WATER RESOURCE MANAGEMENT

NISHI SINHA

The book deals with the various problems concerned with water resource management in different parts of the country. Ours being a vast country with different soil and climatic condition the problems faced by the inhabitants in different areas are quite different from each other. The Ganga plains endowed with rich soil and adequate water resource also happen to be the most fertile stretch of land in the world. The ample availability of water which seems to be a boon for the agro-climatic condition of this area seems to become a curse during the monsoons. The area is perpetually devastated by floods keeping the economy perennially in low gear.

The sharing of water of Ganga and its tributaries between India, Nepal and Bangladesh is purely a political issue since most of the rivers of this area originate in Nepal and thereafter drain India, Nepal and Bangladesh. For the construction of dams upstream all the concerned nations have to cooperate since they are the recipients of the benefits.

While we have ample water in Eastern India, in Western India we are faced with salinity of water which takes place as a result of water logging due to excessive canal irrigation. One sometimes wonders whether man himself is his own enemy since we have to face so many man made problems.

To reduce the excessive seepage in these areas one must take recourse to lining of canal. Yet in areas which are deficient in groundwater one has to see to it that conditions are suitable for artificial recharge of water.

In the tribal and hilly areas the requirements are quite different. Here one has to put in extra effort for taking out water by tubewell. These areas are peculiar since they have plenty of water in the river during the rains but as soon as the rains are over the river dries up making things difficult for the inhabitants of the area.

For a balanced and proper development of any area one must resort to irrigation by canal as well as tubewell that is conjunctive use. Flood control measures also have to be adopted so that the economy thrives well.

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NISHI SINHA has been working as a free-lance journalist since the mid-seventies. Although in the initial stages of her career she concentrated on cultural, social and political issues, later her focus of attention shifted to economic issues and water resource management. She has been writing on water resource management since 1985. Her first few articles on this subject were published in *The Statesman*. From 1988 onwards she started contributing articles on water resource management in a regular manner to Financial Express, Delhi. She started writing articles on this subject for The Observer of Business and Politics in 1991, and Yojana (published by Planning Commission) in 1992.

On economic issues she contributed articles regularly to Economic Times, Calcutta since 1980. She later on switched over to writing articles on economic issues for Financial Express, Delhi (1988), The Observer of Business and Politics (1991) and Yojana (1992).

She was a columnist on gardening with National Herald, Delhi for over two years. A book written by her "Gardening in India" was published by Abhinav Publishers in June, 1993. The book has been very well received in the market.

On social and political issues she was writing for the Statesman, Delhi (1985-90) and earlier Amrita Bazar Patrika, Calcutta (1979-86). Before joining the press she was with AIR, Patna. Her talks have been broadcast from the external services of AIR. Her musical feature "Bihar Ke Ritu Parv Geet" was adjudged first for Asia Pacific Broadcasting Contest at the national level.

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Preface

Born and brought up in the State of Bihar with the Ganga plains in the North and hilly terrains in the South, I had a chance of observing problems related to water resource management at a close quarter not as an expert but as a layman in my childhood and youth. I am a person who likes to study nature closely and since water resource management is closely related to the interplay of various aspects of nature so I am greatly interested in it. The plains of North Bihar though well drained by rivers are devastated by floods during the monsoons almost every year leading to loss of human lives and miseries which cannot be measured in terms of money besides loss of property which runs into crores of rupees. In the tribal belt of South Bihar due to excessive flow the rivers are flooded in the rains but as soon as the rains are over they dry up. For exploitation of ground water one needs diamond rigs in this area.

I have tried to present the various problems faced by the people in different parts of the country and also tried to find out some or other solutions to them. I do not know to what extent I have been able to communicate to people. I only hope that the problems and solutions given by me in this book are of some use to the people of the areas concerned.

From my early childhood, I have been a mute spectator to the vagaries of nature—agricultural operations in full swing, lush green stretch of crops after a lusty monsoon, and, then, suddenly, everything razed to the ground by the ferocity of the floods. This phenomenon, repeated year after year, without any let up in human endeavour, led me to think in my solitude on the issues confronting water resource management as possible solutions to avert the untold miseries of the poor farmers. This book is a product of such introspection, discussion and lively debates with those who are known authorities on the subject.

Dr. Triyugi Prasad, Director, Centre for Water Resources Studies (Patna) and earlier Associate National Professor happens to be my friend philosopher and guide as far as water resource management is concerned. I must also thank Mr. R.C. Bhatia and Mr. M.M. Manchanda who have helped me with all the typing work. My husband, Mr. R.K. Sinha, IAS has all through encouraged me not only in writing this book but in writing as such and so I must thank him.

NISHI SINHA

Foreword

It gives me great pleasure to write a foreword to this book on Water Resource Management by Mrs. Nishi Sinha. Certain aspects of this critical area of economic management have been virtually upstaged by the prolonged controversy over the Narmada dam. That water is a precious input gets short shrift not so much because of concern for rehabilitation of people uprooted by the large dams, as of efforts by the environmental lobbies to turn such concern into an instrument of prolonged confrontation with the administrative machinery. While it is important that there should be effective relocation of villagers dislodged by the construction of big multi-purpose projects, yet this cannot be allowed to hold up, often for indefinite periods, serious efforts at effective utilisation of the avilable water resources.

Long years after Independence and after 40 years of planned development we are still groping in the dark for a strategy that would work. A lot of water gets washed into the sea because of poor acquifers and a breakdown of the water tables. Over-exploitation particularly during periods of persistent drought has led to a virtual ruin of the water tables and have damaged the acquifers. Even where there is a heavy rainfall, after the monsoons the same places face a scarcity of clean drinking water. This is a national tragedy and reflects badly on the quality of water resources management.

There has been a lot of talk about linking the national rivers and even now some experts are seriously thinking of merging the big northern and southern rivers. But the expenses on such a plan and its physical complexity make it both economically and technically infeasible atleast at the present juncture. Effectively, there is really very little that the Government can do to cope with the ravaging floods of Brahamputra and making its abundance contribute to agricultural growth in other regions that are perpetually short of water. While year after year large parts of Assam are simply overwhelmed by the fury of Brahamputra, also known as Tsangpo, if all the water could be channelled into the other parts of the country, we will have a more bountiful and viable farm sector.

While provision of drinking water is a major priority, there are still several areas which go without safe drinking water. The resources that are available below and above the ground level have to be tapped judiciously and not ruined through excessive or reckless exploitation. Mrs. Sinha has focussed on these and other issues and I am confident that this book will generate a lot of public interest besides fostering greater awareness of the need to improve the quality of water resource management.

K.S. Ramachandran
Senior Editor, Financial Express

CONTENTS

Chapter 1

The Role of Water Resources in the Rise and Fall of Empires

Water resources for irrigation and other benefits constituted the base of the rise of civilizations in India. It dominantly contributed to the prosperity of several empires that flourished in India's past. Inadequate attention to it invariably resulted in peril and disaster. Irrigation development, though undertaken during the British period to subserve the colonial interests, came in association with modern technology and organisational infrastructure. With this inheritance, free India took up the colossal task of economic reconstruction in which water resources development for multiple benefits was accorded the highest priority. India's achievements in this field through successive five-year plans are impressive but far from adequate. The tasks and targets to be achieved in the future make it imperative that water resources development be pursued with much more vigour taking into account new factors such as regional imbalance, international co-operation and ecology.

As water is an essential condition of life on this planet, water resources have been a decisive factor in the growth and development of human civilizations throughout history. All the ancient civilizations were distinctly and predominantly hydraulic in character as they not only owed their origin to reliable sources of water to meet their diverse needs but also their course of development and as the distinctive characteristics acquired in agriculture developed and became the mainstay of the economic life of people, they migrated to river valleys in search of fertility of soil, congenial agro-climate and sources of water which he could manipulate for the irrigational and related requirements. This also spelt an end to nomadic way of life and gave rise to permanent human settlements bound to the lands tilled for agriculture. Concomitant requirements for agricultural activities and productions made it necessary for people to organise themselves into some form of government, to engage in trade and commerce and to acquire skills in related arts and artisanship. In addition to agriculture, rivers were found useful for several of these purposes and functions, such as inland transport, drainage and water supply. Thus, rivers played central roles in the life and living of these people and consequently their civilizations came to be known as river valley civilizations.

Prime examples of ancient river valley civilizations of the world are Egyptian civilization in the Nile river valley, the Mesopotamian civilization in the valley of the rivers Euphrates and Tigris, the Harappan civilization in the Indus river valley and the Chinese civilization in the Huang-Ho river valley. All these civilizations, which existed and flourished from 3000 to 2000 B.C., had the common feature that their basic economic activity was agriculture which was not only made possible but rather got a great impetus from the beneficial effects of the respective rivers. There are historical evidences to show that certain engineering measures were adopted during those times in order to enhance as well as sustain these beneficial effects and also to protect against damaging phenomena of floods. Rise of towns, trade, commerce and various branches of knowledge and arts all followed from the basic prosperity provided by agriculture. Fall from the ancient glory enjoyed by these civilizations and gradual decay of some of them were partly prompted by mankind's creeping inability to cope with the adverse and damaging consequences of his interference with the hydrology and hydraulics of the respective rivers in his attempts to derive benefits.

Magadh, the lower middle region of the Ganges valley, had been the centre of several flourishing empires of ancient India. The two most prosperous and prominent empires in this region had been the Maurya Empire, founded in around 320 B.C. and the Gupta Empire, founded in around 320 A.D. In the written accounts available for these periods, specific mention of the use and management of the water resources of this region for agricultural development and the extensive utilization of the river systems for inland transport as a dominant factor in promoting trade and commerce is found. In the Maurya period, tremendous effort was made for irrigation development in order to derive maximum advantage from the fertile lands. Definitive evidence of canals and tanks constructed for irrigation and of irrigated agriculture in the Magadh region is found. A major reservoir called Sudarshana Lake was constructed at the foot of Mount Girnar in western India. Cultivation of generally two and occasionally three crops in a year, including rice and wheat, was routinely and profitably done. Prosperity based basically on agricultural production gave rise to remarkable developments in various fields such as trade and commerce, sculpture, art and architecture, science, philosophy, religion and politics. The book Arthshastra written by Kautilya of this period is considered a classical treatise on state-craft, diplomacy, economic and public administration and gives a description of the state activities and functions carried out in the Maurya Empire. In the Gupta period, acclaimed as the 'golden period' in India's history in view of the enhanced prosperity enjoyed by the people, there is an evidence of further development in water resource management and ultilization for agriculture. Drainage of water-logged lands, bringing fallow land under cultivation by providing irrigation, construction of storage reservoirs and canals and repairs of old works for further development of irrigation in this region were done. The repair of the Sudarshana Lake at huge public expenditure was done. While rice was extensively cultivated in water abundant regions, new types of crops in conformity with the prevailing agro-climate and water availability came into being. Mention of surplus agricultural production and export of agricultural produce is clearly found in the historical accounts. Development of inland navigation for the transport of goods took place on a much more extensive scale. The consequent material prosperity gave rise to some of the most astounding contributions in the fields of science, literature, fine arts and sculpture ever made in Indian history.

India, particularly North India, witnessed a period of upheavals, frequent foreign incursions and internal disturbances since about 9th century. Its history for the next six centuries or so was marked by an absence of stable political regime. The economic and developmental activities were bound to be adversely affected by these unstable conditions. However, the important role that water resources played even during these periods is underscored by several instances. Agriculture was still the predominant economic activity in these times, as almost the entire revenue of the state was derived from the agricultural production based taxation. Dug wells, some of which were equipped with certain mechanical lifting devices, were extensively used during these periods for irrigation. This, coupled with congenial agro-climate and fertile land in the Gangetic valley, maintained the agricultural production at a level sufficiently high not to have caused any noticeable economic distress in a period marked by frequent invasion and plunders. Of course, increase in population necessitated more lands to be brought under cultivation. A corresponding increase in irrigation facilities, however, was also considered essential to maintain agricultural productivity and to promote superior variety of crops. In the 14th century, two reservoirs and a very elaborate network of canals were constructed for the purpose in the Gangetic and the Indus valleys by the Tughluq rulers. An additional water-tax was levied on the farmers of the irrigated areas in view of their increased agricultural productivity.

South India, which did not directly suffer from political unpheavals during this period was less fortunate in matters of fertility of lands and congeniality of agro-climate. Consequently, water resources development was more compulsively required to sustain agriculture in this region. Construction of small-size tanks to trap and store surface runoff of streams and diversion of river water by means of what they were called 'anicuts', a type of weirs, were undertaken and developed in this region as means of irrigation. Evidence of a few major dams constructed in the 15th and 16th century such as Madag Lake and the Bhebar Lake for the purpose of irrigation is also available.

When Mughal empire was established in the 16th century, India by and large passed through a period of political stability for the next two centuries. Although arts, crafts and architecture noticeably flourished in India under the patronage of the Mughal emperors, agriculture remained the predominant economic production activity. Irrigation by means of tanks, canals and wells was widely taken recourse to by farmers to free agriculture from its helpless dependence on the vagaries of monsoons and to boost agricultural production. The rulers took several reformation steps to rationalize the land-based or production-based taxation, the revenue structure and the land ownership procedures. Major effort at irrigation developments either in terms of expansion of irrigation or improvements of techniques does not seem to have been made in this period. Consequently, both agricultural production as well as productivity gradually fell, forcing the later rulers to repressive measures for collection. This caused disaffection among the farmers and led to revolt by them against the oppressive regime. This gravely undermined the grass roots hold of the Mughal empire, leaving it very vulnerable to machinations of the European companies. Thus, neglect of irrigation development and relevant water resources management, whose adverse effects on agricultural cumulated over time, took ultimately the toll of the mighty Mughal empire.

India enjoyed yet another period of political stability for two centuries under the British rule. The European companies which took advantage of the internal dissensions and weaknesses of the prevailing rulers in capturing power and assuming the role of rulers, were primarily motivated by the interests of trade and commerce. Hence, no attention was paid to agriculture and related water resources development in the initial periods of the British rule. Two situations, however, forced a change in the attitude of the British Government towards irrigation and associated developments in the country. One was that due to progressive deterioration of erstwhile irrigation works in the country and other factors, agricultural production fell, resulting in successive incidences of famine. In the first half of the nineteenth century, various parts of the country came in the grip of famine seven times, taking a toll of approximately one and half million people. The second factor which prompted the British Government to change its attitude to irrigation development in the country was the realization that India had to serve as a colonial source of supply of raw materials and agricultural produce for the British industry. This led the British Government to constitute two commissions, (i) the first Famine Commission in1880 which emphasised the need for direct state initiative in the development of irrigation and recommended that irrigation be given priority over other competing fields, such as the railways, and (ii) the First Irrigation Commission in 1901 which recommended renovation of several existing defunct or dilapidated irrigation works and proposed new schemes. It drew up a 20-year plan envisaging a huge public expenditure to irrigate 2.6 million hectares. Following the first Irrigation Commission's Report in 1903, an accelerated construction of public irrigation works, began, both as protection against famines as well as for additional agricultural yields. In pursuance of these recommendations important irrigation projects, mostly river-diversion works of considerable size, were undertaken. Some storage works in the south, tank irrigation projects in central and southern India and tubewell irrigation scheme in western U.P. were also implemented.

Two features marked the irrigation development during the British rule. One was its uneven distribution in the country. Protective irrigation projects were planned and executed for those areas which were drought affected and liable to be stricken with famine. Productive irrigation projects were implemented in areas which were most prospective for colonial ends and purposes. Secondly, irrigation development came to India through the British alongwith relevant technology and organisation. An infrastructure to use, generate and impart this technology was also developed. Thus, an engineering institution, such as Thomson College of Engineering at Roorkee established around 1850 and a research organisation such as Central Water and Power Research Station at Pune, set up in 1916, also came as part and parcel of irrigation development during the British period. Although irrigation research was not very much organised and institutionalised, some pioneering contribution was made in this field by various individuals such as Sir Arthur Cotton, R.G. Kennedy, Gerald Lacey and others. On the organisational side, public works departments of the provincial governments developed for the purpose provided very effective management and administrative instrumentality to design, construct and operate irrigation projects.

When India gained independence in 1947, its dominant long term objective was to build up its economy. India's first Prime Minister, Mr. J.L. Nehru was quite forthright and categorical in his statements made on several occasions that free India's most important problem was its poverty. As a matter of fact, the prime motivation for India's long struggle for freedom was the growing pauperisation of its teeming millions as a result of the colonial economy imposed upon it. In free India's endeavour for economic reconstruction and regeneration, agricultural development was to be accorded the highest priority, not only because food production was to be substantially increased and had to keep pace with the expanding population but also because it was essential to build up the grass roots economy of a country more than 80% of whose people depended on agricultual or agriculture-based activities for their livelihood and occupation. This could only be achieved through increasing the productivity of its culturable land. The scope for increasing the extent of culturable land itself was very limited. The only viable strategy for the purpose was expansion at that time. Out of total irrigation potential of 113 million hectares, only about 22 million hectares were under irrigation from various sources at the time of independence. There was ample water resources available to realize this ultimate goal in irrigation. Out of a total annual surface water runoff of the order of 176 million ha-m 67 million ha-m, are utilizable and can be harnessed to Irrigation. Moreover, approximately 27.5 million ha-m is annual recharge and hence available as groundwater resources. Thus, water resource on an aggregate basis was not a constraint for desired irrigation expansion. The space-time distribution, however, of this water resource was not in conformity with the multi-seasonal needs for agriculture. Suitable changes in this distribution had to be brought about and necessary infrastructural facilities created through various engineering projects. It was assessed that 58 million ha could possibly be brought under irrigation through major and medium projects while the remaining 55 million ha could be covered through minor projects, most of which would be based on the exploitation of groundwater.

It was a stupendous and staggering national task by any standards. But India could embark on this with considerable confidence because of the tradition and experience it enjoyed in the matter from time immemorial and because it inherited from the British predecessors an appropriate irrigation infrastructure for modern irrigation development. Of course, there was to be a qualitative change in free India's approach towards further irrigation development. First, irrigation development was now to be planned and pursued as an instrument of economic regeneration and prosperity of the nation, rather than as a measure for famine prevention and food production. Secondly irrigation development was not to be selective but made as extensive as possible so that irrigated agriculture becomes more a norm for Indian agriculture. Thirdly, irrigation development was not sought to be achieved in isolation but in the framework of comprehensive water resources development. Related water resources problems such as floods and drainage were brought in the ambit of irrigation development and other water resources related benefits such as hydropower were to be integrated with it to the extent feasible.

With this new philosophy, India set upon the course of irrigation development through is strategy of planned economic growth. Irrigation and related developments were accorded very high emphasis and priority among various sectors of development in successive five-year plans, starting in 1952. Gigantic projects such as Bhakra-Nangal project in Punjab (226 m high gravity dam), Nagarjunsagar project in Andhra Pradesh (125 m high masonry dam), Hirakund project in Orissa (61 m high earth dam), and many others were started in the initial plan periods. The nation went through a novel experience which generated tremendous enthusiasm and expectations among the people. In order to underline the critical significance of these projects for the nation set on the course of economic reconstruction, the dams were termed as "temples of modern India" in consonance with the ethos of its people.

These projects were distinct and different from erstwhile irrigation projects not only in size but also in purpose and scope. While most of these projects had irrigation as their dominant objective, they had also other purposes to serve, such as flood control and hydropower. Quite a few projects were planned primarily for benefits other than irrigation. Rihand Dam in U.P. and Koyna Dam in Maharashtra were constructed mainly for hydropower benefits while several dams were constructed on the river Damodar and its tributaries in eastern India for providing flood control benefits to the affected region. Also, water resource development began to be taken not merely as a project-specific activity but as an instrumentality for regional socio-economic transformation, in which several projects and activities were co-ordinated under a single authority to achieve the purpose of comprehensive regional development. Damodar Valley Corporation was constituted for such a purpose on the lines of the Tennessee Valley Authority of the U.S.A. Planned development of water resources for multiple benefits on a regional basis was strongly advocated by the Second Irrigation Commission constituted by the Govt. of India in 1972. A recent change, effected in 1986, in the designation of the concerned ministry at the Govt. of India level, from Ministry of Irrigation to Ministry of Water Resources, also reflects this new perspective. In order to promote comprehensive water resources development on a scientific basis, several river basin organisations have been set up, such as the Brahmaputra Control Board, Narmada Control Authority, Sone River Commission, Ganga Flood Control Commission, etc. A National Water Development Agency was set up recently to investigate the feasibility of inter-basin transfers of water resources on a regional basis. The rationality of integrated development and conjunctive utilisation of surface and ground water resources has also been recognised. To ensure this, the surface water and ground water organisations which existed under separate ministries at the governmental level have been brought under one ministry.

India's achievement in utilization of its water resources for irrigation development is substantial, as may be seen from Table. Self-sufficiency in food production has been essentially realised and the spectre of famine has been effectively banished. Yet, India will have to maintain a steady or even accelerated rate of expansion of irrigation facilities to achieve its target of creating a total of 113 million hectares of irrigation potential by 2000 A.D. This is necessary to cope up with the increasing and variegated demands of foodgrains by expanding population of rising living standards, to strengthen the base of the Indian economy and to increase the export earnings. In other areas of water resources development, such as for flood control, for hydropower development, for inland navigation, for aquaculture, for recreation and other benefits, India's achievement vis-a-vis the feasible potentials in the respective areas has been rather meagre. This is so because of the low priority accorded to them so far.

In assessing the role of water resources development in the future for India, one has to keep in view that India's per capital income and GNP are still very low in comparison to those of other developed nations of the worlds and hence economic backwardness still remains to be India's foremost problem. Because of the vast potential of realizable benefits in different spheres and sectors of national development, water resources development will be a most potent and efficient instrumentality to effectively tackle the problem. This role, however, has been rendered some-what complex by the following factors.

(i) The economic development in post-independence India, substantially contributed and abetted by water resources development, has led to regional imbalances in the country and economic disparity in the society.

(ii) Easy and obvious options in water resources development have been largely utilised. Further development will call for more detailed engineering investigations, more rational economic analysis, and more explicit incorporation of socio-political-legal considerations. The country can no longer afford to shy away from international and complex inter-state as well as legal aspects involved in water resources development without jeopardising its vital long-term interests.

STATISTICS OF IRRIGATION DEVELOPMENT AND FOODGRAIN PRODUCTION IN INDIA

Period	*Major and Medium Irrigation*		*Minor Irrigation*		*Food Production*
	Expenditure (in 10^8 Rs.)	Potential created (in 10^6 ha)	Expenditure (in 10^8 Rs.)	Potential created (in 10^6 ha)	Annual (in 10^5 tonnes)
Pre Plan (Upto 1951)	N.A.	9.70	—	12.90	52
1st Five Year Plan (1951-56)	380	2.49	76	1.16	66.9
2nd Five Year Plan (1956-61)	380	2.14	161	0.73	82.0
3rd Five Year Plan (1961-66)	581	2.23	441	2.22	72.4
Annual Plans (1966-69)	434	1.54	561	1.99	75.0
4th Five Year Plan (1969-74)	1,237	2.60	1,174	4.50	104.7
5th Five Year Plan (1974-78)	2,442	4.12	1,393	3.80	125.0
Annual Plans (1978-80)	2,056	1.79	987	2.70	131.0
Total	7,510	26.61	4,793	30.00	

Chapter 2

Co-operative Development of Indo-Nepal Water Resource

The Co-operative Development of Indo-Nepal Water Resource brings forth several issues related to its various aspects. The sizes and sites for dam as well as consideration of seismicity and siltation affecting their life and risks of failure are valid technical issues which have to be dealt with adequately. Similarly environmental and ecological issues associated with any envisaged plan for water resource development cannot be ignored. The question of national interest and political jurisdiction are bound to have their sway in decision making in this matter related with transboundary and international river basins.

The socio-economics of the concerned region must provide the relevant context in which the current theme is to be considered and discussed. The dominant feature of this socio-economics is the stark poverty prevailing in this populous region which was once the centre of prosperity of Indian Sub-continent. In fact this region is part of one of the two "poverty belts" of the world, so identified in the report of the Willy Brandt Commission of International Development issues. The region which comprises of East U.P., North Bihar and parts of North Bengal in India have certain dominant socio-economic features.

Its a populous region having more than 100 million people with a density of population more than 600/sq. k.m. as against that of India as a whole of about 210/sq. k.m. The per capita income of this region is lower than that of any state in India, with a population below poverty line being approximately 55 to 65%. The population of this region is predominantly rural and its economy agrarian. More than 90% of the people live in villages and depend on agriculture for their livelihood. The workforce engaged in agriculture varies from 85% in North Bihar to 93% in Nepal. More than 60% of the gross domestic product is contributed by agriculture sector. More than 85% of the farmers of this region belong to the categories of marginal (64% to 76%) and small (10% to 20%) farmers. Irrigation has been provided to roughly about 15% to 25% of the cultivable area. Most of the agriculture is rain-fed and depends on the vagaries of monsoon. Agricultural productivity of this region is low. For the principal Kharif and Rabi Crops rice and wheat the productivity of this region is 1.05 tonnes/ha and 1.63 tonnes/ha against an all India average of 1.6 tonnes/ha and 2.03 tonnes/ha and the Punjab yield rates 3.2 tonnes/ha and 3.5 tonnes/ha respectively.

It can be seen that low income from agriculture sector resulting in low level of employment is the obvious reason for the endemic poverty of this region. In case of eastern India it can be explained only by the poor agriculture productivity and production. This region is trapped in the vicious circle of low agricultural performance and poverty, the so called "Low level equilibrium trap".

Poor agricultural performance is paradoxical in view of the high agro-potential of this region-fertile tracts of land to support multiple crop in the year, ample water to meet all crop water requirement, congenial agro-climate for year round cropping and people steeped in the culture of agriculture. The key to understand this paradox lies in prevailing soil water regime which inhibits productive agriculture. Recurrent floods, frequent agricultural droughts, widespread waterlogging and encroachment in the flood plains have seriously distorted and degraded this region.

So far basin wise planning for optimum development of the water resource for comprehensive uses and based on integral resources has not been done for any of the seven major Indo-Nepal river basins. There are a few river basins such as Gandak for which major development have not yet been proposed or suitably identified. Even for the proposed projects only major benefits such as for power and irrigation have been identified and included. Other benefits have either been considered as incidental and minor or not attempted and accounted for. Hence it is difficult to get an idea of the total magnitude of potential benefits from different sectors on account of comprehensive development of the water resource of all the shared river basins.

From the proposed project a total of 20,000 MW of hydroenergy, 50 lakh ha of irrigation and some unquantified flood control benefits have been indicated. This presents benefits from only partial, sub optimal and non comprehensive development of Indo-Nepal river basin. For example hydropower potential of Nepal from all tributaries and rivers is assessed at 83,000 MW. Similarly if conjuncture irrigation, a strategy which has been recognised to be the more suitable for irrigation development of the humid alluvial plains characterising most of the irrigable lands in the Indo-Nepal river basin, is adopted, the irrigation potential of Indo-Nepal water resource development will be considerably more.

Among other benefits, inland navigation is one which is both techno-economically feasible in the case of most of the Indo-Nepal rivers as well as quantifiable. Inland navigation provides by far the cheapest mode of transport per km-tonne of cargo particularly suitable for bulk nonperishable goods. Other benefits such as pisciculture and recreation are valid and legitimate output of Indo-Nepal water resource development.

The economic aspects of Indo-Nepal water resources development relate to costs, benefits and their sharing by the two co-basin nations. Once the projects are formulated, computation of costs is rather a straightforward techno-economic and financial exercise. As benefits relate to various sectors of economy and are spread over future spans of time, their assessment is a more complex exercise. The complexity is further compounded by the fact that while some of the benefits are tangible, direct and quantifiable, others are intangible, indirect and not amenable to quantification. Thus, assessment of costs and benefits involved in comprehensive water resources development of the Indo-Nepal water resources cannot be attempted unless the optimum configurations of plans are determined and plans are formulated. The following statements about the costs and benefits of comprehensive water resources development may, however, be made based on projects already planned with respect to certain rivers in the Indo-Nepal basin.

Costs will be staggering or at least too high for any of the two countries to afford from their internal resources. International financing will inevitably have to be sought. Both direct and spin-off benefits from such development will be colossal. They will revolutionise the economy of the region and usher it securely on the path of prosperity. Based on benefit cost ratio or any other economic criteria, such development will be attractive economic proposition. This aspect will facilitate securing international and institutional funds for investment. Of necessity, the comprehensive plan for development will have to be carried out in phases. The phasing of such implementation will have to be done both on techno-economic rationality as well as on mutually agreed priorities of the two co-basin nations.

Sharing of costs and benefits is tricky and slippery exercise. The co-basin nations can put forward arguments and even principles to suit their respective interests. While there are certain norms and precedents to guide negotiations on sharing, in the ultimate analysis the countries which have been bound for centuries by historical and cultural ties have to be responsive to each other's needs and aspirations. Even if the two nations are moved by their own enlightened self-interests, they will find that, on account of high complementarity of interests in comprehensive water resources development of Indo-Nepal river basins, under all reasonable cost-benefit sharing formula, each nation is to gain tremendously in cooperative development over all feasible unilateral actions.

Co-operative development of international river basins has of late been accorded legal recognition and sanctity. Law has almost kept pace with the increasing understanding of the hydrologic behaviour of the water resources that sustain the life and living of people. Based upon the dichotomy of the upper and lower riparian nations, two theories were propounded. While the territorial sovereignty theory known as Harmon doctrine favoured the upper riparian based on its sovereign right of use of the waters within its own territory, the natural flow theory or the territorial integrity theory sought to protect the interests of the lower riparian by establishing its rights to the natural flow of the river unhampered by the upper riparian. Discarding this dichotomous approach to the use of an international river, the theory of equitable utilization or apportionment was propounded with regard to sharing of waters of an international river by the different riparian states or nations. The underlying postulate of equitable apportionment is equitability and not equality. The idea is that, the use of the river waters be so apportioned that maximum benefits accrue to all the riparian states or nations, keeping in view their present and future economic and social needs. In practice, this theory lends itself to many complexities. The elaborate Helsinki Rules have been framed on the basis of this theory in order to take care of various situations such as prior or existing uses, future or planned uses, same type or different types of uses, concurrent or sequential uses, etc.

A further advance on the equitable apportionment theory is made when the history of community of interest was first enunciated by Prof. F.J. Berber in his book "Rivers in International Law" (1959). It recognises the cardinal hydrologic reality that a river passing through several states or nations is one and should be treated as such to ensure maximum utilization of its waters. Under this theory, the whole basin is regarded as an economic unit irrespective of state boundaries and the waters are vested in the community or divided among the co-basin states. Under an integrated programme of development of a river, dam and other works are to be located at the best possible sites and the benefits accruing therefrom are to be used by the riparian states in need of those benefits.

Such an integrated programme may take two shapes. There may be separate programmes of development of each riparian state but other riparian states are to permit the use of their territory for purposes ranging from information—gathering mission about the basin to the actual construction of the structures and dams for the best utilisation of the river. A more advanced approach is to make a joint effort by the different states to develop the river for their joint benefit without any reference to the state boundaries. The joint approach includes joint planning, joint construction, joint management and joint sharing of expenditure on construction and maintenance.

Recent examples of this approach are the Turkey—U.S.S.R. agreement on the development of Arpa—Chai river, UAR—Sudan Treaty of 1959 on Nile and the U.S.—Canada Treaty of 1961 on Columbia River. The Columbia River Treaty notes the desire of both U.S. and Canada to develop the resources of the Columbia River "in a manner that will make the largest contribution to the economic progress of both countries and to the welfare of their people" and recognises "that the greatest benefit to each country can be secured by cooperative measures for hydroelectric power generation and flood control, which will make possible other benefits as well."

As, for all practical purposes, Nepal and India are the only two co-basin nations for all the rivers originating in Nepal, the issue of development of these rivers and the associated water resources, is, distinctly and dominantly, bilateral. This is so not only from the hydrological point of view but is also in conformity with jurisdictional requirements and legal norms. It is only in the bilateral framework that mutuality and complementarity of interests are perceived, which can form a basis for co-operative actions.

The issue has occasionally been sought to be regionalised by an attempt to involve Bangladesh in this. Such an attempt has been made from different sources and from differing viewpoints. Nepal's proposal at one time to have an all-weather inland navigational route to the sea through the Bangladesh territory in order to provide a sea outlet to this land-locked nation as a part of the package of measures to be adopted for the development of the river Kosi tended to make Bangladesh also a party to the proposed agreement. This was clearly perceived by India to be an inter-basin extraneous proposition, not related to the dominant purposes of the proposed development. Infact, inland navigation being a by far cheaper method of bulk transport of non-perishable commodities, must be considered as one of the purposes of multi-purpose development of the Kosi or even other Indo-Nepal rivers, subject to their techno-economic feasibility. However, there is absolutely no need to regionalise a distinctly bilateral issue on that count. Another angle by which the issue is projected to be regional is a proposal by Bangladesh in which it advocates upstream storages on the Indo-Nepal rivers, all left-bank tributaries to Ganga, both as a means of augmentation of the lean flows of Ganga at Farakka for increasing the respective shares of India and Bangladesh in the lean-weather flow of the river at the point of bifurcation, as well as for moderation of the flood flows in order to provide relief to Bangladesh from floods caused by the river Ganga in its territory. Since provision of upstream storages on the Indo-Nepal rivers would be an essential and important element of all conceivable schemes for the optimal development of Indo-Nepal water resources and since these storages would serve to conserve water for multipurpose consumptive as well as non-consumptive uses, and would absorb flood flows of the upper catchments, development of Indo-Nepal water resources would inevitably and unambiguously be of benefit to Bangladesh. Within the universally accepted norms and practices for riparian rights and responsibilities, the magnitudes of benefits to Bangladesh on both these counts will be determined by unalterable hydrological and other physical factors. Hence, there is no rationale or necessity to make Bangladesh a party to the development of Indo-Nepal water resources, which is, on hydrological, territorial and techno-economic considerations, purely a bilateral matter.

International aspect to the issue of the development of Indo-Nepal water resources can arise only from two considerations, *i.e.* technological expertise and financial support. It must be appreciated in this regard that in this age, technology is essentially international. It is no longer valid to ascribe technology to any country. The complexity of technical tasks to be performed and technological issues to be resolved in development of Indo-Nepal water resources call for the application of highest levels of science and technology, which can come only from an international storehouse and community. There is no reason to shy away from it and to settle for anything less on any extraneous consideration. Similarly, the magnitude of tasks involved will necessarily entail huge expenditure to be incurred in construction. While such an expenditure would be amply justified on economic criteria in view of the colossal benefits resulting from it, initial investment in this venture may be beyond the capacities of the two nations from their internal resources. In the global economic order prevailing today, international financing of such ventures through several intergovernmental financial institutions or through various consortia is a well accepted, viable proposition.

The two states of India which have common borders, and share their river basins, with Nepal are U.P. and Bihar. The eastern part of U.P. and all of Bihar, north of the river Ganga, comprise parts of the river basins shared with Nepal. Effective solution to the chronic and complex problems affecting this region and efficient realization of the immense and multiple benefits related to its water resources critically depend on the basin wide actions for which cooperation of Nepal is imperative. Thus, these two states have a direct and high stake in enlisting the cooperation of Nepal in order to facilitate adopting basin bound measures to their mutual benefit. No doubt, India as a whole would stand benefitted from the development of one of its regions, as the national and regional economics are largely integrated. As this region happens to be an economically backward region of the country, this regional development would also serve the national objective of reducing the regional disparities in development. However, due to competing demands from various regions and states on the nation's attention and resources, the intensities of concern and the priorities of action of the concerned states are bound to be at variance with those of the nation. Hence, pragmatism calls for according commensurate role and adequate scope for initiatives and actions to the two states. This, of course, would be subject to the overall national responsibility in the matter and the demands of protocol for negotiations between two sovereign nations. The role of the state government vis-a-vis that of the centre may be viewed and designed in this perspective. These roles are not competing or conflicting but are rather complementary and co-ordinating. The regional concerns and aspirations can very well be served within the bounds of formality of protocol and responsibility of the nation.

Chapter 3

Flood Control and Rural Development in Eastern India

Flood Control is a precursor to the effectve use of land and water for rural and agriculture development in Eastern India. There is vociferous concern about floods during the floods but the concern abates with the declining flood water. The lack of concern is based upon the notion that flood damages are limited in their spatial and temporal extent to those directly affected and to short periods of time. This is not the case. Flood and poor drainage have a much wider and sustained systemic impact. In most cases in eastern India floods occur frequently leading to under-investment in agriculture particularly in irrigation infrastructure. Due to various constraints our scientists are unable to offer new electronic technology for these problems. On the other hand we find them giving us solutions which are a mixture of known technology and new management skill.

Many people have looked at this region and have recommended a wide range of solutions. Unfortunately none of the studies took a broad look of the option for development of this region. Dr. Peter Rogers of Harvard University feels that before any plans are taken too seriously for the solution of the problem of this area it would be better to have a look at just what is the problem.

He says the appropriate starting problem is to ask "why the level of economic development in the Ganga Basin is so low?" The Brandt Commission on International Development Issues identified this region as one of the two poverty belts of the globe. Some 300 million people live in the region comprising the Indian states of Bihar, West Bengal, Assam, Tripura, Manipur, Mizoram, Arunachal Pradesh, Sikkim and Meghalaya, and the countries of Bangladesh, Nepal, Bhutan and parts of China. Except for West Bengal, all of these areas have levels of economic development well below the average for India as a whole. Approximately 50% of the rural population lies below the poverty line. What factors have limited the rate of economic growth in this region?

It certainly has not been the availability of land and water. The region has extensive areas of well watered fertile plains and the availability of minerals and fuels, the region has both coal and oil and many other minerals in abundance. The climate and the environment are plausible explanations for the backwardness of this region. The average conditions of the climate and the environment appear to be ideal for the species homo sapiens. Plenty of rainfall and riverflow, ideal growing temperature for year round cropping, deep fertile soils on huge, almost flat, river deltas, and plentiful forest reserves characterize the region. Unfortunately the average conditions are not what occur all the time. Those very conditions which make the environment so beign under average climate, turn upon the hapless inhabitants during extreme conditions causing huge floods which inundate the flatlands destroying crops, livestock, housing, roads, bridges, and human life. These extreme conditions occur fairly frequently.

In addition, the floods cause massive disruption which has ripple effects throughout the economy, extending into future months or years, not just in the flooded areas and not confined to the periods of actual inundation. Hence, during large floods such as occurred in 1988 in Bangladesh and Assam and in 1987 in West Bengal and Bihar, the economy becomes paralyzed for periods of weeks, or even months, and takes much longer to return to normality. Whereas it is possible to estimate the direct property losses caused by the floods, the effects of economic disruption are very hard to quantify—but one has to believe that they are at least of the same order of magnitude as the direct impacts, in all probability they are much larger. Moreover, the perpetual threat of flood occurrence keeps the economy in low gear.

In Assam, few years back, the Brahmaputra flooded 17 of the 18 districts rendering 125,000 people homeless and causing over Rs. 7 billion in damages. In Bihar alone during the 1987 flood over Rs. 14 billion were sustained in direct damages. The past floods in Bangladesh have caused the loss of the bulk of the aman crop which is a very serious loss, but this loss is small compared to the disruption of the economy caused by the loss of 200 bridges, 79,000 km of roads and 450 km of river embankments that have been swept away. Add to this the human miseries caused by an estimated thirty million homeless people and then the real scope of the disruption caused begins to emerge. The lost crops can be replaced by next year's harvest; this vital infrastructure will take many years to replace. One high level official estimated that Bangladesh's development has been put back by, at least, one whole five-year plan.

The region does have very high population densities on the arable land. Could this be the cause of the economic backwardness? Population is a difficult parameter—it is difficult to decide if it is a cause or an effect of economic backwardness, or whether it is a positive or negative factor for development. Malthus believed that high population density is the cause of economic backwardness and Boserup would have such high densities as an engine for economic development. In any case, other parts of the world, and even parts of the Indian subcontinent, have managed to develop quite rapidly with similar high population densities.

Indeed, the problem here, as in much of India, is that the population is caught in a "low level equilibrium trap." By this it means that people are too poor to purchase necessary food because they do not have enough employment, and because they are not purchasing the food, aricultural demand does not increase meaning that there is less and less employment for the growing population who are, then, less able to purchase the needed food and so on. The population problem is, hence, an employment problem. If one could create jobs, then the people would be able to purchase food (and other commodities) that would increase the effective demand for agricultural production. Since apart from the flood and drainage problems, the resources are available in this region for expansion of agriculture, then, the major problem must be employment.

It seems clear that in the near future the source of employment in this region will have to be agriculture. Now the puzzle is of how to increase employment in the very sector where most of the people are currently unemployed. To increase employment in agriculture there is need to intensify the use of the land and water. This can be done in the eastern region only by improving the control of water—both for floods and drainage and for irrigation. Moreover, those types of crops which generate most employment per unit area are the crops that have the most meticulous demands for water control (cotton, sugarcane, bananas, fruits, and vegetables).

The generation of such employment, however, is impossible without first addressing the flooding and associated drainage problems. This does not imply that solving the flood problem will lead to rapid development in the region, but, rather that sustained modern development in the region is not possible without first dealing with the flood problems. Once the flood problems have been resolved, only then, can approaches to solving the poverty problem be effectively undertaken.

The analysis of the "problem" suggests a strategy for approaching the development of the water resources of the

Lower Ganges basin. First, the floods and drainage are the critical limiting problems in the region. Second, the techno-socio-economic analyses of all feasible technical options be made, regardless of whether they require regional cooperation or not. Third those technical options that require no regional cooperation, and will also not preclude later regional cooperation, be identified for rapid implementation. Fourth, the other water resource development options, such as hydropower, irrigation, navigation, and municipal and industrial water supplies be evaluated using the same lens of "what can be done with and without regional cooperation." Fifth, a conceptual integrated plan be developed for the whole region. This plan could then be used as the basis for long term bi-lateral and multi-lateral agreements among the riparians in the basin.

In addressing the flood and drainage problems in the eastern region of the Indian sub-continent it is tempting to assume that all solutions must be "regional" solutions. There is certainly a strong rationale for this based upon the nature of hydrology and geomorphology; the river basin is often suggested as an integrated planning unit where all the physical interactions can be completely accounted for. Unfortunately, political boundaries are less likely to follow watershed boundaries. One thing that the twentieth century has taught us is that political imperatives are more important than hydrological ones. Regional solutions are not likely to be accepted unless there are no other comparable alternatives. The onus, therefore, lies with the technical experts to provide cogent analyses of what specifically can be achieved with and without regional cooperation.

Regional cooperation can mean many different things. It could mean, for example, cooperation between the Indian states of Bihar and West Bengal, between West Bengal and Assam, or between and among each and all of the Indian states and territories. It could also mean bi-lateral relationships between India and Nepal, between India and Bangladesh, between Bangladesh and Nepal, etc. But it could also mean trilateral relationships between India, Nepal, and Bangladesh or multilateral relationships between all of the states and nations in the region.

Unfortunately, there are some very hard lessons to be learned by looking at the nature and extent of flood and drainage problems in this region. The first lesson is that there is little incentive for those districts, states, and nations which lie in the upland catchment reaches to pay attention to flood control in downstream locations. By and large, except for a few local patches, flooding is not a concern for them. The second lesson is that even as one moves down the system, for example from Nepal to Bihar, local flood control remedies, such as embankments in Bihar, can greatly exacerbate the flood conditions downstream in West Bengal and Bangladesh. The final lesson is that down in the deltaic parts of the region, in West Bengal and Bangladesh, local solutions, such as embankments and detention basins, become increasingly expensive and less likely to work. While local options do exist for flood control in all parts of the basin, some level of regional cooperation will be required along with local solutions for a satisfactory solution to the problem.

As mentioned earlier, the benefits of flood control and drainage are likely to be very large in the Lower Ganges Basin even in alleviating direct flood damages. It was also indicated that flood control and drainage was a necessary condition for the development of irrigation, water transportation, and other water related benefits. In particular, irrigation development will lead to intensification of land use, change in cropping patterns, and large increase in on-farm and off-farm employment. Approaches should be used to solving the flood problem which would also develop these other uses at the same time with the same facilities. Multi-purpose use of storage reservoirs is one obvious example of integrated development. Upstream storage reservoirs, are not the only way to achieve multipurpose use of the water resources of a region. For example, active development of groundwater reservoirs by extensive irrigation pumping during the dry seasons can provide substantial capacity to store flood and drainage water during the wet periods. To the best of knowledge this has never been used specifically for flood storage anywhere in the world—it is however used extensively for water conservation in many places. Preliminary calculations by Revelle and Lakshminarayana indicate that full development of conjunctive use in the Ganga basin could lead to as much as a 50% reduction in the monsoon flow of the river. As the irrigation potential of the Brahmaputra basin is considerably smaller than that of the Ganges only a small percent of its monsoon flows may be stored underground. Even so, the potential of groundwater storage as an integral part of the flood storage problem in the entire basin looks promising.

The technical options that ought to be carefully analyzed are as follows:

1. Upstream multi-purpose reservoirs.
2. Groundwater storage via conjunctive use of irrigation.
3. Natural detention basins.
4. Artificial detention basins.
5. Emergency floodways.
6. Embankments along the rivers.
7. Channel improvement.
8. Inter-basin transfers.
9. River diversions.

None of these, with the exception of groundwater recharge via conjunctive use, would be considered new technologies. What is new, however, is that the integration and combination of these sets of technologies into a coherent system will require innovative management and engineering software in both the public and private sectors.

As an example of such innovative planning software each of the options needs to be studied for each of the following cases:

1. Only within each state.
2. Only between the Indian states and territories.

3. Between Bihar and Nepal.
4. Between all of the riparians.

The time frame of the analyses should be such that what can be achieved in the short-run (5-10 years), the intermediate run (10-25 years), and the long-run (more than 25 years) be clearly spelt out. It is important that consistency between short-run and long-run developments be ensured. One thing that is believed is that the problems in the region are too pressing to wait for "permanent" solutions that may be over 50 years in the future, although these solutions should never be lost sight of while carrying out shorter-run solutions.

Dr. Rogers feels that they agreed with the Brandt Commission that elimination of rural poverty in the eastern region of India will not be possible without providing stable and reliable water control. While the control and elimination of flooding is a prerequisite it will not, in itself, be sufficient to guarantee the high level of employment needed to eliminate poverty. This can only be attained by complementary investments in the other aspects of water control, irrigation, hydropower (for energizing pumpsets and rural agro-based industries), and water transportation. The technology required to achieve this transformation of the largest pocket of rural poverty in India is already available, and well understood in India today. What is not developed, however, are the skills and abilities to integrate and manage these technologies as functioning systems.

It is envisaged that with proper water control, 1) crop yields will incease substantially, 2) it will be possible to engage in multiple cropping on a much wider basis than is now possible, and 3) a shift to different higher valued, and higher employment generating crops, will be possible. Farm income and employment fifteen times the current levels are clearly within reach due to these factors (plus complementary seed, fertilizer, etc., packages). The eastern region would attain its rightful prosperity and be the new engine for the continued development of the Indian economy. It would then turn from the land of poverty to the land of plenty.

Chapter 4

Reuse of Saline Drainage Water for Irrigation

For almost a decade the Central Soil Salinity Research Institute has been engaged on research on the problems of waterlogging and soil salinity in the arid and semi arid region. Subsurface drainage has proved successful in the rehabilitation and conservation of irrigated land. Efforts for the development of the drainage practises for ameliorating problem soils got a boost with the Indo-Dutch Collaboration Programme on Operation Research for salinity and reclamation taking place in Punjab.

Introduction of canal irrigation in arid and semi arid region having saline ground water interferes with the natural hydrological balance causing rise in water table and resultant salinestion. Saline soil and water contains excessive amount of soluble salts not good for normal agricultural production. Most of the major irrigation projects are affected due to salinity and waterlogging and thereby transforming productive lands to saline waterland .

Though the subsurface drainage system has been found to be ideal for combating waterlogging and salinity, disposal of the saline drainage effluent is a major constraint particularly in areas of poor quality ground water. This problem is more severe in areas with unfavourable hydrological condition and without any natural outlet. It is essential to maintain a favourable salt balance in the root zone as the drainage water rich in salts have to be disposed of from this area. In the absence of natural outlet disposal of saline drainage water into nearby water bodies or low lying areas would create serious environmental problem. Seepage from these areas will salinise the neighbouring areas and also contaminate the ground water.

There are three options for the management of saline drainage water, they are disposal into rivers, in evaporation ponds and its reuse for irrigation.

Subsurface return flow is the irrigation water drained through the crop rootzone. A portion of this return flow percolates vertically into the ground water storage zone and the rest moves laterally along with hydraulic gradient. Compared to subsurface drainage flow the quantity from subsurface drainage is limited and return flow is available only when the water table is above the drains. The quantity of return flow (drainage water) depends on the drain depth and spacing depth and methods of irrigation, leaching requirements, soil hydrological characteristics, intensity and duration of rain, types of crop and seepage from the adjoining area.

Quality of drainage discharge depends on the nature and amount of salts present in the soil profile and the salinity of ground water. The quality of underground water in arid and semi arid areas is generally poor. The seepage of ground water from the surrounding areas also influences the quality of drainage water. The chemical composition of drainage water during the irrigation season (Dec-March) was similar to that of the ground water predominant in chlorides of calcium and magnesium followed by sodium. Drainage water had traces of iron, manganese, boron and nitrates.

A substantial amount of saline drainage water can be discharged into river system having sufficient headwater flow to dilute the salts present in the effluent. The disposal has to be restricted to monsoon season only as most of the flow is diverted for irrigation during the remaining part of the year. The river being the main source of drinking and industrial needs of downstream urban areas, strict adherence of safe standards of quality of water is essential. The disposal of the saline drainage water into the river in the non monsoon season of the year may create serious environmental problem threatening the biological life in the river water. Since maximum discharge of the drainage water is during the monsoon season this problem is taken care of to a great extent.

Evaporation tanks are considered to isolate the saline drainage water when no outlet for disposal to the sea or river is available. The drainage water from the areas is allowed to evaporate. The losses from these tanks should be mainly through evaporation with minimum possible seepage. This requires about 5% of the land areas under reclamation in the arid and the semi arid region. Though this is an accepted practice in many countries the loss of land and the cost of construction are major limiting factors to this technique.

Considerable work has been done in the country for identifying critical limits for use of saline water for crop rotation prevalent in the region. Experimental evidence support the premise that water of higher salinity than termed usable as per the prescribed limits can be raised further for soils provided with subsurface drainage. Reuse of saline drainage water for crop production can be employed as a means to reduce the volume and eventual cost of drainage water disposal.

There are different methods for reuse for irrigation purposes. They are mixing of canal and saline drainage water, cyclic or rotational use of canal and saline drainage water and direct use of saline drainage water.

The modes of application of drainage water for irrigation depends on the quality of water soil type, crop to be grown and the agro-climate condition of the area. The farmers are to be properly educated through field demonstration about the technology and economical gains of using drainage water for crop production without detrimental effects to their crop land.

Feasibility studies on the reuse of highly saline drainage water for irrigation were conducted for five years under field conditions at Sapla drainage project in Rohtak. Information has been generated for different modes of reuse. The desalination of soil is mainly achieved through leaching with rain water conserved in the field by strong bunding. The installation of subsurface drainage system resulted in low soil salinity and water table below one to two metres.

Drainage water of high salinity cannot be reused directly for irrigation. Mixing of high salinity drainage water with canal water can convert the drainage water to an acceptable quality for irrigation.The salinity attained after mixing should be within the permissible limits based on soil type, climate of the area and the nature of crop to be irrigated.

Results of field study conducted on reuse of drainage water diluted with canal water to obtain water of different salinity levels for irrigating the wheat crop were quite encouraging. In the trial canal water was used for pre-sowing irrigation and thereafter saline drainage water of different salinity limits were used for irrigation at different growth stages. The crop yield and soil salinity build up obtained from irrigation with varying salinity level of drainage water were compared with those obtained using canal water.

The optimum level of salinity of drainage water which could be used for successful crop production depends on the amount of rainfall received during the growth period. For example in the initial years 1986-87 winter rains (102 mm) during early growth period seemed to have nullified the treatment effects. A general relation between the wheat yield and salinities of drainage water support use of higher saline water in soils provided with a sub-surface drainage.

Raya (pusa Bold) was found more tolerant to saline drainage water than wheat where canal water was used for crop establishment and diluted drainage water of different salinity level (8 and 15 dspm) were used for subsequent irrigation. Two irrigation of 5 cm depth were applied at flowering and fruit formation stages. The grain yield was higher with irrigation water of 8 ds/m salinity as compared to canal water. The added salts of these levels had a booster effect on the yield as the low salts built up in the profile had no adverse effect on the raya crop which is fairly salt tolerant at later stages of growth.

This supports the view that canal water should be preferred for irrigation in the initial stages of crop establishment followed by saline drainage water for subsequent irrigation at later stages of crop growth.

The salinity build up for soil depends on the salt content of the irrigation water and the amount of water extracted by the plant root from different depths. Application of saline drainage water of high salinity level increased the profile salinity with the increase being more than above 60 cm depth. The variation in soil salinity during field trials show rise in salinity level during growth periods of wheat irrigated with drainage water of different salinities and subsequent lowering of salinity levels by monsoon rains. The subsequent leaching of soil was brought about by the rain water without application of extra irrigation water. The extent of salt leaching and the next crop establishment depends on the amount of rainfall received. Monsoon rainfall in 1987 and 1989 was low (293 mm and 270 mm respectively) and was not enough to leach all the salts from the profile. During 1988 the high rainfall (925 mm) was very effective in leaching. In arid regions where rainfall is less than 350 mm the reuse of drainage water may need large depths of presowing irrigation for leaching the added salts for proper crop growth.

The sodium absorption ratio of drainage water is higher than that of canal water. Consequently use of drainage water may result in increased level of exchangeable sodium which tends to decrease soil permeability. Decreased permeability will not be a hurdle during the irrigation season since the negative effect of the high sodium percentage is offset by increased salinity of the drainage water. Most of the salts will be leached down by the monsoon rains and the amount remaining in the soil will not cause any alkali hazard to the following crop.

Cyclic use also known as sequential application or rotational mode is a technique which facilitates conjunctive use of fresh and saline drainage water. In this technique canal water is replaced with saline drainage water either in predecided sequences or in switching mode. Switching mode implies that after one or more irrigation with canal water subsequent irrigation are given with saline drainage water. The timing and amount of substitution will vary with the quality of the drainage water, soil type, the cropping sequence, the climate and the method of irrigation. With cyclic use of canal and drainage water high crop yield could be maintained because maximum root zone salinity due to continuous use of saline drainage water will not be experienced by the plants when such waters are used for limited irrigation only. The salinity in the rootzone could also be controlled below the critical limit at sensitive growth stages.

Cyclic mode is the more flexible technique for the conjunctive use of saline drainage waters and canal waters provided both are available. Depending on the availability of canal water and the crop characteristic alternate scheme can be tested. One of the useful schemes is sequential application. In this canal and saline drainage waters are applied in a predecided sequence like alternate irrigation with canal and saline drainage waters. In switching mode method many crops being more sensitive at the germination stage this technique has been found more useful. In this after pre-sowing or first irrigation with canal water rest are applied with saline drainage water. The seasonal switching practise is based on two points-availability of canal water during rabi season which is often limited and variation in crop tolerance to soil salinity. A crop rotation is selected in such a manner that more tolerant crop is grown during rabi season while growing a sensitive crop with canal water application during Kharif season. Most crops are sensitive to salinity at germination stage. Irrigation with canal water for seedling establishment and subsequent irrigation with saline drainage water will be a good proposition for better crops yield.

In a study conducted at Sapla Drainage Project area where wheat, barley and raya were successfully grown, the cyclic mode technique has been demonstrated with canal water and saline drainage water—canal water was used for presowing irrigation and thereafter the irrigation were applied as per the decided modes. The high salinity drainage water can be used for irrigation in different cyclic modes without significant loss in wheat yield. This practice will also prevent the soil from becoming highly saline. The excess salts if any in the rootzone due to saline drainage water irrigation will be alleviated by monsoon rains or by the pre-sowing irrigation with canal water which will ensure a good bajra crop in kharif season.

Reuse of saline drainage water for irrigation eventually increases the salinity of drainage discharge and restricts its future reuse for agricultural crop. The practice of using such water in agro-forestry has resulted in identifying salt tolerant trees like Casurina, Tamarix and Prosopis which can be grown with a modest amount of saline drainage water considered unsuitable for agricultural crops.

When saline drainage water is used for irrigation one should keep certain things in mind. Most agricultural crops differ significantly in their tolerance to salt concentration in the root zone. Crops which are semi tolerant to tolerant as well as those with low water requirement should be grown for better returns through reuse of drainage effluent.

The period of germination and seedling emergence is the critical stage of crop growth. A failure at this stage leads to poor germination and the resultant yield decreases. Irrigation with saline water will adversely affect germination. Presowing should be done with fresh canal water.

Saline drainage water adds salt to the soil with each irrigation. In the absence of leaching these salts may over the years accumulate in the rootzone affecting the plant growth. Adequate subsurface drainage will facilitate leaching of these salts from the rootzone during the monsoon period. Experiments show that under subsurface drainage system the critical limit of saline irrigation water for different degrees of yield reduction in crops will be higher. With the provision of subsurface drainage it is possible to use high salinity water for irrigation with less yield reduction.

Alongwith other things consideration should also be given on grain quality and toxic ion accumulation. The results indicate that the grain protein in wheat was not inferior when saline drainage water was used without dilution for irrigating the crop.

No single best method for drainage water reuse exists because of certain constraints. The quality of the water needs to be assessed before deciding on whether it can be used as such or has to be mixed with canal water or cannot be used at all.

The drainage water may not be required at the location and in the season it becomes available. The availability of drainage water in terms of both location and volume would limit the choice of field and the area which would receive drainage water.

Availability of drainage water may not coincide with the demand of irrigation in the cyclic strategy. A means of storing drainage water is therefore required. Depending on the elevation at which water is available the cost of transportation of the water to the site where it is actually required may make the reuse somewhat uneconomical.

Complete reuse of the drainage water within the irrigated area will ultimately lead to an increase in the salt concentration of the drainage water and the soil. Disposal by an outfall drain towards the sea could be an alternative. The cost per hectare though very high at present as agricultural production and land values rise this proposition may prove economically feasible. Financial technical and inter state disputes may also restrict the construction of drainage carrier system to the sea.

Various options have been looked into. The results of the field trial indicate that the saline drainage water of varying salinity level can be used either directly or in conjunction with canal water by blending or by rotational use for irrigation in crop in rabi season without much soil degradation. The extent of salt leaching and crop establishment will however depend upon the amount of monsoon rains and its distribution and the availability of subsurface drainage system. In situation where good quality water is a constraint for irrigation the reuse of saline drainage water would not only permit the expansion of irrigated area but would also reduce drainage disposal and associated environmental problem.

With the increase in population the amount of water required not only for domestic purpose is increasing but also for agricultural purpose more water is required. Since with addition to population more food is required, and for growing more food greater amount of water is needed, so we have to make the best use of the water available so that we can look after well our teeming million of population.

GUIDELINES FOR USING SALINE WATERS (RSC 2.5 meg/l) FOR DIFFERENT CROPS (SOURCE—AICRP—SALINE WATER)

Soil Texture (% clay)	*Crop Tolerance*	*Upper Limit of Ciw (ds/m) in Annual Rainfall Zones*		
		350	350-550	550-750 mm
	S	1.0	1.0	1.5
Fine	ST	1.5	2.0	3.0
(30)	T	2.0	3.0	4.5
	S	1.5	2.0	2.5
Mid-fine	ST	2.0	3.0	4.5
(20-30)	T	4.0	6.0	8.0
	S	2.0	2.5	3.0
Mid-coarse	ST	4.0	6.0	8.0
(10-20)	T	6.0	8.0	10.0
	S	—	3.0	3.0
Coarse	ST	6.0	7.5	9.0
(10)	T	8.0	10.0	12.5

S—Sensitive
ST—Semi-tolerant
T—Tolerant

Chapter 5

Lining of Canal

Water which is a scarce commodity is not only used for drinking and growing crops but also for industrial uses and generation of electricity hence it is necessary that we conserve our water resource to the extent that it is possible. 90% of the utilisable water resource is being used in our country in the agricultural sector. In agricultural sector the water use efficiency is very low compared to that in other sectors. It is estimated that from reservoir to irrigation outlet point conveyance loss in an unlined canal system is to the tune of 40% to 50% of the supplies delivered at the head. This is a colossal waste taking into consideration the ever increasing demand of water for various things including the need for additional production of food grains. There is need for saving these losses. The water thus available may be utilised to provide irrigation facility for growing more food to meet the requirements of our ever growing population. One of the ways to conserve the watèr is to provide lining of canal. Apart from the traditional material like bricks, tiles and concrete used for lining one can also use plastic low density Polyethelene film as a material for canal lining as this has been found to be very effective and useful.

For lining of canal it is important to design the canal system keeping in mind the lining of canal upto the farm gate and within the farm. It should be planned keeping the topography and lay out of the area in mind strictly on the engineering lines and not only the administrative line. It should be planned keeping in mind the location of main canal, branches, canal distributories, minors and water courses and field channels. It should have a supply and distribution net work which is efficient and cost effective and it also leads to economic use of water. It should always have a proper drainage system extending right upto the field.

The carrier system and the distribution system right upto the farm should be lined. One saves about 50% of water by lining the canal. The efficiency of lined canal is almost 90% and that of unlined is below 50%.

The lining of canal leads to delivery of water at higher levels. It is also able to reach areas where there are depressions and deposits which would be otherwise impossible. Lining also leads to higher velocity, less seepage takes place, water-logging is avoided and a more safe and efficient system is provided. If the carrier canals which carry water almost throughout the year are unlined waterlogging takes place. Almost 1 k.m. on either side gets waterlogged. One can retrieve this by lining the canal and also by installing tubewells. The subsoil water level rises at an alarming rate of 0.3 to 1.0 metres per year if the distribution network of distributories, water courses and field channel is unlined. If the rise of the sub-soil water is not checked timely the command area gets waterlogged making the area unfit for cultivation besides causing other problems. Even if one is able to cultivate the land the yield falls badly. It also leads to increased evaporation which is a national loss. Lining of the distribution system, in particular lining of canal upto the farm head, alongwith utilisation of ground water for irrigation is the only method to check the water table from rising and the area getting waterlogged.

Lining of canal is very useful not only from the point of view of conservation of water but because it leads to lots of other benefits also. It has been found out that within few years of lining of water courses 75% of the waterlogged areas get relieved. The yield increases by two times. There is a phenomenal growth in irrigation due to saving in seepage and evaporation. Many times the increase in irrigation is anything between 35% to 50%.

In Punjab it has been found that lining of canal has led to an increase of 35% in irrigation of course over the years. For getting this benefit lining of canal has to be done right from the water head to the farm. The increase in irrigation is even more where areas could not be reached due to depression or deposits.

The analysis of converting unlined system into lined system indicates the system efficiently.

System	*Unlined System (in %age)*	*Lined System (in %age)*
Canal upto outlet	65.0 to 70.0	95.6
W.C. and field channel	67.0	94.0
Overall	47.0	90.0
Increase in availability of water at farm gate	—	90.0

It has been estimated that capital cost incurred in the lining of a system is recovered back in the form of additional produce in a few years.

To save loss in seepage lining of canal has been in vogue for the last few decades in our country. Hard materials like bricks, stone slabs and concrete blocks, soil, cement and asphaltic concrete, these are the things which have been used so far to prevent seepage from canal. But these hard materials have not been able to prevent seepage 100%. So we have to look for something which can be used in addition to the above materials to make seepage 100% foolproof.

For the past few decades L.D.P.E film have been used alongwith the hard material for lining of canals. This has been found to be very effective because of its qualities of water tightness. The National Committee on the use of Plastic in Agriculture had sponsored a study in 1988. This was done to find out the seepage loss in different conditions in lined as well as unlined canal. The study was conducted in the States of Gujarat, Haryana and West Bengal. The outcome of the study showed that there was increase of 6% to 12% in water availability of such canals which are lined by L.D.P.E. film below the hard cover lining compared to canal lined with hard cover line alone.

The L.D.P.E. film is also known as Agri-film. The Water and Power Consultancy services made a study of L.D.P.E. film in preventing seepage and loss of water. It submitted its report 'Economics of Plastic Canal Lining' in 1986. The report says that the use of L.D.P.E. film under hard core material could lead to a saving of water around 0.80 cusecs per k.m. length of an average main canal. The amount of water thus saved could be used for irrigating extra land. The water thus saved is enough to provide irrigation facility to 11.66 ha of paddy and 25.91 ha of wheat. By lining the canal by L.D.P.E. one can get considerable benefit from the existing system of irrigation facility itself.

L.D.P.E. films are advantageous in many other ways. When it is used below the concrete lining it makes the concrete stronger by preventing migration of moisture from concrete to soil. In case any cracks appear in the hard core due to expansion or contraction it further prevents seepage due to its water proof qualities. The other advantages of the use of Agri-films is its compatibility to various chemicals and salts and better chemical resistance.

In Bihar the system of canal lining with Agri-film has not yet been introduced. The reason being it is expensive. The above mentioned State is not only backward but also poor. It was first introduced in Punjab in 1959 in upper Bari Doab canal system. For the next 8-10 years it was used in various other States but only as an experiment with the result that many States used it as a viable material for canal lining. A survey in 1986 revealed that 85 canal reaches in 10 States were lined with Agri-films. Some of the well known projects using

L.D.P.E. films are Kangasbati project in West Bengal, Mahi project in Gujarat, Rajasthan Canal project in Rajasthan, Hasdeo Canal project in Madhya Pradesh and Doiraghat link canal in Uttar Pradesh.

One has to keep in mind the cost involved in lining of canal with L.D.P.E. film, specially which material should be used along with the film to reduce the cost of lining. As is well known in India we use right from stone slab, soil to concrete as cover in conjunction with L.D.P.E. film. This is due mainly to reduce the cost of covering and lining combined together. The cost of L.D.P.E. lining with soil cover is just 50% of the cost of L.D.P.E. lining with concrete cover or any other rigid cover. The cost of maintenance of hard cover is much less as also saving is done due to smaller size of the canal. There are other benefits also in having rigid cover that is reduction in wetted perimeter. If one were to see the long term saving one would be convinced that rigid cover alongwith L.D.P.E. film is the right solution. The laying of L.D.P.E. film below the cover is quite technical so a person proficient in the work should undertake it. It also needs deft handling and good amount of care.

No one has been able to arrive at any definite idea as to what should be the thickness of film that should be used for different components of canal system. The higher the thickness the greater the strength against puncture and weed effect. But the thicker the material the greater the cost involved. All types of thickness from 100 microns to 250 microns have been used as an experiment, but a thickness of 100 microns has been found to be more suitable. For its large scale use in canal system in our country a general guideline would be needed by some one who is an expert in this line, to minimise on the expense involved in its use.

L.D.P.E. film should be protected from prolonged exposure to sunlight as they get affected by ultra radiation making it brittle. As it is very difficult to provide such control at the site of construction heavy black film with carbon black (2.5%) in the finished product would be ideal for its protection.

An experiment has to be made and found out which is the best kind of L.D.P.E. film suited for Indian condition specially since our country is big with different soil and topographic condition. So different kind of film may be required for different areas say the plains, the hilly area and the desert area.

In 1988 Govt. of India established the National Committee on the use of Plastic in Agriculture. It has set up 22 plastic culture development centres in different parts of the country to cultivate the plastic culture technology and its application and to identify areas of further development. The L.D.P.E. film which has been developed has a smooth finish and is vulnerable to puncture. The shortcomings of the film need to be overcome. Under these circumstances it would be proper that the National Committee on the use of Plastics in Agriculture sponsored research activities to recommend formation of new varieties of L.D.P.E. film suited for canal lining under different sites and slope conditions as also for the composite development of L.D.P.E. and L.D.P.E. films.

Lining of canal should be undertaken after due consideration. It is not advisable under all circumstances. All proposals for lining system need careful consideration. One has to keep in mind that lining tends to reduce ground water recharge and reduces the scope of conjunctive uses. In areas where water table is low specially the hilly areas or the desert one would welcome a situation where even mild percolation of water can take place so that the water table becomes higher. And extraction of water if not for other at least for drinking purposes becomes easier. Besides there are areas where lining is not necessary because of the topography of these areas. Areas where diamond rigs have to be used to drill tube wells like in parts of A.P., Maharahtra and South Bihar etc., lining of canal should be undertaken after carefully studying the soil and topography of the area. What is good for one type of soil is bad for another type of soil.

Chapter 6

Involvement of Farmers' Group in Irrigation Management

The possible role of the farmers in the distribution of water in field for irrigation cannot only prove to be a social blocade *but also an economic and political problem.* It is increasingly felt that farmers and farmer's groups participation in the distribution of water and maintenance below the outlet is of considerable significance. Effective irrigation water management is a function of the interaction between water management, farmers and physical system.

The most underrated and misunderstood dimension of irrigation development today is that of the individual and collective irrigation behaviour of farmers. We know a lot about irrigation technology, design and construction of dams and canals, crop water requirement and irrigation practices while the social and organisational aspect of irrigation continue to be Achilles heel in system development, improvement and operation. The increasingly high cost and the low performance of irrigation project in India continue to be a matter of concern at national and international level. Government officials and donors are slowly realising the high economic, social and political costs involved when farmers and users play only a passive spectator role in irrigation project and programme which affect them directly. It is now being mentioned at every level about how the lack of effective farmer involvement in irrigation project is related to the high cost of systems, the perennial problems of operation and maintenance and low irrigation efficiencies resulting in low crop production.

Water management alone cannot promote effective water management. Physical system above the outlet is maintained, managed and operated by water managers. Physical system below the outlet is managed operated and maintained by the farmers to use water efficiently for better crop productivity. So active involvement of farmers to maintain operational efficiency of the irrigation system both below and above the outlet is imperative since it is the farmer who decides which crop to grow, when to grow, where and how much to fertilise, and how much to invest given his risk taking capacity. He is the producer and the risk taker. Irrigation is a community subject and all the farmers of the command area have to adapt themselves to a certain common approach in areas like water allocation, scheduling of canals, equitable distribution of water, importance of timely and adequate repairs of canal network and a proper system to facilitate release of required quantity of water. For increasing efficiency and better performance of the system active involvement of the farmer is necessary.

At present farmers group and associations are mostly scattered and widespread in North and North West parts of India. There is no formal recognition by the Departments. In recent years attempts have been made to organise farmers for proper use and equitable distribution of water.

In Maharashtra, Phad system is practised in parts of Nasik and Dhulia Districts. There are a series of Bandharas on perennial river. The command area varies from a few ha to 50,000 ha. The maintenance of the Bandharas is the responsibility of the Government while maintenance of the system is the responsibility of the farmers. The command area is usually divided into four blocks, each block grows one crop in irrigation season. For irrigation management a Panch Committee is formed out of the General Body and is responsible for water management, settling disputes etc. Some local staff is appointed to assist in the management who are paid both in cash and kind.

Water distribution which is completely managed by the farmers on Nira right bank canal for the last 40 years is functioning smoothly. The water is being used to cultivate sugarcane.

In 1947, Canal Water Panchayat Committee was formed. For every canal there is an advisory committee with Executive Engineer or S.D.O. as Chairman. It has peoples' representatives. It exchanges views regarding water requirement, rotation interval, date of plantation etc. It deals with water Panchayats, receives appeals from water Panchayat and holds irrigation conferences. The Committee's functions includes preparation of rotationwise water requirement, getting feedback regarding unauthorised use, mutual settlement of complaints etc. There are Canal Inspectors also who perform all the functions related to Pani Panchayat Committee. Committee collects part of water rate for its function. Whereas the Central Advisory Committees have been functioning very well and regularly, many of the canals Pani Panchayats have not been well organised.

In Maharashtra after the Malinagar society was formed attempts were made in 1960 to form societies of irrigation to take water on volumetric basis and do initial distribution. This experiment did not succeed. Later on one such society was formed on Godavari Canal and it has succeeded. Two such societies have been registered and have been taking water on volumetric basis on Bhima and Khadak water canal.

In Gujarat there are a few Irrigation Co-operative Societies which are of recent origin. Mohini Water Co-operative Society Kakrapar project is one such. Its headquarters is in village Mohini in Chorasi Taluka in Surat District. It started functioning in 1979. It was assigned 5,000 ha irrigation facility. The responsibility of water distribution, levy and collection of water charges and operating and maintaining the canal system within the area assigned to society was completely taken over from Government. Even though the Mohini experiment is widely acclaimed there has been no replication of this co-operative even in its own command area.

To encourage participation of farmers in irrigation management Government of Gujarat has formed cottage service area Committee at the level of Section Officer, Water management Committee at the level of Deputy Executive Engineer, and project level Committee at the level of Executive Engineer. The main object of the Committees is to develop overall involvement and rapport between farmers and the Department. Experiments are going on in Mahi project in a chak of 40 ha. A small group is formed of 10 to 15 farmers. The sub group leader in a chak forms the Chak Committee. These Chak Committee are proposed to be registered as Societies.

In Andhra Pradesh farmers participation in the implementation of warabandi was initiated in Pochanpad project. Pipe Committees were formed on each outlet. The Committee had 7 to 10 members comprising group leaders mainly from the tail end of chak and pipe President. The leaders and President were chosen by farmers. The Pipe Committees were not made legal entities, so though many functioned, some did not do so quite adequately. The Committee did not function well when the supply at the outlet was not quite reliable.

In Andhra Pradesh, Government had decided to entrust Eluru canal water management to Karshak Parishad. After conducting elections to the Parishad, it is proposed to involve farmers in water management through these Karshak Parishad.

In Madhya Pradesh formation of irrigation Panchayat is provided under the Irrigation Act. The members of the Panchayat are elected out of the farmers who benefit from the canal water. The main function of the Panchayat is to settle the dispute and collect revenue, other water management functions are included also. Since none of the defaulters can become members of the Committee most of the irrigation Panchayats have become defunct. Irrigation Panchayats have by and large been found to be unsuccessful in involving farmers.

District water utilisation Committee was set up under the

Chairmanship of the Collector with representatives of public. The Committee takes decision on water use.

In Tamil Nadu Paikulum Agriculturist and farmers improvement society was founded in 1972 under Paikulum Tank in Tombrapani river Basin. The activities of the society are controlled by different office bearers and 64 administrative members. The society manages water distribution and resolves conflicts. It is functioning effectively even to date.

Khudi Maramath is another example of beneficiary participation which has been in vogue for cultivation in Tamil Nadu in Palar river Basin. The Palar river flows only during flash floods during North East Monsoon. Rest of the period it is dry. The farmers all along the river bank draw water from aquifer. The farmers association themselves maintain these canals which were originally excavated by group of farmers and have been in existence for centuries. The Government is not assisting the farmers in any way. In the Old Delta areas of Cauvery river the Khudi Marmath system for maintenance of irrigation channel is in vogue in all the 1500 A class channel.

One is able to make out one thing that there are very few farmers organisation in the country. Some of the societies which are working well are in reference to cash crop sugarcane. Some of the farmers participation was initiated long time back and very little work in farmers participation has been done in post independence period. Though lot of paper work has been done very little work has taken place in actual practice.

In the Eighth Plan concentrated efforts need to be made to involve the farmers. Unless the farmers participate in water management as well as maintenance of the system, at least in the outlet, irrigation management cannot improve.

It is also felt that since irrigation management is a process by which water is taken and used in the production of food and fibres the farmer who is the key figure in irrigation management has to be involved effectively in all the activities of irrigation management and take an active role. Uptil now the farmers have taken a passive role.

One feels after taking a look at the formal and informal farmers group or association involved in irrigation management in various states that though some localised efforts have been made here and there to organise farmers in small plot areas there has not been a concentrated programme to involve the farmers in irrigation management. It is strongly being felt now that unless farmers are involved in the various activites of irrigation management it will not be possible for the Irrigation Department to ensure equitable and reliable supplies of irrigation water and achieve high efficiency. Farmers involvement improves relationship and understanding between farmers and Govt. functionaries and helps synchronise decision of both. It minimises conflicts and inculcates a sense of ownership and discipline.

Farmers group should be organised according to geographical basis in an irrigation command. Outlet or Chak Committee should be formed with representatives of each sule chak (5 to 8 ha). The Committee should be associated with the planning and construction of water course field channel and field drain. Rotational water supply schedule should be prepared by the Department in consultation with the outlet/ Chak Committee and it should again be handed over to Chak Committee for day to day implementation and resolution of disputes.

Minor level Committee should also be constituted with representatives of the Chak Committee. These Committees should be associated with the preparation of operational plan and also ensure that designated discharges are available at the outlet. At village level irrigation Panchayats should be constituted with minor level Committee.

The formation of the Committee is more easily said than done. So rural social organisation should be employed by the Irrigation Department to educate the farmers receiving water from the canals and organise the chak minor and village level Committees. These social organisations along with the workers of Rural Agricultural Extension Programme should move into the command much earlier than the completion of the irrigation system, educate the farmers on the benefits of irrigation management of water and explain the need and utility of farmers organisation and constitute the Committees. The rural organisation should continue till the Committee starts functioning and functions successfully for a period of one full year spanning all the crop season.

In order to enable the Committees to shoulder the responsibility expected of them training should be given to them. To facilitate this project training centre should be established in each major and medium project and a group of minor projects. The lower staff of the Department should also be trained at these centres.

It is also suggested that to encourage the formation of farmers group or Committee, Government should give a management subsidy of Rs. 100 per ha for two years and Rs. 75 per ha for the third year.

To ensure that the farmers Association are self sustaining and viable a portion of the maintenance allowance should be passed on to them. The farmers group should be encouraged to collect irrigation revenue by passing on a certain percentage of the collection. They should also be encouraged to form Co-operative Societies and water should be supplied to them in bulk for retail distribution. They could also be encouraged for distribution of other inputs required in irrigated agriculture.

It is also suggested that farmers group or Association should be given adequate power by making suitable provision in the Irrigation Act. Legal backing should be given. Model byelaws should be framed and circulated for the constitution of Co-operative Societies.

It is also felt that efforts to constitute farmers association in so called sick project to shake of responsibility of the Department may negate the very philosophy of farmers participation, and, hence, farmers committee should be constituted initially only on successful project.

Careful handling of irrigation project and irrigation management is needed because water which is the base of life also happens to be the bane of life.

Chapter 7

Importance of State Tubewell Irrigation in India

Though there are different modes of irrigation, tubewell irrigation seems to be extremely good from various points of view. Even though irrigation by canal water is a very good solution, it has its own disadvantages. It gives rise to water table. Waterlogging takes place ruining the crops which turns out to be counter productive. These things are applicable in areas which are not hilly. They take place more in such areas which are drained by some river. Best example being the plains of Ganga or for that matter any other river. Here there is a greater danger of water table rising faster. These are also areas where the sodium content in the water is very high which leads to the water being saline. Naturally this water is not suitable for irrigation. In areas which have heavy rainfall the water table is high. Also in areas drained by river and canal. In such areas tubewell irrigation is not only feasible but also quite economical since one does not have to go very deep to get water. Water can be found at quite high level. It is because of the easy availability and the economic nature that the government started sinking tubewell in India way back in mid-forties. To be precise, in 1944-45 in "Dilia" in Rohtas district the first tubewell of Bihar was sunk. They say it is most probably the oldest tubewell in Bihar. In sandy areas it turns out to be less economical. Because of the porous nature of soil water seeps down. At the same time it takes long hours to irrigate the land. It is almost three times more expensive when irrigated by tubewell in sandy soil than in alluvial soil or any other good soil.

In 1960s, the farmers started installing shallow tubewells which became most popular technique in 1970s onwards simultaneously with the wide-spread extension of electricity in rural areas. The planning of irrigation from State Direct irrigation tubewell was mainly oriented on the pattern of canal supply, the DITs being considered as outlets in canal irrigation. The intensity of irrigation canals in Haryana ranged from 50 percent in WJC tract to 62 percent in Bhakra Canal tract. The same intensity of irrigation was provided on DITs. Evidently, the complete chak command was not irrigated. This situation compelled the cultivators to install shallow tubewells in the canal commands and even in DITs chak commands areas and gradually the number of private tubewells increased over the period. On the contrary, the irrigated area particularly in the chak commands of DITs continuously decreased with the increase in private tubewells. The acute shortage of electricity over the years became a serious constraint for DITs to run for full projected period during crop seasons which disturbed Warabandi for share-holders to provide assured irrigation at pre-determined turns. This adverse situation resulted in reduced performance of DITs over the time but the importance of DITs has not declined for marginal and small farmers who could not afford to sink shallow tubewells and essentially depend on public irrigation system. The large tracts of districts Ambala, Yamuna Nagar, Kurukshetra and partly Faridabad, Rewari, Mahendragarh, Bhiwani, Hisar and Sirsa contain DITs for which there is a persistent demand by the farmers but due to lack of fiscal support HSMITC is not able to operate and maintain them efficiently or rehabilitate them.

In adjoining state of Punjab, the State has been providing considerable subsidy through budgetary provisions and performance of more than 1500 DITs is satisfactory to the advantage of farmer community and to the state in terms of higher agricultural production. In the State of Haryana the water scarcity is more acute, as such DITs are of greater significance. In addition to the requirement of irrigation, DITs are useful tools for effective water management as the deeper aquifer potential is tapped without much strain to shallow aquifer. The shallow tubewells age is limited for various reasons whereas DITs are in use for more than 40 years. There is also a need for installation of second generation DITs with increased demand of irrigation and at places due to decline of water table in pheratic shallow aquifer regime. The situation deals with outstanding issues for controlled and regulated operation and maintenance of DITs, improved performance, suitable rehabilitation and new installations without complacency on the part of the State to maintain social equity and crop production.

Haryana has a network of around 1546 DITs in the fresh groundwater areas of the Ghaggar and Yamuna tracts and the Sahibi, Krishnawati, Dohan and Kantli sub-basins. In 1966 at the time of formation of Haryana there were about 632 DITs and 328 ATWs which have increased to 1546 and 1641 respectively by the year 1993. The shallow tubewells have increased from about 25000 to 5.11 lac. The density of shallow tubewells vary blockwise in the range of 5 to 25 per sq.k.m. The direct irrigation tubewells, on demand have been installed for a group of farmers in the chak command as a community facility. The chak area is governed by the principle of equity as in the case of canal command. Each chak normally covers about 300 to 400 acres. The irrigation water is distributed as per Warabandi under normal circumstances, whereas shortage or disruption of electricity supply compels to disturb the Warabandi system and provide water on first come first serve basis. The quick response to requisite repair and maintenance is essential to provide adequate confidence to shareholders. The tubewell operator is a key person at site to manage efficiency and consistency in regular operation and maintenance and avoid operational hazards. In recent times the wage bill has considerably exceeded, whereas the running periods of DITs have highly decreased due to non-availability of electric power sickness of tubewells and slackness of operational staff under constrained conditions. The efforts to involve shareholders as cooperatives in operation and maintenance of DITs are still in the process without much break through and need continuous persuasion. An attempt to transfer DITs to individual shareholders willing to pay subsidised cost has also not succeeded.

The experience gained in Haryana on the first generation State DITs which were planned and commissioned during 1952-1984 (almost outlived their life) reveals that the unassured electric power supply with high voltage fluctuation has lately resulted into high operational rates uneconomical to exchequer. The Government employed operators have also not maintained full efficiency by requisite dedication, punctuality and impartiality in water distribution. As in the case of West Bengal where the Government has provided increased role of Panchayat in development of irrigation through tubewells, shallow tubewells provided at the cost of state exchequer are handed over for the O&M to Panchayats. Similarly O&M of DITs could be assigned partially or completely to individual farmers, collective group of farmers and Panchayats through proper education and mass media as per prevailing socio-economic situation in Haryana. The second generation tubewells shall be provided when the farmers beneficiaries under Panchayats are ready to control these structures to take over the O&M as DITs "Users Association". Some amount of fiscal support as per essentiality could be provided by the Government to implement the scheme.

The national water policy (1986) has attached high importance to groundwater development in overall frame work of the conjunctive use of surface and groundwater. The Central Ground Water Board has been carrying out deep groundwater exploration even upto 2500 ft or more all over the country, particularly in the Indo-Gangetic plains. The shallow tubewells are installed mostly in the range of 100 to 150 ft depth. The first generation of DITs are installed in the depth range of 300 to 500 ft. The large scale installation of shallow tubewells is causing some amount of decline in water table almost all over the fresh groundwater regions. The installation of second generation DITs is generally discouraged or denied without going into critical analysis of various techno-economic factors. It is a paradoxical situation that on one side deep exploration is regularly done at exorbitant cost to exchequer deploying high capacity expensive drilling machineries, whereas, on the other hand, the programme for installation of deep tubewells much below in depth range of deep exploratory targets are discouraged and denied. The policy frame work of national water policy needs to be adopted in true perspectives.

The water supply from DITs is more assured and dependable as compared to shallow tubewells, because of tapping deeper aquifers and optimum design criteria. The availability of electricity is a common essential requirement for all lift irrigation structure, as such a DIT is not an exception. Irrigation can be provided at a most critical stage of crop stages by restrictive waterings. The estimated chak areas irrigable on sustainability concept from different capacity DITs vary in the range of 0.75cs to 1.50cs under doformity rates of controlled extraction. According to the number of waterings essentially required in one or two crop seasons 31 to 375 acre of one chak area can be served at highest number of 4 waterings, and at 1 watering, 124 to 1500 acres, with different capacity tuberwells. Thus, there is a great advantage in regulation of DITs, if properly planned.

The net annual draft from a DIT of 1 cs capacity to serve 4 waterings at 1 ft delta per annum is lesser than the annual recharge in the area receiving 24 inch rainfall and much below for an area with annual rainfall of 36 inch. It reveals that DITs when run under controlled extraction will not affect the water table. It is advisable that less water requirement crops shall be planned and raised in DITs commands to provide sustainability of irrigation. The spread of water from DIT irrigation shall be maximised. The tendency increase delta of irrigation for hybrid variety of crops shall be avoided. The state can stick to a conventional thumb rule to allow only 1 ft annual delta irrigation from tubewells in groundwater depletion area so as to stop rich farmers to extract high amount of groundwater for their cash crops and avoid at later stage any litigation.

The DITs provide every opportunity to control and regulate discharge and contain rate of water table decline as a strong tool in water management. DITs are operated for critical stages of irrigation mainly for marginal and small farmers at crop sensitive times to enhance the crop yields. The amount of groundwater withdrawn is minimal and is not wasted in irrigation system as such DIT irrigation is more efficient.

The DITs contribute towards efficient water management by exploitation of relatively deeper aquifer layers which permit greater hydrological stress on deeper layers and less effect on phreatic water table as compared to shallow tubewells by higher discharge potential from deeper aquifers, and lesser interference with shallow tubewells as also lesser or no effect on water pollution, drought protection structure and technical means of groundwater control and regulation.

The DITs have been facing serious operational constraints over long time which resulted in poor performance. The major constraints are higher interruptions in power supply on rural electric feeders, inadequate location of DITs and imbalanced chak, smaller length of water distribution pipe lines. It suffers from inadequate financial budget allocation and serious fiscal constraint. There is unwanted delay in repair and maintenance, also, non functioning of DITs at crop sowing season. There is mechanical faults and failures. As also discharge requiring redevelopment as less than needed. Water table declines causing pump in efficiency. There is slackness of operators and theft cases. Operators apathy towards cultivators and discrimination in water rates on DITs and private tubewells as also discrimination in water rates on DITs and canals at the same time. Discrimination on subsidy on DITs and canals is there.

These aforesaid deficienices need to be removed or atleast minimised by constant monitoring, prompt decisions at policy levels and rapid action oriented will and attitudes at all levels of implementation and supervision.

The installation criteria for new tubewells would be that aquifer condition suitable to deep tubewells should be there as also uncommanded area from canals. The chosen area should have difficult terrain and backward region. No other source of adequate irrigation should be there. Conjunctive use of surface and groundwater and drainage needs and reliable electric power supply should be there.

In hilly areas one has to use diamond rigs for drilling of tubewells. In these areas the rivers are rainfed. During the monsoon and just after that there is plenty of water in them. Not only that during monsoon there is lot of current in the water because of the gradient. But after the rainy season the people of these areas become desperate not only for irrigation but even for drinking water and water for other domestic use. In such areas tubewell seems to be the only solution for the villages or tribal people. There is such a scarcity of water that the people use the small streams for bathing the cattle and taking water for drinking and cooking from the same stream. The Paharias of Bihar being the best example. In course of the year that is during summer even these streams dry up so the best solution for them for domestic as well as irrigation purpose is the tubewell. No doubt one has to put in a lot of effort in finding out where water is available since these areas are hilly. Also diamond rigs have to be brought for drilling. All said and done it is worth the effort taken for the solution of water scarcity of these areas.

CHAK ARE IRRIGABLE FROM DIFFERENT CAPACITY DITs AT DIFFERENT RATES OF CONTROLLED EXTRACTION TO MANAGE SUSTAINABILITY OF IRRIGATION AND WATER TABLE DECLINE

Annual Operation (Hrs)	*DITs Capacity* (CS)	*Annual Draft* (acre ft)	*Chak Area irrigable for Selective Number of Waterings**			
			1st	2nd	3rd	4th
500	0.75	31	124	62	41	31
	1.00	42	168	84	56	42
	1.50	62	248	124	83	62
1000	0.75	62	250	125	84	63
	1.00	83	332	166	111	83
	1.50	125	500	250	167	125
1500	0.75	94	374	137	129	94
	1.00	125	500	250	167	129
	1.50	187	748	374	249	187
2000	0.75	125	500	250	167	125
	1.00	167	668	334	223	167
	1.50	250	1000	500	333	250
2500	0.75	156	624	312	208	156
	1.00	208	832	416	277	208
	1.50	312	1248	624	416	312
3000	0.75	187	750	375	250	187
	1.00	250	1000	500	333	250
	1.50	375	1500	750	500	375

* Depth of each irrigation assumed 3 inch.

Chapter 8

Leaching of Saline Soil

Irrigation project involving inter basin transfer of water without adequate drainage has disrupted the equilibrium between the ground water recharge and discharge resulting in acceleration to the ground water table. This is the major cause for salinisation in various irrigation commands. Millions of hectares of agricultural land in the country have become too saline to economic agricultural production.Though salt infestation results in gradual yield reduction the severity of the problem is not fully realised till the crop suffers heavily due to excessive salts. In most such cases the land is abandoned for good as the land has become non-productive due to salinisation.

The option left is to reduce the salts to an acceptable level for crop growth by leaching with good quality water. Although subsurface drainage is the key to successful management of water logged saline soil it is not an end in itself. Post drainage management of water logged salt affected soils through leaching and prevention of secondary salinisation should form an integral part of the reclamation technology. Five critical stages could be identified in any leaching programme, that is—preparatory stage, construction stage, leaching stage, leaching cropping stage and normal cropping stage.

Leaching of saline soil is essentially a process whereby water of low salt concentration is applied to displace soil solution of relatively high salt concentration. Excess water is allowed to pass through the rootzone which in turn move the salts away from the rootzone through leaching. The leaching of salts is carried out to reduce salt concentration in the rootzone and reclaim the land for crop production known as one time leaching for reclamation. Leaching is also done to maintain salt balance in normal or reclaimed lands with the objectives of long term crop production.

The importance of leaching to reclaim salt affected lands has been recognised since long. There are reports on leaching of salt affected soil by the state Agriculture Departments (Uttar Pradesh) far back in the year 1882 when mild alkali soils were reclaimed by flooding with water for several months followed by paddy transplantings. The experiments on leaching behaviour of saline and alkali soils continued to be studied to develop site specific technique for reclamation of saline soil. On the basis of these efforts, method for salt removal could be identified into three categories. The method of physical removal of salty soils to fields or land not used for agricultural purpose is not being practised. It is now known that leaching alone is the most effective means of reclamation. Flushing has limited application in certain situation. The method of flushing for salt removal differs from leaching in a way that in the former salts are removed by surface washing of the soil as compared to pushing of salts below the rootzone in the latter. In this method salts move along with excess rainfall or irrigation water as the surface water moves down the slopy land. The water alongwith the salts is removed through a surface drain provided at the tall end. But this technique is useful only under limited situations. Heavy soils are suited to this method of salt removal. Even in these soils limitation on the available slopes, water requirement and the need of a good surface drainage system may restrict the efficient working of this method. Because of high water requirement for sufficient salt removal and several practical difficulties, use of this technique as a means of reclaiming saline soil is limited.

Removal of salts from roatzone is an important aspect in the reclamation and management of salt affected land and in maintaining long term productivity of irrigated land. For efficient leaching it is essential to level the land and bund the fields to be followed by a shallow or deep ploughing to loosen the hardened surface. Smaller plots are ideal for uniformity of leaching. It is difficult to prescribe any specific time of the year for leaching operation since several factors are involved in the process. In general, periods of low evaporation demands are beneficial though availability of water is the major criteria for identifying the time of leaching. In location where water is a limitation, periods just before the rainy season should be preferred because of two reasons. The incoming rainy season with excess rainfall will help in leaching of salts with increased efficiency. At the same time ground water table is lowest at this time of the year and therefore salts are leached to a greater depth. As the salts are moved to a deeper level upward movements of salts at a later stage will be slowed down.

Since reclamation is meant to grow crops leaching should be in conformity with the tolerance limits of the crops to be grown. The cost will be high if salts are leached beyond a threshold value as no additional benefits will accrue, because yields stabilise at the threshold value. Crop tolerant tables can be of help for selecting crops. Once the fraction of soil to be leached is known then the amount of water required could be estimated. A thumb rule that 1 cm. of water should be applied for each centimetre of soil to be reclaimed is the common deciding factor. However the quanitity of water may very with soil texture and fraction of salts to be leached. For medium texture soils (sandy loam) 0.5 cm of water for each centimeter of soil is sufficient to remove 80% of the salts present in the soil profile. The amount of water required to leach a predetermined fraction of salts from known depth of the soil indicate that to leach 85% or 90% salts one would require to pass 0.44 cm/cm and 0.53 cm/cm of water respectively.

In continuous leaching water is ponded continuously over the soil surface to allow water to pass through the rootzone. In case of intermittent leaching water is ponded at intervals. The leaching could be inefficient with continuous leaching because most of the water could pass through miscropores and through established channel such as cracks or root channels. The difference between degree of saturation and rate of water movement are also responsible for difference in leaching efficiency. It is known that a net saving of 30% to 35% can be made through intermittent compared to continuous leaching in the amount of water needed to leach the salts to same degree. The contradictory report in many cases need fresh interpretation taking into account evaporation, time interval between leaching and the amount of water applied initially before allowing redistribution. However intermittent leaching may not be advantageous for highly degraded alkali soils with restricted infiltration rates. The time taken to leach a given fraction will be less in continuous leaching and to save time continuously ponded mode of leaching should be preferred.

Leaching is more efficient with water content below saturation. Rate of application of water to the soil will affect the degree of saturation in the profile. Differences in leaching due to different rates of water application would vanish provided the redistribution time compensated for the difference in time between the water applied at the two application rates. However this is applicable to the situation where evaporation was not allowed in the experiment and hence this finding cannot be transferred straight to actual field situation as evaporation under field condition is difficult to control. The leaching efficiency increased with decreasing application rate compared to continuous ponding. However depending upon the evaporation rate there may or may not be any beneficial effect when rate of water application is reduced below an optimal level. Leaching efficiency improved with an application rate of 3 cm/day compared to steady state (saturated) and non steady state (continuous ponding) but it did not improve further with 1 cm/day. In a trial with still higher evaporation rates the leaching efficiency in fact decreased when application rates were reduced from 3 cm/day to 2 or 1 cm/day. The available information on the subject suggests that leaching efficiency with the sprinkler is usually intermediate of the continuous and intermittent modes of leaching. Therefore investment on the sprinkler irrigation sets for this specific purpose may not be necessary as similar situation if needed could be created by intermittent leaching.

In many situation specific ions affect crop yield more than the total salinity. One such ion is chloride which affects citrus crop even at low level. Another specific ion boron is toxic to many crops but is slow moving. These specific ions need to be evaluated and crop tolerance to these ions should be taken into account in deciding fraction of leaching. Chloride is leached much faster while boron is slow to leach and requires two, three times more water than required normally to leach soluble salts. However under Indian conditions boron requires high amounts of water for leaching. This may be because Indian soils are absent in high level of boron. Moreover application of gypsum to alkali turns boron into insoluble form thus making it ineffective to plant growth.

In arid and semi arid regions having salt affected soils ground water is of relatively poor quality and fresh water is in short supply. These areas offer greater potential for the conjunctive use of saline and fresh water for crop production. Conjunctive use of water should be undertaken if the electrical conductivity and sodium absorption ratio of the saline water is less than the salinity and sodium absorption ratio of the soil. Fresh water should be available in adequate quantities following application of the saline water. With conjunctive use total quantity of available irrigation water (saline+fresh) increased by 18-33 percent with a net saving of 18-40 percent in the fresh water requirement. Exact quantity of saving depends upon initial soil salinity, ground water salinity and the quantity of the ground water applied.

Rainfall is of paramount importance in leaching saline soils or soils irrigated with saline water. In the Indian context rainfall during monsoon substantially affects the annual salt balance. Intensity and duration of rainfall, duration of dry spells between the two rain events and soil condition including initial salinity and its distribution in the profile, initial water content at the time of rainfall and land management practices like land levelling, bunding and surface soil conditon affect the efficiency of rainfall. Levelling and bunding alone improved the rainfall contribution to leaching by 40-50 percent. The leaching effect per unit of rainfall is relatively low in humid regions (coastal saline soils) because of intense storms resulting in high run-off.

In most saline soil, soil salinity is too high for crop growth. For crop production, tolerant varieties of crops are identified so that cropping could be possible. A common belief that more salt tolerant crop should be grown during initial years should be viewed more in the context of the irrigation requirement of the crop to be grown. Barley is a salt tolerant crop with low water requirement. There is every likelihood for the surface salinity to increase if barley is grown as the first crop compared to others like wheat with relatively more water requirement. Similarly rice which is often considered unsuitable for these lands mainly because of the constraints of the water availability and its less tolerance could greatly modify the salt status in the profile. Because of liberal requirement of water in case of rice, crop salinity could be significantly reduced and its benefits to subsequent crops could be immense. It is recommended that one rice crop should be included in the long term crop rotation on such land even after the lands have been reclaimed.

The effect of varying amount of water applied for leaching is that yield increased with increasing amount of water applied except in case when the soil salinity was in the low range. It is mainly because once the threshold salinity is reached there was not much beneficial effect. Without leaching establishment of the subsequent crop was difficult and germination in plots without leaching was poor. The other aspect is without drainage the secondary salinisation is quite high and may interfere in crop production. It is therefore apparent that sub-surface drainage and leaching are essential to reclaim waterlogged saline soils.

The type of soil salinity level at different depths, location of the hard pan with respect to ground surface and depth to water table at the time of leaching are some of the factors that could be modified to influence leaching. For modifying leaching certain things are suggested. Such as subsoiling improves infiltration rate, removes, reduces, natural channel. Tillage with inversion improves infiltration rate of the soil, physically moves the surface accumulated salts to lower depths, improves infiltration rate, controls surface crusting and maintains soil structure. Breaking hard pan improves water movement reduces chances of water table build up. Irrigation practices improve leaching efficiency by controlling the moisture content. Situations resembling intermittent leaching could be created.

One can say that sub-surface drainage and leaching are the two essential components of the reclamation process of water-logged saline soil. Leaching should be practised extensively in States like Punjab, Harayana and Rajasthan to reclaim saline land in a big way.

CROP TOLERANCE TO SOIL SALINITY FOR WORKING OUT LEACHING REQUIREMENT

Sites	*Soil Type*	*Crop*	*Threshold* (ds/m)	*Slope* (%)	*EC* (ds/m)
Sampla	SL	Wheat	4.6	29.0	5.7
		Mustard	6.0	15.0	9.3
		Barley	7.0	19.0	9.6
Karnal	SL	Mangbean	1.8	20.7	3.3
		Mustard	3.8	6.9	11.0
		Sorghum	2.2	10.6	6.9
Agra	SL	Wheat	8.2	19.8	10.7
		Mustard	6.1	20.7	8.5
		Berseem	3.5	12.5	7.5
		Potato	4.4	16.1	7.5
		Tomato	1.3	6.5	9.0
Dharwad	BC	Wheat	2.3	20.5	4.7
		Sanflower	2.8	20.7	5.2
		Sorghum (W)	2.1	3.9	14.9
		Italian millet	6.1	50.0	7.1
		Sataria	1.1	2.2	23.9
Indore	BC	Berseem	2.0	11.2	6.5
		Sanflower	2.8	5.0	12.8
		Maize	0.5	7.9	6.8
Chalakudy	LS/SL	Transplanted rice	0.6	2.7	19.1

W = Winter Season.
SL = Sandy Loam.
BC = Black Clay.
LS = Loamy Sand.

Chapter 9

Role of Irrigation in Agriculture

For increasing the production of agriculture, irrigation is a must. All kinds of methods can be used for this. One can irrigate the land by canal which are supplied water by huge dams or by rivers. Irrigation can also be done by small tanks and ponds available in the village. One can have tubewell and lift irrigation scheme as per the topography of the region. In areas which are flooded ever year one can make retention basin. One has to make four to five feet high wall and direct the flood water in that and release it as and when required. Fish can be also cultivated in these basins. They are based on the Chinese and Portuguese lines. But canal irrigation gives rise to water table which may lead to salinity of water as well as land. So conjunctive use of water is necessary. Here tubewells play a vital role not only in irrigating the land but also bringing down the water table. The best example of canal irrigation and its after effects are Punjab and Haryana where due to excessive canal irrigation water table has gone up leading to waterlogging and salinity of soil.

About 70 percent of the cultivated area in the country lies in regions of medium to low rainfall and bulk of the precipitation occurs during the monsoon months. Further, the rainfall shows wide intra-seasonal variations, unequal geographical distribution and frequent departure from the seasonwise normals.

During the era of planned development which commenced in 1951, provision of irrigation facilities was assigned a high place. At that time the country was dependent on sizeable food imports and irrigation was reckoned an important requirement for improving indigenous production.

Major, medium and minor irrigation schemes were taken up all over the country in large number. A government outlay of over Rs. 25,000 crores financed the major and medium irrigation schemes. In addition the government and public institutions spent over Rs. 14,000 crores on minor irrigation schemes.

As a result of the massive investment made in the irrigation sector, the irrigation potential created in the country increased to over 80 million ha and nearly sixty percent of it was accounted for by minor irrigation works. A distinct feature of development during this period is the enormous contribution made by tubewells. Nearly 30 percent of the present irrigation is accounted by shallow and deep tubewells while forty years back it was negligible. The extension of rural electrification has played a significant role in speedy ground water development.

The data of yields available separately for irrigated and non-irrigated areas based on sampling is limited to help us to directly establish the quantitative contribution of irrigated farming in increasing the agricultural production. However, a broad comparison of yields of a few principal crops grown in some states under high irrigation and some other under low irrigation coverages can be used to substantiate the claim. It is noticed that the average of rice yields in the five states of Punjab, Haryana, Andhra Pradesh, Sikkim and Tamil Nadu where over 90 per cent of the crop is grown under irrigation is nearly 100 percent more than the average of West Bengal, Tripura and Madhya Pradesh where less than 25 percent of the rice area is under irrigation. A similar comparison of yields of wheat in States where the crop is grown predominantly under irrigation, with those of states where it is cultivated largely under rainfed conditions indicates a five fold rise in per unit production. The difference in yields between fully irrigated and totally rainfed areas will be even steeper.

In addition to rise in per unit production of land, irrigation has also helped to achieve increased cropping intensities. A rise of 29 percent in the cropping intensity has been achieved in areas under irrigation whereas the corresponding percentage for non-irrigated area is about 24.

Irrigation has performed reasonably well both on production and stability counts. Though the bulk of the crop area is under rainfed farming, the mass of cereal output of the country now originates from the irrigated segment. Further, irrigation has lowered instability both in aggregate yields and in the areas cropped. Recent experiences have shown that irrigation has helped in minimising rigours of drought as well.

While the role of irrigation in country's increased agricultural production is impressive, there is need for retrospection to meet future requirements of a continuously rising population. Since the 1950s the aggregate growth rate of agricultural production has been nearly a third higher than that of the population rise. As a result, the net availability of food and agricultural products in per capital terms has perceptibly increased. However, the present strategies may lead to stagnancy after a time with respect to yields, as is common with any approach, calling for something new, and increasing the efficiency of irrigation will have to be considered. In any long term perspective for sustained growth of agricultural production, irrigation will have to play a notable role commensurate with the high investment made in it by the nation. Another point to be kept in view is that while there is significant decline of the share of agriculture sector in the GNP, the proportion of households, dependent on agriculture has remained nearly constant. Irrigation activities will have to aim at the improvement of economic condition of farmers through better irrigation management practices and by extending benefits to new areas.

One of the major areas of concern is the large lag in the provision of irrigation facilities and its actual utilisation. Over a tenth of the irrigation potential created with heavy capital investments is reported to have remained unutilised. This position is attributed to a number of factors which include non-assessment of the real potential and the actual utilisation of the various schemes on a realistic basis, lack of requisite infrastructural support, organisational weaknesses, loose coordination arrangements between the departments concerned, lack of farmer involvement, etc.

In the context of the need for efficient and speedy utilisation of irrigation benefits already created, the limitations for long range development of further irrigation facilities have also to be kept in mind. These facilities presently cover around a third of the cropped area. Broad estimates indicate that in the ultimate stage of development of water resources by conventional means, around 55 percent of the gross cropped area expected to develop by 2000 A.D. could be covered by irrigation, leaving out many needy areas. Even these long term estimates prepared years ago when the provisions required for environmental protection were not fully appreciated may have to undergo onward revision and we will have to do, with a fewer future possibilities in major and medium sector in particular.

All these limitations point out to the need for efficient, scientific management of irrigation system. Further, creation of new irrigation facilities from major works is taking place at a cost of Rs. 40 to 50 thousand per ha, and the management of the resources should fully reflect its high value.

A serious problem experienced often in irrigation works under operation is the inability of the system to deliver the original anticipated benefits owing to a variety of unforeseen developments. For instance, in storage reservoirs, sedimentation has been taking place at a much faster rate than was provided for in the project planning, resulting in diminution of storage space and its benefits. Canals have not been able to carry the authorised flows because the assumptions made for the design could not be achieved on the field. Canal cross regulators and flood disposal works provided were found inadequate for efficient functioning of the canal in many cases.

Due to paucity of funds in most instances of major projects, the storage works were completed much ahead of the canal system, and in the context of abundant water availability for the limited areas opened for irrigation the crop pattern got distorted towards high water consuming crops irrespective of suitability or otherwise of the soil. In such situations the development of irrigation facilities along full system as originally envisaged will become totally difficult with head reach beneficiaries claiming prior appropriation of the resource.

A number of pre Plan and early Plan works have been experiencing diminution of benefits. The planners have suggested modernisation of the early systems but in most cases the proposals were capital intensive, raising the question whether the scarce resources should be invested in the areas already receiving irrigation benefits or utilised in new areas. Until sound and economically reasonable steps for restoration of full benefits materialise, the command areas may have to be limited to a realistic scale to facilitate equitable distribution of benefits and scientific water management. Further, pending the implementation of full fledged modernisation schemes, appropriate operational and management strategies will have to be developed for efficient use of the available facilities to the extent feasible, pending major interventions.

A number of problems are experienced in field level management of irrigation supplies. These include inadequacy of on-farm development for efficient water distribution, incompatibility of soils with crops developed, drainage congestion, and above all lack of dependability of irrigation supplies. The problem of soil salinity is experienced in a number of places owing to rise in ground water levels.

Some of the general remedial measures are well known. Among these are provision of drainage facilities, conjunctive use of surface and ground water, efficient maintenance of field channels and field drains and promotion of scientific irrigation management practices.

It is now generally recognised that farmers participation in management would go a long way in promoting sound management practices. But the steps taken so far are in no way commensurate with the task ahead. The maxim of "some for all rather than more for some" which is particularly valid for irrigation system can be achieved only through meaningful participatory management and the administration will have to progressively extend suitable mechanism to achieve it.

While irrigation has significantly influenced agricultural productivity, the yields are distinctly low with respect to international norms. The average cereal yield of 1.7 tonnes per ha achieved in India falls well below the international norm of 3 to 4 tonnes realised in well managed systems of the world. The gap is attributed to a number of factors such as suboptimal use of inputs, obsolete cultivation practices and inefficient irrigation management. Given the sensitivity of crops to water stress and excess water and their effects on yield, the critical dimension of irrigation management emerges as a major determinant of agricultural productivity.

The Indo-US Irrigation Management and Training Project launched in the eighties fully reflects our concern to develop scientific irrigation management through imparting inservice training to irrigation functionaries at various levels and by conducting field level studies in representative areas in live irrigation systems to identify problems and evolve solutions. The thrust was on considering land water resources together so as to ensure sustainable higher productivity through better management. The programme extended over 11 states in the country and there was general agreement on the need for extending this approach on a wider scale.

Given the wide variation in parameters like approaches made towards irrigation development, availability of the resource culture of irrigation management, farmers attitude and the existing type of administrative set up in the individual states, the transformation aimed at is bound to be complex and slow. Further, the area to be reformed and transformed is so vast that it may turn out to be the largest venture of its kind in the world when taken up for implementation seriously.

In the field of irrigation development models it would be most essential to give highest priority to what are known as surface minor irrigation works which will have to include promotion of tank irrigation, water harvesting techniques, farm ponds and moisture conservation measures on field. So far the planning of irrigation development has devolved from top to downwards as far as the broad approach goes. In the light of the emerging environmental considerations and also to ensure realisation of quick benefits from local works, irrigation will have to evolve from the village upwards. Further, situation specific techniques like supply of water through sub-surface irrigation and introduction of drip and sprinkler irrigation will have to be introduced on a larger scale subject to their economic viability.

All these steps require a certain amount of Research and Development support and imparting of new skills and knowledge to the personnel in the irrigation departments through suitable inservice training programmes.

The fact that irrigation management is multidimensional will have to be kept in mind in all our future efforts for planned development of irrigation and its efficient scientific management. The agencies and disciplines involved today are numerous and include Agriculture Extension, Agricultural Research, Energy, Environment, Rural Development, Cooperation, Command Area Development, Agricultural Economics and Banking. Inter Departmental linkages will have to be established among all the concerned agencies, not merely at the departmental heads level but among the field level functionaries as well. A number of conflicts would arise since the individual approach and requirements of these individual agencies may be at variance. These will have to be resolved and synthesised and harmonious approaches evolved. This may require study of multi disciplinary managerial models suitable to different situations, their evaluation and wide dissemination of recommendations.

Irrigation has played a catalytic role in the achievement of increased agricultural production during the last four decades. Owing to constraints for extending cropped area, the future requirements of additional agricultural produce will have to be largely met from efficient use of irrigation water and extending soil moisture and water conservation programmes at the village level. Further, the existing rural irrigation works will have to be carefully conserved by taking up requisite improvement works.

The proportionate distribution of water cannot take place without the involvement of farmers. By farmers one means big as well as small farmers. In the villages might is right prevails. So all types of farmers from different communities must participate in looking into the proper distribution of irrigation water. Villagers can form orgnaisations at the village, panchayat and block level. A bigger organisation at the district level can guide, supervise and look into the cases of litigation which is very common. All these organisations should be non-government organisations. At district level either a senior Magistrate or the District Magistrate could be included in the Committee. Farmers participation is a must in irrigation management. Many a time people with vested interest try to get into such organisation specially politician with a desire to getting hold of the area. Such men should be discouraged and only such of those who own land and are dedicated to the cause should be included in these organisations as members.

Chapter 10

Artificial Recharge Structures Suitable in India

Artificial recharge is the process by which the ground water reservoir is augmented at a rate exceeding that under natural conditions of replenishment. Any man-made scheme or facility that adds water to an aquifer may be considered to be an artificial recharge system.

There are many reasons why water is deliberately placed into storage in ground-water reservoirs. A large percentage of artificial recharge projects are designed to conserve water for further use.

From the point of view of artificially storing water for future use, the basic requirement is to be able to obtain water in adequate amounts and at the proper times in order to accomplish this goal. Some schemes involve the impoundment of local storm run-off, which is collected in ditches, basins or behind dams, after which it is placed into the ground. In other localities, water is sometimes brought into the region by pipeline or aquaduct. In the latter case, the water is an import, and represents an addition to whatever natural water-resources occur in the region. A third approach is to treat and reclaim used water being discharged from sewer systems or industrial establishments.

In certain coastal areas of the world, notably in Israel, the Netherlands and the western part of the United States of America (California), artificial recharge systems are in operation in order to block inland encroachment of sea water. Most of these schemes rely on the injection of fresh water through wells in order to build up a pressure barrier that will retard or reverse encroachment of salty water that was resulted from excessive withdrawals from wells. In schemes of this type, most of the injected water is not directly available for reuse, but serves as hydraulic mechanism to allow a better use of existing ground-water reserves.

Disposal of liquid wastes is another objective of artificial recharge. Sanitary sewage, for example may be filtered, chlorinated or otherwise treated, and then allowed to filter into the ground through spreading areas of special basins and pits. Sometimes, a scheme of this kind is adopted simply to avoid the cost of constructing long sewer mains. A similar type of operation takes place on many industrial sites, where liquid plant-wastes may be placed into artificial recharge facilities. Storm-water is collected in some places as a means of artificial recharge and also to reduce the cost that otherwise would be incurred in transporting the water to distant areas of disposal.

However, as noted above, most artificial recharge projects are planned for the specific purpose of saving or storing fresh water for subsequent use by man. Among these projects some may serve the dual purpose of eliminating objectionable amounts of water at the land surface and, at the same time, putting this water into reserve for eventual extraction.

The suitability of Artificial Recharge structures in a given situation is determined by the claimatic topographic, hydrogeologic and land use conditions prevailing in the area.

Regions experiencing high (1000 mm to 2000 mm/annum) and very high (above 2000 mm/annum) precipitation have adequate surplus runoff water during the rainy season which mostly goes waste as surface runoff. The total number of rainy days are above 75 to 100 and the variability coefficient ranges around 20%. A very small percentage of precipitation (5 to 10%) infiltrates to recharge water table but is quantitatively large enough to cause adequate recharge. In very high precipitation areas (more than 2000 mm/annum) the phenomenon of rejected recharge may occur. The Konkan and Malabar coasts, Assam, other North Eastern States, parts of Lesser Himalayas in U.P. & H.P., Eastern part of M.P., Orissa, parts of Bihar and Bengal fall in this zone.

In such situation need for artificial recharge during rainy season may not exist. The best option is to store surplus water in large reservoirs as far as possible and release it to downstream areas during the non-monsoon periods for direct use to meet the artificial recharge needs.

The second and third order streams in high rainfall regions may keep flowing right through the winter months and the major rivers are perennial. The water diverted, lifted and induced from such stream may be used as source water for artificial recharge.

In the areas having moderate rainfall of 750 to 1000 mm/annum generally have adequate water resources available only during the rainy season. The total number of rainy days in a year may be between 40 to 75 and the coefficient of variation between 25 to 30%. Eastern parts of Punjab, Haryana, U.P., Eastern Central parts of M.P., Eastern Maharashtra, parts of Godavari Delta, Eastern coast & Karnataka fall in this zone.

The surface runoff still accounts for major component of precipitation and infiltration recharge may be 10 to 15% of the annual precipitation. During below normal rainfall years the ground water recharge may not be adequate to saturate the water table aquifers. The second and third order streams may dry up before December-January and only major rivers may carry some water during summer.

The inadequacy of surplus water beyond the rainy season may limit possibility of obtaining source water for artificial recharge. Diversion of supplies released from surface reservoirs in upper catchment or water transferred from surplus basins, water lifted from river flow (wherever available) may be required for surplus irrigation. Hence conserving as much of surface runoff through watershed treatment measures, inducing additional recharge during and after rainy season and conserving ground water out flow through subsurface dykes appear suitable techniques for such areas.

Regions experiencing low to moderate rainfall (400 to 700 mm/annum) may be categorised as semi-arid zones as the average annual precipitation barely suffices water demand. In such areas usually the number of rainy days vary between 25 to 40. The year to year fluctuation being high, the water scarcity years (drought) occur with almost regular frequency. This causes further adversity. Western Parts of Punjab, Haryana, Eastern Rajasthan, parts of Gujarat, Saurashtra, Madhya-Maharashtra, Telengana & Rayalseema, fall in this zone. The E.P.T. losses are higher and infiltration may account for 15 to 20% of the precipitation. Though the infiltration component is percentage wise higher, the total rainfall being limited, the total natural recharge is also limited. The stream flow is mostly restricted to rainy period.

The build up of ground water storage during rainy season does not suffice to irrigate Rabi crop and may be adequate for drinking water use through winter. During summer shortages of drinking water supply occur, which may be acute in below normal rainfall years.

Such areas deserve remedial measures on priority. However due to general paucity of source water, the only option available is to conserve as much of surface runoff which goes waste to the sea during the short rainy period. The rain water harvesting and runoff conservation measures augmenting ground water resources are appropriate in such situation.

The areas experiencing precipitation less than 400 mm/ annum, with number of rainy day between 20 to 30 or even less and rainfall variation coefficient between 30 to 70%, for the arid regions. The major component of outflow is evaporation and drainage is poorly developed. Infiltration may rarely exceed field capacity of soil and ground water recharge may be very small or negligible. The Western Rajasthan desert, parts of Kutch and Ladakh region of J&K fall in this category. Such regions, though experiencing acute need, may be left out of consideration for artificial recharge unless trans-basin water transfer is available. Rain water harvesting is relevant for augmenting drinking water supplies.

In case imported water is available, depending upon surface conditions (sandy/rocky)., topographic situation and salinity profile of soil and zone of aeration, either spreading, or injection methods for confined aquifers (through shafts, dugwells, and borewells) may be chosen.

Toporgraphic situation determines the retention period of surface and ground water within the topographic unit. Steeper gradients (more than 1.10 or 10%) usually for the runoff zones with little possibility of infiltration.

Moderate topographic slopes between 1:10 to 1:1000 (10% to 2%) usually occur on valley sides, downward of pideomont foothill regions. Surface and subsurface retention will be for a longer period depending upon local slope and other conditions.

Within this zone, immediately at the foothills the piedomont belt is located (slopes between 5% to 10%) with characteristic deep water table. The surface drainage is generally located above the water table. This area is suitable for locating recharge basins and percolation tanks for water table aquifer. In alluvial Indo-Gangetic plains, in the piedomont Bhabhar-Kandi belt the deeper aquifers get connected with unconfined aquifers and hence receive part of recharge going to the unconfined systems. This may not be so in case of Semi-consolidated/Consolidated aquifers. At elevations just below the piedomont zone artificial recharge may be effected by percolation tanks, recharge pits, trenches, recharge basins. In the situation recharge of deeper aquifers through Shafts, Gravity inflow wells, or Injection wells may be possible, if suitable source water supply is available.

The broad valley floors or the lowest elevated zone along the major rivers may typically have gentle gradients between 2% to 0.2% or even less in case of flood plain deposits. The movement of both surface and ground water in these areas is sluggish and retention time is more. These are generally categorised as ground water storage zones as all the water moving down the water table gradient converges to this zone. Because of such favourable location the need for artificial recharge may occur in such zones only if it falls in low rainfall or adverse hydrogeologic strata zone. In such situation induced recharge of unconfined aquifer along the river channel will be feasible if the river carried some flow. Another mathod available will be a spreading of treated Municipal waste water (soil aquifer treatment) in the vicinity of urban coglomerates.

In case of artificial recharge through water spreading methods this factor assumes special importance. The depth of soil profile, its texture, mineral composition, organic content, all go to determine its infiltration capacity. The areas having limited thickness of soil cover are easily drained and permit more infiltration as compared to areas with thick soil profile in valley floor. The soils having coarser texture due to higher sand silt fractions have markedly higher infiltration capacity as compared to highly clayey soils which are poorly permeable.

The soils containing minerals which swell on wetting like montmorollinite etc., and with higher organic matter are good retainers of moisture necessary for crop growth but impede deeper percolation.

The land use and extent of vegetal cover also determines infiltration capacity. Barren valley slopes are poor retainers of water as compared to grass lands and forested tracts which not only hold water on the surface longer, but the root system also facilitate seepage during the rainy seasons. Similarly, the ploughed fields facilitate more infiltration as compared to barren fields not tilled.

The hydrogeological conditions of the surface strata forms the most important factors in planning artificial recharge schemes.

Below the soil zone the recharged water moves in moisture fronts through the zone of aeration and the unsaturated flow is governed by the permeability of zone of aeration which in turn varies with moisture content of the front.

The nature of soil, sub-soil, weathered mantle, presence of hard pants, or impermeable layers govern the process of recharge which needs the unconfined aquifer. The saturation and movement of groundwater within unconfined and all deeper confined aquifers is governed by Storativity and Hydraulic conductivity of the geologic strata.

Out of the 6226 Blocks/Taluks/Watersheds, as on January, 1991, 420 Blocks (including 14 Taluks in Gujarat and 80 watersheds in Maharashtra) are grey blocks where the stage of groundwater development is between 65 to 85% and 319 Blocks (including 18 Taluks in Gujarat and 34 watersheds in Maharashtra) are Dark Blocks where the stage of groundwater development is more than 85%. There are 28 dark blocks in Andhra Pradesh, 24 in Haryana, 69 in Punjab, 81 in Rajasthan, 43 in Tamilnadu and 17 in Uttar Pradesh. Due to over exploitation of groundwater in certain areas, the water levels have assumed a declining trend (*e.g.* Mehsana area in Gujarat) which, in addition to the investments on deepening of wells, entail higher lifting cost and in coastal areas has resulted in sea water intrusion (*e.g.* coastal Saurashtra, Gujarat). In several parts of the country declining trends in the groundwater levels have been observed. In such areas, there is need for artificial recharge of ground water by augmenting the natural infiltration of precipitation or surface water into underground formations by some method such as water spreading, recharge, through pits, excavations, wells and shafts etc. The choice of particular method is governed by local topographic, geological and soil conditions, the quantity of water to be recharged the quantity and quality of water available for the purpose of recharge and the techno-economic viability of such schemes.

Chapter 11

Role of Irrigation in the Cultivation of Paddy

Paddy which is a staple food for many advanced and popular countries of Asia, like Japan, China and India being some of them, can be grown in various types of soil and climatic conditions, water being the most important ingredient. It can be grown on sandy loam to alluvial soil, can also be grown on the slopes of mountain. The best example being the lower ranges of Himalayas and eastern as well as the western ghats. Paddy can be cultivated in the delta region of the Ganga and Brahmaputra. Since the water retention capacity of different soil is different the requirement of water is also different. The porous soil needs more water, alluvial soil needs less water. There are areas which due to heavy rainfall and nature of soil yield three crops of paddy. But areas which normally give one crop of paddy if assured irrigation is there give two crops. Patna town can give you two crops of paddy if assured supply of water is there. One cannot depend on rain water alone for the cultivation of paddy because it is highly irregular by nature. To get a steady supply at right time we have to depend on irrigation water which one can also monitor and get in right quantum at the right time.

In tropics and in large part of temperate regions its cultivation season, time of planting/sowing, duration, success or failure is closely linked with the availability of moisture start of rainy season, its spread and duration, intensity variability and reliability of rain. Rice yield bears very poor correlation with total seasonal rainfall. No other crop is more intensely linked up with moisture stress than rice. A good harvest is always associated with a well and evenly spread rainy season. Differences in climate and water regimes largely account for the yield differences.

In drier but well irrigated parts of northern India, rapid jump in rice yield has been attributed to greater water management (irrigation and drainage), fertilization and climatic advantages. But in eastern India with hotter and more humid climate, from among many other factors, water abundance and lack of its control during monsoon season has been held more responsible for low saturation of high yielding varieties. Abundant rainfall is considered more a curse than a boon.

To increase rice yield over space and time irrigation has been inevitable. It stabilises the yield in Kharif season in many situations. Area under irrigation is on increase. But it has never been without mixed blessing of happiness and sorrow. It is estimated that in India out of total irrigated area of 67 mha, 7 mha is suffering from waterlogging. In Orissa out of 1.17 mha under major and medium irrigation projects 12-15% area is suffering badly from waterlogging. It is partly because even in monsoon season canals remain open. If the abundant rain water is utilized to the maximum extent, the hazards of canal irrigation can be minimised. This could be possible only when canal water is used to supplement the requirement. This depends on probability of rainfall occurring during particular stage of growth.

Data on average monthly rainfall are of little utility when considered from crop growth and water requirement points of view. Very high monthly average rainfall, much more than the crop water requirement, might prove of little use. Concentrated over a few days in the beginning of the month, say, when the crop is very young, it might damage the crop. On the other hand, similar rainfall at the end of the month when the young crop has already suffered from serious stress and died might not be of much help. This rainfall if spread evenly throughout the month definitely helps the crop growth better. From this consideration, weekly rainfall data appear more useful, though data for shorter intervals are definitely more useful but enormity of such data over years are definitely more useful. But enormity of such data over years and difficulty in analysis forbid it. If weekly rainfall is much in excess of water requirement, the excess quantity will be considered ineffective. If it is much less or nil to meet the requirement, the crop will suffer from drought and to save it from prolonged drought, irrigation will be necessary. In rainfed areas moisture conservation measures are to be geared up. To predict irrigation need, information on following data are necessary:-

1. Water requirement of the crop on weekly basis during the growth period.
2. Evaporation from open pan and its relationship with crop water requirement, effect of soil moisture stress (excess or deficit) on crop growth.

Irrigation frequency and intensity depends on topography too. With the same rainfall irrigation requirement will be different for the same rice crop grown in different topographic situations (high, medium and low). One can classify rice lands with respect to topography and growth season. Land categories belonging to I and a part of II are not suitable for rice, those in III and IV are medium lands and to a considerable degree water management in these lands is possible. Those in V and VI are low lands. All rain or irrigation water from the top collects in these lands and results in stagnation-waterlogging. Lack of drainage aggravates the situation further. If irrigation on the basis of probabilities of rainfall and water requirement can be controlled in lands of category III and IV, waterlogging can be controlled over time.

Ecological environment of rice is different from that of non-rice crops where some amount of standing water is not required, even saturation proves harmful and these crops can even tolerate deficit upto 60-70% depletion of so called available moisture. It has been estimated that cessation of rainfall for 7-8 days and fall of soil moisture tension to 0.5 bar affects the growth and yield of upland rice though total rainfall during the crop period is much in excess of requirement. The crop responds to irrigation.

During Kharif season there is response to irrigation which is to be assured after 20th August corresponding to post-flowering period. It sometimes appears anomalous because probability of rainfall is high during this period. In uplands because of high topolgraphy more water is lost and effective percolation decreases. In 1984 for the upland rice 'Keshari' only 374 mm out of 1408 mm rainfall received during this period has been considered effective. But such is not the situation for medium and low land rice. Rainfall considered ineffective for upland is lost to the medium and low lands and is considered effective to the extent of standing water desired. Such high lands are not to be put to rice cultivation.

Rice does not need a standing water more than 5 cm at any stage of crop growth and more standing water does not increase the yield further. In the situation of Kharif season when water table in the field is very high, there is standing water everywhere and vast stretches of land is under the same crop seepage and deep percolation losses are the minimum (estimated to be about 27% of total requirement) and there is no necessity to account for more than 5 cm standing water either from rainfall or from irrigation. Saturation upto 30-35 days after transplanting and 5 cm standing water subsequently till 10-12 days before harvest is considered ideal. Water requirement in such situations including the nursery and land preparation varies between 80-110 cm. Effective rainfall in such situations is not more than 50% of the total rainfall.

On the basis of rainfall, soil moisture and evaporation, the moisture balance was calculated in sandy loam soils of Bhubaneswar and it was pointed out that the profile upto 50 cm gets wet from after 23rd week and water surplus begins from 26th week. Loss due to seepage and deep percolation starts after 28th week. After 30th week water accumulates to be more than 5 cm. Any rainfall in excess of the quantity required to maintain 5 cm standing water is considered ineffective.

Experimental results show that a 120 to 140 days variety (100-110 days in the field after transplanting) needs 6, 9, 16, 15 and 4 mm water per day during the periods of recovery, tillering and panicle initiation flowering milk and ripening. The periods of nursery preparation, sowing, trasplanting, beusaning, panicle initiation, flowering and ripening for short (95-115 days) and medium (120-140 days) duration rice have been given. For a direct sown beusaned rice of duration of water requirement is almost the same as for transplanted crop. Data on average weekly rainfall, evaporation, expected values of rainfall at 70, 80 and 90 per cent probability have been presented. With the help of these data it can be stated that irrigation is to be given for weeks to start nursery. This will also help advancing the planting season. If cultivation of rice in uplands is stopped as a matter of rule, there is no necessity of releasing water in the canal till 27th week. It is established that dry nursery is better than wet nursery. For raising nursery in these areas canal water may not be necessary. It can be released during 28th and 29th week to ensure transplanting for which 15 cm water is necessary, even though on the basis of probability the rainfall at 80% is more than evaporation. From 27th to 37th week evaporation is either equal to or less than 80%.

Accumulated water due to rain will carry the crop for a few weeks further. So canal may remain closed upto 39th week. Supply for 2 weeks after this period when probability is low will ensure ripening of rice crop. Thus, analysis of rainfall for ascertaining the probability will help in planning. Canal closure for 10-12 weeks over years will also help reduce the waterlogging. It will also induce to use more high yielding varieties and high levels of fertilization. Such steps will also help to start the summer crop earlier leaving sufficient gap for canal repair, summer ploughing, land preparation etc.

There are dry spells as well as excessive rainfall leading to waterlogging. Waterlogging can lead to the green paddy rotting. Needless to say that dry spells are extremely dangerous for the crop. One can only check this by proper irrigation. During the period when the paddy is about to ripe if there is water in the field either it will not ripen or it will completely rot. Irrigation is the only means by which the proper quantum of supply of water can be assured. Conjunctive use should also be put to use so that the water table is not high and waterlogging does not take place as soon as it rains. In the hilly areas where the water table is low by itself and the extra water drains out on its own the problem of waterlogging is not there. It is due to non availability of irrigated water and the vagaries of monsoon that it is said that the Indian farmer plays a gamble with the monsoon.

RAINFALL, PROBABILITY OF OCCURRENCE, EVAPORATION, CROP GROWTH

Weeks	*R*	*E* (mm)	*Probability %*			*Medium Land Rice*			*Remarks*
			70	80	90	T	D.S.	W.R.	
22	14	68	—	—	—	LP	LP		
(28.5 to 3.6)						N	S	(70mm)	Irrigation for nursery
23	30	67	7	—	—			6	
24	34	50	14	8		—			
25	72	37	22	15					
26	67	27	26	16	6	T			
27	64	26	32	20	7		B		
28	62	29	39	28	16				
29	65	23	38	26	15			9	5 cm standing water
30	84	22	42	28	13				C
31	84	22	40	28	16				A
32	89	26	32	22	12	P.I.			N
33	83	26	34	24	14		R.L.		A
34									L
34	71	22	44	32	19				Closure
35	73	29	42	33	22				
36	71	26	46	33	19			15	

Weeks	*R*	*E* (mm)	*Probability %*			*Medium Land Rice*			*Remarks*
			70	80	90	T	D.S.	W.R.	
37	76	26	32	21	12	F1	F1		
38	46	27	26	16	2				
39	51	27	14	6	—				
40	53	26	14	5	—	R		4	
41	25	23	9	—	—		R	4	
42	36	21	—	—	—				
43	30	26	—	—	—				Irrigation
44	10	24	—	—	—				
45	9	24	—	—	—				
46	5	21	—	—	—				
47	10	21	—	—	—				
48	3	22	—	—	—				
49	3	24	—	—	—				
50	1	24	—	—	—				

* Bhubaneswar (1964-83), ** Data for 1984 (Var. Keshari, 97 days), T—Transplantation, D.S.—Direct Seeded. L.P.—Land Preparation, S—Sowing, P.I.—Panicle Initiation, F1—Flowering, R—Ripening, B—Beusaning.

Chapter 12

Himalayan Water Resources Development: Bilateral Action, Regional Consideration & International Assistance

The Himalayas constitute the most significant element and determinant of the water resources system, both surface water and groundwater resources, of the entire northern part of the Indian subcontinent. Life and living of five countries in the subcontinent, *i.e.*, Pakistan, India, Nepal, Bhutan and Bangladesh critically and dominantly depend on the Himalayan water resources, which have given birth to civilizations in the hoary past, which have dominantly contributed to their rises as well as falls in history and which still dominate the contemporary social, economic as well as political activities and aspirations of the peoples of the region. The Himalayas give rise to and sustain three major river systems, namely the Indus, the Ganga and the Brahmaputra. While these river systems originate in neighbourhood of each other in the Himalayas, all in the vicinity of Mount Kailash, they flow in different directions, traversing various countries. The river Indus follows basically the westerly direction from its origin on the southern slope of the Himalayas and its flows are contributed by five important tributaries, the Jhelum, the Chenab, the Ravi, the Beas and the Sutlej. The catchment area of this river system lies principally in India and Pakistan. The river Ganga flows in the southern and south-eastern directions from its origin on the southern slope of the Himalayas and its important tributaries are Ramganga, Ghaghra, Gandak and Kosi joining it from the north and Yamuna and Sone from the south. The southern tributaries drain also waters of the Vindhyan, Kaimur and othe ranges in Central India. The catchment area of this river system lies principally in India, Nepal, Bangladesh, Bhutan and Tibet. The river Brahmaputra follows the eastern direction in Tibet for a considerable distance after its origin before it enters India and finally Bangladesh. Most of its tributaries join it from the north on its right bank in India as well as in Bangladesh. Basin has been universally recognised to be the most logical and rational unit for the optimum development, efficient utilization and effective management of the water resources of any region. As basin is a closed, self-contained boundary for the hydrological processes occurring within it, it provides a scientific basis for quantitative analysis as well as for studying the side effects and long term consequences of any proposed intervention through engineering measures. Thus, basinwise planning has been accepted to be a cardinal principle of water resources planning. It has been incorporated and enshrined in national water policies, such as that of India.

As basin is a hydrological concept in reality, it will be worthwhile to examine it from that perspective to evolve any action plan. There are two aspects to it. First, the extent of any basin, which is variously called a drainage basin, catchment area or watershed, depends on the location of the point to be considered as outlet for the basin. For example, with respect to an outlet point on river Padma in Bangladesh below the confluence of Ganga and Brahmaputra at Goalundo, the two Himalayan river systems will consitute a single basin. Ganga and Brahmaputra will be considered as separate river basins only with reference to outlet points located upstream of their confluence on their respective river courses. The second aspect is the concept of sub-basins versus basins. For the combined Ganga, Brahmaputra basin with reference to an outlet on river Padma in Bangladesh, Ganga and Brahmaputra will constitute its two sub-basins. With reference to Ganga basin with its outlet at a point upstream of Goalundo on the Ganga river, the basins of all its major tributaries joining it will be its sub-basins. Similarly, the basins of tributaries to these tributaries will be sub-sub-basins with reference to the Ganga basin and will be sub-basins with reference to the basins of the major tributaries.

It must, however, be understood that a sub-basin or a sub-sub-basin is also, like a basin, a closed, self-contained hydrological entity and has therefore the same validity and rationality of serving as a unit of water resources planning. The planning of a tributary sub-basin, however, will affect the development, utilization and management of the water resources in the rest of the basin to the extent that the downstream flows in the river are modified by the incoming flows of the tributary at its confluence.

While the question whether a sub-basin or basin should be adopted as a unit of water resources planning has to be answered in the hydrological context indicated above, a few other real world factors must also be taken into account. The hydrological boundary of a basin or a sub-basin seldom follows, respects or coincides with political, administrative or other man-made territorial divisions or jurisdictions. Speaking generally about the territorial unit of water resources planning based on hydrological rationality, a basin, compared to a sub-basin, will be larger in size, and consequently will have more political, administrative and other complexities, more diversity of physical or socio-economic situation, more conflict of interest, more diffuse objectives, more differentials and hence more divergent priorities in development, etc. A sub-sub-basin, on the other hand, may provide too limiting a scope for considering options and alternatives for engineering measures leading to suboptimal development, inefficient utilization and less effective management of the water resources of the sub-basin and the basin. Formulation of water resources plans, implementation of the projects and operation of the facilities have to be done in this perspective.

All the rivers originating in the Nepalese part of the Himalayas ultimately form into seven tributaries to Ganga, namely, from east to west, Mahananda, Kosi, Balan, Bagmati, Burhi Gandak, Gandak and Ghaghra. Thus, all of Nepal and its rather dense network of rivers form part of the Ganga basin. Out of the aggregate basin area of these rivers of 317,847 sq.km. which constitutes 30% of the entire Ganga basin, 58% lies in Nepal, 40% in India, less than 1% in Bangladesh and about 1% in Tibet. Hence, these rivers may be termed as Indo-Nepal rivers for all practical and action purposes.

The bilateral, regional and international aspects involved in the development of Himalayan water resources must be considered in light of the hydrological realities and the rationality of basin approach indicated above. Five countries, Pakistan, India, Nepal, Bangladesh and Bhutan are variously affected or likely to be benefitted by the Himalayan water resources, both with or without interventions in their natural or existing regimes. However, keeping in view the exposition of the hydrological realities and the rationality of basin approach for the development, utilization and management of the Himalayan water resources, the logic and imperativeness of bilateral or regional responsibility of actions will be clear. In case of the Indus river system, for example, only two countries, India and Pakistan, have to shoulder the responsibility of the optimum development and equitable utilization of this segment of the Himalayan water resources through mutual cooperation and co-ordination. In case of the Ganga river system, one has to recognize first that the optimum unit for water resources development planning is the basin of each of its major northern tributaries or the basin of each of the major tributaries to the river Yamuna. While action plans have to be formulated on the basis of basinwise water resources plans with the optimum unit of basin decided as above, a Ganga basin water resources plan must also be drawn up by integrating the basin plans of the tributaries. Such an integrated Ganga basin plans will be useful to assess the effects of basin development plans and actions on the lower riparians. Cooperation and co-ordination among or between the concerned states and nations have to be called for in this context.

As per the logical strategy, India and Nepal will have to take up the responsibility of developing the Himalayan water resources related to the Indo-Nepal rivers, the aggregate basin area of which constitute about 30% of the Ganga basin. They must formulate and implement plans for optimum multipurpose development and effective management of the water resources of their shared river basins. They owe this not only for the benefit of about 100 million poverty-affected people inhabiting these basins but also for improving the temporal pattern of downstream flows of the river Ganga for the benefit of the lower riparian country Bangladesh, whose 100 million people partly depend on these flows for their livelihood and economic activities. An indicative plan of the Ganga basin, hierarchically based on the integration of basin plans for the tributaries of Ganga and of Yamuna will be useful to assess the effect of the developments in these basins on the downstream flows of the master drainage channel, Ganga. Also, the effects of any modifications to the basin plans, within the limits of acceptability to the co-basin nations, may also be studied on the basis of such an indicative plan in order to achieve improved flow pattern for the benefit of the lower riparians. Apart from the benefits that the lower riparians may derive from improved flow pattern in terms of flood control, irrigation, salinity control and maintenance of navigable depths in downstream channels, they may benefit, through suitable economic and other linkages, from the opportunities and facilities created by optimum basin developments in the region, such as increased availability of electricity and introduction of inland navigation.

Thus this strategy of bilateral actions with regional consideration and perspective is hydrologically rational, practically feasible and economically desirable, and hence must be promoted for the socio-economic emancipation of the teeming millions of one of the two 'poverty belts' of the world, as characterised by the Willy Brandt's Commission on International Development Issues. Of course, there will necessarily be another dimension to this strategy, *i.e.* that of international assistance and involvement. This can arise principally from two considerations, *i.e.* technological expertise and financial support. It must be appreciated in this age, technology is essentially international. It is no longer valid to ascribe technology to any country. The complexity of technical tasks to be performed and technological issues to be resolved in development of Himalayan water resources call for the application of highest levels of science and technology, which can come only from an international storehouse and community. There is no reason to shy away from it and to settle for anything less on any extraneous consideration. Similarly, the magnitude of tasks involved will necessarily entail huge expenditure to be incurred in construction while such an expenditure would be amply justified on economic criteria in view of the colossal benefits resulting from it, initial investment in this venture may be beyond the capacities of the two co-basin nations from their internal resources. In the global economic order prevailing today, international financing of such ventures through several inter-governmental financial institutions or through various consortia is a well accepted, viable proposition.

The success of this strategy for optimum development of the Ganga basin, *i.e.* bilateral actions in the regional context and consideration with international assistance will critically depend on co-operative development of Indo-Nepal water resources. Admitting that mutuality of interests can be the only motivation and basis for the required bilateral action, the prospect for such co-operative development is indeed high. In fact, due to the bounty of nature, there exists an overwhelming complementarity in the benefits to be derived from basinwise development to both the co-basin nations. The irrevocable hydrologic ties binding the two nations can be most rewarding and potent in their common pursuit of economic emancipation and prosperity, and can even provide a basis and motivation for co-operative actions in other spheres. Unfortunately, the nature and magnitude of the significance of these ties were perhaps not adequately appreciated and mutuality and complementarity of interests seem to have been ignored in the immediacy of actions taken in the past resulting in an unnecessary erosion of confidence between the two nations. Recent developments, however, indicate that the matter has now gripped the attention of both the nations in the perspective and spirit and with the urgency and earnestness, that it so rightly deserves. It is hoped that commensurate endeavour and actions will follow without any further loss of opportunities.

The issue of cooperative development of Indo-Nepal water resources was comprehensively deliberated upon in a workshop in May 1992 at Patna. The hydrological basis, multipurpose benefits of co-operative development and various constraints and considerations in such development were discussed. While the technical feasibility, economic viability and above all the socio-economic imperativeness and urgency of cooperative development of Indo-Nepal water resources were highlighted, inhibiting factors were also mentioned with openness.

Some important suggestions are: it is of utmost importance that an openness in discussions as well as transparency of plans and actions in matters of water resources development be maintained and promoted, both within as well as between the two nations. It is essential for overall development that both Nepal and India move towards the creation of a healthy open technical society.

The Universities, research organisations and non-government institutions of the two countries have to play vital and critical roles in water resources development of the shared basins. While the governments concerned must recognise and promote this, these institutions must prepare and equip themselves for the purpose.

Tasks that can begin immediately and with the resources available between Nepal and India themselves should be undertaken in order that institutions building, experience building and confidence building take place with joint actions at the field level as well as in areas of research. Large ventures for which reliance on international financial markets is essential can only be undertaken on such a confident institutional foundation.

In order to ensure that regional considerations are duly taken into account in bilateral actions by the co-basin nations, the process of Indo-Nepalese interaction and decision-making in the matter must itself be transparent and dialogue with Bangladesh must be maintained at all stages to keep it in confidence.

It may be said that the opportunity cost of further delay by the two-co-basin nations in cooperative development of the Indo-Nepal water resources, relating to 30% of the Ganga basin inhabited by people who have long suffered from the paradox of 'poverty in plenty' due to inaction, inappropriate action or inadequate action in the matter is extremely high. It is incumbent on them to shed their inhibitions and move into a new era of cooperative action for the benefit as well as rightful interests and aspirations of the teeming millions of this region.

CATCHMENT AREAS OF CO-BASIN NATIONS IN THE HIMALAYAN RIVER SYSTEMS

River System	*Catchment Areas in Cobasin Nations*		
Main River (Major Tributaries)	*Nation*	*Catchment Area, Sq. km. (%)*	
Indus (Jhelum, Chenab, Ravi, Beas and Sutlej)	India	321,290	(27.6%)
	Pakistan (including parts of Afghanistan and Tibet)	843,710	(72.4%)
	Total	$1.165*10^6$	(100%)
Ganga (Ramganga, Ghghra, Gandak, Kosi on left Bank and Yamuna, Sone on right bank)	India	880,000	(83%)
	Nepal	170,000	(16%)
	Bangladesh	9,000	(0.85%)
	Tibet	—	—
	Total	$1.059*10^6$	(100%)
Brahmaputra (Subansiri, Kamena, Manas, Teesta on the right bank and Dibang, Luhit, Dhansiri on the left)	Tibet	292,670	(49%)
	India	180,480	(30%)
	Bangladesh	72,520	(12%)
	Bhutan	54.390	(9%)
	Total	$0.6*10^6$	(100%)

Chapter 13

Ground Water Development for Agriculture in Eastern India

Eastern India, comprising 15 eastern districts of UTTAR PRADESH as well as the states of Bihar and West Bengal, has a territory of 3.48 lakhs sq. km. and a population 16.61 crores. It accounts for 24.24% of the population of India against only 10.57% of the geographical area, making the region densely populated. The average density of population, in terms of persons per sq. km., in the area is 484 as compared to the national average of 208. In West Bengal it is as high as 621. The economy of the region is predominantly rural and agricultural. With 73.41% of the main workforce being engaged in agriculture as compared to the national average of 66.69%. In Bihar and eastern U.P., it stands at around 79%. Similarly, the percentage of urban population in the area comes to 16.62 which is lower than the country's average of 23.31, revealing the low level of diversification of its economy. Except a small hilly and plateau area, most of the land surface of the region is plain and culturable. The net sown area as a percentage of the total geographical area in the region amounts to 53.36 which exceeds the national average of 43.42. In the alluvial plains, this percentage is higher upto 64%.

Despite this high dependence of the economy of this region on agriculture and the major preoccupation of its people with the agricultural activity, its agricultural performance has been much below the mark. The average yield of foodgrains per hectare in this region has been approximately 1300 kg. during 1984-85 as compared to over 2800 kg. in Punjab in the same period. This has been a basic and dominant contributory factor for economic backwardness of the region, which is reflected by several indicators.

The per capita annual consumption of power, which is regarded as one of the indices of development, came to 106 kWh during 1983-84 as compared to 154 kWh in the country as a whole. The percentage of literate population stands at 30.55 which is lower than the national average of 36.17. The under-development of the economy is reflected in the low level of per capita net domestic product which came to Rs. 583 during 1983-84 (at constant 1970-71 prices) as compared to Rs. 764 for the country as a whole. In Bihar, it stood at as low as Rs. 458. The percentage of rural population below the line of poverty during 1983-84 amounted to around 48 as compared to the national average of 40.

Since agriculture is the main source of livelihood of the bulk of population and is the backbone of its economy the importance of the development of agriculture in any programme of economic regeneration of this region can hardly be overemphasised. Agriculture in this region, however, is still largely dependent on the vagaries of the monsoon, with only 35 percent of the total cultivated area being irrigated and the remaining 65 per cent being rainfed. The whole of eastern India lies in humid zone with an annual average rainfall of about 1350 mm which is sufficient for the kharif crops. The occurrence of rainfall is, however, distinctly seasonal and highly erratic. The onset and the recession of monsoons are quite unpredictable. The consequences of such unpredictability become very serious in a region like eastern India where paddy is the most important crop covering over 70 per cent of the net sown area. This crop is highly sensitive to drought. The entire crop may fail for want of one or two critical waterings. The most pertinent case in point is the severe drought of 1966-67 in Bihar when the production of food grains went down by 51 per cent. *i.e.* from 74 lakh tonnes in 1964-65 to 36 lakh tonnes in 1966-67. Over the same period, the production of rice in the state fell by 70 per cent, *i.e.* from 43.36 to 14.50 lakh tonnes. There are quite a few instances when the production of rice went down by 80% in certain districts. Similarly on account of the complete failure of the monsoon during 1908, the production of Aman rice in such a high rainfall district as Nadia (annual rainfall=1407 mm) went down to 13 per cent of the normal crops output. Herein lies the crucial role of irrigation between rains. It bridges the gap and imparts an element of stability to agricultural activity. Thus, irrigation provides insurance against agricultural droughts and vagaries of rains which are common in eastern India. Again, most of the rainfall over 80% in the area takes place during the four rainy months from June to September, leaving less than 20% annual precipitation for the remaining months of the year. As a result, in absence of irrigation, cultivation is confined mostly to the monsoon months. By providing water during lean months, irrigation extends the period of cultivation beyond the monsoon months and facilitates multiple cropping. In addition, it adds substantially to agricultural output by transforming the cropping pattern in favour of high value and superior crops that require more water in place of inferior crops that require less water, and by facilitating the use of modern inputs, such as fertilizers pesticides and improved seeds. The cruciality of irrigation as a basic productive input has been enhanced considerably by the advent of the new crop technology of green revolution. Controlled and regular supply of water is the essential precondition for the introduction of the new technology which is responsible for the substantial rise in agriculural output in India since the mid sixties. It is no wonder, therefore, if irrigation has been found as the "most proximate cause" of the disparities in the growth of crop output in India. Elsewhere also, such as in Japan after the Meji

Restoration (1868), Korea and Taiwan since the 1920's and Mexico since the 1940's, periods of high rate of growth in agriculture have been periods of extension in area under irrigation besides the existence of considerable irrigation facilities as a result of past investments. The same has been the case in Punjab and Tamilnadu in recent times. In view of the significance of irrigation, considerable effort and investment have been made during the planned period to develop irrigation facilities in the country. A sum of Rs. 19,331 crores had been spent during the plan periods till 1984-85 on irrigation in the country. The net irrigated area has increased from 209 lakh hectares during 1950-51 to 420 lakh hectares during 1983-84. A sum of Rs. 4,997 crores has been spent in the three states in U.P., Bihar and West Bengal over this period on irrigation which comes to 25.85 per cent of all India outlay. The aggregate irrigated area form various sources in eastern India has increased form 55.34 to 89.98 lakh hectares over the same period. If the groundwater in a region is in adequate quantity of acceptable quality and is economically exploitable, it is a viable source for irrigation. It can be utilized as an exclusive source or as an alternative, complemental or supplemental source—in space as well as time-to surface water source. In eastern India, particularly in its alluvial plains which constitute a major part of it, utilisation of groundwater for irrigation is both attractive as well as imperative on several counts.

There is a large body of groundwater underlying the alluvial plains where there are several layers of mostly high yielding aquifers of varying thicknesses, extending upto depths of 1000 m to 3000 m. In these layers of aquifers, groundwater occurs under unconfined, semi-confined or confined conditions. It has also been indicated that groundwaters exist under artesian conditions in very deep aquifers (1500 m or deeper) in an extensive area in the Gangetic alluvial plains of eastern India. The technical feasibility and economic viability of tapping these aquifers are being investigated. Water tables exist at shallow depths, varying from 1 m to 4 m in post monsoon periods to about 3 m to 8 m in pre-monsoon periods. Annual recharge to groundwater from various sources such as infiltration of rainwater, seepage from canals and other water bodies, percolation of irrigation water, etc., is estimated to amount to 50 cm to 75 cm. Apart from this vertical recharge, considerable recharge to aquifers takes place horizontally through absorption of water in a highly pervious zone, called Bhabar Zone, consisting of boulders and cobbles deposited to the sub-Himalayan foothills in a width ranging from 10 km to 20 km. All the rivers that drain the Himalayas must cross this zone, thereby recharging groundwater supplies in aquifers throughout the full thickness of deposits that underlie the plains. The quality of groundwater throughout the upper Gangetic plain is excellent to good, except in a few isolated areas where some caution and investigation are needed to ascertain the quality before planning for large-scale use of groundwater for irrigation.

There is substantial hydrologic interaction between the surface water and groundwater occurrences in the alluvial plains. Due to a relatively high water table obtaining in these plains, regimes of occurrence and distribution of both the surface water and groundwater are interdependent and sensitive to any measure of utilization and management of the water resources. Thus, irrigation exclusively by surface water sources is bound to result in gradual rise of water table in the alluvial plains. This may lead to encroachment of the root zones by water and possibly salinity and also to waterlogging conditions. This situation will adversely affect agricultural productivity and will progressively deteriorate over the years. Thus, exclusive surface water irrigation in the alluvial plains has the danger of proving counter productive. Its only effective antidote is conjunctive use of ground water.

Drainage is an important and sometimes a constraining consideration in irrigation development in the alluvial plains.

Without ensuring efficient drainage, irrigation will not be fully effective or optimally productive. Groundwater utilization promotes sub-soil drainage. Keeping in view the vital significance and vast potential of groundwater irrigation in the eastern India context, groundwater irrigation development *vis-a-vis* surface water irrigation development has not been satisfactory. Nearly 75% of plan outlays on irrigation have gone to creating irrigation potential through major and medium surface irrigation projects, both on an all India as well as eastern India basis, while the ultimate irrigation potential has been assessed to be 73.5 million hectares for surface water and 40 million hectares for groundwater for the whole of India, and 25.71 million hectares for surface water and 18.5 million hectares for groundwater for the eastern India. The three states of this region have nearly 39% of the country's irrigation potential and 46% of the country's groundwater potential as against 17% of the total geographical area and 22% of the total sown area.

At the beginning of the planning era in the country, major emphasis was given on development of surface irrigation with which the objective of flood control was combined where feasible and needed, particularly in eastern India. Due to several reasons, such as long Indian experience in canal irrigation, uncertain assessment of groundwater potential, lack of availability of pumping equipment, constraints of energy requirement for pumping etc., adequate attention was not given to groundwater development in the public sector or in the private sector. From the Third Plan onwards the situation seems to have been changing in favour of groundwater irrigation as evidenced from the expenditure in successive plan periods. In the wake of the severe drought experienced in 1966-67 in eastern India, particularly in Bihar, the rationality of groundwater irrigation and its exclusive advantages over surface irrigation in situations like severe drought were poignantly realised by the people the Government and other concerned organisations. This provided a great impetus and boost to the development and expansion of groundwater irrigation in the country, in general, and in eastern India, in particular. Only 30% of the groundwater irrigation potential in terms of culturable areas, is yet to be developed. It is estimated that no more than 30% of the groundwater potential in terms of safe yield of the groundwater basins, is being utilised.

Groundwater will have to be utilised to achieve maximum feasible irrigation intensity in eastern India, which on the average is estimated to be 25%. This will facilitate multiple cropping, more desirable cropping patterns and cultivation of superior, high value and high yielding crop varieties. Conjunctive groundwater use will have to be promoted in the command areas of surface irrigation projects in order to prevent and reverse the process of increasing waterlogging and salinity. It is estimated that in the Gandak Project 21% and 40% of irrigation potential created are affected by water logging and soil salinity respectively. Similar findings have been reported from Kosi and other projects in the region. Due to these adverse effects, the overall production from the command areas of such projects has not been registering anticipated increases.

Another point regarding groundwater development in eastern India is worth noticing. It seems to have lagged behind other states in the field of groundwater development. The region accounted for about 25 per cent of the total irrigated area through groundwater in the country during 1950-51. This has come down to about 22 per cent during 1983-84, reflecting the relative under development of groundwater resources in the region. The main reason for this state of affairs lies in that India, including eastern India, has been using groundwater as a means of irrigation since time immemorial with the help of open wells which still account for about 44 per cent of the total irrigated area through groundwater in the country. There has been rapid development of tubewell irrigation in the country during the plan periods, including in eastern India. While the expansion in tubewell irrigation in the country as a whole has been simply additive to irrigation through open wells, the same in eastern India has been significantly substitutive, *i.e.* tubewell irrigation has gone to substitute irrigation through open wells. In fact, eastern India has witnessed a net decline in the area irrigated through open well from 14.76 to 3.51 lakh hectares *i.e.* by about 76 per cent during the plan periods. Groundwater irrigation development in eastern India has not taken place commensurately with the need and the potential. As a matter of fact, it has slipped behind other states, in relative terms, in this aspect.

As noted earlier, open wells as a means of groundwater development have lost their popularity in eastern India. Hence tubewells remain the only suitable means for full development of the groundwater resources in the region. The tubewells are of two broad categories, state (Deep) and private (Shallow) While the state tubewells tap deep confined aquifers (more than 100 metres below the ground level), are large in size and are fitted with high power water lifting pumps, say of 17.5 H.P. capacity, the private tubewells tap shallow aquifers (less than 60 metres below ground level), are small in size and are fitted with small power water lifting pumps, typically of 3 to 5 H.P. capacity. The average discharge of a deep tubewell in the area comes to about 150 cubic metres per hour, while that of a shallow tubewell comes to 30 cubic metres per hour. The average cost of a state deep tubewell in the region at 1988 prices will come to around Rs. 6 lakhs. While that of private electric tubewell will come to around Rs. 12 thousand. The average irrigation potential (command) of a state tubewell is kept at 100 hectares while that of a private tubewell comes to 10 hectares. Thus, deep or large tubewells are not suited for the majority of farmers in India, more so in eastern India, who are mostly poor and their land holdings are very small. More than 89 per cent of the holdings are marginal/small accounting for about 50 per cent of the total number of holdings and account for just 7.48 per cent of the area. Thus, the farmers in the region can neither afford to install such costly tubewells nor make full use of them, since their holdings are not only small but also divided and fragmented into several pieces. Of course, the state can install and administer such large tubewells in its own sector for the collective use of the farmers. A good number of such tubewells have been installed in the state sector in several states, including eastern India. In fact, the states of eastern India, particularly, U.P. and Bihar, have been the pioneers in this field. Thus, during 1950-51 the two states of U.P. and Bihar accounted for 100 per cent of the state tubewells in the country. Even now, the region accounts for 37.39 per cent of the total number of public tubewells in the country.

The actual cost of irrigation through state tubewells in the region comes to Rs. 3,323 per hectare which is much higher than that through private tubewells: electric Rs. 1,145 and diesel Rs. 1,474. The cost differential will still be higher if we account for the gestation lag which is not insignificant in the case of state tubewells and which is practically absent in the case of private tubewells. Sometimes, it is argued that state tubewell cater to the needs of small/marginal farmers who can not afford to have their own tubewells. However, it is difficult to conceive the idea of a state tubewell catering exclusively or largely to the needs of small/marginal farmers. There is no practical way to prevent other farmers from taking water from the state tubewells. Again, even if we assume that state tubewells are exclusively meeting the requirements of small/marginal farmers, it appears to be a very costly proposition at the rate of Rs. 3,323 per hectare. There is a market in irrigation water which is cheaper than the cost of irrigation through state tubewells. The average price of water for a 5 H.P. diesel tubewells comes to Rs. 12 per hour. At most 100 tubewell hours will be needed to irrigate (5 waterings) a hectare of crop. Thus, the cost of irrigation by purchasing water per hectare of the cropped area will come around Rs. 1,200 which will be much less than that through state tubewells. Thus socially it seems to be cheaper to send money orders to the small/marginal farmers to get their land irrigated through purchasing water from the market rather than to provide them irrigation through state tubewells, as they are working today in the area.

Under the circumstances, the development of small private tubewells appears to be the most appropriate strategy for the development of groundwater resources in the region. The actual development, too, has been on the same lines. The majority of the tubewells in the region are small, private and shallow. Such tubewells account for about 98.65 per cent of the number of tubewells (private + state) and 88.46 per cent of the area irrigated through tubewells. The development of private tubewells in the region, however, has not been as successful as in many other parts of the country. The installation of these tubewells requires significant amounts of money which may be beyond the reach of the majority of the farmers in the region, who are mostly poor, having small and fragmented holdings. For the same reason, the access to institutional credit has been very limited. The pace of rural electrification, too, has been very slow and limited, producing a dampening effect on the development of tubewells. Thus, the average density of private tubewells in the region comes to 67 per thousand hectares of the net sown area during 1984-85 which is much lower than that in Punjab.

As noted earlier, the installation of tubewells requires good amount of money which may not be afforded by small farmers. The availability of institutional credit, is also positively correlated with the size of land holdings. The sale price of irrigation water, too, is high and not very attractive to an average farmer. On account of these factors, the benefits of private tubewell irrigation have largely remained confined to prosperous regions and farmers. This necessitates an examination of the situation in this regard in the region. Rural electrification has played an important role in the development of groundwater irrigation in the country since the mid-sixties. The eastern India however, has lagged behind other parts of the country in rural electrification. Thus, the percentage of villages electrified in the region as on end 1984-85 came to 51.52 which was much below the national average of 64.28. Again, the process of rural electrification in the region has been extensive rather than intensive. Thus, the average number of electric connections (pumpsets) or electrified village comes to 5.09 which is about one third of the national average of 15.41. In West Bengal, it is as low as 2.02. On accont of this, the average consumption of electricity per hectare of the net sown area during 1984-85 came to 115 kWh which is quite below the national average of 140 kWh. It is as low as 50 kWh in West Bengal. Still, a good number of groundwater structures are fitted with electrically operated pumping devices. Thus, electric tubewells accounted for over 32 per cent of the total number of tubewells in the region in 1984-85. Hence adequate and regular supply of power is of crucial significance for their proper working. For the last one decade, however, the electricity position in the area is far from satisfactory. It is highly erratic and inadequate. This is reflected in the drastic fall in the average working hours per day of electric pumpsets in the region. The worst has happened in Bihar where it has gone down from 3.67 hours during 1975-76 to 1.22 hours during 1978-79.

In view of the erratic electric supply, a good number of farmers have gone in for diesel pumpsets, more particularly since the 1979-80 drought. This has happened on two counts. Firstly most of the new groundwater structures appear to have been fitted with diesel pumps. Thus, between 1980-81 and 1984-85 while these structures rose by 482 thousand, irrigation electric connections rose by only 71 thousand. Dieselisation, however is not an ideal solution to this problem since it is a costlier alternative. The cost of a diesel pumpset is about 50 percent higher than that of an electric one. Their operating charges are still higher. Even if we account for the element of subsidy on electricity supplied to agriculture, the operating cost of an electric pump will be just 45 percent of that of a diesel one. Besides these cost calculations, one great advantage with electric pumps from the farmer's point is that since payment of electricity bill is not daily or weekly, he can postpone payment for months, if he does not have ready cash. This is however, not possible with diesel pumps.

Although there has been increasing realization of the suitability of conjunctive use as a strategy for irrigation development in the alluvial plains of eastern India, it has hardly been implemented so far. This is on account of the fact that there are unresolved issues related to conjunctive use-both in the physical as well as socio-economic domains. Conjunctive use signifies an integrated use of the two interacting sources-surface water and ground water for irrigation as distinct from supplemental use or alternative use in time and space.

In the matter of natural endowments relevant for and conducive to agriculture, such as agro-climate, agronomic properties of the soil and water, eastern India is about the most gifted region of the country. Paradoxically, it is also the economically most backward region of India. For a region in which the prime economic activity is agriculture and where agriculture provides the base and backbone of the economy low agricultural productivity adequately explains the poor economic performance. Low agricultural productivity inspite of attractive natural endowments of the region is explained largely by ineffective management and inefficient utilization of the ample water resources for optimum agricultural development of the region.

Eastern India had been a region of affluence and the centre of Indian prosperity for long periods in history. Having enjoyed almost uninterrupted progress and prosperity till about 1200 A.D., a grey period in its history seems to have set in. The process of gradual decline began to manifest itself in terms of stresses in the lives of people, administrative and political upheavals and other associated phenomena from the late 17th century onwards. The declining conditions in eastern India have dominantly influenced the course of history of the country such as the downfall of the Moghul Empire, the creeping in of the British rule and the mass struggle for freedom. The past prosperity, the gradual decline and the future prospects of this region are vitally and critically related to its agricultural performance and productivity.

Chapter 14

Flood Control of River Ganga

The river Ganga is the most important and sacred river in India. The story of Ganga from the source to sea from old times to date is the story of India's civilization and culture and the rise and fall of empires. The significance of this river in the cultural, social and economic life, aspiration and endeavours of modern India, is still dominant. Having a basin of 8,61,404 sq. kms. in India, constituting 26.3% of India's geographical area and containing 30% of India's population within its basin boundary, this Himalayan river directly affects the life and economy of a major part of the country. With 70% of its basin area cultivable (compared to 30% of the Indus, 33% of the Brahmaputra and 60% of Narmada) of which 77% and 96% are net-sown and gross-sown areas respectively, this river and its tributaries support and sustain the heart-land of India's agriculture.

The river originates in Uttar Kashi of the State of U.P. and after traversing a total distance of 2,525 kms., of which 1,450 kms. is in U.P., 445 kms. in Bihar and 520 kms. in West Bengal it falls into the Bay of Bengal via the river Hooghly in India. A major part of the river goes into Bangladesh. The total average annual flows of the river are 152,000 x 10^6 m^3 at Allahabad, 364,000 x 10^6 m^3 at Patna and 459,040 x 10^6 m^3 at Farraka.

The Ganga basin is the most flood affected of all the major river basins of India and includes the most chronically flood affected regions in the country. The annual flood damages of the Ganga basin states account for about 60% of the total for the country affecting a total area of 4.36 million ha. The incidence of flood however is far from uniform over the entire basin area. It is concentrated mostly in the eastern part of U.P. entire North Bihar and the South, Western Districts of West Bengal. In recent years some part of Haryana and Rajasthan have also been experiencing floods.

In the Ganga basin, floods are caused by a combination of hydrometeorological, hydrological, gemomorphological and topographical factors. The annual rainfall in the basin varies from 40 cm in the Western part to 175 cm in the Eastern. The variation of rainfall in the slopes of Himalayan mountains is from 125 cm to 250 cm. The temporal distribution of the rainfall over the year, however, is very scattered. More than 85% of the annual rainfall takes place on account of South West Monsoon during the four monsoon months of June to September. Such rainfall occurrences transform themselves into similarly skewed river runoffs resulting in high magnitudes of river discharge during July-September compared to those in other months. Often, these discharges are too high for the bankful carrying capacity of the channels in which they flow resulting in overspilling the banks and inundation of the flood plains.

These hydrological and hydraulic processes are further accentuated by two other factors. One is the soil erosion and sediment transportation by the river. Almost all the northern tributaries of Ganga originate in the Himalayas which are geologically young mountains with friable slopes. The rivers bring in a lot of silt whose amount varies with season along with their flow. The amount of silt transported varies from 0.384 ha m/sq km. of catchment area in Ganga at Farakka to 4.5 ha m/sq km. in one of the tributaries of Kosi. While this silt takes part in the important geomorphological process of the formation of flood plains, it also leads to aggradation of river beds, banks erosion and shifting of the river course in the plains. All these cause and exacerbate the flood problem. The second flood accentuating factor is topogaphical. The northern tributaries of Ganga under-go rather abruptly, a large difference in the bed slopes, from very steep in the upstream high rainfall mountainous area to extremely mild in the plains. Thus, the hydraulic capacity of the river carrying high upstream flows suddenly get reduced in the downstream plains necessitating use of the flood plains for temporary retention of high volume of water.

Due to these factors, frequent flooding is experienced in the rivers Rapti, Sarda, Ghaghra and Gandak in eastern U.P., in the rivers Burhi Gandak, Bagmati, Kamala, Adhwara group and Kosi in North Bihar, and in the rivers Bhagirathi, Ajay and Damodar in West Bengal. On account of flood moderating effect of its large basin and accentuating effect of the channel flow the main river Ganga itself is generally not a source of major flooding except in certain reaches where the banks are low. High stages in the river however are frequently the cause of flooding in the tributaries because of congestion and locking of drainage at the confluence.

While floods are natural and hydrological and geomorphologic phenomena, they pose a problem to mankind when they interfere with their life and living. In the Ganga basin, where the density of population and the intensity of cultivable and cultivated land are both very high particularly in the flood prone areas, which provide otherwise congenial factors for living and cultivation, these damages primarily constitute damage to loss of crop, destruction of dwelling and private and public properties, and loss of human lives and cattle head. In monetary terms, total damage is calculated in terms of damage to crops and damage to houses and other private and public properties. In the Ganga basin, as almost 50% of the flood affected area of 4.36 million ha is cropped area (2.13 million ha), damage to crops constitutes 80% of the total flood losses. In terms of population, on an average, 15 million people in the Ganga basin suffer from the occurrences of flood in one way or the other.

The above mentioned flood damages statistics provided by the Govt. represent only direct damages. For areas which are recurrently damaged by floods such as in the Ganga basin, these damages figures are not only incomplete and deficient but also misleading. On the one hand the indirect and intangible damages in terms of miseries to displaced persons, health hazard in the aftermath of flood and frequent suspension of trade, commerce and other activities supporting living due to disruption of road and rail communication far outweigh in significance the damages quantified in monetary terms. On the other, the recurrent occurrence and persistent threat of occurrences of flood serve as disincentive to investment in agricultural and other economic activities. While it makes for low figures of measured direct damages, this also causes the economy of the flood affected area to be in perpetually low gear. In fact, the region subject to recurrent flood in the Ganga basin, *i.e.*, Eastern U.P., North Bihar and part of Southern West Bengal happen to be the poorest in the country in spite of the natural endowments of fertile tracts of land, congenial agro-climate and ample water.

Measures for flood control and flood damage containments were taken from early times on a limited scale by individuals or local bodies. The national attention on the problem was focussed in 1954, when wide-spread and severe flood occurred in various parts of the country. Under a National Flood Control Programme formulated at that time, it was decided to undertake a programme of flood control in three phases, *i.e.*, immediate, short-term and long-term. In the immediate phase, extending over a period of two years, protection of selected towns and construction of embankments in the most vulnerable reaches were taken up. This phase was also devoted to investigations, collection of data and preparation of estimates for short-term measures. The second phase, which was to coincide with the commencement of the second plan in 1957, envisaged flood control measures such as embankments, channels improvement, raising of villages and protection of towns. The third phase was to cover selected long-term measures such as construction of storage reservoirs on the tributaries and additional embankment wherever necessary.

While flood control works were taken up in the indicated phased manner in various flood affected regions of the country, it was always realized that the Ganga basin needed special attention and focus in matters of flood control. Severe flood occurrences in the Ganga basin in 1971, when the direct flood losses in the basin amounted to Rs. 5,800 million out of a total of Rs. 6,280 million for the entire country, highlighted the urgency of concerted effort to be made for tackling in a big way the problem created by floods in Ganga and its tributaries. The Govt. of India accordingly set up the Ganga Flood Control Commission in 1972 with the Headquarters at Patna for preparing a comprehensive plan for flood control for the Ganga basin for drawing up a phased and co-ordinated programme for implementation of works included in the comprehensive plan by the concerned States and for ensuring the implementation of works to proper standards and with effective maintenance. Accordingly, the Commission formulated an outline for flood control in the Ganga basin in 1973 and subsequently drew up comprehensive plan for various sub-basins.

Since 1954, when the National Flood Control Programme was launched, embankment of a total length of 4,581 kms. and drainage channels with an aggregate length of 6,734 kms. were constructed. In the same period, 122 towns were flood protected and 4,601 villages were raised above H.F.L. All these measures provided protection against flood to an area of 4.6 million ha.

From an analysis of the trend of flood damage magnitude, it was seen that the aggregate flood damages were on the increase in spite of these measures both in the country as well as in the Ganga basin. Realizing the need for undertaking more effective and permanent measures for flood control, that so far, only one third of the total flood prone area had been provided with protection, that considerable experience had been gained in planning, implementation and performance of flood control and protection measures, and, as further advance in flood control technology had taken place in the last two decades, the Government of India appointed a National Commission on floods in 1976 in order to improve the effectiveness of flood protection measures adopted since 1954. Incidentally the factors like drainage and flood plain encroachment which have aggravated the flood problems evoke a co-ordinated, integrated and scientific approach to the flood problem fixing priorities of implementation were gone into. The Commission, which submitted its report in 1980, advocated for tackling flood problem in the framework of comprehensive planning for multi-purpose utilization of the land and water resource for optimum production on a long-term sustained basis. In this approach, various alternative measures, physical or otherwise should be considered for flood management and optimum combination of the feasible measures are to be selected in a given situation. In particular, it recommended for the adoption of reservoirs to the extent technically and economically feasible as an important component in any package of measures for flood management. Afforestation and soil conservation measures in the watersheds of rivers and use of natural detention basin in the flood plains for flood modernization were also advocated.

Flood control planning as per these recommendations present special problem in the case of the Ganga basin. Almost all the flood causing northern tributaries of the river Ganga originate in the neighbouring country of Nepal with substantial high rain-fall drainage area lying in that country. All the suitable sites of the reservoirs also lie in Nepal as given in Annexure.

Hence, adoption of reservoirs for flood control, which holds the promise for providing optimum solution to flood problem in the Ganga basin depends on mutual co-operation between India and Nepal. Fortunately, as these reservoirs will also provide other multipurpose benefits for both the co-basin countries, there exists high prospects and potential for co-operation between the two countries in this matter. An objective techno-economic analysis for optimum development and utilization of the shared water resources for multiple benefits will clearly bring out how much is at stake for both the countries in co-operative action and initiatives in this vital sphere.

The intensities of flood flows as well as damageability of flood prone area are rising. In contemporary India, national attention towards these problems of Ganga have been deeply focussed and commensurate endeavour towards their effective and sustained solution has been launched. While considerable success has been achieved on this front, a lot of ground is yet to be covered. In fact, in certain areas, like achieving flood control in the frame-work of multipurpose development of the rivers, precious little has been done. A vast scope for development with multiple benefits such as irrigation, hydro-power and inland navigation along with effective flood control lies in the Ganga basin. When this will be realized hopefully in the coming decades, Ganga will bring a new era of prosperity. A second Ganga Valley Civilization will then dawn in the Indian sub-continent.

Annexure

LIST OF DAM SITES IN NEPAL

Sl. No.	*River*	*Location*	*Catchment Area in sq. km*	*Height of Dam in metre*	*Live Storage Capacity in (10^6 x m^3)*
1	2	3	4	5	6
1.	Karnali	Chisapani	42,894	210	7,700
2.	Karnali	Lakarpata	20,971	197	1,860
3.	Gandak	Kali Gandaki	9,200	214	4,480
4.	Gandak	Burhi Gandaki	6,460	135	770
5.	Gandak	Marsyandi	7,250	140	1,000
6.	Gandak	Seti	2,780	140	1,760
7.	Kosi	Barahkshetra	53,040	200	4,700 (flood cusion)
8.	Kosi	Sun Kosi	16,200	122	1,050
9.	Bagmati	Noonthore	4,250	96	1,560
10.	Kamla	Taltoria	1,530	64	1,040
11.	Kankai	Mainiachuli	1,190	75	590

Chapter 15

Management of Conjunctive Irrigation in Alluvial Regions

In order to achieve improved agricultural performance, sustainably productive irrigation and socio-economic equity in sharing of irrigation benefits, conjunctive use and management of surface and groundwaters is the most appropriate and prospective strategy of irrigation for alluvial regions in general and for humid alluvial regions. Experience of conjunctive irrigation in three states of India, Bihar, M.P. and Haryana, is briefly described here.

In the alluvial plains of India both the surface water and groundwater sources are highly interacting in a hydrological sense and both are feasibly exploitable for irrigation. Due to certain hydrological, topographical, technological and socio-economic factors, both the sources have certain limitations as well as potentialities. The surface waters, comprising mostly the river flows, have dominantly seasonal characteristics and non-uniformity. Unless these flows are regulated by means of storages, created in the upstream, they are inadequate to meet the summer and Rabi irrigation requirements. Consequently, surface irrigation schemes, based on diversion of run-of-the-river flows through a network of canals are incapable of supporting cropping intensities higher than 14% or so. This is, on the one hand, a gross under-realization of the agricultural potential of the area in view of congeniality of the agro-climate and fertility of the land, and, on the other, leads to counter-productive situations due to poor agricultural drainage and waterlogging, particularly in the lower reaches of the command. Both the adverse features of exclusive surface irrigation can be effectively taken care of by conjunctively utilizing both surface and ground waters for irrigation. Adequate availability of groundwater of acceptable quality and at relatively low lifts makes such utilization highly prospective. This additional source of water will take care of both the spatial and temporal inadequacies of the surface water supply, thereby increasing the achievable irrigation intensities to 200 to 300%.

Greater flexibility and better control in supply and application of water to meet the crop water requirements in a more meticulous and assured way will help the farmers in increasing their crop yield and in adopting more diversified and remunerative crops. Also, the groundwater utilization in a planned way will ameliorate waterlogging and improve drainage, rendering irrigation both hydrologically sustainable and agriculturally productive. Thus, conjunctive use of the two sources for irrigation is not only highly imperative and prospective, but also eminently suitable in the humid alluvial regions. This strategy, however, would certainly give rise to and/or bring into sharp focus several management related issues, without resolution of which implementation and operation of this strategy would be problematic and would achieve, at best, only suboptimal results.

No project in India has been planned and designed as a conjunctive irrigation system and perhaps no project is operated that way. However, there are several projects in which conjunctive irrigation features have developed in an adhoc and unplanned manner in course of time in response to the stresses they were subjected to. There are also a few projects in which conjunctive irrigation features have been introduced at a later stage in order to improve its performance or to take care of certain debilitating situation. These cases are mentioned below to illustrate these points.

The Gandak project of Bihar is an international and interstate project, primarily and dominantly for irrigation, involving India and Nepal, and within India, the states of Bihar and U.P. Through diversion of the flow of the river Gandak by means of a barrage at Valmikinagar, the project plans to serve a Gross Command Area (GCA) of 19.5 lakh ha located in eastern U.P. (5.7 lakh ha), North Bihar (13.17 lakh ha) and Nepal (0.63 lakh ha) on both sides of the river. The Main Eastern Canal, known as Tirhut Main Canal (TMC) beyond 9.05 RD (reduced distance = 1000 ft) was planned, to run for a length of 910 RD having a GCA of 6.77 lakh ha in North Bihar. TMC, however, extends only upto 790 RD and the distribution system is completed only upto 704 RD. Further extension and development of the system has been suspended in view of the adverse experience and unsatisfactory performance of the irrigation system below 554 RD, characterised by unreliable supplies for the 'kharif' crops, inadequate supplies for the 'rabi' crops and creation and/or aggravation of the problems of waterlogging and drainage congestion. Disenchantment of the farmers with the irrigation system has led to increasing utilization of groundwater by means of private, state and cooperatively managed tubewells in this area. Although the project was not originally designed nor is it now operated as a conjunctive irrigation system, it has developed substantial features of such a system. This development has led to perceptible improvement in the irrigation performance of the project and may serve as a replicable example, with a considerable scope for perfection towards a truly conjunctive irrigation system, for the development and extension of the project as originally planned. In fact, a committee constituted to examine the desirability of extending irrigation below 704 RD has recommended conjunctive use and management of surface and groundwaters as an appropriate strategy for the purpose.

The Chambal project in the State of M.P. was completed in 1960 in order to provide protective irrigation to both 'kharif' and 'rabi' crops in an area of 3.3 lakh ha. Due to seepage from canals which were mostly unlined, actual irrigation achieved till 1974 was only 1.51 lakh ha and, in addition, waterlogging conditions were created in parts of the command. A modernisation of the project undertaken in the year 1975 with World Bank assistance and completed in 1980 resulted in expanding the irrigated area to 1.89 lakh ha. In the same period, 1975-80, a significant increase in irrigation from groundwater sources through shallow tubewells and dugwells, from 27,000 ha to 47,000 ha, was observed. Encouraged by this experience, a project was prepared to have a planned development of conjunctive use of surface and groundwaters in order to expand the irrigated area, bring some area under intensive irrigation to facilitate cultivation of high-yielding varieties of crops, improve the drainage and finally, increase agricultural production, employment and net income in the project area. A conjunctive use strategy under this project, 104 augmentation tubewells, each having an average discharge of 250 cum/h were constructed along the Ambah distributory to increase the discharge at its head from 9.62 cumecs to 14.43 cumecs. To meet the requirements of continuous operation of the tubewells during certain hours of the day, generally 16 hours a day, and the schedule of canal operation *vis-a-vis* the irrigation demands, six balancing reservoirs have been provided on this distributory. Similarly, 74 augmentation tubewells are under construction in the tail end of the Bhind main canal both to augment the canal supplies as well as to provide direct irrigation. The experience of operation of these state managed augmentation tubewells as well as of the command of a surface irrigation project is yet to be documented and analysed.

The State of Haryana in north western part of India has a gross area of 44.06 lakh ha, culturable area of 28.19 lakh ha and a net sown area of 35.48 lakh ha of which 40% is under irrigation from both surface and groundwater sources. There are two principal sources of surface irrigation, Western Jamuna Canal (W.J.C) drawing upon the flows of river

Yamuna and Bhakra Canal supplied by waters from the Sutlej-Beas rivers. The availability of surface water for irrigation in the W.J.C. command works out to be 1.28 cumecs per 1000 ha at 50% irrigation intensity while that in the Bhakra Canal Command is 1.86 to 2.36 cumecs per 1000 ha at 62% irrigation intensity. This semi-arid state, receiving an average annual rainfall of 540 mm has sought to overcome the more serious deficiency of surface water supplies in the W.J.C command partly by transferring the surplus water of the Bhakra system to the W.J.C. by a Narwana Branch Karnal (N.B.K.) Link and partly by a major programme of groundwater exploitation. Faced by the problem of waterlogging in certain parts of W.J.C. command and the fact that 60% of the aquifers contain saline water, totally or partially unfit for direct irrigation, the state has adopted a particular strategy of conjunctive use. Apart from a large-scale development of private tubewells, numbering around 4.5 lakh, the state has installed 1,650 augmentation and around 1,530 direct irrigation tubewells. The salient points about the conjunctive use strategy comprise installation of tubewells in waterlogged areas both as antiwaterlogging measure as well as for augmenting the canal supplies; installation of tubewells in fresh groundwater zone both for direct irrigation during deficient surface supply periods as well as for its conveyance to saline groundwater and arid zones through the canals; and installation of dual purpose tubewells which act as augmentation tubewells in deficient canal supply periods and as injection wells as a measure of recharging the aquifers during surplus canal supply periods. While this strategy has greatly helped water-deficient Haryana to enhance its irrigation and agricultural performance, its long-term effects are under observation.

The need for conjunctive use and management of surface and groundwaters for improved agricultural performance, sustainably productive irrigation and social equity in the alluvial plains having susbtantial surface water—groundwater interactions is now increasingly realized. Irrigation exclusively from one source has been found to lead to counter-productive consequences in course of time. Several irrigation projects in the alluvial plains of India, particularly surface irrigation projects, have experienced this due to which conjunctive irrigation features have either developed in an ad hoc manner or have been introduced as corrective or ameliorative measures. No major irrigation project in India, however, seems to have been planned, designed and operated as a conjunctive irrigation facility.

Development and opertion of a project based on conjunctive use of surface and groundwaters bring forth several management issues to be resolved. On account of several component technologies involved and various factors influencing management options, the need for appropriate approaches and suitable decision-making tools in this complex exercise can hardly be over emphasised. Mathematical models for ground water and surface water uses for irrigation as well as for simulating conjunctive irrigation will provide such tools.

Chapter 16

Pollution of the River Ganga

Ganga is the most important river of India and it has played a vital role in shaping up its cultural history and socio economic development for the last four thousand years. A major part of river goes in Bangladesh. The main course of the river is joined by a large number of tributaries orginating in the Himalayan range, draining the Northern plains and joining the river, which are Ramganga, Gomati, Ghaghara, Gandak and Kosi. The tributaries joining the river on the other bank include Yamuna and Sone. River Yamuna, which rises in the Himalayan ranges, is joined by several important tributaries such as Chambal and Betwa originating in the Vindhya range and draining the Southern plains. In fact, Yamuna contributes more water than the river Ganga at the confluence at Allahabad. The total average annual flows of the river are 152,000x106 m^3 at Allahabad, 364,000x106 m^3 at Patna and 449,040x106 m^3 at Farakka.

Almost all the towns of the Ganga basin are situated on the banks of the main river or of its tributaries. While the rivers in the Ganga basin and prominently the river Ganga had a critical role to play in the development of the towns and cities, it also had to bear the brunt of its consequences of pollution on account of municipal and industrial effluent, which they necessarily had to receive and carry.

The Ganga in its 2,525 km. length starting from Gangotri in the Himalaya to its confluence with the sea at Ganga Sagar in the Bay of Bengal passes through 29 Class I cities (population over 1,00,000), 23 Class II towns (population between 50,000 and 1,00,000) and 48 Class III towns (population less than 50,000), Kanpur, Allahabad and Varanasi in U.P.; Patna and Bhagalpur in Bihar; and Titagarh, Howrah and Calcutta are some of the important cities situated along the banks of the river. Many small, medium and large industries are also located in these cities and towns.

While these cities and towns depended on river water as well as ground water for the supply of water for their municipal and industrial needs, they almost exclusively use the river for disposal of their municipal and industrial wastes. It is estimated that Class I cities situated on the banks of the river Ganga generate a total of approximately 1500 MLD (million litres per day) of sewage for disposal into the river. Similarly, Class II towns contribute approximately 110 MLD, Class III towns 80 MLD of sewage, which ultimately finds the way into the river—Annexure I.

It is also estimated that out of the total wastes discharged into the river Ganga, sewage constitutes 72% and industrial waste constitutes 25% in terms of volume. In terms of BOD, the pollution loads to the river by these sources are in 1:1 ratio. Other sources of pollution include agricultural and street runoff which grow substantially in volume during the monsoon. Agricultural wastes from cultivated land may contain chemical fertilizers, pesticides and insecticides used by the farmers. A small part of the bacteriological pollution is also caused by excreta of nomadic people living along the banks or in the immediate areas of the river.

Concerned by the growing pollution of the river Ganga, the Government of India launched a massive and concerted programme for prevention and abatement of its pollution. An action plan for the purpose was formulated by the Deptt. of Environment in December, 1984. A high level body—Central Ganga authority—was set up under the Chairmanship of the Prime Minister for determining policies and programmes, allocating resources and mobilising public support for accomplishing this action plan. An inter Departmental steering Committee was established in order to evolve specific plans, programmes and projects for improving water quality in the river, sponsor relevant studies and to over see as well as monitor the implementation of the project by various agencies. In June, 1985, the Ganga Project Directorate was established as a Wing of the Deptt. of Environment to appraise and clear the project prepared by the field level agencies, release funds and co-ordinate the various activities under the action plan on a continuing basis.

The Action Plan has two main objectives—the immediate reduction of pollution load leading eventually to total prevention on the river by means of trunk sewers laid along the river to intercept the drains and sewages coming from inhabitated areas, establishment of self sustaining treatment plant system to treat the intercepted sewage/sullage, utilizing the produced methane gas for power generation, the digested sludge for manurial purposes and the treated effluents for agriculture and irrigation.

The components of the action plan are renovation of existing trunk sewers and outfalls to prevent the outflow of sewage into Ganga; construction of intercepters to divert flow of sewage and other liquid wastes into Ganga; renovation of existing sewage pumping stations and sewage treatment plants and construction of new sewage treatment plant to recover the maximum possible resources specially energy; to operate the pumping and treatment plants and derive the maximum possible revenue to cover at least the operational and maintenance cost of these plants; arrangements for bringing human and animal wastes from location proximate to the sewage digesters for sanitary disposal, production of energy and manure; providing sewage pumping station at outfall points of open drain to direct the discharge from the river into the nearest sewerst and treatment plants; alternative arrangement to prevent discharge of animal and human wastes from cattle sheds located on the river bank; low cost sanitation schemes in areas adjoining the river to reduce or prevent the flow of human wastes into river; biological conservation measures based on proven techniques for purification of streams. Pilot projects to establish cost effective system for diversion of wastes flowing into the river, their treatment and resource recovery, were also considered.

As far as industrial wastes are concerned, under the existing laws, the responsibility for their treatment lies with the industry. However, circumstances may require that plans for sewerage and treatment system should cover industrial effluents as well. It may also be necessary in some crowded areas to accept waste waters of industries in city sewer to be led to the treatment plant provided the industrial waste is free from heavy metals toxic chemicals and is not abnormally acidic or alkaline.

The schemes planned and sanctioned under the action plan comprise construction of trunks sewers for sewage interception and diversion, construction of sewage treatment plant, providing low cost sanitation, construction of electric crematoria, improving river front facilities and carrying out related research activities. Out of a total of 262 schemes sanctioned at a cost of Rs. 3,580 million in the first phase of this action plan, 147 schemes have been completed at an expenditure of Rs. 1,922 million by the end of 1990. Certain schemes for specific purposes have also been formulated under the action plan with foreign assistance and collaboration, such as for technical assistance, training and procurement of priority equipment with World Bank assistance; for water quality modelling and monitoring, bio-monitoring and bio-conservation with Indo-UK collaboration; and for integral sanitation projects for two cities with Indo-Dutch collaboration.

On account of the schemes completed by December, 1990; 360 MLD of the target figure of 873 MLD of domestic sewage has so far been diverted and treated for irrigation, pisiculture and discharge. Water quality of the river Ganga has shown improvement at the station where pollution abatement schemes have been completed in terms of enhanced D.O. and reduced BOD level.

For millenium, the river Ganga has been sustaining the life and livings of millions of people in India. As the dynamic manifestation of its hydrology of a major part of India, it supports agriculture in its most fertile tracts of land and facilitates industry in its densely populated region. However, due to increasing demands to which this river has been subjected over the years in terms of rising population load, as well as other interferences the problems of pollution in its main course of the river has been worsening. For too long, the problem did not receive concerned attention and concerted efforts to solve them. On the one hand, pollution levels were on the increase and on the other, there were increasing demands of good quality water for various uses.

Due to various factors, Ganga basin, which had been the seat of prosperous empires for centuries in the past, presently includes economically most depressed region in the Indian sub-continent.

Annexure I

WATER SUPPLY AND WASTEWATER COLLECTION AND TREATMENT STATUS IN CLASS-I CITIES ON THE BANKS OF RIVER GANGA

	Name of the City	*Name of the District*	*Population (lacs) (1981)*	*Piped Water Supply*	*Estimated Water Supply (MLD) (1981)*	*Estimated Sewage Generated (70% of Col. 5)*	*Percent Covered by Sewerage*	*Treatment*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
UTTAR PRADESH								
1.	Haridwar	Saharanpur	1.46	Yes	20.50	14.35	50%	No
2.	Farrukhabad & Fatehgarh	Farrukhabad	1.61	Yes	19.98	13.99	—	No
3.	Kanpur	Kanpur	16.39	Yes	392.14	274.50	80%	No
4.	Allahabad	Allahabad	6.50	Yes	143.34	100.34	50%	No
5.	Mirzapur	Mirzapur	1.28	Yes	17.1	12.03	—	No
6.	Varanasi	Varanasi	7.97	Yes	180.83	126.58	50%	No
BIHAR								
7.	Chapra	Saran	1.12	Yes	10.86	7.60	—	No
8.	Patna	Patna	8.14	Yes	219.78	153.85	25%	Yes
9.	Munger	Munger	1.29	Yes	11.29	7.90	—	No
10.	Bhagalpur	Bhagalpur	2.25	Yes	22.50	15.75	—	No

	Name of the City	Name of the District	Population (lacs) (1981)	Piped Water Supply	Estimated Water Supply (MLD) (1981)	Estimated Sewage Generated (70% of Col. 5)	Percent Covered by Sewerage	Treat-ment
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
WEST BENGAL								
11.	Braharampur	Murshidabad	1.02	Yes	5.20	3.64	—	No
12.	Nabadwip	Nadia	1.30	Yes	7.00	4.90	—	No
13.	Hugli-Chuchura	Hugli	1.29	Yes	15.35	10.75	—	No
14.	Chandannagar		1.02	Yes	10.68	7.48	—	No
15.	Bhatpara	24 Parganas	2.65	Yes	19.93	13.95	50%	Yes
16.	Barrackpur	—	1.16	Yes	5.44	3.81	—	No
17.	Srirampur	Hugli	1.27	Yes	15.35	10.75	—	No
18.	Titagarh	24 Parganas	2.20	Yes	18.94	13.26	50%	Yes
19.	Panihati	—	2.06	Yes	9.16	6.41	—	No
20.	Bali	Howrah	2.03	Yes	21.63	15.14	—	No
21.	Kamarhati	24 Parganas	2.35	Yes	16.75	11.73	—	No
22.	Baranagar	—	1.70	yes	23.78	16.65	—	No
23.	Howrah	Howrah	13.39	Yes	83.93	58.75	25%	Yes
24.	South Dum Dum	24 Parganas	2.30	Yes	16.40	11.48	25%	Yes
25.	Nalhati	—	1.15	Yes	11.43	8.00	—	No
26.	Calcutta (MC)	Calcutta	41.43	Yes	828.80	580.17	80%	No
27.	Haldia Development Area	Midnapore	0.50	Yes	—	—	20%	Yes

Chapter 17

Water Resource Management in Tamil Nadu

For the last ten to fifteen years Tamil Nadu has been facing drought of various magnitude with the result that the "saying water, water everywhere, but not a drop to drink" is really applicable to the State. Under the present circumstances, Tamil Nadu Govt. for the first time in India has come out with water laws which have been framed by some of the most well qualified people.

The first step towards this has been the formation of Tamil Nadu Water Resources Act. The act provides for Govt. control on all water which include surface, underground, atmosphere and drainage water. For making it effective the provision requires an amendment of the land acquisition Act to eliminate the alternative of levy or penalty for encroachment and also a provision that the encroacher is evicted within a reasonable time. The act says that in allocating water resources the first priority shall be given to domestic and municipal purpose. After this requirement is fulfilled allocation and regulation of water will be done according to the following order of preference. Agriculture will get the second, power and energy the third, water for industrial and commercial uses fourth while rest of the users will get the last preference.

Three types of licences are intended to be issued. Perennial licences for base runoff stream, annual allocation from Govt. constructed storage project, safe yield of aquifer and seasonal licence for water over and above base runoff stream and conditional licence for water within the jurisdiction of Govt. projects under planning. The failure to use water under a valid licence for a period of five consecutive years without due cause will cause forfeiture of the licence.

This however does not prevent P.W.D. for a temporary allocation of water during drought or water shortage as determined in the public interest. Provision will also be made for maintaining a current register of licenced water users and land benefitted by the use of water.

The issue of compensation for easement and right of way is not taken care of but must be considered in the light of existing laws of the State. Compensation for taking of water rights under licence is provided except where temporary diversion reduction or anti capacity closure is necessary due to emergency drought or water shortage period. Application for licence to divert and use water for any other purpose allowed in the act except Govt. construction project and irrigation project and production of Hydro-power will be submitted to the Executive Engineer, P.W.D. in the district. Upon a favourable recommendation the Executive Engineer will issue a licence to the application.

Now how tricky can this be one knows with experience. Though most of the Govt. Departments take lot of time to act the P.W.D. in every state is known for its delaying tactics due to rampant corruption in the Department.

For the development of ground water Govt. will conduct the detailed investigation of potential resource throughout the State. Rules and Regulations will be adopted for the development and exploitation of ground water. No person will be allowed to drill without first obtaining a permit from the P.W.D. in accordance with the form and procedure established by the Department Registration of well drillers and pump installation contractors will be done by the P.W.D. Govt. is expected to develop proper standards for adequate protection of ground water quality. This is being done, as in several areas of Tamil Nadu, ground water is essential for municipal water supplies and instead it is being extracted for irrigation, industrial and other purposes. The potential danger of contamination of aquifer from sea water intrusion is also very likely. To safeguard against this the designation of certain aquifers for protection and management is also essential. As also the drilling of wells and installation of pumps should take place by qualified parties. A permit should be obtained before the drilling is undertaken. Standard for ground water development and utilisation should be developed to ensure maximum protection and efficient utilisation of this valuable resource.

Conjunctive use of water should be encouraged. For this the use of ground water alongwith springs, lakes, streams and other surface water should be done in such a way as to maximise the beneficial uses of water of the State. The P.W.D. will approve private and public sector projects for artificial recharge of ground water. The proposal for recharge will contain source of recharge and determination of adverse effect on existing water users. Exception to priorities during drought may need diversion of licenced water to priority areas as declared by Govt. to ensure equitable distribution of water leased according to necessity during drought or period of shortage.

Govt. will be authorised to determine revenue in the form of water charges for the construction of new projects and maintenance of existing projects to be assessed against the land benefitted according to the type of use and the benefit derived out of it. This will be treated as public revenue. The building and produce of the land will be considered first security payment of water charges.

Many of the old water cess Acts have been incorporated into this new Act to make water charge effective. From a brief examination of rates of cess method of calculation and assessment in various areas of the State one finds that there is little uniformity amongst the District Revenue Offices. Very often rates levied are not collected. There is very little collection of operation and maintenance cost specially from the agricultural sector. The issue of water charges is very complex and sensitive due to the various Acts under which charges are levied. It is proposed that a more uniform and systematic and equitable norms and process for cost recovery and cost sharing be adopted.

In the long run what happens is that the influential people at District level manage things and are either irregular in paying or have excessive amount of dues to be paid since they connive with the powers that be. On the other hand the poor villagers might not have the money to pay the water charges on a regular basis. Though at State Headquarters things are more streamlined. At district level it is easy to make laws but difficult to put them in practice unless the person dealing it is a man of courage and conviction and a good administrator.

The owner of low lying land will be entitled to make drainage channel. But it should be made in such a manner so as to minimise damage to land owners of low lying areas. At the same time it should not prejudice the interest of other users.

The Govt. should be able to declare flood control areas and construct necessary flood control structures. Land within the declared flood control area will not be cultivated or occupied by construction work without prior permission from River Basin Authority.

The P.W.D. will be expected to establish a hydrological and water use data bank for the purpose of planning allocation distribution and management of the States' Water Resource. As a general rule water resource project and programme may be implemented only in accordance with States socio-economic development goals and objectives or for the security and protection of life and property. Regard should be given to economic cost and benefit and ecological changes resulting from the construction of such projects. Government may declare any wasteland or area of land adjacent to any surface or overlying any ground water as a protected area and may adopt rules and regulations to prohibit any activities by owners.

The Tamil Nadu Pollution Control Board should pepare and draft a Tamil Nadu Water quality plan which will consist of assessment of present water quality standard for the whole state, water effluent standard for municipal commercial users and other discharges and discharge permit system. An important programme to ensure compliance with the water quality plan will include a system of penalty sufficient to encourage required compliance.

The formation of water Court has been envisaged so that a party may submit appeal to the water Court or any difficulty or matter arising out of administrative decision made in carrying out of the act. No water Court or Civil Court shall grant a stay or injunction on any matter or dispute arising out of the administrative decision. Stay may be granted in matters related to acquisition of land, designation of right of way refusal of licence or eviction of encroachment from public property and any other matter provided by the rules.

The Tamil Nadu Water Resource Council and Institute for Water Resource be notified by the Government. The Council will be manned by senior bureaucrates and the Chief Secretary shall be the Head of the Council.

Tamil Nadu is a water scarce State from high demand from various sectors. It has become more critical because of past few years of below normal rainfall resulting in drought condition leading to rationing of water for municipal and domestic use. Needless to say that less water is available for agricultural and industrial purposes. During the last decade there has been necessary emphasis on improving the capabilities of Govt. for water development. One of the main hurdles in improving the water management in the State is the present status of water laws. There are presently eight Central Govt. Acts and twenty State Acts related to water matters which are carried out by Departments with numerous Boards and Committees. There is a lack of cohesive set of water policies to direct the agencies carrying out their duties.

At present there are several standing Committees at the Central, State and District level in which the various Departments concerned with water agriculture and environment focus on co-ordinating these activities and establish procedure to carry out their various programmes but they are often limited in their authority and responsibility as well as require their member agencies to follow their decision. For the proper management of the above mentioned areas as well as the environmental issues specially in the coastal region it was deemed necessary to have a council for water resources.

There is also a proposal for the creation of river basin authority which would develop and manage hydrological boundaries of the basin. Experience of many other countries clearly indicate that the basin management approach is highly desirable and successful. In Tamil Nadu general control of water is at the District level which is at an artificial administration boundary as far as the hydrological characteristic of water resource is concerned. The authority's relationship with other authorities and agencies of Govt. and the membership structure of the authority will improve. Main work of it will be data collection and resource management through a basin master plan also and coordination of multiple uses in the basin.

Govt. will encourage water users association. Any group of farmers receiving water from a common source of supply, be it a canal, well, tank or otherwise, not less than ten in number, may form Water Users Association. Such an Association formed will be registered. The primary purpose of the association will be operation, maintenance, development and improvement of water supply from surface and ground water, equitable distribution of water supply, drainage, and promotion of improvement of water utilisation. A person can be a member only if he is either a land owner or lessee or a guardian of a minor who is a lessee or land owner.

Though the qualification for becoming a member have been clearly spelt out it is to be seen to what extent Govt. will stick to this. In the end all powerful persons will become members leaving the poor and needy high and dry. Water which is the source of life has many times also been the cause for many a minor and major crimes specially in rural areas.

Members of the association would constitute general assembly. A meeting of the general assembly will be convened every year. The members of the general assembly will elect members of governing Committee. The Committee will be responsible for carrying out the general purpose of the act, byelaws and rules, manage the activities of the association in delivery and distribution of the water. They will also serve as the communication link between Govt. Departments in dissemination of information and all other matters related to the well being of the irrigators. To call and conduct meetings of the general assembly and Committee, there will be a President, a Manager and a treasurer.

The water users association may request the Collector to earmark land to be used by the Association for common agricultural purpose like social forestry, grazing ground, well and tanks under the provision of Land Acquisition Act.

Already there are significant examples of formal and informal water users association in Tamil Nadu. It is therefore important to grant them legal status so that they are able to carry out many of their activities. They can organise themselves under the Tamil Nadu Societies Registration Act No. 27 of 1975. Such an entity already exists in the Tamaraparaṇi River Basin Act.

Besides other work, the water users association can play a vital role in resolving disputes. Provisions have been made for dispute resolution by the respective association and where necessary to use the traditional "Irrigation Panchayats" to assist in this matter. Where either of the above mentioned organisation are not satisfactory Project Director can look into the matter. In some cases matter can be taken up by Water Courts if cases are directly filed there.

Though the idea behind the formation of the Association is laudable, one finds that generally these associations turn into political organisation which do less work and make more money. The legalities make things cumbersome and one finds that so much of time is wasted in going by rules and regulation that the main purpose of the formation of such organisation may be nullified. Reason being the need for water cannot wait for going by rules and regulations as lot of time is lost. Water might then be available not at the time of drought but when the drought is over, with the result that loss of human life and property will take place. So, unless the rules and regulations are fairly simple such organisation are of no use. They become only pieces of document for the purpose of historical reference.

For the formation of Water Court the Govt. shall appoint at least one Judge as a permanent member of the Water Court and from time to time may appoint one or more members of Water Court to hear disputes arising out of matters. The Judge appointed shall determine the need for more water Courts to hear matters brought in litigation or appeal. Additional Judges of Water Courts may vary according to the location and nature of the litigation. One Judge will be not below the rank of District Judge, the second will be either Collector of the district or an official of an equivalent rank. The third member will be a retired officer of P.W.D.

For hearing a dispute the Water Court shall fix a day and a place in the neighbourhood of the land, tank, lake or canal, whatever it may be. Tricky cases may be sent to High Court. The order passed by the Water Court will be considered the final decision.

The Judge will travel to location but it will be advisable to have the other two members form the area of dispute. The idea behind Water Court is really commendable. In Santhal Pargana in Bihar, Kobhan Supt. use to have mobile courts for disposal of cases of tribal area. They would move from place to place, camp for a fortnight and pass verdict on these cases. This was found very successful but it was abandoned. Now Govt. has again appointed Kobhan Supts. to solve their cases and found it successful since the people do not have to move but the Court moves and the cases are also disposed off quickly. If the idea of Water Court succeeds it should be tried in other parts of our country also. Since ours is mainly an agriculture based economy these will be very useful for the poor farmers. And in times of drought it will save many a life.

Appropriation of water of the State without licence, failure to comply with terms and conditions of the licence, drilling of wells without licence, violation of rule, destruction of hydraulic work or structure due to ill feeling—this may include obstructing any drainage structure—or failure to maintain a structure may lead to cancellation of licence.

Since these things take place in day to day life, specially in the villages, where might is followed more than the rules and regulations, it is in the fitness of things that penalties have been fixed.

It was deemed necessary to have a Water Resource Act in Tamil Nadu because water is essential but available in limited quantity so it was decided that Govt. intervention was necessary for proper management of water resource. The water of the state are the property of the State so it shall ensure the efficient and effective development allocation and distribution and management of water.

It was also felt that the existing laws were inadequate for the development and use of ground water so state should promote the controlled development of ground water, in other words promote conjunctive use of water for the maximum benefit to the people.

Hydrologically, as surface and ground water are interdependent with co-relation between water use and the discharges from waste water, it should be the policy and objective of the State to integrate water quantity and quality control by co-ordinating activities of Govt. agencies. The State should also take all measures to protect intrusion of sea water into ground water. It should also protect contamination of water from other sources.

It was also thought proper that the Govt. includes in the State and Basin master plan preservation and protection of the water shed not only for forest reserves but also for continued water supply. The state should also include possible methods of water modification and interbasin transfer of water. It should establish water quality discharge standard. It was also felt that it is not only the right of people to benefit from the use of water but also their responsibility to assist in the proper development and management of water resources. So with these objectives the state decided to promote the involvement of water users at appropriate level in the operation and distribution of water. With these objectives in mind the Water Resource Act of Tamil Nadu were framed.

Some of the people who have formed the Water Laws of Tamil Nadu are extremely well known people. Dr. Royal El Mori Engineer in Water Supply Department in Washington. He was the Chief Technical Adviser in Tamil Nadu. Mr. La Touche and Mr. A.C. Twart are from Vinnie and partner (London) both are Water Management experts. Mr. Bryon Hylore is from England who looked after quality control. Mr. James Robertson is water resoruces planner. Dr. George Rodesvick a legal consultant of the project. He is a Professor of Law in Colorado University. Mr. Thormton an agricultural Economist and a water Resource economist who was from Vinnie and Partner was also actively involved in the formation of Water Laws of Tamil Nadu. The report has been submitted to Government and now Govt. has to start work. The Act will have to be passed by the Assembly. A senior I.A.S. Officer to the project Manager Water Resources Management Studies, Govt. of Tamil Nadu State.

Taking up big issues at a big level and giving propaganda is a normal practice but putting them into practice is something else. If the State is able to put the Act in practice other States shoud follow suit.With water scarcity becoming a housefold problem due to drought taking place in some States or other on a regular basis water can definitely become a source of not only househod but political problem as has been evident in the past. Let us hope that Tamil Nadu is able to show the way to other parts of the counrty.

Chapter 18

Bihar's Gain from Tubewell Irrigation

Bihar has benefitted a lot from tubewell irrigation in the past twenty years. In districts like Bihar Sharif, Samastipur, Begusarai and others the green revolution which has taken place is all due to tubewell. The district of Bihar Sharif is green almost round the year and is one of the biggest suppliers of potato and green vegetables to almost all parts of Bihar.

Tubewell irrigation is extremely suitable for certain parts of Bihar. We can divide the State into three parts: North Bihar, the plains of South Bihar and the plateau region. Almost 70% of North Bihar is cultivable land. Agriculture suitability is such that according to a professor of Harvard University, Dr. Peter Rogers, it is rated as one of the most fertile stretch of land in the entire world. Agro-climate of North Bihar is such that it can sustain three crops a year. Parts of U.S.A and Europe which are considered to be grainaries have not more than one crop a year.

For getting three crops a year water is needed round the year. Surface water is abundant here but the hydrology is such that though it is abundant in the aggregate, its natural pattern of distribution as well as availability are not in conformity with the agricultural requirement. Though canal water is there but it is not an unmixed blessing. It gives rise to water table and waterlogging which in the long run is counter productive. So the only rational and logical course for agricultural development of North Bihar is to utilise ample ground water resources. Fortunately the quality as well as quantity of ground water are adequately suitable for agricultural purposes, unlike certain parts of the country where due to high sodium content the quality of water is saline.

In the case of South Bihar plains, the rivers are mostly rainfed and not perennial. The water table was never as high as North Bihar even earlier. Due to excessive ground water utilisation it is gradually going down in areas like Bihar Sharif district to the extent that wells have started drying up during summer months. To check this Central Ground Water Board, a Govt. of India Organisation has suggested that no more tubewells should be dug in this district. In 1967 when drought took place plenty of tubewells were sunk in this area to cope up with the water scarcity. The history of tubewell starts at this juncture in Bihar Sharif. The strategy for meeting water requirement for agriculture in South Bihar could be making small reservoir on rivers which generally originate either from the plateau region or the Vindhya hills. They should be adequately supplemented by tubewells. This area has already benefitted a lot from tubewell irrigation.

In the plateau region diamond rigs are needed for sinking tubewells as the rock is very hard. The same is there in Santhal Pargana also. This makes ground water utilisation expensive as well as difficult, as it is highly uncertain whether even after taking the pains of drilling, water will be available or not. In the plateau region a private and social organisation AVARD had taken up the cause of ground water as also UNICEF. AVARD was also given money for this purpose by Kudal Commission. On the Govt. side the officials of tubewell corporation feel that intake well and ordinary dug well can take the place of tubewell in these areas. Intake well is able to cope up with a large area of land.

The first tubewell was sunk in Rohtas district in 1944-45 in

Dilia in Dehri block according to the officials of Minor Irrigation Department. They say that this is most probably the oldest tubewell in Bihar.

In those days there was only one division, the Lift Irrigation Division. It used to control all the South Bihar Divisions also. In 1953-54 in Muzaffarpur a tubewell irrigation scheme was started which used to control the whole of North Bihar right up to Champaran. South Bihar plains have benefitted more from tubewell than North Bihar. It uses the water for Kharif as well as Rabi. In North Bihar during the Kharif season irrigation from tubewell is not required as it gets adequate rain fall. In fact there is problem of water-logging there in this period. Agriculture has benefitted a lot from tubewells in North Bihar in such districts like Samastipur, Begusarai, Khagaria, Naugachia and part of Bhagalpur district. Due to sandy soil, in Purnea, Katihar, Saharsa and Madhepura districts tubewell irrigation is not found economically viable preposition. Due to the porous nature of the soil, it takes 15 to 16 hours to irrigate one acre of land for Rabi crop. Whereas in other districts it takes just three to four hours to irrigate one acre of land. At the same time when it is irrigated by canal water in these areas the water brings with itself some silt every time which is good for the crop. But when irrigated by tubewell the land gets pure water.

The districts which have gained considerably from tubewell irrigation are, in order of priority, Bihar Sharif, more by private tubewell, Patna, more by Govt. owned tubewells, and Bhojpur, more by Govt. owned tubewells. In Rohtas district, Dehri and Sasaram blocks have gained more by private tubewells and other blocks more by Govt. owned tubewells. In North Bihar, the districts in order of priority are: Samastipur—more by private owned tubewells, Begusari—more by private owned tubewells, Naugachia–more by state owned tubewells, Bhagalpur–more by State owned tubewells, and Mokamah, specially Barahiya, more by private tubewells.

Only half of the irrigation done comes to Govt. notice. If

10 acres land is irrigated only 5 acres is entered and charged by Govt. employees. The reason is that while the cultivator saves on government revenue the operator and other junior employees share the booty and Govt. suffers the loss. In area where ground water is more expensive, Govt. investment is more than private investment. On one tubewell, Govt. of Bihar spends nearly Rs. 36,000/- per annum including electricity.

There is a heavy government subsidy on digging of wells. In case of Scheduled Castes 90% subsidy is given. In case of Scheduled Tribes the subsidy is 75%. But taking other heads into consideration the subsidy comes to 100% in case of small and marginal farmers of this caste. For Scheduled Caste having 5 to 10 acres of land the subsidy is again 40%. For small and marginal farmers of upper caste the subsidy is 50% as per the officers of Minor Irrigation Department. And for farmers of upper castes owning more land the subsidy is 25% only. The irrigation capacity of dug well is one hectare per well.

Lift irrigation is also looked after by Bihar Hill Area Lift Irrigation Corporation. The Head Office being in Ranchi but they are working separately. UNICEF is also giving aid for lift irrigation schemes in areas like Santhal Parganas for the upliftment of tribals. One lift irrigation scheme on intake well as it is commonly known can irrigate 90 to 100 hectares of land.

The Govt. tubewells have been handed over to Water Development Corporation of Govt. of Bihar. One Govt. owned tubewell can irrigate 90 to 100 hectares of land. The condition of these tubewells is very bad. Most of them are inoperative. Some tubewells shown in operation are only on paper, not all of them are operative. And those working are also not working upto full capacity. The working capacity generally is 20% to 30% only. At some places starters have been stolen and other vital appliances have been stolen and so on and so forth.

Government of Bihar has gained so much of expertise that they have been sending one Executive Engineer, two Assistant Engineers, and one Junior Engineer with a rig to Maharashtra Govt. on contract basis for sinking of tubewells, for the last ten years. The rig is of course an ordinary one suitable for alluvial soil and sand stone only and not for hilly areas.

Tube well irrigation has proved to be a boon for the State in Bihar. In North Bihar because of high water table. And in the hilly regions due to non-availability of water. Rigs come in handy to take out water when all the rivers dry up during rainy season.

Chapter 19

Economic Development of North Bihar Through Irrigation

The green fertile stretch of land north of Ganga and south of Nepal in Bihar is considered to be one of the most fertile stretches of land in the world. Yet, this region lies in one of the two poverty belts in the world and one of the poorest in the world in terms of per capita income, according to the Independent Commission on International Development Issues under the Chairmanship of Willy Brandt. It possesses the essential poverty characteristics of least developed countries as singled out for special attention by third world countries. The area enjoyed very prosperous periods and flourishing dynasties such as the Maurya and the Gupta. It is apparent that soil and water contributed the most important and critical resource base. Water resource played such a dominant and pervasive role in the lives and economic activities of the people that rivers were consecrated and were integrated with individual and social religious ritual and cultural practices. The tradition is so alive and strong that even now a river like Ganga evokes the deepest religious and cultural sentiments of the people and is part and parcel of their life. In the month of October/ November just after Diwali, chath festival is celebrated in Bihar, which is considered the most arduous of all the festivals. The delinquent behaviour of the ample but ill-developed water resource here has stifled and battered its economy over the years and reduced it to a state of seemingly perpetual poverty. It has an average density of population of 600 persons/km^2 in an area of 47,530 km^2 and with an average per capita income of approximately Rs. 700, this region presents a veritable picture of pervasive poverty. More than 90% of the people live in the rural area and more than 80% depend on agriculture for their livelihood.

The soil and water resource potential of this region is rather impressive. About 75% of its geographical area is cultivable of which nearly 75% is cultivated. The soil is alluvial and calcareous alluvial and gives three crops a year given proper irrigation and drainage facility. The area abounds in cereals, pulses, oil seeds, sugarcane, vegetables and spices.

This lush green area of Bihar receives annual rainfall of 135 cm. Seven major rivers all originating from the northern subregion of Nepal and finally meeting Ganga which forms the southern boundary of north Bihar create an average annual surface water potential of 13.5 million hectare metres. The annual yield from the ground water basin in estimated to be 2.5 million hectare metres.

There is immense hydro-power potential from the rivers flowing through north Bihar. Kosi alone has an estimated potential power of 5000 M.W. Sites suitable for construction of dams in order to realise this potential mostly lie in the upper hilly catchment in Nepal. Similarly all seven rivers and their major tributaries flowing criss cross through the plains of north Bihar are perennial and provide potential for inland transport with a length of at least 3600 km.

Against a backdrop of resource potential actual realisation presents a sharp contrast. Only about 20% of the surface water potential is utilised for all major medium and minor irrigation schemes in this area covering only 18% of the total cultivated area.

Due to monsoon the seasonal distribution of annual rainfall is highly un-uniform. Nearly 80% of the rainfall occurs in the three monsoon months and most of the remaining 20% occurs in the three winter months. All the rivers undergo large changes in elevation in relatively short distances from their origin in hilly tracts to their confluence with Ganga. These rivers carry a large amount of sediment of varying degree. The catchment area of all the rivers is divided by an international boundary with approximately two-thirds of the aggregate catchment area lying in Nepal.

North Bihar is regularly ravaged by floods inflicting a direct damage of nearly Rs. 1,000 million which constitutes about 25% of the annual flood damage of the whole country. The indirect damage to the economy on account of occurrence and threat of occurrence of floods is manifold. Paradoxically on account of vagaries in rainfall, agricultural drought also takes place regularly adversely affecting the crop yields to various extent. Once in four years certain parts come under the grip of severe drought driving small and marginal farmers and agricultural labourers to destitution and desperation. The per capita availability and consumption of power is dismally poor (15 kWh/year) which proves a major constraint in the realisation of the industrial and industry based potential. The facility of inland transport and communication are most underdeveloped suppressing its trade and commerce and giving rise to distortion in the economy. Road and rail communication which themselves are poorly developed on account of backward economy are recurrently disrupted by floods. Due to varying sediment carrying capacity of the river shifting of their course is also quite common. This results in a large number of isolated areas remaining waterlogged most of the year. In areas provided with surface water, waterlogging conditions are aggravated by poor subsurface drainage and exclusive use of subsurface water for irrigation over a long period without conjunctive use of ground water. This causes diminished agricultural production as well as environmental problems.

Given the above mentioned problems affecting this part of the country, it is evident that the genesis lies in its water resource, their undesirable distribution, their ineffective management and ineffective utilisation. Ultimately it is the water resource which will provide the key to the economic emancipation of this poor but potentially rich region.

Water resource development of this area will obviously be aimed at control and management of flood through a combination of measures, provision of 100% of supplemental irrigation through use of both surface and ground water resource, generation of hydropower, development of inland water transport by ensuring navigability of rivers and reducing and eliminating waterlogging by ensuring proper surface and subsurface drainage, as well as combined operation and management of surface and ground water for irrigation.

Protection from the threat of occurrence of floods will stabilise the economy both directly and indirectly. Direct flood control benefits, resulting from prevention of damage to crops, houses land and communication will amount to Rs. 1,000 million annually. Intangible benefits such as elimination of human miseries during floods are substantial but hard to justify. Indirect benefits from flood control such as improved agriculture will occur. Uninterrupted flow of trade and commerce and growth of industries will revolutionalise the economic scene.

Irrigation benefits will result from a more intensive use of a very fertile land and ample water resource existing here. Use of modern high yielding verieties of seed, fertilisers other agricultural chemicals made possible by assured irrigation will lead to at least 50% increase in yield of Khariff crop and 100% increase in the yield of Rabi crop. One can also expect the increase of cropping intensity from about 1.0 to 1.5 with introduction of effective irrigation system. Cropping pattern will also change towards better return from agriculture.

The spin off benefits from flood control and irrigation development are also substantial and significant. The ratio of annual minimum production per capita to annual maximum production per capita will also increase substantially from the present expected value. This will provide more incentives to the farmer for better inputs and increased investment in their agricultural enterprise. This will result in still better agricultural production. The demand for agricultural labour will increase four fold. Along with effective enforcement of land ceiling laws irrigation benefits will mean not only higher production, but equitable distribution of wealth so generated. Thus the social objective of equity which is of paramount importance for the heavily populated plains of Bihar where a large percentage is below the poverty line can be effectively served by this aspect of water resource development.

The area is currently starved of power which is essential for the industrial growth and tubewell operation. The flood control and irrigation benefit will greatly increase the potential for agro based industry such as food processing, sugar and paper. With the availability of cheap power a great handicap in realising this potential will be out of the way. Apart from industrial production its contribution to employment generation will also be significant. Power will also be utilised for operating tubewell which is so very essential for exploiting the ground water resource for irrigation as well as for keeping waterlogging under check.

With the increase in agricultural and industrial production and the consequent increase in trade and commerce the need for land transport will be accelerated. Development of inland water transport will come in handy particularly for movement of bulk commodities as it will work out to be considerably cheap per ton-kilometer than its nearest competitor, rail transport.

Reduction and elimination of waterlogging will affect in two positive ways. First it will increase agricultural productivity per hectare as well as area available for agricultural production. This is particularly significant where more and more areas are getting waterlogged at the present time in the command area of surface irrigation system. Secondly it will lead to improvement of environmental quality and hygienic condition. Although resulting improvement in human health and well being cannot be assigned quantitative benefits its relevance to the process of economic transformation is quite distinct.

Need for water to satisfy municipal and industrial requirement here where 90% of the population is rural is not yet apparent. However once the process of economic transformation is established with the infrastructure handicap removed there is bound to be a rapid growth in urbanisation and industrialisation. Hence the municipal and industrial water supply will assume increasing significance in comprehensive water resource development in this part of Bihar.

Water resource will thus provide the basic infrastructure for the process of economic transformation from poverty to plenty and will also provide the essential ingredient to sustain and accelerate the process of growth once it has set in. Though many more economic activities will increase it is difficult to visualise at present. But one can say that from comprehensive water resource development in north Bihar a rough calculation will put the incremental annual benefit at a minimum of Rs. 20 billion, which will mean, a doubling of the per capita income. Moreover, accrual of such benefits will commensurate with the social objective of employment generation and equity in distribution of benefits which are of such vital importance for north Bihar.

Since water resource has played a vital part in the rise and fall of civilisation not only in India but other parts of world like Egyptian civilisation and Harrappan and Indus Valley Civilisation, it is well expected that the development of water resource will lead this area of poverty amidst plenty to an area of prosperity in plenty. One looks forward to such an era in north Bihar.

Chapter 20

Conjunctive Use as a Strategy for Irrigation Development in North Bihar

North Bihar in endowed with very fertile tracts of land, ample water resources and congenial agro-climate. Frequent occurrence of floods and considerable variability in rainfall are the primary reasons for poor agricultural productivity. Conjunctive use of ground and surface water has been emphasized as a suitable strategy for optimum agricultural development of North Bihar. A research project "Problems and Prospects of Ground Water Utilisation for Agricultural Development of North Bihar" was supported by a grant from the Ford Foundation.

North Bihar, constituting 52,442 sq. km. of area is presently the poorest region in India as indicated by the per capita annual income of approximately Rs. 800. Paradoxical in view of the fact that 80% of the geographical area of the land is cultivable with a high degree of fertility, agro climate is congenial to sustain at least three crops a year and surface water as well as ground water is plentiful. The poor economic performance of this region is explained by a high density of population (640 persons per sq. km.) a major portion of which (about 80%) depends on agricuture and agriculture related activities sustained by a low agricultural productivity.

A number of physical factors have contributed to diminish the agricultural productivity of North Bihar. An average annual rainfall of 130 cm. occurs in this region with substantial annual variability and marked seasonal non-uniformity. On an average 85% of the rainfall takes place in less than 4 monsoon months. Thus water requirements of various seasonal crops are not met. Agricultural drought takes place of various magnitude and at the same time this gives rise to devastating floods and problems of waterlogging. The annual flood damages of North Bihar largely on account of loss of crop and agricultural production constitute about 40% of the national figure. Waterlogging turns the depressed areas into what are known as 'Chaurs' which totally go out of agricultural production and diminish the agricultural yields from other areas also.

Uptill now projects have been implemented and envisaged for this region primarily for flood control and irrigation. The former objective is sought to be achieved almost exclusively from embankments and the latter largely from surface sources. Generally waterlogging and ground water utilisation are not in the purview and hence are not integral part of the projects. If at all drainage schemes are prepared separately, ground water is assigned only a supplemental role to increase the effective command. Conjunctive use of surface and ground water has not as a rule been planned and resorted to.

The research team has taken up an area which is proposed to be served by irrigation cum flood control scheme. It is the Bagmati project which is in the initial stage of implementation and has been formulated to provide irrigation and flood control benefits to an area lying in the lower reaches of the Bagmati and adjoining river basins.

The river Bagmati originates in the Shivpuri range of the hills in Nepal. After traversing a length of 195 km. in Nepal in southward directions it covers a distance of 385 km. in North Bihar in a southward direction before it joins river Kosi. It drains a total area of 13,690 sq. km. out of which approximately 6,000 sq. km. constituting about 44% of the total area lies in North Bihar. The average annual rainfall in the lower reaches of basin which falls in Bihar is 120 cm. and that in the upper reaches which falls in Nepal is 145 cm. Approximately 85% of the annual rainfall takes place in 4 monsoon months of June to September. The average annual flow in the river is around 200 cumecs 80% of which is average monsoon flow and 20% average non-mosoon flow. The average monthly flow during the monsoon period is 375 cumecs which is about 10 times the average monthly flow during the non-monsoon period.

The proposed Bagmati project has three objectives: irrigation, flood control and drainage. For irrigation it intends having a barrage at a site 1.5 km downstream of Dheng Railway Bridge, a left bank canal of 35 km. length and a branch canal of an aggregate length of 195 km. There are other schemes besides these of irrigation. The flood control measure is sought to be achieved exclusively through embankments. The major embankments include left Bagmati embankment of the length of 79.3 km, right bank embankment of length of 77.5 km. embankment in doab of river Bagmati of the length of 21.0 km. Belwa Dhar right embankment of 52 km. length, Belwa Dhar left embankment of 36 km length and the back embankment along Lakhendeyi on both banks of 24 km. length. The drainage project include drainage of only surface water inundating for prolonged period low lying areas and "Chaurs". For this trunk channel of a total length of 311 km. draining 6 chaurs are proposed.

As can be seen the Bagmati project is a surface irrigation cum flood control project. The potential and prospects of ground water utilisation for agricultural development as well as its role in waterlogging in this area have not been investigated in the project. In order to fully assess the prospects as well as problems in ground water utilisation necessary investigations were carried out which were supported by a grant of Ford Foundation as mentioned earlier by Directorate of Water Resources, Bihar College of Engineering.

The water table in this area is at a depth of 3 m. The saturated alluvial extends to a large depth. More than 60 shallow percolation wells were observed for their pre-monsoon and post-monsoon depths of water table. Water table was found to be generally high in this area varying in the range of 2-4 m in summer and 1-3 m in winter. A major portion of ground water is contributed by surface flow from the North which is a high rainfall zone. This is indicated by water table gradient both in summer and in winter. Part of ground water recharge takes place by vertical percolation and infiltration due to rainfall. It is estimated that the annual recharge of ground water is of the order of 55 cm.

At present, in the Bagmati project area, canal irrigation has not yet been introduced, whatever irrigation takes place is done mostly through tubewells. Less than 25% of the safe yield is being used for agriculture by way of private and public tubewells covering less than 20% of the cultivation area. Inspite of attractive prospects and potential in ground water utilisation to boost agricultural production in this region, there are several reasons for the existing situation of low utilisation of ground water. A major factor is that most of the farmers are small or marginal farmers having holding less than 2 ha in the area. More than 90% of the holding covering about 55% of the total cultivable area are owned by such farmers who simply cannot afford to provide themselves with this facility. Added to this is the lack of incentive or positive disincentive on the part of environmental and hydrological factors. Fertile land and normal adequate rainfall in the monsoon season ensure a substantial level of income to these farmers from Kharif crop. Residual soil moisture and the winter rains are also generally suitable for the Rabi crop. Thus this normal congeniality of agro-climate does not adequately motivate the farmers to be enterprising enough to go in for tubewell irrigation. This is corroborated by the fact that over 70% of the existing tubewells were installed in this area in the severe drought of 1979-80. Even this adversity and general evidence that tubewell irrigation leads to a definite and substantial improvement in returns from agriculture have not stirred the small and marginal farmers to take recourse to tubewells. This is a circular cause and effect relationship between economic status and private initiative in the use of ground water for irrigation. A positive disincentive for farmers to invest in tubewells in this area is the frequent occurrence and persistent threat of floods and consequent damage to crops.

Another economic factor which has inhibited development of tubewell irrigation in this area is the paucity of adequate and reliable source and energy supply required for operating the tubewell. Electrical energy is either non existent inadequate or erratic and hence is not relied upon for the purpose. This has been a major cause for the non performance or poor performance of public tubewells in this region. Diesel operated tubewells are now common. The inconvenience and unreliability in diesel availability and the cost involved however have been a deterrent factor in wide spread adoption of tubewell irrigation by means of diesel pumps.

The desirability, the prospect and the imperativeness of conjunctive use and management of surface and ground water for optimum irrigation development are rather obvious. The irrigation facility envisaged in Bagmati project is rather low in view of the agro-climate conformity of the area, the fertility of the land and the aggregate availability of water. It can optimally be increased to more than double. This can be achieved if ground water is also utilised in conjunction with surface water particularly for Rabi crop when the river has deficient flow. Irrigation from surface water resource alone cannot ensure a higher irrigation intensity through the proposed project in which no storage of water is provided for. The barrage, an important component of the project will only serve to divert the river flow into the network of canal. Consequently the project is not likely to meet the needs of Rabi irrigation on account of the deficiency due to less water in the river in those months. The irrigation intensity will also fall below the envisaged level in years when there is deficient rainfall. Ground water utilisation must be made an integral part of irrigation strategy in this area in order to achieve the optimum irrigation intensity which is more than double the project irrigation intensity. Conjunctive use is also necessary to achieve stability in irrigation intensity in the years to come.

Conjunctive use of ground water alongwith surface water for irrigation is necessary from the consideration of water-logging and sub-surface drainage. Water table exists at shallow depths throughout the area of Bagmati project and the low lying pockets have been turned into "Chaurs"—area of permanent surface water inundation. This is accentuated by irrigation from surface water and in the long run such irrigation schemes even prove to be counter productive. Ground water utilisation lowers the water table, helps surface drainage and is thus an antidote for this impending adversity. Thus it is necessary to resort to ground water utilisation to maintain the sub-surface hydrologic equilibrium for optimum agricultural production.

If ground water is utilised for irrigation in a major way seepage of canal water becomes a source of replenishment of ground water and is thus not to be considered as a loss of valuable water having the potentiality to irrigate fields. In fact seepage from canals is considered as an essential and desirable process in the conjunctive use strategy preventing the necessity to line the canal which is a costly proposition and is absolutely not possible to be adopted by a poor country like ours.

Tubewell irrigation also enhances the farmers access to and control of water for irrigating their field. Certain high patches of land in the command area which cannot get the benefit of canal irrigation due to adverse gravity can also be provided with irrigation by the conjunctive use strategy. Thus it enhances net effective command of irrigation and promotes better cropping pattern uniformity throughout the command area.

By giving a close look to the problems related with water resource one comes to the conclusion that there is ample scope and hydrological desireability to substantially increase ground water utilisation for agricultural development in Bagmati project area and by inductive reasons in the whole of North Bihar. Ground water in the aquifers and surface water in the river of this region must be considered as hydrologically interacting and for utilisation purposes complementary sources. It has to be accorded a dominant role and surface water has to be developed and managed with conjunctive use in mind. In view of the high water table in the area this is imperative in order to avoid the potential danger of waterlogging and consequent decrease in productivity. Conjunctive use and management of surface and ground water is the optimum strategy for the development of water and related land resource in this region. As this region suffers both from recurrent floods and frequent droughts this strategy should preferably be adopted in this area.

Provision of power will have to be an integral part of any plan of water resource and related agricultural development. With power as an uncertain commodity no plan will succeed in full measure.

In the given context of the economic profile of the farmers of this area, appropriate public initiative has to be taken in promotion of ground water utilisation for agricultural development. In any case there should not be any disincentive for the farmers to use ground water *vis-a-vis* other source of water.

Conjunctive use of surface water and ground water for agricultural development will ensure a crop of more than double against what has been provided for the proposed Bagmati project. In the given situation of fertile and most suitable agro-climatic condition this will lead to a major increase in the agricultural production. For a region having the lowest per capita income in the country where approximately 90% of people depend on agriculture or agricultural related activities, this will be a prescription for its rapid economic development and progressive prosperity.

Chapter 21

Flood Control in North Bihar Problems and Prospects

There has been tremendous development in the Western part of India, Punjab, Haryana, Gujarat, Maharashtra and Western U.P. with the result that India is gradually becoming two countries of the rich and the poor. The question is why is it happening. It is difficult to believe that people in eastern India and Bihar are lazy. Because they do work tremendously hard. The model used in the western part of the country is very successful. Agriculture is done very successfully in area which are canal irrigated areas which are in arid zone. With wide range of inputs one can get corresponding increase in agricultural production. If one applies the same technology in eastern states it does not work. For instance, take Kosi, the model of Punjab doesn't work. The main reason is perhaps flood and lack of communication. There is definitely something gravely wrong. It has something to do with climate, may be because Bihar is very humid. Then there is the problem of floods which is sometimes there in Western states, almost every year in the eastern states but Bihar has serious problem.

The technology is not very well developed for irrigated agriculture in flood prone areas. It is necesary to do something, to devise some technology during the floods that will help the farmer and enable him to intensify agriculture. As it is not possible to increase employment in agricultural sector under the present circumstances one has to stabilise in agriculture—more inputs, fertiliser, high yielding variety of seed etc. The only way to do is by controlling floods and arranging for proper drainage. Flood damages not only standing crops but roads, bridges, railway lines and houses. The cost of flood control is very high, if you look at it in a narrow way, the benefits are small. But the benefits are not just the crop but its potential. It is not just what one loses now but the difference—if one had the flood control measures what one would have lost. The amount of money that is spent on flood control at one time will go on giving remuneration in years to come. It is not the loss but potential loss if one could have the flood control—there would be tremendous difference in productivity and employment. Agricultural labour in Bihar works for 15% to 20% of the possible number of working days in a year. With flood control one could work 200 days in a year instead of 50 to 60 days in a year. This will have tremendous effect on income, effective demand and demand for agricultural products. That is how one gets more economic benefits like in the western part of India. The demand for consumer product is high there because everybody is prepared to spend and this brings about a whole lot of development. In the east, people have a low income so production of consumer good is also low because nobody is prepared to buy them. In Bihar people do not have income as they have a low level of living. People waste their time in chatting because they do not have employment because there is a stable subsistence farming.

In Bihar they can try enbankments on river. On Kosi for instance it was quite effective from 1954 to few years back when there was major flood. That has not been a good solution because the river carries a good amount of silt. The gradient of the river changes from Nepal to Bihar; they bring a lot of silt. The silt is deposited between enbankments then the bed of the river rises. One has to go on making the enbankments higher because the bed keeps on rising. This is exactly what happened in Kosi. The bed of the river is nearly two feet higher than the level of land on either side. Earlier when floods came they damaged crops. But now since the bed of the river has risen it is very dangerous because if the enbankments break then the water comes with a great force and people get killed. So building enbankment on rivers does not look like a good solution. Its temporarily possible, its very expensive and very dangerous.

The question is what can be done. Can one store water in Nepal by building dams, this was suggested in early fifties, or, one could store the water on land in Bihar. That is a proposal which is being examined. Its on a Chinese and Portugese Model—that is to build huge detention basins. The basic point is one can prevent the floods, live with the floods, allow the floods to come only when and where one wants them to instead of their coming here and there and this is a good strategy which is interesting and has no problems concerning international agreements. When one says this one is talking of thousands and thousands of square kilometres and not thousands of square yards. But politicians and engineers of Bihar say that they cannot do that. If one thinks about the alternatives—what are the alternatives? Can one have agreement with Nepal to store the water in Nepal? Is that easy and economically good. The embankment option is expensive and dangerous and the other option of storing water on land has not been tried as yet. It is quite interesting and instead of just being passive about it one should think about its uses. It can be used for fisheries, cold storage during winter, one can also grow crops in those areas with the water made available. It can also be used as ground water. The problem is how to bring about a combination between storage, embankments, some drainage changes, ground water recharge, some dredging. These are the sources which should be exposed.

Dr. Peter Rogers spent almost five months in Bihar in 1981 and has been visiting the state on a regular basis. He discussed the problem related to water resources. The engineers have a very narrow view. He suggested embankment and dredging. Dredging does not seem to be a good solution because of the amount of silt the river carries. The engineers themselves also know that dredging is not possible because it is a very expensive proposition. They did not want to consider the upstream storage also.

The whole thing needs a detailed analysis of the situation. If one thinks about it as a flood problem one thinks about one solution; if one thinks about developmental problem one thinks of many solutions. There are large areas in Bihar which are flooded every year. One can make low bandh and raise the flooded areas and store the water in the fields. This will keep the extra water out of Ganga and other rivers and lessen the congestion. It will give control over water in winter and summer months for Kharif and other crops. Large amounts of water will be available throughout the year for different uses. The drainage problem also needs careful tackling in North Bihar, because of haphazard construction of embankments. After giving a close look to the big projects proper drainage facilitiy should be created. Farmers say that some embankments have been built by the Highways Department some by Railways and others by Irrigation Department. A macro drainage system is needed as there is no coordination between drainage systems.

Inspite of varieties of good fruit there is no fruit processing plant in North Bihar because the transportation system is poor. Due to floods the roads and bridges are damaged every year. By the time the roads and bridges are repaired the monsoon sets in and the areas are flooded again. Its a chain reaction. The justification for investment is very good when one thinks of the all round development.

The people of Bihar should not wait for help from the Central Govt. Self help is the best help. It needs lot of thinking, lot of planning and lot of manpower. All these can be managed by the local people. Lot of exacavation, lot of low bandh, one, one and a half metre high embankment not big super structure are needed. All these can be done with some supervision. A dedicated man is needed to guide them. Waiting for Govt. help is useless. Engineers say that there are projects waiting for last ten years or so with some objection or other. Neither India nor Bihar is a poor state. The potential is collossal. The trouble with Bihar is no one wants to do anything; they are always waiting for someone else to do it. The Chief Minister Bihar says there are a hundred thousand employees in Bihar in theWater Resources Department. In U.S. the whole engineering system has got thirty thousand employees. Why doesn't the Govt. take stock from the employees. In Samastipur 95% of the tubewells are not working. Why doesn't someone probe into the problems and finds out as to what is wrong with all the tubewells. Why doesn't the Govt. throw out inefficient employees and stream line the department. This is one of the major questions because there is something seriously wrong if with one lakh employees the Irrigation Department of Govt. of Bihar is not working efficiently. Employing one lakh employees means spending a lot of resources. But there is no question in the Assembly neither is the Govt. bothered as to what the employees are doing when Govt. is spending a fortune in paying salaries. Tubewells do not work because there is no electricity either. Bihar has so much coal. Why doesn't Govt. provide electricity. Someone has to start somewhere instead of waiting for help from Centre. There is tremendous amount of resources in Bihar. It has coal, it has mineral and above all its has the most fertile stretch of land in the world. From horizon to horizon the best soil is there in North Bihar. Twenty to thirty years back one could say it is feudal society, not now. Floods and development are important issues and might provide a vehicle for new ways of thinking in a political sense.

With a little support from the state Govt. the problem could be solved by the local people. In fact if this problem is solved all the other things will start happening. Ultimately the people who belong to that area will benefit and not others.

In India everything is compartmentalised. The Planning Commission does not understand what the Central Water Commission wants to say. The Planning Commission most of the time accepts what the Central Water Commission suggests. The engineers of the Central Water Commission have incredibly narrow view and provide standard type of solution which has no flexibility. People in the Planning Commission do not have any option, so they accept it. The Planning Commission is generally manned by bureaucrats who are generalists who do not have an indepth knowledge of water resource development. The biggest problem in Bihar and India arises because of compartmentalisation. All the resources are there, intellectual resources are there but how to mobilise them. The unfortunate thing for India is the brain drain from which the west seems to benefit. These views were expressed by Dr. Peter Rogers Professor of Economics in the Institute of Applied Science of Harvard University in an informal discussion. Dr. Rogers has shown keen interest in the development of eastern India specially North Bihar by visiting the area again and again.

Chapter 22

Development of Minor Irrigation in Tribal Areas

Minor Irrigation is fairly well developed in certain parts of India specially where the water table is high, like the Ganga plains and the plains in other parts of the country. But in the tribal belt not only the topography creates some amount of problem since most of the tribal areas fall in some sort or other of hilly area but lack of fund also creates a major problem. Unlike their effluent counterparts who can get a tubewell dug for themselves at their own cost or with some Govt. subsidy, these semi literate poor people neither have their own funds nor are able to exert pressure to push Govt. files to get loans sanctioned for themselves.

The economy of the tribal is based on primarily rural and agricultural allied activities. As per the 1971 census the all India population of India was 533.534 millions out of which 36.405 millions are scheduled tribes. Against this cultivators comprise 57.56%. As per 1981 census out of a total population of 665.288 millions in India 51.629 millions are scheduled tribes of which 54.43% are cultivators (excluding Assam where census could not be held in 1981). There are no scheduled tribes in Haryana, J.K., Punjab, Chandigarh and Pondicherry. The percentage of Tribal cultivators among the tribals in various States are Andhra Pradesh 43.21%, Bihar 63.06%, Gujarat 45.94%, Himachal Pradesh 76.91%, Karnataka

40.81%, Kerala 20.54%, Madhya Pradesh 60.78%, Maharashtra 39.53%, Manipur 86.3%, Meghalaya 69.55%, Nagaland 83.86%, Orissa 52.15%, Rajasthan 78.05%, Sikkim 66.45%, Tamil Nadu 47.33%, Tripura 64.03%, Uttar Pradesh 78.74%, West Bengal 31.04%, Arunachal Pradesh 91.40%, Dadar and Nagar Haveli 73.09%, Goa, Daman and Diu 11.6% and Mizoram 78.81%.

The scheduled tribes generally live where productivity of land is low. Shifting cultivation and dry upland cultivation are traditionally the most important source of livelihood. Agriculture is the primary source of livelihood of the majority of tribal population in the country. This consists of terraced cultivation as wet rice cultivation besides upland cultivation. The typical topography, of undulating and hilly area has made tribal area agriculture less profitable. There is a need to subject the proven technology and practice of the developed areas to adaptive research for tribal areas. Tribal tracts include extensive rain fed areas and incidence of irrigation is somewhat small. Dry farming techniques for greater cropping intensity are an urgent necessity in this area. Tribal area land being mostly without irrigation double cropping and multiple cropping are practised by tribals only to a minimum extent. The cultural practises would need revision in some cases to procure a second crop being raised on moisture left at the end of first crop.

The total tribal area in the country during 1980-81 was 50.2 million ha out of which 16.7 million ha is under cultivation. Against this only 1.109 million ha is covered under irrigation. Thus only 6.64% of the tribal area is provided with irrigation facilities against an all India average of above 30%.

On account of the existence of a large number of catchment both major and minor in the tribal area the potential for irrigation in these areas is considerable. Minor irrigation projects which are giving immediate benefits to tribals are to be identified and should be selected for execution on priority basis. Utilisation of irrigation potential created in tribal area is low mainly on account of lack of farm development and inadequcay of field channels. Inadequacy of field channel is seen in several lift irrigation projects taken up by the State Governments. Lift well, shallow and deep tube, well, water harvesting structure, check dam and tank/pond have to be resorted to in the tribal areas.

Under minor irrigation Rs. 28,050 millions was provided for VIIth Plan outlay against which Rs. 4,969.2 millions was under tribal sub-plan which is only 17.72%. The Central Government provides special central assistance to the tribal areas as an additive to the state tribal sub plan. States decide the allocation sectorwise looking into the gap required to be filled. Since the tribal area needs special attention it is suggested that Minor Irrigation/Ground Water Department in the State should have a separate wing for tribal areas directly under the control of Chief Engineer. The funds and subsidy meant for tribal area should be routed through this wing. A set of schemes both surface and ground be prepared after proper survey.

Flow of fund to tribal sub-plan should not be on percentage basis. It should be based on the criteria that during the VIIIth Plan all the states should have at least 40% cultivated area under irrigation as against 6.64% in 1980-81.

Fund should be earmarked for minor irrigation under special Central assistance. Central Ground Water Board and State Ground Water Organisation should be made responsible for carrying of location specific surveys for siting the location for specific wells and bore wells in hard rock areas.

Subsidy for tribal farmers for private minor irrigation work should be as follows:

Marginal farmers	100%
Small farmers	75%
Other farmers	50%
Group of farmers co-operative	80%

The cost of energisation of tubewells and wells in tribal area is comparatively high and within the existing norms of

Rural Electrification Corporation it is not viable to extend electrical lines to energise these wells and tubewells. The tubewells and wells in tribal areas have thus to be operated on diesel pump which increase the overhead cost of the tribal farmer. State Government should provide grant to State Electricity Boards for meeting the increased cost on account of long distances on which lines have to be taken in these areas for energisation of tubewells.

In areas where transmission lines do not exist, solar pumps should be installed free of cost. The cost incurred should be met by the Department of Non-Conventional Energy.

In the Ministry of Water Resources a special cell should be set up to monitor the implementation of minor irrigation development in Tribal areas. The cell so created should get the specific composite project for improving agriculture productivity preapared by the State Govt. which may be funded by grants/loans under external assistance given by so many countires.

Minor irrigation outlay under the tribal sub-plan should be provided on the scale so that at least 40% of net cultivated area of tribals is brought under irrigation. Ground Water Development and Surface Water, Lift irrigation Schemes where ever feasible should be taken up on priority basis in tribal area.

Effort should be made to complete all ongoing surface water Minor Irrigation Project taken by the State Irrigation Department which have been for more than three years under construction in next two years time for which advance plan assistance may be given by the Centre to the State Govt.

As far as possible water shed management approach should be applied in the tribal area under which the programme of Minor irrigation and soil conservation should be actually co-ordinated.

If the irrigation project belongs to Govt. Water should be provided free to the tribal farmers for the first five years so that they get enough time to develop crops successfully and are in a position to pay the water rates. More active water management and intensive support will be necessary in the tribal area in order to ensure that the completed minor irrigation projects are effectively utilised.

Since there is hard rock beneath in many parts of the country like Andhra Pradesh, Maharashtra and Bihar, Diamond rigs are needed to pierce the hard rock and reach the water. Government should see to it that plenty of Diamond rigs are made available and expertise is also developed in operating them.

Co-operatives should be formed to see that equitable distribution of water is done to each farmer. In the villages might is right prevails. The Co-operatives should not only help in distribution of water but also see that water is carried through field channels to the actual farm.

DETAILS OF TRIBAL AREA IRRIGATED

('000 hectares)

Name of State/UT		Tribal Area	Net Tribal Area Cultivated	Net Tribal Area Irri-gated	% Area Irrigated
1.	Andhra Pradesh	3377.8	902	93	10.31
2.	Arunachal Pradesh	—	—	—	—
3.	Assam	934.7	432	25	5.78
4.	Bihar	4360.4	1798	53	2.95
5.	Goa	7.2	—	—	—
6.	Gujarat	2446.0	313	32	3.94
7.	Haryana	—	—	—	—
8.	Himachal Pradesh	2395.4	32	8	25.00
9.	J & K	—	—	—	—
10.	Karnataka	2539.7	407	34	8.35
11.	Kerala	612.8	27	1	3.70
12.	Madhya Pradesh	16346.1	5448	191	3.50
13.	Maharashtra	3930.7	1299	34	2.61
14.	Manipur	2012.6	72	—	—
15.	Meghalaya	—	296	111	37.5
16.	Mizoram	—	—	—	—
17.	Nagaland	—	859	59	6.87
18.	Orissa	6889.6	1578	66	4.18
19.	Punjab	—	—	—	—
20.	Rajasthan	1973.9	1665	278	16.70
21.	Sikkim	444.4	41	4	9.75
22.	Tamilnadu	205.8	78	8	10.25
23.	Tripura	667.9	123	4	3.25
24.	Uttar Pradesh	9.2*	50	17	34.00
25.	West Bengal	849.9	366	65	17.76
Total States		50004.1	16286	1083	6.65
Total UTs		195.3	418	26	6.22
All India Total		50199.4	16704	1109	6.64

* Scheduled Tribes are scattered in Uttar Pradesh.

Union Territories.

1.	A&N Islands	195.3			
2.	Daman & Diu	Included in Goa.			
Total UTs		195.3	418	26	6.22

NOTE: 1. Base 1981 Census.

Chapter 23

Kabar Lake—To be Declared Kabar Jheel Panchi Vihar

There are nearly 300 species of migratory birds which come from Siberia and other parts of Europe during the period November to February every year to the wet lands of Kabar lake. They go back every year in summer. To protect these birds India signed a pact with Soviet Union. This place is very important from the point of ecology, fauna, flora and landscape. It is essential therefore to protect, preserve and develop the environment. Besides birds from beyond the boundaries of the country, other birds also migrate from lower ranges of the Himalayas within the country. Taking this into consideration Central Govt. has declared Kabar lake as Bird Sanctuary and renamed it as Kabar Jheel Panchi Vihar. A letter from the Central Govt. has suggested to stop Irrigation depts scheme of drainage of water from the lake. If this is not implemented then not only wet land will be reduced but migratory birds and migration in winter will be disturbed. Irrigation Deptt. of Govt. of Bihar has been advised to postpone the work of drainage of water till the approval of the Ministry of Forest and Environment is received.

Lots of land of the lake is disputed Govt. land. Govt. had asked Collector Begusarai to examine this. He had also been asked to exercise the powers vested in the Wild Life Protection Act 1972 under sections 53 to 57, sub-sections (1) and (2) and declare areas listed in the enclosed list as closed for a year from the date of publication of the gazette so that permission for shooting of wild life during this period is not granted. The enclosed area will be called Kabar Jheel. It is a beautiful picnic and boating spot also. A scheme has been prepared for the purpose of development of the lake as tourist centre and bird sanctuary by Govt. of Bihar. The Central Govt. should support the scheme, as conditions are far better here than the famous Bharatpur Bird Sanctuary which falls permanently in a drought prone area. There are reports of migration of birds from Bharatpur Bird Sanctuary to Kabar lake where there is no shortage of water and the area is lush green round the year. The scheme which has been taken up by Govt. of Bihar for the development of the lake is expected to cost Rs. 10 crores. The scheme is ready and is under process in the State Department of Environment, Govt. of Bihar. The department of Environment does not take sanction, unlike other Deptts. of State Govt., from the State Finance Deptt. on schemes of greater environmental importance, such of those which are considered important in the context of national interest.

Kabar lake which is situated in Begusaria Distt. of Bihar falls in two blocks Cheriya Bariyarpur and Bakhari. It is probably an ox-Bow lake which was a part of the flow channel of Burhi Gandak but in course of time got separated from the main river. The area of the lake is 17-18 sq. miles which expands to hundreds of sq. miles in rainy season. In terms of acreage it is 6,737 acres. In summer water is located in few pockets only. The deepest pockets of the lake Mahalaya and Kochalaya extends to 410 acres of land; excepting this most of the land belongs to raiyats. There are two types of rights. First one is the landlord who is the owner of the land and second is that of the sahnis who more or less depend on the lake for the sake of their livelihood. The second type of right was customary in beginning but it became legal in 1885 when the owner of an Indigo factory who had some right on the lake wanted to deprive the sahnis of their privilege of free fishing. They did not yield to his demand so the case was taken to Calcutta High Court which gave them the right to fishing. There has been no legal complicacy over the right of bird trapping and killing of birds in the lake. Apart from the right and concessions of sahnis the ownership of the land continues to be with the respective landlords who cultivate the shallow land in summer by sowing paddy. In summer the activities of the sahnis get restricted.

It is also interesting that the lake has been divided into 15 villages around Kabar lake and the sahnis of these villages mostly catch fish or birds in their own zone. Those engaged in fishing and catching birds in the lake do not give any money to the land owner nor is there any binding for this.

There are 1839 famlies of sahnis around Kabar lake with a total population of 10,774. Nearly one fourth of them (2,667) are working. There are 1,301 families of sahnis with a population of 7,397 who are engaged in fishing and bird trapping.

Sahnis engaged in fishing are economically inferior to those who have taken to other profession. Bird trapping is a subsidiary profession of fishing but it gives them good money as they are able to make Rs. 1,500 per family/per annum. But bird trapping requires an initial investment of Rs. 2,500 for nets and bamboo and other things and has to be replaced every third year.

Migratory birds which mostly are water birds come in winter. Besides the migration of bird in winter from beyond our frontier there are movements of smaller and less spectacular kind from North Bihar—the base of Himalayan foot hills. Here the changes in the season are quite pronounced which causes the local migration movement. From across the border of our country such birds as cotton teal, Printail, Juffed Pochard, Red crested pochard, White eved pochard and Common teal come. While from the foothill of Himalayas with in the country, Ducks, Jeals, Pochards, Coots, Geese, Stroksibis, Moorhens and Jacanas are common migrants.

These birds can be seen swimming in the lakes and flying low in large flocks over the lake and adjacent villages from November to February. The whole lake looks like a birds' paradise where different types of birds swim, dive and even run over its clear calm and deep water. Food for these birds is plenty. Days are very calm and soothing to their mind but the nights are very cruel when these innocent birds are caught for human consumption.

These birds travel at a height of 3,000 to 5,200 metres and even to 6,000 metres to shorten their journey very considerably.

In Kabar lake bird trapping is quite well organised. The nets are spread against the direction of wind when the moon is not so bright. Sahnis visit their nets early in the morning and collect their birds alive. In daytime the nets are taken off and the birds fly back to their natural surrounding. Till 1982 the aristrocrats used to indulge in hunting of birds by gun. With the untiring effort of the forest officer, Mithila Division, along with the help of Sahnis, this has been completely stopped.

There are various reports of the number of birds trapped every year. According to a report published sometime back nearly 30,000 birds are netted in the month of November another 30,000 in the month of December some 5,000 in January and 2,000 more in the month of February. Altogether 70,000 birds are netted and marketed in winter. These birds are brought for forward transportation for marketing at four important points, Jai Mangal Ghat, Gwari Ghat etc. Then they are brought to Manghol which is a big market. In 1983-84 nearly 33,954 birds were netted. In 1984-85 nearly 1,34,635 birds were netted.

Many Sahni families earn their daily bread from fishing. This business falls to its minimum in summer. Not much work for development of fisheries has been done. Katala, Rehu, prawns and other good variety of fish is found here. Collecting snails is also an important occupation here. Lime is derived from snail which is used in pan. It is also used in making pearl tile for flooring of house. The famous button factory located in Mahasi in North Bihar is primarily based on such snails. Many people are engaged in taking out Makhana which is a very expensive food item.

From ecological point of view Kabar is a wet land and is a subject of scientific research. In summer crabs lobsters shrimps, segment worms and frogs are able to move in and out of the lake. Fish follows the deepest pockets of water in summer and birds fly back to their native place. Sahnis search another means of livelihood. Plankton is not available in plenty in the lake. The growth of rooted vegetable includes weed, rarecut, reeds etc. The vegetation dries up in summer. At places it is ploughed, uprooted and even burnt, when the monsoon arrives the offspring of the vegetation starts germinating. By end October it is well established again.

When the water recedes the farmers plough the land and sow paddy. Paddy is able to be harvested by the end of December. Many insects, rodents, birds and mammals find their food in their vegetation. The cycle again changes. Funny though it may sound, it is good for the birds and ecological system.

While discussing the ecological system of the lake we must give utmost attention to sahnis who are ecological dominants. If everything was left to themselves nature would have taken care. But with modern techniques of trapping of birds, fishing and use of various types of insecticides and chemicals ecological imbalance may take place. Already Pink headed duck has almost become extinct. International conventions and conventions at national level have been taking place for the protection of these birds. Birds can produce lots of offspring to maintain viable population.

For draining out the water of Kabar lake and adjoining ponds a scheme was prepared in 1951. In this scheme all smaller lakes around this were joined with it through various channels. The water of Kabar thus collected was joined with Chano river through a drainage channel. This canal was again extended through Chano river and was connected with river Burhi Gandak. Initially the canal was deep enough to drain out the water of the lake within a few weeks. For years the drainage system was successful. The submerged land became available for rabi crop. But after few years the mouth of the channel got silted and the drainage system no longer remained effective.

Drainage Division Manjhol had again prepared a scheme to drain out the water of the lake into river Burhi Gandak through a short channel. However till the fate of the Kabar lake is decided it is unlikely that the scheme will be finally approved.

At present the organised threat in the ecosystem is to the migrant bird. For the conservation of these birds the first step to be taken is to devote attention towards the drainage system. It should not be taken up. The other step should be to stop mass and uncontrolled trapping of birds. Trapping should be allowed for only scientific and educational purpose. The main aim should be to tackle the employment of Sahnis and rehabilitate them. Much work has already been done in other countries for the development of pond ecology on the basis of polyculture. Development of polyculture in Kabar lake should also be done by suitably manipulating the habitat. Various types of plants, fishes, amphibian, reptiles and mammals can be reared on commercial basis by utilising the various niches of pond ecosystem. The fishing sahnies can be suitably employed in this work. To begin with fisheries and duck farming can be started.

Netting equipment of all the sahnis engaged in bird trapping should be procured by Govt. by giving them due compensation. The other adjoining ponds should be developed for cultivation of fish. Govt. can bear the initial investment. Any employment generated should be given to the sahnis only. Cultivation of paddy without disturbing the habitat of the bird should continue in the shallow parts of the ponds. This will not only reduce the growth of unwanted weed, but also generate good amount of food for the visiting birds. The insects that come to the paddy field are food for these birds so they should not be destroyed. The surplus land under the Land Ceiling Act should be distributed to landless sahnis. Waste-land which is not being utilised properly should be developed so that the people can gain well from it. The original craft prevalent in the area should be identified and revised to generate employment to the local people. Co-operatives could be encouraged to rearing milching animals and they should utilise the facility of milk plant. Intensive integrated area development programme should be started to benefit the people with the various schemes of the govt.

Unless a crash programme for all round development of the area is taken immediately it might become too late and the migratory birds may stop arriving and some of the permanent birds may also become extinct in times to come.

Chapter 24

Pollution of Damodar River by Major and Medium Industries

It is a matter of great concern that the people of the tribal belt of Palamau, Hazaribagh, Giridih and Dhanbad Distt. of Bihar are being supplied water for drinking and other domestic purpose from River Damodar. Although this issue has been highlighted in one of the seminars organised by the State Deptt. of Environment in Bihar there is need to highlight it at a national level. So that like the Ganga Action Plan a special plan supported by Central assistance is formulated and the action part implemented both by Bihar and West Bengal as the river is important constituent of their Ecological system.

River Damodar originates from Palamau Distt. of Bihar and after traversing through three of the mineral rich Distts. of Bihar it enters Purulia Distt. of West Bengal and then joins river Hooghly. There are a number of industrial as well as ordinary towns and human habitation which are totally dependent on the river for their water supply. Almost the entire route of the river in Bihar is a hilly terrain so it is very difficult to exploit underground water in this region. In the absence of reliable alternate source of water most of the towns and villages of Palamau, Hazaribagh, Giridih and Dhanbad Distt. situated on the banks of the river depend on river water for domestic as well as industrial use.

In 1948 the DVC Project came up; before that though the river was famous for creating havoc the water was clean. Today the river has been tamed by our engineers but the water is extremely polluted by discharge of industrial effluents as well as discharge by civic bodies of towns located on river Damodar and its tributaries. So much of toxic and hazardous effluent is discharged, that the colour of the water is blackish at most of the places.

There are 46 major and medium industries located in Giridih and Dhanbad Distt. of Bihar and Asansol and Durgapur of West Bengal. Besides this the run off water from fields using pesticides, and soil erosion because of increased mining activity is also contributing its share in the increase in the quantity of solids in the river water. Out of the 46 industries mentioned above 27 are in Bihar, out of this 13 are coal washeries, 6 thermal power stations, 4 coke over plants, 2 fertilisers and chemical plants, 1 steel plant and 1 cement plant.

All the 13 coal washeries situated on the bank of the river belong to Coal India with the exception of one which belongs to TISCO. The discharge from these washeries contain much more solids than what is prescribed by the Board for Industrial effluents.

Out of the 6 thermal power plants situated on the bank of river Damodar in Bihar, Chandrapura, Bokaro and Patratu thermal power plants are bigger in capacity. They use a different variety of coal for boiler in which all the ash is washed by water which forms a slurry. Though there are slurry ponds where most of the solid settles down yet again the discharge of waste in the river from the slurry pond contains solids higher than that prescribed by the Pollution Control Board. Needless to say that the other three thermal plants also discharge water which is polluted beyond the prescribed limit.

There are 4 coke oven plants on the route of the river in Bihar. Most of these plants recover the tar which is a by-product. The effluents from these plants include, besides other things, tar oil and ammonia which are dangerous for aquatic life when mixed with water.

The other major industries situated on the bank of the river are Bokaro Steel Plant, Indian Explosives, Gomia, the Fertiliser Factory owned by Govt. at Sindri and a Cement Factory of A.C.C. at Sindri. The Cement Factory discharges very little pollutants. But the other three factories have effluents which are extremely damaging in nature. Though there are treatment arrangements for effluent in the rest of three industries it needs constant monitoring by the authorities to see whether the plant for treatment of effluents is functioning properly.

The Central Pollution Board has prescribed norms for determining the fitness of water for the use of water for different purposes like drinking, bathing, raw water for water works etc. But these criteria should not be the only guidelines for deciding on the quality of water for particular use because in that case many other things will have to be tested and checked.

The 27 big and small towns as well as villages situated on the banks of river Damodar in Bihar take water from the river for water supply among dwellers, and their civic bodies also discharge the waste water in river Damodar. About 66,000 kilolitres of untreated domestic waste water is added every day in river Damodar. The untreated waste water has high bacterial contamination and other pollutants.

Every industry and local body has to take permission for discharge of effluent on land or river from Bihar State Pollution Control Board under the "Water Prevention and Control of Pollution Act" applicable in the State of Bihar. The Board can exert pressure on industries and local bodies to discharge polluted water after treatment so that it confirms to the standard laid down by the board. The significant pollution control method may include measures like—all types of industries could join together to chalk out a project for recovery from effluent and reuse of effluent to the maximum. The plant for treating the waste water should be constantly monitored. It has been found that big plants have been constructed for treatment of discharge but lack of interest leads to the plant not working to its optimum capacity hence the effluent is not treated well. The existing plant should be increased in size and new plants should come up for treatment of waste water coming out of towns and villages which empty in the river. This may need underground sewerage system. Since it needs a lot of money and funds are limted till such a time that more fund is made available the towns can be divided into a number of segments so that for each segment cheap short term measures such as the oxidation plant can be constructed to partially treat the effluent before it is discharged in the river. Even before they reach the river they can be used for irrigation if found fit under norms set for agricultural uses of water.

Industries which discharge chemical and toxic substances should segregate their drains for, various chemical treatment before finally treating the effluent for reducing the effect of pollution. This will help in minimising the initial as well as recurring cost of effluent treatment.

There should be a time bound programme for effluent treatment facility. The industries should not be allowed to cite examples of financial constraints. The civic bodies should install sewage treatment facility. Industries should be encouraged to use their own recycled waste water. If higher charges are levied on water supplied to industries they will be compelled to economise on it. In that case cleaner and greater quantity of water will be available for domestic consumption. Since water is available at a cheap rate industries are not compelled to set up effluent facility and recycling system. Providing clean and safe water for domestic purpose should be given first priority.

Index