सत्यमेव जयते

GOVERNMENT OF INDIA

MINISTRY OF WATER RESOURCES

COMMON GUIDELINES FOR PREPARATION OF SCHEME ON MANAGEMENT OF DECLINING GROUND WATER TABLE FOR SUSTAINING FOOD PRODUCTION IN STATES OF PUNJAB, HARYANA AND WESTERN UTTAR PRADESH

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FOREWORD

Groundwater has played a significant role in steadily improving the country's agricultural economy. It is contributing about 50 percent of irrigation water, 80 percent of water for domestic use in rural areas and 50 percent of water for urban and industrial areas. Because of its easy availability and reliability, this resource has been indiscriminately exploited for irrigated agriculture in many parts of the country without regard to the quantum of its annual recharge through natural processes. This has resulted in sharp decline in groundwater table posing serious problems in sustaining food production. Food production is also declining in areas affected by waterlogging and the associated problem of soil salinity. The problem is particularly acute in some parts of the command areas of a number of major and medium irrigation projects.

Artificial recharge of groundwater, reclamation of waterlogged areas, enforcement of appropriate regulatory measures, demand side management and training of key stakeholders especially the farmers on conservation and efficient use of water, is a viable option for proper groundwater management. While scientific methods for planning, design and implementation of artificial recharge and anti-waterlogging measures have been developed and successfully implemented in many parts of the country, there has been a long felt need for evolving common guidelines for preparation of schemes for groundwater management on a large scale in diverse geo-climatic conditions. The objective of the guidelines is to ensure uniformity in formulation of groundwater management schemes and also to provide a standardized framework for their techno-economic appraisal.

These guidelines, prepared by WAPCOS Limited, adequately meet these requirements and I hope, will be useful to all those who are concerned with the onerous task of groundwater management to ensure food security on a long term sustainable basis.

BACKGROUND AND APPROACH

BACKGROUND

Haryana, Punjab and Western Uttar Pradesh covering a geographical area of 174400 sq km is popularly known as “The Food Bowl” of India. Haryana and Punjab are growing wheat and water intensive paddy in major part of their cultivated areas while in Western Uttar Pradesh besides wheat and paddy water guzzling sugarcane is also grown. Thus vast alluvial area in this region is under extensive agriculture and irrigation. Though these states have large network of canals, the area irrigated by ground water resources is over 70% mainly because of its easy availability and high reliability during the need of the local farmers.

Ground water based irrigation has led to a situation wherein, fresh ground water resources are depleting at an alarming rate, and areas underlain by brackish/saline ground water are getting waterlogged due to faulty management in neighbouring canal commands in the south western parts of the Punjab and west-central parts of Haryana. The phenomena of declining of water table and degradation of land by water logging and salinity are likely to reduce the food-grain production by 25%. It is also a question of losing farm income and overall livelihood of rural dwellers.

While anti-waterlogging measures are already being implemented by the state governments under the Command Area Development Programme, the problem of declining ground water table still needs to be addressed on a large scale, for which Detailed Project Reports (DPRs) are required to be prepared by the state governments based on detailed scientific studies. In order to ensure uniformity in preparation of DPRs, this Ministry has prepared these Guidelines which, for the present, are meant for the states of Punjab, Haryana and Western Uttar Pradesh but could also be replicated in rest of the country, if necessary.

APPROACH FOR PREPARING THE DPRS

The studies undertaken by the Central Ground Water Board and the State Governments indicate that the average annual decline in ground water table in Haryana, Punjab and Western Uttar Pradesh is 76 cm to 100 cm. It is obvious, therefore, that in order to prevent further decline of ground water table, artificial ground water recharge has to be done on a massive scale to match the present quantum of ground water pumping. In parallel with these measures, appropriate legislative and administrative measures have also to be taken to control and regulate further exploitation of ground water resources. Therefore, in order to achieve these objectives major schemes with large geographical coverage have to be taken up and completed in a time bound manner. A clear distinction has to be made between these schemes and small water harvesting schemes that are implemented under watershed development programmes of the Ministry of Agriculture, Rural Development, Environment & Forests etc. and under Mahatma Gandhi National Rural Employment Guarantee Act (MNAREGA). However, for integrated development, the major schemes and small schemes have to be complementary and not mutually exclusive, but care needs to be taken to ensure that there is no duplication of effort.

In the command areas of some canal systems, there is serious problem of waterlogging and resultant soil salinity which is adversely affecting food production. Since remedial measures for such problems are taken under the command area development programmes, this aspect is not required to be covered in the DPRs.

Conjunctive use of surface and ground water aims at environment friendly and balanced use of waters from the two sources. This is essentially intended to prevent over exploitation of ground water and is therefore not relevant in the context of the situations where this resource is already over exploited and corrective measures on a large scale are required to be taken. This aspect, therefore, need not be covered in the DPRs.

RATIONALE FOR SEPARATE GUIDELINES

This Ministry has already issued "Guidelines for preparation of Detailed Project Reports of Irrigation and Multipurpose Projects" which, interalia, aim at optimal utilization of surface and ground water resources to achieve the developmental objectives in these sectors. Corrective measures to deal with the problem of declining ground water table are not treated as part of developmental planning and design. In fact conjunctive use of surface and ground water is required to be considered in planning and design of irrigation and multipurpose schemes to prevent decline in ground water table. Separate guidelines are, therefore, required for preparation of DPRs for large scale corrective measures, both structural and non-structural, to prevent further decline in ground water table where this resource is already over exploited, but its continued utilization is necessary for sustaining the current level of food production.

However, in preparing these guidelines, care has been taken to ensure that these are neither in conflict with various other guidelines issued by this Ministry and other Government Departments nor encroach upon their scope and operational jurisdiction. In this context, the objective and scope of some of the relevant Guidelines are briefly discussed below:

(i) Command Area Development and Water Management Programme (CAD&WM)

This programme is to be implemented in a holistic manner so that it not only improves water use efficiency but also increases agricultural productivity and brings sustainability in irrigated agriculture in a participatory environment. The main elements of the guidelines are:

(a) Criteria for inclusion of the project under CAD&WM Programme
(b) Funding Pattern
(c) Procedure for release of Central Assistance
(d) Monitoring and Evaluation

These guidelines stipulate preparation of DPR for projects under CAD&WM and also specify a format for the DPR. The format does not cover the aspect of declining ground water table. It, however, covers interalia, “Reclamation of Waterlogged areas”.

(ii) Accelerated Irrigation Benefits Programme (AIBP)

These guidelines are for funding of Major, Medium and ERM of irrigation projects which are in advanced stages of construction, and surface water minor schemes of North-Eastern and Hilly states and undivided Koraput, Balangir, Kalahandi (KBK) districts of Odisha so that irrigation benefits start accruing within the next four financial years and next two financial years respectively. During XII Plan, for non special category states, the individual surface Minor Irrigation Scheme having CCA of 20 hectare and cluster of Minor Irrigation within a radius of 5 km total CCA of 50 hectare benefitting tribal areas, drought prone areas, desert prone areas and left Extremism affected areas will be eligible of assistance under AIBP. The Schemes to the taken will be decided in consultation with Planning Commission. The key elements of the guidelines are:

(a) Eligibility criteria for funding
(b) Terms of funding and mode of disbursement
(c) Monitoring of projects
(d) Formats of MoUs to be signed between the State Government concerned and MoWR
(e) Format for undertaking to be given by the State Government concerned for inclusion of new Surface Minor Irrigation Schemes

Schemes that are meant to address the problem of declining ground water table are not eligible for funding under AIBP.

(iii) Minor Irrigation

Minor irrigation schemes, with a CCA of upto 2000 ha, utilize surface or ground water or both. The problem of declining ground water is not resolved under such schemes.

For Minor Irrigation Schemes following guidelines have been issued:

(a) Guidelines for filling of Quarterly Progress Reports and Annual Progress Reports
(b) Guidelines for inspection by Supervisors
(c) Guidelines to destroy Minor Irrigation Sensus records

(iv) National Rural Employment Guarantee Scheme (NREGS)

This scheme under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) enacted in August 2005, provides a legal guarantee for 100 days of employment in every financial year to adult members of every rural household at a statutory minimum wage. The assured employment is for unskilled manual work on certain types of public works which include the schemes relating to water and related sectors such as the following:

(a) Water conservation and water harvesting including contour trenches, contour bunds, boulder checks, gabion structures, underground dykes, earthen dams, stop dams and springshed development;
(b) Drought proofing including afforestation and tree plantation;
(c) Irrigation canals including micro and minor irrigation works
(d) Provision of irrigation facility, dug out farm pond, horticulture, plantation, farm bunding and land development
(e) Renovation of traditional water bodies including desilting of tanks
(f) Flood control and protection works including drainage in water logged areas including deepening and repairing of flood channels, chaur renovation, construction of storm water drains for coastal protection;

These works are carried out by different Departments of the State Governments under diverse funding arrangements. Though some of these works are intended to augment ground water recharge, these are not designed for large scale recharge to match the enormous amount of irrigation pumping on a long term sustainable basis.

(v) Watershed Development Projects

The guidelines issued by the National Rainfed Area Authority stipulate the following criteria for selection and prioritization of watershed development projects:

(a) Acuteness of drinking water scarcity.
(b) Extent of over exploitation of ground water resources
(c) Preponderance of wasteland/degraded lands.
(d) Contiguity to another watershed that has already been developed/treated.
(e) Willingness of village community to make voluntary contribution, enforce equitable social regulations for sharing of common property resources, make equitable distribution of benefits, create arrangements for the operation and maintenance of the assets created.
(f) Proportion of schedule caste/schedule tribes
(g) Area of the project should not be under assured irrigation.
(h) Productivity potential of the land.

Under the Watershed works, following activities are included:

(a) Ridge Area Treatment:

- Regeneration of vegetative cover in forest and common lands
- Afforestation
- Staggered trenching
- Contour and graded bunding
- Bench terracing

(b) Drainage Line Treatment

- Earthen checks
- Brushwood checks
- Gully plugs
- Loose boulder checks
- Gabion structures
- Underground dykes

(c) Water Harvesting Structures such as low cost

- Farm ponds
- Nalla bunds
- Check dams
- Percolation tanks
- Groundwater recharge through wells, borewells and other measures.

(d) Land development including in situ soil and moisture conservation and drainage measures.

It would be clear from the above guidelines that the watershed development programme does not envisage large scale ground water recharge to match the enormous amount of irrigation pumping on a long term sustainable basis.

NATURE OF GUIDELINES

These guidelines are secular in nature dealing with technical, socio-economic and environmental aspects to be considered in preparing the schemes, and are not linked/affiliated with any of the schemes or funding mechanisms of Government of India.

SECTION-1

CHECKLIST

1.	Has the need for Artificial Recharge been Properly established, especially in the context of sustaining food production	
2.	In case the project area has the problem of waterlogging, have appropriate measures for reclamation been proposed	
3.	Have the issues concerning clearance of the scheme by competent authority been addressed on the following points? a) Economic viability b) Subsidy if proposed c) Sharing of costs d) Sharing of benefits e) Acceptance of submergence area f) Compensation of land required to be paid for acquisition g) Any other issues	
4.	Has the concurrence/clearance from the Department dealing with source water e.g. Canal/River/Stream water been obtained.	
5.	Meteorological & hydrological surveys: have the following factors been taken into account? a) Rainfall, rainy days, rainfall intensity etc. b) Evaporation/ Evapotranspiration c) Availability of surplus water d) Yield of basin and flood for designing spillways e) Sediment load	
6.	Field surveys Have the following surveys been carried out? a) Regional Hydrogeological survey b) Detailed site hydrogeological survey c) Soil survey d) Infiltration studies	
7.	For construction of structures A. Have the following investigations been carried out? a) Foundation conditions of check dams, percolation tanks, bunds, reservoirs, nala bunds b) Sub-surface strata conditions for Recharge wells, underground dams (Sub-Surface dykes)	

	c) Spillway design B. Material survey a) Soils for impervious, semi pervious, pervious zones of surface/sub-surface dams b) Sand/rock/bricks and tiles (for wells) c) Cement d) Steel/Steel pipes/Slotted pipes/well screens	
8.	Land acquisition a) Have the land acquisitions required for structures, inundation and source water supply channel/pipe line been decided? b) Has the modalities of acquisition of land been discussed?	
9.	Design a) Has the final location of each structure been decided? b) Has the layout of structures been marked out? c) Have the design details of individual structures been finalised?	
10.	Construction Programme schedules: a) Has the proposed construction programme been prepared and synchronised for timely construction? b) Have the Agencies undertaking the work been identified?	
11.	Have the demand side management measures been discussed in detail such as: i) Changes/modifications in cropping pattern ii) Changes in irrigation practices such as switch over to drip/sprinkler/micro-sprinkler system	
12.	Has the quality of ground water been ascertained and found suitable for application to agricultural fields. In case the quality is poor, have remedial measures been specified.	
13.	Have the water conservation measures such as the following, been discussed with specific proposals: i) Minimising losses in conveyance/distribution systems, field channels/water courses etc. ii) Improving water use efficiency through a) Improved agricultural practices b) Improved methods of water application in the field	
14.	Has a detailed proposal for IEC activities and training of farmers and NGOs been given together with estimated	

	cost	
15.	Has specific proposal for O&M of artificial recharge structures been given	
16.	Has a proposal for training of personnel responsible for formulating the scheme been given	
17.	Has a programme of monitoring the performance of the scheme been discussed	
18.	Has a proposal for institutional strengthening at the grass-root level been given such as a) Formation/strengthening of WUA b) Formation of Self-Help Groups etc.	
19.	Have the cost estimates for all the structural and non-structural measures proposed been given	
20.	a) Are the cost estimates based on the schedule of rates b) For items not covered in the schedule of rates, have rate analysis been given	
21.	Financial resources a) Have the yearwise requirement of funds been worked out? b) Have the sources of funds been identified?	
22.	Ecological Aspects Is the area going to experience any of the following environmental/ecological problem? a) Inundation of habitated land b) Creation of water logging c) Deterioration of quality of groundwater	
23.	Public Participation, Cooperation a) Have the implications of the scheme been explained and discussed with the local population? b) Have the aspects of the scheme involving people's active participation been worked out?	
24.	Have the linkages of the scheme with various other schemes of the Central /State governments and district administration been clearly established to avoid duplication and/or overlapping of activities.	

SECTION-2

SALIENT FEATURES

The following salient features and any others as applicable to the scheme shall be furnished:

1. **Name of the scheme**

2. **Location**
    a. State
    b. District
    c. Taluka/Block
    d. Village(s)

3. **Scheme area with reference to**
    a. Degree Sheets
    b. Index Plan

4. **Cultivated area under the scheme (hectare)**
    a. Under the command of an irrigation scheme
    b. Rainfed cultivated area
    c. Total cultivated area

5. **Food grain crops (Average for the last 5 years)**
    a. Area (hectare)
    b. Crop yields (tonnes/annum)
        - Crop – 1
        - Crop – 2
        - Crop – 3 etc.

6. **Non-food grain crops (Average for the last 5 years)**
    a. Area (hectare)
    b. Crop yields (tonnes/annum)
        - Crop – 1
        - Crop – 2
        - Crop – 3 etc.

7. Irrigation water requirement (annual)

a. Food crops (MCM)

b. Non-food crops (MCM)

c. Total (MCM)

8. Water requirement for other uses (annual)

a. Domestic both urban and rural (MCM)

b. Industry (MCM)

c. Any other (MCM)

d. Total (MCM)

9. Total annual water requirement for all uses (7.C+8.d, MCM)

10. Total annual water availability from all sources

a. Surface water

b. Ground water

c. Total

11. Net annual water deficit, if any (9 – 10.c)

12. Water quality problem, if any

a. Bacteriological pollution

b. Chemical pollution

13. Groundwater depletion in terms of lowering of water level during the last 10 years (m)

14. Proposed structural measures for ground water recharge

a. Type 1 - No.

b. Type 2 - No.

c. Type 3 - No etc.

15. Proposed non-structural measures

a. Demand side management (Type of measures)

b. Water conservation measures (Type of measures)

c. IEC activities (Type/nature)

d. Training programme for farmers (Number and coverage)

e. Institutional strengthening (Nature/number)

16. Expected recharge benefits (MCM/annum)

17. Estimated cost of scheme

18. Economic analysis

- B-C. Ratio
- IRR

19. Annual phasing of expenditure

20. Apportionment of cost among different agencies.

21. Socio-Environmental impacts.

SECTION-3

REPORT

Chapter 1. Introduction

Following important items and additional items, if any, relevant to the scheme shall be discussed briefly under this chapter:

1.1 Aim (s) of the scheme and the context

1.2 Location of the scheme including longitude and latitude and district (s), block (s), basin/sub-basin/watershed.

1.3 General climatic conditions of the district and scheme area in particular.

(i) Type of climate such as:

(a) Humid

(b) Sub-humid

(c) Arid

(d) Semi arid

(ii) Rainfall

(a) Average annual

(b) Rainfall distribution

(c) Number of rainy days

(iii) Temperature

(iv) Humidity

(v) Potential Evapo-transpiration (PET)

(vi) Wind: Velocity, direction

(vii) Solar radiation: Sunshine hours, intensity etc.

1.4 General description of topography and physiography

(i) Elevation range (maximum, minimum and general)

(ii) Landform such as:

(a) Hilly

(b) Highly disected plateau

(c) Moderately disected plateau

(d) Pied mont zone/Foot hill zone

(e) Ravinous terrain

(f) Valley slopes

(g) Plain area

(h) Sand dune area

(i) Delta region

(j) Coastal plains

(k) Karstitic terrain

1.5 Population

(i) Affected (no.)

(a) General

(b) S.C.

(c) S.T.

(d) O.B.C.

(e) Total

(ii) Benefited (no.)

(a) General

(b) S.C.

(c) S.T.

(d) O.B.C.

(e) Total

(iii) Occupation (no.)

(a) Agriculture

(b) Other than agriculture

1.6 Land use and socio-economic aspects (including tribal, backward and drought prone areas)

Chapter 2. Agriculture

Details of the following important items shall be discussed under this chapter.

(i) Soil type, thickness and extent

(ii) Cropping pattern

(iii) Area under irrigation

(a) Surface water

(b) Ground water

(iv) Methods of water application in the fields

Chapter 3. Crop yields

(i) Following important items and additional items relevant in the context of food production and rural income generation shall be discussed in this chapter. Details of food crops and non-food crops shall be given separately:

(a) Kharif crops

(b) Rabi crops

(c) Summer/hot weather crops

Following details for each crop shall be given:

- Name of crop
- Area under each crop (ha)
- Crop yield per hectare
- Total crop yield
- Value of each crop (Rs.)
- Total value of crop
    - Food crop
    - Non-food crop

(ii) Overall trend of food production shall be given for the last at least five years and a reasonable target for sustainable food production shall be indicated to serve as the basis for arriving at irrigation water requirement

(iii) Reasonable targets for sustainable production of non-food crops shall be given in the context of improving income of the farmers

Chapter 4. Requirement for various uses

Following items and additional items, if any, relevant to the scheme shall be discussed in this Chapter:

(i) Present water requirement for

(a) Irrigation

(b) Domestic uses

(c) Industry

(d) Any other

(ii) Future water requirement for

(a) Irrigation

(b) Domestic uses

(c) Industry

(d) Any other

Chapter 5. Water availability

Following items and additional items, if any, relevant to the scheme shall be discussed under this chapter:

(i) Water availability from surface water sources for different dependabilities such as 100%, 90%, 75%, 25%, etc. in the context of various existing and committed uses.

Actual water availability due to existing interstate Agreements, awards by Tribunals, inadequate capacity of canal system etc shall also be discussed together with details of water supply actually received during the last 5 years.

(ii) Details of water availability from various ground water sources during the last 5 years.

(iii) Net water balance monthwise or crop season wise separately for the present and future scenarios, highlighting the need for augmentation of water supply for

(a) Irrigation

(b) Other uses

(c) Total

Chapter 6. Need for augmentation of Water Supply

Following items and additional items, if any, relevant to the scheme shall bediscussed in this chapter:

(i) Augmentation of supply from surface water sources:

(a) Possibility of additional supplies from existing sources/systems
(b) Feasibility of developing new sources under other schemes eg.
  - Schemes under construction
  - Proposed schemes under advanced stages of planning and design
(c) Total augmentation due to (a) and (b).

(ii) Augmentation of supply from ground water sources:

Following aspects shall be examined and discussed:

(a) Present stage of development of ground water in the district especially in the project area clearly highlighting the limitation for further development through additional ground water structures

(b) Extent of augmentation required through artificial recharge of ground water

In the overall context of the above studies, following technical details shall be discussed.

- Hydrogeological set up
  - Water bearing properties of litho units
  - Depth to water levels and seasonal fluctuations (pre-monsoon and monsoon)
  - Water table contours
  - Long term water level trends.

- Ground water resource availability
  - Location (shallow and deep) and extent of potential water bearing strata/aquifer based on field observation/tests
  - Quantum available (based on "Ground Water Resource Estimation Methodology")
  - Status of present utilization.

- Ground water development prospects

  (Ground water Report for the district concerned prepared by Central Ground Water Board and /or State Ground Water Board may be referred for guidance)

Note: Also refer Para 7 – Hydro-geology.

Chapter 7. Hydro-geology

Following important items and additional items, if any, relevant to the scheme shall be discussed in this chapter:

(i) Geological formations

(ii) Major rock types

(iii) Structural features

(iv) Nature of vadose zone/unsaturated zones

- **(a)** Moisture conditions
- **(b)** Presence/absence of impervious layers in Vadose zone (ie hard pans)

(iv) Aquifer systems

- **(a)** Phreatic
- **(b)** Semi confined
- **(c)** Confined

(v) Depth of aquifer zones

(vi) Hydraulic characteristics of aquifers

- **(a)** Transmissivity
- **(b)** Storavity/specific field
- **(c)** Hydraulic conductivity

(vii) Aquifer boundaries

(viii) Depth of water level and its seasonal fluctuations

(ix) Ground Water structures

(a) Type, number

(b) Depth range

(c) Yield range

(d) Aquifer tapped

(x) Ground Water resources

(a) Annual recharge

(b) Annual draft

(c) Stage of ground water development

(xi) Ground water level trends

(xii) Potential for artificial recharge

Chapter 8. Ground water

Following items and additional items, if any, relevant to the scheme shall be discussed in this chapter:

(i) Unconfined and confined aquifers

(a) Potable

(b) Brackish

(c) Saline

(ii) Any special problem (Sea water intrusion, bacteriological/chemical pollution, high fluoride high Arsenic etc.)

Chapter 9. Need for artificial recharge of Ground water

Following items and additional items, if any, relevant to the scheme shall be discussed in this chapter, with reference to the studies specified in paras 6, 7 and 8.

(i) Quantification of water shortage

(a) Quantification of water shortage for different uses

(b) Period of shortages

(c) Location of deficit areas

(ii) Quality problem

(a) Control of sea water intrusion

(b) Dilution of chemical pollution due to natural causes

(iii) Special problem

(a) Control of land subsidence

(b) Water logging

(c) Soil salinity/Alkalinity

(d) Sub-surface hard pan, Kankar agglomerate

(e) Any other

Chapter 10. Existing Artificial Recharge Structures and their impact

As per the "Common Guidelines for Watershed Development Projects" of Government of India (Annex VIII Para 6.5) the Gram Panchayats are required to maintain Asset Registers for watershed development projects. The Project Implementing Agency (PIA) and Watershed Committees (WC) are required to carry out Monitoring and Evaluation to ascertain that the project objectives (including increase in groundwater table) have been achieved (Annex VIII, Para 11.4 – g).

Based on the inputs from these sources following aspects shall be discussed in this Chapter:

(i) Existing artificial recharge structures: Type, location and year of construction. These structures shall be numbered, mapped and registered

(ii) Benefit in terms of increase in groundwater table

(iii) Increase in cropping intensity and agricultural productivity.

These benefits shall be duly considered in estimating the requirement of non-committed surplus water to be brought for the additional recharge structures to be constructed under the scheme.

Chapter 11. Source Water for Recharge

Following main aspects shall be discussed in this chapter:

(i) Sources of water such as:

- **(a)** Insitu precipitation in the area through rain water harvesting
- **(b)** Nearby stream/spring
- **(c)** Surface water supplies from large reservoirs located within a reasonable distance
- **(d)** Surface water supplies through trans-basin water transfer
- **(e)** Any other specific source

(ii) Quantum of non-committed water available for recharge

(iii) Time for which water is available

(iv) Quality of water and pre-treatment required

(v) Conveyance system to bring the water to the proposed recharge site.

Note: For details refer Annex-I "Source Water for Recharge".

Chapter 12. Proposed Measures for Artificial Recharge

Following main items and additional items, if any, relevant to the scheme shall be discussed in this chapter:

(i) Techniques of artificial recharge suitable for various sites/locations, such as:

(A) Direct Methods (Surface Spreading)

- Flooding
- Ditch and furrows
- Run off conservation measures
    - Bench terracing
    - Contour bunds and contour trenches
    - Gully plugs, nallah bunds/field bunds

- Check dams, Gabion structures
- Percolation tanks

- Stream modification

(B) Direct Methods (Sub-Surface techniques)

- Injection wells (Recharge wells)
- Gravity head recharge wells
- Recharge pits and shafts

(C) Indirect Methods

- Induced recharge from surface water sources
- Aquifer modification
  - Bore blasting
  - Hydro-fracturing

(D) Combination Methods

- Sub-surface dykes
- Fracture sealing cementation techniques

Note: ***For details refer Annex.II "Planning of Artificial Recharge Schemes" and Annex-III "Artificial Recharge Techniques and Designs"***

(ii) Number and size of each type of recharge structure proposed

(iii) Design of structures and conveyance system required to bring the source water to the recharge site

Chapter 13. Demand Side Management Measures

Following items and additional items, if any, relevant to the scheme shall be discussed in this chapter:

(i) Water Conservation Measures

Following measures to the extent relevant and feasible shall be discussed:

- Performance improvement of irrigation system and water utilization
- Proper and timely system maintenance
- Rehabilitation and restoration of damaged/and silted canal systems to enable them to carry designed discharge
- Selective lining of canal and distribution systems, on techno-economic consideration, to reduce seepage losses
- Restoration /provision of appropriate control structures in the canal system with efficient and reliable mechanism
- Adopting drip and sprinkler systems of irrigation for crops, where such systems are suitable
- Adopting low cost innovative water saving technology
- Renovation and modernization of existing irrigation systems
- Preparation of a realistic and scientific system operation plan keeping in view the availability of water and crop water requirements
- Execution of operation plan with reliable and adequate water measuring structures
- Revision of cropping pattern in the event of change in water availability
- Utilization of return flow of irrigation water through appropriate planning
- Imparting trainings to farmers about consequences of using excess water for irrigation
- Rationalization of water rate to make the system self-sustainable

***Note: Refer Annex*-IV.**

- Formation of Water Users Associations and transfer of management to them
- Promoting multiple use of water
- Introducing night irrigation practice to minimize evaporation loss
- In arid regions crops having longer root such as linseed, berseem, lucerne guar, gini grass, etc may be grown as they can sustain in dry hot weather
- Assuring timely and optimum irrigation for minimizing water loss and water-logging
- Introducing rotational cropping pattern for balancing fertility of soil and natural control of pests
- Modern effective and reliable communication systems may be installed at all strategic locations in the irrigation command and mobile communication systems may also be provided to personnel involved with running and maintenance of systems. Such an arrangement will help in quick transmission of messages and this in turn will help in great deal in effecting saving of water by way of taking timely action in plugging canal breaches, undertaking repair of systems and also in canal operation particularly when water supply is

needed to be stopped due to sudden adequate rainfall in the particular areas of the command

- With a view to control over irrigation to the fields on account of un-gated water delivery systems, all important outlets should be equipped with flow control mechanism to optimize irrigation water supply
- As far as possible with a view to make best use of soil nutrients and water holding capacity of soils, mixed cropping such as cotton with groundnut, sugarcane with black gram or green gram or soyabean may be practised
- It has been experienced that with scientific use of mulching in irrigated agriculture, moisture retention capacity of soil can be increased to the extent of 50 percent and this in turn may increase yield upto 75 percent

(ii) Water Use Efficiency in Irrigation System

(A) Based on the available data, a broad assessment of the water use efficiency shall be carried out vis-a-vis the efficiencies considered in the design of the scheme such as:

(a) Conveyance efficiency

(b) Field channel efficiency

(c) Field application efficiency

(d) Water use efficiency for the scheme as a whole

Note: Refer Annex V

(B) Specific measures proposed for increasing water use efficiencies such as the following shall be discussed together with the time frame for their implementation

<u>Structural Measures</u>

- Regular/periodic maintenance of canals by clearing off weed/vegetation growth etc.
- Restoration of sections of all channels to their design sections
- Repair of damaged lining of canals
- Selective lining of canals in reaches with permeable soil strata
- Lining of field channels/water courses having high losses

- Regular maintenance of gates and shutters of hydraulic structures to eliminate/minimise water loss through leakages
- Repair/replacement of damaged gates/shutters
- Improving distribution networks by providing appropriate control structures in canals and distribution system
- Installation of water meters to ensure volumetric supply of irrigation water to farmers
- Restoration/rehabilitation of canal structures

Non-Structural measures

- Involvement of farmers in the management of irrigation system (Participatory Irrigation Management) – ***Refer Annex-VI.***

  The status of Water Users Association in the Command area shall be discussed with details such as the following:

  - Formation of WUAs if there are none at present
  - Strengthening and empowering the existing WUAs
  - Need for appropriate legislation and formulation of rules there under

Note: These aspects shall be discussed in greater detail in the Chapters on Institutional and legislative reforms.

- IEC activities and training of farmers in new technologies in water management

  Following aspects and additional aspects, if any, relevant to IEC activities and training of farmers shall be covered

  - Concept of water use efficiency
  - Critical stages of growth for watering the crops and their effect on yields
  - Crop species and varieties and their response to irrigation and other inputs
  - Varieties of crops suitable for local conditions
  - Time, depth and pattern of sowing of crops
  - Plant population (row spacing) and orientation and their impact on water use efficiency
  - Use of anti-transpirants to decrease transpiration
  - Mulching to improve water use efficiency

- Use of shelter belts/wind breaks
- Specific water saving techniques such as puddling of paddy fields
- Improved methods of irrigation such as:
  - Sprinkler
  - Drip
  - Micro-sprinkler
  - Land levelling and shaping
  - Construction supervision of on farm developmental works under the guidance of WUA
  - Construction supervision of water harvesting and artificial recharge schemes under the guidance of WUA

Note: The programme for IEC activities and training of farmers and their cost estimates shall be framed in consultation with the Agriculture Research Institutes, Krishi Vigyan Kendras, Water & Land Management Institutes, Extension Services of the Departments of Agriculture etc., as may be relevant and feasible.

Chapter 14. Implementation Mechanism

Specific proposals for implementation of the scheme shall be discussed covering aspects such as the following:

- Various agencies who would implement different components of the scheme
- Coordination mechanism for different activities
- Mode of implementation e.g Departmental, on Contract

Chapter 15. Implementation Schedule

This shall include time schedule of implementation of various components of the scheme.

Chapter 16. Operation and Maintenance

Specific proposals for operation and maintenance of artificial recharge structures shall be discussed in this chapter.

Note: Refer Annex VII for relevant guidelines.

Chapter 17. Impact Assessment of Recharge structures

A detailed programme of monitoring of recharge structures for assessment of their impact shall be given covering details such as but not limited to the following:

- Installation of monitoring devices for
    - Water level
    - Demarcation of zone of influence
        - Method and frequency of water level monitoring
        - Method and frequency of monitoring water quality parameters such as:
            - pH
            - EC/TDS
            - TH as $CaCO_3$
            - Ca
            - Mg
            - Na
            - K
            - CO_3
            - HCO_3
            - Cl
            - SO_4
            - NO_3
            - Fluoride

Chapter 18. Institutional Strengthening /Reforms

In the specific context of ground water management for sustainable food production in a relatively small administrative unit like a district or a block; or a hydrologic unit like a sub-watershed, the institutional strengthening/reforms at the grass-root level shall be discussed in this Chapter (Reforms/strengthening at higher levels to be taken up under the State's Water Sector Restructuring Programme).

Following main aspects shall be covered in detail.

(i) Training of personnel responsible for formulating the scheme

(ii) Formation /strengthening of Water Users Associations (WUAs) in the relevant part of the Command area of an existing irrigation project.

Following roles and responsibilities of WUA shall be discussed:

- Water allocation to WUA in different irrigation seasons
- Responsibilities of WUA
    - ➢ Receiving water from the Department and distributing the same amongst WUA members and non-members
    - ➢ Collection of water charges from the farmers and timely payment to the Department
    - ➢ Carry out normal system maintenance
    - ➢ Conflict resolution

(iii) Formation of formal and informal groups of farmers, women and self-help groups for integrated watershed management in non-command areas.

Note: ***Refer Para 6 – "Institutional arrangements at the village level and peoples participation" – Annex VIII.***

Following main functions and additional functions, if any, relevant to the scheme shall be discussed.

(a) Watershed Development & Management that may include the following:

- ➢ Afforestation
- ➢ Development of grass lands
- ➢ Contour bunding and terracing of agricultural fields
- ➢ Contour trenching
- ➢ Contour cultivation
- ➢ Strip cropping
- ➢ Gully plugging
- ➢ Stream bank protection against erosion
- ➢ Farm ponds
- ➢ Check dams
- ➢ Control and regulation of grazing

(b) Control and regulation of ground water use

(iv) Time frame for completing the reforms proposed under (i) (ii) and (iii)

Chapter 19. Legislative Reforms

Matters relating to existing ground water regulation in general and in the specific context of the proposed scheme shall be discussed together with the following:

(i) Proposed legislative reforms

(ii) Time frame for their implementation

Note: Refer Annex-IX "Draft model bill for the conservation, protection and regulation of ground water"

or

Bill passed by the state legislature on the above lines.

Chapter 20. Cost Estimate

Cost estimate of a ground water recharge scheme shall include the following:

(i) Cost of pre-investigation studies

(ii) Cost of structural measures

- **a)** Afforestation works
- **b)** Watershed management works
- **c)** Artificial ground water recharge measures
- **d)** Fabrication/installation of monitoring devices

(iii) Cost of non-structural measures

- **a)** Training of personnel responsible for formulating the scheme
- **b)** IEC activities
- **c)** Training of farmers

Chapter 21. Economic Evaluation

Economic evaluation of the scheme shall be given covering the following main aspects:

(i) Net Present Cost (NPC)

(ii) Net Present Income (NPI)

(iii) Net Present Value (NPV)

(iv) Benefit Cost Ratio (NPV/NPC)

(v) Internal Rate of Return

Note: Refer Annex X.

Chapter 22. Linkages with other schemes of Central/State Government

Linkages with various on-going and proposed schemes of Central/State governments shall be indicated so that there is no duplication or overlapping of activities such as:

(i) On-farm developmental works – These may also be included under Command Area Development Works which are usually implemented by the CADA of the state government.

(ii) Watershed Development Works – These are carried out under different programmes of the Central/State Governments depending upon their geographical or functional jurisdictions, such as:

a) Programmes of Ministry of Agriculture

- Soil conservation in the catchment of River Valley Projects
- Soil conservation in the catchment of flood prone rivers
- National Watershed Development Project for rainfed areas
- Watershed Development for shifting cultivation areas of North-eastern region
- Reclamation of marginal and shallow ravines

b) Watershed management works of the State Forest Department

c) Programmes of Ministry of Rural Development

- Drought Prone Area Programme
- Desert Development Programme
- Integrated Watershed Development Project

d) Schemes of Ministry of Environment and Forests

- Integrated afforestation and eco-development project
- Area Oriented Fuel Wood and Fodder Project Scheme

e) Watershed Management related to reservoir projects.

f) Mahatma Gandhi National Rural Employment Guarantee Act (MNERGA)

The provisions of the schemes such as those mentioned above can be dovetailed to benefit the farmers by way of increased crop yields.

COMMON CONVERGENCE

<u>Background</u>

In order to assess the performance of various ongoing projects/programmes of watershed development, a series of evaluation studies have been conducted by ICAR (Indian Council of Agricultural Research) Institutes, State Agriculture Universities (SAUs), National Remote Sensing Agency (NRSA) etc. Besides, impact assessment studies were carried out by the Ministry of Agriculture, Ministry of Rural Development, Planning Commission, ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) and the Technical Committee constituted by the Department of Land Resources (DoLR). These studies support the observation that in several watersheds, the implementation of the programme has been effective for natural resource conservation by increasing the productivity of the land, bringing additional area under agriculture, employment generation and social upliftment of beneficiaries living in the rural areas. But these successes have been sporadic and intermittent. The overall impact at the state and national levels has generally been inadequate.

In order to achieve the various objectives of watershed development of different Ministries/Departments and to address the "**emerging issues of ground water recharging and convergence to create a critical mass of investments**" the Government of India has brought out

Common Guidelines for Watershed Development Projects. These Guidelines broadly indicate a fresh framework for the next generation watershed programmes.

Some of the important activities included in the watershed development programme are:

- **a.** Ridge Area Treatment: All activities required to restore the health of the catchment area by reducing the volume and velocity of surface run-off, including regeneration of vegetative cover in forest and common land, afforestation, staggered trenching, contour and graded bunding, bench terracing etc.
- **b.** Drainage line treatment with a combination of vegetative and engineering structures, such as earthen checks, brushwood checks, gully plugs, loose boulder checks, gabion structures, underground dykes etc.
- **c. Development of water harvesting structures such as low-cost farm ponds, nalla bunds, check-dams, percolation tanks and ground water recharge through wells, bore wells and other measures**
- **d. Nursery raising for fodder, fuel, timber and horticultural species. As far as possible local species may be given priority**
- **e. Land Development including in-situ soil and moisture conservation and drainage management measures like field bunds, contour and graded bunds fortified with plantation, bench terracing in hilly terrain etc**
- **f. Crop demonstrations for popularizing new crops/varieties, water saving technologies such as drip irrigation or innovative management practices. As far as possible varieties based on the local germplasm may be promoted**
- **g.** Pasture development, sericulture, bee keeping, back yard poultry, small ruminant, other livestocks and other micro-enterprises
- **h.** Veterinary services for livestock and other livestock improvement measures
- **i.** Fisheries development in village ponds/tanks, farm ponds etc.
- **j.** Promotion and propagation of non-conventional energy saving devices, energy conservation measures, bio-fuel plantations etc.

The new approach envisages a broader vision of geo-hydrological unit normally of average size of 1,000 to 5,000 ha. If resources and area exist, additional watersheds in contiguous areas in clusters may be taken up.

The Manual on Artificial Recharge of Groundwater of MoWR, Government of India recommends that "Planning of recharge scheme may be done at Mega level (State or Basin level), Macro level (District or Sub-basin level) and Micro level (Block or Watershed level)".

Each Watershed development project is expected to achieve, interalia, the following results by the end of the project period:

(i) Increase in ground water table due to enhanced recharge by watershed interventions.

(ii) Increase in cropping intensity and agricultural productivity reflecting in overall increase in agricultural production.

(iii) Increase in income of farmers/landless labourers in the project area.

Approach to ensure Convergence

The Nodal agency of the state government responsible for preparation of the scheme on management of declining ground water table shall hold formal consultations with various other Departments/Agencies who have stakes in groundwater management or related issues, before, during and after formulation of the scheme. Indicative guidelines are as follows:

(a) Before formulation of the scheme

- Assessment of availability of groundwater vis-a-vis demand for various uses
- Assessment of deficit
- Rate/trend of depletion of groundwater table
- Groundwater abstraction points for various uses
- Amount of annual recharge required for sustainable use
- Agreement on the size of the groundwater planning unit
- Various related issues to be addressed in formulating the scheme

(b) During formulation of the scheme

- Type and size of various types of structures to be constructed by different agencies
- Estimated cost of different structures to be obtained from different agencies responsible for their construction
- Modalities of construction, construction planning and phasing of expenditure
- Modalities of O&M by different agencies

- Mechanism for monitoring of performance and benefits

(c) After formulation of scheme

- Apportionment of cost among different agencies

SOURCE WATER FOR RECHARGE

1.0 Availability of source water is one of the basic prerequisites for taking up any artificial recharge scheme. The source water available for artificial recharge could be of the following types:

i) Insitu precipitation in the watershed / area
ii) Nearby stream/ spring / aquifer system
iii) Surface water (canal) supplies from large reservoirs located within the watershed/basin
iv) Surface water supplies through trans-basin water transfer
v) Any other specific source(s)

The availability of water for artificial recharge from all these sources may vary considerably from place to place. In any given situation, the following information may be required for a realistic assessment of the source water available for recharge.

i) The quantum of non-committed water available for recharge
ii) Period for which the source water will be available.
iii) Quality of source water and the pre-treatment required.
iv) Conveyance system required to bring the water to the proposed recharge site.

Rainfall and runoff available constitute the major sources of water for artificial recharge of ground water. Rainfall is the primary source of recharge into the groundwater reservoir. Other important sources of recharge include seepage from tanks, canals and streams and the return flow from applied irrigation. For proper evaluation of source water availability, a thorough understanding of rainfall and runoff is essential. Collection and analysis of hydrometeorological and hydrological data have an important role to play in the assessment of source water availability for planning and design of artificial recharge schemes. These are elaborated in the following sections.

2.0 Determination of Average Rainfall

In resource evaluation of a drainage basin, average depth of rainfall of a number of rain gauges is required. The average is usually obtained by any of the three methods; Arithmetic mean, Theissen polygon and isohyetal. The first one is a simple average whereas the other two give weighted averages.

2.1 Arithmetic Mean Method

Source: Manual on Artificial Recharge of Ground Water, MOWR, Govt. of India

In this method, the average depth of rainfall is computed as:

P = (P1 + P2 + P3 + ………………+ Pn)/ n

Where, P is the average rainfall, n, the number of years of data and P1, P2, P3 ……… Pn, Precipitations measured at stations 1, 2, 3 ……… n.

2.2 Theissen Polygon Method

In this method, weights are assigned to each rain gauge depending on its relative location. This method involves constructing polygons around each gauge, which are a result of perpendicular bisectors of lines joining two adjacent rain gauges. The polygon thus formed form the boundary of the effective area assumed to be controlled by the gauge, or in other words, the area closer to the gauge than to any other gauge. The ratio of the area of each polygon to the total area is the weight. The average or weighted rainfall is the sum of the product of the rainfall and weight of each gauge. P1 to Pn are the rainfall at gauges 1 to n and A1 to An are the areas of the respective polygons (Fig. 1.0).

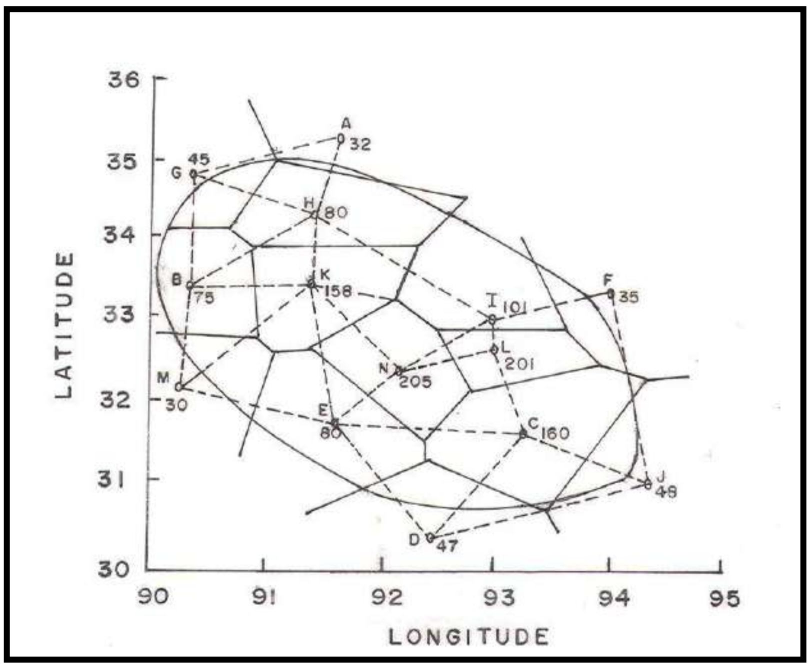


Fig. 1: Theissen Polygons

An example for working out average rainfall using this method is shown in **Table. 1.**

Table 1- Example to Work out Weighted Average Using Theissen Polygon Method

Rainfall (mm)	Area (sq km)	Weight	Weighted Average Rainfall (mm)
165	18	0.011	1.8
371	311	0.192	71.2
488	282	0.174	84.9
683	311	0.192	131.1
391	52	0.032	12.5
757	238	0.147	111.3
1270	212	0.131	166.4
1143	197	0.121	138.3
Total	**1621**	**1.000**	**717.5**

Weighted average is worked out as 717.5 mm

2.3 Isohyetal Method

In this method, isohyets are drawn connecting points of equal rainfall and areas between two successive isohyets computed (**Fig.2**). The weight in this case is the ratio of the area of two successive isohyets to the total area. The weighted average is given by the sum of the products of weights and average contour value of corresponding isohyets.

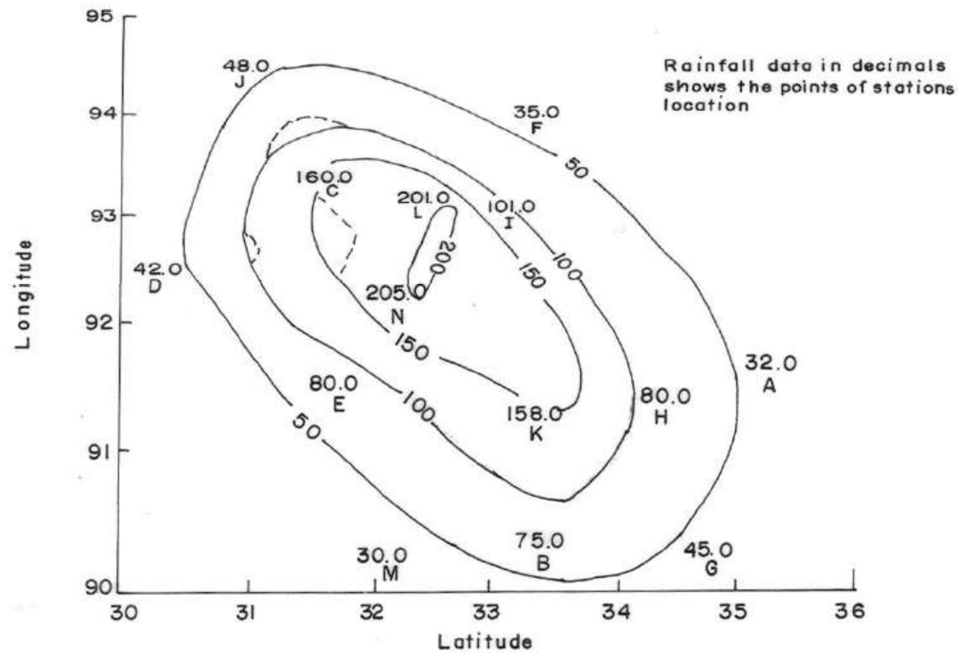


Fig. 2: Isohyetal Method

An example for working out average rainfall using isohyetal method is shown in **Table. 2.**

Table 2 - Example to Work out Weighted Average Rainfall Using Isohyetal Method

Isohyet (mm)	Area enclosed (sq km)	Area Net (sq km)	Weight	Mean Rf (mm)	Weighted Average Rainfall (mm)
1270	34	34	0.021	1350	28.35
1020	233	199	0.123	1170	143.91
760	534	300	0.185	890	164.65
510	1041	508	0.313	640	200.32
250	1541	500	0.308	380	117.04
<250	1621	80	0.049	200	9.80
		1621			**664.07**

Weighted average is worked out as 664.07 mm

The arithmetic mean method gives equal weights to all the rain gauges. Apart from being quick and easy, it yields fairly accurate results if the rain gauges are uniformly distributed and are under homogeneous climate. The polygon method is laborious. But once weights of each rain gauge are computed, it gives results quickly. This method takes care of non-uniform distribution of rain gauges. However, variability in rainfall due to elevation differences is not taken care of. Another serious drawback of this method is a situation when the polygons are to be redrawn due to addition or deletion of rain gauges to the network. The third method overcomes most of the deficiencies of the other two. However, drawing isohyets and computing weights every time estimations are to be made is tedious. The accuracy of the method also depends on the skill with which the isohyets are drawn. It is reasonable to rely on polygon method for averages of plain areas and the isohyetal method for hilly areas.

3.0 Runoff

Precise estimation of runoff is the basic and foremost input requirement for the design of recharge structures of optimum capacity. Unrealistic runoff estimates of catchments yield often leads to the construction of oversized or undersized structures, which, in any case, must be avoided. Runoff is defined as the portion of the precipitation that makes its way towards rivers or oceans as surface or subsurface flow. After the occurrence of infiltration and other loses from the precipitation (rainfall), the excess rainfall flows out through the small natural channels on the land surface to the main drainage channels. Such types of flow are called *surface flows.* A part of the infiltrated rainwater moves parallel to the land surface as subsurface flow, and reappears on the surface at certain other points. Such flows are called *interflows*. Another part of the *infiltrated* water percolates downwards to ground water and moves laterally to emerge in depression and rivers and joins the surface flow. This type of flow is called the *subsurface flow* or *ground water flow*.

3.1 Estimation of Runoff

Runoff can be estimated by various methods. These can be classified under the following headings:

- Empirical formulae and tables
- Runoff Estimation based on Land Use and Treatment.
- Rational Method

- Empirical formulae for flood peak

3.1.1 Empirical Formulae and Tables

3.1.1.1 Binnie's Percentages: Sir Alexander Binnie was probably among the first to study the relationship of runoff to rainfall with a view to express the former as a percentage of the latter (Table.3)

Table 3-Binnie's Percentages for Computation of Runoff

Annual Rainfall (mm)	Runoff (%)	Annual Rainfall (mm)	Runoff (%)
500	15	900	34
600	21	1000	38
700	25	1100	40
800	29		

The percentages are based on observations on two rivers in Madhya Pradesh.

3.1.1.2 Coefficients: The runoff 'R' in cm and rainfall 'P' in cm can be correlated as R = KP, where 'K' is the runoff coefficient. The runoff coefficient depends on factors affecting runoff. This method is applicable only for small projects. The usual values of K are as given in **Table 4.**

Table 4 - Usual Values of Runoff Coefficients (K)

Type of Area	K
Urban Residential	0.3 - 0.5
Forests	0.05 - 0.2
Commercial & Industrial	0.9
Parks, farms, Pastures	0.05 - 0.3
Asphalt or concrete pavement	0.85

3.1.1.3 Barlow's Tables: T.G. Barlow carried out studies of catchments mostlyunder 130 sq km in Uttar Pradesh and gave the following values of K (in percentage)for various types of catchments (**Table 5**).

Table 5 - Barlow's Percentage Runoff Coefficients

Class	Description of Catchment	Percent runoff
A	Flat, cultivated and black cotton soils	10
B	Flat, partly cultivated-various soils	15
C	Average	20
D	Hills and plains with little cultivation	35
E	Very hilly and steep, with hardly any cultivation	45

These percentages are for the average type of monsoon and are to be modified by the application of the following coefficients according to the nature of the season as shown in **Table 6.**

Table 6 - Barlow's Runoff Coefficients for Different Natures of Season

Nature of rainfall	Percentage of Flow in Catchments of Different Type				
	A	B	C	D	E
1. Light rain, no heavy downpour	0.70	0.80	0.80	0.80	0.80
2. Average or varying rainfall, no continuous downpour	1.00	1.00	1.00	1.00	1.00
3. Continuous downpour	1.50	1.50	1.60	1.70	1.80

He divided special tropical rainfall into the following four classes:

(i) Negligible falls: All rainfalls under 12 mm a day unless continuous forseveral days; also rainfalls 12 to 40 mm a day, when there is no rain.

(ii) Light falls: All rainfalls up to 25 mm a day followed by similar or heavierfalls. Steady pours of 25 to 40 mm a day, when there is no rain of similaror greater amount before or after that.

(iii) Medium falls: Rainfalls from 25 to 40 mm a day when preceded orfollowed by any but light falls.

(iv) Heavy Falls:

(a) All rainfalls over 75 mm a day or continuous falls at 50 mm a day.

(b) All rainfalls of an intensity of 50 mm or more per hour.

He gave the runoff percentages as shown in the following table by combining the typeof catchment and nature of the season **(Table 7).**

Table 7- Barlow's Runoff Percentages

Nature of rainfall	Percentage of Flow in Catchments of Different Type				
	A	B	C	D	E
1. Negligible falls	-	-	-	-	-
2. Light falls	1	3	5	10	15
3. Medium falls	10	15	20	25	33
4. Heavy falls	20	33	40	55	70

3.1.1.4 Strange Tables: These tables provide quick and easy access to daily runoff, which is given as a percentage of total monsoon rainfall **(Table 8b)** or as a percentage of daily rainfall **(Table 8a).** These are based on extensive studies in the then Bombay Presidency but can be applied in similar areas.

Table 8(a) -Percentage of total monsoon rainfall

	Good Catchment			Average Catchment			Bad Catchment		
Total Mon- soon Rainfall in Inches	Percentage of Runoff to Rainfall	Depth of Runoff due to rainfall in inches	Yield of Run-off from Catchment per square mile in Mcft	Percentage of Runoff to Rainfall	Depth of Runoff due to Rain fallin inches	Yield of Run-off per square mile in Mcft	Percentage of Run-off to Rainfall	Depth of Runoff due to Rainfall in inches	Yield of Runoff per square mile in Mcft.
1	2	3	4	5	6	7	8	9	10
1	0.1	0.001	0.002	0.1	0.001	0.001	0.05	0.0005	0.000
2	0.2	0.004	0.009	0.15	0.003	0.006	0.1	0.002	0.004
3	0.4	0.012	0.028	0.3	0.009	0.021	0.2	0.006	0.014
4	0.7	0.028	0.65	0.5	0.021	0.048	0.3	0.014	0.032
5	1.0	0.050	0.116	0.7	0.037	0.087	0.5	0.025	0.058
6	1.5	0.090	0.209	1.1	0.067	0.156	0.7	0.045	0.104
7	2.1	0.147	0.341	1.5	0.110	0.255	1.0	0.073	0.170
8	2.8	0.224	0.520	2.1	0.168	0.390	1.4	0.112	0.260
9	3.5	0.315	0.732	2.6	0.236	0.549	1.7	0.157	0.366
10	4.3	0.430	0.999	3.2	0.322	0.749	2.1	0.215	0.499
11	5.2	0.572	1.329	3.9	0.429	0.996	2.6	0.286	0.664
12	6.2	0.744	1.728	4.6	0.558	1.296	3.1	0.372	0.864
13	7.2	0.936	2.174	5.4	0.702	1.630	3.6	0.463	1.087

14	8.3	1.162	2.699	6.2	0.871	2.024	4.1	0.581	1.349
15	9.4	1.410	3.276	7.0	1.057	2.457	4.7	0.705	1.638
16	10.5	1.600	3.930	1.8	1.260	2.927	5.2	0.840	1.951
17	11.6	1.972	4.581	8.7	1.479	3.435	5.8	0.986	2.290
18	12.8	2.304	5.353	9.6	1.728	4.014	6.4	1.152	2.676
19	13.9	2.641	6.135	10.4	1.980	4.601	6.9	1.420	3.067
20	15.0	3.000	6.970	11.25	2.250	5.227	7.5	1.500	3.485
21	16.1	3.381	7.855	12.0	2.535	5.891	8.0	1.690	3.927
22	17.3	3.806	8.842	12.9	2.854	6.631	8.6	1.903	4.421
23	18.4	4.232	9.832	13.8	3.174	7.374	9.2	2.116	4.916
24	19.5	4.680	10.873	14.6	3.510	8.154	9.7	2.340	5.436
25	20.5	5.150	11.964	15.4	3.862	8.973	10.3	2.575	5.982
26	21.8	5.668	13.168	16.3	4.251	9.876	10.9	2.834	6.584
27	22.9	6.183	14.364	17.1	4.637	10.773	11.4	3.091	7.182
28	24.0	6.720	15.612	18.0	5.040	11.709	12.0	3.360	7.806
29	25.1	7.279	16.911	18.8	5.459	12.683	12.5	3.639	8.455
30	26.3	7.890	18.330	19.7	5.917	13.747	13.8	3.945	9.165
31	27.4	8.495	19.733	20.5	6.370	14.799	13.7	4.247	9.866
32	28.5	9.120	21.188	21.3	6.840	15.891	14.2	4.560	10.594
33	29.6	9.768	22.693	22.2	7.326	17.019	14.8	4.884	11.345
34	30.8	10.472	24.323	23.1	7.854	18.246	15.4	5.236	12.164
35	31.9	11.165	25.939	23.9	8.373	19.454	15.9	5.582	12.969
36	33.0	11.880	27.600	24.7	8.910	20.700	16.5	5.940	13.800
37	34.1	12.617	29.312	25.5	9.462	21.984	17.0	6.308	14.656
38	33.53	13.414	31.163	27.4	10.060	23.372	17.6	6.760	15.591
39	36.4	14.196	32.980	22.3	10.647	24.735	18.2	7.098	16.490
40	37.5	15.000	34.848	28.1	11.250	26.136	18.7	7.500	17.424
41	38.8	15.826	36.767	28.9	12.537	27.575	19.3	7.913	18.383
42	39.8	16.716	38.835	29.8	13.190	29.126	19.9	8.358	19.417
43	40.9	17.587	40.858	30.6	13.860	30.643	20.4	8.793	20.429
44	42.0	18.480	42.933	31.5	13.546	32.199	21.0	9.240	21.466
45	43.1	19.395	45.058	32.3	15.283	33.793	21.5	9.697	22.529
46	44.3	20.378	47.342	33.2	16.003	35.506	22.8	10.189	23.671
47	45.4	21.338	49.572	34.0	16.724	37.179	22.7	10.669	24.786
48	46.5	22.320	51.854	34.8	17.493	38.890	23.2	11.160	25.927
49	47.6	23.324	54.186	35.7	17.493	40.639	23.8	11.662	27.093
50	48.8	24.400	56.686	36.8	18.336	42.514	24.4	12.200	28.343
51	49.9	25.449	59.123	37.4	19.086	44.342	24.9	12.724	29.561
52	51.0	26.520	61.611	38.2	19.890	46.208	25.5	13.260	30.805
53	52.1	27.613	64.151	39.0	20.709	48.313	26.0	13.806	32.075
54	53.3	28.782	66.866	39.9	21.586	50.149	26.6	14.391	33.433
55	54.4	29.920	60.510	41.8	22.440	52.132	27.2	14.960	34.755
56	55.5	31.080	72.205	41.6	23.310	54.453	27.7	15.540	36.102

57	56.6	32.262	74.951	42.4	24.196	56.213	28.3	16.131	37.471
58	57.8	33.524	77.883	43.3	25.143	58.412	28.9	16.762	38.941
59	58.9	34.751	80.734	44.1	26.063	60.550	29.4	17.375	40.367
60	60.0	36.000	83.035	45.0	27.000	62.726	30.0	18.000	41.817

Table 8(b) Strange Table Showing Daily Runoff Percentage

Daily Rain-fall, mm	Runoff Percentage and Yield when the State of Ground is					
	Dry		Damp		Wet	
	%	Yield	%	Yield	%	Yield
5	-	-	4	0.20	7	0.35
10	1	0.10	5	0.25	10	1.00
20	2	0.40	9	1.80	15	3.00
25	3	0.75	11	2.75	18	4.50
30	4	1.20	13	3.90	20	6.00
40	7	2.80	18	7.20	28	11.20
50	10	5.00	22	11.00	34	17.00
60	14	8.46	28	16.80	41	24.60
70	18	12.61	33	25.10	48	33.60
75	20	15.00	37	27.75	52	41.25
80	22	17.60	39	31.20	55	44.00
90	25	22.50	44	39.60	62	55.80
100	30	30.00	50	50.00	70	70.00

Note: - for good or bad catchment, add or deduct up to 25% of yield.

For use of these tables, catchments have been classified as Good, Average or Bad as follows:

- Good catchment: Hills or plains with little cultivation and moderately absorbent soil.
- Average catchment: Flat partly cultivated stiff gravely/Sandy absorbent soil
- Bad catchment: Flat and cultivated sandy soils.

3.1.1.5 Ingles and De Souza's formulae:

Based on studies carried out for catchments in Western Ghats and plains of Maharashtra, C.C. Inglis and D'Souza gave the following relations:

For Ghat (Hilly) area, R = 0.85 P - 30.5

Where 'R' and 'P' are runoff and precipitation respectively, both expressed in cm.

For plains R= (P-17.8) P/254

3.1.1.6 Lacey's Formula: As per this formula, runoff (R) can be computed as**:**

$$P/ [1+ (304.8/P) \times (F/S)]$$

Where S = a catchment factor

F = monsoon duration factor

Lacey's values for the factor F / S for Barlow's classification of catchments are given in **Table 9.**

Table 9 Values of Lacey's Factor (F / S)

S.No.	Nature of rainfall	Class of Catchments				
		A	B	C	D	E
1.	Very Short	2.0	0.83	0.50	0.23	0.14
2.	Standard Length	4.0	1.67	1.00	0.58	0.28
3.	Very Long	6.0	2.50	1.50	0.88	0.43

3.1.2 Estimation of Direct Runoff from Rainfall

In this method of runoff estimation, the effects of the surface conditions of a watershed area are evaluated by means of land use and treatment classes. Land use is the watershed cover and it includes every kind of vegetation, litter and mulch, and fallow as well as non-agricultural uses such as water surfaces (lakes, swamps, etc) and impervious surfaces (roads, roofs, etc.). Land treatment applies mainly to agricultural land uses and includes mechanical practices such as contouring or terracing and management practices such as grazing control or rotation of crops. The classes consist of use and treatment combinations actually to be found on watersheds. Land use and treatment classes are readily obtained either by observation or by measurement of plant and litter density and extent on sample areas.

Hydrological Soil Groups: There are four soil groups that are used in determining the hydrological soil cover complexes, which are used in a method for estimating the runoff from rainfall. A generalised soil map of India, giving the broad classification of all the major soils in India is shown in **Fig.3**. Major characteristics of these groups are described in **Table 10**. The classification is broad but the groups can be divided into sub-groups whenever such a refinement is justified. The infiltration rates and permeability of soils in different groups are shown in **Table 11**and **Table 12** respectively. In these tables, infiltration rate is the rate at which water enters the soil at the surface and which is controlled by surface conditions and permeability rate is the rate at which water moves in the soil, which is controlled by the nature and characteristics of soil horizons.

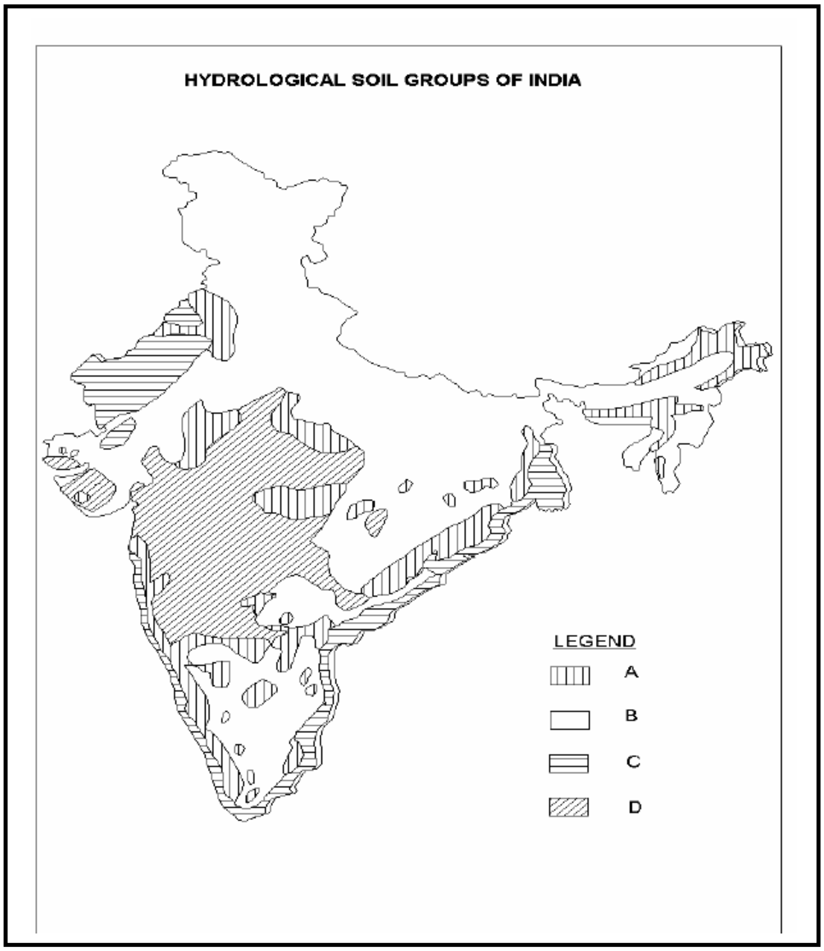


Fig.3 - Hydrological Soil Groups of India

Table 10 - Hydrological Soil Groups

Soil Group	Description
A	Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
D	Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material.

Table 11- Infiltration Rates

Sl. No.	Class	Rates / hr in		Remarks
		Inches	Millimetres	
1	Very Low	Below 0.1	1Below 2.5	Highly clayey soils
2	Low	0.1 - 0.5	2.5 - 12.5	Shallow soils, clay soils, soils low in organic matter
3	Medium	0.5 - 1.0	12.5 - 25.0	Sandy loams, silt loams
4	High	Above 1.0	Above 25.0	Deep sands, well aggregated soils

Table 12 - Relative Classes of Soil Permeability

Class	Permeability	
	Inches/hr.	**mm/hr.**
Slow		
1) Very slow	Less than 0.05	1.30
2) Slow	0.05 to 0.20	1.31 to 5.00
Moderate		
3) Moderately slow	0.20 to 0.30	5.01 to 20.00
4) Moderate	0.80 to 2.50	20.01 to 50.00
5) Moderately Rapid	2.50 to 5.00	50.01 to 130.00
Rapid		

6) Rapid	5.00 to 10.00	130.01 to 250.00
7) Very Rapid	Over 10.00	Over 250.00

Land Use and Treatment Classes:

The commonly used land use and treatment classes are briefly described below. These classes are used in determining hydrologic soil- cover complexes, which are used in one of the methods for estimating runoff from rainfall.

a. Cultivated lands: These include all field crops such as maize, sugarcane, paddy and wheat.
b. Fallow lands: These are lands taken up for cultivation, but are temporarily out of cultivation for a period of not less than one year, and not more than 5 years. Current fallow lands are cropped areas kept fallow during the current year.
c. Uncultivated lands include:
    - Permanent pastures and other grazing lands.
    - Cultivable waste, which are lands available for cultivation whether or not taken up for cultivation or abandoned after a few years for one reason or another. Land once cultivated but uncultivated for 5 years in succession shall also be included in this category.
d. Forest area includes all lands classed as forest under any legal enactment dealingwith forest or administered as forest whether State owned or private and whetherwooded or maintained as potential forest land.
e. Tree crops include woody perennial plants that reach a mature height of at least 8feet and have well defined stems and a definite crown shape.
f. Lands put to non-agricultural uses are areas occupied by buildings, roads, railroads etc.
g. Barren and uncultivable lands include areas covered by mountains, deserts etc.

Rainfall – Runoff Equations:

The data generally available in India comprise rainfall measured by non-recording rain gauge stations. Rainfall-runoff relation developed for such data is given below

$$Q = [(P\text{-}Ia)^2] / [(P\text{-}Ia) + S]$$

Where Q is the actual runoff in mm, S, the potential maximum retention in mm, and Ia, initial abstraction during the period between the beginning of rainfall and runoff in equivalent depth over the catchment in mm.

In areas covered by black soils having Antecedent Moisture Conditions (AMC) II and III, Ia in the equation is equal to 0.1S, whereas in all other regions including those with black soils of AMC I, Ia is equal to 0.3S.

In order to show this relationship graphically, 'S' values are transformed into 'Curve Numbers (CN)' using the following equation

$$CN = 25400 / (254 + S)$$

Using the above equation, the following equations have been developed:

$$Q = [(P-0.3S)^2] / [(P+0.7S)] \text{ -------------------- } 1$$

$$Q = [(P-0.1S)^2] / [(P+0.9S)] \text{ -------------------- } 2$$

Equation 1 is applicable to all soil regions of India except black soil areas referred to in the section on 'Hydrological Soil Groups'. Equation 2 applies to black soil regions. This equation should be used with the assumption that cracks, which are typical of these soils when dry, have been filled. Therefore, equation 2 should be used where AMC falls into groups II and III. In cases where the AMC falls in group I, equation 1 should be used. The rainfall limits for AMC conditions are shown in **Table 4.13**

Table 13 - Rainfall Limits for Antecedent Moisture Condition

AMC	5 – Day Total Antecedent Rainfall (cm)	
	Dormant Season	Growing Season
I	< 1.25	< 3.5
II	1.25 to 2.75	3.50 to 5.25
III	> 2.75	> 5.25

Values of CN for different soils are given in **Table 14.**

Table 14- Runoff Curve Nos. for Hydrologic Soil Cover Complexes (Watershed Condition II & Ia = 0.25)

Land Use/ Cover	Treatment/ Practice	Hydrologic Condition	Curve Number for Hydrologic Soil Group			
Fallow	Straight Row	-	77	86	91	94

Row Crops						
	Straight Row	Poor	72	81	88	91
	Straight Row	Good	67	78	85	89
	Contoured	Good	65	75	82	86
	Contoured and Terraced	Poor	66	74	80	82
	Contoured and Terraced	Good	62	71	78	81
Small Grain	Straight Row	Poor	65	76	84	88
	Straight Row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
	Contoured and Terraced	Poor	61	72	79	82
	Contoured and Terraced	Good	59	70	78	81
Close seeded legumes or rotation meadow	Straight Row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Contoured and Terraced	Poor	63	73	80	83
	Contoured and Terraced	Good	51	67	76	80
Pasture or Range		Poor	68	79	86	89
		Fair	49	69	79	84
	Contoured	good	39	69	79	84
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
		Good	6	35	70	79
Meadow (Permanent)		Good	30	58	71	78
Woodlands (FarmWoodlots)		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads			59	74	82	86
Roads (Dirt)			72	82	87	89
Roads (Hard Surface)			77	84	90	92

3.1.3 Rational Method

This method was originally developed for urban catchments. Thus, the basic assumptions for development of this method were made for urban catchments. However, this method is fairly applicable to small agricultural watersheds of 40 to 80 hectares size (Chow, 1964).

The Rational method is based on the assumption that constant intensity of rainfall is uniformly spread over an area, and the effective rain falling on the most remote part of the basin takes a certain period of time, known as the time of concentration (Tc) to arrive at the basin outlet. If the input rate of excess rainfall on the basin continues for the period of time of concentration, then the part of the excess rain that fell in the most remote part of the basin will just begin its outflow at the basin outlet and with it, the runoff will reach its ultimate and the maximum rate. That is, the maximum rate of outflow will occur when the rainfall duration is equal to the time of concentration.

The above processes are explained in **Fig. 4.** Consider a drainage basin, which has rainfall of uniform intensity and of longer duration. On plotting the relationship between the cumulative runoff rate Q and time, the rate of runoff shows a gradual increase from zero to a constant value. The runoff increases with increase in flow from remote areas of the basin to its outlet. If the rainfall continues beyond the time of concentration, then there is no further increase in the runoff, and it remains constant at its peak value.

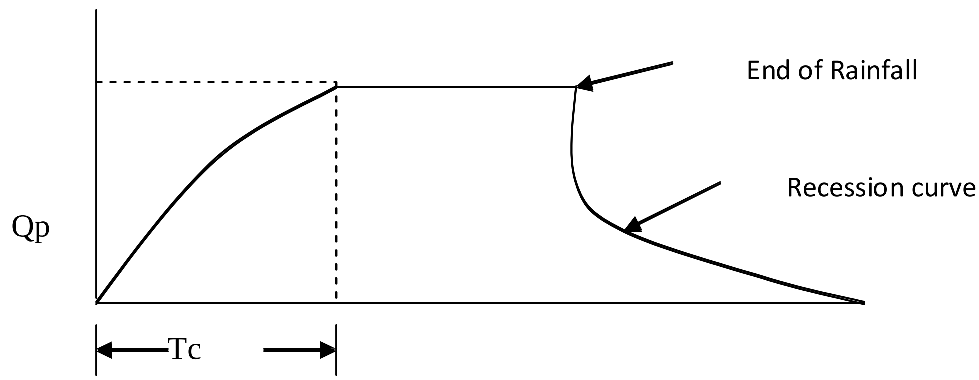


Fig. 4- Runoff Hydrograph Due to Uniform Rainfall

The relationship for peak runoff Qp is then expressed as:

$$Qp = C\ I\ A$$

Where, C = coefficient of runoff

A = area of the catchment (drainage basin)

I = intensity of rainfall.

In metric units, this equation is expressed as.

$$Qp = 1/3.6 \times C\ I\ A$$

Where, Qp = peak runoff rate (m^3/s)

C = coefficient of runoff

I = mean intensity of precipitation (mm/h) for a duration equal to time of concentration, and for an accidence probability.

A = area of the drainage basin (km^2).

Runoff Coefficient Factor (C):

The runoff coefficient factor (C) encompasses all other factors that affect the surface runoff, except the area (A) and the intensity of rainfall (I). It is defined as:

$$C = Qp/AI$$

Under ideal conditions, C represents the ratio of runoff volume to rainfall volume. Ideal conditions are rare. Consequently, the values of C are significantly lower than the values obtained through the above ratio. A summary of the values of C developed by different research works in India for different soil conditions are given in **Table 15.**

Table 4.15 - Values of Runoff Coefficient Factor (C) for Different Soil Conditions in India.

Type of Vegetation	Slope Range (%)	Runoff Coefficient (C) in		
		Sandy Loam Soil	Loam / Loam Clay Soil	Stiff Clay Soil
Woodland and forests	0-5	0.1	0.3	0.4
	5-10	0.25	0.35	0.5
	10-30	0.3	0.5	0.6
Grassland	0-5	0.1	0.3	0.4
	5-10	0.16	0.36	0.55
	10-30	0.22	0.42	0.6
Agricultural land	0-5	0.3	0.5	0.6
	5-10	0.4	0.6	0.7
	10-30	0.52	0.72	0.82

Intensity of Rainfall: The formula for the intensity of rainfall is expresses as:

$$I = KTr^a / (Tc + b)^n$$

Where I is the intensity of rainfall, Tr, the recurrence interval, Tc, Time of concentration, and a, b, n are constants.

The values of parameters K, a, b, n for different zones of India have been developed by the ICAR scientists, and are shown in **Table 16**.

Table 16 - Values of Parameters for Intensity – Duration - Return Period Relationships for Different Zones of India.

Zone	K	A	b	n
Northern zone	5.92	0.162	0.50	1.013
Central zone	7.47	0.170	0.75	0.960
Western zone	3.98	0.165	0.15	0.733
Southern zone	6.31	0.153	0.50	0.950

Time of Concentration (Tc):

For determination of the time ofconcentration, the most widely used formula is the equation given by Kirpich (1940).However, for small drainage basins, the lag time for the peak flow can be taken to beequal to the time of concentration. The lag time can be determined by the Snyder'sequation.

The Kirpich's equation is given as:

$$Tc = 0.01947\ L^{0.77}\ S^{-0.385}$$

Where

Tc = time of concentration (min)

L = maximum length of travel of water (m)

S = slope of the drainage basin = HIL

H= difference in elevation between the most remote point of the basin and its outlet(m) and L, the maximum length of travel (m)

The time of concentration can also be determined as:

$$Tc = 0.1947\ (K)^{0.77}$$

Where $K = \frac{(L)^{1/3}}{H}$

The time of concentration is sometimes also determined by dividing the length of runwith the average velocity of flow based on the slope of the channel as given in **Table17.**

Table 17 Average Velocity Based on Channel Slope

Channel Slope %	Velocity (m/s).
1-2	0.6
2-4	0.9
4-6	1.2
6-10	1.5

3.1.4 Empirical Relationships for Determination of Peak Runoff

Empirical relationships can be applied to regions for which these are developed. There are some popular Runoff formulae in use in India, three of which are given below:

Dickens Formula: This formula was developed in the year 1865. It states that

$$Qp = Cd\ A^{3/4}$$

Where

Qp = peak discharge rate (m3 /s).

Cd = a constant (Dickens'), ranging from 6 to 30.

A = Drainage basin area (km^2).

For Indian conditions, suggested values for Cd are given in **Table 18.**

Table 18 Suggested Values of Cd for Indian Conditions

Region	Topography	Cd
Northern states	Plains	6
Hills	-	11-14
Central states	-	14.28
Coastal area	-	22.28.

Ryve's Formula

Ryve's formula was reported in the year 1884. It states that

$$Qp = C_r\ A^{2/3}$$

Where

Qp = Peak discharge rate (m^3/s).

A = Drainage basin area (km^2).

Cr = A constant (Ryves), as shown in **Table 19**

Table 19 Values of Ryves Constant

Region	Cr
Within 80 km from east coast	6.8
80-160 km from east coast	8.5
Hills	10.2

The Ryves formula is recommended for southern states of India.

Ingle's Formula: This formula was developed in areas of old Bombay state.

It states that

$$Qp = 123 A / (A+10.4)^{1/2}$$

Qp = Peak discharge in Cumecs

A = Area of the catchment in sq km

Example

A catchment has an area of 5.0 km². The average slope of the land surface is 0.006and the maximum travel depth of rainfall in the catchment is approximately 1.95 km. The maximum depth of rainfall in the area with a return period of 25 years is as tabulated in **Table 20**.

Table 20 - Maximum Depth of Rainfall in an Area with a Return Period of 25Years.

Time duration (min)	5	10	15	20	25	30	40	60
Rain fall depth (mm)	15	25	32	45	50	53	60	65

Consider that 2.0 Km² of the catchment area has cultivated sandy loam soil (c=0.2) and 3.0 Km² has light clay cultivated soil (c = 0.7). Determine the peak flow rate of runoff by using the Rational method.

Solution: The time of concentration is given by Kirpich's equation.

$$Tc = 0.01947\, L^{0.77} S^{-0.385}$$

$$= 0.01947\, (1950)^{0.77}\, (0.006)^{-0.385} \text{ min}$$

$$= 47.65 \text{ min.}$$

The maximum rainfall depth for 47.65 min duration would fall between the periods of40-60 min and is located at 7.65 min after the 40 min period at which the maximum rainfall depth is 60 mm, as per the available data.

The rainfall depth during the 7.65 min period = $\frac{65-60}{20} \times 7.65 = 1.9$ mm

Therefore, for 47.65 min duration, the rainfall depth = 60 + 1.9 = 61.9 mm.

The average rainfall intensity = maximum rainfall depth/Tc

(During the period of time of concentration)

$$= \frac{61.9 \times 60}{47.65} = 77.96 \text{ mm/hr}$$

$$\text{Runoff coefficient, } C = \frac{(20 \times 0.2) + (3.0 \times 0.7)}{5.0}$$

$$= \frac{0.4 + 2}{5.0} = 0.5$$

$$\text{Peak runoff rate, } Q_p = \frac{CIA}{3.6} \text{ m}^3\text{/s}$$

$$= 1/3.6 \times 0.5 \times 77.96 \times 5.0$$

$$= 54.138 \text{ m}^3\text{/s.}$$

3.2 Quality of Source Water

The physical, chemical and biological quality of the recharge water also affects the planning and selection of recharge method. Physical quality of recharge water refers to the type and amount of suspended solids, temperature, and the amount of entrapped air whereas chemical quality refers to type and concentration of dissolved solids and gases. Biological quality refers to type and concentration of living organisms. Under certain conditions, any or all of these characteristics can diminish recharge rates.

Physical Quality

If suspended solids are present in the recharge water, surface application techniques re more efficient than subsurface techniques. Even though suspended particles may cause clogging, the infiltration surfaces are accessible for remedial treatment. Where indirect methods of recharge are used, suspended solids pose virtually no problem. Under such conditions, induced recharge would probably be one of the best methods. Ditch and furrows method is also well suited for large amounts of suspended solid loads because the steady flow of water inhibits settling. Basins should not be indiscriminately subjected to turbid water because surface clogging is almost certain to occur. If basins must be used for recharge with turbid water, they can be used in series, whereby the first basin acts as a clarifier for subsequent basins. This method requires more land, however, and is feasible only where land is readily available.

Where suspended solid loads in recharge water are high, subsurface application techniques, including deep pits, shafts, and wells, are prone to failure. Unless pretreatment measures are provided, subsurface techniques should not be considered when the source water is turbid because clogging of injection wells is particularly troublesome, and well redevelopment is costly.

Chemical Quality

Recharge water should be chemically compatible with the aquifer material through which it flows and the native ground water to avoid chemical reactions that would reduce effective porosity and recharge capacity. Chemical precipitation and unfavourable exchange reactions, as well as the presence of dissolved gases, are causes for concern. Cation exchange reactions involving sodium in recharge water may cause clay particles to swell or disperse, thereby decreasing infiltration rate oraquifer permeability. Dissolved gases may alter aquifer pH or come out of solution, forming gas pockets that occupy pore space and decrease aquifer permeability.

Toxic substances in excess of established health standards must not be present in therecharge water unless they can be removed by pre-treatment or chemically decomposed by a suitable land or aquifer treatment system. If artificial recharge is for drinking purpose, then the source water must conform to the drinking water standards in vogue.

Biological Quality

Biological agents such as algae or bacteria may also be present in recharge water.Organic wastes may contain harmful bacteria or promote their growth and decay or organic materials may produce excess nitrate or other by-products. Growth of algae and bacteria during recharge can cause clogging of infiltration surfaces and may lead to the production of gases that further hinder recharge efforts. Although surface spreading removes most bacteria and algae by filtration before the recharge water reaches the aquifer, surface clogging can reduce the infiltration rate considerably. Injection of water containing bacteria and algae through wells is generally not recommended because it causes clogging of well screens or aquifer materials, which is difficult and costly to remedy.

The quality of source water is thus vitally important wherever direct recharge techniques are contemplated. In cases where insitu precipitation or water supplied from canals are used for recharge, no constraints on account of water quality may arise. However, in cases where waters in the lower reaches of rivers or recycled municipal/industrial waste waters are proposed to be used, the quality of water requires to be precisely analysed and monitored to determine the type and extent of treatment required.

In cases where the recharge is contemplated through spreading techniques, raw waste water can be used after primary sedimentation and secondary (biological) treatment to take advantage of filtration and bio-degradation that occurs as the water passes through the upper soil layers and zone of aeration. On the other hand, if the water is to be used for direct recharge, secondary treatment should be followed by chemical clarification (coagulation-flocculation-clarification). The water is then allowed to pass through adequate filter beds. The filtration is followed by tertiary treatment involving air tripping, granular activated carbon treatment, reverse osmosis and disinfection, in that order.

The consideration of chemical quality of source water will thus lead to decisions about the extent and type of treatment required, arrangements for treatment plants and the cost of source water. In case it is not possible to ensure the desired quality standard from the treatment, such source(s) may be avoided for recharging the ground water.

PLANNING OF ARTIFICIAL RECHARGE SCHEMES

1.0 An artificial recharge scheme may be aimed at recharge augmentation in a specific area for making up the shortage in ground water recharge compared to the ground water draft either fully or partially. The area involved in artificial recharge projects may range from a watershed, a limited area covering an urban, rural or industrial centre or administrative units like Mandal/Block to large basins or larger administrative units like Districts/States. Though the steps involved in planning are essentially the same, the planning is done on different scales as per the required objectives and the area involved. Thus, planning of recharge scheme may be done at Mega level (State or Basin level), Macrolevel (District or sub-basin level) and Micro level (Block or Watershed level) at progressively larger scales. It is advisable to do State/Basin level planning at 1:2000,000 scale, District / Sub-basin level planning at 1:250,000 scale and Block /Watershed level planning at 1:50,000 scale and so on. Proper scientific investigations aimed at assessing the need and feasibility of an area for artificial recharge are necessary prerequisites for planning and implementation of any successful artificial recharge project. Detailed consideration of the following aspects is necessary for evolving a realistic plan for an artificial recharge scheme.

i. Establishment of ground facts, which include

- Need for artificial recharge
- Estimation of sub-surface storage capacity of the aquifers and quantification of water required for recharge
- Prioritisation of areas for artificial recharge
- Source water availability
- Assessment of source water
- Source water quality
- Suitability of the area for recharge in terms of climate, topography, soil and land use characteristics and hydrogeologic set-up

ii. Appraisal of economic viability

iii. Finalisation of Physical Plan.

iv. Preparation of a Plan document covering all the aspects mentioned above

Source: Manual on Artificial Recharge of Ground Water, MOWR, Govt. of India

1.1 Establishment of Ground Facts

An appraisal of the ground facts relevant to the need and suitability of an area for artificial recharge helps in deciding upon the most suitable scientific strategy for the formulation of artificial recharge schemes. The most important considerations in this regard are described in brief in the following sections.

Establishing the Need

Assessing the need for recharge augmentation in a scientific and objective manner forms the first step in planning a recharge scheme. Artificial recharge may be required for tiding over deficit situations in summer/winter seasons though sufficient water may be available for the year as a whole, or to combat perennial deficit situations getting compounded over the years. In the former case, there is need for building up additional ground water storage as and when it is available and to conserve it to ensure that the available supplies last through the lean season. In case where the ground water deficit gets compounded due to overexploitation, artificial recharge measures will often have to be coupled with economy measures for preventing misuse of water and regulation of ground water development through legislation for them to be effective.

The need for artificial recharge also requires to be prioritized according to its importance in the overall development perspective of the nation. Such prioritization will also help in deciding the economic viability of the scheme being contemplated. Recharge for catering to drinking water needs in adverse situations, preventive recharge to combat saline water ingress/land subsidence and augmentation of water supply to projects of strategic importance fall under the highest priority. A benefit cost ratio of 0.9: 1 or even less may be acceptable depending upon the conditions under which the project is being implemented. Providing subsistence irrigation in semi-arid and drought-prone areas comes under the next category where a benefit cost ratio of 1 may be considered adequate. Recharge augmentation for industrial use and irrigation augmentation in humid areas have the least priority and a benefit cost ratio of 1.5:1 or higher may be required in such situations.

In cases where the objective of recharge is replenishment of de-saturated aquifer zones or to arrest/reverse decline in ground water levels, the benefit cannot be directly reflected in terms of BC ratio as the benefits are mostly intangible. In such cases, a long-term declining trend of ground water levels, in the absence of significant negative departure of rainfall, may be attributed to over-development of ground water resources. Data pertaining to a period of at least 10 years is recommended for examining the trend of ground water levels in an area.

Estimation of Sub-surface Storage Capacity of Aquifers

The scope for artificial recharge in an area is basically governed by the thickness of unsaturated material available above the water table in the unconfined aquifer. Depth to water level, therefore, provides the reference level to calculate the volume of unsaturated material available for recharge. Depth to water level recorded during post monsoon period is used for the purpose as areas where the natural recharge is not enough to compensate the ground water withdrawal, can be easily identified using the water level data. The average water levels for a period of at least 5 years is to be used in order to nullify the effects of variation in rainfall.

Contour maps prepared from the average post-monsoon water level data with suitable contour intervals can be used for assessment of available storage space. The intercontour areas between successive contours are determined and the total area in which the water levels are below a certain cut-off level (say 3.00 m.bgl in phreatic aquifers), multiplied by the specific yield of the aquifer material gives the volume of subsurface storage space available for recharge. The cut-off water level is so selected to ensure that the recharge does not result in water logging conditions in the area.

After assessing the subsurface storage space, the actual requirement of source water is to be estimated. Based on the experience gained from field experiments, the average recharge efficiency of the individual structure is to be specified (say 60-90%). To arrive at the total volume of actual source water required at the surface, the volume of water required for artificial recharge is calculated by multiplying the volume of subsurface storage space with the reciprocal of recharge efficiency of the structure proposed.

Sample worksheets for estimation of sub-surface storage capacity and volume of water required for recharge is shown in **Table 1** and **Table 2** respectively.

Table 1 Sample Worksheet for Estimation of Sub-surface Storage Capacity

Sl.No.	Basin	Watershed	Geographical area (sq.km)	Area identified for Artificial recharge (sq.km)	Depth to water level (Post monsoon) Below cut-off level (m)	Volume of unsaturated Zone(M Cu m)	Average specific yield (%)	Total subsurface storage potential as volume of water (M Cum)
1	2	3	4	5	6	7=(5x6)	8	9=(7x8)
1								
2								
3								
4								

Table2 Sample Worksheet for Estimation of Volume of Water Required for Recharge

Sl. No	Basin / Sub basin / Watershed	Area Identified for Artificial Recharge* (Sq.km)	Sub surface Storage Potential** (M Cu m)	Recharge Efficiency (%)	Surface Water Requirement (M Cu m)
1	2	3	4	5	6=(4)x100/(5)

*As in column 5 & ** column 9 of Table 5.1

Prioritisation of Areas for Artificial Recharge

It may not always be possible to implement artificial recharge projects in the entire area even though the need is established, due to various constraints such as lack of source water, shortage of funds for implementation of the projects etc. In such cases, it may be necessary to identify areas that require recharge augmentation most and to implement recharge projects accordingly.

Prioritisation of areas for artificial recharge is normally done by overlaying post monsoon depth to water level maps with maps depicting the long-term trend of ground water levels. From these maps, it is possible to demarcate areas with various combinations of depth to water levels and water level trends. For example, if a depth to water level map having 3 m contour intervals is combined with a water level trend map with 0.1 m/year contour interval, it is possible to demarcate areas having)

a) Water levels in the range of 3 to 6 m.bgl and declining trend of 0.10 to 0.20m/year.

b) water levels deeper than 9.00 m bgl and declining trend in excess of 0.40m/year or

c) Water levels deeper than 12.00 m bgl, but with a long term rising trend of 0.2to 0.4 m/year.

d) Water levels in the range of 5.0 to 10.0 m with declining trends during both pre-monsoon and post-monsoon season.

Normally, areas having deeper water levels and declining water level trends are given higher priority identification of area feasible for artificial recharge. Areas having shallow water levels / rising water level trends are not considered for inclusion inartificial recharge plan.

Availability of Source Water

A realistic assessment and quantification of the source water help design the storage capacity of the structure. Otherwise, there is a possibility of arriving at an improper design of the recharge structure. Various aspects of assessment of source water availability have been dealt with in the chapter on 'Source Water'. In cases validated data on non-committed surplus runoff / any other possible source of water and its distribution in time and space is available with appropriate agencies, the same can be considered. The quality aspects of the water to be utilized for recharge needs to be ascertained from the available data and if required through detailed analysis.

1.1.1 Suitability of Area for Recharge

The climatic, topographic, soil, land-use and hydrogeologic conditions are important factors controlling the suitability of an area for artificial recharge. The climatic conditions broadly determine the spatial and temporal availability of water for recharge, whereas the topography controls the extent of run-off and retention. The prevalent soil and land use conditions determine the extent of infiltration, whereas the hydrogeologic conditions govern the occurrence of potential aquifer systems and their suitability for artificial recharge.

Climatic Conditions

In regions experiencing high (1000 to 2000 mm/year) to very high (>2000 mm/year) rainfall, such as the Konkan and Malabar coasts, North-eastern States, parts of lesser Himalayas in Uttar Pradesh and

Himachal Pradesh, eastern part of Madhya Pradesh and parts of Bihar and Bengal, a major part of the water received during the rainy season goes as surface runoff. Only 5 to 10 percent of the total precipitation may infiltrate into the ground and reach the water table, which may be sufficient for adequate recharge. In areas of very high rainfall, the phenomenon of rejected recharge may also occur.

Most of such areas may not require artificial recharge of ground water and the best option is to store as much of the surplus water available as possible in large surface reservoirs, to be released to downstream areas during non-monsoon periods for direct use or to be used as source water for artificial recharge in suitable areas. The second and third order streams in such regions may have flow throughout the winter and the major rivers are normally perennial. The water in these streams and rivers, diverted, lifted or drawn through induced recharge may also be used as source water for artificial recharge.

In areas having moderate rainfall (750 – 1000 mm/year) such as eastern parts of Punjab and Maharashtra, eastern and central parts of Madhya Pradesh, parts of *Godavari* delta, eastern coast and Karnataka, adequate ground water resources are generally available only during the rainy season. A major component of the precipitation goes as surface runoff in these areas too and recharge may be 10 to 15percent of annual precipitation. Ground water recharge is normally not sufficient to saturate the water table aquifers in deficit rainfall years. The second and third order streams normally do not have any flow during a major part of winter and only major streams may have some flow during summer.

The non-availability of surplus runoff beyond the rainy season may impose a severe constraint on artificial recharge to ground water in these areas. Diversion of water released from surface water reservoirs in the upper reaches of the catchments, water transferred from surplus basins or lifted from rivers wherever available may be required for sustaining irrigation water supplies. Hence, conserving as much of surface runoff as possible through watershed treatment measures, inducing additional recharge during and after rainy season and conserving ground water outflow through subsurface dykes may be suitable for such areas.

In semi-arid regions with low to moderate rainfall in the range of 400 to 700 mm/year, the annual precipitation may not even suffice to meet the existing water demand, and droughts may occur with regular frequency due to variations in rainfall. Western part of Punjab and Haryana, eastern Rajasthan and parts of Gujarat, Saurashtra, central Maharashtra and Telengana and Rayal seema regions of Andhra Pradesh fall under this category. The evapotranspiration losses in these areas are quite high and even though 15 to 20 percent of water gets infiltrated into the ground, the total groundwater recharge will be limited because of the low rainfall. The stream flow in these regions is mostly restricted to the rainy season.

The replenishment of aquifers during rainy season generally is not enough to cater to the irrigation requirements during Rabi season in such areas, though it may be adequate for drinking water use through winter. Shortage of drinking water supplies is common during summer, which may be acute in years of deficit rainfall. Though recharge augmentation is warranted, due to lack of availability of source water, the only option available is to conserve as much of the surplus surface runoff during the short rainy season. Rainwater harvesting and runoff conservation measures for augmenting the ground water resources are appropriate in such situations.

In areas falling in arid zone, such as western Rajasthan desert, parts of Kutch region of Gujarat and Ladakh region of Jammu and Kashmir, the annual precipitation is less than 400 mm, the number of rainy days between 20 and 30 or even less and the coefficient of variation of rainfall is normally between 30 and 70 percent. The major component of outflow is evaporation and drainage is poorly developed in these areas. Infiltration of water may rarely exceed field capacity of soils and ground water recharge may be very small or negligible. Such areas may be left out of consideration for artificial recharge in spite of need unless trans-basin water is available. Rainwater harvesting may be contemplated in such regions for augmenting drinking water supplies. In case imported water is available, spreading or injection methods (for confined aquifers) may be considered depending on surface conditions (sandy/rocky), topographic set-up and salinity profiles of soils and the zone of aeration.

Topographic Set-up

The topographic set-up of an area controls the retention period of surface and groundwater within a topographic unit. The gradients are very steep (more than 1:10) in the runoff zones, with very little possibility of infiltration. Such areas on hill-slopes maybe suitable only for water conservation measures like gully plugging, bench terracing or contour trenching, aimed at slowing down surface runoff and thereby causing more infiltration, which may go as delayed subsurface seepage either to the unconfined or deeper confined aquifer systems.

Moderate topographic slopes between 1:10 and 1:100 usually occur on valley sides, downward of piedmont foothill regions. Surface and subsurface retention of water in these areas will be for longer durations depending upon slope and other conditions. The piedmont zone, with characteristically deep water table is located immediately at the foothills. The surface drainage is generally located above the water table. These areas are suitable for locating recharge basins and percolation ponds for recharging the water table aquifer. These unconfined aquifers may or may not recharge the deeper aquifers depending upon their hydraulic connectivity. At elevations just below the piedmont zone, artificial recharge through percolation ponds, recharge pits, trenches and recharge basins is normally feasible. In this transition zone, the piezometric heads of deeper aquifers may be initially located below the phreatic surface but at lower elevations, the situation may be the reverse. In the former situation, recharge of deeper aquifers through shafts, gravity inflow wells or injection wells may be feasible if sufficient source water supply is available.

The broad valley floors or the zone of lowest elevation occurring along the major rivers may typically have gentle to very gentle gradients. The movement of both surface and ground water in these areas is sluggish and retention time, in general, is high. These areas are generally categorized as ground water storage zones as all the water moving down the water table gradient converges in this zone. The deeper semiconfined aquifers often contribute water to the unconfined zone through upward leakage due to higher piezometric heads. The need for artificial recharge in such areas may arise only when they are located in low rainfall zones or have adverse hydrogeologic conditions. In such situations, induced recharge of unconfined aquifer along the river channel will be feasible if the river has some flow. Soil Aquifer Treatment (SAT) of treated municipal waste water may also be possible in the vicinity of urban agglomerations.

Soil and Land Use Conditions

Soil and land use conditions are of vital importance if artificial recharge through surface spreading methods is contemplated in an area. Various factors such as the depth of soil profile, its texture, mineral composition and organic content control the infiltration capacity of soils. Areas having a thin soil cover are easily drained and permit more infiltration when compared to areas with thick soil cover in the valley zones. Soils having coarser texture due to higher sand-silt fractions have markedly higher infiltration capacity as compared to clay-rich soils, which are poorly permeable. Soils containing minerals, which swell on wetting like montmorillonite etc. and with higher organic matter, are good retainers of moisture necessary for crop growth but impede deeper percolation.

The land use and extent of vegetation also controls the infiltration capacity of soils. Barren valley slopes are poor retainers of water as compared to grass lands and forested tracts, which not only hold water on the surface longer, but also facilitate seepage during the rainy seasons through the root systems. Similarly, ploughed fields facilitate more infiltration as compared to barren fields.

Hydrogeological Factors

Hydrogeological conditions of the area are also among important factors in planning artificial recharge schemes. The recharged water moves below the soil zone in moisture fronts through the zone of aeration. The unsaturated flow is governed by the permeability of zone of aeration, which in turn varies with moisture content of the front. Usually, in case of consolidated and semi consolidated rock formations, the subsoil zone passes into weathered strata, which, in turn, passes into unweathered rock. The hydrogeologic properties of the weathered strata are generally much better as compared to the parent rock due to higher porosity and permeability imparted by weathering. The nature of soil, subsoil, weathered mantle, presence of hard pans or impermeable layers govern the process of recharge into the unconfined aquifer. The saturation and movement of ground water within unconfined and all deeper semi confined and confined aquifers is governed by storativity and hydraulic conductivity of the aquifer material. Aquifers best suited for artificial recharge are those, which absorb large quantities of water and release them whenever required.

The geologic formations encountered in India have been classified into three groups based on their hydrogeologic properties and ground water potential. The broad hydrogeological characteristics of each group and the suitability of artificial recharge methods in each are given in **Tables 3**. The geologic formations in the highly mountainous Himalayan Region, except for the Quaternary valley fill deposits have not been covered in this classification on account of the adverse topographic conditions. Site selection criteria and design guidelines of artificial recharge structures mentioned in the tables have been described in the subsequent chapter.

Table 3 Suitability of Artificial Recharge Structures for Different Hydrogeological Settings

Group I: Consolidated Formations:

This group covers the hard crystalline igneous and metamorphic rocks, as well as hard massive indurate Pre-Cambrian sedimentary formations. The late Mesozoic, early Tertiary and Deccan and Rajamahal Volcanics, which cover a large area of the country, are also included in this group:

Geologic Age	Rock Formation	Rock Types	Hydrogeologic Characteristics	Artificial Recharge Structures Suitable	Remarks
Archaean (4000 to 1500 million years)	Archaean Complex Dharwars Aravallis to equivalent formations.	(a)Granites Gneisses, Charnokites, Khodalites (b)Schists, Slates Phyllites Granulites (c)Banded Haematite Quartzites (Iron ore series)	These formations have negligible to poor primary porosity. Secondary openings like joints, fractures, shears and faults give rise to limited fracture porosity. Weathering and denudation aided by secondary openings and structural weak planes add to the porosity & permeability of rock mass. Solution cavities (Caverns) in carbonate rocks may, at places give rise to large ground water storage/circulation.	1. Percolation tanks 2. Nalah Bunds 3. Gully plugs 4. Contour Bund 5. Bench Terracing. 6. Recharge pits and shafts. 7.Gravity recharge wells 8. Induced recharge wells in favourable situations. 9. Ground water Dam (Underground Bandhara) and Fracture sealing cementation. 10. Borehole Blasting & Hydro fracturing. 11. Various combination of above methods as per the site situations.	1. The storage capacity and diffusivity of aquifer being generally restricted; only limited artificial recharge may be accepted through a single structure, which benefits a limited area. More structures, spread over the watershed are required to create significant impact. 2. Injection recharge wells are not considered suitable due to limited intake possible in the deeper aquifers
Pre-Cambrians (1500 to 600 million years)	Cuddapahs, Delhi & equivalent systems.	(a)Consolidated sandstones, shales, Conglomerates (b)Limestones, Dolomites (c)Quartzites, Marbles (d)Intrusive granites &Malani	Ground water circulation is generally limited to100m depth but if major deep fractures are present, it may occur down to much deeper levels. Storativity value of unconfined aquifer is generally low. Hydraulic conductivity may vary widely depending on fracture incidence. Leaky confined/confined aquifers may be present in layered formations.		

Jurassic Upper cretaceous to Eocene (110 to 60 million years)	Rajmahal traps Deccan traps	volcanic (a)Basalts, Dolerites (b) Diorites and other acidic derivatives of Basaltic magma.			

Group-II: Semi Consolidated formations:

The sedimentary formations ranging in age between the Upper Carboniferous to Tertiary, which though lithified are relatively less consolidated and soft as compared to the consolidated formation have been included in this group. The hydrogeologic characteristics of the group are intermediate between the consolidated and the unconsolidated groups.

Geologic Age	Rock Formation	Rocks Types	Hydrogeologic characteristics	Structures suitable for Artificial Recharge	Remarks
Upper Carboni-ferous to Jurassic (275 to 150 Million years) Eocene to Lower Pleisto-cene (60 to 1 Million years)	Gondwana Group Jurassics of Kutch and Rajasthan, Bagh beds, Lametas& Cretaceous of Trichinapalli&Chharat Hill Limestone, Murees of Jammu, Rajmundri Sandstone, Subathus, Dagshai and Kasaulis of Shimla hills, Jaintia, Barail, Surma, Tipam, Dupitila and Dihing of Assam , upper, middle & lower Siwaliks of Himalayan Foot Hill Zone, Tertiary Strata of Rajasthan, Kutch, Gujarat, Pondicherry,	(a)Boulder pebble bed (b) Sandstones (c)Shales (d) Coal seams (a) Sandstones (b) Calcareous Sst. (c) Shales (d) Quartzites (e) Limestones (a) Nummuliticshales&limestones (b) Carbonaceous shale, (c) Sandstones (d) Shales (e) Conglomerates (f) Ferrugeneous sand stones (g) Calcareous sandstones	Among the sedimentary rocks included in this group, the pebble & gravel beds, sandstones and boulder conglomerates possess moderate primary porosity and hydraulic conductivity, which is governed by texture, sorting, degree of compaction and amount of cementing material. The hydrogeologic potential of limestones is governed by degree of karstification. The shales have poor potential. In the Gondwana group, the Talchir boulder bed, the Barakars, Kamthis and their equivalent formations possess moderately good potential. This group occurs in parts of West Bengal, Bihar, Orissa, Maharashtra and Andhra Pradesh. Tertiary sandstones of Rajasthan, Gujarat, Kutch, Kerala, Tamil Nadu, Andhra Pradesh and Orissa have relatively better hydrogeologic potential. All the semi-consolidated formations in the peninsular areas occur as innumerable small outcrops and do not have wide regional distribution. These are therefore only locally significant. The semi-consolidated group is extensively exposed in the lower and outer Himalaya ranges extending through J & K, H.P, Punjab, Haryana, U.P., Sikkim, West Bengal, Assam and the North Eastern States. The hydrogeologic potential of these formations becomes relevant only when these	1. Percolation Tanks 2. Nalah Bunds 3. Gully plug 4. Bench terracing 5. Contour Bund 6. Groundwater dams 7. Stream Modification 8. Recharge Basin, Pits and shafts 9. Gravity recharge wells 10. Induced Recharge **Confined Aquifer** 1.Injectionwells infavourable situation.	1. Sand- stones form the main rock type having potential for artificial recharge structures.

	A.P, Ratnagiri (Maharashtra), Baripada (Orissa), Quilon, Varkalli (Kerala), Cuddalore (Tamil Nadu)	(h) Pebble beds &boulder conglomerate (i) Sands (j) Clays	occur in the valley areas. The Murees, Dagshai, Kasauli, Subathus and lower Siwaliks are relatively hard & compact and have poor potential. The predominant sandstone members of middle Siwaliks lying at higher elevations do not form aquifers. The upper Siwaliks display moderate ground water potential in suitable topographic locations. Similar is the case with Tertiary Sandstones of N.E. States.		

Group-III: Unconsolidated Formations

In this group, the youngest geological formations of Pleistocene to Recent age, which are fluviatile or aeolean in origin, wh ich have not been lithified and occur as loose valley fill deposits have been included. Such formations hold good hydrogeologic potential.

Geologic Age	Rock Formation	Rocks Types	Hydrogeologic characteristics	Structures suitable for Artificial Recharge	Remarks
1	2	3	4	5	
Pleisto-cene to Recent (1 Million yrs. To Recent)	(a) Morains of Himalayan Valleys &Ladakh Region. (b) Karewas of Kashmir (c)BhabharTarai and equivalent piedmont deposits of Himalayan foothills. (d) Indo-Ganga-Brahmaputra alluvial plains (e) Narmada, Tapi, Purna alluvial deposits. (f) Alluvial deposits along courses of major peninsular rivers. (g)Coastal Alluvial and mud flats	(a)Mixed boulders, cobbles, sands and silts. (b)Conglomerates, sands, gravels, carbonaceous shales and blue clays (c) Boulder, cobble, pebble beds, gravels, sands, silt and clays (d) Clays & silts, gravels and sands of different textures, lenses of peat & organic matter, carbonate and siliceous concretions (Kankar) (e) Clays, silts, sands and gravels. (f) Clays, silts, sands and gravels.	The morain deposits occupy valleys and gorges in interior Himalayas.Ground water development is negligible. It will be premature to think of artificial recharge in these areas. Karewas are lacustrine deposits displaying cyclic layers of clayey,silty and coarser deposits with two intervening well-marked boulder beds. Hydraulic connection between deeper and shallower beds is likely to be poor due to horizontality of intervening clayey layers. The Bhabhar piedmont belt contains manyproductive boulder, cobble, gravel and sand aquifers in fan deposits of major drainage. The surface gradients are high and the water tables deep. The rivers have shallow, broad and flat beds located much above water table. The deeper aquifers of alluvial plains arpe expected to merge with unconfined zone in Bhabhar region. Tarai belt represents down-slope continuation of Bhabhar aquifers having higher recharge heads. The deeper confined aquifers display artesian and flowing artesian conditions. The area wasa marshy malarial tract due to shallow water table of unconfined aquifer. The Indo-Ganga-Brahmaputra alluvial plains formthe most potential ground water reservoir with a thick sequence of sandy aquifers down to great depth. The unconfined sand aquifers have been known to extend downto moderate depth (125m). Within such depths, the aquifers locally behave like confined zones and could regionally form part of an unconfined system. Deeper aquifers below the regionally extensive clayey layers are leaky confined/confined. The texture of sand strata, degree of	1. Flooding 2. Ditch & Furrow 3. Contour Trenches 4. Recharge Basin 5. Stream Modification 6. Surface irrigation 7. Injection well 8. Connector well 9. Recharge pits & shafts 10. Induced recharge. .	1. The valleys and gorges in interior and outer Himalayas have not been fully explored and exploited for ground water resources and thus any scheme for artificial in these areas is not suggested at this stage. 2. Bhabhar region, being the recharge zone for most of the deeper aquifer systems in alluvial plains, offer possibilities of augmenting ground water reservoir by construction of contour trenches recharge basins and pits. Stream flow, available for a very limited time during monsoon period requires to be fully utilized for recharge of deeper aquifer. 3. Tarai belt being a natural discharge zone in the foothill region is presently not conducive for any artificial recharge. Sluice valve control of artesian wells is

		(g) Clays, silts and sands(salt marshes)	sorting and uniformity and compaction determines the Storativity and hydraulic conductivity of individual stratum. The older alluvium, occurring away from the present river channels, and strata below 400 m. depth are more compact and hence permeability is relatively less.		required to conserve groundwater outflow from deeper aquifers

Geologic Age	Rock Formation	Rocks Types	Hydrogeologic characteristics	Structures suitable for Artificial Recharge	Remarks
1	2	3	4	5	
	(h)Aeolean Deposits of Western Rajasthan and parts of neighbouring states.	(h)Very fine to fine sands and silts.	The unconfined aquifers generally show high Storativity (5to25%) and high Transmissivity (500to3000m2/day) and have great capacity to accept and store recharged water. The leaky-confined aquifers receive recharge in areas where unconfined aquifers have higher hydraulic heads (tracts along major canals) and provide leakage recharge to the unconfined aquifer wherever the relative heads are reverse (mostly along courses of major streams). The deeper confined aquifers generally occurring below 200 to 300m depth have low Storativity (0.005to0.0005) and high Transmissivity (300to1000m^2/day). The alluvial valley fill deposits of Narmada, Tapi and Purna fault basins are predominantly silty /clayey with few sand gravel lenses within 100m depth. Deeper strata are more clayey and are perhaps partly Pleistocene/ tertiary. The quality of ground water at deeper levels is inferior. The aquifers have moderate ground water potential (Storativity4x10^{-6} to1.6x102andTransmissivity100to1000m ^{2}/day). The aeolean deposits (sand dunes) of western Rajasthan and parts of		4. In alluvial plains, canal irrigation over extensive tracts have given rise to incidental recharge of aquifers in most of the States, which forms the best supplementary recharge, provided the adverse effects like water-logging and salinisation of land are avoided through proper irrigation practices. 5. In aeolean deposits (sand dunes) of western Rajasthan, and parts of Haryana, Delhi and Punjab, unintended recharge may form the most appropriate option if canal water transferred from other basins becomes available.

			Haryana, Delhi and Punjab are very fine to fine grained, well-sorted sands and silts. Due to their location in arid region, they do not receive adequate natural recharge and water table is normally deep. The coastal sands and mud flats are generally restricted in width and thickness and do not merit detailed consideration.		

1.2 Investigations for Proper Planning

Various inputs are necessary for proper and scientific planning of artificial recharge schemes in any terrain. Scientific investigations leading to a better understanding of the characteristics of sub-surface formations are to be taken up for realistic determination of these inputs. These can broadly be grouped into two categories namely *viz.* general studies and detailed studies.

General Studies

These studies are aimed at assessing the need and scope of artificial recharge in an area. The procedure to be followed for establishing the need for artificial recharge in an area to augment the ground water resources has already been described in detail in an earlier section of the chapter.

Once a case of over exploitation of ground water is proved, the need for augmentation of ground water resources through artificial recharge is justified. In case of entire watersheds, overlaying of maps depicting the long-term decline in water levels and cumulative departure of rainfall from the normal can help in identification of areas requiring recharge augmentation.

Once the areas requiring artificial recharge are identified, the next step is to decide on the appropriate techniques for recharging the aquifer. The synthesis of all available data relevant to ground water is the first step in this exercise. These data include a) all sources of recharge like rivers, tanks, canals etc., b) rainfall distribution pattern, c)hydrogeological parameters with emphasis on lithological characteristics, d) nature of the terrain, e) intensity of ground water development and irrigation practices and f)chemical quality of surface and ground water etc. The data is generally available in reports/records of various Central and State Government agencies. However, the data available often have considerable gaps. It is therefore necessary to have detailed studies to supplement the available data and for preparation of a scientific data base for proper implementation of suitable artificial recharge schemes.

Detailed Studies

Once the need for and suitability of the area for artificial recharge to ground water are identified on the basis of data collected from the general studies, areas identified as suitable for recharge augmentation are studied in detail using Remote Sensing techniques and through hydrometeorological, hydrological, geophysical, hydrogeological and hydrochemical investigations to ascertain the scope and feasibility of artificial recharge. These studies are to be oriented in such a way as to collect and analyse necessary data, which are to be used as inputs for proper planning of artificial recharge projects. The major inputs expected to be provided by the studies mentioned are given below **(Table 4).**

Table 4 - Details of Studies Required for Planning Artificial Recharge Schemes

Sl.No	Type of Study	Inputs Anticipated
1	Remote Sensing Studies	Spatial variation in the infiltration characteristics of various litho-units. Drainage characteristics and Lineament intensity. Distribution of various geomorphic units.
2	Hydrometeorological Studies	Rainfall amount, duration, daily and hourly rainfall intensity, variability of rainfall.
3	Hydrological Studies	Source water availability, infiltration characteristics of major soil types and various land use categories
4	Geophysical Studies	Thickness of weathered zone in hard rocks Thickness and characteristics of granular zones in sedimentary terrain. Stratification of aquifer system and spatial variability in hydraulic conductivity. Vertical hydraulic conductivity Discontinuities such as dykes and fault zones.
5	Hydrogeological Studies	Regional hydrogeology and aquifer characteristics Behaviour of ground water levels Ground water potential Ground water flow pattern and hydraulic connection between ground water and surface water bodies.
6	Hydrochemical Studies	Quality aspects of source water for artificial recharge. Spatial and temporal variations in ground water quality.

Remote Sensing Studies

Remote sensing, with its advantages of spatial, spectral and temporal availability of data has now become a very useful tool in assessing, monitoring and locating ground water resources. Satellite data provides quick and useful baseline information on various parameters controlling the occurrence and movement of ground water such as geology, structural features, geomorphology, soils, land use, land cover, lineaments etc. All these parameters used to be studied earlier independently due to non-availability of data and lack of integrating tools and modeling techniques. A systematic study of these factors leads to better delineation of areas suitable for artificial recharge, which are then studied in detail through hydrogeological and geophysical investigations.

Visual interpretation of Satellite Imagery, with emphasis on terrain analysis is being used widely for selection of sites suitable for recharge augmentation. Aspects, which are given special attention for the study, usually carried out with Satellite Imagery or False Colour Composites (FCC) on 1: 50,000 scale include stream course delineation, land form analysis, outcrop pattern analysis, fracture pattern analysis and land use analysis. These studies can provide valuable information on drainage density and lineament intensity, which helps in the identification of suitable sites for recharge. Various geomorphic units can also be delineated, which also help determine the type of recharge structures suitable for the area.

Apart from visual interpretation, digital image enhancement techniques are also being increasingly used for deriving geological, structural and geomorphological information. Digital Image Enhancement techniques are found to be extremely useful as they improve the feature sharpness and contrast for simple interpretation. Various thematic layers generated using remote sensing data such as lithology, structure, geomorphology, land use/land cover, lineaments etc. can be integrated with slope, drainage density and other collateral data in a Geographic Information System (GIS) framework and analysed using a model developed with logical conditions to arrive at suitable sites for artificial recharge.

Image rectification and preparation of a GIS file through visual interpretation of standard False Color Composite (FCC) data can be done to extract expressions of subsurface moisture conditions. Techniques such as Edge Enhancement are Band Rationing are useful techniques for digital image interpretation.

Observations from satellite data must be complemented by field checks, existing geologic maps and topographic sheets.

Hydrometeorological Studies

Rainfall and evaporation are two of the most important parameters, which are required for proper planning of artificial recharge schemes.

Detailed information pertaining to the amount, duration and intensity of rainfall in a given area is a necessary pre-requisite for planning recharge schemes. Rainfall data is normally available at offices of

India Meteorological Department (IMD), Revenue Offices such as Collectorates, Taluk/Block/Mandal offices, Irrigation project dam sites and Agricultural Universities/ Colleges etc.

Long-term average rainfall is an important parameter for assessing the storage capacity of various artificial recharge structures. On the other hand, daily and hourly rainfall data is essential for planning water conservation schemes such as farm ponds, contour trenches, roof top rainwater harvesting schemes and also for designing filters for runoff recharge schemes.

Long-term average rainfall, dependable average rainfall and probability of incidence of a particular amount of rainfall in a given area can be calculated using long-term rainfall data of IMD Stations for 100 to 150 years. For computations of daily and hourly rainfall intensity, data available with other agencies can be used.

Evaporation data is useful for assessing the potential losses from the free surfaces of ponds and other surface water storage structures. Data related to daily/seasonal/monthly evaporation losses is helpful for identification of most effective recharge schemes in an area. The period/duration of ground water recharge with minimum evaporation losses can be determined from this data.

Hydrological Studies

Hydrological investigations are useful for ascertaining the availability of source water for recharge. These investigations are required to be carried out in the watershed, sub basin or basin where the artificial recharge schemes are envisaged.

A detailed account of the hydrological investigations for artificial recharge schemes have already been discussed under the heading 'Source Water' earlier in the manual.

Geophysical Studies

Geophysical studies can provide useful information pertaining to the characteristics of sub-surface lithological formations, which influence the type of recharge mechanism suitable for a particular area. These studies are normally taken up to complement the data collected through hydrogeological investigations.

The main purpose of applying geophysical methods for the selection of appropriate sites for artificial recharge studies is to assess the unknown sub-surface hydrogeological conditions economically, adequately and unambiguously. They are usually employed to narrow down the target zone and to pinpoint the probable sites for artificial recharge structures. The application of geophysical techniques is also useful for bringing out a comparative picture of the sub-surface litho-environment and to correlate them with the hydrogeological setting. Besides defining the sub-surface structure and lithology, geophysical studies can also help in studies for identifying the brackish/fresh ground water interface, contaminated zones (saline) and area prone to seawater intrusion.

In the context of artificial recharge, Geophysical studies are particularly useful for gathering information pertaining to

i. Stratification of aquifer systems and spatial variability of hydraulic conductivity of different zones.
ii. Negative or non-productive zones of low hydraulic conductivity in unsaturated and saturated zones.
iii. Vertical hydraulic conductivity discontinuities such as dykes, faults etc.
iv. Moisture movement and infiltration.
v. Direction of ground water flow under natural/artificial recharge processes.
vi. Salinity changes in aquifers with depth / saline water ingress.

Surface Geophysical techniques such as Electrical Resistivity Surveys, Self Potential (SP) surveys, Very Low Frequency (VLF) Electromagnetic Surveys and Shallow Refraction Seismic Surveys are commonly used for identification of sites for artificial recharge structures. Physical parameters like rock resistivities, magnetic susceptibilities, shock wave velocities etc. are measured in these investigations and interpreted to gather information pertaining to sub-surface rock types, rock water content, structural controls on ground water movement and ground water salinity. Subsurface methods such as Spontaneous Potential, Neutron, Natural Gamma, and Closed Circuit Television (CCTV) logging techniques are also useful for collecting valuable information from boreholes in the study area. As compared to surface methods, which measure parameter values representative of a combined subsurface layer sequence, subsurface methods measure the value of the physical parameter concerned for each individual layer.

Hydrogeological Studies

A detailed understanding of the hydrogeology of the area is of prime importance in ensuring successful implementation of any artificial recharge scheme. A desirable first step toward achieving this objective is to synthesize all available data on various hydrogeological parameters from different agencies. Regional geological maps indicate the location of different geological strata, their geological age sequence, boundaries/contacts of individual formations and structural expressions like strike, dip, faults, folds, fractures, intrusive bodies etc. These maps also indicate the correlation of topography and drainage to geological contacts.

Maps providing information on regional hydrogeological units, their ground water potential and general pattern of ground water flow and chemical quality of groundwater in different aquifers are also necessary. Satellite imagery provide useful data on geomorphic units and lineaments, which govern the occurrence and movement of ground water, especially in hard rock terrain. A detailed hydrogeological study, aimed at supplementing the regional picture of hydrogeological set up available from previous studies, is imperative to have precise information about the promising hydrogeological units for recharge and to decide on the location and type of structures
to be constructed.

Detailed Hydrogeological Mapping:

The purpose of detailed hydrogeological mapping is to prepare the following maps, which facilitate an understanding of the ground water regime and its suitability to artificial recharge Schemes

i. Map showing the hydrogeological units demarcated on the basis of their water-bearing capabilities, both at shallow and deep levels.
ii. Map showing ground water elevation contours to determine the form of the water table and the hydraulic connection between ground water and surface water bodies like rivers, tanks and canals.

iii. Maps showing depths to water table, usually compiled for the periods of maximum, minimum and mean annual positions of water table.
iv. Maps showing amplitudes of ground water level fluctuation.
v. Maps showing piezometric heads of aquifers and their variations with time.
vi. Maps showing ground water potentials of different hydrogeological units and the levels of ground water development.
vii. Maps showing chemical quality of ground water in different aquifers.

The usage of the above interpretative maps is additive, i.e., their combined usage provides greater knowledge and understanding of an area than when a map is used in isolation. The maps mentioned above will help determine

a) whether any gaps exists in the data on sub-surface geology of the area
b) Whether the available data on aquifer parameters is sufficient in case the area shows promise for artificial recharge to the deeper aquifers.
c) Whether the available ground water structures are sufficient to monitor the impacts of artificial recharge to ground water.

Aquifer Geometry:

The data on sub-surface hydrogeological units and their thickness and depth of occurrence are necessary to bring out the disposition and hydraulic properties of the unconfined, semi-confined and confined aquifers in the area. For surface water spreading techniques, the area of interest is generally restricted to shallow depths. The main stress is on knowing whether the surface rock types are sufficiently permeable to maintain high rate of infiltration during artificial recharge.

Hydrochemical Studies

A detailed study of the quality of source water is vitally important whenever direct recharge techniques are contemplated. In cases where *in situ* precipitation or water supplied from canals are used for recharge, no constraints on account of water quality may arise. However, in cases where waters in the lower reaches of rivers or recycled municipal/industrial waste waters are proposed to be used, the quality of water requires to be precisely analysed and monitored to determine the type and extent of treatment required.

1.3 Appraisal of Economic Viability

Economic viability is another critical parameter to be ascertained before taking a decision to implement any artificial recharge scheme. The appraisal of economic viability has to be carried out after taking into account all possible expenses including those for investigation, source water (conveyance, treatment), construction of recharge structures, operation and maintenance etc. All benefits should be appropriately accounted for and assessed in order to decide the acceptability of the scheme as per its priority in the overall scheme of development.

Important guidelines for carrying out economic appraisal of ground water recharge projects are furnished below:

i. The inputs and outputs should be distinguished as 'tradables' and 'non-tradables'.
ii. It is to be assumed that the project under consideration will not change the price of the output.
iii. Certain adjustments have to be made for converting financial prices to economic prices by applying appropriate conversion factors.
iv. The economic analysis should consider the effects of the project on both the producer and the user.
v. Labour and wages under skilled and unskilled categories have a special significance in the valuation for economic analysis. The real contribution to the economy probably varies according to region, type of labour and season. Hence, an extensive labour market survey is required for proper restructuring of the analysis.
vi. Although the computational part of the appraisal is rather straightforward, the essential purpose of the exercise is to ensure that the project has a positive impact on the efficient application of the resources of the nation.
vii. The outcome of the economic appraisal of a development project is decisive for the acceptance of the project.

viii. If the project is acceptable from the economic but not from the financial point of view, it implies that the project will contribute to an efficient application of the resources, but with additional financial support.

ix. If the project yields attractive returns to the Government but does not make a contribution to the efficient use of national resources, additional policy measures may be required to rectify the situation.

It is important to carry out the benefit cost analysis for all major public works before deciding the allocation of funds. The benefit cost analysis presents the quantifiable efforts and environmental and social aspects of any public projects in terms of money. Hence, it is an important instrument to guide investments for better planning and designing of the proposed layout.

The analysis of the financial benefits and costs requires the expression of cash flow elements under the non-financial operations in comparable terms. Costs are related to investments occurring during the lifetime of the project. Benefits, on the other hand, originate from the productive use of the projects. Both costs and benefits are, therefore, expressed in quantitative terms and translated into monetary terms by using market values of the inputs and outputs concerned. As the costs and benefits occur at different points of time, it is customary to express both in terms of their present value by applying appropriate discounting factors to make them comparable. After accounting for both costs and benefits against their market values, appropriate criteria are applied to determine the profitability of the project.

The benefit cost analysis of projects, also called Project Appraisal is done before the decision is taken to invest. The Project Appraisal includes financial, economic and social Benefit Cost analysis. The economic evaluation of the project, on the other hand, is done to analyse the performance and effects of the project after it has been executed.

The computational details of benefit cost analysis of artificial recharge projects are described in detail in the chapter on 'Economic Evaluation of Recharge Projects' in this manual.

1.4 Finalisation of Physical Plan

The finalization of physical plan for artificial recharge involves the following steps:

i. Preparation of lay-out plan of the project area on an appropriate scale showing the locations of proposed structures and source water conveyance systems.
ii. Determination of the number of structures required for recharge.
iii. Identification of tentative locations of proposed structures
iv. Preparations of design specifications and drawings
v. Working out the time-schedules for completion of various stages of the scheme.
vi. Planning of financial aspects such as source of funds, allocations required at various stages, schedules of repayment etc.
vii. Identification of the agency for executing the scheme.

ARTIFICIAL RECHARGE TECHNIQUES AND DESIGNS

The selection of a suitable technique for artificial recharge of ground water depends on various factors. They include:

a) Quantum of non-committed surface run-off available.
b) Rainfall pattern
c) Land use and vegetation
d) Topography and terrain profile
e) Soil type and soil depth
f) Thickness of weathered / granular zones
g) Hydrological and hydrogeological characteristics
h) Socio-economic conditions and infrastructural facilities available
i) Environmental and ecological impacts of artificial recharge scheme proposed.

1. Artificial Recharge Techniques

Techniques used for artificial recharge to ground water broadly fall under the following categories:

I. Direct Methods

A. Surface Spreading Techniques

a) Flooding
b) Ditch and Furrows
c) Recharge Basins
d) Runoff Conservation Structures

i) Bench Terracing
ii) Contour Bunds, Contour Trenches and Field bunds
iii) Gully Plugs, *Nalah* Bunds, Check Dams
iv) Percolation Ponds

Source: Manual on Artificial Recharge of Ground Water, MOWR, Govt. of India

e) Stream Modification / Augmentation

B. Sub-surface Techniques

a) Injection Wells (Recharge Wells)

b) Gravity Head Recharge Wells

c) Recharge Pits and Shafts

II. Indirect Methods

A. Induced Recharge from Surface Water Sources;

B. Aquifer Modification

i) Bore Blasting.

ii) Hydro-fracturing.

III. Combination Methods

In addition to the above, ground water conservation structures like Subsurface dykes (*Bandharas*) and Fracture Sealing Cementation techniques are also used to arrest subsurface flows.

Aquifer disposition plays a decisive role in choosing the appropriate technique of artificial recharge of ground water (Todd and Mays, 2005) as illustrated in the **Fig. 1.**

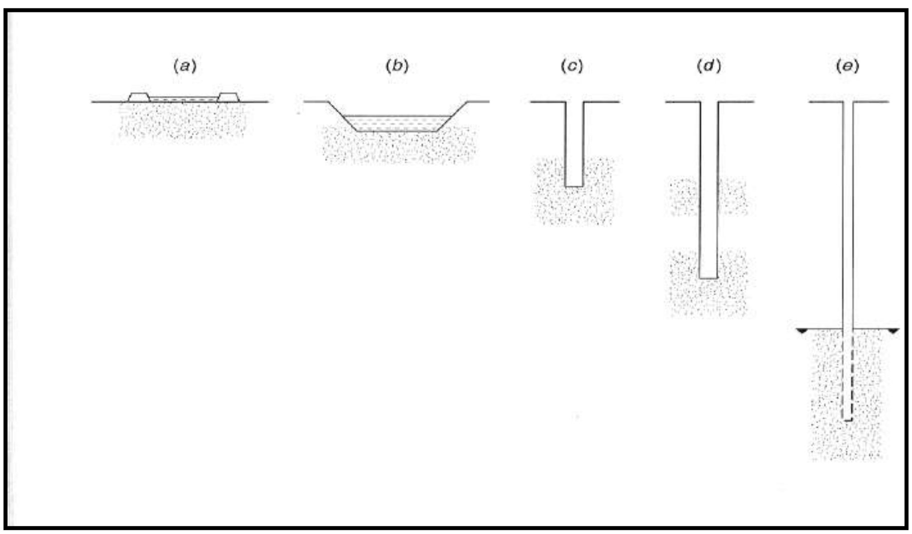


Figure 1 - Recharge Systems for Increasingly Deep permeable materials:

Surface Basin (a), Excavated Basin (b), Trench (c), Shaft or Vadose Zone Well (d) and Aquifer Well (e)

1.2 Direct Methods

1.2.1 Surface Spreading Techniques

These are aimed at increasing the contact area and residence time of surface water over the soil to enhance the infiltration and to augment the ground water storage in phreatic aquifers. The downward movement of water is governed by a host of factors including vertical permeability of the soil, presence of grass or entrapped air in the soil zone and the presence or absence of limiting layers of low vertical permeability at depth. Changes brought about by physical, chemical and bacteriological influences during the process of infiltration are also important in this regard.

Important considerations in the selection of sites for artificial recharge through surface spreading techniques include

i) The area should have gently sloping land without gullies or ridges.
ii) The aquifer being recharged should be unconfined, permeable and sufficiently thick to provide storage space.
iii) The surface soil should be permeable and have high infiltration rate.
iv) Vadose zone should be permeable and free from clay lenses.
v) Ground water levels in the phreatic zone should be deep enough to accommodate the recharged water so that there is no water logging.
vi) The aquifer material should have moderate hydraulic conductivity so that the recharged water is retained for sufficiently long periods in the aquifer and can be used when needed.
vii) The most common surface spreading techniques used for artificial recharge to ground water are flooding, ditch and furrows and recharge basins.

1.2.1.1 Flooding

This technique is ideal for lands adjoining rivers or irrigation canals in which water levels remain deep even after monsoons and where sufficient non-committed surface water supplies are available. The schematics of a typical flooding system are shown in **Fig. 2.** To ensure proper contact time and water spread, embankments are provided on two sides to guide the unutilized surface water to a return canal to carry the excess water to the stream or canal.

Flooding method helps reduce the evaporation losses from the surface water system, is the least expensive of all artificial recharge methods available and has very low maintenance costs

1.2.1.2 Ditch and Furrows method

This method involves construction of shallow, flat-bottomed and closely spaced ditches or furrows to provide maximum water contact area for recharge from source stream or canal. The ditches should have adequate slope to maintain flow velocity and minimum deposition of sediments. The widths of the ditches are typically in the range of 0.30 to 1.80 m. A collecting channel to convey the excess water back to the source stream or canal should also be provided. A typical system is shown in **Fig. 3(a)** and three common patterns *viz.* lateral ditch pattern, dendritic pattern and contour pattern are shown in **Fig.3 (b).** Though this technique involves less soil preparation when compared to recharge basins and is less sensitive to silting, the water contact area seldom exceeds 10 percent of the total recharge area.

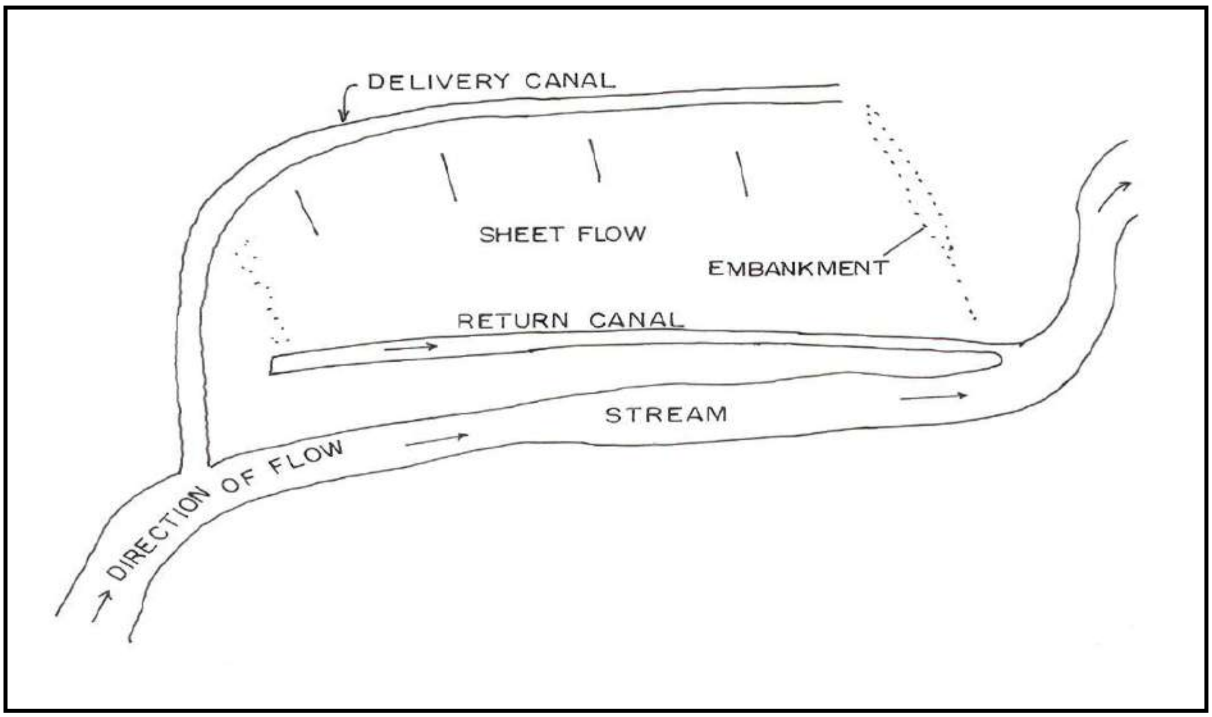


Fig.2 - Schematics of a Typical Flood Recharge System

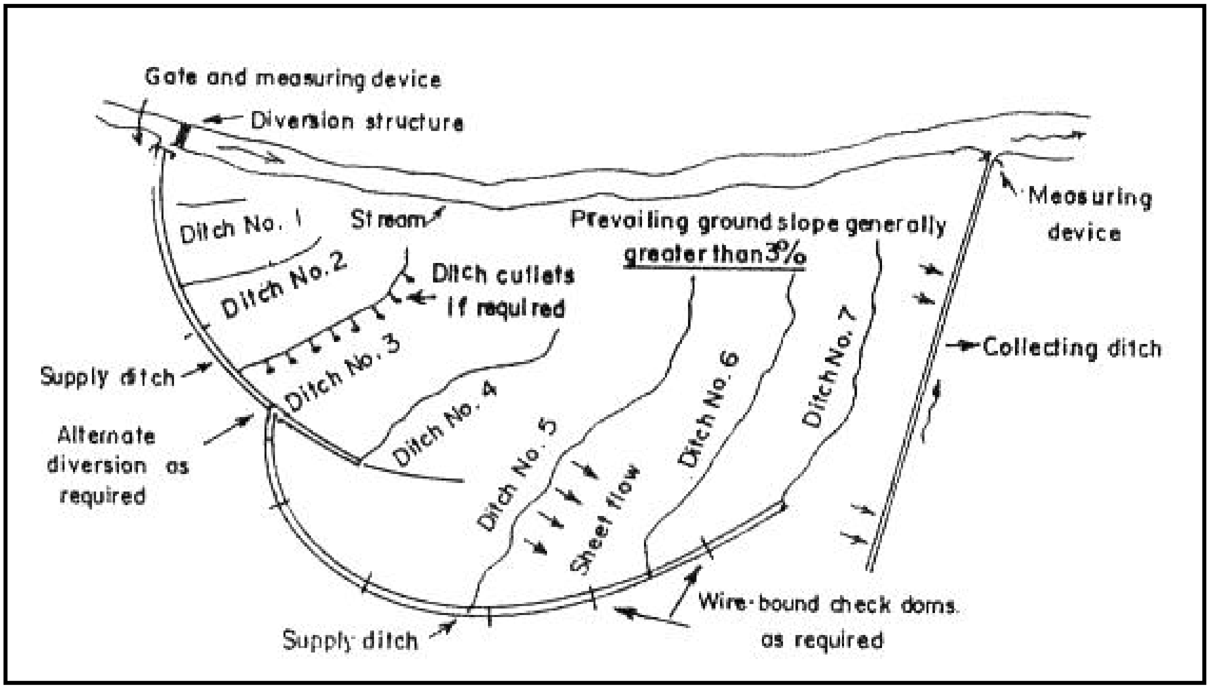


Fig 3(a) - Schematics of a Typical Ditch and Furrows Recharge System

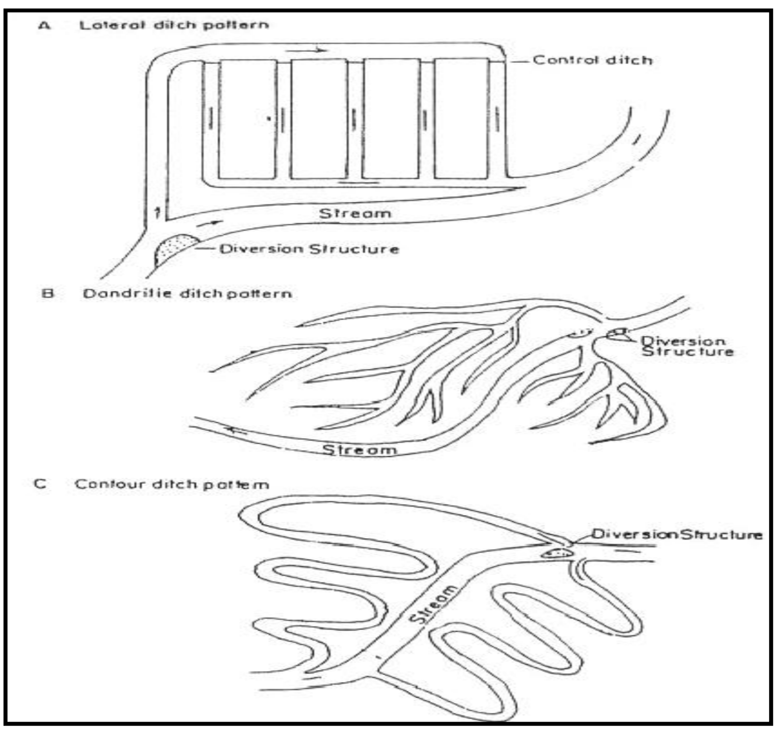


Fig 3(b) - Common Patterns of Ditch and Furrow Recharge Systems.

1.2.1.3 Recharge Basins

Artificial recharge basins are commonly constructed parallel to ephemeral or intermittent stream channels and are either excavated or are enclosed by dykes and levees. They can also be constructed parallel to canals or surface water sources. In alluvial areas, multiple recharge basins can be constructed parallel to the streams **(Fig. 4)**, with a view to a) increase the water contact time, b) reduce suspended material as water flows from one basin to another and c) to facilitate periodic maintenance such as scraping of silt etc. to restore the infiltration rates by bypassing the basin under restoration.

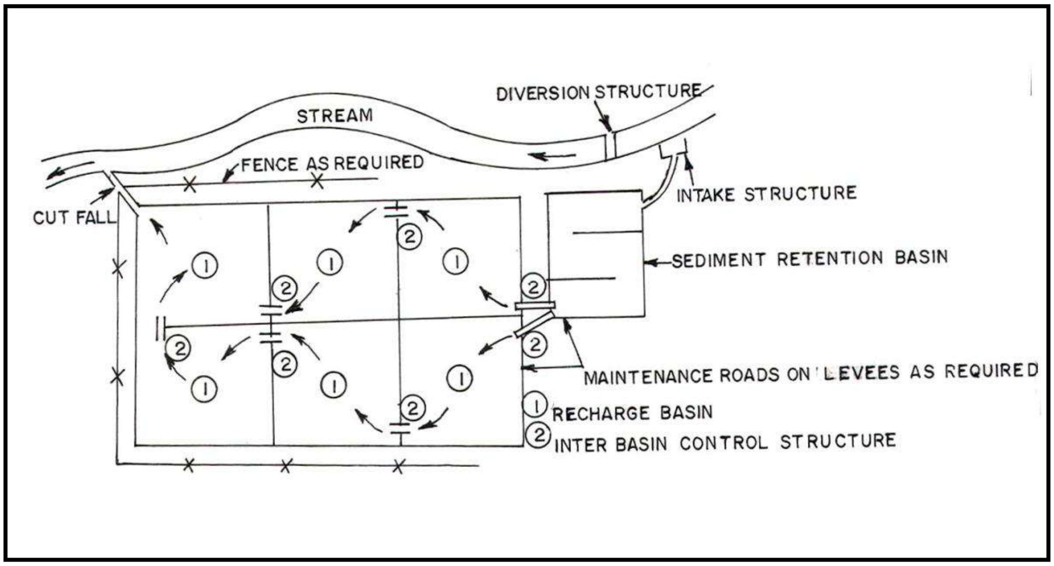


Fig. 4 - Schematics of a Typical Recharge Basin

In addition to the general design guidelines mentioned, other factors to be considered while constructing recharge basins include

a) area selected for recharge should have gentle ground slope.
b) the entry and exit points for water should be diagonally opposite to facilitate adequate water circulation in individual basins,
c) water released into the basins should be as sediment – free as possible and
d) rate of inflow into the basin should be slightly more than the infiltration capacity of all the basins.

1.2.2 Runoff Conservation Structures

These are normally multi-purpose measures, mutually complementary and conducive to soil and water conservation, afforestation and increased agricultural productivity. They are suitable in areas receiving low to moderate rainfall mostly during a single monsoon season and having little or no scope for transfer of water from other areas. Different measures applicable to runoff zone, recharge zone and discharge zone are available. The structures commonly used are bench terracing, contour bunds, gully plugs, *nalah* bunds, check dams and percolation ponds.

1.2.2.1 Bench Terracing

Bench terracing involves leveling of sloping lands with surface gradients up to 8 percent and having adequate soil cover for bringing them under irrigation. It helps in soil conservation and holding runoff water on the terraced area for longer durations, leading to increased infiltration and ground water recharge.

For implementing terracing, a map of the watershed should be prepared by level surveying and suitable benchmarks fixed. A contour map of 0.3 m contour interval is then prepared. Depending on the land slope, the width of individual terrace should be determined, which, in no case, should be less than 12 m. The upland slope between two terraces should not be more than 1:10 and the terraces should be leveled. The vertical elevation difference and width of terraces are controlled by the land slope. The soil and weathered rock thickness required, vertical elevation difference and the distance between the bunds of two terraces for different slope categories are furnished in **Table.1.**

In cases where there is a possibility of diverting surface runoff from local drainage for irrigation, as required in case of paddy cultivation in high rainfall areas, outlet channels of adequate dimensions are to be provided. The dimensions of the outlet channels depend on the watershed area as shown below in **Table 2.** The terraces should also be provided with bunds of adequate dimensions depending on the type of soils as shown in **Table. 3.**

Table 1 - Soil and Weathered Rock Thickness, Vertical Elevation Difference and the Distance between the Bunds of Two Terraces for Different Slope Categories

Land Slope (%)	Required Thickness of Soil and Weathered Rock (m)	Vertical Separation (m)	Distance Between Bunds of Two Terraces (m)
1	0.30	0.30	30
2	0.375	0.45	22
3	0.450	0.60	20
4	0.525	0.75	18.75
5	0.600	0.90	18
6	0.750	1.05	17.5
7	0.750	1.20	17
8	0.750	1.20	15

Table: 2 - Dimensions of Output Channels for Different Watershed Areas

Area of watershed (ha)	Channel Dimensions (m)		
	Base Width	Top width	Depth
< 4	0.30	0.90	0.60
4-6	0.60	1.20	0.60
6-8	0.90	1.50	0.60
8-10	1.20	1.80	0.60
10-12	1.50	2.10	0.60

Table: 3 - Dimensions of Terraces in Different Soil Types

Type of Soil	Soil Thickness (cm)	Base Width (m)	Top Width (m)	Height (m)	Side slope
Light	7.50 to 22.50	1.50	0.30	0.60	1:1
Medium	22.50 to 45.00	1.80	0.45	0.65	1:1
Medium Deep	45.00 to 90.00	2.25	0.45	0.75	1:1
Deep	> 90.00	2.50	0.50	0.80	1:1

In areas where paddy is cultivated, water outlets of adequate dimensions are to be provided to drain out excess accumulated water and to maintain water circulation. The width of the outlets may vary from 0.60 m for watersheds up to 2 ha to 3.0 m for watersheds of up to 8 ha for rainfall intensity between 7.5 and 10 cm. All the outlets should be connected to natural drainage channels.

1.2.2.2 Contour Bunds

Contour bunding, which is a watershed management practice aimed at building up soil moisture storage involve construction of small embankments or bunds across the slope of the land. They derive their names from the construction of bunds along contours of equal land elevation. This technique is generally adopted in low rainfall areas (normally less than 800 mm) where gently sloping agricultural lands with very long slope lengths are available and the soils are permeable. They are not recommended for soils with poor internal drainage e.g. clayey soils. Schematic of a typical system of contour bunds is shown in **Fig.5.**

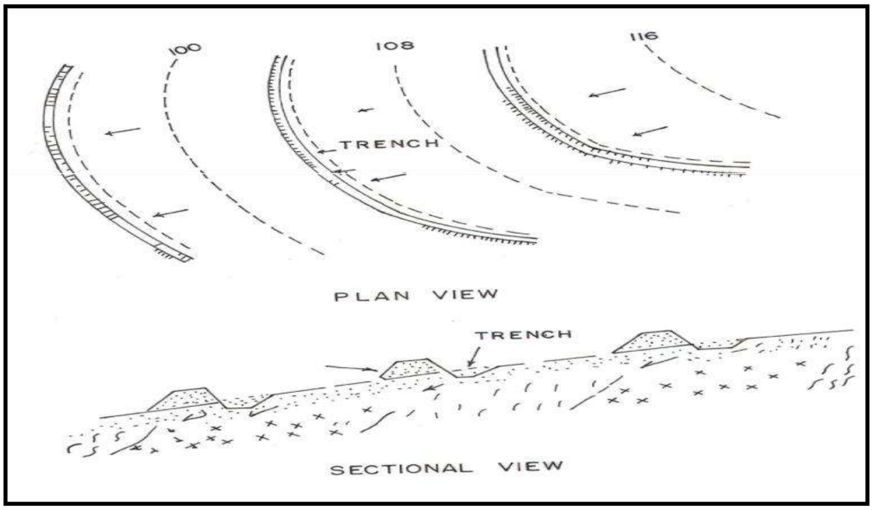


Fig.5 - Schematics of a Typical Contour Bund

Contour bunding involves construction of narrow-based trapezoidal embankments (bunds) along contours to impound water behind them, which infiltrates into the soil and ultimately augment ground water recharge.

Field activities required prior to contour bunding include levelling of land by removing local ridges and depressions, preparation of map of the area through level surveying and fixing of bench marks. Elevation contours, preferably of 0.3 m interval are then drawn, leaving out areas not requiring bunding such as habitations, drainage etc. The alignment of bunds should then be marked on the map.

The important design aspects of contour bunds are i) spacing, ii) cross section and iii) deviation freedom to go higher or lower than the contour bund elevation for better alignment on undulating land.

1.2.2.2.1 Spacing of Bunds:

Spacing of contour bund is commonly expressed in terms of vertical interval (V.I), which is defined as the difference in elevation between two similar points on two consecutive bunds. The main criterion for spacing of bunds is to intercept the water before it attains the erosive velocity. Spacing depends on slope, soil, rainfall, cropping pattern and conservation practices. Spacing of contour bunds is normally calculated using the formula

Vertical Interval (V.I) = 0.305 (XS+Y), where

X is the rainfall factor,
S is the land slope (%) and
Y is the factor based on soil infiltration and crop cover during the erosive period of rains

The rainfall factor 'X' is taken as 0.80 for scanty rainfall regions with annual rainfall below 625 mm, as 0.60 for moderate rainfall regions with annual rainfall in the range of 625 to 875 mm and as 0.40 for areas receiving annual rainfall in excess of 875 mm. The factor 'Y' is taken as 1.0 for soils having poor infiltration with low crop cover during erosive rains and as 2.0 for soils of medium to good infiltration and good crop cover during erosive rains. When only one of these factors is favourable, the value of Y is taken as 1.50. Vertical spacing can be increased by 10 percent or 15 cm to provide better location, alignment or to avoid obstacles.

The horizontal interval between two bunds is calculated using the formula

Horizontal Interval (H.I) = V.I x 100/Slope

1.2.2.2.2 Cross Section of Contour Bunds:

A trapezoidal cross section is usually adopted for the bund. The design of the cross section involves determination of height, top width, side slopes and bottom width of the bund.

The height of the bund depends on the slope of the land, spacing of the bunds and the rainfall excess expected in 24-hour period for 10-year frequency in the area. Once the height is determined, other dimensions can be worked out depending on the nature of the soil.

Height of the bund can be determined by the following methods:

a) Arbitrary Design: The depth of impounding is designed as 30 cm. 30 cm is provided as depth flow over the crust of the outlet weir and 20 cm is provided as free board. The overall height of the bund in this case will be 80 cm. With top width of 0.50 m and base width of 2 m, the side slope will be 1:1 and the cross section, 1 sq m.

b) The height of bund to impound runoff from 24 hour rain storm for a given frequency can be calculated by the formula

$$H = Re \frac{V.I}{50}$$

Where:

H is the depth of impounding behind the bund (m),
Re is the 24 hour rainfall excess (cm) and
VI is the vertical interval (m)

To the height so computed, 20 percent extra height or a minimum of 15cm is added for free board and another 15 to 20 percent extra height is added to compensate for the settlement due to consolidation.

Top width of the bund is normally kept as 0.3 to 0.6 m to facilitate planting of grasses. Side slopes of the bund are dependent on the angle of repose of the soil in the area and commonly range from 1:1 for clayey soils to 2:1 for sandy soils. Base width of the bund depends on the hydraulic gradient of the water in the bund material due to the impounding water. A general value of hydraulic gradient adopted is 4:1. The base should be sufficiently wide so that the seepage line should not appear above the toe on the downstream side of the bund. Size of the bund is expressed in terms of its cross-sectional area. The cross sectional area of bunds depends on the soil type and rainfall and may vary from 0.50 to 1.0 sq m in different regions. Recommended contour bund specifications for different soil depths are shown in **Table 4.**

Table 4 - Recommended Contour Bund Specifications for Different Soil Depths

Soil Type	Soil Depth (m)	Top Width (m)	Bottom Width (m)	Height (m)	Side Slope	Area of Cross section (sq m)
Very Shallow Soils	< 7.5	0.45	1.95	0.75	1:1	0.09
Shallow Soils	7.50 to 23 .0	0.45	2.55	0.83	1.25:1	1.21
Medium Soils	23.0 to 45.0	0.53	3.00	0.83	1.50:1	1.48
Deep soils	45.0 to 80.0	0.60	4.20	0.90	2:1	2.22

The length of bunds per hectare of land is denoted by the Bunding Intensity, which can be computed as

$$\text{Bunding Intensity} = \frac{100\,S}{V.I}$$

Where:

S is the land slope (%) and

V.I is the vertical interval (m)

The earthwork for contour bunding includes the main contour bund and side and lateral bunds. The area of cross-section of side and lateral bunds is taken equal to the main contour bund. The product of cross sectional area of the bund and the bunding intensity gives the quantity of earthwork required for bunding / hectare of land.

1.2.2.2.3 Deviation Freedom:

Strict adherence to contours while constructing bunds is a necessary prerequisite for ensuring maximum conservation of moisture and soil. However, to avoid excessive curvature of bunds, which makes agricultural operations difficult, the following deviations are permitted

a) a maximum of 15 cm while cutting across a narrow ridge,

b) a maximum of 30 cm while crossing a gully or depression and

c) a maximum of 1.5 m while crossing a sharp, narrow depression not exceeding 5 m in width.

1.2.2.3 Contour Trenches

Contour trenches are rainwater harvesting structures, which can be constructed on hill slopes as well as on degraded and barren waste lands in both high- and low- rainfall areas. Cross section of a typical contour trench is shown in **Fig.6.**

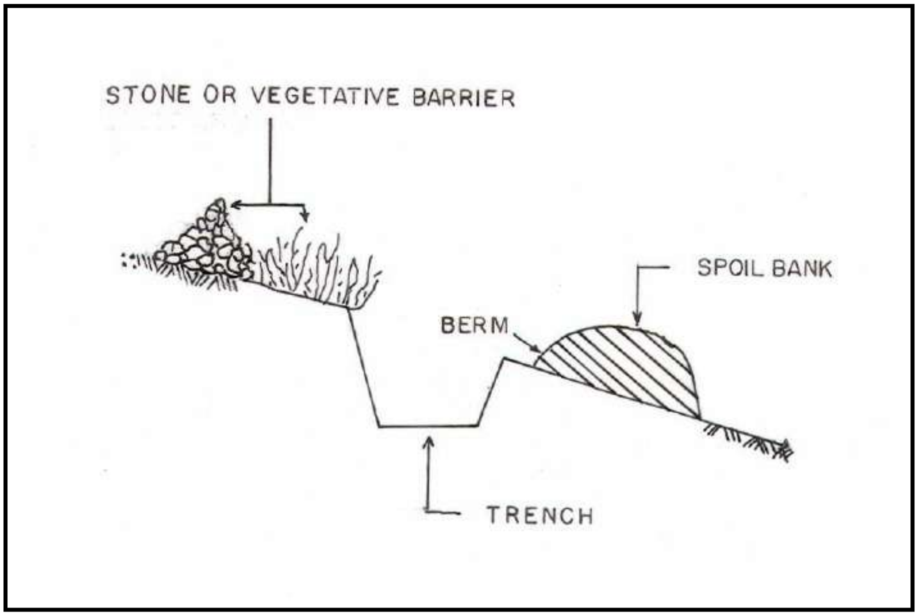


Fig. 6 - Schematics of a Contour Trench

The trenches break the slope at intervals and reduce the velocity of surface runoff. The water retained in the trench will help in conserving the soil moisture and ground water recharge.

The size of the contour trench depends on the soil depth and normally 1000 to 2500 sq. cm cross sections are adopted. The size and number of trenches are worked out on the basis of the rainfall proposed to be retained in the trenches. The trenches may be continuous or interrupted and should be constructed along the contours. Continuous trenches are used for moisture conservation in low rainfall area whereas intermittent trenches are preferred in high rainfall area.

The horizontal and vertical intervals between the trenches depend on rainfall, slope and soil depth. In steeply sloping areas, the horizontal distance between the two trenches will be less compared to gently sloping areas. In areas where soil cover is thin, depth of trenching is restricted and more trenches at closer intervals need to be constructed. In general, the horizontal interval may vary from 10 m in steep slopes to about 25 m in gentle slopes.

1.2.2.4 Gully Plugs, *Nalah* Bunds and Check Dams

These structures are constructed across gullies, *nalah*s or streams to check the flow of surface water in the stream channel and to retain water for longer durations in the pervious soil or rock surface. As compared to gully plugs, which are normally constructed across 1st order streams, *nalah* bunds and check dams are constructed across bigger streams and in areas having gentler slopes. These may be temporary structures such as brush wood dams, loose / dry stone masonry check dams, Gabion check dams and woven wire dams constructed with locally available material or permanent structures constructed using stones, brick and cement. Competent civil and

agro-engineering techniques are to be used in the design, layout and construction of permanent check dams to ensure proper storage and adequate outflow of surplus water to avoid scours on the downstream side for long-term stability of the dam.

The site selected for check dam should have sufficient thickness of permeable soils or weathered material to facilitate recharge of stored water within a short span of time. The water stored in these structures is mostly confined to the stream course and the height is normally less than 2 m. These are designed based on stream width and excess water is allowed to flow over the wall. In order to avoid scouring from excess runoff, water cushions are provided on the downstream side. To harness maximum runoff in the stream, a series of such check dams can be constructed to have recharge on a regional scale. The design particulars of a cement *nalah* bund are shown in **Fig.7.**

The following parameters should be kept in mind while selecting sites for check dams / *nalah* bunds:

i) The total catchment area of the stream should normally be between 40 and 100 ha. Local situations can, however, be a guiding factor in this regard.

ii) The rainfall in the catchment should be preferably less than 1000 mm / annum.

iii) The stream bed should be 5 to 15 m wide and at least 1m deep.

iv) The soil downstream of the bund should not be prone to water logging and should have a pH value between 6.5 and 8.

v) The area downstream of the Check Dam / bund should have irrigable land under well irrigation.

vi) The Check dams / *Nalah* bunds should preferably be located in areas where contour or graded bunding of lands have been carried out.

vii) The rock strata exposed in the ponded area should be adequately permeable to cause ground water recharge.

Check dams / *Nalah* bunds are normally 10 to 15 m long, 1 to 3 m wide and 2 to 3 m high, generally constructed in a trapezoidal form. Detailed studies are to be made in the watershed prior to construction of the check dam to assess the current erosion condition, land use and water balance. The community in the watershed should also be involved in the planning and selection of the type and location of the structure.

For construction of the check dam, a trench, about 0.6 m wide in hard rock and l.2 m wide in soft impervious rock is dug for the foundation of core wall. A core brick cement wall, 0.6 m wide and raised at least 2.5m above the *nalah* bed is erected and the remaining portion of trench back filled on upstream side by impervious clay. The core wall is buttressed on both sides by a bund made up of local clays and stone pitching is done on the upstream face. If the bedrock is highly fractured, cement grouting is done to make the foundation leakage free.

1.2.2.5 Percolation Tanks

Percolation tanks, which are based on principles similar to those of *nalah* bunds, are among the most common runoff harvesting structures in India. A percolation tank can be defined as an artificially created surface water body submerging a highly permeable land area so that the surface runoff is made to percolate and recharge the ground water storage. They differ from *nalah* bunds in having larger reservoir areas. They are not provided with sluices or outlets for discharging water from the tank for irrigation or other purposes. They may, however, be provided with arrangements for spilling away the surplus water that may enter the tank so as to avoid over-topping of the tank bund.

It is possible to have more than one percolation tank in a catchment if sufficient surplus runoff is available and the site characteristics favour artificial recharge through such structures. In such situations, each tank of the group takes a share in the yield of the whole catchment above it, which can be classified as

i) 'free catchment', which is the catchment area that only drains into the tank under consideration and
ii) 'Combined catchment', which is the area of the whole catchment above the tank.

The difference between the combined and free catchment gives the area of the catchment intercepted by the tanks located upstream of any tank. The whole catchment of the highest tank on each drainage shall be its free catchment. Moreover, each tank will receive the whole runoff from its free catchment, but from the remainder of its catchment it will receive only the balance runoff that remains after the upper tanks have been filled.

1.2.2.5.1 Site Selection Criteria:

The important site selection criteria for percolation ponds include:

i) The hydrogeology of the area should be such that the litho-units occurring in the area of submergence of the tank should have high permeability. The soils in the catchment area of the tank should be sandy to avoid silting up of the tank bed.
ii) The availability of non-committed surplus monsoon runoff should be sufficient to ensure filling of the tank every year.
iii) As the yield of catchments in low rainfall areas generally varies between 0.44 to 0.55 M Cu m/sq km, the catchment area may be between 2.50 and 4.0 sq km for small tanks and between 5.0 and 8.0 sq km for larger tanks.
iv) Selection of the size of a percolation tank should be governed by the percolation capacity of the strata rather than the yield of the catchment. In order to avoid wastage of water through

evaporation, larger capacity tanks should be constructed only if percolation capacity is proven to be good. If percolation rates are low to moderate, tanks of smaller capacity may be constructed. Percolation tanks are normally designed for storage capacities of 8 to 20 M cft. (2.26 to 5.66 M Cu m).

v) The depth of water impounded in the tank provides the recharge head and hence it is necessary to design the tank to provide a minimum height of ponded water column of 3 to 4.5 m and rarely 6 m above the bed level. This would imply construction of tanks of large capacity in areas with steep gradient.

vi) The purpose of construction of percolation tanks is to ensure recharge of maximum possible surface water runoff to the aquifer in as short a period as possible without much evaporation losses. Normally, a percolation tank should not retain water beyond February.

vii) The percolation tank should be located downstream of runoff zone, preferably toward the edge of piedmont zone or in the upper part of the transition zone. Land slope between 3 and 5 percent is ideal for construction of percolation tanks.

viii) There should be adequate area suitable for irrigation and sufficient number of ground water abstraction structures within the command of the percolation tank to fully utilise the additional recharge. The area benefited should have a productive phreatic aquifer with lateral continuity up to the percolation tank. The depth to water level in the area should remain more than 3 m below ground level during post-monsoon period.

1.2.2.5.2 Investigations Required:

An area, preferably the entire watershed, needing additional ground water recharge is identified on the basis of declining water level trends both during pre and post monsoon, increase in the demand of ground water and water scarcity during lean period etc. Areas having scarcity of water during summer in spite of incidences of flood during monsoons may also be considered for artificial recharge.

A base map, preferably on 1:50,000 scale showing all available geological, physiographical, hydrogeological and hydrological details along with land use, cropping pattern etc. is a pre-requisite for the scientific planning. Survey of India toposheets, aerial photographs and satellite imagery of the area may be consulted to gather preliminary information about the area under study. The nature of catchment as regards to the general slope, land use, forest cover, cropping pattern, soils, geology etc.

should be understood to assess their influence on runoff.

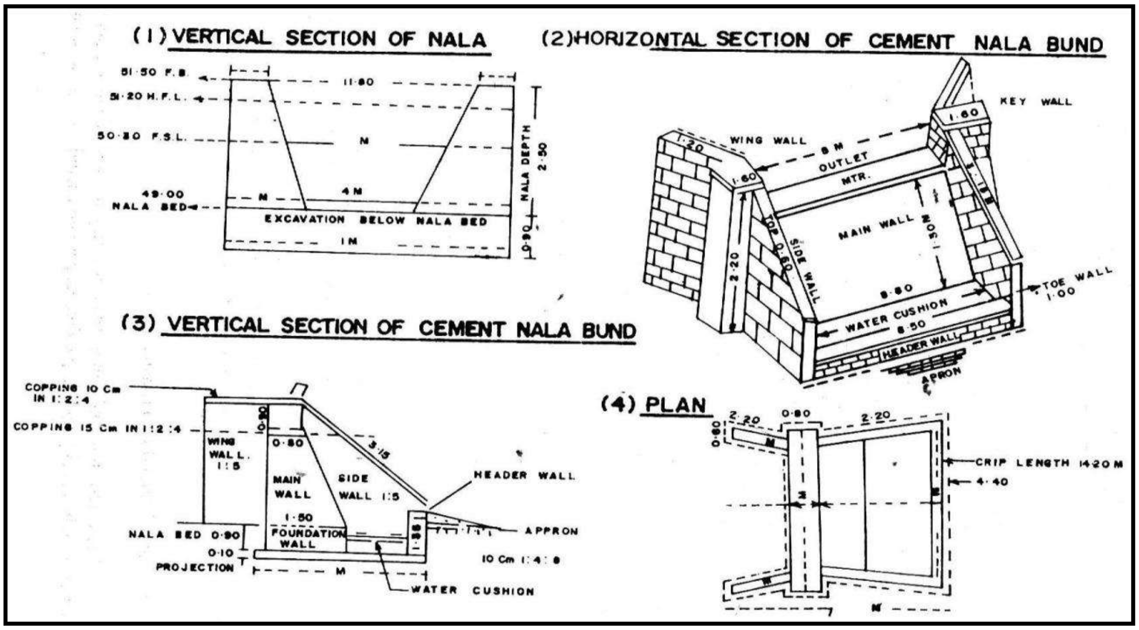


Fig. 7 Design Aspects of a Cement *Nalah* Bund

The rainfall data of rain gauge stations located in the watershed or in its immediate vicinity is to be collected during the preliminary investigations. The intensity and pattern of rainfall, number of rainy days and duration of dry spells during the monsoon are to be analyzed. The dependability of normal monsoon rainfall and the departure of actual rainfall from normal rainfall are also worked out along with other weather parameters.

Percolation tanks are to be normally constructed on second or third order streams, as the catchment area of such streams would be of optimum size. The location of tank and its submergence area should be in non-cultivable land and in natural depressions requiring lesser land acquisition. There should be cultivable land downstream of the tank in its command with a number of wells to ensure maximum benefit by such efforts. Steps should be taken to prevent severe soil erosion through appropriate soil conservation measures in the catchment. This will keep the tank free from siltation which otherwise reduces the percolation efficiency and life of the structure.

Detailed geological and hydrogeological mapping is to be carried out in the area of submergence, at the tank site and also downstream of the site to find out the permeability of vadose zone and aquifer. The potential of additional storage and capacity of aquifer to transmit the ground water in adjoining areas is also assessed based on aquifer geometry. Infiltration rates of soils in the probable area of submergence are to be determined through infiltration tests. Aquifer parameters of water-bearing formations in the zone of influence may also be determined to assess the recharge potential and number of feasible ground water structures in the area. Periodic water level measurements along with ground water sampling for water quality may be done before and after the construction of percolation tanks. Detailed geological investigations may be carried out to study the nature and depth of formation at the bund (dam) site for deciding the appropriate depth of cut off trench (COT). This will help in reducing the visible seepage and also ensure safety and long life of the structure. The depth of foundation and its treatment should be considered on the basis of nature of formation while designing and constructing the dam wall and waste weir.

1.2.2.5.3 Engineering Aspects:

A percolation tank is essentially an earthen structure with a masonry spill way. It should be designed with maximum capacity utilisation, long life span, cost-effectiveness and optimum recharge to ground water in mind. Storage capacity, waste weir, drainage arrangements and cut off trench (COT) are the important features of percolation tank that need proper design. The overall design of the percolation tank is similar to that of an earthen dam constructed for minor irrigation.

Detailed topographical survey to demarcate the area of submergence in natural depression and alignment of dam line in the valley is to be taken up prior to construction of the structure. A number of sections along and across the drainage are prepared and the best suitable site is identified. The land availability and possibility of land acquisition is explored during the survey. The spillway site is demarcated and is designed in such a way that it allows the flow of surplus water based on single day maximum rainfall after the tank is filled to its maximum capacity. The depth of foundation for masonry work of waste weir etc. is decided depending on the nature of formation. Cut Off Trench (COT) is provided to minimize the seepage losses across the streambed. The depth of COT is generally 2-6 m below ground level depending upon the subsurface strata. In order to avoid erosion of bund due to ripple action, stone pitching is provided in the upstream direction up to High Flood Level (HFL). The sources for availability of constructional material, especially clay and porous soil for earthwork and stone rubble for pitching are to be identified.

a) Design of Storage Capacity:

The storage capacity of a percolation tank may be defined as the volume of water stored in the tank up to the Full Tank Level (FTL). The storage capacity can be computed by using the contour plan of the water-spread area of the tank. The total capacity of the tank will be the sum of the capacities between successive contours. The smaller the contour interval, the more accurate the capacity computation will be. The summation of all the volumes between successive

contours will be required for computing the storage capacity of the tank. When contour plan is not available and only the area of the tank at FTL is known, then the effective volume of the tank may be roughly computed as the area multiplied by onethird of the depth from FTL to the deep bed of the tank.

The tank is designed to ensure maximum utilisation of its capacity. A structure of optimum capacity is the most cost effective. An under-utilized structure leads to unproductive expenditure incurred on extra earthwork. The design of storage capacity of a tank depends mainly upon the proper estimation of catchment yield, which is calculated as,

Q = A * Strange's Coefficient

Where, Q is yield at site and A is area of the catchment.

Strange's coefficients for various amounts of monsoon rainfall for three categories of catchments, i.e. good, average and bad are available from Strange's tables provided in standard Hydrology text books. The rainfall data of 40-50 years, collected from the nearest rain gauge station, may be used for design purposes. The percolation tanks are to be designed for a realistic percentage of the yield of the catchment considering the temporal distribution of monsoon rainfall. Another important consideration is the fact that water stored in a percolation tank starts percolating immediately and the terminal storage in the tank is not the cumulative storage from different spells of rain. The concept of storage capacity of percolation ponds thus differs significantly from that of an irrigation tank.

The catchment yield and basin configuration drawn from topographic surveys at site determine the height of the percolation tank. The top of dam wall is normally kept 2- 3 m wide. Upstream and downstream slopes of the dam wall are normally taken as 2.5:1 and 2:1 respectively as recommended in design manual for minor irrigation tanks. The design particular of a typical percolation tank is shown in **Fig.8** along with all relevant details.

b) Design of Tank Bund:

The tank bund, for all practical purposes, is a small-sized earthen dam and its design and construction should be carried out in accordance with the principles applicable to earthen dams.

The bunds of a percolation pond may be of three types, i.e.

Type A: Homogeneous embankment type **(Fig. 9(a))**

Type B: Zoned Embankment Type **(Fig. 9(b))**

Type C: Diaphragm Type **(Fig. 9(c))**

Tank bunds in India are mostly of Type A and are constructed with soils excavated from pits in the immediate vicinity of the bund and transported to the bund.

The most commonly adopted standards used for fixing the dimensions of tank bunds, particularly in South India are given in **Table 5.** In favourable soils such as gravels, black loams etc., the side slopes of the bund may be kept at 0.5:1 for smaller tanks with water depths not exceeding 2.50 m and 2:1 for larger tanks up to 5.0 m deep. In light sandy or black clayey soils, on the other hand, the slopes may be kept between 2:1 or 2.5:1.

Table 5 - Common Dimensions of Bunds of Percolation Tanks

Si.No	Maximum Water Depth (m)	Free Board (m)	Width of Top of Bund (m)
1	1.5 to 3.0	0.90	1.20
2	3.0 to 4.5	1.20	1.50
3	4.5 to 6.0	1.50	1.80
4	Over 6.0	1.80	2.70

The upstream face of the tank bund is generally riveted with stone apron or riprap **(Fig. 10)** so as to protect it against erosion and if this is done, then the upstream slope generally adopted is 1.5:1, even up to 6 m depth. For inferior soils or greater depths, however, the riveted slope may be made flatter, say 2:1.

In this way, for average cases, a 1.5:1 slope will generally be adopted for upstream face and 2:1 slope for downstream face.

This practice is contrary to the standard recommendations adopted in many countries where the upstream slope, even when riveted, is kept flatter than the downstream slope because of the soil being saturated. There are, however, thousands of tanks in Tamil Nadu with slopes of 1.5:1 and failure by slipping of this slope is rare. Hence, the prevailing practice can be easily adopted. In very small tanks and in cases where the upstream slope is heavily riveted, upstream faces have been given 1:1 or even steeper slopes in actual practice, but such steeper slopes are not recommended.

c) Waste/ Surplus Weir:

The waste/surplus weirs are constructed for discharging the excess water from the tank into the downstream channel after it is filled so as to avoid the rise of water in the tank above the Maximum Water Level (MWL). The water will start spilling over the crest of this escape weir as and when it rises above the FTL and the discharging capacity of this weir will be so designed as to pass the full flood discharge likely to enter the tank with a depth over the weir equal to the difference between FTL and MWL.

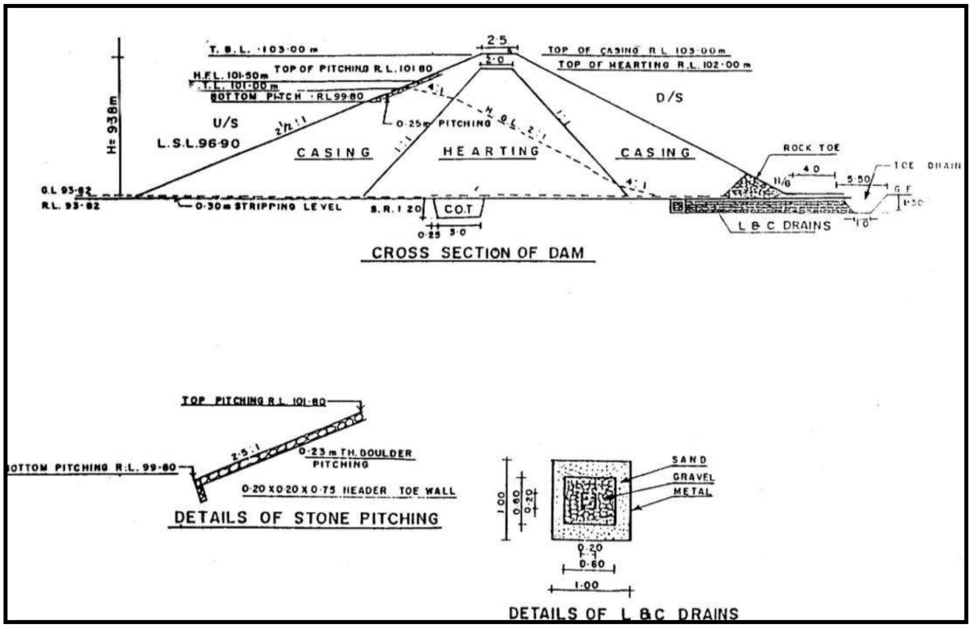
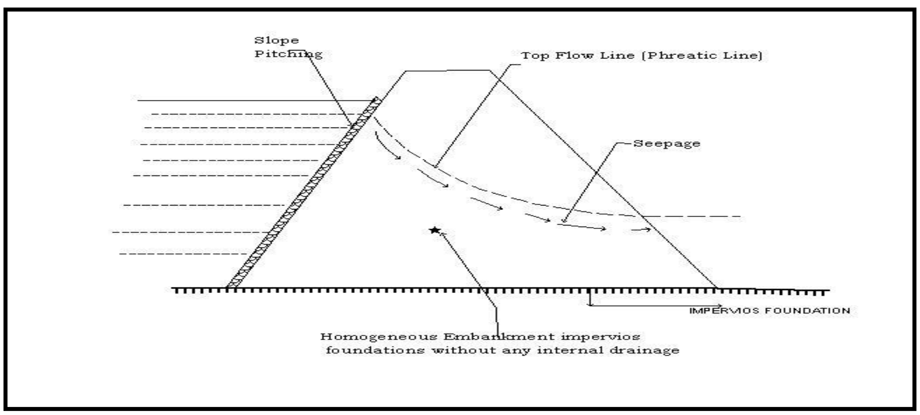
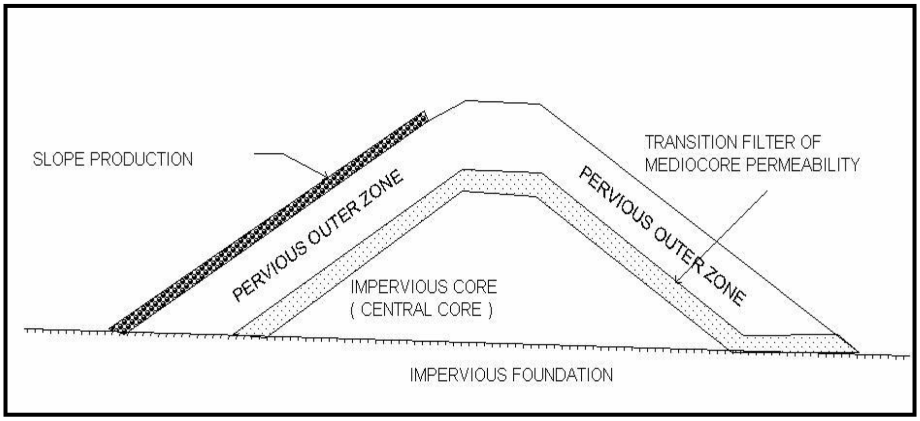


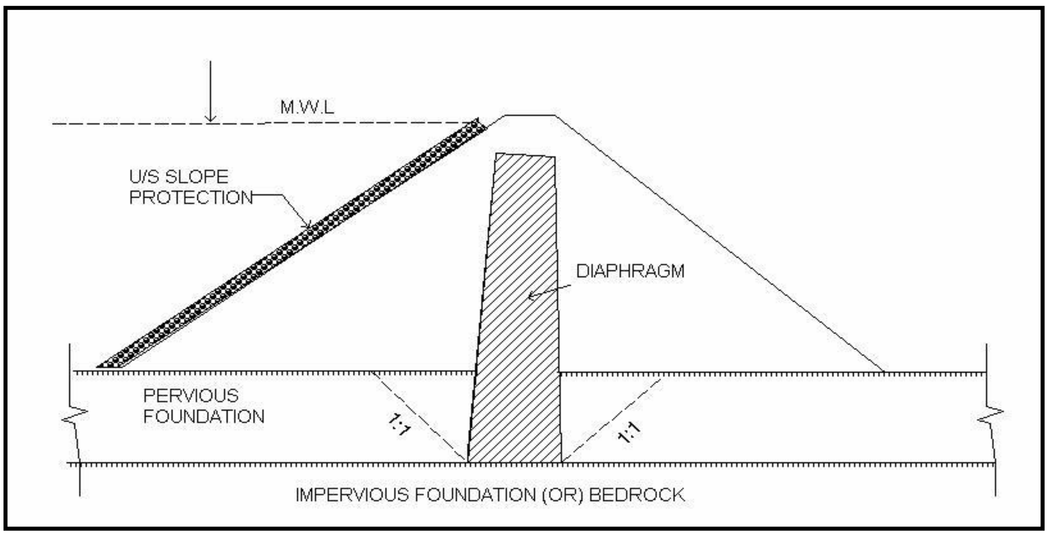
Fig.8 Design Aspects of a Typical Percolation Pond



Homogenous Type



Zoned Type



Diaphragm Type

Fig.9 - Common Types of Bunds of Percolation Ponds

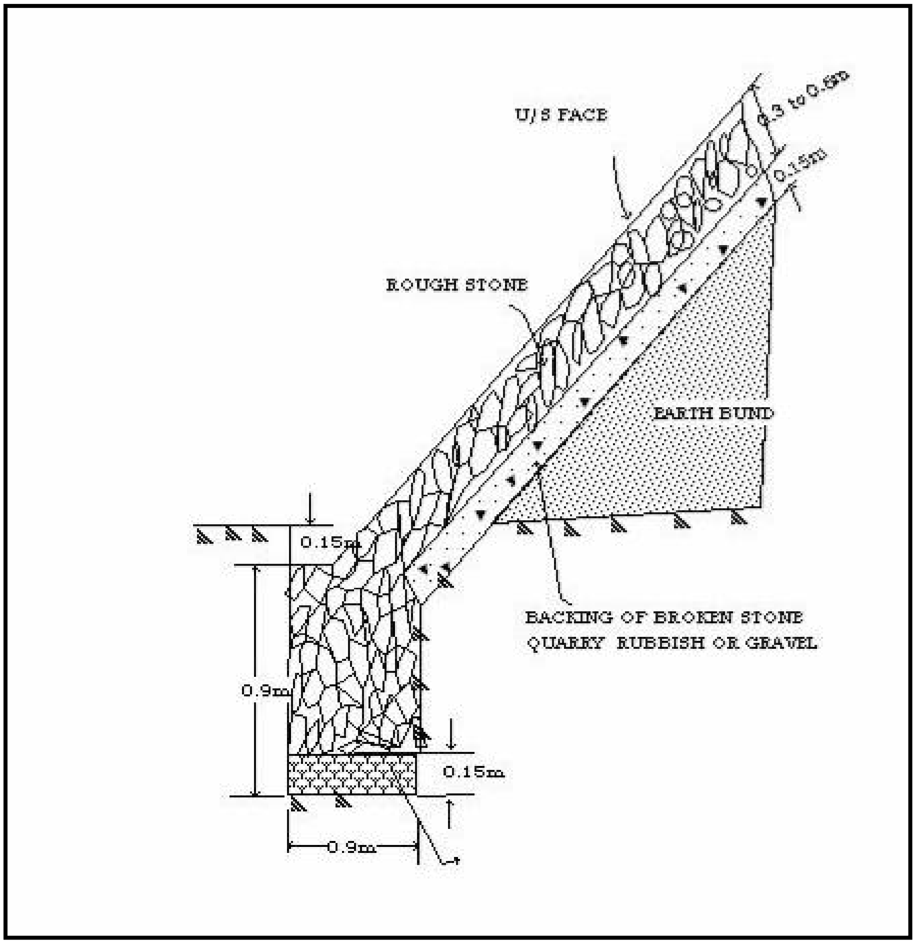


Fig.10 - Upstream Revetment of Tank Bunds

Although the effective storage capacity of a percolation tank is limited by FTL, the area submerged by the tank bund and revetment is dependent on MWL. Hence, in order to restrict the dimensions of these, it is desirable to keep the difference between FTL and MWL as small as possible. On the other hand, the smaller the difference, the longer will be the surplus escape required in order to enable it to pass the given discharge. Hence, the difference (H) between FTL and MWL is fixed on a compromise basis in each particular project so as to obtain maximum economy and efficiency. In small and medium sized tanks, the usual difference between FTL and MWL is kept between 0.30 and 0.60 m and is rarely allowed to exceed 0.90 m.

Surplus weirs are similar to river weirs (i.e. Diversion weirs or *anicuts*) and are classified into the following three general types

Type A: Masonry weirs with a vertical drop

Type B: Rock fill weirs with a sloping apron and

Type C: Masonry weirs with a sloping masonry apron (glacis)

i) Masonry Weirs with Vertical Drop (Type A):

A typical cross section of such a weir is shown in **Fig. 11(a).** This weir consists of a horizontal floor and a masonry crest with vertical or near-vertical downstream face. The raised masonry crest does the maximum ponding of water but a part of it is usually carried out by shutters at the top of the crest. The shutters can be dropped down during floods so as to reduce the afflux (the rise in the Maximum Flood Level (HFL) upstream of the weir caused due to the construction of the weir) by increasing the waterway opening. This type of weir is particularly suitable for hard clay and consolidated gravel foundations. However, these weirs are fast becoming obsolete and are being replaced by modern concrete weirs.

ii) Rock-fill Weirs with Sloping Aprons (Type B):

These weirs are also known as 'Dry Stone Slope Weirs'. A typical cross section of such a weir is shown in **Fig. 11(b).** It is the simplest type of construction and is suitable for fine sandy foundations like those encountered in alluvial areas in North India. Such weirs require huge quantities of stone and are economical only when stone is easily available. The stability of such weirs is not amenable to theoretical treatment. With the development of concrete glacis weirs, these weirs are also becoming obsolete.

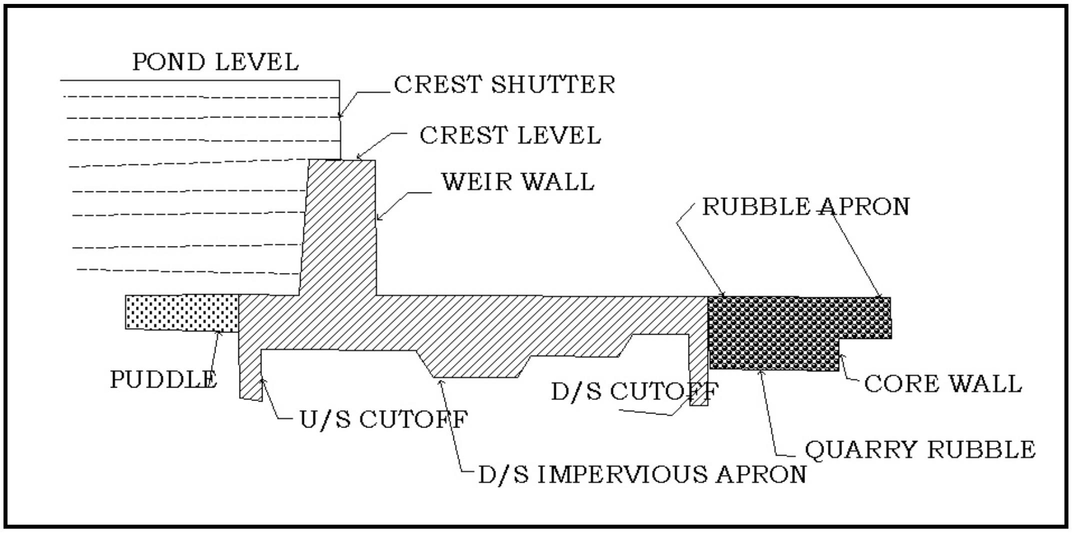


Fig. 11(a) - A Typical Masonry Tank Weir with a Vertical Drop.

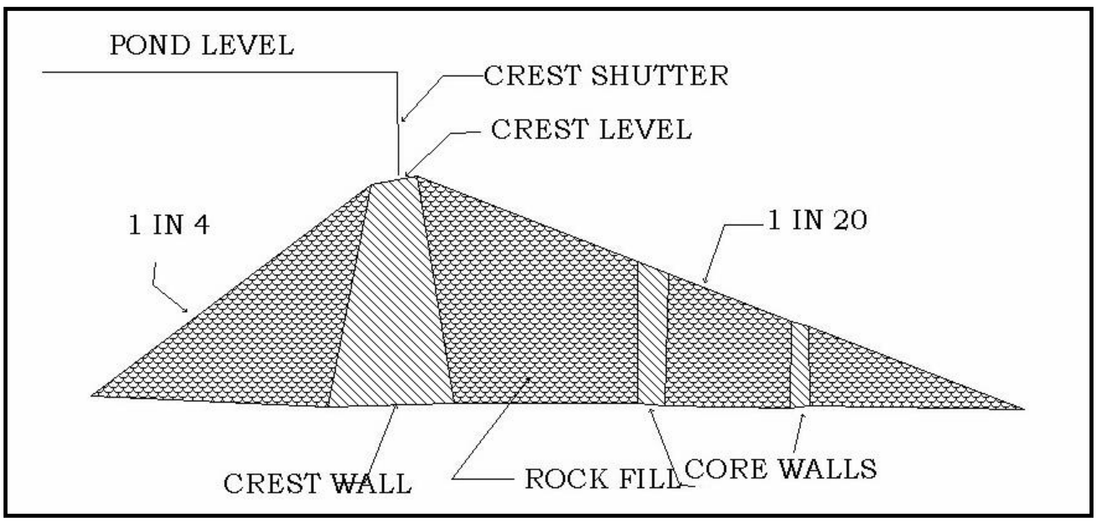


Fig. 11(b) - A Typical Rock-filled Weir with Sloping Aprons.

iii) Modern Concrete Weirs with Sloping Downstream Glacis (Type C):

Weirs of this type are of recent origin and their design is based on modern concepts of sub-surface flow. A typical cross-section of such a weir is shown in F**ig: 6.11(c)**. Sheet piles of sufficient depths are driven at the ends of upstream and downstream floor. Sometimes, an intermediate pile line is also provided. The hydraulic jump is formed on the downstream sloping glacis so as to dissipate the energy of the flowing water.

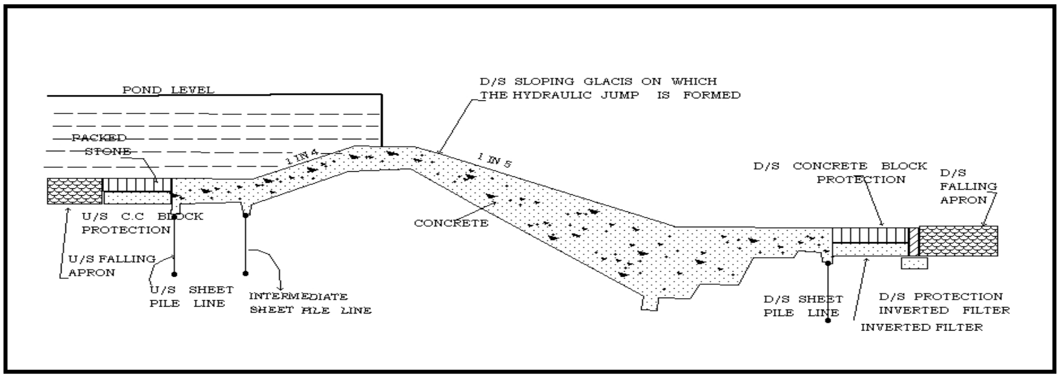


Fig. 11(c) - Typical Cross-section of a Modern Concrete Weir with Permeable Foundation.

Besides these three important types of weirs, a combination of type A and type C may also be used. In such weirs, a number of vertical steps are made instead of providing a horizontal or sloping downstream apron. Such weirs are called Type D weirs or 'weirs with stepped aprons' and is shown in **Fig.11(d)**. A & D types are most commonly used in percolation tanks.

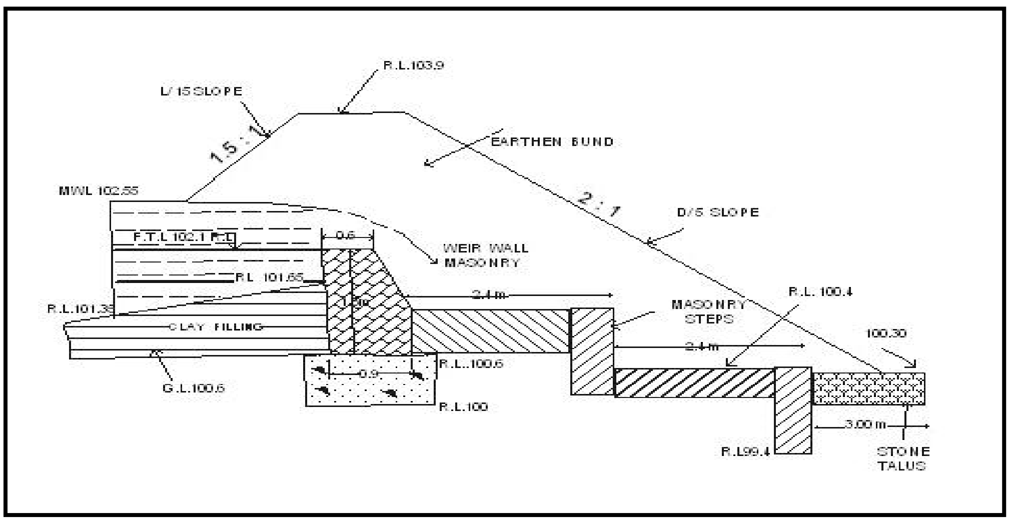


Fig. 11(d) A Typical Stepped – Apron Tank Weir

d) Design Aspects of Waste Weirs

- **i) Width of floors of Weirs**: The widths of horizontal floors of type A and D weirs from the foot of the drop wall to the downstream edge of the floor should never be less than 2(D+H) where D is the height of the drop wall and H is the maximum water head over the wall. In major works, this width may be increased to 3(D+H). The rough stone apron forming a talus below the last curtain wall may be of varying widths depending on the nature of the soil, velocity and probable quantity and intensity of annual runoff. It would generally vary from 2.5(D+H) to 5(D+H) depending on local conditions.

ii) **Length of Surplus weirs:** In order to determine the length of surplus weirs, it is necessary to determine the maximum flood discharge that may enter the tank after it is filled up to full tank level. If the tank is an independent one, the flood discharge can be estimated using Ryve's formula

$$Q = CM^{2/3}$$

Where ‘Q’ is the estimated flood discharge in cubic meters/second, ‘M’ is the area of the catchment in square kilometers and ‘C’ is known as ‘Ryve’s coefficient’ usually ranging from 6.8 to 15 depending upon the topography of the catchment and intensity of rainfall over the catchment. If the tank is part of a group of tanks, the flood discharge likely to enter such a tank is calculated using the formula

$$Q = CM^{2/3} - cm^{2/3}$$

Where ‘Q’ is the estimated flood discharge in cubic meters/second that is likely to enter the tank in question, ‘M’ is the combined catchment area of all tanks above the surplus of the tank in square kilometers, ‘m’ is the intercepted catchment area in square kilometers by the upper tanks, ‘C’, Ryve's coefficient varying from 6.8 to 15 and ‘c’, modified coefficient which generally varies from 1/5 to 1/3 of C.

In case of catchments of less than two square kilometers, it is better to adopt discharges obtained by calculating the runoff from the catchment with a precipitation of 2.54 cm/hour (Equivalent to 1 Inch/Hour). The flood discharge obtained from a catchment with 2.54 cm precipitation can be calculated from the following formula:

$$Q = 7M^{2/3}$$

Where 'Q' is the discharge in cubic meters/second obtained due to a precipitation of 2.54 cm/hr and 'M', the area of the catchment in square kilometers.

After assessing the flood discharge and fixing the FTL and MWL with reference to the storage requirements, the length of the surplus weir can be calculated from the formula

$Q = 2/3\ C_d\ LH2\ gH$ or $2.95CdLH^{3/2}$, where

'Q' is the quantum of flood water in cubic meter/second to be discharged, 'L', the length of the weir in meter, 'H', the head over the weir or the difference between MWL and FTL in meters and 'Cd, the coefficient of discharge, which varies depending upon the type of weir as given below in **Table. 6.**

Table 6 - Coefficient Discharge for Various Types of Weirs

Sl. No	Type of weir	Value of Cd	Reduced Formula for Discharge per Meter Length of Weir
1	Weirs with crest width up to 1 m	0.625	$1.84H^{2/3}$
2	- do- with width >1m	0.562	$1.66H^{2/3}$
3	Rough Stone sloping escapes	0.50	$1.48H^{2/3}$
4	Flush escapes	0.437	$1.29H^{2/3}$

iii) Scouring Depth: This is controlled by the type of formation and also on discharge and is calculated by using following formula

D = 0.47 (Q / f) 1/3, where

D is depth of scouring in meter,

Q is maximum discharge in m3/sec. (silt factor)

f is coefficient of rugocity, which is taken as

f = 1.0 for hard rock

= 0.75 for soft rock

= 0.45 for gravel (*Murrum)*

= 0.30 for soil

e) Design of Water Cushion:

Depth of water cushion is calculated by using following formula.

$$D = c(d)^{1/2} \times 3\ (h)^{1/2}$$

Where, D is depth of water column in m,

h is difference between level of water passing over the weir and that of tail water (m)

d is vertical drop (m) and

c is a constant (coefficient of rugocity)

Length of water column (L) is calculated using following formula,

$$L = 6\ (d)^{1/2}$$

f) Design of Spill Channel:

The Spill channel is designed on the basis of Maximum flood discharge (Q), bed width (L), maximum flood lift (H) and bed slope. The area of cross section (A) of waste weir is worked out as L * H (Sq m) and wetted perimeter (P) is worked out as L + (H*D) in metres.

Hydraulic mean depth (R) is calculated as, R = A/P

Velocity (V) = (1/N) * $R^{2/3} \times S^{1/2}$ (m/sec),

Where S is the slope and N is taken as 0.03

Capacity of discharge Q = A * V (m^3 / sec)

The section capable of discharging floods equal to Q value estimated is adopted for the spill and approach channel.

g) Design of Cut off Trench (COT):

A trench excavated below the ground surface along the bund line is known as cut off trench (COT). The depth of excavation depends upon the type of subsurface strata. A trial pit is excavated and dug wells and stream sections are also studied to determine the maximum depth of COT. It is recommended to dig COT down to the hard strata, or down to the depth equal to H (height of water column), whichever is less. The COT is then filled up to the ground by clayey soil. Clay is commonly used for filling. If COT of appropriate depth is not provided, the chances of visible seepage losses from the structure become high.

h) Design of Hearting and Casing:

Hearting is the impervious core of the percolation tank bund, which is constructed of clayey material. The slopes of the hearting are 1:1 both on upstream and downstream sides. Its height is up to the highest flood level (HFL) of the dam. The hearting is covered with casing from all the sides. The material used for casing should be porous and devoid of clay content.

i) Stone Pitching:

Stone pitching is done on the upstream face of the bund to protect the structure from erosion, which may be caused by the wave ripple action of water stored in the tank. The pitching is done using boulder and stone pieces of 20-30 cm size. It is done on the upstream side from bottom to the HFL. In some cases, strip pitching is also done below the HFL for few meters.

j) Dam Drainage Arrangement:

Longitudinal and cross drains are provided below the bund in casing zone to drain out the water seeping into the structure during different stages of filling to prevent formation of sludge around the structure. For this, excavation is made down to 1m along the dam line beneath the casing zone. Cross drains are also excavated to ultimately drain out the water of longitudinal drains. These drains are filled with porous material in layered sequence of sand, and gravel

Toe drains are constructed at the downstream of dam wall to drain out water away from the structure.

k) Rock Toe:

A rubble hump is normally provided over the ground surface on downward side of the tank, to protect the dam from slippage and sliding of casing zone.

1.2.2.6. Modification of Village Tanks as Recharge Structures

The existing village tanks, which are normally silted and damaged, can be modified to serve as recharge structures. Unlike in the case of properly designed percolation tanks, cut-off trenches or waste weirs are not provided for village tanks. Desilting of village tanks together with proper provision of waste weirs and cut off trenches on the upstream side can facilitate their use as recharge structures. As such tanks are available in plenty in rural India, they could be converted into cost-effective structures for augmenting ground water recharge with minor modifications.

1.2.2.7 Stream Channel Modification / Augmentation

In areas where streams zigzag through wide valleys occupying only a small part of the valley, the natural drainage channel can be modified with a view to increase the infiltration by detaining stream flow and increasing the streambed area in contact with water. For this, the channel is so modified that the flow gets spread over a wider area, resulting in increased contact with the streambed. The methods commonly used include a) widening, leveling, scarifying or construction of ditches in the stream channel, b) construction of L – shaped finger levees or hook levees in the river bed at the end of high stream flow season and c) Low head check dams which allow flood waters to pass over them safely.

Stream channel modification can be employed in areas having influent streams that are mostly located in piedmont regions and areas with deep water table such as arid and semi arid regions and in valley fill deposits. The structures constructed for stream channel modification are generally temporary, are designed to augment ground water recharge seasonally and are likely to be destroyed by floods. These methods are commonly applied in alluvial areas, but can also be gainfully used in hard rock areas where thin river alluvium overlies good phreatic aquifers or the rocks are extensively weathered or fractured in and around the stream channel. Artificial recharge through stream channel modifications could be made more effective if surface storage dams exist upstream of the recharge sites as they facilitate controlled release of water.

1.2.3. Subsurface Techniques

Subsurface techniques aim at recharging deeper aquifers that are overlain by impermeable layers, preventing the infiltration from surface sources to recharge them under natural conditions. The most common methods used for recharging such deeper aquifers are a) Injection wells or recharge wells, b) Recharge pits and shafts, c) Dug well recharge, d) Borehole flooding and e) Recharge through natural openings and cavities.

1.2.3.1 Injection Wells or Recharge Wells

Injection wells or recharge wells are structures similar to bore/tube wells but constructed for augmenting the ground water storage in deeper aquifers through supply of water either under gravity or under pressure. The aquifer to be replenished is generally one with considerable desaturation due to overexploitation of ground water. Artificial recharge of aquifers by injection wells can also be done in coastal regions to arrest the ingress of seawater and to combat problems of land subsidence in areas where confined aquifers are heavily pumped.

In alluvial areas, injection wells recharging a single aquifer or multiple aquifers can be constructed in a manner similar to normal gravel packed pumping wells. However, in case of recharge wells, cement sealing of the upper section of the wells is done to prevent the injection pressure from causing leakage of water through the annular space of the borehole and the well assembly. Schematics of a typical injection well in alluvial terrain are shown in **Fig.12.** In hard rock areas, injection wells may not require casing pipes and screens and an injection pipe with an opening against the fractures to be recharged may be sufficient. However, properly designed injection wells with slotted pipes against the zones to be recharged may be required for recharging multiple aquifer zones separated by impervious rocks.

The effectiveness of recharge through injection wells is limited by the physical characteristics of the aquifers. Attempts to augment recharge may prove to be counter-productive in cases where the aquifer material gets eroded due to the massive movement of ground water flow, especially in unconsolidated or semi-consolidated aquifers. Failure of confining layers may also occur if excessive pressure is applied while injecting water. These may result in clogging and/or even collapse of the bore/tube well.

1.2.3.1.1 Site Selection and Design Criteria

i) A proper understanding of the aquifer geometry is the most important factor in implementation of successful recharge schemes through injection or recharge wells. Detailed studies of the vertical and lateral extents of the aquifer and its characteristics are necessary prerequisites for such schemes. Grain size distribution of granular aquifers is another important parameter in the case of sedimentary aquifers.

ii) Recharge through injection wells increases chances of clogging of well screens and aquifer material, resulting in decreased injection rates. Clogging may be caused by suspended particles and air bubbles in the source water, formation of chemical precipitates in the well, source water or aquifer material, proliferation of bacteria in and around the injection well and swelling and dispersion of clay in the aquifer being recharged. Clogging may be minimized by proper treatment and removal of suspended material from source water, chemical stabilization and bacterial control. Using non-corrosive materials for pipelines and well casings may minimize clogging by corrosion products. Chlorination of source water prevents development of bacterial growth. Acid treatment helps in removing calcium carbonate precipitates from the gravel packs and aquifers. Periodic development of wells through surging, swabbing and pumping can considerably improve the efficiency and life of injection wells.

iii) As clogging increases the well losses considerably, the efficiency of injection wells should be taken as 40 to 60 percent as compared to pumping wells of similar design in the same situation.

iv) Adequate care should be taken to ensure that the water being used for recharge is not contaminated. The water being recharged should be compatible with the formation water to avoid any precipitation and resultant clogging. The relative temperatures of source and formation waters also affect the recharge rate.

v) For optimum benefits, it is advisable to have injection – cum – pumping wells to be used both for ground water recharge and extraction under favourable conditions.

vi) The following considerations are important in the design of an injection well

a) The permissible pressure head of hydraulic injection in terms of water column may be worked out as 1.2 times the depth to the top of the confined aquifer, which represent the hydrofracturing pressure of the confining layer. In consolidated strata, however, this pressure is likely to be much higher. Injection of water at pressures exceeding this limit can result in the rupture of the confining layer.

b) The rate of recharge likely to be accepted by the aquifer may be worked out on the basis of observed discharge-drawdown relation of the existing pumping wells tapping the same aquifer. If the aquifer parameters are known, the recharge rates may be worked out from theoretical considerations using appropriate formulae. However, it is always desirable to determine the actual intake rates through injection/recharge tests in the wells.

c) The diameter of the conductor and casing pipes and the bore/tube well are to be worked out from the rate of recharge estimated. Usually, pipes with nominal diameters of 100mm, 150mm, 200mm and 250mm can handle flows up to 50 Cum/hr, 150 Cu m/hr, 250 Cu m/hr and 400 Cu m/hr respectively.

d) In case the well is being proposed as an injection – cum – pumping well, the well assembly should be so designed to accommodate higher flows while pumping.

e) The inner diameter of the housing pipe has to be two nominal diameters higher than the pump bowl size and the length of the housing pipe should be adequate to accommodate seasonal and long-term fluctuations, interference effects of surrounding wells in addition to expected drawdown and desired pump submergence.

f) The casing material used for the well must be similar to the one used for production wells and should have adequate tensile strength and collapsing pressure. In case chemical treatment is anticipated during development, the casing pipe and screens should be made of corrosion-resistant material.

g) The recharge well should be designed to fully penetrate the aquifer to avoid additional head losses due to partial penetration. In hard rocks, the top casing should be adequate to cover the unconfined zone.

h) Artificial gravel packs should be provided around screens in case of screened wells in unconsolidated and semi-consolidated formations. The gravel pack should be so designed to arrest the inflow of aquifer particles into the well.

i) It is advisable to achieve exit velocity comparable to entrance velocity recommended (0.03m/sec) for pumping wells to reduce incrustation and corrosion by providing appropriate open area for passage of water into the aquifer. The desired open area can be achieved for a given thickness of aquifer by adjusting well casing diameter and percent open area of the screen using the relation

Total area of the screen x Percent open area = Volume x Entrance Velocity.

j) Injection wells may be designed to recharge a single aquifer or multiple aquifers.

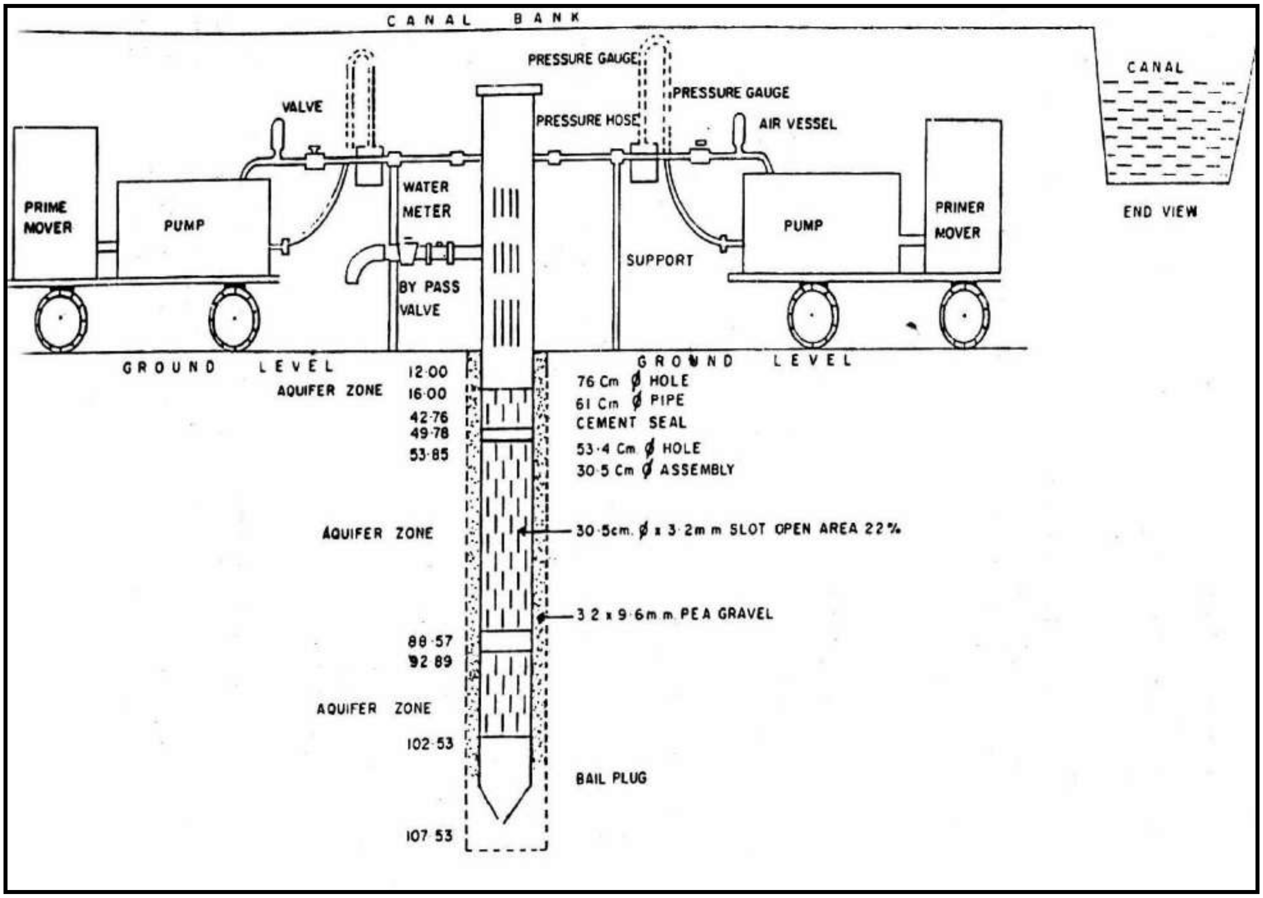


Fig.12 - Schematics of a Typical Injection Well in Alluvial Terrain

k) For pressure injection, conductor pipes of suitable diameter should be used to reach the aquifer with an inflatable packer to be placed around the pipe just above the screen. In a dual injection well, the inflatable packer is a must.

vii) Injection of water into the well should be started at rates below the preestimated injection rate, which is then progressively increased, taking care to ensure that the pressure build-up remains below the permissible limit. Once the maximum permissible injection rate is attained, the well should be regularly monitored for injection rate, injection head and quality of water.

viii) The Specific Injection Capacity of the well, computed as the ratio of the quantum of water applied to the head build-up in the well is determined on commissioning a recharge well. The Specific Injection Capacity of the well reduces with time due to clogging. When the injection rate falls below accepted economic limits, the well is required to be redeveloped.

1.2.3.2 Gravity Head Recharge Wells

In addition to specially designed injection wells, existing dug wells and tube/bore wells may also be alternatively used as recharge wells, as and when source water becomes available. In areas where considerable de-saturation of aquifers have already taken place due to over-exploitation of ground water resources resulting in the drying up of dug wells and lowering of piezometric heads in bore/tube wells, existing ground water abstraction structures provide a cost-effective mechanism for artificial recharge of the phreatic or deeper aquifer zones as the case may be. Schematics of a typical system for artificial recharge through dug wells are shown in **Fig.13.**

1.2.3.2.1 Site Characteristics and Design Guidelines

i) In areas where excess surface water is available during rainy season and the phreatic aquifers remain unsaturated, surface water can be pumped into the dug wells for augmentation of ground water resources.
ii) Wells with higher yields before getting dried up due to the desaturation of aquifers should be selected for recharge as they prove to be more suitable for ground water recharge when compared to lowyielding wells.
iii) The recharge head available in gravity head recharge wells is the elevation difference between the surface water level in the feeder reservoir /tank and the elevation of water table or piezometric head. The recharge rates in such cases are likely to be much less when compared to pressure injection and will also keep on reducing with build-up of the water table in the aquifer.
iv) Pumping of wells during periods of non-availability of recharge water helps in removing the silt that may enter the well during recharge. However, more rigorous development may be essential in the case of deep bore/tube wells
v) Care should be taken to ensure that the source water is adequately filtered and disinfected when existing wells are being used for recharge. The recharge water should be guided through a pipe to the bottom of well, below the water level to avoid scouring of bottom and entrapment of air bubbles in the aquifer.

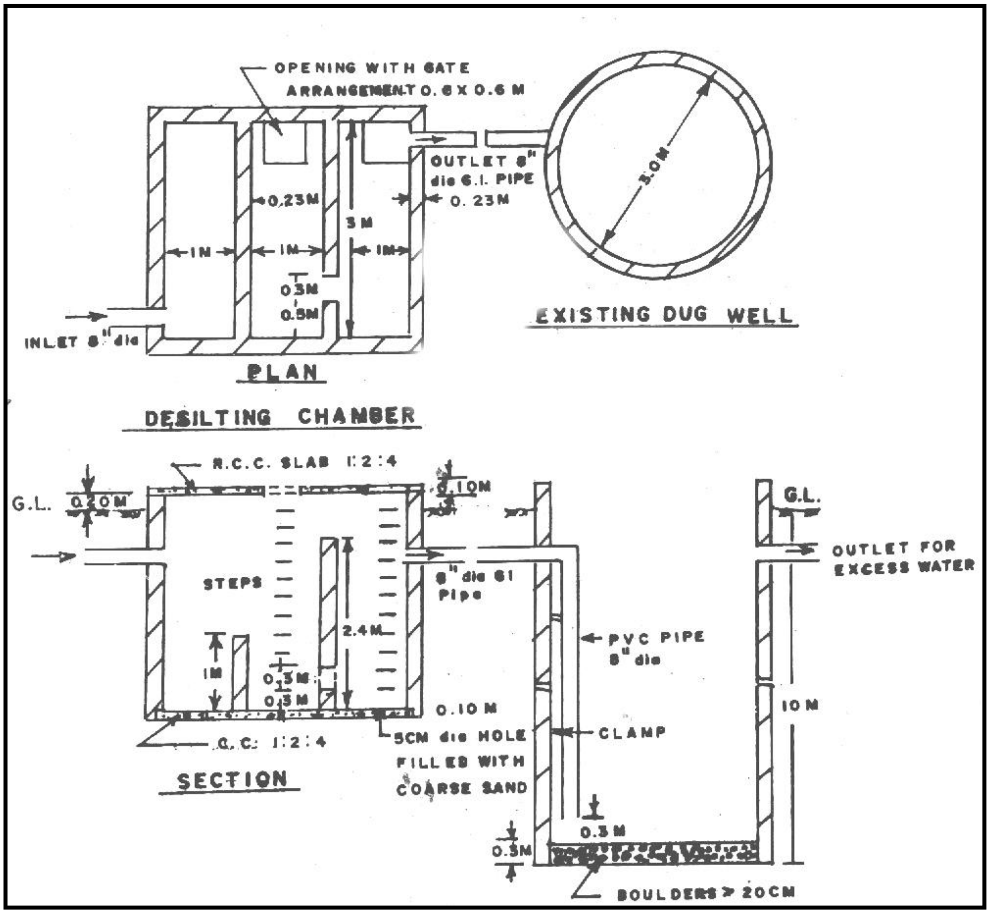


Fig.13 - Schematics of a Typical System for Artificial Recharge through Dug Well.

1.2.3.3 Recharge Pits and Shafts

Recharge pits and shafts are artificial recharge structures commonly used for recharging shallow phreatic aquifers, which are not in hydraulic connection with surface water due to the presence of impermeable layers. They do not necessarily penetrate or reach the unconfined aquifers like gravity head recharge wells and the recharging water has to infiltrate through the vadose zone.

1.2.3.3.1 Recharge Pits:

Recharge pits are normally excavated pits, which are sufficiently deep to penetrate the low-permeability layers overlying the unconfined aquifers (**Fig.14)**. They are similar to recharge basins in principle, with the only difference being that they are deeper and have restricted bottom area. In many such structures, most of the infiltration occurs laterally through the walls of the pit as in most layered sedimentary or alluvial material the lateral hydraulic conductivity is considerably higher than the vertical hydraulic conductivity. Abandoned gravel quarry pits or brick kiln quarry pits in alluvial areas and abandoned quarries in basaltic areas can also be used as recharge pits wherever they are underlain by permeable horizons. *Nalah* trench is a special case of recharge pit dug across a streambed. Ideal sites for such trenches are influent stretches of streams. Contour trenches, which have been described earlier also belongs to this category.

1.2.3.3.1.1 Site Characteristics and Design Guidelines

i) The recharging capacity of the pit increase with its area of cross section. Hence, it is always advisable to construct as large a pit as possible.
ii) The permeability of the underlying strata should be ascertained through infiltration tests before taking up construction of recharge pits.
iii) The side slopes of recharge pits should be 2:1 as steep slopes reduce clogging and sedimentation on the walls of the pit.
iv) Recharge pits may be used as ponds for storage and infiltration of water or they may be back-filled with gravel sand filter material over a layer of cobbles/boulders at the bottom. Even when the pits are to be used as ponds, it is desirable to provide a thin layer of sand at the bottom to prevent the silt from clogging permeable strata.
v) As in the case of water spreading techniques, the source water being used for recharge should be as silt-free as possible.
vi) The bottom area of the open pits and the top sand layer of filter-packed pits may require periodic cleaning to ensure proper recharge. Recharge pits located in flood-prone areas and on streambeds are likely to be effective for short duration only due to heavy silting. Similar pits by the sides of streambeds are likely to be effective for longer periods.
vii) In hard rock areas, streambed sections crossing weathered or fractured rocks or sections along prominent lineaments or intersection of lineaments form ideal locations for recharge pits.

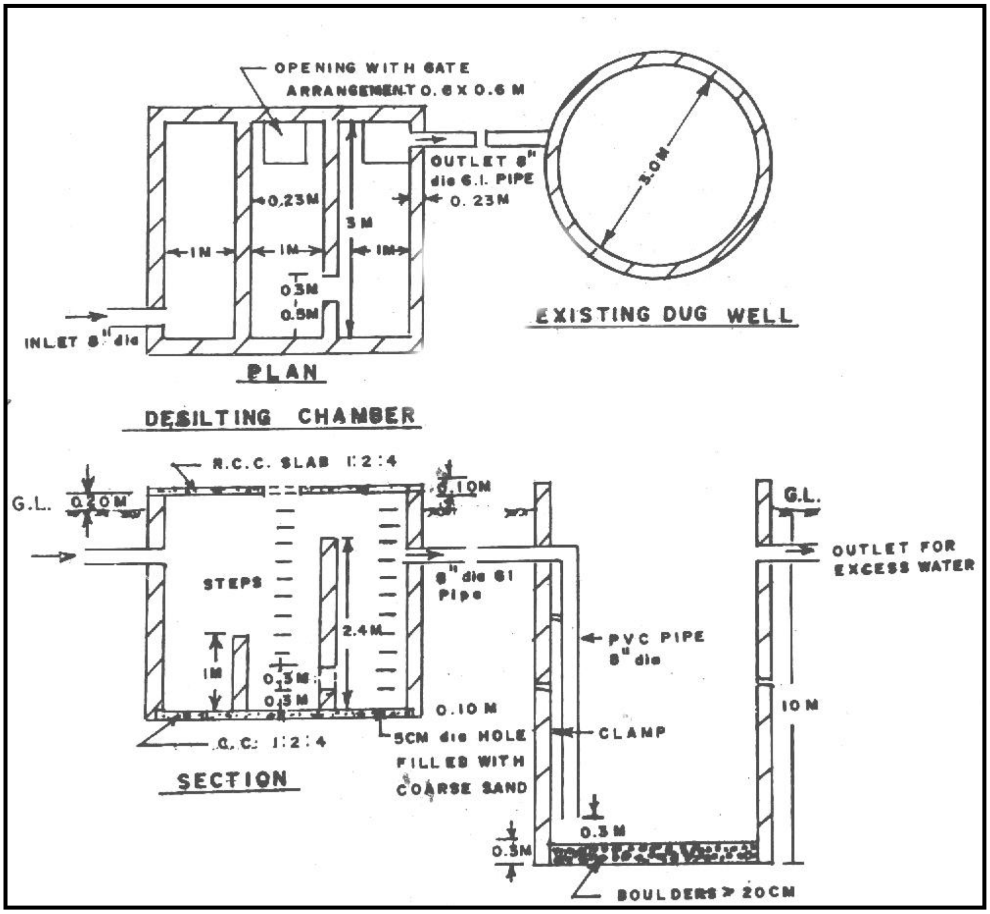


Fig.14 - Schematics of a Recharge Pit.

1.2.3.3.2 Recharge Shafts

Recharge Shafts are similar to recharge pits but are constructed to augment recharge into phreatic aquifers where water levels are much deeper and the aquifer zones are overlain by strata having low permeability **(Fig.15)**. Further, they are much smaller in cross section when compared to recharge pits. Detailed design particulars of a recharge shaft are shown in **Fig.16.**

1.2.3.3.2.1 Design Guidelines

i) Recharge shafts may be dug manually in non-caving strata. For construction of deeper shafts, drilling by direct rotary or reverse circulation may be required.

ii) The shafts may be about 2m in diameter at the bottom if manually dug. In case of drilled shafts, the diameter may not exceed 1m.

iii) The shaft should reach the permeable strata by penetrating the overlying low permeable layer, but need not necessarily touch the water table.

iv) Unlined shafts may be back-filled with an inverse filter, comprising boulders/cobbles at the bottom, followed by gravel and sand. The upper sand layer may be replaced periodically. Shafts getting clogged due to biotic growth are difficult to be revitalized and may have to be abandoned.

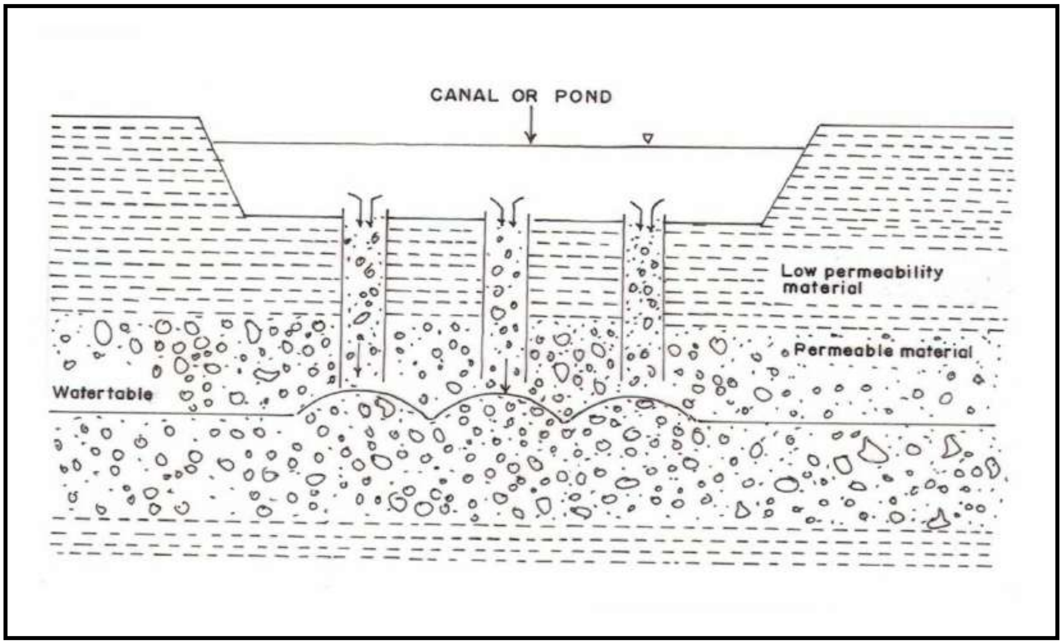


Fig.15 - Schematics of Recharge Shafts

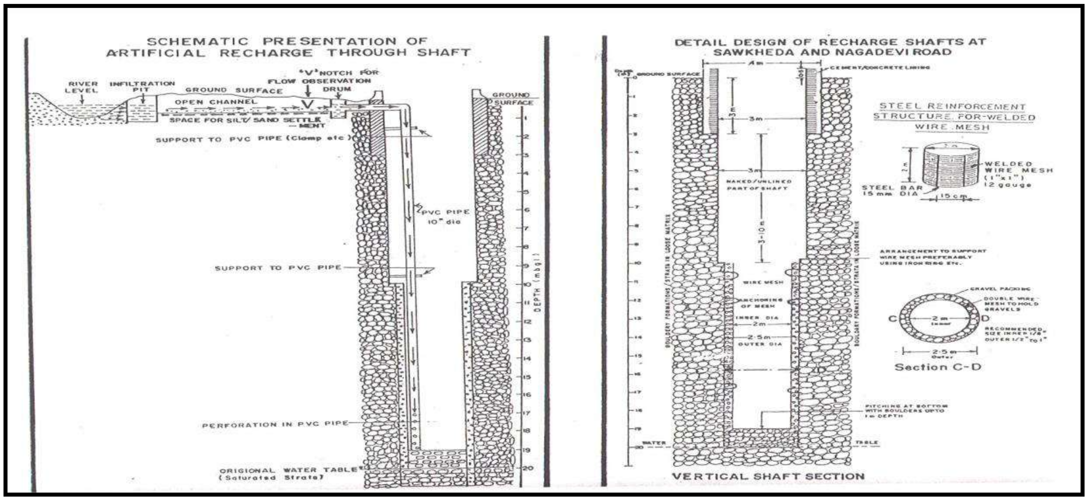


Fig.16 Design Particulars of a Typical Recharge Shaft

v) Deeper shafts constructed in caving strata may require lining or casing. In such cases, the shafts need not be completely back-filled and a reverse gravel-sand filter, a few meters thick, at the bottom of the shaft will suffice. In such cases, the water from the source may be fed through a conductor pipe reaching down to the filter pack.

vi) The source water should be made as silt-free as possible before letting into the shaft by providing suitable filters.

1.3 Indirect Methods

Indirect methods for artificial recharge to ground water does not involve direct supply of water for recharging aquifers, but aim at recharging aquifers through indirect means. The most common methods in this category are induced recharge from surface water sources and aquifer modification techniques.

1.3.1 Induced Recharge

Induced recharge involves pumping water from an aquifer, which is hydraulically connected with surface water to induce recharge to the ground water reservoir. Once hydraulic connection gets established by the interception of the cone of depression and the river recharge boundary, the surface water sources starts providing part of the pumping yield (**Fig.6.17).** Induced recharge, under favorable hydrogeological conditions, can be used for improving the quality of surface water resources due to its passage through the aquifer material. Collector wells and infiltration galleries, used for obtaining very large water supplies from riverbeds, lakebeds and waterlogged areas also function on the principle of induced recharge.

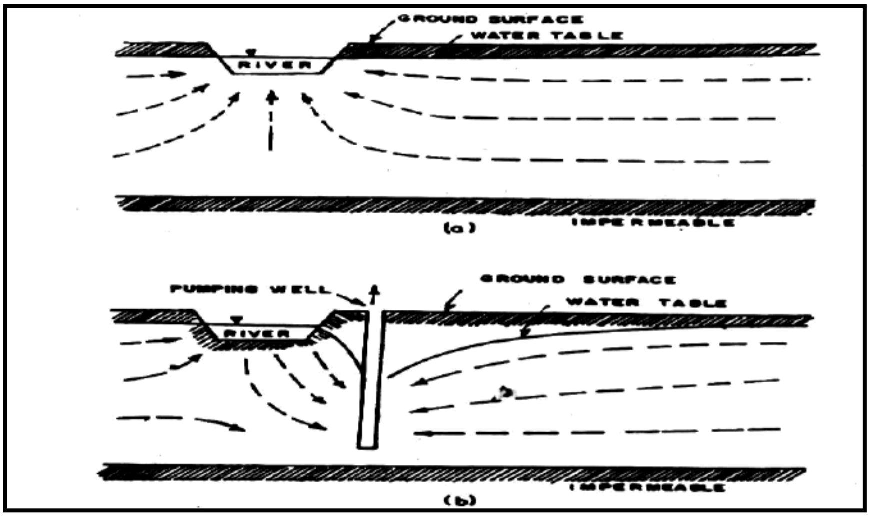


Fig.17 - Principle of Induced Recharge through Pumping of Wells near a Stream

a) Natural Flow Pattern b) Change in Flow Pattern Due to Pumping.

In hard rock areas, abandoned buried channels often provide favorable sites for the construction of structures for induced recharge. Check dams constructed in the river channel upstream of the channel bifurcation can help in high infiltration to the channel when wells located in the channels are pumped with high discharge for prolonged periods.

1.3.1.1 Design Guidelines

i) Quality of source water, hydraulic characteristics and thickness of aquifer material, distance of the pumping wells from the river and their pumping rates are the important factors controlling the design of schemes for induced recharge.

ii) For implementation of successful induced recharge schemes from stream channels, pumping wells should be selected at sites where water in the streams has sufficient velocity to prevent silt deposition.

iii) Dredging of channel bottom in the vicinity of the existing pumping wells may have to be carried our periodically to remove organic matter and impervious fine material from the beds of the channel.

iv) For wells constructed in unconfined alluvial strata for induced recharge, the lower one-third of the wells may be screened to have optimum drawdowns. In highly fractured consolidated rocks, dug wells penetrating the entire thickness of the aquifer should be constructed with lining above the water table zone and the curbing height well above the High Flow Level (HFL) of the stream.

1.3.2 Aquifer Modification Techniques

These techniques modify the aquifer characteristics to increase its capacity to store and transmit water through artificial means. The most important techniques under this category are bore blasting techniques and hydrofracturing techniques. Though they are yield augmentation techniques rather than artificial recharge structures, they are also being considered as artificial recharge structures owing to the resultant increase in the storage of ground water in the aquifers.

1.4 Combination Methods

Various combinations of surface and sub-surface recharge methods may be used in conjunction under favorable hydrogeological conditions for optimum recharge of ground water reservoirs. The selection of methods to be combined in such cases is site-specific. Commonly adopted combination methods include a) recharge basins with shafts, percolation ponds with recharge pits or shafts and induced recharge with wells tapping multiple aquifers permitting water to flow from upper to lower aquifer zones through the annular space between the walls and casing (connector wells) etc.

1.5 Ground Water Conservation Techniques

Ground water conservation techniques are intended to retain the ground water for longer periods in the basin/watershed by arresting the sub-surface flow. The known techniques of ground water conservation are a) Ground water dams / sub-surface dykes / Underground 'Bandharas' and b) Fracture sealing Cementation techniques.

1.5.1 Sub-Surface Dykes / Ground Water Dams / Underground '*Bandharas*'

A sub-surface dyke / ground water dam is a sub-surface barrier constructed across a stream channel for arresting/retarding the ground water flow and increase the ground water storage. At favorable locations, such dams can also be constructed not only across streams, but in large areas of the valley as well for conserving ground water. Schematics of a typical sub-surface dyke are shown in Fig**.18.**

1.5.1.1 Site Characteristics and Design Guidelines

i) The primary objective of a sub-surface dyke is the creation of a subsurface storage reservoir with suitable recharge conditions and low seepage losses. Valley shapes and gradients are important considerations for site identification.
ii) Optimally, a valley should be well defined and wide with a very narrow outlet (bottle necked). This reduces the cost of the structure and makes it possible to have a comparatively large storage volume. This implies that the gradient of the valley floor should not be steep since that would reduce the storage volumes behind a dam of given height.
iii) The limitations on depth of underground construction deem that the unconfined aquifer should be within a shallow to moderate depth (down to 10 m bgl) and has a well-defined impermeable base layer. Such situations occur in hard rock areas and shallow alluvial riverine deposits.
iv) The dyke is ideally constructed across narrow ground water valleys, generally not exceeding 150 to 200 m in width. On the basis of a thorough study of a water table contour map of the area, a narrow ground water valley section where the flow lines tend to converge from up-gradient direction, usually coinciding with a surface drainage line should be identified. The requirement of narrow flow section is usually fulfilled in watersheds in hard rock terrain having rolling topography where relatively narrow depressions separate hard rock spurs.

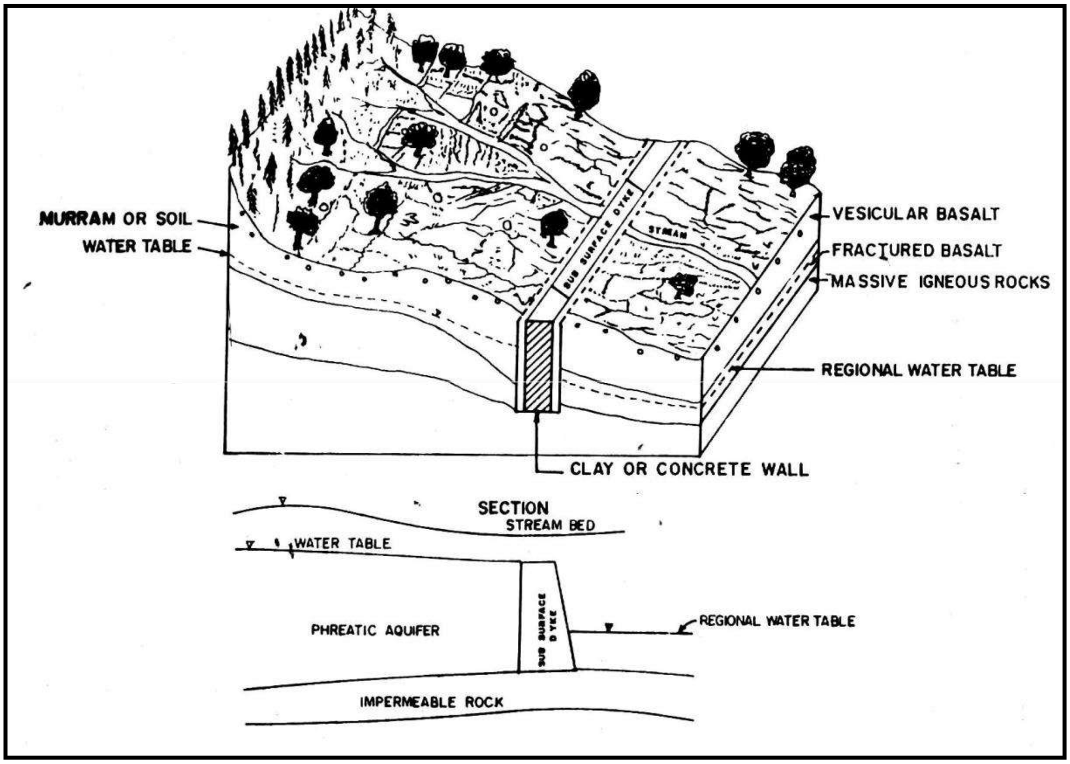


Fig.18 - Schematics of a Subsurface Dyke in Basaltic Terra

v) The drainage valley across which the subsurface dyke is constructed should carry a seasonal stream that goes dry in winter and summer and the water table should be located well below the riverbed, preferably throughout the year (The stream should be preferably influent or may be effluent for a very limited period during rainy season). The valley section should preferably have a moderate gradient (less than 1%) so that the benefit spreads sufficiently in the up-gradient direction.

vi) The thickness of aquifer underlying the site should be adequate (more than 5 m) so that the quantity of ground water stored is commensurate with the effort and investment. Normally, in hard rock watersheds, the drainage courses have a limited thickness of alluvial deposits underlain by a weathered rock or fractured aquifer, which in turn passes into consolidated unaltered aquitard. This forms an ideal situation.

vii) The sub-surface dyke directly benefits the up-gradient area and hence should be located at a sufficient distance below the storage zone and areas benefiting from such recharge. This implies construction of ground water conservation structures in lower parts of the catchments but sufficiently upstream of watershed outlet.

A sub-surface dyke may potentially deprive the downstream users the benefit of ground water seepage, which they received under a natural flow regime. Care should therefore be taken to see that a large number of users are not located immediately downstream and those affected are duly compensated through sharing of benefits. Care should also be taken to ensure that the water levels in the upstream side of the dyke are deep enough not to cause any water logging as a result of the dyke.

viii) For construction of ground water dam/ sub-surface dykes, a trench should be dug out across the ground water depression (streambed) from one bank to the other. In case of hilly terrain in hard rocks, the length of the trench generally may be less than 50 m. In more open terrain, the length may be usually less than 200 m but occasionally even more. It should be wide enough at the bottom to provide space for construction activity. In case of shallow trenches down to 5 m depth, the width at the bottom should be 2 m. For deeper trenches down to 15-20 m, deployment of mechanical equipment may be required. In such cases, width of 5 m at the bottom is recommended. The side slopes within alluvial strata should be 2:1 to make them stable. In case of more consolidated substrata, the slope could be steeper. The width at the surface should be planned accordingly.

ix) The bottom of the trench should reach the base of the productive aquifer. In case of hard rock terrain, below a limited thickness of alluvial fill, weathered zone and underlying fractured aquifer may occur. The trench should be deep enough to penetrate both highly weathered and fractured strata. In case of more open terrain in consolidated or semi-consolidated strata, the alluvial thickness may be larger and the trench should end below the alluvial fill deposit. In order to minimize or avoid problem of dewatering during construction, the work should be taken up by the end of winter and completed well before the onset of rains, as water table is at lower elevation in this period.

x) The cut-out dyke could be either of stone or brick masonry or an impermeable clay barrier. For ensuring total imperviousness, PVC sheets of 3000 PSI tearing strength and 400 to 600 gauge or low density polyethylene film of 200 gauge is also used to cover the cut out dyke faces. In the case of relatively shallow trenches within 5 m depth, where good impermeable clay is available within an economic distance (3 km), the cut-out dyke could be entirely be made of clay. In case good impermeable clay is not available, a stone masonry wall of 0.45 meter thickness or a brick wall of 0.25 m thickness may be constructed on a bed of concrete. Cement mortar of 1: 5 proportion and cement pointing on both faces is considered adequate. In the case of very long trenches, for economic considerations, it may be necessary to provide masonry wall only in the central part of dyke and clay dyke suitably augmented by tar felting, PVC sheet etc. on the sides.

xi) In case of clay dykes, the width should be between 1.5 and 2m depending on the quality of clay used. The construction should be in layers and each fresh layer should be watered and compacted by plain sheet or sheep foot rollers of 1 to 2 ton capacity. In absence of roller, the clay should be manually compacted by hand ramets. Where the core wall is a masonry structure, the remaining open trench should be back-filled by impermeable clay. The underground structures should be keyed into both the flanks of stream for one meter length to prevent leakage from sides.

xii) The top of the underground structures should be located between 1 to 1.5 m below the streambed to permit overflow in high water table stage for flushing of salinity of ground water stored behind the dyke. The alignment of the dyke should be shown by fixing marker stones on the banks and whenever there is change of alignment in between. Before back-filling the sub-surface trench, piezometric tubes should be installed on both the faces of the dyke for measuring water levels. Such piezometers should be located in the central part, and in case of wider dykes at additional one or two locations.

xiii) Sites for construction of subsurface dykes have to be located in areas where there is a great scarcity of water during the summer months or where there is need for additional water for irrigation. Some emphasis also needs to be laid on finding sites where land ownership conditions would make constructions more feasible. Single ownership is ideal in the absence of which it has to be implemented on a cooperative basis.

1.6. Suitability of Artificial Recharge Structures under Combinations of Factors

Based on the discussions regarding various artificial recharge methods and structures, an attempt has been made to prescribe structures suitable for different slope categories, aquifer types and amount of precipitation received.

A matrix **(Table 7**) has been developed for easy visualization of these combinations and their possible variations. Three broad columns represent three distinct hydrogeologic settings normally encountered in nature. Each of these columns is split further to represent areas based on the adequacy of rainfall received. Areas receiving annual precipitation of less than 1000 mm and not having access to any surface inflow source are taken as areas with limited source water availability.

Four different slope categories have been considered in the matrix, representing runoff zone, piedmont zone, transition zone and storage zone. Indirectly, this classification also takes into account the status of ground water flow in the aquifer. Within each row the upper box represents the unconfined aquifers and the lower one represents for the leaky confined and confined aquifers.

The matrix thus tries to separate out 48 different combinations, all of which may not be relevant or suitable for effecting artificial recharge. Further, it is to be remembered that in a natural situation there are smooth transitions of conditions stipulated from one column or row to the other. Hence this tabulation will serve the purpose of broadly identifying recommended method or structure. The final choice should be governed by actual relevance of factors at a given site.

Table 7 - Artificial Recharge Structures suitable under Combination of different Topographic slopes, Hydrogeologic groups and Rainfall distribution.

Topographic slope	Hydrogeologic Group						Aquifer situation
	Consolidated		Semi Consolidated		Un-consolidated		
1	Rainfall						
	Adequate	Limited	Adequate	Limited	Adequate	Limited	Unconfined/confined
	2	3	4	5	6	7	8
Steep Slope (20 - 10%) Runoff zone	Bench Terrace Contour Trench	Gully Plug	Bench Terrace Contour Trench	Gully Plug	-	-	Unconfined
Moderate Slope (10 to 5%) Piedmont zone	Bench Terrace Contour Trench Gravity Head Recharge Well*	Nalah Bunds Contour Bunding Percolation Tanks *Nalah* Trench Gravity Head Recharge well* Bore Blasting	Bench Terrace Contour Trench Gravity Head Recharge Well*	Nalah Bund Contour Bund Percolation Tanks *Nalah* Trench Gravity Head Recharge Well	Ditch & Furrow Recharge Basin Pits & Shafts Contour Trench Gravity Head Recharge Well	Recharge Basin Pits* & Shafts* Contour Trench Gravity Head Recharge Well	Unconfined
	Deep Gravity Head Recharge Well Hydro fracturing Fracture Seal Cementation		Injection Well* Recharge Shafts*				Confined
Moderate to Gentle Slope (2 to 5%) Transition	Nalah Bunds Contour Bunding Percolation Tanks Recharge Pits Canal Irrigation* Induced Recharge	Nalah Bunds Contour Bunding Percolation Tanks Recharge Pits Sub-surface dyke Canal Irrigation*	Recharge Basin Canal Irrigation* Induced recharge Stream Channel Modification Recharge Pits	Recharge Pits Stream Channel Modification	Flooding Recharge Basin Stream Channel Modification Induced Recharge Gravity Head Recharge Well* Canal Irrigation*	Stream Channel Modification Gravity Head Recharge Well* Ditch & Furrow Recharge Basin* Recharge Shaft* Sub-surface dyke (In	Unconfined

	Sub-surface dyke Fracture Seal cementation					shallow alluvium)	
	Gravity Head Recharge Well* Hydrofracturing Deep Fracture Seal Cementation		Recharge Shaft* Gravity Head Recharge Wells* Injection Wells* Hydrofracturing		Recharge Shafts* Gravity Head Recharge Wells* Injection Wells*		Confined
Gentle Slope (< 2%) Storage Zone	Surface Irrigation Recharge Basin Recharge Pits Gravity Head Recharge Wells	Induced Recharge Recharge Basin Recharge Pits Gravity Head Recharge Wells	Recharge Pits	Flooding Canal Irrigation* Induced Recharge Surface Spreading Infiltration Gallery	Flooding* Surface Spreading* Infiltration Gallery		Unconfined
	Gravity Head Recharge Wells (On Lineaments or their intersections)		Injection Wells		Injection Wells Connector Wells		

Note: Rainfall is considered 'adequate' if annual precipitation is more than 1000 mm.

*Indicate availability of source water supply through canals, trans-basin transfer or treated wastewater.

(Modified After: Manual on Artificial Recharge of Ground Water, CGWB (1994)).

RATIONALISATION OF WATER RATES

(Recommendation of the National Commission for Integrated Water Resources Development Plan)

With the background of the past proposals, especially the detailed ones made by the Vaidyanathan Committee, the following general principles are recommended by us:

- There should be rationalisation of basic principles of fixing the water tariffs in all the states.

- The Irrigation Commission (1972) had recommended rate structure linked with value of gross product of irrigated hectare irrespective of the working expenses. Vaidyanathan Committee had tied up the rates with O&M cost and a part of the capital cost without reference to value of the product. It is felt that both these approaches should be combined so that the rates are adequate to cover annual O&M costs and also cover a part of the productivity gains of the farmers. As it is difficult to assess the precise productivity impact of irrigation alone on crop-by-crop basis, the tariff should be linked to the gross value of products and not to incremental benefits. The cash crops should pay higher rates as their farmers have greater capacity to pay.

- The water rates should accordingly cover the entire annual O&M cost plus one percent of the gross value of the produce/ha in respect of cereal crops and higher percentage in case of cash crops.

- These rates should be levied as single part variable tariff for the present. However, the logic of charging a basic fixed rate along with a variable part is quite logical and should be followed up with the State Government.

- Some states have supplementary levies like betterment charges, mandi-charges etc. The states may consider continuing these additional charges.

- The revised water pricing structure should be such that the rates are substantially lower for those who accept group volumetric supply than for individual farmers. Also the WUAs should be allowed to collect somewhat more money to an approved extent over and above the prescribed water rates to encourage them improving the system under their charge.

- Though area, crop and season based tariffs are in force in various states at present they require inter-se rationalisation to reflect varying degrees of water consumption by various crops and their economic values.

- Looking to the extremely low existing rates and the policy of subsidising water which has been continuing since several decades, it is not practicable to enhance the water rates in one single step. Subsidies in the rates in the form of lower percentage applicable to gross value of the products will have, therefore, to be continued for sometime and gradually phased out.

- Past O&M expenses have been found to be very low because of inadequate budget allocations. Realistic O&M costs/ha should be worked out by each state on pilot representative systems by allotting adequate funds. These figures should be used for fixing of rates. However, in working out the cost, the ceiling rates on establishment charges should be followed.

- There should be two distinct components of irrigation water charges; one for O&M and other related to the value of the product. The O&M component should be fully utilised for the operation and maintenance of the respective portions of the system. The second part should be used to modernise the system with supplementation, from budget allocations. Each state will have to decide the natural proportion of the two components based on its figures of O&M and the productivity of the crops. The financial procedures should be modified to make this possible, so that the farmers are encouraged to pay the enhanced rates. At present, all the receipts flow into the common consolidated fund of the state and expenditures are provided for in the departmental budget commonly for all projects.

- The rate structure should differentiate between the seasons and also the crops in such a way that production or benefits are optimised per unit of water or at least indicate the intention. Thus the rates should be so rationalised that the water intensive crops are charged proportionately more as compared to less water consuming crops.

- On the basis of previous hydrological records the existing surface irrigation projects should be classified into those with performance.

- Reliability of (a) 75 percent or above and (b) less than 75 percent. Considering a minimum reliability of 50 percent, the water rates for the latter should be two-thirds of the full rates fixed for the former. This is with the view indirectly to compensate the farmers under less reliable projects for loss of production during lean years. Even in respect of (a) there should be declared rates of rebate for non-supply of the assured quantum.

- The objective should be to achieve volumetric measurement ultimately, though gradually and this should be kept in mind at every stage.

- The change should encourage user group formation and give adequate incentive to group consumers, who can be supplied water on volumetric basis, over individual consumers who have to be charged on crop area basis.

- The pricing for water of lift irrigation scheme should be worked out on the basis of the capital and O&M costs of these schemes. As this water will be easily measurable, the tariff should be fixed on volumetric basis. The schemes can be categorised according to lift ranges and rates be fixed for different categories. As the conveyance losses will be very low in case of lift schemes, the gross irrigation requirement will be much less. The capital costs would also be low. Even then, because of high operational costs, the rates/ha may work out to be somewhat higher than those for gravity flow irrigation.

- An important issues in fixing the basis for tariff for irrigation water is equity consideration. It is argued that increasing water charges will adversely affect small and marginal farmers. It is therefore, proposed that farmers with large holdings, say exceeding 10 ha may be levied a suitable surcharge. While the point is well taken, it may also be argued that small and marginal farmers' interest is taken care of by separate measures under which subsidised inputs and credit at concessional rates are provided to them. It is not feasible nor is there need to provide each and every input at subsidised rates, specially irrigation water which is the scarcest of all inputs.

Moreover, there are only a very limited numbers of large farmers. Any surcharge will, therefore, not yield significant amounts.

- In the case of supplies for industrial purposes, the principle of user pays, polluter pays has to be applied and water charges fixed accordingly, adding a premium for security, in water-scarce regions. In the case of domestic supply a certain fixed quantity per connection may be free, in addition to the public taps, and charges increased progressively for larger use.

Water Pricing Authorities

The above are broad guidelines and the details have to be worked out and operationalised in each state, perhaps separately for regions in large states or even for projects. We believe that suggesting a uniform formula for the entire country would have no practical value. We, therefore, propose that a Water Pricing Authority be constituted in each state by statute, on the analogy of the Energy Pricing Authorities and the general principles, with suitable modifications, incorporated as guidelines for the Pricing Authority. The pricing structure suggested by the Authority, after hearing all the parties concerned, should be binding on all concerned. Any subsidy proposed to be given by the State Government for any particular use would be transparent and given as such as a subsidy for such time as the government decides. The subsidy should not affect the funds for the water sector. We believe that the constitution of independent pricing authorities would help bring about the long over-due changes in the pricing of water.

WATER USE EFFICIENCY GUIDELINES FOR IRRIGATION

Irrigation sector is the biggest consumer of water as more than 80% of available water resources in India are being presently utilized for irrigation purposes. However, the average water use efficiency of Irrigation Projects is assessed to be only of the order of 30-35%.

The productivity of farm land has to be increased for increased production of food to keep pace with the increasing population. This requires that maximum agricultural land is brought under irrigated cultivation and multi crop farming. However, the land and water resources are finite and scarce. Thus increasing the water use efficiency of existing irrigation projects, projects under execution and contemplated for execution is of vital importance for maintaining food security and making available water for other developmental needs.

1.0 CONCEPT OF WATER USE EFFICIENCY IN IRRIGATION

Irrigation projects use extensive open channel conveyance systems to distribute water from source to individual farm plots. The delivery of irrigation water to individual farm plots incur a significant loss of water due to: a) seepage; b) evaporation; c) leakages in structures, gates, shutters; and d) poor water management in the distribution network. While designing any irrigation system, an assessment of these losses is made and taken into account in total requirement of irrigation water so that system meets the crop water requirement of its command.

Water Use efficiency in agriculture has been defined in various terms by various people. In economic terms, it has been defined as the value of agricultural produce in monetary terms per unit of water consumed for the production of said produce i.e. so many Rupees per cubic meter of water. However, most common and widely accepted definition of water use efficiency in agriculture/irrigation sector is the ratio between the actual volume of water consumed by crop/plant during evapo-transpiration and the volume extracted or derived from a supply source. In mathematical terms, it can be expressed as:

$$Ef = \frac{Vu}{Ve}$$

Source: Guidelines for Developing Water Use efficiency in Urban Rural, Industrial & Irrigation Sector, Central Water Commission, Govt. of India

Where:

Ef - Water Use Efficiency;

Vu - Volume of water utilized by crop/plants for Evapo-transpiration (in m3) i.e. water used for plant growth;

Ve - Volume of water extracted from the supply source (in m3).

The loss of water, while it is conveyed from source to individual farm plots, takes place in the following components of irrigation system:

(i) Losses in main & branch canals, distributaries, minors & sub-minors;

(ii) Losses in field channels and water courses during distribution of irrigation water from field outlets to individual farm plots; and

(iii) Losses in field application i.e. during application of irrigation water to individual farm plots.

These losses are taken into account in design of irrigation systems by considering the following efficiencies of its various components:

Conveyance Efficiency (Ec): It is ratio between water received at the field inlet to a block of fields and that extracted from source;

Field Channel Efficiency (Eb): It is ratio between water received at the field inlet and that received at the inlet of the block of fields;

Field Application Efficiency (Ea): It is ratio between water directly available to the crop and that received at the field inlet;

Water Use Efficiency of Project (Ep): It is ratio between water directly made available to crop and that extracted from source; Ep=Ea. Eb. Ec.

Conveyance and Field Channel efficiency are sometimes combined and called as Distribution Efficiency (Ed); Ed = Ec. Eb

Field Channel and application efficiency are sometimes combined and called as Farm Efficiency (Ef); Ef = Eb. Ea

2.0 PRESENT PRACTICE OF DESIGN OF IRRIGATION PROJECTS IN INDIA

In India, the Irrigation Projects are normally being designed based on values of efficiencies of various components of Irrigation Project given in technical publication of Ministry of Water Resources, Government of India with the title, 'Guidelines for Estimating Irrigation Water Requirement'. The following efficiencies of various components of Irrigation System have been prescribed therein based on FAO Paper 24(1977):

(i) Conveyance Efficiency

- Continuous Supply with no substantial change in flow: 90%;
- Rotational Supply in projects of 3000-7000 ha and rotation areas of 70-300ha with effective management: 80%;
- Rotational supply in large schemes (> 10000 ha) and small schemes(<1000ha) with respective problematic communication and less effective management:
  - Based on predetermined schedule: 70 %;
  - Based on advanced request: 65 %.

(ii) Field Channel Efficiency

• Blocks larger than 20 ha:
  - Unlined: 80 %
  - Lined or piped: 90 %.

• Blocks less than 20 ha:
  - Unlined: 70 %
  - Lined or piped: 80 %.

(iii) Field Application Efficiency

- Varies from 55% to 80% depending on method of irrigation, slope, soil typeand depth of irrigation water.

Measures recommended for increasing Water Use Efficiency

A. Structural Measures

- Regular/periodic maintenance of canals by clearing off weed/ vegetation growth etc.;
- Restoration of sections of all channels to their designed sections;
- Repair of damaged lining in canals and regular maintenance of lining so that progressive damage to lining could be avoided;
- Selective lining of canals in reaches passing through permeable soil strata;
- Lining of field channel/water courses having high losses;

- Regular maintenance of gates and shutters so as to eliminate losses on account of leakages.
- Repair / Replacement of damaged gates and shutters;
- Improve control in distribution networks by providing appropriate control structures in canals and distribution system;
- Installation of water meters for ensuring volumetric supply of irrigation water to farmers;
- Rehabilitation & Restoration of Structures.

B. Non-Structural Measures

- Involvement of farmers in the management of Irrigation Systems for ensuring equitable distribution and efficient use of irrigation water;
- Formation of Water Users Associations in the command area and giving them the responsibility of distribution of irrigation water and maintenance of Irrigation system progressively starting from field channels;
- Adopting Participatory Irrigation Management practices.
- Training of farmers so as to educate them on various issues related correct agricultural practices and the advantage of optimal irrigation and harms of over Irrigation.
- Providing agricultural extension facilities in the command of each Project.
- Appropriate pricing policy for irrigation water to avoid wastages and over irrigation.

PARTICIPATORY IRRIGATION MANAGEMENT (PIM)

1. Objective

Objectives of PIM are very wide and very much related to increased production per unit of water of the WRD systems. Experience on user managed systems shows that several tasks in irrigation management are handled by farmer groups more efficiently and at reduced cost. Response to any deterioration of the conveyance system involves instant rectification by the farmers resulting in more efficient use of water. Stealing or unauthorized use of water is easily countered. Waste of water is minimized. Within the constraints of the main system, irrigation water distribution can therefore improve considerably.

2. Prospects, Problems and Issues

The necessity to ensure farmers' participation and effecting consequential changes and introducing the reformers in the irrigation departments are widely accepted. However, there are several issues whichare relevant to the success of such a reform which need to be considered and decided.

3. Size scope and functions of WUAs

A) Size

The following factors determine the size and scope of WUAs.

i) Reliability of availability of water apart from its quantum is very crucial for success of irrigated agriculture. This is a basic issue which will not only dictate the structure of WUA but also be the key issue for success of the WUAs. The problems of WUAs which receive water from storage or from run-of-the river source vary significantly. In the first case the availability is assured and known at the beginning of the season. Therefore it would be possible to work out the shares of WUAs in a definitive manner. The WUAs in turn would be geared up not only to share the water amongst the users but also be prepared in advance to share the shortages as the uncertainties in supplies are much less due to storage back up. This will also enable them to plan their crops and be prepared to receive water in their turn in known quantities. Such a situation would be more conducive to the formation and efficient functioning of WUAs.

Source: Report of the working Group-National Commission for Integrated Water Resource Development Plan, MOWR, Govt. of India

In contrast, a run of the river system will depend largely on the vagaries of nature. At best the availability can be planned based on judicious judgment which is generally calculated on 75 percent availability basis. Such a situation might not be able to instill a sense of confidence in WUAs and its members about reliability of supplies and as a result there will always be a tendency to receive and may also result in conflicts amongst and within the WUAs. This would affect the efficient functioning of WUAs and the members would feel reluctant to invest in other agricultural inputs which eventually adversely affect the productivity.. in such case, it would, perhaps, be better to workout water availability figures on different percentages of availability – say 90 percent; 70 percent and 50 percent etc and prepare distribution schedules in respect of each of these so that scarcity is more evenly shared. Perhaps it would also be desirable to fix varying rates for the bulk supply of water in respect of each of these availability figures.

ii) Size of Holdings

The nature of WUAs and its features will materially depend on the size of holdings coming under the WUA. The associations which comprise members having larger holdings shall in general be more flexible and it would be easier to enforce reforms and would have better results. In such cases more powers and responsibilities could perhaps be given to the associations and far reaching reforms including water charges undertaken. This factor would also have bearing on the size of association

iii) Cropping pattern

Each region/area has a traditional cropping pattern and any change in it is resisted. However, with better understanding among farmer and prospects of increasing economic gains, the pattern would change to commercial and more remunerative crops seeds as oil seeds, sugar cane, bananas etc. To support this change ground water potential should be fully exploited.

iv) Socio-economic conditions

Socio-economic conditions of a region shall have a direct bearing on the nature of the WUAs. In socially and economically backward areas/regions, the formation and functioning of WUAs will be more difficult. Firstly there would be lack of willingness to form WUAs on the part of users. Secondly they would be reluctant to put in financial contributions needed for successful functioning of the association. Thirdly and more importantly, they would prefer to lice under the tutelage of Government subsidized regime, even if inefficient rather than take up the management themselves.

v) Education and awareness amongst farmers

This is an important parameter affecting the formation and functioning of WUAs. An educated and aware community will be amenable to change and reform and would be willing to share the responsibility for the greater good of the community. In fact they would welcome such a move as they can foresee the improvement in the services that would be forthcoming. In other case there would be reluctance for any change because of ignorance even if no other reasons exist.

vi) Agro-Climatic Conditions

This movement of creating WUAs would be more relevant in the areas/regions where agro-climatic conditions permit agriculture as a basic economic activity.

B) Scope

The scope could vary from being only marginal (in which users association would interact with the agencies in delivering water according to a time schedule) to an effective and coherent association willing to own a part of irrigation system and be responsible for all its activities including its O&M, deciding water rates and collecting the same, appointment of staff etc. therefore is essential that scope of individual WUAs or a group of them is precisely decided right in the beginning. This should be primarily decided by the willingness and capabilities of the constituents and it depends on the obtainable attendant conditions as discussed in the foregoing Para. In the regions where water availability is reliable and size of holding s are big and constituents are educated and are preferably engaged in cash crops, WUAs can be entrusted with larger responsibilities with wise scope and similarly other combinations could be thought of.

C) Functions

On the basis of experience and the conditions generally obtainable the following patterns can be suggested which could be adopted in a particular region with modifications as needed:

i. To receive water in bulk to be dispensed in a specified area (i.e at all the outlets serving that area) under the command and take the responsibility of distributing water amongst its members in a predetermined equitable manner and supply information needed for billing the stake holders. These WUAs would ensure economical use of water and also resolve conflicts amongst the stake holders. The maintenance of field channels which is done at the cost of farmers shall also be looked after by these WUAs. Such WUAs would generally have outlet committees constituted under them all other responsibilities such as O&M, fixing and collection of water charges and other management activities shall lie with the state. Such a pattern would entail minimal decentralization. However, these WUAs should have a legal status with some teeth to ensure implementation of its decisions. In such a case, the role of government agencies would be quite prominent but it shall have to be clearly defined vis-à-vis the WUAs while deciding their legal status.

ii. To receive water at the head of a channel (minor or a distributory) and take the responsibility of dispensing water to the entire area coming under its command. The responsibilities of such a WUA would be far greater than envisaged under (i) above. The responsibilities of such WUAs would inter alia include the following:

- Making schedules for distribution of predetermined quantities of water to be received at the head.
- Ensuring distribution as per schedule to the clients.
- Recording the irrigated areas in its commands.
- O&M of the canal under its control including outlets and field channels.
- To have interface with the government agency at the channel head and the state staff a appropriate level.

Legal and financial issues relating PIM & WUAs are dealt in the Report of the Working Group on "Legal, Institutional and Financial Aspects".

4. Problems and constraints in the implementation ofPIM

The main problems which need to be addressed inter-alia include the following:

(a) For implementation of any reform agenda, it is essential to declare a policy. At national level, national water policy has been adopted in which the message for reform in water sector is clear and loud. It is essential that each state adopts a well defined and implementable state water policy along with Action Plan for its implementation.

(b) The development of irrigation, specially during the planned development period after independence has been a highly subsidized activity. The reasons for such subsidy are well known and were perhaps essential in that phase of development to bring about the green revolution whose results have been rewarding. This has with time created vested interests in favour of government agencies and in favour of farmers, specially influential ones. Therefore the reluctance to change and reforms is natural and understandable. The community has to bemotivated to change from the regime of subsidies to that of self sustainability along with self management. The motivation will be in making the community realize that the advantages of better service resulting from self-management and self sustainability far outweigh the limited advantage of subsidies which in any case cannot continue perpetually.

(c) The contemplated reform would not be looked upon favourably by state irrigation administration and bureaucracy as it would seem to encroach upon their traditional role and authority and may eventually result in shrinkage of their case. Secondly there is an urgent need for paradigm shift from administration which basically aims at application of rules, to management which basically aims at achieving goals, objectives and outputs. This would naturally involve a radical change in institutional and organizational structure and reorientation of man power.

(d) Yet another impediment in implementing the reform agenda is frequent changes in the administrative personnel. The successful implementation of reforms specially during the initial stages, will depend on the government personnel. It is to be appreciated that it is not a routine task and needs personal involvement apart from understanding the intricacies of the emerging issues. It is therefore necessary that tenure postings are ensured at such positions which are responsible for the implementation of the reform agenda.

(e) The present administrative system suffers from lack of transparency in its functioning. The information relating to water availability and amount for O&M to be carried out for the structures in the minors and distributaries should be legitimately made available to the users.

(f) Majority of farmers is not aware of their rights and responsibilities. They would need to be educated about the crucial role they will have to play in the proposed PIM. However cautions action must be necessary to avoid creation of such pressure groups which may be able to press for undue advantages from the government machinery.

5. Phasing of switch over to WUAs

This could be initiated almost without delay after making statements and taking a conscious decision at the state level. A legal framework should be created to enable efficient functioning of WUAs. However, the reforms should in the initial stages, be taken up in selected areas as a pilot exercise on a time bound basis and monitored closely. The size and location of such areas in the state should be judiciously chosen so that they are representative. The experience gained therefore should form the basis for future decisions.

WUAs within the chosen areas may be implemented in phases. Similarly the administrative reform could also be phased. In the first phase the state staff upto appropriate levels be made responsible to WUAs while could be gradually withdrawn and the WUAs could recruit their own staff. The state staff should continue to provide technical assistance.

OPERATION AND MAINTENANCE

1.0 Periodic maintenance of artificial recharge structures is essential because infiltration capacity reduces rapidly as a result of silting, chemical precipitation and accumulation of organic matter. In case of surface spreading structures, annual maintenance consists of scraping the infiltration surfaces to remove accumulated silt and organic matter. In the case of injection wells, periodic maintenance of the system consists of pumping and /or flushing with a mildly acidic solution to remove encrusting chemical precipitates and bacterial growths on the well screens. The intervals between periodic cleanings can be extended by converting injection wells into dual purpose wells. However, in the case of spreading structures constructed with an overflow or outlet mechanism, annual desilting is a must. Structural maintenance is normally carried out either by government agencies or through initiatives of stakeholders.

Success of artificial recharge schemes and related developmental activities primarily depend on the cooperation of the community and hence, should be managed at the local level. From a basin management perspective, the division of a basin into many micro-catchments is, hence, an essential recognition of the community role. The success of implementation and optimal utilisation of the schemes depend on participation and active contribution of the public.

Several issues are to be considered in the operation and maintenance of artificial recharge structures. These have been categorised as issues of high concern and moderate concern. Safety, optimisation techniques and programs, value of wet-dry cycles, frequency of pond cleaning and condition of filters attached to the structures fall under issues of high concern, whereas security issues and rising groundwater levels are among those of moderate concern in this regard.

2.0 Operational Data Requirements

Realistic estimates of the quantum of water entering and leaving the recharge area/basin/sub-basin are essential for assessing the volume of water that is recharged. Stream gauging stations in streams are needed if natural flows or a combination of natural flow and imported water are being recharged. In case the entire water being recharged is imported, suitable devices should be used to measure the inflow into the structure. The accounting of a system that has both surface and sub-surface recharge structures should also include devices to measure precipitation and

Source: Manual on Artificial Recharge of Ground Water, MOWR, Govt. of India

evapotranspiration, which should be added to the inflow and outflow respectively. Initial measurements should be of sufficient frequency to determine how each of the parameters being measured varies with time. Once the variation is determined, a schedule that provides accuracy and economy can be set, which should integrate all the data being measured for optimizing data collection costs.

The data that should be measured for a recharge system include but are not limited to the following:

- Flow rate, duration and quality of source water.
- Inflow and outflow rates, duration and quality of inflow and outflow into and out of each unit of the recharge system.
- Recharge rates versus time for each unit and for the system as a whole.
- Depth to water and quality of ground water in the area being recharged and adjacent areas.
- Power usage by individual units and for the system as a whole.
- Depth to water in the recharge structures versus time (in case of surface structures)
- Thickness and composition of surface clogging layer when the structure is dry(in case of surface structures).
- Pressure versus time (in case of pressure injection)
- Depth to water in recharge well versus time in case of gravity head recharge wells.
- Precipitation and evaporation from surface ponds.
- Temperature of water at inflow and outflow locations.
- Time, rate and volume of pumping for each structure and for the system as a whole.

The data mentioned above helps fine-tune the recharge facility and provides the basis for corrections in case of problems. Periodic tests of pump efficiency, sampling of water quality and ground water level measurements should also be made and recorded on a defined schedule.

Measurement of any flows that pass downstream of the last recharge structure is needed if the total recharge from the operation is to be assessed. The volume of water passing the downstream gauging station, adjusted for precipitation and evaporation can be subtracted from the measured inflow volume to determine the quantum of water recharged.

2.1 Water Level Measurement

Measurement of ground water level in the aquifer, also known as ‘static water level’or ‘potentiometric head’ is very important in artificial recharge schemes. Water levels have to be measured after a sufficient time has elapsed since stoppage of pumping or recharge to allow the water level to become stabilized and the drawdown/mounding effects to be minimized. Measurement of water levels in wells adjacent to a surface or subsurface recharge structure are also important as they help determine the shape and rate of growth of the recharge mound.

2.2 Water Quality Measurement

Complete water quality sampling and testing of a recharge scheme including source and aquifer should be done initially to determine the suitability of water for the intended use. The testing will provide a basis for the design of any other water quality treatment facilities that may be needed. After implementation of the scheme, periodic water quality assessment should be made. Proper training should be imparted to the personnel involved to ensure that the samples are not contaminated during collection and transportation.

3.0 Preventive Maintenance

Preventive maintenance of artificial recharge structures implies a periodic action taken to forestall major repair or replacement of its components. It may be drying up and scarifying of recharge ponds, periodic pumping of recharge wells, or regular application of lubricants / protective substances to the mechanical parts or replacement of minor parts that are subject to deterioration or repeated failure. It also involves regular observation and recording of the behaviour of both static and dynamic components of the system to detect changes in their inherent condition that indicates the need for unscheduled maintenance. These include reduction in the recharge rates, temperature of mechanical parts or rate of settlement.

3.1 Maintenance of Surface Recharge Structures

Artificial recharge structures such as percolation ponds and check dams are examples of ‘wet/dry cycle’ operation (ASTE, 2001) in which the structures get filled up one or more times during monsoon and remain dry during the summer season. These structures can be maintained by removing the silt deposited at the bottom of the structure periodically. The optimal amount of cleaning would remove the accumulation of surface material that has reduced the recharge capacity of the structure.

4.0 Potential Problems

The Problems normally encountered in recharge projects are mainly related to the source water available for recharge, which generally require some sort of treatment before use in recharge installations. They are also related to the changes in the soil structure and the biological phenomena, which take place when infiltration begins, to the changes of land ownership and legal aspects.

4.1 Suspended Material

A major requirement for waters that are to be used in recharge projects is that they should be silt-free. Silt may be defined as the content of un-dissolved solid matter, usually measured in mg/l, which settles in stagnant water having velocities not exceeding 0.1 m/hr. This definition comprises a large variety of materials such asclay particles, organic matter and fine particles of calcite. The silt content of river water depends upon the type of soils in the area of run-off, the vegetative cover of this area, its topographic slopes, meteorological characteristics prevailing in its catchment and intensity of rainfall.

Suspended matter may clog the soil in two different ways. Near the surface, the interstices of the soil may be filled up and a layer of mud may be deposited on the surface. On the other hand, they may penetrate deeper into the soil and accumulate there. A layer of mud is formed on the surface by particles, the settling velocity of which exceed infiltration velocities. Smaller suspended particles are filtered out in the uppermost layer of the soil. The filtration process is governed not only my mechanical factors, but it seems to be strongly influenced by electro-chemical surface forces. Still finer particles, especially very fine grains of montmorillonite clay, are carried further into the soil. Observations in spreading grounds composed of medium-grained dune sands, showed that these particles become lodged at depths ranging from 10 to20 m below the surface, and some of these particles are carried even deeper. Semipervious layers situated deep below the sand filter out even those particles and become progressively clogged.

Methods to prevent or minimize the clogging effect by suspended matter can be classified into the following broad groups:

a. Periodical removing of the mud cake and scraping of the surface layer
b. Installation of a filter on the surface, the permeability of which is lower than that of the natural strata (the filter must be removed and replaced periodically)
c. Addition of organic matter or chemicals to the uppermost layer
d. Cultivation of certain plant-covers, notably certain kinds of grass

Scraping of the surface layer is effective only in coarse-grained soils. In soils composed mainly of sand, repeated compaction by heavy machinery may easily nullify any benefit gained from scraping. Various chemicals and organic matter have been used to restore infiltration capacities. These include gypsum, various organic compounds, cotton-gin trash and alfalfa (grown while the pond is still wet and then spaded under). The growth of a permanent grass-cover has proved to be an effective method for maintaining infiltration capacities, but it is difficult to select a grass which grows under a given climatic and soil condition and is able to withstand alternate periods of flooding and drying.

Clogging by biological activity depends upon the mineralogical and organic composition of the water and basin floor and upon the grain-size and permeability of the soil. The only feasible method of treatment developed so far consists in thoroughly drying the ground under the basin. Experiences seem to indicate that short periods of operation (about one month), followed by drying, are more effective than prolonged periods of operation, even if they are followed by a prolonged and most thorough period of drying during the hot summer.

Clogging and consequent destruction of bore holes may occur as a result of erosion of the aquifer. If velocities of flow are too high, fine sand and particles from local clay layers may be dragged outward into the aquifer and clog it or even cause collapse of the well. The common-sense precautions against these mishaps in semi-consolidated aquifers are to keep injection rates somewhat below the rate of proved safe continuous pumping and to avoid frequent sudden changes of the injection rate, which may cause vibrations. Experience has shown that no deterioration of the aquifer occurs if these reasonable precautions are taken.

Air bubbles, which are sucked into the well through the injection pipe, cause violent vibrations when they finally escape upwards. The possibility of air seepage must therefore be completely eliminated. The only certain way to achieve this is to design and operate the installation so that positive pressures (exceeding atmospheric pressure) are maintained everywhere in the injection pipe, even if this entails a reduction of injection rates.

Bore holes are much more prone to silting than spreading grounds. No acceptable standard of turbidity can be given. Clarity of the Water should conform to the standards of good drinking water. Clogging of the bore hole wall by bacterial growth may occur, even if water of potable standard is injected. Even when chlorination at the well-head carried out, the wells may still require periodic re-development by mechanical means and pumping.

4.2 Environmental Problems

A number of environmental problems may stem from artificial recharge schemes. Such projects usually have to be carried out in the vicinity of densely populated and industrial areas, where large quantities of water are needed. The close vicinity of spreading-grounds to population centers often creates various kinds of problems. In particular, it is well known that stagnant water serves as a breeding ground for mosquitoes, flies and a variety of other biological nuisances. The best remedy is to operate parts of spreading-grounds in sequence, so that water remains in each part for a shorter period than the larvae stage of the insect's life-cycle. This remedy may, however, lead to unrealistically large land requirements.

Other types of damages can also be generated by such projects. Artificial recharge is a procedure designed to raise ground water levels, which, under certain circumstances, can cause substantial damage such as inundation of basement of buildings. Damages may also be claimed if the recharged water is of interior quality to that previously enjoyed by nearby well-owners. Such might be the case where saline water, originating from treated sewerage effluent, is recharged into a fresh water aquifer. In such instances, more water is made available, say, for irrigation, but the practice may simultaneously create a deterioration of water used for drinking purposes.

There is no general solution for such problems. Each case has to be studied independently, taking into account the physical, economic, human and legal aspects. There is no doubt, however, that in most cases the overall benefits of such projects in water-short areas largely transcend the drawbacks.

4.3 Water Quality Problems

Various chemical processes such as adsorption, ion-exchange, oxidation and dissolution are expected to occur during the process of artificial recharge. Adsorption processes can occur at several levels from precipitated flocs to individual ion adsorption. Iron oxyhydroxide and organic flocs are particularly sticky substances and usually get adsorbed on aquifer particles and reduce the amount of water that can move through the aquifer. Acidification can be attempted to recover some permeability.

Ion-Exchange is significant if the aquifer water is brackish to saline. The clay particles typically have Sodium in exchange positions and these sodium ions are stable in high TDS conditions. Artificial recharge results in a reduction in TDS due to injection of lower TDS water and this increase reaction between dissolved ions in ground water. Calcium will replace the sodium in the exchange position, converting the clay to calcium rich clay. This exchange destabilizes the attached clay particles and allows them to move into the pore spaces of the aquifer, causing plugging.

Most aquifers are under either moderately oxidizing or reducing environments. Artificial recharge process with recharge water of more oxidizing nature than the ground water will destabilize the equilibrium of native ground water oxidation reduction conditions and cause chemical reactions to occur. Siderite (Iron Carbonate), Pyrite and Marcasite are the most susceptible to oxidation by recharge water. Depending upon how much of these minerals are present in the aquifer, the plugging of pores by iron oxyhydroxide flocs takes place. This plays a major role in areas where the pollutants get release and mobilized in an aquifer.

Solubility is a complex process that can involve several phases. Formation of calcite due to chemical reaction can be considered as an example. Carbon-dioxide participates in macrobiotic reactions and depending on PH, carbonic acid, bicarbonate and carbonate form in sequence with increasing pH. Finally, with sufficiently high calcium and carbonate concentrations, Calcite precipitates.

5.0 Physical, Biological and Chemical Compatibility of Water

Artificial recharge through injection wells can be effectively achieved if the recharge water is chemically and physically compatible with the native ground water. If the recharge water has similar chemical and physical characteristics, it will mix with the ground water without producing any undesirable effect in the aquifer media. It is impractical to determine whether the two waters are compatible by using only the few known factors and also it will be difficult to monitor the physicochemical environment in the aquifer system which is subjected to stress and strain through artificial recharge.

5.1 Physical Compatibility

i) Temperature

Two physical properties that relate to the compatibility of the recharge water and native ground water are viscosity and density. Viscosity and density are inversely proportional to temperature. If the injected water is colder than the native groundwater, the injected water tends to settle towards the bottom owing to its greater density and viscosity. Cold water has greater viscosity and therefore moves through the interstices of an aquifer less freely than warm water. Thus, if the temperature of water in an aquifer is reduced, the effective permeability of the aquifer also gets reduced.

ii) Suspended Material

The presence of small amounts of suspended material in recharge water will seriously affect the performance of an injection well and the aquifer materials adjacent to the well. The degree of clogging depends not only upon the amount of sediment but also upon the composition of the sediment, the size of the particles, the composition of the aquifer materials and interstitial space in the aquifer. The effect of clogging in an injection well can be recognized by observing the injection rate and water level in the injection well. Clogging due to silt entry into the injection well causes a steady increase in the head.

In order to minimize the entry of silt in the recharge well, effective filtration of surface water through slow-sand filter is generally followed. Depending upon the turbidity level of surface water, two-stage filtration can be adopted if required with a rapid filtration stage followed with slow filtration. It is necessary to monitor the turbidity of recharge water periodically. During the recharge process, if the records of water level and injection rate indicate clogging, it is necessary to surge (back flush) the injection well with heavy discharge pumps for a short duration. Surging helps in the removal of silt settled in the well section and in the aquifer zones adjacent to the well. If the recharge process is continued without surging, the suspended particles may enter into the interior part of the aquifer and it would be difficult to remove the particles settled in the interstices. It is advisable to do the surging periodically, irrespective of any indications of clogging.

iii) Air

Air introduced into a well during recharge may affect the permeability of the aquifer through both physical and chemical processes. The air bubbles occupy the space in the interstices, thereby reducing the effective porosity and block the movement of water. The bubbles are normally tightly held on to the aquifer materials by molecular attraction and get diffused very slowly. In fresh water used for injection, the ratio of dissolved oxygen, nitrogen and other atmospheric gases is virtually constant at normal water temperature, unless the oxygen content is reduced or increased by biological activity. Clogging by air bubbles is easily recognized by a sharp increase in injection well water level immediately after recharge operations start. The air clogging is easily seen by formation of air foaming when the injection operation is stopped. Physical entrapment of air in the recharge well can be minimized by carrying the injection pipes, some distance below the static water level in the well. Surging operations may help in removing some air clogging near the well screen.

5.2 Biological Compatibility

Biological suitability of the recharge water is also an important factor controlling effective artificial recharge. Pathogenic bacteria can render a ground water unfit as a source of drinking water. Other harmless bacteria species may lead to coloring of ground water and cause unpleasant taste and odour. Bacteria in a suspended matter multiply rapidly when their food supply is abundant. When they enter the recharge well along with recharge water and multiply in the well screen openings or in the gravel pack, resulting in clogging or reduction in intake rate. In the case of bacteriological clogging, the rise in injection head reaches its maximum value after
some days only. When biodegradable matter is present in the injection water, a complete sealing of the well may occur within one or two weeks. Pre-treatment through slow sand filtration of injected water and chlorination may prevent the growth of bacteria in an injection well. Maintaining a residual chlorine level of 1-2 mg/l in the injection well is recommended for minimising the biological clogging.

5.3 Chemical Compatibility

Borehole injection operations encounter difficulties when the recharge water reacts with the native ground water or with the aquifer material. The reaction may lead to formation of insoluble deposits in the pore spaces, hindering the ground water movement. Three reaction stages over time and space may be distinguished:

i) At the very beginning of the recharge process, the native ground water is displaced by the recharge water. During the initial phase of recharge experiment, a mixed zone (a zone containing recharge and native groundwater) is expected to form and in this zone, the reactions may take place. This is particularly disadvantageous with well injection, where in the immediate vicinity of the well a small reduction in pore space appreciably increases flow resistance. Formation of mixed zone cannot be prevented, but it is possible to prevent the formation of a mixed zone in the near vicinity of the well by injecting an amount of non-reactive water, which effects deposition at a distance sufficiently away from the well so that the intake capacity of the well is not affected.

ii) With passage of time, all the native ground water in the aquifer is replaced by recharge water. Reactions are now only possible between recharged water and aquifer matrix. Mostly, the reactions may result in an increase of the mineral content of recharged water.

iii) During the recovery of recharged water from the wells, the abstracted water from the recharge well will, in the initial stages, be very close to injected water in quality. With passage of time, extraction will be a mixture of recharge water and native ground water. As a result of incompatibility of recharge water and native ground water, blocking of the formation will again take place around the wells used for abstraction.

COMMON GUIDELINES FOR WATERSHED DEVELOPMENT PROJECTS

Government of India

2008

Contents

1. Preface

1) In 1994, a Technical Committee under the Chairmanship of Prof. C.H. Hanumantha Rao, was appointed to assess the Drought Prone Areas Programme (DPAP) and the Desert Development Programme (DDP) with the purpose of identifying weaknesses and suggesting improvements. The Committee, after careful appraisal, opined that the “programmes have been implemented in a fragmented manner by different departments through rigid guidelines without any well-designed plans prepared on watershed basis by involving the inhabitants. Except in a few places, the achievements have been sub-optimal. Ecological degradation has been proceeding unabated in these areas with reduced forest cover, reducing water table and a shortage of drinking water, fuel and fodder” (Hanumantha Rao Committee, 1994, Preface).

2) Against this backdrop, the Committee made a number of recommendations and formulated a set of guidelines that brought the DDP, the DPAP and the Integrated Wastelands Development Programme (IWDP) under a single umbrella. The watershed projects taken up by the Ministry of Rural Development (MoRD) from 1994 to 2001 followed these guidelines. In 2000, the Ministry of Agriculture revised its guidelines for its programme, the National Watershed Development Project for Rainfed Areas (NWDPRA). These guidelines were intended to be common guidelines to make the programme more participatory, sustainable and equitable. However, the MoRD revised the 1994 Hanumantha Rao Committee guidelines in 2001 and yet again in 2003 under the nomenclature “Hariyali Guidelines”.

3) In the meanwhile, emerging issues of ground water recharging and convergence to create a critical mass of investments demanded innovative guidelines. At the advent of the Eleventh Plan period, our main challenge is to move the nation decisively in the direction of "inclusive growth". Rainfed areas of 85 million hectares out of the 142 million hectares of net cultivated area, have suffered neglect in the past. High untapped productivity and income potential exists in these areas.

4) An insight into the rainfed regions reveals a grim picture of poverty, water scarcity, rapid depletion of ground water table and fragile ecosystems. Land degradation due to soil erosion by wind and water, low rainwater use efficiency, high population pressure, acute fodder shortage, poor livestock productivity, underinvestment in water use efficiency, lack of assured and remunerative marketing opportunities and poor infrastructure are important concerns of enabling policies. The challenge in rainfed areas, therefore, is to improve rural livelihoods through participatory watershed development with focus on integrated farming systems for enhancing income, productivity and livelihood security in a sustainable manner.

5) The National Rainfed Area Authority (NRAA) has been set up in November 2006, keeping in mind the need to give a special thrust to these regions. A close analysis of various types of rainfed situations would reveal that soil and water conservation, watershed development and efficient water management are the key to sustainable development of rainfed areas. The watershed approach has been accepted as a major theme for development of rainfed areas with a view to conserving natural resources of water, soil and vegetation by mobilizing social capital. Various studies have pointed out the central preoccupation of watershed development projects with soil and water conservation and relative neglect of issues relating to balanced use of natural resources and livelihoods.

6) In order to assess the performance of various ongoing projects / programmes of watershed development, a series of evaluation studies have been conducted by ICAR (Indian Council of Agricultural Research) Institutes, State Agriculture Universities (SAUs), National Remote Sensing Agency (NRSA) etc. Besides, impact assessment studies were carried out by the Ministry of Agriculture, Ministry of Rural Development, Planning Commission, ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) and the Technical Committee constituted by the Department of Land Resources (DoLR). These studies support the observation that in several watersheds, the implementation of the programme has been effective for natural resource conservation by increasing the productivity of the land, bringing additional area under agriculture, employment generation and social upliftment of beneficiaries living in the rural areas. But these successes have been sporadic and

intermittent. The overall impact at the state and national levels has generally been inadequate. Additional demand and supply driven socio-economic and risk managing paradigms are emerging.

7) It is in this context that in coordination with the Planning Commission, an initiative has been taken to formulate “Common Guidelines for Watershed Development Projects” in order to have a unified perspective by all ministries. These guidelines are therefore applicable to all watershed development projects in all Departments / Ministries of Government of India concerned with Watershed Development Projects.

8) Out of the total geographical area of the country of 329 MH, about 146 MH is degraded and 85 MH is rainfed arable land. This includes degraded land not only under private ownership, but also the one with the departments of panchayat, revenue and forest. All these lands are prioritized for development under various watershed development projects under these guidelines. During the 11th Five Year Plan, major thrust would be laid on developing the untreated areas.

9) These Guidelines broadly indicate a fresh framework for the next generation watershed programmes. The key features of this new unified approach can be broadly outlined as follows:

I. Delegating Powers to States: States will now be empowered to sanction and oversee the implementation of watershed projects within their areas of jurisdiction and within the parameters set out in these guidelines.

II. Dedicated Institutions: There would be dedicated implementing agencies with multi-disciplinary professional teams at the national, state and district level for managing the watershed programmes.

III. Financial Assistance to Dedicated Institutions: Additional financial assistance would be provided for strengthening of institutions at the district, state and national level to ensure professionalism in management of watershed projects.

IV. Duration of the Programme: With the expanded scope and expectations under this approach, the project duration has been enhanced in the range of 4 years to 7 years depending upon nature of activities spread over 3 distinct phases viz., preparatory phase, works phase and consolidation phase.

V. Livelihood Orientation: Productivity enhancement and livelihoods shall be given priority along with conservation measures. Resource development and usage will be planned to promote farming and allied activities to promote local livelihoods while ensuring resource conservation and regeneration. The new approach would systematically integrate livestock and fisheries management as a central intervention and encourage dairying and marketing of dairy products. In the rainfed areas, the animal resources become a major source of income for the people. When effectively integrated with the Watershed Development Projects, a comprehensive animal husbandry component would contribute significantly to ensuring a better and sustainable livelihood for the people of the rainfed areas.

VI. Cluster Approach: The new approach envisages a broader vision of geo-hydrological units normally of average size of 1,000 to 5,000 hectares comprising of clusters of micro-watersheds. If resources and area exist additional watersheds in contiguous areas in clusters may be taken up. However smaller size projects will be sanctioned in the hilly/difficult terrain areas.

VII. Scientific Planning: Special efforts need to be made to utilize the information technology and remote sensing inputs in planning, monitoring and evaluation of the programme.

VIII. Capacity Building: Capacity Building and training of all functionaries and stakeholders involved in the watershed programme implementation would be carried out on war footing with definite action plan and requisite professionalism and competence.

IX. Multi Tier Approach: There would be a multi tier ridge to valley sequenced approach, which should be adopted towards the implementation of the Watershed Development Projects. The higher reaches or the forests are actually where the water sources originate. The approach, therefore, will be to identify an area, and first look at the forest and the hilly regions, in the upper water catchments wherever possible. When suitable treatment is undertaken, with the support of the Ministry of Environment and Forest, or from the States' forest programmes or other sources, then the hardest part of the watershed is tackled. Forest department is managing structures such as check dams, contour-bunds etc. to arrest the erosion and degradation of the forests, which in turn, actually benefit the lower tiers. Thus, in the upper reaches, which are mostly hilly and forested, the onus of implementation would mainly lie with the Forest Departments and the Joint Forest Management Committees (JFMC).

The second tier is the intermediate tier or the slopes, which are just above the agricultural lands. In the intermediate slopes, the Watershed Management approach would address all the necessary issues by looking at all the best possible options including treatment, cropping pattern, horticulture, agro-forestry etc.

As to the third level of the plains and the flat areas, where typically, the farmers are operating, there would be a large concentration of labour intensive works. The watershed development process would be synergized with the employment generating programmes such as the National Rural Employment Guarantee Scheme (NREGS), Backward Regions Grant Fund (BRGF) etc thus providing strong coordination.

10) These guidelines coupled with the flexibilities inherent in them would provide an enabling framework for the planning, design, management and implementation of all watershed development projects in the country. As soon as these Common Guidelines are approved, they will apply to all schemes concerned with watershed development of all departments of Government of India.

New watershed projects will be implemented in accordance with these Common Guidelines with effect from 1st April 2008. Already sanctioned and ongoing projects will follow previous guidelines. For interpretation of any of the provisions of these guidelines, the NRAA will be the final authority. If any modification in any of the provisions of these Guidelines is contemplated by any of the Nodal Ministry, then such modification would need to be ratified by the Executive Committee of the NRAA.

2. Guiding Principles

11) The common guidelines for Watershed development projects are based on the following principles:

i) Equity and Gender Sensitivity:

Watershed Development Projects should be considered as levers of inclusiveness. Project Implementing Agencies must facilitate the equity processes such as a) enhanced livelihood opportunities for the poor through investment in their assets and improvements in productivity and income, b) improving access of the poor, especially women to the benefits, c) enhancing role of women in decision-making processes and their representation in the institutional arrangements and d) ensuring access to usufruct rights from the common property resources for the resource poor.

ii) Decentralization:

Project management would improve with decentralization, delegation and professionalism. Establishing suitable institutional arrangements within the overall framework of the Panchayati Raj Institutions, and the operational flexibility in norms to suit varying local conditions will enhance decentralisation. Empowered committees with delegation to rationalise the policies, continuity in administrative support and timely release of funds are the other instruments for effective decentralization.

iii) Facilitating Agencies:

Social mobilisation, community organisation, building capacities of communities in planning and implementation, ensuring equity arrangements etc need intensive facilitation. Competent organisations including voluntary organizations with professional teams having necessary skills and expertise would be selected through a rigorous process and may be provided financial support to perform the above specific functions.

iv) Centrality of Community Participation:

Involvement of primary stakeholders is at the centre of planning, budgeting, implementation, and management of watershed projects. Community organizations may be closely associated with and accountable to Gram Sabhas in project activities.

v) Capacity Building and Technology Inputs:

Considerable stress would be given on capacity building as a crucial component for achieving the desired results. This would be a continuous process enabling functionaries to enhance their knowledge and skills and develop the correct orientation and perspectives thereby becoming more effective in performing their roles and responsibilities. With current trends and advances in information technology and remote sensing, it is possible to acquire detailed information about the various field level characteristics of any area or region. Thus, the endeavour would be to build in strong technology inputs into the new vision of watershed programmes.

vi) Monitoring, Evaluation and Learning:

A participatory, outcome and impact-oriented and user-focused Monitoring, Evaluation and Learning system would be put in place to obtain feedback and undertake improvements in planning, project design and implementation.

vii) Organizational Restructuring:

Establishing appropriate technical and professional support structures at national, state, district and project levels and developing effective functional partnerships among project authorities, implementing agencies and support organizations would play a vital role.

3. Technology Inputs

12) Technology enables us, inter-alia, to strengthen programme management and coordination, undertake activity based project planning, formulate action plans, streamline sanctions and release of funds, create useful data bases, assess actual impacts of projects, make effective prioritizations, prepare sophisticated DPRs, document best practices and case studies and facilitate the free and seamless flow of information and data.

13) Thus, the endeavour would be to build in strong technology inputs into the new vision of watershed programmes. At the State and National levels, core GIS facilities, with spatial & non-spatial data, would be established and augmented with satellite imagery data received from NRSA, ISRO and Survey of India. All the GIS layers for various themes would be overlaid having a geo-referenced base layer up to the level of village boundaries in the first instance. This core GIS data may be given controlled access/distribution over network for local project planning. Application software for web-enabled integrated watershed development, spatial & non-spatial data standards and meta-data would also be worked out. Once such a knowledge base is in place, it would be possible to define watershed project boundaries with assignment of unique-identification (unique-id) to each project. It would also be possible to map treatment area with respect to their respective administrative formations in terms of villages, blocks and districts.

14) Remote sensing data would be utilized for finalizing contour maps for assessment of run-off and for identifying structures best suited for location of projects. This would result in cost and time optimization in project implementation. Technology would also contribute immensely in assessing the actual impact of various programs in a given area. Due to availability of latest remote sensing techniques, it is now possible to assess periodic changes in geohydrological potential, soil and crop cover, run-off etc in the project area.

15) Information connectivity would be extended to all the districts and project implementation agencies. This Watershed information network would reach right up to the project areas. Each District and State centre would be equipped with IT and domain professionals with

desired skills. Thus technology inputs would bring about a paradigm shift in the implementation and management of the area development programmes.

16) A National Portal will be created which will host the data generated for all watershed projects in the entire country. Inputs will be compiled from all concerned Ministries / Departments including Ministry of Rural Development / Ministry of Environment and Forest / Ministry of Agriculture. The National Portal will be commissioned and maintained by the NRAA.

4. Institutional arrangements at National, State and District levels

Following the spirit of the Guiding Principles, appropriate institutional arrangements would be made at various levels for effective and professional management of watershed development projects.

4.1 Role of National Rainfed Area Authority

17) National Rainfed Area Authority (NRAA) would, inter-alia, be responsible for:

a) Supporting the process of preparing strategic plans for watershed based development projects at the state and district level keeping in view specific agro-climatic and socio-economic conditions.
b) Assisting in the preparation of state specific technical manuals for the multi-disciplinary and integrated approach required for implementation of these projects together with the standards and specifications etc.
c) Supporting State Level Nodal Agencies in identifying resource organizations and establishing capacity building arrangements.
d) Facilitating action research relevant to watershed development programme in different agro-climatic regions.
e) Conducting studies, evaluation and impact assessment from time to time so that the benefits of these are available for improving the quality of watershed management projects.

f) Facilitating convergence of different schemes and projects of Government of India which are having similar objectives.

g) Accessing additional funds from other sources including private sector, foreign funding agency, etc and facilitate its use to fill up critical gaps in the programme as well as upscale successful experiences through innovative organizations at field levels.

h) Acting as an effective coordinating mechanism between all bodies/ organizations/ agencies/ departments/ ministries etc who are involved in watershed programmes.

i) Organizing regional and international conferences, seminars and workshops, study tours, and information sharing.

j) Providing technical knowledge inputs and expertise.

k) Such other activities as may be decided by the governing body of NRAA / Government from time to time.

4.2 Institutional arrangements at the Ministry Level

18) Whereas each Ministry is free to set up its own mechanism to oversee watershed development programmes, it shall also have the option to set up a Nodal Agency at the central level in the Department for managing and implementing watershed development projects. These nodal agencies will comprise of professional multi-disciplinary experts experienced in the fields of agriculture, water management, institution and capacity building etc.

19) The Nodal Agency at the central level in the Department / Ministry, among others, will perform the following important functions:

   a) Facilitate allocation of the budgetary outlay for the projects among the States keeping in view the criteria as specified in the Guidelines.

   b) Interact with State and District Level Agencies, facilitate and ensure smooth flow of funds to the District Watershed Development Units as per the fund flow norms as well as recommendations from the State Level Nodal Agencies.

c) Actively support capacity building programmes at all levels.

d) Strongly support, augment and initiate Information, Education and Communication (IEC) activities with modern IT inputs.

e) Ensure close monitoring through on-line systems.

f) Establish suitable systems for field visits, monitoring, social audits and impact assessment through interaction with state and district level agencies for effective implementation of the projects at ground level.

g) Prepare a panel of evaluators or evaluation agencies and undertake evaluation studies, impact assessment studies and such other evaluation tasks as deemed fit from time to time.

h) Support as well as facilitate participation in national, regional and international conferences, seminars and workshops, study tours, research / field studies and information sharing.

i) Act as an effective coordinating mechanism between all bodies, organizations, agencies, departments, Ministries etc. which are involved in watershed programs.

j) Undertake all such activities which are useful for the purposes of ensuring that watershed programmes become major vehicles for the overall and all-round development of rainfed areas in the country.

20) The Funding support for the Nodal Agency at the central level will come primarily from the budget of the respective Department / Ministry after suitable review of the existing staff and infrastructure already available and actual requirement. It may also receive support from other Institutes and Agencies both national and international, corporate entities, and such other organisations which seek to support programmes on watershed mode.

4.3 National Level Data Centre and National Portal

21) The National Data Centre and National Portal under the overall aegis of the NRAA would be a national level facility for extending, storing and generating watershed and land resource information, data and knowledge. The National Data Centre (NDC) would collate summary

data for the entire country, archival data, data for programme and fund flow management. This centre is planned to be equipped with various GIS thematic layers for cadastral, watershed, soil, land use, socio-economic parameters, habitation etc. It shall have application support for area development programmes, rural employment, land use planning, master data for integrated layers, and high end GIS data for district level planning and monitoring.

4.4 State Level Nodal Agency

22) A dedicated State Level Nodal Agency (SLNA) (Department / Mission /Society/ Authority) will be constituted by the State Government having an independent bank account. The state should be given the flexibility to utilise or strengthen an existing state level agency/department/organisation. Central assistance for SLNA will be transferred directly to the account of SLNA and not into the State Government budget.

23) The SLNA will sign an MOU with the Departmental Nodal Agency setting out mutual expectations with regard to performance, timelines and financial parameters including conditions related to release of funds to SLNA. The SLNA will be required to review the programme and provide enabling mechanism to set up State Data Cell and ensure regular reporting to the Central Government/ Nodal Agency at the central level in the Department. There would be multidisciplinary professional support team at the State level to implement the programme.

24) The Development Commissioner / Additional Chief Secretary / Agricultural Production Commissioner/ Principal Secretary of the concerned department or their equivalent nominated by the State Government will be the Chairperson of the SLNA. The State Level Nodal Agency will have a full-time CEO who may be a serving Government officer on deputation or appointed on a contract of not less than three years with the State Level Nodal Agency. Such a contract will set out the terms and conditions of engagement as well as clearly defined goals against which the performance of the CEO will be closely monitored.

25) The SLNA would consist of one representative from the NRAA, one representative from the Central Nodal Ministry, one representative from NABARD, one representative each from the State Department of Rural Development, Agriculture, Animal Husbandry and allied sector, one representative from Ground Water Board and one representative from an eminent voluntary organization and two professional experts from research institutes / academia of the state. There will be also representation from NREGA, BRGF and other related implementing agencies at the state level. The SLNA will sanction watershed projects for the State on the basis of approved state perspective and strategic plan as per procedure in vogue and oversee all watershed projects in the state within the parameters set out in these Guidelines.

26) A Team of 4 to 7 professional experts will assist the State Level Nodal Agency. This team will be selected by the State Level Nodal Agency either on deputation from experts available from the line departments or in case such experts are not available, they may be engaged on contract basis from the open market by a transparent process. Their disciplines will, inter-alia, include agriculture, water management, capacity building, social mobilisation, information technology, administration and finance/ accounts, etc. A requisite number of administrative staff will support this team of experts.

27) The main functions of the SLNA will be to:

a) Prepare a perspective and strategic plan of watershed development for the state on the basis of plans prepared at the block and district level and indicate implementation strategy and expected outputs/outcomes, financial outlays and approach the Nodal Agency atthe central level in the Department for appraisal and clearance.
b) Establish and maintain a state level data cell from the funds sanctioned to the States, and connect it online with the National Level Data Centre.
c) Provide technical support to District Watershed Development Units (DWDU) throughout the state.

d) Approve a list of independent institutions for capacity building of various stakeholders within the state and work out the overall capacity building strategy in consultation with NRAA/Nodal Ministry.

e) Approve Project Implementing Agencies identified/selected by DWDU/ District Level Committee by adopting appropriate objective selection criteria and transparent systems.

f) Establish monitoring, evaluation and learning systems at various levels (Internal and external/ independent systems).

g) Ensure regular and quality on-line monitoring of watershed projects in the state in association with Nodal Agency at the central level and securing feedback by developing partnerships with independent and capable agencies.

h) Constitute a panel of Independent Institutional Evaluators for all watershed projects within the state, get this panel duly approved by the concerned Nodal Agencies at the central level and ensure that quality evaluations take place on a regular basis.

i) Prepare State Specific Process Guidelines, Technology Manuals etc in coordination with the Nodal Ministry/ NRAA and operationalise the same.

28) The Funding support for the State Level Nodal Agency and the state level data cell will come primarily from the budget of the Department of Land Resources, Ministry of Rural Development after suitable review of the existing staff and infrastructure already available and actual requirement. It may also receive support from other Institutes and Agencies both national and international, corporate entities, and such other organisations which seek to support programmes on watershed mode. Each State Level Nodal Agency and state level data cell will be provided with an initial capital grant to meet establishment costs and a recurring grant per annum to meet its annual expenses. The actual amount would depend upon the level of staff and infrastructure already available and the actual requirement. Till such time, SLNA is set up, the existing arrangement regarding sanctioning of project and flow of fund will be continued. However, all out efforts should be made by the States to set up SLNAs within a period of 6 months.

4.5 District Watershed Development Unit (DWDU)

29) In districts, where the area under the watershed development projects is about 25,000 hectare, a separate dedicated unit, called the District Watershed Development Unit (DWDU) will be established at the district level, which will oversee the implementation of watershed programme in each district and will have separate independent accounts for this purpose. Where the area under Watershed Development Projects is less than approximately 25,000 hectare, the projects will be implemented in accordance with the existing arrangements. However, in such cases one officer shall be exclusively appointed within the DRDA either on contract or on deputation to coordinate watershed projects at the district level. DWDU will function in close co-ordination with the District Planning Committee. There will also be a representation in DWDU for NREGA, BRGF implementing agencies at the district level. Alternatively, the mechanism of approval and implementation of project by the District Level Committee / collector may continue to prevail.

30) DWDU will be a separate unit with full time Project Manager and 3 to 4 subject matter specialists on Agriculture/ Water Management / Social Mobilisation/ Management & Accounts appointed on the basis of their qualification and expertise on contract/deputation/transfer etc. The Project Manager, DWDU would be a serving government officer on deputation or would be recruited from open market by means of a transparent process. If he/she is a serving Government officer, his/her posting will be done by the State Government. If open market recruitment is necessary, this will be done by the SLNA. The Project Manager, DWDU will sign a contract (for a period not less than three years) with SLNA that will spell out well-defined annual goals, against which his/her performance will be consistently monitored. The arrangements for setting up/ strengthening the DWDUs/District Data Cell will be financially supported by the Government of India after review of available staff, infrastructure and the actual requirement.

31) The functions of DWDU will be as follows:

a) Identify potential Project Implementing Agencies (PIAs) in consultation with SLNA as per the empanelment process as decided by the respective state governments.

b) Take up the overall responsibility of facilitating the preparation of strategic and annual action plans for watershed development projects in respective districts.

c) Providing professional technical support to Project Implementing Agencies (PIAs) in planning and execution of watershed development projects.

d) Develop action plans for capacity building, with close involvement of resource organizations to execute the capacity building action plans.

e) Carry out regular monitoring, evaluation and learning.

f) Ensure smooth flow of funds to watershed development projects.

g) Ensure timely submission of required documents to SLNA / Nodal Agency of the Department at central level.

h) Facilitate co-ordination with relevant programmes of agriculture, horticulture, rural development, animal husbandry, etc with watershed development projects for enhancement of productivity and livelihoods.

i) Integrate watershed development projects/ plans into District Plans of the district planning committees. All expenditure of watershed projects would be reflected in district plans.

j) Establish and maintain the District Level Data Cell and link it to the State Level and National Level Data Centre.

4.6 Role of Panchayati Raj Institutions at district and intermediate levels

32) The full responsibility of overseeing the watershed programme within the district will lie with the DWDU which will work in close collaboration with the District Planning Committee (DPC). The DPC will provide full governance support to the programme. The DPC will approve the perspective and annual action plans relating to watersheds projects in the district. DPC will integrate the watershed development plans with over all district plans and also oversee its implementation. DWDU will help the DPC in providing oversight and ensuring regular monitoring and evaluation of the programme. The District Panchayat / Zilla

Parishad will have an important role of governance in matters relating to the co-ordination of various sectoral schemes with watershed development projects, review of progress, settling disputes etc. Where the Panchayat system is not in operation, this role will be played by the DWDU/District Autonomous Councils.

33) Similarly, Intermediate Panchayats have an important role in planning the watershed development projects at the intermediate level. They can also provide valuable support to PIAs and Gram Panchayats/ Watershed Committees in technical guidance with the help of their subject matter specialists.

5. Institutional Arrangements at Project Level

5.1 Project Implementing Agency (PIA)

34) The SLNA would evolve appropriate mechanisms for selecting and approving the PIAs, who would be responsible for implementation of watershed projects in different districts. These PIAs may include relevant line departments, autonomous organizations under State/ Central Governments, Government Institutes/ Research bodies, Intermediate Panchayats, Voluntary Organizations (VOs). However, the following criteria may be observed in the selection of these PIAs:

- They should preferably have prior experience in watershed related aspects or management of watershed development projects.
- They should be prepared to constitute dedicated Watershed Development Teams.

35) Voluntary Organizations (VOs) will have an important role in the programme and their services will be utilized substantively in the areas of awareness generation, capacity building, IEC and social audit among others. As far as direct implementation of the programme is concerned, Voluntary Organizations (VOs) with established credentials may be chosen as PIAs on the basis of detailed criteria as enumerated below.

35.1) The Voluntary Organizations (VOs) would need to satisfy the following criteria to be selected as PIA:

a. Should be a registered legal entity of at least 5 years standing.
b. Should have had at least 3 years of field experience in the area of community based Natural Resource Management and livelihood development.
c. Should not have been blacklisted by CAPART or any other Department of Government of India or State Government.
d. Should be equipped with a dedicated, multidisciplinary team with gender balance.
e. Should furnish three years balance sheet, audited statement of accounts and income returns. All accounts of the organization should be up to date.
f. Should furnish the profile of its Board of Directors.
g. Should have successfully implemented projects independently.

35.2) It will be subjected to the following conditions:
i) At any point of time, one VO cannot be assigned more than 10,000 ha area in a district.
ii) At any point of time, one VO cannot be assigned more than 30,000 ha area in a State.
iii) In any case, not more than 1/4th of the total Projects at a time in a State to be implemented by VOs.

36) Selected PIAs will sign a contract/MOU with the concerned DWDUs/ District Level Committee as referred in para 29 that will spell out well-defined annual outcomes, against which the performance of each PIA will be monitored each year and evaluated on a regular basis by institutional evaluators from a panel approved by the SLNA / Departmental Nodal Agency at the central level.

37) Each PIA must put in position a dedicated watershed development team (WDT) with the approval of DWDU. The WDT will be hired on contract / deputation / transfer etc for a term not exceeding the project period. The composition of the WDT will be indicated in the contract/ MOU. No programme funds for DPR and watershed works under any

circumstances should be released to either the PIA or Watershed Committee (WC) unless the composition of the WDT has been clearly indicated in the MOU/ contract and the team members are fully in place.

5.2 Roles and Responsibilities of the PIA

38) The Project Implementing Agency (PIA) will provide necessary technical guidance to the Gram Panchayat for preparation of development plans for the watershed through Participatory Rural Appraisal (PRA) exercise, undertake community organization and training for the village communities, supervise watershed development activities, inspect and authenticate project accounts, encourage adoption of low cost technologies and build upon indigenous technical knowledge, monitor and review the overall project implementation and set up institutional arrangements for post-project operation and maintenance and further development of the assets created during the project period.

39) The PIA, after careful scrutiny, shall submit the Action Plan for Watershed Development Project for approval of the DWDU/DRDA and other arrangements. The PIA shall submit the periodical progress report to DWDU. The PIA shall also arrange physical, financial and social audit of the work undertaken. It will facilitate the mobilization of additional financial resources from other government programmes, such as NREGA, BRGF, SGRY, National Horticulture Mission, Tribal Welfare Schemes, Artificial Ground Water Recharging, Greening India, etc.

5.3 Watershed Development Team

40) The WDT is an integral part of the PIA and will be set up by the PIA. Each WDT should have at least four members, broadly with knowledge and experience in agriculture, soil science, water management, social mobilisation and institutional building. At least one of the WDT members should be a woman. The WDT members should preferably have a professional degree. However, the qualification can be relaxed by the DWDU with the approval of SLNA in deserving cases keeping in view the practical field experience of the candidate. The WDT

should be located as close as possible to the watershed project. At the same time, it must be ensured that the WDT should function in close collaboration with the team of experts at the district and state level. The expenses towards the salaries of the WDT members shall be charged from the administrative support to the PIA. DWDU will facilitate the training of the WDT members.

5.4 Roles and Responsibilities of WDT

41) The WDT will guide the Watershed Committee (WC) in the formulation of the watershed action plan. An indicative list of the roles and responsibilities of the WDT would include among others, the following:

a. Assist Gram Panchayat / Gram Sabha in constitution of the Watershed Committee and their functioning.
b. Organizing and nurturing User Groups and Self-Help Groups.
c. Mobilising women to ensure that the perspectives and interests of women are adequately reflected in the watershed action plan.
d. Conducting the participatory base-line surveys, training and capacity building.
e. Preparing detailed resource development plans including water and soil conservation or reclamation etc. to promote sustainable livelihoods at household level.
f. Common property resource management and equitable sharing.
g. Preparing Detailed Project Report (DPR) for the consideration of Gram Sabha.
h. Undertake engineering surveys, prepare engineering drawings and cost estimates for any structures to be built.
i. Monitoring, checking, assessing, undertaking physical verification and measurements of the work done.
j. Facilitating the development of livelihood opportunities for the landless.
k. Maintaining project accounts.
l. Arranging physical, financial and social audit of the work undertaken.
m. Setting up suitable arrangements for post-project operation, maintenance and future development of the assets created during the project period.

6. Institutional Arrangements at the Village Level and People's Participation

6.1 Self Help Groups

42) The Watershed Committee shall constitute SHGs in the watershed area with the help of WDT from amongst poor, small and marginal farmer households, landless/asset less poor agricultural labourers, women, shepherds and SC/ST persons. These Groups shall be homogenous groups having common identity and interest who are dependent on the watershed area for their livelihood. Each Self Help Group will be provided with a revolving fund of an amount to be decided by the Nodal Ministry.

6.2 User Groups

43) The Watershed Committee (WC) shall also constitute User Groups in the watershed area with the help of WDT. These shall be homogenous groups of persons most affected by each work/ activity and shall include those having land holdings within the watershed areas. Each User Group shall consist of those who are likely to derive direct benefits from a particular watershed work or activity. The Watershed Committee (WC) with the help of the WDT shall facilitate resource-use agreements among the User Groups based on the principles of equity and sustainability. These agreements must be worked out before the concerned work is undertaken. It must be regarded as a pre-condition for that activity. The User Groups will be responsible for the operation and maintenance of all the assets created under the project in close collaboration with the Gram Panchayat and the Gram Sabha.

6.3 Watershed Committee (WC)

44) The Gram Sabha will constitute the Watershed Committee (WC) to implement the Watershed project with the technical support of the WDT in the village. The Watershed Committee (WC) has to be registered under the Society Registration Act, 1860. The Gram Sabha may elect/appoint any suitable person from the village as the Chairman of Watershed Committee. The secretary of the Watershed Committee (WC) will be a paid functionary of

the Watershed Committee (WC). The Watershed Committee (WC) will comprise of at least 10 members, half of the members shall be representatives of SHGs and User Groups, SC/ST community, women and landless persons in the village. One member of the WDT shall also be represented in the Watershed Committee (WC). Where the Panchayat covers more than one village, they would constitute a separate subcommittee for each village to manage the watershed development project in the concerned village. Where a watershed project covers more than one Gram Panchayat, separate committees will be constituted for each Gram Panchayat. The Watershed Committee (WC) would be provided with an independent rented office accommodation.

45) The Watershed Committee will open a separate bank account to receive funds for watershed projects and will utilise the same for undertaking its activities. The expenses towards the salaries of the WDT members and Secretary of Watershed Committee (WC) shall be charged from the administrative expenses under the professional support to the PIA.

6.4 Secretary, Watershed Committee

46) The Secretary of the Watershed Committee (WC) will be selected in a meeting of the Gram Sabha. This person would be an independent paid functionary distinct and separate from the Panchayat Secretary. He would be a dedicated functionary with no responsibilities other than the assistance to the Watershed Committee (WC) and would work under the direct supervision of the President of Watershed Committee (WC) and would be selected on the basis of merit and experience. The expenses towards the honorarium to be paid to Secretary of Watershed Committee (WC) will be charged from the administrative support to the PIA. The Secretary will be responsible for the following tasks:

a. Convening meetings of the Gram Sabha, Gram Panchyat, Watershed Committee for facilitating the decision making processes in the context of Watershed Development Project.
b. Taking follow up action on all decisions.

c. Maintaining all the records of project activities and proceedings of the meetings of Gram Panchayat, Watershed Committee (WC) and other institutions for Watershed Development Project.
d. Ensuring payments and other financial transactions.
e. Signing the cheques jointly with the WDT nominee on behalf of the Watershed Committee.

6.5 Role of Gram Panchayat

47) The Gram Panchayat would perform the following important functions:

a. Supervise, support and advise Watershed Committee from time to time.
b. Authenticate the accounts/ expenditure statements of Watershed Committee and other institutions of watershed project.
c. Facilitate the convergence of various projects/ schemes to institutions of watershed development project.
d. Maintain asset registers under watershed development projects with a view to retain it after the watershed development project.
e. Provide office accommodation and other requirements to Watershed Committee.
f. Allocate usufruct rights to deserving user groups/ SHGs over the assets created.

7. Criteria for selection of watershed projects

48) The following criteria may broadly be used in selection and prioritisation of watershed development projects:

a. Acuteness of drinking water scarcity.
b. Extent of over exploitation of ground water resources.
c. Preponderance of wastelands/degraded lands.
d. Contiguity to another watershed that has already been developed/ treated.

e. Willingness of village community to make voluntary contributions, enforce equitable social regulations for sharing of common property resources, make equitable distribution of benefits, create arrangements for the operation and maintenance of the assets created.
f. Proportion of scheduled castes/scheduled tribes.
g. Area of the project should not be covered under assured irrigation.
h. Productivity potential of the land.

8. Project Management

49) The major activities of the Watershed Development Projects will be sequenced into (I) Preparatory, (ii) Works and (iii) Consolidation and withdrawal Phase. In view of the expanded scope and expectations under the watershed development programme, the project duration could be in the range of four to seven years depending upon the activities and Ministries/Departments. The DPR should mention the detailed justification for the proposed project duration. The project duration may be spread over 3 different phases as decided by the Nodal Ministry and as given below:

Phase	Name	Duration
I	Preparatory Phase	1-2 years
II	Watershed Works Phase	2-3 years
III	Consolidation and Withdrawal Phase	1-2 years

8.1 Preparatory Phase

50) The major objective of this phase is to build appropriate mechanisms for adoption of participatory approach and empowerment of local institutions (WC, SHG, and UG). WDT will assume a facilitating role during this phase. In this phase, the main activities will include:

a) Taking up entry point activities to establish credibility of the Watershed Development Team (WDT) and create a rapport with the village community. The entry point activities, inter-alia, will include:

- Works based on urgent needs of the local communities such as revival of common natural resources, drinking water, development of local energy potential, augmenting ground water potential etc.
- Repair, restoration and upgradation of existing common property assets and structures (such as village tanks) may be undertaken to obtain optimum and sustained benefits from previous public investments and traditional water harvesting structures.
- Productivity enhancement of existing farming systems could also be an activity that helps in community mobilization and building rapport.

b) Initiating the development of Village level institutions such as Watershed Committees (WCs), Self- Help Groups (SHGs) and User Groups (UGs) and Capacity Building of different stakeholders on institutional and work related aspects.

c) Environment building, awareness generation, undertaking of intensive IEC activities, creating involvement and participatory responses.

d) Baseline surveys needed for preparation of Detailed Project Report (DPR), selection of sites and beneficiaries. Every effort must be made to collect gender-disaggregated data to adequately reflect the situation and priorities of women.

e) Hydro-geological survey of the watershed to map out zones of potential groundwater recharge, storage and sustainable groundwater utilisation.

f) Building up a network of technical support agencies.

g) Preparation of the DPR, including activities to be carried out, selection of beneficiaries and work-sites and design and costing of all works, ensuring that the interests, perceptions and priorities of women, dalits, adivasis and the landless are adequately reflected in the DPR.

h) Working out detailed resource-use agreements (for surface water, groundwater and common/forest land usufructs) among User Group members in a participatory manner based on principles of equity and sustainability.

i) Participatory monitoring of progress and processes.

51) Preparation of DPR: DPR preparation is a crucial activity at the district level, which is to be facilitated by the WDT for an identified project area. The technical inputs in the form of resource maps and cadastral maps have to be made available at local level. It is necessary to capture the entire database of DPR in a systematic manner as a structured document at the initial stage itself.

52) DPR preparation requires a strong PRA exercise and comprehensive beneficiary level database separately for private land and community land development with linkages to the cadastral database. This will facilitate spatial depiction of the action plan. The DPR should include, among other things, the following:

a) Basic Information on Watershed including rainfall, temperature, location including geographical coordinates, topography, hydrology, hydrogeology, soils, forests, demographic features, ethnographic details of communities, land-use pattern, major crops & their productivity, irrigation, livestock, socio-economic status etc.

b) Details of expected/proposed User Groups & Self Help Groups, master tables for private land / common land activities, contribution to watershed development funds, information on soil and land-use, existing assets related to water harvesting, recharging and storage etc. needs to be provided plot-wise.

c) Problems Typology of the Watershed including an account of the major problems requiring intervention from the perspective of enhancing livelihood potential/carrying capacity as well as conservation and regeneration of resources.

d) Description of Proposed Interventions (physical and financial, including time-table of interventions) along with technical details and drawings certified by the WDT.

e) Detailed Mapping exercises.

f) Institutional mechanisms and agreements for implementing the plan, ensuring emphasis on participatory decision-making, equity and sustainability of benefits, and post-project sustainability.

g) Expected Outcomes and Benefits, especially with respect to livelihoods for different segments, benefits to women and regeneration/conservation of resources, etc.

53) The DPR will be prepared by the WDT for integrated development of the watershed area with active participation of the Watershed Committee (WC). The WDT should utilize various thematic maps relating to land and water resources in the preparation and finalization of the DPR. This DPR shall necessarily include the clear demarcation of the watershed with specific details of survey numbers, ownership details and a map depicting the location of proposed work/activities for each year.

54) The DPR for the watershed shall be in tune with the District Perspective Plan. The permissible works relating to soil and moisture conservation under NREGS, BRGF, and Artificial Ground Water Recharge must complement the micro watershed plan. District agricultural plans may also be consulted while formulating the District Perspective Plans.

55) This DPR will be a part of the MIS from which details will be arranged into various layers on GIS as a monitoring, management, accounting and analytical tool besides serving as a source of information and a link to the state level data cell in the SLNA and National Data Centre in the NRAA. The DPR may be summed up using a standard planning tool such as Logical Framework Analysis (LFA) that includes goals, purpose, outputs, activities, inputs, challenges and measurable indicators of progress.

56) The overall responsibility for the preparation of a technically sound and high quality DPR would lie with the Project Implementing Agency (PIA). After approval by the Gram Sabha, the PIA shall submit the DPR for approval to the DWDU/DRDA/DP. Alternatively, the mechanism of approval and implementation of projects by district level committee / collector may continue to prevail.

57) Each watershed has unique characteristics and problems. Its treatment and management would therefore require careful consideration of various site specific factors like topography, nature and depth of soil cover, type of rocks, water absorbing capacity of land, rainfall intensity, land use etc. All works must be planned in a location-specific manner, taking into account the above factors along with local demands and socio-economic conditions of the watershed.

58) The ridge-to-valley principle with multi tier sequenced approach has been indicated in detail at Preface on Para 9(IX).

8.2 Watershed Works Phase

59) This phase is the heart of the programme in which the DPR will be implemented. Some of the important activities to be included in this phase are:

a. Ridge Area Treatment: All activities required to restore the health of the catchment area by reducing the volume and velocity of surface run-off, including regeneration of vegetative cover in forest and common land, afforestation, staggered trenching, contour and graded bunding, bench terracing etc.
b. Drainage line treatment with a combination of vegetative and engineering structures, such as earthen checks, brushwood checks, gully plugs, loose boulder checks, gabion structures, underground dykes etc.
c. Development of water harvesting structures such as low-cost farm ponds, nalla bunds, check-dams, percolation tanks and ground water recharge through wells, bore wells and other measures.
d. Nursery raising for fodder, fuel, timber and horticultural species. As far as possible local species may be given priority.
e. Land Development including in-situ soil and moisture conservation and drainage management measures like field bunds, contour and graded bunds fortified with plantation, bench terracing in hilly terrain etc.

f. Crop demonstrations for popularizing new crops/varieties, water saving technologies such as drip irrigation or innovative management practices. As far as possible varieties based on the local germplasm may be promoted.

g. Pasture development, sericulture, bee keeping, back yard poultry, small ruminant, other livestocks and other micro-enterprises.

h. Veterinary services for livestock and other livestock improvement measures

i. Fisheries development in village ponds/tanks, farm ponds etc.

j. Promotion and propagation of non-conventional energy saving devices, energy conservation measures, bio fuel plantations etc.

8.3 Consolidation and Withdrawal Phase

60) In this phase the resources augmented and economic plans developed in Phase II are made the foundation to create new nature-based, sustainable livelihoods and raise productivity levels. The main objectives under this phase are:

a. Consolidation and completion of various works.

b. Building the capacity of the community based organizations to carry out the new agenda items during post project period.

c. Sustainable management of (developed) natural resources and

d. Up-scaling of successful experiences regarding farm production systems /off-farm livelihoods.

61) An indicative list of various activities during this phase is given below:

61.1) Consolidation of various works

a. Preparation of project completion report with details about status of each intervention;

b. Documentation of successful experiences as well as lessons learnt for future use.

61.2) Management of developed natural resources

a. Improving the sustainability of various interventions under the project;

b. Formal allocation of users right over common property resources (CPRs);
c. Collection of user charges for CPRs;
d. Repair, maintenance and protection of CPRs;
e. Sustainable utilization of developed natural resources;
f. Involvement of gram panchayat/corresponding institutions (as a governance body) in addressing the above aspects.

61.3) Intensification of farm production systems/off-farm livelihoods

a. Up scaling of successful experiences related to above aspects through revolving fund under the project as well as credit and technical support from external institutions;
b. Promotion of agro-processing, marketing arrangements of produce and similar off – farm and informal sector enterprises.
c. Farmers may also be encouraged to develop non pesticidal management, low cost organic inputs, seed farms and links with wider markets to fetch competitive price.

61.4) Project management related aspects

a. Participatory planning, implementation and monitoring of activities to be carried out during consolidation phase;
b. Terminal evaluation of project as per the expected outcomes.

62) Federations could be formed at the level of a cluster of villages in order to support economic activities at scale. These would further strengthen and activate the linkages established with external resource agencies for knowledge, credit, input procurement, sale of local produce, carrying on processing activities to the point of exports. In these activities, bankability of activities will be attempted. At the same time, local-level institutions are expected to reach maturity and exit protocols become operative for the PIA. The Watershed Committees (WCs) may use the Watershed Development Fund for repair and maintenance of structures created in Phase II.

63) The classification of activities in the three phases must not be understood in a rigid manner. Many of the Phase III activities may even start in many watersheds during Phase I and/or II itself. Phasing of activities needs to have an internal logic and integrity that must flow through the entire action plan. This will depend on a host of factors such as the prevailing initial conditions, needs and possibilities in each village, response of the community etc. Such flexibility must be built into the action plan and is to be seen as a distinguishing feature of these guidelines.

9. Allocation of funds, approval of projects and release of funds

9.1 Allocation of Funds to States

64) The Nodal Ministry / Department would allocate the budgetary outlay for the projects among the States keeping in view the following criteria and past performance of the state (physical and financial) viz. unspent balance, outstanding utilisation certificates, percentages of completed projects out of total projects etc except in those schemes where States have flexibility to allocate funds between watershed and other schemes.

a. State level perspective and strategic plans in watershed based development projects.
b. Percentage of rainfed area in the state to total cultivated area in the country.
c. Percentage of wastelands/ degraded lands in the state to the total geographical area of the country.

9.2 Allocation of Funds to Districts

65) The State level nodal agencies will distribute funds to the districts keeping in view the following criteria:-

a. District level perspective and strategic plans in watershed based development projects.
b. Percentage of rainfed area in the district to the total cultivated area of the state.
c. Percentage of wastelands/ degraded lands/ panchayat lands in the district to the total geographical area of the state.

9.3 Approval & sanction of Watershed Development Projects

66) By the end of February each year, the States will submit detailed Annual Action Plans indicating ongoing liabilities as well as new projects which they wish to take up. The Department Nodal Agency at the central level will thereafter, based on total available budget for the year and the criteria as given in Para-64 and 65, allocate specific amounts for individual states from whom proposals have been received. After States have received their allocation against ongoing and new projects, they will be free to sanction their projects within the State allocation. On receipt of the sanction orders for the new projects from SLNA; the Nodal Ministry would release funds directly to the district level agency. The existing release procedure of Departmental Nodal Agencies may however continue if release of funds to the district level agency is not feasible.

67) The distribution of budget for specific watershed projects for the various components therein is given below:

Budget component	**% of the Budget**
- Administrative costs - Monitoring - Evaluation	10 1 1
Preparatory phase, including: - entry point activities, - institution and capacity building, - Detailed Project Report (DPR).	4 5 1
Watershed Works Phase: - Watershed development works, - Livelihood activities for the asset less persons, - Production system and micro enterprises.	50 10 13
Consolidation phase	5
Total	**100**

68) The expenditure under the various components of the project budget will be subject to following conditions:

i) The payments of salaries to the WDTs/ Secretary of the Watershed Committees etc. would be exclusively charged from the administrative cost component.

ii) Savings, if any, in each component of the project cost can be utilised for activity in watershed works only.

iii) Purchase of vehicles and other equipments etc., and construction of buildings are not allowed. However, purchase of Computers and related software is permitted.

iv) PIAs belonging to Line Departments may preferably outsource to VOs/CBOs community mobilization and capacity building activities.

69) Existing unit cost for watershed development is Rs. 6000 per hectare which was worked out during April 2001. However, during 11th Plan it is being suitably revised in order to take care of the following three aspects: (a) promotion of livelihoods including improvement of productivity through farming systems, (b) complete coverage of area under the watershed including common/ forest land and (c) general escalation in cost of material as well as minimum wages of labourers.

9.4 Procedure for release of instalments

70) The central share of funds shall be released to the DWDUs / agency for the three phases of the implementation spread over the project period in the following manner or as decided by the Nodal Ministry.

a. The first instalment comprising of preparatory phase activities viz., 20% of the central share will be released straightaway upon the sanction of the project by the SLNA.

b. The second instalment comprising of 50% of the central share towards the project cost will be released on proper certification and submission of documents after completion of the preparatory phase and 60% expenditure of the first instalment.

c. The third instalment of 30% i.e. 25% of the central share towards the works phase of the project cost and 5% for the consolidation phase will be released on proper certification of expenditure of 75% of the total funds released supported by relevant documents. However, the existing arrangements for flow of funds by the concerned Ministries may continue if the above mechanism is not feasible.

71) The release of funds to district implementing agencies / State Government will be done directly on the basis of specific annual proposals received from each district keeping in view their ongoing commitments and the new projects sanctioned and the overall budgetary provision for the district and upon approval of their action plans by the SLNA. DWDUs / Agencies shall release the funds to the PIAs and the watershed committees within 15 days of the receipt of the fund.

9.5 User Charges

72) The Gram Sabha through the Watershed Committee (WC) shall put in place mechanism for collecting user charges. No charge will be taken from landless, destitute or disabled / widow headed households for work done on private or public land. The user charges collected shall be credited to the WDF for maintenance of assets created during the project.

9.6 Watershed Development Fund

73) One of the mandatory conditions for selection of villages for watershed projects is people's contribution towards the Watershed Development Fund (WDF). The contributions to WDF shall be a minimum 10% of the cost of NRM works executed on private lands only. However, in case of SC/ST, small and marginal farmers, the minimum contribution shall be 5% of the cost of NRM works executed on their lands. However, for other cost intensive farming system activities such as Aquaculture, Horticulture, Agro-forestry, Animal Husbandry etc on private land directly benefiting the individual farmers, the contribution of farmers will be 40% for General category and 20% for SC & ST beneficiaries and the remaining cost of the activities i.e. 60% for the General and 80% for SC/ST category will come from the project

funds subject to a maximum limit of an amount equal to double of the standard unit cost norm for Watershed Development Project.

74) These contributions would be acceptable either in cash at the time of execution of works or voluntary labour. A sum equivalent to the monetary value of the voluntary labour would be transferred from the watershed project account to the WDF bank account that will be distinct from the Watershed Committee (WC) bank account. User charges, sales proceeds and disposal amounts of intermediate usufruct rights shall also be deposited in the WDF bank account. Income earned from assets created under the project on common property resources shall also be credited to WDF.

75) The Secretary, Watershed Committee (WC) shall maintain a completely separate account of the income and expenditure of the WDF. Rules for operation of the fund should be prepared by the Watershed Committee (WC) and ratified by the Gram Sabha. The WDF bank account should be operated by the President of the Gram Panchayat and any member from the SHG nominated by the Gram Sabha. Alternatively, the guidelines for the management and utilization of the WDF may be evolved by the concerned Nodal Ministry.

76) After completion of Phase II, at least 50% of the WDF funds shall be reserved for maintenance of assets created on community land or for common use under the project. Works taken up on private land shall not be eligible for repair/maintenance out of this Fund. The remaining money may be used as a revolving fund to advance loans to the villagers of the project area who have contributed to the fund. Individuals as well as charitable institutions should be encouraged to contribute generously to this Fund.

9.7 Coordination with other schemes / projects

77) Eleventh Five Year Plan offers an opportunity to converge and harmonise resources of different schemes and Programmes specially those under Bharat Nirman and other flagship schemes with watershed development projects. Mandatory preparation of district level plans will be in a position to enable convergence and synergies at the grass-root level. The

DPR may elaborate gaps to be filled or watershed activities to be taken up out of BRGF, NREGS, artificial ground water recharging, renovation and repairs of tanks, water bodies and any other available sources. Marketing and value addition is also possible under the revised APMC Act. Efforts should be made to converge all relevant schemes at project level.

9.8 Foreclosure of projects

78) Despite the best intentions on the part of the authorities and participating communities, despite the careful preparation of the detailed project report, and even despite careful monitoring, there would still be instances of projects which may still get stalled or from a particular point onwards, make no progress whatsoever. In such extreme cases where pursuing the project further would only be a waste of time, energy and resources, the extreme step of foreclosure may be resorted to. The project work should start within three months of the receipt of first instalment by DWDU / agency. This is to be judged from expenditure statement, failing which project will be withdrawn and released instalment will be adjusted in release of other projects to the State.

79) Steps can also be initiated for suo-moto foreclosure by the State / Central Government under the following circumstances:

a. Consistent apathy on the part of State and District Level Authorities towards the project.
b. Non-submission of DPR / approved work plan for two years after the expiry of preparatory phase without any valid justification.
c. If any matter relating to project is subjudice in any court of law and no order for staying the project activity has been passed by the court.
d. Any other reason which justifies foreclosure as decided by District/State/Centre from time to time.

10. Capacity Building Strategy

80) Capacity building support is a crucial component to achieve the desired results from watershed development projects. These Guidelines broadly define the contours of the capacity building strategy for watershed development projects in the country. NRAA would facilitate the evolution of operational strategies for capacity building in each state in consultation with SLNA and other resource organizations. The capacity building strategy and activities enumerated below by NRAA, Nodal Agencies at the central level, consortiums of resource organizations should be funded separately over and above the earmarked budget for institution and capacity building in the preparatory phase of the watershed development project.

10.1 Key Elements of Capacity Building Strategy

81) NRAA will collaborate with various resource organizations for developing national level as well as state specific capacity building strategies. Key Components of Capacity Building Strategy are the following:

- Dedicated and decentralised institutional support and delivery mechanism
- Annual Action Plan for Capacity Building
- Pool of resource persons
- Well prepared training modules and reading materials
- Mechanism for effective monitoring and follow-up.

10.2 Resource Organizations and Developing Partnerships

82) National Institute of Rural Development (NIRD), National Institute of Agricultural Extension Management (MANAGE), Central Arid Zone Research Institute (CAZRI), Central Soil and Water Conservation Research and Training Institute (CSWCRTI) and its regional centres, Central Research Institute for Dry land Areas (CRIDA), Water Technology Centres (WTCs), Indian Institute of Remote Sensing, Dehradun, Institute of Rural Management, Anand (IRMA), Indian Institute of Forest Management (IIFM), National Remote Sensing Agency

(NRSA), Indian Space Research Organization (ISRO), Soil and Land Use Survey of India (SLUSI) are some of the well known national level institutions that could impart capacity building inputs to senior government officers at national/ state/ district levels.

83) There are also several reputed voluntary organizations/ resource organizations with considerable expertise and experiences related to watershed development projects such as AKRS (P) (Gujarat), MYRADA (Karnataka), WOTR (Maharashtra), Dhan Foundation (Tamilnadu), Samaj Pragati Sahyog (MP), Development Support Center (Guajarat), AFARM (Maharashtra), WASSAN (Andhra Pradesh), ARAVALI (Rajasthan), PRADAN (Jharkhand), CYSD (Orissa), Seva Mandir (Rajasthan) and so on, in different parts of the country. Some of them are already functioning as resource organizations for watershed development projects in collaboration with state governments.

84) NRAA would help the State Governments in preparing the comprehensive list of all such resource organizations across the country and profile their expertise and capacities. As part of this process, NRAA and SLNA identify National/ State/ District level resource organizations. Based on this analysis, NRAA facilitates formal partnerships between the Ministries/Departments/ SLNA/ DWDU and resource organizations from government/ voluntary/ ICAR backgrounds. These resource organizations could operate at national/ state/ district/ sub district level, depending on the need and capacity building strategy of each state. SLNA develops clear Terms of References (ToRs) with resource organizations. Depending on the need, NRAA / SLNA could also form Consortium of Resource Organizations to provide necessary capacity building support to the watershed development projects at various levels.

11. Monitoring, Evaluation and Learning

11.1 Monitoring

85) Regular monitoring of the project will have to be carried out at each stage. Online monitoring must become a feature of all projects. Monitoring should include process and

outcome monitoring. The PIA shall submit quarterly progress reports (countersigned by the Watershed Committee (WC) President) to the DWDU for further submission to the SLNA. The DWDU will have one member exclusively responsible for monitoring.

86) Different streams of monitoring are proposed. The role of the SLNA is critical in ensuring that the following systems are followed at the appropriate levels:

- Internal Monitoring by project teams (PIA/DWDU)
- Progress Monitoring
- GIS/ Web Based On-Line Monitoring
- Self Monitoring by communities
- Sustainability Monitoring
- Social Audits
- Independent and External Monitoring by independent agencies
- Process Monitoring

11.2 Evaluation

87) There will be a national panel of Evaluating Agencies in each Ministry. A minimum percentage of evaluations and impact studies will be carried out by national level agencies that will ensure objectivity as well as infuse a national perspective.

88) There will also be an SLNA panel of evaluators, approved by the Departmental Nodal Agency at central level. The panel will include only institutions and agencies – not individuals. The SLNA will enter into a formal contract with these agencies. The DWDU may choose any agency from the SLNA approved panel, the only condition being that the agency should not belong to the area being evaluated.

89) Each evaluation will include physical, financial and social audit of the work done. Evaluators are to be seen not so much as inspectors but as facilitators. However, they will be very strict in ensuring that these guidelines are being followed. Fund release will depend on a favourable report from the evaluators.

90) The concurrent and Post-Project evaluation would be conducted to assess the status of watershed related interventions. A separate set of guidelines on evaluation will be issued in due course by the respective Ministries.

11.3 Learning

91) Systematic efforts are to be made by the WDT/WC to learn from the field experiences as also from feedback of independent sources. The following methods are proposed to enable the learning process at different levels.

a. Systematic analysis of monitoring data (all types of monitoring) on a regular basis by internal team and sharing with project authorities/ policy makers.
b. Engaging services of independent academic and voluntary organizations by the DWDU, for taking up research and action research projects.
c. Initiating pilots on new themes and innovative models.
d. Organizing regular sharing, reflective and learning events to learn from field experiences, monitoring exercises and academic/ research studies. These events could be organized at district, state and national level.

11.4 Outcomes / End Results

92) Each Watershed Development Project is expected to achieve the following results by the end of the project period:

a. All the works/activities that are planned for the treatment and development of the drainage lines, arable and non-arable lands in the watershed area are completed with the active participation and contribution of the user groups and the community at large.
b. The user groups/panchayats have willingly taken over the operation and maintenance of the assets created and made suitable administrative and financial arrangements for their maintenance and further development.

c. All the members of the Watershed Committee and staff such as Watershed Secretary and Volunteers have been given orientation and training to improve their knowledge and upgrade technical/management and community organisational skills to a level that is appropriate for the successful discharge of their responsibilities on withdrawal of the Watershed Development Team from the Project.

d. The village community would have been organised into several, homogeneous self-help groups for savings and other income generation activities which would have achieved sufficient commitment from their members and built up financial resources to be self sustaining.

e. The increase in cropping intensity and agricultural productivity reflecting in overall increase in agriculture production.

f. Increase in income of farmers/ landless labourers in the project area.

g. Increase in groundwater table due to enhanced recharge by watershed interventions.

ACRONYMS

BRGF	Backward Regions Grant Fund
CAPART	Council for Advancement of People's Action & Rural Technology
CAZRI	Central Arid Zone Research Institute
CEO	Chief Executive Officer
CPRs	Common Property Resources
CRIDA	Central Research Institute for Dry Land Agriculture
CSWCRTI	Central Soil & Water Conservation Research & Training Institute
DDP	Desert Development Programme
DoLR	Department of Land Resources
DP	District Panchayat
DPAP	Drought Prone Areas Programme
DPC	District Planning Committee
DPR	Detailed Project Report
DRDA	District Rural Development Agency
DWDU	District Watershed Development Unit
GIS	Geographical Information System
GP	Gram Panchayat

GPS	Global Positioning System
GS	Gram Sabha
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crops Research Institute for Semi-Arid Tropics
IEC	Information, Education and Communication
IIFM	Indian Institute of Forest Management
IRMA	Institute of Rural Management, Anand
ISRO	Indian Space Research Organization
IT	Information Technology
IWDP	Integrated Wastelands Development Programme
JFMC	Joint Forest Management Committee
LFA	Logical Framework Analysis
MANAGE	National Institute of Agricultural Extension Management
MoRD	Ministry of Rural Development
MOU	Memorandum of Understanding
NABARD	National Bank for Agriculture & Rural Development
NAEP	National Afforestation & Eco-development Project
NDC	National Data Centre
NGO	Non-Governmental Organization
NIRD	National Institute of Rural Development
NRAA	National Rainfed Area Authority
NREGA	National Rural Employment Guarantee Act
NREGS	National Rural Employment Guarantee Scheme
NRSA	National Remote Sensing Agency
NWDPRA	National Watershed Development Project for Rainfed Areas
PIAs	Project Implementing Agencies
PRA	Participatory Rural Appraisal
RVP&FPR	River Valley Project & Flood Prone River Project
SAUs	State Agricultural Universities
SC	Scheduled Caste
SGRY	Sampoorna Grameen Rojgar Yojana
SHGs	Self Help Groups
SIRDs	State Institute of Rural Development
SGSY	Swarnjayanti Gram Swarozgar Yojana
SLPSC	State Level Project Sanctioning Committee

SSR	Standard Schedule of Rates
ST	Scheduled Tribe
SVOs	Support Voluntary Organizations
SLNA	State Level Nodal Agency
SWAN	State Wide Area Network
UGs	User Groups
VOs	Voluntary Organisations
WC	Watershed Committee
WCs	Watershed Committees
WDF	Watershed Development Fund
WDT	Watershed Development Team
WTCs	Water Technology Centres

DRAFT MODEL BILL FOR THE CONSERVATION, PROTECTION AND REGULATION OF GROUNDWATER

Preamble

Recognising the unitary nature of water and the integration of surface water and groundwater;

Recognizing that natural resources constitute an integral whole and must be treated as such;

Recognising the need to realise constitutional guarantees linked to groundwater *and whereas* the Supreme Court of India has recognised the right to water as integral to the right to life; and further specified variously the corresponding duties of the state;

Recognizing the need to strengthen the regulatory powers of gram sabhas, panchayats and municipal bodies related to groundwater in line with Articles 243G and 243W of the Constitution;

Recognizing that diverse conditions and needs require different specific solutions and recognising the need to differentiate rural and urban areas, while providing a single legal framework;

Recognising the need to resolve contestation and conflict not only between users of groundwater but also between different types of uses;

Recognising the common pool nature of groundwater, which has an intricate relationship with rainwater and surface water (through natural recharge) and with surface water (natural discharge);

Acknowledging that various levels of groundwater protection are necessary, the highest priority being given to areas demarcated as groundwater protection zones that need to be established and protected, and that shall be accorded the highest priority in both planning and management:

Be it enacted by the State Legislature in the ___ year of the Republic of India, as follows:

Source: MOWR, Govt. of India

Chapter 1 – Preliminary

1. Short Title, Extent and Commencement

1. This Act may be called the_____ Act for the Protection, Conservation and Regulation of Groundwater, 2011.
2. It extends to whole of the State of ______.
3. It shall come into force ninety days after its adoption by the state legislature.

2. Objectives

1. The objectives of this Act are to ensure that groundwater is protected, conserved and regulated so as to:
    a. Meet basic human needs and livestock needs;
    b. Promote sustainable groundwater use in the public interest, based on a long-term protection of available resources;
    c. Ensure that the protection, conservation and regulation of groundwater is integrated with the protection, conservation and regulation of surface water to ensure conjunctive use of surface water and groundwater;
    d. Ensure the implementation of the principle of subsidiarity;
    e. Protect ecosystems and their biological diversity;
    f. Reduce and prevent pollution and degradation of groundwater;
    g. Ensure that present and future generations have access to sufficient quantity and quality of basic water; and
    h. Ensure protection against gender discrimination and past inequalities in access to water.

3. Definitions

1. In this Act, unless the context otherwise requires:

a. ‘Aquifer’ is a geological formation that stores and transmits water;

b. ‘Appropriate authority’ is the lowest possible public authority, including gram sabhas, gram panchayats, block panchayats, district panchayats, ward sabhas, municipal authorities and the State Government;

c. ‘Artificial recharge area’ includes catchment areas of percolation tanks, recharge ponds, infiltration tanks and all such appropriate measures from where water is harvested for recharge to aquifers.

d. ‘Basic water’ means the basic safe water requirements of each human being for drinking, cooking, bathing, sanitation, personal hygiene and related personal or domestic uses, with an additional requirement for women for their special needs; and includes water required for domestic livestock;

e. ‘Gram Sabha’ refers to the assembly of persons whose names are included in the electoral rolls at the village level;

f. ‘Groundwater’ means water, which exists below the surface in the zone of saturation and can be extracted through wells or any other means or emerges as springs and base flows in streams and rivers;

g. ‘Groundwater Protection Zone 1’ refers to critical natural recharge areas of an aquifer and those areas that require special attention with regard to the artificial recharge of groundwater and shall include areas at and around natural discharge from the aquifer, specifically in the form of springs, seepages to streams, rivers and wetlands:

Explanation:

(i) Areas comprising Groundwater Protection Zone 1 shall not be compromised in any way that will reduce, obliterate and hinder the natural recharge functions of the aquifer.

(ii) Areas comprising Groundwater Protection Zone 1 shall include vulnerable areas that require special attention and regulation, including areas affected by presence of arsenic and fluoride in groundwater and areas where groundwater has suffered saline water ingress.

h. 'Groundwater Protection Zone 2' refers to areas from which groundwater is extracted through wells and other such groundwater extraction mechanisms, and where problems of groundwater over-extraction or contamination or both are evident on the basis of assessments made from time-to-time.

i. 'Groundwater Security Plan' means an aquifer-based plan, as prepared under Sections 14-16 of this Act;

j. 'Livelihood' means an activity or occupation or employment including self-employment that provides sustenance to an individual or family;

k. 'Municipality' refers to a Municipality, a Municipal Corporation or similar body of local urban governance by any other name;

l. 'Pollutant' means any solid, liquid or gaseous substance present in such concentration as may be, or tend to be, harmful to groundwater and impacting human and non-human life;

m. 'Rainwater harvesting' means the technique or system of collection and storage of rainwater, at micro watershed scale, including roof-top harvesting, for future use or for recharge of groundwater;

n. 'Safe yield' means the amount of water which may be abstracted from an aquifer at a rate that will not reduce the supply to such an extent that it would not be recharged to the original level by the annual natural recharging process of that locality and, as such, rendering such abstraction harmful to the aquifer, quality of the water or environment;

o. 'Ward Sabha' means a body consisting of persons registered in the electoral rolls relating to a Ward;

p. 'Well' means any structure sunk for the search or extraction of groundwater, including open wells, dug wells, bore wells, dug-cum-bore wells, tube wells, filter points, collector wells, infiltration galleries, recharge wells, disposal well or any of their combinations or variations.

2. Terms not defined in this Act have the meaning assigned to them under other laws.

Chapter 2 – Mandatory Principles for Protection, Conservation and Regulation of Groundwater

4. Non-discrimination and Equity

1. a) Every person shall have access to water without any discrimination, including as to caste, creed, economic status, land ownership, place of birth, race, religion and sex.

   b) In case groundwater forms the only source of water supply in an area, the principle in sub-section (a) specifically extends to groundwater resources.

   The appropriate authority shall ensure equitable distribution and access to groundwater strictly in compliance with priorities prescribed under Section 10 of this Act and in consonance with Section 8 of this Act.

   The appropriate authority shall ensure the sustainable use of available groundwater without compromising the needs of future generations.

5. Subsidiarity and Decentralisation

1. Conservation, use and regulation of groundwater shall be based on the principle of subsidiarity.
2. The constitutional provisions for decentralisation of powers and functions in urban and rural areas shall be the basic organising principle for conservation, protection and regulation of groundwater.
3. Different conservation, protection and regulation measures may be used in different parts of the state in accordance with the availability of groundwater in a specific aquifer and the nature and type of groundwater catchments.

6. Protection, Precaution and Prior Assessment

1. Groundwater resources (aquifers) shall be protected from such impacts that affect the equity of access and sustainability of the resource.
2. Precautionary steps shall be taken by the appropriate authority at all levels and by every user of groundwater to protect it from depletion, deterioration, biological and chemical pollution, as well as

to prevent and/or reduce adverse impacts on the environment due to the use of groundwater.

3. Effective schemes and measures shall be formulated and implemented to conserve, replenish and recharge groundwater.

4. Any single use of groundwater, surface water or land and forest resources or activity in relation to these resources, which is likely to have significant negative impacts on local sources of groundwater shall be subjected to an environmental and social impact assessment, as defined at Section 43 of this Act, and protective, preventive and precautionary measures shall be implemented accordingly.

7. Integrated Approach

1. The protection, conservation and regulation of groundwater shall be undertaken in such a way that it is integrated with the protection, conservation and regulation of surface water resources on a watershed basis, land and forest.

Chapter 3 – Right to Water, Legal Status and Groundwater Use

8. Right to Water

1. Every natural person has the fundamental right to be provided basic water of acceptable quality for leading a healthy and dignified life.

9. Legal Status of Groundwater

1. Groundwater is the common heritage of the people of India held in trust, for the use of all, subject to reasonable restrictions to protect all water and associated ecosystems. In its natural state, it is not amenable to ownership by the state, communities or persons.

   Explanation: In this section, groundwater refers to the resource defined by aquifers.

2. The state at all levels is the public trustee of groundwater.

3. The appropriate authority must ensure that water is protected, used, developed, conserved, managed and regulated in a sustainable and equitable manner, for the benefit of all persons and ecosystems.

4. Without limiting sub-section (3), the appropriate authority is responsible for ensuring that water is allocated and used equitably in the public interest, while promoting environmental values.

10. Water Use Prioritisation

1. The appropriate authority shall abide by the water use prioritisation set out in this section while discharging its duties as trustee of groundwater.

2. The first priority and charge on groundwater shall be meeting the right to basic water for rural and urban residents, consistent with the objective of sustaining aquifers and ecosystems indispensable to the long-term maintenance of the resource.

3. Other priorities will be allocated among primary and secondary uses.

4. Primary groundwater uses, besides basic water and ecology mentioned in sub-section (2), shall include in no order of priority:

- Direct use of groundwater for livelihoods, including agriculture and non-agriculture based livelihoods; and
- Municipal use, including public facilities for recreation.

5. Secondary water uses shall include in no order of priority:
    a. Commercial activities, including power generation, industry and large-scale commercial farms;
    b. Private facilities for recreation; and
    c. Other purposes.

6. The use or appropriation of water for secondary purposes, which is likely to have significant negative impacts on local sources of groundwater, shall be subjected to an environmental and social impact assessment, as provided under Section 43 of this Act.

Chapter 4 – Groundwater Protection Zones and Groundwater Security Plans

A. Groundwater Protection Zones

11. Demarcation of Groundwater Protection Zones

1. Groundwater protection zones shall be demarcated in order to:

    a. Protect the natural recharge and discharge areas of the aquifer from threats such as physical deterioration, including loss of exposed surface area, change in land-use pattern and causation of chemical and other pollution;

    b. Protect the natural identity of the aquifer and the needs of groundwater dependent ecosystems;

    c. Protect vulnerable areas that require special attention and regulation, including areas affected by presence of arsenic and fluoride in groundwater and areas where groundwater has suffered saline water ingress;

    d. Provide for sufficient quantity and safe quality water required to meet the basic water supply for human and animal needs; and

    e. Provide for water for livelihoods.

2. The demarcation of groundwater protection zones shall take into account all the following factors:

    a. Existing uses and users of the aquifer;

    b. Existing water uses and users in the recharge area(s);

    c. Availability and quality of groundwater in the aquifer;

    d. Social, environmental and economic implications of the demarcation;

    e. The need for the demarcation of such recharge areas into groundwater protection zones in terms of their capacity or need to solve groundwater depletion and/or contamination; and

f. Availability or existence of other options or alternative measures.

12. Procedure for Demarcation and Notification of Groundwater Protection Zones

1. The State Groundwater Board shall, in consultation with appropriate authorities constituted under this Act, including information and monitoring cells constituted under this Act and supporting institutions notified under this Act, demarcate natural or artificial recharge areas of an aquifer or aquifers as groundwater protection zones.
2. The State Groundwater Board may also consult any other institution or agency to assist with the demarcation of groundwater protection zones.
3. The State Groundwater Board may call for technical data and evidence from information and monitoring cells, supporting institutions or any other agencies mandated or obliged under law to maintain such technical data and evidence. The State Groundwater Board may also approach central agencies such as the Central Groundwater Board and Central Water Commission for this purpose.
4. The State Groundwater Board shall prepare proposals for the demarcation of groundwater protection zones based on the aquifer-mapping programme that identifies groundwater protection zones, along with their current status.
5. In addition to compliance with the provisions of Chapter 10 concerning public consultation and transparency, the proposals for demarcation and declaration of each groundwater protection zone shall be notified to the public and the appropriate institution by a preliminary notice in the Gazette and in at least two local language newspapers having circulation in the area concerned.
6. The State Groundwater Board shall submit proposals for demarcation and declaration of each groundwater protection zone to the appropriate authorities – namely gram sabhas, ward sabhas, gram panchayats, block panchayats, district panchayats, municipal authorities and the State Government as the case may be – falling within the geographical limits of each of zone, for discussion and approval, with or without modification.
7. If the appropriate authority feels that the proposal of the State Groundwater Board needs revision or is invalid, it shall file a representation before the State Groundwater Board within 30 days from the formal submission of the proposal under sub-section (5) of this section. Consultations will then

be held with the State Groundwater Board to come to a final decision within 45 days of the filing of the representation:

Provided that if an amicable final decision is not possible the matter shall be decided by arbitration and the arbitrator shall be appointed by the State Government.

8. a) Objections, if any, against the proposed declaration of any area as a groundwater protection zone, shall be made before the appropriate authority within a period of 60 days from the date of publication of the notice.

   b) Any person preferring the objection shall provide the grounds of objection, supported, where possible, by technical data and evidence.

   c) The technical data, requested for filing objections, shall be made available to such persons immediately.

   d) If any delay is caused in providing the requested data/information, the period allowed for filing objection shall be extended in proportion to the delay.

   e) The objections shall be considered by the appropriate authority, which, with the consultation of both parties (the State Government and the objecting party) shall arrive at the final decision.

   f) The final decision shall be binding on both parties.

   g) The appropriate authority shall notify its decision within a period of 45 days from the formal submission of the objection.

9. If no objections or representations referred to in sub-sections (6) and (7) have been filed within the period referred to in that sub-section, the appropriate authority shall declare the demarcated area to be a groundwater protection zone.

10. Where a proposal to identify a groundwater protection zone has been approved, the State Groundwater Board shall notify the groundwater protection zone in the Gazette.

11. a) The notification issued under sub-section (9) above shall be reviewed periodically.

b) The review shall be due on completion of three years and shall be done before the expiry of five years from the date of notification.

c) On expiry of the above mentioned period, a fresh review shall be conducted based on a new assessment of the aquifer.

12. All the steps prescribed above shall be completed within a period of six months from the date of preparation of the proposal by the State Groundwater Board.

13. Regulation of Groundwater Protection Zones

1. Groundwater protection zones will be accorded the highest priority in terms of groundwater protection and regulation.
2. Appropriate authorities shall take all possible measures to conserve and protect groundwater protection zones, in particular in the context of groundwater security plans.
3. Wherever an area has been notified as a Groundwater Protection Zone 1:
   a. No extraction or use of groundwater, apart from use as basic water, except under special sanction by the appropriate authority, shall be allowed in the Groundwater Protection Zone; and
   b. Rules regarding, among others, forestation and deforestation, a prohibition of waste disposal of any kind and the banning of any mining lease shall be developed and implemented by the appropriate authority in the manner prescribed.
4. Wherever an area has been notified as a Groundwater Protection Zone 2, a set of rules regarding distance (from structures created or activities taken up to augment and/or protect recharge, including percolation tanks, recharge ponds, and social fencing of natural recharge areas) to new wells, pumping regulation for existing wells as well as other regulatory protocols shall be developed depending upon hydrogeological and socio-economic conditions.
5. The regulation of groundwater protection zones shall incorporate appropriate energy pricing and energy rationing means as additional instruments in areas where abstraction is above the safe yield.

   Explanation: This sub-section shall not preclude adoption of appropriate energy pricing and energy rationing means in other areas that the State may prescribe from time to time.

6. Wherever an area has been notified as a Groundwater Protection Zone 2, groundwater shall be allocated and extracted in a regulated manner, so as to maintain the water balance in the concerned aquifers. To achieve this, the appropriate authority, with the help of information and monitoring cells and supporting institutions shall:
   a. Determine the safe yield of any aquifer coming under the purview of the respective protection zones;
   b. Require that an aquifer be used on an equitable and sustainable basis, including restricting abstractions so that they do not, individually or collectively, exceed the safe yield of the aquifer; and
   c. Carry out programmes for the recharge of aquifers:

Provided that where the area suffers from a severe long-term drought, extraction beyond the annual recharge may be allowed for basic water needs on the condition that in subsequent years of adequate rainfall, additional recharge measures shall be taken to compensate the extra withdrawal.

B. Groundwater Security Plans

14. Preparation of Groundwater Security Plans

1. The appropriate authority shall prepare and oversee the implementation of a Groundwater Security Plan in consultation with elected local bodies and in consultation and coordination with information and monitoring cells and supporting institutions.
2. The Groundwater Security Plan shall be prepared at the lowest possible administrative level, taking into account the fact that where an aquifer does not fall under the jurisdiction of a single gram panchayat, block, district, ward or municipality, the plan must be prepared at the level of the authority under whose jurisdiction the whole aquifer falls:

   Provided that where the aquifer extends beyond the boundaries of the State, the State Government shall prepare the Groundwater Security Plan in coordination with other state(s) under whose jurisdiction the aquifer also falls.

3. A groundwater security plan shall be prepared for every aquifer falling partly or entirely under a groundwater protection zone defined in Section 11 of this Act and where an aquifer does not fall under any groundwater protection zone, the appropriate authority may determine necessary measures to be taken, including the preparation and the implementation of groundwater security plans.

4. The Groundwater Security Plan shall be based on scientific maps and database provided by information and monitoring cells and supporting institutions and on a determination of the estimated average annual recharge of groundwater.

15. Content of the Groundwater Security Plan

1. The aquifer-based Groundwater Security Plan shall provide for groundwater conservation and augmentation measures, socially equitable use and regulation of groundwater, and priorities for conjunctive use of surface and groundwater.

2. The Groundwater Security Plan shall contain, besides a description of groundwater aquifers and catchments, a statement of rights, duties, management responsibilities, priorities of use and tariffs, if any.

3. The Groundwater Security Plan shall incorporate customary rules and practices for protection of groundwater, to the extent that they do not conflict with the mandatory principles under Chapter 2 of this Act and the appropriate authority shall document customary practices as part of the preparation of the Groundwater Security Plan.

4. The Groundwater Security Plan shall be based on the principle that transfers of water outside of the area concerned by the Plan are prohibited, unless the appropriate authority agrees by a three-fourth majority or a decision to this effect is taken by the appropriate authority at the next higher level, where the basic water needs of other panchayats, blocks, districts, wards and municipalities cannot be met without a transfer.

5. a) Where there is more than one micro-watershed within the area under consideration separate sub-

plans for each micro-watershed shall be prepared.

b) The Groundwater Security Plan prepared by the appropriate authority shall integrate them in a consolidated plan.

c) Where micro-watersheds straddle beyond the jurisdiction of the appropriate authority, the Groundwater Security Plan shall be prepared by a committee drawn from the appropriate authorities of each authority under which the micro-watershed is found in proportional number to the extent of area falling under the jurisdiction of each concerned appropriate authority.

d) Groundwater security plans shall be integrated at the mili-watershed level and at the macro-watershed level with the assistance of information and monitoring cells and supporting institutions, in consonance with groundwater aquifer boundaries and surface river basin boundaries.

6. The Groundwater Security Plan shall include remedial measures, including:

   a) Incentives for weaning out water-intensive crops and sanctions against continuing water-intensive crops;

   b) Incentives for the adoption of water-conserving technologies, such as drip irrigation and sprinklers;

   c) Setting up artificial recharge structures;

   d) Promoting the use of energy-efficient pumps;

   e) Community based sharing of groundwater from a more limited number of wells; and

   f) Other measures as may be appropriate to the specific aquifer or the situation under which groundwater overexploitation has occurred.

16. Adoption and Validity of the Groundwater Security Plan

1. a) The Groundwater Security Plan, formally adopted by the appropriate authority and endorsed by the State Groundwater Advisory Council, shall be binding.

   b) The State Groundwater Advisory Council shall have the responsibility to notify the plan.

c) The Groundwater Security Plan shall be binding from the date of notification.

2. The Groundwater Security Plan shall be valid for a period of five years from the date on which it becomes binding. It shall be revalidated or amended after every five years:

   Provided that where compelling reasons, such as significant hydrological changes or drought, warrant it, revision or amendment may be made before the expiry of five years.

Chapter 5 – Institutional Framework

A. Rural Areas

1) GRAM PANCHAYAT GROUNDWATER COMMITTEE

17. Constitution and Membership of the Gram Panchayat Groundwater Committee

1. The Gram Sabha shall by resolution, recorded by the Gram Panchayat, elect a Gram Panchayat Groundwater Committee:

   Provided that where there exists a village water and sanitation committee under the jurisdiction of the Panchayat and the Gram Sabha resolves to vest all the functions and powers of the Gram Panchayat Groundwater Committee under this Act to such village water and sanitation committee, then the latter committee shall be the Gram Panchayat Groundwater Committee under this Act.

2. The strength of the committee, the qualifications of the members and the terms and conditions under which they holds office shall be as prescribed by the Gram Sabha.

3. In constituting the Gram Panchayat Groundwater Committee, adequate representation shall be given to scheduled castes, tribes and women:

   Provided that in places where Gram Panchayat level watershed and irrigation committees or institutions exist, the Gram Panchayat Groundwater Committee shall include representatives of those committees;

   Provided further that the Gram Panchayat Groundwater Committee may also include representatives of community-based groups, such as self-help groups and women's groups.

4. Every member of the Gram Panchayat Groundwater Committee shall forthwith be deemed to have vacated her or his office if she or he is recalled through a secret ballot by a majority of more than half of the total number of members constituting the Gram Sabha within the gram Panchayat in accordance with the procedure, as may be prescribed:

   Provided that any member shall be recalled only on the ground of actions done by the member in violation of the powers, functions, duties and responsibilities of the Gram Panchayat Groundwater Committee;

Provided further that where a member is recalled, the Gram Sabha shall elect another representative in her or his place within a period of sixty days of recall of such member.

18. Functions of the Gram Panchayat Groundwater Committee

The functions of the Gram Panchayat Groundwater Committee shall include:

a. Preparation of the Panchayat Groundwater Security Plan and presentation of the same to the Gram Sabha for approval:
   Provided that the Gram Panchayat Groundwater Committee shall ensure, while preparing the Plan, that it complements and is integrated with other water-related plans, such as drinking water security plans that may be required under other laws or government schemes.

b. Implementation of the Panchayat Groundwater Security Plan;

c. Registration of all wells and other sources such as springs within the gram panchayat boundaries used for secondary uses as defined at Section 10 of this Act;

d. Registration of all wells and other water sources such as springs within the gram panchayat boundaries found in areas declared as groundwater protection zones;

e. Collection of information from all source including persons or agencies engaged in activities, such as drilling of tube wells and construction of open wells and to discharge this function the Gram Panchayat Groundwater Committee shall obtain a log from drilling agencies;

f. Granting of permits under Sections 37-40 of this Act; and

g. Regulation of use of groundwater sources within the gram panchayat boundaries, except domestic wells using pumps of 1.5 hp or less.

2) BLOCK PANCHAYAT GROUNDWATER COMMITTEE

19. Constitution and Membership of the Block Panchayat Groundwater Committee

1. Every block panchayat shall form a Block Panchayat Groundwater Committee.
2. The strength of the committee, the qualifications of the members and the terms and conditions under which they holds office shall be as prescribed by the Block Panchayat:
3. In constituting the Block Panchayat Groundwater Committee, adequate representation shall be given to scheduled castes, tribes and women:

   Provided that in areas where block panchayat level water and sanitation, watershed and irrigation committees or institutions exist, the committee must include representatives of those committees.

4. Every member of the Block Panchayat Groundwater Committee shall be liable to be recalled by the Block Panchayat. Recalling shall be made by the Block Panchayat by a resolution passed by the majority of the total membership. Recalling shall be made only on the ground of actions done by the member in violation of the powers, functions, duties and responsibilities of the Block Panchayat Groundwater Committee. Where a member is recalled, the Block Panchayat shall elect another representative in his or her place.
5. The Block Panchayat Groundwater Committee shall be assisted by information and monitoring cells and supporting institutions in effective monitoring of groundwater extraction and groundwater quality, protection and recharge of groundwater aquifers.

20. Functions of the Block Panchayat Groundwater Committee

1. The functions of the Block Panchayat Groundwater Committee shall include:

   a. Consolidation of Gram Panchayat groundwater security plans into a Block Groundwater Security Plan on a mili-watershed and macro-watershed basis, with the assistance of the Block Groundwater Information and Monitoring Cell;

   b. Coordination of the planning process between Panchayats sharing aquifers where the aquifer boundary does not correspond with boundaries of a single Panchayat. In the case of local aquifers, the same would apply to watersheds shared by Panchayats, especially watersheds that include multiple aquifers.

c. Monitoring and supervising implementation of gram Panchayat groundwater security plans in terms of the block level plan;

d. Advising and recommending changes and modifications of gram Panchayat groundwater security plans on the basis of information provided by information and monitoring cells and supporting institutions;

e. Ensuring that the groundwater security plan of a Panchayat does not restrict the options of another Panchayat;

f. Determining groundwater protection zones straddling more than one Panchayat within the territory of the block and adopting norms for their management and regulation;

g. Granting of permits under Section 37-40 of this Act; and

h. Ensuring in times of groundwater scarcity that groundwater security plans do not come in the way of the sharing of available groundwater among Panchayats in the block.

B. Urban Areas

1) WARD GROUNDWATER COMMITTEE

21. Constitution and Membership of the Ward Groundwater Committee

1. Every ward of a municipality, where groundwater is extracted for any use, shall form a Ward Groundwater Committee.
2. The strength of the committee, the qualifications of the members and the terms and conditions under which they holds office shall be as prescribed by the Ward Sabha:
3. The Ward Sabha shall ensure proportional representation for scheduled castes, tribes and women.
4. Every member of the Ward Groundwater Committee shall forthwith be deemed to have vacated her or his office if she or he is recalled through a secret ballot by a majority of more than half of the total

number of members constituting the Ward Sabha within the ward in accordance with the procedure, as may be prescribed:

Provided that any member shall be recalled only on the ground of actions done by the member in violation of the powers, functions, duties and responsibilities of the Ward Groundwater Committee;

Provided further that where a member is recalled, the Ward Sabha shall elect another representative in her or his place within a period of sixty days of recall of such member.

22. Functions of the Ward Groundwater Committee

1. The functions of the Ward Groundwater Committee shall include:

   a. Preparing and overseeing the implementation the Ward Groundwater Security Plan with the consent of the Ward Sabha;

   b. Determining groundwater protection zones within the territory of the ward and adopting norms for their management and regulation;

   c. Registration of all wells and other sources such as springs within the ward boundaries used for secondary uses as defined at Section 10 of this Act;

   d. Registration of all wells and other water sources such as springs within the ward boundaries found in areas declared as groundwater protection zones;

   e. Granting of permits under Section 37-40 of this Act; and

   f. Regulating the use of groundwater sources within the ward boundaries, except domestic wells using pumps of 1.5 hp or less.

2) MUNICIPAL GROUNDWATER COMMITTEE

23. Constitution and Membership of the Municipal Groundwater Committee

1. Every Municipality shall form a Municipal Groundwater Committee.

2. The strength of the committee, the qualifications of the members and the terms and conditions

under which they holds office shall be as prescribed by the Municipal Council:

3. The Municipal Council shall ensure proportional representation for scheduled castes, tribes and women.

4. Every member of the Municipal Groundwater Committee shall forthwith be deemed to have vacated her or his office if she or he is recalled through a secret ballot by a majority of more than half of the Municipal Council in accordance with the procedure, as may be prescribed:

   Provided that any member shall be recalled only on the ground of actions done by the member in violation of the powers, functions, duties and responsibilities of the Municipal Groundwater Committee;

   Provided further that where a member is recalled, the Municipal Council shall elect another representative in her or his place within a period of sixty days of recall of such member.

5. The Municipal Groundwater Committee shall work in close coordination with other water-related institutions within the municipality, in particular with the institution providing water and sewerage services, if any.

24. Functions

1. The functions of the Municipal Groundwater Committee shall include:
   a. Endorsing ward groundwater security plans where they have been prepared;
   b. Preparing a consolidated Municipal Groundwater Security Plan based on ward plans for the same, on a mili- and macro-watershed basis;
   c. Determination of groundwater protection zones straddling more than one ward within the territory of the municipality and adopting norms for their management and regulation;
   d. Granting of permits under Sections 37-40 of this Act; and
   e. Coordinating measures taken at the ward level.

3. District Groundwater Council and State Groundwater Advisory Council

1. DISTRICT GROUNDWATER COUNCIL

25. Constitution and Membership of the District Groundwater Council

1. Every district shall form a District Groundwater Council, consisting of one representative from each of the Block Panchayat groundwater committees and the municipal groundwater committees.

2. The strength of the committee, the qualifications of the members and the terms and conditions under which they hold office shall be as prescribed by the District Panchayat:

3. The District Panchayat shall ensure proportional representation for scheduled castes, tribes and women.

4. Every member of the District Groundwater Committee shall forthwith be deemed to have vacated her or his office if she or he is recalled through a secret ballot by a majority of more than half of the District Panchayat in accordance with the procedure, as may be prescribed:

   Provided that any member shall be recalled only on the ground of actions done by the member in violation of the powers, functions, duties and responsibilities of the District Groundwater Committee;

   Provided further that where a member is recalled, the District Panchayat shall elect another representative in her or his place within a period of sixty days of recall of such member.

5 The District Groundwater Council shall be assisted in its functioning by information and monitoring cells and supporting institutions.

26. Functions of the District Groundwater Council

1. The functions of the District Groundwater Council shall include:
   a. Preparing a consolidated District Groundwater Security Plan based on block and municipal plans for the same, on a macro-watershed basis;
      a. Reconciling the groundwater security plans of the blocks and municipalities within the

district;

b. Determining groundwater protection zones straddling more than one block and/or municipality within the territory of the district and adopting norms for their management and regulation;

c. Take appropriate measures to foster the transfer of groundwater to Panchayats, blocks and municipalities whose groundwater availability is insufficient to meet primary groundwater uses; and

d. Coordinating measures taken at the block and municipal level.

2. STATE GROUNDWATER ADVISORY COUNCIL

27. Constitution and Membership of the State Groundwater Advisory Council

1. The State Government shall, by notification, establish, with effect from such date as may be specified in the notification, a Council at the State level to be known as the State Groundwater Advisory Council.

2. Where a State Groundwater Authority exists, it shall act as State Groundwater Advisory Council. Where it does not, the State Government shall set up a Council comprising of:
   a. One representative of the Central Groundwater Board;
   b. One representative of the State Groundwater Board;
   c. Member Secretary of the State Pollution Control Board;
   d. An officer not below the rank of Chief Engineer of the Irrigation or Water Resources Department;
   e. An officer not below the rank of Joint Secretary of the Department of Panchayats and Rural Development;
   f. An officer not below the rank of Chief Engineer of the Public Health and Engineering Department or State Water and Sanitation Mission;

g. An officer not below the rank of Joint Secretary of the Department of Industries;

h. Two representatives from Gram Panchayat groundwater committees;

i. Two representatives from Block Panchayat groundwater committees;

j. Two representatives from district groundwater councils;

k. Two representatives from ward groundwater committees;

l. Two representatives from municipal groundwater committees; and

m. Two independent experts having experience in hydrogeology, ecology or social science.

3. The State Groundwater Advisory Council shall be supported by the State Groundwater Department, the Water Department in the absence of the former or any other department dealing with water resources.

28. Functions

1. The State Groundwater Advisory Council shall provide advice and support to all groundwater bodies constituted under this Act.

2. The State Groundwater Advisory Council shall in particular:

a. Endorse and notify groundwater security plans;

b. Ensure that the conservation and use measures adopted in rural and urban areas do not contradict each other;

c. Determine groundwater protection zones straddling more than one district within the territory of the state and adopting norms for their management and regulation;

d. Maintain and monitor a database on the implementation of Block and Gram Panchayat groundwater security plans;

e. Advise and recommend to district councils and municipalities changes and modifications in district and municipal groundwater security plans;

f. Conduct awareness enhancement programmes at the district, block and village levels;

g. Conduct capacity building programmes at the district and block levels;

h. Collect information from groundwater based source creation activities, such as drilling of tube wells or construction of dug wells, with the help of gram Panchayat groundwater committees.

4. Information and Monitoring Cells and Supporting Institutions

29. Constitution of Information and Monitoring Cells

1. District groundwater information and monitoring cells, block groundwater information and monitoring cells and municipal groundwater information and monitoring cells shall be constituted to assist and help the appropriate authority for the effective implementation of this Act.
2. These cells will draw on existing institutional, scientific and technical capacity at all levels within the state, in particular the State Groundwater Department and its district offices or the State Pollution Control Board and its district offices.

30. Notification of Additional Supporting Institutions

1. The State Government may also notify agencies constituted under law, which the State Government may think suitable to assist and help the appropriate authority for the effective implementation of this Act:

   Provided that suitable institutions may include, the State Groundwater Department, the State Pollution Control Board, the Groundwater Department, the Public Health Engineering Department, the Irrigation Department, the Water Resource Department, the Department of Forests, the State Water and Sanitation Mission, zonal/regional offices of the Central Groundwater Board, block resource centres (National Rural Drinking Water Programme), water user associations and biodiversity management committees.

31. Functions of Supporting Institutions

1. Information and monitoring cells constituted under Section 29 and supporting institutions notified under Section 30 shall be duty-bound to assist and help the appropriate authority as per demands

from the appropriate authority from time to time.

2. Information and monitoring cells and supporting institutions shall deliver the required assistance within a reasonable time period, as specified by the appropriate authority:

   Provided that information and monitoring cells and supporting institutions may take longer than the time period specified by the appropriate authority on reasonable grounds, subject to the satisfaction of the appropriate authority.

3. The appropriate authority may seek assistance from information and monitoring cells and supporting institutions at the appropriate level for fulfilling its duties and functions under this Act and this may include assistance:

   a. For the provision of information on groundwater for planning purposes;
   b. For the preparation of groundwater security plans;
   c. For the preparation of a format for the registration and details of wells;
   d. To assist compliance with groundwater security plans;
   e. To assist the process of social and environmental impact assessment;
   f. To fix the terms and conditions of permits for extraction of groundwater for various uses;
   g. For evaluating the damages caused by any user of groundwater to individuals, property and environment; and
   h. For conducting studies and surveys where required.

4. The State Government shall, in a manner specified in Rules, require supporting institutions notified under this Act to:

   a. Periodically evaluate and monitor groundwater availability and quality, and organise groundwater surveys to ascertain the status of groundwater and the user profile;
   b. Make an inventory of surface water sources and catchments;
   c. Prepare, publish and periodically update groundwater and surface water digital maps,

including micro- and mili-watershed levels;

d. Prepare, publish and periodically update integrated river basin maps, including surface water, groundwater, land and forest resources;

e. Set up and periodically update a groundwater digital database and a natural resource database management system;

f. Make available data to appropriate authorities and the public;

g. Conduct awareness enhancement programmes at the district, block, village, municipal and ward levels;

h. Undertake capacity building measures to train institutions constituted under this Act;

i. Mobilize the expertise and resources from any national or international specialized scientific or civil society or other institution for the purpose of enhancing the knowledge, understanding, dissemination and coordination of groundwater related issues relevant to the state; and

j. Keep a register containing particulars of permits.

Chapter 6 – Duties of Groundwater Users, Water Harvesting, Recycling and Reuse, and Waterlogging

32. Duties of Groundwater Users

1. Every user of groundwater shall ensure that:
   a. Groundwater is not wasted, depleted or contaminated and no substance that pollutes groundwater is directly discharged on or into the ground;
   b. Groundwater is conserved through appropriate agricultural and industrial practices, including by giving priority to using recycled water;
   c. Measures are taken to replenish or recharge groundwater, including in recharge zones, for instance, through afforestation and reforestation; and
   d. Rules regarding groundwater protection zones are followed.

2. Whoever uses and manages surface water and land resources in a way that is inconsistent with the Groundwater Security Plan shall phase out such activities, in particular the release of any effluent that contaminates groundwater resources either temporarily or permanently.

33. Water Harvesting and Catchment Conservation

1. The appropriate authority shall encourage rainwater harvesting and catchment conservation as per geological conditions. It shall undertake all possible steps in integrated natural resources conservation, use and regulation for the augmentation of groundwater resources within its jurisdiction, through integration and convergence of all natural resources related developmental schemes and projects.

2. Notwithstanding anything contained in any other law for the time being in force, the gram panchayat groundwater committee or ward groundwater committee as the case may be, may impose stipulated conditions for providing rooftop rainwater harvesting structures in the building plan of an area of 50 m^2 or more. Such stipulations shall be binding on concerned government agencies sanctioning or approving building plans. A building number, a tax assessment, and permanent water and electricity connections shall be extended only after compliance of the

directions given in this regard.

3. Catchment conservation shall be done by using appropriate groundwater recharge structures or pits depending on the nature of the terrain/soil and condition/geology of the area.

34. Recycling and Re-use of Groundwater

1. The appropriate authority shall encourage recycling and, in particular, foster re-use of water for non-potable urban, industrial, and agricultural use, as well as augmentation of potable water supplies through indirect reuse.

35. Waterlogging

1. The appropriate authority shall discourage and prevent such activities that are likely to lead to potential waterlogging of land. It shall undertake all possible regulation for the protection of land against waterlogging within its jurisdiction.
2. The Gram Panchayat Groundwater Committee or Ward Groundwater Committee, as the case may be, may impose stipulated conditions for regulating activities in waterlogged areas that lead to worsening of the waterlogging condition. The Gram Panchayat/ward sabha, in consultation with the District Groundwater Information and Monitoring Cell, shall take steps to mitigate waterlogging through proper interventions related to soil treatment and land drainage.
3. Waterlogging mitigation measures shall be adopted by using appropriate processes and technologies, in due consultation with appropriate information and monitoring cells.

Chapter 7 – Basic Water from Groundwater Sources

36. Basic Water

1. Everyone is entitled to the same quantity of basic water regardless of, among others, caste, class, gender, economic status, land ownership and place of residence.

2. The quantity of basic water shall in no case be less than 70 litres per capita per day1 of groundwater and/or surface water, depending on their respective availability:

   Provided that the state shall ensure that Gram Panchayats and municipalities are progressively able to provide at least 70 litres per capita per day.

3. Every drinking water supply agency extracting groundwater shall comply with the Manual of the Central Public Health and Environmental Engineering Organization, Bureau Indian Standards specifications or standards adopted by the State Government as modified or revised from time to time:

   Provided that the Block Groundwater Information and Monitoring Cell or Municipal Groundwater Information and Monitoring Cell shall monitor compliance with these standards;

   Provided further that information of these guidelines and standards shall be provided to groundwater committees and local elected bodies at village, block, district, ward and municipal level, and to water supply agencies by the State Groundwater Board, through the district and block level groundwater information and monitoring cells.

4. Where basic water is not provided by any drinking water supply agency, and people depend on groundwater for their basic water requirements, it shall be the duty of the Block Groundwater Information and Monitoring Cell, the District Groundwater Information and Monitoring Cell and the State Groundwater Board to provide information on water quality in accordance with the Manual of the Central Public Health and Environmental Engineering Organization, Bureau Indian Standards specifications or standards adopted by the State Government as modified or revised from time to time, and to suggest appropriate measures to be undertaken at local level for quality improvement to the local appropriate authority:

Provided that the appropriate authority shall take the suggested measures without unreasonable delay, which shall in no case be more than twelve months.

5. The supply of basic water from any groundwater source shall require consultation and concurrence of the Gram Panchayat Groundwater Committee or Ward Groundwater Committee.

Chapter 8 – Groundwater for Livelihoods and Irrigation

37. Groundwater for Livelihoods and Irrigation

1. Every person is entitled to use groundwater for their livelihood needs.

2. The livelihood pattern and the resultant needs should be incorporated in groundwater security plans.

3. The Groundwater Security Plan shall take into account the availability of water through surface water projects and provide for groundwater for the livelihood needs through an integrated approach:

   Provided that in case of severe drought or where the area has been declared a Groundwater Protection Zone 2, limits may be imposed for restricting water use by the appropriate authority.

4. Major or medium irrigation projects using groundwater shall be based on a permit system allocated by the appropriate authority in consonance with the groundwater security plan. The procedure for issuing permits shall be the same as that outlined in Chapter 9.

5. Major or medium irrigation projects using groundwater may be subject to paying a water rate to the Panchayat, as determined by the Gram Panchayat Groundwater Committee, to be used for groundwater conservation and augmentation activities.

6. In any area that has been declared a Groundwater Protection Zone 2 and where water intensive cash crops are grown, an undertaking shall be obtained for a change from water-intensive crops and such undertaking must be incorporated in the permit.

7. In the command areas of irrigation systems where water user associations have been established under the law, the said water user associations may levy and collect from the farmer or any other person using groundwater such fees, as they may deem appropriate.

Chapter 9 – Industrial, Commercial and Other Bulk Uses of Groundwater

38. Permits to Abstract Groundwater for Industrial Use or Infrastructure Projects

1. No one shall abstract groundwater for industrial use or infrastructure projects without a permit issued by the appropriate authority, as defined in this chapter:

   Explanation: Industrial use includes, but is not restricted to groundwater extracting industries, bottling plants and other commercial activities consuming more than 10 kl of groundwater a day and agencies – government or private – responsible for water supply using groundwater.

   No permit for industrial, commercial or other bulk uses of groundwater shall be granted in a Groundwater Protection Zone 1 and permits for industrial, commercial or other bulk uses of groundwater in a Groundwater Protection Zone 2 shall be granted only if such uses are in conformity with the provisions of the Groundwater Security Plan in the concerned area.

39. Procedure for Applying for Permits

1. Whoever has been abstracting groundwater for industrial use or infrastructure projects at the time of commencement of this Act, shall apply for a permit within 120 days of the commencement of this Act.

2. If on examination of the application for a permit, it is found to be allowable, a conditional permit may be granted and reasonable time shall be allowed to the holder of permit to comply with the conditions:

   Provided that if the permit is not granted the activity shall be stopped immediately after the denial of the permit.

3. Permits shall be granted by the appropriate authority after obtaining the prior informed consent of the concerned gram or ward sabha.

4. The appropriate authority shall grant or refuse to grant a permit on the basis of a social and environment impact assessment conducted as per the stipulations of Section 43 of this Act:

Provided that no applicant shall be refused of a permit unless she or he has been given an opportunity to be heard.

5. The appropriate authority shall be helped by information and monitoring cells and supporting institutions and can seek the advice of the State Groundwater Advisory Council.

6. Every application for a permit shall contain such particulars and in such manner accompanied by such fee as may be prescribed.

7. The applicant for a permit shall disclose all relevant information to the appropriate authority regarding the use of and implications on groundwater of the planned activity. Such information shall be provided in good faith.

8. The appropriate authority may seek additional information from the applicant if information submitted under sub-section (6) is found to be insufficient to facilitate the decision making process:

   Provided that the applicant shall provide such additional information within a month;

   Provided further that where the applicant fails or refuses to provide the requested information, the application shall be deemed to be incomplete and liable to be rejected.

9. The decision regarding the grant or refusal of permit shall be intimated by the appropriate authority to the applicant within a reasonable time period and in any case not later than six months from the date of receipt of the application.

40. Terms and Conditions of the Permits

1. The permit may be granted with terms and conditions as prescribed by the appropriate authority, taking into account the different groundwater requirements of different industries and the specific processes used and such terms and conditions may include but are not restricted to:
   a. The maximum quantity of water that may be extracted;
   b. Precautions to prevent contamination of groundwater by mandating existing pollution control standards and measures;

c. Details of conservation measures, including rainwater harvesting, to be taken;

d. Groundwater recharging measures;

e. Recycling a prescribed proportion of the extracted groundwater;

f. Treating wastewater to bring it to prescribed standards before it is discharged; and

g. Adopting and practising the most water efficient practices and technology.

2. The permit shall be in accordance with the groundwater security plan in force in the area and with water use prioritisation outlined at Section 10 of this Act.

3. The permit granted for a specified purpose shall not be used for any purpose other than that for which it has been granted.

4. The permit holder shall be prohibited from selling, by whatever name or form, groundwater extracted under the permit to someone else for commercial use and/or gain.

41. Cancellation, Transfer and Validity of Permits

1. Non-compliance with the terms and conditions of the permit constitutes a ground for cancelling the permit and compliance shall be monitored by the authority that granted the permit, including the District Groundwater Council and State Groundwater Advisory Council:

   Provided that the authority having granted the permit shall give the permit holder an opportunity to be heard before cancelling any permit.

2. Permits issued under this section shall be inalienable. However, permits granted to a natural person shall be inherited by his or her legal heirs and shall continue to be valid for the remaining period as long as the legal heirs continue the activities done by the deceased permit holder. Further, on transfer of the property for the benefit for which the permit was granted, the permit shall continue to be valid so long as the nature of the activity continues unaltered by the new owner.

3. The permit shall be valid for a period fixed under the permit. The period of validity for the permit shall in no case exceed five years. However as far as possible the period fixed for the validity of

permit shall be for a minimum period of one year. The appropriate authority may suspend the permit for a limited period in situations of emergency and/or request the permit holder to provide basic water from their own sources to nearby habitations in such cases of emergency.

4. Once the validity of the permit has expired, continuation of the permit shall require a fresh application by the permit holder complying with all the conditions of an original application.

42. Pricing of Industrial Use of Groundwater

1. Industrial or bulk groundwater use shall be priced and a water rate, as prescribed by the appropriate authority shall be charged.
2. Funds collected under this section shall be used for groundwater conservation and augmentation activities.
3. The groundwater rate charged under sub-section (1) is in addition to the water cess that may be paid under the Water (Prevention and Control of Pollution) Cess Act, 1977.

43. Mining

1. Any person planning reconnaissance, prospecting, general exploration, detailed exploration or mining in respect of any major or minor minerals, including sand mining, shall prepare and file a prospecting plan with the appropriate authority of the area concerned, indicating steps proposed to be taken for the protection of surface and groundwater to minimise the adverse effect of prospecting operations on groundwater and the environment in general.
2. Any person preparing and filing a prospecting plan under sub-section (1) and any person having undertaken mining operations for a major or minor mineral shall take immediate measures, as prescribed by the appropriate authority of the area concerned, to restore, as far as possible, water regimes and the ecosystem in general in the areas in which prospecting or mining operations have been conducted.
3. Any person undertaking mining activities shall support groundwater enrichment activities in their watershed and provide drinking water from their own sources to nearby habitations in case of emergency in the manner prescribed by the appropriate authority.

Chapter 10 – Social and Environment Impact Assessment, Transparency and Accountability

44. Social and Environmental Impact Assessment and Public Consultation

1. It shall be duty of the appropriate authority to conduct social and environment impact assessments:

   Provided that in order to carry out this obligation, the appropriate authority shall enlist the help of information and monitoring cells and supporting institutions, as well as any other agencies which the appropriate authority may think fit, as and when required;

   Provided further that in no case the promoter of the project, which is subjected to the social and environment impact assessments, shall be involved in this process.

2. The social and environment impact assessment shall include, but not restricted to, assessment of short-term and cumulative:

   a. Impacts on quality and quantity of groundwater in the concerned area and beyond;

   b. Impacts on agricultural production and its socio-economic impacts;

   c. Impacts on drinking water sources, including public drinking water supply systems in the concerned area and beyond, and its socio-economic impacts;

   d. Impacts on livestock and other living beings; and

   e. Impacts on the ecosystem.

3. There shall be a public hearing on the project, convened by the appropriate authority, in the area where the project is proposed to be implemented:

   Provided that the appropriate authority shall provide 60 days pre-hearing notice regarding the conduct of public hearing;

   Provided further that the above said notice shall be given through gram or block panchayat offices and/or ward or municipal offices and publication of such notice shall also be made in at least two local language newspapers having circulation in the concerned area.

4. The date of the public hearing under sub-section (3) shall be fixed more than 60 days after the date of publication of the social and environment impact assessment report by the appropriate authority.

5. The social and environment impact assessment report shall be subjected to examination by an expert group constituted for this purpose and the appropriate authority shall ensure the conduct of such examination:

   Provided that the expert group constituted under this sub-section shall consist of two non-official scientists, an independent expert on groundwater and an independent environmental expert.

6. The expert group shall give their recommendation to the appropriate authority within 30 days after receiving the copy of the social and environment impact assessment report and report of the public hearing.

7. The requirements of this section are in addition to any other requirements, which may be stipulated by any other law in force.

45. Duty to Establish Transparency Systems

1. It shall be the duty of the appropriate authority at all levels to create an effective, appropriate and citizen-friendly transparency regime for the present Act.
2. Access to information as defined in this Act shall extend to all persons.
3. The minimum content, periodicity, and other details of the information to be put out proactively shall be specified by Rules.
4. The transparency regime for provision of information to any person shall include, but shall not be restricted to:
   a. Proactive mandatory disclosure;
   b. Inspection of all documents and offices;
   c. Making accessible the copies of documents, records and samples of material; and
   d. Ensuring the transparency of the decision-making processes.

5. All requests for information within a district shall be fulfilled within seven days and those outside the district within 15 days:

   Provided that any request for information not complied with within the time period specified shall be considered a deemed refusal.

46. Duties of Proactive Disclosure

1. Appropriate authorities at all levels shall proactively disclose information.
2. It shall be the duty of the appropriate authority to disseminate the records in such a manner that a layperson can understand the information easily. This obligation shall also include the dissemination of information in a consolidated and summarized form, wherever appropriate.
3. Proactive disclosure shall include, but is not be restricted to:
   a. Reading aloud essential information as per prescribed format and manner specified by the Rules;
   b. Hanging or putting up information on notice boards at the Gram Panchayat, block, and district levels and the establishment of painted wall boards at prescribed locations and in the prescribed format and manner specified by the Rules;
   c. Publishing of information through newspaper advertisements, press releases, or the printing of leaflets and reports and by making announcements through the audio-visual media, such as, community radio, radio and television; and
   d. Availability of key records on the Internet. There shall be free and open access to the websites related to this Act where, as much of the information as prescribed, including summaries and consolidated information, shall be uploaded regularly.

47. Social Audits

1. Social audits of activities undertaken in pursuance with this Act shall be conducted in every twelve months. It shall be the obligation of the gram sabha or ward sabha, as the case may be, to conduct social audits, as required above, of activities undertaken in pursuance of this Act within the Gram

Panchayat or municipal ward:

Provided that this mandatory social audit may be linked to social audits required under other laws or government schemes and guidelines.

2. The relevant authorities shall make available all relevant documents including the tender documents, bills, vouchers, copies of sanction orders and other connected papers to the Gram Sabha or Ward Sabha for the purpose of conducting the social audit.
3. The findings of the audit shall be read out in the gram or ward sabha and shall also be circulated to the State Groundwater Advisory Council and, as appropriate, to the District Groundwater Council or Municipal Groundwater Committee.
4. The appropriate authority shall encourage independent audits, carried out by civil society or citizens groups.
5. All social audits shall be universal and open, allowing for ongoing social audit (concurrent) as well as post facto social audits.
6. The Groundwater Grievance Redressal Officer shall take necessary action on the findings of all social audits, including directions to initiate criminal prosecution.
7. The Groundwater Grievance Redressal Officer may impose a fine and/or award compensation on the basis of the findings of the social audit, within a reasonable time period and in any case not later than six months.

Chapter 11 – Offences, Penalties and Liability

48. Offences and Penalties

1. Whoever does any activity, which prejudicially affects the quality of groundwater or availability thereof shall be punished with imprisonment, which may extend to one year and six months or with a fine, which may extend to one lakh rupees or with both.
2. If a user convicted under sub-section (1) repeats the offence, such user shall be punished with a fine for an amount double the maximum prescribed under sub-section (1) in addition to imprisonment that may be prescribed under sub-section (1). If such user holds a valid permit granted under this Act, such permit shall be cancelled with immediate effect.
3. Any supplier of water who supplies or causes to be supplied groundwater which fails to meet the quality standard prescribed under law shall be punished with a fine which may extend to five thousand rupees.
4. Whoever extracts or causes to be extracted groundwater from a groundwater protection zone and fails to comply with instructions or directions given by the appropriate authority under this Act or specified by the Rules shall be punished with imprisonment which shall not be less than six months and which may extend to three years and with a fine which may extend to ten lakhs.
5. Whoever, being an owner of a building liable to be fitted with mechanisms for harvesting rainwater for recharging groundwater as per the requirements under this Act, fails to do so, shall be punished with a fine, which may extend to five thousand rupees. In addition to the penalty imposed on her or him, she or he shall be required by the Groundwater Grievance Redressal Officer to comply with the requirements of law within a stipulated time. In case of failure on the part of the owner of the building, the appropriate authority shall take steps to install or restore such mechanisms and the expenditure incurred for this shall be collected from the owner as arrears of land revenue or as a judgment debt realisable through execution proceedings initiated before the Groundwater Grievance Redressal Officer.
6. Whoever contravenes any of the provisions of this Act or fails to comply with any order or direction given under this Act or its Rules, for which no penalty has been elsewhere provided in this Act, shall

be punishable with imprisonment, which may extend to three months or with fine, which may extend to ten thousand rupees or with both.

7. If an offence punishable under this Act is committed at any time by a company, every person who is in charge of and responsible to the company for the conduct of its business at the time of the commission of the offence and the company shall be deemed to be responsible for the offence and shall be personally liable under the Act. This also includes criminal liability:

   Provided that where any offence under this Act has been committed by a company and it is proved that the commission of the offence is with the consent and connivance or attributable to any neglect on the part of any Director, Manager, Secretary or other officer of the company, such Director, Manager, Secretary or other officer shall be deemed to be responsible for that offence and shall be liable to be proceeded against and punished accordingly.

   Explanation: For the purpose of this section:

   a. 'Company' means anybody corporate and includes a firm or other association of individuals; and
   b. 'Director' in relation to a firm means the partner in the firm.

49. Civil and Administrative Remedies

1. Whoever violates the Groundwater Security Plan prepared and implemented under this Act shall be liable to be sued. Any act done or any omission to do an act in violation of the Groundwater Security Plan shall be an actionable wrong.
2. The appropriate authority at the level in which the Groundwater Security Plan is drawn up and monitored shall be the body responsible for initiating and continuing the legal action against the violators.
3. The appropriate authority shall designate an officer who shall initiate the legal proceedings against the violators of the Groundwater Security Plan.
4. An application to remedy/rectify the violation shall be preferred before the Groundwater Grievance

Redressal Officer having jurisdiction over the area from where the dispute arose.

5. The appropriate authority may give directions to any person to remedy any violation of rules and regulations or provisions of this Act. It may also impose fines for the violations, remittance of which shall be a condition for restoration of the permit cancelled or suspended.

6. Nothing under this provision shall bar the exercise of the power of cancellation, suspension, and modification of the permit granted by the appropriate authority by way of an administrative order for violation of the conditions of the permit.

7. Any person aggrieved by the administrative directions issued against her or him by the appropriate authority may raise a dispute under this Act.

8. Any individual, group, community, or non-governmental organization, can file a petition before the Groundwater Grievance Redressal Officer seeking remedy against the violation of the Groundwater Security Plan.

9. No action shall be initiated by any person, other than the designated officer, under this section unless he had served thirty days notice to the concerned authorities for initiation of legal action:

   Provided that the Groundwater Grievance Redressal Officer may allow the initiation of legal action without serving the above said notice if she or he is satisfied regarding the urgency of the matter or if she or he is convinced that no purpose is going to be served by issuing such a notice.

10. The Groundwater Grievance Redressal Officer can issue an injunction against the perpetrator of the violation, or issue a mandatory injunction to compel positive actions to remedy the situation or direct the violator to pay compensation for the violation.

11. Industrial or commercial users shall be strictly liable for substantial harm to groundwater quantitatively and qualitatively and for the degradation of the land as well as damage caused to public health.

    Explanation: Inherently hazardous uses of groundwater include but are not limited to the direct pumping and/or release of potential hazardous effluents into aquifers, extraction of groundwater beyond the specified permit accorded to an industry, and activities destroying the recharge capabilities of areas notified as Groundwater Protection Zone 1.

12. The Groundwater Grievance Redressal Officer may provide for restitution of property damaged and for restitution of the environment for such area or areas or compensation to victims who suffered health hazards or faces threat to health as well as for the damages caused to the environment as she or he may think fit.

13. The Groundwater Grievance Redressal Officer may impose a fine for violations of the Groundwater Security Plan or any other provisions of this Act and such fine shall not exceed the amount prescribed as fine under the penal provisions under this Act.

14. The Groundwater Grievance Redressal Officer may cancel the permit granted in cases of violation of the Groundwater Security Plan or conditions of the permit or suspend it for a specific period in addition to any other order she or he may pass in a petition for rectification of the Groundwater Security Plan violation.

15. The Decision of the Groundwater Grievance Redressal Officer shall be binding on all parties to the complaint.

16. No Action shall be initiated before the Groundwater Grievance Redressal Officer unless it is certified that all appropriate measures to settle the dispute by mediation and conciliation have failed. The manner in which the certificate of failure of mediation and conciliation is to be issued and authenticated shall be provided by Rules.

17. Nothing contained in this provision shall limit the power of the Groundwater Grievance Redressal Officer to entertain any complaint or application without prior notice being given to the appropriate authority for taking action or without the failure report of the conciliation and mediation if she or he is satisfied that the case requires urgent actions to be taken or that it will not serve any purpose to wait for the completion of the prerequisites mentioned earlier.

50. Cognizance of Offences

1. Offences under this Act shall be cognizable and triable by a magistrate of first class or by any other judicial forum created/empowered in this behalf.

2. The magistrate may take cognizance of the offence either *suo moto* or on a complaint filed by the appropriate authority.

3. Any person interested in the matter on her or his personal behalf can initiate prosecution of any person who commits any offence under this Act. Before initiating the prosecution, the person interested shall give one month notice to the appropriate authority intimating her or his intention to initiate prosecution:

   Provided that it shall be within the power of the court to allow the person interested in the matter to initiate prosecution against anyone who violated the provisions of this Act without serving the notice mentioned above if the court is satisfied that the matter is of urgent nature or that no useful purpose is going to be served by issuing the above-mentioned notice.

51. Compounding of Offences

1. Offences prescribed under this chapter, except under Section 47 sub-section (4) may be compounded by the appropriate authority with the permission of the court.

2. On compounding the offences, the conditions laid down under rules for the imposition of fees for compounding shall be complied with.

Chapter 12 – Dispute Resolution

52. Dispute Resolution Avoidance, Mediation and Conciliation

1. Every dispute under this Act shall be referred to be settled by mediation or conciliation at the appropriate level, by mediators and conciliators.

2. Every Panchayat Groundwater Committee or Ward Groundwater Committee shall make available by consensus a list of persons of repute and integrity to act as conciliators and mediators, to be published by the District Panchayat. In order to facilitate the process of mediation and conciliation the state shall publish a list of persons available for acting as mediators and conciliators in every local area.
3. The settlement reached under this process shall be final and binding and shall be authenticated by the process prescribed under Rules.
4. Any dispute, which fails to be resolved under the mediation and conciliation shall be referred to the court for adjudication with a statement of failure report.
5. In case of any grievance of no reference of dispute for adjudication on failure of mediation and conciliation, the aggrieved party may approach the court for permission to file suit for adjudication of the dispute.

53. Appointment of a Groundwater Grievance Redressal Officer

1. The State Government shall appoint in every block a Block Groundwater Grievance Redressal Officer and in every municipality a Municipal Groundwater Grievance Redressal Officer. The manner of selection, appointment and conditions of service shall be fixed by Rules formulated by the State Government in this behalf.
2. No one shall be appointed as Groundwater Grievance Redressal Officer unless she or he has experience and qualification in the field of law or hydrogeology or science and technology or social service or management or water policy or human rights or public administration.
3. Every Groundwater Grievance Redressal Officer shall hold office for a term of five years. The

Groundwater Grievance Redressal Officer shall be eligible for re-selection for a second term, and shall not be eligible for any further terms.

54. Disqualification for appointment as Groundwater Grievance Redressal Officer

1. The Groundwater Grievance Redressal Officer shall not be eligible for appointment if she or he:
    a. Is a public servant or a non-official holding any office of profit under the government at the time of appointment;
    b. Has been convicted and sentenced to imprisonment for an offence involving moral turpitude or corruption under the Prevention of Corruption Act, 1988;
    c. Has been suspended, removed or dismissed from the service of the government or a body corporate owned or controlled by the government; or
    d. Has, in the opinion of the appropriate authority, such financial or other interest as is likely to affect prejudicially the discharge of his or her functions as a Groundwater Grievance Redressal Officer.

2. The Groundwater Grievance Redressal Officer shall not hold any post under the government or any office of profit receiving remuneration from the state exchequer during the period in which she or he holds the post.

55. Nyaya Mitra

1. In every district, there shall be a Nyaya Mitra to assist the Groundwater Grievance Redressal Officer in the discharge of her or his duties.
2. No one shall be appointed as a Nyaya Mitra unless she or he holds a bachelors degree in law, with eligibility to enrol as a lawyer, from a recognised institution or university.
3. The manner of selection, terms of appointment and remuneration of the Nyaya Mitra shall be as prescribed by Rules.

56. Jurisdiction and Procedure

1. The Groundwater Grievance Redressal Officer shall have jurisdiction over all complaints arising under this Act, within the territorial jurisdiction for which she or he is appointed.
2. For the purposes of this section, the Groundwater Grievance Redressal Officer shall have the same powers and obligations as are vested in a civil court under the Code of Civil Procedure, 1908 while trying a suit in respect of the following matters, namely:
    a. The summoning and enforcing attendance of any defendant or witness and examining the witness on oath;
    b. The discovery and production of any document or other material object as evidence;
    c. The reception of evidence on affidavits;
    d. The requisitioning of the report of the concerned analysis or test from the appropriate laboratory or from any other relevant source;
    e. Issuing of any commission for the examination of any witness; and
    f. Any other matter, which may be prescribed.
3. The Groundwater Grievance Redressal Officer shall pronounce his or her decision in public immediately after finishing the hearing or at any subsequent time, not exceeding fourteen days.
4. The Decision of the Groundwater Grievance Redressal Officer shall be binding on all parties to the complaint.
5. Copies of the decision shall be given to the parties immediately free of cost and a copy shall be sent to the concerned Gram Panchayat Groundwater Committee or Ward Groundwater Committee.

57. Appeals

1. Appeals from the decisions of the Block Groundwater Grievance Redressal Officer can be preferred to the Gram Nyayalya set up under Section 3 of the Gram Nyayalayas Act, 2008.
2. Appeals from the decisions of the Municipal Groundwater Grievance Redressal Officer shall lie before the sub-court.

Chapter 13 – Miscellaneous

58. Pre-existing Rights

1. Pre-existing rights will continue to be valid for a period of one year from the date of commencement of this Act.
2. No compensation is due for any legal or other rights that become extinguished as a result of this legislation.

59. Drilling Agencies

1. Drilling agencies must be registered with the District Groundwater Council.
2. Drilling agencies must provide the appropriate authority with full details of the drilling activities planned and undertaken.
3. Drilling agencies must have a hydrogeologist possessing the prescribed qualifications on their payroll.

60. Funds Collected under this Act

1. Any fees, cess, penalties or grants received from the government or money received from any other source by way of gift or otherwise shall be set apart in a separate account and shall be used to further the objectives of this Act.

61. Protection of Action Taken in Good Faith

1. No suit, prosecution or other legal proceeding shall lie against the Government or any officer or other employee of the Government or any authority constituted under this Act or any member, officer or other employee of such authority in respect of anything which is done or intended to be done in good faith in pursuance of this Act or the rules made or orders or directions issued there under.

62. Effect of this Act on Other Laws

1. Notwithstanding anything contained in any other law for the time being in force, the provisions of this Act shall have precedence and overriding effect.

63. Power of the State Government to Make Rules

1. The State Government may, by notification, make rules to carry out the provisions of this Act.
2. Every Rule made under this Act shall be laid before the state legislature during its next session.

64. Power of Local Authorities to Make Byelaws

1. Consistent with the Rules made by the State Government under this Act, local authorities may, by notification, make byelaws to carry out the provisions of this Act.
2. Every byelaw made by local authorities under this Act shall to be sent for approval and endorsement by the State Legislature. The byelaws will take effect after such endorsement is made by the State Legislature.

65. Power to Make Regulations

1. Subject to the provisions of this Act and its Rules, the State Government may make regulations to carry out the purposes of this Act.

66. Power to Remove Difficulties

1. If any difficulty arises in giving effect to the provisions of this Act, the State Government may, by order, published in the Official Gazette, make such provisions not inconsistent with the provisions of this Act, as may appear to be necessary or expedient for removing the difficulty:

   Provided that no order shall be made under this section after the expiry of two years from the date of commencement of this Act.

2. Every order made under this section shall, as soon as may be after it is made, be laid before the State Legislature.

STATEMENT OF OBJECTS AND REASONS

- Groundwater is the backbone of India's agriculture and drinking water security in urban and rural areas. It is also important for the industrial sector in a large measure and, if left unregulated, may lead to serious inter-sectoral conflicts. A serious groundwater crisis prevails currently in India due to excessive overdraft and groundwater contamination covering nearly 60 percent of all districts in India and posing a risk to drinking water security of the population, as more than 80 percent of India's drinking water needs are serviced by groundwater resources. In addition to overdraft and biological and chemical contamination, excess groundwater and waterlogging is also a serious problem in many regions, impacting livelihood security of large sections of society.

- The acute problems relating to groundwater warrant a change in perspective and approach in its use and management. It is necessary to acknowledge the hydrogeological characteristics of groundwater and its integral link to land, vegetation and surface water resources, and perceive it as a 'resource' rather than a 'source'.

- In acknowledgement of the ubiquity of groundwater and its importance to all sections of society, it is necessary to recognize it as a common pool resource and adopt an aquifer-based approach to its management.

- The existing legal framework derived from common law principles and judicial interpretation that recognizes private property rights in water is inappropriate for the emerging status, conflicts and dynamics of groundwater.

- In recent decisions, superior courts in India have affirmed the common property nature of groundwater and have recognized the need to govern this resource under the concept of 'public trust'. Further, existing groundwater law principles and legislation fail to incorporate the many legal principles that have emerged in the rapid development of environmental law.

- It is imperative to recognise groundwater as a natural resource vital to life, livelihood and environment, and to change the existing legal status of groundwater. Respect for established fundamental rights and application of accepted norms and principles of environmental law is another key change needed to respond to the contemporary challenges. Most importantly, regulation and improvement of groundwater is inevitable to ensure safe and adequate drinking water for everyone and thereby for the realisation of the right to water. Given the highly decentralised way in which groundwater is being used, the regulatory and institutional framework need to apply the principle of decentralisation and participation effectively by replacing the existing centralised licensing mechanism.

- The Government of India has earlier attempted to recommend a statutory framework to regulate groundwater. The latest version of the existing model bill is the Model Bill to Regulate and Control the Development and Management of Groundwater, 2005. This model bill has failed to take notice of recent legal developments, such as the 73rd and 74th amendments to the Constitution of India vesting powers to Panchayats and Municipalities in the management of water that includes groundwater. In addition, it has not been widely adopted by states and even where it has, it has not been effectively implemented.

- A new legal framework with norms, principles, procedures and institutions suitable to address contemporary and imminent challenges is therefore required.

- The overall objectives of the Model Bill are thus to ensure the qualitative and quantitative sustainability of groundwater resources, equity in groundwater use, not just within users but across uses as well and efficiency in the use of groundwater as a common pool resource, through an appropriate institutional structure and participatory processes.

- To achieve the above objectives, therefore, the Model Bill for the Conservation, Protection and Regulation of Groundwater, 2011 is hereby enacted.

ECONOMIC EVALUATION OF RECHARGE SCHEMES

1.0 Economic viability is a critical parameter to be ascertained before taking a decision to implement any artificial recharge scheme. The appraisal of economic viability has to be carried out after taking into account all possible expenses including those for investigation, source water (conveyance, treatment), construction of recharge structures, operation and maintenance etc. All benefits should be appropriately accounted for and assessed in order to decide the acceptability of the scheme as per its priority in the overall scheme of development. Economic analysis of artificial recharge projects aims at ascertaining their economic and financial viability.

1.1 Benefit Cost Analysis

It is important to carry out the Benefit Cost Analysis for all major public works before a decision is taken on the allocation of funds. The Benefit Cost Analysis presents the quantifiable efforts, environmental and social aspects of any public projects in money terms.

The analysis of the financial benefits and costs requires expressing the cash flow elements under the non-financial operations in comparable terms. Costs are related to investments occurring during the lifetime of the project. However, benefits originate from the productive use of the projects. Therefore, both costs and benefits are expressed in quantitative terms and translated into monetary terms by using market values of the inputs and outputs concerned. Actually, the costs and benefits occur at different points of time. In order to make them comparable, it is customary to express both in terms of their present value by applying the appropriate discounting factors. After accounting both the costs and benefits against their market values, appropriate criteria are applied to determine the profitability of the project.

The Benefit Cost analysis of the projects is sometimes also called Project Appraisal. This Project Appraisal is done before the decision is taken to invest, whereas evaluation sometimes is done to analyze the performance and effects of the project after it has been executed.

Source: Manual on Artificial Recharge of Ground Water, MOWR, Govt. of India

The most important factors of project appraisal are Financial, Economic and Social Benefit Cost Analysis next to Institutional, Environmental, and Social impact assessments.

1.1.1 Financial Benefit Cost Analysis

The financial Benefit Cost analysis views any project from the point of view of the INVESTOR. The analysis would suggest/indicate the investor whether it is worthwhile to invest in the project in comparison of other investment opportunities. In practice, the investor may be a private person, a non-government Organization, or a government institution.

In evaluating the advantages of an investment opportunity, it is essential to give proper weightages to two major aspects, i.e., Liquidity Analysis and Profitability Analysis.

The liquidity analysis would demonstrate whether, for the entire lifetime of the project, receipts from equity capital and borrowing plus the annual income (Cash inflows) will be sufficient to meet the obligations for payments to be made (Cash outflows.)

Cash inflows, in this context, comprise the following elements.

i) Investment funds, which may consist of equity capital or loans,

ii) Loans and credit, during operation, and

iii) Revenues from sales and subsidies.

On the other hand, Cash Outflows to be considered include

i) Investments in fixed assets, working capital, pre-investment costs, preparatory surveys etc.,

ii) Interest, dividends and repayments and

iii) Direct payments.

For the project to be economically viable, the profitability analysis should show that various sources of finance involved would yield an acceptable financial return.

Measure for Profitability

This analysis becomes very crucial for identifying better opportunities for the investor's money. A number of methods have been developed to measure the profitability of investments. The commonly used methods are, i) Benefit Cost Ratio (B/C) Ratio), ii) Net Present Value (NPV) and iii) Internal Rate of Return (IRR). These methods are described below in brief.

a) **Benefit Cost Ratio**: The Benefit Cost (B-C) ratio, also known as 'Profitability Index' (PI) or 'Desirability Factor' is being widely used in the initial stages of project appraisal. It is defined as:

$$\textbf{B-C Ratio} = \frac{\textbf{Present value of total benefits}}{\textbf{Present value of total costs}}$$

If B-C ratio > 1, the project is considered to be attractive and profitable.

If B-C ratio <1, the project would not earn the inputs back and are thus not recommended for execution.

Limitation:

Without more information such as net benefits of running costs, cost escalation considered for gross benefits etc., the B C ratio is not well defined.

Hence, NPV and IRR should be considered in addition to B C ratio for proper evaluation of projects.

b) **Net Present Value (NPV):** The Net Present Value is uniquely defined and widely used in the selection of ground water development projects and artificial recharge projects. It is defined as the difference between the present value of total benefits and the present value of total costs. In this method, the inflows and outflows expected in future are discounted for a change in the value of money. Accordingly, cash flows expected in future years are discounted and their values at the beginning of the project are arrived at. Discounting presumes that money, like the other factors of production, has a cost. Discounting is done at the interest rate, which is the cost of capital, known as the discount rate. Interest rate and discount rate are practically the same, the only difference being the point of view. Interest assumes looking from the present to the future, whereas discounting look backwards from the future to the present.

The net present value of investment proposal is computed as

$$\sum_{t=0}^{n} \frac{c\,ft}{(1+k)^{t}}$$

Where

cft = Cash flow occurring at the end of year 't',

n = Life of the project and

k = Cost of capital used as the discount rate.

If NPV> 0 (Positive), the project is considered to be profitable and will yield more benefits than the investments.

The following example describes the procedure for calculation of NPV.

Assuming 'n' as 5 years, 'k' as 10%

Years	0	1	2	3	4	5
Net Cash flow -	1000	200	200	250	350	400

$$NPV = \frac{1000}{(1+0.1)^0} + \frac{200}{(1+0.1)^1} + \frac{200}{(1+0.1)^2} + \frac{250}{(1+0.1)^3} + \frac{350}{(1+0.1)^4} + \frac{400}{(1+0.1)^5}$$

$$= 22.1$$

Hence, the project can be accepted as the NPV is positive.

c) **Internal Rate of Return (IRR):** Though the NPV, which gives the net present value in absolute terms and Benefit Cost ratio, which gives the ratio of profit to cost consider the time value of money, neither of these methods indicate the rate of return. The Internal Rate of Return is a measure of the return on the investment that the project yields. It is the discount rate that equates the present value of cash inflows with the present value of outflows of the project. In other words, it is the discount rate that causes a project's net present value to equal zero and profitability index to equal unity.

It is represented by the rate 'r' such that,

$$\sum_{t=1}^{n} \frac{c\,ft}{(1+r)^{t}} = 0 = NPV$$

Where,

cft = Cash flow for period 't' whether it be a net cash out flow or inflow.

N = Life of the project.

If the initial cash outlay or cost occurs at time '0', the above calculation cab be expressed as,

$$Cfo = \frac{Cf_1}{(1+r)^1} + \frac{Cf_2}{(1+r)^2} + \frac{Cf_3}{(1+r)^3} + \text{-----------} + \frac{Cf_n}{(1+r)^n}$$

The rate 'r' discounts the stream of future cash flow through Cf_1……Cf_n to equal the initial outlay at time '0'

The accepted criteria generally employed for the IRR method are to compare the IRR with the required rate of return known as "cut off rate. If IRR exceeds the required rate, the project is acceptable. The following example describes the procedure for calculation of IRR.

n = 5 years

Years	**0**	**1**	**2**	**3**	**4**	**5**
Net Cash flow -	**-1000**	**200**	**200**	**250**	**350**	**400**

IRR is the value of 'r' which satisfies the equation NPV = 0.

$$1000 = \frac{200}{(1+r)^1} + \frac{200}{(1+r)^2} + \frac{250}{(1+r)^3} + \frac{350}{(1+r)^4} + \frac{400}{(1+r)^5}$$

The value of 'r' is calculated by trial and error method

For r = 10%, NPV equals to 22

For r = 10.5%, NPV equals to 7.5

Therefore, IRR will be nearer to 10.5%

Interest and Inflation

In financial analysis the rate of interest to be used is the actual interest to be paid for financing of the project. Generally, it is the market rate of interest or interest foregone if the necessary funds are withdrawn from a bank account or other investment opportunities.

Sometimes, if the funds allotted for the project are offered at an interest rate that deviates from the market rate in positive or negative way, the actual (annual) costs of interest and repayments have to be taken into account.

For all practical purposes, the base of the profitability analysis of any project should be an assumption of constant prices. But it is nearly impossible to control the inflation as such, and the assumption of constant prices is only justified as long as the relative value of inputs and outputs does not change over time.

Uncertainties and Sensitivities

The uncertainties involved in the calculation of benefits and costs should be minimal so that the outcome of any Benefit Cost analysis is realistic and not over-optimistic. However, these variables could be related to the level of costs and incurrence of cost. In order to avoid too low a cost, it is customary to include a contingency allowance of 20-25%. An extended construction period will decrease the present value of costs.

The quantitative assessments of benefits in some cases are fairly accurate but are not that easy in most of them. They vary widely depending on the efficiency of the future operator or the actual value of the benefits remaining far below the expectations. As an example, some of the irrigation projects or artificial ground water recharge schemes in which the peoples'/ farmers participation is not adequate may yield benefits below expectations. An extended construction period will decrease the present value of benefits.

To verify the effect of the changed conditions, it is recommended to carry out a sensitivity analysis so that information regarding the level and time of occurrence of critical data of benefits and costs vary.

1.1.2. Economic Benefit Cost Analysis

The main component of economic benefit cost analysis is to evaluate the resources in a national context. The analysis views it from the national point of view such that the benefits add to the national economy.

There are certain aspects, which are to be fully understood for such analyses to be correct and realistic. The effects of the projects such as external effects, valuation of benefits and costs, labor wages and perfect completion are to be studied in detail. Though these effects constitute a cost or benefit to the society, they are not reflected in the project's financial receipts or in expenditures. In addition to this, some aspects of ecological damage and pollution of soil, water or air may have to be taken into account in the analysis. It follows that the valuation inputs and outputs of the project differ in financial and economic analysis. Hence, it is customary to introduce certain conversion factors to transform financial prices into economic prices.

Conversion Factors

The financial analysis simply uses the market prices of inputs and outputs whereas in economic analysis, the prices that express the real scarcity of the inputs and outputs have to be used. Some conversion factors are required to transform financial prices into economic prices. These factors are derived according to the commodity and the region of operation. In many cases, however, it is neither possible nor practical to use specific standard conversion factors.

Capital and Interest

The valuation of capital in terms of the rate of interest or the rate of discount constitutes the economist's interest for evaluating any project proposals. Sometimes, it becomes beyond the limits of the planner to determine the economic rate of interest (accounting rate of interest). In fact, a responsible government agency should determine the rate of interest to be used in the economic analysis in such a way that it helps in adopting a uniform rate for all projects and the results of the analysis comparable.

Economic Appraisal

The economical appraisal of any ground water development/recharge project is critical as the benefits are not only indirect but also time-consuming. Certain guidelines for economic appraisal are summarized below:

a. The inputs and outputs should be distinguished as ‘tradables’ and ‘nontradables’.
b. The assumption always is that the project under consideration will not change the price of the output.
c. Compared to the calculation in financial prices, some adjustments have to be made by applying appropriate conversion factors converting financial prices into economic prices.
d. The economic analysis should not only consider the effects for the producer, but also for the user.
e. Labor and wages under skilled and unskilled categories have a special significance in the valuation for economic analysis. The real contribution to the economy probably varies by region, type of labor and season. Hence, an extensive labor market survey is required for proper analysis.
f. Although the computational part of the appraisal is rather straightforward, the essential purpose of the exercise is to ensure that the project has a positive effect on the efficient application of national resources.
g. The outcome of the economic appraisal of a development project is decisive for the acceptance of the project.
h. If the project is acceptable from the economic point of view but not from the financial, it implies that the project will contribute to an efficient application for national resources with additional requirement of financial support.
i. If the project yields attractive returns to the Government but does not make a contribution to

the efficient use of national resources, it requires additional policy measures to rectify the situation.

1.1.3 Social Benefit Cost Analysis

The financial and economic benefit cost analyses are concerned mainly with the profitability of investments and on the efficient use of national resources. However, it is to be borne in mind that not only the growth of the wealth and welfare, but who gets the benefit out of it is also equally important. Sometimes, a ground water development/recharge project may have excellent financial and economic returns but the benefits are distributed to only a small group of people who are already relatively well-off. In such cases, social justice has not occurred. In other words, not only the growth but the distribution of benefits is important. This is the essence of Social Benefit Cost analysis.

The task becomes easy if the impact of the development project on the distribution of welfare and the proper beneficiaries are identified. Social Benefit Cost analysis is, thus, a part of the project appraisal and is always pursued by major International Financing Agencies.

It should be realized that any project, validated on the basis of social welfare considerations would have a definite recognized price. Hence, as a marker, the project preferred on the basis of social point of view will not be identical to that which is preferred from an economic point of view.

1.2 Socio-economic and Financial Appraisal of Artificial Recharge Schemes

The economic and institutional aspects of artificial recharge ground water are important but somewhat elusive. Experiences with full-scale artificial recharge operations of ground water in India are still limited and, as a consequence, the cost information on such operations is incomplete. The available data in certain hydrogeological environs, where recharge experiments are initiated and are in progress, suggests that the costs of ground water recharge vary substantially. These costs are a function of availability of source water, conveyance facilities, civil constructions, land acquisition, and ground water pumping and monitoring.

Apart from the purely technical aspects of ground water utilization, the economical and institutional problems may ultimately prove more critical in determining the efficiency of the artificial recharge projects. Although literature on the economics of ground water deals with specific problems of ground water management, there are certain common principles, which have to be taken care of for assessment of costs and benefits.

User Cost

The change in storage of ground water at any time is simply the difference between the recharge rate and extraction rate. It is also to be noted that the effective use of ground water is attained when the difference between benefits and costs is maximized in positive direction over time. In fact, the water pumped in the current period results in lowered water table in future periods. Therefore, the incremental cost of pumping from thus lowered level has to be accounted for, and is called the user cost. Under deteriorated conditions of lowered water levels, the overall pumping should be carried over to the point where the benefits from the last unit of water exceed the extraction cost plus the user cost. Similarly, if the ground water levels rise by any other mechanism developed through certain artificial recharge methods, the extraction cost becomes minimized over a time with no user cost. Hence, the change in the user cost over a time is dependent upon the discount rate and the effects of ground water storage on pumping costs.

Steady State Pumping Condition

In certain circumstances, over-exploitation of ground water may be optimal and efficient from economic point of view. This becomes true in cases where the total benefits generated through excessive ground water development are much more or quite high relative to total costs. At this juncture, the over-exploitation may be fully justified from an economic perspective. Of course, it is evident that the over draft conditions could not be continued indefinitely.

In some situations, the ground water level will be lowered until a point is reached at which the costs of extraction are greater than the benefits generated from various uses to which the water has been put. At this point, it is not economical to abstract ground water at rates greater than the recharge rate. Thus, the relative magnitude of costs of pumping and benefits ensure that only the annual recharge is being extracted. This means that the long-term pumping rates should not exceed long term recharge rates for a given aquifer. This ultimate hydrologic condition is referred to as the Steady State (i.e., the difference between the recharge rate and the extraction rate equals zero)

Artificial Recharge Component

For obtaining the economics of artificial recharge of ground water, an artificial recharge component is to be included in the analysis. Additionally, the source water cost and the benefits of use must be also be accounted for. It is essential to establish whether supplemental sources of water should be used for ground water recharge or for direct use. It is economically not viable if the price charged for ground water is less than the marginal cost of recharge. Further, the selection of appropriate artificial recharge structure suitable for the existing hydrogeological environment of the proposed area is a must. Otherwise, the benefit cost analysis and other economic measures for ground water use and management are likely to yield negative results.

The principles mentioned above guide the socio-economic and financial analysis of projects for artificial recharge to ground water. A step by step description of inputs and outputs are shown below for developing benefit cost analysis of recharge projects. Under this, it is necessary to highlight some of the inputs, specially the recharge inputs for some proposed artificial recharge structures, for better appraisal of the benefits.

1.3 Recharge Potential of Some Artificial Recharge Structures

Various artificial recharge experiments carried out by different organizations in India have established the feasibility of the methods in unconfined, semi-confined and confined aquifer systems. However, economic considerations make some particular methods viable in a particular area or for a particular aquifer. Consequently, it is possible to estimate upper limits of quantities of recharge through each artificial recharge structure based on studies carried out in different hydrogeological set-ups. Some of the typical recharge estimates are given below in general form with field examples from alluvial unconfined/semi confined aquifer systems.

Check Dam & Percolation Tank

i) Average water spread area = 'a' Hectares

ii) Seepage Rate = 'b' Cu m/sec/million sq m of wetted perimeter

iii) Inflow and storage period = 'c' Days

iv) Quantity of induced recharge in MCM

$$\frac{a \times 10 \times b \times 3600 \times 24 \times c}{10^6 \times 10^6} = \text{'P' MCM}$$

As a case example, assuming the water spread area of each check dam/percolation tank as 10 hectares, inflow and storage period of 100 days, monsoon seepage rate as 2.6 cu m/sec/million sq m of wetted perimeter and considering 4 to 5 floods during the rainy season, surface water recharge of nearly 2.25 MCM through each structure could be considered as realistic. Further, by construction of recharge tube well in the storage area, increase in the quantum of recharge could be ensured.

Spreading Channel

i)	Total wetted perimeter for full length of spreading channel = 'a' million Sq m	=	'a' million sq m
	a. Seepage Rate = 'b' Cu m/sec/million sq m of wetted wetted perimeter	=	'b' Cu m/sec/million sq m of
ii)	Availability of water in Channel	=	'c' days.
iii)	Quantity of induced recharge in M Cu m		

$$= \frac{a \times 10 x\ b \times 3600 x\ 24 \times c}{10^6 \times 10^6} = \text{'q' M Cu}$$

As a case example, considering the length of spreading channel as 10 km with bottom width of 3 m and top width of 5 m with 1:1 slope, the total wetted perimeter for full 10 km length of spreading channel works out to 0.085 million Sq m. Further, assuming the seepage rate of 10 cu m/sec/million Sq m of wetted perimeter and availability of recharge water for nearly 100 days in a year, it is estimated that a recharge of nearly 5 MCM/yr could be made into the aquifer system.

Recharge Tube well

i. Injection recharge rate = 'a' lps
ii. Number of days of recharge = 'b' days
iii. Quantity of recharge in MCM = 'R'

$$= \frac{a \times 86.4 \times b}{10^6} = \text{'R' MCM}$$

Considering the injection rate of 5 lps, nearly 0.15 MCM of water could be artificially recharged through each injection well in a year.

Underground Dams /Subsurface Dykes

Considering a cut-off at 9m and area of effective sub-surface storage of 100 hectares in up-stream of each under ground check dam, the specific yield of river bed as 20% and 4 to 5 wet spells during the rainy period of 100 days, it is expected that through each underground dam with 2 recharge tube wells, about 1.0 MCM ('S' MCM) of surface water could be artificially recharged into the aquifer system.

For any programme of artificial recharge to ground water, the above unit recharges estimated for each method should be multiplied by the proposed number of units under each category such that the total cumulative input to the ground water would be quantified. This information is vital for the financial, economic and social benefit analysis.

1.4 Financial Outlay

For arriving at the cost outlay for the artificial recharge projects, it is essential to identify the mechanism through which the whole process occurs. It is not only the costs of the structures of the proposed measures but also certain relevant costs involved in pre and post project studies which are essential to be included in the total costs. Costs involved for the investigative techniques such as Hydrogeological, Hydrometeorological, Hydrological, Geophysical and Geochemical studies for identifying suitable locations/areas for implementing artificial recharge schemes should be included. If possible, financial assistance should be provided to organize small pilot study projects before undertaking any major projects.

It is also necessary to take environmental aspects into consideration and, hence, financial support should be provided to the afforestation works in the vicinity of the project area. This attempt will enhance the ground water recharge, reduce soil erosion and improve the health of the watershed.

Watershed management through soil management and water conservation methods provides an enhanced ground water recharge into the flow system. Therefore, it is recommended that appropriate fund allocation for watershed management should be provided.

Monitoring of the ground water regime for assessing the sustainability of the project objectives and benefits requires certain committed funds. The funds may be utilized for procuring instruments, setting up of laboratories, research and development etc.

The summarized details of Cost Outlay of artificial recharge projects are given below:

a.	Cost of pre-investigative Studies	Rs. CR1
b.	Cost of afforestation works	Rs. CR2
c.	Cost of watershed management works	Rs. CR3
d.	Cost of construction of the suggested measures	Rs. CR4
e.	Cost of monitoring ground water regime	Rs. CR5

	Total cost of project	**Rs. CR**

1.5 Benefits of Suggested Measures

As mentioned earlier, the present day trend of over exploitation of ground water has resulted in faster depletion of water levels. As a result, the users have to periodically replace/repair the pumps and in many cases re-drill tube wells. This phenomenon, which has now become common in many parts of the country results in very high operational costs toward ground water development over a period of time.

Augmentation of ground water resources in such areas will not only help in bringing up or in stabilizing of water levels but will also reduce the user's financial commitments toward the replacement of pumps or re-drilling of tube wells.

Since artificial recharge of ground water is a time-consuming process, the benefits would be felt only over a period of time and will mostly be of indirect nature, as the measures adopted are mainly oriented towards protecting and improving the natural ground water environment.

It is fair to assume that once the aquifer system is augmented with additional recharge component, the institutional finance for ground water development will be available to the users. The indirect benefits, which are economical as well as social, could be summarized as below:

a. Control over further depletion of ground water levels, obviating the need for replacement of high head pumping machinery.
b. Sustained abstraction of ground water ensures long term irrigation, manifold increase of agricultural area and economic cropping patterns.
c. Minimization of frequency of re-drilling of tube wells over time
d. Changes in the energy consumption scenario due to rise/ stabilization of water levels.
e. Restoration of well irrigation in areas where wells have gone dry.
f. Provision of drinking water facilities in habitations hitherto having no such sources
g. Increase in employment potential by using local labor either skilled or semi-skilled.
h. Increase in per-capita income of the local people resulting in better living standards. People's participation in the development work enhances the benefits.
i. Restoration of institutional finance not available earlier for construction of wells / tube wells in overexploited areas.
j. Environmental improvements helping in reduction of pollution hazards.

1.6 Financial Appraisal of the Benefits

It is slightly elusive to view the indirect benefits in real financial terms. In order to have a near-realistic assessment, the financial amounts are shown in general form below.

i. Considering 'Z' MCM of additional recharge to ground water which otherwise goes as surface Runoff, its total value even at a rate of Rs. per 1 m3 works out to rupees 'R1.'
ii. The replacement of pumps, say every 5 years for about 100 tube wells per year result in saving

of Rupees 'R2' per year (Cost of the pump around Rs. 7,500).

iii. On an average, 100 tube wells are re-drilled every year. The annual savings on this account are expected to be nearly Rupees 'R3' (Average cost would be around Rs.1,75,000 per well in alluvial area).

iv. Considering the electrical energy saving of 500 KW per tube well per year, the total savings for 'X' number will be of the order of 500 x 'X' KW. Even if valued at the rate of Rs. 1.0 per KW, the total annual saving could be of the order of nearly Rupees 'R4'.

v. Considering a surplus ground water potential of 'Z1' MCM through the above measures after meeting the existing abstraction, an additional irrigation potential of nearly Z1 MCM x h hectare = H hectares (1 MCM irrigates 100 to 150 hectares under normal cropping pattern) is created.

vi. Considering an average return at the rate of 'r' Rupees per hectare under the existing cropping pattern, the additional income from agricultural return is likely to be H x r = 'R5' Rupees (one Hectare yields an average annual return of Rs. 15,000 under existing cropping pattern).

vii. The financial benefits are summarized below for assessing the benefit cost ratio of measures for artificial recharge to ground water (**Table 1.0)**

Table 1.0 - Summarized Financial Benefits of Artificial Recharge Schemes

a.	Cost of surface water which goes as runoff	Rs. R1
b.	Savings against pump replacements	Rs. R2
c.	Savings against re-drilling of tube wells	Rs. R3
d.	Savings in electrical energy consumption	Rs. R4
e.	Income form additional agricultural production	Rs. R5
f.	**Total financial benefits**	**Rs. BR**

1.7 Profitability Analysis

The benefit cost ratio is the ratio of present value of total benefits to the present value of total costs. This ratio expression can be slightly enlarged to suit the ground water recharge projects, which are mainly financed by State or Central Government Departments. In most such projects, the returns to the Government are minimal when compared to investment of capital on other projects.

Therefore, it is assumed that the annual benefits of 'BR' Rupees will offset the capital cost investment of Rupees 'CR' in a tolerable period of say 'Y' years. Application of this criterion is essential to determine the profitability of the project. For working out a B/C ratio, it is customary to take the ratio of total benefits to the Annual Cost of expenditure (in Rupees 'AR') for the ground water development projects.

This annual cost of expenditure includes i) Interest loss at the market rate of the total cost, ii) Maintenance & Repair charges at the feasible percentage rate of the total cost iii) Depreciation of civil works at the rate permissible, and iv) Some miscellaneous expenditure at a reasonable percentage of the total cost. The above approach is detailed below for the estimation of B/C Ratio (**Table 9.2)**

Table 2 - Computation of Annual Cost of Expenditure

A.	Annual Total Benefits	Rs. BR
B.	Cost of the Total Project	Rs. CR
C.	Annual Expenditure	
	a) Interest loss 'n' say 10% b) M & R charges say 2.5% c) Depreciation of civil works n say 5% d) Miscellaneous expenditure n say 1% **Total**:	Rs. AR1 Rs. AR2 Rs. AR3 Rs. AR4 ----------- **Rs. AR**

Therefore, the Overall Benefit Cost Ratio = $\frac{\mathbf{BR}}{\mathbf{AR}}$

If the B/C ratio is greater than 1, the project is considered to be attractive. As most of the ground water recharge projects belong to 'social obligatory' type of expenditure on the part of Government, weightage towards the B/C Ratio should be viewed with less priority

1.8 Case Study

Conservation of water through artificial recharge is often the only alternative in drought- prone areas.

Construction of percolation tanks is practiced in Maharashtra to conserve and recharge the ground water in drought prone areas of the State.

A detailed study of 7 percolation tanks in parts of Baramati taluka of Pune District covering an area of 66 Sq.km with an average storage capacity of 0.13 MCM was taken up for financial analysis to see whether they are cost effective or not.

Based on the study, Dr. S.S.Rao of NABARD has concluded that the financing of percolation tanks is not economically viable without any subsidy from Government. The tanks not only serve for recharging the ground water but also serve as community tanks, are environment friendly and help control soil erosion. Therefore, it was recommended based on the study that a minimum 75% of subsidy should be allowed for construction of tanks. Similarly, 30% of subsidy should be allowed for the construction of wells and for the costs of pump sets. The summarized results of the case study given below indicate the required percentage of subsidy for keeping the project cost effective and viable (**Table 3).**

Table 3 - Summarized Results of Case Study

Si. No	**Indicator**	**Subsidy Nil Well (30%) P.Set (30%)**	**Subsidy for Tank (50%) Well (30%) P.Set (30%)**	**Subsidy for Tank (75%)**
1	B/C ratio at 15% discounted rate	0.50	0.82	1.16
2	RR at 15% discount	0.38	9.11	19.49
3	Water rate in Rs/Cu m	3.66	1.71	1.60 1.08 Estt. & OM Tank (100 % subsidised)
4	Repayment Schedule % of repayment to net incremental income 1st year	182.50	96.40	57.30

	2nd to 9th year 10th to 15th year	237.30 221.70	126.10 115.20	76.10 65.20

As seen from above, the scheme is not financially viable unless the Government provides a subsidy of at least 75% for tank and 30% for well and pump sets and also provide the charges for maintenance and establishment of tank during its construction and subsequent maintenance.

A formatted example on financial analysis of an artificial recharge Scheme is given below for a better understanding of the computational procedures (**Table 4**).

Table 4 - Format with an Example of Financial Analysis of Artificial Recharge scheme.

A) Scheme Information		
1	Type of scheme	**Percolation tank**
2	Location	Baramati Taluka, Pune District
3	Capacity of percolation tank	0.13 MCM
4	Total irrigated area prior to scheme	12 ha.
5	Additional irrigated area after scheme	10 ha.
6	Additional ground water structures after scheme	6 wells with pump sets
7	Life of the scheme	15 years
B) Investment Information		
1	Construction cost of AR scheme @ Rs. 9,000/1000 cu m	Rs.12,48,000
2	Cost of 6 Nos. additional wells @ Rs.22,500/- well	Rs.1,35,000
3	Cost of 6 nos. of pump sets (5 HP) @ Rs. 12,100 per set	Rs.72,600
4	Total cost of investment	Rs. 14,55,600
5	Government subsidy on construction cost of percolation tank	Rs. 9,36,000

	(75%)	
6	Government subsidy on wells and pump sets (30%)	Rs. 62,280
7	Cost of investment after subsidy	Rs. 4,57,320
8	Year wise cost of investment and income in percentage Cost: Income: Recurring Cost:	0 yr 1st yr 2 to 15th yr 100 0 0 0 50 100 0 50 100
C) Financial Information		
1	Interest rate on loan	11.5%
2	Repayment period for Tank and wells Pump sets	15 years 9 years
3	Recovery of instalments – First year Second year	Interest Capital-interest
4	Discharge from Pump sets, 6 nos, @ 5 lps	30 lps
5	Running cost of pump sets (Electricity)	Rs. 11.19/hr.
6	Replacement of pump sets	10 years
7	Residual value of pump sets at the end of 9th year	30%
8	Establishment charges @ 1% of cost of percolation tank	Rs. 12,480
9	O&M of percolation Tank @ 2% of cost of Percolation tank	Rs. 24,960
10	Land revenue (Rs/ha) a) Pre A.R.Scheme b) Post A.R. Scheme	 Rs. 80 Rs. 133

D. Comparison of Cropping Pattern, Yield, Cost of Cultivation and Rate of Crops for Pre and Post Period of Construction of Percolation Pond.

Cropping Pattern	Irrigation in ha.		Depth of Irr. (m)	No. Of Irr.	Yield Qtls/ha		Total Yield		Cost of cult./ha		Income Rs/qtl.	Gross	Income	Gross cost of Cultivation		Net income (Rs)		Water Req. (cum)	No. of pumping hours
	Pre	Post			Pre	Post	Pre	Post	Pre	Post				Pre	Post	Pre	Post		
Hyb. cotton	2	2	0.90	10	8	19	16	38	4000	5002	750	12000	28500	8000	10004	4000	18496	18000	167
Hyb. Maize	1	2	0.45	6	20	30	20	60	1500	2500	300	6000	18000	1500	5000	4500	13000	9000	83
Jawar	5	4	0.22	5	10	27	50	108	1000	2330	205	10250	22140	5000	9320	5250	12820	8800	81
Ground nut	4	4	0.15	6	5	17	20	68	2500	4854	800	16000	54400	10000	19416	6000	34984	6000	56
Wheat	0	4	0.45	6	0	25	0	100	0	3644	350	0	35000	0	14576	0	20424	18000	167
Gram	0	6	0.20	4	0	15	0	90	0	3414	500	0	45000	0	20484	0	24516	1200	111
Total	12	22										44250	203040	24500	78800	19750	124240	718000	665

E. Calculation of Incremental Income and Recurring Costs.

Si.No	Particulars	Pre (in Rs.)	Post (in Rs.)
1	Cost of cultivation	2 4,500.00	78,800.00
2	Interest on 75% of cultivation cost @ 11.5%	2 ,113.13	6 ,796.00
3	Land Revenue @ Rs 80/ha(pre) and @ Rs. 133 (post)	9 60.00	1 ,596.00
4	Running Costs of Pump Sets @ Rs. 11.19/hr	Nil	7,441.00
5	Total Cost	2 7,573.13	9 4,633.00
6	Gross Income	4 4 ,250.00	2 ,03,040.00
7	Net Income	16,676.87 (A)	1,08,406.50 (B)
8	Net Incremental Income (B-A)	-	91,729.63
9	Recurring Cost (Pre Cost-Post Cost) x 75% (25% of expenditure is expected to be incurred by the farmer)	-	50,295.28

F) Cash Flow Statement

Particular	Years															
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Initial Investment	457320	0	0	0	0	0	0	0	0	72600	0	0	0	0	0	
Recurring Cost	0	25148	50295	50295	50295	50295	50295	50295	50295	50295	50295	50295	50295	50295	50295	50295
Total Cost	457320	25148	50295	50295	50295	50295	50295	50295	50295	122895	50295	50295	50295	50295	50295	50295
Benefits	0	79395	158790	158790	158790	158790	158790	158790	158790	158790	158790	158790	158790	158790	158790	158790
Residual Value										21780						21780
Total Income	0	79395	158790	158790	158790	158790	158790	158790	180570	158790	158790	158790	158790	158790	158790	180570
Net Income	457320	54247	108495	108495	108495	108495	108495	108495	130275	35895	108495	108495	108495	108495	108495	130275

Summary of Economic Analysis

1.	Discount Rate	:	15%
2.	Net Present Cost (NPC)	:	649994
3.	Net Present Income (NPI)	:	755072
4.	Net Present Value (NPV)	:	105078
5.	BCR (NPV/NPC)	:	1.16
6.	IRR % when NPV=0	:	19.49

H) Repayment Schedule

Investments Details	**Bank Loan (Rs)**	**Ist Year (Int. only) (Rs)**	**2nd to 9th year (Cap +Int)**	**10th to 15th year (Cap + Int)**
Pump set (Elec.)	50,820	5,844	10,052	
Cost of A.R. Pro.	3,12,000	35,880	45,873	45,873
Cost of Wells	94,500	10,868	13,894	13,894
Total	**4,57,320**	**52,592**	69819	59767
% of Repayment to Net Incremental Income		**57.30**	**76.10**	65.20

I) Estimation of Economic Water Rate

1.	Equated Instalment	:	Rs. 69,819
2.	Annual Energy Cost for 665 hrs @ Rs. 11.19/hr	:	Rs. 7,441
3.	Establishment Charges 1% of Tank Cost	:	Rs. 12,480
4.	O&M of Tank 2% of Tank Cost	:	Rs. 24,960
5.	Total Annual Cost	:	Rs. 1,14,700
6.	Discharge (cu m/hr)	:	71,800

7.	Water Rate/cu m	:	Rs. 1.60
8.	Total Annual cost with 100% Subsidy on Estt. and O&M of Tank	:	Rs. 77,260
9.	Water Rate/cu m	:	Rs. 1.08

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