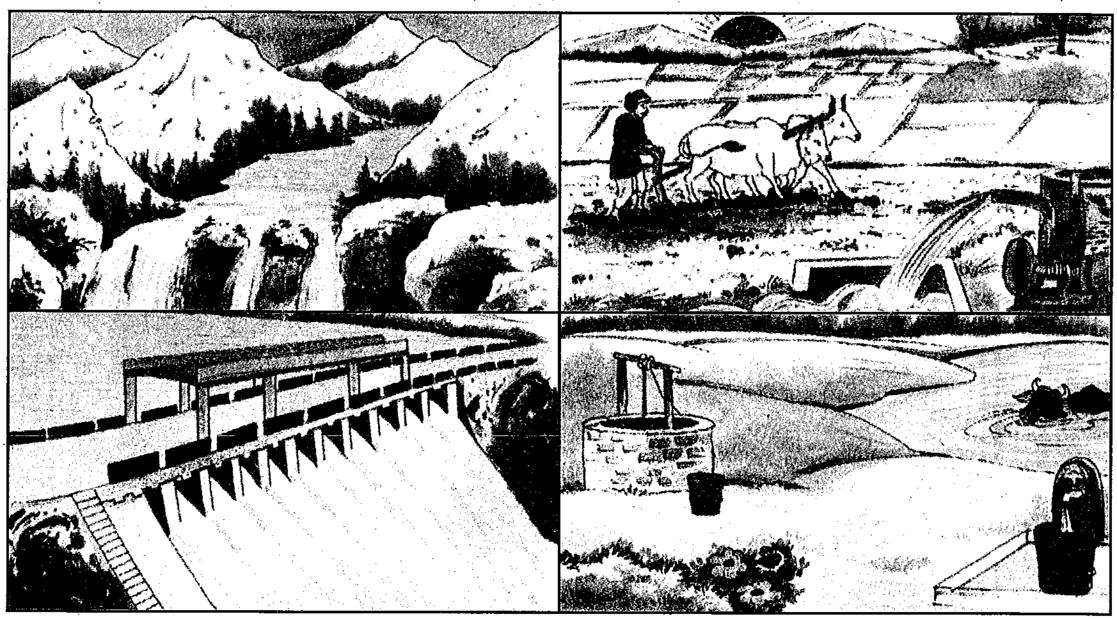
PDWR-03

Vardhaman Mahaveer Open University, Kota



Performance Evaluation of Irrigation Projects

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Vardhaman Mahaveer Open University, Kota

Performance Evalution of Irrigation Project

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Course Production

Yogendra Goyal
Asstt. Production Officer
Vardhaman Mahaveer Open University, Kota

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Performance Evaluation of Irrigation Projects

UNIT-1

PRINCIPLES OF OPERATION SYSTEM & EQUITABLE WATER DISTRIBUTION SYSTEM

Structure

1.0 Objectives

The objective of this unit is:

- To understand the basic concept of operation system
- To understand the basic concept & principles of water regulation
- To understand the equitable water distribution method 'Warabandi'

1.1 Introduction

The efficient operation of an irrigation system depends upon many variable comprising of technical and social parameters. The basic objective should be to optimize per unit use of water to achieve the optimum production level.

This unit highlights the two most important aspects:

- Operation is the process of delivery of water for irrigation in a specific way. It should be capable to meet the local conditions.
- Through effective operation, the desired objectives of the project can be achieved.

In operation of irrigation system, water regulation is an important function, to enable proper allocation of irrigation supplies to each segment of the operational area of the farmers' organization.

It is also equally important that the irrigation water should be made available at the minor and outlet level, are distributed among all the landholdings in a chak proportional to the size of the landholding. Hence, water regulation in the system has to be followed by a rotational water supply among farmers. The latter exercise is also known as warabandi.

The unit will consist of explaining the various operational aspects of water regulation and warabandi.

WATER REGULATION

1. Release supply schedule	a. Quantity b. Duration c. Interval between supplies
2. Mode of suppy	Full supply Half supply Continuous Intermitent
3. Duration of supply	Period to cover the entire command (one cycle)
4. Interval between irrigations	
5. Quantities to be supplied	

IRRIGATION SUPPLY

Regulation includes:

- Fixing the dates of release of water for irrigation;
- Pattern of water supplies to different reaches in the command;
- Period and pattern of availability water;
- Quantity of supply;
- Changes in regulation in response to emergencies;
- Adopt suitable crop pattern; and
- Water allowance.

ROTATIONAL WATER SUPPLY (RWS) - OR WARABANDI

This method helps to:

- Provide equitable quantity of water to each farmer irrespective of location of field and in proportion to size of landholding in the command;
- Know water schedule;
- Advise in agricultural production planning and procurement of agricultural inputs;

- Develop the sense of ownership among the farmers; and
- Bring about discipline among the water users.

1.2 Principles of operation

Irrigation system operation is the main process in irrigation management. Basically, operation is the process of releasing, conveying and dividing water in the canal system to ensure predetermined flows at prescribed times for specified durations at demarcated points of delivery.

An essential feature of operation is an agreed plan according to which operation is carried out every season. The plan is also called the seasonal operation plan.

The seasonal operation plan is aimed to:

- assist in effective day-to-day operation,
- provide a basis for monitoring of the water delivery,
- provide a basis for longer-term review and evaluation of policy and operational practices in the light of the operational experiences.

Operations aim is to introduce an irrigation service which is reliable, predictable and, where appropriate, equitable. These are the objectives of irrigation system operation.

AN EFFECTIVE OPERATION PLAN CONSISTS OF:

- SUPPLIES ARE AS PER ALLOCATION/AVAILABILITY
- SUPPLIES ARE ASSURED TO BENEFICIERIES
- TIMING OF SUPPLIES ARE KNOWN IN ADVANCE TO THE BENEFICIARIES.
- WATER SHOULD BE DISTRIBUTED EQUITABLY.

How to meet the objectives of operation?

To adequately meet the objectives of operation there is a set of prerequisites:

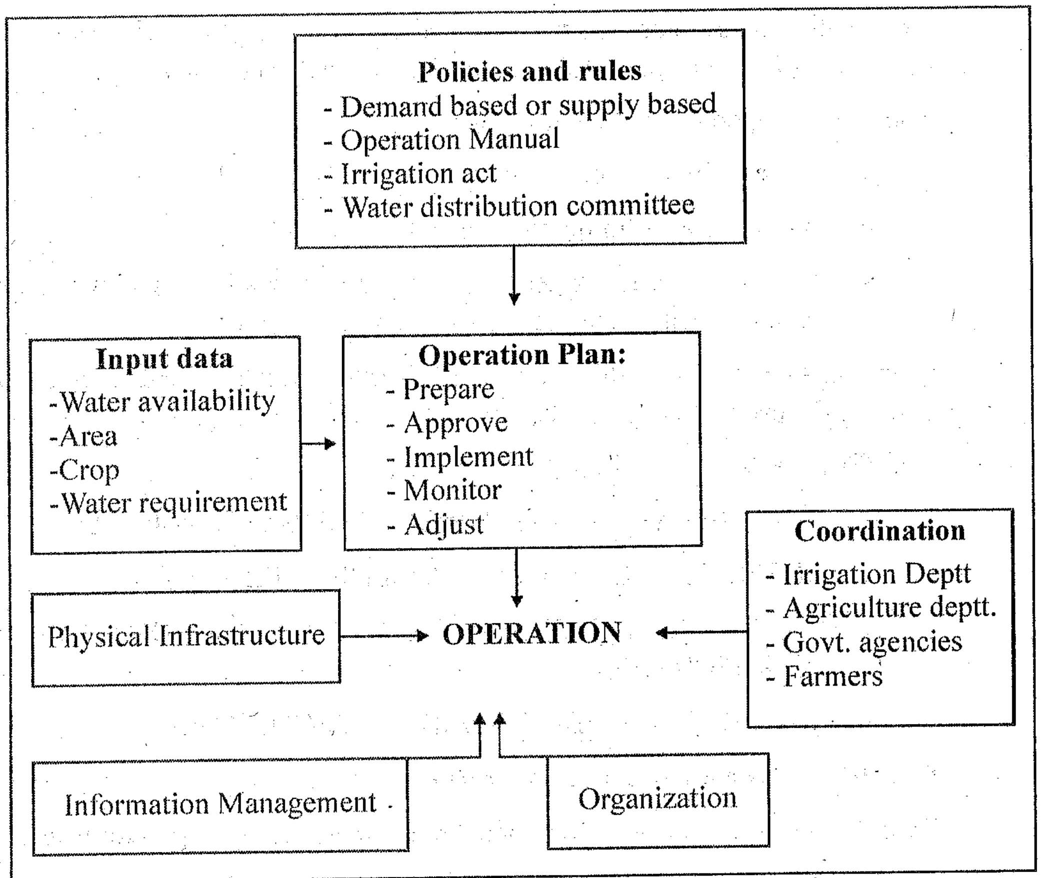
- A properly designed irrigation system is needed. Overall design of the system as well as technical features has bearing on operation. This aspect of design will not be dealt within this unit.
- Presence of control structures for regulating & controlling the flow
- The objectives should be laid down in main policies of operation and described in an operation manual, local (government) orders and irrigation acts.
- Well defined rules and instructions are necessary to prepare, approve, implement, monitor and adjust the operation plan.
- Technical features of the canal system for control of water levels and flows, influence the operation.
- An effective organisational structure to support the realization of operation tasks.
- Appropriate information system in the irrigation project, within the irrigation

department, and between the department and other agencies, including the water users.

- Coordination between the irrigation department, other Government agencies and water users is important in the operation.

An important feature of irrigation system operation is that these prerequisites are interrelated and are mutually dependent. This is reflected as below:

Interrelationship of prerequisites for Irrigation Operation



1.3 Policies and rules

Each irrigation project has a set of objectives or goals. Generally, the aim is that the project will deliver water in a manner which facilitates maximum agricultural production and extends benefits of irrigation to as large a number of farm families as possible.

In order to meet the objectives of the project, several activities have to be carried out. Operation policies and operation rules for the project, dictate how this should be done.

Operation policies

Policies are framed in line with the objectives of the project, and provide guidance for operation of the system.

For instance, these policies indicate the access to water resources and the irrigation service. In most of the case, operation policies have been outlined in the project reports. The policies take into consideration the existing irrigation laws, water rights and present system of water allocation.

Proper knowledge of the operation policies is thus essential for successful operation.

Operation rules: For making irrigation service reliable, predictable and equitable, present operation policies should be reviewed, taking into consideration these objectives, and revised operation rules developed for each project under the project.

Rules covers:

- planning of water deliveries (e.g. determination of irrigation service, preparation of the operation plan, approval of the operation plan),
- water deliveries (e.g. mode of canal operation, releases from the reservoir, irrigation scheduling),
- monitoring of operations.

Ideally, these rules should be provided in the Operation and Maintenance (O&M) manual for each project.

The O&M manual describes the policies and rules. It deals with general organisational aspects, operation and maintenance procedures, and administrative and financial policies. The operation section of the O&M manual covers the following aspects:

- Detailed operation policies, rules and specifications,
- Procedures for operation planning,
- Procedures for operation of headworks and irrigation system,
- Procedures for control of emergencies,
- Procedures for monitoring and evaluation of the operation.

In addition, the manual contains a description of general project features, like command areas and buildings.

The manual is very useful for the management of an irrigation project, because:

- it is a reference book for day-to-day project operation and maintenance at every level in the project,
- it will guide the manager of a project to make decisions in line with the recommended practice,
- it provides basic data on the project.

When a manual is not available, the project manager should start the preparation of one. The best approach would be to do it step-by- step:

1. Formulate scope and requirements of the manual, including specific operation procedures and data needs.
2. Collect data (project details, present policies and rules).
3. Process and analyse data, undertake further study if required.
4. Frame operation policies and rules.
5. Compile information and prepare the manual.
6. Get approval of the manual.
7. Update the manual periodically as needed.

1.4 Operation plan

In each irrigation project, operation plans are to be developed at two different stages. The first stage is the period of formulating the project, during which the plan known as the Design Operation Plan (DOP) is prepared. The DOP is the reference plan and is entirely based on the historical data on dependable river inflows into the reservoir and on rainfall over the command. With the DOP as the reference and taking into consideration the real availability of resources (both water and rainfall) for use just before the commencement of the season, a Seasonal Operation Plan (SOP) is to be prepared. The SOP must be approved by the water distribution committee consisting of officials & water user association members, representative farmers of the area before it can be implemented.

Formation of Water distribution Committee:

The water distribution committees should be formed at various stages. Generally for Major projects, it is headed by Divisional Commissioner & superintending Engineer as member secretary. For medium projects, District collector is the chairman of water distribution committee & Executive Engineer is the member secretary while for Minor project, SDO of the area acts as the Chairman & Assistant Engineer is the member secretary.

The SOP is always the plan which is to be used for implementation in operating an irrigation system. However, in certain cases like wet season crops, where the actual resources (water and rainfall) availability before the commencement of the season is not known in advance, and can only be anticipated, DOP itself is to be taken as SOP for the project and proceeded further for implementation. The SOP indicates how water will be released, conveyed and divided during the season. With this reference document, the project manager can ensure that the project objectives are achieved.

The DOP is developed in three steps:

1. Broad principles of operation are laid down. These are part of the project report and include:

   - mode of canal operation   opening and closure date of releases
   - water allocation for the project.

2. Both the DOP and SOP are to be based on the above principles. This plan states:

   * releases to other users   * start and closure of releases
   * mode of supplies   * release schedules
   * rules to respond to specific situations.

In practice, the releases vary from season to season, because the rainfall and inflows will vary. Guidelines for responding to such variations are an important aspect of the plan.

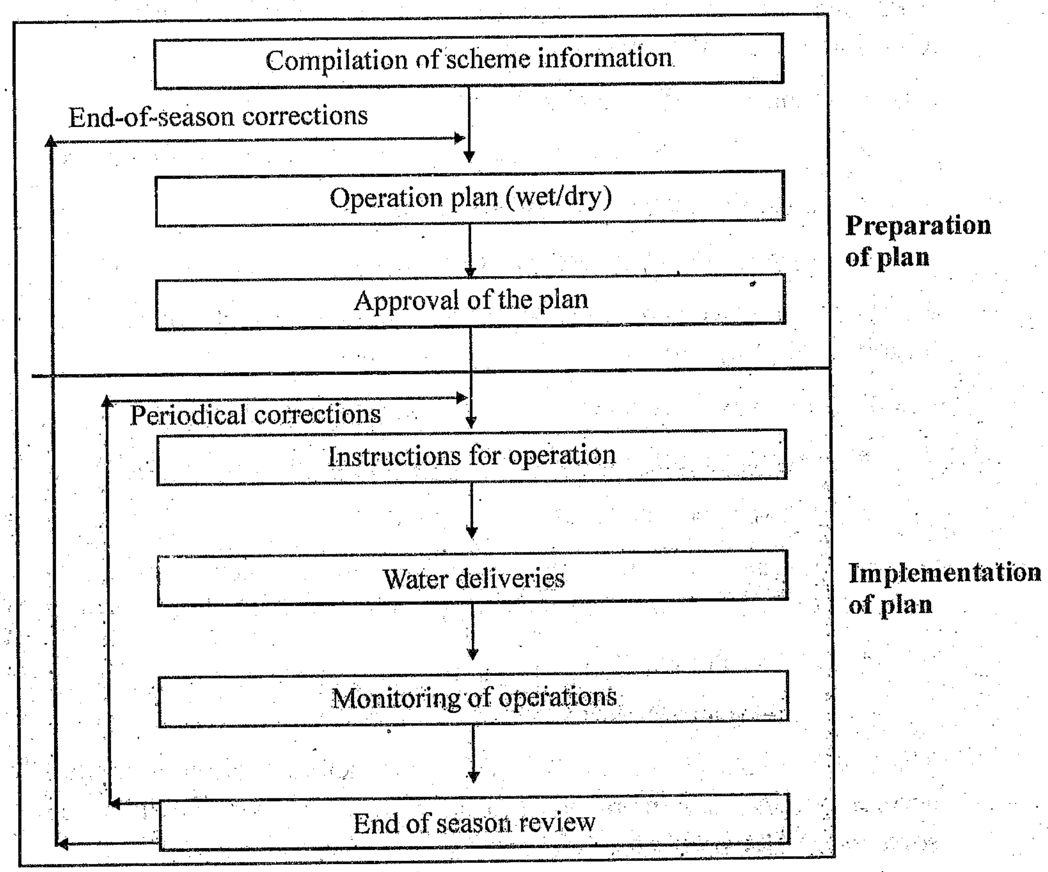
3. Approval of SOP by the water distribution committee.

The principles of operation and the operation plan as prepared take into consideration:

*project objectives   * operation policies and rules for the project

*availability of water and water allocations   * past operation performance.

Flow Chart of the Operation Plan



1.5 Implementation

After approval of the SOP by water distribution committee, detailed operation schedules and instructions will be communicated to the operating staff for implementation.

Schedules of operation will also be communicated to the users and other agencies. For the water users this is very important since they should know in advance the dates of deliveries and amount of water to be supplied. This information enables them to make timely arrangements for land preparation and other farming activities.

Under operation, water delivery is a straight forward affair since regulation is only practiced at the headworks and offtakes to the distributaries. Water delivery will take place according to fixed irrigation schedules.

The main irrigation systems in general, operate on the upstream control principle. According to this operation principle, upstream regulation of the water flow releases the total predicted requirements into the head-reach and then regulates the levels and flows at cross-regulators to provide the planned flow to the distributary heads.

The distributaries and minors are run according to the on/off principle. In principle the canals will be operated at a constant fixed flow, where variable supplies are controlled by the duration and interval of the irrigation turns. This operation principle is called the ungated proportional operation system. No adjustable controls are needed and all distribution is through proportional division of water.

In some cases, for instance in canals having a distinct kharif and rabi cropping pattern, distributaries will continue to be operated according to the fully regulated operation system. Gated structures will provide control of flow to minors.

The operation staff will be engaged in:

- controlling the gates at headworks and offtakes to distributaries
- controlling the water level in the system
- measuring of flow at the gates at headworks and offtakes to the distributaries.

In practice, however, operation is a complex matter and water delivery relies on many factors which may interfere with the planned supply.

Interferences may occur due to:

- unexpected climatic conditions: e.g. excess rainfall, or long dry spells,
- unexpected water losses in the system,
- changed agricultural practices leading to unexpected demands for water, e.g. request for extension of the irrigation season due to late planting,
- farmer interferences,
- political interferences.

The operation staff has to deal with all these factors in order to operate the system according to the plan. In practice the operation plan or manual will provide a guide to solve most of the problems.

1.6 Monitoring of operation

Monitoring is an important aspect of operation. It is the process of collecting information, analysing it and reviewing the implementation of the operational plan.

In most projects, data collection is already being carried out. These data can be converted into information on the performance of the project, to serve as a feedback for adjusting or modifying the operation plan.

Monitoring is needed to assess the operation and to see whether:

- water is available as anticipated in the operation plan,
- water is delivered according to the operation plan,
- there are any unexpected, adverse effects of the operation on soil, crop and environment,
- the plan has been successful or not in meeting the agricultural and economic objectives of the project.

Rescheduling of operations

The operation plan is based on average and historical data (inflow and rainfall) with a certain dependability. During the irrigation season, it may well be that the actual information differs from the data used in the planning of operations. Rescheduling of the plan may then be necessary.

In particular rescheduling of the plan is required under the following conditions:

- in response to rainfall, especially in the kharif season
- in response to water storage in the reservoir or river flows
- in response to emergencies.

An effective monitoring system will reveal the altered circumstances and, depending upon the situation, changes in the operation plan should be made. The results of the monitoring may lead to:

- mid-term corrections in the ongoing operation plan through a revised irrigation release schedule,
- revisions in the operation plan for the next season.

Rules for such action, where necessary, are normally laid down in the operation plan or operation manual.

End of the season review

The end of the season review is to compare the objectives of operation planning with actual irrigation performance. The outcomes of the review can be used to revise the operation plan for the next season.

1.7 Management of water distribution system

Management of water distribution system involves two dimensional aspects as follows:-

(A) Technical:

It involves technical aspects of the system like planning, designing and operation upto the outlet.

(B) Social:

It involves, social aspects like cooperation of users, water users organisation, local people's influence etc.

1.7.1 Factors of a good water distribution system

Following are some important indicators of a successful distribution system.

(A) Appropriateness.

(B) Equity

- (i) Between large & small farmers
- (ii) Between location i.e. from head to Tail.
- (iii) Equitability of time as per land holdings.

(C) Predictability

(D) Adequacy

(E) Timeliness

(F) Flexibility

(G) Incentive to users

(H) Less Scope for malpractices.

1.7.2 Types of water distribution system

Water distribution methods can broadly be classified in two types under gravity system of irrigation:

(A) Flexible Methods: These methods involve much flexibility in demand as well as in operation. Following methods are covered under the flexible methods.

(i) On Demand Method.

(ii) Modified demand method.

(iii) Continuous Method.

Out of the above three, first two are not in practice in Rajasthan and only the continuous method is being adopted in some of the projects where the water is available in ample quantity.

(B) Rigid Methods : These methods do not allow the flexibility. In these types of methods supply is controlled and water distribution is based on predetermined schedule or plan which is strictly to be followed with rigidity. Under this head mainly the Rotational Water Distribution is covered, which has been found to be quite successful in Rajasthan by the name of "Warabandi".

1.8 Rotational Water Supply (WARABANDI)

Making irrigation water available to all farmers in a chak on a rotational basis in an equitable manner is an important requirement in irrigation management. This is called Rotational Water Supply (Warabandi). This helps in achieving the following:

1. Provides equal volume of water to each acre irrespective of the location.
2. Helps the farmers to know in advance the days, period of availability of irrigation water, allotted to their field.
3. Helps to preplan agricultural operations including inputs, as security of irrigation is ensured.
4. Ensures equity among the farmers in irrigation water supply irrespective of tail-enders or top enders and rich or poor farmer.
5. Enables the farmer to feel that irrigation water is his personal property (relating it to time) and motivates him to use his share to the best of his interest. And
6. Brings about discipline in water use and eliminates unauthorized or illegal irrigation.

In Warabandi the essential requirements are:.

i. Ensuring the supply of designed flows in the minor and at each outlet;

ii. Developing proper distribution network of field channels upto each holding within the chak; and

iii. Allocating a time and day for flow of water to each individual farmer and working out irrigation schedules.

1.8.1 ENFORCEMENT OF "WARABANDI"

For enforcement of "Warabandi" for its purpose as mentioned above, there is a provision in Rajasthan Irrigation and Drainage Act, 1954-55, rule 11, Section 4, which reads as following:

"In case the Divisional Irrigation officer is of the opinion that the distribution of irrigation water in a "Chak" is not being ensured equitably and economically and "Warabandi" is essential, he may enforce - "Warabandi" in the chak concerned after giving adequate publicity through Panchayat of his intentions of doing so. Appeal if any against the orders of Divisional Officer shall be to the Superintending Irrigation Officer within 15 days from the date of issue of the order and his decision in the matter shall be final."

Breach of such Warabandi will be an offence punishable under section 55 (9) of the act.

1.8.2. MANAGEMENT OF "WARABANDI"

The irrigation water distribution in Warabandi System is mainly the two tier operation as following:-

(A) Upper tier:

In this tier the system is managed by the State, which involves maintenance and operation of the system upto outlet to fulfill the requirements of **"Warabandi".**

(B) Lower tier:

This is the part of system below outlet and is to be managed by cultivators. The distribution of water is done on a seven days rotation basis with the help of an approved roaster, which is prepared by the department for the usefulness of the farmers.

1.8.3. TYPES OF WARABANDI

Broadly speaking there are mainly two type of warabandi.

i) Panchayati Warabandi : managed by Farmer"s Organisations.

ii) Sarkari Warabandi: Enforced by the Government.

1.8.4 Systems of warabandi

In view of the system of water distribution in a Chak Warabandi can further be categorised as following:-

i) Nakewar Warabandi.

ii) Gol Warabandi

iii) Khatewar Warabandi.

1.8.5. Forms of warabandi.

As far as scheduling of Warabandi is concerned, Warabandi can be planned in three forms as following:

i) Non Continuous Warabandi.

ii) Continuous Warabandi (weekly temporary)

iii) Continuous Warabandi (weekly permanent).

In the present time in western part of Rajasthan, in the command areas of Gang Canal

System, Bhakhra Canal System, continuous weekly permanent warabandi is prevalent.

1.8.6 Chak:

Chak is an area which will be irrigated (receive water) under particular outlet. At present, the top enders in the chak or the more powerful farmers appropriate the water without any regard to the needs of others. This results in over irrigation by some and deprivation of the legitimate share to others, particularly in the tail end reaches.

The size of the chak under each outlet (pipe) is determined by the topography of the area and is generally upto a maximum of about 100 acres. Projects are designed for a duty taken in project planning. Duty is an area irrigated by 1 cusecs of water flowing for entire crop period. This means that a continuous flow of 1 cusec for the entire crop period will provide irrigation for entire duty period. However, a minimum flow through the pipe will be 0.5 cusec to provide the required driving head.

In general, a minor has between 4 to 10 pipes serving about 200 to 1000 acres. The pipes are normally provided with shutters to regulate the discharge or designed on automatic proportional modular (APM) basis in order to secure the designed flow.

Once the water is let out into the chak, it belongs jointly to the farmers of the chak and it should be their responsibility to distribute it.

1.8.7 Warabandi - Process:

THE CONCEPT.

"Warabandi" is a System of equitable water distribution by turn in proportion to the land holdings within an outlet command. **"Wara"** - means **"turn"** and **"Bandi"** means **"Fixation"** i.e. **"Warabandi"** means *"fixation of turns"* which is adopted according to a predetermined schedule specifying the day, time and duration of supply to each irrigator.

By local names it is called "Shojapali" in Gujarat, Maharashtra and Karnataka, "Warabandi" in North India, "Osrabandi" in some parts of Uttar Pradesh and "Varavaram" in some parts of South India.

A chak may be divided into blocks of continuous fields called zones based on physical location of field channels and convenience of water distribution by rotation. Each chak may be divided into 4 to 8 zones depending upon the extent, and each zone may consist of about 6 to 8 farmers.

Water (in terms of time) is supplied to each zone under a outlet, one after the other. Within the zone one farmer irrigates his lands after the other, according to the schedule. However, each farmer obtains water for a specific period on the specified day or date.

The detailed timing schedule is to be formed. In working out warabandi, weekly rotation is generally adopted, as days are easy to remember by the farmer than dates. However, rotation can be worked out for different periods also, if required. If the interval between waterings required by the crop is longer than once a week the field can be divide into two or more parts which get irrigation in turns, or arrangements with neighbors can be made to arrive at proper intervals.

The farmers in each zone become an interested group. This provides the motivation to work together within the group and also gives collective power to them to bargain or settle issues with other groups protected with such participation, as groups are stronger than individuals, and any injustice would become a group issue.

The canal systems under major & medium irrigation projects are not closed at night. Hence the water, if not used in the nights, will go to waste into field drains. Hence it is necessary to organize the use of water both night and day.

In case of minor irrigation projects, the tanks, irrigation channels are generally closed in the night and there is only day time irrigation.

1.8.8 Work details:

In Warabandi system in a chak, each farmer has to get the same quantity of water per acre. To ensure this it is necessary to take into consideration the following factors.

A The travel time for the water from the outlet to the inlet point to the holding

B Seepage losses in the field channels.

Flow velocities in the normal field channels will be one foot per second with a slope of 1:1000 and 1.5 feet per second with a slope of 1:500. Water losses in the channel system are in relation to slope. In slopes 1:1000 losses are generally around 15% per 1000 feet and in slopes 1:500 losses are 10% per 1000 feet. This is mostly in light (red soils), but less, by about 50 percent in heavy soils.

1.8.9 Preparation of warabandi roster

For preparation of Warabandi plan or the schedule for a particular chak, the chak plan (map of chak) is needed with the following information / details within it.

i) Details of C.C.A. (Culturable Command Area).

ii) Sanctioned Alignment of Water Course duly marked.

iii) List of farmer's alongwith the details of land holdings.

iv) Location of Naka points on the Water Course.

v) Reach wise nature of Water Course.

vi) Filling time (Bharai) from one Naka to the other.

vii) Depletion time (Jharai)

It is prepared to be completed in 7 days period i.e. 168 hours. The turn should start at head of the Water Course at 6.00 AM on Monday and will end on 6.00 AM on next Monday, after completing 7 days i.e. 168 hours. The calculation of time allocated per unit area of the chak and the time further allocated to the individual farmer for his land holding in computed by using following formulae:

(i) Flow time for a unit area of the Chak (T) in Hours.

$$(T) = \frac{168\text{-Total Bharai} + \text{Total Jharai}}{\text{Total C.C.A. of the Chak.}}$$

(ii) Flow time for a farmer (I)

(I) = Flow time for unit area (T) x his area + his Bharai - his Jharai.

"Bharai" is generally zero in the case of last farmer and "Jharai" is zero for all the farmer excepting the last.

The turns are fixed on the basis of first come first served from the head downwards. The operation of schedule presents no difficulty.

A model calculation in which Warabandi is explained below step by step.

The steps for working out Warabandi schedule are as follows:

Step 1 : Obtain ownership plan along with field channels layout.

Step 2 : Divide the chak area into zones within the chak each zone may have 6 to 12 farmers. This is to be done in consultation with the fanners.

Step 3 : The area of each individual holding within each zone has to be shown in table. If one fanner holds more than one piece of holding within a zone, each holding has to be dealt with separately.

Step 4: Since water requires time to travel from one distribution box to the next, all farmers in the chak share this time as loss. The travel time is a function of slope. Since slopes vary, care has to be taken in calculating the time.

Step 5: Conveyance losses of water in the field channels to individual farmers holding have to be borne by all fanners. Losses accumulate from box to box. If for instance, the first farmer and second farmer on a field channel have each 2% losses in their field channel stretch, the second farmer has to bear also the loose of the first farmer thus has actually 4 % loss. The accumulation of length of channel for each individual plot is carried out.

Step 6: The slope of each field channel stretch is taken from the map for determination of travel time.

Step 7: The conveyance time is calculated by taking the appropriate slope into consideration.

Step 8: Each farmer in the command area is allocated a 'basic time'. This is equal to the time of irrigation available divided by the areas (acres) in the chak. Since the irrigation is for 24 hours 7 days in a weak, 168 hours are available for irrigation.

Step - 9: The conveyance time is now calculated.

Step-10: The transmission losses during conveyance of the water in the field channel are 10 percent for a slope of 1:500 and 15 percent for a slope of 1:1000. A farmer in the lower end of a zone has to bear the losses of all previous farmers plus the losses occurring in their field channel which is only used by him.

Step - 11 : Following the determination of transmission losses in percentage these have to be converted into time. If we consider 10 percent loss over a certain length of time, only 90 percent of water will reach the field. In order to get 100 percent of the volume into the field the water has to run more than 10 percent longer that is 100/(100-10) = 1.11 times longer.

In case of the first farmer in zone one having a total transmission loss of 4.35 percent and 2.29 hours basic time, the formula to be followed would be 2.29 x 4.35 / 100 = 0.099 hours or 0.1 hour. It can easily be seen that total transmission losses increase with distance from the water source and that the tail end farmer have the highest transmission losses to bear.

Step-12: Each individual farmer is compensated for the losses due to conveyance in terms of time. The availability time during one week is however only 168 hours minus the transport time.

Step-13: Since now every plot is compensated with time for transmission loss, transport time of be added. Summing up of all final times will result in 168 hours.

Step-14: Final time, which indicates decimal hours, is converted into hours and minutes.

Step-16: With this finally the time schedule with days are worked out.

In all this, the filling time is considered as negligible

The schedule is worked out for 24 hours, and seven days in rotation. While the zone is to follow the calculated rotation time, the rotation within the zone between farmers may change by the farmers of the zone. Thus while the hours given for each farmer remain constant the timing may be changed by mutual agreement between the farmers in the zone.

It can be seen that at the head of the system, the time allocated to each acre is less than the time allocated to an acre at the tail end of the channel. This is due to the water losses which are to be shared equally.

1.9 Organisation

The most crucial elements in organisation for operation are the units with well defined responsibilities, and the linkages between the different units.

In a large project, the superintending engineer functions as the project manager and is responsible for overall direction and coordination in medium projects, Executive Engineer is responsible for overall directions & coordination.

Separate units for administration and finance assist the project manager with personnel matters and budgeting.

A planning and monitoring unit, working under the project manager, is responsible for development of the operation plan, and monitoring its implementation. The unit is in close contact with other concerned agencies.

One O&M division, is responsible for the operation and maintenance of the reservoir and main canal system. Water delivery, monitoring and evaluation, and maintenance of the main canal system and headworks are the most important tasks. O&M field divisions are responsible for water delivery and maintenance in the sub-divisions and sections. These divisions coordinate with the water users and other agencies to ensure proper delivery of water.

The operation staff is usually also available for other activities. For instance, maintenance tasks are often assigned to them, especially since these can be carried out during the off-season. The ungated offtakes in the distribution system considerably reduce the workload of the operation staff. As a result more time is available for maintenance work and other assignments. The duties of each staff category should be described in the O&M manual of the system to be prepared as per local needs, availability of water, cropping system etc.

1.10 Information systems

Effective operation and water distribution depends on the timely flow of data and information to assist in controlling the day-to-day activities. It also provides a basis for longer-term review and evaluation of the progress of the project towards achievement of its objectives. Availability of proper data is essential for the development and monitoring of the operation.

Data and information on operation & distribution need to be collected, processed and presented in a form suitable for use by the manager of the project, the department or other agency, according to prescribed formats and procedures.

Within the field of operation, important data refers to:

- water resources: storage status, inflows and rainfall
- water demands: cropping plan
- canal status: discharge, water levels and losses
- irrigation schedules: opening and closing of canals

Managing the flow of data and information is a critical activity. For optimal results, the activity has to suit the specific needs at different levels of the organisation.

For instance, the project manager needs only a weekly and monthly status of the deliveries, whereas the field operating staff needs data on an hourly or daily basis.

1.11 Coordination

An irrigation system does not function in isolation. For operation purposes it should maintain contact with the whole societal environment. For an irrigation system to operate efficiently, it is important to closely coordinate with many agencies, particularly:

- Agriculture department: submission of cropping plans, participating in developing of irrigation schedules and releases in the project level irrigation committee.
- CADA: coordination of agricultural development in the project area;in particular in participating in developing of irrigation schedules and releases in the project level irrigation committee.
- District administration: joint action for flood operation and emergencies.
- Irrigation department: releases to other projects in the basin.
- Power Corporation: scheduling of releases for power generation to be incorporated in reservoir operation schedule. The live example of synchronizing irrigation demand to the power generation/supply can be seen in Chambal Valley Development project Kota.
- Village administration: supply of drinking water to villages according to schedule.
- Water users: participating in developing of irrigation schedules and releases in project level irrigation committee.

Such coordination is usually formalised in government orders or project instructions. Details regarding meetings to be attended or chaired, and frequency of meetings, are laid down. However, very often, the irrigation official has to deal with unscheduled requests for cooperation, usually related to demands for water.

Relations with the water users

Farmers have a special role in irrigation system operation. First of all, they are responsible for water distribution below the outlet. A normal pattern in many projects is to have water users' associations or pipe committees.

These are organised according to government procedures. Operation and water delivery is preferably arranged through the system of Warabandi or any other suitable rotational methods. The role of the irrigation department is confined to delivering water at the outlets according to the operation plan.

Delivering water at outlet level should be discussed with WUA and finally approved.

In the water distribution committee, WUA may offer suggestions for adopting certain measures to improve the operation in a particular canal or in the whole system. WUA, therefore, are likely to be involved in the monitoring of water delivery in canals. For this reason, they could be organised into canal committees. When required, the project management should provide support to these committees. Effective communication with farmer leaders should be promoted by the project manager.

The water users committee, distribution level committee, project level committee have been formed on most of the projects. In future it is likely that the entire operation of system up tp project level shall be administered by the WUA & thus operation plan will be prepared by them in consultation with the irrigation department. It is expected that department should function as a advisory body & real time operation should be managed by the beneficiaries.

1.12 Summary

Successful operation & distribution of water in an irrigation system is possible where:

- The project manager has a thorough knowledge of the operation policies and operation rules.
- An essential part of the operation is the development of an operation plan and the subsequent implementation of the plan and its monitoring.
- A structured irrigation system ensures that the operation plan can be implemented effectively with few gate settings according to the adopted plan.
- An organisation structure which is established along functional units with clear responsibilities supports the efficient execution of operational tasks.
- A well-established information system ensures that operations are based on correct information which is available at the right time.
- Processing and distribution of information follows well- defined paths.
- Linkages with other agencies and the water users are essential for developing the operation plan. They are maintained through good coordination and communication.

1.13 Self Assessment Test

1. What is water regulation ?
2. How you will form water distribution committee ?

1.14 Key words

Water distribution committee

DOP

SOP

Warabandi

Bharai

Jharai

1.15 Suggested readings

Land and water management in Irrigated areas by ATUL GARG AND KAILASH BHARGAVA.

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UNIT-2

KNOWING THE IRRIGATION SYSTEM

Structure

2.0 Objectives

The aim of this unit is to acquaint the students/user to know the different components of an irrigation system, its basic function and basic principles of preparation of an operation plan of irrigation system.

This module describes the broad layout of an irrigation system and the hydraulic and operational characteristics of its main components.

2.1 Introduction

For an irrigation system, the source of water may be from the surface flow or ground water. Reservoirs and diversion weirs use surface water. Ground water is lifted from open wells and tube wells to be used for irrigation. For the irrigation water to reach different parts of the command from its source, it has to be conveyed and distributed through a canal system. This canal system comprises of canals of different sizes and various types of structures.

For improving the performance of existing irrigation systems through improved operational procedures, this envisages preparation of a seasonal operation plan (SOP) for the wet and dry season every year. This is then finalised after acceptance by the water distribution committee. As a member of the water distribution committee, the farmer representative has a role to examine the SOP with special reference to water delivery at the outlets and assist the scheme manager in finalising the plan. A practical understanding of the water delivery plan and the role of the physical system either in providing operational flexibility or in putting an operational constraint is essential.

For this the farmer representative must have a clear concept of the irrigation system, its various components, their functions and the hydraulic characteristics of the main and distributary canals.

2.2 Basic concepts of an irrigation system

Irrigation may be defined as the means to bring surface water or ground water from a source to the fields for growing of crops.

The main aim of irrigation is to supplement natural rainfall with artificial supply of water with the specific purpose of:

- increasing crop yields,
- insuring against the uncertainty of monsoon,
- promoting crop diversification.

Distinguished by the source of water, an irrigation system can be classified into three types:

- Reservoir system,
- Diversion or run-of-the-river system,
- Ground water system.

Distinguished by the size of its command, an irrigation system is classified as a:

- Minor irrigation project (2,000 ha and below),
- Medium irrigation project (2,000 - 10,000 ha),
- Major irrigation project (above 10,000 ha).

2.3 Functions of an irrigation system

An irrigation system has three main functions (excluding the functions below the outlets). They are:

- Harnessing of water,
- Conveyance of water to the command,
- Controlling/regulating flow,
- Delivery of water at the outlets.

2.3.1 Harnessing of water

For any irrigation, rainfall is the primary source of water. But mostly it is not available according to the requirements of crop. For a farmer, the timeliness of rainfall is more important than the total amount of rainfall in a season or year. Occurrence of rain when the crops do not require water may prove harmful to the crops; similarly failure of rainfall, when crops need water may reduce the crop yields or even damage the crops.

The rainfall in most parts of India is seasonal, i.e., it occurs during a particular period of the year; and the other months are normally dry.

Irrigation in the dry season can therefore be possible only if water is available from a source other than the rainfall.

Artificial supply of water is needed for:

- Ensuring a regulated supplementation of water during rainy (or wet) season,
- Providing irrigation during the dry season.

The artificial supply of water is achieved in many different ways.

When it rains over the catchment area of a river basin, a small portion of water evaporates; some water enters into the soil and the remaining water flows into small streams and tributaries. The water from the tributaries collects into a river and runs down to sea. Structures are built to control this uncontrolled flow of water and use it for irrigation. These man-made works include storage reservoirs, river diversion works like anicuts and barrages, etc., and lift irrigation schemes.

It is easy to build dams where the river gorge is narrow and the flanks high. In the upper reaches, the rivers normally flow through hilly areas which provide suitable locations for building dams. Therefore, most reservoirs are built in these reaches. For a river diversion work, the requirement is a minimum continuous flow throughout a crop season. In the lower reaches, the rivers normally flow through plains and generally become perennial. In these areas, therefore, water is diverted for irrigation by constructing river diversion works. In areas where ground water is available in abundance and at shallow-depths, ground water (lift irrigation) schemes are quite popular and common.

The main components of storage and diversion schemes are described later.

2.3.2 Conveyance of water to the command

Conveyance of water from the reservoirs or river diversions to the fields for irrigation takes place by means of a network of canals. The canal system through which the irrigation water flows before reaching the water delivery point consists of:

- Conveyance system (main canal and branch canals), .
- Distribution system (distributaries and minors).

2.3.3 Controlling/Regulating flow

For covering maximum area under, efforts are kept to provide flatter slopes for conveying water. Thus to maintain desired quantum of supply at desired elevation servral control structures are built across the canal system. The main objectives of these control structures are

- To regulate supply
- Maintain desired elevation & flow depth
- Proper distribution of supply in branches, distributories etc.

2.3.4 Delivery of water at the outlets

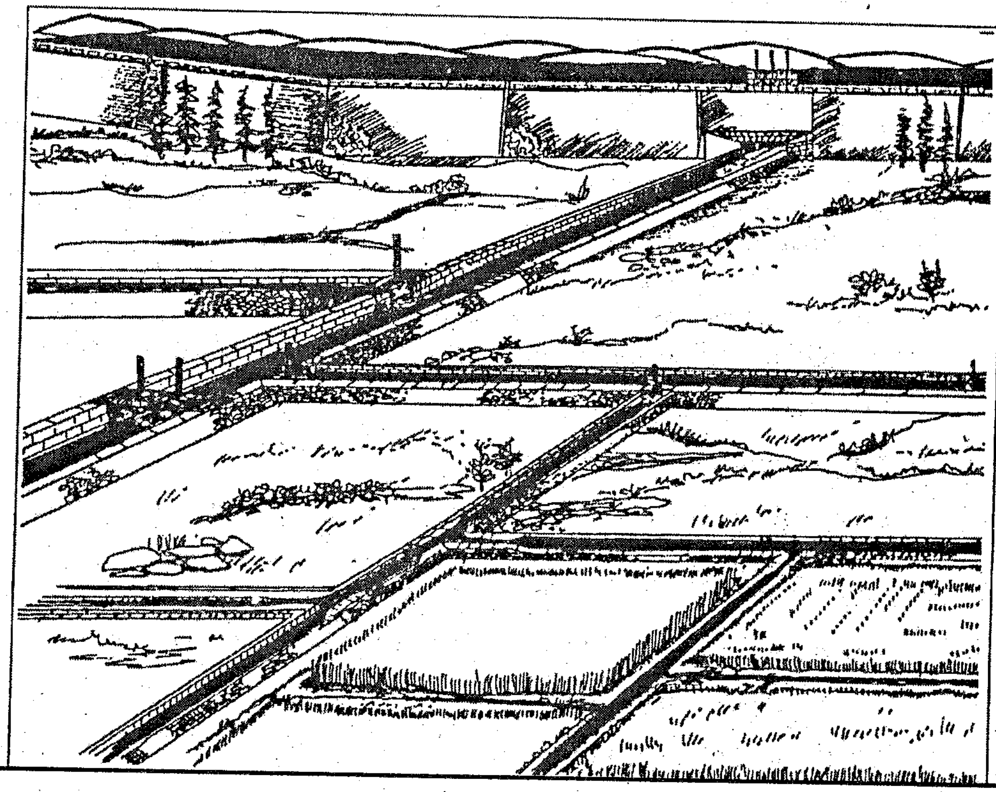
In any irrigation system serving small farms, it is not possible to deliver water to satisfy the individual needs of the crops or farmers. Therefore delivery of water is made at an aggregate level and the point where such delivery is made is the outlet. An outlet command is called a chak. A group of fields, together forming a chak, jointly draw water at the outlet.

The distribution of water to individual fields within the chak is through a network of small water courses, field channels and farm channels. Figure 1 gives an overview of an irrigation system.

The canal system is managed by the irrigation department upto the outlet and by the farmers below it. **An outlet is thus the interface between the two managements.**

The success of an irrigation system, in meeting its objectives depends, to a large extent, upon how reliably water is delivered at the outlets by the' irrigation department and how efficiently it is distributed among the farmers below the outlets.

Overview of an irrigation system



2.4 Head works

Depending upon the objectives and location, head works can be divided into two classes:

- Diversion works,
- Storage works

Diversion works are provided for diverting the water from main river stream to canal network. These structures are usually provided on perennial rivers. The storage resulting from such type of structures are generally less & their main aim is to raise the water level & thereafter diverting the water into cannal system. While under storage works, the main objective is to store water during monsoon season & made available for irrigation during requirement of water by crop for their growth.

Diversion works

Diversion works usually consist of:

Main structures covered under diversion works are weirs & barrages.

Weir : It is an obstruction constructed across the river to effect local storage & raise the water level locally & to divert part or all the supplies in the cannal. The only difference between & weir & a dam apart from strucural is onle heigh & the quantum and period for which supply is stored. In weir maximum ponding of water is done against the raised crest of structure or partly ponding may be done by shutters.

Barrage : This is similar structure as that of weir and its objective is similar to that of weir. The main difference between weir & barrage is that in barrage maximum ponding is done through raised shutters/gates while in weirs maximum ponding is done by raised crest. Thus barrage can also be defind as a gate contolled weir with low crest. The advantage of barrage over weir is during period of high floods & better regulation of system. During high floods, the gates of barrage are raised to clear off high flood level so that there is minimum afflux (raising of water level due to obstruction in flow).

Advantages of barrage over weir :

1. Better contorl on the river floods, both inflow & outflow are regulated by means of operation f gates.
2. Better control over silt entry in the canal system.
3. Better of river sedimentation due to presence of scouring sluices.
4. Improved facilitie of inspection & repairs.

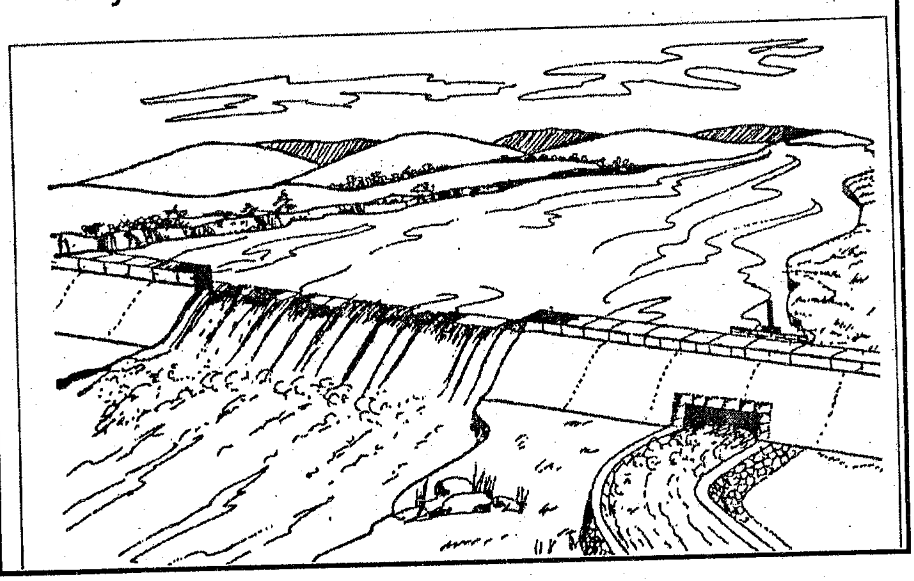
The only disadvantage of barrage is its high initial & operation cost as compared to weirs.

The features of diversion works are as under :

- A weir or a barrage across the river of sufficient height to maintain a water level suitable for supply to the canal system, i.e. a level which can command the area to be irrigated and can provide sufficient depth of flow in the canal to carry the required supply,
- a head sluice (also called a head regulator) for each canal taking off from the diversion weir to control the flow into the canal,
- scouring sluices with their sill at about deep bed level of the river for flushing out the bed silt, (normally scouring sluices are placed on the extreme flank of the weir adjoining the head regulators),
- flood banks, connecting the weir flanks with high ground for preventing the water from outflanking the weir because of the heading up of the water caused by the construction of the weir across the river.

A general layout of the head works of a diversion scheme is as below

Lay out of a diversion scheme head works



Storage works

In storage works, the main structure is construction of a dam across river to creat a storage of water. A dam is a hydraulic structure built across a river or stream to impoiund part of runoff from the catchment area located on its upstream side. Various types of dam are Gravity dam, Arch dam, Butress dam, earth & rockfill dam. Depending upon the topography of area, geology & nature of foundation, location of spillway, safety conditions, availability of construction materials, earthquake zone, purpose & economics aesthetic consideration, the type of dam is decided.

Gravity dam :

It is the dam which depends on selfweight to resist the action of water stored on the upstrem side. It is a rigid type of dam generally constructed of concrete, masonry etc. Its shape is approximately triangular in section with a suitable top width for traffic & operational purposes.

Arch Dam :

It is a curved dam convexed upstream the depends princiaplly on arch action for its stablility. The water load is transferred by arch action to the abutments. This type of dam is built across deep gorges with strong abutmens.

Buttress dam :

This is also called hollow dam. It is constructed in concrete consisting of water supporting upstream face of deck, usually RCC slab supported by buttress generally in the form of equally spaced conterforts that transmit water load & weight of deck to the foundation.

Earth and rockfill dam :

This is non rigid structures built with the help of soil & rock across the river stream for ponding water. The suitable soil from nearby area is placed & compacted so as to create a barrier for water storage purposes. This type of dam is provided with an overflow section constructed either in masonry or concrete. As compared to other dams, this type of dam is most economical & easily proveided in sites located in seismic zone.

The main components of a storage reservoir are:

- a dam which impounds water, (it is generally constructed of masonry, concrete or earth),
- one or more outlet sluices, called head regulators, through which irrigation water is drawn into the canals,
- surplus works to dispose off the inflows in excess of the storage capacity of the reservoir.

2.5 Canal system

The canal system can be described in two parts:

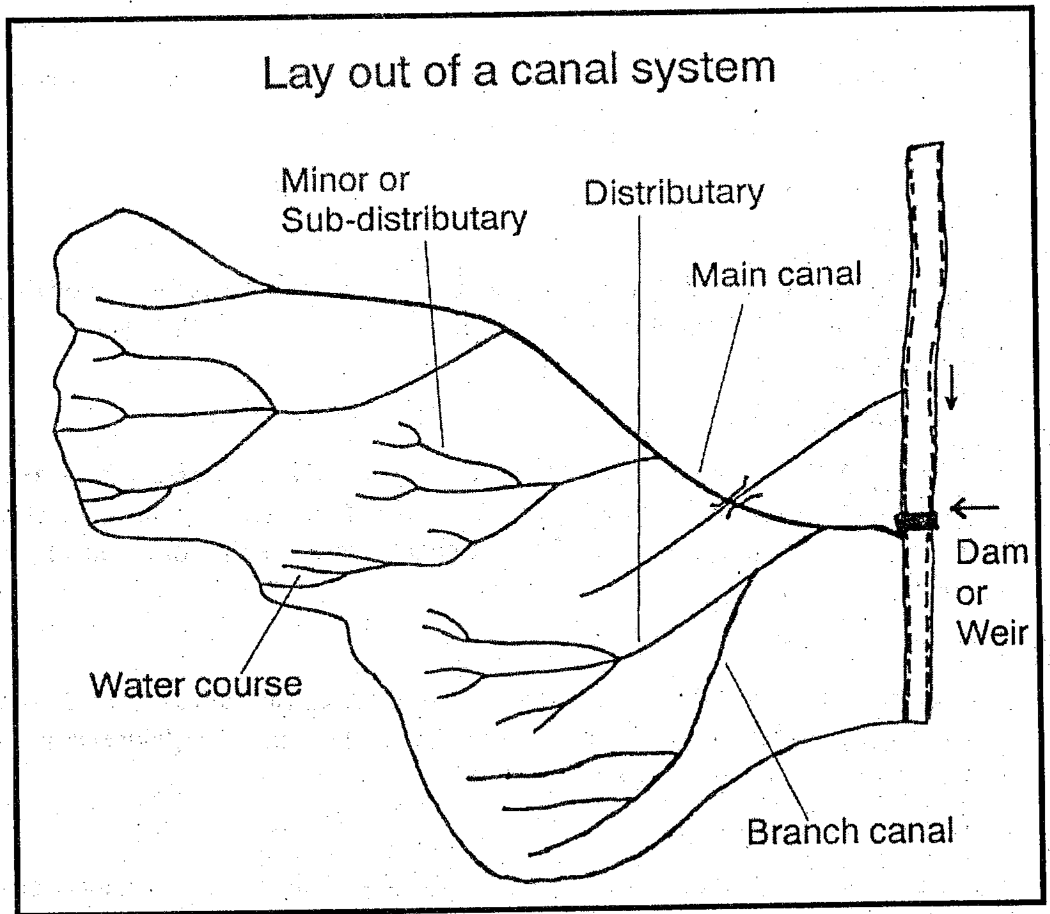
- conveyance canals
- distributary canals

Conveyance canals The conveyance canal s consist of:

main canal

branch canals

a general layout of a canal system



Main canals take their supply directly from the head works. In some cases the topography of the command requires the main canal to branch off into two or more canals. A branch that takes off from the main canal and conveys water to a major part of the command area is called a branch canal. Along their length, the conveyance canals require many canal structures of different types to successfully convey water to the distributaries. These structures can be categorized as:

- Conveyance structures,
- Protective structures,
- Control structures,
- Measurement structures.

Conveyance structures

The main and branch canals normally run on contour. They have to therefore cross a number of streams. At such crossings, cross- drainage works are provided. Depending upon the size of the stream and the site conditions different types of cross drainage (CD) works are provided. The CD works commonly found on canals include aqueducts, under tunnels, super passages, canal syphons and level crossings.

The cross drainage works can be classified as :

Cross drainage works

Canal over the drainage		Drainage over cannal		Discharging drain into canal		Combining canal & drainage
Aqueduct	Syphon aqueduct	Canal syphon	Super passage	Syphon super passage	Inlet	Level crossing

Aquaduct :

An aquaduct is defined as a drainage crossing in which the canal is carried over the drainage channel & the bottom of the canal trough is above the high flood level in drainage channel.

Syphone Aquaduct :

A syphon aquaduct is defined as a drainage crossing in which the canal is carried over the drainage channel & drainange channel is carried under pressure while passing under the canal. i.e. High flood level in drainage channel is above the bottom level of canal trough.

Canal syphone :

A cannal syphon is defined as a drainage crossing in which the drainage channel is carried in a trough over the canal & the bottom trough level of the drainage channel is above the high flood level in canal.

Syphon super passage :

A syphon super passage is defined as a drainage crossing in which the drainage channel is carried in a through over the canal & canal is carried under pressure while passing under the drainage channe. i.e. High flood level in canal is above the bottom trough level of drainage channel.

The canals also have to sometimes cross existing cart tracks, roads and railway lines. At such crossings, suitable cross-communication works like culverts and bridges are provided. These are known as VRB for village Road Bridge, DRB district Road Bridge.

Protective structures

In certain situations like heavy rainfalls or storms etc., damages to canals are likely to occur due to uncontrolled excess flow within the canal. In order to protect the canal from such damages, protective structures are provided along the canal at suitable locations to dispose off the excess flow. Escape weirs and escape regulators fall under this category.

Control structures

From the operational point of view certain structures are essentially required on the canals. These are called control structures. According to their functions, they are described as:

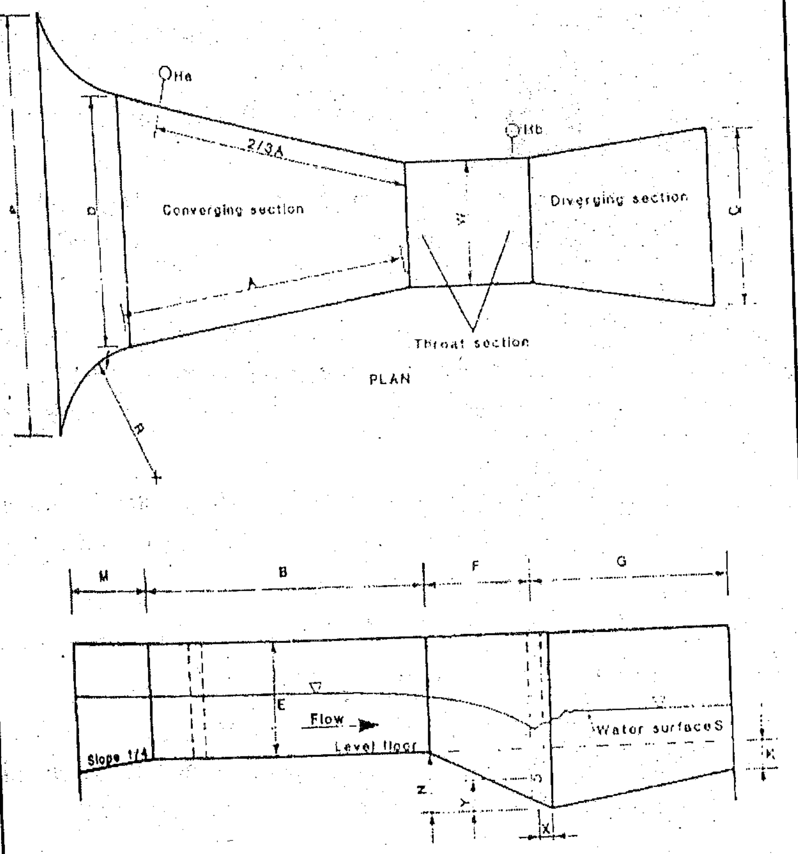
- Water level control structures,
- Water flow control structures.

For controlling the water levels in the canals, water level control structures are provided. Cross regulators and duckbill weirs belong to this category.

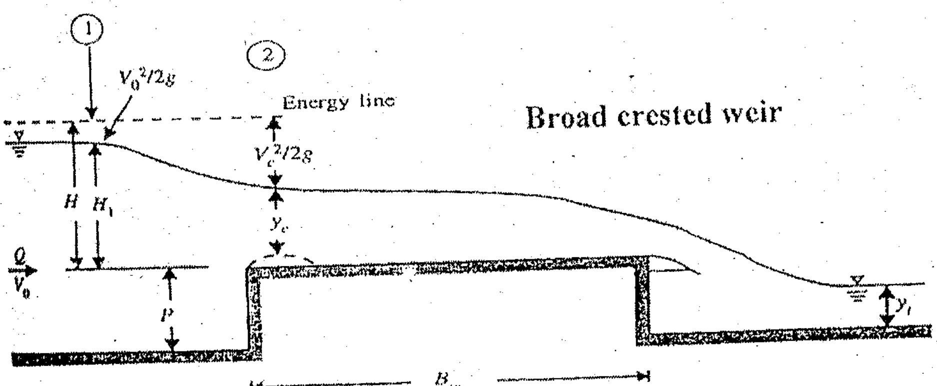
For controlling the water flow at the offtake points water flow control structures are provided. Offtake sluices, proportional distributors, pipe outlets, orifice semi-modules, open flumes and tail clusters come under this category.

Measuring structures

During operation, the flow in the canals has to be measured at selected locations for ensuring reliable and equitable supplies at the outlets. This is done with the flow measuring structures. Broad crested weirs, Parshall flumes and cutthroat flumes, etc. belong to this category.



Parshall flume



Distributary canals

The distributary canals receive the water from the main and branch canals and deliver it at the outlets. These canals consist of distributaries (also called majors) and sub-distributaries (commonly called minors).

The distributaries take off from main or branch canals and supply water to the minors or sometimes directly to the outlets. Along its length a distributary requires certain structures for proper delivery of water to the outlets. They include:

- sluice structures,
- measurement structures,
- drop structures.

An offtake sluice diverts and controls the water into a distributary from the main or branch canal. It has a gate for adjusting the discharge according to the requirements. Some distance below the offtake sluice a flow measuring structure is generally provided to measure the discharge.

Sluice structures are also provided along a distributary for diverting and controlling water into the minors. These sluices are also normally provided with gates for adjusting the discharges.

However, gated control is normally confined upto the distributary head (offtake sluice). The distribution of water below this is normally through ungated proportional structures. The commonly used ungated sluices are ungated pipe outlets, open flume outlets and orifice semi modules.

Since the distributaries generally run on ridges, they have to negotiate steep slopes. In order to have easy bed gradients, distributaries are provided with appropriate number and type of drop structures.

A minor is a small channel which receives water from a distributary and delivers it to outlets. The minors have similar structures as distributaries.

Along its length a minor has a number of outlets for supplying water to the chaks. Traditionally these outlets are also ungated. Like distributaries, minors also generally run on ridges and require a number of drop structures to have an easy gradient.

Chak system

Water is delivered to a chak at the outlet which is the lowest point of water delivery by the irrigation department. This point is also called chak outlet.

The size of a chak is not uniform and generally varies from 20 ha. to 60 ha.

Below the chak outlet the distribution of water among individual farm holdings is the responsibility of the farmers themselves.

This distribution is done through water courses and field channels. A number of small structures like drops and distribution boxes are required on these channels for proper distribution and control of water. All the water courses and field channels along with the structures on them are initially constructed by the government; but thereafter they are required to be operated and maintained by the beneficiary farmers.

2.6 Summary

Irrigation systems can be categorised as storage schemes, diversion schemes and ground water schemes. Distinguished by the size of their command, the irrigation systems are classified as minor, medium and major schemes.

The main functions of an irrigation system are to:

- harness water,
- convey water to the command,
- deliver water to the fields.

The main components of an irrigation system are:

- head works (storage or diversion works)
- conveyance canals (main and branch canals),
- distributary canals (distributaries and minors)
- chak system.

For proper conveyance of water from the source to the command and distribution of water to each outlet, a variety of structures is required on canals. They can be classified as:

- conveyance structures (aqueducts, super passages and canal syphons, etc.),
- protective structures (escape weirs and escape regulators),
- **control structures:**

1. Water level control structures (cross regulators and duckbill weirs, etc.);
2. Water flow control structures (offtake sluices, proportional distributors, open flumes, and orifice semi modules, etc.);
3. Measurement structures (Parshall flumes, broad crested weirs and cutthroat flumes, etc.).

2.7 Self Assessment Test

1. Describe the physical features of an Irrigation system?
2. What is irrigation and its main purposes? Describe briefly?
3. Define the meaning of head works & describe the various diversion works?
4. Describe the command area and discuss briefly its features ?
4. Classify the category of an irrigation system by its size?
5. Briefly describe the various types of control structures and canal conveyance system?

2.8 Key words

1. **Command Area means** "an area within the defined boundary which can be covered by a water resource project.

2. **Gross Command Area :** It is the area lying between defined set of boundary which can be irrigated by a diversion/storage scheme.

3. **Culturable command area :** Culturable area is that part of gross command area, on which cultivation is possibe i.e. Gross command area minus sum of uncultivable area (ponds, forest, roads, residential area, cart track etc.)

4. **Irrigable Area :** It is defined as percentage of CCA proposed to be irrigated annually as per the availability of water in the project.

5. **Intensity of Irrigation :** It is the percentage of irrigable area to the Culturable command area.

6. **Headwork means** "the structure built across the river/stream for diverting the water or for storage purposes".

7. **Canal system means** "the artificial carrier system used for diverting the water from head works to various destination & distribution in the command area.

8. **Chak means** the area irrigated under one outlet.

9. **Outlet means** the water delivery point from canal to the farmer's field.

2.9 Suggested readings

1. Training modules under NMWP Project, Ministry of Water Resources, Govt. of India 1992.
2. Training modules of Irrigation Management & Training Institute Kota for middle & junior level officers.
3. Training modules for Irrigation & CAD Department, Govt. of Andhra Pradesh 1998
4. Irrigation Engineering & Hydraulic Structures by S.K. Garg.
5. Text book of Irrigation Engineering & Hydraulic Structures by R.K. Sharma.
6. Irrigation Engineering by B.C. Punmia

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UNIT-3

IRRIGATION EFFICIENCIES

Structure

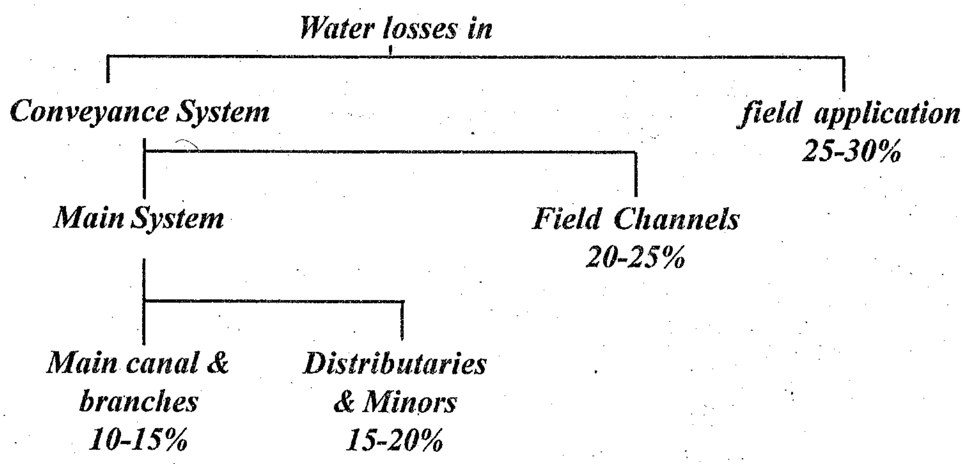
3.0 Objectives

- To identify the loss of Irrigation water
- To understand the type of losses
- To determine the amount of losses
- Finally to determine the efficiency of irrigation system

3.1 Introduction

A substantial part of the water that is released at head into a canal system is lost during its travel up to point of its delivery before it is utilised by crop. In unlined, normally maintained conveyance system, it has been established that about more than 50% of the water that is released into canal system is lost during its travel from head to crop roots.

Estimated ranges of water losses at various stages are indicated in following flow chart.



A realistic assessment of quantum of water loss during its travel from head to fields of crops is of great significance not only in planning for construction but also for ensuring reliability and equity in supply during actual operation of system. Besides, assessment of losses also helps in making choice for lining of channels.

(i) Expressed as percent loss, conveyance losses are given by

$$\% \text{ loss} = \{ (V_i - V_o) / V_i \} \times 100$$

Where as V_i is volume released into system and V_o is the volume delivered out by the system.

(ii) Losses are also expressed as percent loss per 100-M length of channel (generally used for field channels)

$$P = \{ (V_i - V_o) / V_i \} \times 100 \times (100/L)$$

Where L = Length of channel in metres.

(iii) Conveyance losses are also expressed in terms of wetted area as:

$$V = \{(Vi - Vo) / P\} \times L \times 10^6 \quad \text{per million sq. area}$$

Where P = Wetted Perimeter per unit length of the channel

and L = Length of the Reach.

3.2 Conveyance efficiency:

Conveyance efficiency of a system is the total amount of water delivered out of the system as percent of the total volume delivered into the system.

$$\text{Efficiency} = (V_o / V_i) \times 100 \ \%$$

During steady flow conditions, it can be expressed as

$$\text{Efficiency} = (Q_o / Q_i) \times 100 \ \%$$

Where Q_o = Discharge delivered out of the system and

Q_i = Discharge delivered into the system.

3.3. Types of Losses:

Depending upon the state of flow, losses are classified as

(i) Transient losses

(ii) Steady state losses.

3.3.1 Transient losses: These are losses which occur during the period beginning at the instant the water is released into system till attainment of steady flow conditions. These losses can be sub-categorised as:

(a) Short term losses which occur for a short period on account of breaches.

(b) Storage losses which occur due to filling in local depressions or widened sections of channels.

(c) Initial high losses to bring dry soil into saturated state.

(d) Switching losses due to switching of water from one field to another and from one system to another.

None of these losses can be measured individually and are derived indirectly.

3.3.2 Steady State losses: These are losses which occur continuously during operation of system and are classified as:

(a) Visible leakage

(b) Evaporation losses

(c) Seepage losses.

3.3.2 (a) Visible leakage losses occur due to piping through holes into canal banks rendered by rodents and insects which live in burrows. This can-be measured by diverting leaking water into nearby drain and installing a flow-measuring device there in. These are also controllable and can be minimised by timely and adequate maintenance of channels.

3.3.2 (b) Evaporation losses, usually very small in magnitude, these losses depend upon water surface area, depth, temperature, humidity, wind velocity and sun-shine hours. These losses can not be helped out and take place 24 hours a day, through out the year and range from 3mm to 10mm per day, totalling about 1500 mm per year.

Evaporation losses are insignificant as compared to seepage losses and constitute about 1.5-2% of steady state losses which in turn work out to about 0.25-0.75% of the total losses.

3.3.2. (c) Seepage losses constitute the major loss of irrigation water from a canal system being about 97.5-98% of total losses.

Depending upon the position of water table, seepage losses are further subdivided into:

3.3.02. (C)-(i) Absorption losses:- Absorption losses take place when water table is considerably low. Water seeping from canal

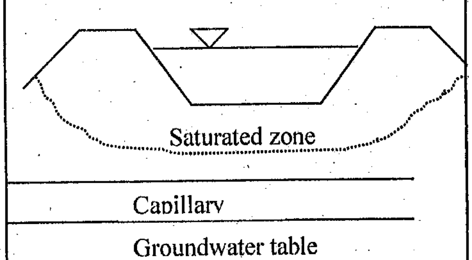


Fig:1 ABSORPTION LOSSES

bank and bed, first fills the pores of the soil around it but after the loss is balanced by evaporation & transpiration of seepage water re-emerging at the surface by capillary action. The seeping water therefore does not augment the ground water supplies, but its does compensate for the evaporation and transpiration loses from soil.

The rate of loss depend up to depth of flow, H.G. line slope but is independent of seepage head.

Deposition of silt carried by canal water considerably reduces these losses.

3.3.2.c (ii) Percolation losses: Percolation losses occur when the ground water table is high and near canal bed. There is a zone of continuous saturation from canal bed to the ground water and thus direct flow of water takes place since hydraulic -grade line joins water surface level in canal to the ground water. These losses therefore directly augment the ground water and depend upon seepage head "H". The rate of percolation is very high as compared to absorption losses.

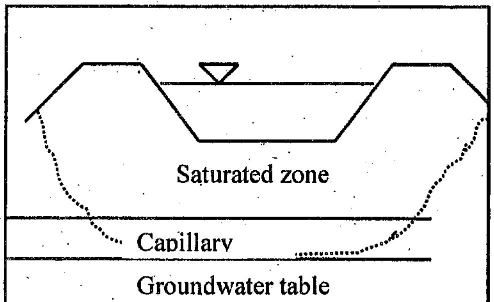


Fig:2 PERCOLATION LOSSES

3.4. Factors affecting Seepage Losses:

(i) Permeability of construction material & soil strata through which the canal passes.

(ii) Position of ground water table.

(iii) Drainage conditions of the sub-soil

(iv) Wetted perimeter.

(v) Condition of the canal.

(vi) Depth of flow and its velocity.

(vii) Amount of silt carried by the water

(viii) Regulation of canal.

3.5 Assessment of Seepage Losses

3.5.1. Analytical Method:

The method is of particular value for canals, which are in planning stage. The method is based upon coefficient of hydraulic conductivity of soil and boundary conditions of flow system. The method is applicable only in channels aligned along watershed, which are not normally subjected to recharge from the ground water. (For details I.S. 9447-1980 may be referred to)

3.5.2 Empirical Method:-

(a) Etchevery and Harding Values:

For design purposes, Etchevery and Harding have given conveyance losses in cumec per million square metres (Cumec/mSqM) of wetted perimeter in various types of soil strata as under:

Type of Soil	Losses (cumecs/M sqm)
Impervious clay- loam	0.9 - 1.2
Ordinary Clay- loam or Silty- clay	1.2 - 2.7
Sandy -loam	3.6 - 5.2.
Loose Sandy- loam	5.2 - 6.1
Gravely Sandy soil	7.0 - 8.8
Porous Gravely soil	8.8 - 10.6

(b) U.P. Irrigation formula.

$Q = (1/200)(D + B)^{2/3}$ Cumec / Km. length of Channel

Where D = Depth of flow and B = Bed width of channel (in metres.)

(c) Punjab and Haryana Irrigation formula

$K = 1.9\ Q^{1/10}$

Where K = losses in Cumec / m SqM and Q = Discharge in Cumecs.

(d) David and Wilson formula for lined channels.

$$S_L = 0.45\ C \times (P_W \times L \times D^{1/3}) \ / \ (4 \times 10^6 + 3650\ V^{1/2})$$

Where S_L = Seepage losses ; P_w = Wetted Perimeter. V = Velocity of flow ; D = Depth of flow. L = Length of channel ; C = A Constant.

Table for Values of Constant 'C'

Concrete lining	1.
Bitumen or Cement –mortar	10.

(e) Pavlovasky Formula.

$$S_L = 0.0116\ B_w + 2Y \times C$$

Where S_L = Seepage losses (Cumec / Km.) B_w = Canal width at water edge.(M)

Y = Depth of flow. (M) C = Coeff. of Infiltration (Metres / day.)

Values of Ci: Heavy Loam (0.5); Medium to light Loam (0.05 - 0.1); Sandy -Loam (0.1 - 0.5) ; Loam (0.25 - 0.5) ; Fine Sand (1.0 - 5.0); Medium grained Sand (5.0 - 20.0) ; Dusty -Sand (0.5 - 4.0).

3.6 Actual Field Measurements

In this method actual field measurements are taken in the system under operation. Various methods are:

(a) Ponding Method.

(b) Inflow- outflow method.

(c) Tracer Technique.

(d) Seepage meter method.

(a) Ponding Method.:- As the name implies, losses are determined by measuring loss of water from a ponded reach of the canal. A reach of channel is isolated by constructing temporary bund or bulkhead on existing control structure. Measurements may be done by constant or falling level method. Seepage losses are computed from:

(i) Rate of loss of water from the pond.

(ii) Dimensions of wetted perimeter.

(iii) Assessment of evaporation losses.

Equipment required is two staff gauges, two hook gauges, evaporation pan and equipment to replenish water

Though entire procedure in laid-down in IS-9452- (Part-I)/1980, some important points are stated below.

Criteria for selection of site:

(i) Curved reach should be avoided.

(ii) Nature of material in the isolated selected reach should have small variations.

(iii) Reach should have no structure or source of additional inflow or loss.

(iv) Site must be easily approachable.

(v) Minimum length of pond be more than 10 times its bedwidth.

Limitations.

- Normal running of the canal is interrupted.
- Construction/demolition of pond may be costly.
- Arrangement for large quantity of water is needed to initially fill it and subsequently replenish the pond.
- Though result is accurate, it does not show reach-wise variations in the pond length.
- Actual running conditions are not simulated in standing pool, suspended materials may settle down reducing seepage losses.
- There may be variation in ground water table through out the ponded length from that in ponded reach.
- Assumed effect of variation in head is neglected.

Merits:

- Suitable for any canal.
- Suitable for more accurate results in small seepage losses.
- Can be applied to smaller reaches of canals.

(b) Inflow-Outflow Method: The method utilises measurement of discharge at the U/S and D/S ends of the reach under study and working out the difference between the two, to give evaporation plus seepage losses. By

Deducting evaporation losses and other losses if any from the inflow and outflow, seepage losses are worked out.

I.S. 9452-Part- (iii) (1980) gives all details about this method, however some important points are stated below.

Equipment Required are set of two Flumes/Notches/Current meters, Stop watches, Survey equipment, Spirit levels, Shovels, Gunny bags, Plastic sheets etc.

Precautions:

- As far as possible, all outlets from the canals should be closed and preferably sealed otherwise another discharge measuring device must be installed there.
- All measuring devices must be well calibrated, maintained and checked before use.
- Steady flow conditions must be maintained during study.
- Water levels during study must be regularly measured and recorded.

Limitations: -

- Losses worked out are total losses in the entire reach, for position of water table, temperature, humidity, etc. at the time of experiment.
- Results may not be accurate for smaller reaches and low discharges due to limitations of accuracy of measuring devices.
- Adequate arrangements are required in longer reaches of bigger canals for measurement especially control of leakage from off-taking channels
- Reach-wise distribution of losses is not possible.

Merits: -

- Method can be used without rendering canal system out of operation.
- Losses are obtained under conditions simulative to actual runnings of canals.

(c) Seepage Meter Method: Seepage Meter is a device used to measure local seepage for a small area under normal operating conditions of canal at a time. However, by taking readings at several points along the channel section, a fairly average value can be determined.

The method involves pressing a cylindrical bell into the channel bed. Attached to this bell is a plastic bag filled with water. The water that seeps into the channel bed is replaced by water in the bag that is under the same pressure as the channel flow. and thus represents the some head against the channel surface. Seepage rate can be computed from the knowledge of area of the bell, the seepage from the bell is determined by weighing the plastic bag before and after the test and the elapsed time

Seepage Ratio (SR) in determined by

$$SR = Q / (A \times T)$$

Where Q is the volume of water seeped through the channel bed of area A in elapsed time T.

Limitations :

- Seepage meter works well union bed material is disturbed leading to over assessment of seepage rate.

- Difficult to install and use for greater depths of flow, higher velocities and highly vegetated channels.

(d) Tracer Techniques: In this, traces (a mixture of radioactive isotopes) are incorporated into a sample to make possible observation of its course.

Method is more useful in sub-surface flow measurements and can not be used in open channels because water is used by habitants for purpose other than Irrigation also.

3.7 Self Assessment Test

1. Describe the various stages of losses?
2. Describe various types of losses in the conveyance system?
3. Define conveyance efficiencies & calculate overall efficiency of the project based on the average losses in the system?
4. Describe the factors affecting losses?
5. Describe the different methods for measuring losses?

3.8 Key words

Seepages means "Transfer of water from one body to other through voids present in soil medium".

Discharge means "rate of flow of water per unit time".

Velocity means "the distance traveled per unit time".

Mean velocity means "average velocity across the depth of flow.

Slope means "rate of change in bed elevation with respect to distance a dimensionless unit. Generally defined in ration of vertical height to horizontal length.

3.9 Suggested readings

1. Discharge Measurement structures – editor M.G. Bos.
2. Weirs & Flumes for Flow Measurements by P. Ackers, White etc.
3. Water Measurement manual by U.S.B.R.
4. Irrigation Engineering & Hydraulic structures by S. K. Garg.
5. Indian Standard Codes of Practices.
6. Training modules under NMWP Project, Ministry of Water Resources, Govt. of India 1992.
7. Training modules of Irrigation Management & Training Institute Kota for middle & junior level officers.
8. Ackers, P., White, W.R., Weirs and Flumes for Flow Measurement, John Wiley & Sons, 1978
9. Chow, V.T., Open-Channel Hydraulics, McGraw-Hill, 1959
10. French, R.H., Open-Channel Hydraulics, McGraw-Hill, 1986
11. Subramanya, K., Flow in Open-Channels II ed., Tata McGraw-Hill, 1997

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UNIT-4

IDENTIFICATION OF MAINTENANCE PROBLEMS OF CANAL AND PRACTICES FOR IMPROVING THE SYSTEM

Structure:

4.0 Objectives

"A stitch in time saves nine"

This unit deals with the topic covering general maintenance plan. It broadly covers:

- describes the physical and social causes for the degradation of the physical works in irrigation systems,
- identifies the general requirements for maintenance,
- outlines procedures for preparation and implementation of maintenance plans.

4.1 Introduction

A common problem in all physical systems is the recurring cycle of construction-deterioration-reconstruction. In irrigation schemes, deterioration of the infrastructure affects timely and equitable delivery of irrigation supplies. This in turn inhibits agricultural production. To overcome this problem, the infrastructure needs to be maintained properly season after season so that dependable water deliveries can be maintained over time.

Operation and maintenance of any irrigation system is a complex and dynamic learning process and needs a technological approach for sustaining it over a longer period. Deterioration of any civil work due to its continuous use and with respect to time is an inevitable phenomenon. The rainfall, flood, high wind velocities bringing the blown sand, burrowing animals, cattle encroachment and offensive activities are the major causes to damage the irrigation system. All these activities cause recurring damages, erosion, silting, vegetative growth, seepage losses etc. and thus irrigation system require timely and adequate maintenance otherwise, further deterioration will take place and structure will collapse and require to be reconstructed.

The most serious problem in the earthen channel is sedimentation and in lined channel is formation of cavities behind the lining panels which eventually leads to failure of the lining panel. Erosion may be the serious problem in some of the channels and it can be check by maintaining the proper canal section. Similarly, seepage losses from the earthen channel can be quite significant, particularly when operating at higher levels. The vegetation or aquatic growth is the another problem, which can be control by removing it manually or by mechanical means. The involvement of farmers in maintenance of irrigation system may further reduce the maintenance problems and improve the efficiency of irrigation system. The concept of participatory irrigation management being propagated and implemented recently is a mile stone step in maintenance and optimizing the productivity of an irrigation system.

The maintenance is also needed due to social reasons in addition to physical reasons, as under:-

- Cutting of canal banks for personnel interest.
- Inserting unauthorized pipe outlets below the bank to draw more water.
- Putting obstruction dike in the canal to raise the water level to draw more water.
- Tempering the existing outlet.
- Not following the "warabandi".
- Allowing the cattle to cross or to bath in the canal.
- Unauthorized use of canal banks for motoring the trucks, tractors and cart.
- Unauthorized cutting of canal plantation.
- Removal of lining blocks for personnel interest
- Removing of gauge strips and dismantling of parapet wall by the notorious inhabitants.

4.2 Causes of system degradation

There are several causes for the gradual degradation over time of the physical system in an irrigation scheme. These are:

Operational wear and tear Examples are:

- Normal wear and tear due to service loads.
- Abnormal wear and tear due to: unsystematic operations.
- Improper designs and inadequate maintenance.

Weathering action Examples are:

Damage by wind, rain, sun, lightning, storms, floods, etc.

Wetting and drying, heating and cooling.

Contact with saline water and other aggressive agents.

Damage by pests Examples are:

Interference in performance due to weeds, rodents, animals, and human vandalism.

4.3 Categories of maintenance

Maintenance activities are of three categories:

1. Ordinary repairs
2. Special repairs
3. Emergent repairs

In the case of mechanical and electrical equipment one more category can be added, namely, preventive maintenance. This refers to the practice of replacing parts according to a predetermined schedule to pre-empt failure or breakdown of the equipment while performing. "Prevention is better than cure" is the philosophy behind such action.

4.3.1 Ordinary repairs

Ordinary repairs Ordinary repairs (also known as normal maintenance) focus on fair wear and tear of the physical system each year due to causes discussed earlier. In this category are also included petty repairs carried out departmentally through the services of baledar, if any, and temporary labour employed on daily wages.

Examples of such petty works are:

- Repairs of minor leakages in irrigation channels.
- Filling potholes/ruts in the canal banks and service roads.
- Closing minor breaches in small channels.
- Clearing unwanted vegetation and plants from the canal banks, beds and along service roads.
- Lubricating gates and other mechanical parts.
- Repainting name-boards, gauges and markers on canal banks inspection roads, etc.

4.3.2 Special repairs

These activities relate to repairs which are not caused by fair wear and tear of the system during its normal course of performance. The need for these arises either due to faulty design and operation of the system or inadequate maintenance. Examples of such cases are:

- Silting or scouring of canal bed and banks.
- Failure of canal lining.
- Damages to protective works, energy dissipators, waste weirs, etc.
- Works to check excessive conveyance and operation losses.

Recurring need for such works calls for a thorough review of the design and operation procedures. Until more permanent solutions are found to such recurring problems, special repairs have to be carried out to sustain efficient performance of the system. Normally these repairs are carried out during the canal closure periods.

4.3.3 Emergent repairs

These are works of unusual repairs which disrupt the integrity and performance of the system unless attended to urgently.

Examples of such works are:

- Damages by floods
- Piping in canals
- Breaches in the system
- Incipient system failures
- Damage or destruction of control and regulatory structures

These works should be taken up at the first sign of distress in the system. It is not necessary to go through the formal procedures of prior sanction of estimates and allocation of additional budgets before taking up such works. Additional budget is made available for such emergent works (over and above the annual budget allocation for normal maintenance) from what is known as "contingency fund" of the state government.

It may, sometimes, be necessary to close parts of the system to carry out such repairs. Promptness and speed of restoration are of prime importance in such repairs.

Regardless of the type of maintenance, time is the essence of the activity. Postponement of repairs merely adds to the cost. It also interferes with normal performance. As is often said, "a stitch in time saves nine".

4.3.4 Physical Phenomenon causing maintenance problem:

(i) The rate of sedimentation and conveyance losses are more than estimated.

(ii) Less volumes of water are received in the reservoirs than computed in the project estimates.

(iii) There is lack of awareness and culture in general maintenance of the system from headworks to outlets.

(iv) The deferred maintenance due to insufficient budget, untrained staff and lack of culture has also multiplied the problem.

(v) The siltation of channel, poor condition of control structure.

(vi) Presence of weed or vegetation or improper section due to which canal are unable to deliver required quantity of water.

(vii) More number of pipe outlets than designed.

(viii) Uncontrolled outlets.

(ix) Insufficient drainage network at many sites leading to water logging condition.

(x) No provision of gauges at control poi nts.

(xi) Heavy seepage losses - System losses are much more than estimated.

Conveyance losses in canal are 2 to 3 times or even more ranging from 2 to 20 cusecs per million sq. feet of wetted perimeter.

(xii) Canal F.S.L. are not properly maintained - This leads to obstruction in canal. Sometimes farmers put obstruction to take water to higher elevated areas.

The structure wise maintenance problems can be summarised as below.

4.3.5. Unlined channel :- However, the channels are designed and constructed with non scouring and non silting velocity in order to achieve their regime section but effective performance do not exist due to the following reasons.

(i) Excessive sediment entry from the reservoir into the main canal.

(ii) Improper side slopes, berms in high cut reaches.

(iii) Canal not running at its designed discharge resulting in lower velocity & deposition of sediment.

(iv) Due to problem narrated in (iii) above, excessive weed growth thereby chocking of section & further reducing the velocity. The Chambal system has acute problem of weed growth due to its five tanks enroute.

(v) Re-entry of excavated earth/silting due to rain and wind.

(vi) Improper design of structure causing erosion of down stream of structure.

(vii) Canal banks get eroded due to heavy rainfall or animal drinking.

4.3.6. Lined Channels : The lining if not designed properly creates maintenance problems.

(i) Under cutting of bank due to non provision of adequate drainage.

(ii) Lining on unstable slopes causes failure.

(iii) Removal of blocks.

The process of cavity formation begins with seepage through joints into the irrigation channels. During this process of cavity enlargement, the concrete panels begins to deteriorate lined irrigation channels & eventually failure of panels.

4.3.7. Irrigation Channel Embankments: The physical environment of an irrigation channel embankment plays a tremendous role in expected maintenance problems.

(a) Fill Embankment :- A major problem with earthen fill embankment is leakage/ piping as a result of biological life living just above the phreatic line.

In particular rodent burrowing holes or crabs in the embankment pose the greatest threat to the safety of embankment. The live example of this situation is Chambal main system.

(b) Cut Embankment :- Inadequate slope & berm causing falling of earth inside & widening of section.

(c) Service road embankment: -

(i) Due to encroachment of freeboard surface run-off flows from the irrigation channel & generally service roads are not graded thus causing maintenance problem.

(ii) Deterioration due to vehicular traffic.

(iii) Inadequate maintenance results in roadway depression and pot holes further the vehicular traffic further deteriorates surface.

(iv) Sometimes soil is excavated from the outside bank by the nearby villagers or by the deptt. for maintenance of road surface for filling up trench to be cut during piping for filling up breach etc. All these activities expose the hydraulic gradient line which in turn causes a breach.

(vi) Outer bank erosion can be the result of :-

(i) The cross-slope grading of the roadway being too steep so that surface runoff has a relatively high velocity.

(ii) The bank slope being ,too steep thus causing exposure of hydraulic gradient & finally causing soil erosion.

(iii) The bank height being too high.

4.3.8 Sedimentation: There is a tremendous variation in the amount of sedimentation that occurs in irrigation channels. This sedimentation carried from surface drainage inflows into the irrigation channel is the result of :

1. Sediment transported by the flows into the canal head works.
2. Roadway and berm erosion.
3. Erosion from cut banks.
4. Overflow from adjoining earthen channels or ponds into the channel.
5. Animals crossing the earthen or lined channels with subsequent erosion resulting in the animal pathways.

The basic philosophical approach towards sedimentation should be the elimination of all sources of sediment, so that no sediment enters the irrigation channels.

4.3.9 Aquatic and vegetable growth: One of the most persistent maintenance problems, besides sedimentation, is aquatic growth. The most difficult to control are under water weeds, some sediment for establishing roots, while a few species can attach to brick or concrete. This is a frustrating problem because once the aquatic growth has been removed from a channel, it will grow again within one or two months. As a result there is considerable' reduction of the discharge capacity (20-25 percent) of the Irrigation Channel.

4.3.10 Drainage:

(i) Surface Drainage: The primary purpose to prevent surface run-off from entering the Irrigation Channel in order to avoid.

a) To prevent sediments load with the surface run-off.

b) The potential for cavity enlargement or formation is lined channels.

c) To prevent the ponding of water alongside the Irrigation channels.

Ponded water will eventually percolate into the soil & raised the ground water table, which in turn increases the seepage rate that weakens the earthen channel banks and sediment transport through the joints in lined channels.

(ii) Sub Surface Drainage: When lined irrigation channels are constructed in cut areas, the soil water pressures behind the lining panels can increase significantly, particularly during the monsoon season. This condition results in higher seepage rates into the channels, and consequently, greater sediment transport through the lining joints. Also, these increased hydraulic pressures can cause wall panels to fail by sliding or flood panels to fail by increased hydraulic uplift pressures. Sub surface, preferably, the adjacent land will be at or below, the invert elevation of the Irrigation Channels.

4.3.11. Structures:

(i) Gate structures : Due to high velocity passing through a gate opening there will be some scour immediately downstream. Every effort should be made to operate the gates in a manner that minimise scour.

(ii) Fall structures: The very nature of their hydraulic design, will result in considerable scour immediately down stream.

(iii) Drop structures (syphons) : Drop structures consist of

a) Inlet structure with / without gates U/S b) A concrete chute or pipeline in between inlet and outlet structures.

c) A stilling basin and an outlet transition structure.

Sometime, cavities form near the head wall of the inlet structure and in the embankment overlying the concrete pipeline. These cavities can result from:

a) surface drainage into depression or

b) Leakage from concrete pipe joints. These occur due to hydraulic pressure nearby roadway. It is a visible evidence of scour in down stream hence proper means for improving the hydraulic energy dissipation in the still basin be sought.

(iv) Bridges: Generally, concrete bridges are in good structural condition.

The only problems is breaking of railings as well as serious rain cuts along the bridge abutments. Measures should be taken to divert any rainfall away from the irrigation channel.

For lined channels, often cavities are formed behind the lining panels underneath the bridge because of surface run-off near the abutments. If the bridge settles, then additional pressures will be placed on the lining and these may be prone to cracks.

(v) Tail cluster: A tail cluster is a structure constructed in brick/masonry at the tail of distributory or minor which may be feeding the fields at their tail. It helps in heading up of water at F.S.L. and then directing the water on to the rail outlets. Animals or people cross at these tail structures, they damage the structure & their sill gets lowered at places. This result's in non-building up of the required head at the tail and non drawal of shares of supply by the outlets. The only way to check this is to block the animals or people path way or repairing it regularly before each Irrigation reason.

(vi) Under canal Tunnels (Nallah syphon): To convey natural surface drainage waters under neath the Irrigation channels. In some cases, more compacted backfill drain. Should have been placed behind the headwalls of the inlet and outlet structure to be culvert drains.

The maintenance problems associated with drain culvert is the removal of sediment and shrubbery in the outlet and inlet structure.

(vii) Other structure: The primary difficulties have been the grading and shaping of the soil surface surrounding the structure. In some cases, rain cuts alongside the structure will result in sediment reaching the channel. Only in a few cases has their scour endangered the structure. However, for lined channels, these rain cuts have frequently resulted in cracks, broken or failed lining wall panels nearby.

4.3.12 Social phenomena covering Maintenance Problems.

Many maintenance needs in an irrigation system are due to social reasons in add ition to the physical reasons. They are as follows :

(1) Cutting of canal embankment, extra unauthorised pipe outlets inserting below the bank to draw more water than one's due and legitimate share.

(2) Putting obstruction dikes, Tampering outlets for drawing more water into the outlets.

(3) Lack of adequate maintenance of W.e. including field drains and not 1 following the Warandi.

(4) Allowing the cattle to cross or to bathe in canals.

(5) Unauthorised use of the canal-service road by bullock carts, trucks, tractors etc.

(6) Removal of lining blocks panels for personal use such as temporary bathing/ washing of clothes.

(7) Removal of gauge strips from the gauge well or sites.

(8) Water course not being maintained & cleaned by cultivators before the irrigation season.

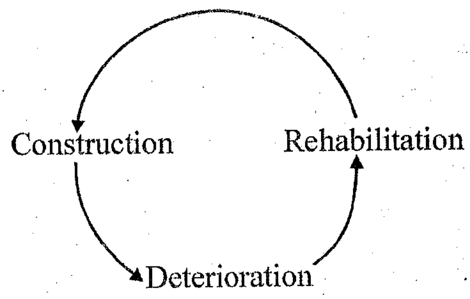
(9) Unauthorised removal of canal plantation / trees.

4.4 Maintenance plan

The history of irrigation development in India can be traced back to prehistoric times. Vedas and ancient Indian scriptures made reference to wells, canals, tanks and dams which were beneficial to the community and their efficient operation and maintenance was the responsibility of the state.

Civilization flourished on the banks of the life. According to the ancient Indian writers, the digging of a tank or well and canal was amongst the greatest meritorious act of a man.

Common problem in all irrigation systems is the vicious cycle of irrigation construction followed by deterioration of the system because of inadequate maintenance and then rehabilitation (which means again reconstruction) followed again by deterioration.



Hence proper attention must be given for timely maintenance of the system.

4.4.1 Collection of Information & formation of maintenance report

An important stage in the maintenance phase is the preparation of the maintenance plan every year. There are four sources of information to identify the maintenance needs:

- Inspection notes of the scheme officials.
- Completion report on annual operations.
- Presentations at the water distribution committee meetings.
- Direct information from farmers and canal inspectors.

Information from all these sources can conveniently be entered in a register maintained in the office of the scheme head for reference as needed.

Generally, the responsibilities of O&M officials for inspecting project components and the schedule for such inspections should be given in the departmental maintenance manual. However, no such manual has been prepared by many state governments.

The schedule of inspection is different for canals and structures. As a rule, all structures in the system are inspected before and after the monsoon season, with particular attention to their substructure. Main canals and related structures are inspected during the canal closure periods. Delivery channels are inspected during their off period of rotation. A sample checklist for use by all the inspecting officials of the project is presented in annexure I. These checklists accompany the inspection reports and provide a valuable basis for preparing the maintenance plan.

Farmer representatives attending the water distribution committee meetings sometimes bring up matters relating to the maintenance and upkeep of the system. Notes from these meetings are also a good source of information for the maintenance plan.

Direct submissions from farmers and canal inspectors on maintenance needs constitute yet another source.

Based on the information from the sources mentioned above, the maintenance plan for the year is prepared at the scheme-level and evaluated. If the total cost of works to be done does not exceed the standard annual maintenance budget of the scheme, further steps are taken to sanction the estimates, invite bids and let out the works.

In case the cost exceeds the normal budget then the components of works need prioritization. Items of work which cannot be postponed even for one season receive priority over items which can wait until extra funds are available. Such additional works are normally categorized as "special repairs".

The maintenance plan is prepared annually and is in two parts, viz.,

- The main report (provides basis for technical proposals, rates and costs, the implementation schedule and the agencies for carrying out works).
- The appendices (extracts from inspection reports, summary of previous year's completion report on maintenance, details of maintenance needs attended to the previous year and cost of each component, estimated cost of works, etc).

An outline of the contents of the main report is presented in annexure II.

The maintenance cost should be related to the operational efficiency to be achieved and the quality of irrigation service to be rendered in conformity with the stated objective(s) of the scheme.

If the needed maintenance is not done periodically, the operational efficiency falls, gradually in the initial years and more steeply in later years resulting in the further deterioration of system. Thereafter a special programme of rehabilitation has then to be undertaken to achieve the desired level of system capability.

4.4.2 PREPARATION OF MAINTENANCE PLAN:

The scientific preparation of a maintenance plan is a totally missing concept in operation & maintenance of an Irrigation system. The maintenance is a "continuous Learning process" & involves technological approach for sustaining an irrigation system over a longer period.

The objective of preparation of a scientific maintenance plan should be

(i) Maintaining rather than rehabilitating.

(ii) Documenting maintenance needs.

(iii) Using existing flow controlling structure for water measurement.

(iv) Develop more detailed physical knowledge about the happening within the system.

(v) Allocating costs for maintenance as per priority & available budget & documenting it for future use.

A scientific approach for improving maintenance consists of following phases.

4.4.3 Problem identification (Diagnostic Analysis) : It consists of following steps.

(a) ENTROPIC PROCESSES (SURVEY): Conducting a walk through on the system & documenting maintenance needs in sample proforma attached. It should be for (i) Main system (ii) Tertiary system (iii) Drainage system.

(b) OPERATION CONTROL SURVEY: Document the operation control survey with following consideration

(i) Is the system is in order technically to support an adequate, equitable, timely & dependable water supply?

(ii) How does the actual operation of minor compare to the designed operating procedures?

(iii) What are the constraints in alignment, section, grades, pucca structure, water profile etc.

(iv) Observed losses at different point if any.

(v) Maximum & Minimum water level achieved during last irrigation season.

(c) MAINTENANCE NEED INFORMATION SURVEY: Conduct a maintenance need survey with certain structured proforma & priorities the requirement by physical inspection. While documenting the events.

- Talk to farmer & obtain information
- Talk to canal Inspector
- Talk to concerned Mistri / J.En
- Talk to Agriculture officer / supervisor & obtain information regarding crops, damages to crops if any on account of maintenance & operation failure if any.

(d) Report preparation on Maintenance requirement, hydraulic requirement & public utility requirement etc.

4.4.4. DEVELOPING SOLUTIONS:

- By Developing Primary maintenance plan
- By Developing Essential structural plan
- By Developing Contigent maintenance Plan
- By Developing Catch up maintenance Plan
- By Developing preventive maintenance Plan

4.4.5. IMPLEMENTATION OF SOLUTIONS:

- Implement minimum maintenance
- Implement essential maintenance
- Continue improving preventive maintenance programme

Problem identification is part of Diagnostic Analysis done to find system constraints and its causes.

Discussion herein therefore is being limited to development part of maintenance plan only. Factors to be considered while preparing maintenance plan.

(i) Available maintenance manpower & its Job related functions.

(ii) Available maintenance equipment & no. of hours of its requirement & output.

(iii) Available material.

(iv) Availability of financial resources.

4.4.6 PRIMARY MAINTENANCE PLAN: The primary maintenance includes the works which are required to be taken up every year or every irrigation season.

The plan should illustrate

(i) Physical description of work

(ii) List of works to be executed e.g.

- Jungle clearance - Weed clearance - Silt clearance - Filling of cuts / breach etc.

(iii) Marking of these works on bar diagram or on L - Section.

(iv) Quantity & cost estimates.

(v) Details of work to be executed by Departmental Manpower (vi) Detail of work to be undertaken by other agencies.

After preparing this plan a subjective assessment of maintenance funds required every year can be determined.

4.4.7 ESSENTIAL STRUCTURAL MAINTENANCE PLAN : This plan includes the works and programme related with flow regulation and structural maintenance.

(i) Essential structural Maintenance

(ii) Proposed flow measurement programme for ensuring equity of water distribution

(iii) Maintenance & upkeep of gates, Rubber seal, etc.

(iv) Maintenance & upkeep of gauges etc.

The requirement under this plan may not be every year but certain minimum expenditure shall have to be included in yearly maintenance fund programme to meet the desired water measurement & regulation & assessment of seepage losses.

4.4.8 CONTIGENT MAINTENANCE PLAN : There are certain contingencies which may develop during the course of regulation. This may be include

- Canal piping
- Damage to canal Dowels
- Canal breaches
- Any other unfore seen item

It is therefore essential to anticipate such requirement & prepare a plan to meet out the casualties. Certain part of allocation shall have to be kept reserved for such items therefore necessary provision while preparing plan may be kept so that operation of canal is not disturbed.

4.4.9 "CATCH UP" MAINTENANCE PLAN: This plan includes programme which is being catching upon deferred maintenance such as

- Repair of crest of falls
- Increasing free board U/S of pucca structures
- Repair of damaged lining
- Puddling work etc.

These works are being executed after the canal closure & in turn prevent the deferred maintenance needs. It also increases the flow characteristics thereby improving hydraulic efficiency.

It is therefore essential to document events in "ENTROPIC PROCESSES' and prepare a plan. This requires separate financial provisions to be utilised at the end of each irrigation season.

The plan should classify category of works to be completed in time frame & should be marked on "L - SECTION" so that works to be executed yearly may be indicated on L-section of each Minor/branch/Main canal etc.

Thereafter, it is high time for technocrats to critically examine the maintenance activity & present a good, acceptable document & plans based on scientific calculations. The practice of preparing adhoc & stop gap plans should henceforth be stopped.

4.4.10 TERTIARY SYSTEM:

System below outlets can be termed as tertiary system presently their construction, maintenance & operation is collective responsibility of farmers.

It is advised that maintenance plan for tertiary system may also be prepared by Irrigation/ Agriculture official. The steps involved will remain the same as described for Macro Network. The department should implement this maintenance plan through farmers participation.

4.4.11 HUMAN RESOURCE NEED IN MAINTENANCE:

Routine maintenance works are generally carried out using available man power with the department. The available manpower further helps in

- planning a detailed maintenance plan
- Execution of maintenance plan
- Ensuring quality of works
- Monitoring the works
- Preparation of compilation report

4.5 Implementation

A proper schedule atleast one year in advance should be prepared for implementation of maintenance, published & distributed among the project officers & water user associations as it has been done in several projects. A typical schedule for the implementation of the maintenance plan is proposed as below for the project level:

Particulars	**Proposed period**
Preparation of maintenance plan	November 30
Preparation of cost estimates	December 31
Proposal for additional funds	January 15
Invitation of bids and settlement of Contract for normal maintenance works	February 28
Invitation of bids and finalisation of contract for special repairs	March 31
Completion of maintenance works (except petty works which can be done even during operation phase)	May 31
Preparation of completion report on maintenance implementation	September 30

Maintenance works are implemented through two agencies:

- Departmental agency.
- Contract agency.

All petty works which are not susceptible for accurate measurements and other works which can be carried out by the O&M staff are done departmentally. Examples are trimming and dressing of inspection roads, removal of shrubs and vegetation from canal banks, filling earth in rain gullies, oiling and greasing mechanical parts and dewatering by pumps. For such purposes, besides the O&M staff, additional help as needed is engaged temporarily on contract basis.

The maintenance works are supervised by the O&M staff for quality in accordance with the departmental specifications and sound engineering practice. The departmental standards prescribe the characteristic qualities and acceptance criteria for the works.

4.6 Completion report

At the end of each irrigation year a completion report on maintenance should be prepared. This would indicate:

- The action plan for the year
- Implementation and achievement
- Constraints (causes)
    - Physical (design/operation deficiencies)
    - Temporal (inadequate closures)
    - Financial (inadequate budgets)
    - Social (public interference)

Lessons learnt and remedial actions proposed should be included in the next year action plan.

The report should be prepared by concerned Assistant Engineer for the maintenance programme within his jurisdiction. This is aggregated at the Subdivision and the Division levels. Thereafter, it is sent for review by the authority one step higher than the head of the scheme.

4.7 Monitoring

For purposes of control a suitable management information system (MIS) should be developed to monitor the maintenance activities. Information needed relates to:

- Whether inspections have been done as scheduled. ?
- Whether maintenance plan has been prepared in time. ?
- Whether maintenance activities have been implemented as planned. ?
- What was the budget allocation and what expenditure was incurred?
- Whether completion report on maintenance activities during the year has been prepared on time?

- Vulnerable components
  - Piping
  - Slips
  - Seepages
  - Silting
  - Scouring

4.8 Summary

The salient points regarding proper upkeep and maintenance of the system are summarised below:

- The recurring cycle of construction-deterioration-reconstruction and upkeep is an inevitable process in any irrigation system. Proper maintenance of the physical system is a prerequisite for improved irrigation service.
- "Prevention is better than cure "A stitch in time saves nine". These maxims govern the strategies for maintenance.
- Maintenance works should be planned well ahead of their implementation, particularly taking note of closures and idle times of the system.
- Pre-planned inspections of the canals and structures reduce maintenance costs and contribute to timely and reliable water deliveries.
- If maintenance funds are limited, priority should be given to the maintenance of components which immediately affect the planned flow or planned levels of water.
- Maintenance activities should be monitored and reviewed each year.

4.9 Self Assessment Test

1. What are the main causes of system degradation, define briefly with examples?
2. Define maintenance and various categories of maintenance.
3. List the sources for preparing a maintenance plan?
4. How to conduct a walk through survey for preparing maintenance plan?
5. How to prioritize maintenance & its needs ?
6. What is the need for preparing an annual completion report on maintenance?
7. What are the general maintenance problems, describe most critical failure problem?
8. Identify possible gaps between actual practices of maintenance with respect to maintenance plan ?
9. Prepare an effective MIS system on maintenance planning?

4.10 Key words

Piping means "formation of earthen pipe /cavity in embankment due to rodent hole, crab, erosion etc causing the leakage of water from canal/storage".

Slips mean "settlement of embankment/lining with respect of its supportive structure".

Seepages means "Transfer of water from one body to other through voids present in soil medium".

Silting means "deposition of earth/silt particles in bed /slopes of structure".

Scouring means "erosion of earth/silt particles from bed /slopes of structure due to water flow".

Gully erosion means "cavitations in slopes due to runoff water during rains".

Aquatic weeds means vegetation having either root in water or in earth but their habitat is in water.

MIS means "management information system" i.e gathering data/information from field, planning, execution, completion, weakly reports etc.

4.11 Suggested readings

1. Training modules under NMWP Project, Ministry of Water Resources, Govt. of India 1992.
2. Training modules of Irrigation Management & Training Institute Kota for middle & junior level officers.
3. Training modules for Irrigation & CAD Department, Govt. of Andhra Pradesh 1998
4. Irrigation Engineering & Hydraulic Structures by S.K. Garg.
5. Text book of Irrigation Engineering & Hydraulic Structures by R.K. Sharma.
6. Irrigation Engineering by B.C. Punmia

Annexure 1

Checklist for maintenance

Name of irrigation channel: Date of inspection:

Inspected Reach: Km (   ) Inspected by:

Category: O/S/E (0: ordinary repairs, S: special, E: emergent)

Signature:

SN	Item inspected	Condition when inspected	Category of repair O/S/E
1.	**Earthwork**		
a)	gully erosion		
b)	slips		
c)	bed silt		
d)	seepage		
e)	piping		
f)	Re sectioning		
g)	other		
2.	**Lining**		
a)	panels		
b)	joints		
c)	subgrade		
d)	other		
3.	**Masonry**		
a)	pointing		
b)	plastering		
c)	revetment		
d)	cavities		
e)	Replacement		
f)	other		
4.	**Concrete structures**		
a)	plastering		
b)	cracks		
c)	cavities/erosion		
d)	foundation erosion		
e)	other		

5.	**Mechanical Structures**		
a)	shutters/gates		
b)	gate seals		
c)	piping		
d)	painting gates		
e)	other		
6.	**Drains**		
a)	silt clearance		
b)	repairs to masonry		
c)	revetment		
d)	vegetation		
e)	other		
7.	**Inspection road**		
a)	surface pot holes		
b)	resurfacing		
c)	side drains		
d)	other		
8.	**Miscellaneous**		
a)	Shrub clearance		
b)	aquatic plants		
c)	painting marker boards and marker		
d)	oiling/greasing		
e)	other		

Annexure 2

Outline content Report to accompany maintenance estimate

1. The project

   Historical background

   Salient features of the scheme

2. Performance (previous year)

   The number of days for which the canals operated;

   Delivery pattern (total number of outlets, number of outlets which did not deliver water; number that delivered less water than authorised).

3. Carryover works

   Comment on maintenance needs attended to the previous year

   Carryover works from previous year(s).

4. Inspection summaries

   Maintenance works planned in current year based on the inspection reports

5. Rates and costs

   Analysis of rates Estimated cost of departmental works and works on contract Cost summary:

	Amount	Percent
Irrigation		
Drainage		
Tools and plant (T&P)		
Establishment		

Abstract of estimate Detailed

estimate or bill of quantities

Line diagram of the system and other plans as needed

Performa of Salient features of Project

1. **Year of commissioning of the scheme**

2. **Planned GCA (ha)**
   - CCA (ha)
   - ICA
   - Kharif (ha)
   - Rabi (ha)

3. **Water allocation**
   - Kharif (M.Cu.m) :
   - Rabi (M.Cu.m) :
   - Total (M.Cu.m) :

4. **Canals**	Right	Left
Head discharge (cumecs)		
Length (km)		
Lining C.C. (M.Sqm.)		
Masonry (M.Sqm.)		
CCA ('000 ha)		
Distributaries (km)		
Minors/subminors (km)		
Outlets (No.)		

5. **Structures**

	Main canal (No.)	Other canals (No.)
Cross regulators		
Offtake regulators		
Syphons		
Aqueducts		
Super passages		
Escapes		

Drops

Measuring devices

Bridges

6. Drains

Catch drains and toe drains (km)

Constructed collecting drains (km)

Drops & other structures (No.)

Natural arterial drains (km)

7. Inspection roads	Main canal (km)	Other canals (km)
On the canal banks Elsewhere		

8. Other

◆◆◆

UNIT-5

PARTICIPATORY IRRIGATION MANAGEMENT

Structure

5.0 Objectives

After independence large-scale construction of irrigation projects under successive plans were taken up thereby increasing the irrigation potential of Rajasthan from 0.40 million ha in 1951 to about 3.2 million ha at present. Due to several reasons created potential is not being utilised properly & large area remains un-irrigated which a water deficient state like Rajasthan can not afford which is of size of 10.4% of the country's area having only 1.16% of the country's surface water resource. Present lecture describe the necessity of user's participation in management of irrigation system with special emphasis on legal support provided for its implementation in Rajasthan.

5.1 Introduction

As mentioned above the irrigation potential created is not utilized properly. The annual revenue realised from water charges is very less as compared to the non-plan expenditure on Irrigation Organisation including establishment & interest on capital outlay. Generally funds needed for the maintenance of the irrigation systems are not provided and due to inadequacy of maintenance funds & lack of proper practices of water management, the condition of the existing irrigation systems is going from bad to worse successively. Due to poor water management, the area in the command of irrigation projects is becoming increasingly waterlogged & saline & going out of cultivation.

In the irrigation projects constructed in successive plans, the construction above the canal outlets received attention whereas the design, construction & maintenance of irrigation system below the outlet did not receive proper attention except on some of the projects. This has caused lot of problems of over out-letting from canals, inefficient water use & wastage of precious water. The Irrigation Systems are more administered than managed. Water users have no participation in administration of the Systems. They mostly depend on the irrigation agency for water supplies. A farmer is concerned with timeliness, adequate quantity & regularity of water supply to his field and advance information of the same to him. There is no incentive for economy in water & no deterrent against over-uses. This is not reflected even in the water rates, which are not on volumetric basis but on area basis. Canal offences & defaults being in excessively large numbers are hardly possible to be properly dealt with.

The above contributory factors have created under-performing irrigation systems, devoid of equity in water distribution between head & tails, strongly entrenched interests of those farmers who have opportunity to have excessive water supply at the cost of those who thus do not receive adequate supplies. Irrigation infrastructure is having widespread deterioration. Service to the farmers is poor & marked by insensitivity. Agriculture production per unit of water & her unit of area is low.

There is thus an obvious need for paradigm shift, involving farmers in the management of irrigation system as a partner. It is experienced that when farmers' participation is taken in the management of irrigation systems they have comparative advantages of:

- Having better local knowledge of problems / fellow irrigators/ farmers' needs & irrigation problems,
- Having direct incentive to manage the system in productive manner,
- Better on-the-ground presence than even the most dedicated agency staff,
- Improved design, construction, Operation & Management.
- Lower costs to Govt.
- Organised farmers for management of irrigation systems constitutes a social capital, which can have many cascading advantages.
- Improved services to the farmers.
- Better utilization of water promoting its more equitable distribution.
- Better recovery of irrigation dues.

5.2 BACKGROUND

Management of Irrigation System by farmers had been practiced even in ancient times in the country for which incentives were given to the farming community. Arthshastra of Chanakya, fourth century A.D., provided concessions in taxes to farmers participating in or undertaking construction & maintenance of tanks & diversion works. People participated in the construction & management of weirs & canals built on Tung Bhadra River in 13th - 16th Century A.D. Also before advent of British Rule, certain parts of irrigation systems maintained by the Govt. were called "Sarkari" & lower parts of irrigation systems maintained by the farmers were called "Kudir maramat" (farmer - maintenance). Farmers' groups in Tamil Nadu, Andhra Pradesh & Karnataka used to maintain many tanks. Similarly 'Phad' System in Maharashtra used to be managed by the beneficiary farmers.

During British period, with modern systems & practices, large dams & projects were built in many parts of the country & the Govt. tended to extend its control & activities over construction & management of these projects. As such peoples participation in such projects lost its momentum, and irrigation system came to depend more & more on government rather than for being people centric.

5.3 CONCEPT OF PARTICIPATORY IRRIGATION MANAGEMENT

Participatory Irrigation Management (PIM) refers to involvement of water users in all aspects of irrigation management at all levels. "All Aspects" means initial planning, design construction, extension, improvement, renovation/modernization, operation, maintenance, revenue assessment & recovery, supervision, financing, decision, rules, monitoring & evaluation. "All levels" means full physical limits of the irrigation system viz. quaternary, tertiary, secondary, main, project & sector levels as well as from lowest level function to the highest-level function including setting of policies. The participatory mechanism will include information sharing, consultations, joint assessment, shared decision making, collaboration & empowerment of the water users. Farmers' participation can be promoted by formation of Farmers Organisations (FOs) like Water Users Associations (WUAs), Distributory Committee and Project Committees.

5.4 LEGAL PROVISIONS IN RAJASTHAN

To provide legal support to the Farmers Organisation (FOs) for the farmers' participation in management of irrigation systems in Rajasthan an act titled The Rajasthan Farmers' Participation in Management of Irrigation Systems (RFPMIS) Act, 2000 was enacted and the same has come into force on and from 20th day of July, 2000. Rules 2002 have also been notified. In India about 10 states have enacted special acts related to PIM including Andhra Pradesh, Madhya Pradesh, Tamilnadu, Rajasthan, Maharashtra, Orissa, Chattishgarh, Karnataka, Gujrat, Uttar Pradesh, Bihar etc.

As per the Act, the objects of the Farmers' Organisation shall be to promote and secure distribution of water among its users, adequate maintenance of the irrigation system, efficient and economical utilisation of water to optimise agricultural production, to protect the environment, and to ensure ecological balance by involving the farmers, inculcating a sense of ownership of the irrigation system in accordance with the water budget and the operational plan.

Some of the legal provisions are described below. For detailed description readers are advised to refer RFPMIS Act & Rules.

5.4.1 Delineation of Water Users' Area and Territorial Constituencies and Constitution of Water Users' Association

The Project Authority will, by notification delineate every command area under each of the irrigation systems on a hydraulic basis which may be administratively viable; and declare it to be a water users area for the purpose of this Act. In respect of the command area under the minor and lift irrigation systems, the entire command area may, as far as possible, form a single water users' area. This Water Users' Association shall be called by its local distinct name. Every Water Users' Association (WUA) shall consist of all the water users who are landowners in such water users' area as members. All members shall constitute the General body of the Water Users' Association and all adult members shall have right to vote.

Every water users area shall be divided by the Project Authority in to number of territorial constituencies (T.C.) depending upon area of WUAs. Number of T.C.s will be four, six,