NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE

RESEARCH ACTIVITIES
1988-89

ABSTRACTS
of
REPORTS

AUGUST, 1989

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INTRODUCTION

One of the main objectives of the National Institute of Hydrology (NIH) is to undertake, aid, promote and coordinate systematic and scientific studies in theoretical and applied hydrology so as to improve the present practices in planning, design and operation of water resources projects. Since the inception of the Institute in 1979 and during the 6th five year plan (1980-85), the work in the Institute was carried out with six scientific divisions with main emphasis being laid on computer oriented research and studies in various aspects of hydrology. During the 7th five year plan the emphasis of the Institute has been considerably enlarged with fourteen scientific divisions and stress on field studies also.

The scientific activities at the Institute are carried out under the following fourteen problem oriented divisions :

(i) Hydrologic Design
(ii) Mountain Hydrology
(iii) Surface Water Analysis and Modelling
(iv) Flood Studies
(v) Groundwater Assessment
(vi) Conjunctive Use
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(xii) Information System and Data Management
(xiii) Remote Sensing Applications
(xiv) Hydrological Investigations

The Institute has a well established computer centre with VAX-11/780 computer and its peripherals, and well documented technical library. In order to disseminate the knowledge to field organisations and also to document the field problems studied at NIH in appropriate form, during the year 1988-89 the Institute has prepared a number of reports under the following categories :

1. Technical Note : This describe critical review of relevant literature of the study area concerned so as to highlight the views of research studies and their application of the problem concerned and suggest needs for further research.

2. Technical Report : This includes the description of a methodology for dealing with some specific hydrological problem alongwith some specific application whereever possible.

2. Case Study : This describes the relevant literature review specific methodology, data use, and discussion of results. A greater emphasis is made on a particular field problem.

4. Status Report : This describes the review of research work done at national and international levels in the concerned area. It also includes identification of research needs.

5. User's Manual : This explains specific method/programmes, the capabilities of the programme, preparation of data input for the programme and the interpretation of output of the programme.

The abstracts of the reports prepared during 1988-89 are presented here. The abstracts of reports prepared prior to this period have been brought out earlier in five volumes, for 1979-84, 1984-88, 1985-86, 1986-87 and 1987-88 respectively.

TECHNICAL NOTES

LONG TERM PREDICTION OF GROUNDWATER REGIME IN AN INTERNAL DRAINING BASIN

An internally draining basin is one which is entirely without well defined natural streams or artificial surface drain. An example is the internal basin occupying the western Haryana and north eastern Rajasthan with a constrained outlet to the western part of the Ghaggar Basin in the vicinity of Sirsa. Introduction of surface water irrigation in an internally draining basin changes the groundwater balance of the area which may lead to water logging and soil salinization. Any action which reduces deep percolation slows down the rate of water table rise. These actions are canal and channel lining, improved water application systems, improved water management at farm level and afforestation. It is envisaged in the present study to review the methods to evaluate the efficiency of each of the actions in controlling water table rise in an internally draining basin.

MATHEMATICAL MODELLING OF SOLUTE TRANSPORT IN GROUND WATER FROM A POINT SOURCE OF POLLUTION

Considering the large number and variety of pollutants that may be released to the subsurface and the wide range of geological, hydrological, chemical and biological situations that are encountered, it is necessary that a highly systematic approach must be followed in developing a capability for predicting subsurface transport of the pollutant to meet the goal of groundwater pollution control. Accordingly, the major thrust of pollutant transport research should be directed towards the development of mathematical models that integrate physical process with pollutant properties and environmental characteristics to yield quantitative estimates of subsurface transport of the pollutant.

In the present note, a review of the existing methodologies of solute transport phenomena has been made, making a focuss on methodologies which will permit accurate prediction of the effect from a point source pollutant activity on the quality of groundwater at points of withdrawal or discharge.

The basic concepts of the transport phenomenon have been described in detail and various mathematical models to solve the advection-dispersion equation have been critically reviewed.

STORM DRAINAGE ESTIMATION IN URBAN AREAS

In the technical note, 'Storm Drainage Estimation in Urban Areas', the need for estimation of urban runoff has been identified. With the rapid growth of population all over the world, the urbanisation is increasing at a very fast rate. This increased urbanisation has given rise to the problem of quick drainage of excess storm water from the inhabited areas. A reliable estimate of the storm water to be drained is important for economic design of any drainage system. The various approaches evolved in different countries for the estimation of storm water runoff have been reviewed. Modelling of urban watersheds can be useful for the reliable estimate of runoff if the required data are available. The available models for the estimation of urban runoff have been described in this report with particular emphasis on some important models. These include well known models like SCS procedure, TRRL Hydrograph Model, Storm Water Management Model and Wallingford Procedure.

The runoff estimation practices in India has been examined and it is found that the approach so far used is largely based on empirical relations which have several limitations and assumptions, not commonly met in practice. Though the use of these empirical relations may be admissible for small and simple drainage systems, reliable results can not be expected for large and complex drainage systems.

A large number of models for the estimation of runoff in urban areas have already been developed in economically developed countries and the same may be modified to give reliable results for Indian conditions. For this purpose it is required to maintain a record of streamflow, rainfall and other hydrological data on urban watersheds.

SOLUTION OF DRAINAGE PROBLEMS IN COASTAL AREAS

The coastal saline areas extend about 6000 kms in length and are spread over in a thin belt of width varying upto 50 km along the sea coast of the country. According to latest information, the area of salt affected soils in India is about 8 million hectares. Out of these, 3.1 million hectares is affected with Coastal salinity. The salinity problem occurs in the coastal

tracts of West Bengal, Orissa. Andhra Pradesh, Pondicherry, Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat and Goa. Frequent inundation of land during high tide with saline sea water and ingress of sea water through drains and rivers cause salinization of the soils. The ground water table remains at shallow depth with high salt content. During the dry periods of the year salt moves along with water from the water table to the soil surface by capillary action. The water evaporates and leaves the salts on the soil surface which results in low crop productivity in coastal areas. The coastal tract shows wide variations in different area with respect to soil characteristics but in general the soil are medium to heavy textured and are saline in nature while the sodic soils are found only in a few pockets in Andhra Pradesh & Tamil Nadu. Sodium Chloride is the drainant salt except in Kerala, where Sodium Sulphate constitutes the major component. The soil is acidic to neutral in reaction.

In this review note, the various reclamation measures have been high lighted. Reclamation of salt affected soils can be carried out according to the local conditions by preventing the tidal water inundation through construction of bunds, leaching of salts from the soil profile and through application of suitable amendments in the case of acid sulphate soils and sodic soils and adoption of other suitable soil water crop management practices.

ESTIMATION OF EVAPOTRANSPIRATION LOSSES FROM AGRICULTURAL LANDS

Evapotranspiration from agricultural lands forms an important part in the root zone water balance study. For last few years due to continued occurrence of drought conditions, it has become important to conserve soil moisture from rainfed crops. Knowledge of water requirements (or ET) of crops has value in several areas of agronomy, including irrigation, evaluation of drought severity and in hydrological studies. Evapotranspiration can be determined from direct measurements, empirical climatic formulae, or by using evaporation measurments as indices. Direct measurements are performed by many techniques including tanks and lysimeters, soil water depletion, field

plots, energy balance and water balance methods etc. In this report it has been envisaged to review all available methods for estimating evapotranspiration from agricultural lands and present status of these methods, limitations, adaptability and usefulness in terms of data availability including recommendations for further research under Indian conditions.

ESTIMATION OF EVAPOTRANSPIRATION

Next to rainfall, evaporanspiration is the most important term in the water balance of catchment areas. The subject of evaportanspiration, which includes evaporation of water from land and water surfaces and transpiration by vegetation, is becoming increasingly more significant. Therefore, it is of interest to develop and test methods for estimating evapotranspiration.

A knowledge of evapotranspiration is necessary in planning and operating water resources development. Evapotranspiration data are essential for estimating water requirements for irrigation, and are useful for estimating municipal and industrial water needs, rainfall disposition, safe yields of ground water basins, water yields from mountain watersheds, and streamflow depletions in river basins. Actual measurements of evapotranspiration under each of the various physical and climatic conditions of any large area are time-consuming and expensive. Thus, rapid and reliable methods are needed by hydrologists for estimating evapotranspiration.

To make a fair estimate of the evapotranspiration losses, one must conduct the extensive field surveys, and use one or more of the appropriate calculation methods. A common approach to predict evapotranspiration is to estimate the potential atmospheric energy available at the plant and soil surfaces, then determine the proportion of this energy utilized for conversion of liquid water to vapour depending on the water availability or rate of transmission from within the soil profile. Several methods to estimate the potential evapotranspiration have been developed and tested. They contain one or more atmospheric variable, or an indirect measurement of them, which are often combined with a representation of the surface conditions and interactions. Some are based on the physics of combining the vertical radiation budget with turbulent boundary flow over the land surface. More

empirical methods based on solar radiation, air temperature, air humidity, pan evaporation, or some combination of these have proven to be practical. Several models of the complete dynamic evapotranspiration process have been developed in recent years which vary considerably in complexity from single equations with empirical coefficients to very detailed physical representations. The utility of each method depends upon its requirements for input data, location calibration, and expected accuracy.

The present report deals with the major system processes which determine evapotranspiration. The report provides a summary of : theory of evaporation and evapotranspiration; measuring techniques for evapotranspiration; estimating evapotranspiration from meteorological data; and the recent numerical model studies.

ASSESSMENT OF GROUND WATER IN HARD ROCK AREAS

The present study is an attempt to evaluate the ground water resources occuring in the hard rock regions. In this note the various disciplines involved in hydrogeology are discussed specifically in relation to ground water resources study. The review includes the definition of the aquifer geometry, the determination of hydraulic properties of the aquifer in the hard rock regions, the assessment of ground water in the hard rock region and the various lithological and structural relations in adopting the methods for ground water exploration. The hydrochemistry of the ground water and the various modes of contamination of ground water are also included in the study. The economics of dug wells and dug-cum-bore wells in hard rock regions are discussed in the note.

REGIONAL GCM FOR THE MONSOON AREA

Monsoon, which affect the largest land masses, have been the subject of study on every scales from simple local studies to circulation simulation on global scales. The global general circulation on one hand and the hydrological cycle on the other are the nature's mechanism to maintain balance of water and temperature on earth. During the last two decades, many investigators have coupled the hydrologic process models and the

atmospheric general circulation models, but there exist gaps in the hydrological parameterization for the interlinking of atmospheric-land surface processes. Sensitivity tests on GCMs have revealed that the fluctuations in sea surface temperature, soil albedo. ground hydrology and snow cover are likely to influence the intensity of monsoon rains. These need to be validated using surface and subsurface data.

This note gives a review of the existing monsoon circulation models with special emphasis on the regional aspects. Different physical processes which affect Indian mogsoon are also dealt with. The sensitivity of the monsoon circulation model output to surface albedo, soil moisture and evapotranspiration, snow cover, sea surface temperature has been discussed. The need of the quantitative forecast of precipitation for use in the forecasting of runoff is emphasized.

RISK ANALYSIS

Risk has been classically defined as the probability of exceedance of a design criterion or performance parameters. It is essentially a method of dealing with the problem of uncertainity. In this sense, water resources engineers have been considering risk for a long time. The selection of the design flood for hydraulic structures is a problem which depends largely on a statistical or deterministic study of historical data. Further, it also depends on the availability of relevant and economic data together with consideration for environmental elements, public safety etc. However, apart from the risk assignable to extreme natural events directly related to their randomness, the concept of risk has taken on a new significance resulting from efforts by man to control and use natural resources for his benefit. Because of nonlinear characteristics of the transformation from the natural input events to desirable output events and because of the interconnected and multivalued characteristics of all man made water resources system through which such transformations occur, investigations of the risk problem have become complex with detailed analysis required for each sub-component of the total problem. Also, uncertainities in the input data derived from man-made measurements as well as errors in human performance and judgement cause changes in the random characteristics of the desirable outputs.

In general different inputs for risk analysis in water systems are (i) Extreme value distributions, (ii) Analysis of floods, (iii) Time series model and (iv) Data collection and analysis.

The method of economic design of spillway has been discussed. The risk failure of each compouent i.e., hydrologic, hydraulic and structural are also disussed. The study is under progress.

RESISTIVITY TECHNIQUE FOR MONITORING SOIL SALINITY

Soil salinity problem in agricultural fields arises due to excessive soluble salts present in the soil, the inorganic electrolyte in the soil solution being the major contributor. Conventionally the salinty of the soil is measured in the laboratory for which soil and/or soil water samples may be collected and analysed in different ways, which involves much labour, time and expenses. For these reasons, a rapid, inexpensive in-situ or remotely sensing method which make use of the spatially varying soil salinity-bulk electrical conductivity relation, will be of great help in modern agriculture. The resis tivity method, which has served the ground water exploration purposes for nearly a century has been proved to be of much use in establishing the soil salinity - electrolytic conduction relation.

In this report the relationship between conductivity and soil salinity, why and how the soil resistivity is converted into the conductivity values, the advantages of the field techniques over the laboratory techniques are presented. Various methods applicable for in-situ measurement of soil salinity have been bri efly discussed. For the bulk soil conductivity sensors, the basic concepts, theory and principles, effects of water content and entrapped air on electrical conductivity-salinity relationship, the various calibration procedures and field application of the four-electrode method have been comprehensively reviewed. Light has also been thrown upon the new techniques such as Electromagnetic (EM) induction method and Time Domain Reflectometry (TDR) method with their advantages and disadvantages outlined. Finally a comparison of various methods for measuring salinity intrinsically, has also been made.

GROUND WATER RECHARGE USING TRACER TECHNIQUES

Ground water recharge is that amount of surface water which reaches the permanent water table either by direct contact in the riparian zone or by downward percolation through the over lying zone of aeration. It is this quantity which may in the long term be available for abstraction and which is therefore of prime importance in the assessment of any ground water resource. Both natural and artifical tracers are being used in the country and abroad to study the soil moisture transport and estimate the direct recharge to the ground water. The methods most commonly used are : Isotopic tracer injection method and (ii) Environmental tracer method.

The injection of tritiated water below the active root zone and subsequent coring for samples in order to construct a profile of tritium concentration with depth provides one method for estimating recharge. Injections of the tracer are made at a number of locations about 10 cm apart along a line. In this way the lateral spread of the tracer becomes of the order of a few decimeters owing to molecular diffusion. Subsequently cores are taken and cut into 10 cm sections for analysis in the laboratory. The core samples are weighed before and after extraction of the water by vaccum distillation at about 80°C, in order to obtain the soil water content of the individual cores. The accuracy of this technique is function of the velocity of downward displacement, which in turn is dependent on the amount of recharge and the field capacity of the soil. Many examples of this technique have been described in the report.

The second method makes use of environmental tritium for the estimation of groundwater recharge. The presence of tritium in groundwater indicates that at least some of the water has been reached during the last few decades. During the early years of environmental tritium measurements, the converse conclusion, that absence of tritium implied that recharge was not occuring, failed to take into account that the unsaturated zone might be so deep that the recharging water had not yet reached the water table. Today the presence of tritium still provides at least qualitative information on recharge. In the early 1960s the concentration of tritium in precipitation reached a maximum after the moratorium on the atmospheric testing of thermonuclear devices. This peak of tritium has been used for studying the infiltration of water

through the unsaturated zone and for estimating the average recharge over the period from the peak in concentration in 1963 to the time of measurement of the tritium profile with depth.

SOIL MOISTURE MOVEMENT IN AGRICULTURAL FIELDS

Soil moisture content is the critical state variable that determines the response of a soil plant system to any water input. Continual monitoring of soil moisture content is therefore, of significance in irrigation management. At the field level, this is most conveniently done by soil water balance studies. The different physical processes making up the soil water balance are, infiltration from rainfall or irrigation, redistribution of the infiltrated water in the soil water zone, plant water uptake mainly in the form of actual evapotranspiration and percolation out of, or capillary rise into, the soil reservoir. Ideally, these processes are best quantified by considering the physics of water flow in unsaturated soils.

Different agricultural practices cause varying changes in soil moisture status in the fields. Determination of soil moisture content, its variation in time and space and redistribution during and after rainfall or irrigation are necessary in order to decide when to irrigate and what is the optimum quantity of water needed in agricultural fields. Successful crop production requires an adequate supply of soil moisture throughout the growing season. A major portion of the soil moisture supply comes from precipitation agents which man has been trying to modify in order to ensure his water supply. Many examples on influence of variation on land cover, soil properties and topography on surface soil moisture have been mentioned in the report. It is well documented that the presence of vegetation tends to diminish the soil moisture variation caused by topography, while the effects of minor variation in soil type are usually insignificant.

INSTRUMENTATION FOR SNOW MEASUREMENT

Reliable measurement of snowfall and estimation of snowcover is important for estimation of snowmelt. Unlike in the other countries where the areas of snowfall and accumulation are easily accessible, in India the rugged terrain and mountains do not permit continuous observation of the snow and

related data by manual means. There is, therefore, need for automation of measurement Also, the measurement of snow by conventional snow gauges is prone to errors due tc drifting snow, undercatch due to wind etc.

In this technical note, the technical aspects of various types of snow gauges and other techniques for estimation of snowcover have been reviewed with a view to examine their utility and applicability for snow measurement in the Himalayan Catchments. The review has indicated several new types of instruments which can continuously sense and record the snowfall and its water equivalent. The effect of various shields on improving the catch efficiency is also discussed.

The reliability, accuracy, design and maintenance of the instruments have also been discussed. It has been suggested that existing DCP's in the Himalayan regions must be equipped with compatible snow sensors and the number of DCP's should be increased in the Himalayan region.

FOREST INFLUENCES ON GROUND WATER

Forest Influences on groundwater storage can be estimated from evapo-transpiration and discharge relationships. Studies have been done in various countries to establish relationship between forests and groundwater, however, these have not been on extensive scale. The findings of these studies have not been very coherent as studies conducted in the USA claim that water tables collapse as a result of deforestation or forest fires; while studies done in Switzerland do not seem to indicate any effects on ground water as a result of forest cover changing to grass. In an International Symposium held in 1980 in Helsinki, Guillerne (1980) reported while describing the influence of deforestation on groundwater in temperate zones that there did not seem to be any historical evidence of any direct influence of deforestation on the lowering of water tables. On the other hand there have been opinions that logging of tropical forest watersheds had caused wells, springs, streams, and even major rivers to cease flowing. There have also been opinions that roots of forest exhibit 'sponge' effect that soaks up water in the wet periods and let it release slowly and evenly in dry season to keep water supplies adequately restored. In its forestry sector policy paper, the world bank has advocated reforestation of upland watersheds partially on the grounds that

it will indicate dry season flows and raise groundwater well levels. On the contrary, most of well conducted experiments have universally given increased total water yield over the year. There are instances where trees have been planted to arrest rising groundwater level in water logged areas.

In view of the prevailing state of knowledge, it is necessary to conduct systematic study to spell out effects of forests on groundwater. For this purpose, a comprehensive review of literature is proposed. Also it is proposed to have a catchment where data of changes in land use over years and groundwater levels are available that a possible correlation between these two could be established. The data being collected by other organisations relating to the proposed study would be used for arriving at some definitive conclusions.

MOVEMENT OF CONTAMINANTS IN THE SUB-SURFACE ENVIRONMENT

The mechanism of ground water pollution is quite different from that of surface water and is more complicated. The wide range of sources is one of the many factors contributing to the complexity of ground water quality assessment. Since the source activities primarily responsible for release of pollutants into the subsurface cannot be eliminated, therefore the goal of groundwater protection efforts necessarily be the control or management of these sources to ensure that released pollutants will be sufficiently attenuated within the subsurface to prevent significant impairment of ground water quality at points of withdrawal or discharge. This goal can be effectively achieved only if control and management options are based on by definitive knowledge of the transport and fate of pollutants in the subsurface environment. Such knowledge is also required for establishment of criteria for design, location and operation of new potential sources of pollution in order to permit maximum practible use of the subsurface as a pollutant receptor while assuring minimal entry of pollutants into ground water and movement of any pollutants which do enter ground water to points of withdrawal or discharge. Knowledge of transport and fate is also required for assessing the probable impact on ground water quality of existing source, such as hazardous waste dumps and spill sites, in order to determine a level of remedial action that is both cost, effective and sufficient to present serious

degradation of ground water quality. Finally, development of improved methods for removing pollutants from the renovating already polluted aquifers is dependent on knowledge of the subsurface behaviour of such pollutants.

The present technical note includes the review of the fate and transport mechanism of the pollutants entering the subsurface environment both in unsaturated and saturated zones. The report also covers the basic physics, related mathematics and process details.

WATER REQUIREMENT OF VARIOUS EUCLAYPTUS SPECIES AND THEIR EFFECT ON GROUND WATER REGIME

Eucalyptus are generally considered to be Australian in origin, they are essentially Austro-Malayan, with a natural latitudinal range from 7°N to 43°S. Several species occur naturally in the land mass of Papua New Guinea and in some of the eastern islands and the Phillippines. The genus eucalyptus was first described and named by the French botanist L. Heretier in 1788. By the year 1800 19 species of eucalyptus had been named. This increased to 27 by 1820 and 149 by 1860. In 1934, W.F. Blakely published 'A key to Eucalyptus' in which he described 500 species and 138 variations.

Eucalyptus have been introduced in many countries of the world for shade, shelter, firewood, timber, railway sleepers, raw material for pulping etc. Now eucalyptus plantation have become the world's major plantation crop for wood production. More than 59 countries in the world are developing extensive plantation of eucalyptus forests. Total area under eucalyptus plantation is round 4 million ha. In India after the countrywide trials with over 170 species, only five have been found promising. The Mysore gum' or 'Eucalyptus hydride', which is mostly eucalyptus tereticornis is the most prominent one. More than 4.5 lakh hectares had been planted by 1979 in India.

In this report, efforts has been made to collect the available literature in India and abroad on eucalyptus. Main stress has been focussed on varieties of eucalyptus, their water consumption and their impact on groundwater regime. Of late a lot of controversy has arisen due to high water consumption so eucalyptus has become controversial species for afforestation in India.

It has been reported that water consumption in eucalyptus hybrid at field capacity was nearly six times higher than at 1/3 field capacity. It has also been reported that eucalyptus is a shallow rooted species, confined to a depth of about 3 metres and no adverse effect on hydrological cycle due to planting of blue gum revealed, nor there was evidence that local groundwater and soil moisture regime and water quality have been upset adversely in Nilgiris. So one should not generalise that all species of eucalyptus are heavy consumers of water.

VARIOUS TECHNIQUES FOR ENVIRONMENTAL IMPACT ANALYSIS OF WATER RESOURCES PROJECTS

Water resources development projects represent an integral part of the entire complex of development aimed at the remaking of nature useful for man. Due to acute crisis of energy and depleting raw material resources the development plans are taking up a major step forward. However many large projects induce significant impact on the environment. After a careful study of the beneficial effects and negative impacts of a water resources development project (WRDP), one can draw a significant conclusion that there is a great need of thoroughly analysing the environmental impacts of WRP's before they are actually taken up expected outcome may lead to many considerations which may significantly alter the design of WRP's but may also ensure environmental protection.

The present report is the third in the series of studies taken up by the Institute. Earlier two reports highlighting the positive impacts of water resources projects and identification of hydro-environmental indices were prepared by the Institute. After identification of about 60 indices, it was considered appropriate to study and analyse various techniques of Environmental impact analysis. The report discusses various methods of EIA like adhoc techniques, environmental indices, matrix assessment, checklist method, network methods, overlay techniques, energetic methods and environmental impact statement methods. The various methods have heen explained taking hypothetical examples. The use of such methods on actual case studies as done by developed countries has also been attempted.

The methodologies discussed in the report are thus meant as a guideline for the macro. These are easy to apply, quite robust, however generating (procuring data for such studies is still a question mark. The report shall definitely serve the purpose of giving an understanding of how much data are required, and if limited data are available which will be most suitable technique to arrive at EIA conclusions.

REVIEW OF INFILTRATION STUDIES

Infiltration is an important component of water balance. Information on infiltration from various types of soils under different land use conditions is needed in hydrological studies.

Infiltration rate is the soil characteristic determining the maximum rate at which water can enter the soil under specific conditions. The infiltration rate decreases rapidly initially and approaches a constant rate over a period of time. Infiltration rate is affected by antecedent soil moisture and variation in bulk density.

The major soil groups found in India are alluvial soils, black soils, red soils and laterite soils. In addition to these, other groups of soils also exist which include forest soils, desert soils and saline and alkali soils. A number of studies on infiltration rates and cumulative infiltration were carried out by a number of organisations and researchers in different soils under varied conditions of land use, land treatment and crop types. Field and laboratory studies on infiltration were carried out using sprinklers and rainfall simulators.

In this note, a review of the studies carried out by the various researchers has been made. The review indicated that the heavy textured soils like black cotton soils have poor infiltration rates as compared to light soils. Also land treatment like tilling and compaction affected infiltration rates significantly. Inter cropping and crop rotations also helped modifying infiltration rates appreciably.

Field and laboratory studies using sprinklers and rainfall simulators have helped study of infiltration conditions through simulation of varying rain intensities.

TECHNICAL REPORTS

OPERATION OF A RESERVOIR WITH REAL TIME DATA - MACCHHU RESERVOIR

The procedure for the operation of a reservoir is based on the data concerning the inflows into the reservoir and the demands for which the releases have to be made. The working rule for the operation of a reservoir system is generally based on the experience and ingenuity of the concerned engineer prior to the advent of the computers. The working rules thus formulated naturally lead to non-optimal utilisation of water resources in the reservoir. With the advancement of computers and availability of optimisation techniques in the literature, the procedure for the preparation of working rules have brought out better utilisation of the water in the reservoirs. However, even these procedures are based on the data that are being collected and transmitted to the control room manually.

With the availability of telemetric system in the recent past and with the introduction of automation in the equipment used for the data collection, the possibility of obtaining the data at the control room on a regular frequency (as may be desired) has become possible. With the enormous data that is available and the reliability with which these data can be utilised for the development of working rules, it has become imperative to modify the procedures of the preparation of working rules for the operation of reservoir. This report deals with the preparation of such operation procedure including the software development and testing it with the real time data of Machhu reservoir. The type of demands that are considered for the preparation of working tables include conservation and flood control. The report also deals with development of suitable reservoir simulation model keeping in view of the above two demands.

OPTIMUM DISTANCE BETWEEN DUG WELLS IN ALLUVIAL AREAS

Most of the wells in India are dug wells of large diameter with huge storage in them. The formulation of the strategy for the optimum management of the ground water in such cases requires a thorough understanding of the

interaction of these wells with the aquifer system. It has already been established that in case of dug wells with large storage, the drawdown in the wells would be comparatively smaller than that of bore wells. In view of this, it is important to find the number of wells that can be constructed in the aquifer system so that a required ground water extraction is possible with minimum energy cost.

Most of the time, the interference of the wells causes reduction in the yield. In the present report a technique has been proposed to find the optimum distance between dug wells so that the yield could be maximum.

REGIONAL RAINFALL RUNOFF RELATIONSHIP FOR CAUVERY BASIN

Hydrological analysis for water yield etc. of an ungauged catchment can be estimated using regional rainfall-runoff relations. These regional analysis are done using available long series of rainfall and discharges within the catchment or in and relating then to the region specific features. Cauvery basin being large and having number of gauging point where long period records are also available form suitable for such studies. Since the data collection is minimal after Cauvery is chosen for this purpose. Linear relationship between rainfall and runoff is obtained for the station with long records. These relations are then related to the topography and other well defined characters like normal temperature, rainfall etc. Attempts are made to defined dimensionless graphs for this purpose.

STUDY OF SPRINGS AND HYDROLOGIC MODELLING OF SPRING FLOW

Springs are outlet through which the groundwater emerges at the ground surface as concentrated discharge from an aquifer. Springs are part of the groundwater system can be taken as a flowing well with constant head. They could occur in various sizes from small trickle to large streams. Conditions required for having a spring are manifofd and these are various combinations of geologic, hydrologic, hydraulic, pedologic, climatic and biologic controls. A few spring may indicate the existence of thick transmissive aquifers whereas frequent small springs tend to indicate thin aquifers of low transmissivity. Springs not only aid in the evaluation of groundwater potential of the area, it can be used to meet and supplement the different

requirements for water of the area. There are various types of spring flow domain depending on aquifer geometry and other physical factors. Discharge rate from a spring depends on the size of the recharge area above it, the rate of precipitation in the area, aquifer geometry, geology and geomorphology of the area, storage coefficient and transmissivity of the aquifer.

There are many springs in the Himalayas, Western Ghats and other places in the country. But, yet there is no systematic study of the spring flow for harnessing them as a dependable source of water. There is enough scope of research in this regard particularly in respect of the mathematical modelling of spring flow.

Jacob Bear (1979) suggested a simple mathematical model to analyze the unsteady flow of a spring with steady state recharge. In the present study, the model suggested by Bear has been improved upon to account for time variant recharges that contribute the spring flow with the help of discrete kernel approach. Variations of spring flow discharge with time in response to variable recharge input for different aquifer parameters have been presented. Another model of spring flow visualising the flow domain as pipe flow as encountered in fractured rocks has been developed.

DESIGN OF DRAINAGE SYSTEM IN HEAVY SOIL

Heavy soil occupies about 72.9 million ha areas in India. They are distributed in order of extent in the states of Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Rajasthan, Orissa and Uttar Pradesh. Inspite of high potential productivity of these soils and favourable climatic conditions, the soil remains under utilised due to number of problems like low water intake rate and due to poor internal drainage. There are several techniques available for draining heavy clay soil. The solution depends essentially on the ratio of rate of precipitation to the rate of downward flow through the soil system consisting of poorly pervious layer. The various techniques of draining heavy clay soil described in this report are subsurface drainage, mole drainage, surface drainage and well drainage.

Studies have shown that the mole drainage and open ditch drains (surface drainage) are not very successful in heavy soil for a number of

reasons. Well drainage is particularly suited to these soils which can also help in achieving water economy through the conjunctive use of surface and ground water. The chimney drains, which is a sub-surface drainage system, have shown good results for draining heavy soil especially in Black Cotton soils of Maharashtra. It also seems to be less expensive than the conventional burried pipe drainage system

INTERCEPTING DRAIN

The first step towards solving an agricultural drainage problem is to identify the cause. Sometimes what appears to be a major drainage problem can be solved by a simple remedy once the cause is recognized. An example of this is water logging which is caused by water coming in from outside the wet area. This problem can be abated by a single drain which intercepts the flow. The function of an intercepting drain is to reduce the flow and lower the flow line of the water in the problem area. The flow rate intercepted by a drain is equal to the average velocity multiplied by the cross-sectional area of the aquifer intersected below the water table. which is equal to the effective depth of the drain times the length of the drain. The flow to an interception drain will be essentially a time variant one. In the present study unsteady flow to an interception drain of finite length running parallel to a canal has been analysed. The analysis has been done for a tile drain and for an open ditch. The variation of rate of flow with time has been found and the change in water table position due to functioning of the drain has been estimated for various length and position of the intercepting drain.

EFFECT OF TRIBUTARY JUNCTION ON ROUTING CHARACTERISTICS

For accurate routing of floods in river networks using the St. Venant's equations, the junction imposes a computational difficulty because of the mutual backwater effects of the channels joining at the junction. Various methods have been developed to predict the progress of a flood wave along a junction. These have been briefly discussed and the overlapping method using four-point implicit finite difference scheme has been described in detail in this report. Having surveyed the different methodology and experience of

various authors/implementors, the data requirement needed for finding the solutions to such problems faced by water resources engineers has also been given separately.

Conventionally, the downstream backwater effect is simply ignored and the computations for the network are proceeded in a cascading manner towards the downstream, leading to unrealistic results. The overlapping segment method faithfully simulates the flood flow in the network and the computer results agree well with those obtained by the time consuming solution of all the flow equation of the entire network. Conversely. the commonly used sequential cascading channel method produces inaccurate results, particularly when the downstream backwater effect is important and reverse flow occurs.

EFFECT OF SURFACE WATER GROUNDWATER INTERACTION ON ROUTING CHARACTERISTICS

In alluvial rivers the phenomena of water exchange between aquifer and stream is very common. The flow from or into the stream decreases or increases the quantity of water flowing in the stream which affects the routing process. A program has been developed by USGS for streom flow routing taking into account the quantity of flow from or into the stream. In this study, this program has been applied to flood data of River Tapti for the reach Hathnur to Gidhade. A sensitivity analysis has also been made. The storage coefficient, transmissivity, wave celerity, width of the aquifer for finite aquifer and the retardation coefficient for the case when the aquifer is semi-infinite and the stream is separated from the aquifer by a confining bed, should be selected very carefully for the successful application of the model. Further, it can be concluded that the model is suitable for the situation when lean flow occurs in the stream to have significant storage in the aquifer in comparison to the flow in the stream and a distinct effect on routing.

FLOOD PLAIN ZONING DOWNSTREAM OF MACHHU DAM - II

Floods play havoc in our country every year. The magnitude of flood depends upon topography, intensity of rainfall, its duration and also on the

land cover and soil conditions when the heavy spell of rainfall occurs. Flood plains are generally heavily populated, since they are very fertile and easily accessible. In recent years there have been somewhat indiscriminate developments in food plains which has led to considerably more damage due to floods besides the loss to crops and other properties. There is need for taking up both short term and long term structural and non structural measures of flood control and flood plain management. This study describes a non-structural flood control measure termed as 'flood plain zoning', which is more suitable for flood plain situations, wherein much development has not taken place and allow such developments to take place which are not susceptible to severe damages. Flood plain zoning is defined as 'restricting/ regulating any human activity in the flood plain of a river, which are affected by overflow of water from the channels and streams. A typical flood plain zoning study has been done for the area downstream of Machhu Dam-II using flood hydrographs corresponding to 100, 200, 500 and 1000 years return periods, 1979 flood, design flood and dam break flood of Machhu Dam-II. In this study the flood levels at particular places have been computed using 'DAMBRK' model to estimate the water surface profile along the reach under consideration. Using the estimated water surface profile, the delineation of flood plain has been made under various zones. The zones which are identified in this manner could be used for planning, and control of developments in the flood plain of Machhu river downstream of Machhu Dam-II.

APPLICATION OF DAM BREAK MODEL TO DHAROI DAM

Dam failures are often caused by overtopping of the dam due to inadequate spillway capacity during large inflow to the reservoir from heavy precipitation-runoff. Usually the response time available for warning is much shorter than for precipitation-runoff floods. Therefore, the protection of public from consequences of dam failures has taken an increasing importance as population have concentrated in areas vulnerable to dam break disaster. This study involves simulation of the dam break flood wave (assuming a hypothetical failure) of Dharoi Dam in Gujarat State using U.S. National Weather Services DAMBRK Model. In this study, dam break shape has been assumed as trapezoidal. Using the data as supplied by the Irrigation Department, Govt. of Gujarat, peak flows, peak stages and time to peak flow and

peak stages are estimated for various sizes of dam break at dam site and other sites specified downstream of Dharoi Dam. The results thus obtained could be used for regulating developmental activity downstream of dam and evolving disaster management strategies.

REGIONAL FLOOD FREQUENCY ANALYSIS OF A TYPICAL REGION

Flood frequency analysis is a useful technique to provide an estimate of flood magnitude for specific recurrence interval from the limited sample data. There are various frequency distributions available which are used for modelling the peak flood series at a site. Generally, the inference about the best fit distribution is made based on some goodness of fit criteria. As a result, different flood estimates are obtained by the hydrologists based upon the test criteria adopted. It leads to different best fitting distributions at the same site or different sites of the same region. In order to avoid such problems, hydrologists are always in search of a robust distribution for fitting the peak flood series. Furthermore, because of the sample variations present in the short hydrological records, frequency estimates of rare events based upon at site frequency analysis are subjected to large error and thus unreliable. There are many sites in the same region, where hydrological data are not available but design flood estimates are needed for the design of small/medium structures. For these situations regional flood frequency analysis provides consistent estimate of design flood for gauged as well as ungauged catchment in the region.

In this study, procedures and results of at site and regional flood frequency analysis using the annual peak flow series of varying record length for twelve gauging sites of some rivers in Godavari basin sub-zone 3f have been presented. Predictive ability of different frequency analysis methods have also been tested through Monte-Carlo experiment based on bias, root mean square error and coefficient of variation computed from 1000 samples for different sizes corresponding to different recurrence intervals in search of a robust regionalisation method.

UNSATURATED ZONE MODELLING (BARNA SUB-BASIN)

Mathematical modelling of hydrologic system processes is a powerful tool to water resources engineers and scientists involved in the development

and application of the integrated approaches for efficient planning, design and management of water resources projects. An accurate estimation of generated streamflow and ground water fluctuations form most important aspects in the mathematical modelling of hydrological processes. The flow through the unsaturated zone plays an important role as all other components of the hydrological cycle including the stream flow generation and water table fluctuations primarily depend on boundary data from unsaturated zone. The unsaturated zone links the fast responding overland flow with the slower responding overland flow with the slower responding saturated sub-surface flow. A correct simulation of unsaturated zone flow is, therefore, a pre-requisite for modelling the generated stream flow and water table fluctuations accurately.

Keeping in view the importance of the unsaturated zone modelling, a study has been taken up involving the application of SHE model, which is a physically based distributed modelling system developed by three European organisations viz. the Danish Hydraulic Institute, the British Institute of Hydrology and the French Consulting Company SOGREAH jointly, to Barna sub-basin of Narmada Basin. In SHE model the unsaturated zone flow is described by one dimensional Richard's equation which constitutes the basic governing equation of the flow processes. In order to obtain the solution of Richard's equation, the prior knowledge about the soil physical properties is essential. In this application study different sensitivity runs would be made after changing some important physical properties of the soil available in Barna sub-basin having the same parameter values for other components. The sensitivity of the parameters involves in the solution of Richard's equation would be tested and the importance of the parameters would be high-lighted for the field investigation.

STAGE - DISCHARGE RELATIONSHIP FOR KHANAPUR ON RIVER MALAPRABHA

The water level and the volume of water passing a site in river provides useful information about the flow which is very essential for planning and design purposes. Though water levels are measured more frequently either manually or with automatic water level recorders measurements of

discharge are carried out only daily or twice daily. Information on discharge over shorter durations such as hourly or three hourly are required for hydrological design and flood estimation. For the estimation of discharge from water level observations, it is customary to establish relationship between the water level (stage) and the volume of water (discharge).

There are several techniques of developing stage-discharge relationship which include graphical, mathematical and analytical approaches. The institute has developed a rating curve analysis procedure which uses Hermition interpretation which accounts for the slope and curvature of the rating curve. The essential features of the methodology are

(i) initial adata analysis using simple graph plot
(ii) double log plot for application of grouping of data and graphical estimation of parameters
(iii) application of the least squares technique, and
(iv) interpretation of results.

Malaprabha is a river in the western ghats flowing in an easterly direction. The river is gauged at Khanapur. The catchment area upto Khanapur is 326 sq. km. The discharge is measured daily by current meters. An automatic water level recorder is also functioning near the site since 1984. Daily gauge-discharge data is available since 1972.

Using the procedure developed in the Institute stage-discharge relationship for the Khanapur gauge site is developed for converting hourly gauges by the water level recorder.

GEOMORPHOLOGICAL CHARACTERISTICS OF RIVER BASINS IN WESTERN GHAT REGION

Geomorphology is science of landforms. It describes landforms and attempts to explain the evolution of landform in terms of lithology, structure, climate and geomorphology. The advance knowledge of geomorphology of the region is of importance in the field of flood control measures and engineering projects, since the geomorphological characteristics of river basins in mountainous areas affect runoff process and formation of flood in these areas.

Parameters of Hydrologic models describing rainfall-runoff process may be estimated either by optimisation technique using rainfall-runoff data or using topographical and climatic information of the basin. Since most of the locations in mountainous areas are either ungauged or sufficient data is not available for them, the study of geomorphological characteristics of such areas become much more important and significant. Thus one of the main objectives of geomorphological studies is to regionalise the hydrologic models describing rainfall-runoff process.

Various geomorphological parameters which have mostly been used by various investigators can be broadly classified as those describing (1) Linear Aspect of Channel System (2) Areal Aspect of Channel system, and (3) Relief Aspect of the basin.

The river systems of western ghats region are non-snowfed. Since the rain falling over these basins is directly converted into overland flow and channel flow, it becomes all the more important to have clear idea of geomorphological characteristics of these basins.

The main objectives of present study is to evaluate some of the widely used geomorphological parameters of few selected sub-basins in western ghats region. The study may be useful at finding out effect of geomorphology on watershed runoff response and identifying those parameters which are more closely related to runoff in western ghat region.

LAPSE RATE STUDIES IN THE HIMALAYAN REGION

The temperature distribution in the various elevation zones of the snow covered basin-depends on the temperature lapse rate used in the snowmelt models. The value of lapse rate significatly influences the snowmelt computation. Generally a constant temperature lapse rate (6.5°C/Km) is used in the snowmelt studies. It is understood that use of standard value for all the regions and complete duration of snowmelt may result in underestimation or overestimation of the snowmelt-runoff.

The pattern of lapse rate variation throughout the year has been studied in the Satluj catchment and for only snowmelt season has been studied for the Himachal region in western Himalayas. Mean daily and mean monthly

LR is computed for various altitudes. It is found that lapse rate is very high in the month of February/March and very low in Aug./Sept. in the Satluj basin. It varies even in the snowmelt season significantly. In the Himachal region LR does not vary as much with time as in the Satluj basin.

MONITORING OF GROUND WATER POLLUTION FROM SEWERAGE WASTES IN BAHADRABAD, HARDWAR (U.P.)

Sewage is placed on or below the land surface in a variety of ways. Wide spread use of septic tanks and drains in rural, recreational and sub-urban areas contribute filtered sewage effluent directly to the ground. In some regions liquid sewage that has not been treated or that has under gone partial treatment is sprayed on the land surface.

Untreated sewage from Bharat Heavy Electrical Limited (BHEL), Hardwar is being spready on the crop land near Bahadrabad. The areas of the disposal site is about 15 sq. km. and the sewage is used as irrigation water. The site is bound by canal on the southern side. The studies were conducted in this area. The samples from different sites have been collected (sewage samples from the sewage pumping stations, and water samples from the wells or hand pumps around the site). The analysis of the water samples collected, show relatively low conductivity in case of shallow aquifers (300-500 mho) as compared sewage water (500-600 mho). The water from tubewell as well as hand pumps located on the other side of canal showed low conductivity (200-300 mho). Nitrates are high in the samples collected from nearby areas. The conclusions have been drawn regarding effect of land fills and ground water quality from these limited field experiments.

MODELLING OF WATER QUALITY IN HINDON RIVER, SAHARANPUR DISTT. (U P.)

The biological, chemical and physical processes of the ecosystem are represented by means of mathematical equations. These are the relationships between two or more state variables and between forcing functions and state variables. It is however, not possible that one equation represents whole systems, most of the processes have several mathematical equations and set of such relations is called mathematical model. Water quality models

generally serve two basic purposes firstly to provide basic scientific insights and understanding about the relationships between material input and water quality changes and secondly to forecast water quality which inturn assists in managing and planning water quality standard.

In the present report a very comprehensive water quality model namely QUAL-II, given by Texas Department of Water Resources, U.S.A. for Environmental Protection Agency, USA has been implemented and used to study the water quality variations in Hindon River (U.P.). QUAL-II is a comprehensive and versatile stream water quality model which can simulate upto 13 water quality parameters such as dissolved oxygen, biochemical oxygen demand, temperature, algae, ammonia, nitrate, nitrite, phosphate, coliforms etc. QUAL-II is written in Fortran-IV and is compatible to most of modern day computers. It requires an average of 51000 words of core storage. The data available in Hindon River were used and some coefficients were suitably used in the study. The programme has been successfully used on the river, however it has been concluded that the requirement of data for running such a comprehensive model is large and special efforts are needed for collecting such data.

DIGITAL MAPPING OF SURFACE WATER BODIES (ONG SUB-BASIN ORISSA)

Digital Image Processing of the data aquired by the sensors on board space borne platforms, is the most economic and fast method for various types of studies pertaining to Remote Sensing. The digital method has an edge over the visual processing as the Digital Image aquired by the sensor has the finer details than the finished out product in the form of photo-images. The digital data is available in the form of CCTs. With the availability of advanced computer technology the digital image processing and analysis is becoming more and more convenient, accurate, to the point, precise and versatile.

Since the water bodies over the earth surface are one of the most prominent and district objects, it is most desirable to try various techniques and to develop new methods to delineate the water bodies on the face of the Image. Such theme maps do communicate the information in a wider spectrum of knowledge.

In the present study an attempt has been made to prepare theme maps depicting surface water bodies using satellite data. Digital data contained in Landsat CCTs bas been analysed on VAX-11/780 Computer System of the Institute. Various techniques of digital analysis have been attempted for the purpose of mapping water bodies and a suitable methodology for such mapping has been suggested. It has been found that density slicing of functionally enhanced data provides reasonably good estimate of surface water bodies.

STUDY OF MOVEMENT OF STORMS IN MAHANADI BASIN

Tropical storms known as depressions and cyclones, move over the Indian subcontinent releasing in their wake large amounts of rains which cause floods. The magnitude of flood and its duration are to a great extent controlled by the spatial and temporal distribution of rainfall. This in turn is controlled by the speed and direction of movement of the storms. The direction of storm movement has profound influence on rivers with large catchment areas.

Modelling of moving storms has been attempted by several authors using both dynamical and statistical approaches. In an earlier study carried out in the Institute the statistical technique of inter-station cross correlation has been applied to model the movement of storms in the Narmada basin where the storm and flood waters move in the same direction.

In the present study statistical analysis of short duration rainfall in the Mahanadi basin is carried out to study the movement of storms which move in a direction against the direction of river flow. Five storms which occurred during the years 1973, 1979, 1980 and 1982 were analysed. The movement of the storms is related to the flows at Hirakud and Tikkarpara to study the effect of storm movement on river flow.

The results indicated the usefulness of the statistical technique for modelling the movement of the tropical storms and its potential in flood forecasting.

SIMULATION OF DAILY RUNOFF OF TWO SUB-BASINS OF RIVER KRISHNA USING TANK MODEL

The tank model developed by Sugawara for daily analysis has been used to simulate streamflow of Malaprabha sub-basin upto Khanapur and Malathi sub-basin upto Kalmane.

Malaprabha is a tributary of river Krishna. The catchment area of Malaprabha upto discharge measuring site Khanapur is 326.0 sq. km. Using daily observed flow data of Malaprabha at Khanapur for the period 1981 to 1984, the tank model has been calibrated. The input rainfall data are based on the observed daily rainfall at Kankumbi, Gunji, Desur and Khanapur. The calibration of the model was carried out by simulation of observed flows in 1981 and 1982. The simulation was good, the fit of 1982 being better than that of 1981. The calibrated model has been used to simulate daily streamflows during 1984 and 1985 which were found to be within 10% of observed streamflows. The model was calibrated using data of 1979 and 1980 The tank model has been tested with independent data of 1984 and 1985. In first and last week of July 1984 flow was under estimated but performance of the model in general was satisfactory. Good fit of the computed hydrograph was observed except first week of Oct in 1985. The model performed well for peak flows as well as lien season flows.

Malathi is a tributary of river Tunga in the Krishna basin. It has catchment area of 280.3 sq. km. upto the discharge measuring site Kalmane. Observed daily rainfall data at Agumbe, Sringeri and Magarvalli were used for simulation of daily streamflows at Kalmmane. The comparison of computed hydrograph with observed hydrograph for the monsoon period of 1979 and 1980 was found to be satisfactory. The model has been tested with two sets of independent data of streamflow of two years each; 1981-82 and 1983-84. The performance of the model was satisfactory. The simulation of flows during 1982 and 1984 were found to be good than those of 1981 and 1983. This was due to the fact that the antecedent conditions get adjusted during the simulation of the starting year of comparison.

STORAGE DETERMINATION OF A MULTIPURPOSE RESERVOIR TUNGBHADRA

From the number of multi-purpose reservoirs in the country which were constructed since independence and some of the reservoirs are constructed presently and there are many more projects which are at the planning stage. Most of the projects are meant for multiple purposes i.e. they have to meet the various types of demands both conservative and conflicting types. The reservoir capacity computation is the primary parameter based on which such reservoir depends. With the latest techniques were not available, some of the reservoirs have been constructed based on the thumb rule facts. Some of these may be optimally utilised since they have been designed conservatively and some of them have been designed requiring better and optimal utilisation of the existing reservoir computation. In order to identify the reservoir capacity required to meet the demands both at present and in future, this report is expected to compute the reservoir capacity on one of the existing multi purpose reservoirs. To consider the real life problem, Tungbhadra reservoir has been considered to determine the storage of a multipurpose reservoir to meet the existing demands and thereby determining whether there is any further scope for the development of water resources in the region by optimally utilising the water in the reservoir.

RESERVOIR OPERATION FOR CONSERVATION PURPOSE PONG RESERVOIR

Some of the reservoirs in the country have been designed to cater for the conservation purpose. However, no standard procedures are being adopted for such a reservoir. The conservation demands themselves may vary like industrial and municipal water supply, irrigation etc. Proper priorities have to be assigned for such varied types of demands keeping in view the demand pattern. This report is expected to deal with the operation procedures for operation of reservoir for conservation purpose and develop a computer model for such operation. In order to make report practically oriented, the data from the Pong reservoir will be used and computer model thus developed will be tested using the data of Pong reservoir.

CASE STUDIES

REMOTE SENSING STUDIES FOR SEDIMENTATION IN TUNGABHADRA RESERVOIR

For the qualitative study of sediment distribution, the black & white multidate and multiband landsat images of Tungbhadra reservoir were visually interpreted at different scale. The original image were enlarged to 4 X using large format enlarger to extract optimum information regarding the sediment distribution pattern. An interpretation key was used for qualitative mapping of different turbidity levels using all the four spectral bands. The water level and turbidity level were marked using multiband & multiband images to observe the changes in the water spread and turbidity levels in different seasons within the reservoir. Grey level slicing techniques has also been used to identify different suspended sediment concentration level in the reservoir. All the 4 bands sliced to increase the sensitivity as well as analytical ranges. The area of the reservoir water spread has been measured from multidate imageries to prepare area capacity curve. Reservoir water level corresponding to date of imageries have been noted down from sedimentation survey report 1985. Volume of the reservoir between two subsequent date are calculated using presmoidal formula

$$V = \frac{H}{3} (A_1 + A_2 + \sqrt{A_1 A_2})$$

the cummulative volume has been calculated taking the volume of the reservoir water from area capacity curve prepared by reservoir authorities.

HYDROLOGICAL ASPECTS OF DROUGHT 1986-87

In view of the gravity of the drought situation during 1986-87, the Institute sent-out scientific and technical teams six times to the states of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Rajasthan to acquaint with the drought situation and to collect necessary data and information for drought studies with emphasis on hydrological aspects. To start with, four districts in each state namely Banswara, Barmer, Ajmer

and Udaipur in Rajasthan; Khargone, Jhabua, Dhar and Sidhi in M.P.; Cuddapah, Anantpur, Chittoor and Prakasam in M.P.; Bijapur, Belgaum, Gulbarga and Raichur in Karnataka; Ahmadnagar, Solapur, Pune and Satara in Maharashtra; and Jamnagar, Rajkot, Ahmedabad and Surendranagar in Gujarat were selected for analysis. On the basis of available data and the analysis, conclusions have been drawn in respect of hydrological aspects of drought during 1986-87 and results compared with the report for year 1985-86 carried out by the Institute.

In case of rainfall analysis the daily, monthly and annual rainfall data have been subjected to various types of analysis viz. seasonal departure analysis from 1970-87, monthly departure analysis for 1986-87, probability analysis of annual rainfall from 1901-87, Harbst's analysis of monthly rainfall of monsoon season from 1951-87 and dry spell analysis of daily rainfall data from 1981-87. The analysis has indicated that in general the areas selected for study are drought affected areas and year 1986-87 recorded seasonal rainfall deficit of more than 20% of normal.

The ground water level data for about 12 years (1976-1987) as available for 23 districts as located in six states have been analysed and a trend in premonsoon and postmonsoon ground water level has been worked out which has been compared with the trend in rainfall. In general, declining trend in ground water level has been observed in all districts with some exceptions. However, due to non-availability of abstraction data exact correlation between rainfall and ground water regime could not be established.

The analysis of stream flow data was done for nine selected sites in Krishna basin. At these sites stream flow data of least 20 years was analysed. The various types of analysis included comparison of simple flow hydrographs with long term values, development of flow duration curves and low flow index values and deficit volume and deficit duration analysis. The results indicated that during 1986-87 the conditions experienced drought.

The report is an attempt of the drought studies division of the Institute to highlight the hydrological aspects of drought in six states during 1986-87. Further studies with more types of analysis will be included in forthcoming such reports.

IMPACT OF DROUGHT ON AGRICULTURE IN DISTRICT KHARGONE OF MADHYA PRADESH

Drought has become a global problem nowadays due to its regular occurrence worldwide. India too is one of its victim because India's economy is based on agriculture, so there is a need to assess the impact of drought on agriculture. District Khargone of Madhya Pradesh has been chosen for the purpose because it is regularly affected by drought.

To determine the intensity of drought in Khargone district, seasonal rainfall analysis has been done and departure of rainfall for the year 1985-86 has been carried out from the normal rainfall of district, which shows that district Khargone is affected by drought in the year 1985-86.

Affect of this drought is considered on seven major crops of district i.e. jowar, rice, ground nut, bajra, maize, cotton and wheat. For this purpose, the yield of these crops for year 1985-86 has been compared with the average yield of years 1976-80 and the yield of drought-unaffected year 1977-78. The comparison shows a significant decline in the yield of 1985-86.

GEOMORPHOLOGY AND DRAINAGE PATTERN IN SABARMATI BASIN

In developing countries like India the quick appraisal of dimension of the physical environment for biological management is the prime necessity. This is more so in the semi arid land where the imbalance exist between the scarce physical endowment and bountiful biological needs. Water is the precious commitities is such lands. Keeping in view this phenomenon an attempt has been made in this study to map and analyse the drainage network and geomorphic units of the sabarmati basin.

Landsat imagery of band 4,5,7 covering sabarmati basin were analysed for the texture, shape, size and pattern to study the different land forms and drainage pattern developed under different climatic environment. The study enabled to identify the land form such as hilly ridges, pediment, plain, macine land cape. The basin area, stream number, stream length, total stream length, bifurcation ratio, drainage density have been calculated. It can be concluded that a reliable drainage network can be obtained from satelite imagery and aerial photography in the shortest possible period.

MULTITEMPORAL FLOOD PLAIN MAPPING OVER A PERIOD OF 15 YEARS IN THE AREA COVERED IN LANDSAT FRAME 146-046 (FROM ALLAHABAD TO BUXER, U.P.)

River characteristics are concerned with the structure and form of rivers, including channel configuration, channel geometry (cross sectional shape), bed form and profile characteristic. Channel morphology changes with time and is affected by water discharge, including velocities, sediment load, quantity and sediment characteristics; the composition of bed and bank material and other factors. Prediction of when & where future erosion will occur and the extent of such erosion is very uncertain because of the many interacting factors involved.

For study of dynamic behaviour of a river, measurements taken with conventional ground based instruments is a time consuming and expensive procedure. Their main disadvantage however is that they provide only a point measurement which is unlikely to be representative of the whole. Whilst Remote Sensing techniques are unlikely to ever match the accuracy of ground based measurements they are capable of providing a measure of surface variability which can never be appreciated from the ground. Because of the repetitive nature of satellite coverage, space borne observation are particularly suited for monitoring dynamic changes in surface parameters in remote areas or areas that are difficult to access.

This report describes characteristics of river Ganga using remotely sensed data. The area of study lies between east longitudes 81°45″ to 84° and north latitude 25° to 26°. The area is covered under four frames of Landsat imagery. The features such as streams, sediment deposit etc. were delineated and depicted on a 1 : 250,000 scale base map.

SABARMATI BASIN LAND USE/LAND COVER MAP

Land use denotes the man's use of land for various purposes such as forest, agriculture, urban etc. Landuse data is an important basic information for any basin as it affects the environment and economy of the region. For hydrological studies, land cover and landuse are significant as they determine

to a large extent the prccess of runoff generation and are excellent indirect indicators of the hydrologic conditions and the geomorphic characteristics of a region.

The conventional land use mapping consumes considerable time to acquire and compile the data to produce a map of current land use of an area. By the time such a map reaches the public or the planners, it becomes out of date. The data has to be collected to meet specific limited needs using definitions of use classes which are appropriate for only that need, It is widely accepted that the only practical way of obtaining synoptic converage is by employing a form of remote sensing. In this context, space and aerial observations are particularly well suited for determination of land cover and use, not only because they can survey large areas, but also because they update this vital information which can be easily quantified on a regular basis.

The role of space image in providing a synoptic view and improved perspective of the problem relating to land use has been illustrated by the present study. The area taken for land use mapping is Sabarmati basin. The study area lies between east longitudes 71°15 to 73°30′ east and latitude 22° to 24°45′ North. Visual interpretation of landsat data were used for the preparation of hydrologically significant land use maps.

STATUS REPORTS

WATER CONSERVATION THROUGH LAND TREATMENT MEASURES

The basic source of water on the earth is precipitation which may be in the form of rainfall or snowfall. Estimates have been made that the entire country received about 400 m ha.m of precipitation during a year. Out of this about 115 m ha.m. flow as surface runoff, 215 m ha.m seeps into the form of evaporation from streams and land surface. The country has been facing severe drought conditions for last 2-3 years in succession due to deficiency of rainfall. Keeping in view the continuing nature of drought conditions it may be worthwhile to review all land treatment measures which help in conserving water. These treatment measures may be basically employed for increasing runoff from land surface in areas where less rainfall is received. These measures may include physical clearing of land surface, management of vegetation on upland watershed, use of mechanical measures etc.

In the present report a detailed review of all land treatment measures have been presented and effectiveness of all measures have been discussed based on available results. The viability of these techniques for conditions in the country would also be discussed. This will be helpful in planning overall strategy for water management.

USER'S MANUALS

DEVELOPMENT OF SOFTWARE FOR DATA STORAGE & RETRIEVAL SYSTEM AND IMPLEMENTATION ON PC/AT

This report gives details of a Data Storage and Retrieval (DSR) System for hydrological data developed at NIH.

A Data Storage and Retrieval (DSR) system may be defined as a collection of interrelated data stored together without harmful or unnecessary redundancy to serve multiple applications. Specific data item(s) may be searched/retrieved from this system very quickly and easily.

Using the DSR system, data are stored in such a way that the storage of data is independent of the programmes which use them. A common and controlled approach has been adopted in adding new data and modifying/retrieving the existing data from the data base. The data are structured so as to provide future application development simpler, faster and easier.

The major tasks performed by this package are :

(i) Validation of incoming raw data (available on disk), their organization and thereby creation of the master file.

(ii) Retrieval of data from the master data file.

(iii) Maintenance and updation of the master data file.

These functions are performed with the help of simple commands developed specially for this purpose.

The characteristics of the developed system are :

* Physical and logical data independence
* Protection from loss or damage
* Easy data updating procedure
* Accuracy and consistency
* Privacy of use

* Timely data availability
* Integrity controls
* Controlled radundancy
* Fast searching and retrieval.

A report generator has been included in the system which can be used for printing the data in the desired format.

POWER TRANSFORMATION TECHNIQUE IN BASIC FOR FLOOD FREQUENCY ANALYSIS

Frequency analysis is a very useful technique for the estimation of design flood corresponding to a specified recurrence interval from the limited data. Generally sample data is fit to several frequency distributions and then a suitable distribution is considered for estimating the floods of required recurrence intervals, instead of fitting a probability distribution to raw data, sometimes the data is transformed, so that it conforms to a particular distribution of known characteristics for the purpose of flood frequency analysis. Power transformation (Box & Cox) is one of the powerful techniques for transforming any data series to near normal series.

The user's manual describes the power transformation technique in detail and the computer programme transforms the given series of annual maximum peak flood to near normal distribution using power transformation. It then performs the flood frequency analysis on this transformed series using the method of moments for estimating 50, 100, 200, 500, 1000, and 10000 years return period floods using two approaches based on the criteria that (i) coefficient of skewness is nearly zero and (ii) coefficient of skewness is nearly zero and coefficient of kurtosis nearly equal to 3.0.

The programme is useabe both on VAX-11/780 Computer system as well as on IBM compatible Personal Computer with minor changes which have been described in the programme itself. The user's manual also lists the sample input and corresponding generated output of one selected example.

SOFTWARE PACKAGE ON PUMPING TEST DATA ANALYSIS

A user manual has been prepared to evaluate aquifer parameters from pumping test data. The manual contains efficient programmes using which type curves for confined and leaky confined aquifers can be prepared. An efficient programme has also been developed for preparation of type curve for unconfined aquifer having delayed yield characteristics. The finite values of delayed yield parameter have been considered in the programme. A search technique based on Marquadot algorithm has been included to find aquifer parameters for different type of aquifers.

DOUBLE MASS CURVE ANALYSIS FOR HYDROLOGIC VARIABLES USING COMPUTER GRAPHICS

Raw data should be carefully reviewed and adjusted for errors resulting from instrumental and observational deficiencies until they are made as accurate as possible. Double mass curve analysis tests the consistency of the record at a station by comparing its accumulated annual and seasonal precipitation with the concurrent accumulated values of mean rainfall for a group of surrounding stations.

A computer programme for Double Mass Curve analysis has been developed using graphics.

SOFTWARE DEVELOPMENT OF STORAGE DETERMINATION OF A MULTIPURPOSE RESERVOIR

Estimation of storage to satisfy the specified demands is a basic step of planning of a water resources project. Sequent peak method, which is an automated equivalent of well known mass curve method, has been in use since long to compute single estimate of the design capacity of a storage reservoir. In this report, a generalized computer based technique using simulation and optimization methods has been developed for computation of storage of a multi-purpose single reservoir at a desired reliability. The conflict between various conservation demands is resolved by assigning priorities to them which are user specified. Allocation to various demands is made according to their relative priorities.

The developed program can be used for storage determination of a multi-purpose reservoir knowing the required yield; also in computation of yield knowing the reservoir storage. It also performs reservoir operation computations. The application of the program to a hypothetical case is also given to illustrate the program usage.

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