STATE OF ART REPORT

Scientific Contribution
No. : INCOH/SAR-15/97

INTEGRATED PLANNING OF RIVER BASIN SYSTEMS AND MANAGEMENT

Hari Krishna

INDIAN NATIONAL COMMITTEE ON HYDROLOGY
(Committee Constituted by Ministry of Water Resources, Govt. of India)

INCOH SECRETARIAT
NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE - 247 667, INDIA
1997

Scientific Contribution
No. : INCOH/SAR-15/97

INTEGRATED PLANNING OF RIVER BASIN SYSTEM AND MANAGEMENT

Prof. Hari Krishna
Consultant and
Former Engineer - in - Chief
Irrigation Department, Lucknow, U.P.

INCOH SECRETARIAT
NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE - 247 667, INDIA
1997

The presentation of material throughout the publication does not imply the expression of any opinion whatsoever on the part of Indian National Committee on Hydrology (INCOH) or the publishers.

Published by :

Dr. K.K.S. Bhatia
Member Secretary, INCOH & Scientist F
National Institute of Hydrology
Roorkee - 247 667, India
Phone : 01332-72906, 72907 & 72908

Printed at :

Anubhav Printers & Packers
15, Civil Lines, New Hardwar Road,
Roorkee - 247 667, India
Phone : 01332-71237, 72007

PREAMBLE

It has been estimated that the total world population will be around 6.5 billion by the year 2000, with the most rapid growth in the developing countries. By that time, the countries within the humid tropics and the other warm humid regions will represent almost one-third of the total world population. This proportion will continue to rise in the 21st century. The developing and under-developed countries thus quite clearly are the regions facing potentially serious water problems. Hence, it is urgent to question as to whether the fields of hydrology and water resources management have the appropriate methods in place to meet the rising demands that will be made on the water resources. Hence it becomes very important and expeditious to review and update the state-of-art in different facets of hydrology and component process. This calls for compiling and reporting present day technology in assessment of water resources and determining the quality of these water resources.

The Indian National Committee on Hydrology is the apex body on hydrology constituted by the Government of India with the responsibility of coordinating the various activities concerning hydrology in the country. The committee is also effectively participating in the actities of UNESCO and is the National Committee for International Hydrology Programme (IHP) of UNESCO. In pursuance of its objective of preparing and periodically updating the state-of-art in hydrology in the world in general and India in particular, the committee invites experts in the country to prepare these reports on important areas of hydrology.

River basin systems are elborate and complex and are planned, designed and operated to meet varied conflicting demands of agriculture and other uses from limited sources of supply. Traditional planning and management procedures cannot cope with the problem of efficient planning and management of complex large systems for allocation of limited supplies among varied uses and obtaining increased benefits in keeping with the aspirations of the people. Modern concept of system analysis and use of computer are required to be increasingly applied in planning and management of river basin development. River Basin management studies are elaborate exercises. They require a rational assessment of total water resources in the basin, an efficient utilization of the water resources, and a unified strategy towards varied sectoral consumptive and non consumptive water uses, accounting for environmental impacts and minimisation of negative side effects. The intergrated management and distribution of water includes consideration of interbasin transfers, groundwater management including conjunctive use with surface waters and integrated operations of resorvoir storage and releases.

The report provides a review of the status of integrated planning and management of river basin systems and gives in brief, a few selected Indian and foreign case studies and describes important aspects of the procedure for such planning and management.

The Indian National Committee on Hydrology with the assistance of its erstwhile Panel on Water Resources Systems has identified this important topic for preparation of this state-of-art report and the report has been prepared by Prof. Hari Krishna, Former Engineer-in-Chief, Irrigation Department, U.P. and presently a consultant. The guidance, assistance and review provided by the Panel are worth mentioning. The report has been compiled and finalised by Dr. K.K.S. Bhatia, Member-Secretary and Sri R. Mehrotra, Scientist-in-charge, Indian National Committee on Hydrology.

It is hoped that this state-of-art report would serve as a useful reference material to practising engineers, researchers, field engineers, planners and implementation authorities, who are involved in correct estimation and optimal utilization of the water resources of the country.

(S.M. Seth)
Executive Member, INCOH
& Director, NIH

Roorkee

CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

Water resource development plays an important role in achieving multifaced economic and social development of a nation. Accordingly it has received a place of pride in the development plans of India. The country has made substantial economic progress during its planned development of forty years, yet the rate of growth has been slower than targetted. There is growing realisation that the growth rate must be accelerated and steps must be taken for strengthening the procedures for planning and improved management of water, land and other resource heritage in keeping with avowed plan objectives of social justice and self reliance.

As regards planning , river basin development concept has come to be recognised and comprehensive development of river basins based on full exploitation of total resources must be aimed. Yet, water resource projects are still being planned to cater to the immediate and short term needs and objectives for which pressures exist, without taking into account the gamut of possibilities of development in the river basin. In view of this approach, total water resources are not being put to full use and maximum benefits are not being derived. Also full potential of many a beneficial projects can not be harnessed in future and it becomes a loss for ever to the humanity.

There is urgent need for planning of river basin systems in a manner that would lead to full and comprehensive development of total resources of the basins, side by side with water, by centralised organisation instead of having patchwork of plans on project-to-project basis by separate departments and agencies for separate purposes.

The projects are not being planned and managed efficiently and fuller benefits are not being realised. Also, water supply relative to ever increasing water demands is declining and sooner or later the water resource will be in short supply with respect to the water demands. Already the shortages are being experienced in many States. Thus in development of water resources, the stress should be laid on economic use and conservation of the resources and maximum benefits should be obtained from use of each unit of availabe resources. A number of management measures and techniques that would achieve this objective need be adopted.

The object of the report is to review the status for integrated planning and management of water resource system of river basins and to suggest measure and procedure, that would result in conservation and economic use of water resources.

2.0 HISTORICAL BACKGROUND

River basin development has been in vogue since early times in history. The water use has however been limited to irrigation and urbanised water supply, and in some cases for inland transport. Dykes had been used for prevention of flood damage. In the 20th Century hydro-power development also became an importand purpose. In recent times, storage reservoirs with the wide ranging possibilities for multipurpose development of water resources have been universally adopted, which have been further enhanced by contemporary advances in technology.

Initially, river basin development constituted primarily to the construction of smaller projects and development of water resources for immediate needs and objectives. In course of time, however, the concept of integrated development through construction of large projects involving coordinated and harmonious development of various component system units in relation to all reasonable possibilities in a river basin came to be recognised.

Lately, the concept has changed to the comprehensive development of the river basin for general welfare of the people, aiming at development of total water resources alongside development of land, minerals, industry and trade. Concern is also being expressed for environmental quality and social betterment. The objective of planning has become the resolution of conflicting and ever increasing and changing demands for varied inter-sectoral uses of water for general economic welfare of the people.

In view of the ever increasing demands for economic and non-economic purposes, need for efficient water management, to derive maximum benefits from use of limited water resources, has achieved great significance. Objectives of environmental quality and social betterment have also to be kept in view in management of river basin developments.

3.0 WATER RESOURCES DEVELOPMENT & MANAGEMENT SCENARIO

India is endowed with substantial water resources, in accordance with latest estimates of Central Water Commission, annual runoff of its river systems aggregates to 1800 Km^3 constituting 4 percent of total annual water flows of the world. As the population of India is about 16 percent of world's population, there is greater pressure on use of water to meet the demands in this country. The need for conservation and efficient utilization is far more in our case than elsewhere.

According to the assessment by the Central Water Commission in April 1987, utilizable annual surface water flows have been placed at 684Km^3. According to a rough estimation by the central ground water board, annual utilizable ground waters have been annual utilizable ground waters by the Central Ground Water Boards have been assessed at 422 Km^3. (CWC, 1987). So far 40% of the total utilizable supplies have been put to use for irrigation (423 Km^3) and other consumptive uses of domestic and industrial water supply (36 Km^3). Central Electricity Authority have assessed hydro-electric potential of the country at 60% load factor at 84000 MW and additional installation of 94000 MW from pumped stroage schemes (CEA, 1988). 15 Million KW of Hydropower (against a potential of 178 million KW) has been developed. Remaining potential for irrigation and other consumptive uses and for generation of hydropower still remains to be harnessed. Large areas get annually affected by floods and need flood control measures to protect them. Navigation also requires attention.

A broad assessment of water requirements for irrigation and water supply for domestic, industrial and other purposes has been made extending upto year 2025 by the Central Water Commission in their publication entitled. "Water Resources of India". April 1987, and these requirements has been estimated at 1050 Km^3 (CWC, 1987) as per table below:

Annual Requirment of Fresh Water

Unit : Km^3

		1985 AD		2000 AD		2025 AD	
		Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water
1.	Irrigation	320	150	420	210	510	260
2.	Other uses	40	30	80	40	190	90
i)	Domestic & Live stock*	16.70		24.20		40.00	
ii)	Industries*	10.00		30.00		120.00	
iii)	Thermal Power*	4.30		5.80		15.00	
iv)	Miscellaneous	39.00		60.00		105.00	
	Sub-total	360	180	500	250	700	350
	Total	540.00		750.00		1050.00	

Flood control and Navigation may require some supplies. Hydropower generation may also require some releases in excess of downstream needs. Hence the water supplies are lesser than the ultimate needs. Full attention must be paid for efficient management of water resources. Inter-basin transfer from regions with adequate supplies to areas with deficient supplies will increase further utilization for irrigation and other purposes (MOWR, 1980).

Plan document specifies that existing project should be modernised and rehabilitated and operated efficiently for getting fuller benefits from them. Operation and maintenance procedures are to be improved and standardised. Crop yields from irrigated agriculture as well as dry farming need to be improved by use of better agricultural and land water management practices. Use of high technology and peoples greater participation in management should be encouraged. Along side, planning procedures should be improved. As the river basin forms a unit within which integration of decisions on water and land management as problem related policies can take place most effectively, river basin plans should form the basis of all future development. Use of conservation measures in augmentation of water supplies such as economy in water use, reduction of water losses, water harvesting, recycling of ground water recharge through integrated use of surface and ground water, reuse of return flows and ground waters and inter-basin transfer of surplus flows should be adopted. Integrated and multipurpose operation of projects always increases efficiency of management and should be increasingly used. Use of high technology such as use of software programmes, compatible personal computers, scientific management information system and introduction of limited automation results in increased efficiency of management and should be increasingly adopted in planning and management. (MOWR, 1987).

4.0 INSTITUTIONAL FRAME-WORK

To discharge its functions with respect to water resource development, the states have multiplicity of departments and agencies. Planning and execution of urban and rural water supply project is normally handled by Public Health Engineering Departments of the States. Major and medium irrigation as well as multipurpose projects and storage reservoirs, minor irrigation projects , tubewell projects and drainage and embankments are usually planned, executed and managed by State Irrigation Departments. Command Area Development Authorities have been established in many commands of major projects for integrated approach for land and water related resources development. In some states, minor irrigation and / or tubewells are handled by separate departments/ corporations. Many states have separate ground water investigation organizations as well. Hydropower Development is normally with the State Electricity Boards and Hydropower Corporations. However, in many States the responsibility of planning of hydroprojects as well rests with the irrigation department, together with execution of their civil works.

The Central Water Commission and the Central Electricity Authority are advisory bodies of the Government of India to assist it in formulation of appropriate policies for optimum development of water resources in the country. They also assist the State Governments in resolution of complex technical problems of planning and design. The Central Ground-water Board advises the Government of India on the assessment of ground water resource and programme of its exploitation.

For giving national direction to flood control efforts in the country, a Central Flood Control Board has been set up which lays down the general principles and policies in connection with flood control measures, considers and approves master plans for flood control works, as submitted by States of river commissions and arrange necessary assistance in connection with planning and execution of flood control works. (CBIP, 1965) Central Pollution Control Board has been created to deal with environmental protection in water development and management (Maximor, 1973).

Navigation and harbour improvement are handled by the Ministry of Transport and Shipping, Government of India.

Sometimes, in case of inter-state projects, inter-state Control Board are set up, to assist the state in their management, by the executive order of the Central and concerned State Government

Realizing the importance of hydrological research for rational development of water resources of the country, the Government of India has established National Institute of Hydrology in the year 1978 with its Headquaters at Roorkee. The Institute has excellent capabilities for taking up research, consultancy, training and field research in hydrology. The Institute has few regional centres for taking R & D works in states. The work of the institute covers all aspects of hydrology including use of systems theory for intergrated water resources management.

Central Ground Water Board, Central Soil and Materials Research Station, Central Water and Power Research Station are other premier organisations under the Ministry of Water Resources who are engaged in R & D work in water resources.

5.0 NATIONAL WATER POLICY

National Water Policy to guide the development and management of water resources had been defined only in 1987 and adopted by the Ministry of Water Resources, Government of India. It provides guidelines for the development of water resources in the country. It lays emphasis that water is a scarce and precious natural resource to be planned, developed and conserved as such and on an integrated and environmentally sound basis, keeping in view the needs of the people. The prime requisite for resource planning is a well-developed information system. Resource Planning in the case of water has to be done for a hydrological unit such as drainage basin as a whole or for a sub-basin. All individual developmental projects and proposals should be formulated by the States and considered within the framework of such an overall plan for a basin or sub-basin, so that the best possible combination of options can be made.

Water should be made availabe to water short areas by transfer from other areas including transfers from a river basin to another, based on a national perspective, after taking into account the requirements of area/ basin.

Water resource development projects should as far as possible be planned and developed as multipurpose projects. Integrated and coordinated development of surface and ground waters and their conjunctive use should be envisaged right from the planning stage. Recycling and reuse of water should be integral part of water resource development. There should be a master plan for flood control.

Special efforts should be made to investigate and formulate projects either in or for the benefit of areas inhabited by tribal or other specially disadvantaged groups such as scheduled castes and scheduled tribes. Priority should be given to the need of drougt-prone areas. These should be made less vulnerable through water conservation measures, the development of ground water potential and transfer of surface water from surplus areas where feasible and practicable.

There should be a close integration of water-use and land-use policies. Water allocation in an irrigation system should be done with regard to equity and social justice.

Efforts should be made to involve farmers progressively in the various aspects of managment of irrigation system. The efficiency of utilization should be improved (MOWR, 1987)

The success of the national water policy will depend entriely on the developnent and maintenance of a national commitment to its underlying principles and objectives. Many steps are however required to be taken including enactments for effective implementation of national water policy. Till such steps may be taken, the planning, implementation and management of water resources projects will contiune to be handled by the state and Central Govts. as here-to-fore. River Basin Plans and guidlines projected by the national water policy will however govern during this period also in all the future planning and management of water resources.

6.0 INTEGRATED RIVER BASIN PLANNING

6.1 Planning Concept

The object of river basin planning study is to obtain optimum development of water resources of river basins to meet the varied and changing needs of the people residing in the basin and thus make greatest contribution to the well-being of the people of riparian basin states.

The planning consists of an orderly consideration of the coordinated and multipurpose development of water, land and other related resources of the river basin in relation to all its reasonable potentialities and selection of an appropriate river basin plan from a large number of alternatives which meets the aspirations of participating states and serves the varied national objectives. The study is carried out by a planning team, set up for carrying out the study as soon as the involved States and the Centre agree for it. The selected plan provides a frame-work of ultimate development, to decide the pattern of growth of water development for varied uses.

It may be mentioned that the planning activity must be conceived and implemented in close interaction with the decision makers. Ultimately, it must be seen that the river basin plan forms an integral part of the regional and national perspective plan using large scale inter-regional and national economic models or extension of mixed integer programming model. This may require consideration of inter basin transfer of water supplies and consequent modification of the river basin plans. (Krishna, 1987)

6.2 Planning Process

The planning process involves the adoption of a systematic approach to determine the diverse tasks required for development of a comprehensive plan. During the study period, the public and the decision makers are kept fully aware of the assumptions being made and full implications of the various plans of actions being considered.

The planning process (WRC - 1980) consists of the following major steps:

1. Setting the plan objectives,
2. Establishment of supply and demands,

3. Formulation of alternatives,
4. Evaluation of alternatives, and
5. Selection of recommended plan

In view of interlinkages, several of the component studies are carried out simultaneously and feed-back may occur at any step to previous step (Fig.1).

The river basin is sub-divided into a number of sub-basins in consultation with participating states for the purpose of the study to simplify planning procedure. A set of system configurations, scales of development and inter-linkages of system- and / or operation policies to satisfy the needs and objectives are developed for each sub-basin. Preliminary screening is carried out to limit the alternatives to a manageable number.

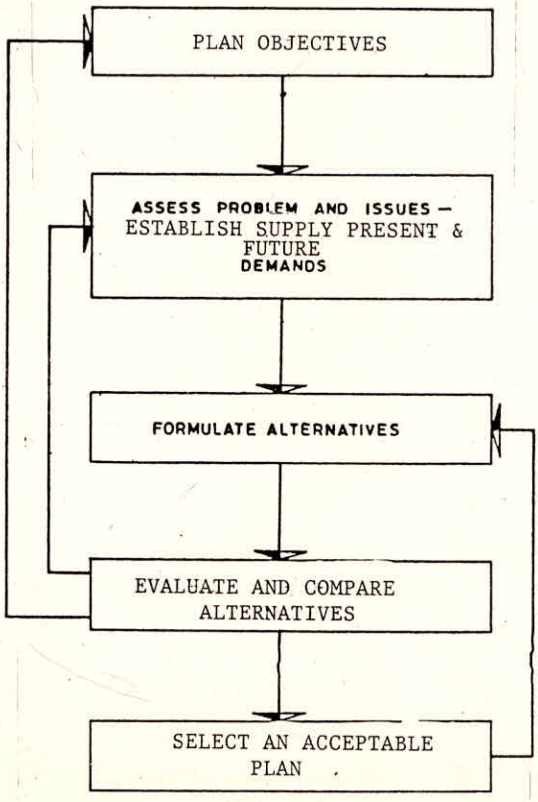


Fig. 1 : The planning process

6.3 Plan Formulation

6.3.1 Plan objectives

The goals and objectives of river basin plan are defined at the start of the study. Problems and opportunities are identified. A document is prepared that describes in details the goals that must be achieved and the issues that must be tackled. The goals are set in consultation with the government at various levels and with public involvement. National, regional and local perspectives are kept in view while defining problems and issues.

National objectives that provide the basis of formulation of plans for conservation and use of water and related resources are enhancement of national economic development, social well-being and environmental quality. Emphasis is laid on development of tribal areas, hill areas, drought prone areas, water short areas and other disadvantaged areas. The plan objectives of self reliance, equity and social justice and removal of poverty are also given due importance.

National water policy (MOWR, 1987) lays down allocation priorities for water use as follows;

In the planning and operation of system, water allocation priorities should be broadly as follows:-

- Drinking water
- Irrigation
- Hydro-power
- Navigation
- Industrial and other uses.

However, these priorities might be modified if necessary, in particular region with reference to areas specific consideration.

6.3.2 Establishment of supply and demands

Once planning objectives are defined and planning criteria are established, problem identification and setting of present and future water demands become the first planning task. It includes appraisal of water, land and related resources (supply) identification of existing water and land development (Planning base) and assessment of present and future water demands (needs) for various sub-basins.

Existing water, land and related resources (supply) - An inventory is made to determine the extent of available water and land resources of the river basin and to identify opportunities for further use and conservation of these resources. Assessment of available water resources is basic requirement for planing their use to meet the present and future demands.

- Assessment of water resources -

Surface and ground waters are two facets of the total water resources. Both components are thus considered in assessment of total water availability of each sub-basin. Whenever feasible, conjunctive use of surface and ground waters and reuse of return flows are considered in arriving at total water resources in a sub-basin, available for utilization. A fraction of water used for various consumptive uses may however, return back to the drainages and is available for reuse. A concept is therefore, established for return flows, specially from consumptive uses such as irrigation and domestic and industrial water supplies.

From management point of view, QUANTITY WITHOUT ANY REFERENCE TO QUALITY is not relevant. While a certain quality of water may be usable for agricultural purposes, it may not be usable for industrial activities. Thus the water availability is determined in respect of both quantity and its quality.

i) Surface water -

Surface water availability is assessed from historical records of long term observed run-off data at various points of extraction as available. However, when long term data extending for a peroid of 30 years or more is not available, it may become necessary to carry out analytical studies to simulate surface water availability at points of extraction, where data is lacking, with operation of appropriate hydrologic models. All the observed and generated data is brought to a common base representing present stage of development. There are a variety of approaches for such assessment. The planner may select an approach which is considered by him best suited for a particular situation.

Rational Hydrologic Models based on rainfall and runoff relationship which is established from observed run-off data and corresponding weighted rainfall for specific drainage basins and takes into account the catchment characteristics, such as topography, potential evapotranspiration, land-use distribution and antecedent moisture condition, is one such approach. In this approach a matrix of run-off coefficients for monthly periods in monsoon and for lumped period of non-monsoon season are obtained. The limit of rainfall, which may not produce any run-off coefficients for monsoon months may in this analysis include the effect of base flow component. However, for non-monsoon period, the base flow component is separately accounted for and is not reflected in the assessment of overall run-off coefficient for lumped period of non-monsoon season.

Stochastic model studies are also made when considered necessary for generation of long range run-off series extending upto 100 years or more to study the impact of variation of water availability on management policy.

ii) Ground water -

Where ground water is an important source of supply, its potential is ascertained by carrying out ground water balance studies using computer assisted numerical solutions. The development of ground-water is limited by the physical feasibility of utilization of groundwater which is related to the aquifer characteristics and is dependent upon the hydrologic capacity or safe yield of the basin aquifers and its water quality. Information on type of ground water extraction structures based on the study of ground water conditions and hydrogeological set-up is also collected. Appropriate conjuctive use systems are considered ensuring optimal use of surface and ground waters for various scenarios.

iii) Return flows -

An assessment of the return flows, from consumptive uses, that are usable and available for recycling is made. A portion of withdrawls to meet the irrigation and domestic and industrial water supply returns to the stream and becomes available for reuse. In case of irrigation, while a certain amount of water is required for crop water needs during crop seasons for use in transpiration by the plants and for evaporation, some portion is wasted as surface run-off and another portion is lost through percolation. Surface run-off and part of percolation losses may however, appear as return flow. In case of domestic water supply, only a small portion of supply is consumed and balance is lost underground, or returns to the stream with or without treatment. Similarly, substantial portion of water sypply is available for reuse in case of many industrial uses. For example, a large portion of water used as cooling water returns to the source though at a higher temperature.

- *Assessment of water demands* -

Existing Water and land development and use is evaluated and serves as planning base. The information about public concern is obtained on needs for improvement of socio-econimic conditions, and of deficiencies related to drought, flood drainage, saline lands etc.

The purposes for which land water resources must be developed in each sub-basin are identified based on study of opportunities and public concerns. Irrigation, domestic (rural and urban) and industrial water supplies, and hydropower generation are recognised beneficial water uses for all areas. Flood control is normally an incidental benefit except in humid areas where it is considered as one of the main purposes. Navigation has recently received much attention from the Government of India and Ganga and Narmada rivers have already been declared as national water-ways. Recreation, wild-life habitats and waste disposal are normally considered incidental purposes. We have normally basic policy options for water allocations for sectoral uses of irrigation, domestic and industrial water supplies and hydropower generation and flood control. Sometimes, other purposes are also specified. Minimum flow required in the stream for ecological considerations must always be accounted for. Sectoral water demands are established for each class using special sectoral models (USGS, 1973).

In assessment of overall water demands, the various components of water demands are grouped and classified in the first instance according to their relation to and effect on sources of water supply as withdrawal, in-stream requirement and on-site uses (UN, 1975).

Water supply for domestic and industrial uses and for irrigation are typical examples of consumptive uses. The water is conserved and released to meet these demands. Domestic (rural and municipal) water supply is priority use. The industrial water supply is also considered a priority use and as far as possible its demand is met.

Hydropower generation is non-consumptive use but requires water supply. The water is released in the stream after hydropower generation without any effect on water quality and is available again for consumptive and other uses.

Inland Navigation is also a non consumptive use. It requires a certain depth of flow depending upon type of cargo to be handled. When water is required to be released for keeping a stream navigable, it is in-stream water demand. In stagnant pools, navigation represents on-site use of water.

Flood control is an in-stream use. In case of detention reservoirs and on-stream storage projects with flood control, empty space is required to be reserved for absorbing excess flood peaks when necessary and reducing flood flows in the stream below to keep them within permissible limits that can not cause undue flood damage. In case of flood-ways, the excess water only may be diverted to a stream in an adjoining basin where it may not cause flood damage.

Flow required for waste disposal and tor ecological consideration is also an in-stream use. Recreation and fish and wild life conservation when not requiring releases of flow are examples of on-site uses.

- Projection of water demands

The water demands depend upon variety of social, economic political and technological variables. The variables such as population growth, level of economic development, land use pattern and hydrologic variables may not pose great problem in establishing future scenarios. But consideration of variables such as national system of water law and the legislative measures and economic and fiscal policies will not be so simple, as it is not possible to visualise developing any meaningful estimate of probabilities for change in policies and policy directions in the future. Forecasting of demands for water in future thus require considerable discretion in excercise of judgement in the development of policy specifications because of large number of policies and consequently alternative scenarios involved. In such cases, a few combinations of mutually consistent policies are obtained for development of alternative scenarios and implications of each set is evaluated separately. In case of the opportunities provided by technological innovation, it is even more difficult to assess potential technical advances and evaluate their impact on water demands in future. Consequently, this aspect is generally not taken into accont for developing plans of future water uses.

The process of projecting the water demands implies projecting the form and size of economy of the future, and establishing the water demands based on water use per unit of output, (UN, 1975). The water demands that can be met economically with a degree of reliability and are acceptable to the public and decision makers are obtained.

The life of the river systems are normally 100 years, but in view of inherent uncertainty involved in projections, the water demands are therefore projected for a period of 25-50 years. These estimates are periodically brought up-to-date and modified for subsequent planning and management studies, to account for divergence between expectation and reality as the time elapses.

- *Integration of supply and demand*

The starting point is an economic and social base study coupled with the formulation of first set of alternative future scenarios including that without any of the alternatvie plan. A procedural frame-work for water demand projections and integration of supply and demand is schematically shown in the flow chart (Fig.2). Projection of water demand is followed by comparison of water demands with available water resources. If water shortages occur in some of the sub-basins, regrouping of demands against potential sources of supply is done, or iterative revision of projection of water demands are made (Cano, 1973).

The comparison is carried out, using Loss-flow Model, after Woolman and Bonem, Resources for the Future, as distinct from withdrawal-flow model, which allows the planners to aggregate the effect of withdrawal uses without consideration of their location within the basin. While withdrawal flow model is suited for management planning studies, where data is scanty as may often be the case in developing countries. In this model withdrawal uses (after accounting for prospective withdrawals from ground water) and in-stream flow-requirements are summarised as the sum of losses and the ruling in-stream required flow and to compare this quantity with expected flows (before losses) for critical time periods. The comparison is made as though all the streams of the basin constitute a single stream

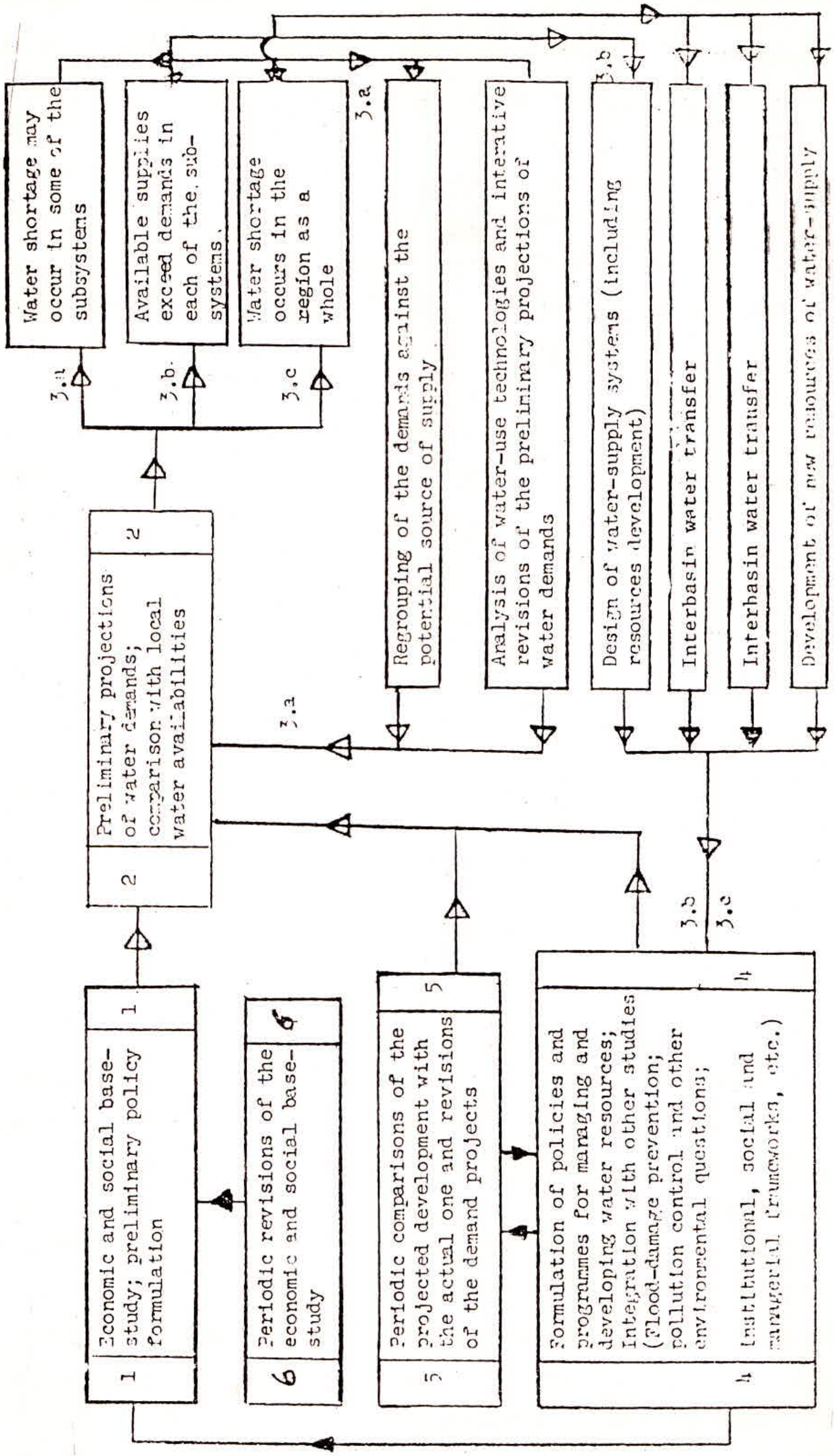


Fig 2 : Flow chart of river basin water demand projection and integration exercise of specified characteristics along which and in which all water using activity is located. The degree to which supply and demand matches for specific level of water resources development and with specified probabilities of attaining a given flow can be ascertained without a need to know the precise location of activities except those at the discharge end of the basin.

The required dilution flows are computed assuming the aggregated waste load projected for the basin throughout the length.

If flow uses other than dilution flows are not rigidly met, and an in-stream quality standard is to be maintained over interval when other flows are inadequate for the existing level of treatment, either treatment levels or dilution flows must be raised. The water resource planner can determine what controls over flows are needed to assure adequate dilution flows then needed, and with what levels of treatment these flows are consistent for a designated in-stream quality standard. The flow-treatment combination may be selected on the basis of minimising aggregate costs of treatment and flow regulation or in accordance with the objective of minimum disturbance of the river's natural regime.

If requirement is defined as the sum of losses and in-stream required flows, it implies that activities will seek such locations and will adopt such degree of internal circulation as is needed for withdrawals to confirm to available flow at any single point, but neither precise location, nor degree of recirculation need to established "a priori". Special cases may need, however, be tested. The loss-Flow Models provide relatively simple way of aggregating basin supply where demand data is scanty (UN, 1975).

The additional information :eceived from such comparisons is used for extension and reformation of policies and programmes for development and managing the water resources of the basin. Regrouping of water demands among the various uses of supply and re-examination of demand projections are usually required also in comparing alternative measures for mitigating foreseable water shortage.

Establishment of future water demands and comparisons and integration of supply and demand forms part of management planning study as well and are discussed again at relevant place.

6.3.3 Formulation of plan alternatives

A set of alternatives for various sub-basins are established. Various sub-basin plans are then evaluated and ultimately integrated into basin plans. Promising river basin plans are tested to determine their ability to satisfy the needs and goals.

Sub-basin Plans - Planning criteria is established and plan formulation is then started. It takes into account use and management of water, land and related resources of the river basin for meeting present and future demands of the basin. Variety of screening, coordinating and simulation mathematical models are developed, adapted and used.

Measures to achieve various objectives are identified and a number of alternative development plans to meet the present and future needs that have been established are generated for each sub-basin. Optimal use of natural resources is kept in view. Environment aspect is given due emphasis. A number of alternative plans are generated.

Development plans are generated for consumptive use demands for irrigation and domestic and industrial water supply. Integrated system with conjunctive use of surface and ground waters are planned. Consideration is given to recycling and reuse of water supplies. Water Balance Studies are made. The element of flood control is added. All structural and non-structural measures for flood control and other uses are taken into account. Hydropower generation is maximised by judicious and integrated operation of reservoir. The study includes flood period simulation, if any flood control pool is provided in reservoir storage.

- Integration of sub-basin plans into the basin plan

Sub-basin plans are integrated into basin plans. Integration may require adjustment of demands in the sub-basins. Integrated operation of various measures specially reservoirs may enhance benefits and hence operation studies provide the optimal policy for maximisation of hydropower generation also that can be absorbed in the overall power grid.

Suitable programming models are adopted in these studies. Optimisation models establish the overall farmework, and are used to integrate the various aspects relevant to future development. Appropriate simulation models operating on weekly basis are developed which can perform in combination with optimisation models.

Few promising plans that have been tested for their ability to satisfy the needs and goals are taken up for detailed evaluation studies.

6.3.4 Evaluation of plan alternatives

Principles of evaluation and quantitative standards for carrying out river basin planning studies are established by the Government or defined by the planners based on the experience of other countries. These permit the measurement of the impact of the plans in terms of various defined objectives and goals. Where quantitative standards can not be applied, objective values are defined in respect of the effect of the plan.

The evaluation of alternatives is an iterative process in combination with the formulation step. All beneficial and determental effects are quantified in physical terms.

In evaluation process, the relative success of each alternative plan to meet the various planning objectives is assessed. Incremental effects of each alternative plan are then estimated by comparing benefits for all modelled alternatives with the alternative of simulated unplanned alternative to check the extent of improvement upon existing conditions.

Incremental benefits and costs associated with impacts contributing to the economic goals are analysed according to traditional cost-benefit techniques. Incremental non-economic impacts including those associated with planning objectives of environmental quality and social betterment are evaluated through a scoring procedure. The scores for non-economic impacts are then weighted to reflect the relative values of each gain or loss for the people of the river basin. Beause multiple goals contain inherent conflicts, these can not be maximised simultaneously. The impact of each alternative on the competitive range of objectives can best be compared on an evaluation matrix. By comparing the economic benefits directly with the scoring indices for various alternatives, decision makers can assess, if improvement in environment and social inputs are at least worth the incremental costs. If facilitates the trading -off required to achieve an optimal balance between multiple goals of river basin planning.

6.3.5 Multi objective analysis

While dealing with the problem of two objectives, the net benefits for the objectives are displayed graphically along the two axes as illustrated in Fig.3. Potentially optimal solution lies along the boundary of the region which contains all feasible solutions. Optimal solution lies at a point where social utility is maximised. In an exercise with three objectives, the mix of features associated with the future development of river basin can be displayed on three dimensional surface as outlined in the Fig.4. Points on this surface represent extreme mixes of three major goals of economic growth, environmental quality and social betterment for a future scenario and provide trade-off between these goals. (Environment Canada, 1975)

An optimal balance is desired between defined goals. It requires consideration of a large number of economic and social measures. Ultimately other resource management features such as land-use planning, urban design and transportation need to be taken into account to arrive at an acceptable balance between economic growth, environmental quality and social betterment. (Framji and Krishna, 1989)

6.3.6 Selection of acceptable plan

Evaluation Criteria such as acceptability, completeness, effectiveness, efficiency, certainty, geographical scope, economic benefit cost ratio, reversibility and stability are

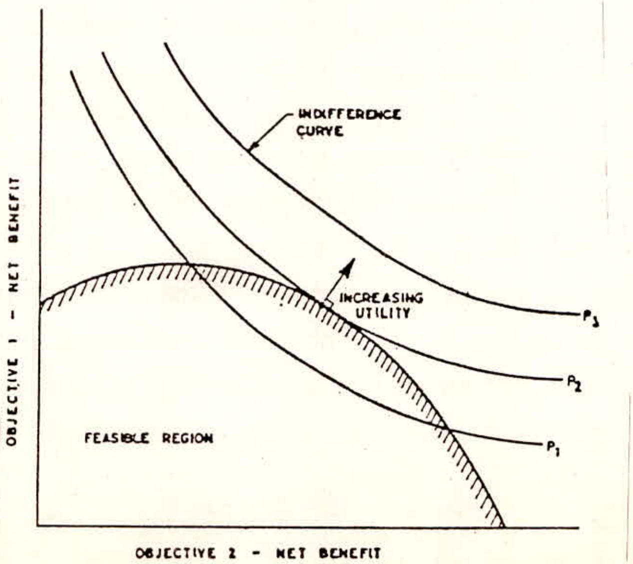


Fig. 3 : Multi-objective repersentation (2 objective)

considered while selecting the plan. A river basin plan that is most acceptable to the decision makers is selected after considration of the information on the alternatives presented in the recommendations. The plan so selected serves as a guide for all development programmes in the basin. Before adoption of a plan, the management studies are carried out and if, it so indicates, the plan is modified.

6.4 Planning is a Continuous Process

Substantial efforts is needed in preparation of a final plan before it meets the approval of the decision makers and forms the basis for programme of implementation. Thereafter also, it takes long time for the appropriate authority to implement the plan constituent project units. During this waiting period the plan constituent project units.and the political, technological and financial reassessment of the plan may take place by the Government and the public. The plan may be examined from other criteria than those considered during planning study. Alternatively, priority and feasibility may change in view of factors not accounted for initially. The planning process it thus a continuing exercise. (Environment Canada, 1975) The overall river basin plans need periodic review and are generally updated every 10-15 years till they are implemented, to account for changing conditions and new technology.

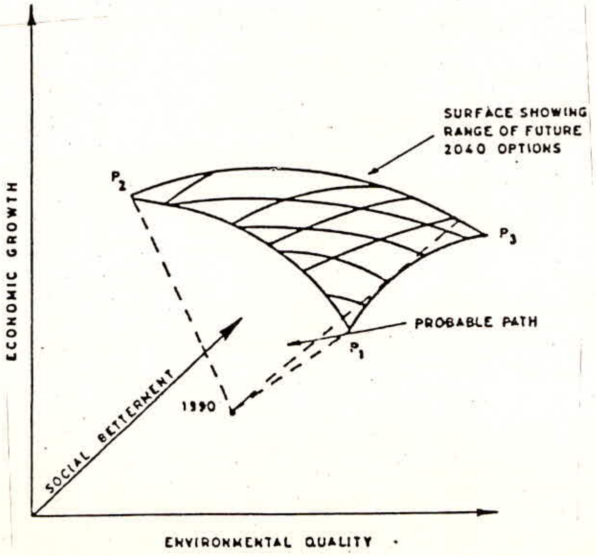


Fig. 4 : Example of future options in multi-objective river basin planning - (3 objective)

7.0 INTEGRATED RIVER BASIN MANAGEMENT

7.1 Management Planning Process

Water resources river basin systems are elaborate and complex systems. These are formed through combinations of a large number of systems units, such as storage, diversion, regulation, and conveyance and specific facilities to serve a variety of purposes which may be complementary or competitive and meet the water demands of the people for their general welfare. As water resources are limited, these are to be conserved and allocated among variety of uses to meet the projected demands, in the best possible manner.

Integrated River Basin Management involves accounting of consumptive and non-consumptive uses of water, including those not involving with-drawal, paying attention to environmental impact from sectoral uses of water. It includes appropriate ground water management schemes including their coordinated conjunctive use with surface water and integrated landuse and water management , ensuring a rational treatment of surface watersheds to prevent pollution, specially in the case of groundwaters. It requires systematic planning using system analysis and modelling techniques to improve efficiencies in storage, operation and distribution systems as well as to optimise the allocation of water among various users as a prerequisite for rational utilization of water, and unified strategy for water withdrawal, distribution, treatment and discharge, promoting integrated water supply and disposal systems. Developemnt of non conventional water supplies, including the enhancement of existing ones are also considered (Calcagne, 1987).

The operative steps are as follows:

* The available water resources in the sub-basin or basin are appraised and updated with respect to the source, extent, character and dependability to supply.

* The projections of water demands for various purposes are made basing them on study of alternative future socio-economic scenarios.

* Overall water dependable supply, corresponding to a hypothetical year with 75 per cent dependable flow availability and ground-water potential equivalent to that for the

year of normal rainfall, and projected water demands are compared and integrated with available supplies.

* Crop planning studies are carried out based on soil surveys, soil and land classification, economic and social scenario, agroclimatic conditions, needs and other parameters, and feasible croppoing patterns for various agroclimatic zones in the river basins are established.

* The reservoirs and river system operation studies are perfomed for establishment of salient features of operating policy to meet the projected water demands of conservation uses. The studies are carried out: (i) for a hypothetical year as above and to obtain design demand patterns by iterative studies that can be managed with such supplies and (ii) for planning horizon using surface water resource availability for that period, as ascertained by hydrologic studies, to obtain information on the extent of demands that can be met in years of short supply and on the excess supply available after meeting the demands in years with better water availability.

* Where flood control is one of the main purposes, integrated operation of reservoirs having flood control are also carried out.

* Groundwater management studies are made for determining usables groun water potential for meeting the irrigation demands.

* Channel system operation studies are carried out for various channel systems.

(i) Review of channel system layout, (ii) Simulation of the channel behaviour in operation under steady state, dynamic state and emergency transient flow condition and (iii) development of policy for regulatioin and scheduling of canal systems to serve water demands on full and partial development of demands.

* Simulation studies for river basin system operation are carried out operation policies are finalised.

* Rules and procedures for operation and management are developed and guidelines

for water distribution and resolution of conflicts are established.

* Peoples participation in water management is considered.
* Management Information systems are devised.
* An effective communication system is planned.

7.2 Appraisal of Available Water Supplies

Long time elapses in the prepartion of a river basin plan, before it is accepted and becomes the basis for programme of implementation. There may also be substantial waiting period till the project is approved by competent authority and work on the project is taken up. During this period, additional hydrologic data on various extraction points may become available. It is thus always necessary to take up hydrologic studies and update the surface water availability using appropriate hydrologic models. Long term surface run-off data for years of observed discharges and monthly generated run-off data for other years will then become available. 75% dependable annual surface flows are obtained from long terms runoff series based on stockastic studies and its distribution pattern in monthly and weekly flows which is based on study of trend from observed discharges. With additional data on ground water system being available, ground water potential is also updated by carrying out further studies. The updated data is then used in studies for integration of supply and demand and for operation studies for management planning.

Total water resoruce supply (quantity and quality) coordinating surface and ground waters and considering reuse of return flows as feasible, are taken into account in meeting the demand.

7.3 Projection of Water Demands

Projection of water demands are also updated using additional information and studies that becomes abailable during the period that has elapsed from the planning study made at the time of preparation of river basin plan.

Only demands that are real and can be met from available resources are considered. The demand for various purposes are assessed as follows:

- Municipal water supply

Rural and Urban water supply demands are based on per capita consumption. It increases with increase in population. It may also increase with change of habits from a rise in standard of living, based on projections of the distribution of urban and rural population to be provided with orgainsed water supply and prescribed rates of water supply. The demand includes requirements of water for livestock population also. Funds available for investment may sometimes restrict the withdrawals for rural and munucipal supplies and hence this aspect should also be taken into account.

- Industrial Water Supply

The demand for industrial uses requires careful study. The industrial water supply demands are based on projections of industrial development in private as well as public sectors based on Government policy and on the trends prevalent in the basin and experience form elsewhere. Large amount of water is used for industries for manufacturing processes including withdrawal for cooling conventional thermal and nuclear power plants. The water, however, for cooling need not be of high quality. But the discharge of heated water can create problems of thermal pollution. It may also be understood that the simple once through-flow process has large requirements of water as compared to the use of inplant recirculation and treatment process. The application of water recycling system within the production process as well as reuse of successive and concurrent uses of water within the same industry or other industries complexes should be considered. The industrial use of water requires the use of river or natural drainage system to dispose off industrial wastes. The quality of effluents and waste products from the industry going to the water bodies may have thus to be controlled in accordance with rules and regulations under the Pollution Control Act.

- Irrigation Water

The irrigation demand for agriculture is substantial though variable. It depends upon the cropping pattern, cropped areas and agriculture practices. Modern technology is being applied more and more in management of irrigation systems. Demographic and socio-economic trends are projected to ascertain the requirements of food grains for the population upto target datas keeping nutritional aspect in view. Projection of land use patterns including land development and reclamation for increased agricultural production consequent to introduction of irrigation are made. Crop patterns based on agroclimatic scenario and keeping in view the requirements of foodgrains and other crops with a view to achieve self sufficiency and attain surplus production are established. Crop water demands are based on climatological approach taking into account likely crop calendar and agricultural practices and developments. Effective rainfall which represents the portion of rainfall that becomes available to partially satisfy evapotranspiration demands of crop is accounted for in establishing net crop water needs. Systems losses are also provided for. The demand for irrigation is based on the study of crop water needs and losses established taking into account agricultural comparison with potential of irrigation development from use of surface as well as groundwater.

- Hydroelectric power generation

Water needed for power generation to supply the share of power plant in the overall power system is assessed. In case of reservoir projects where water demand is in excess of water needed downstream for consumptive uses or conservation uses such as navigation, and other uses and flow for requirements downstream, trade-off studies may dictate the hydropower requirements.

- Flood control

Requirement of flood control may be governed from consideration of flood damage to be prevented. In humid areas, it may be one of the main purposes and empty space may have to be kept reserved in the storages for absorbing flood peak and reducing flood flows downstream of reservoir within permissible limits that will not cause undue flood damage. Where feasible, the space reserved for flood control in the reservoir may be allowed to fill towards the end of monsoon for use for conservation purposes.

- Navigation

Whenever water is to be released for keeping the stream in stretches downstream of reservoir as navigable, the requirements may be established from the cargo to be handled.

- Other uses

There may be prior use rights or flow requirements for ecological considerations or inter-state and international agreements which must be passed downstream.

7.4 Integration of Water Supply and Demands

In this study, comparison of available water supply and the demands based on most probable future scenario of economic and social base is made. If the supplies can meet the projected demands, the water demands are adoped as such. If however, shortages occur, it is ascertained as to what extent these can be met by possible inter basin transfer. Otherwise, regrouping of water demands against potential sources of water sypply is done, and analysis of water use technology together with trade-off analysis is made and projected demands are adjusted. The comparison is carried out adopting "Withdrawal Flow Models" (UN, 1975). This study is made for a hypothetical year with 75 percent dependable surface flow availability and ground water potentiality for a normal rainfall year.

Withdrawal flow models which are concerned with ove all supply, storage and withdrawal aspects within a river system, are useful tools for s 'ch study. These models take into account effect of precipitation, run-off, groundwater flow, evaporation and diversion and storage changes. These are hydrologic coordination models. Entire storages are considered as individual units and principle of continuity is applied. Study is iterative and matching of demands and supply is attempted till available supplies and demand match. These are operated on the principle of routing the water from uppermost part of the basin to point of discharge and comparing, after computing at each point of use enroute, the withdrawal requirements and the amount of flow that must be left flowing in stream with expected flow and yield from aquifer management under various conditions of flow regulation. It is assumed that adequate information is available on prospective use and internal rate of recirculation in use systems, and that there is no restriction of water discharged from upstream being reused a number of times on the downstream, subject to specified quality for which a treatment flow schedule has been prepared. The in-stream flow uses which are ruling are also taken into account.

The maximum withdrawals on each of the independent tributaries are ascertained and aggregated and withdrawals at each point on the main stream are compared with the flow requirements to determine which aspect is ruting. The water quality aspect is also considered and in-stream dilution flows, if required, are estimated.

7.5 *Planning of Crop Patterns*

Irrigation is a major water use accounting for about 90 percent of consumptive uses. Great attention should, therefore, be given to plan croping patterns, that are likely to develop on introduction of irrigation facilities, should consequently receive due consideration and would give maximum productivity with use of available water supplies.

Soils and agroclimate, socio-economic structure, and water availability for irrigation have bearing on the type of crops that can be grown in an area. Therefore, while deciding on the cropping patterns, in an area information is collected on soil and land classification and soil conditions based on detailed soil surveys and agroclimatic factors from meteorological records. Soil and land capability, with respect to crops that can be grown in the area, is ascertained based on the water availability for irrigation, and socio-economic conditions of farmers. The cropping patterns that have been practised in the area prior to introduction of irrigation and the cropping patterns that have developed over time in irrigated tracts in comparable situations else-where serve as a guide in assessment of CROPPING PATTERNS that can be expected with no constraint on water availability, in the area after introduction of irrigation. It is kept in view that crop intensities ranging from 150 percent to almost 200 percent have been achieved in some of areas with substantial assured water supplies for irrigation.

During wet years all the water demands of irrigated agriculture for maximum condition of productivity are met, but during years of short supply, entire cropping patterns are not made but supplies are made to maximise benefits from unit of available water supplies. Lot of research has been carried out in the country for maximisation of agricultural production from limited resources and the results can be used to plan cropping patterns and distribution of water supplies for irrigating the crop. Production functions for principal crops with regard to yield vis-a-vis amount of irrigated water represented by number of waterings and amount of fertilizers, which are the important inputs, are identified. Possibility of likely technological advances in agricultural practices apart from other factors are also kept in view. The cropping patterns for various levels of water supplies are established. Appropriate mathematical models are developed to plan the scheduling of water supplies among crops when they are short and plan additional crops that should be grown when supplies are in excess. A scenario is developed which gives the gamut of range of crops and feasible cropping intensities that can be managed with increasing availability of water for irrigation. Crop water demands are worked out for use in water management studies.

7.6 System Operation Study, for Reservoirs, Barrages, and Interlinked River System for Varied Conservation Uses

The system may comprise a river system with a number of storages and diversions to serve various conservation and consumptive use demands as also may have to serve the purpose of flood control and pass supplies down stream of study sub-basin or basin for priority rights and conservation uses or flows for ecological considerations. A diagramatic representation of a typical river basin is shown in Fig.5.

Apporpriate operation model for operation of system of storages and diversions, forming points of major extractions, for conservation uses and for flood control on a given river system upto the terminal point at the end of the sub-basin or basin leading to other sub-basin or ending into the sea, is developed. Simulation model is capable of providing water resource a best alternative from a very large number of alternatives (Riley, 1970). The model is proved and is operated on the basis of constraints of the system and the operation policy devised in earlier studies for meeting weekly water demands and to serve objective of flood control, if any.

The operation of the model provides policy directions to enhance the benefits. The operation study for interstate river basin has to confirm to interstate agreements for releases form study sub-basin to down-stream sub-basin for meeting its share of supply. A graphic representation of an outline of overall model and its associated data catalogue is presented in Fig. 6.

The study is carried out in stages :-

In the first stage the restraints and constraints of water quality, existing and planned development projects, interstate agreements on sharing of water, priority rights or flow requirement for ecological considerations are defined along with varied demands and operation study is performd with various existing and planned storages and diversions in place on the river system with water availability scenario of 75 percent dependable surface flows to meet demands.

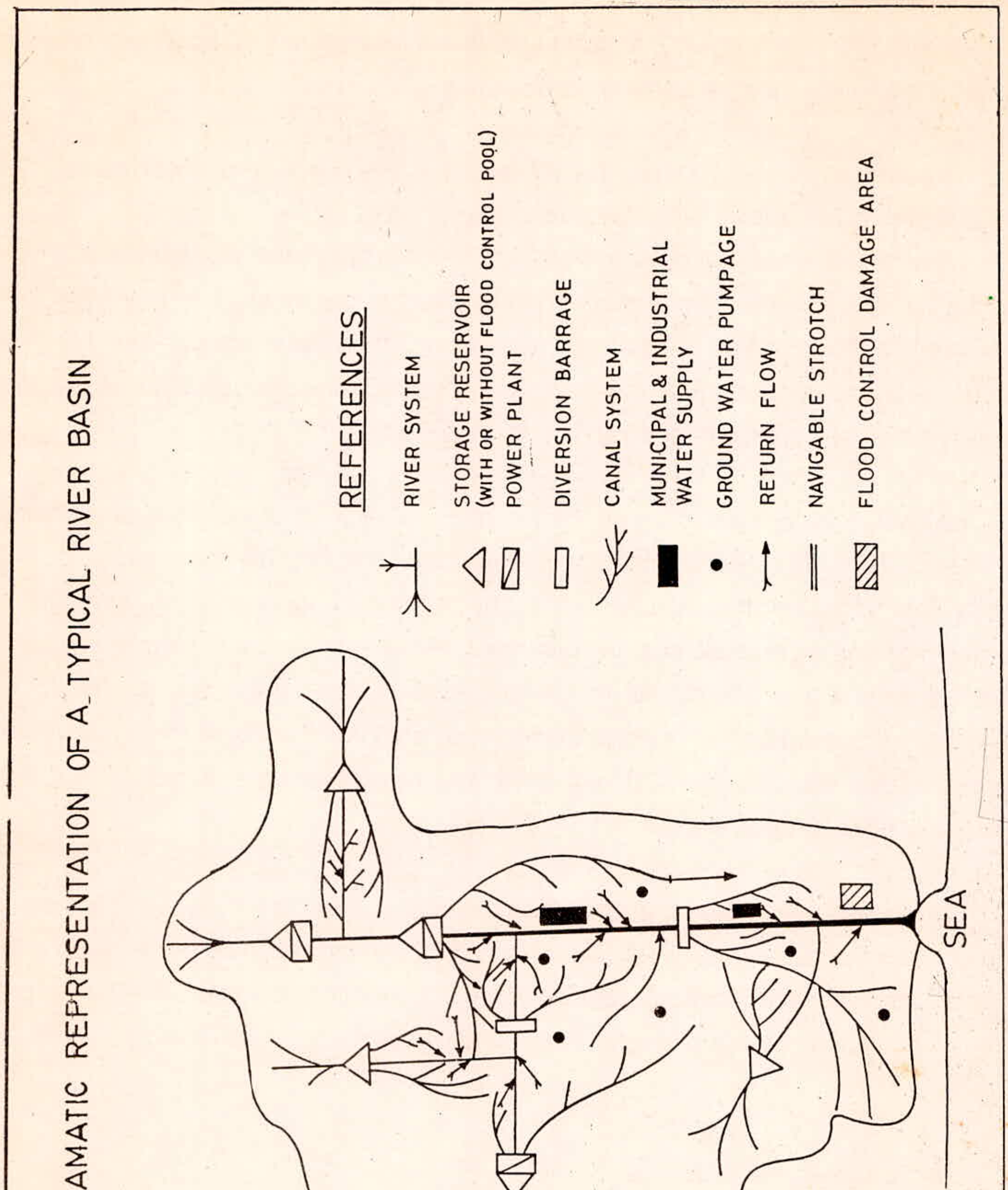


Fig. 5 : Digramatic representation of a typical river basin

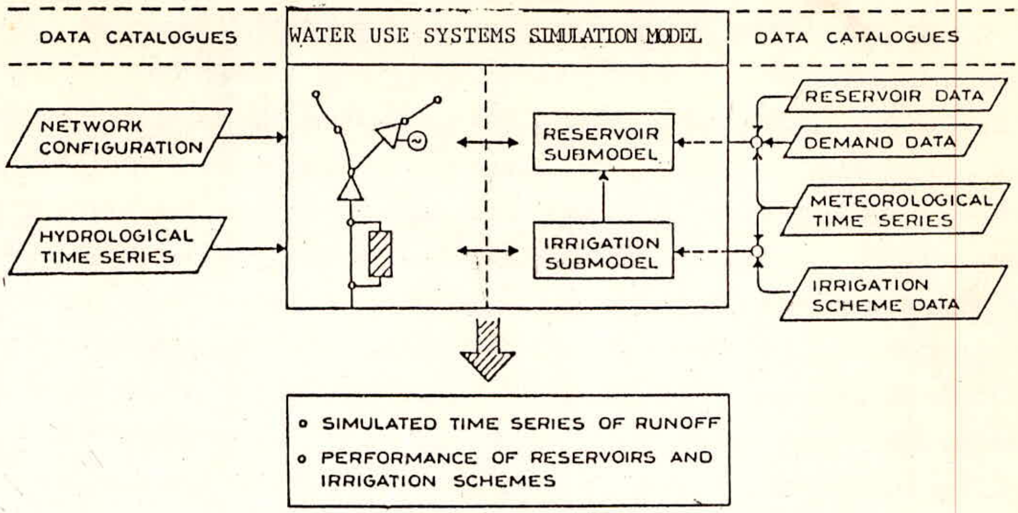


Fig. 6 : Outline of reservoirs system simulation model

Possible groundwater extraction to meet part of the demands, if feasible and influence of return flows on water availability is taken into account. Weekly decision period may be adopted in the study. Demands for various uses that can be met satisfactorily by the available supplies as indicated by earlier study are adopted for the first iteration. If the study indicates any imbalance between supplies and demands, the water demands are adjusted and study is repeated till these accord with availablility of supplies. If necessary, additional projects that are feasible are identified and form part of the operation study.

In the second stage operation study with various existing and planned diversions and storages in place on the river system, for surface flows, for a sufficiently long term historic and / or generated data extending for 30 years or more as available, and ground water possible feasible utilization in a year of normal rainfall as ascertained from groundwater study is carried out based on weekly decision period, using restraints and constraints as defined earlier. Domestic and industrial water demands are priority uses and have to be met in full. The shortages or surplusses in water availability are, therefore, absorbed by the irrigation which constitutes a major water user. As it is not possible to know in advance whether a particular year is dry or wet, no change in crop patterns can be implemented during monsoon season. The balance of surface water availability for use during non-monsoon period upto on-set of next monsoon season can, however, be determined with a certain degree of determination at the end of monsoon period. The extent of storages in reservoirs at end of monsoon would be known and thus likely surface flows to be available during non-monsoon period in different years. Adjustment of cropping patterns for non-monsoon period during dry and wet year can thus be made based on likely water availability. Also possibliltiy of mining of ground water table for meeting demands through ground water during dry year and ground wäter storage of surplus supplies during wet year is considered, if such possiblities exist. The cropping patterns that are feasible and can be served, are introduced during dry and wet years. This study gives the extent of various consumptive and other uses that can be met in dry years, as also information on the surplus water after meeting demands of extended cropping patterns in some of wet years that is available for further use.

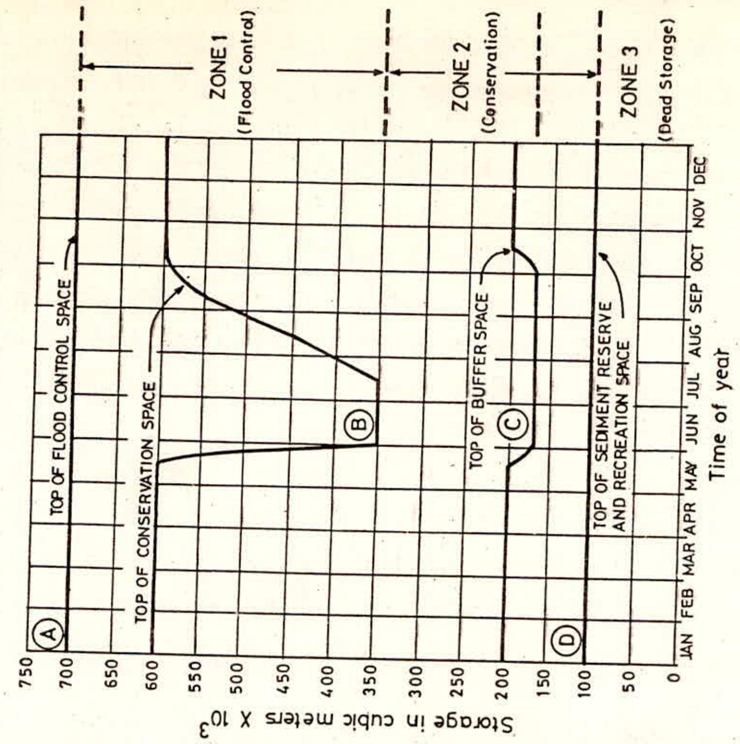
7.7 Integrated Operation of Reservoir with Flood Control

The study is carried out separately in the initial stage itself for sequential operation of the system of reservoirs for short internal historical and synthetic floods to determine requirements of flood control and conservation storage for each reservior, in the system, with flood control as one of the main purposes, and establish the rule curves and seasonal varying conservation pool boundaries which are the target levels for different modes of operation (HEC, 1977) corresponding to maximum permissible releases related to desired cost effective flood control benefit. A balance of flood control storages among the reservoirs is obtained in case of a system with more than one reservoir with flood control as one of the main purposes, which maximises the system net benefits. An appropriate simulation model that incorporates the stream routing procedures is adopted for the study. A diagram showing reservoir storage allocation zones and seasonal varying conservation storage boundaries for a multipurpose reservoir is illustrated in Fig. 7.

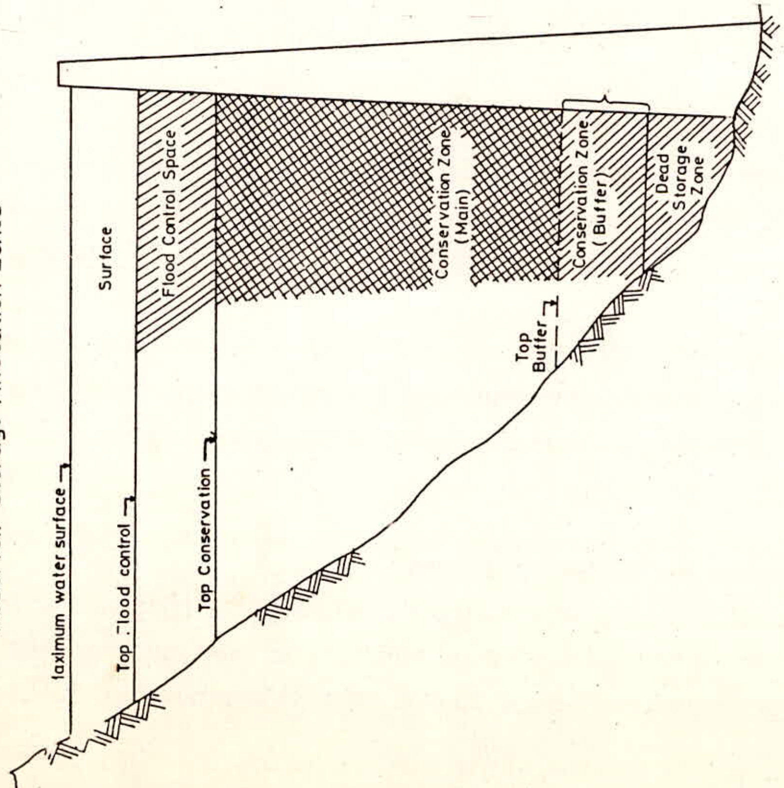
7.8 Groundwater Management

Development of groundwater sources can be flexible and phased. The importance of groundwater is of particular significance in regions subjected to frequent and protected

Example of Seasonally Varying Storage Boundaries for a Multipurpose Reservoir



Reservoir Storage Allocation Zones



droughts when these can be mined. The potential of ground water storage during period of drought can be exploited through management technique of induced artificial recharge.

Groundwater management contributes significantly to the total supply of water to meet the demands. Judicious ground water development simultaneously with drainage in a river basin can help to reduce water-logging and salinity conditions, associated with large scale irrigation from use of surface waters alone. However, adequate caution must be exercised in management of ground water sources to avoid over exploitation and its consequences regrading water-table depletion, saline intrusion and interference with linked surface water.

Aquifer integrates its storage and distribution system by itself and interacts with natural and man made systems of water distribution and storage of surface water, consequently conjunctive exploitation of surface and ground water resources is a prerequiste to achieve conservation and optimal allocation of water sources for all consumptive uses.

System analysis techniques and simulation models are now well known tools and are extensively used to improve efficiency and effiacy of conjunctive use systems (Calcugno, 1987).

The relation between agricultural water use and municipal and industrial water uses and the influence of water management system is shown in the diagram of Fig. 8. (R. Communications, 1982).

Appropriate Lumped ground water models are used to determine the utilizable recharge from irrigation for meeting the irrigation water demands. The possibility of mining of aquifer in period of droughts and of storage underground during wet years will be governed by the natural recharge.

7.9 Mathematical Models for System Operation

The system operation studies as detailed above are carried out using mathematical models that are developed, or using available suitable programmes, such as HEC 5C developed at the Hydrologic Engineering Centre, Davis and WUS Model developed at Danish Hydraulic Institute, Denmark.

RELATION BETWEEN (a) IRRIGATION AND (b) MUNICIPAL AND INDUSTRIAL USES AND INFLUENCE OF WATER MANAGEMENT SYSTEMS

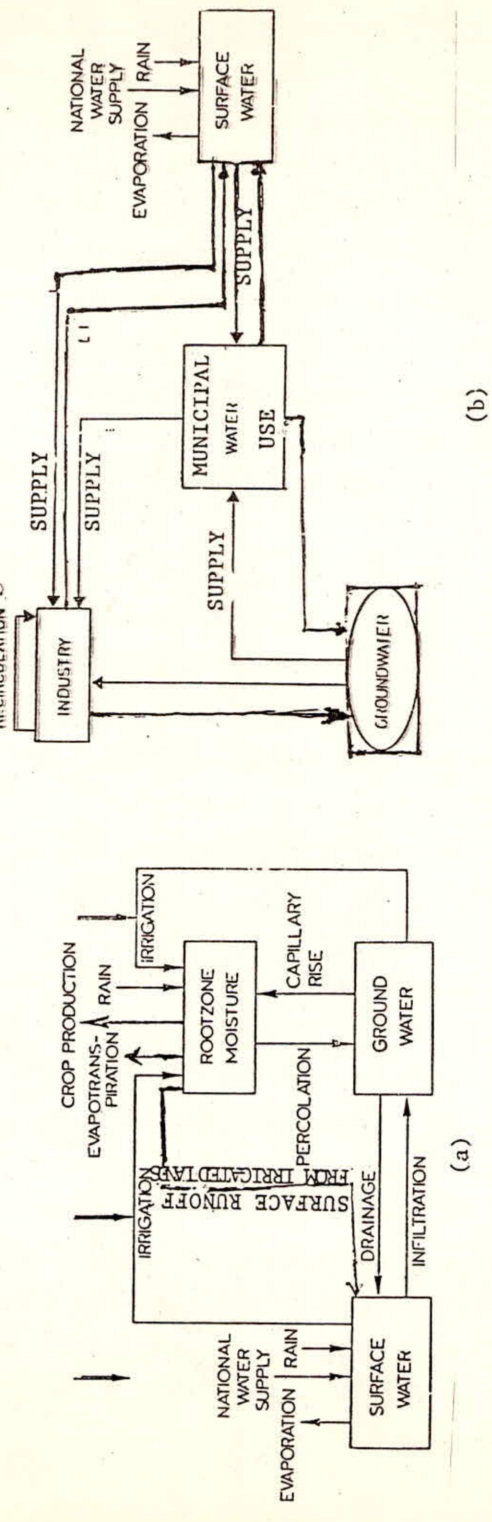


Fig. 8

HEC 5C is a versatile programme and can be used after adaptation in many situations with advantage. Stream routing programme as described in Engineering Manual "Routing of Floods through River Channels" by U.S. Army Crops of Engineers is also incorporated in this programme. Specially the programme may be used to determine:-

a) Flood control and conservation storage requirements for each reservoir in the system.
b) The influence of a system of reservoirs on the spatial and temporal distribution of run-off in a basin.
c) The evaluation of operational criteria for both flood control and conservation (including hydropower for a system of reservoirs).
d) The expected annual flood damages, system costs, and system net benefit for flood damage reduction.
e) The system of existing and proposed reservoirs or other alternatives including non-structural alternative that results in the maximum net flood control benefits for the system by making stimulation runs for selected alternative systems (HEC, 1975).

WUS Model, a Water Use Simulation Model, is simply a mathematical representation of the river basin encompassing the configuration of the main stream and its tributaries, the hydrology of the basin in space and time, existing as well as potential sechemes throughout the basin and their various uses of water.

The river system is represented by a network of branches and nodes. The branches, representing individual stream sections, receive water according to the current hydrological conditions and by possible return flows from irrigation schemes, while water is abstracted or stored or released at the intermediate bodies according to a user-defined configuration of schemes and storage reservoirs with assumed operational rules. Since the model accounts for the effect of storage reservoirs for irrigation, hydropower, flood control and other purposes as well as pumped and gravity irrigation schemes, it includes a separate sub-model for representing the current conditions of storage reservoirs and an irrigation sub-model for determining the current demands and irrigation return flows from all schemes considered (DHI -1985). A graphic representation of the overall model and its associated data catalogues is presented in Fig.6.

7.10 Channel System Management Operation

Schematic Representation of Study: Steps for Channel System Management are shown in Fig. 9 . The various steps are described in the following paragraphs.

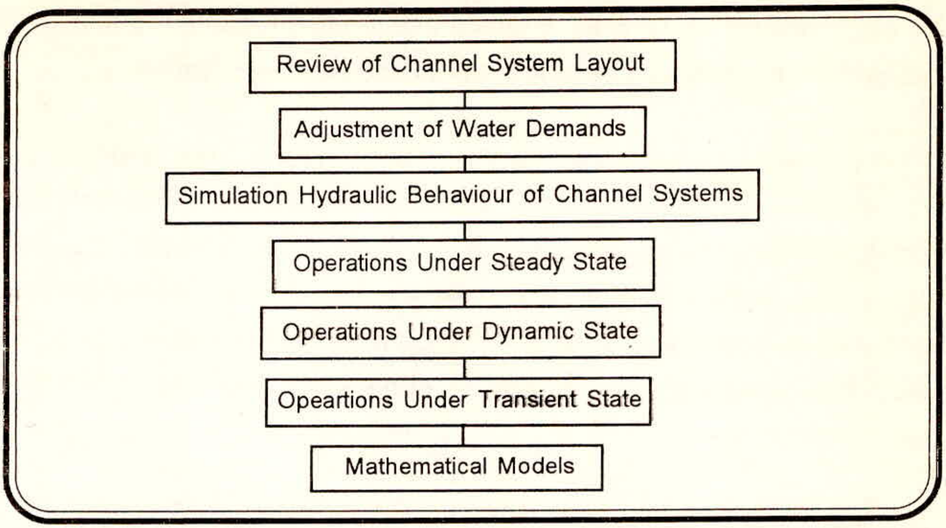


Fig. 9 : Schematic representation for channel management system operation study procedure

- *Review of Channel System Layout*

The channel system may be required to be operated to meet the fairly constant demand for municipal and industrial water supply and variable irrigation demands of cropping patterns likely to be served. The capacity of channel system is fixed from consideration of meeting varied demands on it. Sufficient number of cross regulators are provided to maintain the adequate water level at regulators in the canal during low discharges also, sufficient to feed the off-taking channels. Adequate number of security structures, drainage crossings and falls are necessary. Metering devices at discharge sites are necessary. Sufficient number of escapes are also required on the main canal to serve as safety valves for escaping excess flows in event of breaches occurring in main canal or meeting requirement of sudden closures of major off-taking channel system due to cessation of demands or breaches in those systems.

On canal systems where municipal or industrial water supply is major use, it becomes necessary to provide parallel channel system and /or storages near the points or their use specially to meet the demand when canal is closed for inspection and repairs during slack demand period, sometimes during April/ May and October / November.

The general layout of canal system including longitudnal sections of the various channels are reviewed, and it is ascertained that it has adequate regulators, falls, cross drainages and metering device for efficient regulation of canal systems.

For lined canal system, it is also studied if there are adequate drainage arrangement in the bed and sides of the canal system with regard to soil and water table conditions to safeguard against failure during drawdown, and regulation rules and procedures with respect to rate of lowering water surface level to suit the rate of drainage of soil behind the canal lining. It will also be examined if there are adequate humps or dwarf regulators for keeping the canal bed weighted in places where water table is high and without it the bed could be damaged due to uplift pressures from underneath in the event of emptying the canal.

- *Adjustment of Water Demands*

Weekly water demands for irrigation and domestic and industrial water supplies are established. Other requirements to be passed down, may be, for ecological considerations and needs of lower participating state, are also established. Canal system closure periods are defined for seasonal inspection and repairs, during periods of slack demand for maintaining channel systems in good health. The establishment of weekly demands may require adjustments or irrigation demands in weeks where they are unduly high or too low with respect to the proposed carrying capacity of the irrigation channel system: In doing so, the peaks may be knocked off, or variations in demand smoothened.

- *Simulation Hydraulic behaviour of channel systems*

The hydraulic behaviour of a channel during operation is characterised by its response to operation (i) under steady state conditions at different discharges within operation limits, (ii) under dynamic state during variation of discharges from one stage to the other and (iii) under transient conditions. The study is carried out for main canal and distributory systems in a number of steps using suitable mathematical models for hydraulic channel behaviour.

- *Operation under Steady State*

Channel systems are operated for varying levels of discharges under steady state conditions and the hydraulic behaviour with respect to the water levels at various points for varying discharges. A proper value of rugosity coefficient is adoped. It may be mentioned that the effect of crest of fall will be indicated by backwater curves on lower discharges. The study may be carried out with regulators in position for range of operating discharges.

- *Operations under Dynamic State*

The channel systems are then operated from one steady state condition to the other, with discharges varying at prescribed increments from empty state to the maximum canal discharge and then from maximum canal discharge to the empty state. This study gives the lag period of response from an intermediate regulation point. Such information is essentially needed for drawing regulation orders for time difference that must elapse in regulation orders for various canals starting from headworks towards the tail end.

- *Operations under Transient State*

The channel systems are then operated for evaluation of channel behaviour during transient flow conditions in the main canal, that occur when a distributory system is suddenly closed in emergency operation. At such time the head-regulator of main canal may immediately be manupulated but there would be sudden rejection of water supplies from main canal head-works upto the canal regulator at which the distributory system has suddenly been closed. A part of the rejected supplies can be absorbed in pondage above the maximum discharge level upto its banks in the canal depending on the free-board, and the remainder part can be wasted through intervening escapes, if any. The operation of model gives the information on the rate of closing of canal regulator gates (corresponding to the amount of flow suddenly rejected) and transient flow conditions represented by the celerity wave, the extent of pondage conserved in various reaches of canal and the remainder flows to be wasted by opening of escapes. The studies for simulation of hydraulic behaviour of channel system provides useful information for use in regulation of channel systems, such as discharge stage relationships of different reaches of canal systems; the time lag for the effect of varying flows from headworks of channels to reach the point of regulation for various off-taking channels; and the desired speed of closing of canal regulator gates and the requirement of free board to absorb celerity wave and for conservation of water above full supply level in pondage in canals in company with wastage of excess supplies through escapes during transient flow conditions.

- Mathematical Models

A number of unsteady open channel flow simulation packages using mathematical techniques are available. But these packages may not generally satisfy the requirements of complex irrigation channel systems. The dynamic wave operational (DWOPER) package developed by Hydrologic Research Laboratory of the National Weather Service, USA is based on the one dimensional non-linear differential Saint- Venant's continuity and dynamic equation governing unsteady flows in an open channel. This package which has a number of Sub-routines is closer to the needs of complex system for operation and simulation. Even this model requires to be adapted to Indian conditions. It has been succesfully employed on Al-Hassa Irrigation network in Saudi Arabia (Hussain 1986) and for studies on a complex system in Indian context. It has a number of sub-routing of the program in terms of sequence in which each sub-routine is called.

7.11 River Basin System Simulation

The figures of demand data obtained from the channel system scheduling studies become the data catalogues input for the operation of the integrated reservoirs system simulation model as defined in Fig.10, using the network configuration and hydrologic time series data as established. The model is operated and a number of iterative studies are carried out and river basin system operation scenario where benefits from the system operation are maximised is adopted. An optimal system operation policy is obtained.

7.12 Regulation and Scheduling of Channel Systems

A water distribution and allocation system should fulfill the crieteria of productivity, equity, stability and utility to farmers. Adoption of improved management techniques can achieve these objectives. The improved management addresses to the question how the available water supplies (quantity and quality, timing and place, and probability) can be redistributed to meet the demand of all users keeping in view the criteria of productivity, equity, stability and utility to farmers (Chambers, 1980).

After the weekly demand pattern has been adjusted and closure periods in the two seasons, when the crop-water needs are low have been defined for carrying out seasonal inspection and repairs for various channel systems, the channel system scheduling starts. Main canals, branch canals and distributaries are operated for continuous running during

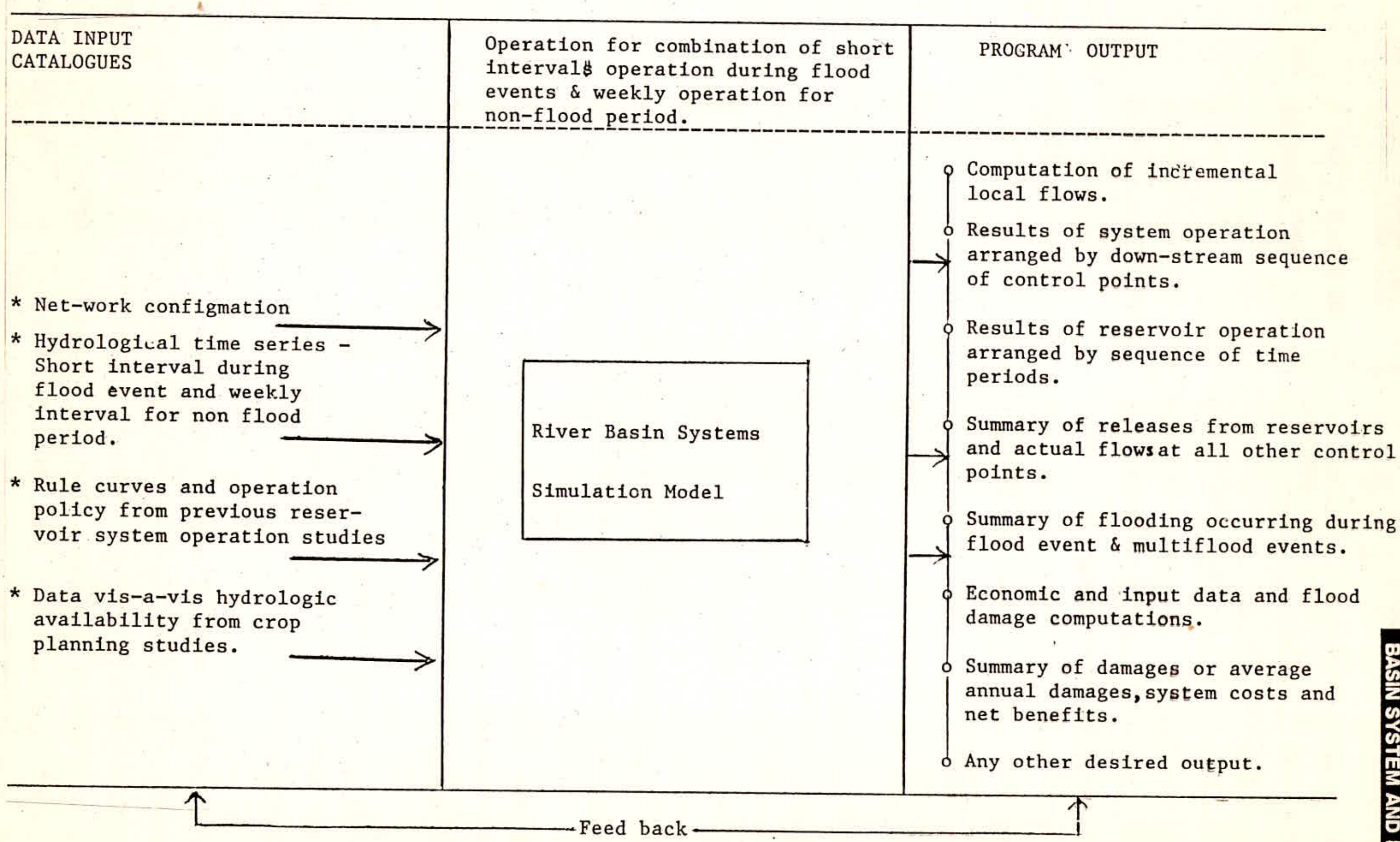


Fig. 10 : Outline of integrated river basin systems simulation model

the two seasons . Minor distribution channels operate according to a schedule of roster in a manner that they operate at full discharge during the weeks of their running. The supply levels in the main canals, branches and distributaries are mentioned by manuplation of gates at cross regulators. The system schedule is framed keeping view the time difference or lag period of response from one state to another at heads of various minors and reaches in conveyance and distribution channel system to accord with the regulation schedule in a particular week when the discharges are varied at channel head or from intermediate regulator point. The channel system is then operated using channel operation simulation model on weekly demand basis for the two seasons over the year and refinements are made in the systems channel scheduling as indicated by the operation of the model in the previous iteration.

As water demands take time to develop fully, studies for channel system scheduling are carried out for both conditions , i.e. at full and partial development. While the irrigation demands may develop within 3 to 5 years, the development period for municipal and industrial demand may extend to 25 years or more.

Different scenarios of water demands at partial and full development are obtained and the channel systems are operated to meet the demands for a hypothetic year with 75 percent dependable surface water flows and with groundwater availability corresponding to normal rainfall year. It provides necessary information about lacuna in regulation of supplies, if any, and on formulation of guidelines for regulation, rostering and scheduling of supplies in the channel systems.

The study is also carried out for water demands for adjusted crop patterns to be served during dry and wet years for obtaining guidelines for rostering and scheduling of supplies during such situations.

7.13 Procedures for Operation and Management

Experience of operation of canal systems in the country and abroad has shown that there is much scope of improvement in management of river basin systems to serve the objective of increased agricultural production and serving other needs with economy in cost of management . There are many important considerations. Detailed rules and procedures of regulation and inspection and maintenance must be formulated. For their implementation a proper managment information and reporting and monitoring system that provides day-to-day knowledge of available supplies regulation and control should be devised. A suitable orgainsation that would function should be established.

Detailed rules and procedures for regulation of water supplies in river basin system to meet the water demands are framed based on experience and information obtained from water basin system simulation studies. In case of irrigation portion of projects, participation of water users in management is advocated.

Detailed inspection and maintenance (routine, annual and emergency) procedures for storages, diversions and channels and other facilities should be devised for proper upkeep of component systems and for sustained benefits from the overall system.

The management information and reporting, and monitoring system provides regular information on status of available supplies at head-works and regulators in channel systems, hydraulic behaviour of channel systems and management as also and points of regulation on channel system.

An effective tele-communication system is an essential requirement for efficient managment of river basin system components for not only receiving and dissimination of use in upkeep of channel and other system components and knowing the status of their performance, but also for prompt flow of instructions for regulation and distribution of water supplies in the river and canal systems. A network of service roads and availability of transport vehicles is also necessary for conduct of regular inspection and visit of staff to manage and regulate the system components and contact the farmers, and other water users, and attend promptly to the emergencies.

On modern irrigation systems, for distribution of water among farmers within the outlet command serviced by proportionate open flume outlet, a flexible warabandi system adapted to suit the local conditions is established and farmers are trained to operate it themselves.

The concept of water user's cooperative society or association for distribution of canal water supplies among water users has proved effective and must be encouraged.

Elaborate operation and management procedures should be formulated to serve as guide for cooperation among various management units and water users.

The operation and management staff should be given orientation to manage the system efficiently for welfare of the water users. They must be well versed in operation and management and inspection and maintenance procedures.

7.14 Peoples' Participation in Water Management

In the democratic set-up, people's participation in management is a forward step towards democratisation. Water users' Association (WUA) as far as possible should be introduced in stages to manage the distribution of supplies among the farmers of the outlet command. Irrigation Cooperatives exist in many countries e.g. in the U.S.A., Chile, Netherland, Peru, Argentina, and Spain. There are cooperatives of users functioning in other areas of water use, for domestic drinking water in various Latin American countries, for the generation and distribution of hydroelectric power in some countries , for waterway shipping on the Denube, etc. (Coan, 1973).

Success story of a cooperative society of farmer of 6 villages registered in 1978 for water distribution on a number of subminors of the Bhastan Monor, of Kakrarpar Irrigation project (on Tapi River) in Gujarat State of India is a good example in this field. The activities of the society extend for a command area of 525 hectares and has a membership of 216 farmers. Its objectives are (i) to promote the sense of cooperation and self reliance among the farmers, (ii) to distribute water among farmers according to warabandi having consideration of the needs, (iii) to train the farmers for economic use of water and aviod wastage, (iv) to realise water rates fixed by the government and pay the same to the government in time, (v) to maintain the system within outlet command and advise the members about new farm techniques, practices etc. and (vi) to purchase equipment, implements etc. for agricultural operations. On part of the government, the sections of the subminors were put in good condition, additional outets were provided to limit the CCA to 8 hectares per outlet, lining of water courses were provided in vulnerable reaches and extensions were carried out to sub-minors/ water courses. In initial period of three years one manager, one mistry and two clerks were also provided by the Government to the Society . The water-supply to the cooperative society is in bulk on volunteer basis. Encouraged by the experience, twenty cooperative societies have been registered in Ukai-Kakrapar Command Area upto 1986 (Shah, 1986).

Peoples' participation in water management on irrigation projects may however be accomplished in stages. The associations can in the first instance be established at each outlet serving about 40 hectares area. These association may be responsible for distribution of water supplies for irrigation within the outlet command to various fields. Later, Federation of water Users' Association can be formed to include the management of all minor irrigation channels with a discharge of upto one cumecs when the experiment of association within outlet command becomes successful and farmers are willing to shoulder higher responsibilities. Water to the Federation in such cases should be supplied on volumetric basis for being distributed and managed beyond the outlet commands by the Farmers' Association themselves. The concept should usually be developed by taking up pilot programmes on the newer canal systems and before extending it to the newer as well as older canal systems.

The duties of the water user's association may include the maintenance of the onfarm works and collection of the fees from the members which takes care of the water charges and also their contribution towards the maintenance. For these associations to be viable, they may in the long run orgainse other cooperative activities, such as supply of inputs extension service, marketing banking agroprocessing and other agricultural related activities. The activities may also include the construction and operation of community wells, providing facilities and repair of agricultural equipment and their availability on hire. The Federation on WUAS can coordinate the activities of the WUAS and serve as a link between the WUAS and the government.

7.15 Management Information System

Management information system covers a wide range of activities starting from periodical collection of data and information on hydrology, water use demands, behaviour of component units and regulation and distribution of water supplies, to the information on the outcome of alternatives of management actions. It provides insight necessary to carry out the adjustments in regulation and distribution of supplies on the basis of study of water availability, water demands, and system behaviour. Objective of the management information system is to establish effective management control.

The traditional system of data assembly and storage in registers and analysis by numerical methods for use in management control is not efficient. By adoption of computerised process for storage, retreieval and analysis of data and information, each information can be checked before storage, errors are reduced and functions are integrated. Computerisation improves efficiency and provides greater flexibility of operations. The output can be processed in required formats and printed for personal examination and study. Computerised management information system has following sub-systems:-

i.) Information Collection and Storage Sub-System -

A variety of information obtained from monitoring and operation and management activities are collected, stored and digitised in a special data-base. The information is organised in a number of files according to type and characteristics of data.

ii) Information Management Sub-System -

An integrated database management system (dBase IV) has proved flexible and has been satisfactorily applied for large and complex water resource systems. It can handle processing and retrieval of large amount of records and number of files on periodical information in regard to water supplies, water demands and distribution of supplies on river basin systems, comprising storage reservoirs, diversion works, power stations, river channel and canal systems, -

iii) Information Analysis Sub-System -

Statistical analysis of data is an improtant requirement of management. A general use statistical analysis package (SAP) or dbstat can be used for basic and advanced statistical analysis of information on hydrology, water demand and water distribution.

Information Display and Output Sub-System:

The available package can be adopted for display of assessment results in formats such as tables and graphs. The output can be printed on a line printer or displayed on a colour terminal as an image or plotted as maps in colour using a plotter, as per requirement.

An outline diagram showing interaction of data base with the various management softwares is given in Fig. 11.

7.16 Telecommunication System

i) System Requirement -

An effective tele-communication system is the essential requirement to transmit data and information needed for operation and management of water resource systems efficiently to meet the varied demands, and to handle emergencies.

A large number of data is required to be collected concerning the system and the service area through telecommunication system, generally to plan operation and management and upkeep of water resource systems. Some of the important data to be collected in this regard is as follows:

1. Gauge and discharge data at headwards and control points on the canal systems and their distribution systems.
2. Data on gate operation at control structures.
3. Information on and status of water demands.
4. Rainfall data in the command.
5. Reservoir levels in case of storage schemes, and gauge and discharge data upstream of diversion works for water availability.
6. Information on gate operation of spillways at storage and diversion works.
7. Gauge and discharge information for drainages crossing the canal systems in the event of floods.
8. Information on gauges and discharges of river systems at strategic points.
9. Information on status of upkeep and maintenance of system components.
10. Information on breaches, damages from floods and interference by public.

The telecomunication systems is also used to convey regulation orders and issue

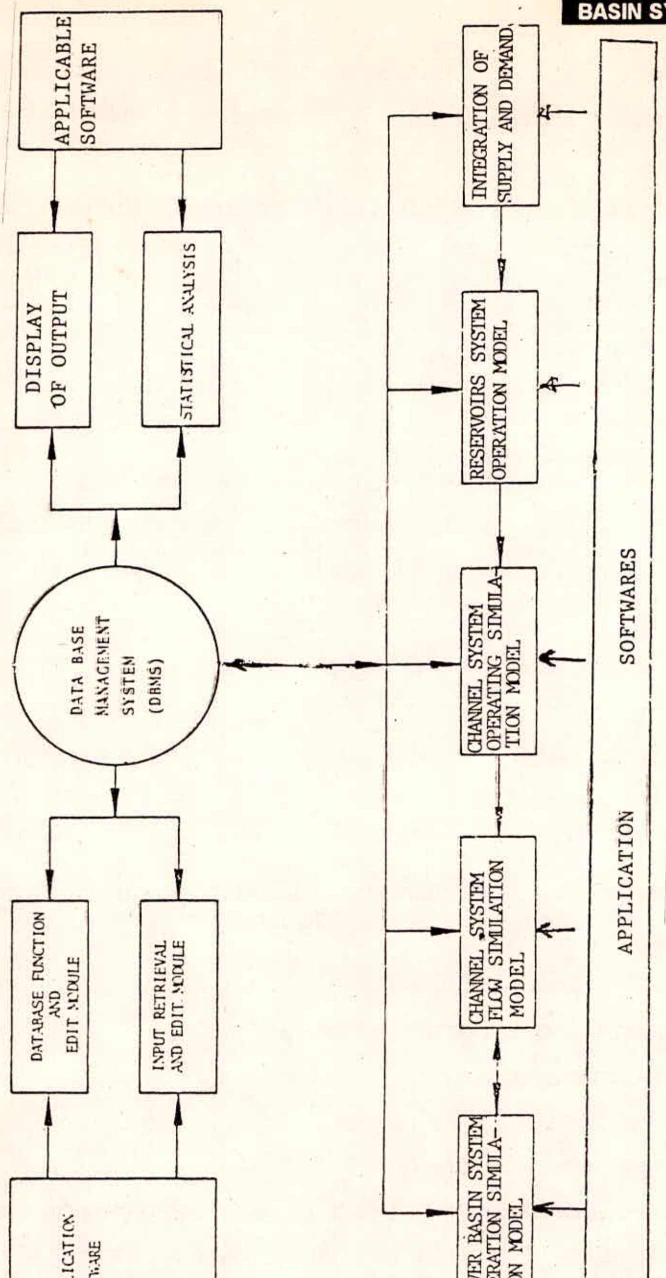


Fig. 11 : Outline digram showing introduction of DBMS with various management softwares

other direction, and monitor the performance of the water resource system as well as compliance of the regulation orders and the directions. The staff can also contact superiors with its help for seeking guidance in normal and emergent situations.

ii) System Choice -

A variety of communication schemes are considered and a schemes that meets the specific needs of the system is selected. Some of the factors which are taken into account are as follows:

1. Type and amount of data to be handled and other functional requirements.
2. Extent and nature of information to be transferred to digital data or on voice frequency.
3. Topography of the terrain and distances involved between stations.
4. Availability of the system in local market.
5. Obstacles in frequency allocation in case of radio link.
6. Reliability of the functioning of the system
7. Scope of updating the system configuration in context of changing technologies.

The number of levels of control in the system depends upon the size of the overall water resource system. There are normally control stations at four levels - A, B, C and D. Master control level A is situated at the control headquarters which is connected to all other stations for receiving information for taking decisions and for communicating with them in normal and emergent situations. Level B stations are main control points in the overall system at the headquarters of senior managers and administrators responsible for integrated overall management of the component systems in their jurisdiction and taking decision on various matters, under the policy directions of the main control stations. Level C stations are subsidiary control points functioning under the administration of Level B Station for management of the sub-systems. D level stations are located at the sub-divisional headquarters and at regulation points. Different type of configuration of telecommunication systems are sometimes proposed to suit the special requirement of the system

Various types of communication schemes can be planned as a dedicated communication link for a river basin or sub-basin system. The choice is made after considering a number of schemes. The various feasible systems that can normally be considered in formulation of the Scheme are (i) radio frequency communication (ii) micro wave communication link (iii) optical communication link and (iv) VHF/ UHF communication link . The advantages and disadvantages of different systems are taken into account while taking decision on selection of a scheme.

Where feasible, scheme of VHP / UHF communication link is established. In addition, sometimes microwave communication links between level A and level B stations is considered desirable and may be adopted. It may not be necessary to own a new microwave system, when it is feasible to hire dedicated microwave channels from existing system with the Department of Telecommunication. Other form of communication through cable or radio communication at high frequency is also provided in some stretches.

The communication link serving a river basin system is often connected to the general network of the telecommunication department also at strategic points for contacting the heads of the department of the government in emergent situations.

8.0 WATER MANAGEMENT OF IRRIGATION PROJECTS

The management and regulation of water resource systems is so far being planned designed and constructed based on conventional upstream control and is being regulated and operated manually in the developing countries.

8.1 Regulations of Supplies

According to prevailing practice, various projects in a river basin are regulated and managed separately even when they have linkages and are located in one state. The assessment of demand is made on the basis of communication received from the field staff for various sub systems. The assessment of water availability in a system is made, taking into account the supplies to be received from other systems or to be diverted or passed down for use on other systems, if any as established by tradition. The supplies estimated to be available for use on the systems are distributed equitably among various sub-systems considering their water demands and previous performance which serves as guide. The judgement of the controlling authority is exercised in deciding the distribution among sub-systems. Weekly rosters are made on the basis of estimates of supplies to be available which are continually refined marginally on the basis of variations in supplies in its jurisdiction in the upper control system for ensuring that the allocated share of supplies is received by various distribution systems and interests of the units in lower reaches are safeguarded. As the supplies to the off taking channels are released in accordacne with their share based on their approved rating curves often higher discharges are utilized in the upper reaches and consequently lower reaches suffer from shortage of water. There are many reasons for this situation. It may not be intentional on the part of regulating staff. The rating curves may be out-of date requiring revision and thus offtakes in upper reaches may be receiving more supplies than their share. There may be mistakes in manipulation of gates which is done manually. There may also be interference from public specially during periods of short supplies. Similar is the case of regulation of supplies on a distributory among its minors and or regulation on a minor among its outlets.

Distribution of supplies among farmers- The policy for distribution of supplies from outlets requires the supplies to be distributed equitably among farmers fields. On many developed systems, warabandi has been adopted. But there are many systems where warabandi has not been adopted. Where, there is no warabandi operative in outlet commands or there are impediments for flow of water in water courses and field channels, the problems of distribution of supplies at outlets among the farmers causes many problems.

8.2 Administration and Management

The information on behaviour of system which is collected manually takes time in compilation at the appropriate levels and requires great amount of vigilance. There are often problems of communication in knowing the adverse situation or lack of speedy implementation of orders to remedy the situation.

The implementation of regulation itself suffers from the disadvantage due to its being handled manually and the lack of coordination. Present communication of data and messages, through dedicated telegraph lines on older projects is out of date. It is slow to operate and often out of action. There is an urgent need to improve the system of management to suit the changing conditions.

9.0 COMPUTERISATION IN WATER MANAGEMENT

Computerisation has been adopted for water management on many large systems in the world. Computer based programmes, have been adopted on large systems in USA on TVA Reservoirs System, and Water and Power Resources Services Systems. The use of automation has not been planned at this stage.

Computerisation on TVA Reservoirs System - Tennessee Valley Authority (TVA) have developed in 1975 a set of mathematical models (daily - weekly) which are used as decision aids for planning and real-time operation and day-to-day multipurpose water management of TVA reservoir systems (TVA, 1975). The TVA configuration is shown in Fig.12. The hardware required for implementation of the water management methodology consists of a small dedicated real-time processor and peripheral equipment (see Fig.13).

TVA did not consider automated complex system operation for their reservoir system at that stage. All models used, especially the weekly and daily iteration models, the various input data forecasting models input / output analysis programmes are coordinated by on-line computer facility in the water control centre at Knoxville. This equipment has the capability to handle analog and digital input and output. If monitors automatically at predetermined intervals, important data such as flows, reservoir levels, water quality and meteorological parameters. These are logged and checked against desired targets. Alarms are promoted, if corrective action is required. The small read-time computer is connected to TVA's large general purpose host computer in Chattangogn, where the data is collected in an on-line data base. The real-time processer in Knoxvile has the capability to initate, either in a normal batch mode or in an immediate mode, programmes on the host machine, automatically, on a scheduled basis or at the request of the operator. All large "number cruching" programmes are executed on the host machine. The results of these runs are available to the operator via the real-time processor or directly from a line printer.

At the water control centre in Knoxville, the operator interacts with the computer system by means of cathode ray tube (CRT), displays and typewriter keyboards. The operator can request a variety of tables, graphs or charts depicting the status of the system or programme out-put. Commands may be issued by the operator through the keyboard or

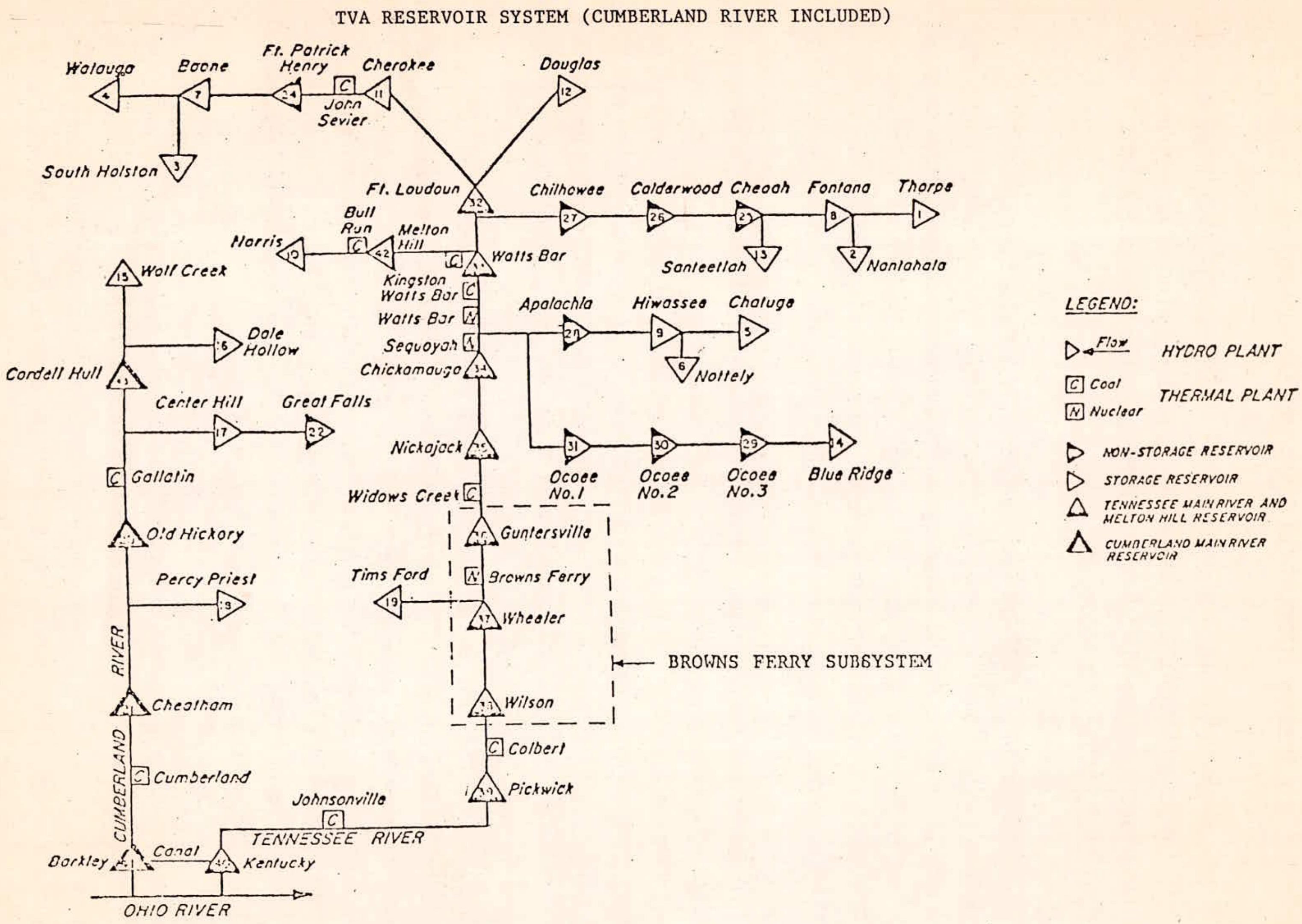


Fig. 12 : TVA reservoir system (cumberland river included)

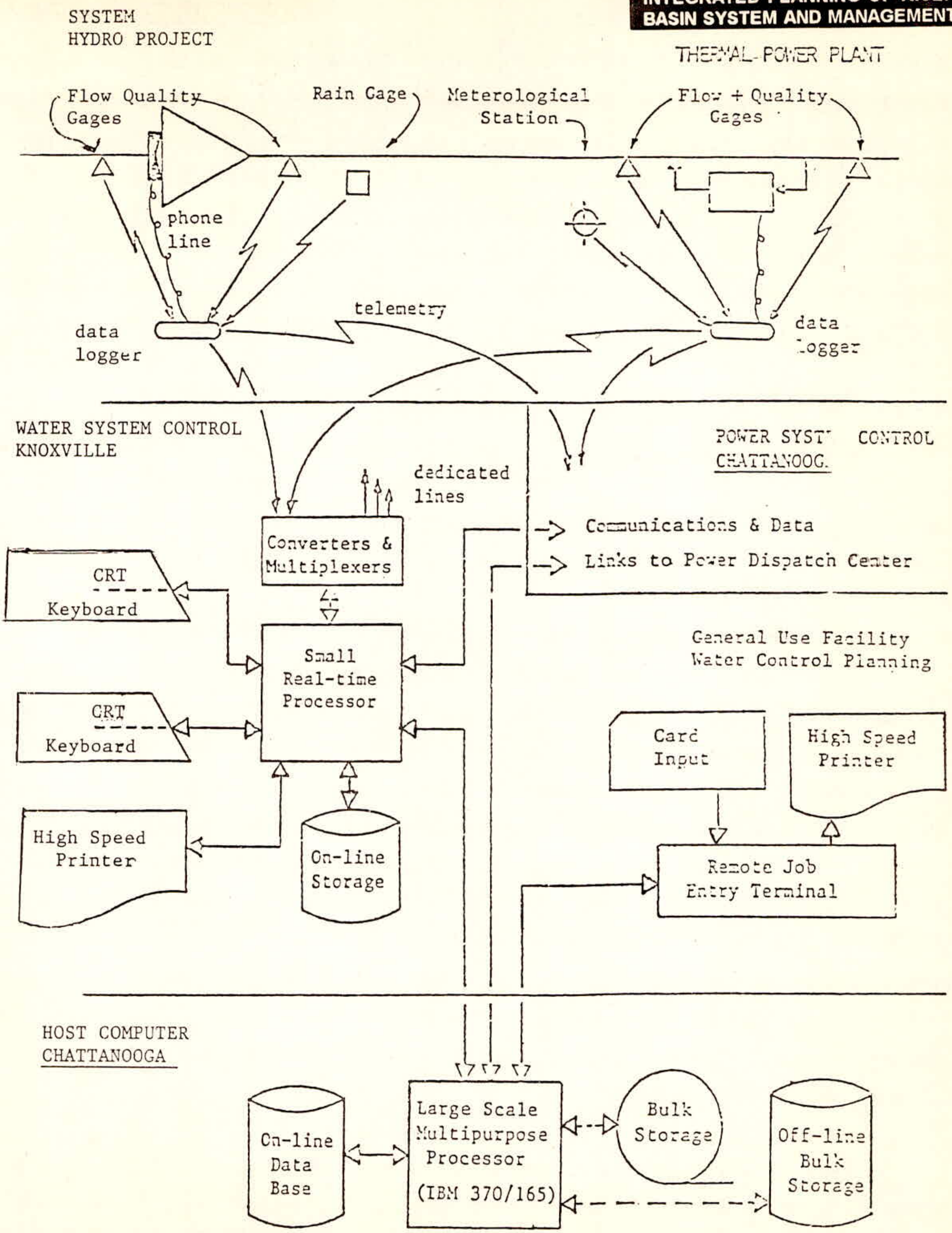


Fig. 13 : Envisioned computer configuration for water resources management - TVA reservoirs system

by touching `poke points' on the CRT with a light pen. The real-time operator either responds directly to the command or passes it along to the host computer. A low speed printer keeps a hard copy log of operator actions short responses and alarm conditions. A disk storage device connected to the real time processor provides storage for the processors programme library and temporary data storage. It also acts as a communication buffer for messages between the real time processor and the host machine. High speed printing for the Knoxville water control centre can be produced by a general purpose remote job entry terminal. This terminal is independent of the real time processor and has limited capabilities as a backup in the event of failure of the real time processor . The water control centre has communications and data links with the power system dispatch centre at Chattanooga for data sharing and for proper coordination of reservoir operations. After the operation schedule is developed upon the power dispatch centre relays the commands back to the water control points in the system which are mostly hydroplants. As mentioned earlier, no complex system automation has been visualised at that time.

Computerised Water System Management by Water Power Resources Service -

In view of extensive use of water for irrigation, the increasing demand imposed by municipal and industrial developments and increased attention being given to water conservation, necessity was felt by Water Resources Service, USA for ensuring efficient use of available water supplies. It implied efficient storage, efficient distribution of water through a service of canals, laterals and farm water courses and efficient application of water to the field. Accordingly, a computer supported programme that can provide tools and concepts for improving project operations for effective utilization of irrigation water was developed by the Water & Power Resources Service, (Buchheim, 1980). The Total Irrigation Management Service (TIMS) is multi-applications programme. It integrates the on-farm water management with the operation of the distribution system to achieve total water management at the irrigation project level. Programme is simple to operate and can be used on smaller mini-computers.

The programme can provide the irrigation and district association, using various levels of irrigation scheduling and systems scheduling. The levels vary with the intensity of the service provided , but all delegate to the irrigator and the district the final decisions of water applications and deliveries. The levels or irrigation scheduling consist of the intense field irrigation scheduling and the less intense lateral scheduling level and the less intense delivery requirements level. Any of these levels of intensities can be tailored to meet the need of the irrigators of districts.

10.0 AUTOMATION ON WATER RESOURCE PROJECTS

10.1 Automated Systems

There has been spectacular advancement in technology and automation is being adopted in advanced countries on a large scale on many of their projects for managing and controlling the regulation distribution of supplies. Fully automated systems have been in vogue in advanced countries on large systems such as California Aqueduct in USA and Rhone River System in France. These have been installed in developing countries on smaller systems in Jordon, Moracco and Saudi Arabia, Computer Control of the Al-Hassa Irrigation System (Hussain, 1980) is a good example. The automated systems work on the principle of release of supplies on demand basis. These are remote controlled systems, having (1) a centre control computer at the main control station which is linked to sensors for monitoring , regulator gate positions, water levels/ discharges at various regulation porints and (2) field units at component system control and subsidiary control stations.

The computer system configuration at the centre control station as well as at main central centres should have the capability to perform the tasks allocated to them as per regulation requirement. The computer should be used for data logging, data analysis and statistical analysis pertaining to water delivery to meet the demands, execution of application support software and application of general use software for engineering managerial report generation and administration uses. At the Central Control Station , main frame computer is required while at the main control offices, mini computers connected with a number of micro computer as subsidiary work station serve the purpose. The configuration of the computers and their detailed specifications depend upon the extent of automation, data handling and their use for various tasks. Once the required extent of automation and data to be handled is defined, the detailed specifications can be prepared.

A generalised set-up includes data storage on hard disks, and magnetic tapes with their hardware support with back-up units, number or printers (i.e. high sped line printer, letter quality printer and laser writer) and plotters, digitisers to digitise maps and channel configurations and cassettes tape readers.

An outline of configuration of central computer control is diagrammatically shown in Figure 14.

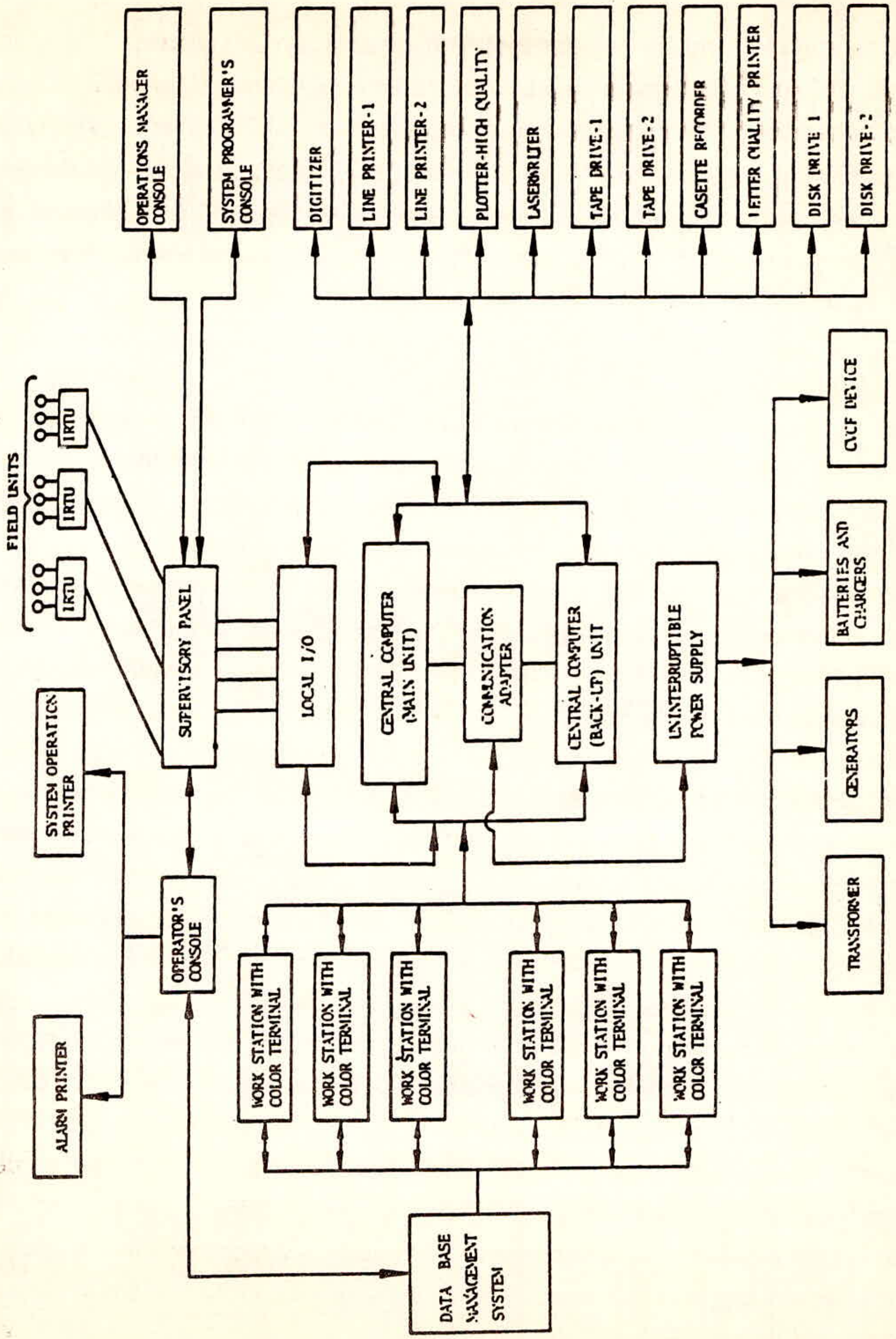


Figure 14 : An outline of configuration of central computer controls

- Al-Hassa Irrigation Automation System

It is an irrigation and drainage project. The irrigation system consits of 160kms, of main canals, 265kms of sub main canals and 1100kms of lateral off takes. The project irrigates a cropped area of 6000 hectares by gravity system and 4000 hectares by lift system. The source of water supply is from 13 Natural Springs. The command area is divided in three parts each containing a pumping station and a reservoir. 1500kms. of main sub-minors and laterals of drainage ditches have been provided to carry salty water to evaporation seas in the desert. (Refer Fig.15).

The Central Control Computer and CPU is located on the headquarters of the Irrigation Authority. Communication Centre is also located in the computer room . The principal interaction between the computer and irrigation system operators is through a colour visual display with keyboard. A second console is used to display alarm messages and other periodically changing data. The system programme performs developmental work on the back-up machine. The operations manager has a remote terminal to monitor the system performance and plan new operation methodologies, and the Water Research Department has access to the historic data to simulate the irrigation system and develop new water development alternatives.

The central control system software makes the major decisions regarding the operation of valves, gates, pumps etc. and performs a number of management function such as initiation of commands to field units to perform control functions and acquistion of real time data, calculations of improtant operating variables, modification of operating schedules and notification to the operator of abnormal conditions. Other softwares are - data base management system DBMS and a stastical analysis package. A high speed printer prepares standard report. Irrigation schedule notifactions are sent to the farmers. The farmers also receive a monthly and yearly summary of irrigation water delivered. The automation system inculdes scheduling software that performs the task of allocation and scheduling of available water supplies for maximising the benefits. The Al-Hassa, Irrigation Network Model is a modified version of the Dynamic Wave Operational Model (DWOPER) of National Weather Service. Automation system provides services through better control and improved scheduling and allocation of scares water resources and results in reduction of water losses (Hussain, 1980 and Hussain 1986).

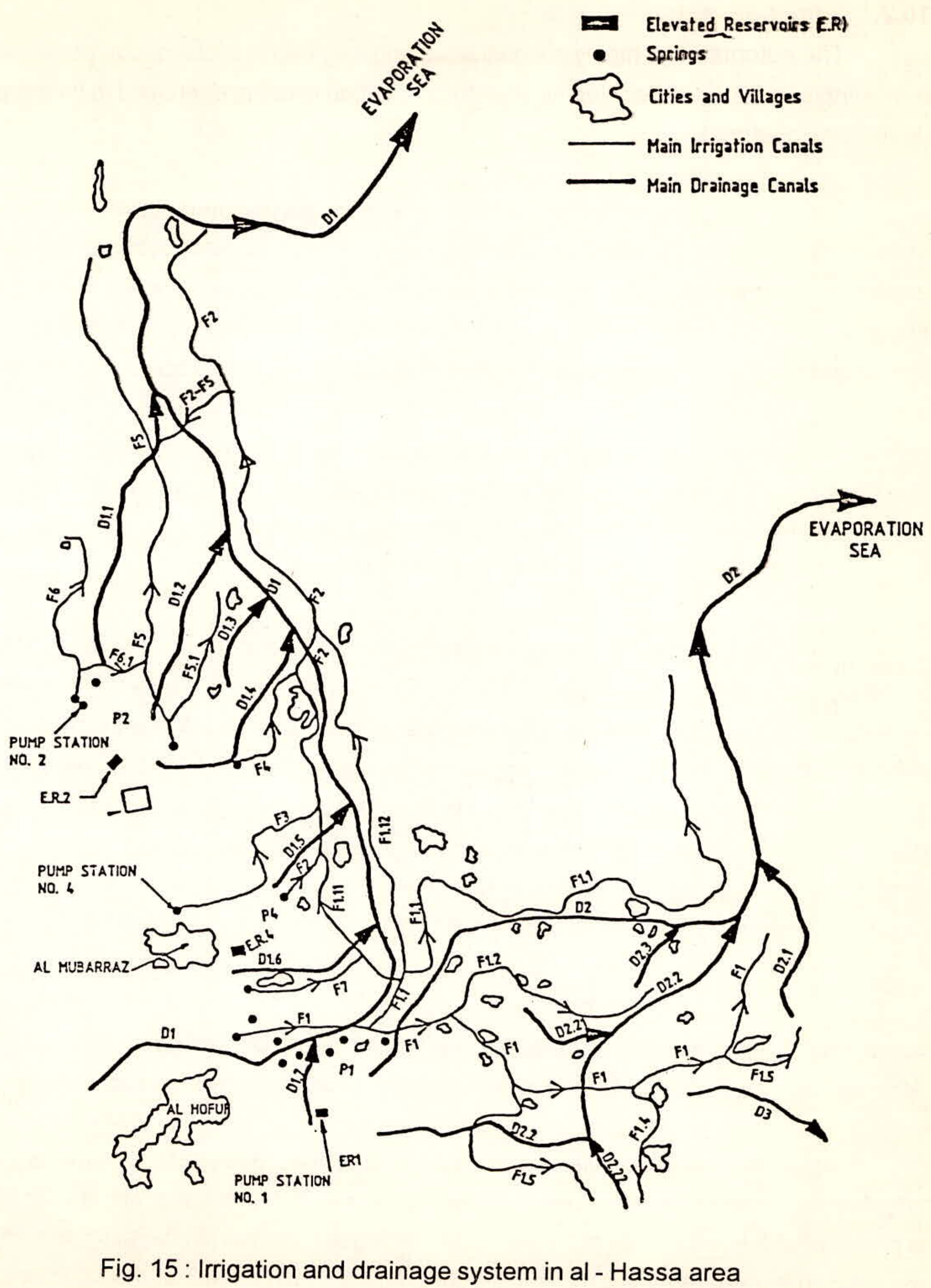


Fig. 15 : Irrigation and drainage system in al - Hassa area

10.2 Semi Automated Systems

The automation is highly sophisticated and may cause problems of management in prevailing conditions of developing countries. Caution is being exercised in its adoption in developing countries.

Though full automation may ultimately be adopted on some of the large projects in developing countries, its adoption will take time. Also full automated systems developed in advanced countries can not be adopted in developing countries as such in situations prevalent there and will need to be adopted to suit the prevailing conditions. Firstly, the water resource systems with irrigation as a major user, do not operate on demand basis and secondly the water demand of individual farmers can not be predicted with precision. Farmers have normally small holdings. They grow their crops according to their whims and requirements and have limited means and it is difficult to assess outcome of integration of their activites. Demand prediction is possible only where water supplies are made to large public or private farms, and principle of on-demand rather than equity is applicable.

Computerisation is however, being implemented on increasing scale in collection, storage, processing and retrieval of data. As a corollary, an elaborate management information system as well as an effective tele-communication link are being adopted as important tools of management of the canal systems . For efficient distribution of water supplies among farmers on irrigation projects, warabandi in the outlet commands for equitable distribution of water among farmer is another prerequisite requirement. Another step in direction of modernisation is electrical operation of regulator gates and provision of flumed heads for channels called minors and proportionate open flumes for outlets.

Computerisation for channel flow simulation and for scheduling and rostering of supplies and partial automation in regulation of main canals, branches and large distributries is being considered for implementation in stages on large canal systems.

However, these partiallly automated systems are proposed to function to meet the irrigation water demands based on equity criteria of distribution among farmers. The system is provided with hydraulically controlled gates on regulators, that can be set to automatically maintained a predetermined water level upstream or down stream of the structure.

11.0 COMPUTERISED / AUTOMATED OPERATION IN INDIAN WATER RESOURCE PROJECTS

Computerised / Automated operation is being considered for water management on complex systems of Narmada Canal Project, Gujarat and Subarnarekha Multipurpose project, Bihar. Computer software is being developed and system operation studies have been planned.

(1) Narmada Canal System, Gujarat - Use of computer in Water Management is being proposed on the canal system. A computer at the central control centre with field units with computerised management information system is being proposed . The computer would be used for data analysis and system regulation and scheduling . The distribution of water will be done manually. Automation is being considered at this stage for regulation of main canals, branches and distributaries, with no direct outlets, upto 8.5 cumecs discharge. The water regulation and distribution of supplies in minors and in outlet commands is being proposed to be carried out in the traditional way. The studies are being carried out for management system to be adopted. Extent of public participation in management is yet to be decided.

(2) Subarnarekha Multi purpose Project System - Use of computer in water management is being considered for the system. A system of central computer centre with a number of field units is planned with an effective telecommunication system. System scheduling would be managed on computer while irrigation scheduling below the outlets may be done in normal way. Possibility of peoples participation in water distribution is also being examined. The channel system design is being reviewed to see whether the automation can be introduced at a later date. An elaborate computer based information system is being advocated . Studies are being carried out and schemes are under consideration of the Government Schematic representation of Subarnarekha Multipurpose project component is given in Fig. 16.

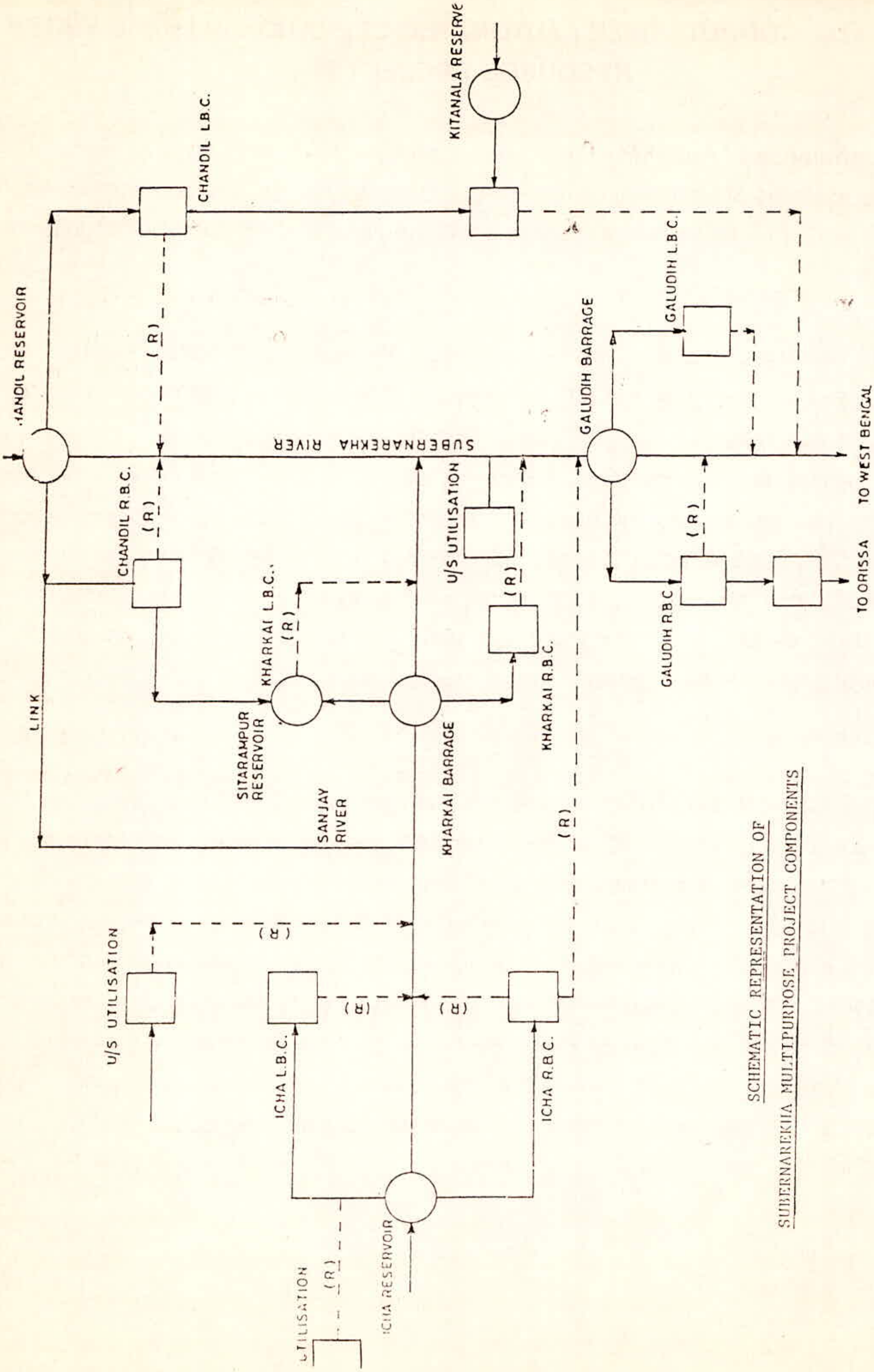


Fig. 16 : Schematic representation of subernarekha multipurpose project components

12.0 CONCLUSIONS

River basin systems should be planned for comprehensive and integrated development of water, land and other related resources of the river basins for welfare of the people, and to meet planned national objectives.

As water resources are limited and will soon be in short supply relative to ever increasing water demands , the emphasis should be laid on economic use and conservation of the resources and maximum benefit should be obtained from each unit of water resources. The complex river basin systems should be managed efficiently and system operation and management planning should receive due attention.

System operation and management of large water resources systems is however, complex. The complexities stem from large size of systems composed of number of storage, diversion, conveyance and facility system units operated as an integrated system to meet varied and competing uses from limited source of surface and ground waters and host of other factors such as uncertainty in assessment of real time lows at storage and extraction points , competitive and conflicting demands of varying areal and spatial distribution scheduling of supplies in long canal distribution system, and problem of maintenance for sustained benefits.

Traditional planning, and management procedures cannot cope with the intricate problem of management of these complex large systems for allocation of supplies among various users and obtaning maximum benefits from water uses in keeping with aspirations of the people with least detriment to the environment . Modern techniques of system approach and use of computer in planning and management of river basin development need to be applied on increasing scale.

Management planning studies should be performed at the planning stage to decide upon desirable plan, and then these should again be conducted at the implementing stage. These studies should be carried out also during operation periodically to obtaining fuller benefits therefrom. The management planning studies may constitute a number of component studies such as appraisal of water resources, projections of water demands, integration of supply and demand, planning of crop patterns, integrated operation of the complex channel systems and overall river basin system, detailed operation and management procedures, elaborate management information systems, computerised data base analysis and regulation and consideration of computerisation / automation to a feasible degree.

Modern technology should be increasingly adopted in planning and management of river basin systems.

REFERENCES

1. Buchheim , J. F. et al, 1980, "Water System Management Users`Guide", REC-ERC-80-3, Engineering and Research Centre, Water and Power Resources Service.

2. Calcagne Alberts T.J. 1987, "Water Utilization and Conservation Techniques in Domestic, Industrial , Agricultural , Navigational and Energy Uses", International Hydrologic Program, United Nations.

3. Cano Gullermo J., 1978, "New Approach to Water Resources Administration in Developing Countries", Proceedings of International Seminar on Water Resources Administration, New Delhi.

4. Central Board of Irrigation and Power, 1965, "Administration and Financing of Irrigation Works in India", Publication No. 77, New Delhi.

5. Central Electricity Authority, 1988, "Hydroelectric Power Potential of India ", Department of Power, Ministry of Energy, New Delhi.

6. Central Water Commission, 1987, "Water Resources of India", New Delhi.

7. Chambers Robert, 1980, "In Search of a Water Revolution: questions for managing canal irrigation in the 1980s", A report of a planning workshop on Irrigation Water Management, International Rice Research Institute, Los Banos, Laguna.

8. Dansih Hydraulic Institute, 1985, "Mathematical Models for Water Resources Development and Management of River Basins", Denmark.

9. Environment Canada, 1975, "Monograph on Compreshensive River Basin Planning", Information Centre, Ottawa.

10. Framji K.K., and Krishna Hari, 1989, "River Basin Planning", National Seminar on New Perspective in Water Management, Delhi.

11. Hussain T., et al, 1986, "Unsteady Flow Simulation through Al- Hassa Irrigation Scheme, using channel Network Model", Symposium on Water and its Resources in Quassim Region, CAKSU, Buraydah, Saudi Arabia.

12. Hussain T., et al, 1980, " Computer Control of the Al- Hassa Irrigation System", UPM, Tehran, Iran.

13. Hydrologic Engineering Centre, 1975, "Computer Program 723 - 500, EEC 5C, Reservoir Systems", US Army Corps of Engineers, Davis, USA.

14. Hydrologic Engineering Centre, 1977, "Reservoir System Analysis for Conservation, US Army Corps of Engrs, Davis, USA.

15. Krishna Hari, 1977, "Inter Sectoral and Inter Regional Water Allocations", First IWRS Seminar on Intergrated Water Resources Management for Drinking, Agriculture, and Industry, Policy and Issues, Hyderabad.

16. Maximov, A, 1973, "Some Aspects of Water Use and Conservation at the National level", Water Management for Arid Lands in Developing Countries, Water Development Supply and Management, Vol.13, Editors Biswas Asit , K., et al, Pergamon Press.

17. Ministry of Irrigation, 1980, "National Perspectives for Water Resources Development", New Delhi.

18. Ministry of Water Resources, 1987, "National Water Policy", New Delhi.

19. Riley J. Paul, 1970, "Computer Simulation Water Resources Systems", Proceedings of the second International Seminar for Hydrologic Professors on systems analysis of Hydrologic Problems, Utah State University, Logan.

20. Rijkswaterstaat Communication, 1982, "Policy Analysis for the National Water Management of the Netherlands". Government Publising office, The Hague.

21. Shah K.B., 1986, "Water Cooperatives for Water Distribution below Outlets", Proceedings of Symposium of Evolving Criteria for Improved Planning and Management of Irrigation Projects, Vol.1, New Delhi.

22. Smith Doughlas V., 1970, "Stochastic Irrigation Planning Models, "Centre for Population Studies, Harvard University, Cambridge.

23. Tennessee Valley Authority, 1973, "Planning and Operation Methods for the River and Reservoir Systems", Knoxville.

24. United Nations Secretariate, 1975, "Water Demand Forecasting".

25. US Geological Survey, 1973, " A Report on Planning and development of Puerto Rico".

26. Water Resources Council, 1980, "Proposed Rules, Principles, Standards and Procedures for Planning Water and Related Land Resources", Washington D.C. Part II, pp. 25332-334.

CONSTITUTION OF INDIAN NATIONAL COMMITTEE ON HYDROLOGY

i.	Chairman Central Water Commission, New Delhi	Chairman	
ii.	Director National Institute of Hydrology, Roorkee	Executive Member	
iii.	Dy. Director-General Geological Survey of India, Calcutta	Member	
iv.	Chairman Central Ground Water Board, Faridabad	Member	
v.	Dy. Director-General India Meteorlogical Department, New Delhi	Member	
vi.	A Senior Scientist National Remote Sensing Agency, Hyderabad	Member	
vii.	Member (D&R) Central Water Commission, New Delhi	Member	
viii.	Director (B&S) Research, Design & Standards Organization, Lucknow	Member	
ix.	Additional Director Indian Institute of Tropical Meteorology, Pune	Member	
x.	Director Central Designs Organization, Gujarat, Gandhinagar	Member	
xi.	Chief Engineer (Designs) Irrigation Department, U.P. Roorkee	Member	
xii.	Director, Central Designs Organization West Bengal, Calcutta	Member	
xiii.	Director, BODHI, MP Bhopal	Member	
xiv.	Chief Engineer & Director Water Resources & Development Organization, Karnataka Bangalore	Member	
xv.	Chief Engineer, Central Designs Organization Maharashtra, Nasik	Member	
xvi.	Dr. B.V. Rao, Indian Institute of Technology Bombay	Member	
xvii.	Dr. T. Prasad, Director Centre for Water Resources Bihar College of Engineering Patna	Member	
xviii.	Dr. N.V. Pundarikanthan Director, Centre for Water Resources Anna University Madras	Member	
xix.	President Indian Association of Hydrologists, Roorkee	Member	
xx.	Director (R&D&SA) Central Water Commission New Delhi	Member	
xxi	Senior Scientist National Institute of Hydrology, Roorkee	Member Secretary	