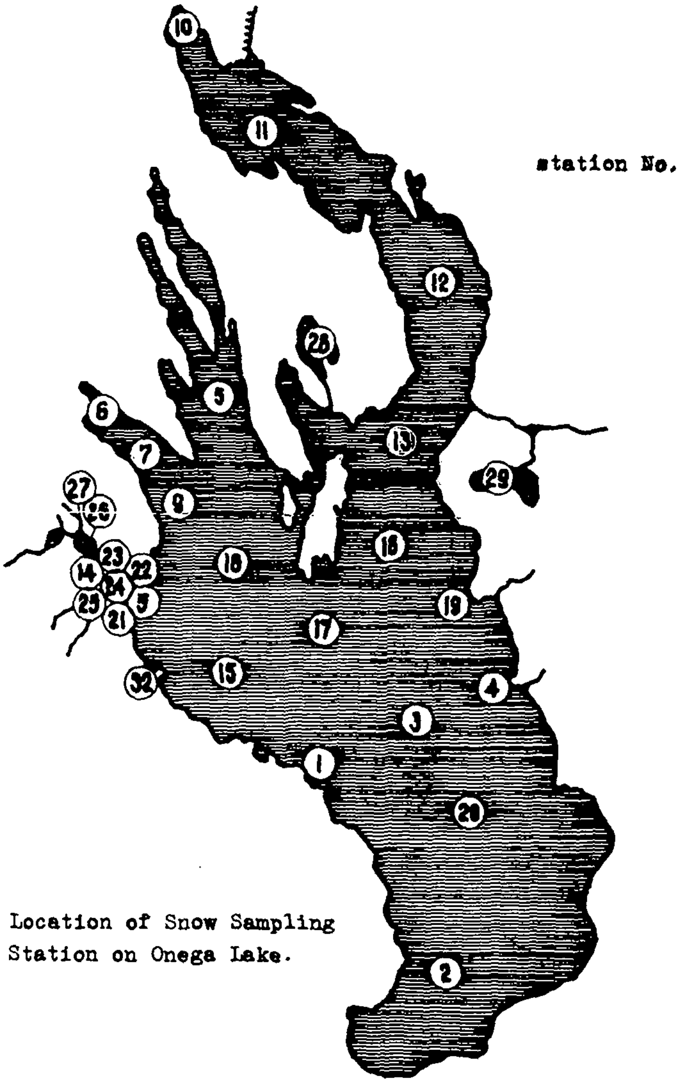


Fig..4 Location of Snow Sampling
Station on Onega Lake.

Vozhge, Lacha as well as the storages in the upper Volga and Sheksna.

3. Search for Adequate Mathematical Models of Pollutants Effect on Brightness of Snow Cover

The search may be grouped with the tasks of regression analysis of the results of chemical analysis of snow samples taken at specially designated stations; also subject to regression analysis were measurements of optical characteristics of space images of areas around the stations. Background data for regression analysis are entered into empirical tables. By processing the data, it is possible, using for every pollutant a least-square technique, to build a certain number of type (2) models, which, in fact, are linear or non-linear functions. How far these are adequate to the relationship being modeled is determined by the correlation coefficient. In the case of Onega Lake, the empirical table was prepared on the basis of snow sample analysis and of the results of MCY-C image processing, the date and time of picture-taking are given in Table 2.

Table 2. Date and Time of Space Photography of Onega Lake Area Using Scanner MCY-C

Date	13.05 85	04.05 86	09.03 87	13.03 87	15.03 87	16.03 87	09.04 87
Time of photography (Moscow time)	10.16-10.22	8.42-8.48	9.39-9.45	9.51-9.56	9.58-10.04	10.02-10.11	9.35-9.38

Snow cover reflection characteristics were identified with the density of obtained from space; images of respective points the density was measured by a microphotometer based on MV-40 photometer and a set of MSP-4c multirange projector. Interim results of the search for adequate mathematical models of the type (3.2) and of optimum combinations of spectral ranges of space photography for evaluating the pollution of the snow cover are given in Table 3. Because space pictures obtained at different times were used in the search, it appears that a statistical check of hypotheses on preferable times

Table 3. Correlation Between Content of Pollutants and Snow Cover Reflection Characteristics

Regression Equations	Snow Pollution Parameters									
	Phosphorus (P)	Total nitrogen (N)	Total iron (Fe)	Silicon (Si)	Organic matter (O)	Oil products (H)	BOD 20 (B)	Carbon (C)	Calcium (Ca)	Suspended solids (SS)
1	2	3	4	5	6	7	8	9	10	11
$C=\frac{K_1-a_o}{a_1}$	0.82	0.65	0.45	0.23	0.22	0.42	0.03	0.61	0.62	0.46
$C=\frac{K_2-a_o}{a_1}$	0.70	0.29	0.12	0.17	0.14	0.19	0.24	0.42	0.49	0.40
$C=a_o+a_1 \ln K_1$	0.80	0.65	0.37	0.07	0.33	0.14	0.26	0.58	0.60	0.43
$C=a_o+a_1 \ln K_2$	0.64	0.19	0.30	0.11	0.33	0.22	0.27	0.33	0.46	0.37
$\ln C=\frac{\ln K_1-a_o}{a_1}$	0.83	0.67	0.66	0.06	0.24	0.24	0.27	0.61	0.71	0.46
$\ln C=\frac{\ln K_2-a_o}{a_1}$	0.69	0.07	0.42	0.08	0.28	0.01	0.25	0.29	0.56	0.54
$\ln C=\frac{K_1-a_o}{a_1}$	0.84	0.67	0.69	0.22	0.12	0.08	0.03	0.64	0.74	0.50
$\ln C=\frac{K_2-a_o}{a_1}$	0.76	0.17	0.48	0.10	0.01	0.11	0.22	0.39	0.61	0.56
$\ln C=a_o+\frac{a_1}{K_1}$	0.77	0.54	0.61	0.10	0.28	0.23	0.34	0.58	0.65	0.41
$\ln C=a_o+\frac{a_1}{K_2}$	0.58	0.03	0.33	0.04	0.34	0.01	0.25	0.20	0.47	0.51

1	2	3	4	5	6	7	8	9	10	11
$C=a_o+\frac{a_1}{K_1}$	0.74	0.61	0.30	0.02	0.37	0.02	0.33	0.53	0.55	0.40
$C=a_o+\frac{a_1}{K_2}$	0.52	0.07	0.16	0.04	0.37	0.23	0.27	0.25	0.39	0.34
$C=\frac{a_1K_1}{1-a_oK_1}$	0.72	0.44	0.48	0.17	0.16	0.16	0.50	0.59	0.65	0.25
$C=\frac{a_1K_2}{1-a_oK_2}$	0.59	0.13	0.41	0.13	0.26	0.08	0.07	0.13	0.49	0.43
$C=\frac{a_1}{\ln K_1-a_o}$	0.76	0.47	0.50	0.16	0.11	0.22	0.11	0.62	0.70	0.30
$C=\frac{a_1}{\ln K_2-a_o}$	0.68	0.06	0.43	0.20	0.20	0.06	0.08	0.23	0.59	0.44
$C=\frac{a_1}{K_1-a_o}$	0.76	0.47	0.50	0.05	0.01	0.16	0.15	0.33	0.65	0.43
$C=\frac{a_1}{K_2-a_o}$	0.73	0.02	0.42	0.26	0.14	0.05	0.17	0.62	0.74	0.33

of snow cover photography from space to determine the degree of its pollution might be possible. Experience indicates that determination coefficients in regression equations obtained on the basis of springtime pictures, just before intensive snow melt, are usually higher than those of the regression equations based on the results of winter-time pictures. This may be due to the fact that in spring reduced albedo of polluted snow accelerates its melting more than does the factor of radiation balance and heat transfer, compared with winter. Incidentally, this fact may be used to advantage in marking an optimum choice of sites for sampling stations. The set, of the stations can provide maximum information by supplying the data relating to the task of identification of spatial distribution of chemical elements and compounds polluting the snow cover of water bodies. The sampling stations should be located in areas of maximum observed variability of snow cover pollution. In this case, the least-square technique provides high reliability because the matrix in the respective system of normal equations is well conditioned. It seems expedient to plan the location of sampling stations using maps prepared on the basis of pictures of snow cover of homogeneous brightness areas obtained through space photography during the pre-vernal period. "Densitron" unit can be conveniently used for the purpose. In particular, "Densitron-3" makes it possible to regiater 6 picture density gradations, each having its own colour code. Fig. 5 shows an example of Onega Lake snow cover, based on a picture taken on 27 May, 1987. For the sake of clarity, 3 gradations of the image optical density have been selected the darker shade snow on the lake, the snow of medium albedo values and the lighter shade snow. The differences observed stem from the effect of the shores, the "locked" position of the coves and even from the latitude of the area (in the south part of the lake the snow melt began, accompanied by the formation of a snow crust with a lower value albedo). The whitest snow observed was in the central part of the lake and in the Povenetsk Cove.

4. Statistical Verification of Hypotheses Regarding Effect of Various Pollutants on Reflection Characteristics of Snow Cover

The data of Table 3 are, in fact, the results of verifying such hypotheses. As the data on error distribution in the statistics of observations used were not available, it was difficult to find the adequate mathematical models of the effect. In case when error dis-

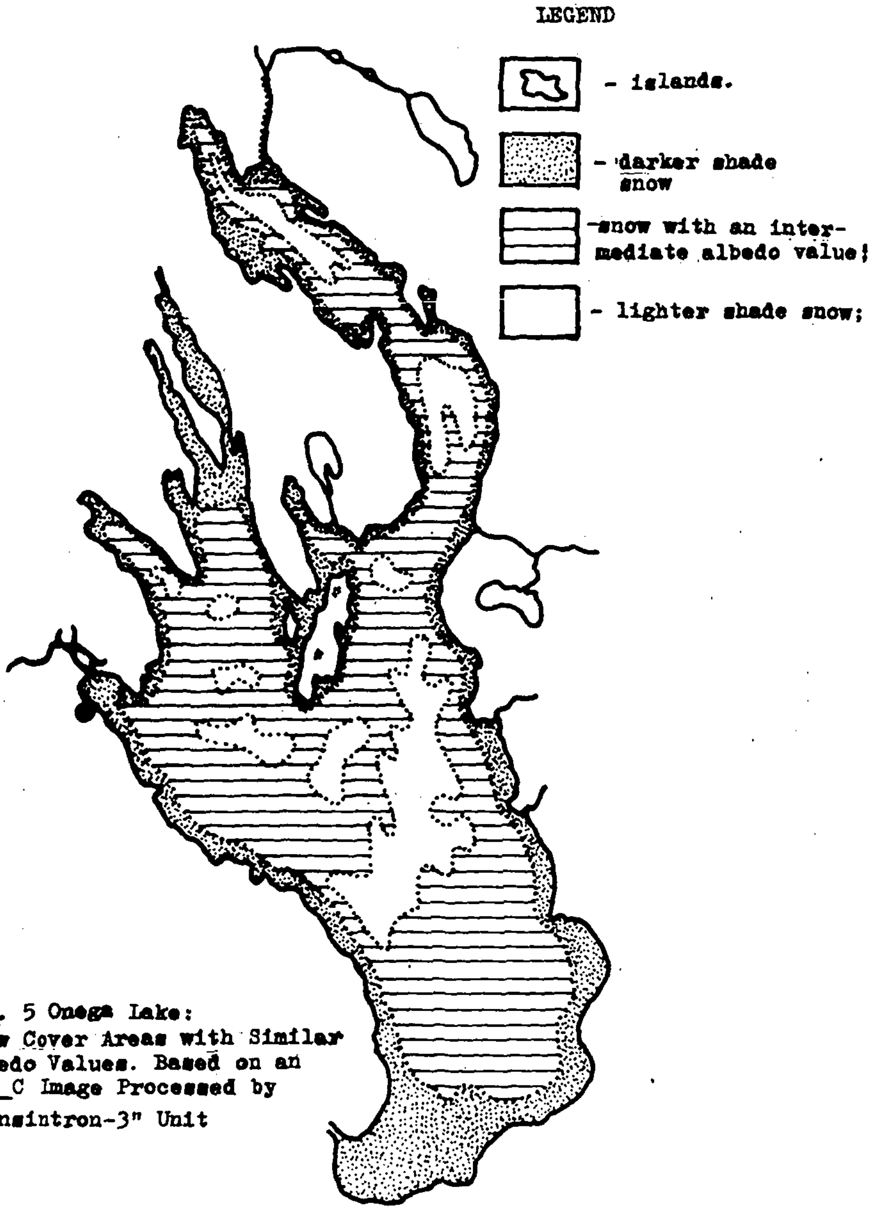


Fig. 5 Onega Lake:
Snow Cover Areas with Similar Albedo Values. Based on an MCY_C Image Processed by "Densintron-3" Unit

tribution is of unlimited dispersion, the least-square technique is known to lead to inconsistent estimates of regression coefficients. For this reason, in choosing the adequate model it was necessary to consider not only the correlation coefficient, but also the values of regression coefficient errors.

For most of the identified pollutants (content of phosphorus, total nitrogen, carbon and calcium concentration), maximum correlation coefficients, with consistent estimates of regression coefficients, were observed when comparing the data of snow-gauging surveys of 1985 with the space image parameters of 13.05.85. Apparently, this is due to the later date of space photography, because in the course of snow melt, the snow undergoes compaction, and the concentration of pollutants per unit volume increases which, in turn, results in the decrease of the snow surface albedo. Regression dependences on optical transmission coefficients in the visible range of photography (K_1) proved to be adequate to all of the above-listed indicators. True, in the case of calcium concentration and phosphorus content, meaningful correlation coefficient were also observed for the dependences on optical transmission coefficients in the IR-range (K_2). Since the physics of light reflection from the polluted snow cover is not yet studied at a sufficient depth, more research is required to provide an explanation to the observed spectral distribution of correlation coefficients.

For total nitrogen, a linear dependence dictated by K_1 value proved adequate:

$$N = 0.11(\pm 0.07) + 2.0(\pm 0.7) \cdot K_1$$

(correlation coefficient R = 0.65).

For phosphorus content, carbon and calcium concentration, non-linear dependences with the same type of non-linearity proved adequate:

$$\ln P = -5.8(\pm 2.1) + 7.7(\pm 1.4)\ K_1$$

$$(R = 0.84)$$

$$\ln Ca = 0.11 + 2.04(\pm 0.69)\ K_1$$

$$(R = 0.65)$$

$$\ln C = -0.61 + 7.58(\pm 2.63)\ K_1$$

$$(R = 0.64)$$

These equations can be used to quantify the spatial distribution of the indices under consideration.

Of all the correlation dependences of the snow cover quality indices and space image parameters in the IR-range, the meaningful correlation coefficients were noted for phosphorus content and calcium concentration only, where maximum correlation coefficient was in accordance with dependence:

$$\ln P = -5.4(\pm 0.02) + 6.3(\pm 1.6)\ K_2$$
$$(R = 0.76)$$

Thus, the distribution of image brightness both in the visible and in the IR-range matched in the best way the spacial distribution of phosphorus content while that of calcium concentration was matched poorly. Carbon and total nitrogen concentrations affected the brightness distribution in the visible range caly.

Of particular interest was multiple correlation and regression analysis of experimental results because the generation of multiple regression equations with consistent estimates of parameters would make it possible to evaluate the differences in the spatial distribution of the snow pollution indices under study. However, the generation of multiple regression dependences was difficult due to the presence of a fairly close correlation of independent variables (K_1 and K_2). A significant increase of the correlation coefficient, when an attempt to include a second independent variable in the regression equation was made, was only observed in the case of calcium concentration. Then, the regression equation assumed this form:

$$\ln Ca = 0.092 + 0.31(\pm 0.10)\ K_1 - 1.31(\pm 0.93)\ K_2$$
$$(R = 0.685)$$

The errors in the estimates of regression coefficients, when K_2 variable was introduced in the equation, became greater compared with an adequate paired regression equation.

In the case of iron ions concentration, maximum correlation coefficients (unlike the other parameters) were observed when the results of the 1987 snow gauging survey were compared with the space image obtained on 16.03.87. Adequate for this parameter proved a non-linear equation of the same form as the one used in the case of phosphorus content, carbon and calcium concentration:

$$\ln Fe = -6.4 + 55(\pm 11)\ K_1$$
$$(R = 0.69)$$

There were no meaningful correlation when the results of the

1987 snow-gauging survey were compared with the data of other space surveys undertaken in 1987. Apparently, the relationship observed was due to considerable releases of industrial pollutants into the atmosphere with a significant amount of iron particles on the day of survey.

5. Calculating the Mass of Pollutants Accumulated in Snow Cover of a Water Body

When calculating the mass of pollutants accumulated in the snow cover, and designing mapping models of pollutants' spatial distribution, a prior processing of space survey materials is required. The mapping models are built on the basis of regression dependences of pollutant concentrations on the space image parameters, the procedure of space survey being determined by the objectives of mapping model design.

When it is necessary to know the spatial distribution of pollutants over the entire area of water body, it is expedient to carry out segmentation of the water body image into areas characterized by a comparatively homogeneous distribution of brightness values. Image segmentation into areas of similar brightness can be done visually or with the aid of special equipment for analogous or digital processing. In case of digital recording of the image on a magnetic carrier, the segmentation can be done on a versatile electronic computer, using a method based on analysis of two-dimensional brightness bar charts (if multiple regression equations are applied) or of one-dimensional brightness ranges (if paired regression is applied).

When areas of similar brightness within each of the delineated segments (on the water body image) are identified, the mean value of brightness and its dispersion are calculated. Then, on the basis of regression dependences on the space image parameters, evaluation of pollutant concentration for each of the identified areas is carried out, and a confidence interval of the evaluation obtained is calculated. The interval is determined by brightness dispersion within the identified area and by the confidence interval for estimated values of dependent variables in the regression equations.

If the effect of specific sources of pollution is to be evaluated, it is more expedient to segment the images by a different method. First, in the image the areas of abnormal brightness must be identified. These areas are situated side by side with the sources of pollution under study, and in fact are the zones affected by these sources. The total mass of pollutants contributed by specific sources is estimated as an integral of regression functions taken over the affected zone area.

To calculate the total mass of pollutants released into Onega Lake, we used the first of the above-described approaches in 1984-1985, 1986-1987. "Densitron-3" unit was employed to delineate homogeneous areas in the Onega Lake image. Adequate for all the indicators evaluated, except iron ions concentration, were considered regression models constructed when comparing the results of the 1985 snow-gauging surveys with the space survey materials dated 14.05.85. For iron ions concentration, a regression model designed when comparing the results of the 1987 snow-gauging surveys with the parameters of a space image obtained on 16.03.87 was considered adequate. Table 4 features the results of total pollutants input evaluation.

Table 4. Mass of Chemical Substances (T) Accumulated in Snow Cover of the Onega Lake Area

	Phosphorus (Total)	Nitrogen (total)	Ammonia nitrogen	Organic matter	Hydrocarbons	Phenols	Tanning agents	Sulfates	Mineral matter (total)
1984-85	110	6170	874	26800	490	33	2180	31700	36000
1985-86									
1986-87									

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PROTECTION OF GROUND WATERS AGAINST POLLUTION

Dr. G.I. Kaplin

The role of water resources in human activity is constantly growing. However, in many parts of the world, the feasibility of meeting the adequate quality water requirements poses a serious problem. This is due to an extremely non-uniform distribution of water resources and to pollution of water bodies by the wastes of industries, public utilities and agriculture.

A particularly complex task is that of meeting water requirements of the population for domestic and drinking purposes. Therefore the 1981-1990 period has been proclaimed by the UN General Assembly as "The International Drinking Water Supply and Sanitation Decade".

Rational utilization of ground waters is of very great importance for implementing water management tasks because as a source of municipal water supply ground waters have certain advantages over surface waters. They are of better quality, do not require costly treatment and are better protected against pollution. Ground water resources are not subjected to considerable seasonal and perennial fluctuations, their sources may be tapped close to the user. The rate of abstraction may increase gradually as the requirements grow. For this reason, there has been, of late, a much heavier utilization of ground waters worldwide for municipal water supply, and in the arid regions - for irrigation as well.

In the Soviet Union (1, 8) the share of ground waters in the overall balance of municipal water supply has gone up to 70%. At present, over 60% of towns in the USSR meet their water supply requirements at the expense of ground waters; about 20% of the towns use combined sources of water supply (surface plus ground waters) and less than 20% of the towns meet their public utility requirements with surface waters only. For the last few years there has been a substantial increase in the abstraction from aquifers for crop irrigation, mainly in the southern regions of the USSR (Northern Caucasus, Transcaucasian Republics, South Kazakhstan, Central Asia). In all, around 30 km^3/year of ground waters is abstracted in the USSR at present; by the year 2000, this figure is expected to increase to 65-70 km^3/year.

The share of ground waters in the overall water supply balance of the country also grows. In 1940, it accounted for only 4-5%, at present, it has increased to 20% (11, 12). For the last 80 years, the water supply has increased 7.5 times overall, while the use of ground waters for the last 40 years has grown 15-fold, and at the present rate the annual increment roughly amounts to 5%.

According to the estimate made by the USSR Ministry of Geology, the total utilizable water resources of the country amount to over 10.000 m^3/s (2). Nearly 50% of the total utilizable ground water resources are renewable which indicates a fairly high level of reserves. Considering that at present in the USSR around 10% of the surveyed utilizable ground water resources are being used, the potential of water resources development is considerable (4).

In the US, the role of ground waters is great, with the annual abstraction rate of 90 to 100 km^3 which accounts for about 20% of the total water abstraction for all purposes, including industry. For the last 20 years ground water abstraction had doubled. The main ground water user is irrigated farming, which accounts for about 65% of the total utilized ground water.

Ground waters constitute the main source of municipal water supply for urban and rural population in many European countries. For example, in Bulgaria, Hungary, GDR, Austria, Belgium, Denmark, Switzerland, FRG, the Netherlands the ground waters account for 60 to 100% of the total water use for these purposes; in Britain, France, Poland, Czechoslovakia, Italy, Sweden and Finland - from 30 to 50%. Ground waters are widely used in Australia, in some African and Asian countries (Iran, India, PRC, Pakistan, Saudi Arabia, Japan, Tunisia, Egypt, Morocco, Libya). In some of these countries, the abstraction rate of ground waters, mainly for irrigation, amounts to 20-50 km^3/year (Iran, India).

Nowadays, the development of urbanization, industrial production and agriculture leads to a change in the quality of both the surface and ground waters. Until recently this was believed to have been caused by all kinds of point sources of pollution. However, at present there exists a definite trend toward regional change in the quality of ground waters. This is due to rapid development of agriculture. Although the pollution of ground waters by industrial wastes is essentially local, it is omnipresent to such an extent that can be regarded as a regional phenomenon.

The growing importance of ground waters as a natural resource, making the social and economic progress possible, requires their protection against pollution.

Therefore, while dealing with water protection issues, it appears necessary to evaluate various objects whose interaction determines a disturbance of the natural hydrochemical regime of ground waters and results in a change of their quality. A successful implementation of this task can be provided for by a substantiated, purposeful systematic arrangement of the initial data.

It appears wise to use for the purpose a hierarchic structure, a typical form of which is the "tree", its trunk and branches reflecting the different levels of the objects being studied, of interrelations among them. The hierarchic structure makes it possible to see the importance and place of particular factors in the inner development of the integral system (5, 6).

In the study of the changing quality of ground waters, it is necessary to consider a complex real system, whose interacting complex comprises the components "ground waters" and "environment". The "environment" may include objects internalizing the notion of "ground waters" and determining their pollution. For example, ground waters with pollutants may, under certain conditions, cause a pollution of exploited aquifer.

In the system under consideration, "ground waters" constitute one of the first-order objects. It may be classified on the basis of several characteristics of the same level, because they are not subordinated to one another, but describe the object in important though different, aspects. Among such characteristics may be:

- ground water recharge conditions (infiltration from the ground surface, lateral seepage, seepage from other aquifers);
- nature of interrelations between surface and ground waters (a surface water stream recharges or drains the ground waters);
- nature of water exchange (active, impeded very slow).

The other first-order object within the studied system is the "environment" comprising manageable and unmanageable units. The effect of the former ones on ground waters can be controlled, but the effect of the latter ones is uncontrollable. In the former case, the problems of water protection optimization are solved, in the latter case, development of the pollution process is prognosticated.

Second-order objects may include the sources of pollutants in-

Migration patterns of the transporting medium:

- pore space of the rocks;
- rock fissures;
- karst cavities and canals;
- absorptive openings.

Mode of pollutants' inflow:

- downward, in the course of periodic seepage through the aeration zone;
- with subsurface flow, continuously, the spread of pollutants is intensified after precipitations at points of ground water recharge;
- continuous percolation through the aeration zone;
- from surface water sources, through the side boundary of the stratum;
- at direct overflow through absorbing mine workings;
- from a polluted aquifer;
- from the water-bearing bed when it is subjected to drainage.

Special indicating signs (criteria) serve for evaluating the processes of ground water pollution, such criteria being just one of the manifestations of geological prospecting signs, widely used in the geological science.

The criteria of ground water pollution are the signs demonstrating a genetic relationship between ground waters and a particular pollution source. This relationship is manifested by the so-called focal points of pollution, i.e. segments of aquifers (or aquifer complexes) with ground water quality parameters differing from normal characteristics for a particular aquifer.

The signs are subdivided into geo-structural, lithological, hydrogeological and geomorphological, amenable to further, more detailed, classification.

Geo-structural signs:
- mode of rock occurance;
- uniformity of the water-bearing mass extent and thickness;
- presence or absence of tectonic fissures.

Lithological signs:
- mineral and petrographic composition of rocks;
- physical and mechanical properties of rocks.

put into the aquifer, such as:

- lagoons, evaporators, settling basins for waste waters;
- buried storages of industrial wastes;
- absorbing pits, wells and boreholes;
- ash and slag spoils and tailing ponds;
- surface runoff from inhabited areas and industrial enterprises;
- polluted surface water bodies/streams and marine waters;
- runoff from farmlands, where chemicals and fertilizers are applied;
- agricultural and effluent irrigation fields; filtration fields of industrial enterprises;
- animal wastes from livestock farms;
- sub-standard ground waters hydraulically connected with a protected aquifer;
- polluted grounds;
- drained area of certain mineral deposits;
- sites of industrial emergency waste release, defective severage network.

From the standpoint of historic or geological time, the quality of ground waters is not a constant value and, under the man-induced conditions, the processes of ground water quality changes are significantly accelerated. It is therefore very important to determine the conditions under which pollutants propagate from the source of pollution (9).

Here, the following can be considered as the first-order objects:

- the transporting medium, influencing the pollutants' pathway to ground waters;
- ways of movement of this medium, determining to a large extent the rate of pollutant penetration in the ground water;
- character of the pollutant's inflow, indicating the type of space-time connection between the ground waters and the environment.

The transporting medium comprises:

- effluents seeping through the seration zone into the subsurface flow;
- precipitations;
- irrigation water;
- waters of surface water-bodies and streams drained by the subsurface flow;
- ground waters (including saline).

Hydrogeological signs:

- conditions of ground water recharge, areal extent, and discharge;
- hydrodynamic characteristics of ground waters.

Geomorphological signs:

- orographic conditions;
- nature of relief dissection by erosion.

The search signs make it possible to analyse the "ground waters - environment" system, to establish the importance of various interacting factors, and, after synthesizing the data obtained, to substantiate the particular water protection measures, whatever their purpose: prevention, localization or rehabilitation.

Implementing water protection measures constitutes a purpuseful impact on the natural- and - man-induced system. This impact is based on cognizance of specific laws that govern the progress of a concrete material system, which eventually allows to direct the evolutionary process toward achieving an equilibrium in the development of the system and thus avoid the detrimental anthropogenic effects.

The elaboration of water protection measures as applied to ground waters is above all based on an all-round analysis of the natural conditions of a particular area. In this respect, it is essential to evaluate natural protection of aquifers against pollution and make special delineation of areas for this purpose. Methodological recommendations for the latter have been drafted by VSEGINGEO Institute (1, 7).

Protection of ground waters is understood as a degree of aquifers being "covered" by impervious deposits that make it impossible or difficult for pollutants to reach the aquifers. The thicker the cover, the more reliable the protection of aquifers against any kind of pollution.

The delineation of areas is based on specifying the factors that predetermine the ground water protection conditions. The following factors are studied: the aeration zone (its thickness, geological/lithological structure, availability of impervious corks, consistency of their water-physical and sorption properties); the top confining bed on which ground waters are formed (distribution, thickness, lithological composition of constituent rocks); hydrodynamic isolation of the aquifer under study from adjoining aquifers and from the surface waters; conditions of recharge, distribution and drainage of confined and ground waters; chemical composition of ground waters within the protected aquifer and the composition of water-bearing rocks that determine the physico-chemical properties in the "pollutant - water - rock" system; filtration properties of rocks, the physico-chemical characteristics of aquifers that determine changes in the chemical elements migration rates; local conditions of intensive filtration (physico-geological processes, tectonic features, mining, etc.); availability and nature of vegetative cover.

At the early stages of studies, the priority order of the above factors is set, with their absolute and relative role in protecting the ground waters against pollution being determined. This is followed by mapping which is carried out separately for confined and ground waters because of their specificity and substantial differences in the hydrodynamic characteristics, recharge conditions, distribution and discharge. On the basis of combinations of natural factors, ground waters can be empirically classified by the degree of protection against pollution.

If natural protection of ground waters is insufficient, the measures to protect ground waters against pollution are developed on the basis of the forecast of pollutants migration in the subsurface flow.

Pollutant composition, manifestation and effects, allow to distinguish bacterial, chemical and mechanical pollution of ground waters.

Bacterial pollution is characterized by the presence in ground waters of various pathogenic bacteria and viruses, whose main sources of input in the aquifers are: municipal effluents filtration fields, livestock farms, meat factories, slaughterhouses, feedlot farms, hide-and-skin processing factories, storages of liquid and solid animal wastes, and products of food-processing and leather industries; irrigated croplands using municipal sewage waters and animal farm wastes; all kinds of waste pits; defective sewerage network and sewage cesspools; absorption well, boreholes and pits for delivering sewage waters, to the aquifers; polluted surface water sources seepage in the water abstraction area and during flood periods.

A peculiar featurs of bacterial pollution is its local character, i.e. it does not spread far from the source of pollution and does not lead to formation of large sources of pollution. It rarely exceeds 0.5-1.0 km^2, and it may be greater in karst areas only (up to 5-10 km^2). Other features of bacterial pollution consist in that it is temporary and affects mainly the ground waters close to the surface. All these features are due to the limited survival period of pathogenic bacteria in ground waters.

In the last few years, the likelihood of chemical pollution of ground waters has grown due to the rapid development of industry, the extensive use of fertilizers and chemicals in agriculture, the use of industrial effluents for the irrigation of agricultural fields. At present, chemical pollution is most wide-spread. It manifests itself in new substances entering the composition of ground waters, or in increased content of the natural composition components which transforms the quality of ground waters to the extent where they fail to meet the water user requirements. Unlike bacterial, chemical pollution may be of long duration and difficult to remove in view of the absence of sorption and interaction with the water-bearing rocks.

The main source of chemical pollutants input into the ground waters are industrial and municipal effluents. The focal points of chemical pollution are: sewage lagoons (accumulators, evaporators, tailing dumps and sludge ponds, stilling basins, filtration fields, etc.); solid waste storages (dumps, ash, sludge- and salt-spoils, etc.); storage sites for oil products, raw materials and finished chemical products (water-soluble); areas of enterprises and individual shops, defective sewarage network; agricultural lands treated with fertilizers and chemical or irrigated by sewage waters; absorption boreholes and wells used for transfer of sewage waters to the aquifers; artesian saline water wells; buried accumulators of sewage waters; polluted surface water streams and water bodies in seepage abstraction areas; seas, salt lakes and saline water aquifers, when ground water is tapped through intake structures.

Industrial effluents are often mixed up with domestic sewage, leading to combined chemical and bacterial pollution.

Analysis of chemical pollution records shows that the major sources leading frequently to a protracted and stable pollution are the existing and buried storages of industrial wastes and effluents. The size of industrial effluents storages is usually considerable and runs into hundreds and even thousands of hectares. Their depth ranges from 5-10 to 30-50 m and sometimes is more than that. Capacity of accumulators often reaches 5 to 10 mln m^3.

A protracted utilization of industrial effluents lagoons leads to formation of large-scale foci of ground water pollution that occupy hundreds and thousands of hectares.

Pollution with solids manifests itself when there is a high content of suspended matter, and colloids in the water. In ground waters, this kind of pollution is rare. If the filtering mass is composed of sands, the mechanical admixtures are trapped in a few centimetre layers of the filtration pathway; in fissured rocks, the mechanical pollutants may reach somewhat deeper; it is only in heavily-karsted deposits that solids are capable of migrating over long distances.

Thus, by the scale of harm manifestation, the above-described types of pollution may be ranged as follows: chemical, bacterial and with solids.

As chemical pollution of ground waters is caused by seepage of industrial effluents and by runoff from agricultural lands into aquifers, attention must be paid to the state of ground waters in industrialized areas and in areas of intensive farming.

The area of pollution focal points is determined by the length of time during which the source of pollution has been in existence, by the composition and volume of waste waters coming into aquifers, by the subsurface water intakes in the vicinity of the sources as well as by the hydrogeological conditions of the area where the source of pollution is located.

Most adverse areas in respect of ground water pollution are river valleys with well-developed alluvial deposits. Here, the ground waters are usually close to the surface and poorly protected, if at all, against the penetration of pollutants. The deeper aquifers are reached by pollutants through "lithological windows" in the impermeable roof, through absorption well or as a result of polluted surface waters being trapped by infiltration intakes.

The composition of pollutants that impair the quality of ground waters or make them unusable depends on the type of industries and on the effluents. For example, concentrating mills of non-ferrous metallurgy contribute to the pollution of ground waters phenols, rodanides, cianides, salts of heavy metals, sulfates, etc.; food industries pollute with organics; petrochemical industries pollute with oil products, phenols, surfactants.

The type of industrial production determines to a large measure the type of basins and storages for industrial wastes. For example, in the case of mining, thermal engineering, metallurgical and some chemical industries where two-phase wastes are produced, it is usuall to arrange tailing- and sludge ponds, hydro-ash spoil heaps, "white seas"; in the case of oil-processing, pulp-and-paper, food and some chemical industries where liquid wastes prevail, they build stilling ponds, lagoons, evaporators, filtration fields. Domestic sewage and sometimes industrial effluents are used in effluent treatment or agricultural fieds.

The need for measures to protect ground waters against pollution is established on the basis of analysis of natural protection of the aquifers and of the forecasts of pollutants migration in the subsurface flow.

The type of engineering protection measures and their arrangement patterns are chosen on the basis of the geological/hydrogeological conditions of the area to be protected and on the basis of hydrogeological computations.

Such computations are mandatory when new industrial projects are planned or existing ones are expanded, and when the sites for storage of liquid or solid industrial wastes are to be found, when water intakes are to be built and an estimate of usable reserves of ground waters, available near industries or human settlements, is to be made; in areas where ground waters were subjected to pollution.

The rate and extent of pollutants sprend in an aquifer are much affected by the processes of physico-chemical interaction of effluents with ground waters and with the rock of the aquifer. Such processes include molecular diffusion, hydraulic dispersion, sorption and desorption, ion exchange, chemical reactions.

The diversity of effluents compositions and of the likely types of their interaction with rocks and ground waters makes it very difficult to forecast the quality of ground waters under the conditions of polluted water seepage. For this reason, it is customary at present to treat these processes generally, as processes of dissipation (diffusion and dispersion) and absorption (sorption, ion exchange, etc.).

Physical properties of industrial effluents, and, in particular, their density, are also important in the distribution of pollutants over the aquifers. They change the shape and position of the boundary between polluted and clean ground waters within the aquifer.

A quantitative estimate of solutions and effluents migrations consists in establishing their concentration at any point and time on the basis of the initial concentration or volume of particular pollutants that get into the aquifer.

Once the duration of effluents seepage is known and the intensity of seepage is determined, it becomes possible to establish the dimension of the polluted area of ground waters and on this basis decisions are made on the need for and the kind of protective engineering measures.

Water intakes are the most important areas in ground water protection. Here the likelihood of ground waters being polluted depends on whether or not the intake structure water zone overlaps with the polluted area. Polluted waters can only reach the intake if they are inside the water zone.

Forecasting the quality of ground waters in the water intake area includes the following estimates: the possibility of the water zone encompassing the polluted waters; the time it takes the polluted waters to be drawn toward the water intake area; change in the quality of the water at the intake as soon as the first portions of polluted water get drawn to it. Methodology of such calculations is rather complicated and is discussed in detail in special literature.

Rehabilitation of ground water quality is a difficult and complicated task, but, ground waters are to be increasingly used. In view of these two factors, the main aspect of the problem of ground water protection must be prevention of their pollution. To this end, a complex of preventive measures is carried out with a view to preserve the quality of ground waters whenever the potential risk of pollution becomes a possibility. The preventive measures include all kinds of screens, anti-seepage walls and drainage facilities set up in areas of likely inflow of pollutants to ground waters, and intended to minimize or prevent completely the pollution of the aquifers.

A very promising regional protective measure is the setting up of water protection zones with a strictly observed procedure of operating the waterworks and sewarage facilities of enterprises and with monitoring the state of ground waters and surface water streams. Such water protection zones are set up in areas with considerable reserves of fresh ground waters. Considering that the major usable reserves of ground waters occur in the river valleys (nearly 60% of all confirmed reserves in the USSR) and that these waters are most susceptible to pollution, the river valleys must be regarded as priority areas for setting up water protection zones.

In areas of existing ground water pollution, the most important priority criterion in implementing water protection measures is the importance of ground waters for household/potable water supply. On this basis the priority projects of water protection measures include water intakes of centralized water supply for the areas where ground waters are the only or the main source of water supply or where protection of such sources against pollution is preferable compared to the use of alternative sources of water supply.

Among the projects of priority implementation of water protection measures are also those where ground waters constitute the main source of surface water pollution.

As for priority of implementing water protection measures within the target areas being protected, one must proceed from the importance of water protection elements in the context of all the measures for the target area.

On the basis of this principle, the priority measures include those intended to isolate the sources of pollution (improvement of the waterworks/sewarage facilities of industrial enterprises, isolation drainage, impermeable walls, recultivation of buried and discarded lagoons of industrial wastes, etc.).

When the source of ground water pollution is surface water streams, the priority measures should prevent releases of poorly treated effluents into the water courses.

Measures of second order include rehabilitation drainage and treatment of drainage waters.

According to the "Fundamentals of Water Laws of the USSR and Union Republics", ground water protection is the responsibility of enterprises and organizations whose activity has an adverse effect on ground waters. The subsequent decrees of the USSR Council of Ministers state that ministries and agencies of the USSR, the Councils of ministers of the Union Republics, enterprises, offices and organizations bear full responsibility for the conservation of nature, rational use and reproduction of natural resources, and for the timely implementation of nature conservation measures. This fully applies to protection of ground waters against pollution as well.

Elimination of the consequences of ground water pollution is a complex, rather costly and time-consuming task.

When there is a heavy accumulation of pollutants in a stratum, while their desorption capacity is low and so is the percolation of rocks, it may take dozens and even hundreds of years to "shift" the focus of pollution. There have been instances when ground water pollution could not be get rid of at all. In view of this preventive measures are the most important ones measures.

The most radical preventive measure is aimed at maximum treatment of industrial and domestic effluents before they are pumped into storage tanks or released into open water bodies. In other words, conditions must be created that would absolutely rule out the release of untreated effluents. This is encouraged by setting up waste-free production cycles, introduction of recirculating industrial water supply and sewarage, isolation of effluents transporting lines, elimination or treatment of gas/smoke releases at industrial enterprises, monitored limited application of chemicals and fertilizers in agriculture.

To prevent seepage of effluents at industrial sites all aquifers, water supply lines and shops should be provided with a reliable hydraulic insulation and drainage. The insulation is made in the form of a screen from a sand-gravel-clay mixture or a polythylene film laid in foundation of structures. The effluents and solutions accumulated on the screen surface get intercepted by drainage filtering elements and via pipes are fed to water receiving tanks from where they are pumped to the treatment facilities. In a case like this, it is common to use stratum and linear dewatering widely employed in industrial construction and town planning to protect structures against underflooding with ground waters.

In cases when industrial sites create high pollution of air and soils, the surface runoff must also be subjected to collection and treatment.

Depending on the purpose and type of operation, anti-seepage devices can be of two main kinds: for dams and for reservoir basins.

Anti-seepage screens are made of an impermeable clayey ground, a polymer film, a ground-polymer mixture or bitumenous materials. From the standpoints of design and operating conditions, the screens may be of three types: single-laver, double-layer and combined ones.

A single-layer clay screen is a solid layer of compacted impermeable clayey ground of prescribed thickness. Its efficiency depends on the clay material seepage coefficient and on the effective seepage gradient. Such screen allows certain losses of fluid from the storage. Therefore, it can only be used where the storages contain non-toxic or low-toxicity effluents with seepage within strictly specified limits.

To prevent the intrusion of marine waters into fresh water aquifers, a hydraulic screen method can be used, whereby fresh ground waters are pumped through specially-equipped boreholes into the exploited aquifer. So, a fresh water barrier prevents penetration of marine waters into ground waters; at the same time, ground water reserves are recharged in this way.

The choice of engineering preventive measures is preceded by appropriate surveys, studies and hydrogeological calculations, aimed at finding the answers to the following questions:

- can pollutants penetrate the water-bearing strata, and, if so, to what extent?;
- what are the directions and the distance of pollutants spread and what will their concentration be at different points of the stratum at a certain time, and, above all at the ground water intake sites?;
- can pollutants reach the water bodies and water courses by seepage? In view of the current pollution of surface water sources a possibility is estimated of water seepage from these into the water-bearing strata;
- what are the obligatory measures to prevent ground water pollution in designing enterprises, effluent lagoons and basins that may become the sources of pollution?

The possibility of pollutants input into aquifers and its extent are determined on by calculation of seepage losses at the sites of potential sources of pollution; the losses are determined with due account for the geological structure of the sites and for the hydrological regime of the pollution sources.

The next step is to estimate the likely directions of pollutants migration in ground waters, and the possible dimensions of pollution foci.

The rate and distance of pollutants spread are in large measure affected by the processes of physico-chemical interaction between effluents and ground waters and rocks.

When examining a case of aquifer pollution, it is customary to consider three zones, differing by the quantity of pollutants.

In the first zone, the closest to the source, the ground waters are most polluted. Here, the concentration of pollutants approaches that of the pollution source. The third, or the farthest, zone is practically free from pollutants. In between a transitory zone is located, where the polluted and clean waters are mixed by convestive diffusion, their pollution gradually changing from maximum to background.

Under the conditions of a continuous inflow of polluted waters, as time goes on, the boundaries of these zones are shifted in the direction of the seepage flow, which expands the zone of polluted waters.

Pollution localization measures are planned in areas of existing sources of pollution or where the sources have been eliminated, but the focal point polluting ground waters and soils remains, and may become a secondary source of pollution. The purpose of localization measures is prevention of pollutants spread toward the area to be protected (usually, a water intake or a water stream).

The need for localization measures evises when the area under protection is "reached" by pollutants, upsetting the standards of water quality in that area.

Various kinds of drainage and anti-seepage screens are used as localization measures. The main requirements on drainage and drainage screens is that these are to form a depression cone in the pathway between the focal point of pollution and the target area.

Horizontal drainage usually is laid in grounds of low permeability (with the seepage coefficient under 3 to 5 m/day) that are fairly stable on the slopes, the depth of aquiclude up to 10 m. The small depth of horizontal drainage is a serious constreint on its uses.

If the aquifer bedding is deeper than 10 m, vertical drainage is used. When intercepting drainage is employed, the problem of polluted water utilization and evacuation after pumping out has to be resolved.

Anti-seepage screens made of impermeable materials are arranged at the depth of 30 to 50 metres, an obligatory requirement being that the screen should reach the aquiclude bed of the aquifer. The screens are positioned at the border-line separating the unpolluted and polluted waters from the side of the area to be protected.

Impervious screens are made either by forcing solutions through boreholes, to fill the pores and fissures and thus impart a water - impermeability quality to the rock (injection screens) or by arranging a narrow trench or slot, running the entire thickness of the aquifer, and filling it with an impervious material (a "wall in the ground" technique).

In the latter case, the tranches are dug under a layer of a heavy clay solution with the aid of excavators, cable scrapers and special drill-milling rigs. As the trench depth grows, it is gradually filled with impervious solidified and/or loose material, i.e. concrete mix, cement-clay or clay solution.

Anti-seepage screens require a considerable capital investment, 2 to 5 times over that for vertical drainage intended to resolve similar problems. However, in some cases, the use of anti-seepage screens is expedient for the following reasons:

- the screens make it possible to preserve the usable ground water resources of protected water intakes, which cannot be ensured by vertical drainage;
- the screens practically require no operation and maintenance costs;
- further improvements in the technique for the construction of anti-seepage screens (especially, of the "wall in the ground" technique) will eventually result in a considerable reduction of construction costs.

Measures to rehabilitate the quality of ground waters are applied in areas where pollution of water sources has been discovered. Here two alternatives are possible: the source of pollution still exists, or the source of pollution has been eliminated. In the former case, the priority task is to isolate the source of pollution. This can be achieved by arrangement of an anti-seepage screen or an intercepting drainage around the perimeter of the source. Within the focus of pollution, ground waters are rehabilitated with the sid of water intakes. When it is necessary to speed up rehabilitation of ground waters, more temporary drainage facilities are arranged within the focal point of pollution between the protected area and the source of pollution.

Sometimes, when the amount of pollutants accumulated in a stratum is too high, their desorption is low, and where the seepage properties of the rocks src.poor, it may take scores years being the reins and ground waters are absolutely free of pollutants. In other cases, in view of poor desorption of pollutants a complete elimination of the focal point of pollution requires the pumping out 10 to 15 volumes of water.

In order to determine the required amount of water for complete washing out of pollutants from the rock, desorption tests are performed in laboratories, involving the monolith and rock samples obtained in the focal points of pollution.

To expedite the "shift" of the pollution focal point, drainage is sometimes combined with clean water pumping into the rocks, throung injection wells.

The rehabilitation measures also include the treatment of drainage waters.

Analysis of the breakdown of the costs of pollution foci elimination and polluted ground water rehabilitation by vertical drainage shows that out of the total cost of the operations, the construction and operation of drainage waters treatment facilities account for 80 to 85%, the balance of 15 to 20% only being the cost of construction and operation of the drainage system, the pipelines, the observation network.

In conclusion, it must be pointed out that the final choice of measures to protect ground waters against pollution is to be preceded by their technical and economic justification.

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METHODS OF AND INSTRUMENTS FOR ANALYTICAL MONITORING OF WATER RESOURCES

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Monitoring of the state of water resources, above all by the content of major ions, has been in effect in the USSR since the 1930's. Yet, the problem of organizing systematic monitoring in view of the growing impact of human activity, came to the fore in the early 1960's. As from 1972, when the National Service for Surveillance/Monitoring of Pollution of Natural Environment (NSSM) was established, a system of monitoring has been in operation in the USSR, covering, among other things, the state of mainland surface waters.

As a system, monitoring deals with the problem of evaluating and forecasting surface water pollution, and comprises a number of inter-dependent links, among which one of the most important is analytical support of the system. This link determines the quality and, to some extent, the quantity of source information on the chemical composition of water, the nature and level of its pollution. At the same time, being part of the analytical support of the entire system of monitoring the natural environment, this link is to ensure the comparability of the data obtained with the information on the state of other objects of natural environment.

Analytical methods, as the basic component of the monitoring system analytical support, determine to a great extent the capability of monitoring and the scope of problems it can handle. Analytical methods allow to set up generalized indices of water quality and composition, both comprehensive and component-by-component. Theoretically, under conditions of human impact, hundreds of thousands of pollutants of varying toxicity and persistency may find their way to water bodies. Many of these were detected in waters in the course of experiments. For example, over 1.500 compounds were identified in the water bodies of the USA*). Admittedly, a complete analysis of water composition by individual compounds, let alone the forms of their existence, is unrealistic. In this context, a list of priority pollutants was compiled on the basis of occurrence, toxicity and observed concentrations.

In line with this concept, the scientists and experts engaged in the monitoring of the state of water resources, deal mainly with the elaboration of effective procedures for analytical monitoring of the following groups of pollutants: heavy metals, petroleum products, pesticides, phenols, surfactants, and biogenics. They also deal with the problems of analytical monitoring of major ions, natural and specific pollutants.

For a long time, the potentials of analytical monitoring of waters had been limited by inadequate sensitivity of chemical analytical methods. The development of instrumental physico-chemical methods made it possible to broaden the potentials of analytical chemistry of waters. At present, the methods and technical means of measurement on the whole ensure the monitoring of the priority list of the water quality indices. At the same time, the rapid development of instrumental methods opens up new vistas, in resolving newly-emerging problems of monitoring the pollution of water bodies.

Heavy Metals

Up to now, the most widely used methods of detection of heavy metals in waters have been photometry and spectrography. As the detection ranges of these methods usually do not allow measurements in situ in natural waters, the procedures envisage prior concentration.

The main advantage of extraction-photometric methods is that the instruments used are simple and can be easily acquired by any, even the tiniest, laboratory. As a rule, they use methods described in Manuals (2, 3). It must be pointed out that in view of the comparatively low selectivity of many of these procedures, additional operations should be included to eliminate the interference of other natural water components. At times, this leads to a considerable complication of methods and, consequently, to a decrease in their reliability. For example, a widely used dithizon methods of determining Cu, Pb, Cd and Hg, which are often present in waters in combinations with one another and are known to react with dithizon practically under the identical conditions.

The extraction-photometric methods currently used make it possible to analyse rather heavily polluted waters but in a number of cases they fail to ensure a reliable analysis of unpolluted waters. All the more reason not to use such methods for background monitoring. However, taking into account their proximate quality, accuracy and low cost of equipment, photometric methods will continue to be used in future for monitoring the pollution of mainland surface waters.

An emission analysis is very popular with water analysts. The main positive feature of the method consists in that it allows a simultaneous determination of a large number of elements. The procedure employed in network laboratories envisages a preconcentration of metals being determined with the aid of extraction by chloroform in the form of complexes with diethyldithiocarbamate and 8-oxyquinoline (4). This method is good for detecting the presence of Fe, Al, Mn, Cu, Ni, Co, Sn, Ti, Bi, Mo, V, Pb and Ag. Interference can be caused by considerable amounts of iron which may be separated through extraction by sulphuric ether after evaporation of samples, though this is accompanied by the loss of molibdenum and tin. If extraction is performed with amylacetate, only tin is removed with iron. The unfortunate drawback of the method is its relatively prolonged time due to the need of thorough preparation of samples and standards as well as to some other operations.

One of the most promising trends of emission analysis development is the initiation of the spectrum by a high-frequency inductively coupled plasma (ICP). This method is characterized by sensitive detection ranges, which allows direct detection of metals on the level of ug/l units. The high stability of excitation ensures good reproduction of results. Besides, when ICP is used, the effects of a matrix and of "third" elements is substantially reduced. In some cases, this makes it possible to do without standards, simulating the composition of the object analysed, which are necessary when the source of excitation is an electric arc or a spark. These obvious advantages explain the good prospects of the method for natural waters analysis.

An atomic-absorption analysis (AAA) is becoming increasingly popular with analyst-hydrochemists (2, 5). AAA with an air-acetylene flame allows quick determination of the presence of a large number of metals. But the high detection ranges of the method call for pre-concentration, often performed by extraction with chloroform, although direct placement of chloroform extract in the flame notably affects the stability of combustion. This shortcoming is eliminated if a concentration method is used, based on extraction by methylisobutylketone of metal complexes with diethyl- and pyrolydindithiocarbamate.

An electrothermic AAA, with lower detection ranges, makes it possible to detect directly the presence of heavy metals in natural waters at the level of 1 ug/l and even lower. For the last few years, the Soviet and foreign researchers have done a great deal to eliminate a considerable matrix effect, the main drawback of the method.

The use of Lvov's platform was a real breakthrough in the solution of this problem. It was proposed also to use, instead of Lvov's platform, a co-axial platform (6) for analysis, which, while having all the advantages of Lvov's platform, makes it possible to increase the volume of the sample under analysis thereby reducing the detection level. This method allows a direct analysis not only of slightly saline waters but also of marine waters and brines.

Inversion voltammetering is an effective method; which in addition to direct determination of trace amounts of some heavy metals in waters, allows to determine the forms of their existence. A serious constraint to wider use of this method in monitoring laboratories is the necessity of using a mercury electrode. The replacement of the mercury electrode by a hard graphite one has facilitated introduction of this method on a large scale.

Oil Products

Determination of oil and oil products in waters constitutes one of the most difficult problems of analytical hydro-chemistry. The problem becomes more and more involved as new information is coming in on the peculiar features of oil properties and on its behaviour in natural waters.

From the standpoint of aims and objectives of monitoring, the methods of oil analysis in natural waters must meet the following requirements:

- be sufficiently sensitive, accurate and fast for rapid evaluation and prediction of water pollution at different levels of anthropogenic load, including the background load;
- to take into account characteristics of oils behaviour in the water, the diversity of chemical composition of natural waters and of the oils reaching them;
- be acceptable to network laboratories and be based on modern instruments made by domestic industry.

In the USSR these requirements are met through a rational analysis scheme elaborated by the Hydrochemical Institute. The scheme includes a group of methods applicable for determination of individual components of oil products (volatile and non-volatile, including polycyclic hydrocarbons, resins, asphaltenes), the diversity of their chemical components under the conditions of fresh and chronic pollution. This scheme is based on a thin layer chromatographic fractionation (a thin layer of aluminium oxide as a sorbent, hexane-carbon tetrachloride-glacial acetic acid as a mobile phase), in which case different oil products form three or four (if surfactants are to be isolated as a separate zone) chromatographic zones, identified as hydrocarbons, resins and asphaltenes. Pre-separation of oil products is made by extraction using carbon tetrachloride, volatile hydrocarbons are separated by distillation with a solvent in a closed system prior to chromatographic fractionation. The elements are then identified using the IR-spectrophotometric method (= 2926cm^{-1}).

Non-volatile hydrocarbons are identified by IR-, UV-spectrophotometric and luminescent methods (see the Table). Investigations of a large number of water bodies showed that 75% of parallel determinations obtained by these methods provide a satisfactory reproducibility of the data. In other cases, the relative standard deviation reached 50 to 100%, and in 5% of the cases even up to 300%. Errors like these are due to a considerable difference in the group composition of the oils in real conditions because of their fractionation in the course of chemical, biochemical and other transformations which are impossible to take into consideration by choosing proper standards. In order to eliminate this effect, a combined method was devised based on measuring absorption in the IR (=2926 cm^{-1}) and UV (=270nm) ranges and on the computation of the total content of hydrocarbons using the empirical equation $C = 0.22+0.5D$, deduced from the analysis of 22 different samples of crude oil and oil products. Practical study of the method proved its high reliability.

A no-standards method was proposed instead of the gravimetric one, to be used as a direct arbitrage method based on a pyrolytic burning of pre-separated hydrocarbons and their identification by the content of organic carbon on an optical-acoustic gas analyzer. The methodological basis of the method is the affinity of the element composition of the hydrocarbon fractions isolated from vari-

Table Methods of identifying volatile and non-volatile hydrocarbons, polycyclic hydrocarbons, resins and asphaltenes

Component	Method	Conventration range, mg/l	n	Sr, %
Non-volatile hydrocarbons	Luminiscent	0.05-1.00	93	10-15
	UV-spectrophotometric	0.10-0.80	25	10-15
	IR-spectrophotometric	0.08-0.30	40	10-12
	Combined	0.10-0.80	50	8-15
	No-standards, based on organic carbon	0.02-0.10	56	5-10
Volatile hydrocarbons	IR-spectrophotometric	0.10-0.20	36	7-9
Polycyclic hydrocarbons	Luminescent	6 10^{-5}-8 10^{-5}	20	22
	UV-spectrophotometric	6 10^{-5}-8 10^{-5}	20	28
3,4-benzopyrene	Low-temperature luminescence	6 10^{-5}-1 10^{-4}	17	15
Resins,	Luminescent	0.01-0.16	70	10-25
asphaltenes		0.01-0.10	70	15-25

ous oils. Its low detection range (0.01 mg/l) makes it possible to reduce the sample volume to 100 ml. For this reason the method is very convenient for routina analyses.

To identify the resin components of oils, their ability to luminescence under UV radiation ($_{lum}$ = 530-550nm) was used. It was also helpful in identifying the petroleum and biogenic oil products. It was established that for water un polluted by oil, the spectra of luminescence of organics occupying the same chromatographic zone with resins and asphaltenes are shifted to a shorter-wave ($_{lum}$ = 470-480nm) or to a longer-wave ($_{lum}$ = 680-700nm) band compared with the maxima typical for resins and asphaltenes. This idea was the basis for identification criteria.

Unlike other schemes, e.g. used for analysing marine waters, the proposed scheme of systematic group identification and determination of oil and oil products allows to obtain the following information from a sample of 2 to 3 litres in volume:

- more complete results of determining the total content of oil products;
- the content of main oil components: volatile and non-volatile hydrocarbons, resins and asphaltenes;
- information on the nature of hydrocarbons in the water.

Pesticides

In monitoring natural waters, the following are the priority classes of pesticides:

- organochlorinated insecticides (OCI);
- organophosphate insecticides (OPT): defoliants and acaricides;
- triazene herbicides;
- herbicides, derivatives of a chlorphenoxy-acetic acid (2, 4D).

It is usual to conduct semi-quantitative determination of polychloribiphenyls (PCB) simultaneously with identifying OCI of the DDT group.

In the fisheries zones of the USSR the existing standards rule out the presence of practically all of the above-listed groups of pesticides. In fact, the values of MAC depend on the sensitivity of the analytical methods used. In most cases, the content of pesticides is determined by a gas-chromatographic method, the thin-layer chromatography is employed comparatively seldom. The methods of sampling and sample preparation are the same as traditionally used in analytical practice worldwide. The main method of pesticide separation is liquid extraction by hexane. This is accompanied by extract treatment using column chromatography and by treatment with appropriate reagents. Concentration is achieved by evaporating the solvent in the Coudern-Deniche apparatus or in a rotation evaporator, the derivation being done in a traditional manner. Gas-chromatographic fractionation is usually done in a 1-2 m packed column. OCI and derivatives of a chlorphenoxy-acetic acid are determined with the aid of an electron-capture detector. The currently used methods ensure the following detection ranges:

OCI - 2 to 20 ng/l;

OPI - 20 to 80 ng/l;

triazene herbicides - 80 to 150 ng/l;

a group of 2,4D herbicides - 100 to 200 ng/l.

Active reseach is under way with a view to expanding considerably the list of pesticides identifiable by the monitoring network. Another problem currently being resolved is the unification of procedures of sample preparation and of instrumental identification methods used in all the objects of the environment, aimed at setting up a unified system of pesticides monitoring.

Phenols

Phenols belong to the group of most dangerous organic pollutants, and their concentrations is natural waters must be strictly limited. Phenols that occur in the surface waters traditionally are subdivided into two groups: volatile, i.e. removable with steam (phenol, o- and m-cresol, xylenols, chlorphenol, etc.) and non-volatile, i.e. those that cannot be removed with steam (resorcinol, pyrocathechol, hydroquinone naphtols and other multi-atom phenols). This grouping of phenols was adopted because the distilling method could only determine volatile phenol compounds (2). Such an approach was justifiable as the sanitary standards restricting the content of phenols in the water are determined by organoleptic characteristics, typical for volatile phenols. At the same time, this generally-accepted method fails to determine the contribution of non-volatile phenols although their content in industrial effluents is generally higher than that of volatile ones.

Thus, in evaluating the pollution of water bodies with phenols there emerged a problem of obtaining information on the total content of phenols. Taking into account the necessity of analysis under the conditions of a network laboratory, the main attention was paid, in devising an optimum procedure, to the simplicity and accessibility of apparatus. From this standpoint, an optimum method is extraction photometry. Phenols are extracted by a mixture of n-butylacetate and tributylphosphate (3:1). Spiking with tributylphosphate makes it possible to obtain high values of extraction factor at a single extraction. Re-extraction from the organic phase is done by 1 M KOH, and then phenols are identified photometrically with 4-amino-antipyrine at $\approx$ 490nm. The method allows determination of the total phenol content at the level of 1 ug/l and upwards.

Individual Organic Substances

It is often necessary to identify and quantify individual organic pollutants. Most effective for these purposes are gas-chromatographic and chromato-mass spectrometric methods. However even with these highly sensitive and informative methods the task remains extremely complex. Its complexity is due to a number of factors:

1. Rapid variability of composition of organic pollutants between water sampling and sample analysis.

2. Complexity of organic substances mixture. Even the best capillary gas-chromatographic columns frequently fail to ensure a complete fractionation of pollutants isolated from the water. A need arises for labour-intensive and tedious operations to fractionate the mixture by physico-chemical properties into separate classes inside which a fairly satisfactory fractionation is attainable.

3. Rather low (ug and ng per litre of water) concentrations of individual compounds under analysis. As the sample volume fed into a gas-chromatographic or chromato-mass-spectrometric system with a capillary column is very small (0.5 to 2.0 ul) the degree of concentration in the water sample must be very high and reach 10^3 to 10^4.

These problems allow to formulate the basic requirements to schemes and techniques of water sample preparation for CC and CMS analyses:

- possibility of using the methods on the spot, at the water body, with a minimum set of transportable devices, reagents, materials;
- provision of high concentration of analysable compounds in a minimum volume of the concentrate, and, accordingly, of the initial water sample;
- possibility of isolating a wide spectrum of organic and also of individual fractions, distinctly separable chromatographically.

At present, in determination of organic pollutants, gas and liquid extraction are the two most widely used methods of sample preparation for feeding into the chromatograph. Gas extraction is more efficient in determining relatively volatile low-molecular compounds. It is used in two modes: static (analysis of vapour phase above the water sample) and dynamic (blowing off of identified pollutants into a trap with a solid sorbent or a liquid absorbing solution). To allow the use of both concentration methods, modern chromatographs are furnished with special gadgets - vapour phase analysers and systems for the cycle "blowing off - trapping - thermodesorption".

Extraction with water-immiscible solvents is used for compounds poorly soluble in water. Liquid extraction allows isolation from water of practically all classes of organics. However, identification of volatile compounds in the extracts is often made difficult because their chromatographic peaks are overlapped by the peak of the solvent - extracting agent. Therefore, liquid extraction is preferable for compounds of moderate or low volatility. Variation of solvent-extracting agents, and the water sample pH makes it possible to change selectivity of extraction within certain limits and to isolate the required group of pollutants. However, in most cases, additional treatment of the extract is required to remove the co-extracted substances that hinder identification.

Other methods of sample treatment (concentration by sorption, freezing out, boiling off, reverse osmosis, etc.) are so far used on a small scale, mostly in research.

Quantification of organic pollutants in waters with the aid of gas chromatographs furnished with 3-4 types of detectors, including selective detectors, is fairly reliable. Yet the problem of quantitative identification of the compounds can only be solved if a mass spectrometer is used as a chromatographic detector. Chromato-mass-spectrometers are far more expensive compared with conventional detectors but then their scope is much higher. For example, identification of organic pollutants in waste water discharged into a water body under study may take months with a chromatograph used as a detector or it may involve just a few analyses on a chromato-mass-spectrometer. Modern chromato-mass-spectrometers are furnished with powerful computers, libraries of mass-spectres containing records of scores of thousands of organic compounds and may be used to solve various problems of the water body pollution monitoring.

On-line Monitoring Methods

The growing anthropogenic load on the water bodies, especially on the sources of potable water, has necessitated elaboration of special methods and technical means of continuous monitoring. Automatic systems of AHKOC-BI type for water pollution monitoring are being elaborated and set up in some major cities of the USSR. Such systems are based on ACK3B automatic monitoring stations producing information summed-up by the Data Processing Centre (DPC). Multichannel automatic analysers in the stations meter as many as 17 essential water quality parameters (temperature, turbidity, electric conductivity, pH, Eh, oxygen, chlorides, nitrates, nitrites, phosphates, fluorides, sodium, total iron, copper, chromium, UV-absorption as an indicator of dissolved organics content, and the water level). The automatic systems also include mobile hydrochemical laboratories (MHCL) mounted on cross-country vehicles. The MHCLs are intended for both a detailed examination of the state of particular water bodies when the automatic stations signal emergency pollution, and for work under an independent program within the AHKOC-BI system. As MHCL is capable of a field monitoring of over 30 hydrochemical and hydrobiological indices, the information it feeds to the DPC considerably expands the ingredient resolution of the automatic system.

Helicopters have been increasingly used within the last few years in an on-going survey of water bodies. Helicopters make it possible to sample the water and promptly deliver the samples for laboratory analysis. Besides, the use of helicopters allows an analysis of priority parameters of water quality with the aid of portable technical means and filed monitoring test-methods.

OK-120 photocolorimeter with its own power supply unit has been developed for photocolorimetric measurements. KAII-105 portable multi-parameter analyser equipped with an immersion sensor allows a rapid determination of 9 parameters, including temperature, pH, Eh, oxygen, electric conductivity, turbidity as well as the content of chloride and sodium ions. A micro-processor version of the unit, now being developed, will also function as a versatile field ionometer.

The use of visual colorimetry and of reagent test papers served as the basis for the development of field test-methods of semi-quantitative identification of priority pollutants like copper, zinc, iron, surfactants, phenols. For example, a test-method of identifying copper with the aid of reagent test paper allows to analyse natural and waste waters for the presence of this highly-toxic ion with a detection limit below 5 u/l.

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ENVIRONMENTAL IMPACT OF WATER RESOURCES DEVELOPMENT PROJECTS IN BANGLADESH

Mr. A. Sarker, Mr. A. Mazumder

1. Introduction

The aspect of healty environment is receiving attention since the very recent past. Previously it was considered that nature was independently capable of renewing itself despite human intervention. Consequently, as industrialization, urbanization, rural based agricultural development and population continued to grow with time, separate aspect of environment protection suffered in utter neglect.

This is why the environmental impact of development activities started receiving attention since last seventies. The awareness on environmental impact calls for planned development always taking note of safety and protection of environment. In simpler terms, this implies the fact that any permanent change caused by human intervention to the natural setting of a region, called for serious thoughts and attention towards maintaining the natural ecological balance of the environment.

Bangladesh is a rural based agricultural country. Water resources are major input for agricultural development. As such like urbanization and industrialization, water resources development activities contributes significant impact on environment in Bangladesh.

Bangladesh is a land of flat deltaic area of about 1,43,000 sq. km having a population of 100 million and situated in the confluence of three great rivers of the world the Brahmaputra, the Ganges and the Meghna. The three eivers converge in the south-central part of the country and flow together in the Bay of Bengal. Each year enough water flows through Bangladesh to cover the entire country to a depth of 9.0 metre. The rivers are fed by melting snows in the summer and monsoon rains from June to October. Thus the rivers reach peak-flow from July to early September when about one third of the country is flooded.

The Ganges - Brahmaputra - Meghna river delta (64,800 sq.km) includes water ways totalling atleast 24,000 km in length. These water ways increase in number and size from the north-west to the southeast. The drainage area of the Ganges - Brahmaputra - Meghna system covers 15,55,000 sq.km, but only 7,5% of this lies in Bangladesh. The Brahmaputra - Ganges rivers have enormous discharges (the historical peak flood of 12,750 cuseo is about twice that of the Mississippi and an annual flow six times that of the Indus and carries huge sediment load about 2.4 billion tons annually. Subsequently, the silts are deposited on drainage channels causing drainage congestion. The rivers experience major shifts in their channels, greatly complicating water control in the region.

Many small streams through out Bangladesh cause severe flood problems. Teesta, Atrai and Korotoya rivers are main tributaries to the Brahmaputra river; Kushiyara, Surma, Manu, Khoai, Lakhya and Gumti rivers are main tributaries to the Meghna river and Mahananda river is the major tributary to the Ganges rivers. While little Feni, Feni, Karnafuli, Sangu and Mathamuhuri rivers are the tributaries to the Bay of Bengal. The coastal areas of the country in the southern and eastern parts lies in the path of the tropical storms of Bay of Bengal. Cyclone of upto 250 km an hour occur frequently striking the coast about once in every three years on average and driving masses of water to inland to divastate the coastal areas.

Mean annual rainfall in Bangladesh varies from 1500 mm in the west to 5,100 mm in the north-east while most of the country receiving 1,800 to 2,550 mm. About 80% of the rainfall occurs during the monsoon June to September. Bangladesh is characterised by excess water during the monsoon (June-September) and shortage of water during summer (January-May). This is because of un-even distribution of rainfall through-out the year.

As described earlier flood is the major problem in Bangladesh followed by drainage congestion. Shortage of irrigation water is never-the-less significant problem. Water resources development projects in Bangladesh thus consists of flood control, drainage and irrigation projects. Several town protection are also there to protect cities of economic importance against river erosion. Idea of reclaiming land from sea has developed very recently. Ground water irrigation is also practised in a limited scale.

Major Water Development Projects in Bangladesh are sponsored by Ministry of Irrigation, Water Development and Flood Control and Bangladesh Water Development Board (BWDB), a semi autonomous organization under the said Ministry is of the projects. Ministry of Agriculture also sponsors several ground water development projects. These projects are implemented by another semi autonomous organization, Bangladesh Agricultural Development Corporation (BADC) under the agriculture ministry. But Bangladesh Water Development Board (BWDB) shares the major responsibility of ground water development projects also. Bangladesh Water Development Board is mainly responsible for all flood control and drainage project and integrated irrigation project while BADC is responsible to increase agricultural products through minor irrigation schemes and improved application of other agricultural inputs.

Bangladesh Water Development Board, was created in 1972 furcating the then East Pakistan Water & Power Development Authority (EPWAPDA). EPWAPDA was created in 1959 on the recommendation of a United Nations Technical Assistance Mission (Krug Mission). Before creation of EPWAPDA, the then irrigation department was responsible for water resources development. BWDB is entrusted to frame a scheme or schemes for the whole of Bangladesh or any part thereof providing for all or any of the following matters, namely-

a) Construction of dam, barrage, reservoirs, irrigation, embankment and drainage;

b) Flood control including water shed management;

c) Prevention of salinity, water congestion and reclamation of land;

d) Except within the limit of sea ports, maintenance, improvement and extension of channels.

Bangladesh Water Development Board has completed 439 nos. schemes of various sizes, upto June, 1987. The physical components of works completed by BWDB upto 1986-87 are -

Area benefitted from flood protection and drainage improvement	- 2.84 mln. ha.
Area benefitted from irrigation	- 0.191 mln. ha.
Length of flood protection embankment	- 6,520 km
Excavation/re-excavation drainage khal	- 28,500 km
Excavation of irrigation canal	- 3,717 km
Number of hydraulic structure	- 6,095 nos.
Number of bridge/culvert	- 3,584 nos.
Number of Pump House	- 87 (full) 4 (partly)
Number of closure	- 1,044 (full)
Number of barrage	- 5 (full) 1 (under constr.)

BADC was created in 1961 with a view to increase agricultural production through minor irrigation schemes and improved application of other agricultural inputs. BADC was so far the most important agency connected with minor irrigation development and was given responsibility for procurement and distribution of tractors, low lift pumps, shallow tubewells, deep tube wells and crop inputs like seeds, fertilizers and pesticides. At present BADC has about 20,000 DTW, 50,000 STW and 7,000 LLPs in operation. These inputs provide irrigation to an area of about 0.85 million hectare.

Recently BADC has taken up one integrated project namely Barind integrated area development project. This is the first major project of BADC.

2. Major Projects of Bangladesh Water Development Board With Their Social and Environmental Impact.

Bangladesh is a land of rivers. Most of the water development projects are thus concerned with either control of river flood or utilization of river water for irrigation. Drainage improvement is also very common component of water development projects. But due to flat topography, scope of barrage project are very limited. Integrated ground water development projects are also very limited.

Considering the nature of impact on environment, water development projects are grouped into six different categories.

- Project for flood control only.
- Integrated projects for flood control, drainage improvement and irrigation.
- Barrage projects.
- Ground water development projects.
- Land Reclamation Projects.
- Town Protection Schemes.

2.1. Projects for flood control only.

Projects with only flood control component are mainly located along the shore of Bay of Bengal in the coastal districts of southern Bangladesh. A cluster of flood control projects are implemented under the name, Coastal Embankment Project. By virtue of the land location and elevation and many water passages, land was subject to periodic tidal inundation during high tide twice daily as well as monsoon floods during the rainy season. Tidal inundation used to damage growing crops and make the land unfit for cultivation until salt was leached out. Heavy flooding during monsoon used to damage standing crops and otherwise reduce yields. To get rid of above problems flood control project under the name Coastal Embankment Project is taken up with an aim to protect 86 Polders covering an area of 1.10 million hectare through construction of 3,623 km flood protection embankment and 800 nos. sluices. Most of the polders are protected from flood.

In other parts of the country projects with only flood control component are also there. But they are not completely empoldered as coastal embankment project. Single largest flood control project of this type is Brahmaputra right embankment. The project is located in the northern region of Bangladesh on the right bank of the Brahmaputra river. Flood protection features include a continuous embankment of 217.5 km along the right bank of the Teesta, and the Brahmaputra-Jamuna rivers. The structures comprise three large drainage regulators and 22 flushing sluices through the embankment. This project provides flood protection for 23,500 hectare.

Flood control embankment has been constructed on the banks of many other minor rivers.

Submersible embankment are constructed in Haor areas (North-Eastern Bangladesh) to protect crops for a specified period (early monsoon) of the year.

Social and environmental changes for flood control project.

Protection of flood not only stopped intrusion of river and sea water but also brought appreciable changes in society and environment. Flood protection provided security to crops. Agricultural production increased substantially. People started feeling secured. These encouraged additional economic activities. Rate of infrastructure development in the field of education, health and communications accellerated. Water borne diseases reduced. Casualities for natural calamities are reduced. In 1961, 1965 & 1970, tidal surges in the coastal areas of Bangladesh took lives of several lakhs of people and animals. This also left serious setback on environment. Air became polluted. Various diseases like diarrhoea, cholera broke out in the affected areas. Crops and houses were completely damaged. People became food and shelterless. Even no food was available for domestic animal. People's sufferings knew no bounds.

Also in 1985, several thousands of people and animals were killed by cyclonic surges in the east coast of Bay of Bengal. But the degree of damages were less because very little area in that cyclonic zone remained unpoldered. Complete empoldering of coastal areas could prevent the devastation of 1961, 1965, 1970 and 1985.

In the coastal areas flood gives disposition of salt on the agricultural land. This makes the lands un-productive for several years till it leaches out through flood water remains standing only for a short duration.

On the otherhand, water remains standing for long time, if there is river flood in interior river basins including Brahmaputra river basin. Water rises gradually. Loss of lives is not as in the coastal areas. But similar types of epidemic diseases occur. Protection of flood both in coastal and interior areas stops intrusion of silt which increases fertility of land. Embanking also prevents entry of river and sea fish in the polder area and countryside.

In flood protected areas specially in polder areas there remains several low pockets. Water can not be drained out from these low pockets after a certain stage. Due to embanking and flood control structure, river water can not enter also. This prevent inter movement of water from these low pockets after the certain stage. This pollutes the stagnant water and various epidemic diseases occur (example Satla Bagda project in Barisal district).

2.2. Integrated projects for flood control, drainage & irrigation.

Integrated flood control, drainage and irrigation projects are spreaded through out the country. Major flood control, drainage improvement and irrigation project, starting from northern Bangladesh are listed here briefly.

Kurigram flood control and irrigation project.

The project is located in Rangpur district. This is a flood control and drainage project comprising an area of 1,05,670 ha. of which irrigation will be provided to an area of 78,950 ha. with completion of 174 km embankment, 254 km drainage channels & 488 km irrigation channels. The project is under implementation.

Pabna irrigation & rural development project.

The project is under implementation, situated in Pabna district in the north-west Bangladesh, the project aims at providing flood control and drainage improvement to 74,300 hectare and irrigation to 57,895 hectare after construction of 91.75 km of embankment, 105 km of drainage channels, 74 km of irrigation canals, 2 regulators, 3 sluices and 3 pumping plant.

Ganges - Kobadak project, phase I & II.

The scheme is located in north-west Bangladesh covering Kushtia and Jessore districts. It provides flood protection and drainage improvement and irrigation to an area of 1,41,700 ha. Completed physical works are flood embankment 14.5 km irrigation canals 1,010 km drainage channels 916 km, hydraulic structures 448 nos. and pumping plants for 15 nos. pumps of total 153 cumec.

Barisal irrigation project, phase-I.

This is a completed irrigation project in Barisal district with an area of 59,515 ha. Drainage improvement of the area is also another main purpose of the project which consists re-excavation of 966 km drainage khal, construction of 750 nos. of sluices and installation of 2,600 nos. LLPs.

Barisal irrigation project, phase-II.

This irrigation project comprising an area of 48,583 ha., is situated in Barisal district in southern Bangladesh. Drainage improvement of the area is also aimed at the construction of 167 sluices, installation of 950 LLPs and 12 pumping plants.

Dhaka-Narayanganj-Demra project.

This completed project is located in south-east suburbs of capital city Dhaka. It is provides irrigation to 6,073 ha. and flood protection to 5,158 ha. after construction of a dual pumping plant of 14.5 cumec, 45 km irrigation canals and 24.15 km embankment.

Barnal-Salimpur-Kolabashukhali project.

This completed flood control, drainage improvement and irrigation scheme is located in the districts of Jessore and Khulna. The command area of the project is 23,156 ha. with construction of 85.33 km embankment, 13 regulators and 32.2 km roads and drainage channel.

Chalan beel project (polder-D).

This flood control and irrigation project comprising an area of 53,000 ha. is located in the northern district of Natore. The project is under implementation with an aim to construct 133.63 km embankment with sufficient drainage and irrigation inputs.

Manu river project.

This completed flood control, drainage improvement and irrigation project is located in north-eastern district Maulavi Bazar. Construction of 59.57 km embankment, 42 km irrigation canal and 51.52 km drainage channel and installation of a pumping plant of 34 cumec are completed with a view to provide flood protection and drainage to 22,677 ha. and irrigation to 11,740 ha.

Khowai river project.

This project is located in north-eastern Sylhet district. On completion of the project with 128.8 km embankment, 22 hydraulic structures and 96.6 km irrigation canal will provide flood control to an area of 25,780 ha. and irrigation to an area of 6,478 ha.

Chandpur irrigation project.

This completed irrigation project is located in south-eastern Noakhali and Comilla districts. Construction of 96.6 km embankment, 12 sluices, 2 pumping stations, 2 regulators, 354.20 km irrigation canals, 55 miles drainage channels are completed to provide flood protection and irrigation to 56,680 ha.

Karnafuli irrigation project.

This is a completed irrigation and flood control project located in south-eastern Chittagong district. Construction of 77.28 km embankment, 18 regulators, 8 bridges and resuscitation of 138.46 km channel for irrigation are completed to provide flood protection to an area of 23,482 ha. and irrigation to an area of 15,385 ha.

There are several other flood control, drainage improvement and irrigation project located in different parts of the country.

Impact of integrated glood control, drainage improvement and irrigation projects.

Implementation of the projects will ensure full agricultural development with year round crop production by adopting modern agricultural technology and high yielding varieties of crops. Both crop intensity and yield rate will be increased due to flood protection, drainage improvement and irrigation facilities.

This will accelerate other infra-structural development. Education, communication and economic activities have been increasing in completed projects. Enrolement in educational institutions is rising in aggrevative term.

Different on the job training institutions are developed specially in the irrigation project. In Ganges-Kobadak project area on farm training centre for village level officials, farmers - big and small and an on-farm research centre to find answer to local agricultural problems regarding soil condition, suitability of seed variety and so on were established for the first time in the country. Better understanding between the project officials and the farmers and among the farmers themselves developed.

Formation of producers' co-operation, and marketing co-operative for the poor farmers and consumers to counter the exploitation of middle manship took place in irrigation project area specially in Ganges Kobadak project area.

Commercial undertakings at all levels have been facilitated by improvement of logistic and communication system. General health of men, women and children in the completed project area getting better than national average. In the areas of drainage congestions, different epidemic diseases are very common. Skin diseases are very common in drainage congested areas. But in the project areas with drainage improvement provision, these diseases are eradicated to a great extent. In the pre-project condition, areas under Chandpur Irrigation Project need to suffer from Diarrhoea and cholera very severely. Every year hundreds of people have to face death from Diarrhoea and cholera. Even on cholera research institution was established. But after completion of the project the outburst of diarrhoea and cholera were substantially reduced and the situation came under control. In flood controlled and drainage improved area risk of water pollution is minimum. This facilitates availability of pure drinking water. In project areas having irrigation component remains green with crops even in the dry season. This enables nature to attain echological balance in dry season also.

Flood control and drainage improvement project reduces fish production. Fish from rivers and sea can not enter in the project areas. Moreover, low-lying areas are also reclaimed for drainage improvement narrowing the scope for fish production. On the other hand, facilities for production of sweet water fish are increased in irrigation projects. Primary and secondary irrigation canal are used for fish cultivation. Sometimes major drainage channels are also used for fish cultivation.

2.3. Barrage projects.

Bangladesh is a country of flat land. Barrage projects for generation of hydro-electricity and irrigation facilities are very limited. Only one barrage project in the eastern hilly region of Bangladesh namely Karnafuli Multipurpose project is under operation for production hydro-electricity and flood protection in the lower region. However, another barrage project in the northern districts namely Teesta Barrage Project is under implementation. Karnafuli Multipurpose Projects consists of a rolled earthfill dam, 610 meter long, gated spillway having discharge capacity of 15870 cumec.

The project was completed in 1960 and also capable of reducing flood upto 30% in the lower region. While the aim of Teesta project is to provide irrigation to an area of 5.41 Lakh ha. after construction of one barrage with regulators, culverts etc. Construction of two other barrage over the rivers Brahmaputra and Ganges is under active consideration for irrigation.

Impact of barrage project on environment and society Karnafuli Barrage project.

People's belonging to minority groups like Chakma, Mog, Marma, etc. live in the eastern hilly region. Light of modern civilization came in this region after completion of Karnafuli Barrage Project. Virtually there was no communication, educational institutions or health centres in the area before implementation of project. These tribal peoples were isolated with their traditional way of living. They had very little participation in the national activities. But as a part of the project, approach road from port city of Chittagong to the barrage site was constructed through the hills and other modern facilities were created in the project area. All these developed a town near the barrage. These acted as catalyst for infra-structural development in the whole eastern hilly region. Tribal peoples are attracted towards modern civilized life. Communication system, medical and educational facilities increased rapidly. More children started to go to schools.

The main training centre for officials of Water Development Board and Bangladesh Power Development Board has been constructed in the project area. One of major training centre of Bangladesh Navy has been established here. The only technical training institute in the thana level, Bangladesh Swedish Technical Institute has been established in the project area.

Participation of tribal people in national activities increased rapidly. The eastern hilly region form the major forest area of the country. Due to development of modern facilities, government control over the forest management and its utilisation was established. The barrage itself provides generation capacity of 180 MW hydro-electricity which meets the major part of national electricity demand.

The eastern hilly region is very resourceful for raw materials of differ types of industries. Paper Mills, Rayon mills and other industries are developed afterwards in the periphery of the project area. As a result of implementation of the project, tourism has developed in the area. The reservoir of the dam has become one of the largest naturally decorated lakes of the world. The reservoir area is used for fish cultivation also. Fish production has increased tremendously. Major portion of sweet water fish consumption of whole eastern region of Bangladesh area supplied from this lake.

The project created several social problem also. Many homesteads went under water of the reservoir. Some forest area were also destroyed. New settlements by urban people were developed. This became a threat to the tradition of the tribal people used to live over there.

Teesta barrage project.

Teesta Barrage Project is yet to be commissioned. Typical impact for barrage project is also expected here. But as it is constructed over nearly flat areas, its impact will not be as prominent as Karnafuli Barrage Project.

2.4. Integrated ground water development project.

Integrated ground water development projects are concentrated in northern districts of Bangladesh. Surface waters are scarce in northern districts in dry season. That is why ground water irrigation projects are concentrated in northern districts. However, the number of projects are also very limited. One project of this type is completed and another one is under implementation.

Ground water development and low lift pump irrigation.

Project in northern Bangladesh - this completed project is located in northern Bogra, Rajshahi, Dinajpur and Rangpur districts. It provides irrigation facilities to an area of 28340 ha. with 350 nos. deep tube wells to lifts ground water and 686 nos. diesel engine low lift pump to lift water from streams and rivers.

Another deep tube well project namely northern Bangladesh Tube Well Project is under implementation. The project aims at installation of about 1000 nos. DTW including replacement of several DTW installed earlier.

Impact of DTW project on environment & society.

Due to scarecity of surface water in dry season in northern Bangladesh, only one monsoon crop was possible. But introduction of DTW irrigation made the winter HYV crop possible. This boosted up the economic condition of the area which encouraged people to increase their standard of living. More facilities in respect of health, education and marketing were established. Above all the area was appeared to be desert in the dry season. But after introduction of DTW irrigation, vast green paddy fields are visible which puts a possitive inputs to environment.

2.5. Land reclamation project.

In the southern coastal belt, reclamation of land from the Bay of Bengal is under active consideration. Feasibility Study for reclamation of land is conducted. Draft final report is submitted for Sandwip-Noakhali Cross Dam. The project has been identified to be technically feasible and socially attractive. But economically it is not very promising with respect to other projects of concurrent time. Social demand may counter balance the low economic return and the project may be implemented with a short time.

Expected environment & social impact.

In the long run, large area (more than 40000 ha) will be reclaimed from sea. But construction of cross dam linking Sandwip island with Noakhali main land is under active consideration for implementation in near future. This will reclaim about 26,316 ha. of land in 15-20 years period. Reclamation of land will enable lakhs of shelterless people to be rehabilitated. These people lost their houses due to erosion of rivers and sea. Presently these people are living in sub-human condition without minimum required housing, medical and educational facilities. They are living below poverty level. Reclamation of land will help them to get a better environment for living.

2.6. Town protection scheme.

BWDB has also several town protection schemes. Bangladesh is riverine country. Its civilization and commercial activities are concentrated on river banks. Town protection schemes are taken up to protect important ports and commercial centres from river erosion. This not only saves a city but also prevents un-planned re-construction of commercial enterprises, if there were erosion which could create disturbances in city sanitary and health arrangements.

On the other hand, checking of river erosion encourages urbanization.

3. Major integrated project of BADC.

Barind integrated area development project is the single major integrated project of BADC. This, under implementation, project is located in northern districts of Rajshahi, Naogaon and Nowabgonj and aims at providing year round irrigation for 14 nos. upazillas of above districts. The command area will be 40600 ha. when proposed 1000 nos. DTW will comme under operation. Augmentation of surface water, excavation, of ponds and aforestation are also planned.

Impact of the project on society and environment.

This barind tract area is the most dry area of the country and consists of hard red soil with steep slope. In the dry season the area appears to be desert and there is soil moisture depletion. Even in the monsoon, there arises shortage of irrigation water as the area is over drained due to steeper slope.

On completion, the project will not help to attain self-sufficiency in food but will also arrest the process of desertification. It will also check soil moisture depletion.

4. Environmental impact assessment (EIA) in Bangladesh.

Environmental impact assessment of water resources projects has two important purposes, one to assist engineers or decision makers to choose a proper alternative, another is to decrease environmental impacts due to water resources development.

But environmental impact assessment isstill a new concept in Bangladesh. Our ability to evaluate environmental impacts has not kept pace with our engineering know-how in the field of water resources development. Until the recent past our human population used to live in relatively harmony with their environment as our national economy had not yet been industrialized.

Even now human activities in rural area, where vast majority of our people live, do not have a lasting impact on the environment. Obviously, environmental impact assessment in our country is yet concerned with industrialization and urbanization. However, impact assessment for an integrated flood control, drainage and irrigation project is planned. Government of People's Republic of Bangladesh has attached priority to the environmental impact assessment for projects like Dhaka Urban Development, paper and pulp industries, sugar and fertilizer industries and one water resources development project namely Pabna Irrigation and Rural Development Project.

Directorate of Environmental Pollution Control (EPC), a government body is entrusted with the assessment of environmental impact of industrialization, urbanization and water resources development. With its headquarters in Dhaka, EPC has four branch office in four administrative divisions of the country.

In the second five year plan (1980-85) EPC had taken up environmental impact assessment study for several projects of national importance. An amount of Tk. 50 lakhs was allocated for this purpose. Similar types of study also taken up in the Third Five Year Plan (1985-90).

Besides this special study, EPC has a regular project to measure the PH values of river water at different station to assess the degree of river water pollution due to industrialization and urbanization.

EPC is trying to make it mandatory that in future dams, Power stations, high ways, railways and other similar project will have to cleared from the ecological point prior to the approval of government. A proposal initiated by EPC for involving EIA as a pre-requisite for every planning model is under active considerations of the government. It will be incorporated in the Planning Commission proforma, standard proforma for approving a project, if the proposal of EPC is accepted by the government.

5. Methodology and hierarchical structure.

Environmental Impact Assessment (EIA) System can be divided into three parts. The first part is to establish a hierarchical structure of methodologics. The second part is application of evaluating technologies, which include the sampling and application of environmental back ground data, mathematical modeling and other scientific pridicing method. The third is expression of results which belongs tc display techniques. Uptil now, there are four main type of EIA hierarchical structure: namely assessment by ad-hoc, assessment by checklist, assessment by Matrix and assessment by network.

In Bangladesh, assessment by checklist is most frequently used method for first part of EIA study. For the second part of study, sampling and investigation of environmental background data, is commonly practiced. While in the third part of the study, results of first and second part are expressed.

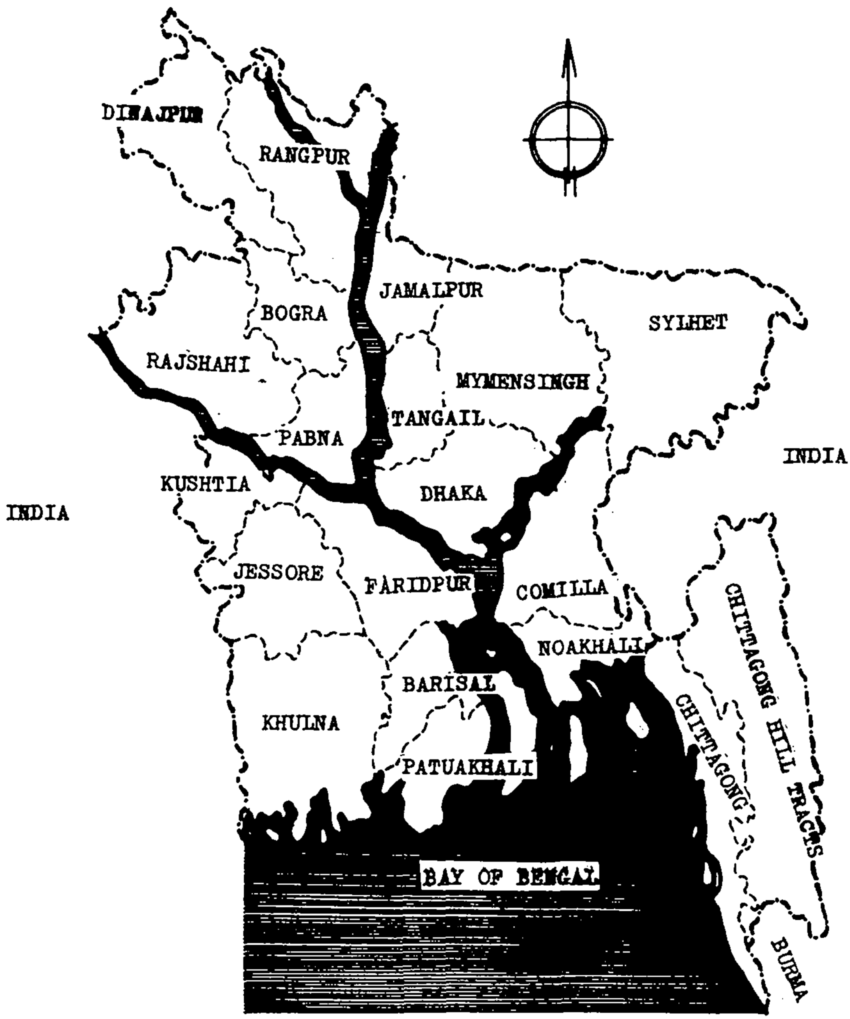

Fig 1 Bangladesh

ENVIRONMENTAL IMPACT CAUSED BY THE OVERDRAFT OF GROUND WATER IN NORTH OF CHINA

Mr. Liu Han Gui, Mr. Wang Wei Zhong

I. Introduction

With the increase of world population, and the growth of agriculture and industry, the problems of water resources have been taken into good consideration by each country. The water resources development in China is not only closely is related with industry and agriculture production, but also directly influences the growth of the national economy. Particularly, the shortage of surface water resources is extremely serious in North China with its arid or semi-arid climate. A series of problems resulting from over withdrawal in some areas has arisen in that part of the country.

China's ground water resources are estimated at 800 billion cubic metres per year. In North China, the potential of ground water is about 280 billion cubic metres (m^3) per year. Actually developed ground water, which is mainly used for agriculture, domestic water supply and industry, is 66 billion m^3 per year in North China, accounting for 23.6 per cent of the estimated ground water reserves there. In agriculture, about 9.67 million hectares of farmland are being irrigated by ground water. About 80 per cent of actually developed ground water is used for this purpose.

Beijing is located in the centre of the Northern China Plain. The total average amount of water resources there is 4.2 billion m^3 per year, of which 2.3 billion m^3 is ground water. At present, the actual water consumption of Beijing is about 4.0 billion m^3 per year. Serious shortage of surface water resources has been experienced since 1980; ground water overdraft has reached 350 million cubic metres per year in the suburbs. Up to 1987, the sum of over-drafted ground water in Beijing was as much as 3.6 billion cubic metres, out of which 1.8 billion cubic metres are in the suburbs.

In the past 20 years, the sum of over-drafted ground water in Tianjin is 17.8 billion cubic metres. There are more than 150 draw-down cones being formed by over-drafted ground water in Tianjin, Shanxi, Shandong, Liaoning provinces, and other provinces and cities in North China. The area where ground water table is more than 10 metres deep as a result of the overdraft covers about 30,000 square kilometres.

II. Effect of the Overdraft of Ground Water

In the previously mentioned areas in North China, the overdraft arising from meeting the demand of domestic needs and development of industry and agriculture has damaged the balance of ground water resources and caused a series of negative effects which can roughly be classified as follows.

1. With the lowering of the water table, the rate of well yield has decreased, bringing about an increase in energy consumption and running cost of water supply. According to incomplete statistics, serious and constant lowering of ground water table on a large scale has been taking place in about 150 cities in China, leading to the development of drawdown cones of various size, which range in depth from 10 to 30 meters, with a maximum of over 70 meters.

Because of the yearly overdraft and lack of adequate ground-water recharge, water table is constantly going down in Beijing. There has been a drawdown cone with a surface area of 1,000 square kilometres in the suburb of the city. The water table is still lowering by the rate of 1 metre per year.

In the coastal city of Gangzhou, the drawdown cone has appeared in 1972. The lowering rate of water table there is now 3 metres per year.

The overdraft of ground water in the city suburbs in North of China not only has caused the constant lowering of water table, but also led to the decrease of well yield and the increase of energy consumption and the running cost of water supply. Due to the lowering of water table, some 10,000 wells for agriculture irrigation have been discarded and more than 30,000 centrifugal pumps previously used for extracting ground water have been replaced by deep-well pumps and submerged pumps, with suction heads of more than 25 metres, at the cost of about 120 million Yuan. As a result, the consumption of energy and the cost of water supply have increased. In the 1950's and 1960's in Beijing, the cost of constructing water treatment works was only about 100 Yuan per 1 m^3 of daily water supply compared with more than 350 Yuan in the 1970's. For the Ninth Water Treatment Works, which is being built, the construction cost is estimated to be over 600 Yuan per 1 m^3 of daily water supply.

2. The overdraft of ground water in the suburbs has caused the progressive depletion of ground water source and land subsidence. In the western suburbs of Beijing, the ground water is about to dry up. As ground water treatment works is no longer capable of delivering water, a new surface water supply plant has to be set up. Water supplying from the Guanting and Miyun Reservoirs, previously for agricultural irrigation, is now used for domestic water supply.

An area of 600 square kilometres in Beijing experienced land subsidence during 1966-1983. An inner area of 190 square kilometres has sunk by 100 mm, while the dropdown in the centre of this area has exceeded 500 mm. In Tianjin, a cumulative amount of subsidence has reached 1,700 mm over the period since 1959 with the annual rate of 85 mm per year. In a city in Shandong, the ground water withdrawal has led to severall falls of the ground, the maximum subsidence has reached 4,000 mm, endangering the life of city residents, and affecting railways and roadbeds.

3. As a result of overdraft and the pollution caused by urban sewage water, the quality of ground water and ecological environment are steadily deteriorating. The lowering of water table and the speeding up of water flow have increased the dissolving of mineral materials in a stratum. Therefore, ground water hardness is increasing yearly. The water hardness at the Seventh Water Treatment Works in Beijing was 17 degrees in French scale in 1964 when the factory was put into operation, but in 1978 it was already 33 degrees. In an area of about 200 square kilometres, standard water hardness has been exceeded. Ground water in an area of 210 square kilometres has been contaminated with nitrates. Owing to pollution, many wells have been discarded, leading to essential financial losses. In Luda, a coastal city in the Liaoning province, the balance of sea and fresh water has been distorted by excessive exploitation of ground water, and sea water has intruded the aquifer of fresh water. The quality of ground water, therefore, has deteriorated. As a result, the once high output of irrigated area has dropped.

The lowering of water table has also caused the disappearance of spring water in some cities. Many scenic spots famous for its spring water are no longer popular. Rivers and streams which were fed by spring water have dried up, bringing damage to the environment. In the eastern part of Inner Mongolia in North China, the lowering of water table, disappearance and death of aquatic plant community have been taken place because of the overdraft.

III. Comprehensive management

The negative consequences of the overdraft of ground water in parts of Northern China have been taken seriously by the departments concerned who have undertaken certain appropriate measures.

1. Enforcement of planning and management of ground water resources

Since the 1970's, 12,000 observation wells have been drilled to monitor the fluctuations in water table level, well capacity, chemical composition of water and water temperature at regular intervals. During the period of 1980-1984 personnel was trained to investigate and evaluate water resources and do research on how to achieve rational use of water resources.

In 1984, the estimation and rational use of water resources in Northeast China was recognized as an important research programme of the country, requiring wide co-operation of various departments. In 1986, seven provinces were organized to draw up a long-term plan of water supply, with the solution of problems associated with regional overdraft of ground water as one of the important tasks.

In order to put the plan into practice and to step the overexploitation of ground water, the government has stipulated, through appropriate legislative acts, that ground water can only be rationally developed through comprehensive plan, prepared on the basis of investigation and assessment of water resources. In the cities of Beijing, Tianjin, Jinan and the provinces of Hebei, Shanxi in North China, local temporary management provisions for water resources development have been introduced, including a licence system for digging wells, aimed at a strict control of ground water abstraction. For new large construction projects that could influence water resources their impact should be estimated and work cannot start without the permission of the authority in charge of water and environmental protection.

2. Water conservation

Saving water is the most efficient way to improve the current situation with regard to ground water resources. It not only decreases the amount of the water withdrawn, but also reduces the threat of pollution. From 1982 to July 1988, the municipal government of Beijing held seven annual water-saving conferences which were attended by 10,000 specialists each with a view to making general mobilization and assigning of water-saving tasks. For domestic water use, the charge on volumetric rate basis has replaced a fixed water charge for any amount of water. Any unit that overuses water will definitely be fined. The general principle is to collect extra money for the amount of water overused. Since 1981, more than 600,000 flow meters have been installed in office buildings, resulting in a reduction of about 40-50 per cent of farmer consumption level, i.e. 31 million m^3 every year. About 330,000 flow meters have been installed in residential buildings, leading to an annual saving annual of 16 million m^3 of water. In industry, there are altogether 18,000 flow meters installed in factories which pay the cost according to the amount of water used. Those factories that have to use more than 3,000 m^3 a month are provided with a planned supply of water. Those which use water in excess of the assigned limits are obliged to pay extra charges at a higher rate. As a result, the amount of water consumed for producing every 10,000 Yuan of industrial output value has decreased from 370 m^3 to 230 m^3. Over 800 water-saving projects which reuse sewage water after adequate treatment, have been set up in industry in Beijing, In this way, 30 million m^3 of water is saved every year. Over 5,400 kilometres of channel have bee lined in Beijing area, raising the coefficient of water efficiency of channel by 20 per cent or so. More than 1,100 kilometres of underground delivery pipe line have been built, decreasing water loss by 30 per cent. Apart from this, such measures as plastic-film covering of canal beds and introduction of dry rice planting have also been taken, saving 200 million m^3 of water each year. The total amount of water saved every year in the domestic sector, industry and agriculture is estimated to reach 300 million m^3 equal to more than 10 per cent of the ground water abstracted annually.

Other provinces and cities in North China have also taken similar water-saving measures which help to improve the situation caused by the overdraft of ground water.

3. Conjunctive water use, artificial recharge of ground water

The North China belongs to a arid and semi-arid area. Rainfall is greatly variable over a year with 70-80 per cent of the total precipitation occurs in flood period. Over 70 per cent of the runoff of rivers and streams, is formed from rainfalls. Therefore, the following measures have been adopted: a) in a flood period, flood water is diverted to the retention reservoir through channels in order to be stored, and; b) in winter time, recharge by seepage of stream and through wells is carried out with the use of treated industrial sewage or water released from a reservoir and water retained in the channel.

The fundamental principle of artificial recharge of ground water is to accumulate water in a wet season for the use in a dry season, i.e. to overlift ground water before flood period in order to enlarge the retention capacity of aquifer and to recharge aquifers during the flood period by seepage.

This work has been done in some plains and valleys, such as Yuantai of Shandong province, Nangong, Qinhuangdao and Shijiazhuang of Hebei province, Shanxi province and Beijing. The programme has demonstrated acceptable result in practice. Along the ancient river course in Nangong, Hebei province, a coefficient of 75 per cent of artificial recharge has been gained by making use of the water in the flood period. Storing water for drought and improving the ability of flood control are the other benefits of this method.

4. Ground water resources protection.

Along with the growth of cities and the development of industry and agriculture, the amount of water used is steadily increasing. Because of the disposal of sewage water from domestic sector and industry, the quality of the water supplied has deteriorated, causing harm to health. Therefore, great importance has been attached by the government to the protection of water resources. The Standing Committee of the Chinese People's Congress has issued "Water Pollution Protection Management in the People's Republic of China" in 1983. Management measures on some important rivers and reservoirs have been taken at various places. The government of Beijing adopted in 1985 "Protection and Management Measures for Water System and Water Resources of Guanting and Rules of Protecting Water Resources of Miyun Reservoir, Huairou Reservoir and Jing-Mi Conveyance Channel", classifying the catchment of the Guanting water system as a 3 classes protection area. Since the strengthening of the protection of water resources, 112 relevant projects have been commissioned, and concentration of phenol, cyanogen, arsenic, mercury, and other elements in water chromium have decreased by 53 per cent. During this period, even though the total output of industry has increased by 2-7 times, the quality of water resources has remained good. The composition of main elements is still below the standard, and the degree of pollution has dropped to a certain extent. In order to ensure the quality of water supplied from the Liao River to Tianjin, four enterprises which caused serious water pollution have been closed down.

The national environmental protection and water management administration has monitored the water quality of seas, rivers, lakes, reservoirs and ground water treatment works in accordance with diverse demands. The water treatment administration has over 170 laboratories throughout the country, responsible for monitoring of water quality in 1,700 river sections. The results are delivered to all the departments concerned in the form of a water quality report.

5. Charges for ground water use

In order to develop and use ground water appropriately and to prevent land surface from subsidence and ground water from being polluted, the municipal government of Tianjin has issued "Temporary Management Measures of Ground Water Resources in Rianjin" and "Management Measures on Collecting of Charges on Ground Water in Tianjin". Any administration, organizations, army, enterprises and individuals who use ground water should pay the charge. Those who overuse water should pay extra at a higher rate. Since the introduction of these measures over 500 enterprises using water for cooling in Tianjin have built 661 cooling towers, recirculating 67 per cent or the cooling water, and thus saving 130,000 m^3 of water every day.

Conclusion

Environmental impact induced by the overexploitation of ground water resources has been taken into account. Many measures have been carried out reasonably and successfully in order to improve the environment and stimulate protection of ground water resources. Therefore, a plan of rational adjustment in water development needs to be made. It is vitally important to improve the water environment in order to promote the development of the Chinese economy and culture.

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ASSESSMENT AND MANAGEMENT OF ENVIRONMENTAL IMPACT IN WATER RESOURCES PROJECTS IN INDIA

Dr. Z. Hasan

1. Introduction

The assessment of environmental impact of water resources development projects was introduced in India in 1978 because of the increasing realisation that the development projects some times resulted into undesirable consequences which would reduce or even nullify the socio-economic benefits for which the project was planned. The emphasis on the design and construction of engineering works without due emphasis on concurrent measures for proper utilisation of the potentials created has been one of the main reasons responsible for many of the adverse consequences.

The objective of considering environmental aspects as part of the development projects is to achieve:

i) sustained development with minimum environmental degradation; and

ii) prevention of long-term adverse environmental side-effects by incorporating mitigative measures so that remedies do not become unmanageable and prohibitive in the long run.

2. Environmental considerations

Since the natural environment can no more be considered a free and inexhaustible resource, all developmental activity impinging upon the natural environment needs to be carefully selected and controlled. Development of water resources is a major challenge to be accomplished in an environmentally sound manner for achieving economic development. This calls for incorporation of ecological parameters in the planning and execution stages of these projects.

Planning Phase

During the planning and feasibility assessment stages of River Valley Projects, the following aspects need to be seriously considered:

i) Locational Aspects

In addition to the techno-economic considerations, site selection must incorporate environmental considerations as well. Some of the major environmental components that need to be kept in view during site selection include:

- short and long-term impact on population/human settlements in the inundated and watershed areas;
- impact on flora and fauna (wildlife) in the vicinity;
- impact on wildlife (including birds) breeding area/feeding area/migratory route;
- impact on national parks and sanctuaries, both existing and potential;
- impact on sites and monuments of historial, cultural and religious significance;
- impact on forests, agriculture, fishery and recreation and tourism, etc.

Being a relatively new discipline, requisite data for impact assessment may not be readily available and may have to be generated through such field-surveys as:

- pre-impoundment census of flora and fauna, particularly the rare and endangered species, in submergence areas;
- census of animal population and available grazing areas;
- land-use pattern in the area with details of extent and type of forest;
- pre-impoundment survey of fish habitat and nutrients levels;
- ground water level, its quality and existing water use pattern;
- mineral resources, including injurious minerals, in the impoundments;
- living conditions of affected tribals/aboriginals, etc.

ii) Physical Aspects

The impoundment creates altered surface water patterns that may have far reaching impact on underground aquifers and their recharge, major aspects to be considered include:

- landslides on the periphery of the reservoir;
- siltation or sedimentation expected in the reservoir-identification of critical areas susceptible to erosion and methods of possible treatment;
- ground water recharge or other ground water charges;

- expected water quality (salinity) charges over time and their effect on riverine eco-system, both impoundment and downstream;

- landuse patterns and practices in the vicinity of waterspread that would affect aquatic vegetation growth patterns;

- potential seismic impact of reservoir loading; and

- favourable aspects of impoundment on project area.

iii) Resources Linkage Aspects

Creation of an impoundment causes considerable disruption and results inevitably in the adoption of alternative land uses. Careful evaluation of the impact should be undertaken of such factors as:

- resources trade-off, such as loss of optional land uses due to impoundment, mineral deposit loss, forest reserve diminution;

- monuments inundated, recreational facilities lost, dislocation of existing settlements, etc.;

- compatibility of dam's creation and operation with present or planned development of the region;

- effect on resident and migrating fish and other aquatic life and assessment of new fishing potential.

iv) Socio-cultural Aspects

Since relocation may strain/disrupt the social fabric of the affected population, efforts should be directed towards betterment of their quality of life and preserving, to the extent possible, the special characteristics of their life-style by adequate provision of:

- population relocation requirements in inundated as well as watershed areas. This aspect has special bearing on the relocation of Tribals and Adivasis, etc.;

- identification of educational and vocational training programmes to be imported to the affected population so that they can cope better with the new life style;

- resettlement area planning for housing and other amenities of community life (water supply, sanitation, schools, health, services, etc.) to be provided at resettlement sites.

v) Public Health Aspects

It is imperative that a serious consideration be given to:

- new health problems or vector patterns that may arise due to changes in water velocities, temperature, quality or other physical change factors caused by water impoundment;

- adequate public health planning to create facilities for migrant construction workers and immigrant influx. Possibility of disease aggravation or new public health problems introduced due to changes in population density and distribution also need to be looked into. Measures to control contamination of surface and ground water due to pesticides and fertilizers need also to be drawn up in advance.

vi) Cost Benefit Analysis

The cost of proposed remedial and mitigative measures, if any, to protect the environment must be included in the project costs. Mitigative measures may include:

- compensatory afforestation;
- restoration of land in construction areas by filling, grading, etc. to prevent further erosion;
- control of aquatic weeds in submerged areas to provide improved habitat for aquatic life;
- measures to salvage/rehabilitate any rare or endangered species of flora and fauna found in the affected area;
- measures to salvage and relocate monuments from inundated zones;
- enforcement of anti-poaching laws;
- establishing of fuel depots to meet fuel requirements of labour force for preventing indiscriminate felling of trees;
- measures to prevent forest fires, over-grazing, etc.;
- public health measures to control spread of water and soil-borne diseases.

Also should be included the cost of:

- field surveys and studies undertaken to create the environmental data-base;
- technical and administrative measures to effectively monitor the observance of suggested safeguards and mitigative measures, etc.

Construction Phase

A judicious sequencing of construction operations and appropriate location of labour camp and project colony, etc. go a long way to reduce environment damage. The following factors are worth considering:

i) All road construction and blasting operations, specially upstream of the reservoirs, should be completed before reservoir filling is commenced so as to reduce excessive sedimentation load.

ii) Excessive blasting resorted to by contractors should be controlled, specially in hilly terrain, so as to check the incidence of land-slides in the area.

iii) Temporary labour camps must be located, to the extent possible, in areas which will later be submerged so as to reduce the loss of forest cover. Even though the sites for resettlement and project colonies are selected well in advance, there should be no need to cut all the trees on these sites. Only those trees should be cut which stand on the residential plots or on the proposed roads and paths. Cutting of these trees should be taken up only when construction operations are imminent.

iv) The extent of clearance under the transmission lines should be related to the height of the standing trees, and the clearance restricted to minimum necessary width.

v) Vegetation on island-formations in the reservoir above FRL should not be removed so that they may be developed as bird sanctuaries at a later stage.

3. Guidelines and government regulations

The Government of India has issued guidelines for preparation of detailed project reports of Irrigation and Multi-purpose Projects (1980) which are being followed by the State Governments and other agencies for preparation of detailed feasibility reports. These guidelines incorporate a chapter on environmental and ecological aspects of the project. The extracts of the guidelines in this respect are enclosed as Annex.I.

In addition to the above, separate guidelines have been prepared by the Department of Environment, Government of India (1985) which cover the relevant environmental aspects concerning River Valley Development Projects. This include aspects relating to submergence area, deforestation, flora and fauna affected, health hazards, catchment area treatment, command area development, water-logging, salinity of soils and effects on aquatic resources, etc. These aspects are required to be covered in the project reports for assessment of the project for environmental clearance.

Government of India has made several regulations to safeguard against environmental pollution. The important regulations and their brief particulars and their objectives are indicated below:

Sl.N°.	Regulations	Objectives
1.	The Environment (Protection) Act, 1986	The Act provide for the protection and improvement of environment and for matters connected therewith. The "environment" includes water, air and land and the inter-relationship which exists among and between water, air and land

		and human beings, other living creatures, plants, micro organisms and property.
2.	Air (Prevention & Control of Pollution) Act, 1981	This Act provides for prevention, control and abatement of air pollution through Pollution Control Boards.
3.	Forest (Conservation) Act, 1980	State Govts have to take prior approval for forest lands for non-forest lands from Govt of India.
4.	Water (Prevention and Control of Pollution) Act, 1977	Act providing for collection of a cess on water from certain industries so as to augment the resources of Central and State Boards for prevention and control of pollution.
5.	Insecticides (Amendment) Act, 1977	To regulate the import, manufacture, sale, transport, distribution and use of insecticides.
6.	Water (Prevention and Control of Pollution) Act, 1974	This Act envisages establishment of Boards for Prevention and Control of Water Pollution so as to maintain and restore wholesomeness of water.
7.	Wild Life (Protection) Act, 1972	This Act provides for the protection of wild animals and birds and for establishing sanctuaries, National parks, Game Reserves and closed areas.
8.	Insecticides Act, 1968	To regulate the use of insecticides to prevent risk to human beings or animals.

4. Assessment and appraisal

Till 1978, all major and medium sized river valley projects were examined at the Centre for their techno-economic viability only for acceptance by the Planning Commission, for inclusion in development plans of the various States. Since 1978, all major reservoir Projects are now referred by the Central Water Commission (CWC/Central Electricity Authority (CEA) to the Department of Environment (DOE) at the Centre for clearance from environmental angle. These Organisations simultaneously examine the project proposals for their viability. Wherever the project proposals involved submergen/cutting of forests, the State concerned refers the project proposal directly to the Union Ministry of Environment & Forests for clearance in terms of the Forest Conservation Act. 1980.

The Department of Environment has constituted an Environmental Appraisal Committee (EAC) represented by experts and representatives of Central Departments to review the scrutiny carried out by the Department of all the projects referred to it by the CWC/CEA. For this purpose, the Department has evolved its own check list of items of environmental impact assessment.

The data furnished by the State Government is examined with this check list of items. The main aspects examined cover the following:

- Extent of submergence with particular reference to forests, type of forests involved, etc.

- Catchment treatment measures and reservoir sedimentation.

- Rehabilitation measures proposed in the project report.

- Command Area Development Plan with special reference to water logging and drainage aspects if any.

- Health hazards if any through water borne diseases.

- Effect of the project on flora & fauna, wild life, etc.

- Effect of the project on mineral deposits likely to get submerged.

- Other ill effects if any from environmental angle.

The data furnished by the State concerned and the mitigative measures proposed are considered by the Department and later discussed in the meetings of the EAC on the basis of the agenda notes prepared for the purpose. The agenda generally brings out the nature and extent of scrutiny carried out by the Department and the main observations, recommendations etc. with regard to the safeguards to be suggested to the Planning Commission while accepting the project proposals. After the Committee accepts the recommendations on the project, as revealed from the scrutiny, the Department finally conveys its acceptance in the form of a clearance letter addressed to the CWC/CEA with copy to the Planning Commission and the State Government concerned. It is obligatory on the part of the project implementing authority to keep in view the various safeguards suggested by the Department of Environment while clearing such projects. Some of the common safeguards suggested relate to the following:

- Necessary arrangements for supply of fuel wood by the project authorities to the labour force during the construction period.

- Restoration of land in the construction area and prevention of soil erosion.

- Compensatory afforestation.

- Drawing up of a master plan for rehabilitation of the oustees.

- To identify the critically eroded areas in the catchment and to undertake catchment treatment works at project cost in at least 20% of the catchment.

- Mechanism for free movement of fish upstream and down-stream of the structure across the river.

- Preparation of CAD report in consultation with the State Soil Conservation Department.

- Covering of River banks with 10m wide green belt.

- Provision of drainage system in the irrigated areas.

- Measures to prevention of endemic health problems.

- Setting up of monitoring units for implementing the suggested safeguards, and

- Alternatives in case of adverse effect on flora and fauna wild life, etc.

Such a clearance by the Department of Environment considerably facilitates separate clearance of the projects by the Union Ministry of Environment & Forests in terms of the "Forest Conservation Act, 1980", in case the project is likely to attract its provisions.

The said Forest Conservation Act which came into effect from 25.10.1980 envisages the sole objective of controlling indiscriminate use of forests for non-forest purposes. The pace of deforestation has been of the order of 1.5 lakh ha. per year over the past 30 years. As against this, after the promulgation of the Act, the rate is reported to have come down to less than 3500 ha/year. The rules framed under the Act and published on 1.8.1981 provide for constitution of the Advisory Committee and its terms of reference. All proposals with the following main points are considered by the Committee for according clearance:

i) whether the use of forest lands is really unavoidable

ii) how the loss will be compensated

iii) extent of soil erosion as a result of implementing the project

iv) whether the area falls in sanctuary, game reserve or National Park, effects on wild life if any.

In the case of large irrigation projects the following points are very carefully and thoroughly considered and fully explained in the proposals to be considered by the Committee:

i) Methodology followed in calculating the submergence area and indication of Full Tank Level (FTL) and High Flood Level (HFL). Felling of trees to be proposed 3-4 metres below FTL.

ii) Inclusion in the project of appropriate cost of soil conservation and- afforestation measures in upper catchment.

iii) Provision of equivalent forest area.

iv) Plan for rehabilitation in non-forest area; and

v) Prior clearance of the Project proposal by the Environmental Appraisal Committee of the Department of Environment.

5. Conclusions

Considerable emphasis has been made on the various aspects affecting the environment by water resources projects. Detailed guidelines have been outlined for the data and information required for the environment impact assessment. The main problem now faced is regarding infrastructural facilities for creating adequate data base after detailed surveys and investigations. Due to lack of basic data the process of impact assessment is retarded in many cases. Similarly, post construction monitoring of environmental problems created by water resources projects needs to be taken up on a systematic basis. It is necessary that Environment Engineering Organisations should be established in developing countries to provide adequate infrastructural facilities to ensure integrated development of water resources with adequate safeguards for sustained environmental quality.

R E F E R E N C E S :

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2) "Guidelines for Environmental Impact Assessment of River Valley Projects" by Department of Environment, Jan. 1985.

3) Lecture Notes - Workshop on Assessment of Environmental Impacts - Their Integration for Planning Water Resources Development Projects and Water Quality Modelling - (6th to 17th Jan. 1986) - CWC, New Delhi.

4) Indo - Soviet Workshop on Evaluation & Modelling of Impacts on Environment of Water Resources Projects - New Delhi. 1985.

Annex I

DATA COLLECTION FOR IMPACT ASSESSMENT*

The following data shall be collected to study the above environmental aspects of the project. The sources from where the data to be collected and whose opinion is to be sought and incorporated within the project report are listed below:

Notation	Department
1.	State Forest Department
2.	Indian Meteorological Department
3.	State Fisheries Department
4.	Zoological Survey of India
5.	State Wildlife Department
6.	State Health Department/State Public Health Department
7.	Botanical Survey of India
8.	Geological Survey of India
Note:	For preparation of this Chapter Department of Environment may be consulted as and when required.

1. <u>Basic information</u>

1.1. Existing land-use in the catchment upto the source of the river or 100 km upstream of the structure whichever is less:

a) Agricultural land (ha.)

b) Forests

i) Reserved

ii) Unreserved

c) Barren land, etc.

1.2. Submerged Area (ha.)

a) Cultivated land

b) Forests

c) Shrubs and fallow

d) Wet lands

e) Area under ponds and tanks, etc.

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* Part of "Guidelines for Environmental Impact Assessment of River Valley Projects" by department of Environment" Jan. 1985.

f) Other uses

g) Total

1.3. Forests types in the catchment and submerged area (type of trees, sparse or thickly wooded and other details)./1.

i) Extent and nature of forest in the area proposed to be cleared for construction of roads, colonies and other uses of the project.

1.4. Proposed Period of Construction

1.5. Labour

a) Estimated strength (peak)

i) Total

ii) Skilled and Semi-skilled (separate)

iii) Un-skilled

b) Availability of labour from the affected area

i) Total

ii) Skilled

iii) Un-skilled

1.6. Population density (per sq.km.)

a) Catchment

b) Submerged area

c) Command

1.7. Villages Affected and Population Displaced

a) Number of villages

b) Population

a) Scheduled Caste

b) Scheduled Tribe

c) Others

d) Occupation of the affected people

i) Agriculturists

ii) Agricultural Labour

iii) Industrial Labour

iv) Forest Labour

v) Artisans

vi) Any other

d) Land Ownership

i) Marginal farmers	(0-1.0 ha.)
ii) Small farmers	(1-2.5 ha.)
iii) Medium farmers	(2.5-5.0 ha.)
iv) Big farmers	(Over 5.0 ha.)

1.8. Resettlement

a) Details of rehabilitation committee, if any

b) Existing guidelines for resettlement and compensation in cash and/or kind, if any

c) Compensation proposed to be paid

d) Resettlement plans for oustees (number of persons and families)

i) In existing villages

ii) At new villages sites

iii) Plan of the new village

iv) Facilities being provided (school, post office, bank, panchayat ghat, police station, roads, drainage, water supply, vocational training, etc.)

e) Proposals to provide vocational training and employment to oustees.

1.9. Details of Development Activity in the Affected area

a) Drought-prone Area Programme

b) Small Farmer Development Agency

c) Rural Development

d) Tribal Development

e) Other programmes

1.10. Sedimentation of the Reservoir

a) Expected rate of siltation

b) Proposed/existing soil conservation programme/measures in the catchment

c) Problems of slips and slides on the periphery of the reservoir and proposed remedial measures.

1.11. Present Flood Situation in the Command

1.12. Wind Rose Diagram, Wind Speed (maximum average) direction (seasonal), etc. at the headworks site/2.

1.13. Frequency of Occurence of Tornadoes, Cyclones, Hurricanes (maximum and minimum wind velocity).

1.14. Ground Water (Command)

a) Depth and seasonal variations (pre and post monsoon)

b) Quality-potable, fit for irrigation/industry

c) Present use

i) Area under irrigation

ii) Extent of industrial use

d) Interaction between the altered surface water patterns and under ground water recharge, etc. (based on the experience of similar projects).

2. <u>Environmental status</u>

2.1. Known Sources of pollution in the region

a) Industrial units

b) Thermal Power House

c) Mining Operations, etc.

2.2. Industrial Development in project area

a) Present status

b) Future plans (10 years)

2.3. Broad Details of the aquatic Life (fish, crocodiles, etc.) Supported by the area

If economically viable, indicate the breeding grounds in the river tributary(s)/area(s) coming under submergence/3.

2.4. Wild Animals and Birds/ 4 & 5

a) Existence in the area

b) Rare/dying species (number), if any

c) Breeding/feeding area(s)

d) Migration routes

e) Is the area a potential wild life sanctuary?

2.5. Flora, Fauna in the submerged area/5 & 7

a) Broad details of the rare/dying species

b) Number of affected valuable wild life

c) Measures proposed to salvage/rehabilitate.

2.6. Tourism

a) Is the area a tourist resort ?

b) Broad details of religious, archeological and recreational centre, wildlife sancturaries, national parks, likely to be affected by the project, etc.

2.7. Broad Details of Endemic Health Problems due to Soil and Water Borne Diseases 6.

3. <u>Environmental impact</u>

3.1. Proposal To Develop The Site To Attract Tourism (recreation, water sport picnic sites, etc.)

3.2. Effect Of The Storage In Flood Mitigation

3.3. Changes In Salinity Of Underground Water Expected And Remedies, If Required

3.4. Expected Waterlogging Problems And Remedies

3.5. Aquatic Life

a) Existence of migratory fish life and proposals for fish ladder, if any.

b) Proposals for fisheries development and crocodile farming, if any.

c) Loss in aquatic production up or downstream, if any.

3.6. Broad Details Of Mines, Mineral, Commercial Timber And Other Natural Resources 1 & 8 Coming Under Submergence With Estimated Loss.

3.7. Broad Details Of Injuruous Minerals Coming Under Symbergence.

3.8. Effect Of Water Body In Enhancement Of Water Borne Diseases/6.

3.9. Broad Details Of Likely Growth Of Weeds (Salvinia, water hyacinth, etc.) Intermittent Host Vectors Like Snails, Mosquitoes/3 &/7 And Proposed Remedial Measures.

3.10. Effect Of Project On Climatological Changes (temperature, humidity, wind and precipitation including modification to micro and macro climate).

3.11. Measures To Prevent Animal Over Grazing And Cultivation Of Pore-shore Of Reservoir To Prevent Premature Silting.

3.12. Likely Impact Of Reservoir Loading On Seismicity.

3.13. Likely Impact Of Population Pressure On (during construction) the area

a) Felling the trees for fire wood

b) Forest fires

c) Overgrazing leading to depletion of pasture lands

d) Visual pollution and damage to scenery

3.14. Arrangement Made For

a) Fuel requirement of the labour force during construction period to prevent indiscriminate felling of trees for fire wood (fuel depots)

b) Compensatory afforestation

c) Enforcing of antipoaching laws

d) Control of sediments and pollution.

4. Proposals for observance and monitoring of suggested safeguards and mitigative measures, etc. during and after construction of the project.

ENVIRONMENTAL IMPACT ASSESSMENT PRACTICES FOR WATER RESOURCES PROJECTS IN REPUBLIC OF KOREA

Dr. Sun Ho Lee, Prof. Soon Tak Lee

Introduction

Urbanization, industrial development, and improved living standard, as envisioned in the nation's economic developments, all call for water supplies in quantity and quality to meet their demand. Concurrently the amount of land for harvesting water supplies are decreasing while demands are increasing. Therefore, large scale water resource developments have been carried out since the 1960's to solve this problem.

In South Korea, it was not until the late seventies that adverse impacts on the environments caused by water resources developments were assessed. As large scale water resources projects were being developed in this small-sized country, the adverse impacts were inevitable on natural, living, social and economic environment. Consequently, the legislation was set to require mandatory impact assessments for all water resources development projects. In addition, measures had been taken to minimize their impact on the environment.

The first section of this report presents a historical perspective on the evolution of the country's environmental legislation. The second half explains practices and measures applied to water resource development projects.

Legislation

The Environmental Impact Assessment (EIA), for various projects, was first introduced in Korea in 1977 when the "Environmental Preservation Law" was promulgated. However, at that time the law only required that there be a preliminary discussion, of the environmental impact posed by the project, between the related agencies.

The preparation of an EIA report became officially required when regulations about EIA was enacted in 1981. Under this law, the executing organization had to carry out an EIA for the project with assessments of all potential adverse impact on the environment and must request the aid of the Environment Administration, which is a government agency, for reviewing the EIA report.

Although there are minor variations in the procedure, when EIA are carried out, the basic form of an EIA system can be described as in Figure 1. The type of a project which require mandatory EIA is specified in the "Presidential Act", and various water resources projects, such as dam construction, estuary embankment and other specific development project, are listed and included in this category.

The EIA for a dam construction and the estuary embankment project which are developed based on the "River Law" or the "Multipurpose Dam Law" must be submitted for review to the Environment Administration before completion of the master plan. For other projects, the basic plan of a project is submitted before an approval.

Particularly, when the Environment Administration deems, after reviewing the EIA report, that a project may cause a remarkable adverse impact on preservation of the environment, an adjustment of the project plan will be requested. The Environment Administration may request the organization or the person in charge of the project to take the appropriate measures to mitigate the adverse effect through consultations with the Central Environment Preservation Advisory Committee. Guide for the preparation of an EIA report is provided, for each item, in the Environment Administration announcement. The report should include a summary of the project, various factors to be considered, an EIA matrix, current environmental conditions, possible adverse impacts and corresponding mitigation measures, post environmental management programs, comprehensive evaluations and conditions, etc.

EIA effects

Since EIA became mandatory for large scale water resources development projects in 1981, EIA for eleven water resources development projects have been carried out thus far (Korea Environment Administration, 1984; 1987) and project names are listed chronologically in Table 1.

Fig. 1. Operation of the EIA system in Korea

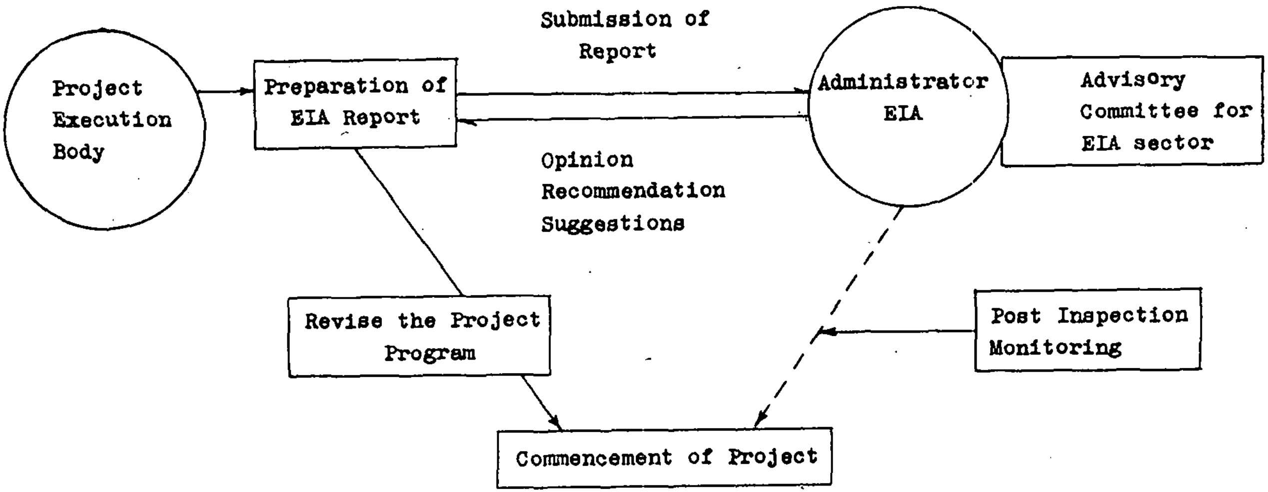

Table 1. Listing of the environmental impact assessment studies in Korea

Year	Project
1981	Water Resources Construction Projects for the 9th and 10th Nuclear Power Plants
1983	Nakdong Estuary Barrage Project
1983	Keum River Region Integrated Agricultural Development Project
1983	Han River Integrated Development Project
1983	Hapcheon Multipurpose Dam Construction Project
1985	Imha Multipurpose Dam Construction Project (I, II)
1985	Third Yeongsan River Basin Development Project
1985	Jooam Multipurpose Dam Construction Project
1986	Han River Integrated Development Project in Kyunggi Province (I, II)
1986	Dalbang Dam Construction Project
1987	Shiwha Region Land Reclamation Development Project

Among the EIA listed, for the Nakdong Estuary Barrage Project, hydrological, water quality, ecological and morphological aspects were considered. To mitigate negative impacts on the environment, the underflow and overflow gates in the barrage, a discharge sluice in the closure dam, and a waterway for fish were included in the design. In addition, environmental guidelines for the operation of the dam has been established. Further details of environmental impacts and mitigation measures can be found in the paper presented by Kim and Choi (1988).

In the Keum River Region Integrated Agricultural Development Project, a potential flood hazard was pointed out. Since the new estuary barrage could raise water stage level higher than before the barrage construction, improvements to the river banks and the development of a barrage operation system were suggested to be included in the project plan.

The Han River Integrated Development Project consisted of excavating the river bottom for navigation, development of recreation parks on flood plains, and widening roadways along the river, and constructing waste treatment plants and sewage collection culverts. The EIA for the project requested measures for several problems such as the deposition of sediments near the submerged weir during flood periods, and the conservation of a wildlife refuge. In addition, the EIA suggested priorities to carry out the project to minimizing adverse environmental impacts.

Case study

The Shiwha Region Land Reclamation Development Project is a recent example of a large scale water resources development to supply water for agricultural and industrial areas in the Gulf of Shiwha along the western coast of the Korean Peninsula.

The main objectives of the project are:

1) to disperse the dense population of Seoul city, the capital city of Korea,
2) to establish a coumpound of polluter industries,
3) to account for the increasing demand for land by enlarging the national territory; and
4) to provide a basis for an all-weather agriculture supported by sufficient water resources.

A general feature of the project includes 8 units of sea dyke (total length: 16.4 km), 3 units of lockgate, reclamation area of 17,700 ha, and construction of a lake (surface area: 5,650 ha) which is capable of impounding 181 million tons of fresh water.

There are two main benefits from this reclamation project which are enlargement of national territory and the development of cultivation farms with fresh water supply in the form of a lake which can provide a main source of income for the community.

Methods used to predict adverse effects on the environment due to this project and possible measures to solve the anticipated problems are presented hereafter.

Environmental Impacts

Due to the construction of the sea dyke, the shoreline around the lake was expected to be changed. It was also expected that the local topography would change due to excavation of the hilly area.

In the field of ecological phenomenon, an on-shore salt water ecosystem was expected to be transferred into a fresh water ecosystem. Consequently, the species of plants and of fish in the project area were expected to be changed because of this changed ecosystem. It was also expected that the quality of coastal water would be influenced up to 1.8 km from the barrage due to the outflow of fresh water through the gate.

Especially, the construction of a sea dyke along the coast was expected to raise the amount of suspended sediments which would eventually deny fishery rights of the neighboring communities. Thus, a new problem regarding the compensation of the fishery right appeared. Along the coast, the local sedimentation would appear for a long period of time due to the weakening of algae in front of the sea dyke.

Mitigation Measures

Unstable slopes and cutting edges in the borrow-pit or quarry site should be stabilized by proper treatment such as grouting, rock anchor, and so on. Vegetations on earth slopes can prevent the slopes from erosion and collapse.

During the construction of access roads and irrigation canals, the earthwork volume for cut and fill should be designed to balance each other in order to minimize material waste and cost. Installation of the sand-proof screen was considered to be effective for controlling the suspended sediment proliferation, and the road was paved to reduce the nuisance that would arise from noise and dust.

A proper selection of the gate location and sufficient depth of water along the centerline of the waterway was required to induce fast flow of the stream water up to the drainage point.

To minimize the lose of farm crops it was recommended to create a wind-control forest and a buffer zone of greenbelt between the expected farm area and industrial complex areas. A moderate measure was prepared for waste water treatment.

The related laws were reviewed to make preparation for lose of cultivating farms and means of living to the fisherman, which was caused by this reclamation project.

For utilizing the lake water in agriculture, a proper waste water treatment facilities were required to lower the BOD concentration of the incoming water. Similarly it was necessary to construct desalinating culverts since it would take a long time to convert salt water in the lake into fresh water.

R E F E R E N C E S :

1) Kim, K.H. and Y.S. Choi. 1988. The Environmental Impact and Mitigation Measures of Nakdong Estuary Barrage Project. Transactions of the Sixteenth Congress on Large Dams Held at San Francisco, USA. p. 231-247.

2) Korea Environment Administration. 1984. Summary Report for Environmental Impact Assessment Studies I (1981-1984). 399 p.

3) Korea Environment Administration. 1987. Summary Report for Environmental Impact Assessment Studies III. 412 p.

ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURE AND WATER RESOURCES DEVELOPMENT PROJECTS (The Malaysian Experience)

Dr. Omar M. Zain

Introduction

In the case of Malaysia, effort to formulate an Environmental Impact Assessment (EIA) procedure began in 1977, and in 1979, an EIA Handbook was drafted to guide project proponents in the conduct of EIA studies. From our record, between 1986-1987 some 26 reports that were subjected to informal EIA were received by the Department of Environment (DOE) for evaluation, including 6 reports relating to water resources development (Table 1).

However because the EIA process was not mandatory, there was much reluctance among the project proponents to conduct EIA studies. Furthermore, many of the studies conducted were inconsistent with the guidelines provided, thus making review difficult.

Bearing these in mind and to ensure socio-economic development do not get negeted by the cost of environmental damage, an Order, known as the Environmental Quality (Prescribed activities) (Environmental Impact assessment). Order 1987, made under the Environmental Quality (Amendment), Act 1985, was gazetted on November 1987. The Order prescribes 19 categories of projects requiring EIA report. The prescribed activities include; agriculture, airport, drainage and irrigation, land reclamation, fisheries, forestry, housing, industry, infrastructure, ports, mining, petroleum, power generation, quarries, railways, transportation, resort and recreation development, waste treatment and disposal and water supply. The Order came into force on 1st April 1988.

Under the Environmental Quality (Amendment) Act 1985, any person intending to carry out any prescribed activity, must submit a report on the impact of the activity on the environment to the Director General, Department of Environment for approval. The report shall be in accordance with the guidelines prescribed by the Director General and shall contain an assessment of the impact such activity will have or is likely to have on the environment and the proposed measures that

Table 1. EIA'S Reports by Project Category Received by DOE, 1986-1988

Project Category	1986		1987		1988	
	P.A	D.A	P.A	D.A.	P.A	D.A
Agriculture			1			
Drainage and Irrigation	1					
Land Reclamation	1			1		
Industry		1	1			
Infrastructure	2		2			
Mining	1					
Petroleum	1	1		2	2	
Power Generation	1		5		1	1
Quarries			1			
Resort and Recreational Development	2					
Waste Treatment and Disposal			2			
Water Supply					1	
TOTAL:	9	2	12	3	4	1

Note: P.A : Preliminary Assessment
D.A : Detail Assessment

shall be undertaken to prevent, reduce, or control the adverse impact on the environment. The Director General may after examining the report, approve it with or without conditions or reject it. The report may be revised and resubmitted for approval.

In addition, the person carrying out the prescribed activity shall provide sufficient proof that the conditions attached to the report are being complied with and that the proposed measures to be taken to prevent, reduce or control the adverse impact on the environment are incorporated into the design, construction and operation of the prescribed activity. Any person who contravenes the above provisions shall be guilty of an offence and be subject to prosecution.

Highlights of the Malaysian EIA Procedure

The environmental impact assessment procedure in Malaysia has been primarily developed as an aid to the environmental planning of new development projects or to the expansion of existing development project. Under the procedure, planners are required to take environmental factors in addition to techno-economic factors into consideration in project planning.

The Malaysian Procedure provides for environmental impact assessment to be integrated into the project planning process. In this respect, environmental factors are considered in project identification, prefeasibility, feasibility and project implementation. This enables environmental values to influence site location, manufacturing process, plant design & layout and etc.

The Procedure provides for:

1. Preliminary Assessment of all prescribed activities.
2. Detailed Assessment of those prescribed activities for which significant residual environmental impacts have been predicted in the Preliminary Assessment.
3. Review of Detail Assessment Reports.

Preliminary Assessment

The objectives of Preliminary Assessment are:

1. To examine and select from the project options available.
2. To identify and incorporate into the project plan appropriate abatement and mitigating measures.
3. To identify the significant residual environmental impact.

Preliminary Assessment should normally be done at an early stage of project planning. Standard procedural steps are provided and the assessment might be conducted "in house" or by a consultant. Some form of public participation is mandatory, Environmental data collection may be necessary and close liaison between the assessor and relevent environment-related agencies is encouraged. The results of Preliminary Assessment are reported formally for examination and approval by the Director General of Environment who will forward his recommendations to the project approving authority.

Project initiators may also elect to go straight into Detailed Assessment. In this case, Preliminary Assessment will still need to be carried out as part of an input for Detail Assessment. For conducting the Preliminary Assessment, the use of matrix is recommended. Each matrix relates a list of project activities to components of the physico-chemical, biological, and human environment. The purpose of the matrix is to help the project planner to:

1. Identify specific sources of potential environmental impact.
2. Provide a means of comparing the predicted environmental impacts of the various project options available.
3. Communicate in graphic form:
   a) Potentially significant adverse environment impact for which a design solution has been identified.
   b) Adverse environment impact that is potentially significant but insufficient information to make a reliable prediction.
   c) Residual and significant adverse environmental impacts.
   d) Significant environmental quality enhancement.

The format of a Preliminary Assessment is shown in Annex 1.

Detailed Assessment

The objectives of Detailed Assessment are:

1. To describe the significant residual environmental impact predicted from the final project plan.
2. To specify mitigating and abatement measures in the final project plan.
3. To identify the costs and benefits of the project to the community.

Detailed Assessment continues during project planning until the project plan is finalised. Standard procedural steps are provided and specific terms of reference based on the results of Preliminary Assessment are issued for each project. The assessment might be conducted "in house" or by a consultant. The assessment method is selected according to the nature of the project, and some form of public participation may be required. Environmental data collection is almost certainly necessary. The results of Detailed Assessment are reported formally to the Director General of Environment. The format of a Detailed Assessment Report is shown in Annex 2.

Review

The objectives of Review are:

1. To critically review the Detailed Assessment Reports.
2. To evaluate development and environmental costs and benefits in the final project plan.
3. To formulate recommendations and guidelines to the project approving authority relevant to the implementation of the project.

Review of Detailed Assessment Report is conducted by an independent Review Panel comprising of members from various diciplines and chaired by the Director General of Environment.

The Review Panel is served by a Secretariat (The Environmental Impact Assessment Unit) in the Department of Environment, Ministry of Science, Technology and Environment. In addition, the Review Panel may ask suitable experts for their specialist advice on specific aspects of the project under review.

The review process is limited to a maximum period of two months. During that period, comment is invited from concerned environment-related agencies and from the public.

Water Resources Development Project in Malaysia

In Malaysia, most of water resources development project that have been received by DOE for informal EIA evaluation fall under the hydroelectric project.

Until the end of 1987, six reports of hydroelectric development were received by DOE for evaluation. Sixty seven percent of the proposed projects were located in East Peninsular of West Malaysia, while the balance, in East Malaysia (Table 2).

From our experience, among the major constraints faced by project proponent/consultant in preparing good EIA reports includes lack of local data to support EIA and shortage of trained manpower to carry out EIA, thus making preparing of EIA reports more costly and time consuming. However in some instances, the issue was not on the availability of data but on determining the sources from where such data could be obtained.

To overcome these problems, there is a need to establish a database centre. The function of the centre could be in the form where it identifies the sources of data, collect, store and dessiminate data to interested parties.

Shortage of trained manpower to carry out EIA was also a serious problem facing by developing countries like Malaysia. In general, training overseas for officers does not solve the problem as only a limited number of people could be trained. In addition, besides the personnel in the environmental agencies, there is also a need to educate the public, the politicians, the decision-makers and the consultants. Therefore it is recognised that there is an urgent need for cooperation among the developed and developing countries to look into this aspect of manpower training so as to ensure effective and effecient implementation of EIA.

Table 2. Water Resources Development Reports Received by DOE, 1986-1987

	Project	1986	1987
1.	Nenggiri Hydroelectric Sg.Nenggiri, Kelantan, West Malaysia.		P.A
2.	Liwagu Hydroelectric Sg. Liwagu, Sabah, East Malaysia.		P.A
3.	Sook Dam Hydroelectric Sg. Sook, Sabah, East Malaysia.		P.A
4.	Pergau Hydroelectric Sg. Pergau, Kelantan, West Malaysia.		P.A
5.	Maran Hydroelectric Sg. Maran, Pahang, West Malaysia.	P.A	
6.	Ulu Jelai Hydroelectric Sg. Jelai, Pahang, West Malaysia.		P.A

Note: P.A : Preliminary Assessment

Conclusion

In the past, a number of environmental impact assessment had been carried out in Malaysia on an ad-hoc basis.

To ensure uniformity and effectiveness of implementation of the EIA procedure, EIA requirements have been written into the law, which came into force on 1st April 1988.

The procedure had been integrated into the existing project planning and decision-making process which provide additional information on environment dimension in addition to techno-economic consideration, for decision-maker to decide on the viability of project proposal. A project which is environmentally sound is likely to be more cost effective and more beneficial to the community.

Lack of local data and trained manpower to carry out EIA seem to be the major problems in preparing a good EIA Report.

R E F E R E N C E S :

1. Environmental Quality (Amendment) Act, 1985.

2. Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order, 1987.

3. A Handbook of Environmental Impact Assessment Guidelines, First Edition, July, 1987.

Annex 1

Format of Preliminary Assessment Report

1. Project Title
2. Project Initiator
3. Statement of Need
4. Project Description.
5. Existing Environment
6. Project Options
7. Residual Significant Impacts
8. Mitigating and Abatement Measures
9. Summary of Conclusions
10. Sources of Data, Specialist Consultation and Public Participation.
11. References

Annex 2

Format of Detailed Assessment Report

1. Project Title
2. Project Initiator
3. Statement of Need
4. Project Description
5. Existing Environment
6. Project Options
7. Results of Preliminary Assessment
8. Detailed Examination of Impacts
9. Options and Benefits
10. Summary of Conclusions
11. Sources of Data, Consultations and Public Participation.
12. References.

MANAGEMENT OF THE ENVIRONMENTAL IMPACTS OF WATER RESOURCES DEVELOPMENT PROJECTS: THE PHILIPPINE EXPERIENCE

Ms. Teodora N. Avila

I. The Philippine water resources

The Philippines has abundant water resources. It has an average annual precipitation of 2,360 mm, an average runoff of about 256,900 MCM (available 90% of the time), 421 watersheds or river basins with drainage areas ranging from 40 to 25,469 sq. km., 59 natural lakes, and large reservoirs of ground water, covering about 50,000 sq. km. concentrated mostly beneath the major river basins. The distribution of these resources however, varies widely with time and place due to the archipelagic nature of the country's geography and local topographic arrangement which influence its climatic conditions.

Philippine waters are used for various purposes, namely: domestic and industrial water supply, irrigation, flood control and drainage, power generation, fisheries, transportation and recreation.

About 64% of the population of the country is now covered by water supply systems from rivers and lakes. On the other hand, irrigation systems in the country cover an aggregate area of about 1,537,360 ha. which is approximately 50% of the total potential irrigable area. The main source of irrigation waters is the country's network of rivers and creeks.

The country has a total of 410 river control and drainage projects distributed throughout its twelve water resources regions (Fig. 1). Although, only six of them are major ones. There are two reservoirs which have been constructed for multi-purposes applications. These are the a) Angat River Multi-Purpose Project, and b) Upper Pampanga River Project, both located in the island of Luzon. A total of nineteen projects were built solely for the generation of hydroelectric power. These generate about 2,132.30 MW.

The development of water resources becomes even more imperative in the light of increasing demands arising from population growth and economic expansion. Towards this end, the government has initiated a water resources development program which calls for the coordinated management and development of water resources for maximum

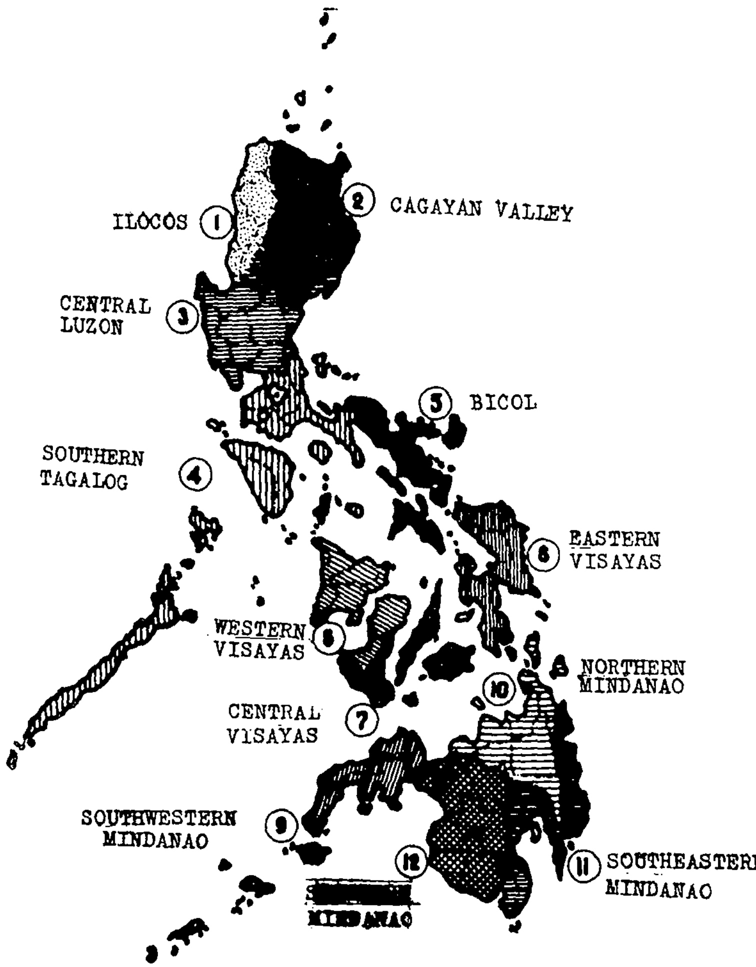

Fig.1 PHILIPPINES
WATER RESOURCES REGION

utilization specifically for the agricultural and industrial sectors.

The irrigation program will be vigorously pursued to increase the present area covered by irrigation facilities to 1.7 million ha. or about 55% of the total irrigable area and to rehabilitate some 723,000 ha. of existing systems. The program will also give importance to watershed management which includes water conservation and erosion and sediment control.

The continued extensive implementation of the flood control program will result in an additional 4,500 ha. of protected land including the historically flood prone areas in the countryside. This will also substantially reduce the huge economic losses caused by floods in Metro Manila and other urban centers.

To improve the health of the population, as well as to support economic activities, through the provision of safe water supply and sanitation facilities, the government aims to increase the coverage of the population served with potable water from 64% to about 79% by 1992.

The government is also intent to rationalize its hydroelectric power generation program. This type of energy source in the country contributes to 33.03% to the country's energy consumption.

Activities undertaken to achieve above targets shall follow a regional development approach, that is water resources projects will be developed where feasible, for purposes of combining irrigation, power, flood control, and domestic and industrial water supply to realize maximum benefits. We recognize however that such development efforts bring with it significant adverse impacts to the environment. It is for this reason that the government also intends to implement nonstructural schemes towards conservation and protection of our water resources. Such schemes include improved management to reduce losses in irrigation and water supply, the regulation of the development of flood plains and flood monitoring to mitigate flood damages, and a comprehensive watershed/riverbasin management program. Likewise, the government intends to strictly implement the provisions of the Philippines Water Code (P.D. N°. 1067) which governs the ownership, appropriation, utilization, exploitation, development, conservation, and protection of the country's water resources.

II. Environmental Impacts of Water Resources Development Projects

Environmental impacts accompanying water resources development projects are numerous and vary in magnitude. In the Philippines, several significant adverse environmental impacts have been documented by the various agencies involved in the development/utilization of water resources. The National Power Corporation (NPC) responsible for dams and reservoirs projects, the National Irrigation Authority (NIA) responsible for highly structural irrigations systems, the Department of Public Works and Highways (DPWH) responsible for flood control and drainage projects, the Local Water Utilities Administration (LWUA) and the Metropolitan Waterworks and Sewerage System (MWSS) responsible for domestic and industrial water supply have identified environmental problems associated with water resources projects.

1. Physical/Chemical Impacts

Among the physical/chemical impacts of water resources development projects, the alteration in the hydrologic regime of watersheds is most significant and a widely observed problem among existing projects. This is so because of its consequences. (secondary and tertiary impacts) which affect both the immediate vicinity (reservoir) and the areas even off the project site e.g., ground water tables, downstream supply of water in terms of the quality and quantity of water that can be utilized for various purposes. This physical impact likewise results to various ecological changes e.g., disruption of food chain which may necessitate an adaptive change in the dynamics and structure of biotic communities, human settlements included. This type of environmental impact is basicaly true for dams/reservoirs projects as well as hydraulic control structures. One example is the operation of the Lake Buni Hydraulic Control Structure in the Bicol Region. It was observed that ground water table in the immediate vicinity of the lake fluctuates according to the shedule of the water draw down. Thus, the release of water for irrigation and hydropower generation, downstream resulted to the drying up of existing shallow wells in the upstream communities.

Another major physical impact is the dramatic change in the land use of the upstream and downstream areas. Construction of dam/reservoirs as well as irrigation systems may necessitate the conversion of thickly forested areas into cleared areas, the placing of agricultural lands, and/or human settlements underwater, or there may be land accretion as a result of river draining embankments. These land use changes generate other impacts highly observable among human communities affected. The impacts would include changes in livelihood patterns; that is forest products gathering activities maybe replaced by cultivation of cash crops within the periphery of the established dams, or commercial activities may replace farming activities due to the loss of fertile agricultural lands.

Other physical impacts such as turbidity, generation of dusts and particulate, siltation, decreased biological oxygen demand and changes in pH in water are short-term impacts and may only occur during the pre-construction and construction phase, assuming proper maintenance is done during the operation stage of the project.

2. Socio-Economic Impacts

In large multi-purpose projects, the range of affected human communities is very extensive and the magnitude of impacts that may be generated, very intensive.

Dislocation of human settlements is a major impact in these types of project. The NPC for instance when conducting the environmental impact assessment of the proposed San Roque-Multi-purpose project in Northern Luzon have predicted job loss to those who are engaged in farming and gold panning in the area aside from other serious consequences of dislocation. Downstream, changes in the method of farming are expected due to the introduction of irrigation systems. In another project, the Kaliwa River Basin Project (Manila Water Supply Project III), 3.19 sq. km. of cultivated areas were inundated leading to losses in income and lands among upland farmers. The rattan gathering activities of the dwellers are expected to be totally stopped once the 29 sq. km. of forested areas are inundated.

Income from fishing activities in productive rivers and lakes were also observed to fluctuate or totally decline as scheduling of water drawn down for large irrigation systems become highly variable. This was observed in Lake Buhi and its tributaries and drainage rivers.

The encroachment of these kind of projects into tribal lands, sacred groves, and burial grounds of ethnic people in the Philippines were met with strong resistance, as in the case of the proposed Chico Dam project in Kalinga Apayao. The project proponent had no choice but to abandon the project after a series of killings arising from the scheduled construction of the dam occurred in the area.

Another group, the Dumagats who are nomadic tribes in the mountain ranges within the Kaliwa River Basin are also starting to strongly protest the Kaliwa-Kanan River Basin Project which is particularly intended to meet the increase in demand for potable water in Metro Manila.

Aside from displacement of people, changes in the pattern of ownership along irrigation channels are expected. Social and political instability may also arise as a result of conflicts of interest in the use of water resources, especially where the upstream users and downstream users and/or the head users and end users of irrigation systems are concerned. The Lake Buhi case presents the inevitable conflict of the use of lake water resources. Upstream communities suffered loss in fish productivity due to exposure (during lowering of water level) and damage (dredging, demolition, etc.) of spawning area and natural habitat of aquatic life to give way to increase agricultural production downstream due to irrigation and increase in commercial and industrial activities as a result of power generation.

The same development projects could also have serious effects upon health. The slow-moving waters of man-made lakes, dams, and irrigation channels may harbour the water-based snail (japonicum snails) host which perpetuates schistosomiasis. This is basically the reason why a component on schistosomiasis control is integrated in project in the country. On the other hand, dam spillways with their fast-flowing water could be breeding sites for simulion blackflies which cause onchocerciasis or river blindness.

3. Ecological Impacts

The clearing of vegetation as well as inundation of land to give way to water resources projects will definitely affect the population, habitat, species diversity, and ecological processes of important ecological systems. Food chain relationships among existing aquatic and terrestial organisms in the project area will be disrupted upon inundation and change in the characteristic flow of water.

In forested areas, movement of wildlife species maybe impaired due to noise created by use of heavy equipment leading to displacement or possible death of indigenous endangered species.

Riverine and lake aquatic biota are also affected as manifested by the removal and death of some littoral, benthic and pelagic species among dammed lakes in the country. Moreover the disturbance of the natural drainage of lakes and rivers and the consequent changes in water quality and quantity which resulted to lake trophy had lead to localize massive fish kills in specific project areas.

The disruption of structure and dynamics of ecological relationships and in some cases loss of irreplaceable natural resources are of course unavoidable impacts that have to be weighed not only in terms of their direct impacts within an ecological system but also in their impacts to the human communities considering that such natural resources are the main economic resource base for survival.

III. Institutional and Legal Arrangements For Management of Environmental Impacts of Water Resources Development Projects

1. Implementing Agencies

Presidential Decree (P.D.) N°. 1067 enacting the Water Code of the Philippines of 1976, identified the National Water Resources Council (NWRC) as the government agency tasked to control and regulate the utilization, exploitation, development, conservation, and protection of water resources. The NWRC was renamed as the National Water Regulatory Board (NWRB) and its technical functions transferred to the Bureau of Research and Standards of the Department of the Public Works and Highways by virtue of Executive Order N°. 124-A enacted on July 22,1987.

Under the present set-up, a Policy and Program Division, specifically its Program Evaluation Section is responsible for the review and assessment of all major water resources development projects. Presently, they are still strengthening such function to come up with a rational project evaluation system for above type of projects. The NWRB though has an established Evaluation Section under its Water Rights Division which evaluates all projects applying for water permits. In fact, this Section has recommendatory powers in the issuance of permits based on the technical feasibility and potential impacts of the projects. Unfortunately, NWRB does not have an Environmental Unit which takes charge of the review and assessment of environmental impacts of water resources development projects.

The government agency responsible in regulating major water resources development projects insofar as environmental impacts are concerned is the Environmental Management Bureau (EMB) under the Department of Environment and Natural Resources. The EMB implements

P.D. N°. 1586 otherwise known as the Environmental Impact Statement (EIS) System of the Philippines enacted on June 11 1978. Under this law, all agencies and instrumentalities of the national government, including government-owned or controlled corporations, as well as private corporations, firms and entities shall prepare, file and include in every action, project or undertaking which significantly affects the quality of the environment a detailed statement on:

a) the environmental impacts of the proposed action, projects or undertaking;

b) any adverse environmental effects which cannot be avoided should the proposal be implemented;

c) alternatives to the proposed action;

d) a determination that the short-term uses of the resources of the environment are consistent with the maintenance and enhancement of the long-term productivity of the same; and

e) whenever a proposal involves the use of depletable or nonrenewable resources, a finding must be made that such use and commitment are warranted.

2. Scope of the EIS System

The EIS System covers all projects considered as environmentally critical and which shall be located in environmentally critical areas. This is provided for by Proclamation N°. 2146 signed on December 14, 1981. The environmentally critical projects (ECP's) as well as the environmentally critical areas (ECA's) were technically defined by the Environmental Impact Assessment (EIA) Group in coordination with other government agencies, NWRB included. One of the categories considered as environmentally critical projects are infrastructure projects which include major dams and reservoirs (this refer to all impoundment structures and appurtenances with storage volumes equal to or exceeding 20 million m^3), major hydroelectric power plants (plants with power generating capacity above 6 MW are considered major projects), flood control/drainage projects and fishpond development projects (considered critical if it will involve utilization of areas equal to or greater than 25 ha. or development projects). Irrigation systems are not defined as environmentally critical projects but since they affect prime agricultural lands which are considered ECA's, then they are also covered by the EIS System.

3. The EIS System Procedure

Project proponents of water resources development projects (NPC, NIA, DPWH, LWUA, MWSS, Riverbasin Authorities) by virtue of P.D.

Nº. 1586 are required to secure an Environmental Compliance Certificate (ECC) before project implementation. An ECC is a document issued by the Director of EMB certifying that the project under consideration will not bring about unacceptable environmental impacts, and if there are, that such impacts shall be properly mitigated.

The basic requirement for all major water resources development projects for the issuance of an ECC is the EIS which is actually a document presentang the results of an environmental impact assessment conducted by the proponents.

Copies of the EIS should be submitted to the EIA Section of the EMB which prepares the information package consisting of the preliminary evaluation, ocular inspection report and notice of meeting arrangements for the members of the EIA-Review Committee (EIA-RC) which shall convene to deliberate on the information package.

The EIA-RC is chaired by the Director of EMB and is composed of technical experts/consultants from different disciplines which evaluates and review EIS's and recommend the issuance or non-issuance of ECC regarding proposed projects.

The EIA-RC may recommend any of the following: a) issuance of ECC; b) ECC denial; c) revision of submitted EIS; d) submission of additional information; e) conduct of a public hearing among parties affected by the project.

The revised EIS or the additional information required shall become basis for further evaluation.

The EMB, through its Legal Division may conduct a public hearing if the project is of substantial magnitude in terms of its size/scale and areas affected. Results of the public hearing shall become an integrated basis for issuance or denial of ECC. It may also require the revision of the EIS whereby all matters undertaken during the activity shall be incorporated.

In all stages of the EIA evaluation process, the project proponent, lead agency, and other regulating agencies which have concern over the project are duly informed of the various decisions for each evaluation stage.

It is also possible that along the process, comments/complaints from affected parties will reach EMB. These documents become integral components to the decision - making process in the eventual conduct of public hearing.

Compliance monitoring activities are also conducted by the EIA Group for major projects including water resource development projects. The activity aims to ensure the proponents' compliance with the stipulation cited in the ECC. Likewise, project proponents of critical projects are expected to submit to EMB a periodic report regarding the environmental status of the project.

Proponents are also encouraged to monitor and to conduct post-auditing activities of their projects to make sure that environmental problems are kept within tolerable level and also to ascertain that prescribed mitigating measures are strictly complied with.

4. Exemption to the EIS System

The EMB by virtue of LOI N°. 1179 may grant exemption to any entity from the requirements of the EIS System for reasons of national interest in compliance with an international commitment and upon recommendation of the Department Secretary concerned with the sector. Such an exemption, however, does not preclude the EMB or appropriate lead agency from requiring the project proponent to institute necessary remedial measures to protect the environment.

5. EIA Methodologies Utilized

The simplest method employed by project proponents in the identification and presentation of impacts is the simple descriptive checklist whereby each impact is evaluated in terms of its magnitude (minor, moderate, high, unknown) and type of impact (negative, positive).

The NPC employs more sophisticated EIA methodologies. These include matrices, overlay maps, economic valuation, and network methods. To measure the magnitude of environmental impacts for specific sectors, descriptive checklists and benchmark comparison using established criteria and standards were used. On the other hand, desirability of water resource development projects is determined through the use of benefit-cost analysis (BCA). Social BCA also proved to be an important tool in the consideration of non-monetary as well as non-commensurate environmental impacts.

The highly sophisticated Battele method of evaluation was specifically employed by NPC in the identification, prediction, and assessment of the environmental impacts of the San Roque Multi-purpose Project in Luzon.

However, despite such relative improvements in the methodologies employed in EIA, expertise in the field is still wanting. Obviously, there is a necessity to train technical staff of project proponents involve in water resources development projects in the identification, measurement, prediction, and assessment of environmental impacts.

IV. Training Requirements for the Environmental Management of Water Resources Development

The expansion of water resources development activities in the country intensifies the growing need for highly skilled manpower to staff the various agencies engaged in water resources development and management. In order to provide a steady source of supply of trained personnel as well as to boost employees morale and efficiency, the NWRB has initiated the development of a continuing program in water resources. This is true for all the aspects of water resources development planning.

In the field of EIA, it is sad to note that only a handful of environmental units in the lead agencies, water resources agencies included, have been created, most of which are ad-hoc in character and constitution. This is basically due to the absence of environmental mandate of these agencies. The NPC is however an exception. It can boast of an interdisciplinary group of experts involve in the conduct of EIA's and the preparation of the EIS's under its Environmental Management Department.

The EIA Group of EMB in charge of processing EIS documents is also small and ad-hoc in nature. Technical personnel have varied professional background which in most cases lacks credit or even informal units in EIA, or environmental planning for that matter. The EIA staff learn to apply the principles of EIA as they become exposed to their expected work and responsibilities.

The problem of course aside from the lack of environmental mandate among lead agencies is closely linked to financial constraints in both the implementing and lead agencies. These agencies simply do not have sufficient funds to formally established the organizational structure needed more so in the building up of capabilities for environmental planning specifically the conduct of EIA and preparation of EIS's.

Obviously, the solution to this problem is more funds not only for the recruitment and support of much needed personnel but for manpower training to upgrade, and in some instances, create skills and expertise in the highly specialized fields of EIA.

Proponents of water resources development projects are specifically advised to form an environmental unit which shall be responsible for the conduct of EIA and the subsequent preparation of the EIS as a component to the agency's program planning and implementation. This would of course imply the need for highly trained EIA specialists which the Philippines at present is in need of.

Specifically, technical personnel of agencies involved in water resources development projects should gain competence in the measurement, estimation, and/or prediction as well as in evaluation of environmental impacts for them to be able to incorporate environmental values into planning and decision-making, and eventually in project implementation.

One should realize however, that environmental impact assessment, as an environmental management tool has still to gain wide acceptance in the Philippines especially among the economists and development planners. Nevertheless, it is hoped that in due time the objectives for which the law was decreed will be attained and that the planners will be convinced of the importance and relevance of incorporating environmental considerations in resource planning and preparation of development projects. It is heartening to know however that the National Economic Development Authority (NEDA), the prime planning body of the Philippines supports and coordinates with EMB insofar as the EIS requirements are concerned and has been advising proponents whose project proposals are scheduled for financial assistance to comply with the requirement.

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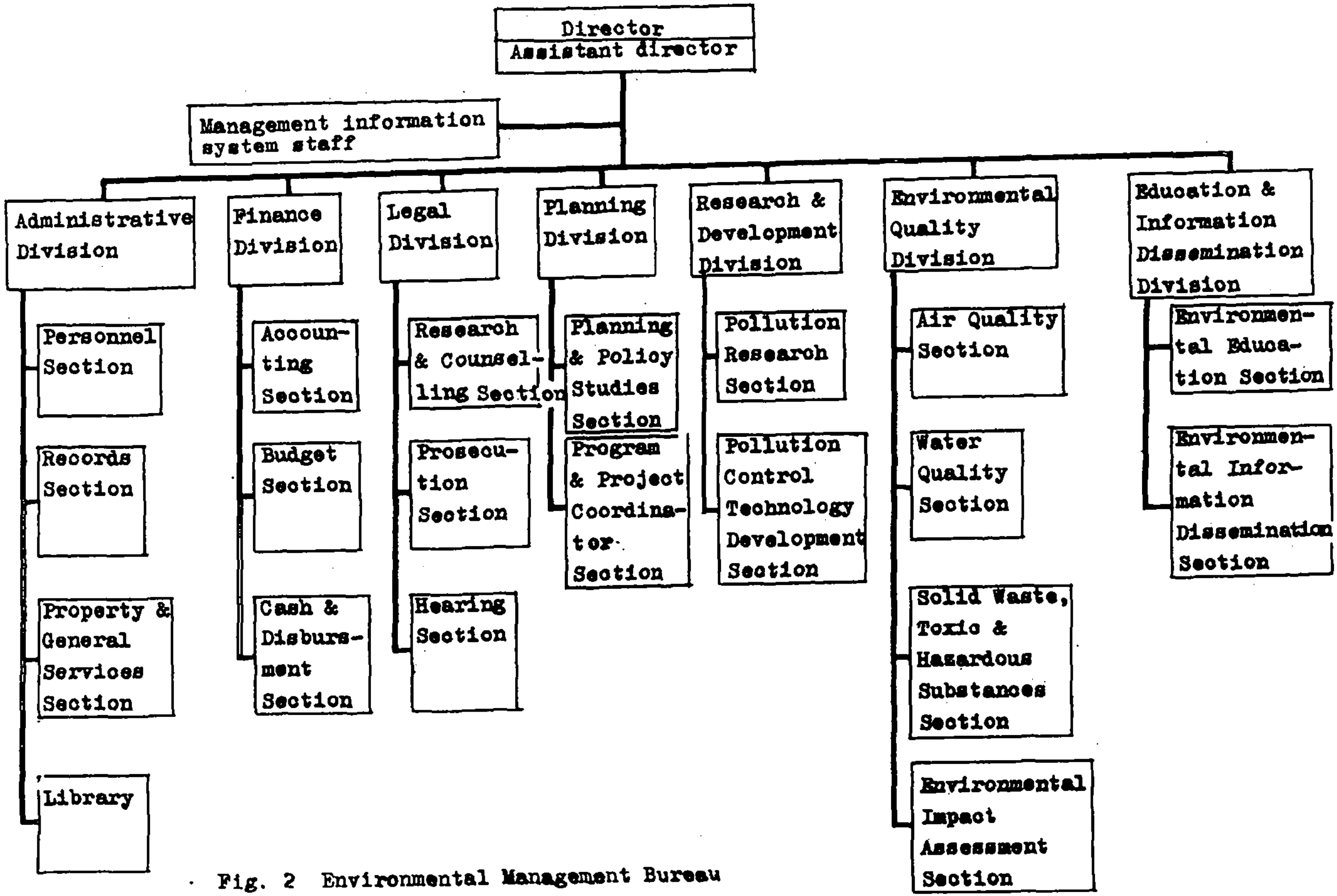
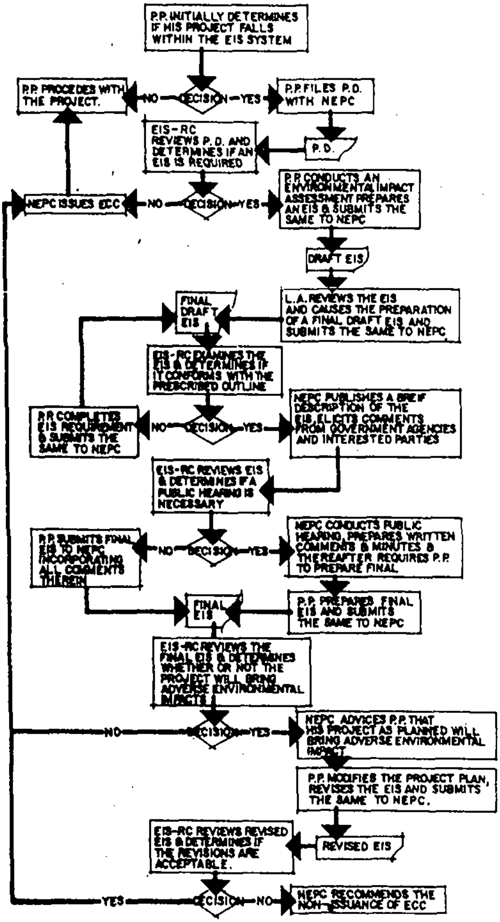


Fig. 2 Environmental Management Bureau



LEGEND:

P.P.	PROJECT PROPONENT	L.A.	LEAD AGENCY
EIS	ENVIRONMENTAL IMPACT STATEMENT	EIS-RC	EIS REVIEW COMMITTEE
P.D.	PROJECT DESCRIPTION	NEPC	NATIONAL ENVIRONMENTAL PROTECTION COUNCIL
ECC	ENVIRONMENTAL COMPLIANCE CERTIFICATE		

Fig. 3 Procedural Flow of the EIS System

ENVIRONMENTAL IMPACT OF WATER RESOURCES DEVELOPMENT PROJECTS IN SRI LANKA

Mrs. J. Amarakoon, Mrs. E. Fernando

1. Country back-ground

1.1. Location, size and topography

The Republic of Sri Lanka is an Island in the Indian Ocean between latitudes 5° 55' and 9° 50' North; and longitudes 79° 42' and 81° 52'. It is situated to the East of the southern tip of the Indian sub-continent separated by a 32.5 km wide strip of shallow water called the Palk Strait.

It has a compact land mass except fot Mannar Island in the north-west, the Jaffna Penninsula in the north and a few sattelite Islands in the North, off the Penninsula.

The Island is Pear-shaped being 434 km from north, to south and 225 km from east to west. Of the total land area of 65,560 km^2 about 20,200 km^2(31%) are used for agriculture, 37,600 km^2 (57%) are under forests and the remaining 7685 km^2 (12%) are water bodies, urban areas or under other uses.

The mountainous area is located in the south central part of the country falling away on each side in successive steps to the sea. The highest peak is 2520 m above sea level and five sixth of the country is at a level below 300 m and about three quarters below 150 m.

1.2. Climate

The climate of Sri Lanka is tropical with mean relative humidity varying from 60% (in the driest areas) to about 95% (in the comparatively wet areas at night). Average temperature ranges from 15°C in the mountains to 30°C in the low-lands. The highest temperatures are observed in April and May and it rarely exceeds 40°C.

Monsoon rains occuring during two distinct periods from May through September (South West Monsoon) and from December through February (North East Monsoon) are responsible for the major part of the annual precipitation. Inter monsoonal rains also contribute to the annual precipitation.

Hydrologically the country can be divided into distinct wet and dry zones. 30% of the land area of the Island is in the west zone which receives the maximum amount of precipitation from both monsoons ranging from 2540 to 5080 mm or even more per year. The balance area of the Island by comparison is called the dry zone and receives about 1270 to 1910 mm of rainfall in a year mostly during the short North-east monsoon period.

1.3. River basins

There are 103 well defined natural river basins starting from the central hills and flow to the sea on all sides of the Island. Sixteen of these streams flow through the wet zone and are perennial. The base flows of these perennial rivers and low and flood discharges tend to be high. The annual precipitation is about 110,000 Mcm, the run-off being about 47%. The wet zone contributes 40,000 Mcm of precipitation of which the run-off is 65%.

1.4. Population

Population of Sri Lanka is 15,837,000 (mid 1985 figures). More than half of the working population of the country work on the land and six out of seven people are directly or indirectly connected with agriculture and related activities.

1.5. Economic aspects of irrigation

The economy of Sri Lanka is essentially agricultural and distinct from plantations of 234,000 ha. of tea, 27,000 ha. of rubber, 428,000 ha. of coconut, there are 766,400 ha. of land under cultivation of paddy (1985 statistics) of which nearly 60% provided with irrigation facilities.

Sri Lanka requires 1,960,000 metric tons of rice annually (1985 population) for consumption. Rice being the staple food of the people and paddy the traditional cultivation laid the emphasis on irrigation. Apart from this cultivation of subsidiary food and cash crops, such as chillies, onions and ground nuts, potatoes is advocated and is done with irrigated water, to conserve foreign exchange assets spent on these imports.

1.6. History of irrigation

The practise of irrigation in Sri Lanka has a long history with the first earth dam believed to have been constructed in 504 B.C.

In the olden days the people settled mainly in the dry zone of the country, as they could not cope with the rate of growth of the forest and the frequent floods in the wet zone. Even in the dry zone they were not spared and were challenged by long spells of droughts which necessitated storing of water. Being forced to meet this challenge they developed irrigation systems and not only built big reservoirs but also constructed complicated channel systems in the down stream. Even successful attempts have been made in the past to construct transbasin canals to augment less yield catchment basins, by making use of high yield catchments.

In the wet zone, which had perennial streams having sufficient baseflow, they learned to construct barrages across these streams to head up the water and water was carried through contour channels to the paddy fields on either bank of the river.

After the country was invaded by foreign rulers, the ancient irrigation schemes were either purposely damaged or entirely neglected till in 1900, when the British Governor realized the importance of the irrigated agriculture to the country and established the Irrigation Department to restore and maintain the existing schemes in the Island.

With the grant of Independence in 1948 shortly after experiencing food shortages during the World War II this restoration programme was launched in a big way and was given high priority, by every successive Government since then.

At present, there are 290 reservoir schemes and 210 anicut schemes which are being operated and maintained by the Department of Irrigation, serving a total of 286,650 ha. of irrigable land.

1.7. On-going development projects in Sri Lanka

Now almost all the existing major reservoirs have been restored and improved and even additional reservoirs have been built or taken up for construction. There are on-going projects to rehabilitate several major reservoirs and all minor tanks too.

Mahaweli Ganga, the longest and the biggest river, has been diverted at various locations to augment supply to basins other than Mahaweli, while reservoirs have been built across it at selected locations, to generate hydro-electricity and to detain water to be released down stream during dry periods. This ambitions program is still not completed. A separate authority has been formed by the Government to implement the programme from its very inception. Once the project is over 106,000 ha. of new lands will have irrigation facilities while 99,600 ha. of already irrigated lands will be assured of adequate water. In parallel to this massive irrigation projects in the dry zone the Government has undertaken flood protection and drainage schemes in the wet zone also.

In the planning stage of massive Mahaweli project there had been several attempts to make an environmental impact assessment of the project in view of the physical change associated with construction of reservoirs, canals and with land use changes such as land clearing and agricultural development as well as the continuing input of the resident human population.

2. The Demand for Water Development and Management

In nature all organisms as a rule live within environments which provide them with adequate conditions of existence. The space where the exchange of matter within the living and non living part of nature takes place, dependent on organic and in-organic mineral substances, is called the ecosystem.

It is the man who interferes with the ecological balance to the most marked degree, especially through economic activity and by growth of population entailing excessive exploitation of natural resources within the complex of all the resources exploited by man, water of particular importance.

As water is needed in greater quantities, a development of water resources and management is particularly important.

2.1. The elements of water resources development

The decisive element in the development of water resources in any part of the world is the use made of atmospheric precipitations. As these precipitations are uneven, man tries to retain water artificially to allocate into his needs.

To accumulate water man builds reservoirs and make use of it when necessary for the improvement of discharge in stresams, irrigation, power generation, supply to housing, etc. Flood waves are held in reservoirs, to be discharged with a decline of high water, a procedure permitting continuous adjustment of the discharge.

From reservoirs and streams with a steady discharge man can supply water to areas suffering from shortage and to areas with a passive water management balance by transport systems.

2.2. Environment and water resources development projects

Large scale water development projects have important environmental repercussions of a physical, chemical, biological, social and economic nature, which should be evaluated and taken into consideration in the formulation and implementation of water projects. Furthermore, water development projects may have unforseen adverse consequences afftecting human health in addition to those associated with the use of water for domestic purposes.

Natural water accumulation in places devoid of outlets usually means exceedingly high ground water tables and often excessive saturation, making impossible the use of such soil for agricultural and other purposes.

Surface water flowing uncontrolled over the land, particularly on soils insufficiently covered by vegetation and which passes through river channels at an increased rate, may cause heavy erosion if the rate and volume of flow reaches a certain value. This then results in disruption of hydrological cycle and direct damage to human environment.

Generally water resources development projects involve two types of environmental changes. The first is the physical change associated with construction works such as tanks, irrigation ways, as well as with land use changes such land clearing and agricultural development. These physical changes usually take place over a short period of time and radically after the point of environmental equilibrium from its former state.

The second type of change is the continuing input of the resident human population. This input is not constant but varies in response to change in the environment and to altered socio-economic conditions. The long range stability of the regional environment depends on the new equilibrium established by the feed back relationships developed between the new population, its new activities and the new environmental setting.

In Sri Lanka, majority of tanks which were used in the past went into dis-use in the past few centuaries. In more recent times many of these have been restored and are now in use for irrigation purposes. More than half the reservoir area in this country is made up of small reservoirs, less than 300 ha. in extent. Small reservoirs in this country are dependent for their water on precipitation, since most of them are distributed in the dry zone. A number of reservoir of large extent exist in the country either for irrigation or as a multi-purpose resource.

Reservoir management requires the maintenances and protection of a pheripherial green belt, the monitoring and regulation of water quality, the development, monitoring and regulation of appropriate fishing activity and the social welfare of communities that depend upon and are associated with the reservoir and its activities.

3. Environmental Problems Associated with Water Resources Development Projects in Sri Lanka

3.1. Public Health

The public health impact of the water resources and settlement project centres around three areas of concern.

a) Alteration of the habitat of disease vectors, primarily that of mosquitoes.

b) Contamination of drinking water supplies, primarily with human waste; but also with agro chemicals.

c) Transitional problems associated with the re-settlement of people.

a) Alteration of insect vector habitats

Water resources development projects generally have significant effects on the habitats suitable for breeding of mosquitoes. These effects derive from the following project related changes; a large increase in acreage of open water for greater portion of the year; a rapid increase in the density of human population within the project area'with an increase of breeding places for house hold mosquitoes.

At least four mosquitoe born diseases exist in Sri Lanka, namely malaria, dengue fever, haemorrhagic fever and filariasis. In Sri Lanka the vector of Malaria is Anopheles Culicifacies. Malaria has become the most threatening of all these four diseases. In the first four years of implementation, the incidence of Malaria increases due to several factors such as the increased volume of open water in the project area, the creation of the standing water for a greater portion of the year, and rapid increase in the density of human population within the project area.

There are however, at least 8 other species of mosquitoes present in Sri Lanka which are known to transmit Malaria in other parts of the world. A.culicifacies breeds in temporary pools which are free of vegetation, or at the fringes of paddy fields. It is therefore of great importance that paddy fields are well drained after harvest to avoid the occurrence of temporary stagnant water.

Over half a million cases of malaria are reported each year in Sri Lanka. Control programmes are focussed around house-spraying four times a year, using malathion. Spraying programmes have proved successful in the past but great care has to be taken to avoid the building up of resistence against a certain insecticide by the mosquitoe population. Therefore, a careful plan for the alternation of different insecticides should be implemented.

On the positive side an increase in the availability and accessibility of health care would be forthcoming.

b) Contamination of drinking water

Contaminated drinking water is the cause of many diseases like cholera, enteric fever, hepatitis, amoebic dysentery and polio. Contamination of open water bodies is to a large extent caused by poor sanitation facilities causing human waste to reach the water without being filtered or purified biologically. The provision of latrines and boiling of drinking water would improve public health considerably. Also the construction of wells or the provisions of pipe born water would be advisable. The well should be dug well away from irrigation waters, to allow natural filtering of the ground water. The quality of the well water should be regularly monitored, to be able to detect pathogenic organisms before a large number of people are infected. Education of the settlers on the causes of the different diseases is of the utmost importance.

One of the consequences of nitrate leaching by both irrigation water and rain water will be is the build up of nitrate in the sub soil waters. Similarlly the concentration of pesticide break down product residues may also increase in shallow wells that are used for domestic water supplies. None of the chemicals which have accute toxicity to man survives long enough under field conditions to reach any sources of domestic water. On the other hand the farmers who drink drainage ways in the field may be exposed to harmful levels.

c) Exposure of non resistant people to certain diseases

The settlement of people from different surroundings into the schemes is likely to cause a transient problem of resistence of these settlers against certain diseases like for instance amoebic dysentery. It is highly recommended to vacinate settlers against communicable diseases before they are settled in new areas.

3.2. Soils and Agricultural Practices

Erosion is a major threat to the long term maintenance of agricultural output through loss of top soil. Aside from the loss of value top soil, erosion also increases the silt load of drainage waters which leads to logging of drainage ways, silting up of reservoirs and alteration of aquatic flora and fauna.

Land preparation, involving the removal of the vegetative cover and trees, and the distruption of the soil surface, could induce erosion and also can grading operations, but it is found that the long terms effects of land preparation would be much less significant than those resulting from the more intense cultivation of upland areas. The forecasted annual loss is as high as 20-30 tons per hectare, a loss which could be alleviated only by careful slope control in fields, as well as by rotation cropping of upland crops, in order to protect from erosion during heavy rains.

Soil loss from irrigation areas due to erosion and siltation effects in down stream water bodies depends on the characteristics of the areas, including slopes, soil erodibility and rain fall intensity. When the number of cultivators in the catchment areas increase or when the project area energy needs are met by fire wood taken from the catchment area, substantially greater percentage of the catchment area will develop potential for erosion.

3.3. Water Quality

Water quality in the project area is affected in various ways. Increased colour, turbidity and suspended solid would result from construction activities as well as from soil loss due to land clearance and subsequent agricultural practices.

Water in the reservoirs and local tanks are effected by agro chemicals used for raising crop yields, mainly pesticides and fertilizers. Surface waters are contaminated due to improper waste disposal and sanitation practices as well as by animal waste in the draw down zones of all tanks.

Because the sources of domestic water in the project area are generally shallow and because there is a great deal of percolation water carrying leachate from cultivated fields through the water table, it will be necessary to monitor the quality of water on a regular basis. A watch should be maintained both for long term changes in water quality and for accidental transient pollution.

3.4. Wild Life

As far as wild life abundance and protection is concerned, Sri Lanka belongs to the leading countries in the developing world. Due to legislation and general attitude towards wild life population, the country is fortunate in possessing a rich variety of wild life including birds. Unlike in many other country, the fauna thrives outside the boundaries of National Parks and Natural Reserves.

The development of new lands for cultivation can only proceed at the expense of natural habitat and the associated fauna and flora. However, social values derive from the cultural and spiritual traditions in Sri Lanka indicate a need to balance development goals with wild life conservation.

3.5. Forestry

The aims of forest conservation and wild life conservation run parallel with forest conservation having more direct and quantityable benefits for mankind.

Forests are very essential part of the country and of paramount importance in any land use planning. Most unfortunately however, Sri Lanka's forests are being destroyed at an alarming rate. Chena cultivation (a tradition of agriculture involving both low land paddy and upland shifting cultivation) is the main cause upto now. If forest destruction continuous at the same rate it is expected that by the middle of the last decade of this century virtually all the forest on the Island has disappeared.

3.6. Tank Fisheries

The formation of new reservoirs results in the replacement of riverine ecosystems with La Custrine with the subsequent elemination fish species and an enhancement of other species which prefer running waters.

Habitats require highly oxygenated, hard gravel substrates as breading or feeding grounds would not be expected to survive a transition to a lake environment. On the other hand fishes which occur in the rivers, what are found primarily in the quite waters along the shore line or in back waters, will be not only survive the impoundment but may increase the population sizes substantially.

3.7. Sea Fisheries

Theoritically, sea fisheries decline as a result of the new projects as the flow of the nutrient-rich fresh water into the sea will be reduced. On the other hand, the consentration of nutrients in agricultural drainage water, both from agricultural origin and domestic origin increases the production of sea fisheries.

4. Environmental Assessment Procedures in Sri Lanka (EAP)

As Sri Lanka's development efforts continue to expand, the protection and management of the nation's environment and natural resources has become a major concern. The guidelines for Environmental Assessment Procedures (EAP) have been prepared as a recommended means of integrating environmental planning and protection measures with proposed development activities in Sri Lanka. It is intended that these Procedures will become part of the decision making process for implementing development projects and programmes.

These guidelines are general in nature in that they can apply to any type of development project. It is expected that each individual agency will adopt its own procedures to implement these regulations. The individual agency procedures will reflect specific agency requirements which should be taken into account in conducting the EAP.

Normally, the EAP will be applied to relatively major proposed development projects and programmes. However, certain types of projects or programmes may be automatically exempted from the EAP process. This may include, for example, emergency relief or assistance, research activities, training programs, other educational programs, nutritional or health care services, minor legislation, security measures, etc. The individual agency procedures will be expected to identify which types of projects will be exempted from the EAP.

It is intended that the environmental Assessment Procedures will be undertaken by the governmental agency which has the main responsibility for implementing a specific project or programme. This "lead" agency will receive technical and administrative inputs from other interested or "cooperating" agencies at appropriate times during the EAP.

4.1. Guidelines for EAP

The EAP is described below is a step wise process, designed to provide environmental information in a series of documents which will be prepared to correspondent with and be incorporated into the successive phases of project preparation:

i. An initial environmental examination (IEE) is the first review of the potential effects which a proposed project will have on the environment. This document is relatively brief and contains, a) description of the project, b) existing environment, c) evaluation of impacts, d) discussion of mitigation and protection measures, e) EA recommendations, f) review and comments.

ii. Scoping is a process of identifying important issues which must be addressed in detail in the environmental assessment. When practicable scoping meeting is held among the interested agencies and parties and sporting document is prepared which will incorporate, a) EA work plan, b) EA schedule, c) staff and resource requirement.

iii. Environmental assessment (EA) is a detailed study of the probable significant effects both beneficial and adverse which a proposed project will have on the environment. The EA document includes the following:

i. Introduction
ii. Table of contents
iii. Summary
iv. Description of Proposed Project
v. Existing environment.
vi. Impact analysis
vii. Mitigation and Protection Measures
viii. Recommended Action.

iv. Environmental Action Plan AP is a implementation plan for specific mitigation, protection and/or enhancement measures which are recommended in the EA. The protection measures which require the formulation detailed implementation plan and therefore inclusion in the AP will be selected on the basis of the recommendation in the EA and the review of the EA by the interested agencies and parties.

v. Supplemental Environmental Report if a major change is made in a proposed project after the EA and/or AP have been completed, then a Supplemental Environmental Report (SER) will be prepared to evaluate the specific impact which may occur due to the new change. A SER may also be warranted with significant new circumstances or information arise which would have a bearing on the proposed project or its impacts.

4.2. Procedures adopted in water projects in Sri Lanka

In Sri Lanka in assessing the environmental impact of water resources development projects, datas are developed in the following areas to describe those characteristics crucial for determining the long term demands likely to be made by the water resources development projects on the environment.

a) Demographic description

Information is obtained from variety of sources including official government censuses and other surveys. From these sources data on family size, age distribution an educational level are obtained. Difference between the population now resident in the project area and those likely imigrate to the project area are also obtained.

b) Consumption habitats

The needs for project area residence for food, consumable goods, construction methods are estimated from census surveys. The effect of increased affluence is also estimated.

c) Energy needs

The requirement of the population for following activities: Cooking, lighting, transportation, cultivation, etc. are obtained from data sources. The change in energy needs of the individual family is determined.

d) Farmers and Farm inputs

The expected application levels of ferlizers, pesticides, and herbicides are determined from the economic of individual farm budgets.

e) Water

The changes of water regime in the project area which results from the implementation of the project are examined in terms of their consequences for public health programmes.

f) Human behaviour

The sanitation habits of the population with regard to practises of boiling water and waste disposal as well as the attitudes towards the use of agro-chemicals are obtained.

g) Soil

The potential for erosion and siltation as a result of changed agricultural practises as well as construction in the projects area are determined.

h) Biological Systems

The altered potential for fisheries development in the project area tanks are determined.

5. Evaluation of Effectivness of the Mitigation Measures

5.1. Public health

Present utilization of active case detention by trained worker might appear as a useful substitute for a more passive technique. However, the method seem to work poorly in this country, except in regions remote from physicians rather than by ACD workers. Active detention agents generally distribute drugs and a patient with malaria is discovered, but this service seem to be redundant in present day Sri Lanka.

The traditional design of open well is changed slightly to assure sanitory conditions. Present wells in the project area have a concrete lining which limits surface and some ground water contamination.

An intensified health education and public information programme is needed to break down cultural habits which are presently conductive to poor health conditions. A nation wide self-help programme of training and education has been instituted by the anti-malaria campaign.

5.2. Erosion

In certain areas of Sri Lanka to reduce erosion, erosion control plantations are established on steep slopes abutting the present timber line and on ridges and mountain tops where there is sufficient soil remaining to sustain them. The loss of soil by erosion can still be reduced by rotational cultivation including upland crops which protect the soil from erosion from heavy rains.

5.3. Fisheries

The major irrigation tanks in some new project areas have been designated for improved fisheries management programme by Island Fisheries Development Division.

5.4. Land use policy planning

At present un-controlled forest clearing causes erosion and siltation. Value of the timber and fire-wood is burnt on the spot. The fertility of large chena cultivation areas is lost because of rotation period becoming shorter and shorter.

It is of the utmost importance that an overall land use plan be made as soon as possible, which define clearly which area are to be kept under forest covers, either for reasons of water management, erosion prevention, timber and fire-wood protection, wild life conservation or a combination of them.

On the planning and policy making level the problems are well understood. On the implementation and enforcement level however, a lack of man-power, means and equipment is often cause of failue to carry out the measures decided upon.

5.5. Wild life

The oldest wild life reserves in the country are the Ruhunu National Park and the Wilpattu National Park. They are poor lands and both of these old reserves lie in the Dry zone of the country. However, more recently a number of other reserves have been established, specially in relation with major irrigation reservoirs.

Those National Parks have been functioning satisfactorily over a long period of time, they are rapidly reaching a critical stage. The major factors contributing to this situation are:

i. Encroachment and illegal activities within national parks.

ii. A large scale clearing of forests as part of major development projects.

6. <u>Training Requirements for Promotion of Environmentally sound Management of Water Resources Development</u>

i. Preparation of an integrated Land Use Plan for the Island as a whole and establishment of a Land Use Authority to function as a decision making and executive body in respect of land use is very essential. Training of District Personnel in integrated land use planning to implement the plans produced in consultation with the central body is necessary.

ii. Creation of a cadre of technically qualified personnel with training in Land Use Planning, Soil Conservation, Crop Production, Fisheries, and Forestry to work at Village Level.

iii. Training of Forest Managers in an integrated manner covering forest resources management, water shed management, wild life management and timber management.
Training of range of personnel in all respects of forestry and wild life management is required.

iv. Health Education Unit should be established as part of the comprehensive health plan for the project areas. Training programmes in all aspects of health education and educational programmes in health disciplines in schools are necessary for successful comprehensive health programme.

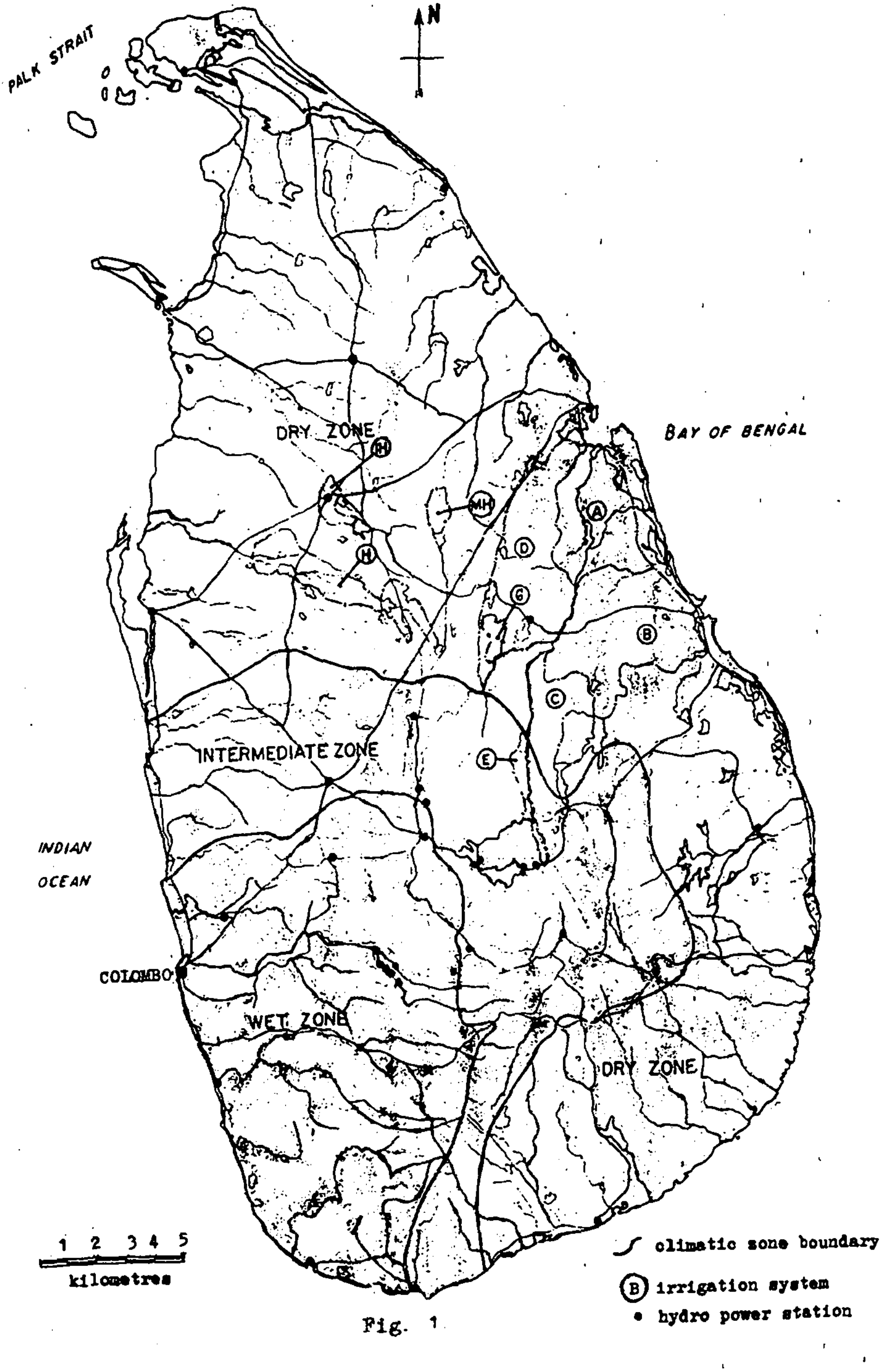
v. It is important to establish a management programme which will control and regulate the application of irrigation water effectively including administrative capabilities, such as manpower training to implement the programme efficiently.

vi. At present there is no Government Agency which is conducting a water quality sampling or monitoring programme in the project areas. However, a well equipped laboratory with highly qualified technical staff is presently operating at the Central Agricultural Research Centre. It is recommended that an integrated water quality monitoring programme be directed from this centre. This would require an increasing trained staff.

7. Conclusion

What is needed now is a plan for further elaboration of the strategy and early implementation of its priority elements.

Environmental impact of the Major Irrigation Schemes, particularly Mahaweli should be continuosly monitored and the information used to initiate early corrective actions where necessary.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OCEAN
COLOMBO
WET ZONE
DRY ZONE
1 2 3 4 5
kilometres
climatic zone boundary
B irrigation system
hydro power station

Fig. 1

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