eight & ten for WUA area of up to 1000 ha, 1001 to 1500 ha, 1501 to 2000 ha and more than 2000 ha respectively.

While dividing a water users area in to territorial constituencies, project authority shall as far as practicable, place area under a direct pipeline or a pipe out let in a territorial constituency. Each constituency shall be assigned a separate serial number. Map/sketch of each water users area showing the boundaries of territorial constituencies shall be prepared by the Project Authority. List containing the survey numbers of the land situated in each territorial constituency shall also be prepared by the Project Authority.

5.4.2 Managing Committee of Water Users' Association and Election of Its President and Members

There shall be a Managing Committee for every Water Users' Association. The Project Authority shall make arrangements for the election of President of the Managing Committee of the Water Users' Association by direct election from among its members by the method of secret ballot (described in detail in Rules 2002). The Project Authority shall also cause arrangements for the election of a Managing Committee consisting of one Member from each of the territorial constituencies of a water users' area, by the method of secret ballot. If, at an election held as mentioned above, the President or the Members of the Managing Committee are not elected, fresh elections shall be held. The Project Authority may, for the reasons to be recorded in writing from time to time, postpone elections.

Where a land owner holds land in more than one territorial constituencies of the water users' area, he shall be eligible to take part in election for membership of the Managing Committee only from one territorial constituency for which he opts.

The President and the Members of the Managing Committee shall, if not recalled earlier, be in office for a period of five years, from the date of the first meeting. The Managing Committee shall exercise the powers and perform the functions of the water users association.

5.4.3 Delineation of Distributary Area and Constitution of the Distributary Committee

The Project Authority may, by notification, delineate every Command Area of the irrigation system, comprising of two or more Water Users' Areas and declare it to be distributary area. There shall be a Distributary committee called by its local distinct name for every distributary area declared. All the Presidents of the Water Users' Associations in the distributary area, so long as they hold such office, shall constitute the General Body of the Distributary Committee including two officials nominated by the Project Authority.

There shall be a Managing Committee for every Distributary committee and the said committee shall consist of such number of members, not exceeding five including President.

The Project Authority shall cause arrangements, for the election by the method of secret ballot of the President and Members of the Managing Committee from among the Members of the General Body of the Distributary Committee. The Government may, for the reasons to be recorded in writing, from time to time postpone elections. If, at an election held as above, the President and the Members of the Managing Committee are not elected, fresh elections shall be held. The term of office of the President and the Members of the Managing committee shall, if not recalled earlier, be co-terminus with the term of general body. The Managing Committee shall exercise the powers and perform the functions of the Distributary Committee.

5.4.4 Delineation of Project Area and constitution of Project Committee

The Government may, by notification, delineate every command area or part thereof, of an irrigation system and declare it to be a project area. There shall be a Project Committee called by its distinct local name for every project area declared. All the Presidents of the Distributary Committees in the project area, so long as they hold such office, shall constitute the General Body of the Project committee.

There shall be a Managing Committee for every Project Committee consisting of nine Members including Chairperson. The Project Authority shall cause arrangements, for election by the method of secret ballot, of Chairperson and eight Members of Managing Committee from among the members of the General Body of the Project Committee. The Government may, for the reasons to be recorded in writing, from time to time, postpone elections. If, at an election held as mentioned above, the Chairperson and the Members of the Managing Committee are not elected, fresh elections shall be held. The term of office of the Chairperson and the Members of the Managing Committee shall, if not recalled earlier, be co-terminus with the term of general body. The Managing Committee shall exercise the powers and perform the functions of the Project Committee.

5.4.5 Disqualifications

A person, who is employee of the Government of India or any State Government of a Local Authority or any institution receiving aid from the funds of the Government, shall be disqualified for election or for continuing as a Chairperson or a President or a Member or a Managing Committee of a Farmers' Organisation. No person who has been convicted by a criminal court for any offense involving moral turpitude committed under any law for the time being in force shall be qualified for election or continuing in the office of a Chairperson or a President or a Member of a Managing committee of a Farmers' Organisation. A person shall be disqualified for being chosen as a Chairperson or a President or a Member of the Managing Committee of a Farmers' Organisation if on the date fixed for scrutiny of nominations for election, or on the date of nominations, he is, of unsound mind and stands so declared by a competent court; an applicant to be adjudicated as an insolvent or an undischarged insolvent; a defaulter of land revenue or water tax or charges payable either to the Government or to the Farmers' Organisation; interested in a subsisting contract made with, or any work being done for, the Panchayat or Panchayat Samiti or Zila Parishad or any State or Central Government or the Farmers' Organisation.

A Chairperson or a President or a Member of Managing Committee shall be disqualified for election to or continuing in office of Chairperson or President or Member of Managing Committee of a Farmers' Organisation if he absents from three consecutive meetings of the Managing Committee without reasonable cause, provided that the disqualification under this sub-section shall not apply in the case of women, who during the advanced stage of pregnancy or during a period of three months after delivery, is unable to attend the meetings.

A person having more than two children shall be disqualified for election as a Chairperson or a President or a Member of the Managing Committee, provided that a person having more than two children shall not be disqualified under this section for so long as the number of children he had on the date of such commencement does not increase and provided further that the birth of an additional child within one year from the date of commencement of this Act shall not be taken into consideration for the purposes of this section.

A person shall become disqualified to continue as Member of Water Users' Association or hold the office of Chairperson or President or Member of a Managing Committee of a Farmers' Organisation, if he ceases to be a land owner in the area of operation of concerned Farmers' Organisation.

5.4.6 Procedure for Recall

A motion for recall of a Chairperson or a President or a Member, as the case may be, of a Managing Committee of a Farmers' Organisation may be made by giving a written notice to Project Authority in form of an application on the plain paper, signed by not less than one-third of the total number of members of the Farmers' Organisation, who are entitled to vote. Provided that no notice of motion under this section shall be made within one year from the date of assumption of office by the person against whom the motion is sought to be moved. If the motion is carried with the support of majority of the Members present and voting at a meeting of the General Body specially convened for the purposes, the Project Authority, shall by order remove the person, against whom motion is carried, from office and the resulting vacancy shall be filled in the manner a casual vacancy is filled.

5.4.7 Casual Vacancies

A vacancy arising in any of the Farmers' Organisation either due to disqualification, death, resignation, recall, or by any other reason, such vacancy shall be filled for the remaining period in the following manner:-

(i) If a vacancy in the office of the President of the Water Users' Association arises, the Managing Committee of the Distributory Committee in which the Water Users' Association is situated, shall nominate one of the existing Managing Committee Members of the Water Users' Association as President of the Water Users' Association. Where the Distributory Committee does not exist the nomination shall be made by the Project Authority.

(ii) If a vacancy of a Member of Managing Committee of water users' association arises, the Managing Committee of the Distributory Committee shall nominate, any one of the Member of Water Users' Associations from that particular constituency in which vacancy has arisen, as a Member of the Managing Committee. Where the Distributory Committee does not exist the nomination shall be made by the Project Authority.

(iii) If a vacancy in the office of a President of a Distributory Committee arises, the Managing Committee of the Project Committee in which the Distributory area is situated, shall nominate, one of the members of the Managing Committee of the Distributory Committee as the President of the Distributory Committee.

(iv) If a vacancy of a Member of Managing Committee of a Distributory Committee arises the Managing Committee of the Project Committee shall nominate one of the members of general body of the Distributory Committee as a member.

(v) If a vacancy in the office of the Chairperson, of the Project Committee arises the

Government shall nominate one of the members of the Managing Committee of the Project Committee as the Chairperson.

(vi) If a vacancy of a member of the Managing Committee of a Project Committee arises, the Government shall nominate one of the general body members of the Project Committee as a Member of the managing committee.

The term of office of a member or a President or a Chairperson of the Farmers' Organisation, nominated as above, shall expire at the time at which it would have expired, had he been elected at the ordinary election.

5.4.8 Duties of the Chairperson / President of a Farmers' Organisation

The duties of the Chairperson / President of a Farmers' Organisation shall be to preside over the General Body Meetings and Managing Committee Meetings and conduct the meetings in a peaceful and democratic manner; to sign and authenticate the minutes of the meetings and other records of the Farmers' Organisation; to exercise casting vote in the event of equality of votes on any matter being decided upon by the General Body or the Managing Committee, as the case may be; to act as a custodian of all records, properties of the Farmers' Organisation; to maintain full and complete accounts of all transactions of the Farmers' Organisation; to sign all contracts and documents on behalf of the Farmers' Organisation; to operate accounts jointly with another member of the Managing Committee duly authorised for the purpose by the Managing Committee; to represent the case of the Farmers' Organisation in any dispute before Distributary Committee or Project Committee or Apex committee or project authority or the Government, as the case may be; to act as an authorised representative of the Farmers' Organisation at all other forums, meetings called by any authority; to be accountable for all transactions; to conduct the affairs of the Farmers' Organisation in a democratic, free, fair and transparent manner; to submit annual reports to the General Body, on the activities of the Farmers' Organisation; to ensure that the available resources with farmer's Organizations are utilise in most efficiency economical manner; to motivate water conservation techniques and to timely and evenly distribute the available water to members following a well define procedure; to act for generation of the financial resources for the farmer's Organisation for sustainability and progress to achieve the objectives; to respect the written guidance of project/ competent authority with regard to technical and financial matters and to act for implementing them; and to implement decision taken by general body with the help and guidance of project/competent authority.

5.4.9 Functions of the Farmers Organisations

Common Functions of the Water Users Association, Distributory Committee and Project Committee

Following functions are to be carried out by WUA, DC & PC in addition to the functions mentioned in next para.

- To promote economy in the use of water allocated ;
- To prepare and maintain an inventory of the irrigation system within the area of operation;
- To monitor flow of water for irrigation;
- To maintain accounts;

- To cause annual audit of its accounts;
- To maintain such other records as prescribed;
- To conduct General Body meeting in the manner prescribed;
- To conduct regular water budgeting and also to conduct periodical social audit in the manner prescribed.
- To encourage avenue plantations in its area of operation.

Functions of Water Users' Association

The Water Users' Association shall perform these functions (in addition to functions mentioned above), to prepare and implement a warabandi schedule for each irrigation season, consistent with the operational plan, based upon the entitlement, area, soil and cropping pattern; to prepare a plan for the maintenance, extension, improvements, renovation and modernisation of irrigation system in the area of its operation and carry out such works of both distributary system and field drains in its area of operation with the funds of the association from time to time; to regulate the use of water among the various outlets under its area of operation according to the warabandi schedule of the system; to prepare demand and collect water charges; to maintain a register of land owners as published by the revenue department; to resolve the disputes, if any, between its Members and water users in its area of operation; to raise resources; to assist in the conduct of elections to the Managing Committee; to abide by the decisions of the Distributary and Project Committee; to encourage avenue plantation on canal bunds and tank bunds by leasing such bunds.

Functions of the Distributary Committee

The Distributary Committee shall perform these functions (in addition to the functions mentioned above), to prepare an operational plan based on its entitlement area, soil, cropping pattern at the beginning of each irrigation season, consistent with the operational plan prepared by the Project Committee; to prepare a plan for the extension, improvements, renovation, modernisation and annual maintenance of both distributaries and medium drains within its area of operation; to regulate the use of water among the various Water Users' Associations under its area of operation; to resolve disputes, if any, between the Water Users' Associations in its area of operation; to maintain a register of Water Users' Associations in its area of operation; to abide by the decisions of the Project Committee; to assist in the conduct of elections to the Managing Committee.

Functions of the Project Committee

The Project Committee shall perform these functions (in addition to the functions mentioned above), to approve an operational plan based on its entitlement, area, soil, cropping pattern as prepared by the Competent Authority in respect of the entire project area at the beginning of each irrigation season; to approve a plan for the extension, improvements, renovation, modernisation and annual maintenance of irrigation system including the major drains within its area of operation at the end of each crop seasons; to maintain a list of the Distributory Committees and Water Users' Associations in its area of operation; to resolve disputes, if any, between the Distributory Committees.

5.4.10 Constitution of sub-committees of Farmers' Organisation

The Managing Committee of a Farmers' Organisation may constitute sub-committee to carry out all or any of the functions vested in each Organisation under this Act. The Sub-Committee will carryout specific functions assigned by the President / Chairperson on recommendation of the managing committee. No member shall represent more than one sub-committee. Sub-comittees constituted under this rule shall carry out such other functions as may be specified by the Government from time to time.

(A) Administration, Finance and Resources sub-Committee-

The Administration, Finance and Resources Sub Committee shall consist of not more than the three members having minimum education qualification of the secondary, nominated by chairperson / president from the members of Farmers Organisation. This sub committee shall examine and put his recommendation about any administrative reforms required for better functioning of the Farmer's organization and methods for raising of resources to achieve financial soundness of the farmers Organisation. The recommendation of the sub committee shall be discussed in the General Body meeting, and a decision be arrived at by voting in favour by at least two third majority of members present.

Deposit and administration of the funds - The Farmers' Organisation shall keep their funds in a Nationalised Bank or a Co-operative Bank or a Post Office. Co-operative Bank means a Primary Agricultural Co-operative Society or the District Central Co-operative Bank or the Rajasthan State Co-operative Bank. The funds shall be applied towards meeting of the expenses incurred by the Managing Committee of the concerned Farmers' Organisation in the administration of this Act and for no other purpose. President of WUA will operate accounts jointly with another member of the Managing Committee duly authorised for the purpose by the Managing Committee.

(B) Works-Sub Committee: (NIRMAN UP SAMITI) for Water Users' Association-

Works sub committee shall have eight nominated members, out of which six members shall be nominated by the managing committee of Water Users' Association, Two members representing head reach; Two members representing middle reach and Two members representing tail reach.

Out of these six members two must represent scheduled castes and schedule tribes (preferably one from each cast) and one shall preferably be a woman member. The rest two members shall be nominated by the competent authority on request of the managing committee out of which one shall be from available technical/ supervisory staff of the department and other shall be either a village level agricultural assistant or any other local government employee nominated by District Collector on the request of the competent authority.

The sub committee so constituted shall have functions/ responsibilities as, the sub committee shall meet fortnightly, during the work of Maintenance/ repair/ improvement/ construction is in progress; it shall decide about work to be taken up on minor. Conduct and assist "walk through surveys" and work out strategies to carry out the work in best economical manner adhering to required specifications and time; it shall recommend about employment/ removal of labour/ supplier/agency/contract required for carrying out the works; it shall finalize the quantity-quality and make etc. of all materials/articles etc.

appeal to the Managing Committee of a Project Committee, whose decision thereon shall be final. Any persons aggrieved by any decision made or order passed by the Managing Committee of a Project Committee may appeal to the Apex Committee, whose decision thereon shall be final.

Any appeal as described above shall be preferred within fifteen days of communication of the decision or the order to the person aggrieved. Every appeal under this section shall be disposed off within thirty days from the date of filing of the appeal by adopting summary procedure.

5.5 IMPLEMENTATION OF PARTICIPATORY IRRIGATION MANAGEMENT PROGRAMME

The challenge of successful functioning of F0s and their sustainability can be met by ensuring; close partnership between the ID & AD officials and the farmers, equity in water distribution, proper maintenance plan, cultivating sense of ownership among farmers, transparency in functioning of WUAs and improved cost recovery and water service. This would require:

- Political support at the grass root level to convince farmers and mobilizing their support for formation & sustainability of FOs,
- Continuous state support in transferring irrigation responsibilities and officials to work as facilitator,
- Comprehensive human resources development program for FO managing committee members and the state officials:
- Continues strengthening of WUAs through monitoring and evaluation program.
- Mobilization of Financial Resources to Sustain Reforms,
- Entrusting Powers to WUAs,
- Priority for other Funds.

5.6 SUMMARY

To efficiently utilize irrigation potential created and to provide irrigation facility to all farmers even to tail enders and to manage the irrigation system properly it is essential to have farmer's participation in management of irrigation system not only at minor level but up to project level. Giving responsibility to users will not only benefit the state government but will also benefit farmers by way of improved agriculture production. Therefore it is necessary to implement the PIM in all major, medium & minor irrigation projects in the state. The legal support provided by RFPMIS act & rules will guide department officials & farmers for successful implementation of PIM.

5.7 SELF-ASSESSMENT TEST

- Why it is necessary to have farmers' participation in management of irrigation system?
- Define Participatory Irrigation Management.
- What is the three-tier system of PIM?

- What are the functions of WUA?
- How a member can be recalled?
- How social audit of a farmers organization is conducted?

5.8 KEY WORDS

- Participatory Irrigation Management.
- Water Users Associations.
- Distributory Committee.
- Project Committee.
- Managing Committee.
- Territorial Constituency.
- Farmers Organizations.
- Land Owner.
- Water Utilizers.

5.9 SUGGESTED READINGS

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UNIT-6

PERFORMANCE EVALUATION OF WATER RESOURCES PROJECT

Structure

6.0 Objectives

This unit deals with the topic covering methods/indicators for evaluation of water resources project. It broadly covers:

- Introduction & future challenges
- Systems in Water Resources Project
- Identification of performance indicators
- Analysis of indicators

6.1 Introduction & Future Challenges

Majority of 20th century witnessed path breaking technological breakthroughs in the fields of industrial production, communication technologies etc, the later half & particularly the last decade saw a gradually building concern on the finiteness of the fresh water availability & the resultant socio-economic impacts. India, though have achieved remarkable progress in the areas of water resources development since independence, is presently experiencing range of issues in water sector primarily due to rapid growth of population, urbanization & industrialization, deterioration of existing system due to deferred maintenance, design criteria etc.

The declining per capita water availability, growing regional imbalances owing to rainfall variation, rising multi-sectoral water demand, inequitable water distribution, low irrigation efficiencies, deteriorating water quality, financial constraints etc are some of the issues posing serious challenges in future.

Presently agriculture sector is the largest consumer of water and consumes more than 80 % of available water. With the increase in water demand for non-irrigation use & reduction in per capita availability of water, the water availability for irrigation use will be curtailed.

The agriculture sector is the mainstay of Indian economy & agriculture and allied sectors contribute nearly 25% of Gross Domestic Production and about 65-70% of the population is dependent on agriculture for their livelihood. Presently total annual agriculture production comes nearly 220 million tones while the total food grain demand by 2050 tunes to be between 420 - 490 million tones. The presently irrigated area yields about 2.75 t/Ha while yield rain fed area is around 0.75 t/Ha. With availability of land as constraints, the possible solution for meeting this food grain demand of future revolves around:

a. Conversion of rain fed area into irrigated area through development of new water resources projects.

b. Use of high yielding crop variety.

c. Bridging the gap between irrigation potential created and utilized.

Of the possible solutions to mitigate food grain requirement, development of new water sources is becoming very costly and of the all-freshwater sectors, agriculture in most cases shows the lowest return of water in economic terms. The matter of using high yielding crop variety is a scientific research work and carries with time. Regarding bridging the gap between irrigation potential created and utilized, about 32 lacs Ha irrigation potential has been created in Rajasthan while the utilization tunes to about 22 lacs Ha only. Thus there is a tremendous scope of improvement of water use efficiency. Studies reveal that mere 1% improvement in irrigation efficiency in India's 90 m Ha irrigated area can save enough water to provide irrigation to an estimated 300,000 Ha at about 30-35% efficiency. Thus irrigation efficiency should be improved from the present average of about 30% to a maximum achievable value of around 60%.

Thus looking to the present era of water availability & future challenges, the slogan of tomorrow should be "more crop per drop of water".

There is a strategic need to "re-invent" water management in agriculture sector based on:

1. Modernization of irrigation infrastructure and institutions.
2. Adoptions of modern methods of irrigation.
3. Saving of irrigation water through scientific approach.
4. Improving service delivery
5. Participatory management of irrigation by stakeholders groups in distribution of water and sharing of costs and benefits.

Looking to the performance of present irrigation system, it is the right time to answer some questions like:

1. Total revenue put in per unit volume of irrigation water stored (Rs/m^3)?
2. Agriculture output per unit command area (Rs/Ha)?
3. Output per unit irrigation supply (Rs /m^3)?
4. Total operation & maintenance cost per unit command area (Rs/Ha)?
5. Total revenue recovered per unit volume of irrigation water stored/supplied (Rs /m^3)?
6. Crop (revenue) per unit irrigation supply?
7. Environmental impacts?

required to be purchased from market through inviting competitive bids by publication or by enquiry under local shopping procedures; it shall regularly supervise the work and satisfy about the quality and progress and recommend to stop the construction and use of material on work in case work is not found satisfactory and order to remove/replace inferior quality work and also recommend for removal of agency contractor found to perform work with inferior quality and workmanship; it shall suggest for change/ modification/ alteration/ addition or delete and deviate from the items of work originally provided in the estimate. However such changes even if within the total sanctioned cost shall be got approved before execution from concern competent Authority empowered to do so; samiti shall have powers to access /scrutinize and audit all vouchers/bills etc. related to construction and O&M activities.

Any decision shall require consent of at least five members and in case of a disagreement over any issue, the committee shall approach to the chairperson of Water User Association, whose decision shall be final.

(B1) Execution of works

The Proposals for conducting maintenance/ Repair and improvement works on Minor and drainage system shall be finalised after conducting a joint walk through in association with representative of project authority. The prioritization shall be done in consultation with competent authority depending upon the availability of funds and necessity of work for smooth running of the system. Project/Competent Authority shall get the estimate prepared and convey technical sanction for execution of such works where required. The work shall be executed by the Water Users Association in association with works sub-committee following the guidelines as given hereinafter.

Procedure for execution of works by Water Users' Association

Water Users Association may execute, repair and maintenance work, out of its own income subjected to following conditions: -

- Kachha works of repair and maintenance involving earthwork, excavation, repair of cuts, filling of depressions, grass cutting, shrub & weed removal, filling of rain cuts, gullies, rills silt removal and repair of banks and service road etc not exceeding Rs 50 per ha. of Culturabale Command Area in a year.
- Pucca work relating to repairs of structures involving plaster/ pointing and repair to damaged masonry/ concrete etc. not exceeding Rs. 20 per ha. of Culturabale Command Area in a year.
- For attending piping, breach amount shall be spent not exceeding Rs. 30 per ha of Culturabale Command Area per year and execution of all such work shall require approval of the managing committee;
- Works exceeding Rs. 50000/- in a year, shall be executed after preparation of proper estimate and issue of technical sanction by the competent authority including deviations up to 20 Percent. Technical sanction will issued by Junior Engineer for more than 50,000 and up to Rs. 1,00,000 per year for M&R works only; Assistant Engineer for more than Rs. 1,00,000 lacs to Rs. 5,00,000 per year for M&R works only; Executive Engineer for more than Rs. 5,00,000 lacs upto Rs. 10,00,000 per year for M&R including all works for extension, improvement and modernisation

etc. and Superintending Engineer for more than 10,00,000 lacs per year for M&R including all works for extension, improvement and modernisation etc.

On Completion of repair and maintenance and regulation works the report about works executed shall be prepared and all related vouchers shall be put up before the managing committee for scrutiny and suggestions for future adoption. The final report shall also be put up before the general body.

Any work related to fresh construction, change from original design and improvement shall require approval of Executive Engineer and Superintending Engineer with in their respective technical/ administrative/ financial limits.

Competent authority can stop execution of work by written order, if work is found to be of inferior quality and workmanship with advice to remove/ terminate agency/ contract with immediate effect.

(C) Water Management and Agriculture sub-committee; (SINCHAI UP SAMATI):-

Water Management and Agriculture sub-committee shall be constituted by president on the recommendation of managing committee as per rules.

The Sinchai Up Samiti shall have functions and responsibilities and fulfilled under the technical guidance of the Project/ Competent Authority as follows. It shall meet frequently during and well before the start of irrigation season and as and when require. It shall see that minor and watercourses and drains of each chak are properly cleaned and maintained to carry the required flows. In case they are not clean it may pursue the concerned outlet farmers / chak samiti to get the clearance done and impose a ban on utilisation of water till proper clearance is done. If required may also approach the Nirman Samiti/Chairperson for carrying out the required maintenance in time. It shall in consultation with Project/ Competent Authority frame a water distribution schedule, stating date, time and quantum of water for a chak. It shall approach the Project/ Competent Authority in case supplies falls short of the requirement and act accordingly to the instructions to get the supplies restored. It shall distribute the available water among the chak and authorise chak samities to draw water on equitable basis adopting certain pre-decided norms of allocating water in turn to individual farmer. It may recommend alteration, in size and position of existing outlet and may recommend removal or fixing of new outlet and change of boundaries of the chak keeping in view the best use of water but no change shall be made unless approved by the Project Authority. However total capacity of all outlets shall not exceed the design capacity of respective carrier channel. It may recommend to declare an area out of command or inclusion of new area in the command of the minor and may recommend use of water through lift in the near by area. It may recommend to engage educated unemployed youth of the village with repute to act as water master who shall perform the following activities. He will maintain record of Water Users Association and Sub Committees and Farmer Organisation under the guidance of Chairperson; Supervise day to day irrigation and assist chak samiti/Farmers in getting water on their turn, and to maintain watch and ward and to ensure safety of structures; Collect Irrigation dues/fees and maintain accounts and records as required and as directed by Chairperson / President; Prepare report of wastage of water and Other related works ordered by Chairperson of Water User Association. Water masters may be reimbursed of his duties on commission basis/contract basis in kind as a share of crop produce or fee collected through farmers or Water Users' Association shall reimburse out of the own resources as may be decided by the General body.

(D) Monitoring, Evaluation and Training Sub-Committee

Monitoring, Evaluation and Training Sub-Committee shall be constituted by Chairperson in consultation with the Competent Authority. This sub-committee shall look after overall monitoring and evaluation and shall suggest any improvement require in functioning of the Farmers' Organisation. It shall also act for introducing various training programs to members of Farmers' Organisation by approaching the related departments in consultation with the Competent Authority / Project Authority. The training shall constitute a regular feature to improve over all working and efficiency of Farmers' Organisation.

(E) Chak Samiti

Managing committee may constitute chak wise Chak Samiti for efficient distribution of water and to implement discussion taken by general body meeting with in the chak concern. Chak Samiti shall consist of three farmer members of the concern chak nominated by the President/Chairperson.

5.4.11 Resources of Farmers' Organisation

The funds of the Farmers' Organisation shall comprise of the following. Grants received from the Government as a share of the water tax collected in the area of operation of the Farmers' Organisation; such other funds, as may be granted by the State and Central Government for the development of the area of operation; resources raised from any financing agency for undertaking any economic development activities in its area of operation; income from the properties and assets attached to the irrigation system within its area of operation; fees collected by the Farmers' Organisation for the service rendered in connection with better management of the irrigation system; and sums received from any other source.

5.4.12 Audit

Every Farmers' Organisation shall get its accounts audited every year. At the end of each financial year, and not latter than three months after the commencement of the new financial year the Farmers' Organisation shall cause its accounts to be audited.

5.4.13 Power to levy and collect fee

A Farmers' Organisation may for achieving its objects and performing its functions, levy such fee as may be specified by the Government from time to time. Where a member has defaulted in payment of fee, the Managing Committee shall prepare a list of such defaulters along with amount due. The President / Chairperson of Farmers' Organisation shall make an application under the Rajasthan Land Revenue Act 1956 for recovery of amount due.

5.4.14 Power to remove encroachments

A Farmers' Organisation shall exercise its power to remove encroachment on irrigation works in their respective jurisdictions through Managing Committee in the same manner as is exercised by the Tehsildar under the provisions of the Rajasthan Land Revenue Act, 1956 and rules made there under.

5.4.15 Offenses and Penalties

Whoever, without any lawful authority, damages, alters, enlarges or obstructs any irrigation system; interferes with, increases, or diminishes the water supply in, or the flow of water from, through, over or under any irrigation system; being responsible for the maintenance of the irrigation system neglects to take proper precautions for the prevention of wastage of the water thereof or interferes with the authorised distribution of water there from, or uses water in an unauthorised manner or in such manner so as to cause damage to the adjacent land holdings; corrupts or fouls, water of any irrigation system so as to render it less fit for the purposes for which it is ordinarily used; obstructs or removes any level marks or water gauge or any other mark or sign fixed by the authority of a public servant; and opens, shuts or obstructs or attempts to open, shut or obstruct any sluice or outlet or any other similar contrivance in any irrigation system; shall, on conviction, be punished with imprisonment which may extend to two years or with fine which may extend to rupees five thousand or with both.

5.4.16 Composition of Offences

A Farmers' Organisation may accept from any person who has committed or in respect of whom a reasonable belief can be inferred that he has committed an offence punishable under this Act, a sum of money not exceeding rupees one thousand by way of composition for such offence. On payment of such sum of money, the said person, if in custody, shall be discharged and no further proceedings shall be taken against him in regard to the offence, so compounded.

5.4.17 Punishment under other laws not barred

Nothing in this Act shall prevent any person from being prosecuted and punished under any other law for the time being in force for any act or omission made punishable by or under this Act, provided that no person shall be prosecuted and punished for the same offence more than once.

5.4.18 Settlement of disputes

Any dispute or difference touching the constitution, management, powers or functions of a Farmers' Organisation arising between members, shall be determined by the managing committee of the Farmers' Organisation concerned. Any dispute or difference arising between a Member and the Managing Committee of a Water Users' Association or between two or more Water Users' Associations shall be determined by the managing Committee of the Distributory Committee. Any dispute or difference arising between a Member and the Managing Committee of a Distributory Committee or between two or more Distributory Committees shall be determined by the Project Committee. Any dispute or difference arising between a Member and the Managing Committee of a Project Committee or between two or more Project Committees shall be determined by the Apex Committee, whose decision shall be final.

Every dispute or difference under this section shall be disposed of within forty five days from the date of reference of the dispute or difference.

5.4.19 Appeals

Any persons aggrieved by any decision made or order passed by the Managing Committee of a Water Users' Association may appeal to the Managing Committee of the Distributory Committee, whose decision thereon shall be final. Any person aggrieved by any decision made or order passed by the Managing Committee of a Distributory Committee may

8. Cost recovery ration?
9. Maintenance cost to revenue ratio?
10. Revenue collection performance?

6.2 Performance Evaluation Studies:

6.2.1 Need for performance evaluation:

Looking towards the present irrigation efficiency of around 30% and increase in gap between irrigation potential created and utilized and further studies reveal that mere 1% improvement in irrigation efficiency in India's 90 m Ha irrigated area can save enough water to provide irrigation to an estimated 300,000 Ha at about 30-35% efficiency.

Thus irrigation efficiency should be improved from the present average of about 30% to a maximum achievable value of around 60%. For improving the irrigation efficiencies, it is necessary to:

- Locate the deficit areas
- Plugging the leakages
- Assessment of areas needing attention

6.2.2 Objectives of evaluation studies:

Performance evaluation studies were started in the 70s with the following objectives:

1. Measurement of gaps between set targets and achievements
2. Reasons for shortfalls and remedial measures
3. Assessment of impacts on environment
4. Selection of best practices and processes
5. Ratification of assumptions
6. Assessment of performance with respect to set objectives
7. Identification of shortfalls
8. Impacts on agro-economic, socio-economic and environment of command
9. Irrigation induced and degradation i.e. Water logging, alkanity/ salinity effected land.
10. Recommendations for closing performance gaps and improving overall efficiency of the system.

6.2.3 Main aspects of performance studies:

Following main aspects have been considered during performance evaluation of irrigation projects in various parts of the country.

1. System Performance
2. Agro-economic impacts
3. Socio-economic impacts
4. Environmental impacts

(a) System Performance: For evaluating system performance of the project, the following parameters are generally considered:

1. Physical achievement
2. Hydrology
3. Distribution Network
4. Command Area Development and irrigation efficiencies.
5. Competing Demands
6. Conjunctive Use of Ground and Surface Water
7. Mitigation of Droughts
8. Managerial Issues

(b) Agro Economic Impact: It has been experienced that irrigated agriculture yields far better results than unirrigated agriculture especially by using high yielding varieties of seeds and fertilizers. The availability of water and its periodicity is main factor in evolving cropping pattern in the command. In performance studies pertaining to agro-economic inputs following parameters are being considered:

1. Cropping Pattern
2. Land Distribution and Holdings
3. Farming Practices
4. Agro-based Industries
5. Extension Services
6. Micro-level Credit Facilities
7. Ancillary Income Generation Sources
8. Rotational Water Management

(c) Socio-economic impact: Irrigation development in command areas increased yield of various agricultural products in many fold and this has elevated the social status of the community at large. Thus while studying socio-economic impacts of irrigation projects, following aspects are being considered:

1. Farm Employment
2. Non-farm Employment
3. Infrastructural and Institutional Facilities
4. Demographic Impacts
5. Literacy
6. Health Care and Family Planning
7. Poverty Alleviation

(d) Environmental Impact: Some sections of the society criticized irrigation projects commenting that these create imbalance in the environment in many spheres. While performing evaluation studies of completed irrigation projects emphasis has been given to evaluate impact of these projects on the environment and for this purpose, following parameters have been considered:

1. Ground Water Table
2. Water Quality
3. Ecology
4. Wild Life
5. Drainage & Water logging
6. Soil Salinity & Alkalinity
7. Forest & Land Use
8. Flora & Fauna

6.3 Common Findings of Performance Evaluation studies:

Studies carried out by various Central Govt. agencies such as Central Water Commission, Planning commission, Central Board of Irrigation and Power, Ministry of Water Resources and some State Govt. reveal some common features regarding various aspects of project performance. Some of these are as given below:

(A) System Performance:

1. System deterioration due to deferred maintenance
2. Shortage in Water Availability
2. Reduction in Canal Capacity
3. Gap in Potential Created and Potential Utilized
4. Industrial and domestic water supply demands increased enormously for which there was no provision at planning stage.
5. Overuse of water by head end cultivators
6. Inadequate flow measurement methods
7. Shortage of supervisory staff

(B) Agro-economic impacts:

1. Introduction of high yielding variety of seeds, resulting in increased water demand of crop.
2. Increase in cropping intensity
3. Change in cropping pattern
4. Increased Use of HYV Seeds, Fertilizers and Pesticides
5. Increase in Yield
6. Increase in income through ancillary sources

(C) Socio-economic impact:

(i) Appreciable increase noticed in

1. Tremendous increase in land value
2. Generation of Farm Employment
3. Economical upliftment of cultivators
4. Infrastructural and Institutional Facilities
5. Literacy
6. Health Care and Family Planning
7. Effect on social evils like drinking liquor etc.

(ii) Living standard of people has been elevated and many people raised above poverty line

(D) Environmental impact:

1. Rise in Ground Water Table
2. Positive Impacts on Flora & Fauna.
3. Water Logging at Places
4. Decrease in Alkalinity & Salinity
5. Increase in Green Covers

6.4. Common Recommendations of Performance Evaluation Studies:

In depth studies of performance evaluation reports of 112 major and medium irrigation projects suggest following measures for optimizing the benefits from these projects.

1. Rehabilitation and Restoration of Damaged/ Silted Canal System
2. Proper and Timely Maintenance of System
3. Selective Lining of Canal and Distribution System
4. Realistic and Scientific System Operation
5. Revision of Cropping Pattern, if needed
6. Restoration / Provision of Appropriate Control Structures
7. Efficient and Reliable Communication Network
8. Reliable and Adequate Water Measuring System
9. Conjunctive Use of Ground and Surface Water
10. Regular Revision of Water Rate
11. Encouragement for Formation of Water Users' Associations
12. Trainings to Farmers
13. Micro-credit Facilities
14. Agricultural Extension Services

15. Encouragement to Farmers for raising Livestock
16. Increasing Non-farm Employment Avenues

6.5 Concept of Benchmarking in Irrigation Systems for evaluating performance:

6.5.1 Concept of Benchmarking in Irrigation Systems:

The best performer sub-system in a irrigation project or the system as a whole resulting into the best performance is considered as a benchmark and other sub-systems in a particular irrigation system or other irrigation projects when compared with the best performer is termed as 'Benchmarking of Irrigation System'. Thus, benchmarking process may be undertaken in two ways i.e.,

(1) Internal Benchmarking or Process Benchmarking and

(2) External Benchmarking or Metric Benchmarking. In the case of internal benchmarking, the comparison is accomplished with various sub-systems of a project whereas in external benchmarking various projects located in almost similar agro-climatic zones are compared. In case of projects located in different agro-climatic zones, weighted parameters are considered for various indicators of benchmarking process.

As per the definition of benchmarking for the irrigation industry coined by 'Australian National Commission on Irrigation and Drainage' (ANCID), benchmarking is a process whereby organizations pursue enhanced performance by learning about their own organization through comparison with their historical performance and with the practices and outcomes of others.

6.5.2 Indicators for performance evaluation:

In all 20 indicators have been considered for aforesaid 4 sub-systems. These indicators are as follows:

(A) System Performance:

- Water delivery capacity Index
- Total annual volume of irrigation water supplied/delivered (m^3/year)
- Field application efficiency
- Annual Relative Irrigation Supply Index
- Annual irrigation water supply per unit command area (Cum/ha)
- Annual irrigation water supply per unit irrigated area (Cum/ha)

(B) Agricultural Productivity:

- Output per unit command area (Rs/ha)
- Output per unit irrigated area - Tonnes/ha cropwise, Rs/ha
- Output per unit irrigation supply (Rs/cum)
- Output per unit crop water demand (Rs/cum)

(C) Financial Performance:

- Cost recovery ratio

- Total O&M cost per unit area (Rs/ha)
- Total cost per person employed on O&M Works (Rs/person)
- Revenue collection performance
- Revenue per unit volume of irrigation water supplied (Rs/cum)
- Maintenance cost to revenue ratio
- Staff numbers for O&M per unit area (persons/ha)
- Total O&M cost per unit of water supplied (Rs/cum)

(D) Environmental Aspects:

- Average depth to water table (m) and Land Damage Index
- Water quality: Ph/Salinity/ Alkalinity Index and Salt balance (tonnes)

6.6 Procedure for Performance Evaluation of Irrigation Projects:

6.6.1 Collection of required data:

In case of internal performance evaluation, data relating to various sub-systems of the project is collected and compiled. If external evluation is to be carried out, data concerning all the projects participating in the process and located in the similar agro-climatic zones is compiled. In case, the projects are not located in similar agro-climatic zone, proper weights are to be assigned to such projects so as to bring them, theoretically, in the similar agro-climatic zones. As may be seen from the list of indicators illustrated in preceding paragraphs, following data is required to evaluate various indicators:

1. Designed discharging capacity of canal to cater peak crop water requirement and actual carrying capacity.
2. Crop water requirement to meet evapo-transpiration needs of the region.
3. Culturable command area of the project
4. Amount of water supplied to various sub-systems or projects
5. Actual area irrigated
6. Staff engaged for running and maintenance of the system and expenditure being incurred on them
7. Details of recovery of water charges
8. Details about crop production
9. Water table details
10. Details of water quality

6.6.2 Analysis of data:

Sometimes data for a particular parameter is not directly available. In such cases, the data is estimated considering all relevant facts and figures. Proper checking and scrutiny of data is also essential to avoid erroneous results. Adequate infrastructure may be provided to collect, compile, scrutinize, analyse and process the desired data. If some important data is continuously missing, arrangement for observing such crucial data is also required.

6.7 Summary

Adoption of scientific methods of monitoring & evaluation of the system based on the outputs does not require much financial arrangements. But there is an urgent need to change present mindsets of both irrigation managers & the cultivators. The managers are required to establish monitoring cell from the existing establishments. The field officers will submit data to the monitoring cell and monitoring cell will prepare an annual report indicating input & output from any irrigation system. This exercise will quantify the cost of water & output per drop of water besides preparing grounds for any forthcoming rehabilitation projects.

Cultivators in turn will develop faith in the system & through equitable water distribution & scientific farming can increase agriculture production for suitable development of country.

6.8 Self assessment test

1. What are performance evaluation studies?
2. What are the environmental impact?

◆◆◆

UNIT-7

BENCHMARKING OF IRRIGATION PROJECTS

Structure

7.0 Objectives

Fierce competition, globalisation and development of new information and communication technologies have forced us to continuously search for and adopt new processes, structures and tools in order to survive and compete in their respective spheres. The explosion of management tools and techniques in the 1990s to help systems successfully change is evidence of this situation. One among these techniques is benchmarking, which has proved to be valuable in helping individual systems evaluate their competitive position.

7.1 Introduction

The average annual flow available in rivers in India is around 1869 BCM. Presently, the national annual average per capita availability is about 1829 cum per year. However, by the year 2050, the estimated annual per capita availability of 1168 cum would take the country at the threshold of water scarce conditions.. The situation in certain parts of the country is likely to be critical and it is estimated that by the year 2050,30% of the geographical area and 16% of population in the country will be under absolute water scarcity condition, with water availability of less than 500 cum per year.

Estimation of water demand and its implications on water quantity and quality is extremely important. Agriculture has the dominant demand and it will continue to predominate for a long time. However, there is considerable scope for rationalisation of its demand and optimisation, of its use. Lower consumption of water in agriculture has a very positive impact on reduction of environmental degradation. For meeting country's need for food grains, the water demand for irrigation for year 2050 has been estimated by the National Commission for Integrated Water Resources Development Plan (NCIWRDP) to be around 628 BCM for low demand and 807 BCM for high demand.

Despite the fact that productivity in irrigated areas has increased as compared to that of rain fed areas, the increase is still below the world standards and developing countries like China. This is coupled with sub-optimal water management including low irrigation efficiencies. There is scope for considerable improvement in productivity and consequent reduction in the demand for water. Applying the right quantity at the right time and using the right cultivation and irrigation practices can achieve conservation of water on the field. Against the backdrop of such a situation of imminent scarcity and inter-sectoral competition on physical and financial resources, the water resources management has to undergo a paradigm shift and deep introspection.

As a first step along the path towards sustainable water development and management we have to use water efficiently. By using water more efficiently, we in effect create a new source of supply. Each liter conserved can help meet new water demands. Measures to conserve water and use it more efficiently are now most economically and environmentally sound water supply options. Irrigation experts and professionals have to strive for the highest standards of water use efficacy and evolve means to achieve them to tide over the impending menace of water scarcity. It should be our endeavour to achieve the low demand scenario for which it is imperative that considerably higher level of efficiency is affected in irrigation water use.

7.2 NEED FOR BENCHMARKING

Fierce competition, globalisation and development of new information and communication technologies have forced us to continuously search for and adopt new processes, structures and tools in order to survive and compete in their respective spheres. The explosion of management tools and techniques in the 1990s to help systems successfully change is evidence of this situation. One among these techniques is benchmarking, which has proved to be valuable in helping individual systems evaluate their competitive position.

Benchmarking is simply the "introspection" since it is a continuous process of measuring one's own performance and practices against the best competitors, and is a sequential exercise of learning from other's experience. It is a fundamental management skill that supports quality and excellence and since the early 1990s has become widely regarded as a skill that should be communicated and utilised day-to-day private and public business operations. Recent developments are utilising the technique for government operations for example, in municipal and state services, in the developed countries. Benchmarking has also broad applications in problem solving, planning, goal setting, process improvement, innovation, strategy setting, and in various other contexts.

Benchmarking is a continuous process. Opportunities for improvement are identified by conducting an internal assessment and making comparative measurements with best practice organisations to determine the performance gap between current practice and best practice. Selected best practices can then be suitably adopted to fit into the organisation's needs and implemented. The cycle of improvement continues.

Benchmarking as a tool can provide with the criterion for prioritisation for rationally utilising the limited financial resources among different systems. By incorporating a Fault Tree Analysis approach as prevalent in Risk Analysis the weak spots in the system and the management practices being adopted can be identified for appropriate interventions. In the irrigation sector that would mean more productive and efficient use of the water i.e. 'more crop per drop' . It has successfully been applied in the Water Supply and Sanitation areas in different conditions. Within the irrigation sector Australia is now advanced in the application of the technique to improve the performance of their irrigation systems in a systematic way.

Within the general efforts of reform, benchmarking in the irrigation system is essential. In the irrigation and drainage sector service users are responding to a variety of challenges. Irrigation systems are coping with a vicious cycle that starts with inadequate maintenance, resulting in poor service that causes limited willingness to pay by users. The latter provides insufficient maintenance funds that further reduces the operational efficiency of the system.

The State Irrigation Departments are also responding to a variety of challenges, including:

- Increasing competition for water, both within the irrigated agriculture sector, and from other sectors.
- Increasing demand on the irrigation sector to produce more food for growing populations. Coupled with the pressure on available water resources, this results in the "more crop per drop" initiative promoted by international agencies such as the International Water Management Institute (IWMI) and the Food and Agriculture Organisation (FAO) of the United Nations.
- Growing pressure to effect cost savings whilst increasing the productivity and efficiency of resource use.
- More private sector and users participation leading to more transparent and accountable (to users) management practices.
- Increasing interest by the wider community in productive and efficient water resource use and the protection of aquatic environments.
- Increasing need for accountability to both government and water users in respect of water resource use and the price paid for water.

By using appropriate performance indicators of benchmarking it is possible not only to improve the water use efficiency and financial viability of the system but also ensure adoption of best management practices and the environmental sustainability in the irrigated agricultural systems, This would also assist in evaluating the efficacy of farmers' participation in irrigation management.

7.3 BENCHMARKING OBJECTIVES

Objectives set forth for benchmarking are:

- Identifying the best management practices.
- Generating competition among various agencies or the projects, units for distributory networks and or Water Users' Associations (WUAs),
- Prioritising and evaluating rehabilitation and remodeling or modernization projects,
- Assessing and monitoring the irrigation efficiency.

7.4 BENEFITS

The following may be considered as main benefits from the benchmarking process :-

(a) **Performance Measuring Tool-** Benchmarking provides an effective tool for measurement of performance of irrigation systems. With the use of benchmarking, irrigation projects taking part in the benchmarking process can be ranked in order of their performance.

(b) **Processes and Procedures-** It introduces better steps, processes and procedures for improving performance and effecting innovation in system / sub-system.

(c) **Quality and Quantity-** It provides improved quality of service with enhanced productivity.

(d) **Continuous Evolution-** It supports continuity in evolution of system. With time, with ever increasing experiences and with continuous improvement and innovation in technology, benchmark is shifting continuously upward with emergence of new best performer in the field or improved level of performance of the same performer. Thus benchmarking brings forth dynamic, relevant and achievable targets of higher level of performance.

(e) **Awareness-** It raises awareness among personnel involved with systems / sub-systems about performance level of irrigation systems taking part in the benchmarking process and their relative strengths and weaknesses.

(f) **Opportunity for Learning-** It provides a platform for learning from others who have achieved excellence in similar fields and gives greater confidence in developing and applying new approaches.

(g) **Solution for Common Problems-** It provides an environment for sharing knowledge, experience and insight among organizations towards looking for solutions to their common problems.

(h) **Sense of Togetherness-** It creates a sense of togetherness among project authorities of participating irrigation projects and increases willingness in them to share information, knowledge and experience with each other with the common goal of overall improvement in performance of irrigation sector.

(i) **Co-operation and Collaboration-** It introduces co-operative and collaborative approaches that give rise to better outcomes.

(j) **Involvement and Motivation-** It creates an atmosphere for greater involvement and motivation of staff and enhances individual and organizational learning.

(k) **Sustainability in Agricultural Production-** Improvement in the level of services to the farmers is a key factor for increasing and maintaining sustainability in agricultural production.

7.5 Data Collection and Analysis

7.5.1 Data Requirements

In any system, such as an irrigation network, there are:

- Inputs
- Processes
- Outputs, and
- Impacts

In measuring performance we are interested in the efficiency with which we convert inputs to outputs, and the potential impacts that (a) the use of these inputs (resources) might have and (b) that the outputs might have on the wider environment. We are also interested in the efficiency with which the processes convert inputs to outputs.

There are a variety of irrigation domains (or systems) in which we are interested, of which the following three are of primary interest:

- **Service delivery:** This domain includes two areas of service provision: (a) the adequacy with which the organization manages the operation of the irrigation delivery system to satisfy the water required by users (system operation), and (b) the efficiency with which the organization uses resources to provide this service (financial performance).
- **Productive efficiency:** Measures the efficiency with which irrigated agriculture uses water resources in the production of crops and fiber.
- **Environmental performance:** Measures the impacts of irrigated agriculture on land and water resources.

The performance indicators that are proposed for use in the benchmarking exercise are linked to these three domains, and their inputs, processes, outputs and impacts. There are many performance indicators that might be used in this context. For the benchmarking exercise only key performance indicators will be used as given in Table2 and detailed in Appendix A-1. The data required to be collected, for this purpose is given in Table-3.

To ensure consistency in the comparison of results, organizations joining the benchmarking programme will need to collect the data required for the calculation of the benchmarking indicators according to the specifications and protocols provided in Appendix A-2 which provides for each indicator the definition, measurement specification and processing needs.

Participating organizations will carry out the primary data processing to convert raw data into the format required for input into the benchmarking spreadsheet. This task must be carried out according to the instruction provided.

The proforma provided for benchmarking contain data in the following categories:

- Summary of benchmarking indicators
- Salient Project Features
- System Performance
- Financial Indicators
- Agricultural Productivity
- Environmental Aspects

Indicator values in the summary worksheet are calculated automatically after the basic data are entered into the appropriate worksheet without user intervention.

Two types of indicators can be considered according to the type of data required:

(a) Indicators based on primary data

(b) Indicators based on secondary data

Some indicators are based on primary data that the organization must collect either as a normal part of its operation or for the specific purpose of benchmarking. Variables such as inflow volumes, revenues collected from water users, and total operation expenditure fall into this category.

Some other indicators rely on the use of secondary data for their calculation. For example, the calculation of evapotranspiration (Etc) relies on climatic data for the location of the irrigation scheme that must be provided in the format specified by the methodology for calculating etc. This type of data may be collected either by the participating organization itself or an external organization. Wherever data are procured from an external organization special attention must be paid to the data processing methodology. This is particularly important when data auditing is necessary to trace possible calculation errors.

7.5.2 Data Units

In order that the data can be compared across different irrigation systems the data should be presented in the units specified in Appendix A2. Data may be collected and processed locally in different units, but should be converted into the required units before entering into the database.

7.5.3 Data Processing and Analysis

Much of the data analysis involves compiling ratios of the data collected to produce the value of the required performance indicator. Participating organizations will be responsible for processing the raw data collected in conformance with the protocols outlined in Appendix A2. It is possible that past data collected by such organizations may have been collected in a variety of formats that may not necessarily comply with these specifications. In such cases, it is necessary to ensure that data are processed in a comparable manner.

7.5.4 Data Audit

There are large volumes of data relevant to the indicators covering water, agriculture, finance etc. Engineers and other professionals working in the field offices generally provide these data. As they are in the lower rungs of the hierarchy, there could be communication gap in understanding the objectivity of the process. Therefore detailed data audit at the system/subsystem level is essential.

7.5.5 Comparative Analysis

The essence of the benchmarking process is to provide organizations with the ability to compare their performance in relation to similar organizations or similar processes. The comparative analysis will consist primarily of ranking performance levels for individual indicators both numerically and graphically.

7.5.6 Program Implementation

Periodic reviews of the programme will be required to ensure that the programme remains flexible and relevant to the benchmarking partners. New performance indicators may need to be added in the future to ensure that emerging issues in irrigation and drainage are reflected in the programme. For example, when a system/sub-system is managed by a Water Users' Association (WUA), indicators relevant to the functioning and effectiveness of the WUA may have to be incorporated.

7.6 SUMMARY

Benchmarking is a continuous process. Opportunities for improvement are identified by conducting an internal assessment and making comparative measurements with best practice organisations to determine the performance gap between current practice and best practice. Selected best practices can then be suitably adopted to fit into the organisation's needs and implemented. The cycle of improvement continues.

Benchmarking as a tool can provide with the criterion for prioritisation for rationally utilising the limited financial resources among different systems. By incorporating a Fault Tree Analysis approach as prevalent in Risk Analysis the weak spots in the system and the management practices being adopted can be identified for appropriate interventions. In the irrigation sector that would mean more productive and efficient use of the water i.e. 'more crop per drop'. It has successfully been applied in the Water Supply and Sanitation areas in different conditions. Within the irrigation sector Australia is now advanced in the application of the technique to improve the performance of their irrigation systems in a systematic way.

7.7 SELF-ASSESSMENT TEST

- What is the necessity of Benchmarking?
- What are the objectives of Benchmarking?
- What are the benefits of Benchmarking?
- What are the categories in which data collection for Benchmarking is to be done?

7.8 KEY WORDS

- **Benchmarking:** Process of measuring one's own performance and practices against the best competitors and is a sequential exercise of learning from other's experience.

7.9 SUGGESTED READINGS

- Guidelines for Benchmarking of Irrigation Systems in India, 2002. Indian National committee on Irrigation and Drainage.
- Yadav Kashindra. Application of Benchmarking in Irrigation Industry. Lecture note.

Table 1
Salient features of the project/system/sub-system*

Code	Item	Possible Option
Location		
D1	State	
D2	District	
D3	Name of the Project/Scheme	
D4	Name of System/Sub-System	
D5	River/Basin/Sub-Basin	
D6	Latitude/Longitude	
Climate and soils		
D7	Climate	Arid Semi-arid Humid Humid tropics
D8	Average annual rainfall (mm)	
D9	Average annual reference crop potential	
	Evapotranspiration, Et_c (mm)	
D10	Peak daily reference crop potential	
	evapotranspiration, Et_c (mm/day)	
D11	Predominant soil type(s) and percentage of total	Clay,Clay loam, Loam Siltyclay, loam Sand
Institutional		
D12	Year first operational	
D13	Type of management	Government agency Water Users Association/ Federation of WUAs
D14	Agency functions (to indicate the extent the agency controls the system/sub-system)	Irrigation and drainage service Water resource management Reservoir management Flood control Domestic water supply FisheriesOther
D15	Type of revenue collection	Tax on irrigated area Charge on crop type and area Charge on volume of water delivered-charge per irrigation Charge based on number of waterings per season

*Considering that the records connected with works, personnel employed etc. are maintained at the level of an irrigation Section, the System/Sub-System adopted should be at least at the jurisdictional level of a Section.

Code	Item	Possible options
D16	Agency entrusted with Revenue Collection	Irrigation Department Revenue Department WUA Others
D17	Land ownership	Government Private
Socio-economic		
D18	Gross Domestic Product (GDP)	
D19	Farming system	Cash crop Food grains crop Mixed cash/ Food grains crop
D20	Marketing	Government marketing board Private traders Local market Regional/national market
D21	Pricing	Government controlled prices Local market prices
Water source and availability		
D22	Water source	Storage on river Run-of-the river including barrage/anicut Groundwater Conjunctive use of surface and groundwater
D23	Water availability	Abundant Sufficient Water scarcity
D24	Number and duration of irrigation season(s)	Number of seasons Number or months per season Season 1 Season 2 Season 3
Size		
D25	Commanded (irrigation) area (ha)	-
D26	Total number of water users supplied	-
D27	Average farm size (ha)	-
D28	Average annual irrigated area (ha) Out of the above Surface water (ha) Ground water (ha) In case of conjunctive use, please give weightage for the waterings from each source	-
D29	Average annual cropping intensity (%)	-

Infrastructure - Irrigation		
D30	Method of water abstraction	Gravity diversion Pumped diversion Groundwater
D31	Water delivery infrastructure (length and %)	Lined channel Unlined Pipelines
D32	Location and type of water control equipment	Control structure at intake of the system/sub- system Type : None Fixed proportional division Gated - automatic local control
D33	Discharge measurement facilities, location and types	Location None Type: Flow meter Fixed weir or flume Calibrated sections Calibrated gates
Infrastructure - Drainage		
D34	Area serviced by surface drains (ha)	-
D35	Type or surface drain	ConstructedNatural
D36	Length of surface drain (km)	NaturalOpenClosed
D37	Area serviced by sub-surface drainage (ha)	
D38	Number of groundwater level measurement sites	
Water allocation and distribution		
D39	Type of water distribution	Supply oriented On-demand Arranged-demand
D40	Frequency of irrigation scheduling at the intake of the system/sub-system	Daily Weekly Twice monthly Monthly Seasonal None
D41	Predominant on-farm irrigation practice	Surface- furrow, basin, border, flood,furrow-in-basin, Drip/trickleSub-surface
Cropping		
D42	Main crops each season with percentages of total command area	-

Table 2

Main Performance indicators for Benchmarking

Domain		Performance indicator
I. System performance	1.	Water delivery capacity Index.
	2.	Total annual volume or irrigation water supplied/ delivered (m3/year).
	3.	Field application efficiency.
	4.	Annual Relative Irrigation Supply Index.
	5.	Annual irrigation water supply per unit command area (Cum/ha).
	6.	Annual irrigation water supply per unit irrigated area (Cum/ha).
II. Agricultural Productivity	7.	Output per unit command area (Rs/ha).
	8.	Output per unit irrigated area - Tons/ha crop wise, Rs/ha.
	9.	Output per unit irrigation supply (Rs/cum).
	10.	Output per unit crop water demand (Rs/cum).
III. Financial aspects	11.	Cost recovery ratio.
	12.	Total O&M cost per unit area (Rs/ha).
	13.	Total cost per person employed on O&M Works (Rs/person).
	14.	Revenue collection performance.
	15.	Revenue per unit volume of irrigation water supplied (Rs/cum).
	16.	Maintenance cost to revenue ratio.
	17.	Staff numbers for O&M per unit area (persons/ ha).
	18.	Total O&M cost per unit of water supplied (Rs./ cum).
IV. Environmental Aspects	19(a)	Average depth to watertable(m).
	19(b)	Land Damage Index.
	20(a)	Water quality: Ph/ Salinity/ Alkalinity Index.
	20(b)	Salt balance (tonnes).

Table 3

Data requirements pertaining to the system/sub-system

1. Current canal capacity of the system/sub-system at the diversion point.
2. Designed Peak irrigation water demand for a month/fortnight.
3. Total daily measured water at the intake of the system/sub-system.
4. Total daily measured water delivery to the field head.
5. Total daily measured water used by evapo-transpiration (for different crops if available).
6. Total daily measured rainfall over irrigated area.
7. Total command area serviced by the irrigation system/subsystem.
8. Total annual irrigated crop area.
9. Total annual tonnage of each crop.
10. Market price/Minimum Support Price (MSP) for the crops.
11. Total volume of water consumed by the crops(ETc). for rice crop percolation lossess need to be included.
12. Total revenue collected from water users.
13. Total management, operation and maintenance (MOM) cost excluding capital expenditure and depreciation/renewals.
14. Total cost of MOM personal.
15. Total number of MOM personal employed.
16. Total revenue due during the year.
17. Periodic measurements of depth to water table.
18. Waterlogged area in the command area after introduction of irrigation.
19. Salinity/alkalinity affected area in the command area after introduction of irrigation.
20. Electrical conductivity of periodically collected irrigation water samples in mmhos/cum.
21. Electrical conductivity of periodically collected drainage water samples in mmhos/cum.
22. Total daily measured drainage water outflow from the irrigation system.
23. Periodic measurement of salt content of irrigation water.
24. Periodic measurement of salt content of drainage water.

Appendix A1

Performance indicators - Definitions & Data Specifications

I System Performance

Indicator	Definition	Data specifications
1. Water delivery capacity Index	Canal capacity to deliver water at system head divided by Peak irrigation water requirement	*Canal capacity to deliver water at system head* Actual discharge capacity of system/sub-system at diversion point. *Designed Peak irrigation water requirements.* The peak crop irrigation water requirement for a monthly/ fortnightly period expressed as a flow rate at the head of the irrigation System' sub-system.
2. Total annual volume of irrigation water delivery (cum/year)	Total volume of water delivered to water users over the year or season. Water users in this context are the recipients of irrigation service and these may include single irrigators or groups or irrigators organized into water user groups.	Measured at the interface between the irrigation agency and water users
3. Field Application efficiency	Water used by crops by evapotranspiration divided by Water delivered at field head	Total volume of water used by the crops worked out from evapotranspiration values Total annual volume of water made available at the field worked out from daily measurement
4. Annual relative irrigation supply Index	Total annual volume of irrigation Water- supplied Total annual volume of irrigation water supplied For paddy rice, percolation losses must be included.	Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage worked out from daily measurements to the system/sub-system. Total annual volume of crop irrigation demand is equal to total annual volume of irrigation water required by the crop less effective rainfall

5. Annual irrigation water supply per unit command area (cum/ha)	*Total annual volume of irrigation water inflow* Total command area serviced by the system/sub-system	*Total annual volume of irrigation water inflow* Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage) into the system/sub-system. *Total command area serviced by the system/sub-system:* The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated.
6. Annual irrigation water supply per unit irrigated area (cum/ha)	*Total annual volume of irrigation water inflow* Total annual irrigated crop area	*Total annual volume of irrigation water inflow:* Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage) into the system/sub-system. *Total annual irrigated crop area:* The total irrigated area cropped during the year.

II. Agricultural productivity

Indicator	Definition	Data specifications
7. Output per unit serviced area (Rs./ha)	Total annual value of agricultural production divided by Total command area serviced by the system/sub-system	*Total annual value of agricultural production* Total annual value of agricultural production received by producers. (In case the price is based on MSP, that value to be adopted) *Total command area serviced by the system/sub-system:* The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated.

8. Output per unit irrigated area (Rs./ha)	<u>*Total annual value of agricultural production*</u> Total- annual irrigated crop area	<u>*Total annual value of agricultural production:*</u> Total annual value of agricultural production received by producers (In case the price is based on MSP, that value to be adopted) <u>*Total annual irrigated crop area of the system/sub-system:*</u> The total irrigated area cropped during the year.
9. Output per unit irrigation supply (Rs./cum)	<u>*Total annual value of agricultural production*</u> *Total* annual volume of irrigation water inflow	<u>*Total annual value of agricultural production:.*</u> Total annual value of agricultural production received by producers. (In case the price is based on MSP, that value to be adopted) <u>*Total annual volume of irrigation water* inflow *into the system/subsystem*</u> Total annual volume of water diverted or pumped) for irrigation (not including diversion of internal drainage) worked out from daily measurements.
10. Output per unit crop water demand (Rs/cum)	<u>*Total annual value of agricultural production*</u> Total annual volume of water consumed by the crops	<u>*Total annual value of agricultural production*</u> Total annual value of agricultural production received by producers. (In case the price is based on MSP, that value to be adopted)

III Financial indicators

Indicator	Definition	Data specifications
11. Cost recovery ratio	Gross revenue collected Total MOM cost	*Gross revenue collected* Total revenues collected from payment of services by water users during the year *Total MOM cost* Total management, operation and maintenance cost of providing the irrigation and drainage service excluding capital expenditure and depreciation/renewals. The O&M cost of Head works. main canal etc, will be added on pro-rata basis to the actual O&M cost of system/sub-system
12. Total O&M cost per unit area (Rs./ha)	Total MOM cost Total command area serviced by the system/sub-system	*Total MOM cost* . *Total command area serviced by the system/sub-system* The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated.
13. Total cost per person employed on water delivery (Rs./person)	Total cost of personnel engaged in I&D service Total number of personnel engaged in I&D service	Total cost of personal engaged in I&D service. Total cost of personnel employed in the provision of the irrigation and drainage service in the system/sub-system. Total number of personnel Engaged in I&D service: Total number of personnel employed in the provision of irrigation and drainage service in the system/sub-system
14. Revenue collection performance	Gross revenue collected Gross revenue invoiced	Gross revenue collected Total revenue collected from payment of services by water users during the year Gross revenue invoiced: Total revenue due for collection from water users for provision of irrigation and drainage services during the year.

15. Average revenue per cubic meter of irrigation water supplied (Rs/cum)	<u>Gross revenue collected</u> Total annual volume of irrigation water delivery	<u>Gross revenue collected</u> Total revenue collected from payment of services by water users <u>Total annual volume of irrigation water delivery:</u> Total volume of water delivered to water users over the year or season. Water users in this context are the recipients of irrigation service and these may include single irrigators or groups or irrigators organized into water user groups.
16. Maintenance cost to revenue ratio	<u>Maintenance cost</u> Gross revenue collected	<u>Maintenance cost</u> Total expenditure on system maintenance. <u>Gross revenue collected:</u> Total revenues collected from payment of services by water users during the year
17. Staffing numbers per unit area (Persons/ha)	<u>Total number of personnel engaged in I&D service</u> Total command area serviced by the system/sub-system	<u>Total number of personnel engaged in I&D service</u> Total number of personnel employed in the provision of the irrigation, and drainage service in the system/sub-system <u>Total command area serviced by the system</u> The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated.
18. Total O&M Cost per unit of water supplied (Rs./cum)	<u>Total MOM Cost</u> Total Water supplied	

III. Environmental Aspects

Indicator	Definition	Data specifications
19 (a) Land damage index	Waterlogged + saline/alkaline affected area Total CCA	Since some waterlogged area may also be *saline/* alkaline affected area, double accounting should be avoided.
19 (b) Average depth to watertable (m)	Average annual depth of watertable calculated from watertable observations over the irrigation area.	
20 (a) Water quality: Ph/Salinity/ Alkalinity.	Ph/Salinity/Alkalinity ofthe irrigation supply and drainage water.	
20 (b) Salt balance (tonnes)	Differences in the volume of incoming salt and outgoing salt.	

Appendix A2

Protocols for Data Collection and processing

Reference to indicator No.1	**Canal capacity to deliver water at system head**
Definition	Actual discharge capacity of main canal at diversion point of system/sub-system
Measurement specification	Location:Discharge capacity must be determined at the system/sub-system head assuming canal freeboard according to canal design specifications.If not yet available, it can be determined using any accepted flow measuring technique including: flow metering, measuring flumes and control sections.FrequencyNeeds to be determined at the start of the irrigation season.
Processing	
Units	Expressed in cubic meters per second (cumecs)
Reference to indicator No.1	**Peak irrigation water requirement**
definition	The peak crop irrigation water requirement for a monthly period expressed as a flow rate at the head of the irrigation System/Sub-System.
Measurement specification	Location:The calculation is based on the designed maximum monthly crop water requirement in the system/sub-system. The- field, distribution and main system conveyance efficiency must be used to index this value to the head of the System/sub-system.Frequency:Calculated each season.
Processing	The maximum monthly crop water requirement should be available from the calculation of crop water requirements for the entire system/sub-system.
Units	Expressed in cubic meters per second (cumecs).
Reference to indicator No.2	**Total annual volume of irrigation water delivery**
definition	Total volume of water delivered to water users over the year or season. Water users in this context describe arc the recipients of irrigation service, these may include single irrigators or groups or irrigators organized into water user groups.

Measurement specification	LocationMeasurement should occur at the point of interface between the irrigation provider and the water user(s).Frequency:The magnitude and frequency of fluctuation in discharge will determine the desired frequency of measurement. Discharge should be monitored at least twice daily to ensure sufficient accuracy. The best accuracy can be obtained from continuous monitoring of discharge by electronic monitoring devices.
Processing	Daily average discharges must be converted into daily delivery volume using the actual delivery time. The total volume of water delivered is the aggregate result of daily volume of supply.
Units	Expressed in cubic meters (cum)
Reference to indicator No.4	**Total annual volume of crop irrigation demand**
definition	Total annual volume of irrigation water required by the crop less effective rainfall. For paddy rice, percolation losses must be included
Measurement specification	Location:Crop evapotranspiration will be calculated using the FAO CROPWAT model for the net area planted to each crop in the irrigated command area. Estimation of effective rainfall may prove to be difficult in some circumstances. There are a variety of methods included in CROPWAT for estimating effective rainfall (Dastane, 1974). The use of the USDA-SCS model is recommended. FrequencyThe preferred Etc calculation period is daily in situations where daily data are not available the shortest possible interval is to be used. The calculation of Etc will include the entire growing season from planting to harvest
Processing	The total annual volume of water consumed by all crops grown in the system is the weighted sum of the water consumed by individual crops as follows: $VET_{net} = (Et_c - R_e)Ai$ where: VETnet= Total volume of water consumed by crops less effective rainfall (cum)i = Crop type Et_c^i = Evapotranspiration from crop i from planting to harvest (cum)Re = Effective rainfall over crop area from planting to harvest (cum)Ai= Area planted to crop i. (ha)For rice crops the average percolation rate will be multiplied by the crop area and growth period to obtain the total percolation volume.

Units	Expressed in cubic meters (cum).
Reference to indicator No.5	**Total annual volume of irrigation water inflow**
Definition	Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage to the system/sub-system).
Measurement specification	Location:Inflow will be measured at the diversion point in case of gravity diversions or at the pump delivery of groundwater or river pumps. In situations where there are additional inflows and/ or diversions for any purpose other than irrigation e.g. urban supply, industrial supply, etc. a mass balance of the net inflow for irrigation must be carried out. Inflows from drainage recovery must be deducted from the inflow amount whereas catchment inflows must be included as irrigation diversions. *Frequency:* The magnitude and frequency of fluctuation in discharge will determine the desired frequency of measurement. Discharge should normally be monitored at least twice daily to ensure sufficient accuracy. The best accuracy can be obtained from continuous monitoring of discharge by electronic monitoring devices.
Processing	Daily average discharges must be converted into daily delivery using the actual delivery time.The total volume of water delivered is the aggregate result of daily volume of supply converted into daily volume
Units	Expressed in cubic meters (cum).
Reference to indicator No.5	**Total command area serviced by the system/sub-system**
Definition	The command area is the nominal or design area provided with irrigation infrastructure that can be irrigated by the system/sub-system.
Measurement specification	This area is usually derived from the design drawings for the irrigation system. Over time areas may go out of production due to a variety of factors, including construction of houses, buildings, drainage channels, etc. Adjustments should be made to the command area to allow for this reduction in irrigable area.

Processing	The command areas for each tertiary unit are measured and aggregated up for the whole system/ sub-system.
Units	Expressed in hectares (ha).
Reference to indicator No.6	**Total annual irrigated crop area**
Definition	The total irrigated area cropped during the year in the system/sub-system.
Measurement specification	The value is the result of the total area nominally commanded by the system multiplied by a cropping intensity factor to take into account the actual intensity of land utilization during the year.
Processing	The area cultivated in each cropping season is the aggregate of the areas planted to each individual crop. The annual irrigated area is the aggregate value or the each season's cropped area. These data are usually collected by the irrigation and drainage organization for operation and accounting purpose and/or by other related agencies that compile production statistics.
Units	Expressed in hectares (ha),
Example	For instance, if the area commanded by the irrigation system is 10,000 ha and the areas cultivated during the year are: wet season 8,000 ha, and dry season 6,000 ha, the total area irrigated by the system is 14,000 ha. The cropping intensity is 1.4.
Reference to indicator No.8	**Total annual agricultural production**
Definition	Total annual tonnage of agricultural production by crop type in the system/sub- system.
Measurement specification	Total tonnage of utilizable production obtained from each crop.
Processing	Records normally compiled by the irrigation and drainage organization or related agricultural organizations are adequate for this purpose.
Units	Expressed in metric tonnes (t).

Reference to indicator No.8	**Total annual value of agricultural production**
Definition	Total annual value of agricultural production received by producers in the system/sub-system.
Measurement specification	The total value of agricultural production received by producers is determined at local (domestic) market prices or Minimum Support Price (MSP).
Processing	Worked out from the yield of crop, area planted for the crop and local price of the crop.
Units	Expressed in Rupees.
Reference to indicator No.10	**Total annual volume of water consumed by the crops**
Definition	Total annual volume of water used by the crop to meet evapotranspiration demand For rice,percolation losses must be included
Measurement specification	Location:Crop evapotranspiration Et_c will be calculated using the FAO CROPWAT model for the net area planted to each crop in the irrigated command area.Frequency: The preferred , calculation period is daily. In situations where daily data are not available the shortest possible interval is to be used. The calculation of Et_c will include the entire growing season from planting to harvest.
Processing	The total annual volume of water consume by all crops grown in the system is the weighted sum of the water consumed by individual crops.
Units	Expressed in cubic meters (cum).
Reference to indicator No.12	**Total MOM cost**
Definition	Total management, operation and maintenance cost of providing the irrigation and drainage service excluding capital expenditure and depreciation/ renewals.
Measurement specification	This item includes all costs involved n the provision of the irrigation and drainage service. Typically these include: • Bulk water fee • Staff cost • Operation cost (e.g. electricity for operation of plant and equipment and water supply)

	• Maintenance cost • Overheads (include administrative expenses of the project worked out on pro-rata basis, insurance, taxes, etc.)
Processing	A single annual value is required for this item. All costs items must be aggregated annually according to the financial calendar of the organization.
Units	Expressed in Rupees
Reference to indicator No.13	**Total cost of personnel engaged in I&D service**
Definition	Total cost of personnel employed in the provision of the irrigation and drainage service in the system/ sub-system
Measurement specification	This item includes the cost of all personnel employed by the organization including contractors and contract employees engaged in the administration, management and operation.
Processing	A single annual value is required for this item. All personnel cost items must be aggregated annually according to the financial calendar of the organization.
Units	Expressed in Rupees.
Reference to indicator No.14	**Total number of personnel engaged in I&D service**
Definition	Total number of personnel employed in the provision of the irrigation and drainage service in the system/sub-system.
Measurement specification	This item includes all personnel employed by the service provider including contract employees engaged in the management, operation and maintenance. if I must be expressed in Equivalent Full Time (EFT) units.
Processing	A single annual value is required for this item. All personnel must be aggregated annually according to the financial calendar of the organization and expressed in EFT units.
Units	Expressed in Equivalent Full Time units. The time of part-time or seasonally employed personnel should be converted to the equivalent full time employment based on the proportion of full time worked.

Example	Full time weekly hours: 48 hours EFT = 1.0 Employee working 24 hrs part-time per week EFT = 0.5
Reference to indicator No.14	**Gross revenue collected**
Definition	Total revenues collected from payment of services by water users in the system/ sub-system.
Measurement specification	This item includes all tile revenues (cash and in-kind) received by the irrigation or drainage service provider as payment for water supply and disposal, and other services using the agency's infrastructure. Where drainage charges are levied separately these must be included in the calculation.
Processing	A single annual value is required for tllis item. V.fhere services are charged on a different basis, e.g. seasonal, bi-annually, etc. the partial figures must be aggregated annually according to the financial calendar of the organization. Payment made in kind must be converted into monetary terms, either using local market prices for the in-kind commodity, or at rates stipulated in the service agreement.
Units	Expressed in Rupees.
Reference to indicator No.14	**Gross revenue collected**
Definition	Total revenue due for collection from water users for provision of irrigation and drainage services for the system/sub-system.
Measurement specification	This item includes all fees levied (cash and in-kind) by the service provider in payment for water supply and other services provided by the irrigation and drainage infrastructure. Where drainage charges are levied separately these must be included in the calculation.
Processing	A single annual value is required for this item. Where services are charged on a different basis, e.g. seasonal, bi-annually, etc. the partial figures must be aggregated annually according to the financial calendar of the organization.Payment to be made in kind must be converted into monetary terms, either using local market prices for the in-kind commodity, or at rates stipulated in the service agreement.

Units	Expressed in Rupees
Reference to indicator No.14	**Gross revenue invoiced**
Definition	Total revenue due for collection from water users for provision of irrigation and drainage services for the system/sub-system.
Measurement specification	This item includes all fees levied (cash and in-kind) by the service provider in payment for water supply and other services provided by the irrigation and drainage infrastructure. Where drainage charges are levied separately these must be included in the calculation.
Processing	A single annual value is required for this item. Where services are charged on a different basis, e.g. seasonal, bi-annually, etc. the partial figures must be aggregated annually according to the financial calendar of the organization. Payment to be made in kind must be converted into monetary terms, either using local market prices for the in-kind commodity, or at rates stipulated in the service agreement.
Units	Expressed in Rupees
Reference to indicator No.16	**Maintenance cost**
Definition	Total expenditure on system maintenance
Measurement specification	This item includes all the costs associated with maintenance of the irrigation and drainage infrastructure either carried out by the organisation or by external contractors. It should not include major repairs or rehabilitation work.
Processing	A single annual value is required for this item. All maintenance costs items must be aggregated annually according to the financial calendar of the organization
Units	Expressed in Rupees.
Reference to indicator No.19(b)	**Average depth to watertable**
Definition	Average annual depth of watertable calculated from watertable observations over the irrigation area in the system/sub-system.

Measurement specification	Location: Watertable depth must be monitored by a network of piezometers distributed over the commanded area of the System/Sub-System in sufficient density to enable the delineation of contour lines of watertable depth. The installation of piezometers must follow the standard guidelines described in F AO Irrigation and Drainage Paper No.38 Drainage Design Factors. Frequency: Watertable levels are typically monitored on a monthly basis.
Processing	Individual readings will be average over the 12-month period to produce a single value required for this item.
Units	Expressed in meters (m).
Reference to indicator No.20(a)	**Water quality Salinity/ Alkalinity**
Definition	Salinity/Alkalinity of the irrigation supply and drainage water
Measurement specification	Location:The salinity/alkalinity of irrigation inflow will be measured at the intake of the system/sub-system. In situations where there are additional inflows these should be monitored separately.The salinity/alkalinity of drainage water will be measured at the point where drainage flows leave the irrigation scheme or just before entering a receiving body of water, e.g. river, lake, etc. Frequency:The magnitude and frequency of fluctuation in discharge will determine the desired frequency of measurement. Weekly or monthly readings are typically used
Processing	A single value of the parameters is necessary each year. Weekly or monthly readings must be converted into weighted average according to- the volume of irrigation supply water or drainage water occurring during the measuring period.
Units	Expressed in micro mhos per centimeter (mmhos/cm).
Reference to indicator No.20(B)	**Salt balance**
Definition	Differences in the volume of incoming salt and outgoing salt.

Measurement specification	Incoming salt: Total amount of salt entering the irrigation area of the system/sub- system through the water supply system. The salinity of irrigation inflow will be measured at the diversion point in the case of gravity diversions or at the pump delivery of groundwater or river pumps. In situations where there are additional inflows these should be monitored separately. Outgoing salt: The total amount of salt that leaves the irrigation area through the irrigation supply and drainage system. The salinity of drainage water will be measured at the point where drainage flows leave the irrigation scheme or just before entering a receiving body of water, e.g. fiver, lake, etc. Additional salt outgoings may occur where irrigation water leaves the system through outfalls or is diverted for other uses.
Processing	The annual incoming and outgoing amounts of salt will be the aggregate of the individual readings collected for each individual period. This may vary in length according to water quality practices although daily readings are preferred.
Units	Expressed in metric tonnes (t).

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UNIT-8

ENVIRONMENTAL IMPACT ASSESSMENT

Structure

8.0 Objectives

Successful development depends on the rational use of environmental resources and on minimizing or eliminating any adverse environmental impacts by improving the planning, design and implementation of projects. The environmental impact assessment provides preliminary information to assist with water resources project design and the development of an Environmental Management Plan for any project.

8.1 Introduction

Environment is the totality of ecosystems for local, to regional and to global. Ecosystem is the dynamic arrangement of plant and animals with their nonliving surroundings of soil, air, water, nutrients, energy, lakes, and grasslands are ecosystems. The commission on ecology and development co-operation distinguishes three categories of environmental impacts:

- Disturbance and / or pollution of the environment
- Depletion and / or over exploitation of the natural resources
- Destruction and or impairment of the natural ecosystem

Other Impacts:

- Loss of wetland
- Change in habitat
- Salinization

Loss of wetland is concern to bird watchers, interested in natural environment and everybody. Wetland is of great value as wildlife habitats, food storage areas, ground water recharge areas and ecological and recreational areas.

Developing countries prefer agricultural productivity while developed countries prefer natural areas.

Irrigation and drainage projects manage water supplies for the purpose of agricultural production. There are various types of irrigation depending upon the source of water (surface or ground water), means of water storage, conveyance and distribution systems, and methods of delivery in the fields. Large scale utilization of surface water for irrigation has been practiced.

The dominant delivery method up to 95 percent worldwide is surface irrigation in which water is distributed over the irrigated area by gravity in overland flow. The other systems are sprinkler and drip irrigation. Although they are relatively new technologies requiring higher initial investment and more intensive management than surface irrigation, sprinkler and drip irrigation show great potential for maximizing the efficiency of water use and reducing irrigation-related environmental problems.

Two consequences of intensive irrigation are salinity and water logging. There are over 250 million ha of irrigated land worldwide, of which nearly 30 million ha are degraded due to the twin menace of salinity and water logging. Barghouti and LeMoigne (1991) indicated that about 1.5 million ha of cropland are being destroyed by salinization each year. They further noted that salinity and water logging have reduced the yields of major crops by approximately 30 percent in Pakistan, Egypt and India.

The developing countries are focusing on more efficient irrigation delivery systems, better on farm water management, and the reclamation of saline and waterlogged lands. To achieve this, horizontal subsurface pipe drainage systems are being installed to lower the water table, and leach salts from the crop root zone.

Agricultural land drainage which includes the construction of ditches and channelization of water courses, as well as fields under drainage can have a variety of effects on the environment. Of the irrigated arid and semi-arid developing countries, Eqypt has the most experience with subsurface drainage. There are about 150,000 ha, of horizontal pipe drains in Pakistan. At least 10 million ha may require drainage. Datta et at. (1992) stated that over 6 million ha of irrigated land in India are severally affected by water logging, and approximately 8 million ha suffer from salinity and alkalinity. However, large-scale subsurface drainage is introduced to India as a result of a Canadian financed project in the state of Rajasthan. There are about 12000 ha of Horizontal pipe drains installed in the Chambal Command Area (CCA) to overcome the water logging and soil salinity problem.

The environmental impacts that could generally arise from irrigation and drainage projects have been discussed by several people, including Hagan and Roberts (1972), White (1978), and Hiliel (1990), among others. Hoffman (1990) noted that drainage in California's San joaquin valley ceased some years after operation, on discovering that high concentrations of selenium in drainage effluent caused a loss of waterfowl in the Kesterson National Wildlife Refuge. The draining of marshes and other types of wet land produces alterations in plant and animal communities. A reduction in wetland acreage can also affects streams and takes by causing changes in water quality and hydrology. The construction of ditches and channelisation of natural streams has a direct local impact on flora and fauna in and adjacent to the water course.

Ditching and field under-drainage systems may also produce downstream effects over considerable area involving alterations in hydrology, channel form, Sediment load, water temperature, chemistry and aquatic biology.

As a results of the above concerns, and to ensure sustainability, agencies such as the World Bank and the International Commission on irrigation and Drainage (ICID) have developed checklists and guidelines to aid in the environmental assessment of irrigation and drainage projects (World Bank, 1991); (,Mock and Bolton, 1991). There are critical water quality- issues that are either now emerging, or have been previously neglected, which require special attention in the planning of new irrigation and drainage projects.

8.2 The potential negative impacts of most large irrigation projects includes:

Water logging and salinisation of soils

Increased incidence of water-borne and water-related diseases

Resettlement or changes in the lifestyle of local population

Increases of agricultural pests and diseases resulting from the elimination of dirt season die back and creation of a more humid microclimate.

The expansion and intensification of agriculture made possible by irrigation has the potential for causing:

Increased erosion

Pollution of surface and groundwater from agriculture biocides

Deterioration of water quality (water quality guidelines for drinking and irrigation)

Increased nutrient levels in the irrigation and drainage water resulting in algal blooms

Proliferation of aquatic weeds

Eutrophication in irrigation canals and downstream waterways

Fertiliser must be used to compensate for high growth rate and loss of nutrients through leaching

Pesticides to control the greater numbers of crop pests and diseases.

Large irrigation projects, which impound or divert waters, have the potential to cause major environmental disturbances resulting from changes in the hydrology and limnology of river basins.

Reducing the river flow changes floodplain land use and ecology

Disrupts riverine and estuarine fisheries

Causes salt water intrusion up the river and into the groundwater of adjacent lands

Diversion and loss of water through irrigation, reduces the water supply for downstream users including municipalities, industries and agriculturists

A reduction in a river base flow also decreases the dilution of municipal and industrial wastes added downstream, posing pollution and health hazards

The deterioration of water quality below an irrigation project can render the water unfit for other users, harm aquatic species

Because of high nutrient content-, result in aquatic weed growth that Clogs water ways and his health, navigation and ecological consequences

The potential direct negative environmental impacts of the use of groundwater supplies arise from overlapping groundwater supplies. This results in the lowering of water table, land subsidence, decreased water quality and salt-water intrusion (in coastal areas).

A number of external environmental factors influence irrigation projects.

Upstream land use will affect the quality of water entering the irrigation area, particularly the sediments content and chemical composition. Use of river waters with a large sediment load may result in canal closing.

The obvious benefits conferred by irrigation are those resulting from increased production of food. Increased vegetative cover for a greater portion of the year helps reduce soil erosion.

8.3 Water logging and Salinization.

Water logging results primarily from inadequate drainage and over-irrigation, and to a lesser extent from seepage from canals and ditches.

Salinity problems, naturally more acute in a,.id and semi-arid areas which have more rapid surface evaporation and saline soils, are exacerbated by irrigation, Water logging, concentrates salts, drawn up from lower in the soil profile.

Alkalisation is a particularly detrimental form of Salinization which is difficult to rectify.

Soils in and semi-arid zones have a natural tendency toward salinization, many of soil related problems could be minimised by installing adequate drainage systems. Water logging and salinization can also be reduced or minimised by using sprinkler or drip irrigation, which apply water more precisely and can more easily limit quantities to no more than the crop needs.

8.4 Social Issues

Social disruption is inevitable in large irrigation projects covering vast areas.

Local people dislocated by the irrigation project face the classic resettlement

problems:

A decrease in the standard of living.

Increased health problems.

Social conflicts.

Deterioration of natural resources in the resettlement area.

The people remaining in the area will like have to change their land use practices and agricultural patterns.

Increased population density and altering the distribution of wealth can have a profound influence on traditional social patterns

Water borne or water related diseases commonly is associated with the introduction of irrigation. The diseases most- often linked with irrigation are schistomiasis, malaria and onchocerciasis, whose vectors proliferate in the irrigation waters.

Increased use of agrochemicals, deterioration of water quality and increased population pressure in the area is other irrigation related health risks.

The reuse of wastewater for irrigation has the potential of transmitting communicable diseases mainly heiminthic.

8.5 Irrigation Efficiency

Inefficient use of water not only wastes water which could go to other users and avoid ecological impacts downstream, but results in land deterioration through waterlogging, salinization and leaching, and decreased crop productivity.

8.6 Project Alternatives

Improve the efficiency of existing irrigation projects and restore degraded crop lands to use rather than establishing a new irrigation project.

Develop small scale; individually owned irrigation systems as an alternative to large, publicly owned and managed schemes

Develop irrigation systems using groundwater- resources, which have less potential for causing environmental damage than surface water systems.

Use sprinkler or drip, irrigation as alternatives to surface irrigation to decrease the risk of water logging, salinization, erosion and inefficient water use-.

Site the irrigation project on the site where negative social and environmental impacts are minimised

8.7 Management and Training

Operation of all controls facilities from the water source to individual farms requires almost constant management

Careful management is essential to the quantity, timing, controllability and predictability of water delivered to the users

Training of a cadre of managers to provide the needed services is required.

Planning and implementation of an irrigation project must be done with the cooperation and collaboration of engineers, soil scientists, hydrologists, public health specialists and economists..

8.8 Monitoring

Factors to be monitored should include:

Climate

Stream discharge

Nutrient content of discharge water

Water table elevations in the project area

Quality of groundwater

Water salinity levels

Chemical and physical properties of soil in irrigation area

Cropping intensity

Crop yield per unit of land and water

Condition of distribution and drainage canals (siltation,weeds & linings).

Incidence of disease and presence of disease vectors

Health condition of project population

Changes in natural vegetation

Changes in wildlife population in the project

Fish population and species

8.9 Policy and Institutional Requirements

While many developing countries including - Egypt, India and Pakistan, have environmental agencies and strong environmental laws, there is extensive water pollution either by irrigation and drainage, or limiting the productivity of irrigated agriculture. The laws are seldom enforced.

Governments should consider assisting, industries to develop and install technologies, which minimise, or eliminate, pollution by rivers, irrigation canals, and agricultural drains.- One reason why pollution laws are seldom enforced is the absence of a reliable water quality monitoring. Countries lack of the field and laboratory facilities, and qualified personnel to undertake a water sampling program, conduct the analyses -and accurately interpret the data. In many cases, the laboratory equipment is unavailable, Sampling procedures do not follow established guidelines. Laboratories do not undertake appropriate quality assurance and quality control procedures. Environmental agencies will have to work with research institution and universities, to train staff, develop manuals and guidelines, and provide essential equipment. The assistance and expertise of regulatory agencies and water quality laboratories in developed countries should be sought.

A rigorous and routine water sampling program for all major rivers, irrigation canals, agricultural drains, and groundwater needs to be developed. This data should be published and frequently analyzed by water management agencies, in case corrective measures are required. Other ecological indicators, eg. Soil properties, crop yields, and habitat species and numbers should be routinely monitored. These policies and monitoring program will lead to improvement in irrigation water quality, and irrigation of environmental damage due to the disposed or reuse of drainage water, and wastewater irrigation.

Planners and designers of irrigation and drainage projects will be required to undertake initial environmental screening and scoping studies, especially when external funds are sought. These initial studies are useful, prior to conducting major environmental assessments and model exercises. Biswas and Geping (1987) emphasised the benefit of a scaling checklist. Based on this concept, a scaling checklist of environmental impacts indicators pertinent to irrigation, drainage and flood control projects was developed.

8.10 Conclusions and Recommendations

Water quality is a major constraint to the sustainability of irrigation and drainage systems. Some of the problems are not new, eg. Irrigation water quality, or the environmental impacts of wastewater irrigation. However, few, if, any attempts are made to resolve the problems.

Horizontal subsurface drainage is being installed in irrigated regions to combat salinity and waterlogging. Irrigation water quality is being severely contaminated by municipal and industrial effluent. Open main drains are also contaminated by sewage. This has severe implications for the agricultural reuse of drainage water. The quality of drainage water needs to be continually assessed to ensure that aquatic biota and receiving water bodies are not being damaged. The reuse of drainage water for irrigation of crops and agroforestry, as well as for fish production ought to be actively encouraged.

8.11 Self Assessment Test

1. What is Environment?
2. Define Ecosystem.
3. What are the Possible Potential Negative Impacts of a Water Resources Project?
4. How Environmental Management Plan (EMP) is to be Prepared?

8.12 Key Words

- **'Environment'** is the totality of the ecosystem.
- **'Ecosystem'** means all surroundings e.g. plants, earth, oceans, air etc.
- **'Quality'** includes parameters within permissible limits.

8.13 Suggested Readings

Ayers, R.S., water quality for Agriculture, FAO Irrigation and Drainage Paper No. 29. Rome, Itly

Mock J.F., Environmental Effects of Irrigation, H.R. Wallingford.

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UNIT-9

ENVIRONMENTAL IMPACT ASSESSMENT OF WATER RESOURSES PROJECTS

Structure:

9.0 Objective:

India has 16% of the world population with only 4% of water resources and 2 % area. Water is the most critical natural resource to sustain human civilization. The environmental impacts that could generally arise from water resources and drainage projects have been discussed by several people. The environmental impact assessment of water resources provides preliminary information to assist with water resources project design and the development of an Environmental Management Plan for any project.

9.1 Introduction:

The environmental impacts that could generally arise from water resources and drainage projects have been discussed by several people, including Hagan and Roberts (1972), White (1978), and Hillel (1990), among others. Water is the most critical natural resource to sustain human civilization. It is one of the important resource due to which bio-culture on this globe has become possible. Ditching and field under-drainage systems may also produce downstream effects over considerable area involving alterations in hydrology, channel form, sediment load, water temperature, chemistry and aquatic biology.

Hoffman (1990) noted that drainage in California's San Joaquin valley ceased some years after operation, on discovering that high concentrations of selenium in drainage effluent caused a loss of waterfowl in the Kesterson National Wildlife Refuge. The draining of marshes and other types of wet land produces alterations in plant and animal communities. A reduction in wetland acreage can also affect streams and lakes by causing changes in water quality and hydrology. The construction of ditches and channelisation of natural streams has a direct local impact on flora and fauna in and adjacent to the water course.

India has 16% of the world population with only 4% of water resources and 2 % area. The distribution of rainfall & its storage's through out the country are generally uneven but it is especially highly uneven in case of Rajasthan. For instance in Rajasthan in south east the average rainfall ranges from 900 mm to 600 mm while in North West, it is limited to merely 100 mm. The per capita annual water availability has been gone down from 5277 M3 in 1955 and is expected to dwindle to 1496 M3 by 2025. It is note worthy here that less than 1000 M3 per capita water availability is an indicator of' water stress conditions'. It varies from as much as 18417 M3 per capita in Brahamputra valley to as low as 411 M3 per capita in east flowing rivers between Pennar and Kanyakumari (excluding Cauvery). Even in Ganga basin the availability varies over a wide range being as low as 740 M3 per capita in Yamuna, 1369 M3 per capita in Sone and as high as 3379 M3 per capita in Gandak basins. As per 1991 census, the per capita availability of water in Rajasthan was about 1000 m3 per annum against national average of 2829 m3 which is likely to reduce in state to about 400 m3 by 2050.

With the creation of Uttarkhand, Jharkhand and Chattisgarh state from UP, Bihar & Madhya Pradesh respectively, the Rajasthan now have become the largest Indian State with 11% of country land, 5.5% population but only about 1% water resources.

9.2 Status of irrigation:

On the eve of independence, scenario of per capita availability of water at national and state level in different time periods, comparative values of physical and other resources - national & state are shown in table-I to table-III below:

Table-I The status of irrigation of India on the eve of independence

Country	Net Area sown	Net Irrigated area	% net area irrigated (col. 3 as % of col. 2)	Area irrigated by source Canals Govt.	Canals Pvt	Total	Wells	Tanks	other
1	2	3	4	5	6	7	8	9	10
Undivided	116.8	28.2	24.1	13.1	2.1	15.2	6.6	3.3	3.1
India			(100)	(46.5)	(7.4)	(53.9)	(23.4)	(11.7)	(11.0)
India	98.5	19.4	19.7	6.3	1.9	8.2	5.3	3.3	2.6
			(100)	(32.5)	(9.8)	(42.3)	(27.3)	(17.0)	(13.4)
Pakistan*	18.3	8.8	48.1	6.8	0.2	7.0	1.3	-	0.5
			(100)	(77.2)	(2.3)	(79.5)	(14.8)	-	(5.7)

Figures in bracket are % of the total net irrigated area

* Estimated figures.

\+ As per report of the 2nd Irrigation Commission, 1972. Country

Table -II PER CAPITA AVAILABILITY OF WATER

Year	Per capita availability of water (in cum) Rajasthan state	Per capita availability of water (in cum) in India	Minimum per capita requirement (in cum)
1951	2028	6602	1000
1971	1725	4349	1000
1991	1042	2829	1000
2000	857	2384	1000
2025	567	1589	1000
2035	506	NA	1000
2045	457	NA	1000

Table -III Comparative Values of Physical and other Resources -National & State

Particulars	National Level	State Level	% as compared to Nation
Total geographical area	328.76 Mha	34.2 Mha	10.4
Population	1000 million	54.8 million	5.50
Total cultivable area	184.376 Mha	25.70 Mha	13.94
Irrigation Pontential (Surface)	16.1Mha (in 1950) 42.9Mha (in 1999)	0.40 Mha (in 1950) 2.83 Mha (in 1999)	2.48 5.46
Ultimate irrigation potential	75.9Mha (Surface water) 64.10Mha (Ground water)	5.12 Mha (surface water) 0.41Mha (ground water)	6.75 0.64
Gross cropped area	131.89 Mha in 1950 189.54 Mha	9.76 Mha (1951-52) 19.38 Mha (1990-91)	7.4 11.29
Area under food-crop as % of total crop area	67%	65%	-
Area -crop as % of gross irrigated area	70%	19.53%	-

Water Resources : National Scenario

1.	Precipitation	4000 Cubic Km
2.	Water resources	1869 Cubic Km
3.	Utilizable (including 450 Water resources cubic km from Groundwater)	1140 Cubic Km
4.	Ultimate irrigation potential by Conventional projects	113-125 M Ha

Successful development depends on the rational use of environmental resources and on minimizing or eliminating any adverse environmental impacts by improving the planning, design and implementation of projects.

Loss of wet land has concern to bird watchers, interested in natural environment. Wetland is of great value as wildlife habitats, food storage areas, ground water recharge areas and ecological and recreational areas.

Developing countries prefer agricultural productivity while developed countries prefer natural areas.

Irrigation and drainage projects manage water supplies for the purpose of agricultural production. There are various types of irrigation depending upon the source of water (surface or groundwater), means of water storage, conveyance and distribution systems, and methods of delivery in the fields. Large scale utilization of surface water for irrigation has been practiced.

The dominant delivery method up to 95 percent world-wide is surface irrigation in which water is distributed over the irrigated area by gravity in overland flow. The other systems are sprinkler and drip irrigation. Although they are relatively new technologies requiring higher initial investment and more intensive management than surface irrigation, sprinkler and drip irrigation show great potential for maximizing the efficiency of water use and reducing irrigation-related environmental problems.

Two consequences of intensive irrigation are salinity and water logging. There are over 250 million ha of irrigated land world-wide, of which nearly 30 million ha are degraded due to the twin menace of salinity and water logging. Barghouti and LeMoigne (1991) indicated that about 1.5 million ha of cropland are being destroyed by salinization each year. They further noted that salinity' and water logging have reduced the yields of major crops by approximately 30 percent in Pakistan, Egypt and India.

The developing countries are focusing on more efficient irrigation delivery systems, better on farm water management, and the reclamation of saline and waterlogged lands. To achieve this, horizontal subsurface pipe drainage systems are being installed to lower the water table, and leach salts from the crop root zone.

Agricultural land drainage which includes the construction of ditches and canalization of water courses, as well as fields under drainage can have a variety of effects on the environment. Of the irrigated and semi-arid developing countries, Egypt has the most experience with subsurface drainage. There are about 150,000 ha, of horizontal pipe drains in Pakistan. At least 10 million ha may require drainage. Datta et al. (1992) stated that over 6 million ha of irrigated land in India are severally affected by water logging, and approximately 8 million ha suffer from salinity and alkalinity. However, large scale subsurface drainage is introduced to India as a result of a Canadian financed project in the state of Rajasthan. There are about 12000 ha, of horizontal pipe drains installed in the Chambal Command Area (CCA) to overcome the water logging and soil salinity problem.

As a results of the above concerns, and to ensure sustainability, agencies such as the World Bank and the International Commission on irrigation and Drainage (ICID) have developed checklists and guidelines to aid in the environmental assessment of irrigation and drainage projects (World Bank, 1991); (Mock and Bolton, 1991). There are critical water quality issues that are either now emerging, or have been previously neglected, which require special attention in the planning of new irrigation and drainage projects.

9.3 Some problems of water resources Development sector and their possible Solutions:

Following main problems of water resources Development sector are identified below which need attention and solution Rajasthan.

1. Decision for planned development of water Water Resources Organization:

The major water utilization departments in isolation or independently at present are often have objectives which are contrary to other's need such as PHED, Irrigation, Ground water dept., Industries dept., mines, forest, DRDA, Local self Govt., Panchyats, Famine relief etc. These dept. are preparing schemes to full fill their own objectives by exploiting the available state waters. To regulate the utilization and exploitation of state water resources optimally, a Rajasthan state water resources council was created in 1992 headed by the Chief minister, Govt. of Rajasthan. A standing committee headed by the Chief Secretary was also set up to assist it. The meetings of the council & standing committee are required to take place at desired frequency and at pre determined intervals. To enable these bodies to take decisions for water development and utilization based upon state water policy, a Rajasthan water resources organization need to be created in the irrigation department which will function as secretariat of these bodies. The Rajasthan water resources organization will assist these bodies to update the assessment of water in different time period & suggest strategies to allocate it to different users based upon the priorities mentioned in state water policy through collection, analysis, processing of data/information regarding available water and its demands. It will also suggest necessary measures to harness balance water potential of the state. It will take care of inter sector coordination to assess temporal & spatial demand of water based upon the population, industry & other growth sectors in a regular manner and will be responsible for the periodical review of the Rajasthan water resources plan i.e. in 2005, 2015, 2025, 2035, 2043 etc. This organization will be responsible for collecting and updating the hydrologic & other data regularly and reassess the available water in a regular manner.

2. Operation & Maintenance Policy of Irrigation Projects:

The present maintenance & operation policy of water resources projects in the state is not well defined especially in projects located south east of Aravallies. Clear operation rules and detailed procedure need to be prescribed for each project based upon its specific potential. In project reports prepared for execution of projects, no planning &

strategies are mentioned as how these projects will be operated, maintained & managed after completion so that they may meet the objectives for which they have been created. The man, material and financial resources needed in different time periods to meet the anticipated objectives of service to the beneficiaries are also not adequately evaluated & planned. The maintenance roster concept is either not known or not implemented. The maintenance & operation functions probably need more frequent and regular monitoring at the level of minister, secretary, Chief Engineer & other functional levels. The comprehensive physical & financial norms at each level are also not explicitly defined. The financial norms issued in 1985 by the finance department on the recommendations of Chief Engineer have not been revised so far. The rationality of financial norms need to viewed in light of increased public awareness, involvement of beneficiary, increased transparency & responsibility to public, more difficult sites, more concern to environment, ecology & rehabilitation measures, the degree of complexity coupled with increased management and administrative costs (major, medium or minor), the increased decision flow channels, etc.

3. Participatory Irrigation Management:

The involvement of farmers' at the level of project formulation need to be included in the proposed farmers' Act. The farmers need to be motivated to contribute at least 20% share in capital cost which should be mentioned in the act. The proposed act must ensure construction, operation & maintenance of tertiary irrigation system to be transferred to farmers' groups to maintain quality of services and generating a sense of ownership. At present the department is fully depending upon the aid from World Bank to initiate PIM. This concept may be partially good, but why department can not initiate these measures from indigenous resources which are economically more sustainable. Few experiment in this direction have taken place, for example at Mahi Project, Banswara recently with the cooperation of farmers & through their motivation operation of canals were successfully made even with less water in reservoir & scare finances. Though these measures require lot of motivation and strong political & administrative will but these measures & strategy are practicable and sustainable. If need to understand that the world bank is giving loan to state Govt. and not an aid which need to be repay with interest by our future generations. The World Bank is providing loan to finance PIM only in 5.0 lac hectare area. The present irrigated area in state is more than 28.0 lac ha. For how long? & for how much amount? and time? State government is going to take loan from world bank if it do not plan its own indigenous strategy to implement PIM concept. To implement all these concepts, desired level of political & administrative ingenuity, will and effective participatory leadership is necessary. This approach can replace thousands of crores rupees external loan. This is the only practical approach and demand for the effective solution to the present problem of water allocation and distribution in irrigation projects. The Govt. and department administrative & technical leadership both can do it by itself committed first itself to participatory approach sending clear message to its officers staff & farmers about their firm commitments & sustained efforts.

4. Periodical Evaluation of Objectives:

Periodical project evaluation shall be carried in relation to the objectives of the project. Objectives need to re defined periodically looking to the changing need of the society. The project operation strategy, accordingly need to be revised periodically if necessary.

5. Farmers' Expectation:

The farmers expect equity in allocation & distribution of water, timely supply (the dates of opening & closing of minors / outlets must be announced before sowing) of water and its reliability. These services need to be maintained if Govt. expects farmers cooperation in water distribution & utilization along with and payment of irrigation charges by them. The effective control of irrigation department over irrigation system can not be maintained if irrigation department do not propagate & pursue these policies effectively. When Govt. do not provide services to farmers, how it expect charges for it. It is a myth that farmers do not want to pay services / charges of water. A passenger is usually willing to pay for reservations charges readily if one gets it in railway compartment.

6. Scarce Value of Water:

The efficient & uniform water application largely depend over its equity in allocation & distribution. The scarcity value of water is the only incentive, which prompt individual farmers to invest both labour & resources in efficient application of input including the water. It only motivate farmers group to make their tertiary & micro net work system efficient to enable conveyance of water to their fields with out much losses. In case equity in allocation of water between various segments of the canal system is effectively planed & implemented, the irrigation agencies will automatically know the difference in water released at head works and actual water delivered to farmers groups at minor heads. This will prompt the department authorities to plug the leakage in the system both due to scarce value of water and also because of social pressure from farmers groups.

Scarcity value of water created through controlled allocation and distribution will prompt the progressive farmers to adopt more & more water saving technology like drip & sprinkler irrigation methods. However, the use of these methods depend upon many factors like the soil type, wind velocity, temperature, availability of power and its cost etc. The adaptability decision in a particular area and scale of economy can be derived by developing farm economy scale models in each command areas.

7. Conjunctive Use of Water:

The study of availability of ground water in each block of project command must be assessed in association with ground water department. The annual natural recharge and recharge from other sources in the block must be assessed on continuous basis. The quality of ground water also need to be analysed. Based upon these parameters, the appropriate strategy to use ground water in conjunction with surface water need to be derived block wise. The close monitoring of ground water régime, regulation & quality of water need to be checked and if necessary corrective measures need to be taken in a particular time period. The related data for efficient and sustained operation need to be monitored at state level and no laxity or mistake in its operation must be tolerated at any levels. The use of saline and sewerage water through mixing with surface water or otherwise can also be planned. The artificial recharge sites are identified in and measures need to be taken to recharge ground water through them. A separate irrigation unit at state level need to be given this task so that expertise in it can be developed through the concept "learning while doing" approach. Luni, Parvati, shekhawati, Ruparel, Banganga, Gambhir, Baney etc river basin.

8. **Water logging, Salilnity & Alkalinity Management:**

A survey of water logged, saline & alkaline area especially in major & medium projects must to carried out immediately by the each project authority. To devise specific preventive and or corrective measures, the source of the problem or the reasons of water logging, salinity or alkalinity in specific location need to be assessed. After assessment of the problem, the work to devise solutions need to assigned to a specific division of IDR in each zone so that expertise and timely completion of this task could also be ensured.

9. **Drought Management - Participation of affected Population:**

It is now clear to large section of the people that appropriate measures need to be planned to contain the recurring drought in the state. In last 50 years several hundreds crores of rupees have been incurred annually to lessen the miseries of the affected population and the livestock. Thousands of crores rupees, man, animal and material resources have been lost of the affected population. The human miseries due to loss of their dear & near ones only can be felt and understood by those who have passed with this trauma. Fortunately, it is possible to fight the drought with determined political & administrative will. This require effective planning of schemes and their effective implementation. The drought affected people's participation in planning of schemes, their implementation and later on their operation and maintenance should be ensured to plug the leakage of resources in implementation of relief works and or other such schemes. The complete transparency in all such works must be ensured by the state Govt. by announcing effective policy. Under irrigation department, a drought scheme planning unit at state level must be created who can develop strategy with available technology to prepare schemes through which intensity of drought can be reduced and advance action plan could be prepared to manage the situation effectively especially to facilitate the demand of drinking water, to generate employment to enable the affected population to buy food & fiber for their family needs. The department need to tackle this problem in wider prospective nested in policy for permanent solution to recurring farmers.

9.4 The potential negative impacts of most large irrigation projects include:

- Water logging and Stalinization of soils
- Increased incidence of water-born and water-related diseases
- Resettlement or changes in the lifestyle of local population
- Increases of agricultural pests and diseases resulting from the elimination of dirt season die back and creation of a more humid microclimate.

9.5 The expansion and intensification of agriculture made possible by irrigation has the potential for causing

- Increased erosion
- Pollution of surface and groundwater from agriculture biocides
- Deterioration of water quality (water quality guidelines for drinking and irrigation)
- Increased nutrient levels in the irrigation and drainage water resulting in algal blooms

- Proliferation of aquatic weeds
- Eutrophication in irrigation canals and downstream waterways
- Fertilizer must be used to compensate for high growth rate and loss of Nutrients through leaching
- Pesticides to control the greater numbers of crop pests and diseases.

Large irrigation projects which impound or divert waters have the potential to cause major environmental disturbances resulting from changes in the hydrology and limnology of river basins.

- Reducing the river flow changes floodplain land use and ecology
- Disrupts riverine and estuarine fisheries
- Causes salt water intrusion up the river and into the groundwater of adjacent lands
- Diversion and loss of water through irrigation reduces the water supply for downstream users including municipalities, industries and agriculturists
- A reduction in a river's base flow also decreases the dilution of municipal and industrial wastes added downstream, posing pollution and health hazards
- The deterioration of water quality below an irrigation project can render the water unfit for other users, harm aquatic species
- Because of high nutrient content, result in aquatic weed growth that clogs water ways and has health, navigation and ecological consequences
- The potential direct negative environmental impacts of the use of groundwater supplies arise from overlapping ground water supplies. This results in the lowering of water tableland subsidence, decreased water quality and salt water intrusion (in coastal areas).
- A number of external environmental factors influence irrigation projects. Upstream land use will affect the quality of water entering the irrigation area, particularly the sediment content and chemical composition. Use of river waters with a large sediment load may result in canal closing.
- The obvious benefits conferred by irrigation are those resulting from increased production of food. Increased vegetative cover for a greater portion of the year helps reduce soil erosion.

Water logging and Stalinization

- Water logging results-primarily from inadequate drainage and over-irrigation, and to a lesser extent from seepage from canals and ditches.
- Salinity problems, naturally more acute in and semi-arid areas which have more rapid surface evaporation and saline soils, are exacerbated by irrigation. Water logging concentrates salts, drawn up from lower in the soil profile.
- Alkalization is a particularly detrimental form of salinization which is difficult to rectify.
- Soils in and semi-arid zones have a natural tendency toward salinization, many of soil related problems could be minimized by installing adequate drainage systems. Water logging and salinization can also be reduced or minimized by using sprinkler

or drip irrigation which apply water more precisely and can more easily limit quantities to no more than the crop needs.

Social Issues

- Social disruption is inevitable in large irrigation projects covering vast areas. Local people dislocated by the irrigation project face the classic resettlement problems:

  A decrease in the standard of living. Increased health problems.

  Social conflicts.

  Deterioration of natural resources in the resettlement area.

- The people remaining in the area will like have to change their land use practices and agricultural patterns.
- Increased population density and altering the distribution of wealth can have a profound influence on traditional social patterns.
- Water borne or water related diseases commonly are associated with the introduction of irrigation. The diseases most often linked with irrigation are schistomiasis, malaria and onchocerciasis, whose vectors proliferate in the irrigation waters.
- Increased use of agrochemicals, deterioration of water quality and increased population pressure in the area are other irrigation related health risks.
- The reuse of wastewater for irrigation has the potential of transmitting communicable diseases mainly helminthes.

Policy and Institutional Requirements

While many developing countries, including Egypt, India and Pakistan, have environmental agencies and strong environmental laws, there is extensive water pollution either by irrigation and drainage, or limiting the productivity of irrigated agriculture. The laws are seldom enforced.

Government should consider assisting industries to develop and install technologies which minimize, or eliminate, pollution by rivers, irrigation canals, and agricultural drains. One reason why pollution laws are seldom enforced is the absence of a reliable water quality monitoring. Countries lack of the field and laboratory facilities, and qualified personnel to undertake a water sampling program, conduct the analyses, and accurately interpret the data. in many cases, the laboratory equipment is unavailable. Sampling procedures do not follow established guidelines. Laboratories do not undertake appropriate quality assurance and quality control procedures. Environmental agencies will have to work with research institutions and universities, to train staff, develop manuals and guidelines, and provide essential equipment. The assistance and expertise of regulatory agencies and water quality laboratories in developed countries should be sought.

A rigorous and routine water sampling program for all major rivers, irrigation canals, agricultural drains, and groundwater needs to be developed. This data should be published and frequently analyzed by water management agencies, in case corrective measures are required. Other ecological indicators, ego soil properties, crop yields, and habitat species and numbers should be routinely monitored. These policies and monitoring program will lead to improvements in irrigation water quality, and irrigation of environmental damage due to the disposed or reuse of drainage water, and wastewater irrigation.

Planners and designers of irrigation and drainage projects will be required to undertake initial environmental screening and scoping studies, especially when external funds are sought. These initial studies are useful, prior to conducting major environmental assessments and model exercises. Biswas and Geping (1987) emphasized the benefit of a scaling checklist. Based on this concept, a scaling checklist of environmental impact indicators pertinent to irrigation, drainage and flood control projects was developed.

9.6 Conclusions and Recommendations

Water quality is a major constraint to the sustainability of irrigation and drainage systems. Some of the problems are not new, eg irrigation water quality, or the environmental impacts of wastewater irrigation. However, few, if any attempts are made to resolve the problems.

9.7 Self Assessment Test:

1. What do you understand by water quality?
2. Define water logging.
3. Define soil salinity and alkalization.

9.8 Key Words:

Irrigation means the supply, distribution and controlled applications of water to agricultural land to improve the cultivation of crops.

Environmental Impact means The effect on the environment of a certain human interference.

Ecosystem means A dynamic arrangement of plants and animals with their non living surroundings of soil, air, water, nutrients, and energy.

9.9 Suggested Reading:

FAO Irrigation and Drainage paper 55; Control of Water Pollution from Agriculture, 1996.

Government of Rajasthan, State Water Policy

Ministry of Water Resources, GOI, National Water Policy, 1987

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UNIT-10

WATER BUDGET BASED ON CROP WATER REQUIREMENTS

Structure

10.0 Objectives

Water is a 'precious commodity' through out the world and its limitation are being felt more acutely in arid and semi-arid tracts, where the greater pan of cultivated areCj is under rainfed agriculture, with scare possibility of irrigation. Our growing population and rapidly diversifying and expending need make water an increasingly scarce resources. The state is facing recurrent drought due to inadequate and erratic nature of monsoon. Not only quantum of rain, duration of monsoon is also less, as a result there is poor inflow in the tank available for irrigation and replenishment of ground water is also meager.

A few perennial river e.g. Kalisindh, Chambal and Mahi are there, but their benefits cannot be divided by the state as they flow through limited area. It has been observed that about 50-60 percent available water is lost during conveyance, run off and seepage losses do occur on account of evaporation also. This further minimizes the availability of irrigation water. Under the circumstances this precious resource is to be efficiently utilized and conserved to meet the evapotranspiration need of the crop at its peak requirement.

Water conservation comprise not only creation of reservoir for storing of water, but also prevention of losses, water use efficiency recycling and reuse of waste water etc. It is therefore of great importance to harness more out of per unit of water applied. It means planning the crop and allocation of water to each crop to meet their evapotranspiration need to increase productivity i. e. water budget.

10.1 INTRODUCTION

For the growth and development and to obtain optimum yield, crops should be irrigated at its critical water requirement stage. While deciding the water requirement, it must be borne in mind that what are the conveyance and field application losses. The amount of losses be added to the net water requirement of the crop to arrive the total requirement of the crop.

10.2 WATER REQUIREMENT OF CROPS

The net water requirement of different crop are being given in the following table; Mostly Kharif crops are rainfed but in the even of failure of rainfall, life saving irrigation be given at flowering and grain filling stages so that productivity is not declined.

Water Requirement of Crops(Unit mm)

S.No.	Crops	Net Water Requirement	Total water requirement
A	Rabi Crops		
1.	Wheat	500-600	750-900
2.	Barley	350-400	525-600
3.	Gram	200-250	300-375
4.	Mustard	250-300	375-400
5.	Dhaniya	300-350	450-525
6.	Linseed	200-250	300-375
B.	Kharif Crops		
1.	Maize	500-550	750-825
2.	Jowar	400-450	600-675
3.	Bajra	300-350	450-525
4.	Groundnut	400-500	600-750
5.	Soyabean	400-500	600-700
6.	Paddy	1500-2000	2250-3000

The above table reveals that in the even of limited availability of water high water efficient corps like gram, linseed, Mustard, Dhaniya in Rabi and Bajra, Jowar, Soyabean, Groundnut in Kharif be grown.

10.3 ECONOMICS OUT OF PER UNIT OF WATER APPLIED

Under the condition of limited water availability early maturing, high water efficient varieties of crops be selected, so that higher profit from per unit of water applied, could be earned. Income from per unit of water applied in Rs. is being summarized in the following table.

S.No.	Crops	Yield Kg/ha	Sale price	Income	Cost	Net Return	Net water Req.	Income per unit of net water applied
1	Wheat	3000	600	18000	7000	11000	5000	2.22
2	Barley	2500	600	15000	55000	9500	4000	2.37
3	Gram	1000	1500	15000	5000	10000	2500	4.00
4	Mustard	1600	1200	19200	5500	13700	3000	4.56
5	Dhaniya	1000	1600	16000	5000	11000	3500	3.15
6	Linseed	800	1500	12000	4500	7500	2500	3.00

The data in the above table reveals that with per unit of water applied highest profit is received from Mustard followed by Gram, Dhaniya and linseed. When available water is scarce the cultivation of wheat/Barley is not profitable.

10.4 CROP PLANNING WITH AVAILABLE WATER:

(a) Under assured irrigation Maize-wheat or Bajra- wheat can be grown. However, highest profit can be e9rned from Groundnutwheat rotation. When extended irrigation is adopted wheat may be replaced by mustard / Gram/ Dhaniya as per need of the area.

(b) Under limited water supply crop plan may be developed as per availability of water. When only one irrigation is available Gram/ linseed or Taramira can be grown. When two irrigation (i.e. Palewa +one irrigation) are available mustard/ Dhaniya/ gram can be grown. When two irrigation after pre-sowing irrigation is available Dhaniya/Mustard can most profitably be grown. Wheat/Barley should be grown only when more than three irrigation's are available or when farmer had his own source of irrigation.

(c) In case of delayed monsoon, moisture be conserved and sowing of Gram/Mustard/ Toriya be done, so that even with one irrigation crops will yield better. In case of early withdrawal of monsoon life saving irrigation be planned for Kharif crops at critical stage of crop requirement.

10.4.1 STEPS TO WATER BUDGETING:

Water saved is water generated therefore to plan water budget one has to ensure the available water, following steps be taken for water budgeting thereafter.

1. Water available for irrigation.
2. Conveyance and field application losses be deducted from the available water to get net water for crops.
3. The data on existing crops and cropping pattern be collected and water requirement may be worked out.
4. Gross water requirement of existing cropping pattern be compared with water available for irrigation and ensure how much area will be put under cultivation.
5. Now develop cropping pattern as per available water and try to extend in

irrigation by selecting high water efficient crops and their varieties.

6. Workouts gross waters requirement of the proposed cropping pattern and compare with the water available. Now ensure with the same water available and change in cropping pattern. How much additional area is covered how much saving in. water observed and what is irrigation intensity with existing system and with proposed system?

7. It should be taken care that the overall efficiency or-the system and designed intensity of the system should not be exceeded failing which canal will not be in a position to cover the proposed area.

An integrated approach has to be developed for efficient implementation of water budgeting and crop planning approach relates to develop co-ordination with officials of irrigation, co-operative and agriculture department to facilitate farmers in getting water, seed fertilizer, plants protection chemicals etc. along with technical know-how as and when needed. Water scheduling be coincided with critical water requirement stage of the crops i.e. of Mustard and Gram irrigation scheduling be coincided with branching and pod formation stage of the crop. Seed and fertilizer should be made available to the farmers before opening of canal so that they could undertake sowing operation well in time.

10.4.2 EXAMPLES

Water Budgeting

1.		CCA of the project	=	8600 Acres
2.		Total water available in tank	=	495 mcft.
3.	(i)	Dead Storage	=	72 mcft.
	(ii)	Eavaporation losses @ 13 %	=	54.99 mcft.
	(iii)	Eonveyance losses @ 30 %	=	110.40 mcft.
	(iv)	water required for drinking purpose @ 6 % total	=	15.45 mcft.
4		Water available for irrigation	=	424.84 mcft.
				(495-252.84)

5. Existing Cropping Pattern

S.No	Crop	Irrigation acre inch	Area in acre	Percentage	water(mcft.)
1	Wheat	16	2860	33.25	165.79
2	Pulses	10	900	10.46	32.60
3	Oilseeds	10	1200	13.95	43.47
	Total		4960	57.66	241.86

6. Proposed Cropping Pattern

S.No	Crop	Irrigation acre inch	Area in acre	Percentage	water(mcft.)
1	Wheat	16	1500	17.44	86.96
2	Pulses	10	2000	23.26	72.46
3	Oilseeds	10	2283	26.55	82.72
	Total		5783	67.25	242.14

7. **Irrigation would be given as below**

Pulses and Oilseeds

Pre sowing irrigation	=	4 Acre inch
First irrigation	=	3 Acre inch
Second irrigation	=	3 Acre inch
Total	=	10 Acre inch

Wheat

Pre sowing irrigation	=	4 Acre inch
4 irrigation's (3 Acre inch each)	=	12 Acre inch
Total	=	16 Acre inch

Note : 242.16 mcft water would be required for proposed cropping pattern, which is available in tank.

Units of Irrigation Measurements

These units are used for getting following information:

1. To workout the area which can be irrigated wittl given quantity of Water.
2. To work out the quantity of water which would be needed to irrigate a given area and crops to be grown.
3. To calculate the time needed for irrigating a given area.
4. To work out the optimum capacity of. entire conveyance system Individually for main canal, distributaries, minors ar1d water courses.

Acre-Inch:

It represents the quantity of water required on one acre area to the height of one inch. One acre inch of water measures about 22464 gallons and weight 101 tones.

Cusec

It is the quantity of water flowing at the rate of one cubic foot per second. As 1 cubic foot of water weighs 62.4 Ibs. Water flowing @ 1 Cusee for one hour will weigh (62.4 x 60 x 60) or approximately 100 tones or one acre inch..

Duty

This denotes the area which can be irrigated by one Cusec of water flowing continuously during the base period.

Delta

This indicates the depth of water in cms. Which would be required for maturing the crop. This depends upon the number of irrigations and their intervals. This provides total water requirements.

AI/DC

This term is infect duty based on day basis (24 hours) and is related to the area of various crops, which are to be irrigated by one Cusec of water.

Base Period:

This denotes the total number of days in any cropping season.

1. Kharif - 1st July to 14th October - 106 c1ays..

2. Rabi - . 15th October to 28/29 February - 137 days.

3. Zaid - 15t March to 30th June - 122 days.

However the period conditions of any area. As such it may vary in different climatic zones,

A. Seasonal storage requirements:

$$\text{Flow in Cusec} = \frac{\text{Area of the crop irrigated}}{\text{Duty of the crop.}}$$

Storage in Mcft = Flow in Cusec x base period (Days) x 0.0864 (one day Cusec)

B. To calculate canal discharge;

$$Q = \frac{\text{Area proposed for irrigation}}{\text{Flow period x AI/DC}}$$

Where:

Q = Discharge in Cusec.

Area = Area proposed for irrigation in acres.

Flow period = In number of days.

AI/DC = Area irrigated per day Cusec in acres.

C. To find out the area that can be irrigated in given quantity of water.

$$\text{Area in acres} = \frac{\text{Quantity of water in Mcft x 23}}{\text{Delta in feet}}$$

One Mcft = 23 Acre feet.

Time required for irrigation

Water requirement in (M3) = Area (ha) x Delta (mm) x 10

Time required for irrigation in hours = Water requirement in (M3)

Delivery of water (M3)/hour

D. Depth of water required in Cms.

$$D = \frac{As.D. (fc - pal}{100}$$

Where:

D = Depth of water required in cms.

As = Specific gravity of the soil.

D = Root zone depth in cms,

Fc = Field capacity in percentage.

Pa = Available moisture in soil in percentage

Now looking to the above example, now we can also calculate the seasonal requirement and the most important is that through we can also calculate the operation of canal based on crop water requirement.

10.5 OPERATION OF CANAL BASED ON CROP WATER REQUIREMENT.

The objective of irrigation is to supply water to the plants. The soil is the medium from which crop draw water and nutrients. Since the plant transpires continuously, water needs to be available continuously. The water stored in the soil supplies this water over an certain period, after which it needs replenishment, which is done in intervals through application of irrigation water, Irrigation provides one of the greatest possibilities for increasing agricultural production in India. This objective can be achieved by adopting, proper scheduling of irrigation, improved operation of water supply and distribution systems.

Most crops vary in their water requirements over the growing season. This is generally due to changes in leaf area and climatic parameters. An appropriate canal schedule help to provide good crops and would encourage the farmers to make judicious use of water. In some projects, water supply schedules are based on fixed internal and/or a fixed depth of water application regardless of the changes in crop water requirements over the growing period and this may cause losses in the yields due to excessive in or inadequate water supply to the crop. It is generally noticed that when a farmer irrigates his field from the tube well, he achieves the optimum water utilization efficiency but in the command area in most of the cases farmers do not achieve this much efficiency, perhaps, because they are not applying right amount of water at right time. Therefore, for high yields, the operation of water supply through canals must be directed toward meeting the crop water requirements over time and acreage. The canal scheduling based on crop water requirement is simple correct and scientific.

During the period of peak water requirement, canals should be run continuously which should thus determine the maximum irrigable area. During the times of lesser demand, prior to or after the peak period, supply could be delivered intermittently on and ON/OFF basis in such a way that crop water requirements would be followed as closely as possible and within practicable limits of operation. To prepare a schedule for the canal operation according to crop water requirements the systematic approach of water budgeting is needed and for which the following data are needed.

a. Cropping pattern in the Command Area.

b. Crop water requirement of each crop.

c. Irrigation efficiencies.

The simulation modules for the water deliveries for the two different minors (examples) in the Rabi season have been prepared to match the water supply versus crop water requirement. The cropping patterns in the command areas of minor 1 and 2 have been shown in table 1. The crop water requirements for each crop of the proposed cropping pattern can be calculated by using the reference evapotranspiration and coefficients.

10.5.1 REFERENCE EVAPOTRANSPIRATION(ETO)

Eto is defined as maximum evapotranspiration that occurs under given climatic conditions with a field having well watered agricultural crop, such alfalfa or Lucerne of the 30-50cm, of top growth. Monthly Eto of the command area is given in tables 2.

10.5.2 CROP-COEFFICIENTS(Kc)

For converting Eto values into Et for crop, suitable crop coefficients i.e. constant factor should be evolved for the crops at different growth stages. The monthly Kc values for some of the rabi crops are given in table 3. The amount of water needed to meet the crop water requirement any amount for land preparation in the command areas of minor-1 and 2 are given in table 5A and 6A respectively.

10.5.3 EFFECTIVE RAINFALL

Effective rainfall means only a portion of total rainfall. In its simplest sense, effective rainfall means useful for utilizable rainfall by the crop. The calculation of monthly effective rainfall is given in table 4. The effective rainfall in season is also shown in the water budgeting tables. Irrigation efficiency is normally expressed in terms of amount stored in the root zone as a percentage of total water released. The efficiencies in the minor command are as :-

Conveyance efficiency(Ec) of minors	=	90 %
Field channel efficiency (Eb)	=	80 %
Field application efficiency(Ea)	=	70 %
The over all efficiency of minors are	=	Ec. Eb. Ea
	=	.9x.8x.7=0.5 or 50 %

Based on the above data collection and preliminary calculations, monthly water budgeting(ten days) tables can be prepared.

10.5.4 SCHEDULING

With the help of these monthly water budget tables, the net irrigation requirement mm/day, net and gross water delivery in canals can be calculated. The unit description is given in table 7. The tables 5B and 6 B gives the month wise (ten daily) account of water release from the minor 1 and 2 respectively for the rabi season. Keeping in mind that the canals will either be design discharge. In order to prepare a schedule for the canal operation, water deliveries at FSL for the number of days per month are calculated. Depending upon the selected interval of irrigation (which should be generally a function of irrigation moisture retention) the duration of ON/OFF operations is developed. The desired interval in the tables 5B and 6B was of 10 days. In many canal schedules the weekly intervals are also adopted.

10.6 A CASE STUDY

National Water Management Project, New Delhi, conducted a case study for Bhadra

Reservoir Project of Karnataka State. The objective of the case study was to increase the efficiency of water use by - estimating crop water demands, improve the canal operational procedures and monitoring of water distribution. In this case study, the distributory wise graphics, of the project were prepared for month wise supply of water versus requirements. Some of the graphics are discussed below.

The graphic for 6/2 scouring sluice, show the actual flow VS advised flow chart for the Kharif season 1990. This graphic shows that the actual supply of water from this distributory was the same in all months from June to November. The supply nearly matched with the demand for the months June July and September only where as the supply was much less than the required demand for the months of August, October and November. The graphic for the distributory 17, show that the actual supply was much less than requirement except for the month July. These graphic show that many times there was a wide gap between actual and required supply of water from the canals. This clearly indicate that considerable amount of water can be saved and its best use can be made by effective, monitoring of water supply versus crop water requirements to increase the crop production in the command area.

Table 1 : The cropping patterns in the command area of minor 1 and 2

Minor No. 1	
C.CA.	1000 Ha.
I.C.A.	900 HA.(90%)
Cropping Pattern	
a. Wheat	40%, 400 Ha.
b. Mustard	30% , 300 Ha.
c. Potato	10% 100 Ha.
d. Gram	5 %, 50 Ha.
e. Berseem	5%, 50 Ha.
Minor No. 2 :	
C.CA.	500 Ha.
I.C.A.	400 HA.(80%)
Cropping Pattern	
1. Wheat	30%, 150 Ha.
2. Mustard	40% , 200 Ha.
3. Gram	10 %, 50 Ha.

Table 2 : Monthly Reference Evapotranspiration(Eto) In the Command Area

S.No.	Month	Eto
1	January	3.2
2	February	4
3	March	6
4	April	7.9
5	May	9.6
6	June	9.1

7	July	6
8	August	4.4
9	September	4.7
10	October	4.9
11	November	4
12	December	3.5

Table 3 : Monthly Crop Coefficents(Kc) for some Rabi Croops.

Month	Wheat	Mustard	Potato	Gram	Berseem
October	-	0.3	-	0.3	0.4
November	0.4	0.5	0.5	0.5	0.8
December	0.7	0.8	0.8	0.7	0.8
January	1.0	0.8	1.2	0.7	1.1
February	1.2	0.5	1.2	0.5	1.2
March	0.6	-	0.9	0.3	0.9
April	0.2	-	0.7	-	0.6

Table 4 : Monthly Effective Rainfall

Monthly Normal Rainfall R/mm	Av. Monthly Consumptive use in mm.							
	25	50	75	100	125	150	175	200
	Monthly Effective rain fall (mm) Re.							
25	15	17	18	18	19	20	21	22
50	25	33	35	36	37	40	41	44
75	42	47	51	54	56	58	61	65
100		50	65	69	73	75	79	83
125		81	75	83	89	91	96	102
150			124	97	104	106	113	120
175				100	117	120	128	136
200				162	125	131	140	148
225					200	142	152	162
250						148	164	175
275						150	173	188
300						260	175	195
350							290	200
								300
	25	50	75	100	125	150	175	200

Correction Factor :

Net depth of water application mm.	Multiplication Factor
25	0.77
50	0.90
75	1.0
100	1.02
125	1.04
150	1.06

Table No. 5A : Water Budget table for Rabi Crop for the minor no. 1(CCA=1000Ha.)

Month	Ten daily	ICA HA	Cropping Pattern (Area in Ha.)										Weigh t Kc Factor	Eto . mm day	Et. mm day	Land prep. mm/ day	Eff. Rain mm/ day	Net Irrig. mm/ day
			Wheat		Mustard		Potato		Gram		Berseem							
			Area	Kc	Area	Kc	Area	Kc	Area	Kc	Area	Kc						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
October	I	-	-	-	-	-	-	-	-	-	-	-	-	4.9	-	-	-	0
	II	350	-		300	0.3	-	-	-		50	0.4	0.31	4.9	1.5	3	-	4.5
	III	400	-		300	0.3	-	-	50	0.3	50	0.4	0.31	4.9	1.5	3	-	4.5
November	I	400	-		300	0.5	-	-	50	0.5	50	0.8	0.54	4	2.2	-	-	2.2
	II	400	-		300	0.5	-	-	50	0.5	50	0.8	0.54	4	2.2	-	-	2.2
	III	900	400	0.4	300	0.5	100	0.5	50	0.5	50	0.8	0.47	4	1.9	2	-	3.9
December	I	900	400	0.7	300	0.8	100	0.8	50	0.7	50	0.8	0.75	3.5	2.6	1.5	-	4.1
	II	900	400	0.7	300	0.8	100	0.8	50	0.7	50	0.8	0.75	3.5	2.6	-	-	2.6
	III	900	400	0.7	300	0.8	100	0.8	50	0.7	50	0.8	0.75	3.5	2.6	-	-	2.6
January	I	900	400	1.1	300	0.8	100	1.2	50	0.7	50	1.1	1.06	3.2	3.4	-	-	3.4
	II	900	400	1.1	300	0.8	100	1.2	50	0.7	50	1.1	1.06	3.2	3.4	-	-	3.4
	III	900	400	1.1	300	0.8	100	1.2	50	0.7	50	1.1	1.06	3.2	3.4	-	-	3.4
February	I	900	400	1.2	300	0.5	100	1.2	50	0.7	50	1.2	0.92	4	3.7	-	-	2.7
	II	900	400	1.2	300	0.5	100	1.2	50	0.5	50	1.2	0.92	4	3.7	-	-	2.7
	III	900	400	1.2	300	0.5	100	1.2	50	0.5	50	1.2	0.92	4	3.7	-	-	2.7
March	I	600	400	0.6	-	-	100	0.9	50	0.3	50	0.9	0.65	6	3.9	-	-	3.9
	II	550	400	0.6	-	-	100	0.9	-		50	0.9	0.68	6	4.1	-	-	4.1
	III	550	400	0.6	-	-	100	0.9	-	-	50	0.9	0.68	6	4.1	-	-	4.1
April	I	550	400	0.2	-	-	100	0.7	-	-	50	0.6	0.32	7.9	2.5	-	-	2.5
	II	50	-	-	-	-	-	-	-	-	50	0.6	0.6	7.9	4.7	-	-	4.7
	III	50	-	-	-	-	-	-	-	-	50	0.6	0.06	7.9	4.7	-	-	4.7

Table 5B - Canal Scheduling of Minor No.: 1 of Rabi Crop, CCA 1000 Ha.

Month	Ten Daily	ICA Ha.	NIR mm/ day	Net Irrig. Supply m^3 /sec.	Net Irrig. supply cusec.	Gross Irrig. Cusec.	Maximum capacity Cusec.	Water supply at FSL days/ month	Recommended operation plan at FSL
October	I	-	-	-	-	-	25Cusec	-	-
	II	350	4.5	0.18	6.3	12.6	-	10	ON
	III	350	4.5	0.2	7	14	-	-	OFF
November	I	400	2.2	0.1	3.5	7	-	17	ON
	II	400	2.2	0.1	3.5	7	-		OFF
	III	900	3.9	0.41	14.3	28.6	-		ON
December	I	900	4.1	0.43	15	30	-	27	ON
	II	900	2.6	0.27	9.5	19	-		ON
	III	900	2.6	0.27	9.5	19	-		ON
January	I	900	3.4	0.35	12.3	24.6	-	30	ON
	II	900	3.4	0.35	12.3	24.6	-		ON
	III	900	3.4	0.35	12.3	24.6	-		ON
February	I	900	2.7	0.28	9.8	19.6	-	24	ON
	II	900	2.7	0.28	9.8	19.6	-		ON
	III	900	2.7	0.28	9.8	19.6	-		ON
March	I	600	3.9	0.27	9.4	18.8	-	27	ON
	II	550	4.1	0.26	9.1	18.2	-		ON
	III	550	4.1	0.26	9.1	18.2	-		OFF
April	I	550	2.5	0.16	5.6	11.2	-		OFF
	II	50	4.7	0.3	1	2	-		OFF
	III	50	4.7	0.03	0.1	0.2	-		OFF
								135days	140days

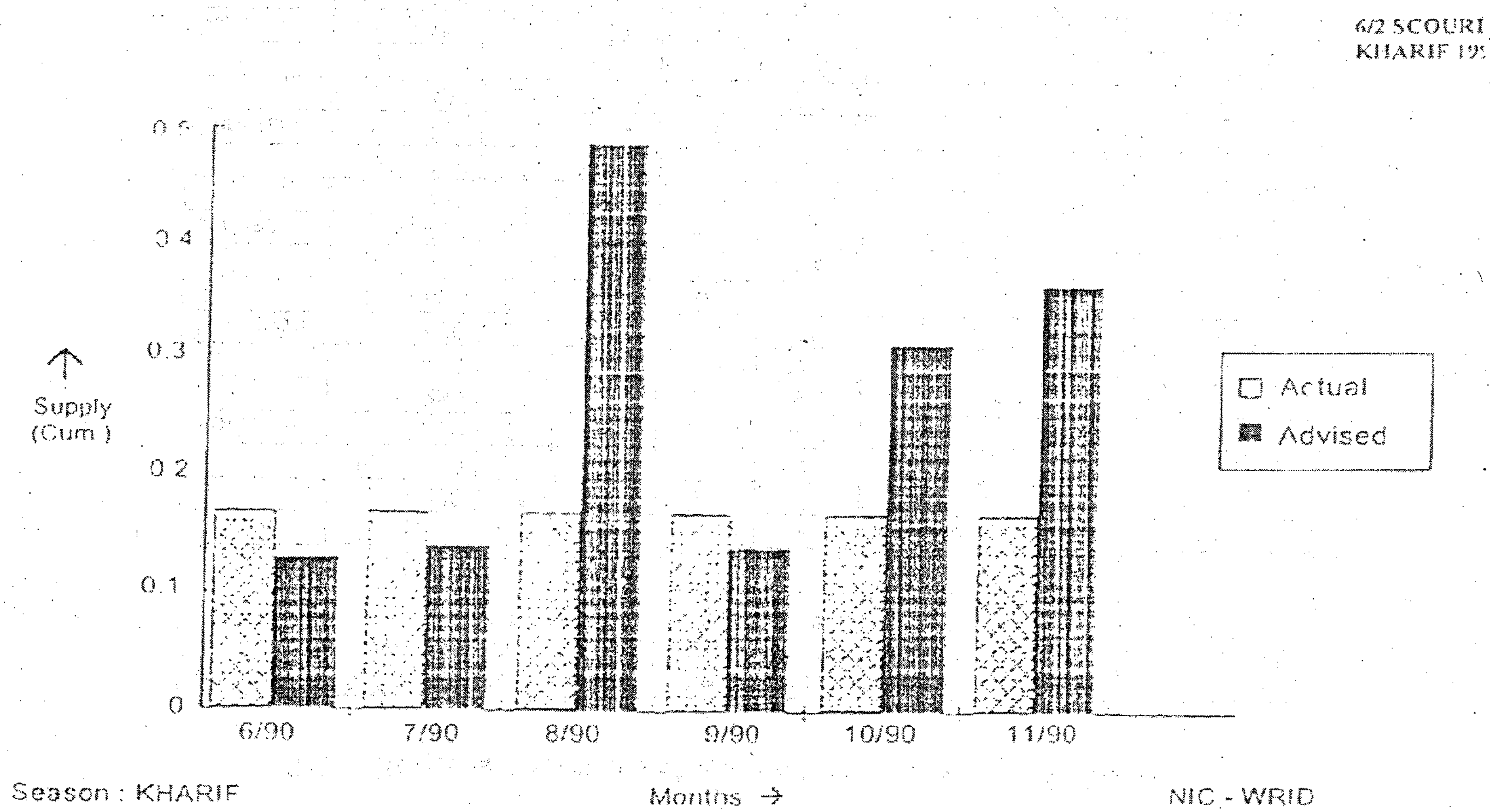
Table No. 6A : Water Budget table for Rabi Crop for the Minor No. 2(CCA=500Ha.)

Month	Ten daily	ICA HA	Cropping Pattern (Area in Ha.)						Weight Kc Factor	Eto. mm day	Et. mm day	Land prep.m m/ day	Eff. Rain mm/ day	Net Irrig.m m/ day
			Wheat		Mustard		Gram							
			Area	Kc	Area	Kc	Area	Kc						
1	2	3	4	5	6	7	8	9	14	15	16	17	18	19
October	I	-	-	-	-	-	-	-	-	4.9	-	-	-	-
	II	200	-	-	200	0.3	-	-	0.3	4.9	1.5	3	-	4.5
	III	250	-	-	200	0.3	50	0.3	0.3	4.9	1.5	3	-	4.5
November	I	250	-	-	200	0.5	50	0.5	0.5	4	2	-	-	2
	II	250	-	-	200	0.5	50	0.5	0.5	4	2	-	-	2
	III	400	150	0.4	200	0.5	50	0.5	0.46	4	1.8	2	-	3.8
December	I	400	150	0.7	200	0.8	50	0.7	0.75	3.5	2.6	1.2	1	2.8
	II	400	150	0.7	200	0.8	50	0.7	0.75	3.5	2.6	-	1	1.6
	III	400	150	0.7	200	0.8	50	0.7	0.75	3.5	2.6	-	1	1.6
January	I	400	150	1.1	200	0.8	50	0.7	0.9	3.2	2.9	-	-	2.9
	II	400	150	1.1	200	0.8	50	0.7	0.9	3.2	2.9	-	-	2.9
	III	400	150	1.1	200	0.8	50	0.7	0.9	3.2	2.9	-	-	2.9
February	I	400	150	1.2	200	0.5	50	0.5	0.76	4	3	-	-	3
	II	400	150	1.2	200	0.05	50	0.5	0.76	4	3	-	-	3
	III	400	150	1.2	200	0.5	50	0.5	0.76	4	3	-	-	3
March	I	200	150	0.6	-	-	50	0.3	0.52	6	3.1	-	-	3.1
	II	150	150	0.6	-	-	-	-	0.6	6	3.6	-	-	3.6
	III	150	150	0.6	-	-	-	0.6	0.6	6	3.6	-	-	3.6
April	I	150	150	0.2	-	-	-	-	0.2	7.9	1.6	-	-	1.6
	II	-	-	-	-	-	-	-	-	-	-	-	-	-
	III	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 6B - Canal Scheduling of Minor No.: 2 of Rabi Crop, CCA 500 Ha.

Month	Ten Daily	ICA Ha.	NIR mm/ day	Net Irrig. Supply m^3 /sec.	Net Irrig. supply cusec.	Gross Irrig. Cusec.	Maximum capacity Cusec.	Water supply at FSL days/ month	Recommended operation plan at FSL
October	I	-	-	-	-	-	10Cusec	-	OFF
	II	200	4.5	0.1	3.5	7	-	16	ON
	III	250	4.5	1.13	4.5	9	-		ON
November	I	250	2	0.06	2.1	4.2	-		ON
	II	250	2	0.06	2.1	4.2	-	21	OFF
	III	400	3.8	0.18	6.3	12.6	-		ON
December	I	400	2.8	0.13	4.5	9	-		OFF
	II	400	1.6	0.07	2.4	4.8	-	19	ON
	III	400	1.6	0.07	2.4	4.8	-		ON
January	I	400	2.9	0.13	4.5	9	-		ON
	II	400	2.9	0.13	4.5	9	-	27	ON
	III	400	2.9	0.13	4.5	9	-		ON
February	I	400	3	0.14	4.9	9.8	-		ON
	II	400	3	0.14	4.9	9.8	-	29	ON
	III	200	3	0.14	4.9	9.8	-		ON
March	I	150	3.1	0.07	2.4	4.8	-		ON
	II	150	3.6	0.06	2.1	4.2	-	15	OFF
	III	150	3.6	0.06	2.1	4.2	-		OFF
April	I	-	1.6	0.03	1	2	-		OFF
	II	-	-	-	-	-	-		OFF
	III	-	-	-	-	-	-		OFF
								127days	130days

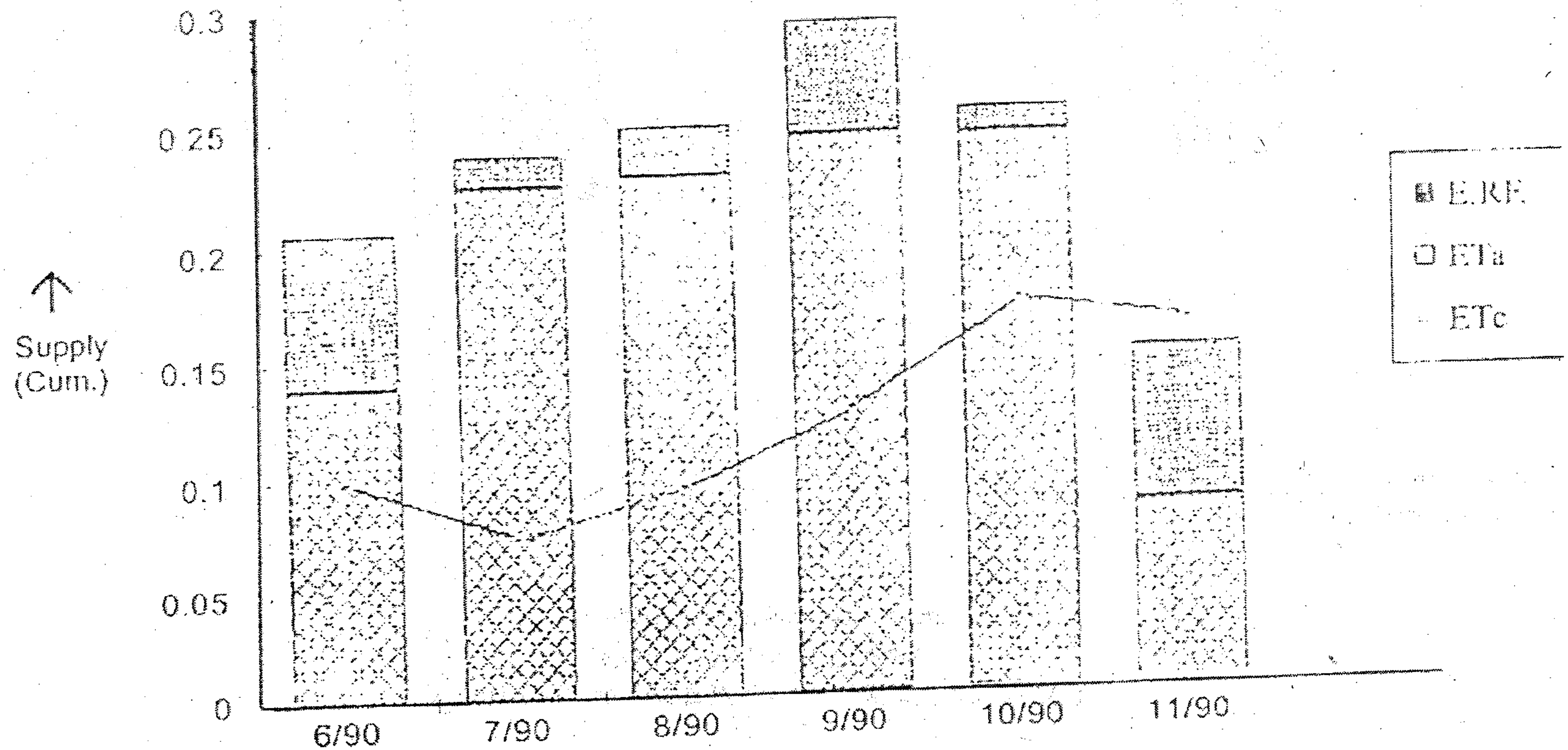
NATIONAL WATER MANAGEMENT PROJECT
Bhadra Reservoir Project
(Supply Vs Advised Flow Chart



NATIONAL WATER MANAGEMENT PROJECT
Bhadra Reservoir Project
(Supply Vs Advised Flow Chart

KHARIF 1990-91

DISTRIBUTARY 9



NATIONAL WATER MANAGEMENT PROJECT
Bhadra Reservoir Project
(Supply Vs Advised Flow Chart

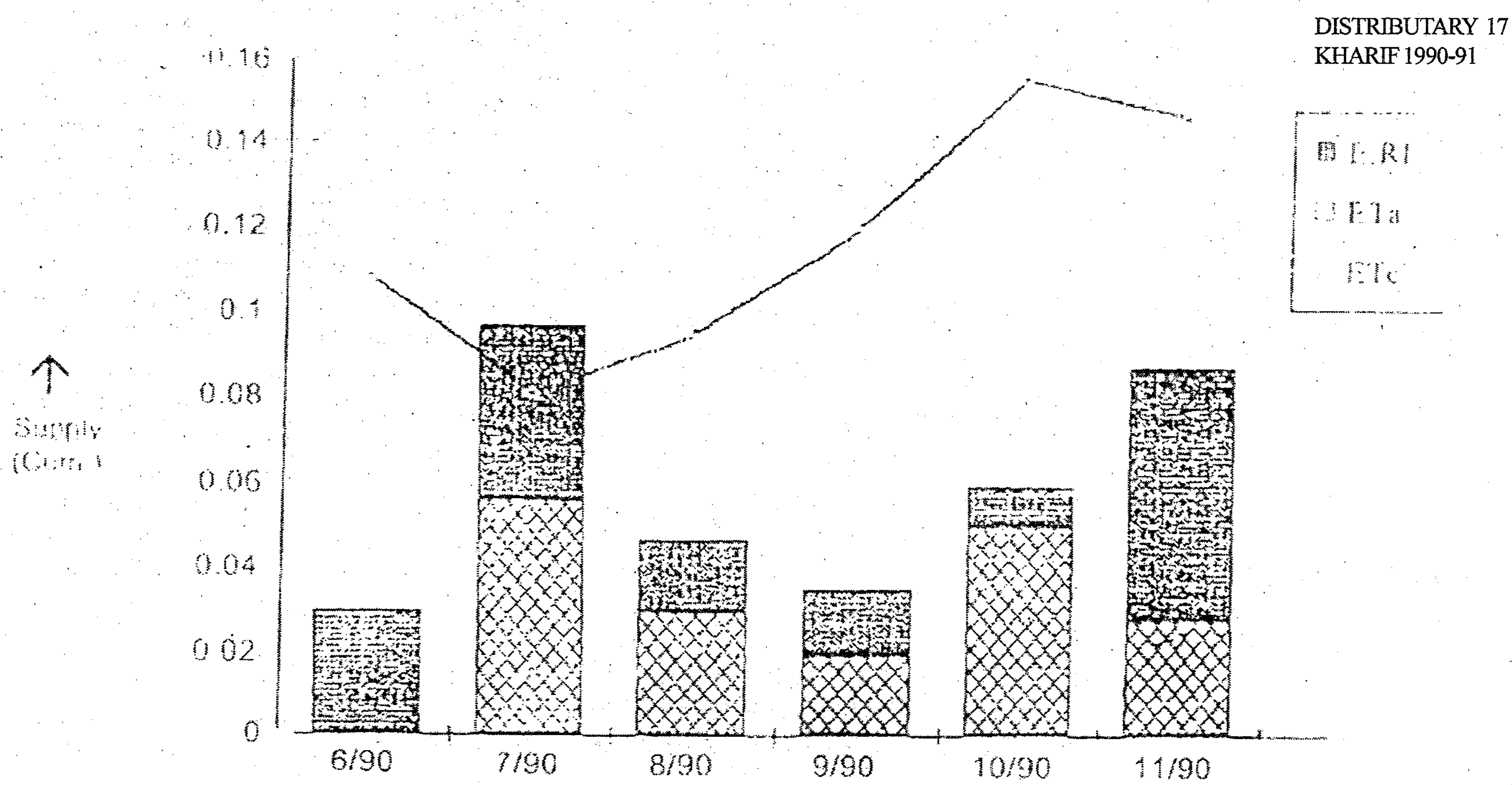


Table No. 7 Unit Description

Discharge	-	Cumecs(m^3/sec.)
Area	-	Ha = 10000 m^2
Irrigation	=	$\frac{Discharge}{Area}$
	=	$\frac{m^3/sec}{10000\ sec.m^2}$
	=	$\frac{m}{10000\ sec.}$
	=	$\frac{1000\ mm}{10000\ sec.}$
	=	$\frac{mm}{10\ sec.}$
	=	$\frac{mm}{10x1/60x1/60x1/24\ day}$
	=	(mm x8640)/day
Irrigation (mm/day)	=	$\frac{(Discharge\ in\ cumecs)x8640}{Area\ in\ Ha.}$
Discharge (Cumec)	=	$\frac{(Irrigation\ Mm\ Per\ day)\ x(Area\ in\ Ha.)}{8640}$

* 1 cumec = Cusec

10.7 SELF ASSESSMENT QUESTIONNAIRE

Now after reading this now you can understand about the principles involved in water budgeting. Please make a brief note on the following:

- What are the factors come in the water budgeting?
- How canal operation can be planned based on crop water requirements?

10.8 SUGGESTED READINGS

Michael, A.M. 1978. Irrigation - Theory and Practice. Vikas Publishing House, Pvt, Ltd.

Michael, A.M. & Ojha T.P., 1978. Principles of Agricultural Engineering, Vol-II. Jain Brothers, New Delhi.

Brouwer, C., International Institute for Land Reclamation and improvement. Irrigation Water Management Training Manual no.5- Irrigation Methods., FAO, Land and Water Development Division.

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