IDENTIFICATION OF PARAMETERS FOR DEVELOPING MANAGEMENT INFORMATION SYSTEM FOR AN IRRIGATION PROJECT

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

WATER RESOURCES DEVELOPMENT

By

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CANDIDATES DECLARATION

I hereby certify that the work which is being presented in the thesis entitled, **"IDENTIFICATION OF PARAMETERS FOR DEVELOPING MANAGEMENT INFORMATION SYSTEM FOR AN IRRIGATION PROJECT"** in partial fulfillment of the requirements for the award of degree of MASTER OF TECHNOLOGY in WATER RESOURCES DEVELOPMENT submitted in Water Resources Development Training Centre, Indian Institute of Technology Roorkee, is an authentic record of my own work carried out during the period July, 2002 to December, 2002 under the supervision of **Prof. V.K. Bairathi**, Visiting Professor and second supervision **Dr. Deepak Khare**, Asso. Prof. of WRDTC, Indian Institute of Technology Roorkee, India.

The matter embodied in this thesis has not been submitted by me for the award of any other degree.

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NOTATIONS

a_n	=	Through the trash rack
A_t	=	Gross area of the opening
AP	=	Andhra Pradesh
BC	=	Benefit Cost
B_t	=	Clear waterway in m
B.M.	=	Bench Mark
BOD	=	Biochemical Oxygen Demand (mg/L)
C	=	Coefficient of discharge
CADA	=	Command Area Development Authority
CAD	=	Command Area Development
Ca	=	Calcium
CO_2	=	Carbon dioxide
C_r	=	Cromium
COD	=	Chemical Oxygen Demand
CCA	=	Cultivable Commanded Area
CL	=	Clay, low plasticity
CH	=	Clay high plasticity
CBIP	=	Central Board of Irrigation and Power
D	=	Diameter of pipe tunnel in meter
E	=	Relative roughness
EPA	=	Environmental Protection Agency
EC_w	=	Electric Conductivity of water
f.	=	Friction coefficient
F	=	Froude number = $V/\sqrt{gD}$
g.	=	Acceleration due to gravity in /sec^2
H	=	Henry's low constant

H	=	head over crest = full supply level u/s + head due to velocity of Approach – crest level
h_f	=	Head loss due to friction in meter
he	=	Head loss at entrance
h_{ex}	=	Exit head loss in m
Hydel	=	Hydroelectric
HYDAC	=	Automated Computerized Survey System
H_2S	=	Hydrogen sulfide
H_2O	=	Hydrogen Oksida
HWL	=	High water level
I	=	Recharge Inflow
I_c	=	Silt intensity in parts per thousand parts of water by volume in the Canal.
I_f	=	Silt intensity in parts per thousand parts of water by volume in river pocket.
I_t	=	The intensity of silt in the flume or river pocket
I_E	=	Silt intensity in the excluder
ICOLD	=	International Comity Large Dams
ISO	=	International Standard Organization
K	=	Allocated turnout discharge
Kb	=	Head loss coefficient for 90^0 Bends
Ke	=	Loss coefficient for entrance
K_{ex}	=	Loss coefficient for exit
Kg	=	Kilogram
Km	=	Kilometer
K_t	=	Loss coefficient for trash rack
Ks	=	The absolute roughness
L	=	Length of the canal in meter
L.W.L	=	Low Water level

LMC	=	Left Main Canal
MCM	=	Million Cubic Meter
MIS		Management Information System
Mg	=	Magnesium
MP	=	Madhya Pradesh
MWS	=	Maximum Water Surface
N	=	Rugosity coefficient
Na^+	=	Sodium
NH_3	=	Ammonia
NRSA	=	National Research Satellite Authority
n_g	=	Mol gas
n_w	=	Mol water
n	=	Maning's roughness coefficient
NWS	=	Normal Water Surface
O	=	Discharge outflow
O & M	=	Operation and Maintenance
OTA	=	Office of Technology Assessment
(OH^-)	=	Hydroxide
P_s	=	Partial pressure of gas, atm
PH	=	The negative log of hydrogen ion activity
PL	=	Provincial Line
POH	=	The negative log of hydroxyl ion activity
Q	=	Discharge
Qc	=	Discharge in the canal
Q_E	=	Discharge in the excluder
Qn	=	Discharge half month
R	=	Hydraulic radius (m)
RSC	=	Residual Sodium Carbonate
R and D	=	Research and Development

R.C.C	=	Reinforcement Cement Concrete
r_1	=	Silt conductive power in offtaking canal
S	=	slope
SC	=	Sandy Clay
SP	=	Sand Plasticity
SAR	=	Sodium Adsorption Ratio
(ΔS)	=	Change in storage of moisture in soil
t_1, t_2, t_3, t_4	=	Time of flow in each channel
USEPA	=	United State Environmental Protection Agency
V	=	Velocity
VOC	=	Volatile Organic Compounds
WUA	=	Water User Associations
WUE	=	Water Use Efficiency
WDP	=	Water Distribution Plan
X_g	=	Equilibrium mole fraction of dissolved gas.
θ	=	Angle of the wall surface with respect to its center line
λ	=	Depth in the parent canal divided depth in the offtaking canal

ABSTRACT

The Management Information System is making available to management accurate and timely information necessary to facilitate the decision making process and enable the organization's planning, control and operational function to be carried out effectively, at minimum cost. It is an important management tool.

It timely information the managers about the achievements of goals, shortcoming and helps in their timely rectification.

To judge the quality of information, the reported facts should be compared with the reality.

The more accurate the information the higher is its quality and more securely managers can rely on it when making decision. In general cost of obtaining information increases as the quality of the desired information become higher.

It is difficult to quantify quality, the value of information and determines its cost effectiveness. It depends upon project-to-project, and level of manager. However, if the potential saving from the information are out weighed by the cost of the information system, or another system can provide the same or better information more cheaply or conveniently the system in use or in vague is not cost effective.

Through information may be in a particular set of forms, yet it requires quick processing for immediate/ quick use.

The management information system for irrigation system provides information on the past, present and near future on relevant events, inside and out side the organizations.

The scope of a formal Information System in an organization is limited by the data that can be obtained, the cost of obtaining, processing, and storing the data, the cost of retrieval and distribution, the value of the information to the user; and the capability of humans to accept and act on the information.

The scope of present study is to identify all relevant parameter for developing management Information System for an Irrigation Project. The scope includes all aspect/

component of an irrigation system from head works up to end results in command area, including utilization of water up to the field.

This study on the identification of parameter for developing MIS is an attempt to compile all knowledge, which is scattered in literature, in an efficient, easy and simple manner and that could be of great help to the farmer irrigation manager in the management of irrigation Project, as well as is the farmer is also a Manager at the field. He is the actual user/waster of water, fertilizers, seeds, and pesticides and in secticides etc. He is also affected most by performance of irrigation system, water logging and salinity and fluctuating markets.

CHAPTER - I

INTRO DUCTION

1.1. GENERAL

Relevant Information is vital ingredient for Operations and Management of any organization. The scope of a formal information system in an organization is limited by the data that can be obtained, the cost of obtaining, processing, and storing the data, the cost of retrieval and distribution, the value of the information to the user; and the capability of humans to accept and act on the information.

A computer – base management information system is designed to both reduce the costs and increase the capabilities of organizational information processing.

Management information system is an integrated, monitoring system for providing information to support the operations, management, and decision making functions in an organization.

Management Information System evolves concept rather than a single large system, and is a federation of loosely integrated subsystems. Functional subsystem of an MIS may be developed separately, guided by a master development plan, and integrated through the data base.

The concept of MIS may be viewed as a substantial extension of the concept of managerial accounting, operations research, and organizational theories related to management and decision making.

First – line supervisor use it for operational control and detailed exemption reporting.

Management use it for special reports and analyses, often employing a staff specialist to manipulate decision models and perform analyses. Because of the complexity of the process of MIS development and need for judgment, there is a need for comprehensive academic training for MIS professionals.

1.1. SCOPE AND OBJECTIVE, OF THE STUDY

The scope of present study is to identify all relevant Parameter for developing Management Information system for an Irrigation Project. The scope includes all aspect/ component of an irrigation system from head works to result up to command area, and utilization of water up to the field.

The objective is to facilitate the decision making process and enable the organizations planning, control and operational functions to be carried out effectively, at minimum cost.

The various component of M.I.S., the process of Management and that of an irrigation project along with the components are explained in chapter I and II.
Identification of Parameters/ Monitoring aspect of Head Work are explained in chapter III and that of canal and command area are explained in chapter IV and V.
In chapter VI, water quality is discussed. The summary and conclusion is given in chapter VII.

I.3. MANAGEMENT INFORMATION SYSTEM (M.I.S.)

It is a formal method of making available to management, accurate and timely information necessary to facilitate the decision making process and enable the organizations in planning, control and operational functions to be carried out effectively, at minimum cost. (Bairathi, 2002).

It is an important management tool. It timely informs the managers about the achievement of goals, shortcoming, and helps in their timely rectification.

The M.I.S. provides information on the past, present and near future on relevant events, inside and outside the organizations. Manager can often detect problem before the issue of any formal control reports. **Thus it is a precise monitoring.**

Management Information System are important both for planning and effective control function. Reliable and latest information are the key factor in planning which help in making corrective changes in time for greater chances of success. **What is going well and what is going wrong can measure how effective is the system.**

I.3.1. CHARACTERISTIC OF M.I.S.

The following are the characteristic of M.I.S :

a) Information quality (accuracy)
b) Information timeliness
c) Information Quantity
d) Information Relevance
e) Information Economics, and
f) Information Processing

a). Information Quality

To judge the quality of information, the reported facts should be compared with the reality. The more accurate the information the higher is its quality and more securely managers can rely on it when making decisions.

In general cost of obtaining information becomes higher as the quality becomes higher. If information of higher quality does not add materially to a manager's decision making capability, it is not the worth the added cost. Though it may be difficult to quantify the quality, yet it can be easily done by choosing the objectives that can be easily quantified. There is lot of difference in quantity and quantification. Quantification refers to some numerical grading, such as A grade, B grade, likewise.

In an irrigation system, a typical example of quality quantification may be how many farmers have received first watering, how much water consumed versus irrigated area etc. and likewise.

b). Information Timeliness

For effective control, corrective action must be taken, applied before it is too latest great deviation from the plan or standard has taken place. Thus the information provided by an information system must be available in time for action to be taken. Timeliness of information depends on situation.

For example information destined for top level managers to monitor progress on long range objectives may be considered timely if it arrives at quarterly intervals. The cost of making it available weekly may not be justified. However, middle and lower level managers responsible for on going operation and related activities need more frequent control information. It may be monthly or fortnightly.

The timeliness may also be determined by organization's policy or events rather than by mere calendar.

c) Information Quantity :

It is not possible for managers to take accurate and timely decisions without sufficient information. Large quantities of irrelevant and useless information should be avoided. If the managers receive more information than they can productively use, they may overlook information on serious problems.

d) Information Relevance :

The information that managers receive must have relevance to their responsibilities, tasks, so as to take corrective action before it is too late to make any changes. The capabilities of computer make it possible to condense information to only the most relevant, useful and timely essentials. Computer can be programmed to report only those situations that require managerial attention.

e) **Information Economics (Usefulness and cost) :**

In designing or improvement of MIS, the managers should consider whether the benefits of the proposed system justify its cost. **The purpose of MIS is to provide managers with the type of information at right time at minimum cost.** It is difficult to quantify in general, the value of information and determine its cost effectiveness. It depends upon project to project, and level of manager. However, if the potential savings from the information are out weighed by the cost of the information system, or if another system can provided the same or better information more cheaply or conveniently then the system in use or in vogue is not cost effective.

f) **Information Processing and Transmission :**

Though information may be in a particular set of forms, yet it requires quick processing for immediate/quick use. Computer are very useful in processing the information. It can also sort out it for various purposes and is also able to transmit immediately, by E-mail/ hot mail etc. on Internet. In some organization computers are also inter connected on vide area net work (VAN). Thus making access to the information to each other.

For example, a scientist wants the details of M.E./ Ph.D. Thesis on a particular subject. He can get the same in a condensed processed manner through Internet on Computer.

Similarly, the operation of canal, gate opening discharge etc. Can be inter linked on computers.

1.3.2. M.I.S. for Various Levels

Different type of information (M.I.S.) is required for different level officers such as Operating level, Middle level, and Top level. The user groups and their information requirement for an irrigation system may be as below :

USER GROUPS AND THEIR INFORMATION REQUIREMENTS

USER GROUP	INFORMATION REQUIREMENT
Top management Personnel/Technocrats (Managers, Planners, Decision makers)	Digested, evaluated, synthesized Tech../Socioeconomic, Statistical/Management/cost information, end results, achievement of objectives.
Research Scientists/Engineer (in R&D and Academic Institutions, Design Bureaus) Faculty and Students.	Scientific and Technical Information of research and Technical Information to back up academic and training programs.
Irrigation /Agricultural Field Staff	Technical Information/know-how information for day to day work and for problem solving, Operation and maintenance manuals.
Extension workers/Land Development Technicians	Technical Information/ show-how information of practical value for transfer and direct application in the field, in local language.
Farmers (end user)	- Do-, information repackaged in simple, easily understandable media for direct use, e.g. weather forecasts. Water delivery schedules, breaches etc. In local language.

M.I.S. for a construction management is different than M.I.S. for operation and management. Many times these are combined. But it should not be done so, rather it should be separately. In this study M.I.S. for only operation management is discussed.

1.3.3. Broad Guidelines for Effective Design of M.I.S.

1. *Include the user on the design team : It is only the user who knows what and when particular information is required by him and how he is going to use it.*
2. *Weigh the money and time costs of the system : If manager justify the design and installation of new system on a cost benefit basis, cost over runs are less likely to occur. The system design should also specify which units of the organization will be responsible for installing and operating the system.*

3. *Favor Relevance and selectivity over sheer quantity.*
4. *Pretest the system before installation.*
5. *Provide adequate training and written documentation for the operators and user of the system.*

1.3.4. M.I.S. for Farmers

M.I.S. of an irrigation system differ greatly from the M.I.S. of a factory/industry or other Govt. Organization. In case of an irrigation system, the farmers (end user) who is directly responsible for the crop production needs lot of information packet in simple and easily understandable media. This information is to be supplied by the management in the interest of high productivity or optimized management. Following information are often wanted by the farmers:

(i) weather forecast – Weather forecast right from few days before the beginning of the sowing season till the end of harvest season are required in every crop season. This helps the farmers to plan the sowing, irrigation scheduling, making use effective rainfall, critical stages of crops, timely cutting of crops, and finally processing, storage and marketing. All these works are affected by weather.

(ii) He is also deeply interested in running schedule of canals, breaches and water availability. Farmer is a direct/ sole manager of the field/ farm.

(iii) He is also interested in crop diseases, likely attack of insects etc.

(iv) Availability of inputs like fertilizer, seeds insecticides, etc. And know-how on the methods of application, may be fertilizer or water etc.

Further dissemination of this information to farmers has to be given through various methods of media such as news papers, wide publicity, through posters, radio talks, T.V., or by villages extension worker or farmer leader etc.

In most other M.I.S system, information for end user may not be required. However, for any other product in a competitive market, its publicity, in formations about quality, guarantee etc. are required and given by the manufacturer to the end user (customer).

1.3.5. M.I.S. for Extension Workers/ Land Development Technicians

The extension works are only link between the farmer and new technology for technology transfer. These extension workers may not be highly qualified. Therefore, the M.I.S. for them is to be in more simple form and language preferably local language of the areas. Various other categories of staff such as Patwari, junior Engineer, canal Chokidars (Watchman) can also be used as extension workers. This work can also be entrusted to water user's association.

Thus in irrigation system, MIS for lower level is also very important, rather as important as for top Managers.

1.4. THE PROCES OF MANAGEMENT

The four fundamental function of management are:

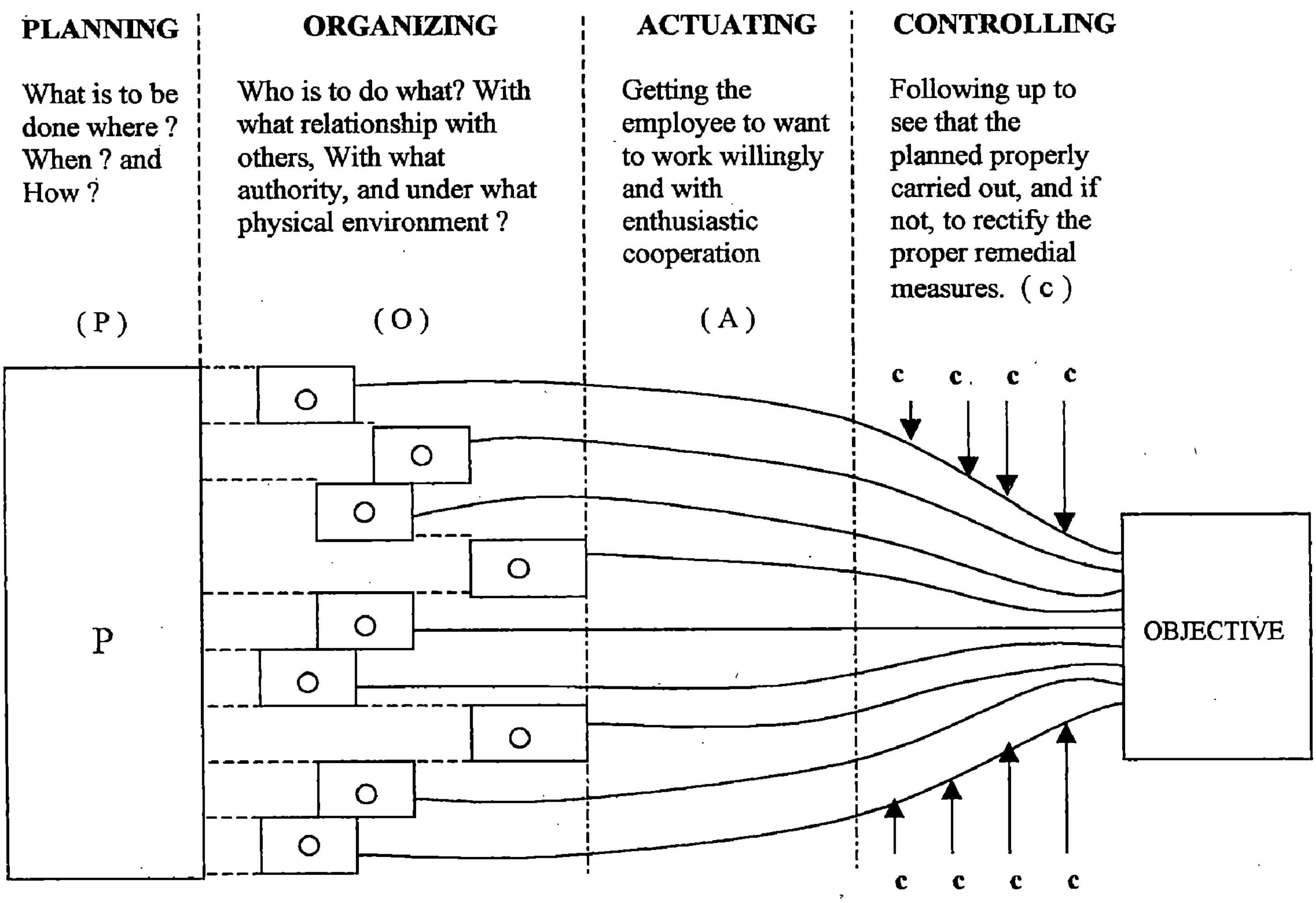
1) Planning, to determine the objectives and the courses of action to be followed.
2) Organizing, to distributed the work among the group and to establish and recognize needed relation ship.
3) Actuating the members of the group to carry out their prescribed tasks willingly and enthusiastically, and
4) Controlling the activities to conform with the plans.

A graphic representation of the management process is shown by figure 1.1

This concepts became more meaningful with the study of table 1.1., where more important activities of each fundamental function of management are listed below.

Strong urge to improve and the current demands placed by economic, social and technological and political forces make the management a dynamic process. **So the manager must be dynamic**. By dynamic means acceptance to change. The management continues to change in response to development of new ideas, tools and rules. Even then, with all the changes, the purpose of management remains the same, that is to accomplish desired results, the objectives. By dynamic means only the number of objectives changes, the methodology of achieving the objective changes.

A good water management is possible only when we know with clarity the various steps of management (shown in figure 1..2.) and only M.I.S forms the basis of such good management.



Management is the art and science of achieving the disserted result at minimum cost.

Figure 1.1. Vital Process of Management

Table 1.1. : Important activities of each fundamental function of management.

THE WORK OF THE MANAGER

PLANNING	ORGANIZATION	ACTUATING	CONTROLLING
1.Clarify, amplify, and determine objective 2.Forecast 3.Establish the conditions and assumptions Under which the work will be done. 4.Select and state tasks to accomplish objectives 5.Establish an overall Plan of accomplishment Emphasizing creativity to New and better means for Accomplishing the work. 6.Estabilish policies, proce-dure, standards and methodS of accomplishment. 7.Anticipate possible future problems. 8.Modify plans in light of control results.	1.Break down work into operative duties. 2.Group operative duties into operative position 3.Assemble operative position into manage-ments. 4.Clarify position requirements. 5.Select and place indivi-dual on proper job. 6.Utilize and agree upon proper authority for each management member. 7.Provide personnel facilities and other resources. 8.Adjust the organization in light of control results.	1.Practice participation by all affected by the decision or act. 2.Lead and challenge other to do their best. 3.Motivate members. 4.Communicate effectively 5.Develop members to realize full potentials. 6.Reward by recognition and pay for work well done 7.Satisfy needs of employees through their work efforts. 8.Revise actuation efforts in light of control results.	1.Compare results plans in general. 2.Appraise results against performance standards. 3.Devise effective media for measuring operations. 4.Make known the measuring media. 5.Transfer detailed data into form showing comparisons and variances. 6.Suggest corrective actions needed. 7.Inform responsible members of interpretations. 8.Adjust controlling in light of control results.

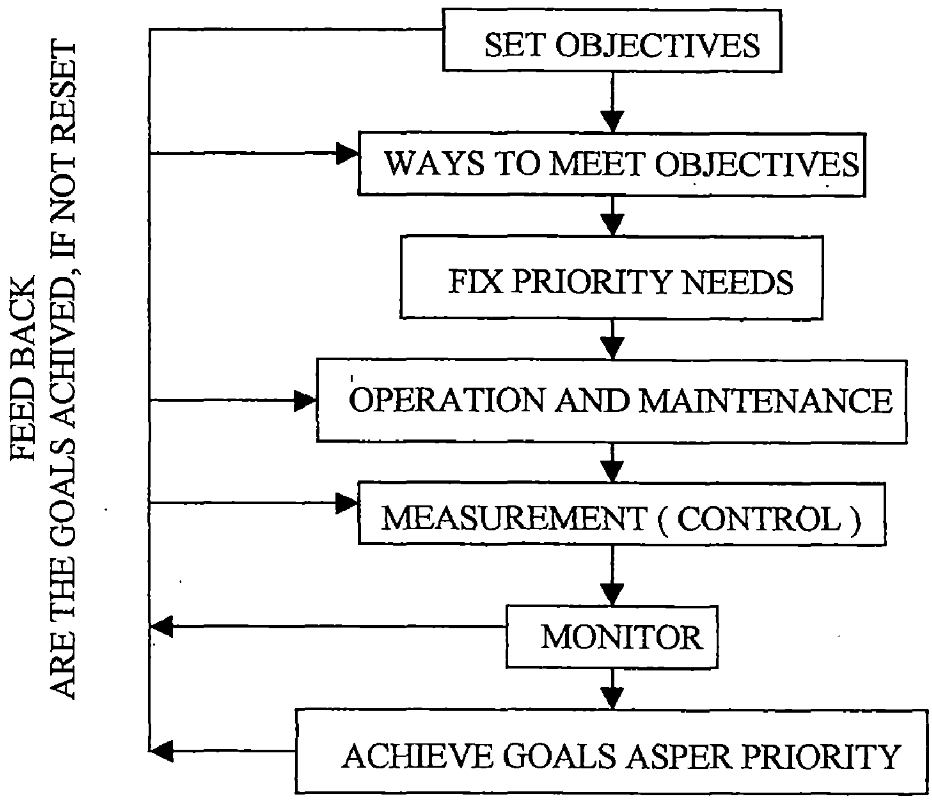


Figure: 1.2. Step in management

1.4.1. OBJECTIVES OF IRRIGATION SYSTEM

The objective of irrigation system change according to the availability of water, for example when ample water is available, the objective may be intensive irrigation and in case of drought it may be extensive irrigation. Thus the objective may also change from project to project, according to size, minor, medium and major projects. Again, it may change from area to area and economic status of the farmers, it may also change according to the land holder's requirement e. g from staple crops lite wheat to cash crops like sugarcane. On some projects, objective has been changed from irrigation to drinking water supply, or share of water supply has been increased. Also increase conjunctive use of ground and surface water, require redefining of objective functions.

Also increase conjunctive use of ground and surface water, require redefining of objective function.

Some of the objectives of an irrigation system may be to:

i). Provide water to a large number of cultivator; the cultivators can further maximize the use of water according to their individual capacity.

ii). In some areas the objective may be intensive cultivation in small areas say 100%, 200%, or 300%.

iii). In a command, land holdings may vary from very small to very large. Then the objective may be to provide water to all minimum land holders and in the some proportion to large land holders.

Further, it depend upon the feasibility of canal management.

iv) Similarly one of the objectives may be to encourage high yielding varieties or cash crops like sugarcane, fruit, vegetables, gardens/ orchards etc. requiring heavy irrigation thus objectives of each project should be defined individually and according to the management feasibility of the system.

In cost and time frame, the vital process of management may be as shown in figure 1.1. Cost proportion shown in the figure may vary from project to project, situation to situation. The above model/ frame will further change from project to project, area to area.

Normally very little time is devoted to planning, clear and explicit formulation of objectives. Many time these are not clear. There fore, often, huge amount is incurred on organization (staffing) and administration and profits are low, industry or factory is unproductive. The expenditure may be wasteful. Then lot of effort is involved in controlling, supervision and results are low. Lethargy and UN-willingness prevail in the organization with clear objectives and job responsibility and use of inter-related data, willingness and enthusiasm increases reducing low efficiency and increase profits.

There can be a set of objectives, primary or main objective and secondary objective. The secondary objectives are to fulfill the primary objectives.

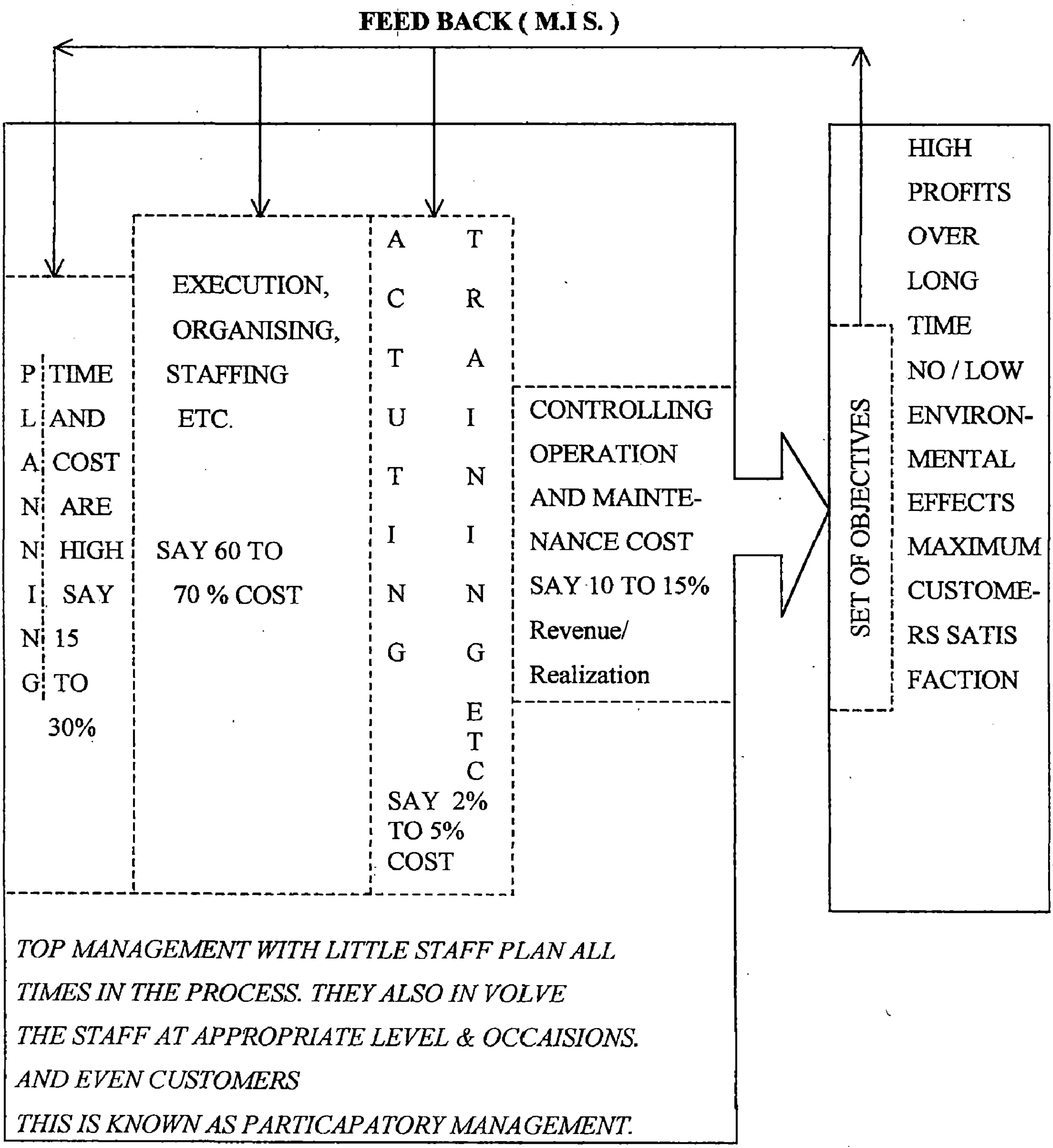


Figure 1.3. Typical example of vital process of successful management

For example, a shoe making co, have primary objective of maximizing its profits. To achieve this objective, it may have to fulfill many secondary objectives in a competitive market.

This objectives may be good looking, attractive, comfortable, long life, easily washable/ palatable, reasonable/ low cost etc.

Figure 1.2. to figure 1.3, along with table 1.1. gives a picture of a management process. Suitable management Information System (MIS) is also developed for proper feed back.

I.5. PERFORMANCE MONITORING, EVALUATION AND DIAGNOSTIC ANALYSIS

Monitoring, Evaluation and Diagnostic Analysis are importance Tools of good management and improvement programs.

These are highly inter – related and over – lapping each other see figure 1.4

Still there are some important distinctions between monitoring, evaluation are discussed below and diagnostic analysis separately. Distinction between them are given in table 1.2.

Monitoring is a continuous process. It involves the continuous assessment of the performance against target set in the project plan, or revised targets set in the project plan, or revised targets set by the project management.

The monitoring function is in effect a project's management information system. Monitoring is an internal project activity and is a essential part of good management. It is an integral part of day to day management. In includes functions such as accounting that are the responsibility of departments not formally designed as monitors. In context of the irrigation schemes, monitoring provides the information on:

(i). Physical achievements: such as dam built, canals laid or cultivable command are created within a defined time period, together with information on how much was spent;

(ii). The performance and impact of a dam in a specified season or agricultural year.

A dam allows kharif season (monsoon) rainfall to be stored for use in case of rain failures and rabi season.

Table: 1.2. Distinction between Monitoring, Evaluation and Diagnostic Analysis.

MONITORING	EVALUATION	DIAGNOSTIC ANALYSIS
a) It is to perform management i. e. It is controlling. b) It is day to day activity. It is continuous, it is management system (MIS). c) May not directly involve everyone. d) Information is received from bottom to top. e) Instruction are issued to bottom	a) It is to know the performance of management, it gives simple results, e.g. efficiency b) It is periodic, may be at interval of 2 or 3 or 5 years. May be for whole or part area. c) Evaluation can be self carried out or by higher ups. d) May be got carried out by independent agency with slight involvement, say corporation regarding data etc.	a) It is to know/ investigate the causes of performance both positive and negative aspects. It reflects causes of results, why it happens so. b) It is occasional only when improvements/ changes are to be carried out. It is carried out in a selected area and time. c) May be done internally by the Boss and by involving everyone. Or may be done with the help of external agency, with full involvement of everyone connected with the system

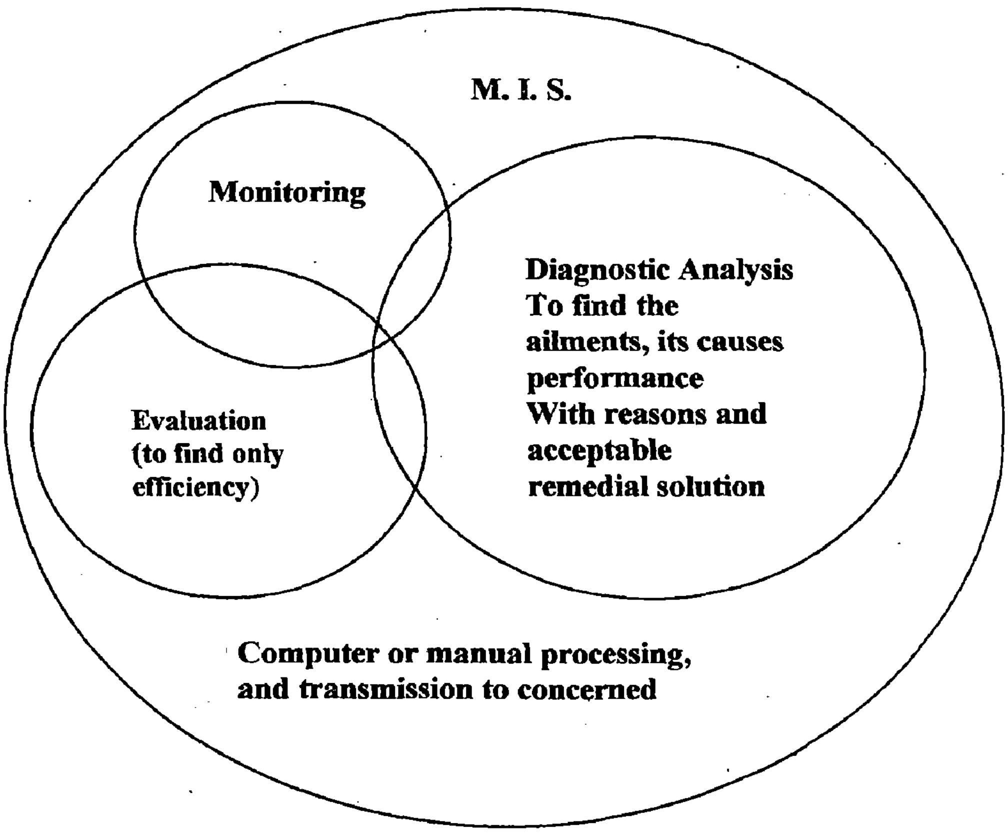


Fig. 1.4. Inter related and over lapping of Monitoring, Evaluation and Diagnostic

The main effect of a dam on agriculture depends on:

a). The proportion of water which is collected in a reservoir and available for release in the Rabi season. Estimation of reservoir losses is a important failure.

b). The proportion of water released into the canal distribution system which reaches the farmers.

c). The area irrigated, and

d). The amount of water supplied relative to the needs of the crops sown, during each stage in their growth.

The impact of a dam may be different on farms near the head, middle and tail of distribution canals.

Monitoring should take above in to account; and

(iii). Factor which cause the performance of dam to significantly differ from expectations.

These might include shifts away from irrigated crop production in the kharif and rabi season. It is essential that monitoring provides managers with this information in a timely manner so that remedial action can taken promptly, and positive lessons incorporated on other projects.

1.5.1. EVALUATION

Evaluation is simply an examination to know the end results of the system, i.e. to know the performance of efficiency of the system. It is like a university examination of students. The concern is mainly how many student have passed a particular examination or what is percentage. Evaluation is a periodic assessment of the overall performance of a project. Following the initial appraisal of a project, evaluation are normally conducted mid term, full term and ex-post. In the case of in the minor irrigation programs, a gap of 5 (five) years between each evaluation may be appropriate.

Sequencing in this way gives farmers adequate time to gain experience of crop production with irrigation provided by the new project.

The objective of each evaluation is to determine the efficiency and impact of a dam over its entire " life ", relative to expectations stated at appraisal. Evaluation after include comparisons with areas outside the project so that changes that would have occurred without the dam can be taken into consideration. It also gives data on cost of operation and maintenance.

Performance evaluation of an irrigation project can also be said as a quantitative measure of quality of operation, efficiency of operation.

For irrigation water is can be – How many liters or kg of water produces 1 Kg of rice or wheat or any other crop or fruits. Water accounts is a parts of performance evaluation.

Similarly for canal following are some important evaluation parameters.

i). Matching of canal deliveries or schedules with crop water requirement at many points as feasible, on weekly or monthly.

ii) Efficiency of canal operation, i.e. is basis gate losses, seepage losses.

On farm

i). Efficiency of outlet operation

ii). Efficiency of water course

iii). Efficiency of water application

Other aspects;

Performance of canal structures.

Diagnostic Analysis

Diagnostic analysis is a critical examination of a system. It is like diagnosis in medical science, may be of a patient or an aged person, that is to find the ailments and the causes of ailments in the patient or system. All detailed surveys, investigation, measurements and interviews are carried out in a D.A. It is a detail evaluation of a project. It explains positive and negative aspects of the system with detailed reasons or causes. It makes us available the efficiency and constraints of the system.

It is require every where, may be in our present life, officer or any field work. In an irrigation system, it is required on (i) main irrigation system; (ii) on farm system; (iii)

Cropping system; (iv) social/economical system; (v) Administrative sub-system; (vi) Environmental sub system.

When the system is very large, small area/some parts of the system are identified, by developing some criteria for choosing the same.

There may be lot of overlapping and there may not be any defined line of cut off between them. However, objective of all is to improve the management or make if effective at least cost.

On the irrigation project these techniques are useful right from beginning i.e. planning survey and design, construction – operation and maintenance. Different performs and methods are required for different stages. Diagnostic Analysis (D.A.) is more used in the operation and maintenance and to carry out any improvement programs.

Better the monitoring, better is the management lesser evaluation is required. With better evaluation, monitoring becomes better, lesser Diagnostic Analysis required. Better the D.A., better techniques of improvement become available which are cost effective. Finally a viable financing improvement programs/ management policy gets evolved. The project operates at a high efficiency over long time, see figure 1.3.

1.5.2. The Relationship Between Monitoring Activities and Evaluation.

Monitoring and Evaluation activities are related. Evaluation is likely rely on data-bases created as a result of monitoring work but is also likely to require broader issues to be considered and need more detailed analysis than at in monitoring.

Evaluation results can be useful in planning subsequent monitoring activities.

1.5.3. Implication for the Institutional " home " of Evaluation.

There is a case for a department that is responsible for monitoring to be incorporated within the management structure of an agency responsible for project implementation. The link between monitoring and evaluation activities suggests that the same unit should participate in these activities. However, there is a case for utilizing external personnel in evaluation along side M & E unit staff. Coming from out side the project, external evaluators have a more detached and objective perspective.

Additionally, since evaluations are carried out periodically, the skills and expertise they require are unlikely to be as highly developed amongst staff in an M & E unit as the skills and expertise used in routine monitoring.

1.5.4. Cautionary Notes.

The modern desktop computer provides unrivalled capabilities to handle and process data. There is an enormous temptation look at spurious relationships between data. Complex analytical functions may be run because they can be; whether they are necessary and whether they are full understood.

The resulting out put can be ready dressed up in a professional looking report and subsequently may become the basis of major investment decisions. It should always be borne in mind that the **quality of data used is the main determinant of the quality report produced.**

In both monitoring and evaluation, it is important to confine analysis to those that are fully understood. The results of analysis must be explained clearly and simply in a report. **Blinding someone with science leaves them blind**.

The main reason for writing a report is to communicate useful information from the monitor/ evaluator to project manager and financier. The right information delivered too late is valueless.

CHAPTER - II

IRRIGATION SYSTEM

2.1. INTRODUCTION

For Water management, configuration of the system components from water source to crop production can be divided into two groups viz. off farm (or main system) and on farm (or tertiary system). Off farm system comprises of diversion and conveyance structures and on farm system composes of distribution and application component. Schematic arrangement is shown in figure 2.1.

2.1.1. Functional Definition of Irrigation

Main function of irrigation system is water delivery to crops in proper quantity, at right time and of appropriate quality.

Equitability in distribution and reliability of supply are necessary schematic is as shown in figure 2-2 (a) and figure 2-2 (b).

2.1.2. Hardware and Software of Irrigation System

In irrigation system can be visualized to consist of hardware and software component. The hardware components are infrastructure, equipment and other facilities. The software comprises of organization, planning, operation and maintenance so as to achieve the desired project target with the help of hardware components. The contents of hardware and software element in main and on farm system are shown in figure 2-3.

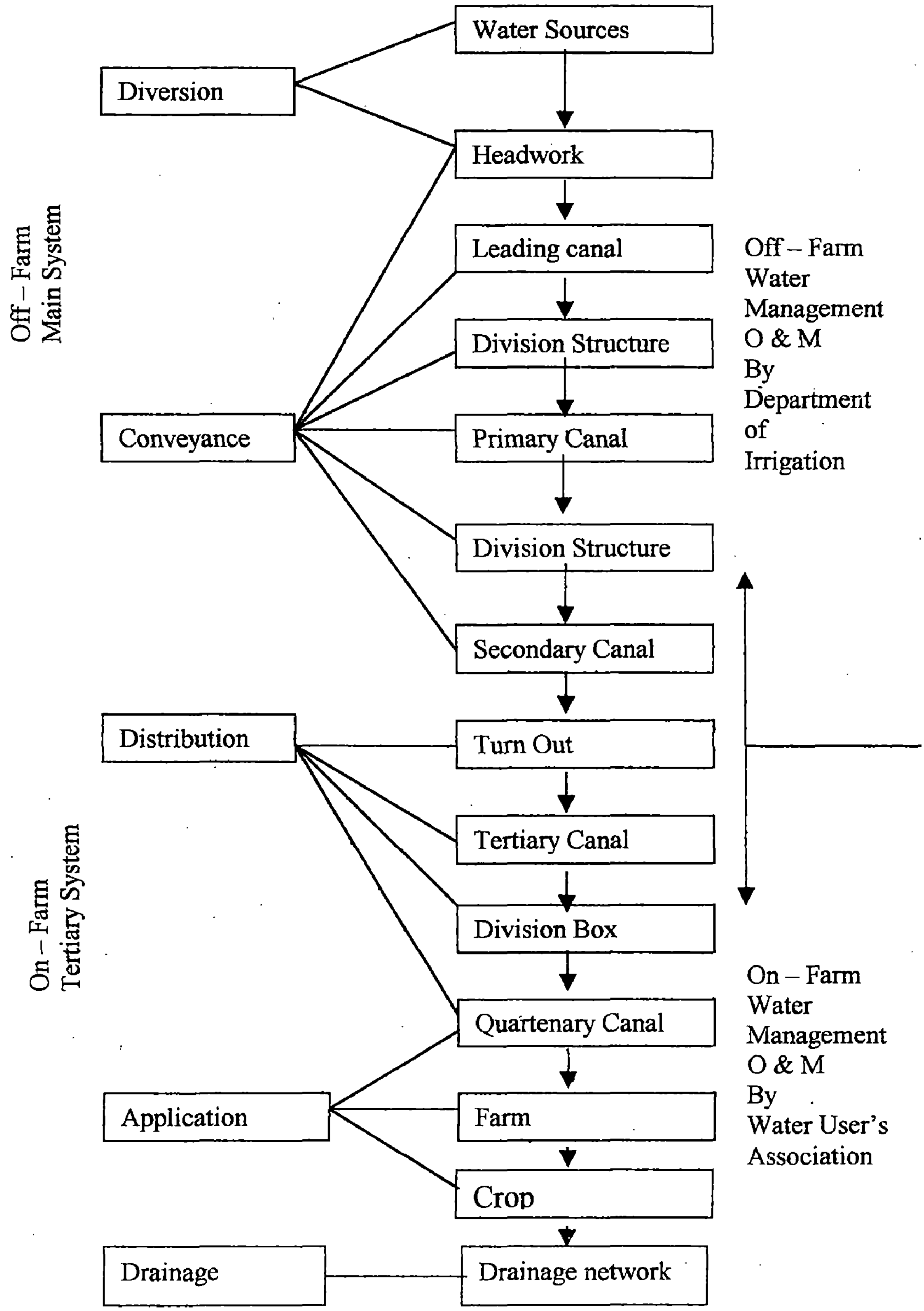


Figure : 2 – 1. Definition of Irrigation System (Configuration sketch).

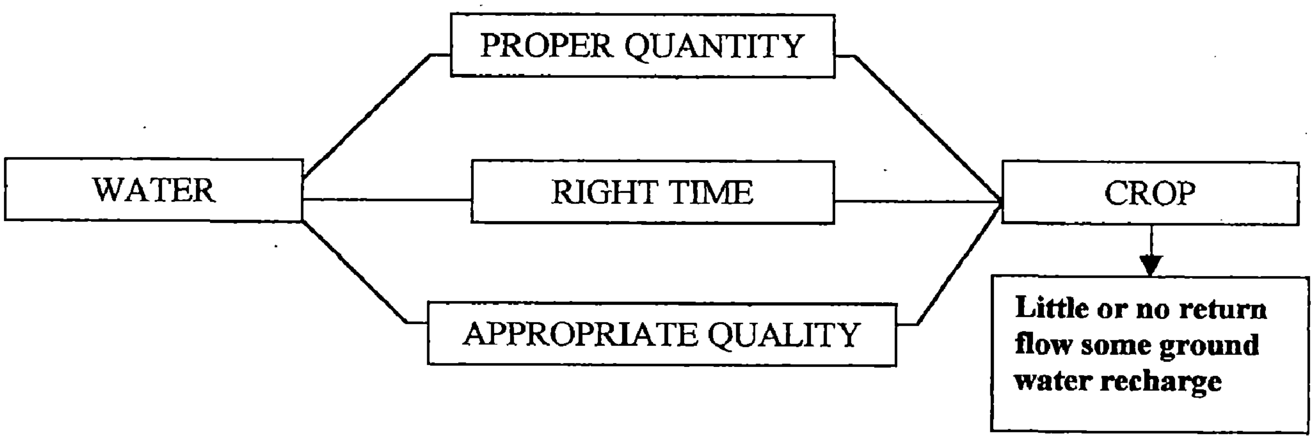


Figure 2 – 2 (a) : Functional Definition of on Irrigation System.

Process of irrigation project implementation and other inputs required to achieve the project targets are shown in figure 2 - 4.

2.2. WATER DISTRIBUTION PLAN

Water distribution plan (WDP) is an important component of irrigation operation implementation programmed. Each project has its own specific water distribution plan to achieve project targets. The operation and maintenance of irrigation system has to be done according to the water distribution plan. If necessary existing WDP and O & M procedures will have to be improved. Major components of Irrigation Implementation are shown in figure 2 – 5.

Operation procedure of Turnout gates:

Turnout gates should be operated taking into consideration the planned water distribution plan, actual water supply and operation rules as shown in flowchart figure 2 – 6.

2.3. DRAINAGE SYSTEM AND ITS O & M MANAGEMENT REGIME

Operation of drainage system is usually easier than that of irrigation system. The facilities such as check gates or regulatory gates which should be regulated or opened/ closed at right time should be installed in the project area. The outlet of drains may be equipped with flap gates.

Make sure that these flap gates Are fully open during low tides.

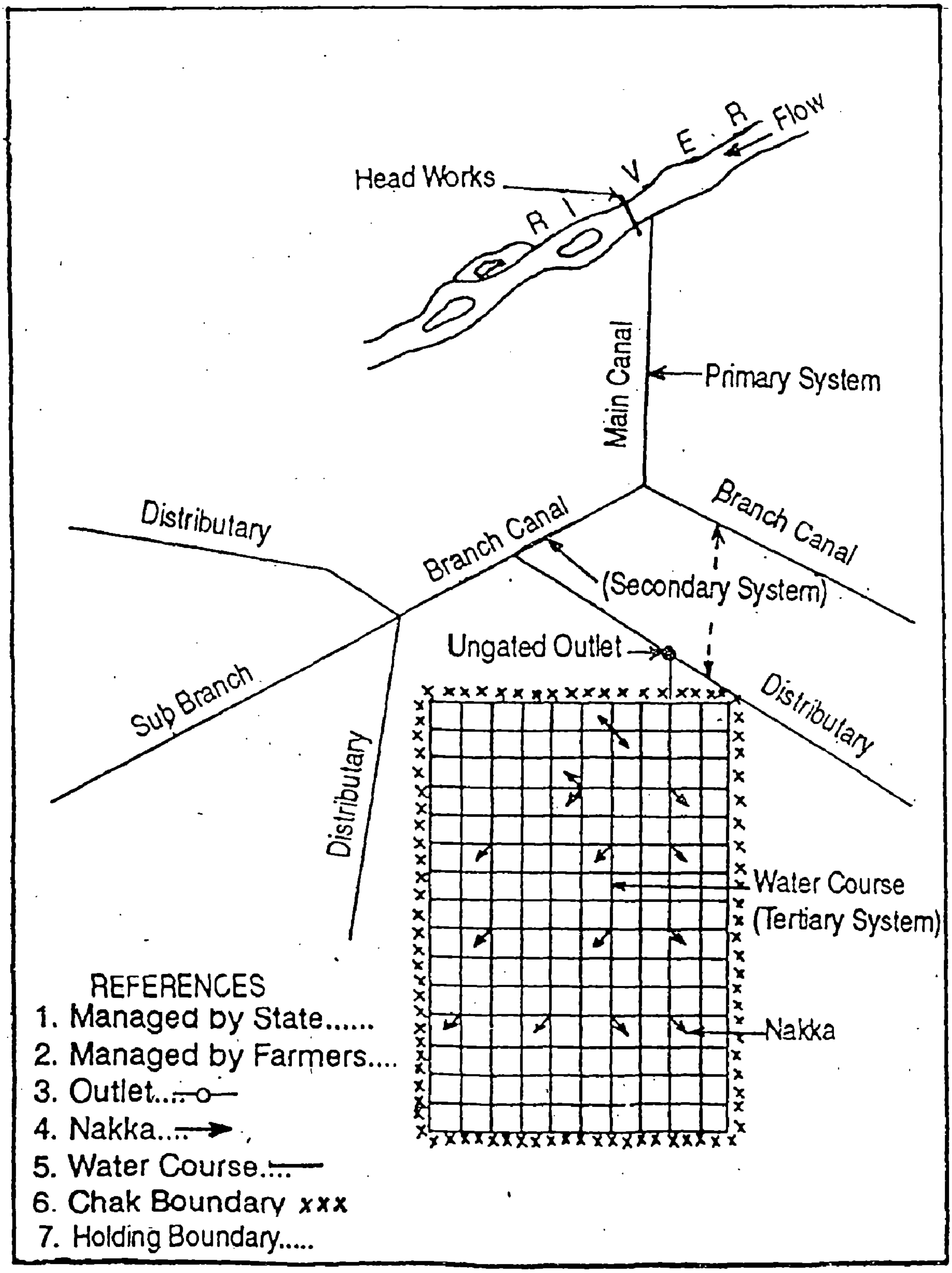


Figure . 2 - 2 (b). Typical Distribution System

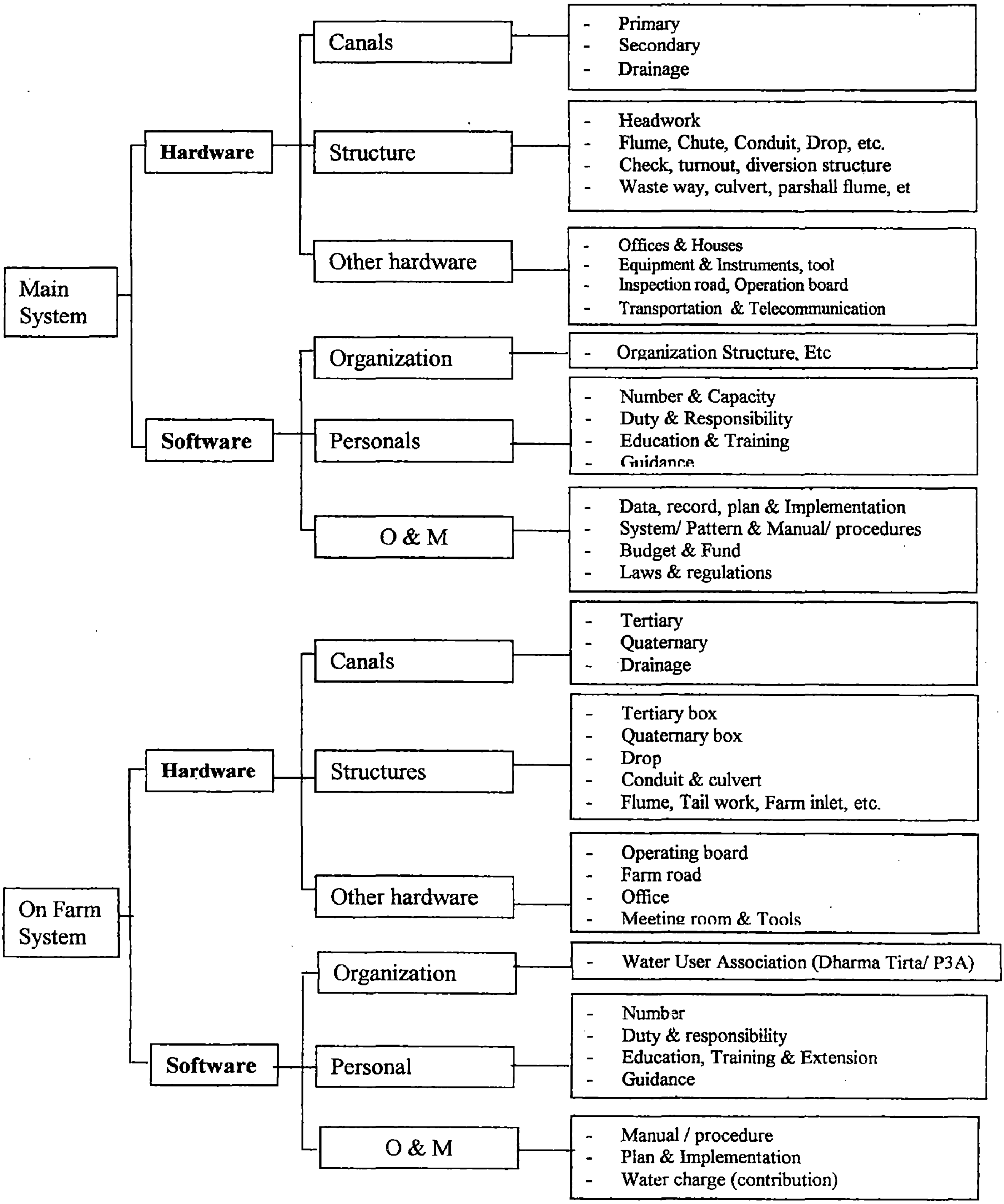
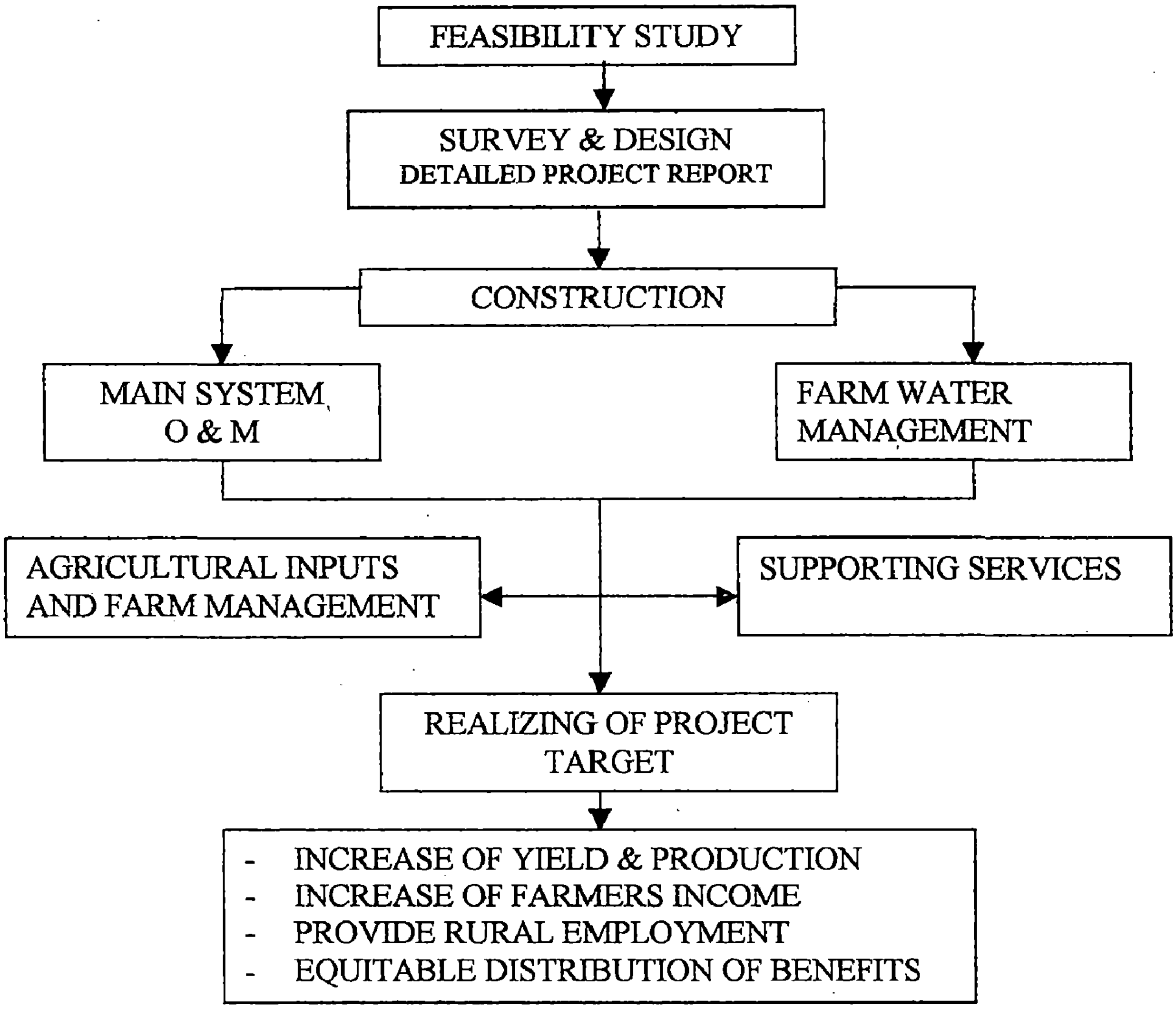
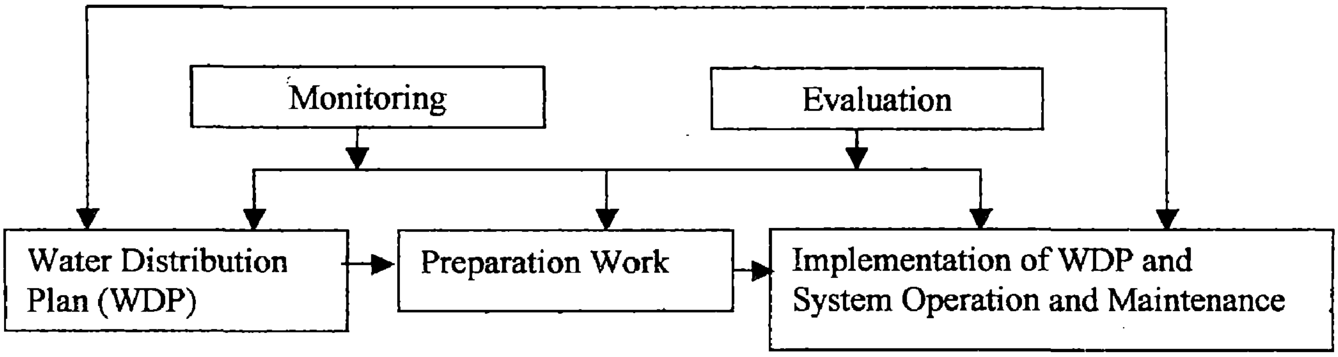


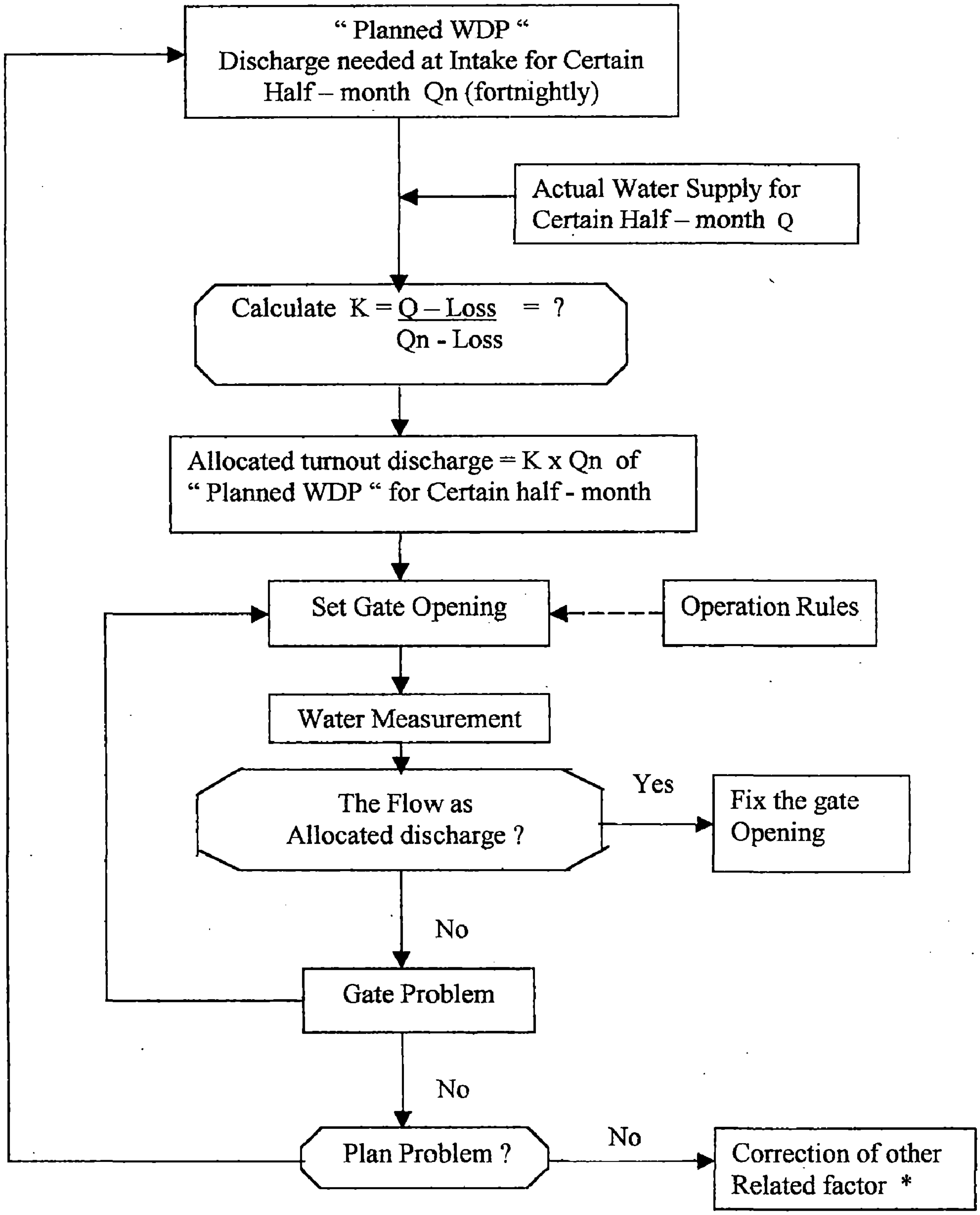
Figure 2 . 3 Hardware and Software Irrigation System



Figure; 2 – 4: Process and Inputs to Achieve Project Target of an Irrigation Project



Figure; 2 – 5 : Major Components of Irrigation Implementation.



* Such as taking too much water and entering foreign water Upstream etc.

Figure; 2 – 6 : Operation Procedure of Turnout Gates

2.4. CLASSIFICATION OF IRRIGATION PROJECT IN INDIA

2.4.1. Minor irrigation project

Earlier Minor irrigation project were surface water development through Irrigation projects (both flow and lift) consisting less than Rs.25 lakhs (Rs.30 lakhs in the hilly areas) and all groundwater development. This financial criterion was replaced with effect from 1st April 1978 by an area criteria under which Minor irrigation would includes projects for a cultivable command area (CCA) up to 2000 ha. Drainage and embankment projects costing less than Rs.2 lakhs each are also included. In some areas, micro storage works to improve moisture regime in the vicinity and percolation tanks to replenish ground water are also constructed under this programmed.

2.4.2. Medium Irrigation Project

According to the procedure laid down, projects with a cultivable command area between 2000 ha and 10,000 ha are treated as Medium Projects and are examined on a Performa basis in the Central Water Commission, (India)

Major Irrigation Project is of Project with cultivable command area of more than 10,000 ha are categorized as Major Projects. These are to be examined in the Central Water Commission New Delhi (India) in detail.

However, event for the projects which are examined on Performa basis, the information that is to be furnished by the State on the Prescribed Performa, should be base on a detailed Project Report. Thus, whatever be the nature of the project, the report that is to be prepared by the State Government, should be detailed so that examination in the Central Water Commission can be fruitful and the projects can be cleared expeditiously. In fact a Detailed Project Report will also be required by State Government for its own use.

MIS for above three categories will be different. However the principles or Parameters remain same. Monitoring aspects of Head works, Canal System, Command area are discussed in chapter III, IV and V respectively hastly water quality is discussed in chapter VI and finally summary and conclusion are given in chapter VII.

CHAPTER - III

HEAD WORKS

The effect of diversions from rivers is to decrease the river discharge downstream of the diversion generally without any overall reduction of the sediment input to river reach upstream.

In general, the effect of weirs/ barrages or storage reservoir is causes a increase in bed level of the river in upstream. The result is aggradation of the channel upstream, degradation downstream and a modification of the downstream flow hydrograph. This causes loss of storage capacity. Also there are evaporation and seepage losses.

3.1. Objectives (Purpose)

1. Reduce cost of operation and maintenance of reservoir or weir/ barrage or keep it at minimal. It includes cost of M.I.S.

   Maintain the life of reservoir, reduce sediment and ensure safety, reduce the harmful effect of reservoirs, evaporation and seepage losses from reservoir area.
2. Diversion losses through gates etc; and theft or lifting
3. Satisfy the customers i.e., provide water to each and every individual beneficiaries.

   Ensure releases in accordance to predetermined norms/ share.

   Up keep proper accounts of water delivery and losses.
4. Upkeep the proper quality of water
5. Collect revenue

3.2. Aggradation and degradation effects of dam on the Channel.

Typical effects of reservoir/dam on the channel (rivers) on the upstream and down stream are shown in fours typical cases in figure 3.1, 3.2, 3.3, 3.4.

As shown in fig. 3. 1 to 3. 4., the effect of raising the bed (base) level of the main channel, also include an increase in bed level for any tributaries entering the pool formed by the main system dam. Figure 3.1. and 3.2. shown the local aggradation in the upstream and scour in the down stream.

Aggradation and Degradation Effects of dam on the Channel

Local Effects	Downstream effects
1. Aggradation of bed 2. Loss of waterway capacity 3. Change in river geometry 4. Increased flood stage 5. Change in base level for tributaries 6. Deposition in tributaries near confluences 7. Aggradation causing a perched river channel to develop a change in the alignment of the main channel 8. Loss of reservoir capacity (sedimentation)	1. Channel degradation 2. Possible change in river form 3. Local Scour 4. Reduced base level for tributaries, increased velocity and reduced channel stability causing increasing sediment transport to main channel 5. Reduced flood stage 6. Little reduce flow down stream, effect on ground water and population. 7. Blocking of channel by local Debris, habitation etc.

Figure 3.3. show two dams A and B, and theirs effects on the channel, which are as under.

1. Dam A causes degradation
2. Dam B causes aggradation
3. Final condition in reach C is the combined effect of (1) and (2).

   Situation becomes complex by combined interaction of dams. Main channel and tributaries must be analyzed using water and sediment routing techniques and geomorphic factors.

Figure 3.4. shows three dams 1,2, and 3, and their effects on the channels as under

1. Reach A may be subjected to aggradation due to excess sediment left in the channel by diversion of clear water and degradation in tributaries caused by lowering of their base level.
2. Upstream of Reach A aggradation and possible change of river form.
3. Reach B may be subjected to degradation due to increased discharge in the channel.
4. Upstream of reach B aggradation and change of river form.

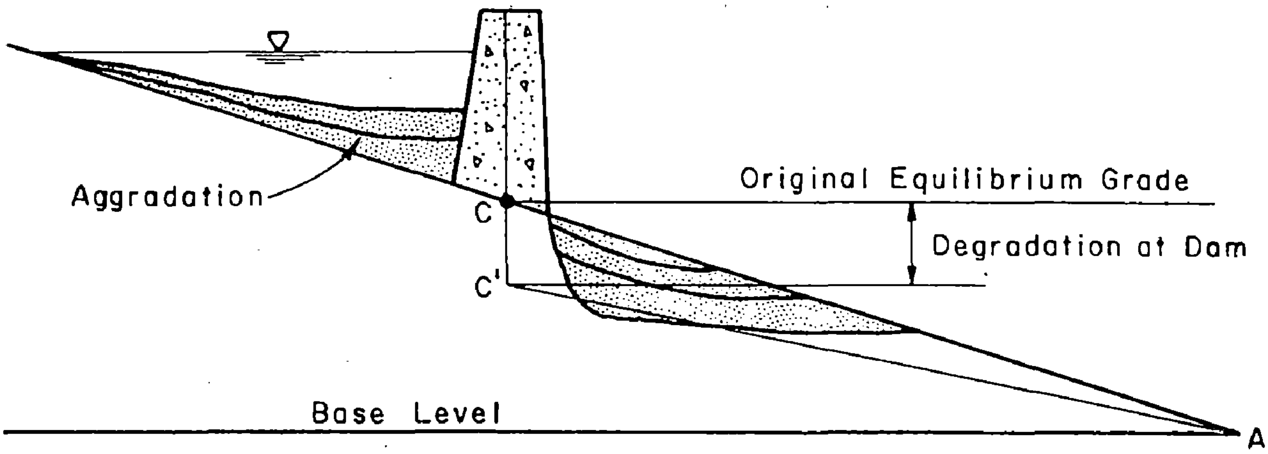


Figure 3.1. Channel adjustment above and below a dam

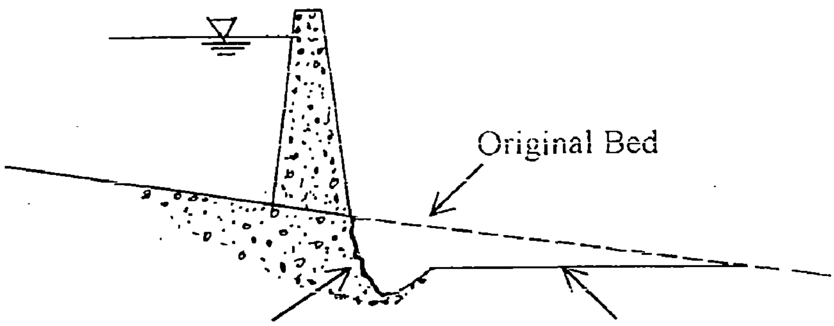


Figure 3.2. Clear water release below a dam

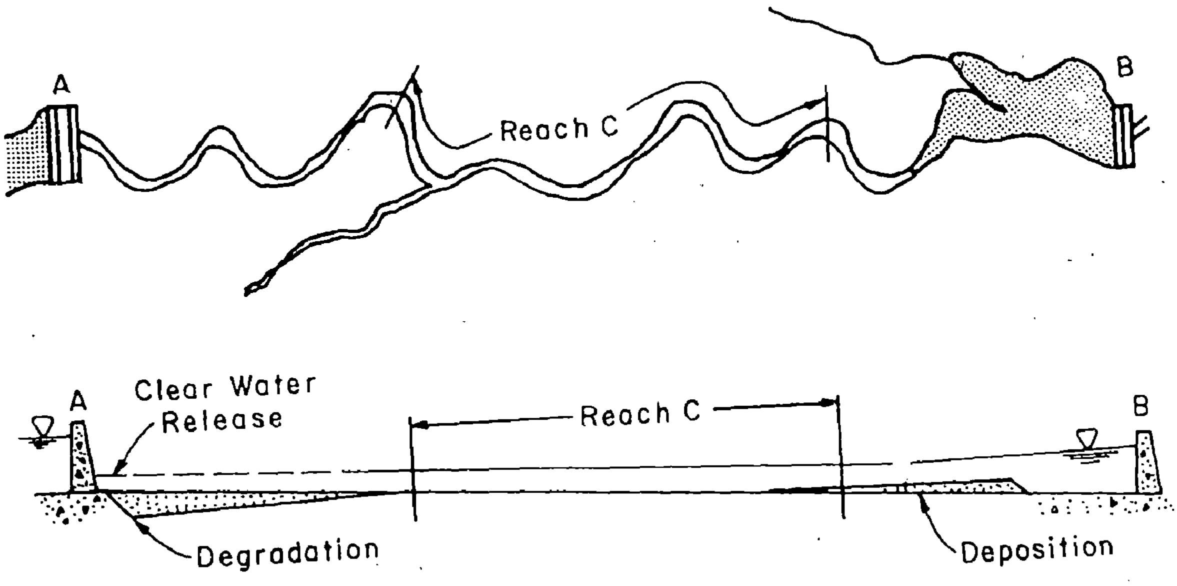


Figure : 3.3. Combined increase of base level and reduction of upstream sediment load

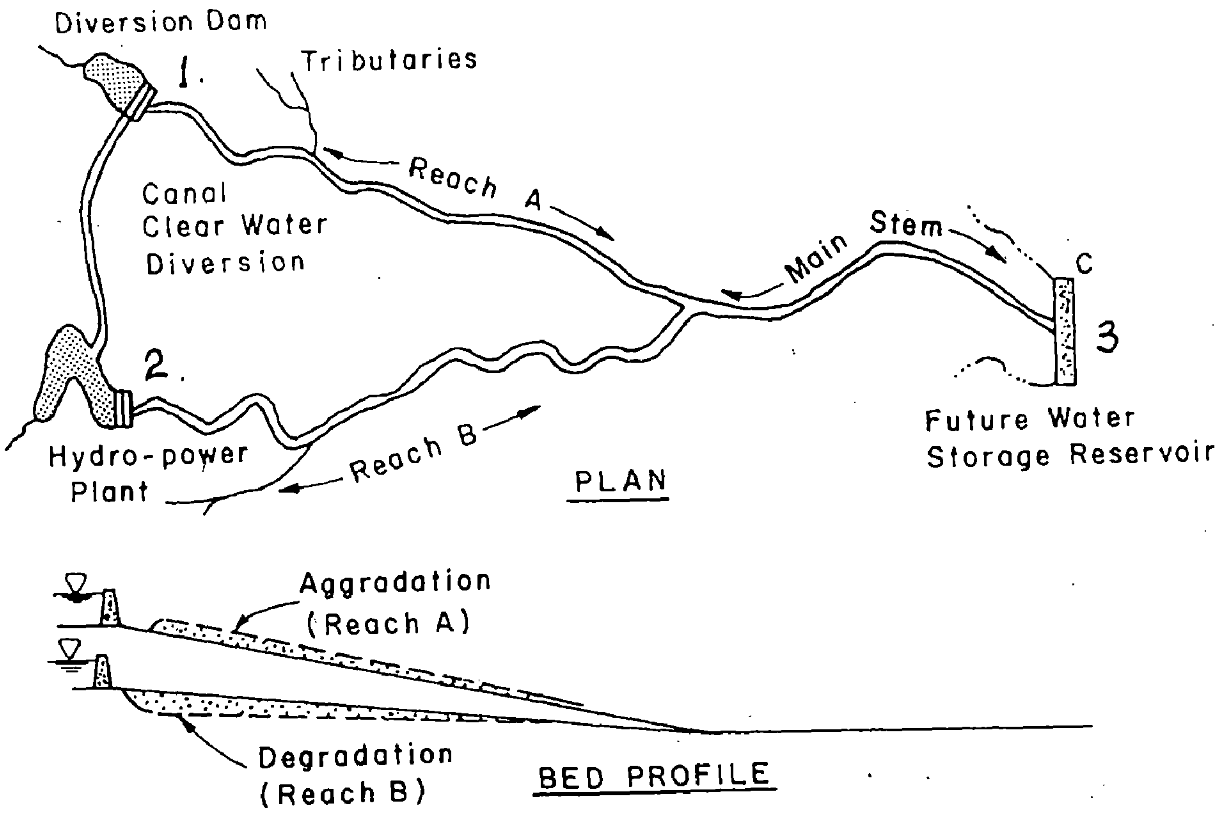


Figure : 3.4. Clear water diversion and release combined with downstream storage

5. If a storage reservoir was constructed at C it could induce aggradation in both tributaries
6. Significant effects on flood stage
7. Other effects Channel instabilities.

A schematic summary view of sediment problem and is control are given in figure 3.5.

Detail aspects of river sediment transport and deposits are dealt in I.S. 4890 – 1968 and only important abstracts are given in appendix 3.1. and therefore not repeated here. The important aspects of sedimentation monitoring of reservoir are briefly discussed below.

3.3. Sedimentation Monitoring

The sediment deposition depend on many factors such as reservoir shape, channel slope, sediment inflow and outflow.

The sediment is product of erosion in the catchment area of the reservoir and hence lesser the rate of erosion the smaller is sediment load entering the reservoir.

The rate of erosion is directly dependent on the nature of rock or soil in a basin or catchment, climatic influence, terrain, physiography and geology of the land. There are various types of erosions which contribute to the process of sedimentation. These are :

(a) Sheet erosion
(b) Gullying
(c) Stream channel erosion
(d) Mass movements, land slides in hilly regions.
(e) Flood erosion
(f) Construction erosion
(g) Mining, and
(h) Industrial waste etc.

There are two classes of erosion

1. Geologic erosion
2. Accelerated erosion.

Accelerated erosion may be caused by any one or more of the following :

i) Agricultural activities

ii) Urbanization

iii) Road and highway construction

iv) Mining operation

v) Gully erosion – altering runoff conditions

vi) Stream/ river bank erosion.

It is estimated that about 6000 million tons of soils are eroded every year in India as a result of sheet erosion. From about 80 million hectares of cultivated lands, 6.2 million tons of nutrients are carried away every year. This is much greater than the quantities we are using at present. Gully and ravine erosion ravage 8000 ha, annually, 0.5 percent ravine catchment is eroded. Annual damage to the table land accounts for Rs, 40 million. Ravines are mostly found along the rivers of Yamuna, Chambal, Sabarmati, Mahi, Gumti and in the ctchmants of the Mayurakshi, Kangsabati in the eastern red soil region. As a conservative estimate the country is losing a total output of 3 million tons of food grains annually. The shifting course of river Kosi by 167 km from east to west between 17.38 and 1964 a period of 226 years is a classic example of stream channel erosion. In Himalayan regions, landslides are extensive and result in poor communication, dislocation of public utilities and sedimentation of downstream reservoirs.

The effect of reservoir sedimentation are felt in many ways; through the direct loss of water storage capacity in the reservoir itself, through increased evaporation losses in the reservoir pool, through increased transpiration losses in delta area, and through the effect on the economy of region depending upon the reservoir:

(1) The most obvious effect of reservoir sedimentation is the depletion of water storage capacity in the reservoir. The decrease of storage capacity prevents the reservoir from supplying the services for which it was designed, thus disturbing the economic life of the region or community which it serves.

(2) Available water supply may also be reduced by increased evaporation losses, as the sediment accumulation may change the area-capacity relationship in a reservoir so that large surface areas are exposed for equal storage than were found before the sediment accumulation.

(3) In most reservoir, sediment accumulation will occur in the backwater area at the head of the reservoir, causing a delta to be formed, which may soon became covered with brush or other types of vegetal cover. The result will be an increase in transpiration losses which may be quite considerable in some cases. For example, at the head of Elephant Butte Reservoir, this non-beneficial consumptive use has been estimated to be equal to about 37 Per cent of the evaporation losses from the lake surface.

(4) More critical loss than the loss on transpiration in the head of the reservoir is on the developments in the valley. Progressive accumulation in the head of the reservoir is on the developments in the valley. Progressive accumulation of silt in the head reaches may inundate the valley developments such as towns, rail roads, etc. The delta area extends upstream as it becomes covered with vegetation forming a screen which traps the sediment. It may, however, be noted that this screening action, when upstream developments are not endangered, will be beneficial in reducing the amount of sediment entering the reservoir.

3.3.1. Back water Deposit

The back water deposit is that material deposited in the back-water reach of stream above the reservoir level. In theory, it should grow progressively, both into the reservoir and upstream, because, as the deposit grows, the back-water effect is extended; however, its growth will be limited as the stream adjusts its channel through the deposit by eliminating meanders, by forming a channel having an optimum width-depth ratio, and by varying the bed from roughness so that these factors in combination, enable the stream to transport its sediment load through the reach.

Above small dams or diversion structures, and ultimately above almost all reservoirs, the back water deposit will fill the channel and result in higher flow levels and possibly in flooding problems. In the case of large reservoirs operated at varying pool levels, the backwater deposit will probably not present a problem until the reservoir is substantially filled with sediment. If here are important facilities at the head of the reservoir they may, of course, be effected within a short time by a rising ground water table or by increased flooding; however, material deposited in the backwater reach during

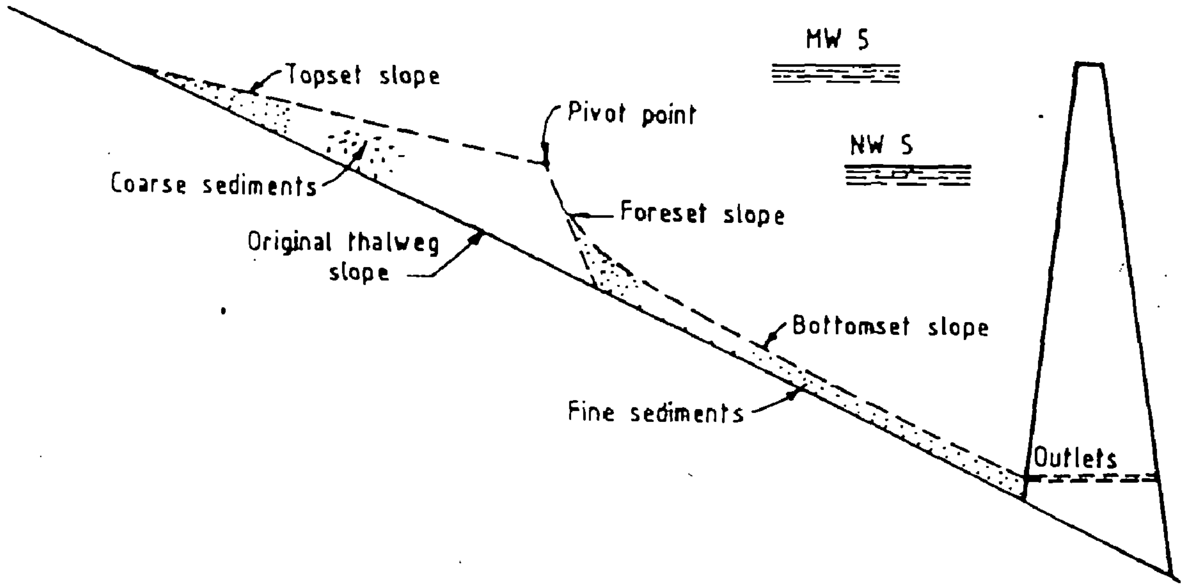


Figure. 3.5. Typical Sediment Deposition profile

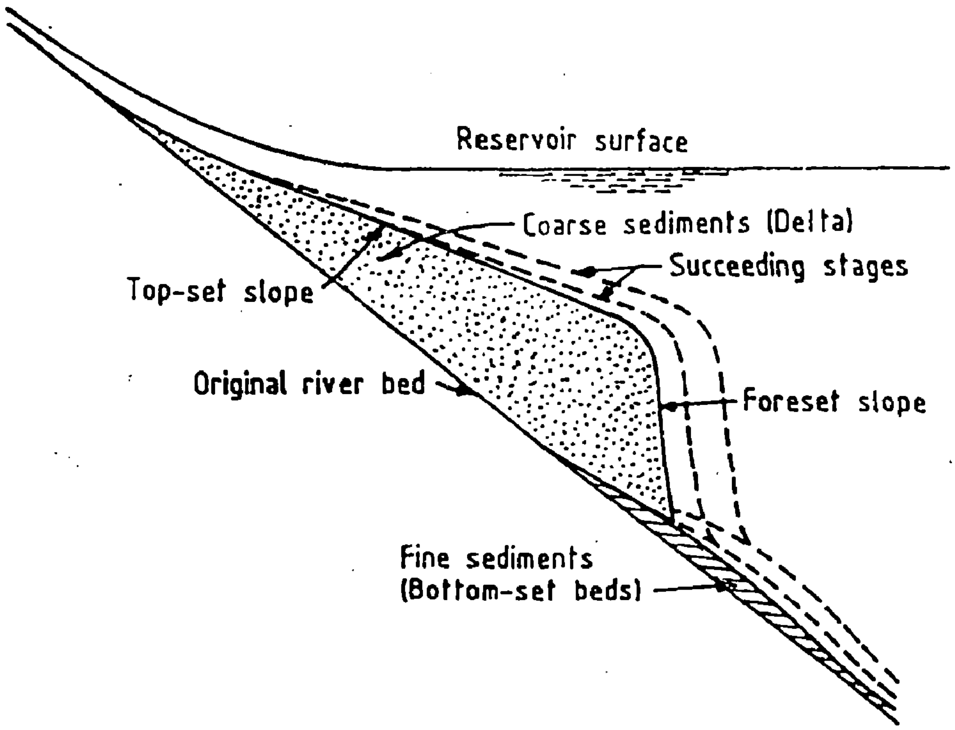


Figure. 3.6. Reservoir Delta Form

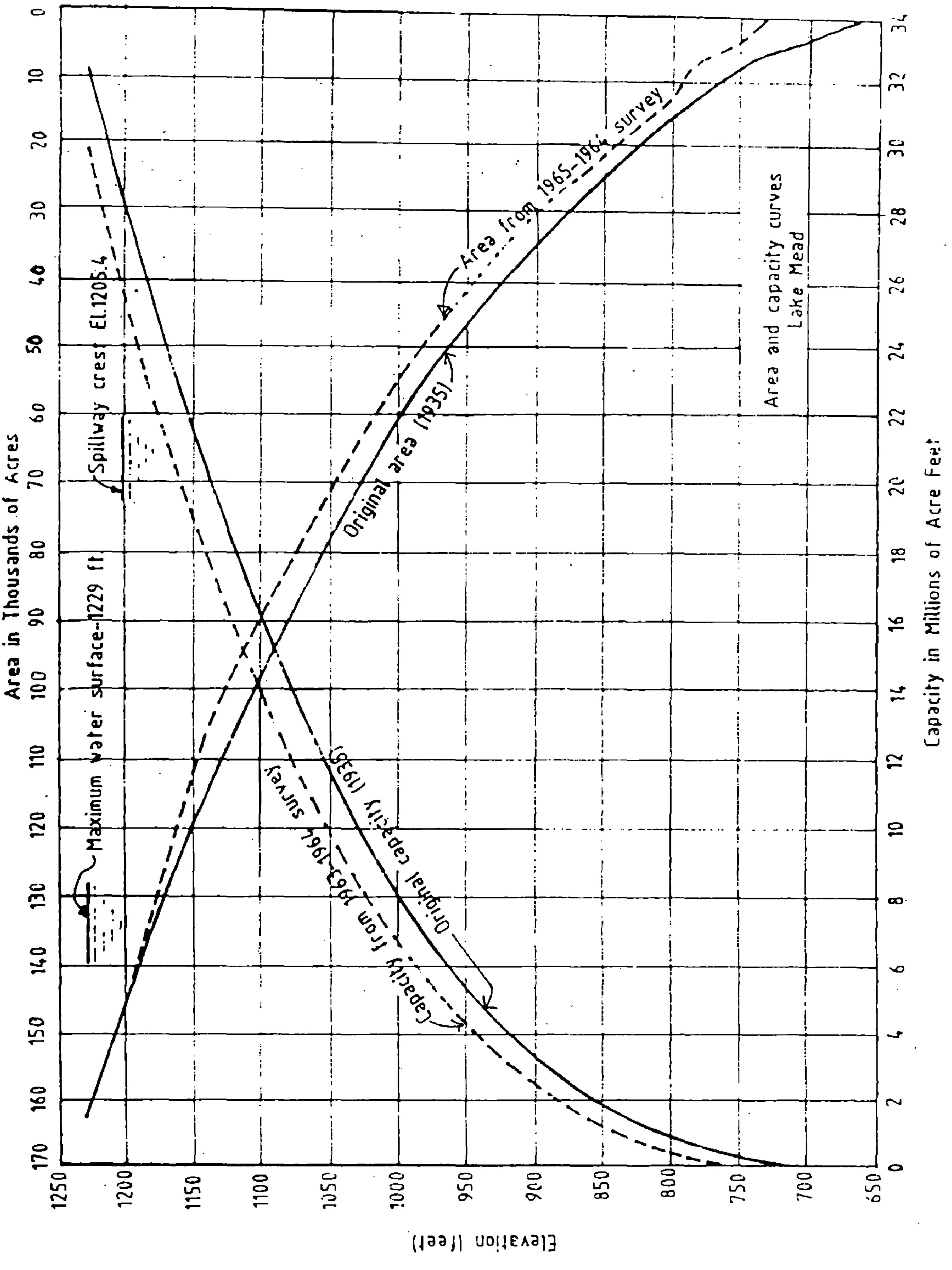


Figure 3-7 : Example area and capacity curves high pool levels is normally eroded and moved into the pool during low pool levels. During at least the first half of the useful life of a large reservoir, the backwater deposit will seldom extend upstream above the maximum level attained by the pool.

Severe backwater deposition problems have resulted in some areas because of the growth of phreatophytes such as salt cedars. These plants grow very thickly and impede the flow of the water and cause the sediment to be deposited. This, in turn, permits further growth, and, in a chain reaction, additional deposition upstream. The outstanding examples of such growth are in the Pecos River (New Mexico) above the Mc Millan Reservoir and in the Rio Grande (New Mexico) above the Elephant Butte Reservoir.
These areas are described by Bondurant (1955) in more detail. Fortunately, the geographic area in which such growth has been a major problem has, to date, been restricted.

Small reservoirs and the pools above diversion structures may become filled to the level of the dam within a short time, and in these cases, backwater deposition might quickly become a major problem. Borland (1971, p 29-4) describes a situation of the Middle Loup River in Nebraska, above the Milburn Diversion Dam, where the water surface elevation, for a given discharge, rose as much as 5 ft in a 16-yr period.

3.3.2. Delta Formation

Sediment of sand size and larger will normally be deposited soon after the flow enters the reservoir. In a relatively narrow reservoir; i.e., one that is sufficiently narrow for the flow to spread evenly across the pool, the coarse sediments will also be spread evenly across the pool to form a delta similar to that shown in fig. 3.5. and 3.6.

The surface of the deposit will be at, or slightly above, the average operating level of the pool, sloping downward at a race of several feet per mile, until the downstream and drops to the bottom of the reservoir at a slope of perhaps 10 ft to 15 ft per mile.

3.3.3. Capacity survey

Capacity survey of reservoir, often called sedimentation survey, is direct measurement process. Quite a few methods have developed in accordance with the different computational procedures but main survey methods are the contour or grid method and the range method.

In contour method, a contour map of the reservoir with suitable scale and contour interval is prepared, from which the capacity of the reservoir at the time of survey is computed. The difference in capacity between the two surveys indicates the loss of capacity due to sediment deposition during the intervening period. While conventional survey procedures suffice for small lakes and ponds, aerial survey techniques are suggested for erosion of large area.

In range method, survey is conducted along selected ranges across the reservoir, and this forms the basis for the computation of cubic content between the ranges.

While contour method of survey is generally applicable for all types of reservoir shapes, use of range method should be limited to relatively straight reaches. A suitable combination may often prove justified in a cost-accuracy trade off.

The longitudinal profiles of Soyama Reservoir, and Koyadaira in japan show the progressive formation and movement of delta-front into the reservoirs, and how the siltation has taken place in the reservoirs. These reservoir are very heavily silted.

Soyama Reservoir had lost 80 per cent in 12 years. In Soyama Reservoir, the fore-set beds had meved half way to the dam. In Koyadaira Reservoir the fore-set bed had practically reached the dam. Figure 3.9. and fig. 3.10. show the longitudinal profile of Soyama and Koyadaira reservoir (Japan). Bhakra /Gobin Sagar reservoir (India) showing original reservoir bed and the present one after recent capacity survey of reservoir. Gradually the delta front is growing see figure 3.8.

Detail of capacity survey are discussed in IS. 13665 – 1993.

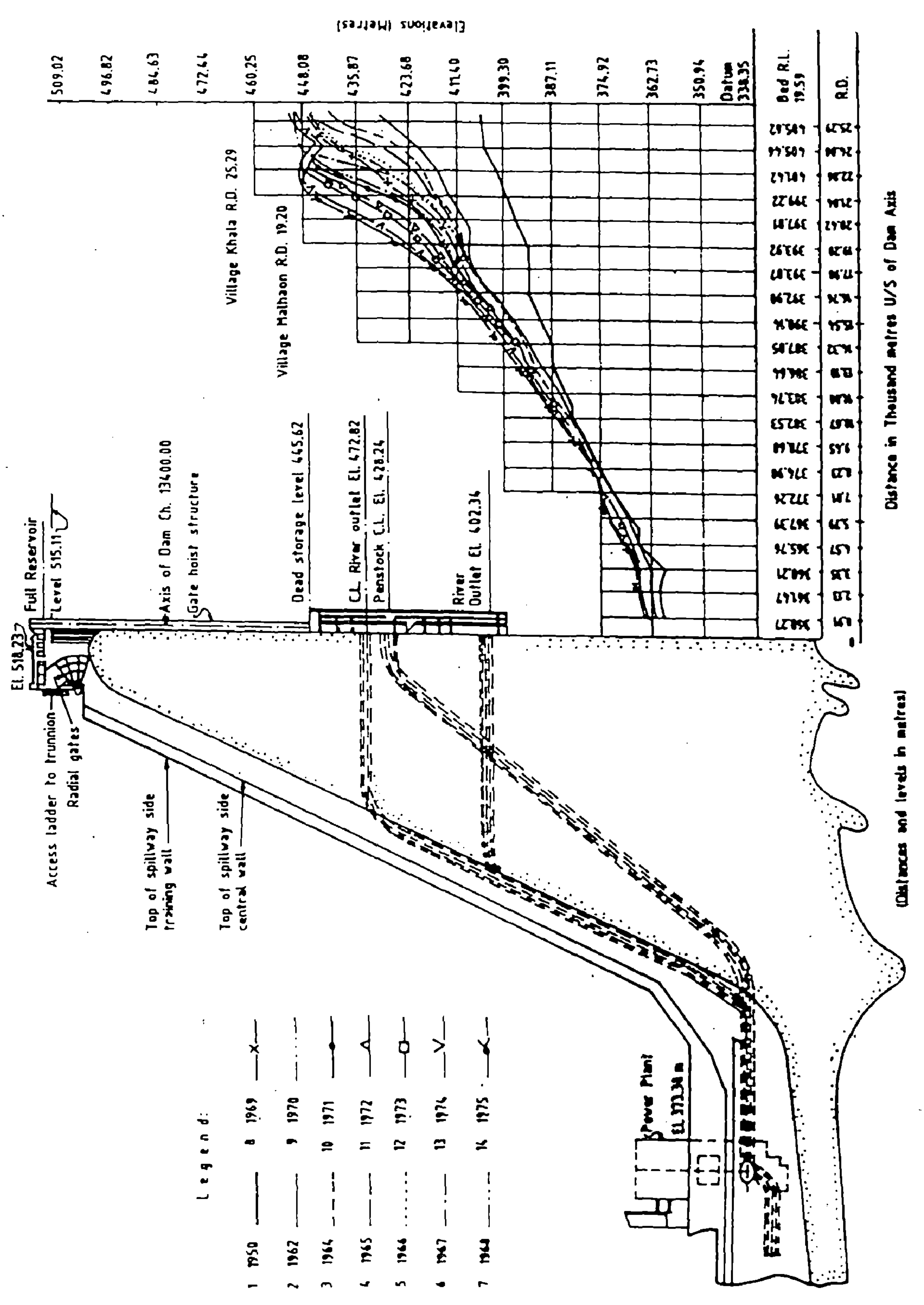


Fig. 3-8. Longitudinal section of Gobind Sagar (Main Channel) showing yearly silt deposit

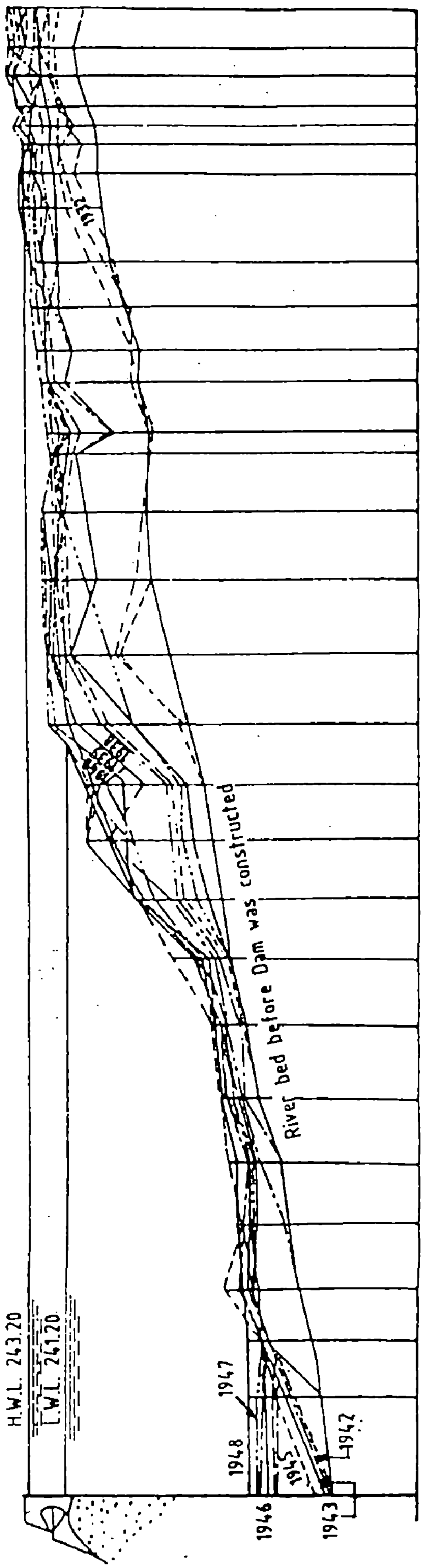


Fig. 3.9. : Longitudinal profiles of Soyama Reservoir (Japan) for different years

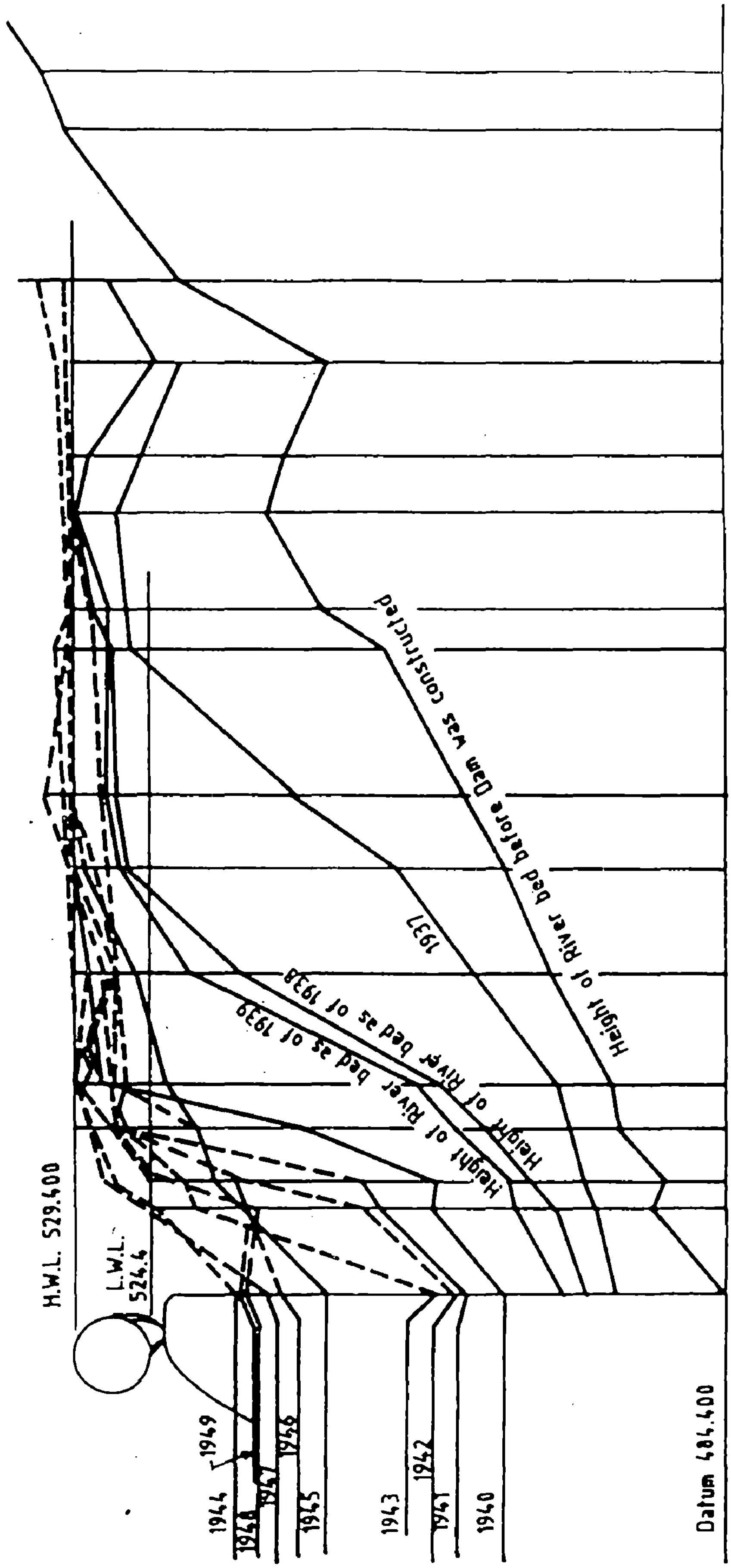


Figure : 3-10. Sedimentation of Koyadaira Reservoir, Japan.

TABEL 3.1. SUMMARY OF RESERVOIR DATA

Sl No.	Name of Reservoir	Year of first Impounding	Catchment Area (Km^2)	Net Sedimeent Contributing area (Km^2)	Catchment Characteristic and land management	Type of Survey	Submerged Area (Ha)	Capacity 10^6 m^3 **Original**	Age (Years)	Capacity 10^6 m^3 **New**	Total Storage Losss (%)	Annual Average Loss (%)	C/I Ratio	Silt Index m^3/100/ Km2/yr
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. a	Bhakra (Punjab)	1958	56,980	56,811	Hilly catchment mostly above 15.000 ft siwalik rock sand and stone clay-glacier fed	Range	17,564	9,868	7	9,578	2,9	0.4	0,7	54,963
b	- do -	- do -	- do -	- do -	- do -	Range	16,868	868	44	9,395	4,8	0.3	0.6	59,500
2	Hirakud (Orissa)		83,398	82,932		Inflow and Outflow	72,724	8,141	10	7,875	3,3	0.3	0.2	2,467
3	Gandhi Sagar (M.P.)		22,533	21,872	Major portion flat and covered with black alluvial soil	Inflow and Outflow	66,046	7,744	5	7,723	0,3	1.3	1.3	14,369
4. a	Panchet (Bihar)	1956	10,966	9,816	Denuded of forest and vegetal cover. Land management poor. Badly eroded land. Cultivated land 50 per cent	Range	15,338	1,580	10	1,484	6,0	0.4	0.4	79,032
4. b	- do -	- do -	- do -	- do -	- do -	Range	- do -	- do -	- do -	1,475	6,7	- do -	- do -	104,800
5. a	Maithon (Bihar)	1955	6,294	5,206	Same as Panchet	Range	10,716	1,357	10	1,290	5	0.6	0.6	107,771
b	- do -	- do -	- do -	- do -	- do -	- do -	- do -	- do -	16	1,240	9	0.5	0.6	131,000

Continue table 3.1.

Sl No.	Name of Reservoir	Year of first Impounding	Catchment Area (Km^2)	Net Sedimeent Contributing area (Km^2)	Catchment Characteristic and land management	Type of Survey	Submerged Area (Ha)	Capacity 10^6 m^3 **Original**	Age (Years)	Capacity 10^6 m^3 **New**	Total Storage Losss (%)	Annual Average Loss (%)	C/I Ratio	Silt Index m^3/100/ Km^2/yr
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
6.a	Mayurakshi (West Bengal)	1955	1,860	1,792	The catchment is denuded with very little vegetal cover. Land management very poor.	Countour	6,738	608	11	581	4.4	0.4	0.7	102,023
b.	- do -	- do -	- do -	- do -	The catchment is denuded with very little vegetal cover roling and undulating in nature.	- do -	- do -	- do -	16	561	7.8	0.5	0.7	164,800
7	Tungabhadra (Mysore)	1953	28,179	25,823	The catchment of thick and thin forest comprising about 25 percent.	Countour	37,799	3,758	19	3,436	8.5	0.5	0.4	65,200
8	Matatila (U.P)	1956 ** 1962	20,729	20,603	Mostly rocky, covered with scrub jungle and limited cultivation	Range	14,243	986	9	903	8.4	0.2	0.2	43,800

3.3.3.1 Contour Survey Method

The basic objective of this method is to prepare a contour map of the reservoir bed. There are quite a few field techniques available, the applicability of which depends mostly on the physical features of the reservoir, its operation schedule, working conditions and availability of instruments and other facilities. The general methods of contour survey are :

(i) Grid contouring;
(ii) Radial contouring;
(iii) Circular contouring;
(iv) Water surface mapping, and
(v) Air survey.

3.3.3.2 Range Line Survey Method

Range method of capacity survey consists of carrying out leveling or sounding along a fixed set of ranges. The objective is to develop the end areas at different cross sections and carry out volumetric computations on their basis. The range layout must be carefully planned and the reference monuments should be connected with a triangulation network supplemented by plane-table or traverse survey, if necessary.

3.3.3.3. Layout of Ranges

As reservoir area is usually surveyed before a dam is built, necessary maps of the area will always be available.

Before the reservoir is filled a paper location of silt ranges is made in sufficient number and in proper locations so that subsequent soundings on these ranges will furnish the necessary data for computation of silt volume. Unless the ranges are located first on the paper, we cannot get a comprehensive idea as to how the ranges would lie with reference to each other and the reservoir as a whole. The points, of course, need modification at site depending on topography, etc.

Detail of range survey are available in CBIP publication no. 89 (1995).

For small reservoirs where the bank contours are relatively straight and parallel, the range system show in fig. 3.11, may be prepared as in USBR practice.

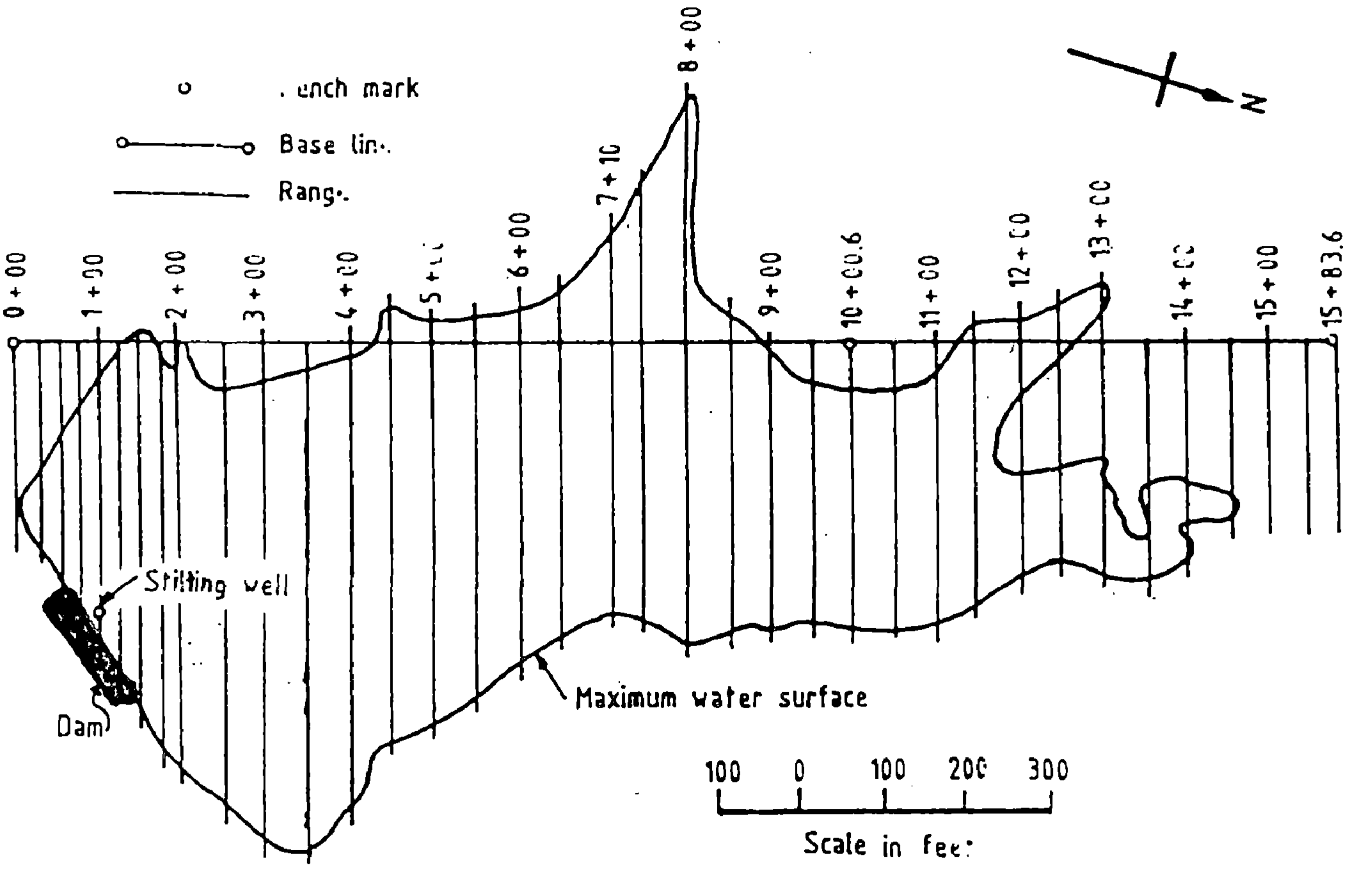


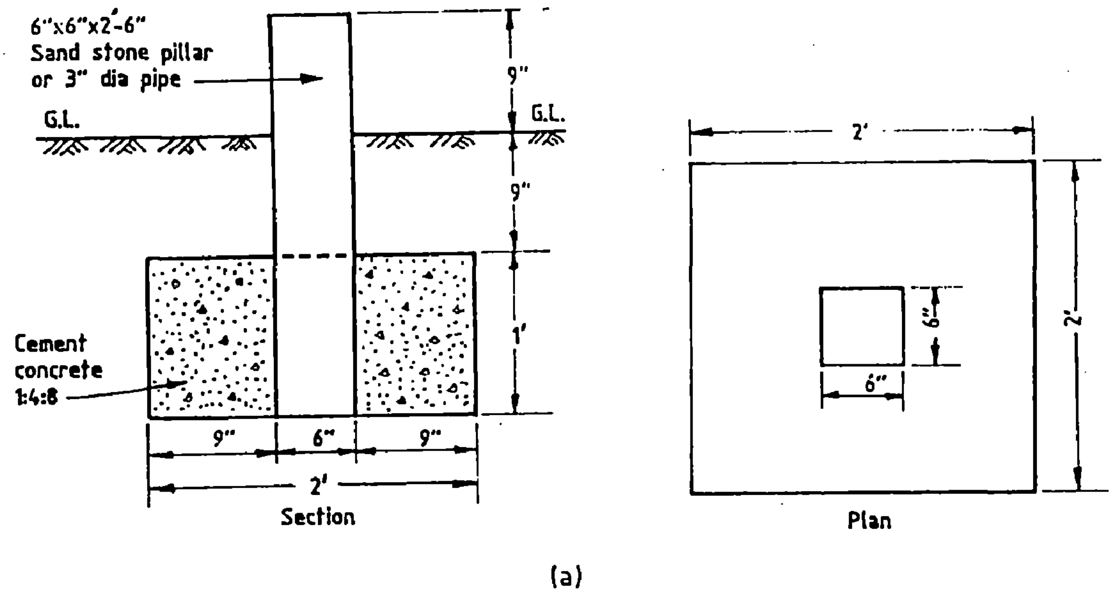
Figure: 3.11. Typical sediment range layout for small reservoir.

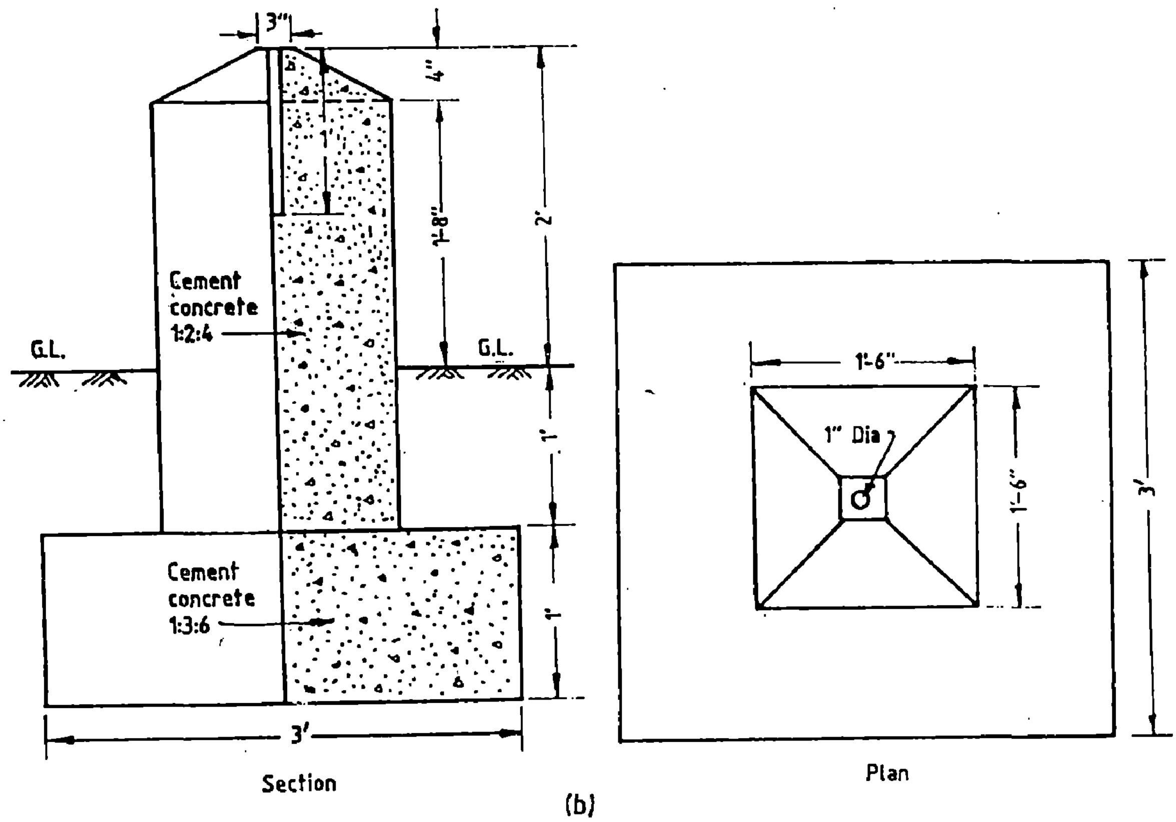
3.3.3.4. Range Monuments

The ends of the proposed ranges should be monumental in the field with a permanent type of monument. They may be of cement or masonry, depending upon the availability of the material in the locality. These monument should be adequately referenced so that they can be found several years later without much difficulty.

More details are given in publication referred above.

The range monuments and bench marks which have been constructed at some of the sites are shown in figs. 3.12.(a), and fig. 3.12.(b), fig. 3.13, shows the layout the silt range monuments, bench marks, and triangulation stations, etc.

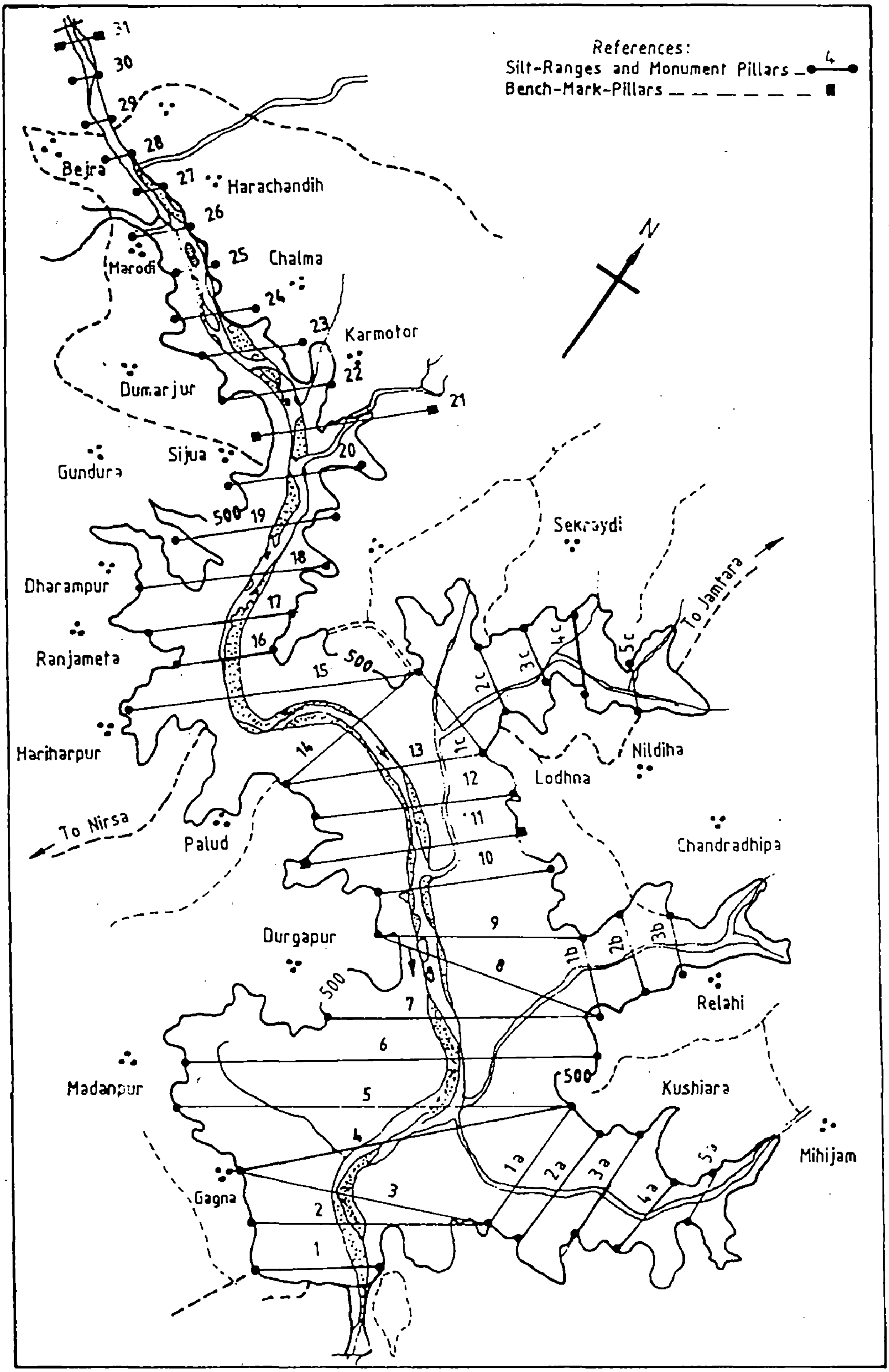




Figure; 3.12 (a) and Fig. 3-12. (b)

(a) Range Monument Pillar.

(b) Bench- mark Pillar



Figure; 3 - 13 . Map showing the silt ranges, monument and B.M. pillars of Maithon Reservoir

3.3.3.5. Automated Systems

The sedimentation survey conducted with the conventional equipment like theodolite, plane table, sextant, range finders, echo-sounders and slow moving boat takes a long time, up to 3 years just to complete one survey of a major reservoir like Hirakud. Assessment of the accuracy of such survey is also difficult. The staff required for sedimentation survey is multifarious. To enable speedy completion and improve accuracy, automated computerized systems have been evolved comprising primarily of (i) Positioning system

(ii) Depth measuring system, and

(iii) Computerized data acquisition, analysis and presentation system.

Much more comprehensive and accurate survey can be conducted with an automated computerized system in much less time and with less staff at a lower cost. One such system evolved and progressively improved upon in Canada is the HYDAC System described in detail in Technical Bulletin No. 105 of Inland Waters Directorate, Canada (1978), main features of which are presented by Shangle (1991) in Reservoir Sedimentation Surveys using High Technology. The following description of this system is reproduced from these sources.

3.3.3.6. Merits of the HYDAC System over Conventional Method

The conventional method is very cumbersome and time consuming. The time taken in survey of big reservoir ranges from 2 to 3 years, whereas this can be achieved within 2 to 3 months with the help of HYDAC System. This two three years time in survey can cause a great deal of error in computation of sedimentation.

3.3.3.7. Use of Satellite Imageries in Sedimentation Survey of Reservoirs

For measurement of sediment deposition in a reservoir, hydrographic survey of underwater area and ground survey for area above low water level are normally resorted to. Instead of ground survey, satellite imageries at various water levels of the reservoir water spread area can be used to prepare area-elevation curve by contour method on the basis of which elevation capacity relationship can be obtained. Advantages of the use of imageries are economy and saving of time.

Satellite sensing techniques, interpretation of data and computation of water spread area have been described and discussed by Anil Kumar et. al (1983). Differences between area of water spread measured by ground survey and from imageries was within 10 percent. Mohanti and Mohpatra (1986) used imageries for sedimentation studies of Hirakud reservoir and showed that results compare very well with hydrographic survey.

Imageries can be obtained from N.R.S.A Data Center, Balanagar, Hyderabad to scales of 1 to 1 million or to double this size. For hydrological purposes, band 7 (MSS7) imageries are found suitable. Imageries can be generated by N.R.S.A. Data Center for any date from 1979 onwards. Data prior to 1979 can be procured from Eros Data Center, Sioux Falls, South Dakota, U.S.A.

Single imagery has an area of coverage of 185 km x 185 km.

3.3.3.8. Interval Between Repeat Sedimentation Surveys

Repeat surveys to asses the rate of reservoir sedimentation is a cost-heavy exercise.

The International Standard Organization has recommended in ISO/DIS 6421 interval between repeat surveys to be 3 to 5 years or after capacity loss of 5% whichever is shorter. The U.S.B.R. guide line is to programmed a repeat survey after loss of 7.5 percent of capacity whereas the Indian practice is to undertake the repeat survey after an interval of 3 to 5 years. Specific criteria for selection of the period is not indicated but the extent of possible error in measurement of sediment deposition has an important bearing on choice of period between repeat surveys.

Total error in measurement of sedimentation in the aggregate error dependent on instrumentation as well as methods adopted in survey and computation. Assuming the total error as 5 percent, the reduction in capacity on account of sedimentation in between repeat surveys has to be significantly more than this error in measurement of 5 percent. If the error in measurement is comparable with reduction in capacity, there is uncertainty about realness of the capacity loss. Data of loss of capacity of some of the Indian reservoirs given by Gupta (1977) is reproduced in Table 3.5. Percentage loss of capacity in 5 years in case of all the reservoirs in this table is less than 5 percent. Repeat survey, interval of 5 years for these reservoirs would be meaningful only if the uncertainly of measurement is much less than the loss of capacity.

In general, large the reservoir, longer the life and hence percentage loss is smaller. The interval between repeat surveys can therefore be larger.

Secondly if the instrumentation and equipment for hydrographic and land survey is conventional and not automated computer compatible survey system, the resulting error could be larger requiring longer interval between surveys.

Criteria for fixing interval between surveys is wanting at present and needs to be evolved on the basis of possible error in measurement and other relevant considerations.

Some of the topics deserving high priority in R and D sector were also named, such as :

1. Scope for use of satellite imageries for preparing elevation – capacity curve for the reservoir between low water level and high water level.
2. Estimation of error in measurement of capacity depending on the number of range lines adopted for hydrographic survey of a reservoir.
3. Preparation of sediment rating curve and its use in estimation of sediment deposition in a reservoir.
4. Improvement in Sediment Index predictors
5. Comparison of different methods for sedimentation survey.
6. Guide lines for selection of equipment for hydrograph survey.
7. Optimum interval between repeat survey of reservoir sedimentation.
8. Comparison of bed load transport estimated using sediment transport functions, adopting bed load samplers and by dune tracking method
9. Formulation of data base and its upgrading.
10. Pilot experiments for dredging/ desilting in medium projects.
11. Effects of soil conservation measures (afforestation/ deforestation).

More than listing of the identified topics, introspection with regard to the shortcomings of the current practice is called for. An attempt in this direction was made in the CBIP Technical Report No. 47 (1992) by considering a few research topics more deeply.

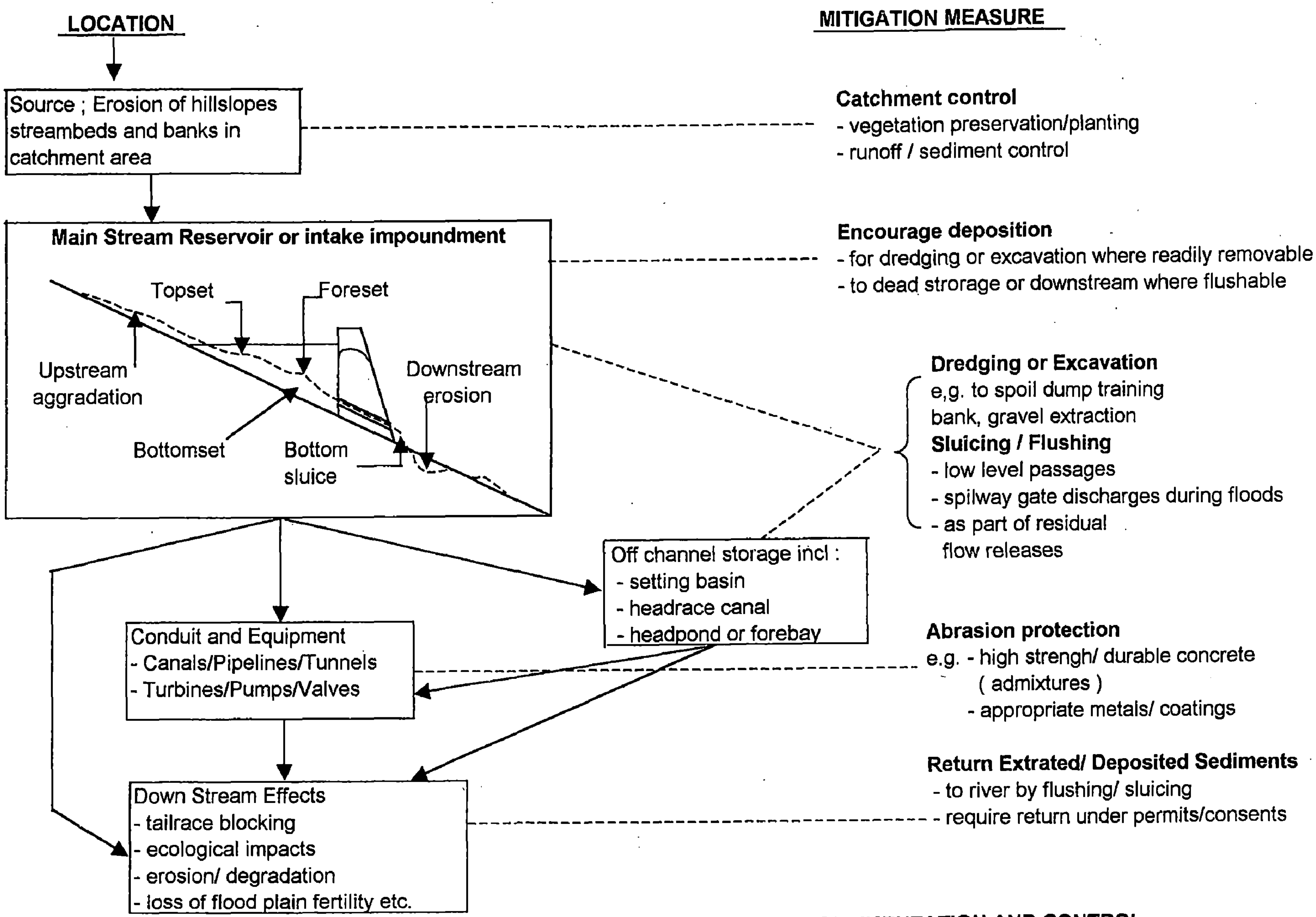


FIGURE 3.14. RESERVOIR SEDIMENTATION AND CONTROL

3.4. Reservoirs Regulation Classification and Monitoring.

For the purpose of regulation, reservoirs are classified into following types :

i) Single Purpose reservoirs :

These reservoirs are developed to serve only one purpose, which may be flood control or any of the conservation uses such as irrigation, navigation, industrial use, municipal water supply, etc.

ii) Multi purpose Reservoir :

These reservoirs are developed to serve more than one purpose which may be a combination of any of the conservation uses with or without flood control.

i) System of Reservoirs

These consist of a group of single/ multiple purpose reservoirs, which may be operated an integrated manner for optimum utilization of water resources of the river system.

In case of system of reservoirs, it is necessary to adopt a strategy for integrated operation of reservoir to achieve optimum utilization of the water resources available and to benefit best of the reservoir system.

3. 5. Classification of Large Dams

A Large dam has been defined by the ICOLD AS either: A dam above 15 m in height measured from the lowest portion of the general foundation area to the crest, or a dam between 10 m and 15 m in height provided it complies with at least one the following conditions :

a) The length of crest of the dam to be not less than 500m.

b) The capacity of the reservoir formed by the dam to be not less than one million cubic meters.

c) The maximum flood discharge dealt with by the dam to be not less than 2000 cubic meters per second.

d) The dam has specially difficult foundation problems, or

e) The dam is of unusual design.

3.6. Important features of Reservoir Monitoring.

The following features of the reservoir should be examined to determine to what extent the water impounded by the dam would constitute a danger to the safety of the dam or a hazard to human life or property.

a. Shore Line

The land forms around the reservoir should be examined for indications of major active or inactive landslide areas and to determine susceptibility of bedrock stratigraphy to massive landslides of sufficient magnitude to significantly reduce reservoir capacity or create waves that might overtop the dam.

b. Sedimentation

The reservoir and drainage area should be examined for excessive sedimentation or recent developments in the drainage basin which could cause a sudden increase in sediment load thereby reducing the reservoir capacity, with increase in maximum outflow and maximum pool elevation. Details of Reservoir sedimentation has been discussed in Para 3.3.(sedimentation monitoring).

c. Potential Upstream Hazard areas

The reservoir areas should be examined for features subject to potential back-water flooding resulting in loss of human life or property at reservoir levels up to the maximum water storage capacity including any surcharge storage.

d. Watershed Runoff Potential

The drainage basin should be examined for any extensive alternations to the surface of the drainage basin such as changed agriculture practices, timber clearing, railroad or highway construction or real estate developments that might extensively affect the runoff characteristics.

Upstream projects that could have impact on the safety of the dam should be identified.

3.7. Reservoir Regulation Plan

The actual practices in regulating the reservoir and discharges under normal and emergency conditions should be examined to determine if they comply with the designed reservoir regulation plan and to assure that they do not constitute a danger to the safety of dam or to human life or property.

3.7.1. Reservoir Operation Rule Curve

Rule curve is the target level planned to be achieved in a reservoir, under different conditions of probabilities of inflows and/or demands, during various time period in a year. Rule curves once prepared should be constantly reviewed and, if necessary, modified so as to have the best operation of the reservoirs. A typical example of a rules curve for is shown in figure; 3.2.2.

3.8. Reservoir Operation During Wet and Dry Season

i) Wet season means the monsoon period. In India it generally varies from June to September. In Indonesia it is period from December 1st to May 31

ii) Releases include flood waters through the spillway, hydropower discharge through the turbine, compensation flow through the auxiliary valve, and any other specified releases either direct from the dam or through power house.

iii) Principal operation rule is to timely store all the inflow water in the reservoir to augment its capacity or dry season releases. Reservoir water levels shall follow rule curve :

   i) Secondary release shall be only available at any time after the reservoir water level is higher than the above listed curve values.

   ii) Flood waters (Q_{spill}) shall be released according to the flood control operation.

   iii) Compensation flow (Qmin) shall be released through the auxiliary river outlet (Q_{Avalve}) whenever no release are performed through the hydropower facilities or the spillway.

   iv) Total release ($Q_{release}$) shall be estimated as follows :

$$Q_{release} = Q_{turbine} + Q_{AValve} + Q_{spill} + [\, Q_{storage} - Losses \,]$$

Rule curve will be prepared separately for dry, wet (monsoon) season, also for normal year, very good year and drought year.

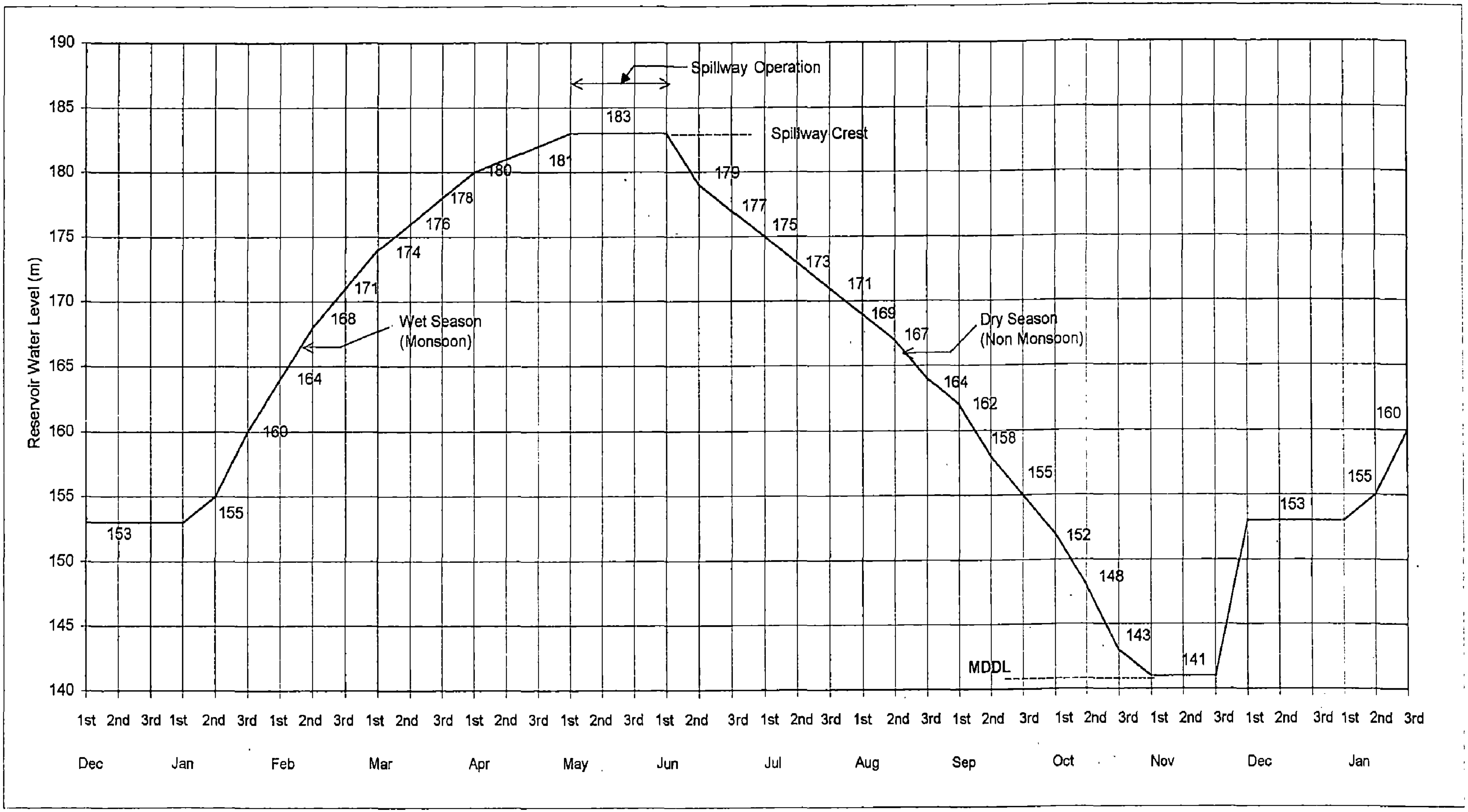


Figure : 3.15. Typical Rule Curve for Reservoir Operation

3.9. Water Accounting of Reservoir

Water storage in Dam is like money deposited in bank. Water has a high value. It is not freely available in the dams, canal, pipelines of water works, filter plants, wells etc. Every system of water storage conveyance, transmission and lifting has a very high cost. Some time this cost is highly prohibitive. Huge investments are made not only in their construction, but also on their operation, maintenance and management.

Therefore, water has to be judiciously supplied and used in measured accountable quantities. Even excess use of water is not free of costs more. Rather it is much more costly in fact excess use of water besides wastage, is harmful, damaging and its disposal is very costly.

The basic approach is computing inflow (runoff into tank) from the tank water level data, take into account the weighted precipitation over the catchments area, the direct precipitation on the reservoir surface, evaporation from reservoir surface, absorption losses, release through the outlet structure, spills. All computation are done from the change in storage with the change in water level. The basic equation developed by Bairathi and Wagnes (1973) for computing monthly inflow from the above factors is as follows :

Monthly inflow = ± (change in storage) + (evaporation) + (absorption) + (spills) + (release) – (direct precipitation on the reservoir surface).

The diagram of above equation is shown in figure 3.16.

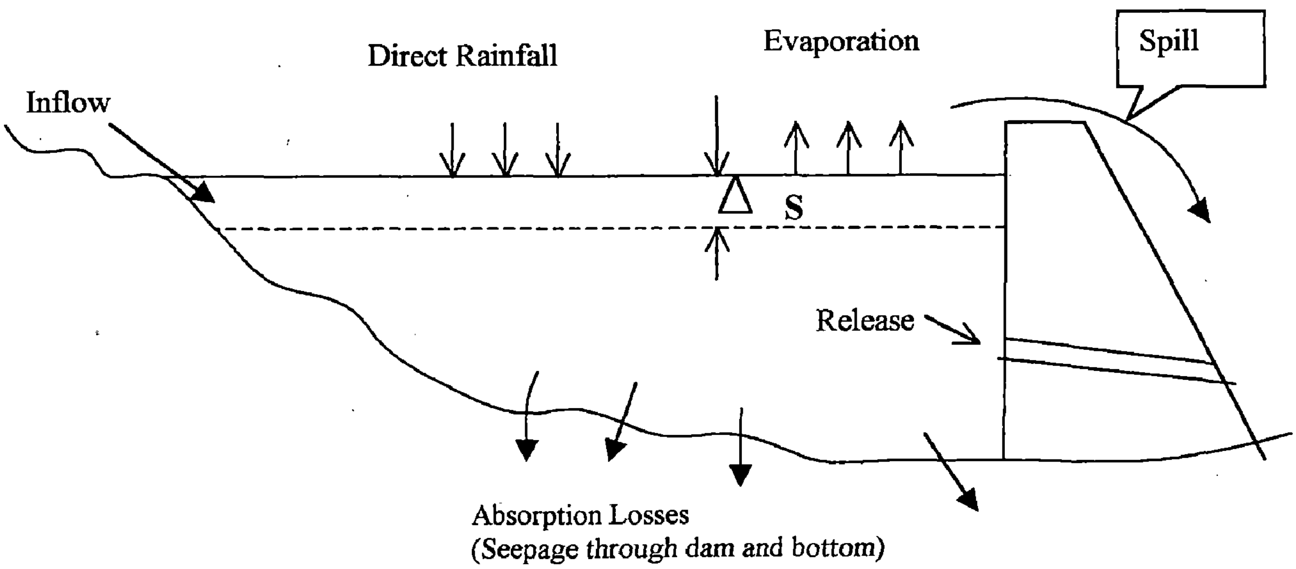


Figure. 3.16. Sketch of Water Accounting

Table 3.2. Form for Calculation of Reservoir Operation

Period	Inflow (m^3/sec)	Evaporation Losses (m)	Area at the Beginning (Km^2)	Area at The end (Km^2)	Evaporation Losses (m^3/sec)	Release (m^3/sec)	Retention (m^3/sec)	Incremental Storage (MCM)	Progressive Storage (MCM)	Storage at the The end of period (MCM)	Storage at the Beginning (m)	Res. Level at the end period (m)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Nov I												
II												
III												
Dec I												
II												
III												
Jan I												
II												
III												
Etc												

The stepwise procedure of table 3.2. calculation of reservoir operation is given below :

(1) = Month of year

(2) = 10 – Day period inflow (90% dependability), m^3/ sec

(3) = 10 – Day period of evaporation losses.

(4) = Reservoir area at the beginning from area elevation curve.

(5) = Reservoir area at the end from area elevation curve of corresponding to reservoir level of (13)

(6) = ((3) x (4))/ (3600 x 24 x 10).

(7) = Releases (m^3/sec).

(8) = (2) – (6) – (7)

(9) = ((8) x 3600 x 24 x 10)/ 10^6

(10) = Cumulative of (9)

(11) = 15.508 (initial storage) + (9)

(12) = Elevation of the preceding row of (13)

(13) = Elevation read and corresponding to the storage of (11).

Table : 3.3. Form to calculate Water Accounting

Date	W.L at Beginning (m)	W.L At end (m)	Change Storage (MCM)	Average Gauge (m)	Absorption Loss (MCM)	Average Area (Km2)	Evaporation Loss (m)	Evaporation Loss (MCM)	Volume of Release (MCM)	Volume of Spill (MCM)	Dam Precipitation (mm)	Dam Precipitation (MCM)	Total (MCM
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1 2 3 31													

Stepwise procedure of calculation :

(1) = Date period

(2) = Reservoir water level at beginning (m)

(3) = Reservoir water level at end (m)

(4) = (5) corresponding to Storage Elevation Curve

(5) = ((2) + (3)) /2

(6) = Absorption loss

(7) = (5) corresponding to Area Elevation Curve

(8) = Evaporation losses

(9) = (7) x (8)

(10) = (Vol. Releases) x 3600 x 24

(11) = (Vol. Spill) x 3600 x 24

(12) = Direct precipitation (mm)

(13) = (12) x 10-3 corresponding to Storage Elevation Curve

(14) = ((4) + (3)) – (6) – (9) – (10) – (11)

Water accounts each reservoir and canals are to be prepared on volumetric basis. The actual water losses are calculated and due share can be debited to each individual stock holders. A constant watch can be kept to reduce the losses. This also helps in knowing the actual over all efficiency of the system. A typical example of water accounting calculation is given in table 3.2.

3.10. Barrages, Weirs and Spillways

i) Inspection of barrage and weirs is necessary to obviate the possibility of extension of damages. Such inspection should usually be carried out annually for all underwater works after monsoon by means of underwater lamps and sounding rods. In addition, detailed inspection in stages should be carried out after drying the upstream floor by isolating portions of the barrage such that each portion is thoroughly inspected against any crack or damage, once every five years.

ii). The repairs, as necessary as result of inspection should be carried out well before the onset of the next monsoon. Any serious defects noticed should be reported to appropriate authorities and decisions taken in time.

iii). The inspection and maintenance may broadly be classified under the following items:

a). Aprons

- Upstream apron and area immediately upstream of it; and
- Downstream apron and area immediately downstream of it.

  The sounding and probing in the area shall be undertaken every year immediately after the monsoon in order to assess the scours and launching of aprons in the vicinity of structures. The non launching portion should be carefully examined, particularly on downstream, to ensure the effectiveness of inverted filter.

b). Impervious Floors :

- Upstream of the gates/ falling shutters; and
- Downstream of the gate/ falling shutters.

A thorough inspection of upstream and downstream floors shall be done after the monsoon. The upstream floor and use of underwater lamps. A careful inspection of joints of the stone-sets should be done where such structures have been carried out in boulder reaches. Minor repairs can be done under water whereas major repairs may be undertaken by isolating the area.

The downstream basin shall also carefully inspected in the cold weather season and the repairs carried out well in time before the onset of monsoon. In the case of deep cisterns requiring expensive cleaning and dewatering, inspection of sandy river reaches can be carried out by probing but in bolder reaches where this may not be possible, dewatering, cleaning and repairs may be carried out by rotation once in bolder stage river should be carefully examined and repairs and replacements made, as found necessary. While dewatering deep downstream basins, care shall be taken to ensure that the design pond level for such condition is not exceeded. This shall be clearly specified in the regulation order.

c). Sediment Excluding Devices

A thorough inspection of the roofs, ducts and mouth of the sediment excluders shall be carried out every year in the cold weather with the help of divers and underwater lamps. Minor repairs may be carried out under water and major repairs by local isolation.

d). Canal Head Regulator

The work shall be carefully examined every year in the cold weather by probing in case of upstream floor and examination under dry condition of downstream floor during closure or isolating the area where closure may not be possible. Visual inspection of upstream floor should also be carried out once in three to five years by isolating the area. All necessary repair shall be carried out in time.

e). Instrumentation and Performance.

It is essential that every year a performance report be prepared on the basis of instrument observations. The observation can be broadly classified under the following subheads:

i) Uplift pressure;

The pressure observation pipe are embedded in the weir or barrage structure generally in piers, and flank walls in such manner as to give representative uplift pressure along and immediately beneath the horizontal floor, at different points along the vertical cut-off. Additional pressure pipes may be installed, if required, to determine uplift pressure at critical points in stratified foundation. The pipes shall be numbered and a permanent record of the observation shall be maintained. The observed uplift pressure should be compared with the design uplift pressure with the help of a graphical plot and any needed remedial measures adopted. Frequency of the observation will depend up[on local conditions. It may generally be enough to take observations once a month during monsoon period and more frequently during the non-monsoon period. It shall be ensured that:

a). The mouths of all pipes are kept closed to obviate the chances of foreign matter finding its way into the pipes and clogging them;

b). Each pressure observation point is given a distinct number; and

c). Each pipe is frequently tested to ensure that its strainer is not choked.

This can be best done with the help of an ordinary hand pump, by working it, till water comes out freely.

ii) Pressure release (drainage) pipes;

Pressure release (drainage) pipes where provided in the downstream floor should simultaneously be checked for the quantity and quality (sediment content) of the discharge. Such observation may be possible only during the dry season when all the gates of the compartments are closed. This is necessary to check the efficient working of the drainage system. A correlation between head of water and discharge should be established and any large variations immediately taken notice of and suitable action taken. As discharge of sediment in the effluent could lead to undermining of the foundations, immediate remedial measures should be undertaken. In extreme cases it may become necessary even to completely block the sediment discharging pipe.

iii) Settlement :

Where appreciable foundation settlements are anticipated, particularly when the structure is founded partially or wholly on clay or other soft soil, surface settlement of the relatively heavily loaded parts of the structure should be observed early in the cold weather every year and remedial measures undertaken if necessary. This can be done by establishing permanent observation points of steel on the structure and doing precise leveling from permanent benchmarks established sufficiently away from the influence of any structure.

3.11. Energy Dissipators at Spillways.

Different type of energy dissipators as listed below are often used alone or in combination of more than one, depending upon the energy to dissipated and erosion control required down stream of a dam.

1. Stilling Basins

a) Hydraulic jump type stilling basin :

i) Horizontal apron type, and

ii) Sloping apron type

b) Jet diffusion stilling basin :

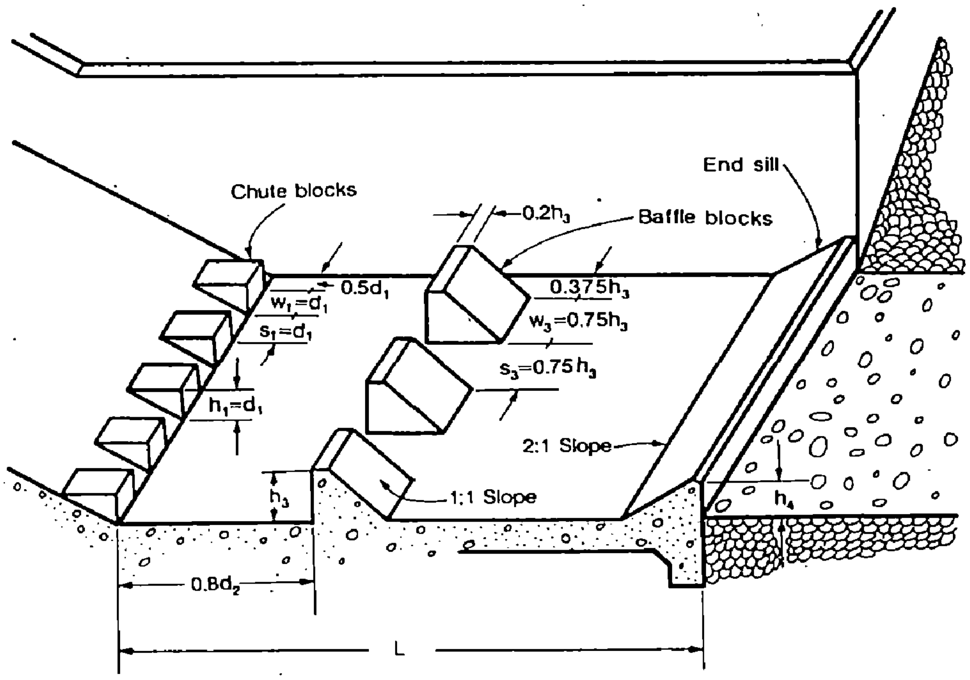
i) Jet diffusion stilling basin

ii) Interacting jet dissipators

iii) Free jet stilling basin

iv) Hump stilling basin

v) Impact stilling basin



Type III Basin Dimensions

Figure 3.17. USBR stilling basin type III for Froude number larger than 4,5 and incoming flow velocity less than 60 ft/s.(source : U.S. Department of the Interior, Bureau of Reclamation. 1987. Design of Small Dams. P. 391.

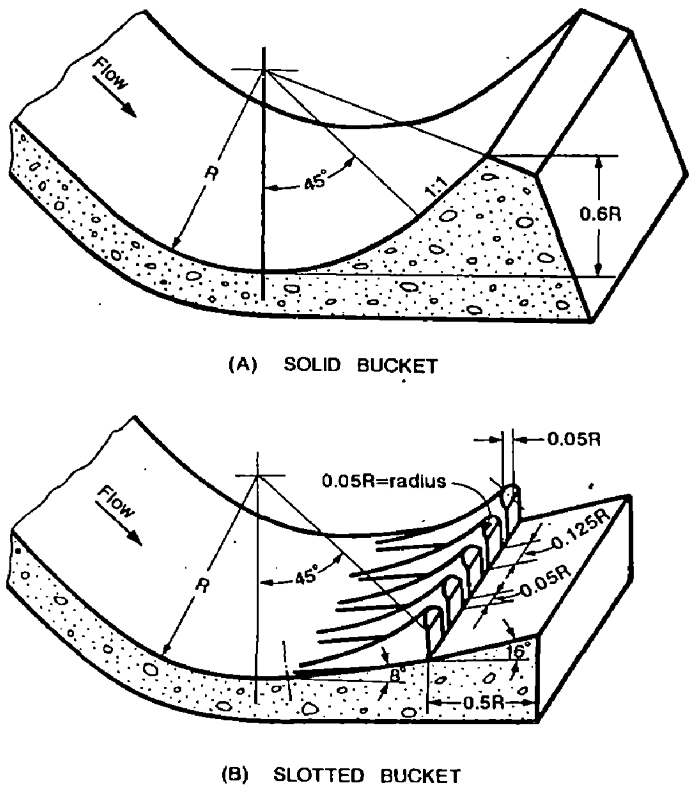


Figure 3.18. Sketch of Submerged bucket dissipators (source: U.S. Department of the Interior, Bureau of Reclamation.1987. Design of Small Dams, P. 398.

2. **Bucket Type Energy Dissipators – These are of the following three type :**

   a) Solid roller bucket,

   b) Slotted roller bucket, and

   c) Ski – jump (or flip or trajectory) bucket

Typical sketches of basin III type and Bucket type energy dissipators are shown in figure 4.12., detailed designs procedures are given in I.S. 10137 – 1982. Their performance for different discharges needs to be watched in a operation programmed. Monitoring of hydraulic jump is discussed below.

3. **Monitoring Hydraulic jump profiles**

Strip gauges should be painted every 10 m on the wing walls and long divide walls to observe the hydraulic jump profile in the prototype under different hydraulic conditions. Following observations shall be taken :

a). Upstream water level to know the head and discharge over the spillway

b). Down stream water level

before the point of jump formation i. e. at d1 and subsequently till tail water level achieved on the plates indicated above :

Check and compare d1 and d2 and the length of the jump.

3.12. Safety Maintenance of Dam and Appurtenant Structures

Every dam reservoir presents a potential danger. A probable failure of the dam means not only the loss of structure and the impounding capacity but the large quantity of water stored may also cause heavy damage to life and property in the areas in the immediate downstream vicinity of the dam on its failure.

The necessity for proper inspection and maintenance of dams and appurtenant structure is evident. The risks of a dam failure can be increased as much by neglect of proper and timely inspection and maintenance as by inadequacies in design and construction.

The dam and appurtenant structure shall be under the overall charge of an officer, who has been specifically assigned inspection and maintenance responsibilities. He should be available at the dam site particularly during flood season.

For unusual conditions like high floods, earthquakes, rock falls mountain slide, etc, which may effect the safety of the dam and appurtenant structures, project authorities shall make arrangements for the following action :

a) Prepare a flood operation Manual, enforcement rules and responsibilities.

b) To issue warning to downstream settlements inhabitants, plants, industries and transportation agencies;

c) To operate the spillway and outlets judiciously in the best interest of public safety, regardless of economic loss through loss in storage and power; and

d) To Inform appropriate authorities immediately of the unusual conditions and impending danger.

An officer in charge of operation shall act quickly in all emergencies. For this purpose the project authorities shall supply instructions on the nature of action to be taken in emergency. For situations where instructions do not exist the officer –in-charge shall use his best judgment.

3.12.1. Maintenance of Records

Records that may be required for proper inspection and maintenance shall be available at site. These shall be properly maintained and kept up-to- date by including latest information available. Data in respect of upstream gauging stations, flood warning system and communication channels, if installed, shall be properly maintained.

In case of concrete/ masonry, Earth/rock fill dams and Barrages/weirs, following records/ data shall be available at site:

1. Geological data on the foundation and abutment.
2. Copies of geological reports, details of special foundation and abutment treatment carried out.
3. A set of drawing according to which the project was constructed.
4. Details and location of instruments embedded/ installed in and around the structure.
5. Summarized data of observations on embedded/ installed instruments.
6. Summarized data on control tests, carried out during construction in respect of concrete, mortar and their constituent materials, if available.

7. Detail of construction history including stage of construction particularly in low blocks where considerable time elapsed prior to resumption of work.
8. Stage-wise construction record of the dam showing volumes and heights achieved in each season and time rate of progress
9. Reports on hydraulic model studies.
10. Record of special compaction done near concrete/ masonry structure, abutment contacts and outlet locations, if available.
11. Summarized records of compaction, control sampling and complete laboratory and field test results on all record samples.
12. Record of relief wells in earth/rock fill dams.
13. Detail drawings of all service facilities like internal lighting, emergency lighting, drainage, etc.
14. Record of corrective measures, repair or treatment that have been done subsequent to completion.
15. Important inspection reports and reports of consultants.
16. Detail of design criteria followed.
17. Photographs showing all phases of construction.

3.12.2. Arch dams and Buttress Dams

Data similar to that listed in concrete/ Masonry dams shall be collected. In additional data may be decided to be collected according to inspection and maintenance requirements of the structure. (Particular attention should be paid to the behavior of abutments and the deflection of the main structure).

3.13. MONITORING BARRAGES/ WEIRS, DAMS AND RESERVOIRS

EFFECT ON THE SYSTEM	PARAMETERS AND FREQUENCY OF MONITOTING
1	2
A. Aggradation Effect at Upstream **1. Primary Effect** i) Sediment deposit in river ii) Sediment deposit in reservoir. iii) Storage reduction in capacity of dam iv) Land slides in hilly regions **2. Secondary Effect** i) Rise in maximum water level ii) Increase loads/ stresses on gates, dam and other structures. iii) Reduction of free board, increase in fetch and wave action. iv) May lead to over flow and break of earthen dams **3. Tertiary effect.** i) Submergence of population areas (houses) ii) The river bed upstream of the barrage, weir is likely to aggradate resulting in increased afflux and reduction in freeboard provided in design. The afflux bunds (earthen embankment) may have to be raised, if found necessary, to restore the designed freeboard.	1. Observe river cross sections Number depend upon size of dam 2. Capacity survey of reservoir . Depends upon size 3. Monitoring water surface elevation in dam (storage capacity, free board). 4. Monitoring water levels and bed levels 5. Increase in the afflux, if any gauges. Monitor regularly one immediately upstream, of the work, one each at 1000 m and 2000 m upstream of the first.

CONTINUED

EFFECT ON THE SYSTEM	PARAMETERS FREQUENCY OF MONITOTING
1	2
B. Degradation and Aggradation Effect at Down stream	
i) Retrogression :	Retrogression of the river bed can be expected downstream of the weir/ barrage. In order that the lowering of the water level at any discharge condition does not exceed that provided for in the design, it is necessary to establish gauges on both banks, one immediately downstream of the work and two more 1000 m and 2000 m downstream of the first and to observe them simultaneously at least once a day. Remedial measures should be undertaken as and when required to ensure safety of the structure. (IS. 7349 – 1974)
ii) Discharge distribution and crossflow : Observations should be taken to find the discharge distribution through different bays of the barrage. If there is significant crossflow and/ or difference in discharge intensities through different bays, remedial measures should be taken to check this tendency for which improved regulations may be great help. (IS. 7349 – 1974)	
iii) Down stream River Training Works. The change in the river course shall be examined and remedial measures taken.	River survey in dry season.
The afflux bunds, guide banks and spurs shall be examined in the dry weather and necessary repairs, pitching and aprons carried out and completed well before the onset of monsoon. An adequate stock of boulders/stone shall be maintained close to the protection works for use in emergency. (IS. 7349 – 1974).	A detailed river survey covering the barrage/ weir and river training works upstream and downstream shall be carried out every year. The survey should preferably extend about one meter above the design flood level on both the banks on upstream side. Similarly the survey on downstream side should extend to a length up to which river bed changes occur

3.14. Inspections for proper safety, Operation and Maintenance.

Periodical inspection of dams and appurtenant structures is necessary to ascertain/ examine their condition and functioning. The main purposes of carrying out periodic inspection are :

a) To ensure the adequacy of the structures to serve the purpose for which they were designed.
b) To verify the condition of the structures and monitor their behavior.
c) To investigate condition that might cause distress to structures, and
d) To study the extent of deterioration based on which maintenance and repairs can be planned.

Adequate inspection shall be carried out by Component personnel to investigate the performance of the dam and appurtenant structures shall carry out adequate inspection. All inspection observations should be compared with the design assumptions and prediction, previous results, results of model studies and test and limiting values, where specified.

Inspection report on the condition of the structures shall be prepared and submitted by the Engineer-in-Charge of Inspection to the concerned higher authorities along with detailed comments. In case of major dams, besides these regular inspection, special inspection of all the works (including the dam, the reservoir and appurtenant works), at suitable intervals, shall be made by a committee of experts.

Safety of the dams is the principal concern of State Irrigation Departments.

Continuous monitoring of the behavior of various components of a dam, regular analysis of the data and timely remedial action can prevent a future catastrophe. Problem do not develop all of a sudden but become acute over a period of time. The general aspects of maintenance of large dams together with special reference to operation of same large reservoir in Rajasthan have been discussed in this paper.

CHAPTER - IV

CANALS SYSTEM

4.1. MANAGEMENT INFORMATION SYSTEM OF CANALS - (ALL ALONG CANALS)

Irrigation system is explained in chapter II Management Information System of head works, canal network and command area are inter linked and interacting. They influence each other and there may be lot of duplicacy. How ever duplicacy is avoided in field, data collection and analysis. The items included under one heading are not repeated and a cross references are given.

4.1.1. OBJECTIVES (PURPOSE) :

1. Reduce cost of operation and maintenance or keep it at minimal. It includes cost of M.I.S.
2. Reduce transit losses and theft
3. Up keep the full discharging capacity of channels
4. Satisfy the customers i.e., provide water to each and every individual beneficiaries/ branches, i.e., distributaries, minors/ industries farmers in accordance to predetermined norms/ share. Up keep proper accounts of water delivery. Also ensure proper use by farmers.
5. Upkeep the proper quality of water.
6. Collect revenue

M. I. S. of canal is most difficult, time consuming and costly. Its requires collection of field data, their analysis. The collection of field data depends upon the size, head discharge of the main canal, its length, discharges and length of distribution up to minors and gross command area of the irrigation system. Even monitoring in the command area, till water is utilized by crops is required for overall assessment. The last aspect of M.I.S. for command area is discussed in chapter V. Here it is restricted to canal network.

Because of the long lengths of canal network and large cost involved it may not be possible to measure discharges, sediment concentration, seepage loss at too many points. Therefore data should be collected only at selected points, analyzed, simultaneously and transmitted to the central points for rectification/ modification of discharges/ other correction by the top managers. For this purpose a canal may be arbitrarily divided into following five categories.

i) Very high capacity canal – say above 300 m^3/s (main canal)
ii) High capacity canal – say 100 to 300 m^3/s (main canal and branches)
iii) Medium capacity canal – say 20 to 100 m^3/s (branches and distributary)
iv) Small capacity canal – say, 1 to 20 m^3/s (distributary and minors)
v) Very small capacity nearly 0.1 m^3/s generally water courses.

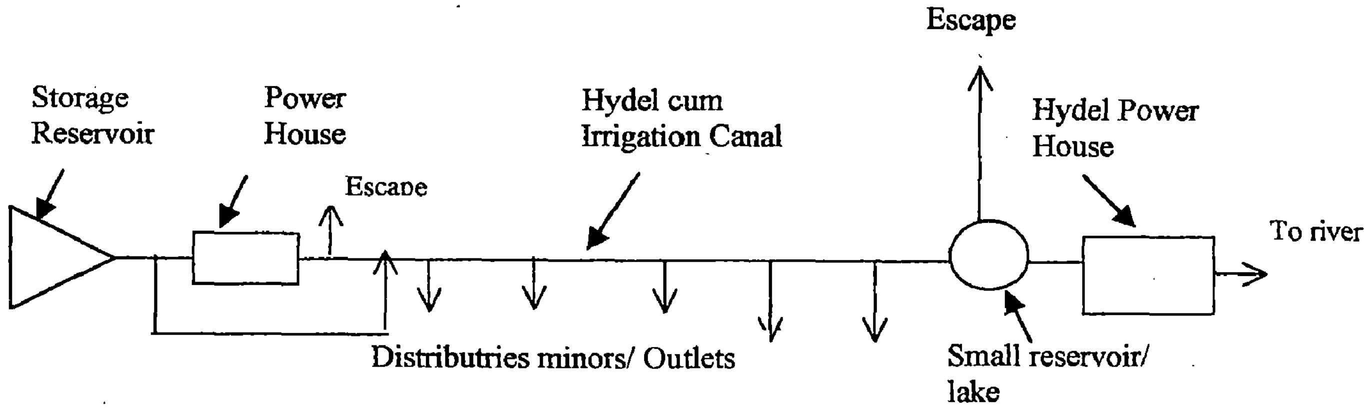
4.1.2. IMPORTANT ASPECTS OF CANAL MANAGEMENT

Canals may be multi purpose or single purpose. Generally combined for irrigation and power.

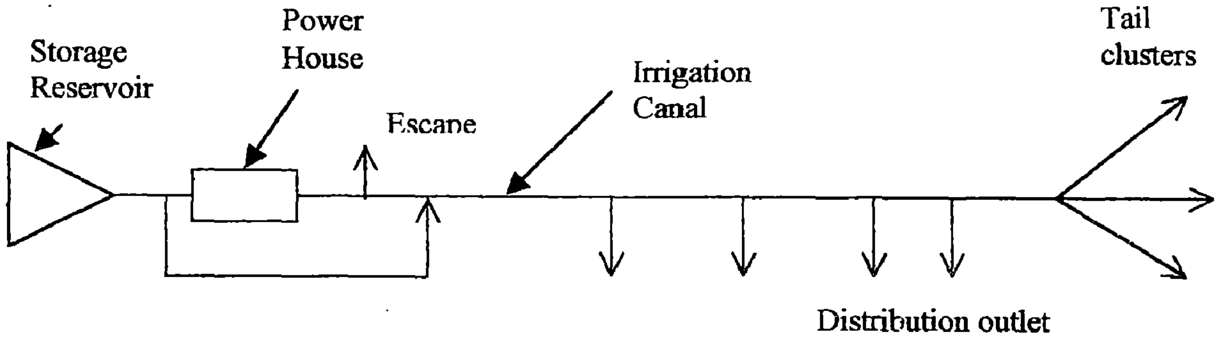
Three types of irrigation cum hydel channels are shown in figure 4.1. The canal may also supply water, for drinking purposes or to industries.

There are generally conflicts between uses. The requirement and running schedule differ.

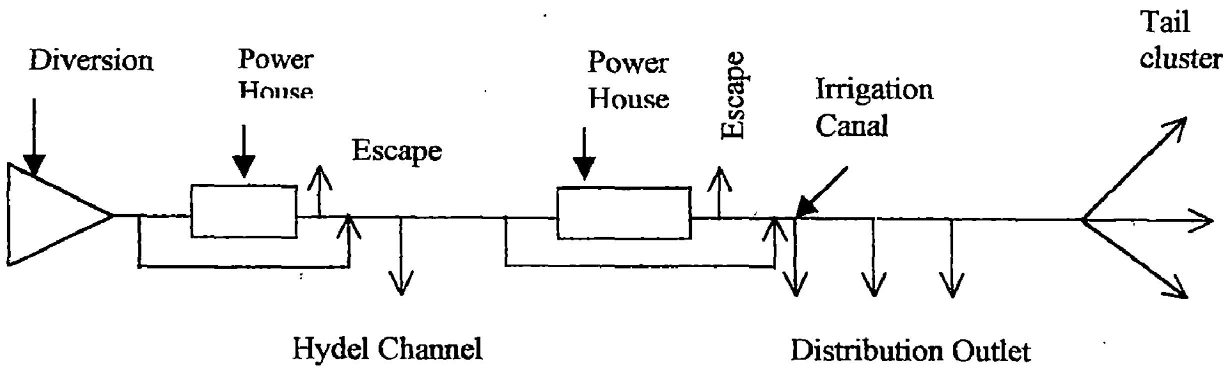
Some canals may be inter state/ or international or may be fed from a series of reservoirs. They stress upon joint regulation. Therefore the authorities stress upon joint management and regulation.



i). Alternative



(ii) Alternative



There may be many Power house at falls

(iii) Alternative

Figure 4.1. Schemes of Irrigation cum hydel channel.

Following parameters are continuously changing in a canal :

i) Sediment transport and deposition – and consequently depth of flow and cross-sectional area.

ii) Weed growth,

iii) Value of Manning's rugosity coefficient

iv) Water requirement availability and distribution between various uses

v) Seepage and operational losses.

vi) Flow characteristics – because of above (v) variances.

This requires – monitoring of following Parameters

i) Monitoring discharges, head losses

ii) Monitoring sediment inflow, sedimentation and out flow

iii) Monitoring seepage losses – all along canal

iv) Monitoring damages to canal banks inner and outer slopes, surface and seepage drains, structures/ repairs and maintenance.

v) Maintaining/ monitoring proper water accounts of canals and each individual farmer, (just like bank account).

vi) Maintaining/ monitoring proper revenue accounts.

4.1.3. MONITORING DISCHARGE MEASUREMENTS

Some of the most common problems observed in the canal system in India are :

i) Incorrect estimation of Maning's roughness coefficient (n) at the design stage. The actual value of ' n ' is often much more than one assumed for design. Thus the canals is unable to pass the required discharge at the required level. The monitoring of actual discharge passing through the canal is possible only by actual discharge measurement.

ii) Failure to identify the reaches of non-uniform flow. For example backwater reaches at structures such as regulators, cross drainage works, bridges etc. And draw down reaches at falls. There may be bottle necks at the structures.

iii) Lack of correct knowledge about the discharge coefficients of the gated and un-gated structures including outlets.

iv) Excess/ over size distribution head works outlets.

v) Inadequate appreciation of the problems of surges and flow stability. These and other difficulties in the canal operation result inability to meet the scheduled discharges to the farmers, the channel system fails in achieving its objective to carry the required discharge at the desired full supply depth.

The solution of all these problems requires discharge measurement. Measurement of efficiency in irrigation system also requires knowledge of the amount of water being applied which in turn requires flow measurement, in the conveyance system at a number of strategic locations.

Roles of discharge measurement

Discharge measurement in an irrigation system has following roles :

1). Prevention of unnecessary losses and wasteful diversions

2). To Ensure equitable water distribution and fulfillment of commitment of supplies.

3). Enforcement of delivery schedules in the Canal.

4). Adequate water application to crop land.

5). Water Accounting

6). Environmental management of Irrigation Projects.

7). Successful General Management of the irrigation project.

4.1.3.1. Strategic Locations of Water Flow Measurement in a Canal

The success of management of an irrigation system depends to a large extent on the correct monitoring of the discharges in the canal network at a number of strategic locations. This is done through continuous flow measuring devices located suitably in the canal system. The discharge measurement devices, temporarily or permanent installation are very costly. Also regular observation requires skilled, devoted and continues staff. Thus it is also very costly. Thus it is measured any at important point. Bairathi, (2002) has indicated. important locations, the purpose of measurement at that location, along with the type of structure/ method and the frequency of measurement required as given in table 4.1.

Table; 4.1. Strategic location, proposed method and frequency of water flow measurement in Irrigation System.

No	Location	Purpose	Type of structure/ method	Frequency of measurement And Remarks
(1)	(2)	(3)	(4)	(5)
1	At the reservoir generally at the sluice gate or any other deeper portion	To assess receipts i.e. in flows (amount of water received in the dam),losses (evapora-tion, seepage, leakage and absorption losses), and releases i.e. consumption	Gauges or water level recorder, semi automatic or automatic	Hourly or 8 or 12 hourly or daily or weekly depending up to the size of the reservoir and variability of inflow(see Notes)
2.	At the head of main canal (D/S of regulator)	To assess issues i.e. releases, losses, enforce Delivery schedules i.e. discharge and time.	Measuring structure with auto recorders (regulating structure can be combin-ed with measuring device) ,(see Notes)	Daily or twice or day. (see Notes) *
3.	At the head of f taking channel (D/S regulator)	- do –	- do -	- do -
4.	At suitable locations in between head and tail of all channels (Main, branch, distributaries or minor) such locations can be fall, cross drainage works, or outlets or otherwise at intervals 3 to 20 Km. Depending upon size of canal	To ensure proper distribution (proportionate/ share or according to demand)	- do -	- do -
5.	At the head of water course, d/s of outlet	To ensure reliability and proper quantity in the outlet.	Flumes or notches with auto recorders	- do -
6.	At the turnout (Nakka) of each individual farmer.	To ensure efficient water application	Portable or permanent small size structures (flumes or notches)	At the time of water diversion in Nakka.

Notes : 1. * The frequency of above observation may generally be daily and more during floods. For very small reservoir and inaccessible places it may be weekly.

2. Where ever measuring structure is combined with a regulating structure, the device must be calibrated at least once in a year by actual measurement.
3. The observations are required when ever the canals is running i.e. from opening date of the canal till closing.
4. Merely gauges are not sufficient to indicate actual discharges.
   It may be more appropriate to install the gauges with reference to a bench mark, used for the entire length of the canal. Thus with the gauge observations, actual water surface slope can be easily determined. This nice give more accurate discharges.
5. It may be seen that the cost of measuring structures is very high and may not be financially practical. But over all cost is very low in lieu of high efficiency. Also cost of installation is very low during construction stage improvement modernization or renovation stage it self.

There are several Indian Standards to measure discharges and list is given in Annexure 1.

4.1.4. MONITORING HEAD LOSSES IN CANALS

Once a canal is completed and water starts flowing in it the water level may not remain same as designed or expected (through it is supposed to be according it). Water level changes according to flow characteristics, energy loss, sediment deposit, and weed growth in the canal net work. There may be more energy loss at certain points and less at other points.

Following type of head losses (i.e. Hydraulic Energy Loss) generally occur in a running canal.

a) Friction Loss
b) Transition Loss
c) Entrance Loss
d) Exit Loss
e) Bend and Junction Loss
f) Head Gate (Head Regulator) Loss
g) Cross Regulator Loss

h) Trash Rack Loss

i) Losses at Bridges and other structures

Head loss from head to trail gives an idea of performance of the canal.

If sufficient care is not taken to account to the above energy losses, water level rises in the upstream to gain extra head or energy for the flow to occur. Some times water level depth of flow rises very much, up to the of banks, endangering safety. Also velocity and discharge decreases. If the losses are small, velocity increases causing erosion of banks and bed.

Each of the above losses are discussed in detail below :

4.1.4.1. Friction Loss

For open channel flow friction may be calculated by using Maning's Formula

$$V = 1/N \, . \, R^{1/3} \, . \, S^{1/2} \text{ (metric units)}$$

(S = energy slope = h_f)

or $$h_f = \frac{V^2 \, . \, N^2 \, . \, L}{R^{4/3}}$$

Where : h_f = head loss due to friction in m

V = velocity of water in m/s

L = Length of the canal in meter,

R = Hydraulic radius = $\left[\frac{Area}{WattedPerimeter}\right]$ in meter,

N = Rugosity Coefficient

h_f increases with increase in weed growth, silt deposition on (unlined canals).

Decrease in R also occurs with flattening of slopes that increases h_f.

A long canal may pass through a tunnel or pipe in some portions. In pipe following full, friction loss can be calculated either by above Maning's formula or by Darcy Waisb'ch formula as under :

$$h_f = \frac{fL}{D} \times \frac{V^2}{2g}$$

Where : h_f = head loss due to friction in m.

f = friction coefficient.

L = length of pipe/ tunnel in m

D = diameter of pipe tunnel in m

V = velocity of water in m/sec

g = acceleration due to gravity in / sec^2

The friction coefficient f, depend upon the Reynold number and the relative roughness Ks/D where Ks is the equivalent sand grain roughness and its value depend upon the surface characteristics.

For new concrete lined tunnel using steel forms the value of Ks varies from 0.015 mm to 0.18 mm. For welded steel lined tunnels, the value of Ks ranges from 0.05 mm to 0.1 m.

Because of fluctuations in the load demand, the turbines keep on accepting or rejecting water. This cause the flow in the water conduit system to be turbulent. For turbulent flow and in the range of Reynolds number between 3000 to 10,000 (normally expected in concrete lined and steel – lined tunnels), the friction factor f is calculated by using for formula :

$$1/f = 2.0 \log_{10} x\ 1/2E + 1.74$$

where : f = friction factor (for use in Darcy's formula)

E = relative roughness = Ks/D

For unlined tunnels, the value of f depend upon the variation in cross – sectional area obtained in the field.

The friction loss factor may be estimated by measuring cross- sectional areas at intervals and determining the value of f by the following formula :

$$f = 0.00257\ \delta$$

$$\text{Where } \delta = \frac{A_{99} - A_1}{A_1} \times 100$$

A_{99} = area corresponding to 99 percent frequency, and

A_1 = area corresponding to 1 percent frequency.

For tunnels of non – circular section, the diameter D in Darcy's formula shall be replaced by 4 R, where R = A/P. The Darcy's formula thus read as follows :

$$h_f = \frac{fL \times V^2}{8\,g\,.R}$$

4.1.4.2.Trash Rack Loss

Trash racks are provided at the intake of a siphon in canal/ or tunnel to prevent the entry of floating debris. Where maximum head loss values are desired, it is usual to assume 50 percent of the trash rack areas clogged. This would result in twice the velocity through the trash rack.

Head loss varies directly as the square of the velocity. Therefore the velocity at the intake is normally restricted/ limited to about 1 m/s for the worst conditions. For maximum trash rack losses, the rack may not be considered clogged when computing the head loss or the loss may be neglected al together. The trash rack loss shall be computed by using the following formula :

$$h_f = K_t \,.\, \frac{V^2}{2g}$$

Where : h_f = trash rack head loss,

K_t = loss coefficient for trash rack = 1.45 – 0.45 $(a_n / a_t)^2$

a_n = net area through the trash rack bars,

a_t = gross area of the opening

V = velocity of water in net area, and

g = acceleration due to gravity

4.1.4.3. Entrance loss

To minimize the head losses and avoid zones where cavitation pressure may develop, the entrance to a pressure tunnel is stream – lined to provide a gradual and smooth changes in flow. For best efficiency the shape of the entrance should stimulate that of a jet discharging into air and should guide and support the jet with minimum interference unit it is contracted to the tunnel dimensions.

Entrance loss shall be computed by the following formula :

$$he = Ke \ . \ V/2g$$

Where : he = head loss at entrance

Ke = Loss coefficient for entrance,

V = Velocity of flow

g = acceleration due to gravity

The value of Ke for circular bell mouth entrance varies from 0.04 to 0.10 with an average value of 0.05 and that for square bell mouth entrances varies from 0.07 to 0.20 with an average value of 0.16.

4.1.4.4.Transition Loss

In a canal/ tunnel transitions are often required at the intake, junctions with de – silting chambers, gate galleries, surge shaft etc., and at outlets. All these transitions cause head loss. To minimize the head loss and to avoid cavitation tendencies along the surfaces, the transitions are normally gradual. Transitions can either be for contraction or for expansion.

For contractions, the maximum convergent angel does not exceed that given by the relation ship.

$$\text{Tan } \theta = 1/F$$

Where :

θ = angle of the wall surface with respect to its center line,

F = Froude number = $V \ / \sqrt{gD}$

V and D = average of the velocities and mean depth/ diameters at the begging and end of the transition, and

g = acceleration due to gravity.

Expansions are more gradual than contractions because of the danger of cavitation where sharp changes in the side walls occur. Expansion angle is generally be based upon the following relationship;

$$\text{Tan } \theta = 1/2V$$

4.1.4.5. Bend and Junction Loss

Bend and junctions in hydraulic canals are unavoidable owing to their functional and constructional requirements. These bends and junctions also cause loss of head which must also be computed.

Bend loss : Bend loss depends upon the relative roughness Ks/D and r/d ratio, where Ks is the absolute roughness, D is the diameter of the tunnel and r is the radius of the bend. The head loss due to bend is given by :

$$hb = K_b.\ V/2g.$$

Knowing the values of Ks/D and r/d, the value of K_b for 90° bends may be obtained from fig. 4.2. and that for bends with deflection angel other 90° from fig . 4.3.

4.1.4.6 .Exit Loss

Where no recovery of velocity head will occur, such as where the release from a pressure tunnel discharges freely or is submerged or supported on downstream floor, the velocity head loss coefficient K ex shall be taken as unity.

Head loss at the exit would be calculated by using the formula :

$$h_{ex} = Kex\ .\ V/\ 2g$$

Where : h_{ex} = exit head loss in m,

Kex = loss coefficient for exit,

V = exit velocity in m/ sec.

g = acceleration due to gravity in m /sec^2

Fig. 4.2. Head Loss Coefficient for 90⁰ Bends

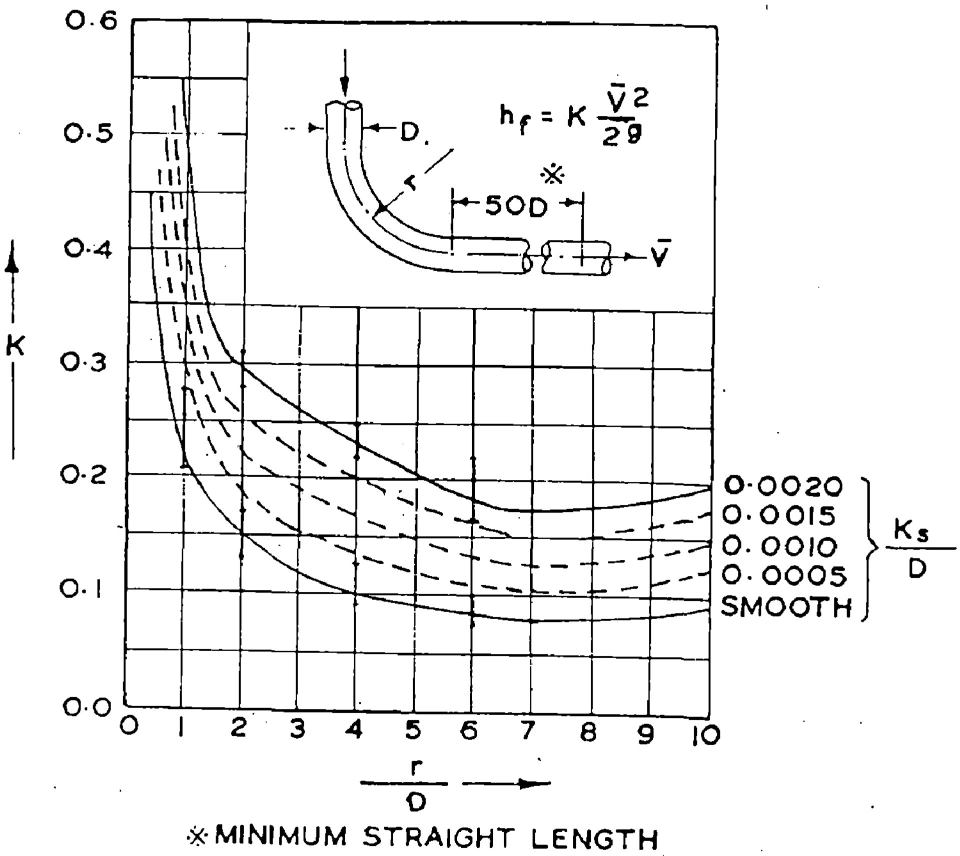
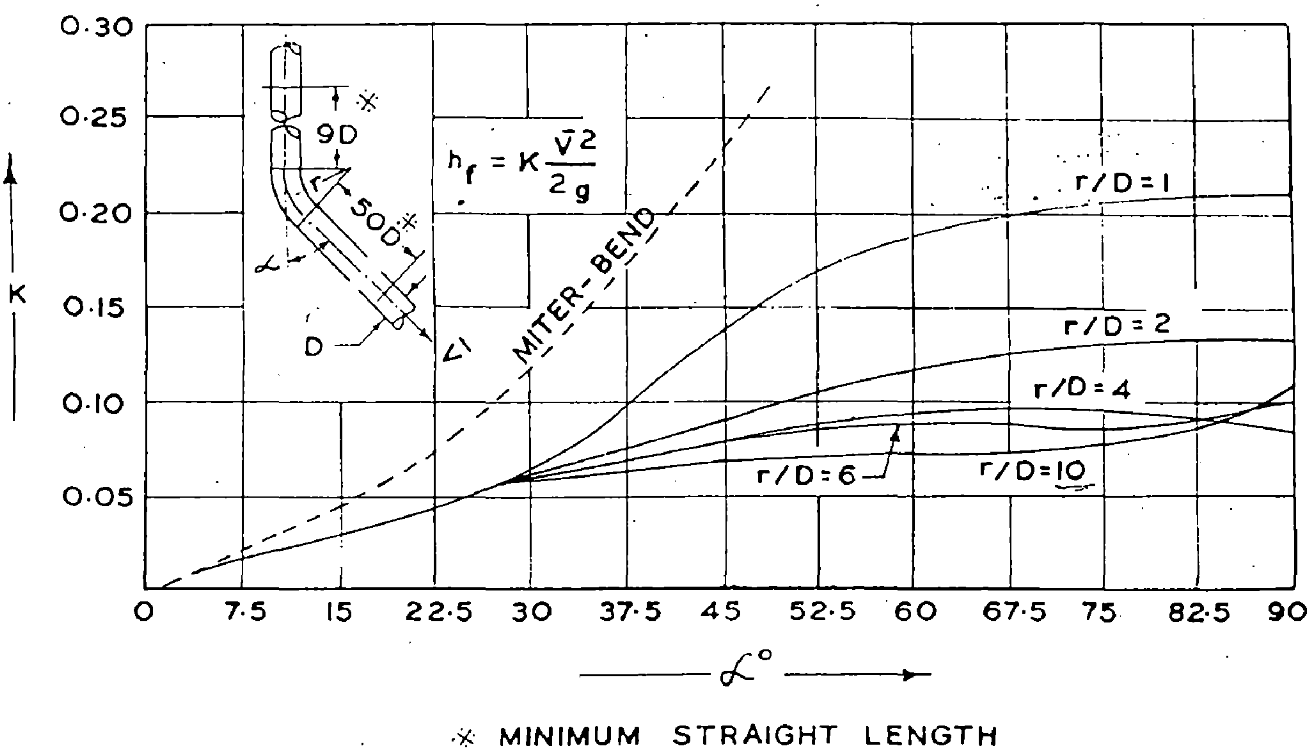


Fig. 4.3. Head Loss Coefficient for Bends Other than 90⁰



4.1.4.7. Air locking in hydraulic pipes/ tunnels

Air may enter and accumulate in a pipe or tunnel as under :

a). During filling, air may be trapped along the crown at high points or at changes in cross – sectional size or shape.

b) Air may be entrained at intake either by vortex action or by means of hydraulic jump associated with gate opening, and

c) Air dissolved in the flowing water may come out of solution as result of decrease in pressure along the tunnel.

The presence of air in a pressure tunnel can be a source of grave damage as detailed below:

a) The localization of an air pocket at the high point in a tunnel or at a change in slope which occasions a marked loss of head and diminution of discharge.

b) The slipping of a pocket of air in a tunnel and its rapid elimination by an air vent can cause a water hammer.

c) The supply of mixture of air and water to a turbine affects its operation by a drop in output and efficiency thus adversely affecting the operation of generator.

The following steps prevent the entry of air in a tunnel :

a) Intake should be designed properly. A shallow intake is likely to cause air being sucked in.

b) Throughout the length of tunnel the velocity should remain constant or increase towards the outlet end.

c) Partial gate openings resulting in hydraulic jumps should be avoided.

d) Traps of pockets along high points and crown should be avoided

e) Thorough and careful surge analysis should be carried out to see that at no point on the tunnel section, negative pressure are developed.

4.1.4.8. Head gate, cross regulator gate and other gate losses :

The losses depends upon the gate opening and are equal to difference of upstream and down stream water level. Down stream water level should not be measured at the energy dissipator is hydraulic jump. It should be measured a little away from it.

4.1.5. Monitoring Seepage losses all – along canal

In general, it has been estimated broadly by Kennedy (1982), Irrigation commission (1972) that nearly 66% (2/3 rd) or water entering a unlined system canal is lost by way of seepage and joints ground water and only 33% (1/3 rd) is utilized by plants. Further, out of total loss, nearly 33% (1/3 rd) water is lost in actual water application in field and remaining 66% (2/3 rd) in the canal and water course conveyance system. Thus really 40 to 50% water is lost by seepage in canal network system and 21% to 15% in the field. Actual figures of losses vary from project to project and may be from 50 to even 80%. This immediately raises the following issues.

(i) Heavy wastage of costly water (huge money invested in canal network).

(ii) Water logging (rise in water table)

(iii) Ground water contamination

All above problem are site specific and vary from project to projects, area to area in a project, and time (with in a year of after years) in same area and are not common every where.

Most people and event, engineers at large, generally blame unlined canals as the root cause of it. The above problem can be seen in a lined canal network. Then they blame the type of lining and it quality.

There are three aspects of monitoring the losses :

(i) Losses from canal net work

(ii) Losses from command areas, and

(iii) Positive and negative aspect of losses

Losses of main canal and branches can be monitored to some extent, through it is also very costly. Monitoring of losses of distributaries, minors, water courses is very costly, time consuming due to very shear number, length and spread aver a larges command area. Still some monitoring can be done at a reasonable cost.

4.1.5.1. Water losses from the canal.

Water losses from the canal can be grouped under following heads :

(i) Operation losses

(ii) Seepage losses and

(iii) Evaporation losses

The operation losses are due to intermittent running of the canals, leakage from the gates. These losses depend upon the manner of operation and the condition of the channel and gates.

Gate losses are due to leakages through the water seals of discharge gates. Many times the gate may not fit well in the grooves and the bottom seal. It may be due to some obstruction or defective installation or tilting of hoisting arrangement. The losses depend upon the type and dimension of the gates, water pressure, type of water seals, surface finish and more or less upon the degree of care taken in the any general rules about the losses. But permissible leakage can be specified as the losses per unit length of the seals in term of liter per second per meter. Seepage losses from the canals may be considerable. Following factors influence seepage losses.

The seepage of water from irrigation canals is a complex process and depend on many factors, some listed below.

1. Soil Factor
   - (i) Soil characteristics of the canal bed and side slopes, permeability
   - (ii) Entrained air in soil, compaction.
   - (iii) Position of impermeable layer in relation to canal
   - (iv) Other geological factors – rocks, joints, crevices
   - (v) Soil moisture tension
2. Topographical Factor
   - (i) Ground slope at right angle to canal cutting/ filling/ one bank canal
   - (ii) Drainage levels of nearby drain and its location
3. Ground Water
   - (i) Position of ground water table in relation to canal
   - (ii) Velocity of flow of ground water, permeability
4. Canal Design and Operational Factors
   - (i) Wetted area or shape of the canal; lining and its effectiveness
   - (ii) Age of the canal
   - (iii) Amount of sediment and its grade

(iv) Salt concentration in the canal water and soil

(v) Frequency of canal uses, i.e. regulation, perennial/non perennial, discharge and water levels in the canal.

(vi) Surrounding vegetation of canal, weed growth.

(vii) Temperature of water and soil.

Above large number of factors, more than 15, effect the conveyance losses considerably. Two typical seepage flow nets shown in figure 4.4. (a) and fig. 4.4. (b), indicate wide variation in losses, three typical physics of seepage losses in irrigation canal are shown in fig. 4.4.1. (A to C)

All the above factors are not stationary all along the entire length of the canal and in time also. All the factor change considerably due to heterogeneity of soil, as the canal pass through different types of topography and geology. In time scale weather is not constant in a year so canal regulation is not constant. Also ground water level change in a year. All parameter change year after year.

Still it has been generally accepted that the seepage loss varies mainly with the texture of the soil and subsoil, and the depth to the water table. It is taken as proportional to the wetted perimeter and is affected by the depth of flow.

4.1.5.2.Seepage Measurement Methods :

There are four following principal methods for measuring seepage losses from operating canal system. A few other methods have been tried, such as the use of salt penetration or radioactive tracer tests but these have not proved to be as reliable as the four listed.

1. Inflow-outflow : This method entails measurements of the irrigation system water inflow, outflow, deliveries, and leakage through gates, etc., makes an estimate of gross losses including seepages as the residual differences, over a specified period of time. The system can continue to operate while measurements are made.

2. Ponding : In this method dams or bulkheads are placed in the canal, water is pounded to the operating depth, and the drop in water surface over time noted and the seepage calculated. The canals may be taken out of operation for several days unless the are done during a time when the canals are not needed.

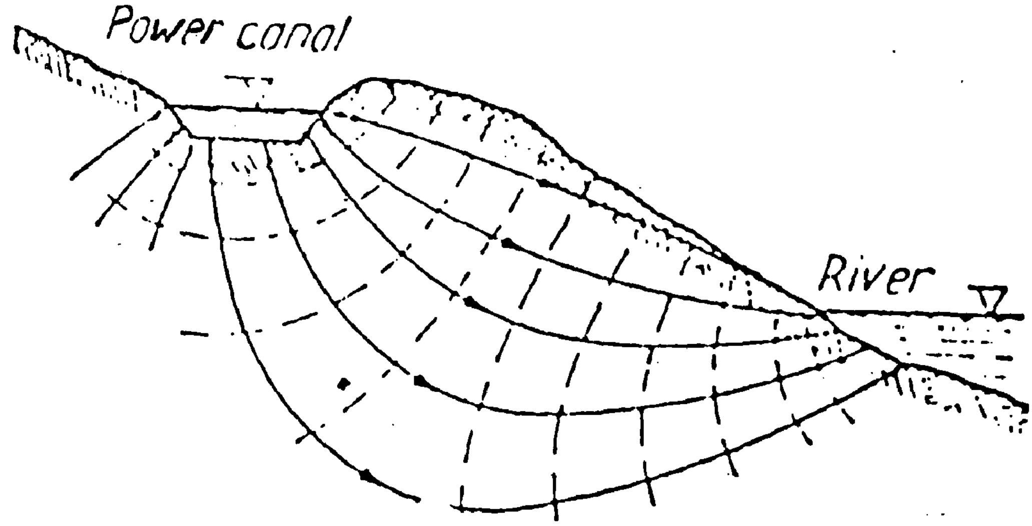


Fig. 4.4 (a). Seepage from elevated canal towards the river

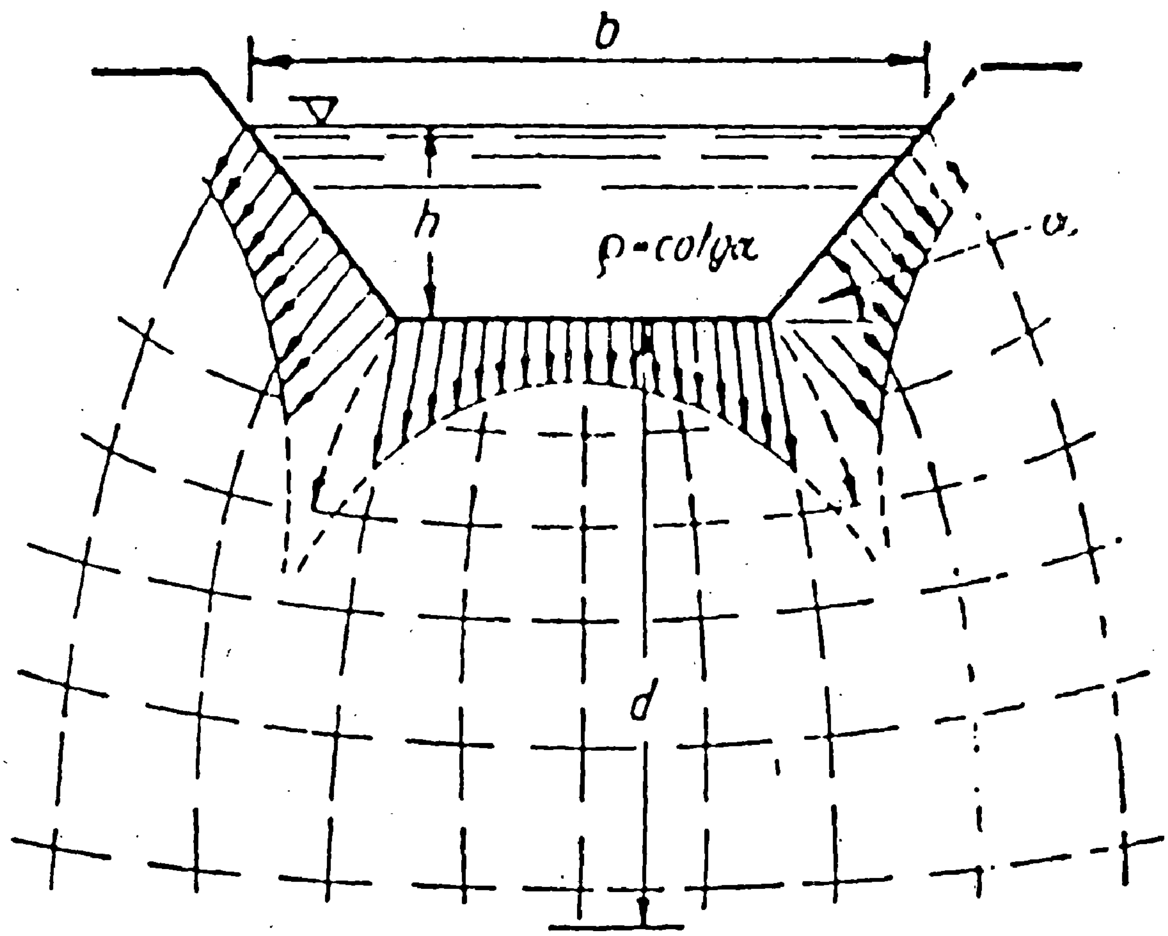
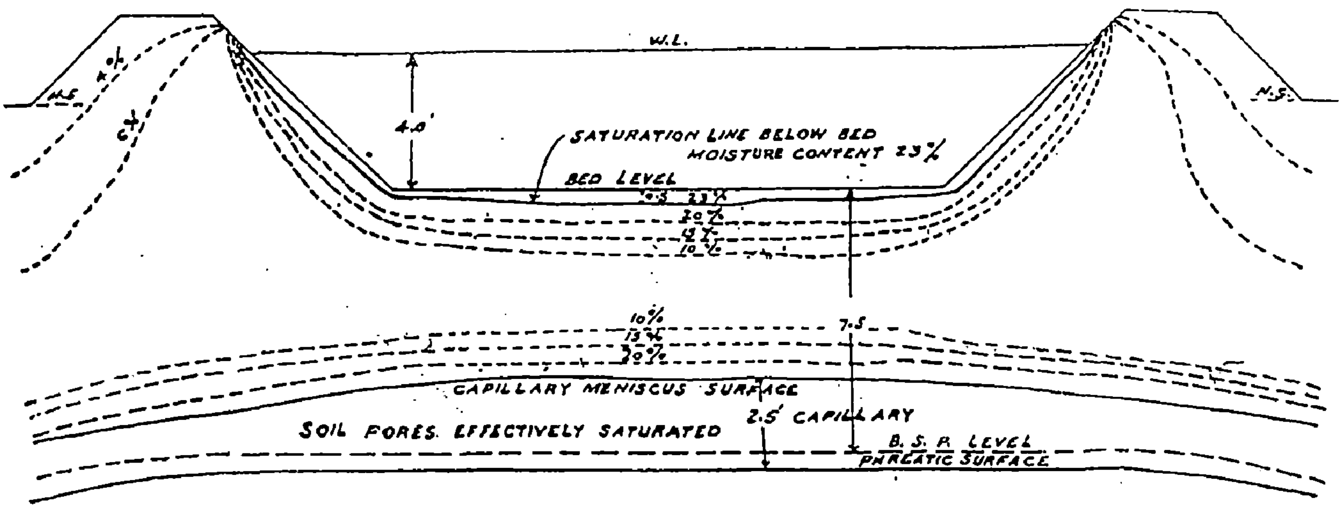
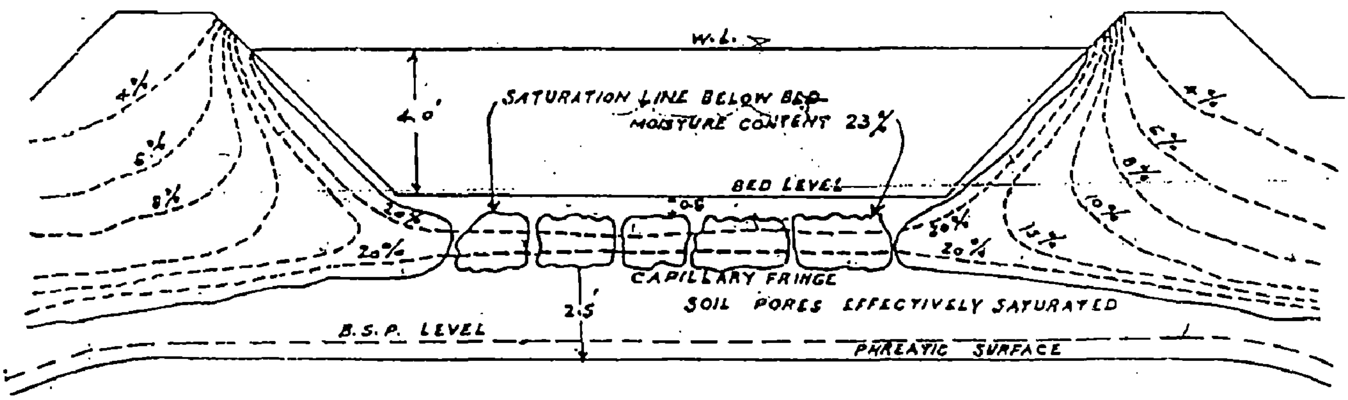


Fig. 4.4 (b). Flow pattern for seepage from the canal in case of deep ground-water table.

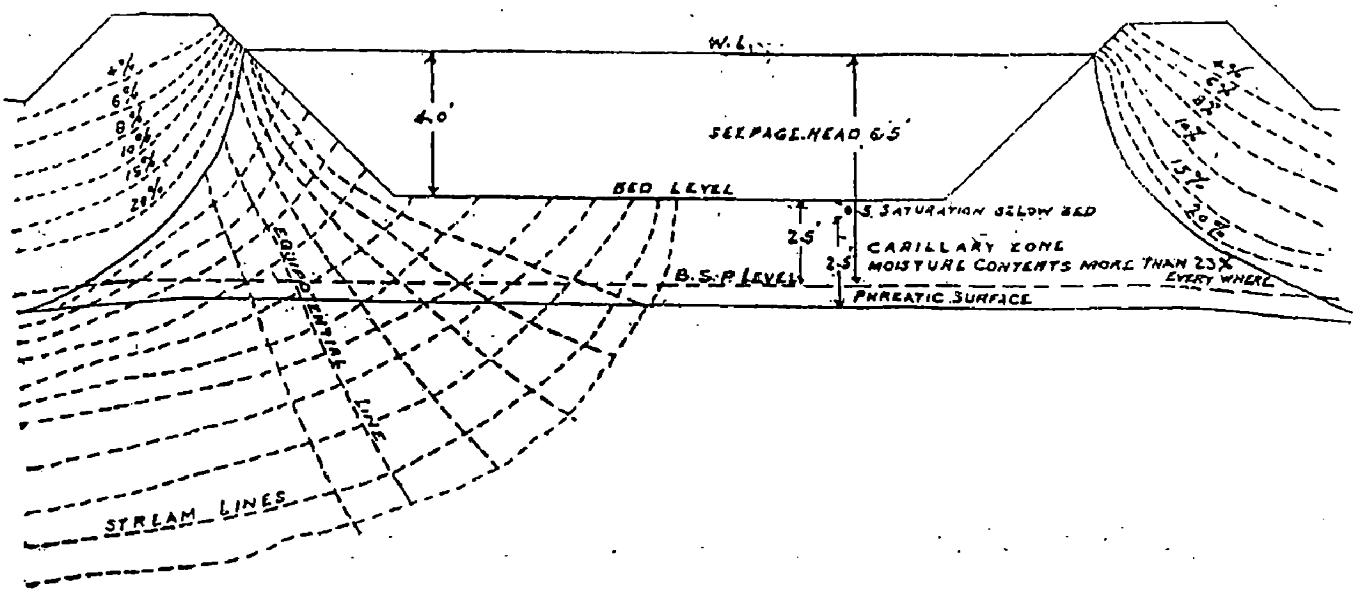
PHYSICS SEEPAGE LOSSES IN IRRIGATION CHANNELS



(A) Rising Spring Level (Unsaturated Conditions) Spring level below bed 7.5 to 4 m
Full Saturated = 23% by weight



(B) Rising Spring Level (Partially Saturated Condition), 4.0 to 2.5 m below bed.



(C) Rising Spring Level, Saturated Condition, Spring level below bed 2.5 to bed

Figure : 4.4.1. (A to C)

3. Seepage meters : Using one of several different types which have been made and tested, spot measurements are made along which have been made and tested, spot measurements are made along banks and beds of operating canals. It isolates a small area of canal (0.8 – 2 sq. ft) (0.07 – 0.19 sq. m.) and measures the seepage under the same head as in the canal.
4. Hydraulic conductivity : The results of soil surveys and extensive determinations of the in –place hydraulic conductivity (permeability) subjacent soil along the canal are used to calculate (estimate) the seepage.

Comparative advantages and disadvantages of these method are discussed below.

Ponding : Ponding test are often considered a "standard" against which other results can be compared.

Advantages	Disadvantages
1. The test procedures are simple and accuracy of data observations generally can be quite good. 2. can be sued during construction stage in completed short lengths of channel, to check on degree of compaction and potential seepage, which may lead to improved work quality. 3. Applicable to both unlined and lined canals.	1. Cannot be used while canals are operating. 2. Does not reflect the velocities and sediment loads of operating conditions. 3. Cost and time of constructing bulkheads or end-dikes become limiting with large canals. 4. Pond may have to be filled several times stabilized. 5. A nearby source of water such as a tube well or water transport by tankers is essential.

Inflow-Outflow : When conducted properly, this method can be considered fundamentally the direct, and potentially correct, method.

Advantages	Disadvantages
1. Reflects actual operating (dynamic) conditions. 2. Observations can be made without serious interruption of irrigation schedules. 3. Equally suitable for all size of channels, large or small. However, as the number of branches or turnouts increase, the number of measurements and problems of stabilizing flows, also increase. 4. Applicable to both unlined and lined canals. 5. Water transport arrangements not required.	1. Highly trained crews of hydrographers are required to make accurate measurements. Usually this would include technicians skilled in current meter measurements, especially on larger canals. 2. Unless an annual, seasonal, monthly, or other fairly long time period is used, it is some times difficult to maintain channels in a steady state for several days, or hours, to make reliable measurements. 3. To bring seepage losses within a measurable range, the test reaches have to be fairly long, which may prevent accurate measurement over short stretches of special interest. 4. Unless off-taking channel gates are closed and made water tight during the measurement period, simultaneous measurements of those channels would have to be made. This may involve the deployment of a large number of observation of a large number of observation parties. If existing structures are to used for ascertaining discharges, they must be calibrated.

Hydraulic Conductive : U.S. Bureau of Reclamation experience has been that simple equations, based on seepage theory can reproduce measured canal seepage rates within 15 percent (9), provided, that all the necessary field data have been obtained. This approach should be used only if soil in, under and adjacent to the test section is thoroughly described, tested for hydraulic conductivity (permeability), and the water table level in relation to the canal is monitored.

Advantages	Disadvantages
1. Reflects actual operating (dynamic) conditions. 2. Provides seepage estimates which need not be corrected for evaporation. 3. Observation can be made without interruption of irrigation schedules. 4. Suitable for all sizes of channels. 5. For all but very small canals, may require less resources (personnel and money). 6. Data required provides more complete understanding of the seepage process for any situation.	1. Requires crews well-trained and competent in performing in-place hydraulic conductivity tests of soils, soil survey crews, and experienced supervising personnel competent in engineering aspect of ground water flow. 2. In locations where two or more canals exist, it may be difficult or impossible to estimate the seepage contribution of each. 3. Difficult to quantify seepage for relatively short sections of canals. 4. Theory not applicable to lined canals, although basic groundwater studies can provide values for seepage from such canals, but usually for only longer periods of time. 5. Evaporation losses must be added to estimated seepage losses to give total transmission losses.

It is easy to measure the discharges at location where the measuring structures are installed, and some staff is pasted at nearby places. Also it may be easy to measure discharges by current meter at Bridge locations. Losses and water accounts can be worked out from the see discharge measurements, as discussed below.

It is difficult to isolate the effect of seepage losses from canal and that from irrigated fields on the ground water level, i.e. recharge to ground water and rise in ground water table.

Therefore combined effect it is monitored in the entire area, command area.

Unlined canal network is not the only cause to above problems, listed in Para 4.2.11. (factor effecting cost of maintenance) and there are several other causes. This fact is more explicit when following more problems are seen in the same command (along with above 3 problems).

(i). Declining ground water levels

(ii). Land subsidence due to Ground water Pumping

(iii). Upcoming of Saline water

For easiness of good understanding first, later these problems are discussed in chapter V.

4.1.6. Maintaining/Monitoring proper water Accounts of canals.

Consider a irrigation channel, with three channels off taking let Q be total supply.

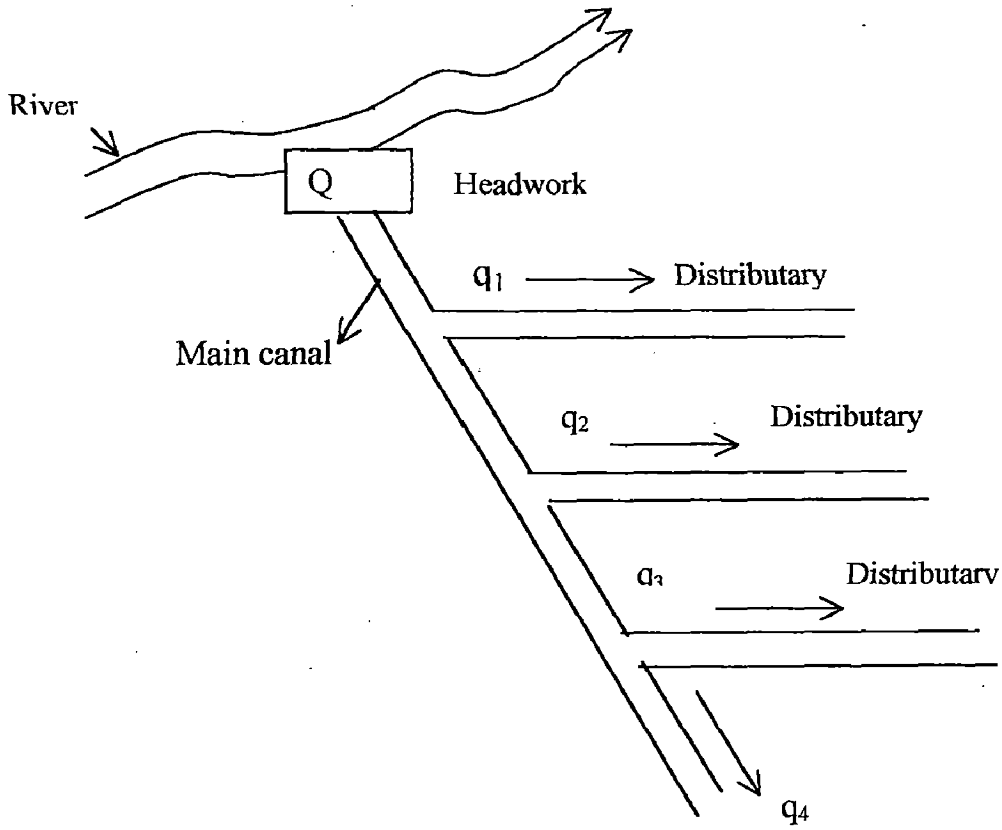


Figure. 4.5. Sketch water accounting in the Irrigation System.

And q_1, q_2, q_3, and q4 be the supply in each individual channels

Than $Q = q_1 + q_2 + q_3 + q_4 +$ losses

This can also be done volumetrically by multiplying with time t_1, t_2, t_3, and t_4 (time of flow in each channel) i.e. Total quantity of water used $V = q_1 t_1 + q_2 t_2 + q_3 t_3 + q_4 t_4 +$ losses. For any irrigation water accounting must be done to know the overall efficiency.

Discharge measurement has been discussed in Para 4.1.3. Also discharge can be worked out from head loss measurement discussed in Para 4.1.4.

Besides observations there can be mobile unit of discharge and loss measurements. This unit can work at selected or random location round the year in the canal net work and command area up to water courses or even in field applications.

4.1.7. Monitoring Sediment Inflow and Out flow

All canals, whether lined or unlined carry some silt. The flow of silt may be more in case of direct flow from weirs/ barrages or low dams or diversion schemes. The silt inflow is less in canals taking off from reservoirs. In reservoir much of the silt is deposited in it and clean water passes down in the canal. However, some silt may also pass in the canal depending upon the inflow/ release pattern and time, location of canal out let and sill level, water level in the reservoir during operation (for example in monsoon season).

4.1.7.1.Sediment/ silt in canals :

Silt inflow in a canal varies according to the silt inflow in the river, and the flow diversion. Silt may also enter into a canal from the topography, through which the canal is passing, such as wind blown sand and rain cuts on the cut slopes or the strom water inflow in the canal at inlets. All canals of IGNP, Rajasthan, India, are subject to wind blown sand/ silt into the canal. Typical example of strom water inflow into the canal are the inlets of Upper Ganga Canal, U.P., India in some canals, failures of inner slopes of banks have also caused silts and debris. This is also a seasonal and occasional phenomenon and is not uniform over time.

Silt is very harmful in power canals. It damages and erodes the blades of the turbines. In irrigation canals silt is useful when transported to the fields. It has high agricultural productivity and is beneficial to the crops. But this silt becomes harmful in irrigation canal also, when deposited in it. It blocks/ reduces waterway, carrying capacity/ discharges and may encourage weed growth on sides. When at high velocity it has an abrasion effect on lining or damages it. In earthen channels the bed and banks are eroded. The phenomena varies from project to project, velocity and nature of banks.
Low velocity helps in strengthening the banks, of unlined canal.

Therefore, the objectives of a canal design, operation and maintenance has been or are :

(i) Exclude entry of silt, debris (or sediment) in the canal, as much as possible, i.e., provide Silt Excluders at the source.

(ii) Whatever has entered may be ejected from a canal to extent possible, so provide Silt Ejectors, at appropriate locations. Pass out some portion of water according to silt inflow.

(iii) Also entrap the maximum silt or as much as possible in Silt traps/ Silt tanks or desilting chambers and flush out or eject at suitable locations. It may be called as a modified silt Ejector.

(iv) And lastly channel design should be such that it is non-silting and non-scouring i.e. carries the silt and passes out to the distribution system and to fields and not power canals. Since the sediment concentration change with time in a year and available water or discharge change.

Silt excluders and ejectors are discussed in Para 4.2.2 and 4.2.3.

The aspect of silt/ or sediment flow monitoring in canals of all size is similar to that in rivers. Detailed guides lines are given in IS. 4890 – 1968, important aspect of which are appended as Appendix 4.

4.2. CANAL STRUCTURES

4.2.1. Main Canal Head Regulators at Weir and Dams

The head regulators can be divided in two types as under :

1. At the head of main channel – off taking from a dam or weir/ barrage
2. Head regulator off taking channels

Sediment exclusion in the case of a main canal offtaking from a river slightly differs from that in a distributory head offtaking from a canal.

In the former sediment exclusion can be aimed at as the river can dispose of its silt passing it down stream.

In a distributory on the other hand , it is proportionate distribution of sediment according to the silt carrying capacity of the canal which should be achieved as the canal cannot dispose of any excess silt.

Energy dissipators in canal are provided at the down stream of regulator and falls.

At the head of main canal following aspect needs monitoring :

i). Water level up stream and down stream along with discharges passing .

ii) Silt inflow and out flow.

iii) Performance of energy dissipators.

4.2.2. Silt or Sediment excluders (IS. 13495 – 1992)

Excessive sediment load in canal can cause damage in variety of ways which results in many serious problems such as :

i). Reduction of channel capacity

ii). Silting up of canal

iii). Damage to power units on hydel canals.

iv). Obstruction to navigation.

v). Silting up of enter mediate storage reservoirs.

Silt excluders are provided in the river pockets of weir/ barrages when river characteristics predominantly occur as given below :

a). When there is high pounding upstream of the barrage to meet the canal discharge requirements;

b) When the river / tributary is bringing sediment load of the order of 1 500 ppm and above, and contains significant percentage of coarse and medium sediment;

c). If the river is in aggrading stage or wherever formation of bed bars/ shoals is noticed due to unfavorable approach condition;

d). Bed building stage of the river may occur due to barrage obstruction to flow as well as improper regulation on the barrage gates;

e). Due to adverse flow curvature upstream of the barrage head regulator, most of sediment load in high river stage may likely to settle in front of the head regulator and may enter its way in the canal;

f). Inspite of suitable location of head regulator, river training measures for arriving favorable curvature of flow, providing divide walls for separating pockets from barrage bays and suitable gate regulation of barrages/ under sluice bays for sand exclusion, a large quantity of coarse material may find its way into the pocket. In the such cases for efficient working of canal, silt excluders are required to be provided in the pocket, and

g). Exclusion of gravels and boulders could be achieved by providing barrage crest at river bed level and pounding operation only during non flood season.

Typical section of sediment excluder see figure 4.6.

Efficiency

The efficiency of an excluder is the percentage reduction in the quantity of sediment which would have entered the canal, had there been no such structure. For determining the efficiency of a sediment excluder, observations regarding the silt intensity may be taken as follows:

a) i) in the undersluice pocket upstream of the excluder tunnels, and

ii) in the canal downstream of the regulator.

or

b) i) in the excluder outfall or at the exit of excluder tunnels, and

ii) in the canal downstream of the regulator.

In the first case under (a) the percentage efficiency of the sediment excluder is worked out from:

$$\text{Percentage efficiency} = [\ (\ I_f - I_c\ )\ I_f] \times 100 \text{ - - - - - - - - - - - - - - } \quad \text{(Eq. 4.1)}$$

Where: I_c = silt intensity in parts per thousand parts of water by volume in the canal, downstream of the canal regulator; and

I_f = silt intensity in parts per thousand parts of water by volume in river pocket.

Generally, it is not possible to take sample of suspended silt in the river pocket. In that case, the intensity of silt in the flume or river pocket is calculated from set of observations mentioned under (b) above.

$$I_t = \frac{Q_C\, I_C + Q_E\, I_E}{Q_C + Q_E}$$

Where; I_E = silt intensity in the excluder,

Q_C = discharge in the canal, and

Q_E = discharge in the excluder.

From the value of I_f thus obtained, the efficiency is worked out as in Eq. 4.1. The efficiency of an excluder varies with river stage. It remains more or less constant so long as conditions of flow, slope and approach to the excluder do not materially change. Suitable river regulation has to be adopted to secure proper approach condition for the excluder.

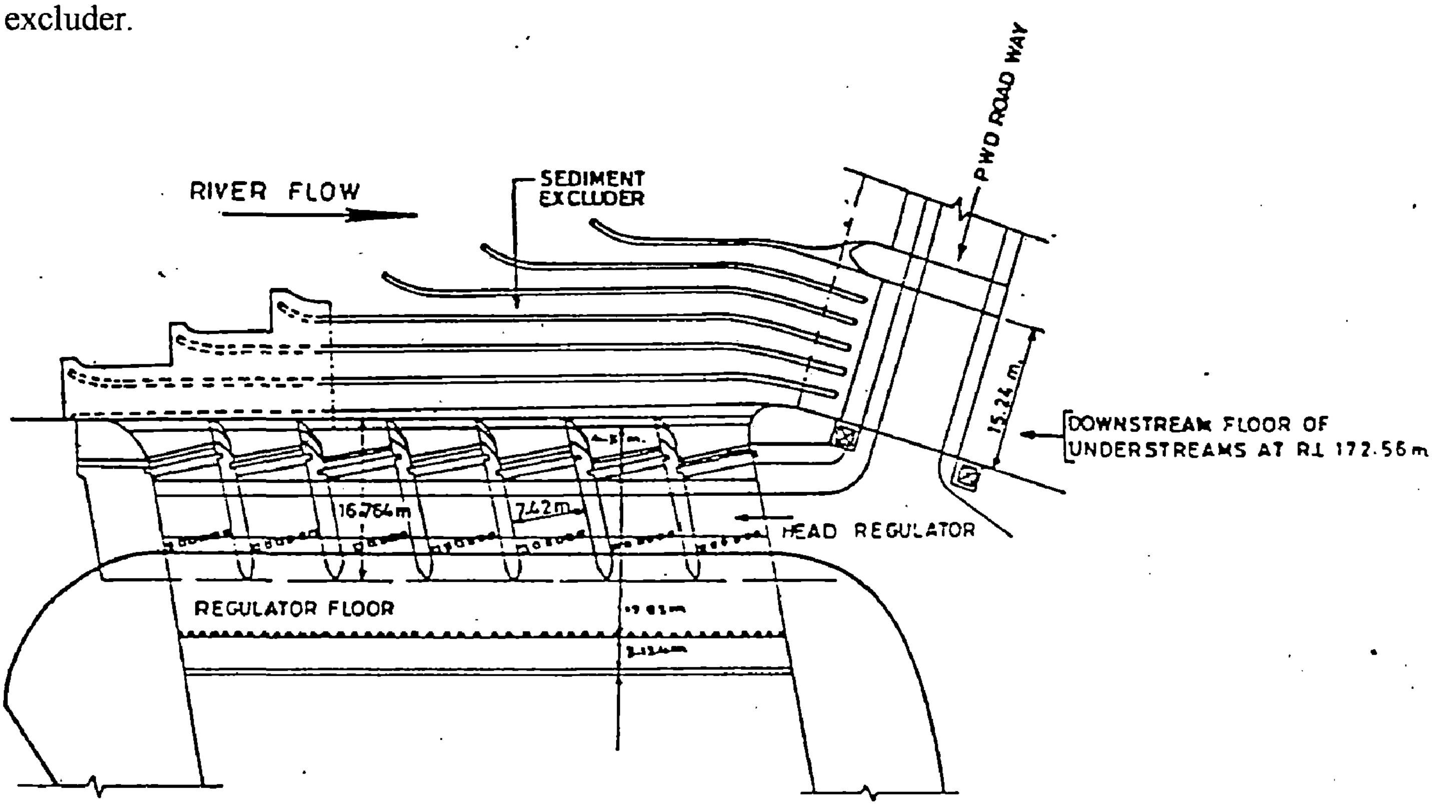


Figure. 4.6. Typical section for sediment excluder at head regulator of a canal

4.23. Silt Ejector

Despite measure which may be taken to prevent sediment entry in the canal, a part of suspended sediment of the river would always enter the canal. If the sediment transporting capacity of the canal is not adequate to carry this sediment, the canal would be silted. In such cases ejectors are provided in the head reaches to eject part of the coarse sediment that entered the canal.

The ejector provided efficient in extracting shingle and gravel entering the feeder. Thereafter larger number of ejectors have since been constructed on various canal system in India.

Though the principle of design of various components of the ejector are the same as for excluder, the following features need careful consideration. Typical of sediment ejector see figure 4.7. and fig. 4.8.

4.2.4. Head Regulator of offtaking canals and Cross Regulators (IS. 7495 – 1974)

Silt conductive power in offtaking canal is obtained from the following expression:

$$R = (r_1)^{0.63} \cdot (\lambda) \cdot 1/6$$

Where : $R = \dfrac{\text{Critical velocity ratio in the offtaking canal}}{\text{Critical velocity ratio in the parent canal}}$

$\lambda = \dfrac{\text{depth in the parent canal}}{\text{depth in the offtaking canal}}$

r_1 = silt conductive power in off taking canal

Critical Velocity Ratio :

The ratio of the critical velocity for a certain grade of silt to that estimated by Kennedy's formula for a standard silt.

Kennedy's Critical Velocity :

The velocity of flow in open channels which will not permit silting or scouring.

Silt Conductive Power (of Offtake) :

The ratio of the silt charge (by weight) of offtaking canal to silt charge of the parent canal.

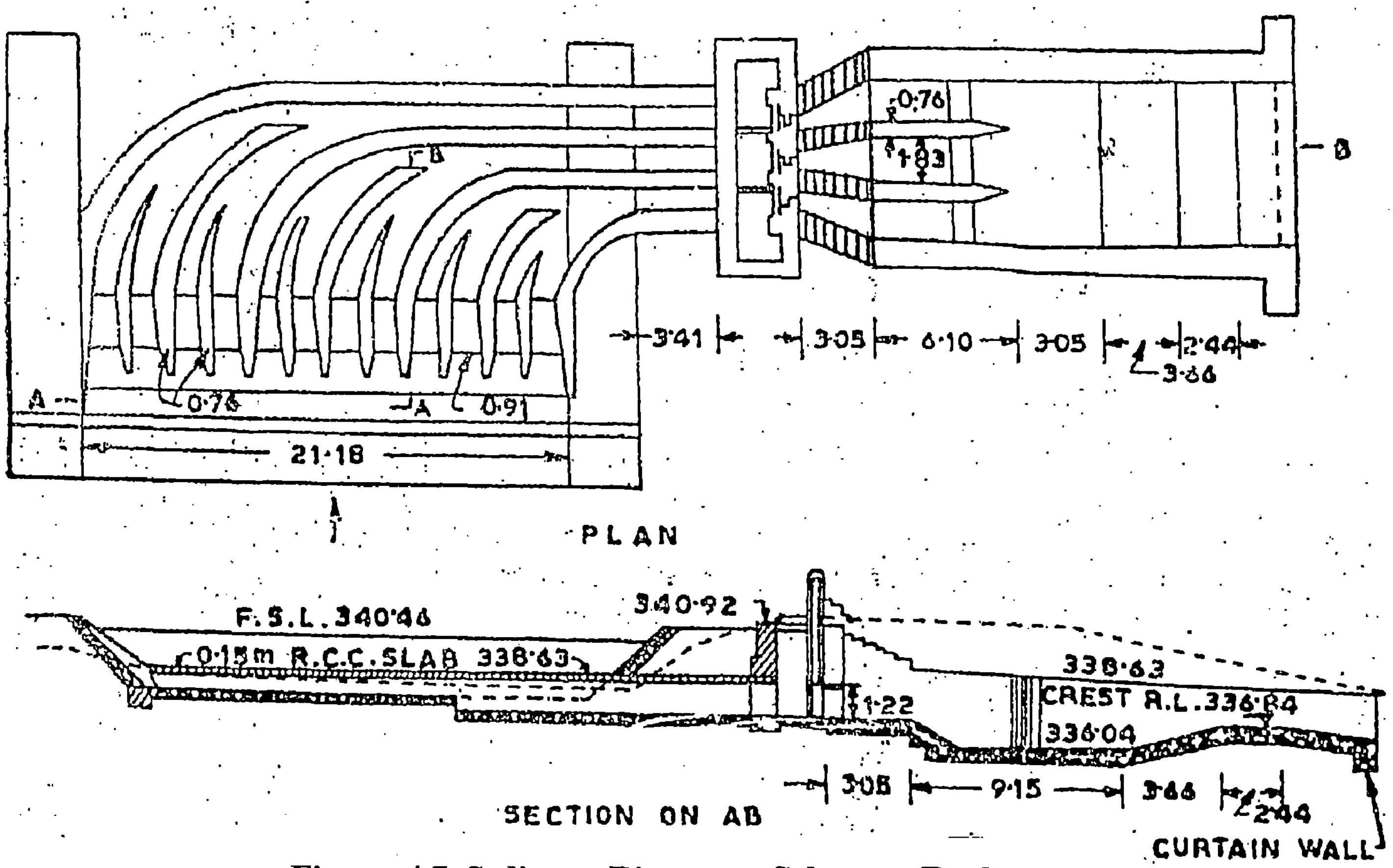


Figure. 4.7. Sediment Ejector on Selampur Feeder

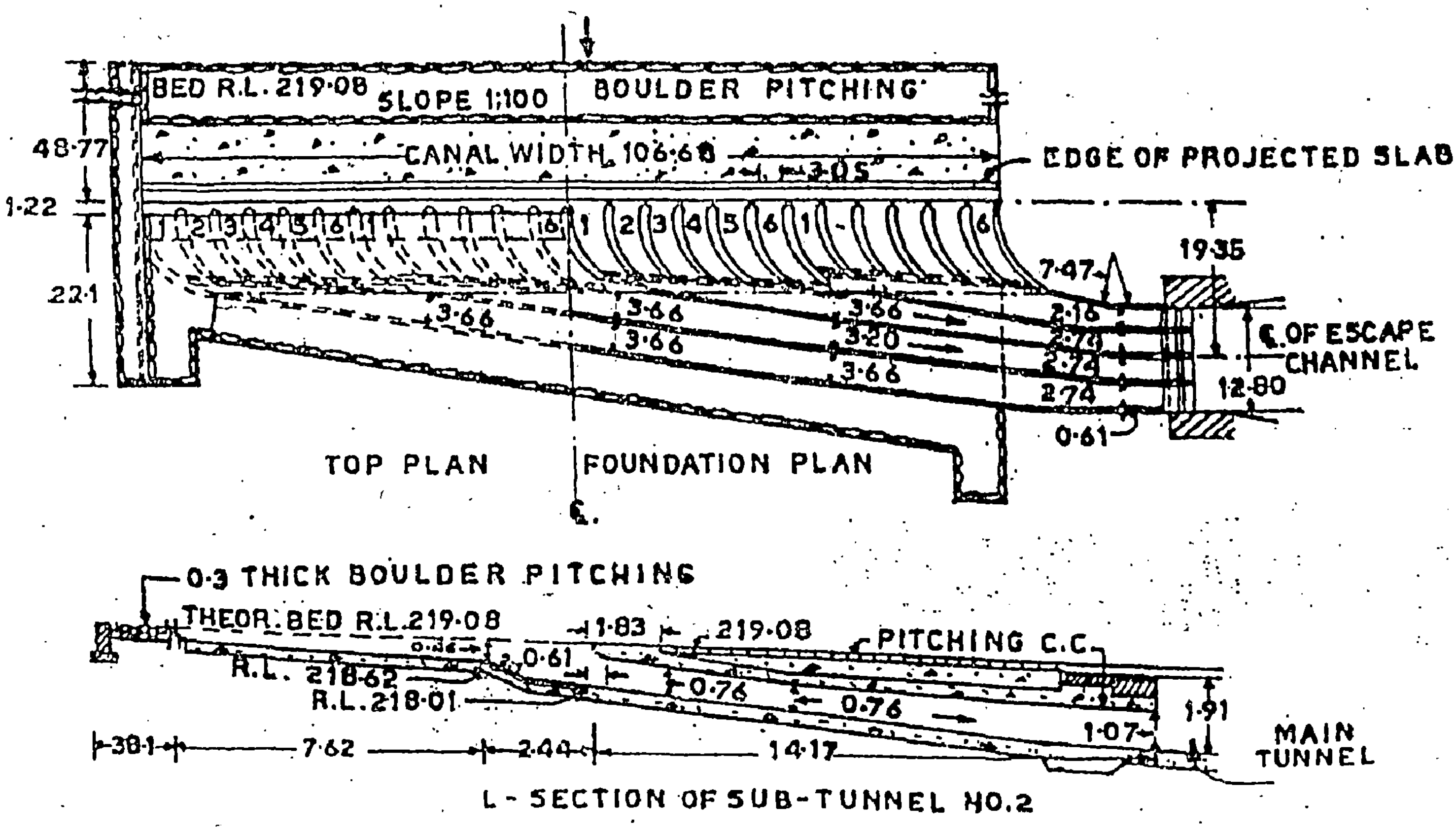


Figure. 4.8. Silting basin combined with Ejector on Sarda

4.2.4.1. Cross Regulator

Cross regulator is structure constructed across a canal provided with arrangements to regulate the discharge for the following purposes :

a). To feed offtaking canals in low supplies.

b). To escape water from canals in conjunction with escapes.

c). To control water surface slope in conjunction with falls, for bringing the canals to regime slope and section.

d). To diver supplies to other canals or part of the same canal to enable repairs and construction work.

e). To control discharge at an outfall of canal into another canal or lake, and

f). To ensure safety of canal lining where subsoil water levels are high.

From consideration of regime of channels it will be better if there are no structures across any channel but to carry on regulation without cross regulators is very difficult. The absence of cross regulators envisages constant supply being drawn from all offtaking channels but as demand on any channel is not constant with respect to time and as often it may happen that a particular channel, may have to be closed due to some repairs or on account of a breach in it, the supply in the parent channel cannot remain constant. If the supply is reduced the level will fall and other offtaking channels will not be able to draw full supply discharge. Thus cross regulator are a necessary evil.

Advantages of cross regulators :

i). When there is no head regulator on main canal the cross regulator to a certain extent minimize the disadvantage from want of head regulator.

ii). When the water level in the main canal is low they help in raising the level and feed the offtaking channel to their full requirements.

iii). They help in raising water level above the design and thus give full supply to lands slightly above the command level of the canal.

iv). They enable the parent channel to be divided into sections for easy regulation.

(v) They help in absorbing fluctuations in various section of the canal and thus reduce possibility of flooding tail reach and causing breaches there. The excess discharge is therefore retained all along the canal.

(vi) They help in closing of beaches in lower sections.

(vii) They facilitate working of the whole system by rotation in days of low supply and thus reduce silting in the branch canals.

(viii) They help in increasing Rabi revenue by ensuring full supply discharge to such of the tracts as do Rabi cultivation.

(ix) They facilitate construction of road bridges with little additional cost.

(x) If the cross regulators were not there all the branches could not be designed with a high full supply level so that much of the area will be thrown out of command.

Disadvantages of cross regulators :

(i). While cross regulators on the parent channel prevent silting of offtaking channels by making system of rotation possible, they by heading up water cause the parent channel to silt. Part of this silt may be washed away when the cross regulator is opened, but it must be admitted that too frequent heading up in case of a canal provided with many cross regulator will affect its working.

A relieving factor however is that in the lower reaches where the cross regulators are more frequent, water is usually clearer.

(ii) Cross regulators put in an undue large power in the hands of low paid establishment, who for personal gain are apt to misregulate. A strict watch, control by rotation tables and surprise visits outweigh their few disadvantages.

Discharge the cross regulator combined with fall shall is worked out using the following equation:

$$Q = C.\ B_t.\ H^{3/2}$$

Where; Q = full supply discharge in m3/s,

C = coefficient of discharge,

B_t = clear waterway in m, and

H = head over crest = full supply level upstream + head due to velocity of approach (ha) – crest level.

In the above formula the exact value of C, The coefficient of discharge depends on many factors, such as the head over the sill shape and width of the crest, its height over the upstream floor and roughness of its surface. Therefore, the value of C be determined by model studies where values based on prototype observations on similar structures are not available. Alternatively cross– regulator are calibrated by current meter observations

4.2.5. Cross Drainage Works

Drainage water intercepted by a canal may be disposed off by any one of the following methods :

(1). By passing the irrigation canal over the drainage. This is achieved through (i) an aqueduct, or (ii) a siphon aqueduct.

(2). By passing the drainage over the canal. This is achieved through (i) a super passage or (ii) a siphon.

(3). By passing the drainage through the canal so that the drainage and irrigation water are intermixed. This is affected by (i) a level crossing, or (ii) an inlet and outlet.

Typical of cross drainage can see figure 4.9 and fig. 4.10.

The following are the main features of monitoring for the best functional efficiency in respect to surface flow :

(1) Peak discharge

(2) Affluxed HFL of the drain

Some times the peak discharge may be more than the designed discharge or water may be inadequate. The afflux may be more than design.

It may not be possible to measure drainage discharge continuously. There fore after energy flood high water level should be measured. Peak discharge can be computed from the flow characteristics of barrel.

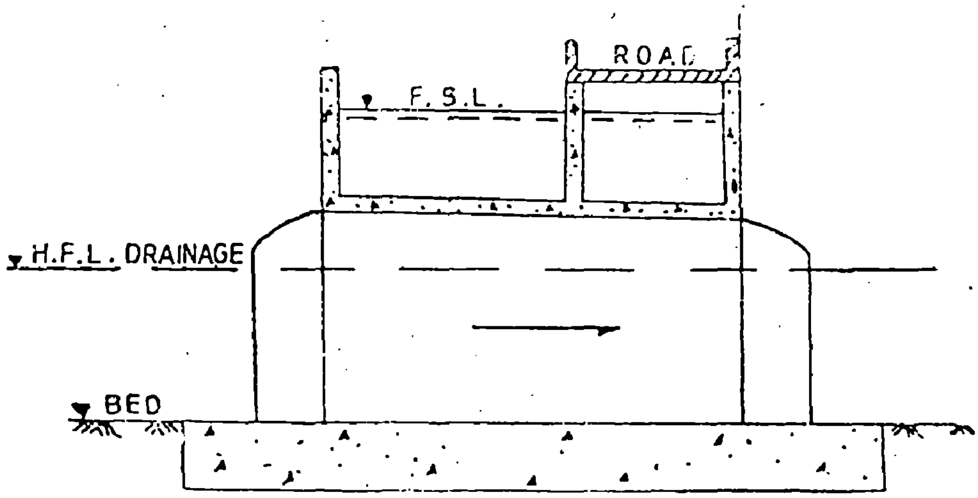


Fig. 4.9. Typical cross section of an aqueduct

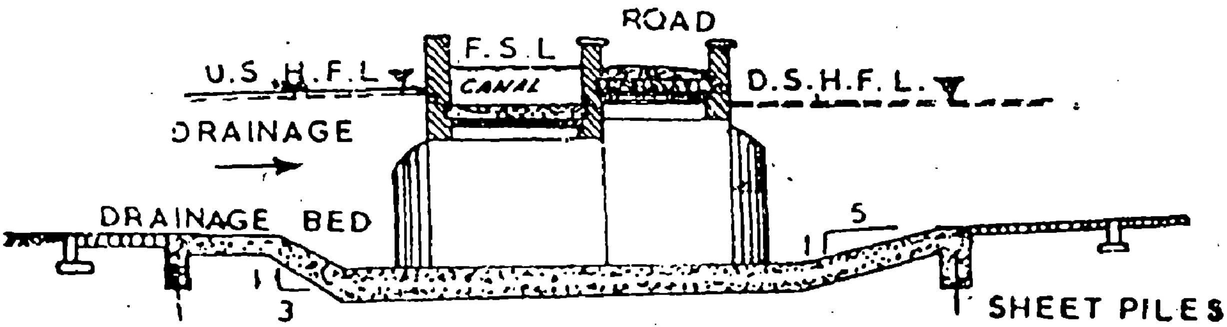


Fig. 4.10.Typical of an Syphon Aqueduct

4.2.6. Falls (Drop Structure)

Whenever, the natural slope of the country is steeper than the longitudinal slope provided in the irrigation channel, the difference is adjusted by constructing falls at suitable intervals. The location of a fall on a channel depends on the topography of the country through which the channel passes. In case of the main canal which does not directly irrigated any area, the site of a fall is determined by consideration of economy in cost of excavation in the channel. In case of the branch or distributary channels, the falls are located with consideration to command area. The procedure is to fix F S L. required at the head of all offtake channel and outlets and mark them on the L – section of the channel. The F.S.L. in the channel may then be so marked that it covers all the command points and allows for a minimum working head of 0.30 meter for the offtake regulators and 0.15 meter for the outlets. The desirability of combining a fall with a regulator, bridge, or some other masonry work, must be given due considerations, as such combination often results in economy and better regulation.

4.2.6.1. Type of Falls

Various type of falls, with different shapes, length and height of crest, have been tried one after the other since the 19th century, when large irrigation projects like Ganga, the Kaveri, and the Eastern and Western Yamina canals were constructed. A short description of various type of falls developed on these project is given below :

i) Ogee Falls

ii) Rapid Fall

iii) Trapezoidal Notch Fall

iv) Vertical Drop Fall

v) Glacis Fall

vi) Modified glacis type

The modifications are in respect of glacis, floor length and spacing, location and design of friction blocks and toe blocks. These glacis type falls may further be divided into;

i) Flumed or unflumed falls depending upon the crest width being smaller or equal to bed width of canal.

ii) Meter or non-meter fall depending upon whether the fall is also to serve as a discharge meter or not.

4.2.6.2. Exit Gradient and Uplift Pressure

The structure should be checked for safe exit gradient in accordance with accepted theories and adequate length of floor and downstream cut off wall should be provided for safe values of exit gradients. An exit gradient of 0.2 to 0.3, depending on type soil and importance of structure, may be considered safe for ordinary conditions. If the overall length of impervious floor is inadequate, the downstream curtain wall has to be deepened to the required extent.

4.2.7. Energy Dissipators at Regulators/ Falls/ Escapes

Energy dissipators in a canal are provided at the down stream of regulator and falls. At falls of more than 2 to 3 m, generally power house are provided still energy dissipators are required for by passing.

4.2.7.1.Types of energy dissipators

Different type of energy dissipators as listed below are often used alone or in combination of more than one, depending upon the energy to the dissipated.

Stilling Basins

(a) Hydraulic jump type stilling basins :

1. Horizontal apron type; and
2. Sloping apron type
3. Impact stilling basin or drop falls

The criteria for design of hydraulic jump type stilling basin of rectangular cross-section with horizontal and sloping apron utilizing various energy dissipators, for example, chute blocks, basin or floor blocks and end sills, are given at IS.10137 - 1982. Typical sketch's are shown in figure 3.17 and fig. 3.18. Monitoring of head losses and hydraulic jump is also explained in Para 3.11.

4.2.8. Bridges

In general, bridges including those combined with irrigation structures are designed for class A loading. Unimportant road bridges may, however, be designed for class B loading. Foot bridges may be designed for a loading of 800 kg/m^2.

Bridges are now usually constructed with R.C.C. decking and masonry substructure. Slab may be provided up to 6 m span beyond which a T – beam would be more economical.

Since very deep foundations are not required for bridges constructed across canal; they are invariably open foundations with concrete pedestals. In bridges of large spans, no floor is provided but the foundations are taken beyond the scour likely to occur when there is a breach in the channel.

Abutments and wing walls are usually designed as gravity structures to restrain the worst combination of various forces specified by Indian Road Congress with adequate factor of safety against sliding and overturning.

Proper inspections needs to be carried out and recorded in every canal closure.

4.2.9. Outlets

An outlet is a device built at the head of a water course to control the flow of water in it. An outlet connects the water course with the distributing channel and may provided a measure of discharge passing through it.

An out let shall be structurally strong and shall not have moving parts liable to derangements or requiring periodic attention.

4.2.9.1. Classification

An irrigation outlet may be classified as follows :

a. A modular outlet (or rigid module).

   It is an outlet whose discharge is independent of water levels in the distributary and which ensures constant or fixed supply within certain working limits.

b. A semi-modular outlet (or flexible module).

It is an outlet whose discharge varies according to the water level in the supply channel but is independent of the fluctuations of water level in the water course so long as the minimum working head is available.

c. A non-modular outlet.

It is an outlet whose discharge varies with the water levels in the distributary and water course.

Following are the important aspects of monitoring :

a. Tempo ring; It should not be tampered by the cultivators; if tampered, it should be easily detected.
b. Head and discharge relations for each outlet.
c. Sediment carried out by the out let

4.2.10. Cost of Maintenance, Monitoring Damages to Canals and Structures

Cost of maintenance of lined canal needs very careful assessment, some time it may be little less or same as unlined canals or may be even more. Initially just on completion i.e. on new canals, the cost of maintenance of lined canals is low and looks attractive. But just after one or two years it may generally be more. All lined canals are also subject to silt deposition and weed growth. Silt deposition and weed growth may be more due to flatter side slopes adopted in lined canal. Initially silt gets deposited on flatter side slopes and than weed stars growing. Weed growing damages lining. Also lining is damaged by the roots of shrubs and trees on the earthen slopes dowel etc above lining and particularly too much in cutting reaches and more in good rainfall areas. Roots of trees penetrates behind lining and cannot be easily extracted or removed. When cut up to the root level the shrubs and trees regrowing, with roots getting thicker. Typical examples are the canals of Mahi Bajaj Sagar Project, Banswara particularly left main canal (LMC) where shrubs tress (particularly Pepal and Babul nees) have created serious problems. These caused upheaval of lining. Also back water pressures (due to choking of drains) damages lining.

However masonry parapet walls on the top of lining and some earth backing behind dowel has helped in reducing growth of trees and penetration of roots. Typical examples are 10.000 kilometers of lined main and distribution network of IGNP in that desert.

Still silt clearance and weed removal is a common feature in most of lined and unlined canal system.

Leaves and seeds of trees in autumn fall in canal and help in germination of seeds and weed growth. Autumn season is sesame tree it is December and January.

The problems of rock falls , slope slip are same in lined and unlined canals, in fact the damage and repair to such lined canal is much more serious and costly. Typical example of serious damage to lining are the canals of Som Kamla Amha projects and many other small projects in Dungarpur district, Rajasthan India. India rock slopes slipped into the canal blocking the entire water way and damaging vertical walls of lining, it is advisable to avoid lining in such areas or better is to prefer closed canal (conduit) section.

Besides silt clearance, weed clearance, and clearance of grass, shrubs, trees on inner slopes, repair of lining , drainage arrangements, have to carried out.

The maintenance of surface banks, service road, surface drains and outer slopes including outer drains remains same in lined and unlined canal.

Thus a realistic assessment of maintenance of lined canal may usually be more than unlined canals. Routine maintenance is normally not less than in unlined canals.

Factor effecting cost of maintenance :

1. Size of the canal – b/d ratio, small medium,high and very high capacity canals.	For identical b/d ratio and capacity cost of maintenance may be same.
2. Topography partial cutting, filling, just cuttings filling heavy cutting, heavy filling, sloping ground Undulating ground.	Identical site conditions are likely to have equal cost of maintenance. Rather damages to lining in more in few cases.
3. Type of soil-Coarse/fine sands/gravel etc.(GP, GM, GW, GC, SC, SP, SW, MU, MH, etc)	- do –
4. Clay (CL, CH). Organic silts and silt clays with low/high plasticity.	
Hillocks/rock cutting.	
Stability of internal and slopes in filling/ cutting reaches.	More in flatter slope lined canals
5. Silt deposition on slopes, weed growth on slopes in free board portion and above in cutting riches.	
Silt entry from source and from area of canal passing its carrying capacity and exclusion, mechanism.	Practically identical cost
6. Climate and site specific conditions for weed germination.	- do – - do -
7. Drainage of rain water, rain cuts etc, and repair of earth section.	Extra in lined canals
8. Repairs of lining	- do -
9. Repairs of drainage behind lining.	
10. Repair of filter toe in heavy filling reaches.	Identical
11.Repair to damage by insects, rats, borrowing animals	Identical

Maintenance costs of distribution system is largely dependent upon their location, the climate and soil conditions.

The evaluation of maintenance costs should in general include above consideration and in the following schedule :

(a). For open canal systems Removal of weeds, moss, and silt Weed control on banks	Essential and to be done as and when required normally 1 to 3 times a year climate region specific may be once annually or at regular intervals according to site specific regular suite maintenance
Maintenance of service/ operating roads.	One in a year or occasional
Repairs to banks and linings, including inner slopes, outer slopes, rain cuts, drains, dowel, etc.	- do –
Clearing maintenance and repairs of drainage arrangement behind lining. Maintenance of structures Maintenance of gates and operation Opening and closer of canals	As per regulation schedule strict control on rate of opening closure required water of heavy filling reactor required for high capacity canal
(b) For pipe system	Once every year
Repair and replacements of pipe lines and appurtenance	Regular water and immediately repairs on notice
Maintenance of structures	Once every year
Removal of debris from structures	Regularly

Cost of Maintenance can be divided in two parts:

(i) **Hydraulic survey**

This essential to know the performance of canal

Also is required to allot the works on contract. Through some routine maintenance may be carried out regularly round the year, but that may not be sufficient.

(ii) **Actual cleaning operation and maintenance.**

This is required to allot the works on contract through some routine maintenance may be carried round the year, but that may not be sufficient.

Hydraulic survey helps in preparation of realistic cost estimates, and reporting the performance behavior of the canal therefore it should be always preferred Budget requirement must also be the kept separately for the two purposes.

The cost of hydraulic survey may be practically same in unlined and lined canal or may increase by 10 to 15% for very wide or deep channels. Hydraulic survey also helps in knowing the flow characteristics of channel and must be carried out once in a year.

Also a walk through survey of service road, inner slope and outer slopes should be carried after rainy season and a detailed survey be carried out once in three years. Grass on outer slope and inner slope should be auctioned every year after first rains, so as to make as many as cuts as possible. However grazing of animals should not be allowed.

All the precautions taken in earthen dam is also required in canal banks of lined or unlined canal.

CHAPTER - V

COMMAND AREA

Water flowing in a network of canals is diverted through a number of outlets to water courses and then to the each every individual farmer, or to small industries. This water to field is further utilized in the command area to irrigated the crops. Some farmers may (actually) take more water then others. Lot of water may be wasted. Revenue (water charges) are realized from farmers on the basis of types of crops and area irrigated. Or it can be charged on the basis of volume supplied i.e. volumetric basis. Because of shear number of individual farmers heavy monitoring is needed in the command area. Water requirement of crops, types of crops, area are all changing with time, season to season, and year to year. Following data/ aspects are required to be properly, adequately and reliably monitored in the whole command area.

(i) Area irrigated by canals, (a) by flow and (b) by lift
- by wells,
- by both (jointly), of irrigation.

(ii) Un irrigated areas, but cultivated, changes in cultivable command area

(iii) Intensity of irrigation

(iv) Cropping pattern
- In irrigated area and un irrigated area

(v) Water requirement of crops

(vi) Change in ground water table

(vii) Degradation of land, water logged areas, saline areas and improvement.

(viii) Water conveyance and application efficiency

(ix) Water quality

The command area of an irrigation project may very from a 100 Ha to Millions of Hectares.

Following data are required for water requirement of crops.

5.1. CLIMATIC DATA

1. Agro – Climatic parameters ; it should be include :

i) Rainfall

This is required to work out effective rainfall. This will change with time and area. Therefore all available data needs to be processed on daily basis. This also needs to be announced for irrigation scheduling.

ii) Temperature, wind, duration, etc.

This required for working out evapotransipiration and irrigation requirement. There may be very few station and they suffice. It can be processed on weekly basis.

iii) Topography

In India, survey of India G.T. sheets are available on different scales up to 1 : 50000. But detail survey and maps are required on a scale of 1 : 5000. This is also a **permanent B.M. data** and should be easily available to all field workers.

iv) Soil

Soil profile and analysis of texture up to a depth of 2 m.

Infiltration of top soil, hydraulic conductivity, and soil profile., below 0.5 m depth and up to ground water table. These do not change much. Therefore this is permanent **Bench Mark data**. These should be collected once and prepared like topographic G.T. sheets on the scale of contour maps, this is often required to monitor and improve the performance.

5.2. IMPACT ASSESSMENT OF CAD PROGRAM :

i) Irrigation Potential :

Area irrigated, season wise, year wise, crop wise, change season to season and its comparison with that planned and designed as per original approved project. Reasons for under utilization of irrigation potential, if any.

ii) Project Efficiency:

a. Study of behavior and efficiency of irrigation system.
b. Review of the operational and distribution practices.
c. Water use efficiency at outlet commands.

d. Adequacy and timeliness of availability of water.

e. Equity with special reference to rotational water supplies in the command area.

iii) Status of Conjunctive use of surface and ground water :

a. Available ground water

b. Present status of use

c. Scope for future

d. Extent of use of sprinkler and drip irrigation system

iv) Environmental impact :

e. Fluctuation of ground water table after irrigation

f. Pre and post monsoon status of ground water in states

g. Area affected by water logging/ salinity/ alkalinity

v). Agricultural Performance

a. Use of high yielding varieties

b. Use of fertilizers

c. Use of pesticides, fungicides, herbicides ,etc.

d. Use of other inputs

e. Credit facilities

f. Extension services

g. Production/ productivity of crops season wise.

vi) Socio - Economic impact

a. Socio – Economic Parameters :

i) Population

ii) Size of land holding

iii) Economic status

iv) Literacy

b. Organizational Review:

i) Review of organizational structure of CADA as well as staff engaged in irrigation system operation.

c. Farmer's participation in irrigation management :

i) Water Users Associations Formed, registered and in actual operation;

ii) Status of functioning of Water User's Associations;

a. Collection of water rates;

b. Maintenance of irrigation system; and

c. Conflict resolution

iii) Comparison of various Models of WUA in States of AP, MP. And Tamilnadu.

iv) Benefit – Cost (BC) analysis of the project

a. The original BC ratio and the present BC ratio with and without CAD expenditure.

b. Assessment of Internal Rate of Return and Economic rate of Return.

5.3 ENVIRONMENTAL MANAGEMENT OF IRRIGATION PROJECTS

Irrigation project are not simple blessings in disguise. They have very high positive and negative environmental impact. In the beginning, there appears more positive aspects rather than any negative impacts. But slowly with the operation of the project, the negative impacts starts coming up and become more and more explicate visible as they become severe. Such impacts are water logging, salinity, deterioration of surface and ground water, mosquitoes and malaria infections, toxic effects on human and animal life

Poisonous affect of insecticides, pesticides etc., and land degradation and finally land and health hazards.

Civilization which developed with irrigation starts perishing with irrigation.

A schematic representation of the potential pollution from irrigated agriculture is shown in figure V – 1. Excess delivery of water causes seepage, deep percolation, rise in water table and related problems. Excess application of fertilizers and chemicals is also degrading the land and quality of return flow.

Details of water accounting, application efficiency are discussed below and that of water quality in chapter VI.

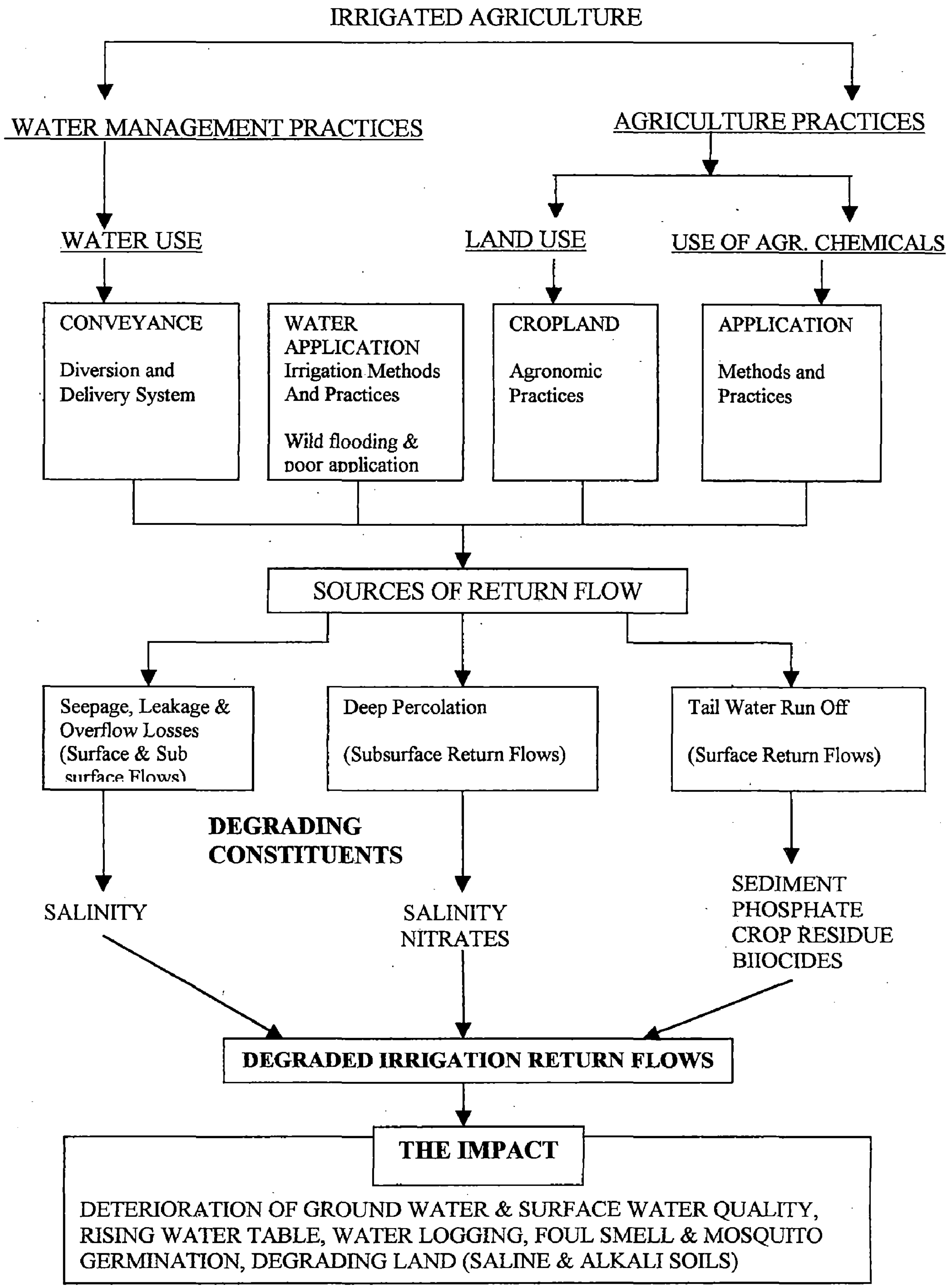


Figure ; V - 1 : Potential Pollution from Irrigated Agriculture

5.4. WATER ACCOUNTING OF FIELD AND EACH INDIVIDUAL FARMER

Some example of water accounting of the irrigation in field is given below :

a) At the irrigation field.

Consider an area a to be irrigated. Let there be inflow q_1 for time t_1 in the cannel of field and q_2 outflow for time t_2.

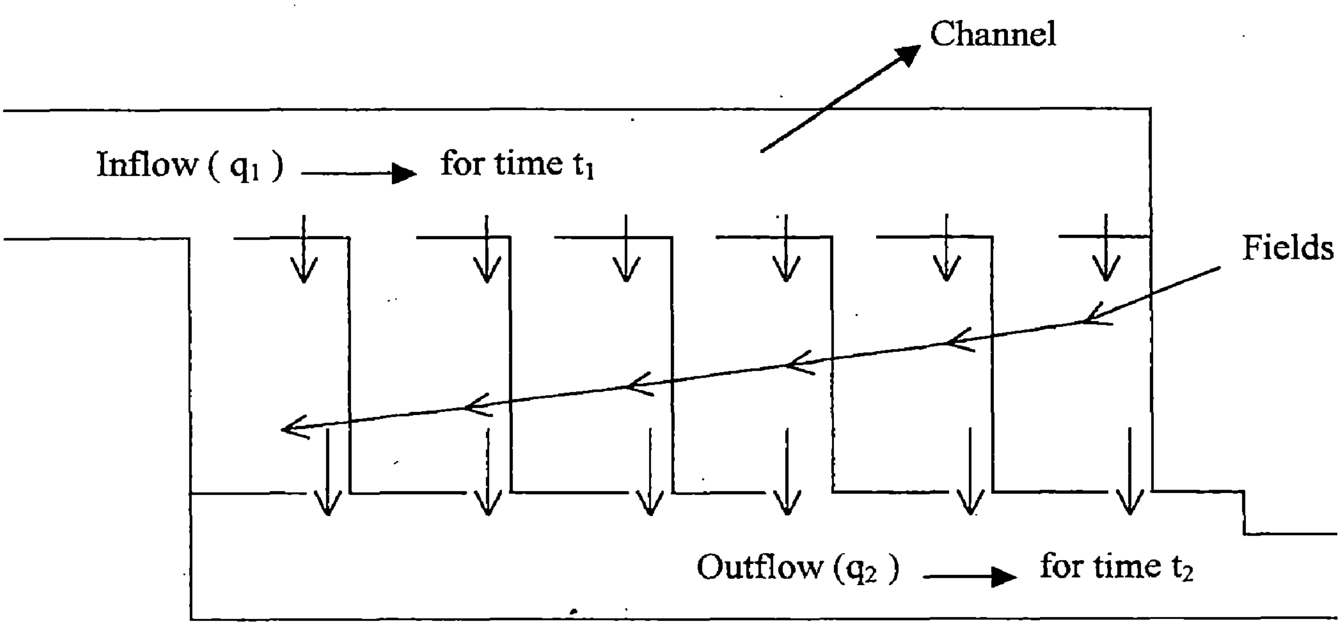


Figure V – 2 : Water accounting in the field.

Total volume of water applied = $q_1\ t_1$ cubic meter

Where q_1 is rate of inflow in cubic meter/ sec. (or cumecs)

t_1 is time in seconds

Volume of water outflow =$q_2\ t_2$ cubic meter

Where q_2 is rate outflow in cubic meter/ sec. (or cumecs), for time t_2 seconds

Volume of water used $qt = q_1.t_1 - q_2.\ t_2$

Depth of water applied $d = qt/A$ or $Ad = qt$

This depth can be compared with crop water requirement.

It may not be possible to monitor each and every field. Therefore it may be done in 5 to 10 % are in a year, by a suitable mobile team.

5.5. WATER LOGGING AND SALINITY

Large parts of several command area found to be waterlogged within ten years of commissioning in various countries. A few examples include the Bhakra, Chambal, Tawa, Mahi Righ Bank Canal, Sarda Sahayak, and Indra Gandhi Canal Command areas in India; Bari Daob, Chenab, and Jhelum Canal Command areas in Pakistan (Yaseen and Chang, 1990); andyuma Valley, Arizona, and San Luis Valley, Colorado, in the United States.

The agricultural land becomes waterlogged when the soil pores within the root zone of the crops get saturated and the normal circulation of air is cutoff. The waterlogging effects the productivity of the land and leads to a reduction in the crop yield. Waterlogging generally occurs because of over-irrigation, high water table and the poor water management.

The depth of water table below the land surface at which the soil tends to become waterlogged and effects the crop yield depends upon the height of the capillary fringe above the water table and also on the type of crop. For most of the agricultural soil, the height of capillary fringe usually varies between 0.9 and 2.5 m. It is more in fine-textured soil as compared to that in coarse-textured soil. The yield of crop is usually effected when the depth of water table below the land surface is equal to or less than the values given below for different crops.

S. No	Type of Crop	Depth of water table
1.	Wheat	0.9 to 1.2 m
2.	Cotton	1.5 to 1.8 m
3.	Rice	0.6 m
4.	Sugarcane	0.9 m
5.	Fodder crops	1.2 m

The causes of water logging may be summarized as follows:

1. Over irrigation; The main cause waterlogging is over irrigation of the land. The excess water applied to the land percolates deep into ground and joins water table. As the ground water storage is augmented, the water table rises. As soon as the water table comes close to the land surface, waterlogging occurs.

2. Inadequate surface drainage; Waterlogging usually occurs when there is inadequate surface drainage of the irrigated land. Heavy precipitation combined with inadequate surface drainage causes flooding of the land. The prolonged flooding (or inundation) results in heavy percolation of water into the ground, which causes a rise of the water table and hence waterlogging.
3. Obstruction of natural surface drainage; If an natural drainage (stream) near the irrigated land is obstructed by constructing an embankment for a road, a canal a railway, etc., the flooding of the area may occur leading to waterlogging.
4. Obliteration of natural drainage; If an existing natural drainage is obliterated (or destroyed), it results in stoppage of natural flow and consequent flooding and waterlogging. Sometimes cultivators, while plugging, obliterate the drainage.
5. Obstruction of a natural subsurface drainage; If there is an impermeable stratum below the land surface at a relatively low depth, it prevents the natural downwards movement of water into the subsoil. It may result in the formation of a high perched water table which may be the cause of waterlogging. Sometimes the foundations of structures, such as causeways, obstruct the movement of water into the subsoil and may cause waterlogging.
6. Imperious top layer; If the top layer of the land is impervious such as black-cotton soil, it obstructs the flow of water in the downward direction. Such land is prone to waterlogging due to over irrigation and flooding.
7. Seepage from canals; Water seeps from the bed and sides of an unlined canal,. It adds to the ground water reservoir and there is a general rise in the water table, which may lead to waterlogging. For example, in the case of the Ganga canal, the water table rose from a depth of 12.2 m to about 4.6 m below ground level in 100 years of irrigation.
8. Construction of reservoir; If a large reservoir is constructed in the region, there is an increase in the water level on the upstream of the dam. Consequently, there is an increase in the inflow to the ground water storage and decrease in the ground water out flow as base flow in the river. The adjoining area may get waterlogged.
9. Defective methods of cultivation; If the defective methods of cultivation are used, there may be pounding up of water on the land surface which may cause

waterlogging. The defective methods of cultivation include construction of high levees (bunds) which obstruct the natural drainage, inadequate preparation of land, failure to smoothen the field after tillage, improper disposal of spoil earth, improper selection of crops and growing crops which require excessive watering.

10. Defective irrigation practice; Waterlogging may also occur due to defective irrigation practice, such as adopting high intensity of irrigation, applying high depth of water and using defective method of application of water like wild flooding.

The causes of water logging in Irrigation projects are showed fig. V – 3. below .

5.5.1. Factor Responsible for the Infertility of Water-logged Lands.

Due to the presence of water at or near the land surface, evaporation takes place continuously. Because of evaporation, there is a continuous upward flow of water from the table if it is high. This upward flow water occurs because of capillary action in the soil. Water brings salts with it. When the water is evaporated , this salts get accumulated at the surface. These salts effect the fertility of the soil.

The following are the main causes of Infertility in water – logged soils:

i). The anaerobic conditions in the soil

ii). The difficulty of carrying out cultivation operations.

iii) The competition between the crop and the natural flora of water – logged soils

iv) The possibility of high concentration of sodium salts in the surface layer which in themselves may be toxic or lead to the formation of alkaline conditions.

Which reference to (i) the growth of normal cultivated crops is dependent upon on adequate supply of nitrogen in the form of nitrates. The process of nitrification, as it is called, is carried out by bacteria which require for their activity the supply of oxygen.

If the supply of oxygen in the soil is reduced due to the presence of excess water, then the nitrification process does not take place, instead, there appears to be a loss of nitrogen from such soil. The anaerobic conditions in the soil, therefore, are only indirectly felt by the crop, since the main effect appears to be on the micro – biological activities in such a soil. Drainage, by keeping the water-table in motion, brings air into the soil to replace the

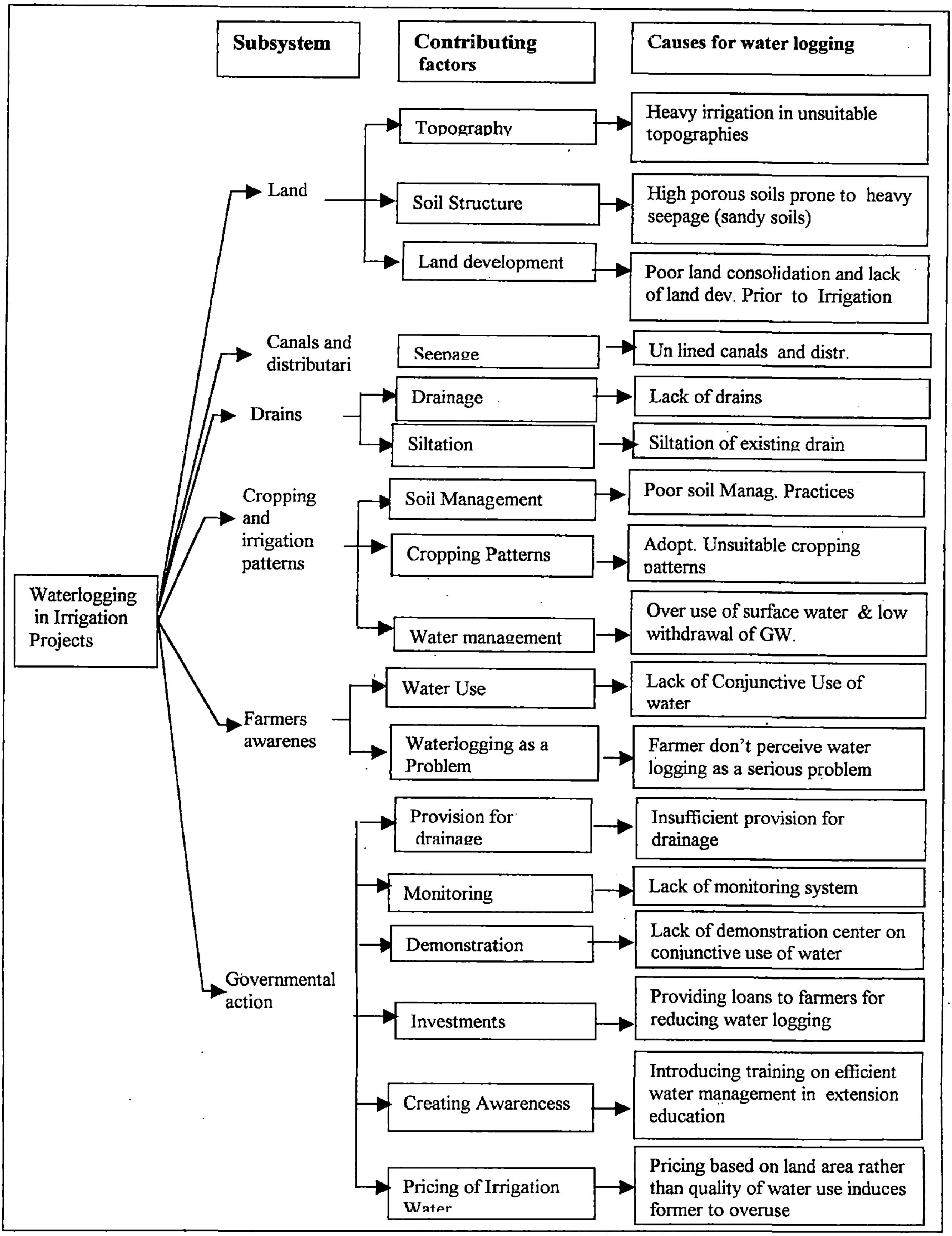


Fig. V – 3 The cause of waterlogging in irrigation projects (After Bowonder, et. al; 1987) water abstracted by the drains. It is on account of the creased aeration that crop growth is so successful after drainage.

5.5.2. Ill Effects of Water Logging

Water logging of land causes a number of ill effects. Some of the main ill effects are given below :

1. **Reduction in growth of plants** ; Because of water logging, there is absence of aeration in the roots of the plants due to which the plant growth is decreased.
2. **Difficulty in cultivation;** As the land becomes waterlogged, the soil becomes slushy and puddle, and the cultivation become difficult.
3. **Increase in salinity;** Water logging generally causes an increase in salinity of the soil. Salt of the soil move upward along with the water from the water table. As the water gets evaporated from the land surface, there is an accumulation of salts and the fertility of the soil is decreased.
4. **Growth of weeds;** Due to availability of excessive water at the land surface, there is growth of water weeds. This results in a decreases of the crop yield.
5. **Increase in natural plants and flora;** Due to availability of excess water at the land surface, there is an increase in natural plants and flora. The plants such as cat tail, reeds, bull rush, grass, etc. grow in the marshy, waterlogged land and there is a reduction in the crop yield.
6. **Increase in plant diseases;** Because of water logging, various diseases occur in the plants, which decrease their growth.
7. **Fall in soil temperature;** There is a fall in soil temperature when the soil becomes waterlogged. Due to lower temperature, there may be a decrease in action of soil bacteria and the growth of plants may decrease.

The percentage of direct yield reduction resulting from water table at various depths are given at Table 5.1 below :

Table 5.1 Percentage of direct yield reduction resulting from water table

Depth to Water Table	Mango	Cotton	Oilseed	Sugar cane	Wheat	Rabi Fodder	Kharif Fodder
< 0.30	100	94	85	85	77	74	71
0.30 – 0.45	100	71	66	66	49	45	27
0.45 – 0.60	100	55	54	54	35	30	0
0.60 – 0.75	100	46	42	42	24	19	0
0.75 – 0.90	91	37	32	32	15	11	0
0.90 – 1.00	76	29	22	28	9	5	0
1.0 – 1.20	61	22	13	13	4	2	0
1.20 – 1.50	38	15	5	5	1	0	0
1.50 – 1.80	7	6	1	1	0	0	0
1.80 – 2.10	0	3	0	0	0	0	0
> 2.10	0	0	0	0	0	0	0
m	**% reduction in yield**						

(source – W. Barber)

From Table 5.1, it is apparent that for sustained production from irrigated agriculture, removal of excess water and salts from agricultural lands is essential.

5.5.3. Measures for Prevention of Water Logging.

Waterlogging can be prevented to a large extent by providing an effective drainage system. The drains may be open drains or closed drains. The type of drain most suitable for a particular site depends upon the purpose for which it is provided and the site condition.

The following other measures are also usually adopted for prevention of water logging or relieving the area, which are waterlogged. In general, all these measures aim at eliminating the causes of water logging discussed in the preceding section.

1. **Controlling the intensity of irrigation;** In regions where there is possibility of water logging, the annual intensity of irrigation should be kept low. In general, the

average annual intensity of irrigation should not be more than 40 to 60%, i.e. the total irrigated area in a year should not be more than 40 to 60% of the cultivable commanded area (CCA).

2. **Providing a drainage system;** Waterlogged can be prevented by providing a properly designed drainage system.
3. **Lining of canals;** The seepage of water from the canals can be considerably reduced by lining of canal. Consequently, the water table does not rise and the water logging is prevented.
4. **Lowering of the FSL of the canals;** The seepage of water from unlined canal can be reduced to some extent by lowering the FSL of the canal. The canal should be designed such that its FSL is as low as possible, consistent with the requirements of flow irrigation for the commanded area. A low FSL results in a small difference of water levels in the canal and in the field. Consequently, the percolation losses are decreased. Moreover, the head at the outlet is decreased which reduces the outlet discharge and prevents wasteful use of water.
5. **Improving the natural drainage of the area;** The natural drainage such as streams and rivers should be improved. It involves removing obstructions to the flow such as weeds, bushes and other vegetations from the stream section. Straightening of the streams and canalizing them into shallow wide reaches improves the natural drainage. Increasing the bed slopes of the streams also improves the drainage. The chances of water logging are considerably reduced if the natural drainage of the area is good.
6. **Prevention of seepage from reservoir;** The seepage from small reservoirs can be reduced by lining the surface of the reservoirs. For large reservoirs, suitably designed toe filters should be provided so that the seepage from the reservoir is discharged into the natural streams
7. **Changing the assessment method;** If the water supplied to the cultivators is assessed on area basis, the cultivator have a tendency to use the excessive water which causes water logging water logging. By adopting the volumetric assessment of water, the excess use of water is controlled and the chances of water logging are reduced.

8. Reduction Water Requirement of Crops in Water Logged Areas

The nearer the water table is to the surface the more can the crop draw upon the water present in the sub soil and hence, the less that need be given in the form of irrigation.

No definite experiments have been laid down to determine the various depths of water-table. Experience at Chakanwali has shown that with crops such as sugar cane, cotton, wheat, with a water-table about 2.5 feet below the surface, 30 percent less water is required to nature the crop than in areas where the water table is situated below 10 feet.

Successful Barani sugarcane crops have been raised in the Chakanwali farm (water logged area) in the Punjab.

If flow that when the water table is within 10 feet of the surface, then water removed by the crop may be wholly or partly, replaced by that rising from the soil water table.

When the water table is situated below 20 feet from the surface, it will have little influence on the water content in the surface soil as the water table approachess the surface.

No evidence recording the amount of water required when the water table is only two feet from the surface is available.

A detailed summary of action needed at various phase of an irrigation projects is given in figure V - 4.

Reclamation of the land is carried out to reduce the salt content and the soil alkalinity. The method to be employed depends upon the soil characteristics, total soluble salts, pH value of the soil, the type and concentration of salts, etc.

5.6. CONJUNCTIVE USE

Conjunctive Use is the combined and integrated management of surface and ground water for optimal utilization of available water resources.

The concept of conjunctive use is a way of thinking about water utilization.

The conjunctive use planning and management is necessary to achieve maximum returns from cropping activities of any area in addition to the solution of the problems of water logging and water table depletion. Optimum beneficial use of water can be obtained by conjunctive use.

5.6.1. Conjunctive use of ground and surface water

Advantages and disadvantages of sub-surface and surface reservoir are given below in table 5.2.

Table 5.2. Advantages and Disadvantages of Subsurface and Surface Reservoir

Sub-surface reservoir	Surface reservoir
Advantages	**Disadvantages**
1. Many large capacity sites available	Few new sites available
2. Slight to no evaporation loss	High evaporation loss, even in humid climate. Generally between 10 to 30 %
3. Require no little land area (for recharge)	Require large land area
4. Slight to no danger of catastrophic structural failure	Ever present danger of catastrophic structural failure
5. Uniform water temperature	Fluctuating water temperature
6. High ecological purity	Easily contaminated
7. Safe from immediate radio active fallout	Easily contaminated by radio active material
8. Serve as natural conveyance systems (canals or pipeline) across lands of other basins)	Water must be convened, through costly network of canals
9. can be pumped out as and when required	High evaporation and seepage losses during storage
10. Initially less costly, structures	May cause water logging and salinity
11. Reduce water logging and salinity	Initial heavy investment required.

- All the above advantages and disadvantages for groundwater are site specific, depending upon the nature of ground can be improved upon, whereas for surface water it varies from project to project.

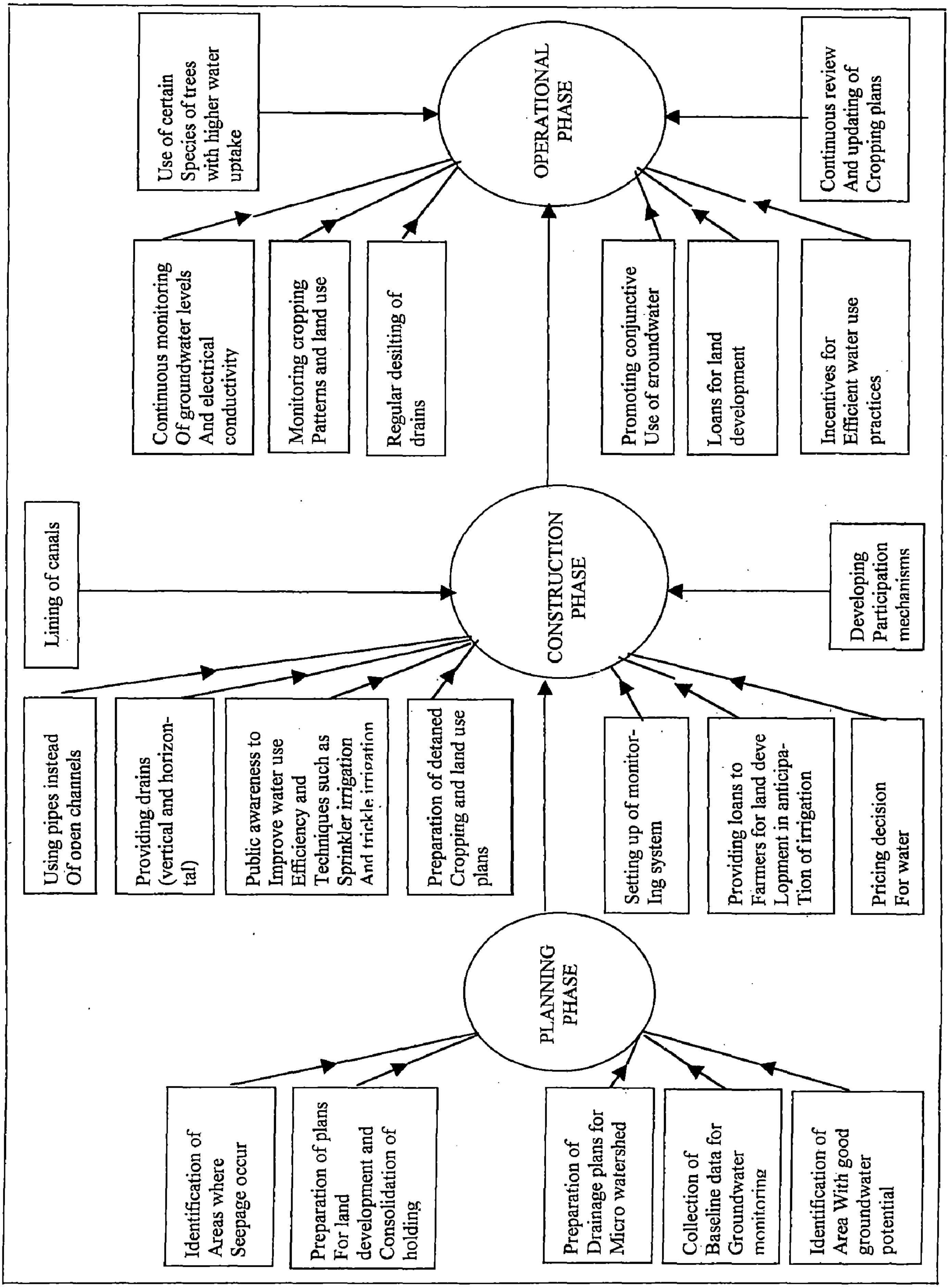


Fig. V – 4. Preventing and controlling waterlogging in irrigation projects (after Bowonder et. al.; 1987)

5.6.2. Declining Water Levels

Over exploration of ground water either for agricultural, domestic, industrial, and other uses is resulting in declining i.e. lowering of and creation of dark zones in certain pockets through out water table the world (Gambolati et al, 1974, Luckey, 1982; Gorgensen, 1982; Navarro and Pazos, 1982; Prihar at al, 1993).

A lowered water table increase the cost of lifting the ground water, thereby affecting both investment and operating costs. The deeper the water table, the ground water, thereby affecting both investment and operating costs. The deeper the water table, the more expensive the cost of drilling, pipes, pump, and prime moves. Also it results in an increase in the amount of energy required to water losses from the canal.

Pump the water. The risk of sea water intrusion in coastal areas is significant. The salinity of water in such areas may increases. The lowered water table may reverse the direction of groundwater flow. When the flow is reversed, the water that normally percolates towards a progressively saline aquifer is drawn backwards. Therefore, the quality of freshwater aquifer may deteriorate with continued pumping.

5.6.3. Land Subsidence due to Groundwater Pumping

As water is pumped from a confined aquifer, the decrease in artesian pressure results in compression of the aquifer material. Most of the water released from storage is derived from compaction of the fine-grained sediments. Excessive pumping causes extensive lowering of the piezometric surface resulting in land subsidence, i.e., the soluble rocks are slowly dissolved locally by groundate. Ground water pumping from such aquifers results in land subsidence, leading to the formation of cup-shaped depressions of the land surface (Foose, 1967).

Land subsidence can severely damage the wells resulting in their failure. One of the possible remedial measures as a safeguard against land subsidence is to reduce pump age to safe yields (Gombalati et al.,1974). For more details, the reader may consult Poland (1984).

5.6.4. Upcoming of Saline Water.

In the canal irrigated areas, due to seepage from canal networks, good quality water percolates to the ground water aquifer. In the case of saline aquifer, it results in the formation of a thin layer of freshwater overlaying the saline water. Pumping the well in the freshwater zone causes the fresh water/ seawater interface to rise below the well. This is referred to as upcoming. If the well penetrates close to the fresh water – salt water interface, the poor quality water may enter the well, causing the well discharge to be of poor quality. The well needs to be designed such that saline water does not mix with freshwater. The upcoming of saline water is described by Bear and Dagan (1968), Schmorak and Mercado (1999), Mc. Whorter (1972), Bouwer (1978), and Goel et al. (1991).

Still lining of canals is generally considered as one of the measures for water conservation and reduction of above problems, every where. This approach along with the economics of lining have done discussed in chapter IV listed in Para 4.11. Is in isolation. It is without due regard to some positive aspects of seepage such as ground water recharge/ redistribution/ transfer to other areas, just like inter basin water transfer or canal water transport or conveyance.

All water which is lost by seepage in an unlined canal system is not total loss and a significant part of it joins groundwater by way of deep percolations, which can be recovered under favorable conditions.

Lining of canal thus affects groundwater availability and therefore, the advantage of lining needs proper evaluation in context of total surface and groundwater system performance. Further more extent of conveyance losses and their contribution to ground water from different of canal distribution network (main canal, distributaries and field channel) are different both in time and space. Therefore the cost effectiveness of lining of various components individually and in combination needs careful assessment for deciding the extent of lining.

Main advantage with ground water is that it can be tapped almost at any place as and when needed, a big flexibility to the farmers, depending upon the pumping capacity. In fact, farmer good agricultural production policy, and irrigation water management requires an irrigation system on demand, according to crops and weather which is vary costly. All unlined canal s are great source to recharge of ground water and also its conveyance over area like surface gravity canals, and economics should be examined in that light.

Only disadvantage with this that, it requires energy for pumping. Advantage of lining therefore be viewed along with the associated loss in groundwater recharge due to reduced canal seepage, and their overall impact on ground and surface water resource availability of the area. An attempt may be made to study the economics of canal lining by using a suitable programming model associated with conjunctive use of surface and groundwater.

5.7. GROUND WATER MONITORING

5.7.1. Introduction

Movement of ground water is a complex process but can be explained through two important principles:

a. Water movement i.e inflow, out flow and moisture status as given under:
   Change in storage of moisture in soil (Δ S) = Recharge Inflow (I) – Discharge Outflow (O)
b. Water movement under unsaturated condition is usually in a vertical direction, i.e Downward in the form of water drops and upwards as capillary water and as water vapor. Movement of water under saturated soil is mostly horizontal to areas with a low hydraulics head from areas of high.

Selection of the proper locations for monitoring wells should be based on a wholistic approach to the evaluation of a specific site. The placement of the wells in this process must weigh and balance data collected in the field, laboratory, and office.

The question "how much monitoring is enough?" when answered in the context of the number of monitoring wells required at a site, will be entirely site specific. In general, the monitoring system designer should ensure that convincing evidence is established for each assumption, and for demonstrating the basic capability of the system to produce ground-water samples representative of both up gradient and down gradient conditions.

" Enough " is a subjective determination, both for the questions of how much monitoring is necessary to provide a monitoring system capable of detecting ground-water contamination, and how much demonstration is required to convince a regulatory agency of that capability.

The number, locations, and depth of the monitoring wells must be such that the system is capable of the prompt detection of any statistically significant differences in indicator parameters.

Besides ground water level monitoring there is a 2^{nd} aspect i.e. Ground water Quality Monitoring, figure V –5 shows a summary of ground water monitoring system design. The aspect of ground water quality monitoring is discussed in Chapter VI. Here only ground water level monitoring is discussed.

5.7.2. Data analysis required for monitoring system design

Geologic factor (related chiefly to geologic formations and their water – bearing properties) and hydrologic factors (related to the movement of water in the formations) must be known in some detail to properly design a ground-water water monitoring system. These data are normally developed in field investigation using methods described elsewhere in this paper. The geologic framework of a site includes the lithology, texture, structure, mineralogy, and distribution of the unconsolidated and consolidated earth materials through which ground water flows. The hydraulic properties of these earth materials depend upon the geologic framework. Thus, the geologic framework of the facility heavily influences the design of the ground water monitoring system. Elements of the geologic framework and the site hydrogeology that should be considered in ground-water monitoring system design include:

a) The spatial location and configuration of the uppermost aquifer and its hydraulic properties (e.g., horizontal and vertical hydraulic conductivities, depth and location of ground-water surface, seasonal fluctuations of ground-water surface elevation);

b) Hydraulic gradient within the geologic materials underlying the facility.

c) Facility operational considerations.

d) Facility operational considerations.

These data are used to establish the location of both up gradient and down gradient wells in the uppermost aquifer. Both up gradient and down gradients wells should be located in

Date: 31.12.2002

To,

The Assistant Registrar (Exams)
Indian Institute of Technology Roorkee
ROORKEE- 247 667

Subject: **Submission of Marks of M.Tech Thesis Viva-Voce**

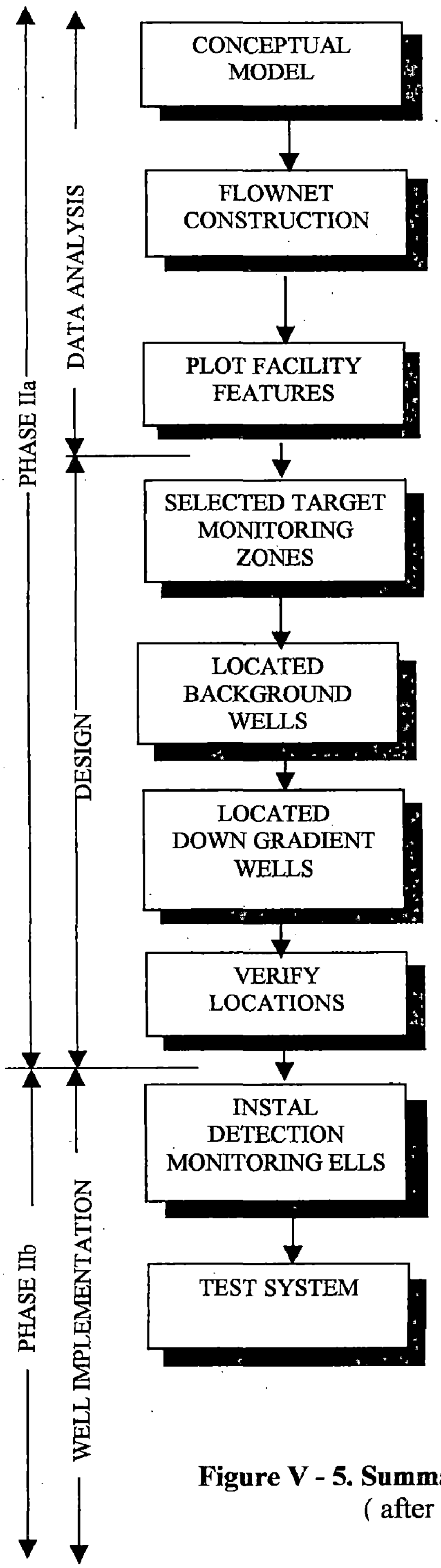
Sir,

Please find enclosed herewith the marks of the students with following details;

Name of Candidate	:Mr. Darmawangsah
Course	: M.Tech. (WRD)

Yours Sincerely,

(DEEPAK KHARE)
Associate Professor,
WRDTC, IIT Roorkee



GEOLOGY/ HYDROGEOLOGY, BENCH MARK DATA
- Surface geology (topography and type depth of overburden
- Lithology and thickness of aquifer (s)
- Type of geologic formation (local stratigraphy and structure)
- Recharge/ discharge area
- Aquifer/ comfining unit (s) permeability and porosity

GROUND-WATER FLOW DIRECTIONS
- Piezometric and/ or potentiometric heads
- Relative hydraulic head between units
- Three dimensional flow directions using flow lines and quipotentials
- Interaction of aquifers
- Rates of ground-water measurement

FACILITY FEATURES
- Base map features
- Cross section with lithology
- Facility base grades established and compared with flow

TARGET MONITORING ZONE
- Uppermost aquifer established
- All reasonable flow paths identified

AMBIENT WATER QUALITY SYSTEM
- Up gradient Design – Simple geology and heads
- Background Design – Complex geology or heads
- Number should have statistical basis

BASIS FOR DESIGN
- Geology and permeable zones
- Flownet analysis
- Target monitoring zones
- Facility waste boundaries

DO THE LOCATION SELECTED MEET CRITERIAL
- State and federal requirements
- Between waste areas and down gradient receptors

FIELD INSTALATION OF MONITORING WELLS
- Use ASTM method
- Update conceptual hydrogeologic model
- Document installation

TEST AND OPERATE SYSTEM
- Performance test all wells
- Use operation and maintenance procedures
- Close and decommission incorrectly placed wells

Figure V - 5. Summary of ground-water monitoring system design process
(after David M. Neelson ,et.al.)

the direction of ground water flow along flow pathways most likely to transport ground water and any contaminants contained in ground water. These pathways should be identified using data gained from existing information and preliminary site investigations. The objective of the preliminary site investigation and subsequent data analysis and interpretation is to provide some or all of the following information :

i) Lithologic characteristic, including :
   - established stratigraphic names
   - classification of hydrologic units
   - extent of hydrogeologic units

ii) Key hydrogeologic characteristics used to develop the site conceptual model, including :
   - hydraulic conductivity
   - porosity
   - hydraulic gradient
   - specific yield

iii) Aquifer characteristics, including :
   - boundaries
   - type of aquifer
   - saturated/ unsaturated conditions

Each piece of data is an important building block in establishing the conceptual hydrogeologic model and targeting zones to be monitored. These data are used in combination to define the uppermost aquifer flow pathways so that target monitoring zones can be selected.

The monitoring program should not be too elaborate. The natural inclination of engineers and scientists is to collect large amounts of data which are never analyzed and do not achieve program objectives. The data often do not provide benefits commensurate with the cost of the collection program. The engineer's task is to propose the minimum monitoring program that will provide a means for continuing surveillance. On his part, the water manager should recognize that the monitoring of surface and ground water supplies is equivalent to the inspection process during construction or manufacturing, and should be prepared to pay a reasonable cost for a monitoring program. One task of the water manager then becomes that of coordinating the existing monitoring activities and expanding them where necessary. At some appropriate interval, the monitoring program must be evaluated to assure that there are no gaps in data collection nor excessive data being collected in one location.

Normally annual reports are prepared presenting the results of the monitoring. These cover the salient features and draw conclusions and make recommendations on various facets of the management plan. Such a reporting period fits well with budgeting and financing procedures. Interim reports might include verbal reports to gatherings of interested parties, less elaborate and more frequent written reports, or an occasional thorough evaluation of the plan itself.

The processing and storage of data is amenable to electronic data processing techniques. The manager should consider such system for storage and retrieval of monitoring data and the printout of reports, maps, and hydrographs for his use.

5.7.2. Water Level Elevations

In formulating a program for measuring water level elevations, the following check list may be useful :

1. Use sufficient number of wells located strategically throughout the area.
2. Keep in mind that wells are continually being destroyed by development and alternative data collection points should be established and maintained.
3. Some time condition within the well or in the immediate vicinity of the well may make it impossible to obtain data at the proper time; substitute data points will be needed.
4. A well preservation and maintenance program may be desirable where ownership of the well is acquired by a cooperator in the management program.
5. Often wells will not be screened or perforated in the aquifer of interest. This may result from multi aquifer conditions or from aquifer that are isolated or discontinuous, or both. It is essential to know which aquifers are screened in each monitoring well.

6. A well drilling program may be required to obtain data at critical or sparsely covered locations. Economy can be achieved by constructing a "nest" of piezometers in a single-drilled hole to determine ground water levels in each of several aquifers. Separation is achieved within the drilled hole by gravel packing the aquifer zones and cement grouting the aquiclude zones.

Water level data can best be presented in the form of ground water contour maps. From these maps, the direction of ground water flow, the influence of pumping, the effects of recharge and the special effects caused by underflow, effluent seepage, seawater intrusion, etc., can be pinpointed. Once the condition and characteristics of the ground water formations are known, the number of data points used in preparing the maps can be minimized, except in areas of special problems where additional data may be necessary.

Maps of lines of equal change of ground water level for a given period are very useful to determine changes. These can be drawn using change in level at data points, or from the intersections of two contour maps representing two periods of monitoring.

Well hydrographs can be used for this purpose also, but have the drawback that they represent only a single point in the formation. However, they have the advantage of depicting in level at the particular point over the period of record.

Where the management plan specifically provides for temporary or permanent dewatering of an aquifer, a valuable map would be one showing lines of equal thickness (isopach) of the remaining saturated portion of the aquifer. This map can be drawn from the data used for the other maps provided the elevation of bottom of the formation is known.

A general inventory of ground water conditions may be determined from contour maps drawn once a year. Such maps are usually prepared from data obtained at the time of annual high ground water levels or for annual lowest ground water levels following the pumping season. Generally, data would be collected at intervals required for preparation of maps and hydrograph for analysis.

The chief aim, of course, is to collect frequently enough to measure the performance of the management plan. These data would permit determination of water remaining in storage, pumping lifts and costs, and general water movement. If the situation warrants special surveillance at particular locations to anticipate ground surface subsidence, waterlogging, dewatering, and other problems, representative wells can be monitored at more frequent intervals or can be equipped with continuous recording equipment. Particular attention should be given to frequency of observation where the management plan in effect is one resulting in non equilibrium conditions, one which causes water levels to fluctuate beyond previously experienced ranges, or both.

5.7.3. Recharge and Extractions

The amounts of recharge and extraction are an important part of the water accounting system associated with a management plan. Measurement of natural and artificial recharge requires evaluation of deep percolation of precipitation, streamflow, applied water, and water spread or injected through wells.

Such measurement involve operating rainfall and stream gauging stations, and often weirs and flumes. Artificial recharge quantities are normally easier to measure then are the item of natural recharge. It is usually advisable to differentiated through a monitoring program between the natural, tributary water recharged and nontributary, reclaimed, or desalted water recharged.

5.7.4. Hydrologic Investigations

Hydrologic investigation for ground water include study of water available for recharging ground water from different sources, extent and location of areas of recharge, ease of recharge and the location and quantity of ground water discharged at the surface. The sources of recharge include both rainfall and water in perennial rivers and canals. The recharge to the ground water also depends upon the permeability of the sub-soil. The location and discharge of springs and wells, depth of water-table, type of vegetation, discharge of ground water into the stream provide valuable information about the ground water. The programmed of investigations for understanding ground water resources of an areas should include :

(i) Preparing inventory of existing wells.

(ii) Study on ground water levels.

(iii) Collection and analysis of water samples for their quality

(iv) Aquifer test to appraise transmissibility and storage property of the aquifers.

(v) Correlation of stream-flow factors with ground water recharge and discharge.

(vi) Estimation of seepage and recharge contribution from canals, lakes, ponds, etc.

(vii) Study and analysis of methodological factor :
Precipitation, evaporation, etc.

(viii) Rainfall-infiltration studies to estimate contribution of rainfall to ground water recharge.

(ix) Evaluation of ground water resources.

(x) Hydrologic analysis of ground water systems through modern mathematical and other techniques.

5.7.5. Preparing Inventory of Existing Wells

In order to determine the quantity of water with drawn from the ground water reservoir during various periods of the years and at various locations, an inventory of wells and tubwells has to be prepared. Following information should be recorded :

1. Geographical location and reduced level.
2. Depth of the well.
3. Diameter of the well
4. Length and type of strainer. If slotted pipe, slot size diameter of strainer, length and diameter of housing pipe.
5. Water level (to be recorded at least twice a year).
6. Gravel packed or not.
7. Type of pumping equipment and its horse power.
8. Discharge and draw down.
9. Pumping record (daily pumping hours).
10. Quality of water.
11. Crop pattern.
12. Area irrigated.

5.7.6. Ground Water Levels

Ground water levels both in the confined and water table aquifers almost constantly keep on fluctuating Water levels in unconfined aquifers are effected by direct recharge from rainfall, seepage from canals and reservoirs, recharge from or discharge to streams, withdrawal from wells, and sometimes changes in atmospheric pressure. Piezometric levels in confined aquifers are effected by surface water stages, surface loading, changes in atmospheric pressures and earthquakes. Water levels in confined aquifers are also influenced by recharge to and withdrawal from the unconfined aquifers. Variations in water-table extending over a period of several years or more or called secular variations.

Fluctuations in water levels indicate both changes in the actual quantity of water stored in aquifers and movement of ground water. The amount of water taken from or added to storage per unit change in water levels in unconfined aquifers is many times larger than in confined aquifer.

The data on ground water-level can be used to obtain following information :

(i) Assessment of ground water availability on the basis of fluctuations in water levels.

(ii) Relationship between water-level fluctuations and rainfall, withdrawals and other factors.

(iii) Demarcation of waterlogged areas and areas with continued downward trend of water-table for many years.

(iv) Estimation of discharge to rivers.

(v) Response of ground water reservoir to withdrawals or recharge.

Natha Sing'h, (1947) and Sharma (1959) have discussed in a systemic manner, the effect of canal irrigation ground water and its monitoring, and reported their details.

Before a canals is constructed in a doab (area between two rivers), following factors may tend to raise the level of the water table.

i) Infiltration from rivers towards bottom of the trough.

ii) Percolation of rain fall in saturated phase

iii) Percolation from well irrigation in saturated phase, (sailab).

iv) Sub-soil flow from upper regions of the doab.

All these may be called the inflow.

The factors tending to lower the water-table are:

i) Sub soil flow towards the lower regions

ii) Soil evaporation from the water table surface

These may be called the "out flow".

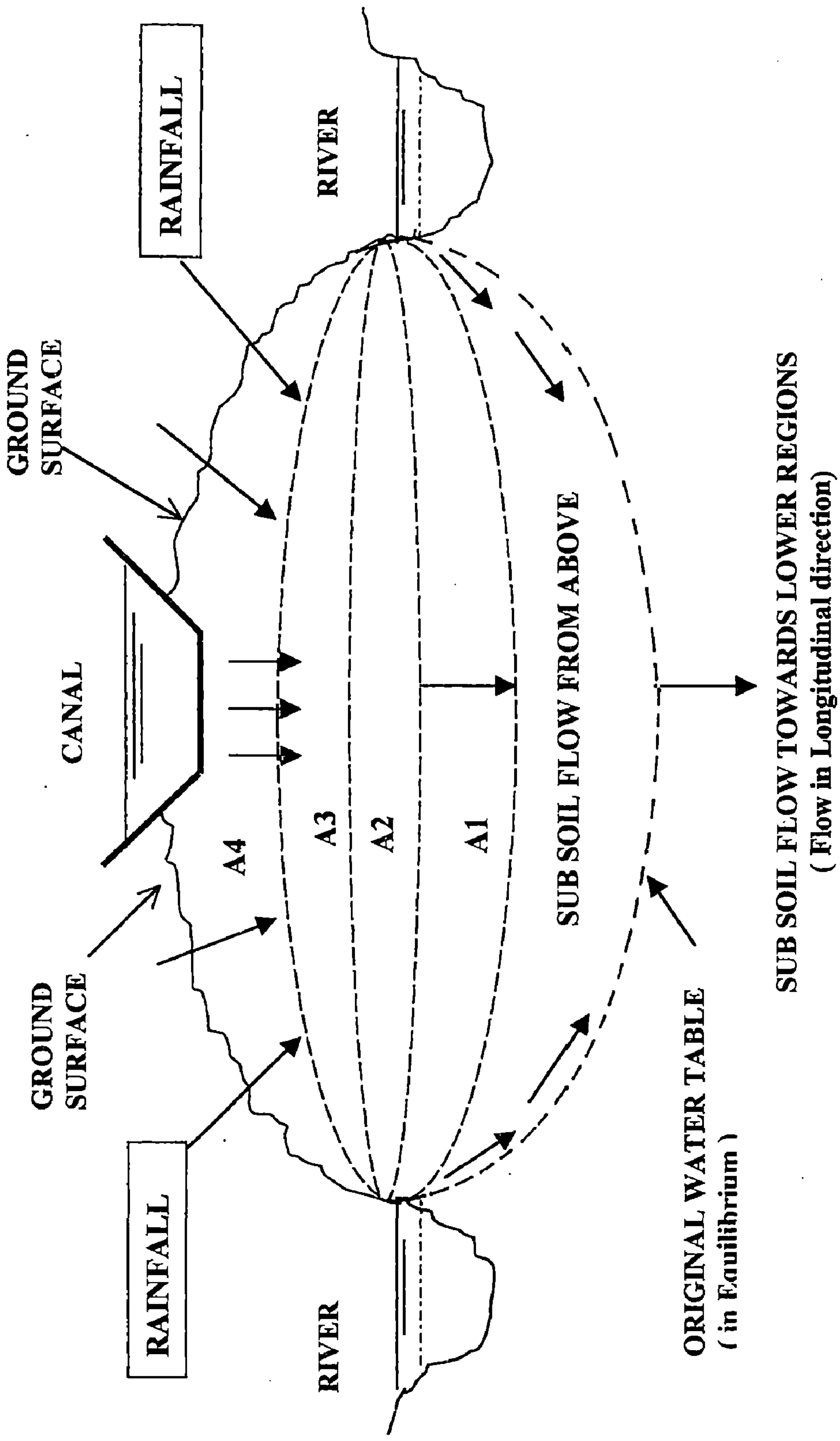
It may be safely assumed that in the pre-canal period the water table was in state of equilibrium. There is no doubt that its level fluctuated with the amount of rainfall from year to year and some times very violently, but there is nothing to show that it was continuously rising. There would be a sudden rise in a year of heavy rainfall but it would adjust it self in a subsequent dry year.

If observations where available for a large number of years for the pre-canal period, it may be that after centuries of fluctuations, the sub soil water table had attained a state of equilibrium. If it were continuously rising the whole area would have been water logged long before the advent of canals. On the other hand if it were continuously falling the water table would have gone down indefinitely.

5.7.7. Ground Water Basin

Like river basin boundaries, ground water also has basin boundaries. But these are not dividing water-shed ridges as in river basin boundary. In ground water basins rivers come boundary, see figure V – 6, V – 7, V- 9 and V - 10.

Figure V – 6 explains the movement of excess water (more than irrigation requirement) and rise in water table. Figure V – 7 is a small scale map of canals and rivers. Well observation lines are shown as PL. 1 to PL.14. A long – section line of topography between PL I to PL.14 is also marked in this map. Figure V – 8 is a longitudinal section of topography along the line market in topography. Figure V – 9 and V – 10 is update of figure V – 9. Figure V – 11 is small map showing zones of different water table. This map could also be in the form of contours of water table. Thus figure V – 6 to V – 11 shows a complete three dimensional pictures of analysis or ground water level observation carried out.



A1, A2, A3, A4 : Stages of rise of water table with seepage from canal and irrigated areas

Fig. V - 6 Illustration of rise in water table (Sharma, 1959)

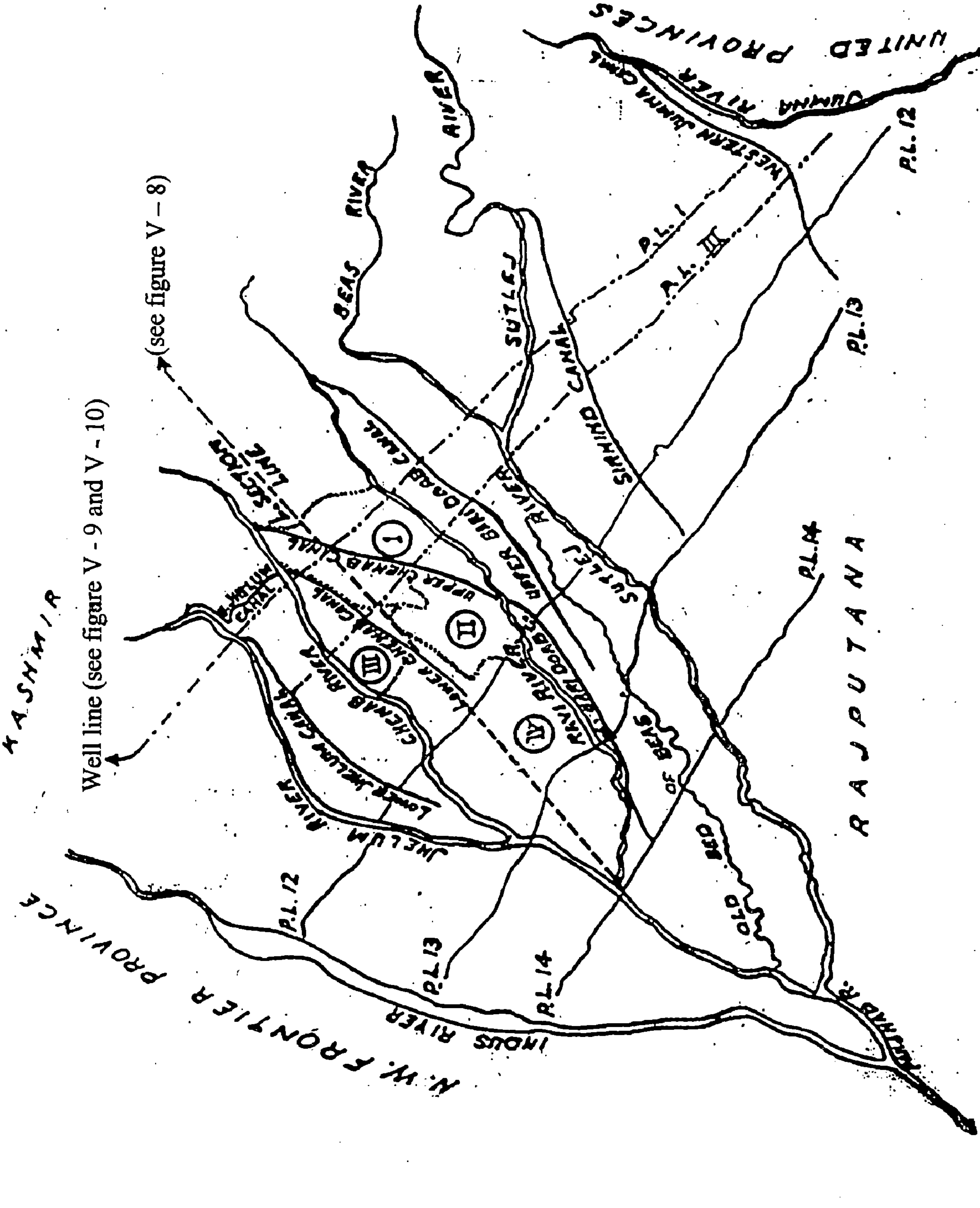


Fig. V – 7 Plan showing well lines in Rechna upper Bari and other Doabs (Sharma,1959)

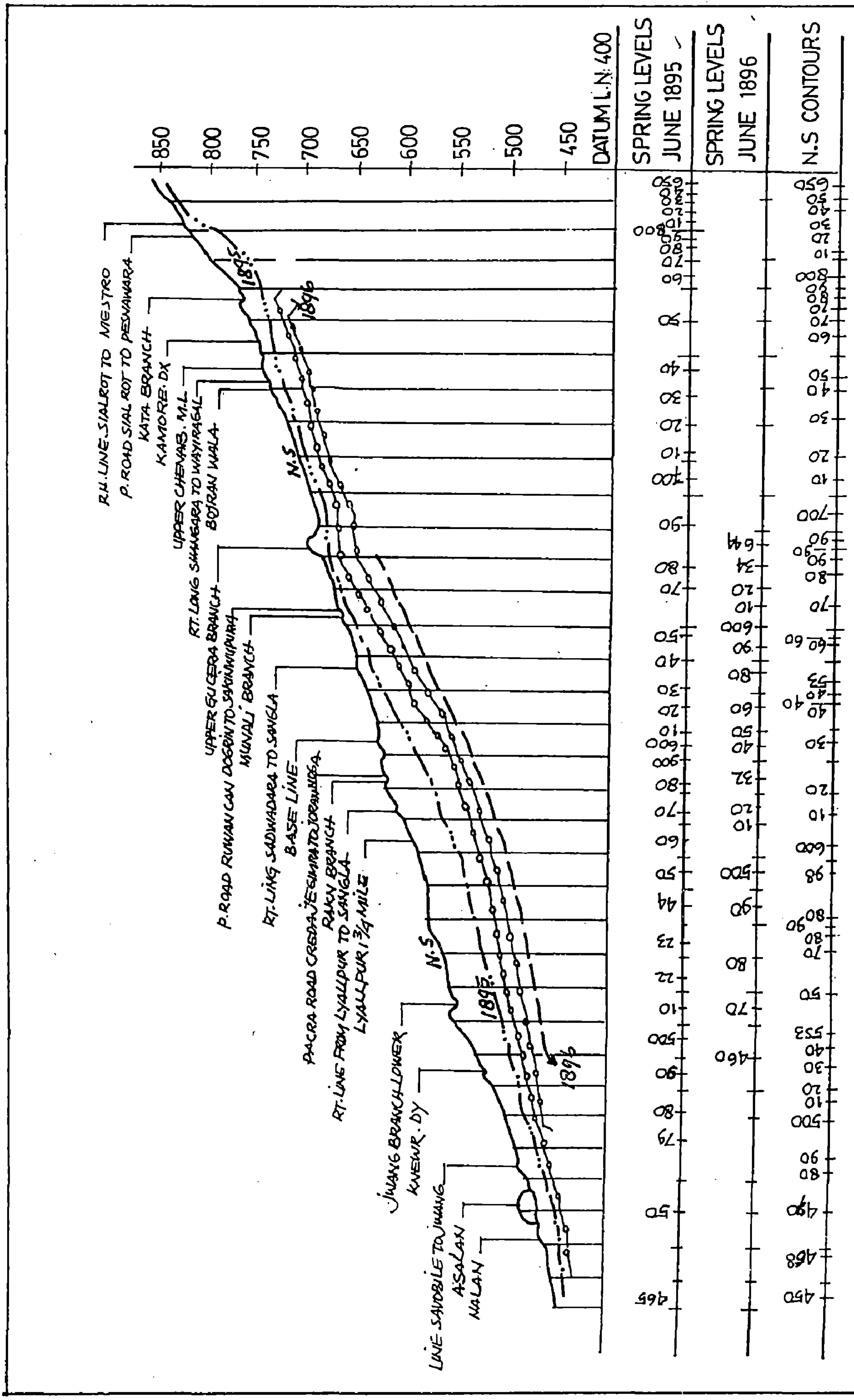


Fig. V – 8.Longitudinal section of the wells/ observed in Rechna and other Doab (Sharma, 1959)

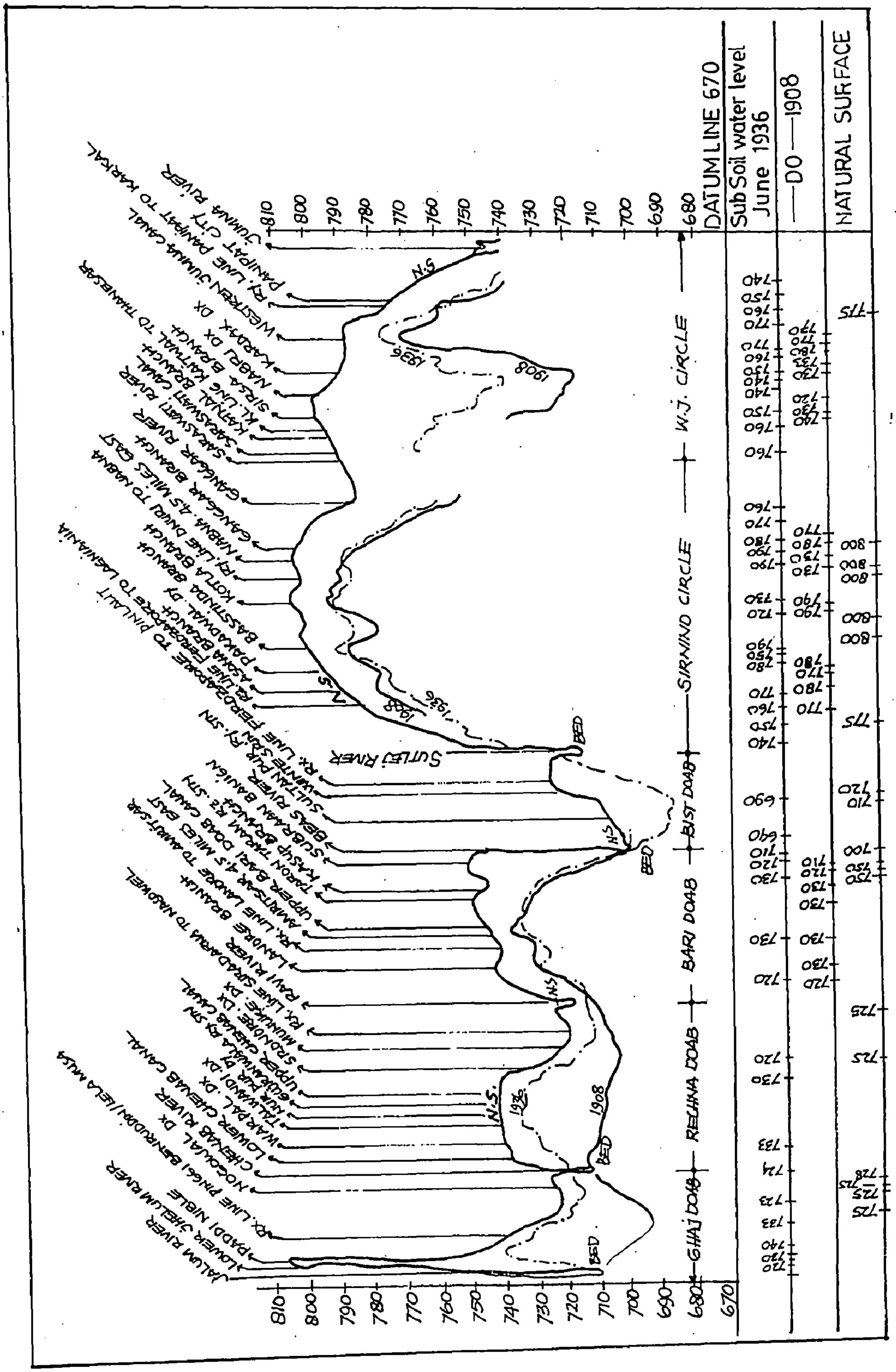


Fig. V – 9 A section across observed wells along provincial line No.1 (Sharma , 1959)

Alluvial Plains Domain

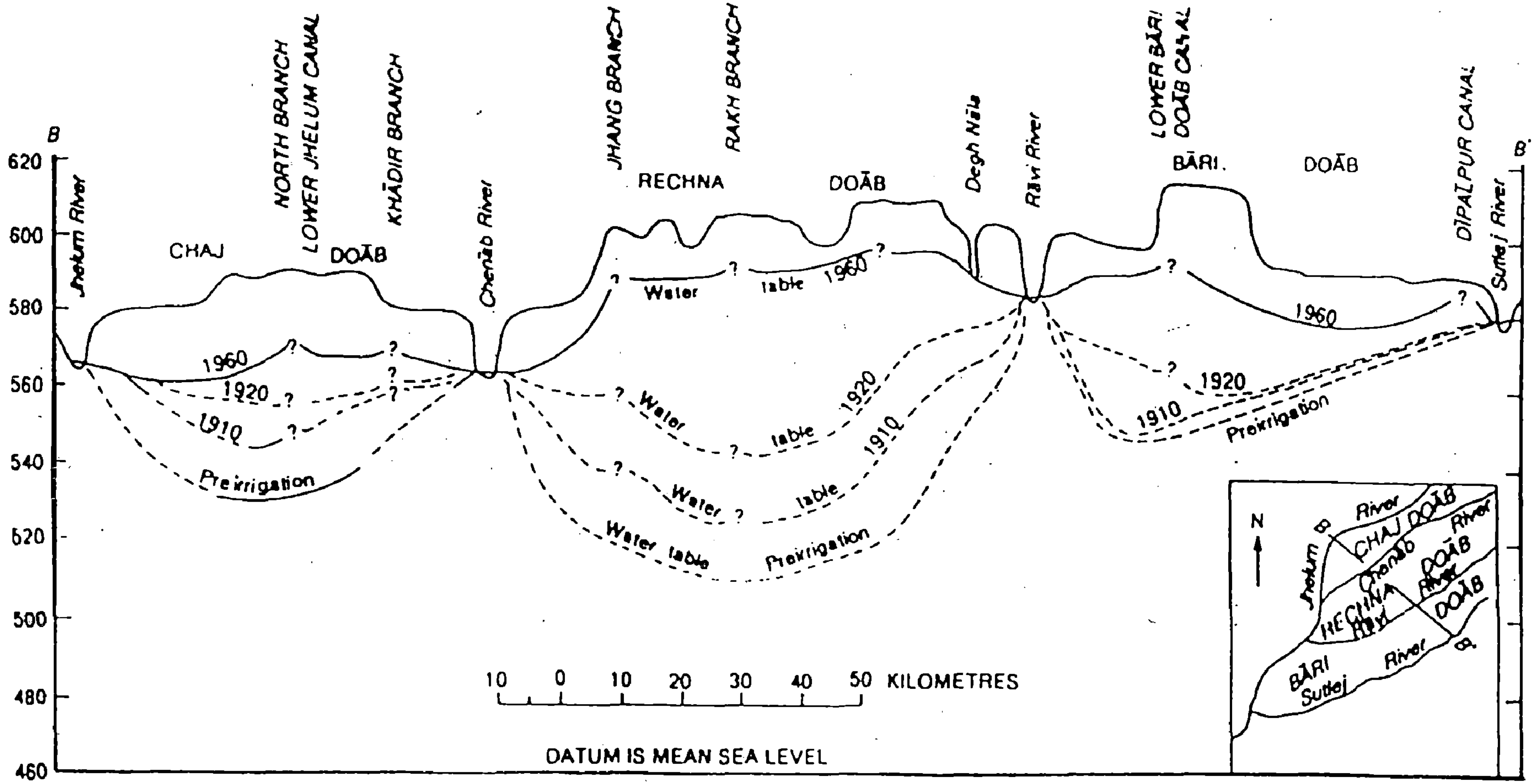


Fig. V-10. The history of rising ground water heads in part of the Indus Plains, Pakistan (after Greenman.rt al., 1967)

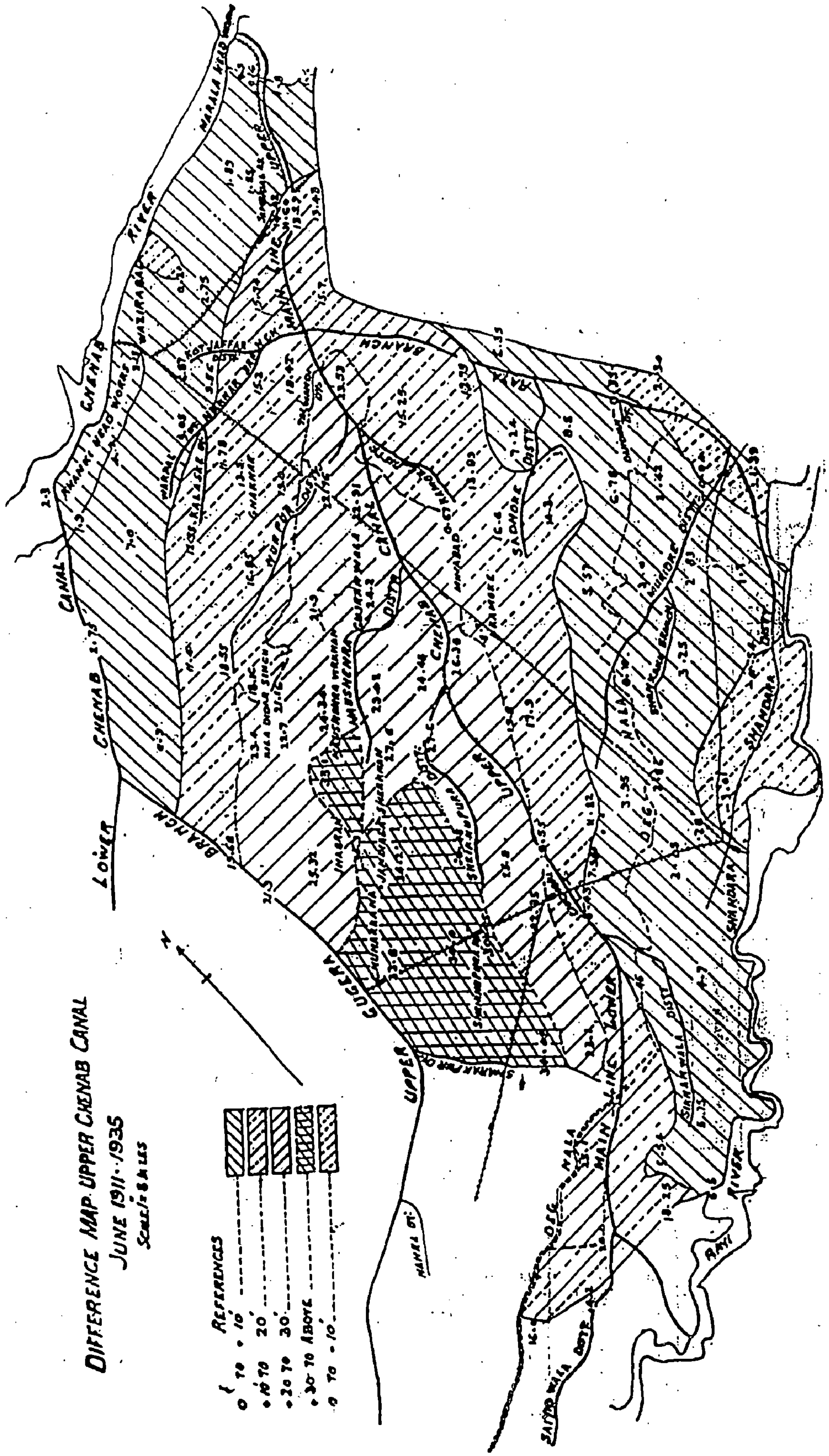


Fig. V-11 :Water table map in Upper Chenab Canal,. Relating to the period from 1911 to 1935. (Sharma, 1959).

When the water table in the pre-canal period is in a state of equilibrium, it can be safely stated that the inflow and out flow must be equal i.e., the sub-soil drainage and soil evaporation are sufficient to cope with the inflow from all the various sources enumerated above.

Now when a canal is constructed in the doab see fig. V – 6. For a good understanding and sake of convenience we the branches and distributaries may be omitted from consideration and assume that the collective seepage of all the irrigation channels and irrigated area takes places from the canal. By the construction of the canal a new source of constant inflow into the sub-soil is introduced. Before the canal the sub soil drainage and soil evaporation were just sufficient to deal the sources of in flow previously operating, but are incapable of dealing with the additional inflow caused by the seepage from the canal.

This naturally results in a continuous rise of water table.

The rise, however, is not uniform every year. In a year of heavy monsoons the rise would be abnormal, which would have gone down to its original level, had there been no canal, but owing to the continuous inflow from the canal, the original would never he attained and same of the rise would become permanent.

A1, A2, A3, A4, in figure V - 6 represent the levels of the water table in the various stages of the rise, subsequent to the opening of the canal.

As the water table rise, the inflow from the rivers decreases owing to the reduction in yield, while the outflow i.e., the sub-soil flow to wards the lower reaches of the doab increase owing to the steeping of the gradient.

This explains why the rise in water table is rapid in the early years of the opening of the canal. The inflow from both the rivers and the canal would be obviously maximum when the bottom of the trough is lowest. When this level rises to the same level as the rivers, the inflow from the rives ceases while the inflow from other sources continuous practically unabated. As soon as the level of the water table rises above the level of the rivers, outflow starts from the water-table towards the rives. Soil evaporation also becomes relatively more active as the distance of the water table from the ground level is reduced.

In these conditions the sources of inflow are :

i) Infiltration from rainfall in saturated phase.

ii) Sub soil flow from upper regions.

iii) (a) Seepage from canals in saturated phase

(b) Infiltration from canals irrigation in saturated phase.

While the sources of outflow are :

i) Sub-soil flow to the lower regions of the doab

ii) Increased soil evaporation

iii) Transpiration by the plants (crops)

iv) Infiltration

v) Seepage drains.

The volume outflow from these sources will continue increasing as the water table rises, until a stage is reached when the out flow becomes equal to the inflow.

This means that in every doab the rise of spring level must come to a stop at a certain level when the water table attains a state of equilibrium. What this level below ground surface will be, depends on the height of water table above rivers and the slope of the ground to-ward rivers and the steeper the slope, the greater the depth below ground at which equilibrium is attained. If the outflow towards the river is small due to poor slope the equilibrium level is then by soil evaporation and the transpiration by the plants. The level in such cases rises up to about within 5.0 ft. below natural surface.

5.8. WELL OBSERVATION

Sharma, (1959). has reported details of procedure of water table well observation on Upper Chenab Canal.

A detailed list of the wells under observation in the Punjab (portion in Pakistan) is given in the list of wells maintained in each circle and the position of each is shown on the Well plan of the canal see figure V - 7. Each well is distinguished by a Roman numeral or capital letter indicating the line of cross section to which it belong and below the Roman numeral or capital letter by a number (in Arabic numerals) showing its serial No. in the line of cross section.

A cast iron plate is permanently fixed in the masonry of each well, as near as possible, to the average natural surface level in the vicinity, bearing on it in raised figures both the cross section and the serial number of the well, and having a projection from which all measurements of the depth to the surface are to be made. These plates are of a standard pattern and supplied on indent by the Superintendent, Central Workshop Division. After the plates have been fixed, the reduced levels of the projecting measurement points should be ascertained by leveling from standard bench marks.

The well observed in the Punjab are shown in fig. V - 8. They are on provincial well lines. In addition there are lot of local well observations made to watch the effect of anti-water logging measures such as drains and pumping schemes. A section cross provincial line No.1 is given in fig. V- 9 and longitudinal section of the wells observed in Rechna Doab along the line shown in fig. V - 8. is given in fig. V -10. The cross section shows the well observation from 1908 and the subsequent rise the opening of the canals in the various doabs. In same cases water surface in the wells is still rising in some, in the water-logged areas they have become established. The subject is discussed in detail in the chapter on water logging.

5.8.1. Water table measurement in wells.

The depth of the surface of water in each well below the measuring point is measured twice a year.

i) During the first week in June and

ii) The first week in October, by the irrigation subordinate scads in whose section the well is situated.

In the case of village drinking wells the measurements are made either at daybreak, or in the afternoon, that is in each case, before the well is used or sufficient time after its working. In the case of the wells used for irrigation the observer should endeavourer, as far as possible, to take the measurement when the well is not working at the time at as long an interval as possible after the last working. If the well is not working at the time of measurement but has been worked during the previous 24 hour the interval which elapsed since it was last worked should be noted. If the well be working or has only ceased working for a few hour the actual depth below measuring point should be recorded, but the observer should endeavourer to ascertain by local enquiry what reduction in this depth would occur if the well were not worked and should separately propose for acceptance this modified depth.

5.8.2. Register of measurements.

A register is maintained in the Divisional and Superintending Engineer's, offices in a prescribed form. The reduced levels of the water surface in the well are worked out. The wells are checked by the Sub-Divisional Officer as underlined.

Difference maps.

A convenient method of exhibiting the well observations in the form of difference maps is explained below. A typical map for the Upper Chenab Canal Area is shown in fig.V-11. These maps show the rise in well observations as distributed over the tract, how far it extends and how it is spread over the various period. The fig.V-11 relates to the period from 1911 to 1935. The Upper Chenab canal was opened in 1912.

5.8.3. Water surface in wells.

The well observation described above are taken in open wells 10 to 12 feet diameter which are sunk 10 feet below normal spring level. They are supposed to record the spring level. Since the wells are open and shallow thy can safely be considered to record the phreatic surface of the ground water reservoir. A reference to fig.11 and 12 of this chapter will show, that the phreatic surface is not a fixed entity. It change with condition of flow in the water. If the water table is rising , it is below the Basic Subsoil Pressure level and if the water table is dropping, it is above the basic soil pressure by an amount which represents the pressure difference (P.D). Head Lost in this change can be as much as couple of feet in clayey soils. This adjustment of phreatic surface level takes place by mere pressure adjustment without any outside additions and subtractions of water. The actual spring level does actually vary in a pit dug at the same place according to dynamic movements of the water table . Commonly, water table is under stood to mean the water surface recorded in the open wells. Phreatic surface or spring level cannot be correctly measured by digging pit in the soil crust on account of soil evaporation.

5.8.4. Water Equivalent of well rise.

A foot rise in the well level does not mean that a foot depth of water have been added to the sub soil reservoir. The actual amount of water needed depends on the effective soil porosity which thickness, the rainfall and the constitution of the soil. The rise of rise of water table multiplied by the effective soil porosity gives the water equivalent for the well rise if the soil is already wet up to hygroscopic moisture content (scientists) wilting coefficient (agriculture engineers), the actual amount of water required shall be further reduced.

Let porosity be 40 percent by volume and let 15 percent by volume be the hygroscopic moisture content, these are the normal values in the soils crust of the Punjab. A well rise of one foot is then 40 – 15/100 = 0.25 ft, = 3 inches of water.

5.9. Interaction of Water User Association with Department

Performance assessment of Water User Association (WUA) should be carried out. A typical annual performance assessment from is given in table 5.3. which can be suitable modified as per the specific requirement.

Table 5.3. Annual Performance assessment

Item	Planned (m^3)	Actual (m^3)	Potential Points	Points Awarded
Water delivery				
Total discharge				
Irrigation water				
Delivery to Yingang canal				
Water delivery days				
Total points				
Irrigated area				
Irrigation area				
Irrigation area X time				
Total points				
Water use Efficiency (WUE)				
WUE of main canals				
WUE of branches				
WUE Of sub-branches				
WUE of whole canals system				
Total points				
Irrigation Duty and Efficiency				
Irrigation duty at the head of main canal (m^3 /ha)				
Irrigation duty at the outlet of sub-branches (m^3 / ha)				
Irrigation duty in field (m^3 /ha)				
Annual gross irrigation water per ha				
Irrigation efficiency at the outlet of sub-branches (ha/m^3 /s)				
Total points				
Rate of functional Structures				
Structures				
Canals and branches (km/number)				
Total points				
Maintenance				
Lined canals (km)				
Silt clearance (km/number)				
Structures maintained (number)				
Total points				
Income and Expenditure				
Total income				
Total expenditure				
Operating and managing cost				
Annual maintenance cost				
Total points				

CHAPTER - VI

WATER QUALITY

A safe potable and reasonable quality water is critical to the survival of all living being human and animal life, all flora and fauna, and even crops and vegetation, (i.e., irrigation of agriculture lands and forest)

Quality of water change according to place and purpose.

6.1.Water Quality Characteristics

Typical samples of surface ground and domestic waste water are to be collected and tested for Physical, Chemical and Biological characteristics of water as summarized in table 6.1. Analytical procedures to analyze natural water samples, to assess water quality are given in detail in American Standard Methods (1995) and Bureau of Indian Standards (IS – 3025 part 12 and IS – 3025 part 32), Methods of sampling and test (physical and chemical) for water and wastewater for density and chloride, are not repeated in this chapter.

6.2. Chemical Oxygen Demand

The chemical oxygen demand (COD) is the oxygen equivalent of the organic matter that can be oxidized by a strong chemical oxidizing agent in an acidic medium. The COD observed in natural streams and rivers is <2 mg/L to 100 mg/L. Potassium dichromate is the oxidizing chemical used in the COD test in North America; however, potassium permanganate is the oxidizing compound in other parts of the world. Silver sulfate is added as a catalyst and to minimize the interference of chloride on the COD test. Mercuric sulfate is also added to inhibit interference of metals on the oxidation of organic compounds. The reaction of the dichromate with organic matter is presented here in a general way :

$$\text{Organic matter } (C_a\, H_b\, O_c) + Cr_2\, O_7^{-2} + H^- \xrightarrow[\text{heat}]{\text{catalyst}} 2C_r^{+3} + CO_2 + H_2O$$

Table 6.1. Physical, Chemical, and Biological Characteristics of Water

Characteristics	Water Source		
	Typical Surface water	Typical Ground water	Domestic wastewater (U.S)
Physical			
Turbidity, NTU			
Solids, total, mg/L			
Suspended, mg/L			
Setteable, ml/L			
Volatile, mg/L			
Filteable (dissolved), mg/L			
Color, (color units)			
Odor, number			
Temperature, °C			
Temperature, °F			
Chemical : inorganic matter			
Alkalinity, mg/L as Ca Co_3			
Hardness, mg/L as Ca co_3			
Chlorides, mg/L			
Calcium, mg/L			
Heavy metals, mg/L			
Nitrogen, mg/L			
Organic, mg/L			
Ammonia , mg/L			
Nitrate, mg/L			
Phosphorous, total, mg/L			
Sulfate, mg/L			
pH. (pH units)			
Chemical: organic matter			
Total organic carbon (TOC), mg/L			
Fats, oils, greases, mg/L			
Pesticides, mg/L			
Phenols, mg/L			
Surfactants, mg/L			
Chemical: Gases			
Oxygen, mg/L			
Biological			
Bacteria, MPN/100mL			
Viruses, plaque forming units (pfu)			

Source: Adapted from National Interim Primary Drinking Regulations (1975)

6.3. Dissolved Gases

a. Gas transfer.

The principle transfer of gas in natural water is the transfer of oxygen from the atmosphere to the water. However, gas transfer also is used to strip hydrogen sulfide (H_2S), ammonia (NH_3) and voltaic organic compounds from water. In both processes, material is transferred from one bulk phase to another across a gas-liquid interface.

For example, oxygen is transferred from the bulk gaseous phase (atmosphere) across the gas-liquid interface into the bulk liquid phase (water). In the case of striping volatile organic compounds (VOC) from liquid, the VOC is transferred fro the bulk liquid phase (water) across the liquid-gas interface into the bulk gaseous phase (atmosphere). Mass transfer occurs in the direction of decreasing concentration.

The rate of transfer across the air-water interface depends on the equilibrium concentration and the turbulence at the interface.

b. Solubility of Gases

The equilibrium of each phase, concentration of gases or voltaic compounds dissolved in water depends on the temperature, the type of gas or volatile compound, and the partial pressure of the gas or volatile compound adjacent to the water. The relationship between the partial pressure of the gas in the atmosphere above the water and the concentration of the gas or voltaic compound in the water is described by Henry's law:

$$P_s = Hx_g$$

Where : P_s = partial pressure of gas, atm

H = Henry's law constant

X_g = equilibrium mole fraction of dissolved gas

$$\frac{\text{mol gas } (n_g)}{\text{mol gas } (n_g) = \text{mol water } (n_w)}$$

c. Dissolved Oxygen.

Dissolved oxygen is important in natural water, because dissolved oxygen is required by many microorganism and fish in aquatic systems. Dissolved oxygen also establishes an toxic environment, in which oxidized forms of many constituents in water are predominant. Typical dissolved oxygen concentrations reported for natural water in stream and rivers throughout the world are 3 to 9 mg/L, which is the concentration of dissolved oxygen in fresh water at saturation at 20° C (68° F).

The observed range of dissolved oxygen concentrations reported worldwide for streams and rivers is 0 mg/L (anoxic conditions) and 19 mg/L (supersaturated conditions). Supersaturated conditions are caused by algal blooms and usually occur late in the afternoon in the summer in temperate climates.

Under night time conditions bacteria and algae consume the dissolved oxygen and the respiration of these microorganisms results in anoxic or anaerobic conditions.

Under anoxic conditions, or periods of zero dissolved oxygen in the water, reduced forms of chemical species are formed and frequently lead to the release of undesirable odors until toxic or aerobic conditions develop.

Biochemical oxygen demand (BOD), the most widely used parameter, is a measure of the amount of oxygen used by indigenous microbial population in water in response to the introduction of degradable organic material.

The 5-day BOD (BOD_5) is most widely used. Typical concentrations of BOD_5 reported for streams and rivers throughout the world are <2 to 15 mg/L and the observed range is <2 to 65 mg/L. As a reference, the effluent limitations established by the U.S. EPA for biologically treated municipal wastewater is 30 mg/L, and many states require municipal effluents to contain an average BOD_5 of 20 mg/L, with concentrations as low as 5 mg/L in water-quality sensitive water segments.

The BOD_5 of natural water is related to the dissolved oxygen concentration, which is measured at zero time and after 5 days of incubation at 20^0 C. The difference is the dissolved oxygen use by the microorganism in the biochemical oxidation of organic matter. The BOD_5 can be calculated as $BOD_5 = D_0 - D_1$ in which BOD_5 is in mg/L and D_0 and D_I are the dissolved oxygen concentrations (mg/L) at time 0 and 5 days, respectively. If the BOD_5 of natural water exceeds the dissolved oxygen concentration at saturation (=9 mg/L), the sample of natural water must be diluted with aerated dilution water and the BOD_5 is calculated as;

$$BOD_5 = \frac{D_0 - D_1 \, (100)}{P\,(\%)}$$

In which P is the percent of sample (natural water) used. The BOD_5 test can also be used to characterize municipal and industrial waste water. However, in these tests, in addition to dilution water, acclimated seed organisms, nutrients, and the presences the samples are incubated at 20° C.

6.4. Sources of Pollution

Sources of contamination of ground and surface water are generally classified into following two broad categories.

i) Point source – such as effluents from industries, discharge of sewerage into a river etc, Bathing Gnats etc.

ii) Non Point source – there are scattered over a vide area or whole of the land surface under consideration. Typical examples are chemicals and fertilizers in the irrigated area.

It is easy to Monitor Point Source, by taking samples at appropriate time intervals and testing the same.

Non Pint Source can be monitored by fix ding appropriate net works of sampling locations.

6.5. Types of Groundwater Contamination

Groundwater is contaminated by a wide range of substances. The United states of America office of Technology Assessment (OTA. 1984) compiled an extensive list of substances that have been found in groundwater. These substances include approximately 175 organic chemicals, 50 inorganic chemicals, biological organisms and radionuclides (App.6). examples of the uses of the substances, which provides insights to the sources of the contaminants, are listed in this appendix.

There after U.S, National Research Council (National Academy of Sciences, 1994) compiled a list of the 25 most frequently detected groundwater contaminants at hazardous waste sites (Table 6.2.)

Table 6.2. Most Frequently Detected Groundwater Contaminations at Hazardous Waste sites

Rank	Compound	Common sources
1	Trichloroethylene	Dry cleaning; metal degreasing
2	Lead	Gasoline (prior to 1975); mining construction material (pipes); manufacturing
3	Tetrachloroethylene	Dry cleaning; metal degreasing
4	Benzene	Gasoline; manufacturing
5	Toluene	Gasoline; manufacturing
6	Chromium	Metal plating
7	Methylene chloride	Degreasing; solvents; paint removal
8	Zine	Manufacturing; mining
9	1,1,1- Trichloroethane	Metal and plastic cleaning
10	Arsenic	Mining; manufactiuring
11	Chloroform	Solvents
12	1,1- Dichloroethane	Degresing; solvents
13	1,2- Dichloroethane, trans	Transformation product of 1,1,1-trichloroethane
14	cadmium	Mining; plating
15	Manganese	Manufacturing; mining; occurs in nature as oxide
16	Copper	Manufacturing; mining
17	1,1- Dichloroethene	Manufacturing
18	Vinyl chloride	Plastic and record manufacturing
19	Barium	Manufacturing; energy production
20	1,2-Dichloroethane	Metal degreasing; paint removal
21	Ethylbenzene	Styrene and asphalt manufacturing; gasoline
22	Nickel	Manufacturing; mining
23	Di (2-ethylhexxyl)phathalate	Plastics manufacturing
24	Xylenes	Solvents; gasoline
25	Phenol	Wood treating; medicines

Source : National Research Council (1994)

Nitrates from fertilizers and animal wastes are prevalent contaminants of groundwater, as well as pesticides from agricultural activities. National surveys of this type of non point source groundwater pollution have been made by the U.S. Environmental Protection Agency and the U.S. Geological Survey (USEPA, 1990; 1992; Puckett, 1994).

6.6. Mechanisms for Groundwater Contamination

Groundwater can be contaminated by localized releases from sources such as hazardous waste disposal sites, municipal landfills, surface impoundments, underground storage tanks, gas and oil pipelines, back-siphoning of agricultural chemicals into wells, and injection wells. Groundwater can also become contaminated by substances released at or near the soil surface in a more dispersed manner, including pesticides, fertilizers, septic tank leach ate, and contamination from other non point sources (National Academy of Sciences, 1993). An illustration of various mechanisms of groundwater contamination is given in fig. 6.1. (from Fetter, 1993).

Unless a substance is placed directly into an aquifer (e.g., via an injection well), it has to pass through the unsaturated (vadose) zone, which has been referred to as "the buffer between human activity and the groundwater sources"(Goldshmid, 1984). Figure 6.2. (from Last, et al., 1994) shows the movement of carbon tetrachloride from a source through the vadose zone to groundwater. The movement of substances through the vadose zone is influenced by the properties of the substance (quantity, volatility, and density), the properties of the geologic material (physical heterogeneity and hydraulic properties). Reaction between the substance and the subsurface environment (sorption, ion exchange, geochemical and microbial transformation), and the hydrologic setting (quantity and time distribution of precipitation, evaporation and transpiration). Thus , not all contamination sources actually result in groundwater contamination. EPA estimates that groundwater contamination has occurred at about 80 percent of the nation's Superfund sites (USEPA, 1993).

OTA (1984) has categorized the sources of ground water contamination into 6 general categories given in table 6. 3.

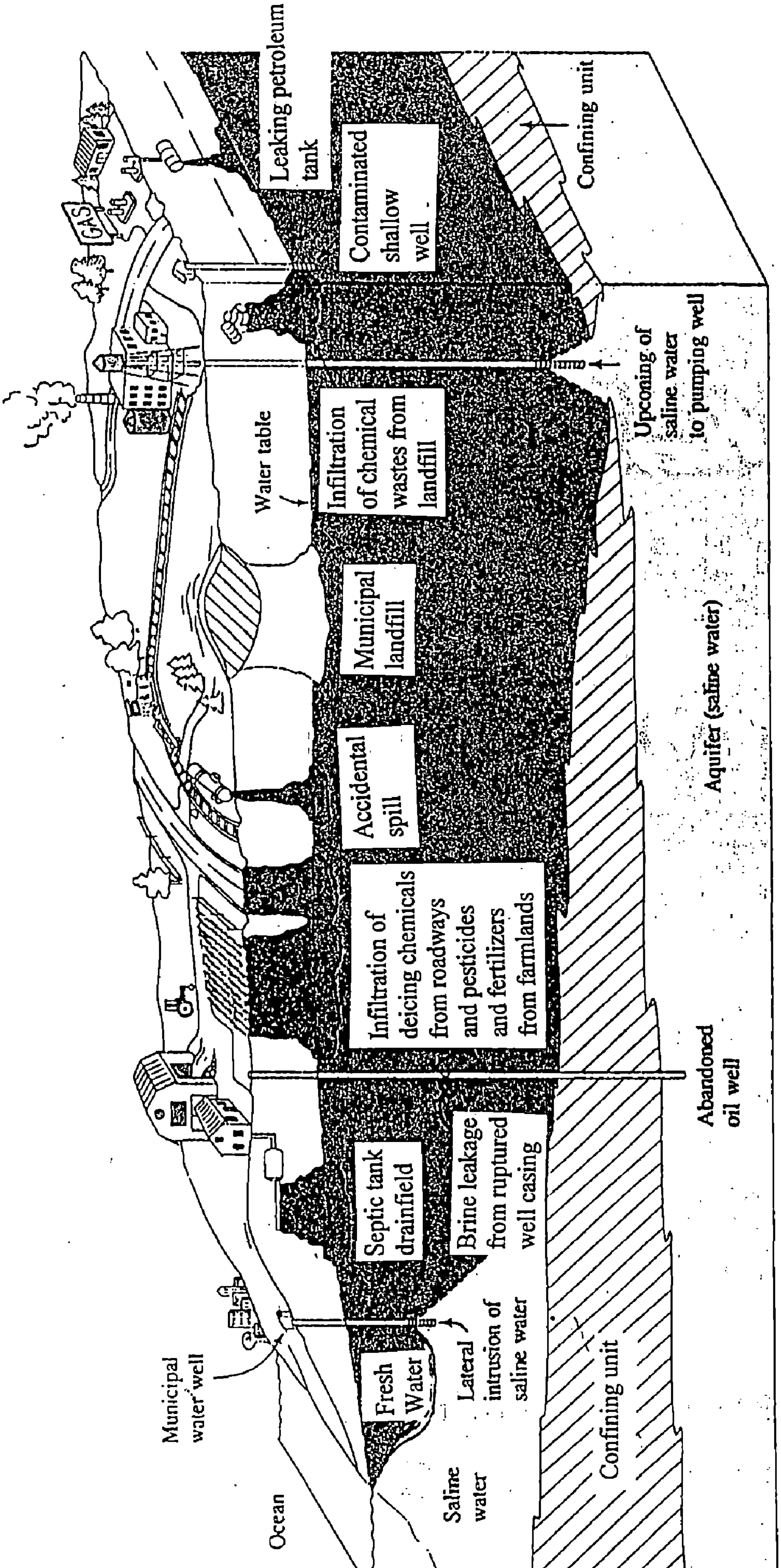


Fig. 6.1. Mechanisms of groundwater contamination (Fetter, 1993)

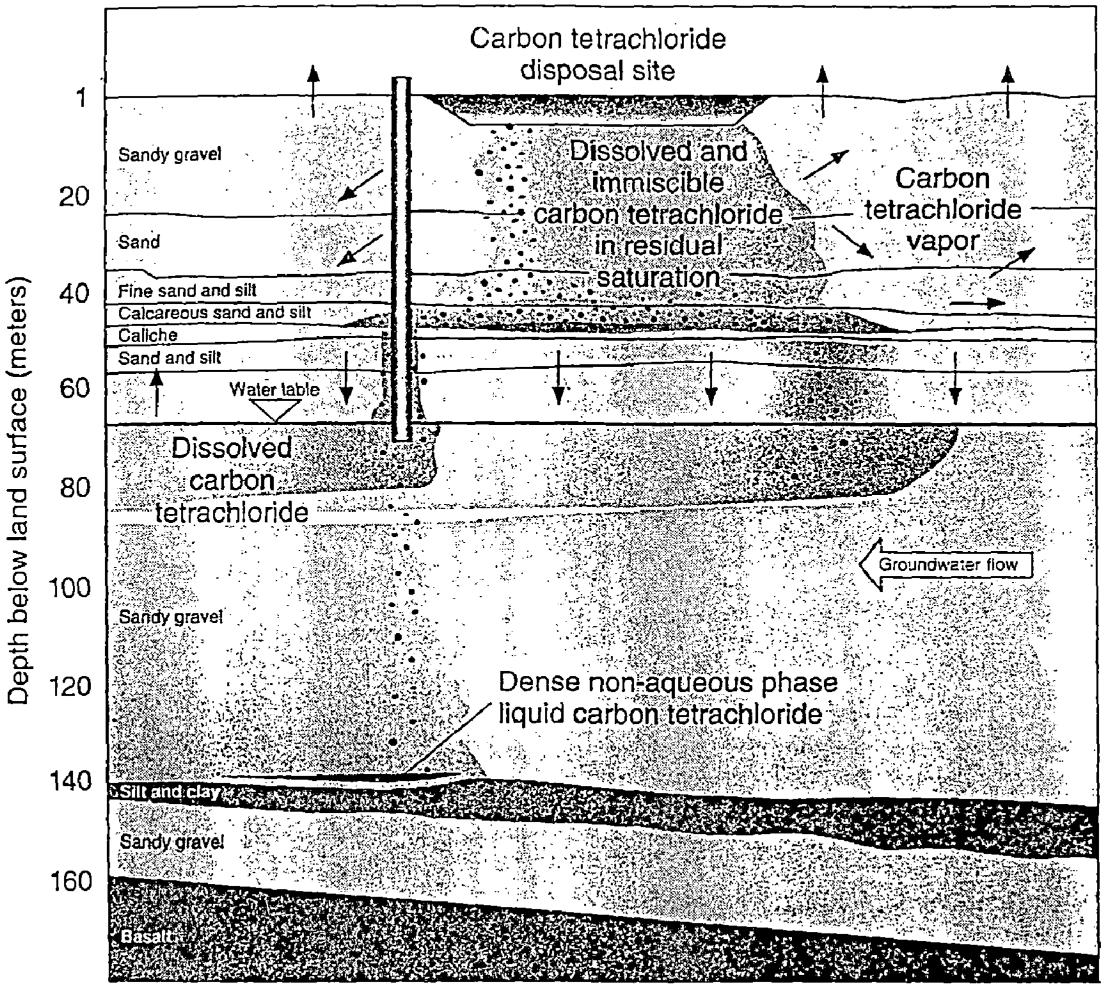


Figure 6. 2. Conceptual model of carbon tetrachloride contamination in the vadose zone and groundwater (Last, et. al., 1994).

Table 6.3. Source categories for Groundwater Contamination with Examples

Source category	Examples
I. Source designed to discharge substances	Septic tanks, cesspools Injection wells
II. Source designed to store, treat, and/or dispose of substances	Landfills, dumps, abandoned hazardous waste sites Above – ground and underground storage tanks Radioactive waste disposal sites
III. Sources design to retain substances during transport	Pipe lines Material transport and transfer
IV. Sources discharging substance as a consequence of other planned activities	Irrigation Pesticide/fertilizer applications Farm animal wastes
V. Sources providing a conduit for contaminated water to enter aquifers	Production wells Monitoring wells
VI. Naturally occurring sources whose discharge is created and/or exacerbated by human activity	Groundwater/surface water interactions Saltwater intrusion

Source : Modified from Office of Technology Assessment (1984).

Federal agencies have developed water quality criteria documents in response to the Federal Water Pollution Control Amendments of 1972 (1973) and various amendments, as well as to the Safe Drinking Water Act (1974) and amendments and promulgation of rules. These documents include:

i) Water quality Criteria, National Technical Advisory Committee to the Secretary of the Interior, reprinted by the EPA. ("Green" Book) USEPA, 1972.

ii) Water Quality Criteria, prepared by the National Academy of Sciences and the National Academy Engineering for the EPA. ("Blue" Book) NAS, 1973.

iii) Quality Criteria for Water, published by the EPA. ("Red" Book) USEPA, 1976.

The National Academy of Sciences (1977), 1980) developed quantitative criteria and established principles for the assessment of risk and safety of drinking water containing chemical constituents:

i) Effects observed in animals when properly qualified are applicable to humans.
ii) No technique is available to establish a threshold for long-term effects toxic agents.
iii) Exposure of experimental animal to high doses of toxic agents is necessary and is a valid technique for identifying possible carcinogenic effects on humans.
iv) Toxic agents and other materials should be assessed in terms of risk to human health rather than as or unsafe.

6.7. Quality of Irrigation Water.

The quality of irrigation water is judged by estimating the parameters like pH, Electrical Conductivity, SAR, RSC and different presence of potentially toxic ions.

pH : pH is the negative log of hydrogen ion activity and pOH is the negative log of hydroxyl ion activity.

The water on chemical dissociation gives rise to

$$H_2 = H^+ + OH^-$$

$$(H^+) + (OH^-) = 10^{-14}$$

pH scale varies from 0 – 14. At a pH 7, the H^+ and OH^- ions activity is equal and solution is said to be neutral. The pH < 6.5 is acidic < 6.5 to 7.5 normal and > 7.5 is alkaline.

6.7.1. Electrical Conductivity

It is the reciprocal of electrical resistance offered by salts. Electrical conductance is used to describe the salt concentration of water because conductance varies with salt content. It is expressed in ds/m.

C_1 to C_4 indicate the classes of water in terms of salt concentration. It is converted into osmatic pressure (EC_w x 0.36); ppm (EC_w X 640) and cations or anions in me/l (EC_w x 10).

Table 6.4. Classification of Irrigation Water and its Suitability (Salinity)

Class	Range of EC (µds/m)	Suitability
C_1.	< 250 Low Salinity	Almost all soil and crops.
C_2.	250 – 750 Medium Salinity	Good to mod drained soil, tolerant to mod. Tolerant crops.
C_3.	750 – 2250 High Salinity	Not used under restricted drainage tolerant crop.
C_4.	>2250 Very high salinity	Not used in ordinary condition

6.7.2. Sodium Adsorption Ratio :

SAR is a ratio for irrigation water used to express the relative activity of sodium in comparison with calcium and magnesium.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Where the cation concentration are expressed in mille equivalent per liter.

Table 6.5. Classification of irrigation Water and its Suitability (SAR)

Class	SAR range	Suitability
S_1	< 10 Low	Almost all Soils and crops
S_2.	10 – 18 Medium	Creates Na Hazards in fine textured soils
S_3.	18 – 26 High	Produces harmful level of esp, requires special management.
S_4.	> 26 Very high	Not suitable

The quality of water based on SAR (Table 6.5.) indicates that SAR < 10 is called low sodium water, 10 –18 medium sodium water; 18 – 26 high sodium water and > 26 very high sodium water. The S_1 to S_4 indicate the classes of irrigation water.

Water Quality rating based on residual sodium carbonate

Class	RSC (me/L)
RSC_0 Excellent	Nil
RSC_1 Good	0.1 – 1.25
RSC_2 Moderate	1.25 – 2.5
RSC_3 Poor	> 2.50

Water Quality rating based on Boron Concentration

Class	Boron (ppm)
Excellent	< 1.0
Good	1 – 2.0
Moderate	2.0 – 4.0
Poor	> 4.0

Classification of Irrigation Water on the basis of Electrical Conductivity (ECW) and its Suitability

Sr. No.	Class of water	Suitability for Irrigation
1	100 – 250. C_1 Micromhos/cm	Can be used for almost all crops and soils. Sandy (2.5 cm/h), loamy sand (1.8 – 2.5), sandy loam (1.2 – 1.8), Clay loam (0.6 – 0.8), Clay (0.1 – 0.2)
2	250 – 750 C_2	Can be use on good to moderately drained soil. Tolerant to moderately, tolerant crop. Soil 1, 2, 3.
3.	750 – 2250 C_3	Can not be use soil having restricted drainage. Only tolerant crop can be grown. Soil 1 and 2.
4.	> 2250 C_4	Can not be use in ordinary condition.

Sodicity Classification as above

Sr. No.	Class of water	Suitability for Irrigation
1.	Low Na (s_1) SAR < 10	
2.	Medium Na (S_2) SAR 10 – 18	May create Na hazard in fine textured soil, high CEC and low leaching, poor drainage.
3.	High Na (S_3) SAR 18 – 26	May produce harmful level of ESP in most soil, Require special management, good drainage, use of O.M, and chemical amendment.
4.	Very high Na (S_4) SAR > 26	Not suitable at all.

6.8. Monitoring Water Quality

Regional or long-term change in water quality should be monitored by establishing a few observation points through the area covered by the management plan. Where the objective is simple to monitor trends in water quality change, annual sampling is quite adequate. More closely spaced data points and more frequent sampling would be needed for special water quality problems, such as sea or other saline water intrusion, upwelling of connate saline water, or artificial recharge of an aquifer with water of quality inferior to that which is naturally recharged, or in areas where there is potential pollution as a result of liquid or solid waste disposal.

Because water quality changes (as opposed to water level fluctuations) are generally the result of actual movement of water, once the basin water quality norms, direction and rate of change, and delineation of aquifer system have been established, the sampling network and frequency can be related to the direction of movement and the travel time to minimize costs.

In areas multi layered aquifers, wells with known perforation levels should be selected as sampling points wherever possible so the aquifer or aquifers monitored are known. Where wells are not properly identified by aquifer, sampling will serve to monitor the quality of extracted ground water, which may be a mixture from several aquifers. This serves to monitor the water supply to local areas..

Complete mineral analyses of ground water samples are not always required. If tracing the effects of the commingling of different water is the primary need, then nitrates, chlorides, total hardness, and total dissolved solids are the constituents of greatest interest. Chloride is one of best indicators of seawater intrusion and other phenomena because it is the least likely to be effected by chemical reaction with soil particles through which the water is percolating. Total dissolved solids can be used to determine a regional increase in salinity because of use and reuse of water and effects of specific waste discharges.

The constituents to be monitored should be selected with reference to the ultimate use of the water. In agricultural areas, specific constituents that might affect the crops are of primary importance. These include boron, sodium ratio, and pesticides.

Nitrogen compounds may be critical if large quantities of treated wastewater, including cesspool effluent, percolate to ground water which is used for domestic supply.

In case where it is desirable to identify the source of water or source of mineralization, or to predict water quality change, sophisticated analysis techniques can be used.

6.9. Ground Water quality Monitoring System

A ground-water quality monitoring system must be capable of yielding ground-water samples for analysis and must consist of :

1). Monitoring wells (at least one) installed hydraulically up gradient (i.e., in the direction of increasing static head) from the limit of the waste management area. Their number, location, and depth must be sufficient to yield ground water samples that are :

    i). representative of background ground-water quality in the uppermost aquifer near the facility; and

    ii) Not effected by the facility; and

2) Monitoring wells (at least three) installed hydraulically down gradient (i.e., in the direction of decreasing static head) at the limit of the waste management area. Their number, locations, and depths must ensure that they immediately detect any statistically significant amounts of hazardous waste or hazardous waste constituents that migrate from the waste management area to the uppermost aquifer.

The detection monitoring system should have:

(i). Sufficient wells, both up gradient (background) and down gradient, to detect discharges from the regulated facility; and

(ii) Wells located within a flow path from the regulated facility in uppermost aquifer.

Furthermore, the uppermost aquifer should have sufficient hydraulic conductivity and extent so that sampling could be conducted within the property buffer zone (not to exceed 150 meters) for non hazardous solid waste sites and at the waste unit boundary for hazardous waste facilities.

An adequate detection monitoring program can be designed for any geologic/ hydrogeologic environment using the above criteria. The following sections present conceptual models for detection monitoring program that provide guidance for monitoring system design for a variety of hydrogeologic environments.

Prior to selecting the location and depths for screened intervals for ground-water monitoring wells, the ground-water monitoring designer must have, at a minimum, accomplished the following :

(i) Performed a complete site characterization;
(ii) Established a conceptual hydrogeologic model for the site;
(iii) Constructed a ground-water floe net; and
(iv) Located facility boundaries and waste disposal areas.

CHAPTER - VII

SUMMARY AND CONCLUSIONS

7.1. SUMMARY

The Management Information System (MIS) of any irrigation or say Multi purpose water Resources Development Project can be divided in three broad categories

I. M.I.S. of Project Preparations, survey, investigation, planning, design etc.

II. M.I.S. of project construction/ execution, including tender documents, allotment of works, progress monitoring and quality control etc.

III. M.I.S. of Project Operation and Maintenance (O & M) after a project has been completed.

M.I.S of all the above three areas can be further subdivided into following three parts.

a) Technical aspects

b) Institutional, organizational, Administrative aspects.

c) Financial aspects

All these three aspects are inter related to each other and affect the success of the project. These require high managerial skills and a coordinated inter disciplinary work.

Often a balanced design of M.I.S. is required.

In this thesis an attempt is made to identify the Parameters and work out the details of monitoring qualitative, quantification for a completed project, i.e. Operation and Maintenance.

The important aspects of MIS, such as quality, timeliness, quantity, relevance etc. are discussed in chapter I. Also important aspect of Management process, its objectives is discussed in this chapter.

Technical aspects of a project has been further divided into following parts and discussed as below:

i) Head works - Weir/Barrages/ dams - chapter III.

ii) Canal works - Canal net work and their related structures such as head regulators off taking channels, silt ejectors, cross drainage works, cross regulators etc. – chapter IV.

iii) Command area development - chapter V.

iv) Water quality – chapter VI

All these aspect are dealt in chapter III, IV, V and VI respectively.

7.2. CONCLUSIONS

1. M.I.S. Formal method of making available to management, accurate and timely information necessary to facilitate the decision making process and enable the organizations in planning, control and operational functions to be carried out effectively, at minimum cost. It is important management tools.

The M.I.S. provides information on the past, present and near future on relevant events, inside and outside the organizations. Manager can often detect problem before the issue of any formal control instructions/ reports. Thus it is a precise monitoring.

Different type of M.I.S. is required for different level officers such as Operating level, Middle level, and Top level.

For effective design of M.I.S include the user on the design team, weigh the money and time costs of the system, favor relevance and selectivity over sheer quantity, pretest the system before installation, provide adequate training and written documentation for the operators and user of the system.

2. Monitoring of head works: In general the effect of weirs/barrages or storage is causes a increase in water level and suchsequently bed level of the river in upstream. The result is aggradation of the channel upstream, degradation downstream and a modification of the flow hydrograph. This causes loss of storage capacity. Also there are evaporation and seepage losses. All these aspects are narrated in listed Para 3.2.

3. M.I.S. of canals – (all along canals): Ii is most difficult, time consuming and costly. Its requires collection of field data, their analysis. The collection of field data depends upon the size, head discharge of the main canal, its length, discharge and length of distribution net work up to minors and gross command area of the irrigation system.

Because of the long lengths of canal network and large cost involved it may not be possible to measure discharges, sediment concentration, seepage loss at too many points. Therefore data should be collected only at selected points, analyzed, simultaneously and transmitted to the central points for ratification/modification of discharge/ other correction by the top managers.

Also ensure proper use of water by farmers, Upkeep the proper quality of water, collect correct revenue.

4. **Water distribution plan** is an important component of irrigation operation implementation programmed. Each project has its own specific water distribution plan to achieve project target, like increasing of yield and production, increase of farmer income, and provide rural employment, equitable distribution of benefits. Thus operation and maintenance of irrigation system has to be done according to the water distribution plan.

Also ensure proper use of water by farmers, Upkeep the proper quality of water, collect correct revenue.

Ill effect or water logging: have been discussed in detail in chapter IV.

Conjunctive Use is the combined and integrated management of surface and ground water for optimal utilization of available water resources. The conjunctive use planning and management is necessary to achieve maximum returns from cropping activities of any area in addition to the solution of the problems of water logging and water table depletion. Optimum beneficial use of water can be obtained by conjunctive use.

Quality of irrigation water: is discussed in detail in chapter VI.

Water flowing in a network of canals is diverted through a number of outlets to watercourses and then to the each every individual farmer, or to small industries. This water to field is further utilized in the command area to irrigate the crops. Some farmers may (actually) take more water then others. Lot of water may be wasted. Revenue (water charges) is realized from farmers on the basis of types of crops and area irrigated. Water requirement of crops, types of crops, area is all changing with time, season-to-season, and year-to-year. Following data/ aspects are required to be properly, adequately and reliably monitored in the whole command area.

(i) Area irrigated by canals, (a) by flow and (b) by lift
- by wells,
- by both (jointly), of irrigation.

(ii) Un irrigated areas, but cultivated, changes in cultivable command area

(iii) Intensity of irrigation

(iv) Cropping pattern
- In irrigated area and un irrigated area

(v) Water requirement of crops

(vi) Change in ground water table

(vii) Degradation of land, water logged areas, saline areas and improvement.

(viii) Water conveyance and application efficiency

(ix) Water quality

5. Water quality: A safe potable and reasonable good quality water is critical to the survival of all living beings, human and animal life, all flora and fauna, and even crops and vegetation, (i.e., irrigation of agriculture lands and forest)
Quality of water change according to place and purpose.

Monitoring Water Quality: Establishing a few observation points through the area covered by the management plan should monitor regional or long-term change in water quality. Where the objective is simple to monitor trends in water quality change, annual sampling is quite adequate. More closely spaced data points and more frequent sampling would be needed for special water quality problems, such as saline water intrusion, artificial recharge of an aquifer with water of quality inferior to that which is naturally recharged, or in areas where there is potential pollution as a result of liquid or solid waste disposal.

Because water quality changes (as opposed to water level fluctuations) are generally the result of actual movement of water, once the basin water quality norms, direction and rate of change, and delineation of aquifer system have been established; the sampling network and frequency can be related to the direction of movement and the travel time to minimize costs.

In areas multi layered aquifers, wells with known perforation levels should be selected as sampling points wherever possible so the aquifer or aquifers monitored are known. Where wells are not properly identified by aquifer, sampling will serve to monitor the quality of extracted ground water, which may be a mixture from several aquifers. This serves to monitor the water supply to local areas..

The constituents to be monitored should be selected with reference to the ultimate use of the water. In agricultural areas, specific constituents that might affect the crops are of primary importance. These include boron, sodium ratio, and pesticides, electrical conductivity and pH- values.

Nitrogen compounds may be critical if large quantities of treated wastewater, including cesspool effluent, percolate to ground water, which is used for domestic supply.

These aspect are discussed in chapter VI

6. **A Very – very brief review of past and present status of M.I.S is given in Appendix I.**

7. **Recently INCID (2002) has brought out a publication system. – Guide line for Bench marking of irrigation system in India. And important Performance indicates are given in Appendix 2.**

8. **A Performa for performance assessment of Water Users Association (WUA) is given in Appendix 3, which can be suitably modified for specific projects.**

9. Detail procedures of sediment monitoring in rivers and canals as per IS. 4890 – 1968 is given in Appendix 4.

10. Other Important Aspects of Management Information System - Environment Monitoring

Environmental management is not nearly forestation, protection of wild life, protection of forest, monitoring pollution in water, air and noise or closing industries, issue legal notices. But it is management of human and natural resources together as a complimentary to each other so as to enable earning a good livelihood, and good environment to live in. It is a conflict resolution of human, animal and other natural resources (Land, water, air, minerals, forests etc.) without affecting their livelihood rather make livelihood easy and economical and produce a good environment to live in harmony with all living beings, Therefore it include :

- Management of urbanization, Development of urban and rural living centers with facilities of work, market, transport, parks, Educational centers, Recreational centers, and gardens with in manageable size.

  It also includes facilities of drinking water, electricity. Telephone lines disposal of human an animal excrete urban and drainage, waste management.
- Disposal of agriculture waste.
- Disposal of Industrial waste.
- Disposal of Poisons produced either by agriculture or industry
- Management of Environmental safe levels land, air, water, and noise, and create cleaning cycles. i.e. Develop recycling process.
- Urbanization has produced maximum pollution. Even city waste/ garbage is dumped in rural areas and polluting the river and canal water. Therefore management of these aspect are also linked with an irrigation system, and can not be easily isolated. Therefore minimum over all aspects needs to be included in any M.I.S. of an Irrigation System.

11. Cost and efficiency of Management

There are very important aspect of any management plan, as these the only measures or accountability of management plan.

Cost of Management of an Irrigation System can be divided in to following parts.

(a). Administrative and staff cost. The staff may be further bifurcated into

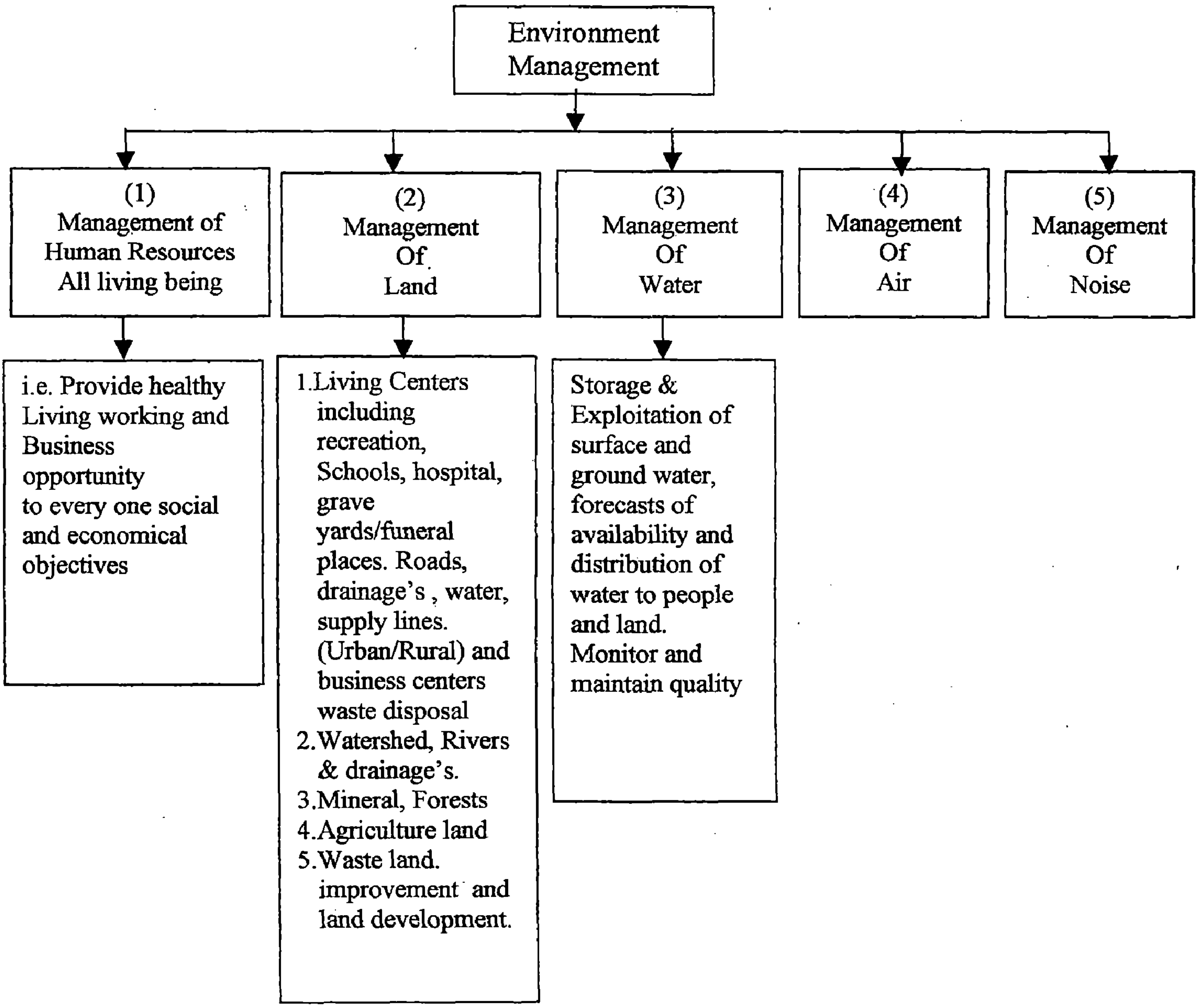
- i). Direct operation and maintenance staff.
- ii) Supervisor and Administrative control staff.
- iii) Staff units of data Processing, monitoring and transmission, (telephone exchange, wireless station, etc.)
- iv) Accounting and revenue staff.
- v) Cost of equipments and theirs maintenance.
- vi) Cost of hydraulic surveys, field data collection, transmission.
- vii) Actual cost of works operation and maintenance.

At few items, staff (personnel's) may have multiple duties to reduce over all.

(a). The efficiency of cost (expenditure) can be indicated in following terms.

- (i) Cost per unit of water from head,
- (ii) Cost per unit of water at various points.
- (iii) % losses of water at various point.
- (iv) Water diverted (at the point of use) per unit of production.
- (v) In case of Irrigation, it could be per unit of Agricultural production, per unit of area.

No effort could be made an above issues and further work is needed in above direction



1, 2, and 3 are highly inter related and effecting each other. Ground geology, minerals and industries are affecting the quality of each.

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ANNEXURE 1.

INDIAN STANDARDS ON METHODS OF MEASUREMENT OF FLOW IN OPEN CHANNELS

1. IS : 9922 – 1981 Guide for selection of method of measuring flow in open channels

2. IS : 9108 – 1979 Specification for liquid flow measurement in open channels using thin plate weirs.

3. IS : 6063 – 1971 Method of measurement of flow of water in open channels using standing wave flume.

4. IS : 6062 – 1971 Method of measurement flow of water in open channels using standing wave flume –fall.

5. IS : 6059 – 1971 Recommendation for fluid flow measurement in open channels by weirs and flumes – weirs of finite crest width for free discharge.

6. IS : 6330 – 1971 Recommendation for liquid flow measurement in open channels by weirs and flumes – end depth method for estimation of flow in rectangular channels with a free over fall (approximate method).

7. IS : 9117 – 1979 Recommendation for liquid flow measurement in open channel by weirs and flumes –end depth method for estimation of flow in non-rectangular channels with a free over fall (Approximate method).

8. IS : 4477(Part 1) –1977 Method of measurement of fluid flow by means of venture-meters Part 1 Liquids

9. IS : 4477 (Part 2) – 1975 Method of measurement of fluid flow by means venture-meters part 2 compressible fluids.

10. IS : 1192 – 1981 Specification for velocity-area methods for measurement of flow of water in open channels (first revision).

11. IS : 2914 – 1964 Recommendation for estimation of discharge by establishing stage-discharge relation in open channels.

12. IS : 9163 (Part 1) –1979 Specification for dilution methods for measurement of steady flow part 1 constant rate injection method.

13. IS : 9119 – 1979 Method of flow estimation by jet characteristics (Approximate method).

14. IS : 4890 – 1968 Methods for measurement of suspended sediment in open channels

15. IS : 6339 – 1971 Methods of analysis of concentration, particle size distribution and specific gravity of sediment in streams and canals.

INDIAN STANDARD ON STREAM GAUGING EQUIPMENT

1.	IS : 6064 – 1971	Specification for sounding and suspension equipment.
2.	IS : 4858 – 1968	Specification for velocity rods.
3.	IS : 3912 – 1966	Specification for sounding rods.
4.	IS : 3910 – 1966	Specification for surface meters (cup type) for water flow measurement.
5.	IS : 3911 – 1966	Specification for surface floats.
6.	IS : 4973 – 1967	Specification for fish weights.
7.	IS : 4080 – 1967	Specification for vertical staff gauges.
8.	IS : 9116 – 1979	Specification for water stage recorder (float type).
9.	IS : 3913 – 1966	Specification for suspended sediment load samplers.
10.	IS : 3917 – 1966	Specification for scup type bed material samplers.

APPENDIX 1

1.1. PAST AND PRESENT SYSTEM OF M.I.S. ON IRRIGATION PROJECTS IN INDIA.

It may be wrong to say that there is no M.I.S. Progress report is a form of M.I.S. It starts from lowest office say junior Engineer and travels through Assistant Engineer, Executive Engineer, Superintending Engineer and Chief Engineer.

Earlier these reports were examined thoroughly at each level i.e. by each officer himself and corrective measures were taken simultaneously. Typical Example are recording of irrigation, revenue, water level monitoring (see chapter VI) etc. Slowly the practice degraded and so the management is new under criticism. Subsequently, big and huge data performs started. These are filled in hurry by subordinate staff but normally no one may have time to sees them. No one may be concerned much in day-to-day jobs. But these are used occasionally for statistical purpose or at the time of annual budget or at crucial of emergent times. There are different forms in different states.

All these forms are still very useful tool for monitoring the system. Details of these are given in depart mental manual of orders. Due to time constrains they could not be included here .

On some projects, very good methods of M.I.S. are well established. For example gauge data of head and tail of each branch, distributors and minor are collected daily, entered in Registers and passed on daily at 8.00 A..M. by canal telegraph lines. Many times done twice a day, and immediate rectification in canal operation is done.

For this purpose, these were gauge readers/ cycle Sawara/ horseman, dark runner. May still be working in some states. Canal Telegraph lines were laid along canals and telegraph offices were located at important strategic points.

Subsequently, wireless station, were introduced on some projects.

Now with computers and internet, these are also being introduced, and with more clarity in data analysis, processing, M.I.S will improve and further improve the Management.

APPENDIX 2.

PERFORMANCE INDICATORS – DEFINITION & DATA SPECIFICATION (As per INCID 2002)

I. System performance

Indicator	Definition	Data specification
1. Water delivery capacity Index	Canal capacity to deliver water at system head / Peak irrigation water requirement	*Canal capacity to deliver water at system head:* Actual discharge capacity of system/sub-system at diversion point *Design peak irrigation water requirement:* The peak crop irrigation water requirement for a monthly/fortnightly period expressed as flow rate at the head of the irrigation system/sub-system
2. Total annual volume of irrigation water delivery (cum/year)	Total volume of water delivered to water user over the year or season. Water user in this context are the recipients of irrigation service and these may include single irrigators or groups or irrigators organized into water user groups.	Measured at the interface between the irrigation agency and water users.
3. Field application efficiency	Water used by crops by evaporation / Water delivered at field head	Total volume of water used by the crops worked out from evapotranspiration values Total annual volume of water made available at the field worked out from daily measurements.

Indicator	Definition	Data specifications
4. Annual relative irrigation supply Index	Total annual volume of irrigation water supplied Total annual volume of irrigation water supplied For paddy rice, percolation losses must be included	Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage) worked out from daily measurements to the system/sub-system. Total annual volume of crop irrigation demand is equal to total annual volume of irrigation water required by the crop less effective rainfall.
5. Annual irrigation water supply per unit command area (cum/ha)	Total annual of irrigation water inflow Total command area serviced by the system/sub-system	*Total annual volume of irrigation water inflow:* Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage) into the system/sub-system. *Total command area serviced by the system/sub-system :* The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated.
6. Annual irrigation water supply per unit irrigated area (cum/ha)	Total annual volume of irrigation water inflow Total annual irrigated crop area	*Total annual volume of irrigation water inflow:* Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage) into the system/sub-system *Total annual irrigated crop area:* The total irrigated area cropped during the year.

APPENDIX. 2

I. Agricultural Productivity

Indicator	Definition	Data Specifications
1. Output per unit serviced area (Rs./ha)	Total annual value of agricultural production Total command area serviced by the system/sub-system	***Total annual value of agricultural production :*** Total annual value of agricultural production received by producers. (In case the price is based on MSP, that value to be adopted) ***Total command area service by the system/sub-system :*** The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated.
2. Output per unit irrigation area (Rs./ha)	***Total annual value of agricultural production*** Total annual irrigated crop area	***Total annual value of agricultural production:*** Total annual value of agricultural production received by producers. (In case the price is based on MSP, that value to be adopted) ***Total annual irrigated crop area of the system/subsystem:*** The total irrigated area cropped during the year.
3. Output per unit irrigation supply (Rs./cum)	***Total annual value of agricultural production***. Total annual volume of irrigation water inflow	***Total annual value of agricultural production :*** Total annual value of agricultural production received by producers.)In case the price is based on MSP, that value to be adopted) ***Total annual volume of irrigation water inflow into the system/sub-system***: Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage) worked out from daily measurements.
4. Output per unit crop water demand (Rs./cum)	***Total annual value of agricultural production*** Total annual volume of water consumed by the crops	***Total annual value of agricultural production :*** Total annual value of agricultural production received by producers. (In case the price is based on MSP, that value to be adopted) ***Total annual volume of water consumed by the crops :*** Total volume of water consumed by the crop to meet evaporation demand. For rice crops this excludes deep percolation losses.

II. Financial Indicators

Indicator	Definition	Data Specifications
1. Cost recovery ratio	***Gross revenue collected*** Total MOM cost	***Gross revenue collected :*** Total revenues collected from payment of services by water user during the year. ***Total MOM cost :*** Total management, operation and maintenance cost of providing the irrigation and drainage service excluding capital expenditure and depreciation/renewals. The O & M cost of Head works, main canal, etc. will be added on pro-rata basis to the actual O & M cost of system/sub-system.
2. Total O & M cost per unit area (Rs./ha)	***Total MOM cost*** Total command area service by the system/sub-system	***Total MOM cost :*** ***Total command area serviced by the system/sub-system :*** The command area is nominal or design area provided with irrigation infrastructure that can be irrigated.
3. Total cost per person employed on water delivery (Rs./person)	***Total cost per personnel engaged in I & D service*** Total number of personnel engaged in I & D service.	***Total cost of personnel engaged in I & D service*** Total cost of personnel employed in the provision of the irrigation and drainage service in the system/sub-system. ***Total number of personnel engaged in I & D service :*** Total number of personnel employed in the provision of the irrigation and drainage service in the system/sub-system.
4. Revenue collection performance	***Gross service collected*** Gross service invoiced	***Gross revenue collected :*** Total revenues collected from payment of service by water user during the year. ***Gross revenue invoiced :*** ***Total revenue due for collection from water user for provision of irrigation and drainage services during the year.***

Continued Financial Indicators

Indicator	Definition	Data Specifications
5. Average revenue per cubic meter of irrigation water supplied (Rs./cum)	***Gross revenue collected*** Total annual volume of irrigation water delivery	***Gross revenue collected :*** Total revenues collected from payment of services by water users. ***Total annual volume of irrigation water delivery*** Total volume of water delivered to water users over the year or season. Water user in this context are the recipients of irrigation service and these may include single irrigation or groups or irrigation organized into water user groups.
6. Maintenance cost to revenue ratio	***Maintenance cost*** Gross revenue collected	***Maintenance cost :*** Total expenditure on system maintenance ***Gross revenue collected :*** Total revenues collected from payment of services by water user during the year.
7. Staffing number per unit area (Persons/ha)	***Total number of personnel engaged in I & D service*** Total command area service by the system/sub-system	***Total number of personnel engaged in I & D service :*** Total number of personnel employed in the provision of the irrigation and drainage service in the system/sub-system. ***Total command area serviced by the system :*** The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated.
8. Total O & M Cost per unit of water supplied (Rs./cum)	Total MOM Cost Total water supplied	
9. (a) Land damage index	Waterlogged + saline/alkaline affected area Total CCA	Since some waterlogged area may also be saline/ alkaline affected area, double accounting should be avoided.
9 (b) Average depth to water table (m)	Average annual depth of water table calculated from water table observations over the irrigation area.	
10 (a) Water quality : Ph/Salinity/Alkalinity	Ph/Salinity/Alkalinity of the irrigation supply and drainage water.	
10.(b) Salt balance (tones)	Differences in the volume of incoming salt and outgoing salt.	

Performance assessment of Water User Association (WUA) should be carried out. A typical annual performance assessment from is given in table 5.1. which can be suitable modified as per the specific requirement.

Annual Performance assessment

Item	Planned (m^3)	Actual (m^3)	Potential Points	Points Awarded
Water delivery Total discharge Irrigation water Delivery to Yingang canal Water delivery days **Total points.**				
Irrigated area Irrigation area Irrigation area X time **Total points**				
Water use Efficiency (WUE) WUE of main canals WUE of branches WUE Of sub-branches WUE of whole canals system **Total points**				
Irrigation Duty and Efficiency Irrigation duty at the head of main canal (m^3 /ha) Irrigation duty at the outlet of sub-branches (m^3 / ha) Irrigation duty in field (m^3 /ha) Annual gross irrigation water per ha Irrigation efficiency at the outlet of sub-branches (ha/m^3 /s) **Total points**				
Rate of functional Structures Structures Canals and branches (km/number) **Total points**				
Maintenance Lined canals (km) Silt clearance (km/number) Structures maintained (number) **Total points**				
Income and Expenditure Total income Total expenditure Operating and managing cost Annual maintenance cost **Total points**				
Crop Yield Assessment Grain Wheat Cotton **Total point**				

APPENDIX 4.

Methods for Measurement of suspended Sediment in open channels (Abstracts from IS. 4980 – 1968)

Table 1. SELECTION OF VERTICALS

(Clause 4. 2, Note 1)

SL No	WIDTH OF THE RIVER	NUMBER OF VERTICALS	LOCATION OF VERTICAL IN NORMAL SECTION WITH SLOPING SIDES	LOCATION OF VERTICALS IN STREAM OF UNIFORM DEPTH AND VELOCITY
(1)	(2)	(3)	(4)	(5)
i)	Less than 30 m	3	25.50 and 75 percent of the width	17.50 and 83 percent of the width
ii)	30 – 300 m	5	20, 35, 50, 65, and 80 percent of the width	10, 30, 50, 70 and 90 percent of the width.
iii)	over 300 m	7	15, 30, 40, 50, 60, 70 and 85 percent of the width.	7, 21, 36, 50, 64, 79 and 93 percent of the width.

Note : These are suggested for tentative adoption in natural and artificial channels until by experimentation more suitable location and spacing of verticals are determined.

TABLE 4.1. METHOD OF SELECTING SAMPLING POINTS IN A VERTICAL

SL No	METHOD AND DESCRIPTION	DISCUSSION	RELIABILITY AND ACCURACY FOR DETERMINING: Concentration Only *	RELIABILITY AND ACCURACY FOR DETERMINING: Concentration and Particle Size	PARTICAL CONCENTRATION	NUMBER OF SAMPLES AND ANALYSES PER VERTICAL
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	***Single point*** A single sample secured at the surface	Arbitrary method unless coefficients have been determined from previous, more complete sampling, and than it is somewhat empirical	Not reliable or necessarily accurate even when a coefficient has been determined	Not at all reliable or accurate	Simplest of all present methods, rapid and easy to use, Readily adapted for use by unskilled observers. Requires previous, more exact sampling for justification	One sample and one laboratory analysis
ii)	***Single-point*** . A single sample secured at any point in the vertical other than the surface.	Arbitrary method unless coefficients have been determined from previous, more complete sampling, and then it is somewhat empirical. A common arbitrary point has been 0.6 depth	Generally not reliable or accurate even when a coefficient has been determined, but more so than a single surface sample. Thoroughness of preliminary investigations will determine, somewhat, the reliability and accuracy	Not reliable or accurate	Simple, rapid, and easy to use, but fractional depth measurements make it less adaptable to use by unskilled observers than single surface method. Requires previous, more exact sampling for justification	One sample and one laboratory analysis
iii)	***Two-point*** Two point selec – ted arbitrarily for convenience and adaptability to the skill of the observer	Arbitrary method with no rational justification	Generally not reliable or accurate for all conditions of a given stream	Generally not reliable or accurate	Fairly simple, rapid, and easy to use. May be used by dependable observers even though inexperienced	Two samples may be combined if of equal volume for a single analysis

* For methods where coefficients are used, comments apply only to individual observations or short period investigations, as over long periods, totals may have a fair degree of accuracy.

Continue

SL No	METHOD AND DESCRIPTION	DISCUSSION	RELIABILITY AND ACCURACY FOR DETERMINING		PARTICAL CONCENTRATION	NUMBER OF SAMPLES AND ANALYSES PER VERTICAL
			Concentration Only *	Concentration and Particle Size		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
iv)	***Three - point*** Arbitrary selection of points at surface, mid-depth, and bottom with equal weights	Points located Arbitrary	Not necessarily reliable or Accurate for all stream condition	Not necessarily reliable or Accurate	Sampling at surface, mid depth, and bottom is the most simple and easiet to use of all methods requring more than two samples may be used by dependable observers even through inexperienced	Three samples may be combined if of equal volume for a singel analysis
v)	***Three – point*** Arbitrary selection of points at surface, mid-depth, and bottom with weight of 1, 2, and 1 applied, respectively	Basis of method is the assumption that the averages of surface and mid-depth sample repre - sent upper-half of discharge and average of mid-depth and bottom represents lower half	Not necessarily reliable or Accurate for all stream condition	Not necessarily reliable or accurate, but more so than three points, surface mid-depth ,and bottom with equal weights	Sampling at surface, mid depth, and bottom is the Simples and the easiest to use of all methods requiring more than two samples. May be used by dependable observers even through inexperienced	Three samples, if of equal volume, surface and bottom samples may by combined for single analysis
vi)	***Precise*** A relatively large number of point Samples at known locations in each vertical, simultaneous with velocity measurements	Rational method for use primarily in special investigations. Number of sampling points depends upon depth of stream, the velocity and sediment distribution, and the degree of accu – racy desired	Reliable and accurate. Accuracy depends upon the curvature of the velocity and sediment distribution curves and number of samples. The most accurate method in use at present	Reliable and accurate. Accuracy depends upon curvature of particle distribution curves, and number of sam – ples. The most accurate method in use at present	Not adapted to routine sampling because of the excessive work required. Its use is limited to research or preliminary work excessive as all samples must be analysed separately	Minimum of four or five samples all to be analysed se – parately

Continue

SL No	METHOD AND DESCRIPTION	DISCUSSION	RELIABILITY AND ACCURACY FOR DETERMINING		PARTICAL CONCENTRATION	NUMBER OF SAMPLES AND ANALYSES PER VERTICAL
			Concentration Only *	Concentration and Particle Size		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
vii	***Straub*** Sampling at 0.2 and 0.8 depth, applying coefficient obtained by mathematical deiation for both linear and curvi - lininear distribution values weighted 5/8 and 3/8 for 0.2 and 0,8 depth, respectively	Rational method, best adapted for use where the vertical sediment distributi - on curve approximates a straight line and the velocity dis - tribution is fairly constant.	Accuracy and reliability depends almost entirely upon the agreement of the actual to the assumed sediment and velocity. In most cases quite reliable	Theoritically not sound if sediment distribution is curvi - linear, but, practically, one of the most reliable methods.	Field work relatively simple for skilled ob – server but adaptable also to dependable ob- servers, even through inexperienced.	Two samples and two analyses
Viii	***Luby*** Sampling points selected at the middle of incre – ments of depth representing equal portion of stream discharge	Rational method if a sufficient number of samples if of equal volume, may be combined and the composition in the vertical. Number of points with respect to depth depends primarily upon curvature of sediment distribut i- on curve, to a lesser exten, generally, upon curvature of vertical velocity curve.	Reliable and accurate if a sufficient number of samp- Les are collected. One of the most reliable and accurate of the present methods except the precise.	Fairly reliable and accurete if a sufficient number of samp – les are collested. One of the most reliable and accurate of the present methods except the precise. Enough samples should be taken so that one will be close to the stream bed.	Requires either an assumed velocity dis – Tribution or previous velocity measurements Too complicated for use except by trained hydrographers. Because of sampling more points a better representation of the actual sediment distri- Bution will probably be obtained than with the Straub method.	Minimum of five sampes may be combined if of equal volume for a single analysis.

Continue

SL No	METHOD AND DESCRIPTION	DISCUSSION	RELIABILITY AND ACCURACY FOR DETERMINING		PARTICAL CONCENTRATION	NUMBER OF SAMPLES AND ANALYSES PER VERTICAL
			Concentration Only *	Concentration and Particle Size		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
ix	*Depth – integra – tion.* Sinmgle sample collected from all points in the ver –tical usually obtained by lowering and rai-sing a slow filling sampler at cons – tant rate. These usually consist of ordinary milk bottle types or specially design-ed slow filling samplers	Rational method on-li it sample is collec-ted proportional to velocity	Relatively reliable under usual conditions but its ac-curacy varies as most of the present equipment does not sample proportio-nal to the velocity and ma-ny samplers do not apro – Ach close enough to the bottom. As used, accuracy depends upon depth of stream and type of sampler	Relatively reliable under usual conditions but its ac-curacy varies as most of the present equipment does not sample proportio-nal to the velocity and ma-ny samplers do not aproach close enough to the bottom. As used, accuracy depends upon depth of stream and type of sampler	As commonly used with simple slow-filli-ng samplers this method is simple, rapid, easy to use, and well adapted to depen-able ovserves, even through in experienced No prevoius measu – rement necessary	One sample and one analysis.

- For methods where coefficients used, comments apply only to individual observation or short investigations, as over long periods, totals may have a fair degree of accuracy.

TABLE: 4.2 CHARACTERISTICS OF SUSPENDED SEDIMENT LOAD SAMPLERS

IS : 4890 - 1968

SL No	TYPE	DESCRIPTION	DISTURBANCE TO FLOW CHARACTERISTIC	INTERMIXING OF SAMPLE WITH WATER	SAMPLING ACTION	FIELD HANDLING	ADAPTABILITY TO VARIOUS FIELD CONDITIONS
1	2	3	4	5	6	7	8
i)	Vertical pipe	With a vertical cylinder or pipe forming the container. Whwn the sampler is lowered to the desired depth, water sediment mixture flows upward through the container. Valves at either end close and trap the sample.	Excessive	Generally excessive	Instantaneous	Necessary to transfer into another container	Offers considerable resistance to current. Not satisfactory when close to stream bed
ii)	Instantaneous vertical	A vertical sampler with arrangement to open the sampler for the instantaneous (rapid) intake of samples at the desired time and depth	Effect not evaluated	None	Instantaneous	Necessary to transfer into another container	Not satisfactorily stream lined or adapted for use near stream bed
iii)	Instantaneous horizontal	With a horizontal cylinder equipped with end valves which can be closed suddenly to trap instantaneous samples at any desired time and depth	Tendencies minimised effect not evaluated	Slight possibility	Instantaneous	Necessary to transfer into another container	Allows sampling very close to stream bed. Adaptable to any stream or depth
iv)	Bottle	Consisting of a standard container held in a case with device for lowering and opening at the sampling point. The mouth is kept open for the minimum time required to fill up the bottle	Excessive effect not evaluated	Some extent, if not opened and closed at site	Bubbling or slow-filling after initial rush	Container with sample detachable	Not capable of sampling close to bed of stream. Has got high efficiency in trapping fine grade sediment and the efficiency is less with the increase in grade
v)	Bottle (modified)	Consisting of a litre capacity container fifteed in a case with device for lowering or raising and opening at the sampling pont. Provided also with separate water intake and air exhaust device for equalising pressure inside and outside the container	Appreciable, Effect not evaluated	Excessive, if not open and closed at the sampling point	Slow-filling; no initial inrush present	Container with sample removable	Not capable of sampling close to the stream bed

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