## Government of India

## Central Water Commission

# GUIDELINES FOR PREPARATION OF RIVER BASIN MASTER PLAN

## Basin Planning and Management Organisation

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CONTENTS Page No.

Annexures

# FOREWORD

Water is a scarce and precious national resource to be planned, developed, conserved and managed in an integrated manner giving due regard to socio-economic and environmental issues. In the past, quite often the planning & development in water sector has been project oriented. With the increase in demand for water and its conflicting requirements for various uses, a stage has already reached for taking up development and management through river basin approach for optimal beneficial utilisation. National Water Policy envisages that water resources planning, development and management will have to be planned for a hydrological unit such as drainage basin as a whole or for a sub-basin multi-sectorally, taking into account surface and ground water for sustainable use incorporating quantity and quality aspects as well as environmental considerations. All individual developmental projects and proposals should be formulated and considered within the framework of such an overall plan keeping in view the existing agreements/awards for a basin or a sub-basin so that the best possible combination of options can be selected and sustained.

Central Water Commission had issued guidelines for the preparation of River Basin Master Plan in 1990. During the last 17 years a number of developments have taken place in water resources sector. The updated National Water Policy (2002) and 'Vision for Integrated Development and Management of Water Resources of the country' were brought out by Ministry of Water Resources, Government of India. Remarkable technological advancement have taken place worldwide in computer hardware and software for analysing the water resources system in a cost effective, comprehensive and reliable manner for integrated planning, development and management at river basin level.

Keeping the above in view, and thrust on "Integrated River Basin Planning, Development and Management (IRBPDM)" and other related issues the guidelines brought out earlier have been updated. New topics on 'Decision Support System (DSS)', IRBPDM, Policy Dialogue Model (PODIUM), etc. have been added to make the guidelines broad based and comprehensive.

I would like to place on record my appreciation for the hard work put in by the team of engineers and staff members of Basin Planning and Management Organization (BP&MO), CWC

I hope these guidelines will help in accelerating the preparation of the river basin plans for integrated and holistic development of water resources of the country.

( S.K. DAS)
Chairman
Central Water Commission

# PREFACE

From the dawn of civilisation, water has played a pivotal role in sustaining life as well as providing the impetus for agricultural and industrial growth. There is a large demand on water for irrigation, hydropower, domestic uses, industrial activities and even more for maintaining an environment and eco-system conducive for sustaining all forms of life. As the demand on the water resources increases with increased developmental activities, a large number of projects are necessarily to be taken up in the same river basin for supplying water for various purposes which many a time conflict with each other. In such a situation, project specific planning will no longer be conducive to the optimal utilization of the water resources. The National Water Policy (2002) lays down that all the developmental projects should be formulated within the framework of an overall plan for a basin/ sub-basin.

The Central Water Commission issued guidelines for the 'Preparation of River Basin Master Plan in 1990'. Since then many new challenges and issues have emerged in water resources sector. With the advent of technological breakthrough in computers, the use of personal computer (PC) based models has become order of the day. Keeping the above in view, the 'Guidelines' have been updated by the inclusion of new topics like 'Decision Support System (DSS); Policy Dialogue Model (PODIUM), 'River Basin Simulation' (RIBASM) – model etc.

I wish to place on record the commendable efforts made by the group of officers and staff of Basin Planning and Management Organisation, CWC in bringing out this 'Publication.'

It is sincerely hoped that this 'publication' would be of immense help in preparing the river basin plan for optimum development and management of the available water resources.

(B.S. AHUJA)
Member (Water Planning & Projects)
Central Water Commission

# PROLOGUE

Water resources planning and development have traditionally been project-oriented. However, as the demand on the water resources increases with increased developmental activities, a number of projects are necessarily to be taken up in the same river basin for supplying water for various purposes which many a time conflict with each other. In such a situation, project specific planning will no longer be conducive to the optimal development and utilization of the water resources. The National Water Policy (2002) lays down that all the developmental projects should be formulated within the framework of an overall plan for a basin/sub-basin. Central Water Commission issued Guidelines for the 'Preparation of River Basin Master Plan' in 1990.

The need for integrated river basin planning, development and management arises from the relationship between the availability of water resources and its possible uses in various sectors. Most development decisions today are multi-disciplinary in nature involving economic, social and environmental dimensions and values. This in effect involves consideration of a large number of factors relating to various disciplines connected with water resources, and an in-depth study and understanding of the basin's developmental requirements, priorities and limitations. Technological advancements in computer hardware and software, have facilitated the analysis of water resources system in cost effective, comprehensive and reliable manner at river basin level. The facilities such as Decision Support System (DSS), Geographical Information System (GIS) and Graphic User Interfaces (GUI) under WINDOWS environment are available for integrated water resources planning, development and management.

In view of the above and considering that many new challenges have emerged in water resources sector, it was felt necessary to update the 'Guidelines' to make it comprehensive. Updated 'Guidelines interalia include new topics on 'Mathematical Model', Decision Support System (DSS), River Basin Simulation Model (RIBASIM), Policy Dialogue Model (PODIUM), Integrated Water Resources Planning, Development and Management (IWRPOM).

I sincerely hope that the publication would be useful for the professionals involved in 'preparation of river basin master plan' for integrated development and management of available water resources in an optimum and efficient manner. Suggestions/comments for further improvement of the document would be highly appreciated.

(S.K. SINHA)
Chief Engineer
Basin Planning and Management Organisation
Central Water Commission

**<u>List of Officers of CWC associated with the preparation of this Guidelines</u>**

| | | | |
|---|---|---|---|
| 1. | Shri S.K.Sinha | - | Chief Engineer (BPMO) |
| 2. | Shri R.P.Saxena | - | Chief Engineer (Nagpur) |
| 4. | Shri M. S. Gupta | - | Director (Water Systems Engineering) |
| 3. | Shri K.C. Idiculla | - | Director (Basin Planning) |
| 4. | Shri Rishi Srivastava | - | Deputy Director (Reservoir Operation) |
| 5. | Shri Shakti Sarraf | - | Deputy Director (Basin Planning) |
| 6. | Shri Ashis Banerjee | - | Deputy Director (Basin Planning) |
| 7. | Shri Shekhrendu Jha | - | Deputy Director (National Water Planning) |
| 8. | Shri Sunil Kumar | - | Deputy Director (Water Systems Engineering) |
| 9. | Shri Kiran Pramanik | - | Deputy Director (Reservoir Operation) |
| 10. | Shri A.K.Sharma | - | Private Secretary (Basin Planning) |
| 11. | Shri Ashok Kumar | - | Personal Assistant, CWC |
| 12. | Shri Swaran Singh | - | Draughtsman Grade-I,(Basin Planning) |
| 13. | Shri Chetan Dev | - | Draughtsman Grade-II (Basin Planning) |

# CHAPTER – I

# INTRODUCTION

Water is a prime natural resource, a basic human need and a precious national asset. Planning, development and management of this important resource therefore need to be governed by the national perspective. It is a key element in the socio-economic development of a country. The Millennium Development Goals (MDG) adopted in the Millennium session of United Nations General Assembly emphatically highlights the vital role of proper water resources development and management for attaining the objectives of holistic development .The demand of water for diverse uses is continuously on the rise due to rapid growth of population, urbanization and industrialization. However, the availability of total water resources remains more or less constant. The concern on the depleting fresh water resources was expressed in the United Nations declaration of the year 2003 as the 'International Year of Fresh Water'. Subsequently, the U N General Assembly in its 58$^{th}$ session 2003 agreed to proclaim the years 2005-2015 as "International Decade for Action-Water for Life" commencing with the World Water Day, March12, 2005 and declaration of the year 2007 as the 'Water Year' by Government of India.

The National Water Policy (NWP) 2002 states that Water is a scarce and precious national resource to be planned, developed, conserved and managed on an integrated and environmentally sound basis, keeping in view the socio-economic aspects and needs of the States. It is one of the most crucial elements in developmental planning. As the country has entered the 21$^{st}$ century, efforts to develop, conserve, utilise and manage this important resource in a sustainable manner, have to be guided by the national perspective.

The United Nations Water Conference held in Mar-del Plata, Argentina in 1977 recommended the formulation of master plans for countries and river basins to provide long-term perspective for planning, including resource conservation using techniques like system analysis and mathematical modeling as planning tools, wherever applicable. International conference on Water and Environment, Dublin (1992), UN Millennium Development Goals (2000), International conference on Freshwater, Bonn (2001), World Summit on Sustainable Development, Johannesburg (2002) and World Water Congress, India(2005) have all recognized the long term perspective for sustainable water resources development & management and its role in poverty eradication. The National Water Policy also recommends that water resource development and management has to be done for a hydrological unit such as a drainage basin as a whole, or for a sub-basin. Special multi sectoral approach is the need of the hour by taking into consideration of surface and ground water. The approach needs to address not only irrigation but other requirements such as, Domestic, Industrial, Energy, Recreational and other uses as well. The importance of planning any project within broad framework of river basin master plan is thus amply emphasized and well recognised.

Most development decisions today are multi objective in nature involving economic, social and environmental dimensions and values. In the past, this fact was not seriously taken into consideration in planning for water resources development. Instead, economic development was considered to be a desirable end in itself, often with little regard to adverse effects on social or cultural systems and the natural environment. As the pace of economic development increases, these effects can no longer be ignored. The need to formulate plans for water resources development in a rational way, the multi-disciplinary nature of water resources planning, development and management requiring co-ordination among various Government agencies concerned with water, and the need to minimise adverse environmental impacts due to water development activities have all added to the complexity of water resources development and management.

Thus, the formulation of river basin master plan is neither a straight forward procedure, nor it is an easy task. It involves consideration of a large number of factors related to various disciplines connected to water resources and an in-depth study and understanding of basin's developmental requirements, priorities and limitations.

In order to assist the Irrigation and Water Resources Departments of the States/Union Territories in the preparation of river basin master plans, broad guidelines were prepared and circulated to all concerned indicating the contents of such a plan, data requirements and broadly the possible approaches. While these guidelines were not intended to be self-contained and complete in all respects, it was considered sufficient to serve as a pointer to the planner in choosing his directions of approach. In fact, the methodologies to be followed in specific cases vary and a generalization is not possible. A guideline like that can at best indicate the requirements. The ways and means to achieve this in specific cases is left to the ingenuity of the planner and analyzer. Keeping in view the updated NWP (2002) and the experience gained over the time, the guidelines (1990) were reviewed and the updated guidelines have been brought out.

# CHAPTER – II

# RIVER BASIN

India is a land of many rivers. Its geographical area of about 329 M.ha is criss-crossed by a large number of small and large rivers, some of them figuring amongst the mighty rivers of the world. The rivers have a great significance in the history of Indian cultural development, religious and spiritual life. Most of the towns were developed along the river reaches, as water is one of the prime necessity for sustenance of life. The rivers of the country are in fact the heart and soul of Indian life.

## 1.0 River System

The river systems of India can be classified into four groups viz., (i) Himalayan rivers (ii) Deccan rivers, (iii) Coastal rivers, and (iv) Rivers of the inland drainage basin. The Himalayan rivers are formed by melting snow and glaciers and therefore continuously flow throughout the year. During the monsoon months, Himalayas receive very heavy rainfall and rivers swell, causing frequent floods. The Deccan rivers on the other hand are rainfed and therefore fluctuate in volume. Many of these are non-perennial. The Coastal streams, especially on the west coast are short in length and have limited catchment areas. Most of them are non-perennial. The streams of inland drainage basin of western Rajasthan are few and far between. Most of them are of ephemeral character.

The main Himalayan river systems are those of the Indus and the Ganga-Brahmaputra-Meghna system. The Indus which is one of the large rivers of the world, rises near Mansarovar in Tibet and flows through India and thereafter through Pakistan and finally falls in the Arabian sea near Karachi. Its important tributaries flowing in Indian territory are the Sutlej (originating in Tibet), the Beas, the Ravi, the Chenab and the Jhelum. The Ganga-Brahmaputra-Meghna is another important system of which the principal sub-basins are those of Bhagirathi and the Alaknanda, which join at Dev Prayag to form the Ganga. It traverses through Uttaranchal, Uttar Pradesh, Bihar and West Bengal States. Below Rajmahal hills the Bhagirathi which used to be the main course in the past takes off at Jangipur while the Padma continues eastward and enters Bangladesh. The Yamuna, the Ramganga, the Ghaghra, the Gandak, the Kosi, the Mahananda and the Sone are the important tributaries of the Ganga. Rivers Chambal and Betwa are the important sub-tributaries which join Yamuna before it meets the Ganga. The Padma and the Brahmaputra join inside Bangladesh and continue to flow as the Padma.

The Brahmaputra rises in Tibet where it is known as Tsangpo and runs a long distance till it crosses over into India in Arunachal Pradesh under the name of Dihang. Near Passighat, the Debang and Lohit join the river Brahmaputra and runs all along the Assam in a narrow valley.It crosses into Bangladesh downstream of Dhubri. The principal tributaries in India are the Subansiri, Jia Bhareli, Dhansiri, Puthimari, Pagladiya and the Manas. The Brahmaputra in Bangaldesh receives the flow of Tista etc. and finally falls into Brahamputra. The Barak river, the Head stream of Meghna, rises in the hills in Manipur.

The important tributaries of the river are Makku, Trang, Tuivai, Jiri, Sonai, Rukni, Katakhal, Dhaleswari, Langachini, Maduva and Jatinga. Barak continues in Bangladesh till it joins the combined Ganga – Brahmaputra near Bhairab Bazar, and the combined stream is known as Meghna in Bangladesh.

The important river systems in Deccan are the Narmada and the Tapi which flow westwards into Arabian sea and the east flowing rivers, the Brahmani, the Mahanadi the Godavari, the Krishna, the Pennar and the Cauvery which fall into Bay of Bengal.

There are numerous coastal rivers which are comparatively small. While only handful of such rivers drain into the sea near the delta of east coast, there are as many as 600 such rivers on the west coast.

A few rivers in Rajasthan do not drain into the sea. They drain into salt lakes and get lost in sands with no outlet to sea. Besides these, there are the desert rivers which flow for some distance and are lost in the desert. These are Luni & others, Machhu, Rupen, Saraswati, Banas and Ghaggar.

On the basis of catchments, the river basins of India could be divided into the following three groups;

i) Major river Basins : River basins with catchment area of 20, 000 sq.km. and above.

ii) Medium River Basins: River basins with a catchment area between 20,000 and 2,000 sq.km.

iii) Minor River Basins : river basins with catchment area below 2,000 sq. km.

According to the above classification, there are 12 major river basins and the remaining medium and minor rivers are combined together to make 20 composite river basins for the purpose of planning and management (Fig. 1)

## 2.2 Water Resources Potential in River Basins

The water resources potential in 20 river basins of the country has been assessed from time to time. As per assessment of water resources (CWC, 1993) the average annual water resources potential of the country is around 1869 BCM. The same figure has been adopted by Standing Sub Committee on “Assessment of Availability and Requirement of Water for Divers Uses in the Country” (2000). Full utilization of all the available water potential is not possible due to the topographical, hydrological, the need for allowing certain amount of water to flow in the river for maintaining the river regime and other constraints. It has also been estimated that out of the average annual water resource potential of 1869 BCM (Fig. 2), the average annual utilisable water resource (surface and ground) is 1123 BCM of which about 690 BCM (Fig. 3) is from surface water and 433 BCM is from ground water. The basinwise water resources potential is presented in Table 1.

## 2.3 Water Resources Availability

Water as an element is abundant on Earth, the pool of annually renewable fresh water is limited and is becoming increasingly scarce relative to needs. The water resources in India are roughly 4% of the World's fresh water resources, whereas the country's population is 16% of the World's population. The average annual rainfall in India is about 1170 mm which corresponds to an annual precipitation of 4000 billion cubic metres (BCM) including snowfall. However, there is considerable variation in rainfall both spatially and temporally (Fig:- 4 & 5). While on the one hand the rainfall is as high as 11000 mm at Mausynram in Meghalaya, it is as low as only 100 mm in the western parts of Rajasthan. Moreover, nearly 75% of the total precipitation i.e. 3000 BCM is concentrated during the monsoon season confined to 4 to 5 months (June to October) in a year.

The **National Water Policy** recognizes water as a prime natural resource, a basic human need for all forms of life and a precious national asset. It also states that planning, development and management of water need to be governed by national perspective. According to the Policy, river basin is the basic hydrologic unit for planning and development of water resources, and therefore the assessment of water resources has necessarily to be basin-wise.

## 2.4 Per Capita Water Avalability

On an average, the total water resources availability in the country remains the same. The per capita water availability in the county is reducing progressively due to increase in population and rapid growth in urbanisation and industrialisation. The average annual per capita availability of water which was around 5200 cubic metre in the year 1951 has gone down to about 1820 cubic metre at present and would further reduce to around 1340 and 1140 cubic metre by the years 2025 & 2050 respectively. This reflects the National level scenario, though the average annual per capita water availability figures at the basin level may vary widely.

## 2.5 Creation of surface storage

Large parts of the country are endowed with only 45 to 50 rainy days a year. Out of this also the major share of rainfall is concentrated in only a couple of days. Water resources development received high priority in the successive Five Year Plans initiated after independence. It has resulted in many achievements that are discernable. Many major, medium and minor water resources projects have been constructed. India ranks third in the world after China and USA in terms of number of large dams. There are about

**Table 1**

**Water Resources Potential of River Basins Of India**

| **S. No.** | **River Basin** | **Catchment area (sq.km)** | **Average Water Resources Potential (BCM)** |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| 1 | Indus | 321289 | 73.3 |
| 2 | Ganga-Brahmaputra-Meghna | | |
| | (a) Ganga | 861452 | 525 |
| | (b) Brahmaputra | 194413 | 537.2 |
| | (c) Barak & others | 41723 | 48.4 |
| 3 | Godavari | 312812 | 110.5 |
| 4 | Krishna | 258948 | 78.1 |
| 5 | Cauvery | 81155 | 21.4 |
| 6 | Subernarekha | 29196 | 12.4 |
| 7 | Brahmani-Baitarni | 51822 | 28.5 |
| 8 | Mahanadi | 141589 | 66.9 |
| 9 | Pennar | 55213 | 6.3 |
| 10 | Mahi | 34842 | 11 |
| 11 | Sabarmati | 21674 | 3.8 |
| 12 | Narmada | 98796 | 45.6 |
| 13 | Tapi | 65145 | 14.9 |
| 14 | West Flowing Rivers from Tapi to Tadri | 55940 | 87.4 |
| 15 | West Flowing Rivers from Tadri to Kanyakumari | 56177 | 113.5 |
| 16 | East Flowing Rivers between Mahanadi and Pennar | 86643 | 22.5 |
| 17 | East Flowing Rivers between Pennar & Kanyakumari | 100139 | 16.5 |
| 18 | West Flowing Rivers of Kutch and Saurashtra including Luni | 321851 | 15.1 |
| 19 | Area of Inland Drainage in Rajasthan | --- | Negl. |
| 20 | Minor Rivers draining into Myanmar (Burma) and Bangladesh | 36202 | 31 |
| | **Total** | | **1,869.4** |

4050 completed large dams and 475 are under various stages of constructions. All these projects have resulted in increasing the live storage capacity from 15.6 BCM at the time of independence to 213 BCM now. Storages held in these dams are insurance against the vagaries of nature. Projects under construction are likely to add another 76 BCM while 108 BCM is to be contributed by the projects under contemplation. Basinwise distribution of storages is given in Table 2. Per capita storage in the country, which is about 207 cubic metre, is way below the storage achieved in many countries. India can store only about 30 days of rainfall compared to 900 days in major river basins in arid areas of developed countries. Therefore, there is an urgent need to vigorously pursue the case for creating storages, wherever feasible, given its projected rise in population, urbanization and industrialization.

Table: 1.8 Basinwise Storage in India
(Projects Having Live Storage Capacity of 10 MCM & above)

| | | | Live Storage Capacities | | | | (Unit:MCM) |
|---|---|---|---|---|---|---|---|
| S.No. | Name of the Basin | Average Annual Flow | Completed Projects | Projects Under Construction | Total (4 + 5) | Projects under Consideration | Percentage of Likely Average Annual Flow [(Col.6+Col.7)/ Col.3]x100 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | Indus | 73305 | 16285.9 | 282.53 | 16568.43 | 2576.39 | 26.12 |
| 2(A) | Ganga | 525023 | 39445.2 | 21215.18 | 60660.38 | 30083.92 | 17.28 |
| 2(B) | Brahamaputra & Barak | 585597 | 2326.92 | 9353.64 | 11680.56 | 41262.88 | 9.04 |
| 3 | Godavari | 110540 | 25124.6 | 6205.79 | 31330.39 | 5841.16 | 33.63 |
| 4 | Krishna | 78124 | 41803.98 | 7743.54 | 49547.52 | 1127.84 | 64.87 |
| 5 | Cauvery | 21358 | 8597.2 | 269.82 | 8867.02 | 261.99 | 42.74 |
| 6 | Pennar | 6316 | 2649.4 | 2170.71 | 4820.11 | | 76.32 |
| 7 | EFR From Mahanadi to Godavari and Krishna to Pennar | 22520 | 1601.44 | 1424.97 | 3026.41 | 945.29 | 17.64 |
| 8 | EFR B/W Pennar and Kanyakumari | 16458 | 1838.41 | 68.49 | 1906.9 | | 11.59 |
| 9 | Mahanadi | 66879 | 12334.8 | 1873 | 14207.8 | 10094.2 | 36.34 |
| 10 | Brahamani & Baitarni | 28477 | 4648.09 | 875.6 | 5523.69 | 8721.19 | 50.02 |
| 11 | Subenarekha | 12368 | 672.02 | 1650.19 | 2322.21 | 1380.5 | 29.94 |
| 12 | Sabarmati | 3809 | 1306.77 | 60.77 | 1367.54 | 99.33 | 38.51 |
| 13 | Mahi | 11020 | 4722.6 | 261.43 | 4984.03 | 11.81 | 45.33 |
| 14 | WFR of Kutch, Saurashtra Including Luni | 15098 | 4726.92 | 797.23 | 5524.15 | 2849.06 | 55.46 |
| 15 | Narmada | 45639 | 7229.5 | 16375.1 | 23604.6 | 465.73 | 52.74 |
| 16 | Tapi | 14879 | 9408.37 | 847.42 | 10255.79 | 286.92 | 70.86 |
| 17 | WFR from Tapi to Tadri | 87411 | 11268.03 | 3464.38 | 14732.41 | 81.69 | 16.95 |
| 18 | WFR from Tadri to Kanyakumari | 113532 | 10236.16 | 1317.54 | 11553.7 | 1453.31 | 11.46 |
| 19 | Area of Inland Drainage of Rajasthan | - | - | - | - | - | - |
| 20 | Minor River Basins Draining into Myanmar and Bangladesh | 31000 | 312 | | 312 | 1.467 | 1.01 |
| | TOTAL IN MCM | 1869353 | 206538.31 | 76257.33 | 282795.64 | 107544.68 | 20.88 |
| | IN BCM | 1869.35 | 206.54 | 76.26 | 282.8 | 107.54 | - |
| 21 | Medium Projects each having Live Storage Capacity of less than 10 MCM for which basin wise breakup is not available | - | 6241.000 | - | 6241.000 | - | - |
| | GRAND TOTAL IN MCM | 1869353 | 212779.31 | 76257.33 | 289036.64 | 107544.68 | 20.88 |
| | IN BCM | 1869.35 | 212.78 | 76.26 | 289.04 | 107.54 | - |

Source : Central Water Commission (WM Directorate)

MCM:MILLION CUBIC METRE — EFR : East Flowing Rivers

BCM: BILLION CUBIC METRE — WFR : West Flowing Rivers

# CHAPTER III

# GENERAL PROVISIONS

The National Water Policy envisages that water resources development and management should be planned for a hydrological unit such as drainage basin as a whole or for a sub-basin, multisectorally, taking into account surface and ground water for sustainable use, incorporating quantity and quality aspects as well as environmental consideration. All individual projects and proposals should be formulated and considered within the framework of such an overall plan keeping in view the existing agreements/awards for a basin or a sub-basin so that the best combination of options can be selected and sustained. There should be integrated and multi-disciplinary approach to the planning, formulation, clearance and implementation of projects, including catchment area treatment and management, environmental and ecological aspects, the rehabilitation of affected people and command area development. The Planning of projects in hilly areas should take into account the need to provide assured drinking water, possibilities of hydro-power development and the proper approach to irrigation in such areas, in the context of physical features and constraints of the basin such as steep slopes, rapid run-off and the incidence of soil erosion. The economic evaluation of projects in such areas should also take these factors into account.

## 3.1 Objectives

The purpose of preparing river basin master plans may be enumerated as follows:

- To prepare a long-term perspective plan for the development of the basin's water resources.

- To develop a comprehensive and integrated approach to the development of water and other natural resources using water with due regard to constraint imposed by configuration of water availability.

- To identify and set priorities for promoting water resources development projects.

- To formulate a short-term action plan consistent with the financial allocations and priorities of Government action plans.

- To contribute towards the formulation of a long-term national master plan for water resources development.

## 3.2 Contents

In general a river basin master plan should cover, but not to be limited to, the topics such as Basin features, Status of water resources development, Assessment of water and related resources, Need for development, Potential projects, Formulation of master plan. The contents under each topic are listed in Annexure - I.

## 3.3 Plan Period

3.3.1 Ideally, there should be a short-term programme or action plan covering the immediate 5-6 years and a long-term programme covering a period of not less than 20 years or when the population is expected to stablise in near future. It is necessary to consider the stabilized population for long term planning with extension schemes to be added as per requirements. It may, therefore, be stated that a river basin master plan should cover a period of about 20-25 years, revised and updated every five years with an action plan for the next five years that would deal specifically with investment for the next five years. This five-year period is also consistent with the five-year plan period adopted for the country as a whole by the national planners.

2.2.1 Planning is a continuous process. Therefore, master plan should be reviewed and modified periodically to incorporate up-to-date information on various factors affecting decision-making. The hydrology may change with availability of more data, the demand projections may change with changes in the rate of growth anticipated, the capacity of the country to finance projects may change as the country develops and there may be changes in the social needs and priorities of projects as the outlook of people changes. Even the goals and objectives may undergo changes. This revision, as indicated in the previous para for short-term action plans, may be carried out every five years.

# CHAPTER IV

# DATA REQUIREMENT

The perspective of a comprehensive master plan requires vast amount of data relating to assessment of water and related resources, estimation of water needs, identification of projects and formulation and evaluation of plans. The exact data requirement will vary depending upon the particular study environments and approach chosen. In general, the data normally needed would be of the following category:

5. Topographical data such as topographical maps, aerial photographs etc.
5. Hydrological data such as stream flow, snow data, watershed characteristics, sediment inflow rate, duration of flooding for various reaches of rivers.
5. Meteorological data such as rainfall, evaporation, temperature, etc.
5. Geo-hydrological data such as aquifer characteristics, ground water elevation, etc.
5. Water quality data for both surface and ground water including sources of pollution and related information.
5. Environmental data such as flora, fauna, historical monuments, wildlife sanctuaries, fisheries etc.
5. Land resources data such as land use, soil survey, land classification, etc.
5. Agricultural data such as cropping pattern, crop water requirement, etc.
5. Demographic data including urban and rural distribution, grouping by age, sex, etc.
5. Power demand survey data including alternative sources available, demand centres, etc.
5. Natural disaster data primarily for flood and droughts. These include disaster-prone areas, damage statistics, mitigation measures, etc.
5. Seismic data, especially in the vicinity of probable storages and structures.
5. Industrial data especially for those which are water-intensive. The data include growth trends, water consumption, possible alternate sources etc.
5. Inland water navigation data such as demand, alternate transport system available, etc.
5. Data on recreational prospects related to water resources development.
5. Data on projects in the basin such as completed and on-going projects and their water consumption (planned as well as actually utilized), potential projects identified including reconnaissance reports for major and medium projects. Data on flood control works carried out in the past and their performance.
5. Drainage works executed, evaluation. Data on drainage congestion problems including near the confluence point of tributary/sub-tributaries with main river, behind of the embankment system due to continuous high stage of Main River.
5. Geologic data such as formations, mineral deposits etc.
5. Economic data related to project/plan evaluation.
5. Financial data such as those required for financial feasibility analysis and also data on sectoral allocation of plan outlays, etc.
5. Legal constraints such as inter-state/international agreements and tribunal awards.

5. Social environment such as water-related institutions, interest groups, public awareness.

Apart from these data, the change in the food intake pattern, virtual export of water, in terms of food grain export from surplus to deficit water basin/sub basin, is also the growing concern of the planners.

The above category of data gives only a broad nature of data requirement. Emphasis on specific data varies from situation to situation. For example, the emphasis on the nature of data to be collected for a river basin in a predominantly arid region will be different from that for a river basin frequented by floods. The level of detail to be given in the master plan decides the extent of data collection.The planner has to decide these factors in individual cases.

# CHAPTER V

# APPRAISAL OF WATER RESOURCES

## 8.1 Purpose

8.1.1 The appraisal of available resources is a basic requirement in all resource planning exercises. Water resource planning is no exception. The purpose of appraising water resources is to determine the source, extent and dependability of supply and the character of water on which an evaluation of their future control and utilization is to be based.

8.1.2 Three aspects should be considered in appraising water resources, i.e., the quantity, the quality and the reliability of available water. In appraising the quantity, it is important to ascertain not only the total quantity available within a certain period of time, but also the distribution of the available quantity with respect to both location and time. In planning the utilization of water resources, the spatial distribution of available water often dictates the location of the various structures while seasonal distribution dictates their size. Quality of water is important especially for uses such as irrigation, domestic and industrial water supplies. Reliability of supply is an important aspect in deciding the value of water.

8.1.3 Water occurs as surface water and ground water. The division between the two is far from rigid. Surface water consists of direct surface run-off, augmented by a portion of ground water that moves laterally under ground and enters water courses. The portion of precipitation that percolates deep down and joins subterranean storage constitutes the ground water. Following is a brief discussion on the methods of appraisal of these two sources of water.

## 8.2 Surface Water

8.2.1 The appraisal of surface water resources generally includes estimation of (i) annual run-off and its monthly/ten daily distribution, (ii) aerial distribution of water resources within the basin, (iii) flood flows, (iv) low flows, (v) return flows and (vi) sediment load. (vii) Export/Import of water through inter-basin transfer. Where applicable, snow melt studies should also be carried out.

8.2.2 For a reliable appraisal of water resources stream flow records for around 40 to 50 years are desirable. In case of short records, temporal extrapolation can be done using suitable techniques. While gauge-discharge observation taken once a day will be sufficient for most yield studies, gauge observations at shorter period (hourly to 6-hourly) are required for flood estimation studies. The data should be compiled carefully and checked for consistency. Suitable gap-filling techniques may be used in case the data records are incomplete. A clear statement should be made in the master plan on the nature, source, reliability and adequacy of the data used.

8.2.3 As already mentioned, in case the length of observed run-off data is insufficient, it may be necessary to obtain long-term data using suitable techniques.

8.2.4 In case where the length of stream flow data is not adequate, but the length of precipitation data is sufficiently long, a statistical correlation is developed between precipitation and run-off using concurrent data and this relationship is used along with long-term precipitation data to obtain long-term run-off data. This method is more widely used and is found to be fairly adequate for annual run-off and monthly run-off during monsoon months.

8.2.5 If the basin is hydrologically homogeneous, the precipitation-run-off relation developed at a station may be used to obtain run-off data at another station in the basin using corresponding rainfall data. Similarly, precipitation-run-off relation can be transferred from an adjacent hydrologically homogeneous basin to the study basin and used.

8.2.6 If long-term run-off data are available at a station in the basin, it can be used to extend the short-term run-off data at some other station in the same basin by correlating the run-off data of concurrent period at the two stations following the same procedures used for precipitation-run-off correlation. In rare occasions, the long-term run-off data at a station may be reduced in the ratio of catchment areas or catchment areas and normal rainfalls at the two stations. But this method should be used very carefully and only in cases where the difference between the two catchment areas is small.

8.2.6.1 A very common constraint encountered in the context of water resources planning is inadequacy of stream flow records. A system designed on the basis of these short term available records may face a problem of being inadequate for the unknown flow sequence, that the system might experience in future. These flow data comprising a single short series do not cover a sequence of low flows as well high flows. The stability of a system has to be evaluated under these conditions which is not possible with the short term historical records alone.

In Hydrology, time series may be in respect of stream flows, precipitation, ground water, lake levels, water temperatures. The synthesis of stream flow data, however is not to analyze a time series but to generate the data based on the historical time series.

8.2.7 New techniques for generation of rainfall data and other hydrological data have been developed. Various stochastic models for generating the hydrologic data are MARKOV PROCESS or AUTO REGRESSIVE (AR) model, AUTO

REGRESSIVE-MOVING AVERAGE (ARMA) model etc. The choice of model will depend on the importance of parameters to be modeled and the data available. Similarly there are various conceptual models available such as Standford Watershed Model, Sacramento Model and Stream flow Synthesis and Reservoir Regulation Model which may be attempted for run-off data generation. The study of model chosen and its suitability should be discussed adequately.

4.0.0 Flood studies are concerned with the peak flows and/or the volume of flood flows. Methods commonly used for the estimation of flood are (a) unit hydrograph method and (b) flood frequency analysis. Flood frequency analysis will not give the volume of flood flows and therefore, in situations where the volume of flood flow is also important this method may not be suitable. A simple method called rational method is sometime used to estimate the peak flood flow for very small drainage areas. In this method, the peak flood discharge is calculated as the product of rainfall intensity and the area covered by rain and a coefficient is applied to the product to account for the losses by interception, detention and infiltration during the rain. For drainage areas larger than a few hundred square kilometers, and for important structures, unit hydrograph method should necessarily be used. The underlying assumption regarding uniformity of rainfall restricts the use of unit hydrograph method to drainage areas not larger than about 5,000 sq. km. If the drainage area is much larger than 5,000 sq. km, then the area may be divided into suitable sub-catchments and separate flood studies may be carried out for each of them and may be finally synthesized. As already mentioned, the flood frequency analysis method will be useful only for estimating the peak flood discharge of a specific return period. The analysis is purely statistical and hence the limitations. A method to synthesise unit hydrograph at an ungauged station from the unit hydrograph derived at another station with comparable hydrological and meteorological catchment characteristics, is also available and can be attempted whereever suitable. Regional approach is also possible. CWC has published reports in this direction for several similar homogeneous hydrometeorological regions of the country for small and medium catchments.

4.0.0 Estimation of sediment load and analysis of its effect are important since sediment deposition in reservoirs depletes their useful capacity and hence their performance. In a wider sense, the process has also an effect on the river morphology. The rate of sedimentation may be obtained either from the sediment discharge observations or from hydrographic survey of existing reservoirs. The estimation of sediment rate from either of the above sources should take into account the differences in sediment producing characteristics of different catchments, effects of soil conservation measures, trends, projections and interception by upstream structures.

The reliability of appraisal of water resources largely depends on the adequacy and reliability of data used for the appraisal. Hence, master plan should evaluate the existing hydrological and meteorological network in the basin, the method of observations and discuss the adequacy and if necessary, suggest measures for improvements. There are guidelines issued by World Meteorological Organisation in this respect. The National Commission for Integrated water resources development recommended that it is desirable to carry out reassessment periodically say once in 5 to 10 years.

## 4.0 Ground Water

Ground water is an important source of water and its development is crucial especially in areas where surface water resources are scarce. In many regions, ground water is the only dependable water source for drinking as well as for irrigation. It is also important as a supplementary source to surface water.

4.0.0 The appraisal of ground water is much more complicated than that of surface water, because unlike surface water ground water is not confined to any channel or exposed to vision for a direct measurement. The basic information needed for assessing the ground water availability are the type and location of aquifers, their thickness/depth and their characteristics such as hydraulic conductivity and storage coefficient. These are obtained from water level observations in wells, surface geological mappings, test drilling and pumping test data. The most important information required by the planner is the annual rate of recharge, because in the long-run, the availability is restricted by the annual rate of recharge. Utilisable ground water is that portion of available ground water that can be economically developed and utilized with the available technological know-how. This should be assessed.

4.0.0 In certain areas, over pumping of ground water from aquifers may cause excessive lowering of water table resulting in undesirable adverse effects such as excessively higher cost of pumping, decrease in available yield, salinity intrusion and ground subsidence. Such areas should be identified and appropriate remedial measures should be recommended. The assessment of utilizable ground water should reflect these considerations.

4.0.0 The existing hydrological network for monitoring ground water levels should be reviewed and their adequacy discussed in the master plan with appropriate suggestions for improvement.

## 4.0 Quality of Water

An appraisal of water resources is not complete without a mention of the quality of the available water. The quality of water is greatly affected by the presence of minerals in soils and rocks through which the surface and ground water flows. But, with rapid industrialization and urbanization, the greatest threat to the quality of water is from urban and industrial water effluent. Run-off from agricultural fields contaminated with pesticides and chemicals further aggravate the situation.

4.0.0 The investigation of quality of water depends upon the purpose of its use. Water used for drinking purposes should not contain any substances harmful to the health. Water for industrial use must be suitable for the specific processes involved in the particular industry. Irrigation water must not contain objectionable salts and other substances, dissolved and suspended beyond permissible limits. Water bodies used for recreational purposes must be free from nuisance creating pollutants and pathogenic bacteria while those for fish breeding should be free from toxic substances and meet necessary standards regarding dissolved oxygen. The water quality standards developed by Central Pollution Control Board for different uses may be followed.

4.0.0 The general steps that may be followed in investigating the water quality in a basin, may be as follows:

( ) Compile all available data on stream and well water quality;
( ) Compile information on the sources of pollution such as industries and urban centres, sewage treatment plants and quality of effluents;
( ) List the existing and anticipated water use points and quality standards for each use;
( ) From (i) and (iii) find out the possible water uses of untreated water;
( ) Estimate the probable cost of treatment;
( ) For ground water, explore the possibility of conjunctive use of brackish and sweet water.

4.0.0 The deterioration of stream water quality due to its contamination by industrial and domestic effluents has increased the awareness regarding water quality among environmentalists and the public in general. Therefore, the planner has to devote particular attention to water quality management in river basin planning. Water quality modeling techniques can be used to determine the degree of treatment required, the relocation of waste discharge points, etc. In general, water quality models are complex; but often simplified assumptions and approximations are made. For example, assumptions of steady state conditions are made in most water quality models even though it is essentially a transient phenomena. Similarly, most models developed are deterministic and one dimentional. Most of them model only BOD and DO concentration. Some of the available models for water quality modeling are QUAL –IIE developed by the Army Crops of Engineers, USA, TOMCAT developed by the Thames Water Authority, UK and DIURNAL model developed by the United States Environmental Protection Agency. Since the subject is a specialized field, it would be appropriate to utilize the services of a well- qualified and experience expert for this part of the planning study.

# CHAPTER VI

# APPRAISAL OF LAND RESOURCES

For agricultural development, water and land resources form the most essential inputs. The availability of land decides both the potential and limitations of agricultural production. Therefore, during formulation of a basin master plan, it is important to have an appraisal of available land resources in the basin and their limitations. The master plan should also discuss the planned growth of developed land areas and proposals for agricultural development. Possible alternate rational uses of agricultural land should also be considered and discussed.

## 8.1 Purpose

8.1.1 The appraisal of land resources should include assessment of existing land use pattern, areas suitable for irrigation, areas requiring drainage and areas that can be reclaimed and used for cultivation. The required data are usually collected through land use surveys, land classification surveys and soil surveys.

8.1.2 Suitability of land for irrigated agriculture depends upon its physical and chemical properties and on socio-economic factors of the region. The physical and chemical properties of land which determine the degree to which lands can be put to agricultural use are the climate, soil, topography, drainage conditions etc. The socio-economic factors determine how far the people may be willing to adopt irrigated agriculture.

8.1.3 Land available in the basin need to be assessed for requirement of any treatment if required, particularly in those areas where cultivable land without treatment is insufficient.

## 8.2 Land Use Pattern

8.2.1 Land use pattern describes the existing division of land under various categories such as forests, culturable areas, fallow lands, areas not available for cultivation such as urban areas, and cropped areas. This will enable a ready assessment of the potential for agricultural development in the basin and to assess whether land resources is a constraint for development.

8.2.2 Land use data are usually available with the revenue authorities and no specific surveys are normally required. However, these data are seldom available basin-wise. They are compiled and published for revenue units such as a district/sub-division/block. Hence, approximation based on area may have to be made. Such approximations are permissible till more detailed surveys are taken up. Satellite imageries may be a handy tool.

## 8.3 Land Classification Surveys

8.3.1 These surveys may be reconnaissance level surveys, semi-detailed or detailed surveys. Reconnaissance and semi-detailed surveys are sufficient for master plan preparation, while detailed surveys are carried out at the time of preparation of detailed project reports.

8.3.2 Reconnaissance surveys are intended to identify the general outline of land features and the extent of areas available for agricultural development. Topographic maps (scale 1:25000) along with data on existing land use pattern will suffice for this purpose.

8.3.3 Semi-detailed surveys are carried out to examine the land features more carefully and to locate potentially irrigable areas. Arable and non-arable lands are identified more accurately at this stage. A larger scale map, say 1:10,000 would be preferable for this analysis. Aerial photographs adjusted to the above scale may also be used.

## 8.4 Soil Surveys

8.4.1 Soil surveys are carried out to determine their fertility, crops that may be grown, yields that may be expected, irrigability of land, water delivery requirements, land development needs such as needs of drainage and specific reclamation practices. Soil survey should cover the following aspects of soil: (i) physical properties such as colour, texture etc; (ii) chemical properties such as pH, soluble salt, salinity, alkalinity etc; (iii) soil erosion; (iv) soil classification such as family, series, type, phase; (v) land capability classification; and (vi) irrigability classification.

8.4.2 The suitability of land for sustained use under irrigation is determined and the basin is grouped into soil irrigability groups. IARI has classified soils into five categories A,B,C,D and E class soils according to increasing limitations of sustained use under irrigation. These are :

Class A : None to slight soil limitations
Class B : Moderate soil limitations
Class C : Severe soil limitations
Class D : Very severe soil limitations
Class E : Not suited for irrigation.

8.4.3 Land capability classification is basically an interpretive grouping of soils primarily meant for agricultural purposes. The classification is based on soil characteristics, external land features such as slope and environmental factors related to drainage such as drainage outlets, depth of water table etc. This classification indicates the suitability of lands for various crops and is of vital importance to planners. On the basis of the criteria given above, land is broadly classified as that suitable for cultivation or arable lands and that unsuitable for cultivation or non-arable lands. There can be further classification under each category depending upon their relative suitability or otherwise for agriculture.

5.0.0 In some basins, water logging and salinity may be major problems. Maps showing areas liable to water logging and salinity along with depth of water table etc. should be prepared. These maps will be useful in planning crops and exploring possibility of conjunctive use of surface and ground water.

# CHAPTER VII

## PRESENT AND FUTURE POPULATION

8.1 Any planning needs the sustainability of the desired system for considerable period, and to design such system one need to know the design parameter for present and for future period. So, compilation of data on present population and its projection to the end of planning period are of vital importance in river basin planning. An accurate estimate of the future water demand depends on an accurate forecast of future population. The estimate of population is useful not only in assessing the water demand, but also in assessing the human resource potential in the basin. Every effort should, therefore, be made to have a fairly reliable estimate of present and future population on which the master plan can be based. Similar projection for livestock population is also required for assessing water requirement for live stock.

8.2 In our country, population census are taken once in every ten years. This gives very descriptive data on population such as rural and urban distribution, gender ratio etc. However, the data given in the census reports are compiled for political divisions such as states, districts, urban agglomeration and so on. Therefore, in order to estimate the population for a river basin, approximations, based on area proportion would have to be made.

8.3 For reliable population projection, the following data are normally required. (i) Bench mark or base line population data; (ii) Vital statistics which provide information on population changes such as births by age of mother, deaths by age of decedent, rates of marriages, school enrolment statistics, migration of population and so on. Bench mark data should contain at least as much detail as the final projection is to include. The normally required details are the growth rate of population, its density, literacy percentage, percentage of urban and rural population and work force.

8.4 Various methods are available for projecting population. The suitability of any method depends on the nature of data available. Some of the methods that can be used for projection of population are the mathematical method, the component method, the economic method and the analogy method.

8.5 The mathematical method allows past populations to be projected using linear or exponential extrapolation of a time series of historical values. This is the simplest and most widely used method. Other methods of mathematical extrapolation using historical values include those assuming a uniform growth of population, a uniform rate of growth of population or a decreasing growth rate of population.

8.6 In cases where detailed data on population are available, another method called component method (or Cohort survival method) may be used. In this method, the future changes in the various components constituting the population growth are worked out. The total population is classified by age and sex. Current birth and death rates are applied for each class and extrapolated into the future. Separate projection for migrant population, both in and out of the basin should be made where this component is likely to be significant. Composition of such migrant population and their economic status are also desirable information that may be assessed.

6.0 A third method of population projection called economic method treats population as dependent variable on economic activity. It takes into account future need for food, raw material, manufactured products and services in the total market area. On this basis a labour force required to satisfy the demand for local production is predicted which in turn is used to predict the population. This method may be useful for larger area like a country as a whole where the economic inter-relationships between production centres may be analysed using models like input-output model.

6.0 Analogy method is used when little or no demographic data is available. In this method, population is projected by transposing demographic figures for areas with comparable social and economic conditions. Since our country has fairly good demographic data, this method may not be generally required. However, for predicting migration component of population, analogy with migration experienced in similar project areas may be employed.

# CHAPTER VIII

# AGRICULTURE

Agriculture is the biggest consumption media of water resources and hence minor deviation in assessment of requirement of water resources may lead to greater variation in resources and time. So, agriculture plays an important role in the economic development in general and particular in context of India. Land and water form the two essential inputs to agriculture. These two resources and their assessment procedures have been discussed in earlier chapters. This chapter will discuss the aspects of agriculture that are important in the preparation of river basin master plans.

## 7.0 Present Status of Agriculture

A general survey of the basin's agricultural sector should be made to assess the present status of agricultural development in the basin. The assessment should include an appraisal of the performance of agricultural sector, appraisal of the important problems faced by the sector and a study of the trend of development of the sector in relation to the national planning framework. The survey should assess the extent of land under cultivation, crops grown, crop rotation, irrigation facilities available, crop yields, marketing facilities, rural population engaged in agriculture, alternate employment opportunities and willingness of the farmers to adopt improved methods and practices. An assessment of available credit facilities through agricultural financial institutions and existing agricultural extension services will also be desirable.

## 8.2 Demand Projections for Agricultural Products

8.2.1 Demand projections of agricultural products are usually made as a range of possibilities as they are dependent on population growth, government pricing policies, personal income and supply of commodities. The demand for particular commodities depends on the food habits of the people and living standards. The demand for cash crops will depend on the exiting and future potential for agro-based industries. Since it is difficult to obtain an accurate estimate of some of these variables, attempts should be made to estimate the range of demands for commodities.

8.2.2 Since the primary objective of planning increased agricultural production is to satisfy the nutritional needs of the population, this forms a rational basis for estimating the food production requirements. Knowing the per capita requirement of major commodities and population projection, the total food production requirement can be estimated.

8.2.3 Considering the world market for food grains and the likely increase in the future, there may be need for exporting food grains or their equivalent in other agricultural products. Considering this, the demand projection should also include the desirability of exports. The marketing facilities and development of road in command area will also influence the tendency to lean more toward irrigation for livelihood and thus increase the irrigation requirement.

# CHAPTER IX

## EXISTING WATER MANAGEMENT SYSTEM

9.1 It is essential to conduct an appraisal of the existing water management system in all major fields of water uses. This should include a description of the existing structural facilities available, water management practices and issues and problems. Information on the existing water use and management will enable the planner to assess the committed water uses and to arrive at net water available for further planning. It will also enable him to study the current practices and correct any deficiencies in future planning.

9.2 By far, irrigated agriculture is the biggest consumer of water in India. Other major water use sectors are domestic and industrial water supply, power generation, navigation, recreation and low flow augmentation. With regard to irrigated agriculture, the area under irrigation from various sources such as surface and ground water sources, state-owned and privately owned sources, irrigation from major, medium and minor projects, irrigation by flow and lift irrigation etc. may be compiled. Most of these information can be compiled from the agricultural statistics published by the district administration. Information on other water uses may be available with local bodies, industrial establishments and other governmental/private organisations connected with water uses.

9.3 An inventory of the existing and on-going water resources structures and their capacities should be made. Data should be collected on their planned, created and utilized potential and the reasons for any under-utilisation of the potential created. Constraints in operating these structures and full utilization of the potential should be investigated. In the case of multipurpose projects, conflicts in the usage of the created facilities for various purposes should be studied.

9.4 An area of crucial importance is the irrigation methods currently practiced and their implications. Water delivery methods employed, such as rotational delivery, continuous delivery and delivery on demand, and their effectiveness in efficient use of water should be discussed. Existence and adequacy of proper drainage system and related problems should also be discussed in the master plan. A review should be made of the existing institutional arrangements for farmers' participation in the water management and standard of maintenance of irrigation and cross-drainage structures.

9.5 The master plan should also contain an account of the problems related to various water uses. Areas experiencing water logging and salinity problems should be identified. Equity in supply of irrigation water, especially to tail enders, conveyance losses, necessity of canal lining and efficiency of irrigation water use should be investigated and discussed. Similarly, problems associated with other existing water uses should also be identified and discussed.

# CHAPTER X

# ENVIRONMENTAL PLANNING

The lack of environmental consideration in the planning of water resources projects can sometimes create severe impacts of irreversible nature on the environment, resulting in ecological destruction. In the last decade or so, wide recognition has been given to the existence of ecological problems associated with water resources development schemes. The NWP (2002) also states that in the planning, implementation and operation of a project, the preservation of the quality of environment and the ecological balance should be a primary consideration. For sustainable development, environmental protection should be an interal part of the development process. The adverse impact, if any, on the environment should be minimised and should be offset by adequate compensatory measures. To ensure that the environmental concerns are dealt within the planning phase of project, procedures have been established in many countries which are called Environmental Impact Assessments (EIAs). The government of India, Ministry of Environment & Forest has formulated a National Environment Policy in 2006. The policy is intended to mainstream environmental concerns in all developmental activities. Even in case when no planning of any water resources development scheme is envisaged in the immediate future in the basin, it is necessary to have environmental status reports prepared for each basin. These reports would serve as benchmark information for future planning.

## 10.1 Environmental consideration

There are number of environmental parameters which are required to be considered and incorporated in the planning stage of the water resources projects.During the planning and feasibility assessment stages of river valley projects the following aspects need to be seriously considered:

(i) Location aspects : Short term and long term impact and population/human settlements in the inundated watershed areas, impact on flora and fauna, impact on wildlife, impact on national parks and sanctuaries, impact on cities of monuments of historical, cultural and religious significance, impact on forests, agriculture, fishery, recreation and tourism etc.

The significance of considering these aspects is to ensure that the site selected is devoid of ecologically sensitive (fragile) areas consisting of biosphere areas, national parks and sanctuaries and sites having rare/endangered species etc. to the extent possible.

(ii) Physical aspects: Landslides, siltation, groundwater recharge, water quality changes, land use patterns etc.

Physical aspects are considered to study the alterations in the surface flow patterns that have far reaching impact on underground aquifer and their recharge.

(iii) Resource linked aspects: Resource trade-off, such as loss of optional land use to impoundment, mineral deposits, monuments inundated, dislocation of existing settlements etc.

The evaluation of these aspects are necessary in view of large scale disruption due to creation of impoundment which may result inevitably in the adoption of alternative land uses.

(iv) Socio-cultural aspects: Population relocation requirements, identification of educational and vocational training programmes to be imparted to the affected population, resettlement areas for housing and other amenities for the resettled population.

Since relocation may strain/disrupt the social fabric of the affected population, consideration of these aspects is necessary to make the quality of life of the affected better or atleast maintained at the same level as earlier.

(v) Public health aspects: New health problems or vector patterns arising due to changes in water velocities, temperature, other physical change factors, adequate public health planning to create facilities for migrant construction workers.

(vi) Cost benefit analysis: Compensatory afforestation, restoration of land in construction areas, control of aquatic weeds, establishment of fuel depots to meet fuel requirement of the labour force, public health measures to control spread of water borne diseases etc.

The cost of proposed remedial and mitigative measures are to be included in the project costs.

A detailed listing of the environmental aspects that are required to be considered during the planning and construction stage of river valley projects are given under 1.4 of 'Guidelines for Environmental Impact Assessment of River Valley Projects' issued by Ministry of Environment & Forests. Only when the integration of environmental aspects in the planning and execution is made a part and parcel of all river valley and other development projects it would be possible to have a rapid economic development on a sustained basis while safeguarding the natural resources including the air, water, land, flora and fauna for the benefit of present and future generations.

## 10.2 Environmental Impact Assessment

Environmental impact assessment has the following steps :

( ) Problem identification and formulation;

( ) Evaluation of alternatives (including consideration of long-term environmental and social impacts) and selection of best alternative;

( ) Monitoring and evaluation.

The detailed discussions on these steps are provided in the UNEP publication on 'Sustainable Water Development and Management-A Synthesis'.

### 10.2.1 Problem Identification and Formulation

Planning for water resources development is initiated in response to needs that already exist as well as to needs that are anticipated for the future. Translating needs into problem formulation is itself a complex process requiring techno-economic skills and political, institutional insights. A wide range of different situations may be encountered at this stage. Among some of the main problems and constraints that could have a direct impact on the problem formulation process are : (i) administrative and hydrological boundaries usually do not coincide, (ii) time and budget allocations are often limited, (iii) various regulations and legislative requirements narrow the range of possible alternatives, (iv) water needs are determined exogenous to the planning process and (v) adequate number of trained persons may not be available.

### 10.2.2 Evaluation of Alternatives and Selection of Best Alternative

Of all the steps enumerated in the evaluation of the alternatives and the selection of the best alternative (best compromise alternative) is the most important part of the Environmental Impact Assessment. A number of methods have been developed for conducting the environmental impact assessment. Some of the commonly used techniques are; (i) ad hoc method, (ii) check list, (iii) matrices, (iv) overlays, (v) networks, and (vi) modeling. Each method has its own advantages and limitations. Example on each of these technique is given in 'Environmental Impact Analysis Handbook' edited by John G. Rau and David C. Wooten (published by Mc Graw Hill) which may be referred to.

While adhoc method gives broad qualitative information, the matrix method and modeling techniques using systems analysis are comprehensive and they present a wide range of alternate possibilities and their consequences in the decision maker's choices. Therefore, the technique that could be resorted to by any project authority would depend upon the available data, manpower and other resources.

### 10.2.3 Monitoring and Evaluation

Monitoring and evaluation has to be an integral part of the management process if water development projects are to be sustainable. As soon as the projects or the development plan becomes operational one of the issues of critical importance is analysis of performance, aimed at determining the extent on which the objectives of the project or development plan are being achieved. The environmental impact assessment, as such, is not a one time affair. It has got to be carried out at regular intervals in order to study the environmental changes/implications of the development vis-à-vis the envisaged one. The constant environmental monitoring mechanism would assist the water resources planners to adopt suitable ameliorative measures where needed. Further it provides a valuable information base for planning future projects. The fundamental requirements for a water development project should have the following: (i) Timeliness, (ii) cost effectiveness, (iii) maximum coverage, (iv) minimum measurement error, (v) minimum sampling error, (vi) absence of bias, and (vii) identification of user's information.

## 10.3 Data for Impact Assessment

The data required for environmental status and impact assessment and their source have been listed in Chapter II of the 'Guidelines for Environment Impact Assessment of River Valley Projects'(1999) of the Ministry of Environment and Forests. The River Valley Project is one of the projects identified for environmental clearance from the Central Government. In this context the provision of the Environment impact assessment notification of MoEF dated 14.09.2006 and Guidelines for Monitoring of Water Resources Project of Central Water Commission (Environment Management Directorate)- March 1998, as amended from time to time should be followed.

## 10.4 Environmental Management Plans (EMP)

Environmental management plans for all likely adverse impacts are necessary to be prepared in advance at the planning stage itself and should become an integral part of the master plan. The rehabilitation measures, afforestation schemes, relocation of historical/cultural monuments, relocation of sanctuaries and wildlife habitats getting affected during the project, counter measures to reduce the problems of water logging and salinity etc. are some of the items that are to be included in the environmental management plans. Regarding Resettlement & Rehabilitation (R&R) the National Water Policy (2002) states that optimal use of water resources necessitates construction of storages and the consequent resettlement and rehabilitation of population. A national policy on resettlement and rehabilitation of Project Affected Families (PAFs) – 2003 has been formulated by MORD, Department of Land Resources, so that the project affected persons share the benefits through proper rehabilitation. States should accordingly evolve their own detailed resettlement and rehabilitation policies for the sector, taking into account the local conditions. Careful planning is necessary to ensure that the construction and rehabilitation activities proceed simultaneously and smoothly.

Catchment management plan which is an integral part of the environmental management plan is aimed to reduce the sediment inflows into the reservoir besides assisting the regeneration of the streams. Various soil conservation measures such as bunding, contour trenching, check bunds, planting of vetiver grass, etc. form an important part of the catchment area treatment programme. The vital role of forests in protecting fragile eco systems, watershed, fresh water resources and as store house of bio-diversity should be recognized. Forest is a primordial component of environment. The provisions laid down under the forest (conservation) rules, 1981 (as amended upto May, 1992) of the Forest ( conservation) Act, 1980 of Central Government and National Environment Policy-2006 should be taken into consideration.

## 10.5 Dam Break Analysis and Emergency Action Plan (EAP)

Construction of a dam involves many considerations including a large no. of potential benefits to be derived from their use but it also create a structure with potential hazards which may result from their unlikely failure. When a man made dam fails, the huge volume of water stored results in a flood wave which may cause irreparable damages to the lives and properties situated along the banks of the river downstream of the dam. The effect of flood disaster can be mitigated to a great extent if the magnitude of flood peak and its time of arrival at different locations downstream of the dam be estimated to plan evacuation measures in advance. It also makes possible to assess the damages that can be caused at various important locations and to formulate the disaster management plan which is a mandatory document to be submitted to Ministry of Environment and Forest for environmental clearance of river valley projects including hydel power, major irrigation and their combination including flood control.

This study needs to be carried out and EAP is required for safety of life and property in the event of extreme disaster.

# CHAPTER XI

# WATER USES

Man uses water for a multitude of purposes. The important uses of water are : irrigation, hydropower generation, domestic and industrial use, inland navigation, fish and wild life preservation, and recreation. Flood management, though not a water use in the strict sense, also may be added to this, since it involves regulation of water and hence affects the availability for other uses. The estimation of future water demand by the various user sectors in the basin is an important aspect of master plan preparation. According to the National Water Policy the priorities of water use should be : (i) Drinking water, (ii) Irrigation. (iii) Hydropower, (iv) Ecology, (v) Agro Industries and non Agricultural Industries and (vi) Navigation and other uses.

## 11.1 General

11.1.1 While considering the uses of water one should differentiate consumptive and non-consumptive uses. Under non-consumptive uses are the generation of hydroelectric power, development of navigation and recreation, for which a certain rate of supply is required but not consumed except incidentally in evaporation and seepage losses.

11.1.2 Irrigation, industrial and domestic water supplies are main consumptive uses of water. Here also, a distinction should be made between actual consumption and water requirement. Taking the case of irrigation, all the water supplied is not consumed by plants. Quite a portion escapes as surface run-off and is lost through percolation which ultimately may return to the stream or add to the ground water storage. Similar is the case with other consumptive uses such as domestic and industrial use.

11.1.3 The return flows from consumptive uses described above join the stream at a downstream point and are available for further use. However, the quality of the return flow may be substantially different from the quality of intake water and may cause deterioration of water quality of stream. This aspect requires to be considered while accounting for the return flow as an available supply downstream.

11.1.4 Another aspect to be looked into is the complementarity between consumptive and non-consumptive uses. If complementarity can be brought about between consumptive and nonconsumptive uses in time and space, much saving of water can be effected and the water use will be most optimal or nearly so. This will also result in considerable saving in the capacity requirements of dams, barrages etc.

## 11.2 Irrigation

11.2.1 Irrigation of land for agriculture represents one of the oldest and most important uses of water, next only to providing water for domestic purposes. The requirement of irrigation water arises out of the necessity to supplement water to the crops either due to aridity and drought or for ensuring the best possible crop returns. Estimates of future irrigation water requirement should be backed by a detailed land and agricultural survey. This should consider the suitability of land for irrigation, suitability and acceptability of cropping pattern and farming practices. Climate and type of soil are other related factors.

11.2.2 Cropping pattern: The existing cropping pattern may undergo changes with the introduction of irrigation. The projected cropping pattern should take into account the agricultural productivity of land, climate and above all the farmer's choice. Experience in areas with similar characteristics will be a guidance in this regard. The cropping pattern is also likely to change with changing market conditions over the life of the project or the planning period. Such possible changes should be visulalised and incorporated. In a large basin, different cropping patterns may have to be adopted for different regions or sub-basins. It may even vary from project to project.

11.2.3 Crop Water Requirement: The term water requirement of crops implies the total amount of water required at the field to mature the crop. It includes evapo-transpiration ($ET_c$), application losses and special needs and does not include transit losses. Special needs include requirement for puddling, transplanting, leaching salts etc.

The crop water requirement may be determined from data collected on yield vs. applied water from fields or experimental plots for specific crops in a specific locality having characteristic values or consumptive use and effective precipitation. If such data are available at field experiment stations in the basin or nearby areas with comparable characteristics, these should be used.

In the absence of such data, crop water requirement may be estimated from ET values. The ET may be measured directly by soil moisture depletion studies by conducting field experiments. Alternatively, many formulae are available for computing potential evapotranspiration ($ET_o$). Some of the more commonly used formulae are the Blaney-criddle, Christianson's and Penman's methods. The modified Penman method which is based on energy concept and aerodynamic principle, is considered more reliable. However this requires a large number of weather parameters such as humidity, wind velocity, radiation, sunshine hours etc. Ministry of Water Resources publication 'A Guide for estimating Irrigation Water Requirements' recommends either Christianson's method or modified Penman method depending upon data availability.

The Food and Agricultural Organisation (FAO) of the United Nations has brought out a publication (No.24) 'Guidelines for Predicting Cropwater Requirement'. The method recommended by FAO considers $ET_o$, a crop coefficient, kc, to reflect the effect of crop characteristics and a correlation factor to take into account the effect of local conditions and agricultural practices on crop water requirement. The guidelines also give approximate ranges of crop evapotranspiration for different crops and may be used in case data necessary to compute $ET_o$ are not available.

11.2.4 Irrigation Water Requirement: Irrigation water requirement of crops is the gross amount of water required to be applied through irrigation. Usually, it is only a part of the total crop water requirement and its amount will depend on the contribution from rainfall and the soil profile.

The part of rainfall falling directly in the agricultural field which contributes towards crop water requirement is called the effective rainfall. The effective rainfall can directly be determined by using suitable field lysimeters. The contribution of soil profile moisture towards crop growth will depend on the capacity of soil to hold water. There is no simple method to determine this and the determination itself is possible only when the ground water level is far below the root zone of crops so that there is no capillary effect.

The net irrigation water requirement is obtained by deducting effective rainfall and soil moisture contribution from crop water requirement. This is the irrigation water to be supplied at the head of field channel. The gross irrigation water requirement will include the seepage and other losses during conveyance. The conveyance losses will mainly depend on soil through which the canal runs and whether the canal is lined or unlined. The conveyance losses may amount to 30% to 40% of the water released at canal head and the total losses including field losses may be as high as 50% to 80%. Therefore, the master plan should critically discuss this issue and suggest suitable measures to reduce losses and increase irrigation efficiency. Lining of canals and alternate methods of irrigation like sprinkler or drip irrigation may be costly propositions, but are worth studying for their economics.

Efficient and equitable distribution of water is an important requirement for proper management of an irrigation project and poor management of project would lead to low yields and thus reduce the economic benefits. Evaluation of the performance of a system as a whole or its components will help in improving the O&M of the project. The "indicators for irrigation performance assessment" published by INCID November, 2001 contains broadly the district aspect and studies required to be carrying out may be referred for this purpose. These indicators were evolved keeping Indian perspective in view and are only indicators and not exhaustive.

Further, irrigation being the largest consumer of water, all those involved in the sector will have to strive for higher standards of water use efficiency to save and conserve this precious resources to get optimal output. In this regard "benchmarking" process is an important management tool in irrigation sector so as to improve water use efficiency and management of irrigation projects. The guidelines "benchmarking of Irrigation systems in India" brought out by INCID (June, 2002) would prove useful to all those concerned with irrigation and water resources development projects.

## 11.3 Power/Energy Requirement

11.3.1 The water use related to power generation comes under two categories : (i) the water requirement for hydroelectric power generation, and (ii) the cooling water requirement for thermal and nuclear power plants. The first one is mostly non-consumptive except for evaporation and seepage losses whereas the second one is partly consumptive and partly non-consumptive.

11.3.2 Before planning for power, a power demand survey to predict the likely demand for power in the basin or other selected geographical areas to be served by the basin development, may be carried out. The projection should consider per capita usage at present, anticipated technological changes and projected population and industrial growth. The projected demand in excess of the potential of existing projects (hydro, thermal and nuclear) is to be used for planning.

11.3.3 The second consideration is the available hydropower potential in the basin. The Central Electricity Authority carries out survey in this regard and publishes a report 'Hydropower Potential of India' from time to time. This may be advantageously utilized. The fossil fuel availability in the basin for thermal power generation has already been discussed under basin resources. It is now a predominantly economic problem and a matter of policy to determine the extent of hydropower and thermal power generation to be planned in the basin. Other related factors to be considered in taking a decision in this regard are the available quantity and quality of fossil fuel, complementarity of water needs for power generation with other uses and the power demand pattern such as base load and peak load etc.

11.3.4 Water requirement for hydropower generation should consider the total water available for generation, the amount and pattern of anticipated power loads and amount of regulation needed to meet load fluctuations and the quantum and pattern of water demand for other purposes. The estimates may be general in character, but should be reliable and in co-ordination with other water uses.

11.3.5 For thermal and nuclear power plants, the water requirement should be based on plant capacities and cooling water arrangements. A distinction may also be made between consumptive and non-consumptive uses. Measures for economical water use including recycling should also be discussed.

11.3.6 Unlike other water uses, the planning for power cannot usually be restricted to the demand within a basin alone. The demand for a region or the nation as a whole is important rather than demand in a basin. Therefore, as a general rule, the planning should attempt to generate hydroelectric power where feasible. The excess power, if any, can always be used elsewhere through regional grids.

## 11.4 Domestic and Industrial Use

11.4.1 Domestic and industrial water requirement should include drinking water requirements and other daily needs of urban and rural population, industrial needs, commercial needs, public needs such as fire hydrants and miscellaneous needs such as livestock, poultry, gardening etc. Out of all water uses, the drinking water has been given the first priority by the Government in the National water Policy adopted in 2002. It further states that drinking water needs of human beings and animals should be the first charge on any available water.

11.4.2 Assessment of future demand for domestic water supply has to be based on the growth of population in the area to be served and its likely consumption of water per capita. The per capita consumption of water will depend on standard of living of the people, social customs and habits, accessibility of supply, quality available, climate, tariffs and economic and educational background. The norms of water supply both for urban and rural areas by CPHEEO, Ministry of Urban Development should be followed. These rates may be used as guidance along with the projected population figures for estimating the domestic water needs.

11.4.3 Industrial water use varies widely among industries. Statistics on average use per unit of production may be available with industries or concerned Government departments. Efforts should be made to collect such data at least for these industries which are water intensive such as paper and newsprint, coal mining, petrochemicals etc. Water demand projection for industries should be coordinated with studies of anticipated industrial expansion and should indicat the location, type of use as well as the amount, quality and location of effluent discharge. Industries when set up will also create an accompanying demand of domestic supply to cater to the needs of new concentration of workers and their colonies. This demand should also be taken into account. The scope for industrial expansion in the basin will primarily depend on the availability of cheap raw material and labour, transport facilities to demand centres and the general industrial policy of State Govt. Information available with industry department and national plan document will provide some idea of the regional industrial growth prospects which may be utilized.

11.4.4 Commercial water requirements are computed based on the number of commercial establishments that are existing and are likely to come up to serve the projected population. An average rate per commercial establishment may be worked out based on survey on existing water use.

11.4.5 Water supply requirement to public facilities are mostly in urban centres. These include requirement of fire hydrants, public parks and gardens, public buildings, public sanitary facilities, public drinking water facilities, etc.

## 11.5. Navigation

11.5.1 Navigation is another water related activity, which requires attention for future demands. Due to general expansion of industry and production, inland navigation, together with other means of transportation, may well emerge as a viable mode of transportation especially for goods. The planner should study such possibilities and incorporate in the master plan. The National Transport Policy Committee (May 1980) has recommended that certain important rivers be declared as national waterways to help develop this third mode of surface transport. Accordingly, ten important waterways have been identified for consideration for being declared as national waterways and two of them, namely, Ganga-Bhagirathi-Hoogli and Brahamaputra have already been declared so. It is also considered to be an energy-saving mode of transport.

11.5.2 Inland navigation requires the maintenance of a specified water depth and width depending upon the size of vessels expected to use that waterway. This necessitates the release of adequate discharges. The detention of water in upstream storages may put some of the existing navigable waterways out of use unless adequate provision is made to release sufficient water downstream. Therefore, the discharge required to be made for maintaining the required water depth in the reaches of river planned for inland navigation should be made. Sometimes water released for some other purposes may simultaneously serve the requirements of navigation. Efforts should be made to plan such complimentary uses as far as possible.

## 11.6 Minimum Flow Requirement

Maintenance of minimum flow in river is also to be considered as a water use since it restricts the quantity of water that can be diverted for other uses. Necessity to maintain minimum flow in river may arise out of the necessity to maintain water quality, river regime, maintenance of river eco-system or other public necessities such as bathing, drinking water for cattle etc. The NWP (2002) states that effluent should be treated to acceptable levels and standards before discharging them into natural streams. Minimum flow needs to be ensured in perennial streams for maintaining ecology and social consideration. Minimum flow requirements at different points in the river system should be assessed and adequate provision should be made in the master plan to ensure this.

## 11.7 Recreation

11.7.1 The water resources planner is interested in outdoor recreation activities associated with the presence or proximity of water, particularly reservoirs. Activities which require direct use of water include boating, ice skating, swimming, water skiing and fishing. Shoreline activities such as picnicking do not use water directly.

11.7.2 The key facility for recreation is the body of water created by the dam. It should present a pleasing appearance and the water should be of desirable quality. Similar to navigation, recreation also requires that a certain range of water level be maintained in the reservoir. However, this should not normally be done to the detriment of other more important water uses. Therefore, it will be most ideal to keep in mind the possible recreational aspects while selecting sites for reservoirs and also while studying the operation of reservoirs to see the range of possible reservoir levels.

Many times, navigable waterways also can be developed for pleasure boating and in such cases the maintenance of navigable depth also serves for recreation.

## 11.8 Aquatic and Wild life

11.8.1 The efforts of the development and management of water resources on the environment available to aquatic and wild life need to be carefully considered in planning. Species are adversely affected by changes in environment to which they are accustomed. Cold water fish inhabit rapidly flowing stream. Reservoirs provide good habitat for warm water fish species while destroying habitat of cold-water fish species. Reservoir submergence may affect the natural habitat of land oriented wild life.

11.8.2 A survey should be carried out for planned as well as existing and under construction projects to study the possible effects of planned development on the different species of fish and wild life in the basin. If the study indicates any adverse effects, remedial measures should be incorporated in the plan to offset such adverse effects. The remedial measures may be in the form of providing fish ways and fishladders, controlled release of water downstream, restriction in the drawdown of storage etc.

11.8.3 Apart from protecting the species, fish culture may be a commercially viable proposition in many reservoirs. The master plan should include an evaluation of the potential of inland water bodies for fisheries development. The factors influencing fish reserves and fish catch potential should be presented and discussed. Similarly, the local market demand for fish and export possibilities to other areas should also be discussed side by side.

# CHAPTER XII

# FLOOD AND DRAINAGE MANAGEMENT

The scientific management and utilization of flood waters is an essential part of water resources development planning. The NWP (2002) emphasizes that there should be master plan for flood control and management for each flood prone basin. It also states that adequate flood-cushion should be provided in water storage projects, wherever feasible, to facilitate better flood management. In highly flood prone areas, flood control should be given overriding consideration in reservoir regulation policy even at the cost of sacrificing some irrigation or power benefits. Flood management can be visualized in two parts; (i) mitigation of flood damages and (ii) utilizing the flood waters for beneficial uses. There is no single method to deal with floods. A variety of structural and non-structural measures are available. Whatever the method or methods adopted, it should be kept in view that flood management strives to reduce the flood damages, but cannot eliminate the hazards from rare events.

## 12.1 Flood Management

12.1.1 Due to increasing pressure on land, there are demands for removal of waters from wet lands under the garb of removal of drainage congestion of these areas. Wet land areas should be properly identified in the basin master plan and only peripheral areas of such wet land should be considered for removal of drainage congestion.

12.1.2 Geo-morphological studies should be taken up for those rivers with bank erosion problem. River channel process studies should be taken up for braided rivers. Embankment, constructed on many rivers are subsequently threatened by the erosive activity of the river, requiring costly anti-erosion works. Such reaches should be identified and studies taken on scientific basis to avoid or reduce such works in future.

12.1.3 For those river basins with mineral wealth, special attention would have to be paid in formulating flood management proposals for optimum utilization of mineral wealth.

12.1.4 Humans occupy and develop the flood plain as if the flood threat does not exist. With the overall development of the basin; the activities of man in the flood plain are only likely to increase. Therefore river basin planning should foresee the likely trend of flood plain occupation and the consequent increased exposure of life and property to flood threats.

12.1.5 Flood control measures mainly come under two categories; structural measure and non-structural measures. Structural measures include reservoirs, embankments, leavees, channel improvements etc. Non-structural measures include flood plain zoning, watershed management, flood forecasting and flood warning. In any given case, instead of a single measure, a combination of measures may be ideal and optimal. Studies to determine optimal combination of flood mitigation measures may be carried out for each individual case. Corresponding to a given design flood of specific frequency, an equal degree of flood protection may be provided by various combinations of flood management measures. By determining the cost of attaining a given level of flood moderation by various combinations of measures, the least-cost combination can be determined. Usually, a marginal value analysis is carried out and the optimum is expressed as a function of frequency of design flood.

12.1.6 The magnitude of flood against which protection is to be provided is also important. The design flood magnitude will depend on the importance of the structure or area to be protected. Ideally, the scale of development should be related to the damage potential as well as to the local conditions and the one with maximum benefit-cost ratio should be chosen. However, such a procedure will require extensive data on damages due to floods of different frequencies and due to such factors as embankment failure etc. which may not be available in most cases. Considering the above difficulty and taking into account the broad criteria being followed at present in the country, the Rashtriya Barh Ayog (1980) has suggested the following criteria for affording protection in different situations.

(i) Predominantly agricultural areas — 25-year frequency flood.
(When so justified a higher frequency flood or the observed maximum flood may be adopted).

(ii) Town protection works, important industrial complex etc. — 100-year frequency flood

Whenever data is available, resource may be taken to detailed studies.

## 12.2 Drainage Management

12.2.1 One of the problems requiring attention in river basin planning is the drainage of surplus water from waterlogged areas and other stagnant water bodies. Surplus water is as harmful to corps as inadequate water. Excess water in the root zone of crops will reduce the essential air circulation in this zone, affecting the growth of plant as well as yield. Water logging may also lead to salinity of soil making it unfit for cultivation. Sustained water logging is also an environmental and health hazard. Therefore, it is necessary that proper preventive and remedial measures be planned and incorporated in the master plan.

12.2.2 Excess water on the land may be due to a variety of reasons. Excessive rainfall, flooding, over-irrigation, seepage from water bodies, poor soil drainage properties and adverse sub-surface geological conditions are some of the important causes leading to waterlogging and drainage problems. Where land has a flat slope and in deltaic tracts subject to tidal ingress, the problem is very acute. In the preparation of the master plan, such areas should be identified and an action programme for a drainage system should be included.

12.2.3 The methods used for drainage may be broadly classified as surface drainage and sub-surface drainage. It may also be a combination of the two. Topography, rainfall intensity, soil characteristics and irrigation methods are important factors which will decide the type and design of drainage system. In many cases, natural water courses may form part of the drainage system. In such cases, they should be properly remodeled for better efficiency. Sub-surface drains are costly and difficult to construct; but are efficient in draining sub-surface water. They may be used in conjunction with surface drains.

12.2.4 While the master plan should give provision for the drainage of waterlogged areas it should also indicate appropriate preventive measures in areas where such conditions have not yet developed. Lining of water distribution system, efficient on-farm water management, proper maintenance of surface drainage system are measures that will reduce the possibility of excessive recharge to ground water. Such measures can, therefore, be advocated in areas where there is possibility that such conditions may develop. Conjunctive use of surface and ground water is also an efficient and effective method in such situations.

11.1.4 Unlike irrigation channels, the maintenance of drainage channels is usually poor. Maintenance is as important as design and construction for efficient functioning. Drainage system often gets clogged due to weed growth and silting up. Since the flow in drainage channels is usually varying in quantity and time, they are more subject to fast weed growth and silting. The master plan should emphasize this aspect.

# CHAPTER XIII

# ECONOMIC ASPECTS OF RIVER BASIN PLANNING

The economic aspects of river basin planning involve the evaluation so far as practicable in monetary terms of the physical potentialities of the basin for alternate courses of action involving types of uses, different configurations and sequences of development in time. Interpretation in terms of monetary values of the consequences of alternate courses of action, though most convenient way for comparison, is not always possible since extra market consequences also become important influences in deciding the project acceptability. This is so because in a welfare economy, economic efficiency measured in terms of market value of what the economy produces is an imperfect measure of economic welfare. The measurement of benefits and costs of developmental programmes should extend beyond mere market values.

## 13.1 General Concepts

13.1.1 In river basin planning, the normal questions that the planner is asked to answer through economic analysis are: which are the projects to be taken up? What are their scales of development? When are they to be commissioned? The study involves the analysis of individual projects as well as the basin or system as a whole. In normal commercial practice, a rigorous financial analysis provides the answer. But, in the case of water which is a public good, the question of equity and other considerations makes the financial analysis an insufficient procedure. A broader economic benefit-cost analysis serves as a more suitable criteria.

13.1.2 No doubt, conditions in the basin will change even if no planned developmental programmes are implemented. Therefore, the economic evaluation requires that the comparison be made between events predicted to occur if the developmental programmes are implemented and those predicted to occur if the planned programmes are not implemented. This is the with-and-without principle which should be preferred for adoption for project/basin evaluation.

## 13.2 Economic Performance Indices

13.2.1 There are mainly four methods or indices that are considered conceptually correct for comparing alternatives. These are : (i) the present worth method, (ii) the rate of return method, (iii) the benefit-cost ratio method and (iv) the annual cost method. The present worth method selects the project or alternative with the largest present worth of the discounted algebraic sum of benefits minus costs over its life. The rate of return is the rate of discount at which the algebraic sum of present worth of benefits minus costs equals zero. Alternatives having a rate of return exceeding the minimum acceptable value may be chosen. Benefit-cost ratio is the ratio of present worth of benefits to present worth of costs and the ratio should exceed unity. In annual cost method, benefits and costs are converted into a uniform annual figures and the alternative with the greatest annual net benefit is chosen. However each of these methods has advantages and disadvantages.

13.2.2 The study group appointed by the Planning Commission recommended in 1961 that benefit-cost ratio should be used for assessing the feasibility of new projects. For simplicity they had also recommended that indirect or secondary benefits need not be considered. Later in 1964, the Committee to Suggest Ways and Means of Improving the Financial Returns from Irrigation Projects also recommended that economic benefit criteria should be adopted for sanctioning irrigation projects and since then benefit-cost ratio criterion is being adopted for project appraisal. The Irrigation Commission (1972) also, has recommended the continued use of benefit-cost ratio. The World Bank uses internal rate of return criteria which is considered more suitable as a basis for making a choice between two investments and where financial return is the dominant consideration.

12.1.2 The working Group formed for preparing guidelines for detailed project report for irrigation and multipurpose projects (1980) felt that detailed studies to review the methods of benefit-cost ratio and internal rate of return for project appraisal should be carried out and recommended the constitution of a committee consisting of representatives from all concerned disciplines. The Planning Commission constituted a committee in 1981 to review the existing criteria for working out B.C. Ratio. The commission gave its report in 1983. The committee was of the view that:

12.1.2.0 The main purpose of cost-benefit analysis in case of irrigation project is to rate projects in order of their desirability keeping in mind the objectives of increasing agricultural production, promoting rural development and improving the income distribution and such a ranking may be required not so much to accept or reject projects in some absolute sense but to determine time-wise priorities.

12.1.2.0 There must be some level of the expected return below which irrigation projects would be rejected because the same objective can be attained in a more cost effective manner.

12.1.2.0 The benefit-cost analysis should not be restricted to the final version of the project, which is posed for approval but should be reflected in the analysis of options at all stages.

The committee has not given any minimum B.C. ratio value. The criteria that is followed at present is that the benefit cost ratio should equal or exceed 1.5 in normal case and should equal or exceed 1.0 in case of chronically drought prone areas.

## 13.3 Benefits and Costs

13.3.1 In the most general sense, benefits are the measure of effectiveness of a set of actions in achieving the set goals. The most convenient way to measure the benefits is in terms of market value of goods and services produced, but there are benefits, which are not amenable to such measurements. Some benefits are correctly registered in markets such as the income from freely marketable crops. Some benefits are incorrectly registered by market prices as in the case of some food grains whose prices are controlled by Government. Some benefits are not registered in markets; but simulated market values can be obtained and for some others it is nearly impossible to think of any kind of market valuation. Examples of these two types are benefits from recreation in public parks and the value of beneficial landscape respectively. Thus benefits are not synonymous with monetary revenues.

13.3.2 Benefits should be measured without regard to whom these accrue. Thus, both primary or direct as well as secondary or indirect benefits are important. For simplicity, only primary benefits are usually evaluated, even though a study of secondary benefits is desirable to see whether they are significant and worth evaluating.

13.3.3 The most convenient way of assigning numerical benefits is to determine the market value of the output it produces. To have uniformity, the transportation costs should be deducted from the ultimate market prices to get the price at the point of production. If the production is expected to be very large relative to the current production, probably it may affect market prices. This should be considered in the analysis of benefits. The only way to do this is to evaluate the demand function for commodities in question considering pre-project and post-project conditions. Where market prices are distorted through Government subsidies, this should also be taken into account.

13.3.4 In cases where markets in the usual sense do not exist and therefore, the willingness-to-pay as a measure of social value or benefit cannot be evaluated, simulation of market prices can be resorted to. Examples are recreation, flood protection etc. Flood control benefits are calculated as the value of damage prevented on the assumption that the occupants of the flood plain may be willing to pay any price upto their potential damage in the absence of the scheme. In the case of recreation various methods are suggested to simulate the situation.

13.3.5 Alternate cost approach is another method of evaluating benefits where market prices are not true reflection of willingness-to-pay. A common case is the evaluation of benefits of hydropower projects. The alternative chosen should be the most economical and likely choice that would be adopted in the absence of the project under study. However, this method should be cautiously used as this presumes that a decision has already been made to achieve the objective by some means regardless of cost. Cost of a single purpose project when compared with the benefit from a component of a multipurpose project may distort the reality due to economy of scale and should be guarded against such mistakes.

13.3.6 In the most general sense, the cost of some particular commitment of resource may be defined as the benefits given up in the most productive alternate use of those resources. Thus costs are not to be equated to cash outflows alone. A very cheap development in terms of cash investment may cause very deleterious conditions at a downstream point. Therefore, in cost analysis, apart from monetory costs which are primary project costs, indirect or secondary costs as well as intangible costs should be taken into account. As in the case of benefits, only the direct project costs are considered for simplicity. However, a study of those secondary effects of projects which may reflect as a project cost ultimately should be analysed and provided for.

13.3.7 The benefits and costs of projects occur over a period of time. Clearly, the value of a unit output accruing after ten years is not the same as that occurring at present. This necessitates the consideration of time value of benefits and costs. They must first be put on a common time base and discounted using suitable interest rate to a point in time, usually the present time or the time at which decision is taken. The rate of interest should reflect the degree of preferences for an early realization of benefit from the project from the point of view of society. The selection of a proper interest rate is a tricky issue in planning. Many simplified solutions are usually adopted such as the interest on long-term borrowings by the Government. As per the Desai Committee formed "To Review the existing criteria for working out the Benefit-Cost Ratio for Irrigation Projects" the rate of return of 9 % was recommended for benefit-cost ratio calculations of water development projects.

13.3.8 Another factor to be considered in the analysis of benefits and costs is the uncertainty associated with the future prediction of benefits and costs. The uncertainty increases with the length of planning period. Yet, when decisions have to be taken which commit resources to long periods, it is not possible to predict values with complete accuracy. This situation can be taken care of by making an allowance for the uncertainty. One method would be to adjust the benefit and costs by a "correction factor" before discounting. Another method would be to add a risk factor to the discount rate. Sometimes the life expectancy estimates are adjusted downwards.

## 13.4 Measurement of Benefits and Costs

13.4.1 Irrigation: The direct benefits of new or supplemental irrigation are the difference between the annual net income from farm produce with irrigation and annual net income without irrigation. The increase in the value of land as a result of the introduction of irrigation is also considered as a direct benefit. The indirect or secondary benefits include increased activities in business and trade and agro-based processing and manufacturing activities. There are also intangible benefits such as greater stability and welfare to community, better health and new employment opportunities. The Working Group report on Guidelines for the preparation of Detailed Project Report for Irrigation and Multipurpose projects suggests that the annual benefits for computing benefit-cost ratio should be taken as under:-

( ) Agricultural production in the area to be irrigated under pre-project conditions.
( ) Agricultural production in the area after completion of the project.
( ) Difference between (a) and (b).

The yield/ha under pre-project and post-project conditions and the prices to be used for the crops may be obtained from the State Agricultural Department. The net income from farm produce should exclude the farming expenses such as fertilizers, seeds, labours etc.

The cost shall consist of the following:

( ) Interest at the rate of 10% on the estimated cost of the project including cost of land development.
( ) Operation and maintenance cost including that for head works;
( ) Depreciation of the project based on assumed life of the project; and
( ) In the case of lift canals, charges for power and depreciation of pumping system;

The benefit-cost ratio is worked out as the ratio of annual benefits to annual costs.

13.4.2 Hydro-electric power: Generally, a new hydropower project supplements and already existing network. The monetary benefits by satisfying the power demand projected through a power-market survey will be equal to the prevailing regional price per unit. The expectation of an increase in power use, if current prices continue, is based on the assumption that the value in use will exceed the price. If the power project is to serve an isolated area, then the benefits will equal to the area under the demand curve between amount of power available with and that available without the project.

Often, evaluation of power projects are done in terms of the cost of the most economical and likely alternative source that would be used to meet the power requirement in the absence of the hydroelectric project under study. The cost of generation by alternative methods must be determined as a part of the study to justify hydroelectric power.

Indirect benefits from power generation may arise due to factors like increased industrial activity as a result of the availability of cheap and reliable power supply. Intangible benefits include increased comforts and conveniences and improved living condition of people and also conservation of non-renewable fuels.

The costs of hydropower generation shall consist of the following: -

( ) Incremental project construction costs attributable to power generation;
( ) Costs of power components such as power house, generators, penstocks, transmission and distribution system etc;
( ) Operation, maintenance and replacement costs of power components; and
( ) Depreciation costs.

13.4.3 Domestic and Industrial Water supply: The benefits from providing domestic water supply accrue to a larger spectrum of people in the society compared to other water uses. The benefits from municipal and industrial water supply projects can be measured by (i) the customers willingness to pay for delivered water when such a measure can be deduced from market information and (ii) the cost of the next best alternative source of supply for those customers who would clearly be supplied by that alternative in the absence of the present project. Method (i) will be a more reasonable approach if sufficient data to develop the demand curve can be obtained. The costs attributable to domestic and industrial water supply will include:

(i) The cost of source development. This may include the intake structures and/or the allocated part of the storage project;
(ii) Transmission, treatment and distribution costs including cost of local storages;
(iii)Operation, maintenance and replacement costs; and
(iv)Depreciation costs.

13.4.4 Flood Management : Flood control benefits generally consist of two components: (i) the damage prevented to the existing and future flood plain area that would exist in the absence of the flood control project and (ii) the enhanced productivity of the flood plain. The damage prevented should be computed based on the present status and anticipated conditions after the completion of the project. The average annual damage should be based on at least 10 years data. If sufficient data is available, it will be advisable to draw a damage-frequency curve and determine the average annual damage corresponding to different frequency floods. Thus the level of protection provided by a given structure and the damage prevented can be correlated.

The damage due to floods may be to agricultural crops, structures and monuments and/or human lives. Some of the damages may be permanent losses, others may be capable of restoration through repairs, rehabilitation etc. A distinction should also be made between preventable and non-preventable damages as also between recurrent and non-recurrent losses. Care must be taken to avoid duplication of benefits.

The costs of flood control projects will usually consist of :

( ) Incremental project construction costs attributable to flood control including exclusive provisions like embankments, channel improvements etc.,

( ) Value of water and power foregone by virtue of reserving some of the storage for flood moderation, and

( ) Operation, maintenance and replacement costs.

13.4.5 Navigation : Improved inland navigational facilities benefit the economy since it is a cheap mode of transport and effect saving of fuel. The benefits may accrue by way of:

(xxii) The amount of cost saved by diverting the present traffic from higher cost modes of transportation to inland or coastal waterways;

(xxii) The new traffic generated by the added navigational facilities. This is measured as the willingness to pay by the new water carrier customers;

(xxii) The income of new business establishments stimulated by the added water transport facilities and savings to existing business which may shift to riverside locations; and

(xxii) Value of recreation provided by the improved waterway.

The following costs may be expected to accrue:

(vi) The construction of navigation features including channel, lock, navigational aids and other facilities;

(vi) Operation, maintenance and replacement costs;

(vi) Value of other benefits foregone as a result of operating the system to cater for irrigation;

(vi) Construction of recreation facilities, if such benefits are included.

13.4.6 Recreation : The benefits from recreation are by way of a quality added to life whose value is beyond monetary measurement. But, the planner has to assign a value to this benefit in order to be commensurate with other project purposes.

There are various methods of recreation benefit evaluation that have been proposed and used. The oldest practice is to select a value per visitor-day based on a judgment evaluation of the quality of the available recreation experience. Other methods are that using alternative-cost approach, user-assigned values evaluated through a questionnaire, correlating admission fee charged with the number of users who may pay for it etc. The most successful method seems to be based on demand curve imputed from expenditures incurred to enjoy outdoor recreation. The recreational cost incurred by the user such as travel, food, lodging etc. reflect the value placed by the user on the particular recreational experience. The costs of recreation include :

iv) Cost of construction of recreational facilities;

iv) Value of other benefits foregone as a result of creating these facilities such as maintenance of a certain reservoir level; and

iv) Operation, maintenance and replacement costs.

13.4.7 Water Quality Management: The benefits from water quality management measures are difficult to locate and quantify. These measures modify the damages inflicted by a given pollution concentration on the water users. The benefits would fall into one or more of the following classes:

) Health improvement to people who use the water in untreated or inadequately treated form in the absence of the measures,

) Reduced water treatment costs by downstream municipalities,

) Reduced treatment costs by industries who draw water from downstream points,

) Value of increased recreation stemming from better quality water, and

) Increased aesthetic value.

The cost of water quality management may include :

iii) Construction of structures such as dams, treatment plants etc.,

iii) Operation, maintenance and replacement costs,

iii) Cost of solid waste disposal, and

iii) Increased air pollution by treatment of waste.

13.4.8 Fishery : Benefits from development of fishery mainly come under two classes : i) the commercial value of the fish catch and (ii) the recreational value of fishing. The commercial value of increased fish catch is evaluated in terms of the expected market prices whereas the benefits from recreation are evaluated as described in para 12.4.6.

The costs may include costs of facilities such as fish ladders, value of benefits foregone, if any and the appropriate operation, maintenance and replacement costs.

13.4.9 Environmental Management : The benefits from environmental conservation such as the preservation of rare species of flora and fauna or unique habitats come under intangible benefits since their monetary values are difficult to assess. The best practice may be to determine the incremental cost of preservation as a function of some quantitative measure of the amount of resource conserved such as the number of rare species of wild life or number of acres of rare flora conserved and make sure that they are compatible. The total cost of conservation should include the direct cost of conservation and the benefits foregone by reducing other project outputs.

## 13.5 Financial Feasibility

13.5.1 In economic analysis, the question is not usually raised as to who will ultimately pay for the costs of the scheme. To say that a project's benefits to the nation will offset its costs is one thing; to decide on whether or not costs are to be recovered and if so the method of recovery is another. Thus financial feasibility of projects is a factor to be looked into.

13.5.2 Financial return through sale of production is not always possible in the case of water resources development which is by and large a collective good. For example, the flood control benefits are enjoyed by the general public especially those in the protected area, whether they choose to "buy" the benefits or not. Moreover, in our country, the majority affected in flooding are the economically weaker sections and charging them goes against the principle of income redistribution through development. Such social considerations, apart from technical difficulties of charging, provide reason for subsidizing or even making the service free.

13.5.3 At present, financial feasibility is not a criterion for sanctioning irrigation projects. For multipurpose projects involving power generation, a financial return statement is prepared for the power component. The National Water Policy recommends that the water rates charged should be adequate to cover the annual maintenance and operation charges and a part of the fixed costs of projects. For hydropower, urban and industrial water supply and navigation projects or these components in a multipurpose project, which have a ready market, it should generally be possible to attain financial viability.

## 13.6 Allocation of Costs

13.6.1 In the case of multi-purpose projects, it becomes necessary to apportion costs among the various project purposes. There is no universal agreement on this issue. The basic principle underlying the allocation is that the savings derived through the use of the combined structure for numerous purposes should be shared equitably by all these purposes. The cost includes separable costs and joint costs. Separable costs are directly attributable to specific purposes and joint costs are shared among the different purposes. Allocated cost should be:

) Not more than the benefits to be achieved by that purpose;

) Not more than the cost of an alternate project built for that purpose; and
) Not less than the cost of items meant for the specific use of that purpose.

13.6.2 IS: 7560-1974 reaffirmed in 1996, gives the guidelines for allocation of cost among different purposes of river valley projects. This describes various methods of allocating costs such as alternate cost method, benefit method, equal apportionment method etc. and their advantages, disadvantages and limitations. None of the methods is suitable for all conditions and the choice of a particular method will be governed by its suitability in specific conditions.

# CHAPTER XIV

# FORMULATION OF MASTER PLAN

Planning aims at consumer's welfare. The objectives of planning is to maximize the production of goods and services which will improve the quality of life of people. In the case of water resources projects, the consumer's utility is linked to such goals as economic development, job creation, environmental preservation, income redistribution and social well-being, to state a few important among them.

## 14.1 Planning Objectives

Water resources planning in most cases is multi-objective. Setting goals is an important step. They must be the right ones and unambiguously stated. Long term and short term developmental objectives should be properly formulated with due regard to the overall national planning objectives. A discussion of the socio-economic scenario of the basin including ethnic divisions, regional imbalances, backwardness, tribal status, etc., priority sectors of water use and related activities and constraints of development should precede the formulation of developmental objectives. The above discussion should bring out the problems in the water resources sector in the basin. Problem identification and goal-setting are two important and related steps in plan formulation.

## 14.2 Water Budgeting

14.2.1 Before embarking on formulation of detailed proposals for basin plan, it would be necessary to check the availability of water to meet the anticipated demands, at least on a rough basis. This will ensure that the planning is within the available resources. This will also help in early conceptualization and formulation of proposals for alternate or additional sources through inter-basin transfers, recycling etc.

14.2.2 An estimate of the quantum of natural surface water as well as ground water available at various control points in the basin should be made. The existing utilizations for various purposes should also be assessed. A distinction should be made between actual and planned utilization and the reason for the shortcomings should be properly accounted. With this information, an estimate of the present water balance scenario at various selected control points in the basin should be made.

14.2.3 Anticipated water demand for various time periods in future, 5 years, 10 years, 15 years etc. may be made and water balance carried out to check whether the availability matches the demand. The water budgeting may be carried out in two steps : first the deficit/surplus at each point may be assessed without considering any modifications in the flow pattern through measures proposed in the master plan. This will bring out the necessity for additional storages in certain reaches for which further investigations can be carried out. This will also indicate the necessity for additional resources through transfers, recycling etc. since the water requirement for different uses are considered, it would be ideal to consider the water quality also as an additional factor in the water budgeting.

## 14.3 Formulation of Alternate Developmental Scenarios

14.3.1 Generating alternate developmental scenarios is an important step in planning. It is a more creative step and experience is a valuable asset than any modern techniques. Various possible measures of water conservation and distribution, integration of their operation and management, conjunctive use of surface and ground water, possibilities of interbasin transfers are some of the possible courses of actions that may be considered in generating the scenarios. Environmental considerations including water quality aspects and provisions of interstate agreements are also to be kept in view. The alternatives should be able to achieve the objectives of planning. It may not always be possible to formulate a number of alternatives. In some cases, there may be a single alternative only to meet the objective.

14.3.2 Identification of measures of water conservations and distribution is an important part of this step. Potential water resources development projects should be identified through study of aerial photographs, topographic sheets, geological maps and field trips. After the preliminary identification through office studies and field trips, reconnaissance level field investigations should be carried out for those projects which are considered feasible in the preliminary screening. These projects which are considered technically feasible should then be subjected to economic analysis and on this basis an identified feasible set of projects are listed for further consideration in the generation of alternate scenarios. A preliminary screening of projects through judgement and/or through modeling can eliminate some clearly inferior and uneconomical projects right at the initial stage itself.

13.2.2 Detailed guidelines in respect of surveys and investigations to be carried out and preparation of detailed project report are contained in the Working Group report `Guidelines for the Preparation of detailed Project Report of Irrigation and Multipurpose Project', 1980. `Investigation Manual for Storage Reservoirs' (Publication No.58 of Central Board of Irrigation and Power) also gives detailed guidelines on investigation of storage reservoirs and may be referred to.

## 14.4 Evaluation of Alternatives

14.4.1 The consequences of alternate scenarios of development has to be evaluated in order to form a basis for deciding the final plan. This step is more well-defined.

Modern analysis techniques such as systems analysis and mathematical modeling can be advantageously used.

The various alternative scenarios are studied and the impacts on the developmental objectives are evaluated. Direct impacts include the benefits accruing to each user group and the costs incurred including adverse impacts on those affected by the development. The evaluation should, as far as practicable, take into account the secondary benefits and costs as well as intangible impacts. More details on benefit-cost measurement and analysis are included in section 12.

## 13.4 Selection of plan

13.4.0 To the planner, this is the last stage in planning. On the basis of the evaluation carried out, a final plan of the several alternatives, is recommended for adoption. The choice may be straight forward in the case of a single objective. If multiple objectives are involved, a trade-off between levels of attainment of each objective may have to be carried out. The impacts on various objectives may be displayed as a scoreboard, which is a table that shows each alternative's impact on the various objectives Based on this factual knowledge, a final choice can be made by the competent authority using judgment and relative importance of different impact.
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13.4.0 The above procedure sounds simple. In practice, there are many difficulties. First, the impact on various objectives may not be in commensurable terms. A common example in water resources is the evaluation of environmental impact. There are a number of methods developed to aid decision making which attempts to reduce the level of subjectivity involved although not possible to altogether eliminate. In most cases however, the situation becomes constrained and the solution becomes obvious by elimination.

## 13.4 Sequencing of projects

Since all the projects identified in a comprehensive river basin plan cannot be constructed at the same time, it is necessary to accord priorities for their implementation. The criteria on which such priorities or ranks are assigned are many. Usually, maximization of present value of net benefits is a rational criteria commensurate with objective of economic benefit maximization of present value of net benefits is a rational criteria factors such as relative urgency to meet basic human needs, regional development considerations, apart from political considerations also become equally important. Staged development of project is also included in this phase of the analysis.

## 8.3 Short Term Action Plan:-

The sequencing of projects over planning horizon as discussed above provides a convenient basis for formulating short-term action plans. Sequencing gives the time at which each project is to be taken up for implementation. The set of projects to be taken up in the immediate future is thus known. As discussed earlier, short-term plan of 5-year duration is convenient for our country. Investment plans are then drawn up for this period for the implementation of the short-term plan. These investment plans should be tied to the national sectorial plan for water resources sector as far as financing is concerned.

## 8.4 Conjunctive use of surface and ground water

8.4.1 River basin planning should consider the optimal development of both surface and ground water. Treating them independently is not the best way to plan their utilization. On the other hand, they should be planned in an integrated manner so that their development and utilization become complimentary in space and time. Thus conjunctive use of surface and ground water has been accepted as an essential part of water resources planning. Therefore, the planner should investigate this aspect and incorporate in the plan.

8.4.2 Possible situation where the conjunctive use of ground water with surface water appear advantageous are: ( i ) as a supplement to surface water in cases where the surface water alone cannot meet the full requirements of water in certain time periods or over the whole year; (ii) to provide full irrigation during certain periods or crop seasons, the remaining periods/seasons being served by surface water; (iii) to provide irrigation to certain pockets of the command, especially towards the tail end of canals, where canal water supply considerably dwindles; (iv) to control waterlogging and salinity in areas where excessive use of surface water will result in raising the water table close to root zone of crops; (v) where exclusive use of ground water may cause lowering of water table and consequent salinity ingress as in coastal areas, use of surface water partly will ease the situations; (vi) where surface water is not adequate to meet the full needs, but ground water is saline, both can be mixed to tolerable limits and used.

8.4.3 The first requirement in planning conjunctive use is a thorough knowledge of the availability and distribution of surface and ground water. A water balance should then be carried out for various sub-basins and at control points in the basin taking into consideration the possible effects of regulation during a certain period or in certain pockets of the command only depending upon the deficit conditions. Other factors relating to conjunctive use explained in the previous para should also be taken into account in deciding whether conjunctive use is to be planned and to what extent.

8.4.4 Having decided on the conjunctive use, the planner will have a number of alternative strategies for the extraction and use of ground water. The relative economies of the various alternatives are to be studied along with social and political implication before arriving at the final choice for execution. Modern techniques such as system analysis and operations research can be used extensively in these studies.

## 14.9 Integrated Water Resources Planning, Development and Management (IWRPDM)

14.9.1 The need for integrated river basin planning, development and management arises from the relationship between the availability of water resources and its possible uses in various sectors. Most development decisions today are multi-disciplinary in nature involving economic, social and environmental dimensions and values. This in effect involves consideration of a large number of factors relating to various disciplines connected with water resources, and an in-depth study and understanding of the basin's developmental requirements, priorities and limitations. Remarkable technological advancements have taken place worldwide in computer hardware and software, in the last decade or so, for analyzing the water resources system in cost effective, comprehensive, and reliable manner for planning and management at river basin level.

14.9.2 Water resources planning has been increasing in complexity with increase in the demand and consequent pressure on the available water resources. Application of modern techniques like systems analysis and mathematical modeling with the aid of fast digital computers can bring about considerable changes in the planning approach.

13.8.2 Systems analysis methods, both optimization and simulation, can be used in water resources planning. Simulation models are more widely advocated for water resources planning because of their versatility in complex situations compared to optimization methods which require many approximations for application in such situations. Opimization can however be used for initial screening of projects and perhaps for detailed single reservoir planning. Nowadays, there is a wider acceptance for optimization cum simulation models which utilize the advantages of both the approaches. A beginning has been made in the application of these modern tools in the Central Water Commission in the studies carried out for the Mahanadi, Godavari, Sone and Sabarmati and Damodar river basins.

13.8.2 Mathematical modeling is also exclusively used for the assessment and evaluation of environmental factors which have become an inseparable part of river basin planning. Other fields where mathematical modeling is widely used are hydrology, agronomy and water quality which are also related disciplines in river basin planning.

13.8.2 Water Resources Planning, Development, and Management analysis generally comprises several phases and activities, which are used to structure the analysis in a logical sequence of steps. The explicit description of these phases, the activities in these phases and the interaction between these activities is referred to as the **analytical (or conceptual) framework**. The analytical framework has three elementary phases i.e. inception, development, and selection. The processes in all these phases are cyclic in nature.The first phase of the process is the inception phase. In the inception phase, the subject and the objective of the analysis are specified. The type, sequence, and duration of the analysis steps are defined that are required to produce the desired information related to the questions to be answered by the study within the available time and financial resources of the study.

In the development phase, an integrated set of computational tools for the analysis are developed. The main block of activities is usually related to data collection and modelling; where various rounds of preliminary analysis are made to ensure that the tools developed for the analysis are tuned to the development of measures to solve water resources problems. Individual measures are developed and screened in this phase and preliminary attempts are made to combine promising measures to management strategies.

The purpose of the selection phase is to prepare a limited number of promising strategies with detailed analysis of their effects on the evaluation criteria for making the final selection. Important activities in this phase are strategy design, evaluation of strategies, and presentation of findings. The results of this phase are included in the final report supported by a summary of the results of development phase.

Depending on the complexity of the water resources system to be analysed, a variable set of coherent models can be used for the quantitative analysis of the water resources system, measures, and strategies. This set of models and related databases forms the “**computational framework**” or Decision Support System.

13.8.2 Decision Support Systems ( DSS )

Decision Support Systems (DSS) are a specific class of computerized information system that support decision-making activities. DSS are interactive computer-based systems and subsystems intended to help decision makers use data, documents, knowledge, and/or models to identify and solve problems and make decisions. A decision support system is a user-oriented computer system that supports decision-makers in addressing unstructured problems. The general concept emphasizes:

- solving unstructured problems which require combining the judgement of manager-level decision-makers with quantitative information,

- capabilities to answer "what if" questions quickly and conveniently by making multiple runs of one or more models,
- use of enhanced user-machine interfaces, and
- graphical displays.

Decision support systems include a collection of software packages and hardware. For example, decision support systems are used for real-time flood control operations of reservoir systems. Making release decisions during a flood event is a highly unstructured problem because reservoir operations are highly dependent on operator judgment as well as pre-specified operating rules and current and forecasted stream flow, reservoir storage level, and other available data. The decision support system includes: data management software , watershed runoff, stream hydraulics, reservoir/river system operation models, a computer platform with various peripheral hardware devices, and an automated real-time hydrologic (stream flow and rainfall) data collection system.

Such systems use quantitative models and database elements for problem solving. They are an integral part of the decision maker's approach to problem identification and solution. A computerized decision support system should have facilities for data management, data analyses, and interaction. Such facilities are vital for problem identification, problem solving, and analysis of the consequences of a decision. The data management function may vary from simple statistical computation to the ability to call up optimization and simulation models. It is evident that decision makers could benefit from improved tools to assist them in making favorable decisions, especially when confronted with conflicting objectives and demands.

A decision support system for application in water resources management should have the characteristics such as: accessibility, flexibility, facilitation, learning, interaction, and ease of use. Water resources problems are generally ill structured, inadequate data, associated with uncertainties, and include non-quantifiable variables.

### 13.8.2 Decision Support System (DSS) for Basin Planning.

Basin Plan formulation comprises several distinct phases and activities, which are used to structure the analysis as a logic sequence of steps. The description of these phases, the activities in these phases and the interactions between activities is referred to as the "conceptual framework". Depending on the complexity of the Water Resources System (WRS) to be analysed, a variable set of coherent models can be used for the quantitative analysis of the WRS measures and strategies. This set of models and related databases forms the "computational framework" or "Decision Support System (DSS)" for Basin Planning.

The combination of the conceptual framework and the computational framework or DSS forms the "analytical frameworks" for water resources planning. The framework is used to analyse relationships between water quantity and water quality issues, between land use and water resources development and between ecosystem development and socio-economic activities in the study region, taking into account social, environmental and economic objectives. The framework also provides support for policy formulation regarding Water Resources Management (WRM) objectives and the development of strategies (including regulations, incentives, investments) needed to reach these objectives. The framework referred and described here is aimed at application in planning at national, regional or at river basin level.

The purpose of the analysis is to prepare and support decisions. A decision process is not a simple linear sequence of steps. Characteristic for a decision support process is the presence of factors that cause a return to earlier steps of the process. Part of the process is thus iterative. Feedback loops are necessary, for example when solutions fail to meet criteria or new insights change the perception of the problem and its solution that might be triggered by the application and use of the DSS.

The decision and assessment of strategies is an iterative process. One could start by developing strategies on the basis of a single objective, for example food production or maximum net economic benefits Comparison of the effects of strategies that are based upon a single objective can lead to compromise strategies by changing some elements in the strategies. A loss with respect to one objective is then traded-off with gains with respect to another one, in such a way that a better overall performance is reached.

The DSS is used for the determination of the effects of strategies. Strategies are generally compared to a situation that represents assumed autonomous developments. The assessment of strategies is based on their effects with respect to the evaluation criteria that were chosen to characterize the objectives of WRM. Criteria have to be comprehensive (sufficiently indicative of the degree to which the objective is met) and measurable ( it should be possible to assign a value in a relevant measurement scale).

It is usually impossible to express all criteria in a single measurement scale like a monetary value. Criteria related to quality of the environment can often be expressed only in descriptive terms. This should however be done in such a way that a ranking of strategies with respect to the criteria is possible on the basis of this description.

14.9.8 DSS –RIBASIM- A Demonstration Study-DSS RIBASIM developed by WL DELFT HYDRAULICS is a generic model package for simulation of the behaviour of river basins during varying hydrologic conditions. The model is a comprehensive and flexible tool to link the hydrologic inputs of water at various locations to the various water-using activities in the basin and to evaluate a variety of measures related to infrastructure & operational management. It provides an efficient handling and structured analysis of the large amounts of data commonly associated with water resources systems. The core of DSS RIBASIM is a River Basin simulation model RIBASIM.

The sub-systems of DSS RIBASIM are:

- An object oriented data base system containing data describing the WRS including the data base management system;
- A set of application models describing the different components in the planning process;
- An analysis system containing various tools for structuring the analysis process and the visualisation & interpretation of the results;
- A graphical user-interface.

**Input Requirement of RIBASIM**

Input for RIBASIM covers the following;

- River basin network schematization: location of surface water reservoirs, aquifers (groundwater reservoirs), irrigation areas, diversion weirs, (river) channels, DMI channels, sub-catchments comprising a system of nodes and links;
- Model data characterising each node and link in the schematization;
- Preferred sources of water for the identified water users in the basin;
- Water allocation rules and operation rules for surface water reservoirs and diversions;
- Hydrologic data (time series of available flow at the system boundaries e.g. From inter-basin transfers, open water evaporation, rainfall, general district water demand and discharges, water district runoff).

**Output Generation**

Simulation results can be processed with a number of standard post-processors into graphs, spreadsheets, maps, and tables. For a quick visual interpretation of results, a number of graphs can be produced on screen (e.g. during calibration testing). The form of the graphs can be adapted according to the user requirements, e.g. the applied cropping pattern, the water allocation, the shortages per user, the actual surface or groundwater reservoir storage, the overall water balance of the basin, and the energy production etc. The results can be further processed with spreadsheet software like MS Excel or directly included in reports produced e.g. with MS Word. Tables range from summaries of the main results (success rate, allocated amounts of water, water shortages, water utilisation rate, failure year percentage, and energy production) to user-defined tables with detailed results per time step for specific variables per node or link.

**Model Schematisation**

Basin planning exercise requires a comprehensive inventory and thorough understanding of all water related systems in the basin. To perform river basin simulations with RIBASIM, a model schematization of the study area is prepared

in the form of a *network*, consisting of nodes connected by links. Such a network represents all the features of the basin that play a role in its water balance.
Four main groups of schematization elements are differentiated in the model:

- Infrastructure (surface and groundwater reservoirs, rivers, lakes, canals, pumping stations, pipelines).
- Various water users (municipal & industrial, agriculture, hydropower, nature, recreation), or in more general terms water related activities.
- Management aspects (reservoir operation rules, allocation, methods).
- Hydrology

Supplies and the water user activities are connected to the network as nodes. The transport of water in the network takes place in links. The transport of water is controlled by the operation rules as specified by the user. The time aspect is brought in by the time series of discharges (inflows), rainfall etc. and also in the form of time series for the water demands.

RIBASIM distinguishes a number of standard nodes and link types with which the river basin network can be constructed. Each type of node and link correspond to a particular part of the model that handles the relevant computations for this type of node or link. The model contains a library of nodes and links that can easily be expanded to include other activities specific to a particular basin.
A short selection of available "node" and “link” features is presented below:

- Irrigation areas: computation of water demand on the network taking into account crop characteristics, irrigation practice parameters, and actual rainfall;
- Conjunctive use of groundwater and surface water for various water users like irrigation and public water supply;
- Water balance of aquifers;
- Pumping capacity and maximum groundwater depth for abstraction from an aquifer;
- Brackish or fresh water aquaculture: flushing demands;
- Minimum flow requirements for sanitation, navigation or ecology;
- Less flow from river stretches to groundwater;
- Run-of-river power plants;
- Hydropower production requirements at surface water reservoirs: firm (guaranteed) and secondary energy, scheduling;
- Computation of pumping energy (from groundwater or surface water to users);
- Return flows from users (agriculture, aquaculture, public and industrial water supplies);
- Additional (backwater) abstractions from surface water reservoir for various water uses;
- Surface water reservoir operation rules (firm storage, target storage e.g. for average maximum energy generation, flood control storage);
- Sub-catchments (water districts) which form a hydrological unit from the viewpoint of water supply and demand;

- Hydraulic description of (part of) river stretches and partitions of surface water reservoir.

The preparation of input data, running of the model and the processing of output data into graphs, maps of the study area, diagrams and tables take entire place via user-friendly menu screens.

**Simulation**

Simulations are made to analyse a specific (present or future) condition over long series of historical years to cover sequences of dry and wet periods. The simulation proceeds in *time steps*, of typically one month, half a month or 10 days.
In essence, RIBASIM is a water balance model. Within each time step a water balance calculation is made, in two phases:

- Target setting phase (demand phase)
  Determination of all the water demands, resulting in targets for the releases from surface water reservoirs, aquifers, and diversion flows at weirs & pumping stations.

- Water allocation phase (supply phase).

Allocation of water to the users according to targets, availability, and allocation rules.

Water allocation to users can be implemented in a variety of ways: in its simplest form, water is allocated on a "first come, first serve" principle along the natural flow direction. This allocation can be amended by rules which e.g. allocate priority to particular users or which result in an allocation proportional to demand. On the basis of a set of simulations, usually made for a range of alternative development or management strategies, the performance of the basin is evaluated in terms of water allocation, shortages, (firm) energy production, overall river basin water balance, water district crop yields and crop production costs, etc.

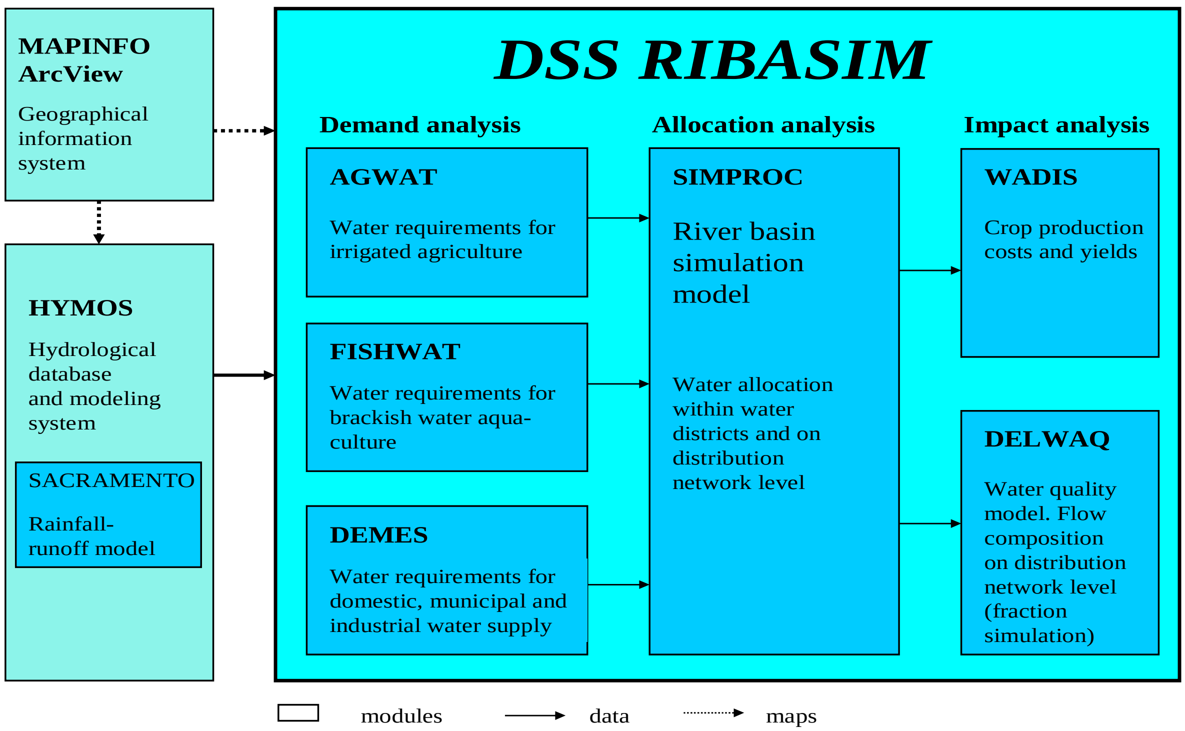
**The types of analysis addressed by the model;**

- Evaluation of the limits on resources and/ or the potential for development in a region or basin, given the available water resources and their natural variations, to what extent can a river basin be developed in terms of reservoirs, irrigation schemes, water supply systems, while avoiding unacceptable shortages for users? When and where will conflicts between water users occur? Which combination of infrastructure and operational management will provide an optimum use of the available resources?

- Evaluation of measures to improve the water supply situation such as measures concerning changes in the infrastructure, operational management, and demand management;

- Evaluation of the origin of water for every location in the river basin as a first step towards an actual water quality analysis, without the necessity of having available information with regard to waste loads, waste water discharges and water quality of (upstream) sources, the effect of measures on the distribution of water from the various sources in the basin is calculated (influence area of a source of water);

Simulation of the water balance of the region/basin forms the basis for such analysis. RIBASIM provides the means to prepare such balance with sufficient detail, e.g. taking into account re-use of water, and with facilities to vary the simulated configuration and to process results.




**Schematic Diagram of RIBASIM**

### 14.9.9 Policy Dialogue Model Simulation (PODIUMSim)

PODIUMSim is an improved version of Policy Dialogue Model. It enables the users to develop scenarios of water and food supply and demand with respect to various policy options at National and Sub-National level. Model can make the projections for the year starting from year 2000 to the year 2050 with a step of five years. It can generate scenarios at sub-national level e.g. at river-basins or at administrative boundaries. The aggregated results show the national picture. The model maps the complex relationship between numerous factors (driven in the model) that affect water and food demand and supply and display output information in both graphical and formats. Projections for future year are

determined in relation to base year data and expected changes in the drivers from the base year to future year. The model enable users to set goals, such as food production for an adequate level of per capita consumption and explore ways of reaching that goal through expanding irrigated area or rainfed area, increasing cropping intensity or importing more food. Likewise scenarios can also be developed in terms of population growth, changes in diets and developments in agriculture and water resources to ensure food security and sustainable water use.
The model is intended for policy planners, researchers, students and others who are interested in developing water and food supply and demand scenarios under different options of policies or hypothesis. The model consists of three main components:

. Annual consumption - demand scenario development at national level,
. Seasonal production scenario development for irrigated and rainfed agriculture at sub-national level, and
. Annual water supply scenarios development at sub-national level and seasonal water demand scenarios development for irrigated sector and annual water demand scenarios for domestic, industrial and environmental sectors at sub national level.

Using the model, various scenarios can be created based on `what if analysis'. Basin or Sub-basin is always an ideal unit for the analysis. The analysis with the help of model can be done for all the basins of the country based on various assumptions to create scenarios for the Nation as a whole. The result obtained from the model enables to assess following items for the Country as well as for the Basin for the target year:

0. Water balance situation – deficit or surplus situation.
0. Food grain requirement and production – deficit or surplus situation.
0. Use and availability of Surface water in the target year.
0. Use and availability of Ground water in the target year.
0. Amount of Return Flow in the target year.

With the help of model, scenarios can be created for various permutations and combinations based upon various assumptions. To create various scenarios all major variables can be changed. The various important variables, for which the scenarios can be created and assumptions can be made by the policy makers, are as follows.

0. Increase in irrigated areas and decrease in rainfed areas according to the various projections made.
0. Increase in irrigation efficiencies of ground water and surface water.
0. Increase in the yield of irrigated as well as rainfed areas.
0. Increase in irrigation intensity.
0. Increase in per capita cereal and pulse consumption according to the international standards

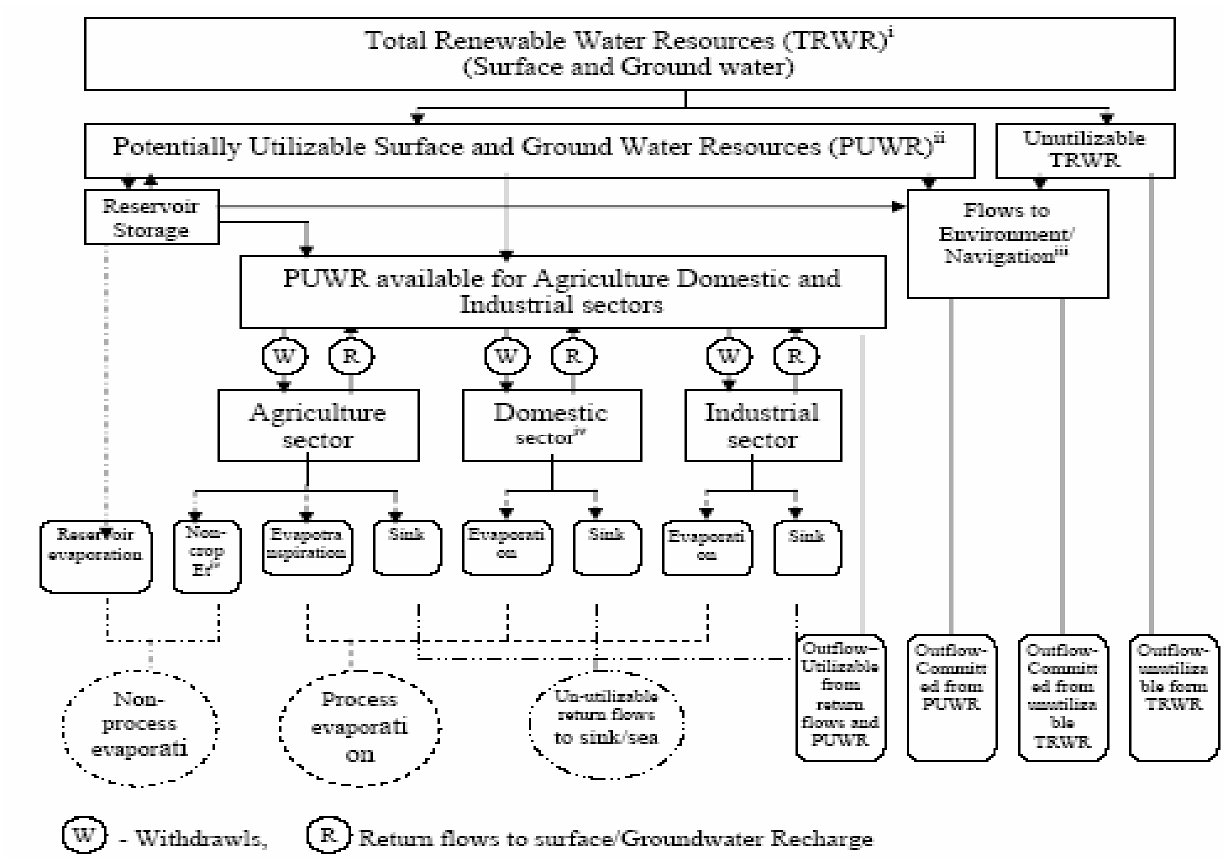
0. Increase in the water availability to rural and urban people.
0. Increase in per capita water consumption by rural and urban people.
0. Increase in population based upon various growth rates.

The model can also help in

) Conjunctive irrigation planning.
) Demand Management of Water Resources
) Integrated River Basin Planning Development and Management
) Sensitivity Analysis.

The flow diagram of water accounting is given below;

**Flow Diagram of Water Accounting in PODIUMSIM**




. TRWR – Total Renewable Water Resources
. PUWR – Potentially Utilisable Water Resources
. Parts of the environment and navigation flows are met from utilizable TRWR and the other parts are met by PUWR

- Domestic sector includes livestock sector water needs.
- Non crop ET is the evaporation and transpiration from the swamps, bare fields, and trees and other crops for which the water withdrawals are not intended for.

# CHAPTER XV

# INSTITUTIONAL MECHANISM

Water resources development taking river basin as a unit cannot be successful unless there is an organization at the basin level for overall planning and management of the basin, irrespective of provincial boundaries. Since most rivers of the country are inter-state, individual States may not be able to take up this assignment. Recognising this, the National Water Policy has emphasized the necessity of formulating river basin organizations.

14.0 The NWP (2002) states that *with a view to give effect to the planning, development and management of the water resources on a hydrological unit basis, alongwith a multi-sectoral, multi-disciplinary and participatory approach as well as integrating quality, quantity and the environmental aspects, the existing institutions at various levels under the water resources sector will have to be appropriately reoriented / reorganised and even created, wherever necessary. As maintenance of water resource schemes is under non-plan budget, it is generally being neglected. The institutional arrangements should be such that this vital aspect is given importance equal or even more than that of new constructions***.**

14.0 It further states that *appropriate river basin organizations should be established for the planned development and management of a river basin as a whole or sub basins, wherever necessary. Special multi-disciplinary units should be set up to prepare comprehensive plans taking into account not only the needs of irrigation but also harmonizing various other water uses, so that the available water resources are determined and put to optimum use having regard to existing agreements or awards of Tribunals under the relevant laws. The scope and powers of River Basin Organisations shall be decided by the basin states themselves.*

Some other of the provisions of National Water Policy-2002, which have bearing on the composition and functions of the River Basin Organisations, are as follows:

*Project Planning*

*There should be an integrated and multi-disciplinary approach to the planning, formulation, clearance and implementation of projects, including catchment area treatment and management, environmental and ecological aspects, the rehabilitation of affected people and command area development.*

*The drainage system should form an integral part of any irrigation project right from the planning stage.*

*The involvement and participation of beneficiaries and other stakeholders should be encouraged right from the project planning stage itself.*

*Participatory Approach to Water Resources Management*

*Management of the water resources for diverse uses should incorporate a participatory approach; by involving not only the various governmental agencies but also the users and other stakeholders, in an effective and decisive manner, in various aspects of planning, design, development and management of the water resources schemes. Necessary legal and institutional changes should be made at various levels for the purpose, duly ensuring appropriate role for women. Water Users' Associations and the local bodies such as municipalities and gram panchayats should particularly be involved in the operation, maintenance and management of water infrastructures / facilities at appropriate levels progressively, with a view to eventually transfer the management of such facilities to the user groups/local bodies.*

The above policy provisions for the integrated development and management of water resources of a basin or sub-basin can be achieved through an organisation namely River Basin Organisation. The proposal for establishment of River Basin Organizations has been under consideration for a long time to suggest the form and role of the basin level organisations. Many Authorities/Boards have been formed in the past for accomplishing specific objectives. Some models of River Basin Organizations (RBOs) being in practice in different countries, are given below;

(a) **Murray-Darling Basin of Australia**

The model of RBO for Murray-Darling Basin of Australia to promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the basin is another example. The structure of the Murray-Darling Organisation consists of a Ministerial Council, Community Advisory Committee, and a Basin Commission. The Ministerial Council is the initiative decision-making forum. The Basin Commission is the executive arm of the Ministerial Council which advises the Council on matters related to the use of water, land and other environmental resources of the Murray-Darling Basin and carries out its decisions. The Commission comprises of a President, two Commissioners from Contracting Government and a non-voting representative from Australian Capital Territory. The Community Advisory Committee provides the Ministerial Council with advice and provides a two-way communication channel between the Council and the Community.

The responsibilities of the Murray Darling Basin Organization include water allocation of the River Murray waters to the States and administration of various key natural resources strategies. It has technical responsibility for water quality, land resources, nature conservation and community involvement. In respect of Water Management, the responsibilities include regulation of the River

Murray and a programme of water quality monitoring to maintain flows and water quality for a range of purposes, including supply of domestic users, live stock and irrigation. The Commission coordinates river management so as to encourage appropriate land-use practices, best practical means of waste treatment, and off-river disposal. It also has responsibility for developing programmes for preservation of native fish and for coordination of management of wetlands.

**(b) Basin Management System in France**

The basin management system in France is organized for six major hydrographic basins which correspond to the four main catchment areas of the country and to two areas of dense population and intense industrial activity. Each of the six basins has a Basin Committee and a corresponding executive agency called River Basin Agency/Water Boards. The Basin Committee – a Water Parliament is made up of local elected authorities, users and the governmental organisations. The power of the Committee lies in drawing up master plan for water resources management and development and coordinating river development schemes according to the Water Act which defines the main guidelines for implementation of the rules and strategy of factors and approving the five-year strategic plan of the River Basin Agency etc. The River Basin Agency while executing the committee's directives are also responsible to the central government for compliance to certain technical matters such as upholding national standards.

**(c) River Basin Commissions in China**

In China, there are seven large River Basin Commissions. The River Basin Commissions integrate planning, implementation and supervision responsibilities for local, provincial and State agencies and coordinate activities of different Ministries (such as the National Environmental Protection Agency) for land and water management in the basin. The Chinese Government acknowledges that there is need to clarify overlap of mandates and some activities between Ministries to modernise institutional arrangements for the improvement of efficiency of programme delivery and to increase technical capacity at all levels. The responsibilities of River Basin Commission are:

- To enforce the national water law on behalf of the Ministry of Water Resources and to cooperate with water departments at local levels in the implementation of law.
- To implement water management and flood control based on the plan approved by the State Council.
- To carry out overall planning, development, utilization and protection of water resources in the basin.

- To coordinate water related activities between provinces and local agencies in the basin.

(d) **Recommendation of the Committee constituted by MOWR**: Considering various aspects and some models of existing RBO in different countries, the Committee recommended, three-tier arrangement for RBOs, i.e. the Council, the Board and the Secretariat.

**Council:** The Council under the Chairmanship of Minister of Water Resources/Irrigation of one of the co-basin States (by rotation) would be responsible for defining the policies and guidelines. The composition of the council shall comprise of Minister of Water Resources/Irrigation/other water related subjects, leader of opposition, MPs, MLAs of the basin states stakeholders, Water Users Associations (WUAs) etc from co-basin States, with a maximum of 15 representatives from each State.

**Board:** The Board under the chairmanship of Principal Secretary of Water Resources/Irrigation of one of the co-basin States (by rotation) would consider various issues and take appropriate decision for implementation in light of policies and guidelines framed by the Council. The River Board would comprise of equal number of representatives from all the Co-basin States. The composition of the Board may be Secretaries (Water Resources/ Irrigation/ other water related subjects), Chief Engineer of Water Resources Departments/Irrigation Department (in-change of the projects in the basin), representative of Stakeholders/WUAs.

**Secretariat:** Secretariat should provide technical and the other inputs to the Board in discharging its functions and power and to ensure the implementation of the decisions. The constitution of the secretariat may differ from basin to basin in view of the varying issues and priorities. However, the Secretariat, adequately staffed, would be multi-disciplinary and would include experts from relevant disciplines.

**Annexure-I**

## CONTENTS OF RIVER BASIN MASTER PLAN

### PART I: BASIN FEATURES

4. Basin setting
4. River system
4. Geological features
4. Climate
4. Socio-economic status
   . Population
   . Urban Centers
   . Food and agriculture
   . Industries
   . Transport
   . Public finance

### PART II: STATUS OF WATER RESOURCES DEVELOPMENT

2. General including past developments
2. Existing and on-going storage and diversion structures
2. Irrigation
2. Hydroelectric power
2. Domestic and industrial water supply
2. Flood and Drainage management
2. Inland navigation
2. Fisheries
2. Recreation and other uses
2. Environmental status
2. Water quality
2. Water legislation/interstate/international agreements
2. Institutional framework.

### PART III: ASSESSMENT OF WATER AND RELATED RESOURCES

#### A: WATER RESOURCES

1. Surface Water
   . Rainfall
   . Temperature
   . Evaporation
   . Stream flow
   . Sediment load
   . Present utilization
   . Virgin flow

. Surface water potential
. Adequacy of network

1. Ground Water
   . Hydrological characteristics of aquifer
   . Estimation of available resources
   . Utilizable resources
   . Present utilization
   . Areas suitable for further exploitation

1. Water quality
   . Data on surface and ground water quality
   b. Appraisal of water quality at critical locations
   c. Water quality standards

**B: ENERGY RESOURCES**

22. Existing hydroelectric projects and their capacities
22. Hydroelectric energy potential in the basin
22. Availability of fossil fuel.

**C: LAND RESOURCES**

4. Land use pattern/culturable area available.
4. Spoil characteristics.
4. Details of forest land and fallow land.

**D: OTHER RESOURCES**

0. Mineral resources
0. Fishery
0. Human resources
   . Extent and distribution
   . Caliber/qualification
   . Employment opportunities
0. Flora and Fauna

## PART IV: NEED FOR DEVELOPMENT

3. Growth potential in the basin
   . Population growth and distribution
   . Agricultural production
   . Industrial production
   . Improvement of transport

3. Food and agriculture
   a. Food grain supply and demand
   b. Present net sown area, gross cropped area and irrigated area

c. Anticipated increase in net sown area and gross cropped area
d. Increase in water demand

3. Electric power
   - Demand Projection
   - Demand centers
   - Alternate sources

3. Domestic and Industrial water supply
   - Urban expansion and water demand
   - Rural water demand
   - Industrial water demand
   - Improvement of public supply system

3. Inland navigation
   - Growth potential
   - Alternate transportation facilities

3. Flood management
   - Identification of flood prone areas
   - Damage statistics
   - Development of flood-prone areas
   - Alternate flood mitigation measures

3. Drought management
   - Identification of drought-prone areas
   - Development of drought-prone areas
   - Drought mitigation measures

3. Water quality
   - Present and anticipated waste load
   - Preventive/remedial measures
   - Minimum flow requirements

3. Fisheries
   - Demand and market
   - River and reservoir environment for fish production

3.Problems of the basin
   - Salinity ingress
   - Drainage and water-logging
   - Erosion
   - Any others

3. Communication facilities
   - Road netwaork
   - Railway lines

## PART V: POTENTIAL PROJECTS

5. Major projects
   e. Water studies
   e. Engineering, geology, cost estimates
   e. Economic evaluation
   e. Financial feasibility
   e. Environmental impact assessment

5. Medium projects
   e. Water studies
   e. Engineering, geology, cost estimates
   e. Economic evaluation
   e. Financial feasibility

5. Minor projects
   e. Water studies
   e. Status (Independent or are part of Major/Medium Project)

5. Ground Water Development
5. Conjunctive Use of Surface and Ground Water
5. Better Water Management

## PART VI: FORMULATION OF MASTER PLAN

8. Establishment of long-term objectives and developmental targets/criteria.
   e. Explain the socio-economic scenarios and constraints of development
   e. Discuss the planning objectives with respect to food production, industrial growth, public health improvement and employment opportunities.
   e. Relate basin planning objectives to the national planning objectives.
   e. Establish water use priorities in various sectors.

8. Preparation of Master Plan
   a. Discuss availability of surface and ground water and their quality as appraised in Part III.
   a. Discuss present and future demand for water as brought out in Part II & IV
   a. Carry out water balance for present as well as future conditions at sub-basin and basin levels and at critical points.

8. Alternate developmental scenarios and Evaluation – Discuss:
   a. Various measures for water conservation and distribution
   a. Possibility of integrating various uses of water
   a. Possibility of integrating various reservoir systems
   a. Conjunctive use of surface and ground water
   a. Integration of environmental/ecological consideration
   a. Incorporation of inter-state/international agreements and tribunal awards.
   a. Possibility/need of inter-basin transfer of water, recycling, recharging for augmenting
   a. Alternate scenarios and consequences

8. Selection of most promising alternative
    a. Impact of alternatives on plan objectives
    a. Decisions analysis
    a. Recommended plan of action

5. Formulation of a phased programme of development.

6. Limitations

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