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PRESENT STATUS OF HYDROLOGY IN INDIA

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ABSTRACT

The crucial role of water as a vital resource is discussed with emphasis on development and management of water resources of India as per the National Water Policy guidelines. The importance of Hydrology in dealing with various problems in water sector is critically examined. The significant achievements of UNESCO's programme in hydrological education and status of hydrological education and training in India is briefly reviewed. The status of R&D activities in hydrology and constraints in development of scientific hydrology in the country are also discussed. Some of the important hydrology related issues and thrust areas for R&D activities are listed.

INTRODUCTION

The water is one of the important natural resource available to mankind. Due to its multiple benefits and the problems created by its excesses, shortages and quality deterioration, the water has a unique role as a resource and deserves special attention of development planners. All life depends on water and through the ages people have been dealing with water. With the growth of human civilization, man's requirement of water have increased considerably and it is being used for irrigation, power generation, navigation, industries, recreation, etc. apart from domestic supplies. With the increasing pressures of rising population, there is a growing need for finding, developing and maintaining suitable water supply and for proper management of this natural resource.

Water as a resource is available as surface water and ground water. Surface flow in streams is made up of flow due to direct response of the basin to precipitation input and the flow from snow melt and baseflow contributions representing delayed smoothed out response. The surface runoff data is thus subjected to seasonal and yearly variations and the information content of surface flow observation is very small. Moreover, surface flow is susceptible to changes in the basin brought about by nature or man's various activities. It is also subject to quality deterioration due to discharge of industrial effluents, sewage, etc. The surface water projects involve decisions regarding major investments generally with insufficient or non-existent flow information. In contrast to this, the ground water data information content is considerably greater than that of comparable surface flow data. Moreover, the initial investment in ground water development project is relatively less. However, for an integrated planning of water resources, both surface water and ground water have to be developed conjunctively. Both these represent two phases of occurrence of the total water potential of the basin and any intervention in one phase affects the other. The development of water resources has to be undertaken through integrated river basin development programmes.

Watershed or river basin implies a drainage area containing a few thousand or a few hundred thousand hectare from which water drains towards a single channel. It is a natural, social and economic unit for community development and conservation or water, soil, forests and related resources. The concept of the small watershed approach to land and water resources development at meso level and river basins at mega level is necessary for integrated planning of resources. This will also involve the application of principles of scientific hydrology for data collection and analysis of planning, design, construction, and operation of water resources development projects.

As the world's human population continues to grow, it is evident that we must all think very carefully in terms of development that meets the needs of the present without compromising the ability of future generations to meet their own needs and aspirations, i.e. truly sustainable development of water resources based on sound environmental principals. A sound scientific understanding should form the foundation upon which rational decisions regarding water resources management should be made.

WATER RESOURCES OF INDIA

The atmospheric water balance for India indicates that roughly out of a total of 1677 million ha-m of water available as water vapour for an average year, only 400 million ha-m precipitates over the country. The surface water resources in the country are estimated at 178 million ha-m of which about 70 million ha-m can be utilized and the groundwater resources are estimated as about 35 million ha-m. The rainfall in India is quite erratic occurring mostly in monsoon months of June-Oct. and is subject to fluctuations in space and time. It has therefore, become obligatory to store the surface runoff during the monsoon periods and use it in fair weather season. It has been estimated that by utilizing the available resources an area of about 113 million hectares can be irrigated of which 40 million hectares is from groundwater exploitation. It is intended that this target is achieved by the turn of the century. This necessitates tremendous effort as well as physical and financial resources. Even after achieving this national target, about 45% of the total cropped area in the country would still have to depend upon the vagaries of monsoons. India is a very vast country with a large population of 684 million (1981 Census) which is estimated to reach 1000 million by 2000 A.D. The food production required for feeding this large population is estimated to be around 230 million tonnes which is nearly twice the present level of production. The total culturable area of the nation is around 189 million hectares and since nearly the entire area is being cultivated, the area under agricultural production can be marginally increased. As such the increase in agricultural production will have to come from improvement in the agricultural technology, extensive and intensive irrigation practices and efficient water use. The ultimate irrigation potential with integrated optimal utilization of surface and groundwater resources is of the order of 150 million hectares. The total hydro-power potential of the country is estimated to be 75000 megawatts at 60 percent load factor. The domestic water supply requirements may reach to about 30.8 x 10^9 m^3 and the indus- trial water requirements may increase to 55.5 x $10^9 m^3$ by the year 2000 A.D. It has been estimated that in next two decades there will be almost doubling up of the different uses of water.

NATIONAL WATER POLICY

In recent years, considerable interest has been generated regarding optimum and efficient utilization of the country's water resources for the benefit of entire nation, over-riding narrow regional considerations. A large number of rivers in the country are interstate in character and as such a national view is as necessary in planning, development and management of river basins. By adopting improved methodology of basin-wise development, by creation of additional storage reservoirs, conjunctive use of surface and groundwater and by interbasin transfer of surplus water to needy areas, it is possible to create an addition irrigation potential of 35 to 37 million hectares. As there is hardly any scope to increase the cultivated areas, as such conservation and efficient utilization for various purposes through storage reservoirs, conjunctive use and water transfer system have assumed importance.

Realising the crucial importance of water for development and planning as the country is preparing itself to enter the 21st Century,a National Water Policy has been formulated, so that this precious resources is planned, developed and conserved as a national resources in an integrated and environmentally sound basis, keeping in view the needs of the States concerned. The water resources planning will have to be done for a hydrological unit, i.e. basin or sub-basin, and suitable data base and information system alongwith necessary infrastructure will have to be established for management of river basin as a unit. For effective and economical management of our water resources the frontiers of knowledge will have to be pushed forward in several directions by intensifying research efforts in various areas. These include hydrometeorology, assessment of water resources, snow and lake hydrology, ground water hydrology, and recharge, prevention of salinity ingress, water harvesting, evaporation and seepage losses, sedimentation of reservoirs, recycling and refuse, use of sea water resources and water management practices. A perspective plan for standardized training will also have to be an integral part of water resources development. The success of the national water policy will depend to much extent on the capabilities of the scientific manpower to take up new challenges (Min. of Water Resources, 1987).

REQUIREMENTS IN WATER RESOURCES DEVELOPMENT

It is recognized that the development and efficient and sustainable use of India's water resources for wide range of purposes is critical to the country's economic well-being for the overall welfare of its people. The large growth of population is one of the basic problems of India. Today's population of 90 crore is expected to be 140 crore in next 30 years. World Watch Institute has recently predicted serious deficits in per capita availability of foodgrains all over the world and particularly in Indian subcontinent, China and Asia. Meeting the food demands of the large and growing population has required development of essentially all the available land that is suitable for agricultural production and the commitment of a very large proportion of the available water resources to irrigation in order to increase cropping intensities and crop yields on the lands. Meanwhile, there are growing and competing demands for water resource development to provide supplies for drinking water and other requirements of urban population, rural communities. industry and power generation. It is also recognized that sufficient water of appropriate quality must be left in-stream during the low flow season to sustain wildlife and meet other environmental demands. And in some cases, it is necessary to maintain river flows for navigation. Moreover, there is a need in many parts of India to develop flood control works to protect populations and their properties and also in many parts of India for development of drought management programmes. There is also need for conjunctive use of surface water and ground water.

The Theme paper on Water Management - Need for Public Awareness, released by Indian Water Resources Society on the occassion of Water Resources Day 1995 brings out various realities in water resources development and management in the country including the following:

(i) Water is a scarce resource

(ii) Creation of storages is essential to optimize use

(iii) Watershed development is complimentary to storage based projects

(iv) River basin is the unit for water management

(v) Environmental and water quality concerns should be viewed in their proper perspective

(vi) Problems of water logging and soil salinity are serious in some irrigated areas

(vii) There is large scope for conjunctive use for irrigation.

It is rightly emphasized that if the water as a resource is not managed properly through concerted integrated effort of all concerned, the country would be heading for a water crisis in near future, with corresponding snowballing effect on all the sectors of the economy.

ROLE OF HYDROLOGY

Hydrology is one of the earth sciences which deals with studies of the waters of the earth, their occurrence, circulation and distribution, their chemical and physical properties and their relation to living things. Engineering hydrology uses hydrologic principles in the solution of engineering problems arising from human exploitation of the water resources of the earth. It seeks to establish relations defining the spatial, temporal, seasonal, annual, regional or geographical variability of water, with the aim of ascertaining social risks involved in sizing hydraulic structures and systems. Engineering hydrology seeks to answer following types of questions:

(i) What is the maximum probable flood at a proposed dam site?

(ii) How does a catchment's water yield vary from season to season and from year to year?

(iii) What is the relationship between a catchment's surface water and groundwater resources?

(iv) When evaluating low flow characteristics, what flow level can be expected to be exceeded 90% of time?

(v) Given the natural variability of stream flows, what is the appropriate size of an instream storage reservoir?

(vi) What hydrologic hardware eg. rainfall sensors and software (computer models) are needed for hydrological forecasting?

There are many approaches to engineering hydrology and all formal models for dealing with hydrological problems are generally mathematical in nature. These could be deterministic, probabilistic, conceptual or parametric, and involve assumptions regarding linearity, time invariance, lumped nature and discrete time intervals. Catchment models can be either (i) event driven (or event) and (ii) continuous process models. Event models are short term and are designed to simulate individual rainfall - runoff events. Continuous process models take explicit account of all runoff components and aim at accounting of the catchments overall moisture balance on a long term basis. Continuous process models are suited for simulation of daily, monthly or seasonal streamflow, usually for long term runoff volume forecasting and estimation of water yield.

The main motivation for the study of hydrology in the past was to improve technologies for the development of water resources. It has tended to follow problem solving approach of engineering profession, relying on mathematical analysis of data (observations) usually made by other persons and often for other purposes. The application of established principles of natural science, thus remained in background and solution of hydrological problems were usually approached in an empirical way. Recently, under the impetus of concern for global change, has led to increased emphasis on development of technologies on a sound scientific basis. While the approach as a applied subject requires broad based undergraduate training followed by specialisation at graduate level, the professional scientific approach demands specialisation at the undergraduate level. Nash et al (1990) have examined in detail various aspects of the education of hydrologists. While stating the major inadequacies of present day hydrology as (a) methodological deficiencies (b) the slowness and unevenness of the advance of scientific knowledge of hydrology through research and (c) the slow diffusion of knowledge from research to practice. the authors have listed the following aims and content of education in hydrology at the university level:

(a) To develop and improve awareness of the totality of interconnected (mainly physical) processes involved in the hydrological cycle;

(b) To provide the maximum possible training in relevant areas of the basic scientific disciplines underpinning hydrology;

(c) To develop the connections between those basic disciplines and the scientific study of various hydrological processes;

(d) To develop more fully and clearly the connections between scientific knowledge of hydrologic processes and the current (and potentially improved) professional practice of hydrology.

The International Hydrological Decade (1965-75) was launched by the General Conference of UNESCO at its Thirteenth Session to promote international cooperation in the field of hydrological research and education as a means for achieving a fuller assessment of the world's water resources and their more rational use. In 1972, the General conference decided to continue and develop the basic objectives of the Decade within the frame work of a long term International Hydrological Programme which started in 1975. This provideda strong impetus for growth of hydrological education and a number of postgraduate courses in hydrology and in water resources development were instituted at a number of universities throughout the world, with the support and sponsorship of UNESCO and WMO.

Hydrologic design and hydrologic forecasting form important components of hydrology. In hydrologic design, the objective is to predict the behaviour of hydrologic variables under a hypothetical extreme condition such as the 100 year flood or the probable maximum flood. In hydrologic forecasting the aim is to predict the behaviour of hydrologic variables within a shorter time frame, either daily, monthly, seasonally or annually. Hydrologic design precedes hydraulic design i.e. the output of hydrologic discharges and headwater levels from which hydraulic design derives flow depths, velocities and pressures acting on hydraulic structures and systems. In practice, hydrologic design translates into hydrologic design criteria i.e. a set of rules and procedures used by various agencies and organisations dealing with water resources development and management. These criteria may vary depending upon the charter and jurisdiction as well as the size and scope of individual projects.

The National Water Policy adopted in September 1987 laid down that resources planning in the case of water has to be done for a hydrological unit such as a drainage basin and appropriate organisation should be established for comprehensive planned development and management of the river basins as a whole. All individual development projects considered within the framework of such an overall plan for a basin or a sub-basin, so that the best possible combination of options can be made.

It has been rightly pointed out by Chitale (1991) that enough attention was not paid to many important issues of hydrology in the past when "demands" and "drawals" were small compared to the availability of water in nature. With growing demands and increasing exploitation, it has become very necessary to have correct appreciation of the exact hydrological cycle of the specific region for proper hydrologic design.

Some of the important areas which need attention are snow hydrology, ground water recharge, lake management, use of modern instrumentation and computational aids, etc. Inter basin water transfer and associated hydrological problems also form an a crucial area of activity and require appropriate hydrologic design criteria for estimation of flood levels corresponding to various risk levels.

UNESCO'S PROGRAMME IN HYDROLOGICAL EDUCATION

Gilbrich (1991) has highlighted the achievements of 25 years (1965-1990) of UNESCO's programme in hydrological education under IHD/IHP which included over fifty meetings, two dozen publications, more than a hundred experts participants in working groups and panels and about ten thousand people who have undergone a training programme. It is mentioned by the author that before the international Hydrological Decade started in 1965, hydrology was at the threshold of becoming an independent subject. In the University curricula some hydrological material was covered as part of water resources development subjects, such as irrigation and hydraulics or as part of courses in physical geography and geomorphology. The UNESCO's coordinating council created a working group on Education and Training of Hydrologists with following terms of reference.

(a) Study information on education of hydrologists in different countries and recommend effective programmes of education for hydrologists and syllabi and to make recommendations concerning them;

(b) Consider existing text books and other publicationsin various languages and to recommend suitable ones for translation and use in different areas, or to propose the preparation of new text books;

(c) Consider and recommend typical education material for use in field training as well as in institutional training;

(d) Consider possible measures to improve teachers qualifications, including the organization or periodical seminars;

(e) Present at an early session of the Council, a report containing proposed actions of the Council in the whole of field of education and training of hydrologists.

HYDROLOGICAL EDUCATION AND TRAINING

There are 67 major river basins and a few hundred medium river basins in the country which can be identified for intensive study and integrated development. The techniques will have to be developed for the collection of reliable and representative data of precipitation, evapotranspiration, infiltration, groundwater recharge, soil moisture, runoff, baseflow groundwater, floods and droughts in addition to other data relating to physiographic and climatic characteristics of river basins. This will involve setting up of good data collection network and facilities for processing and analysis of data. In order to meet the requirements of long range plan for optimal use of water resources, a vast manpower resource will be needed with specialised knowledge and training in various aspects of hydrology. It has been estimated that about 5000 professionaland research hydrologists and about 18000 subprofessionals will be needed in next 20 years or so.

At the beginning of IHD, a few post graduate programmes in hydrology had already started in some countries. The activities and support provided by UNESCO led to crystallization of thinking on subject matters of hydrological education, methodology in teaching hydrology, text books on hydrology, teaching aids, curricula and syllabii, international courses, introduction of modern developments and new subjects, education at undergraduate level, continuing education, visual aids, technician training, training of experts, training of teachers and supervisors, etc.

The post graduate education and training in Hydrology and Water Resources in India has progressed remarkably well. This includes establishment of Water Resources Development Training Centre at University of Roorkee in 1955 with the assistance of ECAFE, UNDP and USAID, starting of UNESCO sponsored International Post Graduate Course in Hydrology at University of Roorkee in 1972 and in Hydrology and Water Resources Engineering at Anna University,Madras. The institutes like Indian Institutes of Technology of Kharagpur, Delhi, Kanpur, Bombay and Madras, Andhra University, Waltair, JNTU, Hyderabad, Bihar College of Engineering, Patna, M.R. Engineering College, Jaipur, many other engineering colleges and Agricultural Universities also provide facilities for post graduate programmes with emphasis on the subjects dealing with 'Hydrology and Water Resources'. However, due to uncertain career prospects for hydrology as a profession in the country, the undergraduate education currently gives varying levels of coverage/emphasis to hydrology subjects in Civil Engineering and Agricultural Engineering areas.

In order to meet the needs of short term and long term plans for water resources development in the country, creation of suitable mechanism for education and training of hydrologists is not only necessary at degree and post-graduate level but also at junior levels, viz. overseer, technician, observer, etc. Adequate trained manpower is necessary to improve the capabilities of operational organisations in the centre and in the states in regard to observation as well as primary and secondary processing of hydrological data. Though there is no regular course for technician training in hydrology, meteorology and other related fields, various organisations like Central Water Commission, india Meteorological Department, Central Ground Water Board, State irrigation Departments, etc. dealing with subjects related to hydrologic cycle have created facilities for on the job and in-service training of personnel. There is, however, no formal training programme for technicians and observers. There is only partial coverage of hydrology as a subject under civil engineering diploma courses to provide some background to personnel at overseer/junior hydrologists level. No formal training at diploma level is available mainly due to absence of cadre. Currently, this vital area for training of personnel at junior levels has been receiving attention mainly due to emphasis being given under International Hydrological Programmes of UNESCO Gilbrich (1991) has highlighted various activities of UNESCO in this direction including compilation of curricula and syllabii for technician training, lecture notes, guidance material for teachers and supervisors of hydrology technicians etc.

The International Hydrological Programme of UNESCO has laid stress on not only regular programmes at P.G. Diploma and Master's degree level, but also on short term courses and workshops for interaction, exchange of ideas and information and continuing education and training of professional field personnel as well as academic faculty. Significant developments have taken place in this area. Summer courses, refresher courses and continuing education programmes are being organised covering various aspects and new technologies in hydrology and water resources, not only by academic institutions like IIT's University of Roorkee, Engineering Colleges but also by Central Water Commission, India Meteorological Department, Central Ground Water Board, National Institute of Hydrology, Central Water & Power Research Sttion, Centre for Water Resources Development and Management, National Remote Sensing Agency, Water & Land Management Institutes, Technical Teachers Training Institutes, Staff Training and Irrigation Research Institutes in States, etc. Karnataka Engineer Staff Training College at Krishnarajasagar, Engineering Staff College at Nashik and other similar State Institutes have been organising short term courses for training of in-service personnel in various areas of hydrology, e.g. estimation of yield, design flood, flood routing, flood forecasting, use of computers in hydrological analysis, etc.

The National Institute of Hydrology was set up at Roorkee in December 1978 by Government of India as a a nucleus for studies and research in hydrology in the country with the objective to undertake, aid, promote and coordinate activities in area of hydrology. Ithas made a remarkablecontributionin this area through organisation of short duration workshops at Roorkee and in different States for transfer of technology with emphasis on analysis, design and software. A large number of participants from Central and State Govt. Organisations as well as academic organisations have benefited from such training. Some of the important areas in which workshops have been organised include:

(a) Flood Estimation by Unit Hydrograph Techniques;
(b) Flood Frequency Analysis;
(c) Ground Water Modelling;
(d) Observation, Processing and Analysis of Precipitation Data;
(e) Flood Routing & Flood Forecasting;
(f) Design Storm & Design Flood;
(g) Reservoir Operation;
(h) Urban Hydrology;
(i) Remote Sensing Applications in Hydrology;
(j) Agricultural Drainage;
(k) Ground Water balance;
(l) Snow Hydrology;
(m) Water Quality Modelling;
(n) Application of SHE Model;
(o) Himalayan Hydrology with emphasis on spring flow;
(p) Low flow modelling & Forecasting;
(q) Project Hydrology.

R & D ACTIVITIES IN HYDROLOGY

A reliable and easily accessible data base providing historical records for all aspects of the hydrological cycle is essential for planning and management of water resources development. This is particularly important when the development of this unitary resources approaches its limits in any basin area and conflict and competition between users becomes a common occurrence. In this situation, a scientifically designed data base, with appropriate coverage of all important aspects of hydrology in space and time, is required for analyses of potentials for new water resources development, for long term planning and real time management of the resources, and for preservation of the resources within the overall environment in both quantitative and qualitative terms.

The main goal of R & D activities in hydrology and water resources is to balance demand and supply of water through environmentally sound water development and management practices following the concept of sustainable development and considering the river basin as a unit. It would be desirable that short term and long term country plans for R & D activities in hydrology are formulated covering basic as well as applied research, and technology transfer needs and priorities. These country plans should be widely publicised for ensuring participation on a large scale. The involvement of various government organisations at Central and State level as well as academic organisations could be specified including the objectives and outputs envisaged for various activities (basic research, applied research, operational procedures, guidelines, manuals, software, standards, training courses, seminars, symposia, workshop, etc.). The tendency for unnecessary duplication is to be avoided and the progress of implementation/studies by various agencies should be coordinated/monitored by a high level committee. The Government funding shall be provided for sound result oriented projects under the country plan and such projects should have provision of monitoring and evaluation by experts. Some of the projectscould involve participation of more than one agency/organisation. Suitable mechanism has to be envolved for pooling together of expertise and infrastructure available in the country in an optimal manner for achieving the objectives of country plans. Besides specific projects and studies, the activities of technology transfer and creation of public awareness should also be carried out in a well planned and coordinated manner.

Seth (1992) reviewed the status of hydrologic design in the country covering the following aspects:

(i) In the area of flood frequency analysis significant developments have taken place. In the initial stages, Gumbel distribution was widely used and investigated. In recent years there have been a number of studies involving use of Log Pearson type III, General Extreme Value and Wakeby distributions. Regional frequency analysis studies have also been carried out and provide better relationships in place of empirical approaches used earlier. PC based computer software has also been developed for use of these approaches at field level.

(ii) In the area of conversion of effective rainfall to direct runoff mostly the studies are based on use of unit hydrograph theory. Further developments in this area have been the use of Nash and Clark models and regional unit hydrograph studies. For rainfall-effective rainfall process to account for abstraction most of the studies involve use of conventional phi index approach. There are however a few studies which have attempted overall modelling of rainfall runoff process using lumped as well as distributed modelling approaches. These include use of NAM, Tank, HEC1, Kulandaiswamy, OPSET, SHE Models, etc. Notable achievement in this area is implementation of computer programs, their adaptation and successful use with Indian data as available in specific cases.

(iii) In the area of water yield studies, efforts are mostly directed on development of monthly, seasonal and annual rainfall runoff relationships using regression approaches.

(iv) For design storm estimation, the methodology adopted is mostly based on WMO procedure involving storm analysis, transposition, maximisation and temporal distribution. The attempts; have been initiated to compile extreme storm data in a systematic manner.

(v) For snow covered areas very few studies have specifically focussed on evolving suitable criteria for hydrologic design. Similar status prevails for Urban areas. There have been some studies and model developments using remotely sensed data.

(vi) Flood routing studies have not been specifically reviewed in this paper. In this area significant developments have taken place starting right from use of Muskingum method to use of other approaches like Muskingum Cunge, Kalinin Milyukov, Lag and route, Kinematic and dynamic approaches. Dam break floods are also being studied. Computer software and technology are being made available through technology transfer programs for field use.

(vii) The developments in the area of preparation of manuals and guidelines, and issue of recommended procedures has been somewhat slow. There is need for an objective and standardised procedure for various hydrologic design variables, viz. design storm, design flood, yield etc. for different physiographic and climatic conditions and data availability situations as well as current status of technological and software development.

CONSTRAINTS IN DEVELOPMENT OF SCIENTIFIC HYDROLOGY IN INDIA

Inspite of its very important role in water resources development of the country, the hydrology as a science and the hydrological profession as such has not yet developed a clear identity of its own. The science of hydrology has generally developed within many different fields of study, including civil engineering, meteorology, geology, physical geography,geophysics, agricultural engineering etc. The career prospects for hydrologists are uncertain. Apart from this the conditions regarding quality of data, its availability etc. have imposed severe constraints in development of scientific hydrology. The water is still a state subject, each state has its own political boundaries which are generally no way related to natural river basin boundaries. There are conflicting demands and claims, and sometimes manipulation of figures to justify such claims on water. This has led to interstate water disputes and made the integrated development of river basins quite difficult. Consequently many urgently needed development plans have been stalled for years. Furthermore, reliability of data collected by different states has also becomes questionable; if it could be obtained somehow. There is no systematic collection of data, and its processing and publication. For some big rivers involved in international water disputes, data though it is collected is generally not available to every body interested. The data regarding snow is very limited and most of the snowfed areas draining into Indian rivers lie in other countries.

There are separate organisations collecting data relating to different phases of water viz. precipitation, surface water, groundwater etc. in the same river basin and there is lack of proper coordination amongst them. Due to all these and many other constraints the development and application of scientific hydrology has suffered. Water resources development has taken place in different states generally keeping in view the interest of states and with scanty or inadequate hydrologic information. Many other problems have also arisen due to water being a state subject. There has been difficulties in establishing the financial responsibility of each state particularly in view of some indirect benefits of water resources development which cannot be measured in terms of money. State have shown reluctance to give water to neighbouring states though they may be in the same basin. Problems have also been faced regarding control of quality of water, soil erosion etc. for rivers flowing from area in the upper reaches of river lying in one state to another state. Even in same state there are separate organisations dealing with surface water and groundwater, though both these represent two phases of water. This has proved to be a constraint in conjunctive use of surface and groundwater based on principles of scientific hydrology. The problems of water logging, salinity etc. in some area could be attributed to this. Generally, the applications of hydrology to water resources development in the country has been within these unfavourable constraints.

WORLD BANK AIDED HYDROLOGY PROJECT

The World Bank aided Hydrology Project has been launched recently involving participation of Govt. of India agencies (Central Water Commission, Central Ground Water Board, India Meteorological Department, National Institute of Hydrology and CWPRS) and the State Govts. of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Kerala, Orissa and Tamil Nadu, to deal with the following needs in the hydrology sector:

(a) To improve hydrological data bases in terms of coverage and accuracy,

(b) To improve capabilities in the concerned organisations for storage, retrieval and interpretation of data elements throughuse of computers, appropriate peripherals and software,

(c) To ensure rapid transfer of data between concerned agencies by connecting computerised data bases through satellite and land communication links, and

(d) To enhance the publication and access of information to eligible users in the public domain.

The status of Hydrology in India has also been reviewed as a part of World Bank aided Hydrology Project. The Staff Appraisal Report (1995) mentions about the status in the following areas:

"1. Development of the Practice of Hydrology in India: Development of surface water resources has been led, since the 1850s, by the need to create large public sector irrigation schemes to secure and increase food production to support the growing population. Until around the end of the 19th century, navigation-on rivers, irrigation canals and single purpose navigation canais - was an important water resource use, but this declined rapidly in the early 20th century. Planning and design of large river diversion structures, their appurtenant canal systems and any reservoir storage created to support these facilities required detailed knowledge of the hydrolgical characteristics of the river on which they were placed. Thus, hydrological skills were developed in state irrigation departments or public works departments which had responsibility for irrigation. Hydrological skills are also required for the design of road and rail systems (particularly their bridges), and for the design of hydro-electric schemes.

2. Surface Water Hydrology: Surface water measurement networks were located originally for project planning and design purposes, and measurements were often discontinued after theshort term purpose had been achieved. Some early networks were established on major rivers mainly for flood warning purposes, and often observed only the river stages. Historically, the networks were not designed to evaluate the surface water resources of a river basin or sub-basin. While the water resources were relatively undeveloped or uncommitted, the lack of total resource information had little consequence. But as levels of development of surface water resources have increased and conflicts between riparian states and users have emerged, the need for such information has grown. Unfortunately, thedevelopment of the river gauging networks has not been planned, in most cases, to meet basin water resource evaluation needs and/or to support basin water planning and management.

Apart from the relative sparsity of properly located river flow observation stations in many basins, a fundamental weakness relates to the practice of hydrometry and the poor quality of the data produced, particularly in state agencies. This can be related to many reasons,-poorly chosen measuring site locations, poor hydrometric practices, inadequately maintained equipment, and poorly motivated gauging and supervisory staff among others- but the result has been to place in question the validity of the hydrological analyses which used the data. And the sparsity of data alone caused design decisions to be made for many projects on the basis of empirical formulae relating rainfall (for which long records were available) to runoff.

3. Groundwater Hydrology: The development of skills in groundwater hydrology expanded rapidly after the creation of the CGWB in 1972 and the SGOs early in the 1970s. The central and state agencies now have very extensive observation networks for measuring water level fluctuations and water quality. Though the periodicity of water level observation needs improvement in most of the networks, and purpose-built observation tubewells with water level recorders are required for key sites, a fundamental weakness is apparent in how hydrological data are analyzed to provide estimates of the resource available fordevelopment.

4. Water Quality: In the Indian peninsula, water pollution monitoring has so far only received low-profile attention, and the interest in water quality has been concerned mainly

with its use for irrigation and domestic water supplies. However, it is now widely recognized that rapid industrialization and urbanization processes, as well as use of fertilizers and pesticides in agriculutre, will contribute considerably to the deterioration of the quality of water resources. The main government agencies involved in the project with an interest in water quality are CWC, CGWB and the State Irrigation or Water Resources Departments and State Groundwater organisations in the participating states. The Pollution Control Boards (PCB) at central and state levels are concerned with particular aspects of water quality and with imposing the related regulations, but the PCBs are not project implementation agencies."

HYDROLOGY RELATED ISSUES AT THE BEGINNING OF 21ST CENTURY

As stated in previous sections, water is going to be the main and crucial issue of the 21st centrury as a principal resource as well as a potential source of conflict. Hydrology as a science has a lot to offer to deal with various risks and uncertainties involved in development and management of water resources in sustainable and environmentally sound manner. Modern techniques of electronic instrumentation, computers, satellite remote sensing, isotopes, mathematical modelling and increased knowledge of physical processes alongwith reasonable mix of practical experience and theoretical base; we can and shall be able to deal with various challenges.

Jha (1996) in his interesting and thought provoking paper on Engineering Education in the 21st century has described the changes likely to occur in the near future in technology, engineering and society; and their implications for engineering education. He has listed the desirable characteristics of the Engineer of the future as follows, which would be equally relevant and applicable for hydrologists.

- A Breadth & Depth of Technical Background in his area of Specialisation
- A Fundamental Understanding of Mathematics, Physical & Biological Sciences
- Some Knowledge of Business Strategies & Management Practices
- Problem-solving Skills
- Innovative and Creative Abilities
- Proficiency in Using Tools of Analysis, Synthesis, Optimisation, Modelling & Simulation
- Communication Skills Both Oral and Written and Ability to Persuade Policy Makers to His/Her Point of View
- Ability for Technological Assessment/Adaptation Upgradation/ Transfer
- Capacity and Willingness to Learn and Keep Learning
- Integrity of Thought and Action-Values with High Ethical & Professional Standard
- A Global Perspective in Engineering Activity
- Awareness of Parameters of International Competitiveness- Quality, Reliability, Safety, Productivity, Cost-Effectiveness
- Concern for people / Society and for Relevance of Engineering Solutions
- Understanding of Impact of Engineering Activity on Society/ Environment
- Capacity to Work in Interdisciplinary / International Engineering Team
- Appreciation & Understanding of World Affairs & Culture.

Rodriguez (1996) has made a detailed coverage of various facets of technical education. He has emphasized the role of skilled technicians. The imperatives of modern technology demand not only engineers and scientists but also abundant supply of technical labour force that can constantly be retrained and taught new techniques. He has also drawn up attention on current trend of many engineers ultimately ending up in professions that have no relevance to their training and education.

The National Institute of Hydrology organised a National Workshop on Thrust Areas of Research in Hydrology in June 1993. Some of the important areas suggested for R&D activities are listed below:

Th1 - Extreme precipitation analysis and design storm studies including those for mountanious area.

Th 2 - Climatic variability and its impact on various hydrological processes

Th 3 - Paleoflood studies, flood routing, dam break flood studies and flood plain zoning.

Th 4 - Water balance and yield studies for river basins and water bodies

Th 5 - Hydrological modelling with special emphasis on physically based and geomorphological approaches.

Th 6 - Project hydrology - methodologies for ungauged/limited data situations and risk based design

Th7 - Application of statistical and stochastic modelling techniques in hydrology for analysis, design, forecasting and regionalisation

Th 8 - Real time operation of reservoirs

Th 9 - Hydrological aspects of drought and development of drought indices

Th 10 -Methodology for estimation of ground water potential

Th 11 -Modelling and analysis of groundwater flow

Th 12 -Ground water recharge

Th13 - Specific problems - water logging, salinisation, saline intrusion, spring flows, artificial recharge, conjunctive use, ground water problems in hard rock areas

Th 14 -Standardisation, development and automation of laboratory and field hydrological instrumentation

Th 15 -Water quality modelling of surface water and ground water

Th16 - Impact of urbanisation, afforestation, deforestation, agriculutre, land use changes

Th 17 -Soil erosion and reservoir sedimentation

Th 18 -Hydrology of lakes

Th 19 -Hydrological problems of snow covered areas and glaciers

Th 20 -Nuclear Hydrology

Th 21 -Remote Sensing in Hydrology

Th 22 -Data base management system

Th 23 -Geographical information system

Th 24 -Software development for hydrological applications

Th 25 -Preparation of manuals, guidelines, standards, namograms, course materials, and audio visual materials for training and technology transfer

Th 26 -Hydrological network design

Th 27 -Techniques for regionalisation of precipitation character-istics

Th 28 -Hydrological forecasting

Th 29 -Analysis of unsaturated flow

Th30 - Development of (i) data acquisition, and (ii) telemetry system for hydrological instrumentation

Th31 - Water quality improvement through water-soil-aquifer treatment system

Th 32 -Urban hydrology

Th 33 -Hydrological problems of deltaic and coastal regions

The Staff Appraisal Report (1995) of World Bank aided Hydrology Project also lists some of areas of technical R&D studies : (a) estimation of return flows from surface water irrigation, (b) basin/sub-basin water resource evaluation, (c) reservoir operation studies, (d) flood forecasting studies; (e) water pollution studies etc.

There is a need for a new approach to water resources development and management with emphasis on considering land use and water use together and also treats the management of fresh water, coastal and marine environment as a whole. All those who have an interest in water development and management and those would be affected by these decisions about water resources management have to work to gether for the achievements of common objectives and goals. An over all comprehensive water strategy has also to con-sider (i) Regional and National Cooperation and Action Plans, Comprehensive River Basin Management, and also has to lay adequate stress on the need to improve and strengthen organisa-tional arrangements and human resources required at various levels. The engineers and scientists in the country dealing with the hydrological aspects of water resources have to be fully pre-pared to adequate the problems and chellanges which are present in the water sector and which are likely to be posed in the 21st century. Various programmes of manpower development through education and training, programmes of hydrological observations and R&D activities in hydrology will have to be adequately planned and implemented for this purpose. The World Bank aided Hydrology Project is a step in this direction.

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