Water Resources Systems

WATER RESOURCES PLANNING & ENVIRONMENTAL CONSIDERATIONS

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Water Resources Planning & Environmental Considerations

Water Resources Planning

The objective of water resources planning is to make the most effective use of available water resources to meet all the foreseeable short and long term needs of the nation. The words 'most effective' imply that the well being of all the people should be maximised, while at the same time the total physical effort is minimized. The words 'short term and long term' imply that water resources must be managed and conserved not only for this generation but for generation to come.

The most appropriate geographical unit for water resources planning is usually the river drainage basin.

STAGES IN WATER RESOURCE PLANNING

Let us briefly review what is involved in water resources planning, before we proceed to details :

Basic Data

Stream flow data: Any plan of water development must take into consideration the amount of water that is available, the amount of water that is required, and how these two can be reconciled. It is more than likely that some stream flow records in the drainage basin have missing years, or have unequal length, or should be extended backwards in time. This may be accomplished by correcting stream flow at one station with stream flow at another station, or with precipitation. After the stream flow data have been completed they must be processed so that they reveal the sort of information that the planning engineer wants to obtain hydrographs, duration curves, mass curves and curves of maximum annual flood peaks are then made. From the information thus obtained, the planning engineer may decide to study the records from a viewpoint of possible redistribution in area or in time. This leads to studies of reservoir capacity, the possibility of river diversions, the possibility of using ground water as a storage reservoir etc. Since the objective of this part of the study is to ascertain the availability of water in the drainage basin for different purposes, such as domestic use and irrigation, the investigation must include sediment movement and water quality.

Geophysical data: Geophysical data are related to the configuration of the ground, the structure and composition of the earth's crest.

Economic data: Economic data is necessary to determine the need, cost, justification, and best over-all plan for water resource developments. Typical items are : population statistics; industrial development and future potential; land values and potential enhancement;

agricultural statistics, fish and wild life resources; pollution damages; hazards to navigation; erosion damages and wage rates.

Jurisdiction data: Water resources planning and development may take place under the auspices of private corporations, local, provincial or federal governments, regional authorities or even international commissions. Each of these jurisdiction can be expected to have different social and physical objectives. It follows therefore that the relative political setting may influence the planning effort. Engineers expect conflict of interest between the several jurisdiction that are involved. If engineers are to maintain a leading position in the water resources planning field, they must be able to recognise such problems, so that they can obtain timely and sound legal advice.

Economic Base Projection

For the near future: It must at least extend over a few decades. This is because of magnitude and complexity of most river basin projects. Complete development may include several years for planning studies, several years for discussion, and several years for design and construction. Hence there may easily be a period of 10-20 years between the beginning of the planning studies and full operation of the project. Most estimates of future trends of population and their economic base are projections of past and present trends. It is generally assumed that there will be no wars or severe depressions, and that the economy of the country will continue to grow roughly at the same rate as it has been in the past.

For far future: It should extend at least over the useful life of the projects that are considered, that is, a period of 50-100 years. It is obvious that any extrapolation of past trend, over such a long future period of time, is of a highly speculative character. It is therefore important that we try to apply logical reasoning.

Water Requirements

Domestic and industrial: Assuming that we have an estimate of the population and the type and size of industries, it is fairly simple matter to estimate the associated water requirements. Per capita requirements of entire city including municipal, commercial and industrial use, may vary depending upon standard of living and type of industries. Associated with the domestic and industrial water requirements are the waste disposal requirements. The stream flow requirements to dilute municipal and industrial effluent so that adequate sanitary river conditions are maintained may be 10 or even 100 times larger than the pure water intake.

Irrigation requirements: The first question that may be asked on this subject would be : is there any need for irrigation ? This leads to an inquiry of the production of crops under natural moisture conditions. After a clear picture has been obtained of present and future demands for agricultural products, the problem arises to determine to what extent irrigation could be applied to increase the present production. This calls for an inquiry into the soil and moisture conditions of the area. It should be noted that irrigation requirements often constitute a major portion of the available water supplies.

Water requirements for irrigation are usually seasonal, with a maximum during the summer and winter months and little or no demand during the monsoons. Water requirements do not vary greatly from year to year, although low-rainfall years usually create a greater irrigation demand than high-rainfall years. Unless the project area is increased, the average annual demand will remain nearly constant.

Navigation requirements: To explore the navigation possibilities in a drainage basin, one must first know the present and future quantity of goods that would be transported by water if it were attractive from an economic view point as compared with possible alternative means of transport. After having established that there will be a good market for water transport, several methods are explored to provide the navigational facilities.

Power requirements: The generation of hydroelectric power is an important use of water. One of the attractive features of water power is its non consumptive use of water. With proper planning in a river basin, a high percentage of the available stream flow may be used through a series of successive plants from the head waters to the mouth of the rivers.

Flood control requirements: It does not involve any consumptive or non consumptive use of water. Flood control and damage prevention measures may be divided into the following general categories : Channel improvements, river diversions, dikes, reservoirs, and flood plain regulation.

Recreational requirements: The enjoyment of people is an important objective in water resource planning. This may be achieved by reserving beautiful areas of rivers, lakes and beaches for recreation.

Development of Plan

Priority of Water Use: Where water is cheap and abundant, it is liberally applied to domestic, industrial and irrigational uses and the “water requirement” of that region appears to be high. Where water is expensive and scarce, elaborate facilities are constructed to minimize intake, and to reuse quantities withdrawn. As a result, the ‘water requirement’ of that region appears to be low. It would therefore be wrong to establish, in advance of the planning study, arbitrary water requirements for different purposes, and then to saturate in sequence, domestic use, industrial use, and irrigation use. Instead, an attempt must be made to equalize the marginal value of incremental water use for each different purpose.

When establishing priority of water use, we should also consider whether or not there is a substitute for the water. For instance, water power can be substituted by thermal or nuclear power; navigation can be substituted by land transport. However, there is no substitute for water for irrigation.

Alternative Plans: We have now come to the heart of the planning study : the most efficient lay out of the actual engineering works. Such an objective is difficult to obtain and the proper solution may not be found without considerable search and study. The investigation of one plan is not enough. The process of conceiving new plans must be repeated until all viewpoints have been considered, and until all reasonably sound combinations have been tried. It may be possible, however, to eliminate a large number of initial proposals with a minimum amount of formalities. A quick calculation may reveal that the cost of some structure is high, or that some proposal is not compatible with established priorities of water use. After this initial process of elimination, it may be expected that a number of promising alternative engineering plans will remain for serious consideration.

Economic Analysis: A mere estimate of the average annual cost of different engineering plans is not always sufficient to be used as a basis for selecting the most feasible project, since different plans may yield different benefits. For this reason, the benefits of each alternative plan must be estimated as well.

Selection of Plan: After having determined the annual costs and the annual benefits of a number of alternative water development projects, the problem arises to select the most feasible project. It is now generally accepted, at least in theory, that this should be the project with the greatest excess of overall annual benefits over annual costs.

PROBLEMS IN PROJECT PLANNING

The Feasibility Report

Because of the large number of possible projects it is fairly common practice to prepare a feasibility or preliminary report on a project as the first phase of its analysis. If this report is unfavourable, the project can be dropped without excessive expenditure of funds. If it is favourable, the decision to proceed for more thorough studies is made. In theory, the project can be rejected even after a favourable feasibility report, but for public projects political considerations may work to avoid any such rejection. Consequently the feasibility report becomes a very important step in the economic analysis of projects, and it is important that the feasibility report should not be based on approximations and short-cut procedures.

In particular the study of hydrology and those factors related to expected water use should be carried to the level of refinement appropriate for final design. Anything less may incur the hazard of a serious error. Accurate maps are also essential in a feasibility report. While this may increase the cost of preliminary studies, it would reduce the cost of the final design for projects.

Standards

Many organisations have prepared design standards. These may not, however, always be appropriate to the particular problems of a given project. These should be studied with reference to the particular problem, and decision made.

Early Construction

Assuming that the economy is functioning fully, a rupee investment postponed for 10 years at 10 percent interest is equivalent to Rs. 2.59. Construction of a project substantially before it is needed constitutes a waste of funds which might profitably be employed gainfully in the interim period. Even increased construction costs over the 10 year period need not necessarily represent a loss resulting from the delay, since increased costs will be at least partially offset by a relative increase in benefits.

Stage construction or investment may be more desirable. If a project is known to be needed 10 year hence it may be quite desirable to buy right-of-way at once to prevent development that would greatly increase cost. There are numerous examples of dams which have been planned for stage construction as growing water requirements increase the required reservoir size. In some cases where a water supply is required immediately, it may be prudent(practical) to install conduits designed to meet anticipated future demands and perhaps, even, a dam large enough for the long-range future. In each case, however, this need should be demonstrated by analysis and not assumed a priori.

The practice of building flood-mitigation works on the basis of anticipated future growth of the area to be protected is especially erroneous. Flood mitigation should not be provided until it is justified by existing values.

Failure to Consider All Alternatives

Probably the most common pitfall is the failure to consider all alternatives. In particular, non-engineering alternatives such as flood-plain zoning may be overlooked by the engineering designer. In addition, simple engineering alternatives are often overlooked especially when they depart from the traditional solutions. To reduce the seepage through a small earth dam, construction of a clay cutoff wall and blanket on the upstream face, though successful is not a final solution. Provision of relief wells on the downstream side can be a useful source of filtered water as well as a seepage-control measure.

Use of Next Best Alternative

In lieu of any other estimate of the benefits of a project, it is not uncommon to use the cost of the next best alternative as a measure of benefits. By judicious selection of the next best alternative, the benefits can be made very large indeed. The only alternative acceptable as a basis for estimating benefits is an alternative which would be built if the project under study were dropped.

MULTIPLE-PURPOSE PROJECTS

Many hydraulic projects can serve more than one of the basic purposes- water supply, irrigation, hydroelectric power, navigation, flood mitigation, recreation, sanitation, and wild life conservation. Multiple use of project facilities may increase benefits without a proportional increase in costs and they enhance the economic justification for the project. A project which is designed for single purpose but which produces incidental benefits for other purposes should not, however be considered a multi-purpose project. Only those projects which are designed and operated to serve two or more purposes should be described as multiple project.

For requirements of various uses(such as power, navigation, irrigation etc.) - see "*planning for water resource projects*" in this module.

Planning for Multi Purpose Projects

Water may serve a variety of purposes, of which the following are the most important ones:

- The supply of clean water to municipalities and industries.
- The carrying away of the wastes from municipalities and industries.
- The irrigation of agricultural lands.
- The production of hydro-electric power.
- The maintenance of sufficient depth of water in navigation channels.
- The provision of recreational facilities.
- Flood control.

In the majority of water development problems, more than one use of water is involved. In some cases, all seven purposes have to be served. Since one form of use or control may be beneficial or detrimental to another form of use of control, we may conclude that in the general case, one must review all possible purposes to be served before proceeding with the development of a plan.

There are two unique characteristics of multipurpose projects, one having to do with making them attractive and the other with making them more complex.

As we pile more and more purposes into a project, the number of beneficiaries increases, and the political support grows. Since water projects are usually subsidized by someone, and since there are usually those who benefit substantially from the projects, it is natural that the political support can become a key factor in decisions about whether the projects will be implemented or not.

The other side of that coin is that the more complex a project becomes, the more difficult it is to gain a major supporter or advocate because the benefits are so widespread. Complex projects can attract the opposition of budget bureaus, which are always looking for ways to cut costs and increase “efficiency". These forces will line up against the advocates, and the outcome will depend on political power.

level is generally made available by closing the spillway gates, and the water is allowed to encroach on this space only during floods.

LONG-TERM PLANNING

In present water development projects it is not uncommon to find components that are 50 or even 100 years old. In a similar vein, it would be a desirable if we could plan our works in such a way that during their *useful-life* of 50 to 100 years they could indeed remain an integral part of future water plans.

To endeavour to obtain this goal, we must be bold enough to look far into the future. This is no easy task nowadays; the world around us is changing rapidly; every day technology presents new possibilities; the world population is rapidly increasing and political philosophies are evolving from one form into another. Therefore, our forecasts of future economic, social and political conditions in the area of study are no more than speculations. However, in some cases there is some virtue in speculative anticipation.

On the one hand, we know from experience that it may take ten to twenty years to collect basic data, to study alternative projects, to analyse these from different viewpoints, to debate them with political representatives, and to reach agreement on the most desirable. development plan. On the other hand, we know from experience how suddenly the demand for certain projects may come. This may happen several times. For instance if some areas experience a few successive years of crop-failure, there could arise such a demand for irrigation.

We may conclude therefore that looking several decades into the future is a prerequisite of adequate water resources planning. It should also be noted that because of the uncertainty of predicting future conditions, any comprehensive future water development plan must be regarded as flexible and subject to continuous review and modification.

INTEGRATED WATER RESOURCE MANAGEMENT (IWRM)

Integrated Water Resources Management (IWRM) is a process which promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment.

IWRM helps to protect the world's environment, foster economic growth and sustainable agricultural development, promote democratic participation in governance, and improve human health. Worldwide, water policy and management are beginning to reflect the fundamentally interconnected nature of hydrological resources, and IWRM is emerging as an accepted alternative to the sector-by-sector, top-down management style that has dominated in the past.

The basis of IWRM is that the many different uses of finite water resources are interdependent. High irrigation demands and polluted drainage flows from agriculture mean less freshwater for drinking or industrial use; contaminated municipal and industrial wastewater pollutes rivers and threatens ecosystems; if water has to be left in a river to protect fisheries and ecosystems, less can be diverted to grow crops. There are plenty more examples of the basic theme that unregulated use of scarce water resources is wasteful and inherently unsustainable.

Integrated Water Resources Management is a cross-sectoral policy approach, designed to replace the traditional, fragmented sectoral approach to water resources and management that has led to poor services and unsustainable resource use. IWRM is based on the understanding that water resources are an integral component of the ecosystem, a natural resource, and a social and economic good.

PUBLIC PARTICIPATION IN WATER RESOURCES MANAGEMENT

Present-day water resources management should be based on an integrated approach and participation of managerial agencies at different levels and from different sectors. Participation of *users* is necessary to establish *realistic prices* for water use and to implement water protection measures with maximum efficiency and effectiveness. The public should be informed of water resources quality and quantity as a water user and a partner in water resources protection.

Thus, integrated water resources management includes a substantial organizational component: preventing or settling conflicts through involvement of *stakeholders* in decision-making processes.

The basin approach and prevention of conflicts between various water users require complete participation of and cooperation between all the stakeholders. To reach a common agreement on to decisions made, it is necessary to involve not only governmental, local and municipal authorities, but also the private sector and public, and strive for a consensus. It would be much easier to implement a strategy and legal, administrative and technical actions under well-established consultation procedures.

Objectives of Public Involvement

The main objectives of the public participation in integrated water resources management are:

- to ensure use of the knowledge and experience of the public and other stakeholders in planning and management processes;
- guarantee identification of decision quality and adaptation to specific conditions;
- provide adequate planning and identification of problems while implementing decisions in practice;
- ensure consideration of public needs and priorities in making managerial decisions.

Basic principles of the public participation

Basic principles of the public participation in integrated water resource management are:

- actively involvement of all the stakeholders and the general public, directly or indirectly;
- the process should be **open** and **transparent**, be conducted fairly and impartially, based on exchange of information, data and knowledge, using all appropriate information media; it is necessary to foresee certain conflicts and solve them;
- suitable mechanisms should be adapted to local conditions, problems and needs of all participants, focusing attention on reaching a consensus;
- participants should adopt a long-term vision on an acceptable condition of studied water body, watercourse or shore, recognizing the differences in their interests, working together and learning from each other;

- the participation should not only consist in solving problems, it is necessary to provide opportunities of **economic welfare** and **nature conservation**, compatible with broader acceptable development objectives.

Advantages of Public Involvement (PI)

The concept of PI has evolved over time through learning and experience. The key advantages of public involvement in decision-making are:

- PI reduces the risk of project failure by improving the quality of planning and decision-making.
- By bringing a diverse range of values and opinions to the table, PI can improve problem solving.
- PI helps in development of the feeling of partnership with local communities. It thereby overcomes the local resistance and provides a conducive work environment.
- PI significantly reduces conflicts between individuals, groups and organizations.
- PI helps in improving the project performance by using the technical expertise of the public.
- The poorer the people, or the scarcer the resource, the more important it is that local communities take part in project planning and decision-making because their survival and well-being may critically depend on it. In some cases, the project in question may be the most crucial chance of development for a generation or more.

Advantages to the Government

- Increased credibility, legitimacy, and positive image through transparent decision-making, particularly when decisions are controversial.
- Improved coordination between governmental departments as per the needs of the PI process.
- Higher level of commitment of all stakeholders to decisions made.
- Reduced risk of serious confrontation, thereby minimising project costs and delays.
- Development of a sense of belonging and responsibility among local communities toward projects.

Advantages to Financing Agencies

- Realistic information about the needs and preferences of local communities.
- Better project database right from the early planning.
- Improved technical design of projects, thereby reduction in costs.
- Increased market share by virtue of positive image.

Advantages to Affected Parties

- Improved understanding of the project and its impact on their lives.
- A project which meets their actual needs.
- Higher chances of success of the project and thereby improvement in the living standards.
- A platform for local communities to voice their concerns at all levels of government.
- Better targeting of benefits.
- Increased levels of accountability of government and developer to local communities.

ALTERNATIVES FORMULATION

The process of alternatives formulation is directly tied to the need for and purpose of the project. Although there are usually a number of different ways to meet the stated needs of a project, it is not necessary to consider every conceivable option. Rather, a reasonable number of alternatives should be identified among the broad range of available options.

The alternatives formulation process needs to be carried out from two perspectives: a means and analysis perspective, and a components and location perspective. These two perspectives consider structural and non-structural means of accomplishing the need and purpose of the project, establishing alternatives selection criteria, establishing data collection requirements, producing the initial set of potential alternatives, defining the location and basic physical elements of project alternatives, and refining the description of the initial alternatives.

Screening of Alternatives

The purpose of the alternatives screening (or comparison) process is to systematically reduce a relatively large number of alternatives to a final few. The process must be objective, defensible and unbiased. This process should be defined, in writing, in advance of its application but after the general range of alternatives is known. It is generally finalized during the data collection stage of alternatives formulation. A competent screening process, such as diagrammed below will:

Include considerations that are important to the project sponsor, regulatory agencies and other stakeholders.

- Allow for comparison of alternatives that are diverse.
- Allow for consideration of engineering, environmental, social, operational and cost factors.
- Allow for testing of screening results using sensitivity analyses.
- Provide for public involvement in its function.

The Final Decision

The final decision as to whether to carry out a project at all and which particular project alternative is to be implemented rests with the project sponsor — the entity that will perform (or construct) the project, will be held accountable for the project's success or failure, and must be capable of obtaining the resources (revenue and mitigation) to make the investments required to implement the project. An entity with such responsibilities cannot be an ad hoc public participation group, a permitting agency or a lending agency.

However, entities other than the project sponsor, such as regulators, have a legitimate role, responsibility and authority in meeting other societal values in the protection of public resources — fiscal and environmental, as well as individual rights. As such, these entities will review the sponsor's final decision in their role as "secondary" decision-makers. In this role, they can deny the implementation of a project without otherwise rising to meet the societal need and purpose of the project. A competent decision-making process must recognize both the responsibilities and limitations of the "secondary" decision-makers and lend credibility and accountability to their responsibilities. "Secondary" decision-makers are generally involved in one of three areas of project implementation: Permitting, Financing or Property Acquisition.

HYDROLOGIC MODELLING

Hydrologic modellers should initially answer two basic questions, and tackle the associated problems. Firstly, there is the question of model choice and secondly the criteria for validating a model should be stipulated. Given a system consisting of numerous processes such as rainfall, evapotranspiration, infiltration, runoff and groundwater flow which are essentially non-linear, time-invariant and spatially distributed, what type and complexity of model is suitable for the stated objective? By definition a model is simpler than the prototype system and one needs to decide on the degree of simplicity. Initially one considers those aspects of the behaviour of the system whichshould be predicted. This involves the identification of the hydrologic variables and the catchment processes which are relevant. Then there is the question of mathematical representation. The degree of sophistication depends on several factors. The main considerations are the nature of the problem, the purposes served, the type, quality and extent of the data and the accuracy demanded. In addition there are questions of staff, computers and costs.

As stated above one of the main considerations in the choice of a model is the purpose or objectives of the work. There are different purposes served in modelling in hydrology and in the general field of water resources. For example, an assessment of available surface and ground water resources may be required for irrigation, hydropower and domestic needs. This can also include water quality aspects. On-the other hand, models may serve operational purposes such as flood forecasting or reservoir control. Each of these will point to a different model structure and orientation. They will also dictate the time frame; the basic time units such as daily or monthly flows, the memory of the processes involved and the time horizon are important. Therefore, the objectives of modelling should be borne in mind in the decision-making exercise.

A model should serve local conditions and needs to be oriented to suit climatic and geophysical characteristics of the area Versatility, flexibility, realism and precision enhance its value. On the other hand, models used in hydrology are almost entirely digital-computer oriented.

Stochastic Models

A set of mathematical equations describing the performance of a system and the chance or random behaviour of events, comprise a *stochastic* model. In comparison with *deterministic* models in hydrology stochastic models may be used to achieve a better understanding of *catchment behaviour* in response to variations in processes such as rainfall, evapotranspiration and infiltration in time and space, if significant physical aspects are incorporated.

Stochastic models are used to simulate *stream flows* with time units of a year or less. More recently daily rainfalls and multi site storm rainfalls have been modelled. Other practical applications are in real time forecasting, flood estimation and assessments of reservoir yield and sediment transport.

It follows that as a pre-requisite to stochastic modelling one should study and analyse the pertinent time series from the catchment area which is modelled. In practice time series are also studied collectively as multiple series formed, for example, from flows in two or more rivers. One adopts this approach when investigating common time phenomena. Consequently, multivariate stochastic models are formulated.

Digital Simulation Models

This type of model has received considerable attention by research workers. However, considerable differences in model structure have been observed. Two basic philosophies exist surrounding the one basic principle that the model should represent, in a conceptual way, the various processes of the land phase of the hydrological cycle. By means of mathematical functions and algorithms the processes of rainfall, infiltration, interflow, percolation, etc., are represented within the model structure. Then by means of parameter variables, the model can be calibrated to produce the measured response of the real watershed. These two philosophies involve the method of calibration and are the mode of automatic parameter optimization of manual, trial and error parameter evaluation.

Statistical Models

Statistical methods have been employed to develop "*models*" that relate a number of measured "independent" variables to predict the "dependent" variable. Regression analyses used in relating upstream discharges and stage to downstream discharges or coaxial correlation techniques must satisfy basic conditions in statistical analysis. The main conditions assume no error in the independent variable, that they are not intercorrelated, and that the variance of the dependent does not rely on the independent variables. In practice this is difficult to achieve. Statistical methods are considered to be the simplest system representation. They are not able to define the interactive hydrologic processes and as such are only suitable for predicting changes within the limit of observed data.

Reservoir Yield Model - Modified Tauxhal Program (CWC)

This program is capable of determining the reservoir yield (water supply and energy) and tradeoffs between them besides providing water for municipal and industrial demands at the required reliability for specified maximum and minimum storage values of the reservoir. The program when used for different values of maximum storage gives the storage-yield functions of the reservoir from which the size of the reservoir can be fixed.

Input to this program are

- Long term inflow series
- Fraction of annual demand of water for irrigation
- Evaporation rate
- Storage-area relationships
- Live storage limits
- Mandatory releases

Method of Calculation. The basic approach of the model is the performance of mass computations. A starting storage is assumed and mass balance computation for each period is carried out considering starting storage, inflow, evaporation loss and outflows. The procedure is continued till the entire inflow series is simulated. The failure years are identified and counted in respect of each use (i.e. irrigation, mandatory etc.). The program uses iterative procedure with *binary search technique* for determining the reservoir yield. The binary search technique requires the values of upper and lower limits to be specified.

UNCERTAINTIES IN WATER RESOURCES ENGINEERING

Uncertainties exist due to our lack of perfect knowledge concerning the phenomena and processes involved in problem definition and resolution . In general, uncertainty due to inherent randomness of physical processes cannot be eliminated. On the other hand, uncertainties such as those associated with lack of complete knowledge about the process, models, parameters, data, and etc. could be reduced through research, data collection, and careful manufacturing. In water resources engineering, uncertainties involved can be divided into four basic categories: hydrologic, hydraulic, structural, and economic . More specifically, in water resources engineering analyses and designs uncertainties could arise from the various sources including natural uncertainties, model uncertainties , parameter uncertainties, data uncertainties, and operational uncertainties.

Natural uncertainty is associated with the inherent randomness of natural processes such as the occurrence of precipitation and flood events. The occurrence of hydrological events often display variations in time and in space. Their occurrences and intensities could not be predicted precisely in advance. Due to the fact that a model is only an abstraction of the reality, which generally involves certain degrees of simplifications and idealizations. Model uncertainty reflects the inability of a model or design technique to represent precisely the system's true physical behaviour. Parameter uncertainties resulting from the inability to quantify accurately the model inputs and parameters. Parameter uncertainty could also be caused by change in operational conditions of hydraulic structures, inherent variability of inputs and parameters in time and in space, and lack of sufficient amount of data.

Data uncertainties include (1) measurement errors, (2) inconsistency and non-homogeneity of data, (3) data handling and transcription errors, and (4) inadequate representation of data sample due to time and space limitations.

Operational uncertainties include those associated with construction, manufacture, deterioration, maintenance, and human. The magnitude of this type of uncertainty is largely dependent on the workmanship and quality control during the construction and manufacturing. Progressive deterioration due to lack of proper maintenance could result in changes in resistance coefficients and structural capacity reduction.

Measures Of Uncertainty

Several expressions have been used to describe the degree of uncertainty of a parameter, function, a model, or a system. In general, the uncertainty associated with the latter three is a result of combined effect of the uncertainties of the contributing parameters.

The most complete and ideal description of uncertainty is the *probability density fun*ction (PDF) of the quantity subject to uncertainty. However, in most practical problems such a probability function cannot be derived or found precisely.

Another measure of the uncertainty of a quantity is to express it in terms of a reliability domain such as the *confidence interval*. A confidence interval is a numerical interval that would capture the quantity subject to uncertainty with a specified probabilistic confidence.

A useful alternative to quantify the level of uncertainty is to use the *statistical moments* associated with a quantity subject to uncertainty. In particular, the variance and standard deviation which measure the dispersion of a stochastic variable are commonly used.

SENSITIVITY ANALYSIS

"Finding the optimal solution to a linear programming model is important, but it is not the only information available. There is a tremendous amount of sensitivity information, or information about what happens when data values are changed."

When we use a mathematical model for a water resource project to describe reality, we must make approximations. The world is more complicated than the kinds of optimization problems that we are able to solve. Linearity assumptions usually are significant approximations. Another important approximation comes because we cannot be sure of the data that we put into the model. Our knowledge of the relevant technology may be imprecise, forcing us to approximate values in A, b, or c. Moreover, information may change. **Sensitivity analysis** is a systematic study of how sensitive solutions are to (small) changes in the data. The basic idea is to be able to give answers to questions of the form:

- If the objective function changes, how does the solution change?
- If resources available change, how does the solution change?

- If a constraint is added to the problem, how does the solution change?

One approach to these questions is to solve lots of linear programming problems. For example, if we think that the price of our primary output will be between Rs.100 and Rs.120 per unit, we can solve twenty different problems (one for each whole number between Rs.100 and Rs.120).1 This method would work, but it is inelegant and (for large problems) would involve a large amount of computation time. The approach is to take full advantage of the structure of *LP programming* problems and their solution.

RELIABILITY ANALYSIS IN WATER RESOURCES ENGINEERING

In many water resource engineering problems, uncertainties in data and in theory, including design and analysis procedures, warrant a probabilistic treatment of the problems. The failure associated with a hydraulic structure is the result of the combined effect from inherent randomness of external load and various uncertainties involved in the analysis, design, construction, and operational procedures described previously.

Failure of an engineering system occurs when the load (external forces or demands) on the system exceeds the resistance (strength, capacity, or supply) of the system. In hydraulic and hydrologic analyses, the resistance and load are frequently functions of a number of stochastic variables. Without considering the time-dependence of the load and resistance, static reliability model is generally applied to evaluate the system performance subject to a

single worst load event.

However, a hydraulic structure is expected to serve its designed function over an expected period of time. In such circumstances, time-dependent reliability models are used to incorporate the effects of service duration, randomness of occurrence of loads, and possible change of resistance characteristics over time.

In reliability analysis, the load and resistance functions are often combined to establish a performance function,

W(**X**), which divides the system state into a safe (satisfactory) set defined by W(**X**)>0 and a failure (unsatisfactory) set defined by W(**X**)<0. The boundary separating the safe set and failure set is a surface defined by W(**X**)=0 which is called the failure surface or limit state surface. The commonly used safety factor and safety margin are the special cases of the performance function.

Alternatively, the reliability index, defined as the ratio of the mean to the standard deviation of the performance function, is another frequently used reliability indicator.

Computation of Reliability

The computation of reliability requires knowledge of probability distributions of load and resistance, or the performance function , W. This computation of reliability is called load - resistance interference .

Direct Integration Method - The method of direct integration requires the PDFs of the load and resistance or the performance function be known or derived. This information is seldom available in practice, especially for the joint PDF , because of the complexity of hydrologic and hydraulic models used in design. Explicit solution of direct integration can be obtained for only a few PDF s.

For most PDFs numerical integration may be necessary. When using numerical integration, difficulty may be encountered when one deals with a multivariate problem.

Mean-Value First-Order Second-Moment (MFOSM) Method - The MFOSM method for reliability analysis employs the FOVE method to estimate the mean and standard deviation of the performance function W(X) from which the reliability index is computed. The MFOSM method has been used widely in various hydraulic structural and facility designs such as storm sewers, culverts, levees, flood plains, and open channel hydraulics. The application s of the MFOSM method is simple and straightforward.

Advanced First-Order Second-Moment (AFOSM) Method - The main thrust of the AFOSM method is to reduce the error of the MFOSM method associated with the nonlinearity and non-invariability of the performance function, while keeping the advantages and simplicity of the first-order approximation. The expansion point in the AFOSM method is located on the failure surface defined by the limit-state equation.

Time-to-Failure Analysis

Any system will fail eventually; it is just a matter of time. Due to the presence of many uncertainties that affect the operation of a physical system, the time that the system fails to satisfactorily perform its intended function is a random variable. Instead of considering detailed interactions of resistance and loading over time, a system or its components can be treated as a black box or a lumped parameter system and their performances are observed over time. This reduces the reliability analysis to a one dimensional problem involving time as the only random variable. The term 'time' could be used in a more general sense. In some situations other physical scale measures, such as distance or length, may be appropriate for system performance evaluation.

Failure and Repair Characteristics - The time-to-failure analysis is particularly suitable for assessing the reliability of systems and/or components which are repairable. For a system that is repairable after its failure, the time period it would take to have it repaired back to the operational state is uncertain. Therefore, the time-to-repair (TTR) is also a random variable.

For a repairable system or component, its service life can be extended indefinitely if repair work can restore the system as if it was new . Intuitively, the probability of a repairable system available for service is greater than that of a non -repairable system.

The failure density function is the probability distribution that governs the time occurrence of failure and it serves as the common thread in the reliability assessments in time to failure analysis. Among them, the exponential distribution perhaps is the most widely used.

In general, the failure rate for many systems or components has a bathtub shape in that three distinct life periods, namely , early life (or infant mortality) period, useful life period, and wear-out life period are identified.

A commonly used reliability measure of system performance is the **mean-time-to-failure (MTTF)** which is the expected time-to-failure.

For repairable water resources systems, such as pipe networks, pump stations, storm runoff drainage structures, failed components within the system can be repaired or replaced so that the system can be put back into service.

The time required to have the failed system repaired is uncertain and, consequently, the total time required to restore the system from its failure to operational state is a random variable.

Like the time-to failure, the **random time-to-re pair (TTR)** has the repair density function describing the random characteristics of the time required to repair a failed system when failure occurs at time zero. The repair probability is the probability that the failed system can be restored within a given time period and it is sometimes used for measuring the maintainability. The **mean-time to- repair (MTTR)** is the expected value of time-to-repair of a failed system which measures the elapsed time required to perform the maintenance operation.

The MTTF is a proper measure of the mean life span of a non-repairable system. For a repairable system, a more representative indicator for the fail-repair cycle is the **mean-time-between-failure (MTBF)** which is the sum of MTTF and MTTR.

SYSTEM RELIABILITY

Most systems involve many sub-systems and components whose performances affect the performance of the system as a whole. The reliability of the entire system is affected not only the reliability of individual sub-systems and components, but also the interaction and configuration of the subsystems and components. Furthermore, water resources systems involve multiple failure modes, that is, there are several potential modes of failure in which the occurrence of any or a combination of such failure modes constitute the system failure. Due to the fact that different failure modes might be defined over the same stochastic variables space, the failure modes are generally correlated.

For a complex system involving many sub-systems, components and contributing stochastic variables, it is generally difficult, if not impossible, to directly assess the reliability of the system. In dealing with a complex system, the general approach is to reduce the system configuration, based on its component arrangement or modes of operation, to a simpler system for which the analysis can be performed easily. Some of the potentially useful techniques for water resources system reliability evaluation are briefly described below.

State Enumeration Method - The method lists all possible mutually exclusive states of the system components that define the state of the entire system. In general, for a system containing M components in which each can be classified into N operating states, there will be N^M possible states for the entire system. Once all the possible system states are enumerated, the states that result in successful system operation are identified and the probability of the occurrence of each successful state is computed. The last step is to sum all of the successful state probabilities which yield the system reliability.

Path Enumeration Method - A path is defined as a set of components or modes of operation which lead to a certain state of the system. In system reliability analysis, the system states of interest are those of failed state and operational state. The tie-set analysis and cut-set analysis are the two well-known techniques.

Conditional Probability Approach - The approach starts with a selection of key components and modes of operation whose states (operational or failed) would decompose the entire system into simple series and/or parallel subsystems for which the reliability or failure probability of subsystems can be easily evaluated. Then, the reliability of the entire system is obtained by combining those of the sub-systems using conditional probability rule.

Fault Tree Analysis - Conceptually, fault-tree analysis traces from a system failure backward, searching for possible causes of the failure. A fault tree is a logical diagram representing the consequence of component failures (basic or primary failures) on system failure (top failure or top event). The fault tree consists of event sequences that lead to system failure.

RISK-BASED DESIGN OF WATER RESOURCES SYSTEMS

Reliability analysis can be applied to design of various hydraulic structures with or without considering risk costs which are the costs associated with the failure of hydraulic structures or systems. The risk-based least cost design of hydraulic structures promises to be, potentially, the most significant application of reliability analysis.

The risk-based design of water resources engineering structures integrates the procedures of economic, uncertainty, and reliability analyses in the design practice. Engineers using a risk based design procedure consider trade-offs among various factors such as risk, economics, and other performance measures in hydraulic structure design. When risk-based design is embedded into an optimization framework, the combined procedure is called optimal risk-based design. Because the cost associated with the failure of a hydraulic structure cannot be predicted from year to year, a practical way to quantify it is to use an expected value on the annual basis. The total annual expected cost is the sum of the annual installation cost and annual expected damage cost.

SUSTAINABLE WATER RESOURCES DEVELOPMENT

Water resource systems that are able to satisfy, to the extent possible, the changing demands placed on them over time without system degradation, can be called "sustainable".

It is important to note that sustainable development is not a top-down but a bottom-up approach. It requires that development efforts are decentralized and local people are involved at all levels of planning, design, and implementation. These days, the notion of sustainability is applied at all levels and in ecological, sociological, and economic terms.

To meet current and future water demands, increased attention should be given to precautionary approaches such as innovative uses of natural supplies and new technologies. In the past we have responded by storing runoff in reservoirs, diverting flows from water-abundant to water-scarce regions, and extracting aquifer resources – methods that provided ample water where and when it was needed. These methods are likely to remain part of most water resources development strategies. Non-conventional water resources, such as water reuse and desalination, are being increasingly used and new technologies such as artificial recharge are also becoming more and more common. Capturing rain at the source through rainwater harvesting is yet another method used to increase the availability of natural water sources. In certain regions, an extreme response has been adopted. In some arid countries, where sufficient renewable water resources are not available, non-renewable groundwater reserves are being exploited to support development.

Demand management and conservation are methods that target efficiency. Conservation begins by reducing high losses from water supply distribution systems. Demand management has gone largely unaddressed since most water utilities still focus on infrastructure development rather than on conservation.

It is worth noting that industry's approach in recent years has been to reduce wastewater and minimize the quantity of processed water needed as this method has proven to be technically feasible and economically advantageous. The demand reduction and efficiency approach should be an integral part of modern water resources management. Its applicability should be promoted while recognizing that it requires a distinct change in the behavioural patterns of institutions, utilities and individuals – a change that will require education, awareness-raising and political commitment to achieve effective implementation.

Institutional responses at different levels are also needed. Some nations have implemented new laws and regulations that point the way forward toward protecting and restoring our water sources. Many nations are adapting emerging technical practices to secure and protect their existing natural water resources and use local knowledge as part of sustainable resource development.

Environmental Considerations

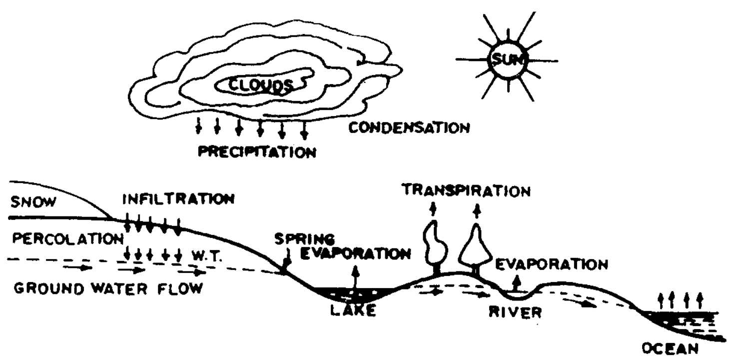
THE HYDROLOGIC CYCLE (ATMOSPHERIC WATER SYSTEM)

The first stage in the hydrologic cycle is the *evaporation* of water from the oceans. This is carried over the continents by moving air masses. If the vapour is cooled to its dew point, it condenses into visible water droplets, which form cloud or *fog*. Under favourable meteorological conditions the tiny droplets grow large enough to fall to earth as *precipitation*.

About two thirds of the precipitation which reaches the land surface is returned to the atmosphere by evaporation from water surfaces, soil, and vegetation and through transpiration by plants. The remainder of the precipitation returns ultimately to the ocean through surface or underground channels.

The entire unending process of circulation and redistribution of water by the atmosphere and the earth is called hydrologic cycle. Hydrologic cycle is defined as the circulation of water from the sea, through the atmosphere to the land, and thence back to sea through various stages and processes like precipitation, interception, runoff, infiltration, percolation etc.

The hydraulic cycle is depicted diagrammatically in figure.



Hydrologic cycle can be represented by equation

$$P = R + E$$

where P is precipitation, R is runoff and E is evaporation.

SOURCES OF WATER

We are really talking about two sources of water when we talk about water supply. They are *groundwater* and *surface water*. We were lucky enough to visit three water companies that showed us how water supply works from both of these sources.

Surface water

Surface water is water in a *river*, *lake* or fresh water *wetland*. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, and sub-surface seepage.

Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water lost.

Human activities can have a large impact on these factors. Humans often increase storage capacity by constructing reservoirs and decrease it by draining wetlands. Humans often increase runoff quantities and velocities by paving areas and channelizing stream flow.

The total quantity of water available at any given time is an important consideration. Some human water users have an intermittent need for water. For example, many farms require large quantities of water in the spring, and no water at all in the winter. To supply such a farm with water, a surface water system may require a large storage capacity to collect water throughout the year and release it in a short period of time. Other users have a continuous need for water, such as a power plant that requires water for cooling. To supply such a power plant with water, a surface water system only needs enough storage capacity to fill in when average stream flow is below the power plant's need.

Nevertheless, over the long term the average rate of precipitation within a watershed is the upper bound for average consumption of natural surface water from that watershed.

Natural surface water can be augmented by importing surface water from another watershed through a canal or pipeline. It can also be artificially augmented from any of the other sources listed here, however in practice the quantities are negligible. Humans can also cause surface water to be "lost" (i.e. become unusable) through pollution.

Sub-surface water

Sub-surface water, or *groundwater*, is fresh water located in the pore space of soil and rocks. It is also water that is flowing within aquifers below the water table. Sometimes it is useful to make a distinction between sub-surface water that is closely associated with surface water and deep sub-surface water in an aquifer (sometimes called "fossil water").

Sub-surface water can be thought of in the same terms as surface water: inputs, outputs and storage. The critical difference is that due to its slow rate of turnover, sub-surface water storage is generally much larger compared to inputs than it is for surface water. This difference makes it easy for humans to use sub-surface water unsustainably for a long time without severe consequences. Nevertheless, over the long term the average rate of seepage above a sub-surface water source is the upper bound for average consumption of water from that source.

The natural input to sub-surface water is seepage from surface water. The natural outputs from sub-surface water are springs and seepage to the oceans.

Water in the ground is in sections called *aquifers*. Rain rolls down and comes into these. Normally an aquifer is near the equilibrium in its water content. The water content of an aquifer normally depends on the grain sizes. This means that the rate of extraction may be limited by poor permeability.

WATER IN ENVIRONMENT & ITS POLLUTION

Comprising over 70% of the Earth's surface, water is undoubtedly the most precious natural resource that exists on our planet. Without the seemingly invaluable compound comprised of hydrogen and oxygen, life on Earth would be non-existent: it is essential for everything on our planet to grow and prosper. Although we as humans recognize this fact, we disregard it by polluting our rivers, lakes, and oceans. Subsequently, we are slowly but surely harming our planet to the point where organisms are dying at a very alarming rate. In addition to innocent organisms dying off, our drinking water has become greatly affected as is our ability to use water for recreational purposes. In order to combat water pollution, we must understand the problems and become part of the solution.

Point & Non Point Sources

According to the American College Dictionary, pollution is defined as: *to make foul or unclean; dirty*. Water pollution occurs when a body of water is adversely affected due to the addition of large amounts of materials to the water. When it is unfit for its intended use, water is considered polluted.

Two types of water pollutants exist; *point* source and *nonpoint* source. Point sources of pollution occur when harmful substances are emitted directly into a body of water. A nonpoint source delivers pollutants indirectly through environmental changes. An example of this type of water pollution is when fertilizer from a field is carried into a stream by rain, in the form of run-off which in turn effects aquatic life. The technology exists for point sources of pollution to be monitored and regulated, although political factors may complicate matters. Nonpoint sources are much more difficult to control. Pollution arising from nonpoint sources accounts for a majority of the contaminants in streams and lakes.

Causes of Pollution

Many causes of pollution including sewage and fertilizers contain nutrients such as nitrates and phosphates. In excess levels, nutrients over stimulate the growth of aquatic plants and algae. Excessive growth of these types of organisms consequently clogs our waterways, use up dissolved oxygen as they decompose, and block light to deeper waters. This, in turn, proves very harmful to aquatic organisms as it affects the respiration ability or fish and other invertebrates that reside in water.

Pollution is also caused when silt and other suspended solids, construction and logging sites, urban areas, and eroded river banks when it rains. Under natural conditions, lakes, rivers, and other water bodies undergo *Eutrophication*, an aging process that slowly fills in the water body with sediment and organic matter. When these sediments enter various bodies of water, fish respiration becomes impaired, plant productivity and water depth become reduced, and aquatic organisms and their environments become suffocated. Pollution in the form of organic material enters waterways in many different forms as sewage, as leaves and grass clippings, or as runoff from livestock feedlots and pastures. When natural bacteria and protozoan in the water break down this organic material, they begin to use up the oxygen dissolved in the water. Many types of fish and bottom-dwelling animals cannot survive when levels of dissolved oxygen drop below two to five parts per million. When this occurs, it kills aquatic organisms in large numbers which leads to disruptions in the *food chain*.

The pollution of rivers and streams with chemical contaminants has become one of the most crucial environmental problems within the 20th century. Waterborne chemical pollution entering rivers and streams cause tremendous amounts of destruction.

Pathogens are another type of pollution that prove very harmful. They can cause many illnesses that range from typhoid and dysentery to minor respiratory and skin diseases. Pathogens include such organisms as bacteria, viruses, and protozoan. These pollutants enter waterways through untreated sewage, storm drains, septic tanks, runoff from farms, and particularly boats that dump sewage. Though microscopic, these pollutants have a tremendous effect evidenced by their ability to cause sickness.

Classification of Water Pollution

The major sources of water pollution can be classified as municipal, industrial, and agricultural. Municipal water pollution consists of waste water from homes and commercial establishments. For many years, the main goal of treating municipal wastewater was simply to reduce its content of suspended solids, oxygen-demanding materials, dissolved inorganic compounds, and harmful bacteria. In recent years, however, more stress has been placed on improving means of disposal of the solid residues from the municipal treatment processes.

The basic methods of treating municipal wastewater fall into three stages: primary treatment, including grit removal, screening, grinding, and sedimentation; secondary treatment, which entails oxidation of dissolved organic matter by means of using biologically active sludge, which is then filtered off; and tertiary treatment, in which advanced biological methods of nitrogen removal and chemical and physical methods such as granular filtration and activated carbon absorption are employed. The handling and disposal of solid residues can account for 25 to 50 percent of the capital and operational costs of a treatment plant.

ENVIRONMENTAL IMPACT OF WATER RESOURCES PROJECTS

A water resource project involving construction of a large dam, can have several effects on the environment of the area. Some of these impacts may adversely affect the ecology and environment, while some others may prove beneficial to the environment, as discussed below:

Negative Impacts

Among the adverse negative impacts, the following effects may be examined and highlighted, while formulating the environmental impact statement for the project:

- Loss of wild life habitat and possible extinction of rare species of the flora and the fauna of the area, likely to be caused by the submergence of the vast tract of the forested area.
- Loss of valuable forest land and the consequent loss of wood, particularly fuel wood.
- Loss of agricultural land due to submergence, and consequent loss of food and non-food crops, and particularly those of vegetables of daily use.
- Loss of religious sites like mosques, temples, etc. needing shifting or relocation.
- Loss of adventure sports and river rafting. Due to the construction of the dam, the original rapid flow of river may not remain available to the river-runners and rafters, thereby reducing their charm and adventure opportunities.
- Displacement and rehabilitation of people living in areas coming under the submergence may lead to overall misery, chaos, and public distress. This factor is extremely important, and must be well planned with compassion and liberal spending.
- Growing pressure of civilization and industrialisation on nearby areas is certainly likely, when once the project is completed, because the project will ensure availability of water, power, and flood free land, inducing development of industries and other human activities. Even during the construction period, there will occur heavy human activities in the area, including movements of heavy machineries, trucks, heavy labour forces, etc. All such activities are likely to cause degradation of the overall environment of the area, and such activities may sometimes cause irreparable harm to the animals and birds living in the sanctuaries which may be existing nearby.
- Post project effects, like salinity and water-logging of irrigated land, caused by over-irrigation in the irrigation command area of the project, may sometimes occur, but can be eliminated by proper control and conservative use of valuable water.
- Reservoir induced seismicity, may increase the susceptibility of the area to the earthquakes. Its possible effects need be examined even on the dam design.
- Adverse impacts are caused to fisheries as the fish is not likely to find the original rapid flow and sea water environment in the river downstream, and the dam will also check and prevent the free up and down movements of the fish in the river. Migratory anadromous fish, like Hilsa, is surely going to be badly affected, and may perish in large numbers. Fish may also perish while passing through the turbines or through the sluiceways along with the water released downstream for power generation and other uses.

Positive Impacts

Among the favourable positive impacts of a dam project on environment, we may count and highlight the following beneficial effects:

- Net improvement in public health is caused due to the availability of ample domestic water supplies, leading to overall sanitation, cleanliness, and better living conditions.
- The overall increase in the production of wood and crops is certain to occur after the implementation of the project, due to flourishing growth of trees and crops in the irrigated command area of the project. Such production may far exceed the loss of wood and crops, caused by the submergence of forests and agricultural land, probably 100 times greater.
- Excellent habitat for fisheries and water liking birds is generally provided by the lake created by the dam on its upstream side.
- Development of tourism and recreation is made feasible by a dam reservoir. Brindavan gardens in Mysore is an excellent example of such facilities, which have been developed on the down-stream side of the Krishanaraja Sagar dam across the Krishna river. Boating facilities in the reservoir lake are also, sometimes, developed to increase and induce tourism and recreation.
- Improved micro-climate is caused in the adjoining areas due to evaporation from the open water surface of the reservoir and from the irrigated command area of the project.
- Overall improved oxygen production is caused due to the increased photosynthetic rate from green crops and trees, likely to flourish in the irrigation command area of the project, and which is likely to far outweigh such losses from the inundation area.
- Development of sanctuaries and wild life becomes feasible, when once adequate sweet water becomes available round the year by the implementation of the dam project. Sanctuaries can then be well planned and developed for the overall growth of wild life and promotion of tourism. Five such sanctuaries have been planned in the execution of the Sardar Sarovar multipurpose dam project.

Conclusion. In totality, it can be stated that the multipurpose water resources projects, do not by themselves, cause any environmental degradation. They only provide benefits and prosperity, and make available food and power, so very necessary for the development of a country. However, it is the haphazard and unplanned development and industrialisation, encouraged by the execution of such water-resources projects, which causes all round environmental degradation.

We must, therefore, make attempts to stop and check such unplanned growths of human and industrial developments, rather than stopping and preventing the execution of the water-resources projects, which are the backbone of existence and prosperity of a nation, and that of the entire community as a whole.

Such a water-resources project, therefore, automatically justifies its environmental-harmony, and in our opinion, there should be no need to examine these aspects separately for every project.

Be that as it may, we have to prepare a statement, called *Environmental Impact Statement* (E.I.S.), and submit the same to the authorities along with the project report. Such environmental examinations and statements have been made compulsory by the Indian Government since April 1987, for every project. Such statements are thoroughly examined by the Ministry of 'Environment and Forests, before giving environmental clearance to the project, without which, administrative and financial sanctions will not be given.

ENVIRONMENTAL IMPACT ASSESSMENT

Development, agricultural and industrial lies at the heart of a nation. For a nation to progress socially, economically as well as politically development processes in different fields are very necessary. This has been true and the super powers could do this at tremendous rates, the Third world is in the process of such developments. This is one side of the coin. Let us also have a look to another side of the coin. What are the costs of such development, not in terms of money but equally or rather more valuable in terms of its *impact* on our environment. The two i.e. development and environment are inseparably linked to each other. Any development process is bound to have its impact on the environment.

If we trace the history of human being, it should be clear that there had been tremendous environmental impacts of industrialized societies. Agriculture, industry and mining had very harmful impacts on our environment. Such impacts led to degradation of our land, forests, water, air, and biological diversity by release of harmful chemicals and other factors.

Industrialization had been a mixed blessing., There was considerable economic growth and increase in GNP per capita and overall standard of living. However, all the development had been at a tremendous environmental cost. Man has virtually reached a stage when natural resources could not be exploited further and development will have to be achieved without destruction of environment.

In our country, In the post-independent period, our ideas were dominated by developmental growth and we did not have a culture of pollution control. Even late Pandit Jawaharlal Nehru wrote in 1957 "We have many large-scale river valley projects which are carefully worked out by our engineers, I wonder however, how much thought is given before the project is launched, to having an ecological survey of the area and to find out what the effect to the drainage system or to the flora and fauna (ecology, environment) of that area. It would be desirable to have such an ecological survey of these areas before the project is launched and thus avoid an imbalance of nature." The total insensitivity at the bureaucratic/administrative level, which persists still, has given the nation a very heavy backlog of pollution and ecological degradation. They look immediate money in destruction of environment, and not in conserving it. We must reverse this picture. There is huge backlog of our 40 years of negative environmental impacts of developmental work. These are to be set right.

The objective of *Environmental Impact Assessment (EIA)* is to ensure that development is *sustained* with minimal environmental degradation. The Ministry of Environment and Forests, Govt. of India has been assigned the responsibility for carrying out environmental impact assessment of developmental projects in various sectors such as multipurpose river valley and irrigation projects, thermal and atomic power, industries, mining, ports and harbours, transport etc.

Environmental Impact Statement (EIS)

In order to ascertain the impact of various developmental projects both on the society as well as on land, water, air, flora and fauna etc., the developmental projects are required to prepare an Environmental Impact Statement (EIS) covering the following:

- Effect on land including land degradation and subsistence,
- Deforestation and compensatory afforestation,
- Air and water pollution including ground water pollution,
- Noise pollution and vibrations,
- Flora and fauna and loss of biological diversity,
- Socio-economic impact including human displacement, cultural loss and health aspects,
- Risk analysis and disaster management,
- Recycling and the reduction of waste,
- Efficient use of inputs.

Projects covered

Projects in the following sectors are being assessed for environmental impact by the Ministry:

- Industry and Mining.
- Irrigation and Power.
- Transport and Communication

The coverage of the project generally includes:

- Those requiring clearance from the Public Investment Board, Requiring international funding,
- Project referred by State Governments or Administrative Ministries,
- Project in sensitive areas,
- Projects on which there are public complaints.

The environmental impact assessment of development projects has so far been done on the basis of "Executive Order" issuing the provisions of the Environment (Protection) Act, 1986, to ensure implementation of the suggested safeguards. This procedure, however, does not cover private sector projects.

Procedure for Environmental Impact Assessment

The Ministry developed guidelines for preparation of environmental impact assessment statement along with questionnaires and checklist for the following:

- Industry and Mining,
- Thermal Power,
- River Valley,
- Rail, Road, Highway Projects,
- Ports and Harbours,
- Airport,
- Communication Projects,
- New Towns,
- Parameters for determining ecological fragility.

The project authorities are requested to provide relevant information as indicated in the guidelines along with the Environmental Impact Assessment Statement/Environmental Management Plan (EMP), a scrutiny of the project proposals are made by the technical staff of the Ministry. After ensuring the prima-facie assessment, it is placed before the Advisory Committee. The Advisory Committee discusses the impact of the project with the project authorities and if necessary, site visits are made for on-the-spot assessment of environmental aspects. Based on their examination, the Appraisal Committee make their recommendations for approval or rejection of a particular project.

SOCIAL AND ECONOMIC EFFECTS OF ENVIRONMENTAL DEGRADATION

- On social front man tries to possess material resources and an account of this harmful by products originate.
- Pollutants presents in environment harmfully effect human health. Ammonia, a pollutant whose major source is the urea plant, causes adverse health effect.
- Arsenic emitted by purification plant in the manufacture of urea causes black foot disease. Similarly dust reduces visibility and is caused through various process plants. All these provide and make society having human being unhealthy possessing shorter span of life.
- Through working out environmental benefits quantitatively is a difficult task yet conflict between quality or environment and economic growth have been experienced. A cost benefit analysis theory states the benefit received on economic fronts are less as anticipated.

SUSTAINABLE DEVELOPMENT OF WATER RESOURCES

Sustainable development means different things to different people, but the most frequently quoted definition is from the report *Our Common Future:*

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Sustainable development focuses on improving the quality of life for all of the Earth's citizens without increasing the use of natural resources beyond the capacity of the environment to supply them indefinitely. It requires an understanding that inaction has consequences and that we must find innovative ways to change institutional structures and influence individual behaviour. It is about taking action, *changing policy and practice at all levels, from the individual to the international.*

Sustainable development of water resources is a key issue in recent Earth Summit. We have only one earth, as in the same way that we, in this part of the world, have only one India. Water is the essential element for strengthening society, economy and environment-- the three pillars in keeping sustainable development. This natural resource is definitely essential to life, production, and ecology. To advocate sustainable development on water resources, one should pursue ultimate harmony and balance between man and nature.

Based on the above ideology, we should gradually accelerate four core schemes of water policies regarding water regulation, water utilization, water rapprochement, and water revitalization; fulfill "sustainable water construction", "watershed oriented organization", "revitalize dynamic water resources industry"; establish everlasting water environment in building a sustainable Taiwan, which conveys multifunctional and diverse aspects of national development plan.

- **Water Regulation**. Integrate comprehensive watershed management, reduce flood damage and loss. The policy should be carried out in structural and non-structural measures. Non-structural measures include flood plain management, damage insurance, flood prevention warning system, green building and super dike. Structural measures is in connection with whole watershed integrated management and ecological engineering.
- **Water Utilization**. Ensure stable quantity and quality water supply for economical and social development. Non-structural measures includes current water conservancy measures development, flexible water resources management, maximum effectiveness of water use, mechanism on water demand, implementation of rational enterprise water utility, supply moderation mechanism for comprehensive agricultural water use, etc. Structural measures are related to employing diversification development; promoting eco-friendly weirs by priorities, utilizing rainwater harvesting, seawater desalination, artificial lakes and off-channel reservoirs.
- **Water Rapprochement**. Improve riverbank surroundings for more water accessible and enjoyable areas.
- **Water Revitalization**. Improve water recycling and reuse. Promote diversification of water supplies. The major purpose is to reach maximum economical effect on water reuse; to promote cost effective reasonable water price, and help revive market

function for water saving. Encourage water recycle, reuse, and renewal (3Rs), for example, elevate industrial consumption recycle rate, combine sewage system and enhance plans on waste water recycling and underground water surcharge and recovery, ensuring ever-lasting water supply to achieve the ultimate goal of water sustainability.

Recently all sorts of flood and drought have claimed lives and countless property, which have imposed serious economic damage on the country. People are urging water resources improvement from traditional river management, reservoir engineering to a broader horizon. Water Resources Agencies in India, with a vision for the future, has proposed unified watershed integration regulation, ecological river regulation, water resources development and administration, along with diverse water resources management packages as working guidance at present.

ENVIRONMENTAL PROBLEMS IN COMMAND AREAS

The adverse environmental impacts at the level of commands are essentially a human induced problem. The problems arise due to mismanagement of irrigation water and flawed policies that do little to check its injudicious use and wastage.

Mismanagement of irrigation water and defective policies are largely responsible for several environmental problems in command areas.

Two problems of considerable importance in surface irrigated areas are water logging and soil salinity. The problems arise because water and chemicals are applied in excess. Also, the drainage aspects of agricultural areas has not been given due attention.

Degradation of soil fertility by water-logging is a common and serious impact of irrigation.

Lowering of Water Table. Over-exploitation of ground water is a serious problem in many parts of the world. Electric or fossil fuel powered pumps and tubewells find extensive use to exploit this vital resource.

The main reasons for the excessive use of ground water are: (i) inadequate availability or absence of surface water, (ii) no disincentive to extract larger quantities of water, (iii) subsidized or flat rates of electricity to extract ground water, and (iv) low rainfall. The decline in water table results in increase in pumping cost over time. Other problems could be land subsidence, induction of rock chemicals in water, and sea water intrusion in coastal areas.

Building-up of nitrate and pesticide residues in ground water. Irrigation has induced the use of more fertilisers and pesticides. Application of more irrigation water without proper drainage leads to increase in soil salinity and alkalinity. As water evaporates, it leaves behind salt particles on the top soil layers. This damages vegetation and disturbs the ecosystem balance.

Important problems related to fertilizer vs. environmental quality are nitrate pollution of groundwater, eutrophication of lake and river water, increased emission of gaseous nitrogen, and metal toxicities. The fertilizer-related pollution is rapidly increasing in many countries. It is affecting agricultural production and deteriorating the quality of land and water.

Pesticides. The agriculture sector is the major user of pesticides. The spurt in the pesticide use has resulted in secondary pest outbreak. The pesticide residues in soil may create a variety of hazards. Soil micro-organisms which cause breakdown of cellulose, nitrification, turn over of organic matter, and other biological materials may be adversely affected by pesticides. Pesticides and chemicals inhibit the microbial population in soil, thereby resulting in reduced nitrogen fixation by symbiotic bacteria. There may be a serious decline in population of earthworm due to pesticide residues and this affects crop yields.

Problem of Weeds. The problem of weed infestation is common in canal irrigation projects. An adequate and reliable supply of water, sunlight, and nutrients provides optimal conditions for weed growth. Bull rush, a type of grass, grows in canals, ditches, drains, and in water logged lands. It disturbs the flow of water causing obstruction to canal flow or drainage. Manual recourse of weed removal is expensive. It is better to drain the area where these weeds grow which limits their growth.

Health Hazards. Spread of some diseases which are injurious to human health is another side effect of canal irrigation. The major water-borne diseases observed in rural areas are dysentery, cholera, malaria, etc.

ASSIGNMENT

Q.1. (AMIE W09, 11, S18, 20 marks): Presuming that all possible water uses - irrigation, municipal and industrial supply, hydroelectric power, navigation, recreation, enhancement of fisheries and wildlife, and the control functions, i.e., flood and pollution mitigation are pertinent, outline the steps required to prepare a plan for water resources development.

Q.2. (AMIE W17, 20 marks): Planning of, say, a large water resources development project is generally based on the determination of the different feasible alternatives, which provide the result/ condition based on the contribution of the various aspects relevant to the project. Describe the methodology (case problem may be used, if needed).

Q.3. (AMIE S13, W14, 5 marks): Write a note on general form of water demand models.

Q.4. (AMIE S12, 8 marks): Discuss the water resources planning methods and objectives.

Q.5. (AMIE S17, 8 marks): Write a note on preliminary planning in the light of water resources planning.

Q.6. (AMIE S16, 6 marks): "Looking several decades into future is pre requisite of water resources planning." Substantiate the statement.

Q.7. (AMIE S16, 6 marks): List the stakeholders and levels of public involvement in water resources planning.

Q.8. (AMIE S17, 4 marks): Enumerate the techniques and activities of public involvement process in the light of water resources planning.

Q.9. (AMIE S17, 3 marks): What are the general advantages of public involvement in the light of water resources planning.

Q.10. (AMIE S17, 3 marks): What are the advantages of public involvement to the government in the light of water resources planning?

Q.11. (AMIE S17, 3 marks): What are the advantages of public involvement to the financing agencies in the light of water resources planning?

Q.12. (AMIE S17, 3 marks): What are the advantages of public involvement to the affected patties in the light of water resources planning?

Q.13. (AMIE W05, 10 marks): What are the characteristics of water resources management/planning problems? Discuss which are the most suitable for quantitative system analysis techniques.

Q.14. (AMIE W10, S11, 7 marks): In your opinion, what are the advantages and disadvantages in involving public in decision making for water resources projects?

Q.15. (AMIE W17, 20 marks): A dam-reservoir system has to be built on a perennial hilly stream for multipurpose uses. Elaborating the multi- purpose uses identify the various factors need to be considered to ensure proper functioning of the reservoir from physical, environmental and economic points of view.

Q.16. (AMIE S05, 7 marks): In a multipurpose project, discuss two purposes - one whose use is compatible and the another, which is not compatible.

Q.17. (AMIE S05, 7 marks): “The basic factor in design and operation of a multipurpose project is compromise”. Substantiate the statement.

Q.18. (AMIE S06, 12 marks): A multipurpose reservoir has to meet the needs of (i) irrigation (ii) hydroelectric power (iii) flood control and (iv) recreation. Discuss the complimentary and conflicting demands (if any) of each of the above purpose that should be taken into account in the optimum regulation of the

Q.19. (AMIE S05, 16, 7 marks): Discuss the various data required to be collected for planning of a water resources project.

Q.20. (AMIE W05, 7 marks): Explain the terms: deterministic model and stochastic model.

Q.21. (AMIE W05, 10 marks): Compare the following types of simulation models used in water resources systems

(i) physical and mathematical models

(ii) discrete and continuous models

(iii) static and dynamic models

(iv) conceptual and descriptive models

(v) lumped parameter and distributed parameter models

Q.22. (AMIE S05, 6 marks): Explain the terms : decision under certainty and decision under risk. Give examples.

Q.23. (AMIE W07, S16, 6 marks): In conjunction with linear programming, describe briefly sensitivity analysis.

Q.24. (AMIE W05, 8 marks): Write a brief note on risk and reliability in water resources system design.

Q.25. (AMIE W05, 10 marks): List and briefly elaborate on different types of uncertainties in water resources systems. Write a short notes on the need for reliability analysis in water resources systems.

Q.26. (AMIE W09, S13, 10 marks): Write short notes on (i) predictive uncertainty (ii) planning horizons.

Q.27. (AMIE S11, 5 marks): What do you understand by "economic life of a project" and "physical life of a project".

Q.28. (AMIE W10, S11, 4 marks): What do you understand by integrated water resources management?

Q.29. (AMIE W12, S16, 7 marks): Define and briefly explain sustainable water resources development.

Q.30. (AMIE S07, 10 marks): Briefly describe atmospheric water system, surface water system and sub surface water system.

Q.31. (AMIE W17, 10 marks): Briefly describe the global hydrological cycle and state the impact(s), if any, of global climate change on the hydrological cycle.

(b) The following information pertaining to the various components of the global hydrological cycle at e available. Determine the amount of water vapour transported annually from ocean to land mass and also show that hydrological balance prevail:

Precipitation on land mass	119000
Precipitation on salt water	458000
Precipitation on inland lakes and water bodies	9000
Evaporation from soil, vegetation	74200
Evaporation from inland lakes and water bodies	9000
Evaporation from salt water	502800

(all figures are in km^3 per year).

Answer: Amount of water vapour transported annually from ocean to land = 119000 – 7400 = 44800 km^3/year

Balance: Check Input (evaporation) = Output (precipitation) You will see that 586000 = 586000 km^3/year. Hence balance prevails.

Q.32. (AMIE S11, 5 marks): What do you understand by "environmental management plan for a project"? Explain with an example.

Q.33. (AMIE S11, 16, W11, 5 marks): What do you understand by environmental impacts of a water resources development projects? Also, explain primary and secondary impacts of a project. How does it help in protection of environment?

Q.34. (AMIE S13, W13, 10 marks): Enumerate the typical environmental consequences of water resources projects.

Q.35. (AMIE S12, 17, 8 marks): List the steps/phases involved in environmental impact assessment of water environment.

Q.36. (AMIE W07, 11 marks): Briefly describe with the help of appropriate examples, environmental considerations necessary in water resources planning.

Q.37. (AMIE W09, 10 marks): Enumerate the typical environmental consequences of water resource projects.

Q.38. (AMIE W10, S18, 10 marks): A dam is proposed across a river in Himalayas. It will supply water for irrigation. List and briefly explain four possible beneficial and four harmful environmental consequences of the project.

Q.39. (AMIE S12, 12 marks): Discuss the positive and negative impacts of water resources projects.

Q.40. (AMIE W10, 6 marks): Write a short note on sustainable water resources development.

Q.41. (AMIE W10, 4 marks): What do you understand by rehabilitation and resettlement?

Q.42. (AMIE S17, 6 marks): Briefly enumerate the environment problems in command areas that are caused by water resources projects.

Q.43. (AMIE W20, 6 marks): Rivers are said to be major source of freshwater in many places. Unfortunately, allow and quality of most of the major rivers have declined in various ways. State the ways how flow and quality of water of river have declined. And also describe briefly the method to deter- mine the quality of water of a river.

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