The case study on artificial recharge structures

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ABSTRACT

The artificial recharge structures aim at augmentation of groundwater reservoir by modifying the natural movement of surface water utilizing suitable civil construction techniques.

Artificial recharge techniques normally address following issues:

- To enhance the sustainable yield in areas where over development has depleted the aquifer.
- Conservation and storage of excess surfacewater for future requirements since these requirements often changes within a season or a period.
- To improve the quality of existing ground water through dilution.
- To remove bacteriological and other impurities from sewage and wastewater so that water is suitable for re-use.

The basic purpose of artificial recharge of groundwater is to restore supplies from aquifers depleted due to excessive groundwater development.

Keywords: Artificial recharge structure, Groundwater, Urbanization, Storage, Environment.

1. INTRODUCTION

The need of water is a challenging problem. Increasing demands for water joined with concerns for environmental protection require a variety of new water management tools. Such tools have application and benefits are worldwide. Tools for the usage of surface water and groundwater supplies is the artificial recharge structures.

Artificial recharge structures for the ground water is the process of adding water to an aquifer through human effort. Many different techniques and purposes exist for cause of Artificial Recharge Structures (ARS) of groundwater, but this discussion focuses on augmentation of a water supply for later use. Projects are varied but usually involve storing surplus surface water in an aquifer for later use. Recovery of the stored underground water commonly is by wells. [1]

Central Ground Water Board (CGWB) has taken up many demonstrative Artificial Recharge projects during the last two decades to develop the methodology and to transfer it to the state agencies for implementing in the similar hydrogeological environment in
hard rock terrain of Andhra Pradesh. Under the demonstrative projects, subsurface dykes, check dams, percolation tanks, recharge bore wells have been constructed to demonstrate the efficacy of these structures. The topic deals mainly with the methodology adopted for the construction of Artificial recharge structures and their impact on ground water regime for sustainable management in hard rock terrain of Andhra Pradesh. As part of the 100 per cent funding under Centrally Sponsored Scheme, Central Ground Water Board has promoted the Rain Water Harvesting and Artificial Recharge Projects (getting the work executed by the State Agencies) on demonstrative basis till recently.

Central Ground Water Board (CGWB) has taken up various steps during the last two decades to develop the methodology and to transfer it to the state agencies for implementing in the similar hydrogeological environment in the different terrains across the country. Under the demonstrative projects, subsurface dykes, check dams, percolation tanks, recharge bore wells have been constructed to demonstrate the efficacy of these structures. [2]

Artificial recharge is a process by which the groundwater reservoir is augmented artificially. The rapid urbanization and deforestation have considerably reduced the groundwater recharge in many parts of the world. The reduction in groundwater recharge and over exploitation of groundwater due to increasing demands, the groundwater table has been depleted in many parts of the world. For example, the groundwater table in some parts of Delhi has been depleted by 20 to 30 meters in a span of 60 years. It is the condition in other major cities in India and other parts of the world. As such, there is a need to increase the groundwater recharge by some artificial means. In this lecture, we will discuss some of the methods use for artificial recharge and the methods use in estimation of groundwater recharge.

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2. NEED FOR ARTIFICIAL RECHARGE STRUCTURE

The process of replenishment of groundwater is a slow process and is often unable to keep pace with the excessive and continued exploitation of ground water resources in various parts of the country. Artificial recharge efforts are aimed at augmentation of the natural movement of surface water into ground water reservoir through suitable civil construction techniques.

The rainfall in India is mostly limited to three months in a year. The natural recharge to ground water reservoir is restricted to this period only in a major part of the country. Artificial recharge techniques aim at extending the recharge period in the post-monsoon season for about three or more months, resulting in enhanced sustainability of ground water sources during the lean season. [4]

There is thus a need to prepare a systematic implementation plan for augmenting ground water resources under various hydrogeological situations. However, specific emphasis needs to be given in the areas where ground water levels are declining and water scarcity is being experienced. In this report, emphasis has been given to the areas with declining trend and deep ground water levels. [5]

3. TYPES OF ARTIFICIAL RECHARGE STRUCTURES

A. Percolation Tank

Percolation tanks are the structures for recharging ground water. These are generally constructed across streams and bigger gullies in order to impound a part of the run-off water. This water, in due course, finds its way into subsoil and recharges the found water. This leads to better recuperation of wells in the downstream areas. Such ponds have become popular in many a place. [6]

![Percolation Tank Diagram](image)

Fig 3.1 Percolation Tank [7]

In Maharashtra, there is legislation to cover percolation tanks. The water is not used for surface irrigation. In Tamil Nadu, where there is over-exploitation of ground water, farmers are now volunteering to spare land for percolation tanks. In the Saurashtra region of Gujarat these tanks are constructed for recharging wells that support peanut production.

B. Check Dam

A check dam is a small, sometimes temporary, dam constructed across a swale, drainage ditch, or waterway to counteract erosion by reducing water flow velocity. Check dams themselves are not a type of new technology; rather, they are an
ancient technique dating all the way back to the second century A.D. Check dams are typically, though not always, implemented as a system of several check dams situated at regular intervals across the area of interest. [8]

Fig 3.2 Check Dam

A typical check dam configuration of height (H), horizontal distance (L), slope of channel (Sc), slope of line connecting spillway and foot of upstream check dam (Se). [9]

C. Recharge Well

A recharge well pushes back surface water into the groundwater system. Usually, a recharge well is one metre in diameter and six metres deep, lined with concrete rings having perforations. These perforations let water seep from the sides. The rings line the recharge well from bottom to top with a steel or concrete ring closing it. [10]

Fig 3.3 Recharge Well [11]

4. PLANNING OF ARTIFICIAL RECHARGE PROJECTS

A. Identification Area: The artificial recharge projects are site specific and even the replication of the techniques from similar areas are to be based on the local hydrogeological and hydrological environments. For the selection of artificial recharge structure site, the first task is to identify the factors facilitating recharge to take place. To find out the suitable sites for nala bund, percolation tank etc, and the following criteria are used:

1. Site selection criteria for nala bunds:
   - The nala bunds should be preferably located in area where contour or graded bounding of lands have been carried out.
   - Nala bunds can be constructed across bigger streams of second order in areas having gentle slopes.
   - The soil in downstream of the bund should not be prone to water logging.

2. Site selection criteria for percolation tanks:
   - A tank could be located across small streams by creating low elevation.
   - Terrain with highly fractured and weathered rock for speedy recharge.
   - Soils in the catchment area should preferably be of light sandy kind to avoid silting up of the tank bed.

3. Other site selection criteria’s:
   - Where ground water levels are declining due to over-exploitation
   - Where substantial part of the aquifer has already been desaturated i.e. regeneration of water in wells and hand pumps is slow after some water has been drawn
   - Where availability of water from wells and hand pumps is inadequate during the lean months
   - Where ground water quality is poor and there is no alternative source of water. [12]
B. Scientific Inputs: In order to plan the artificial recharge schemes following studies are needed

i. Hydrometeorological Studies:

These studies are undertaken to understand the rainfall pattern and evaporation losses and thereby to determine the amount of water that would be available from a given catchment and the size of storages to be built. The main factors to be considered are:

- Minimum annual rainfall during the previous 10 years.
- Number of rainy spells in a rainy season and duration of each spell.
- Amount of rainfall in each rainy spell.
- Rainfall intensity (maximum) 3 hourly, 6 hourly etc. as may be relevant for a region. As a general guide, the one, which causes significant runoff and local flooding, should be adopted.

ii. Hydrological Studies:

Before undertaking any artificial recharge project, it is a basic prerequisite to ascertain the availability of source water for the purpose of recharging the ground water reservoir. For determining the source water availability for artificial recharge, hydrological investigations are required to be carried out in the Watershed/Sub-basin/basin where the artificial recharge schemes are envisaged. Four types of source water may be available for artificial recharge viz.

- Insitu precipitation on the watershed.
- Surface (canal) supplies from large reservoirs located within basin.
- Surface supplies through trans basin water transfer.
- Treated municipal and industrial wastewaters.

'In situ' precipitation will be available almost at every location but may or may not be adequate to cause artificial recharge but the runoff going unutilised outside the watershed/ basin can be stored/ transmitted through simple recharge structures at appropriate locations. In addition, none, one or both of the other two sources may be available in any of the situations; the following information will be required:

a) The quantity that may be diverted for artificial recharge.
b) The time for which the source water will be available.
c) The quality of source water and the pre-treatment required.
d) Conveyance system required to bring the water to the recharge site.

Hydrological studies are undertaken to work out surplus monsoon run off which can be harnessed as source water for artificial recharge.

iii. Soil Infiltration Studies:

In case of artificial recharge through water spreading methods, soil and Land use conditions, which control the rate of infiltration and downward percolation of the water applied on the surface of the soil, assume special importance. Infiltration in its most narrow and precise sense can be defined as "The process water entering into a soil through the soil surface". Although a distinction is made between infiltration and percolation (the movement of water within the soil), the two phenomena are closely related since infiltration cannot continue unimpeded unless percolation removes infiltrated water from the surface soil. The soil is permeated by noncapillary channel through which gravity water flows downward towards the ground water, following the path of least resistance. Capillary forces continuously divert gravity water into pore spaces, so that the quantity of gravity water passing successively lower horizons is steadily diminished. This leads to increasing resistance to gravity flow in the surface layer and a decreasing rate of infiltration as a storm progresses. The rate of infiltration in the early phases of a storm is less if the capillary pores are filled from a previous storm. Infiltration capacity depends on many factors such as soil type, moisture content, organic matter, vegetative cover, season, air entrapment, formation of surface seals or crusts etc. Of the soil characteristics affecting infiltration, non-capillary porosity is perhaps the most important. Porosity determines storage capacity and effects resistance to flow. Thus, infiltration tends to increase with porosity. Vegetal cover increases infiltration as compared with barren soil because:

- it retards surface flow giving the water additional time to enter the soil
- the root system makes the soil more pervious and
- the foliage shields the soil from raindrop impact and reduces rain packing of surface soil.

As water infiltrates soil under natural conditions, the displacement of air is not complete even after many hours. Air spaces in the soil and intermediate zones interfere with infiltration as air is not pushed out by the infiltrating water but is gradually absorbed by water. Due to these phenomena, infiltration rate may start rising towards a new high after a few days of continuous application of water. Surface conditions have a marked effect on the infiltration process and the formation of surface seals or crusts, which forms under the influence of external forces such as raindrop impact and mechanical compaction or through staking, reduces the rate of infiltration.

iv. Hydrogeological Studies:
A detailed hydrogeological study of the project area and the regional picture of hydrogeological setting is necessary to know precisely the promising locations for recharge and the type of structures to be built for the purpose. A desirable first step is to synthesize all the available data on hydrogeology from different agencies. The regional geological maps indicate the location of different geological strata, their geological age sequence, boundaries/contacts of individual formations and the structural expressions like Strike, Dip, Faults, Folds, Flexures, Intrusive bodies etc. These maps also bring out correlation of topography and drainage to geological contacts.

The Map providing information on regional hydrogeological rock units, their ground water potential and general pattern of ground water flow and chemical quality of water in different aquifers are necessary.

Satellite Imagery maps provides useful data on geomorphic units and lineaments, which govern the occurrence and movement of, ground water.

A detailed hydrogeological study besides the regional picture of hydrogeological set up available from previous studies is therefore imperative to know precisely the promising hydrogeological units for recharge and correctly decide on the location and type of structures to be constructed in field.

The hydrogeological investigations required before implementation of an artificial recharge scheme are given below:

(i) Detailed Hydrogeological mapping the purpose of hydrogeological mapping is to present the following maps, which facilitate in the analysis of the ground water regime and its suitability to artificial recharge schemes.
   a) Map showing hydrogeological units demarcated on the basis of their water bearing capabilities, both at shallow and deeper levels.
   b) Map showing ground water contours to determine the form of the water table and the hydraulic connection of ground water with rivers, canals etc.
   c) Map showing the depths to the water table are usually compiled for the periods of the maximum, minimum and mean annual position of water table.
   d) Maps that show amplitudes of ground water level fluctuations and the maximum position of the water table of considerable importance for artificial recharge studies.
   e) Maps showing piezometric head in deeper aquifers and their variations with time.
   f) Maps showing ground water potential of different hydrogeological units and the level of ground water development.
   g) Maps showing chemical quality of ground water in different aquifers.

vi. **Geophysical Studies:**

These studies are expensive and time consuming and require high levels of skill and sophisticated equipment. These are, therefore, economically viable for large ground water development projects and are not suitable for small artificial recharge schemes at local/village level.

a) The main purpose of applying geophysical methods for the selection of appropriate site for artificial recharge studies is mostly to help and assess the unknown subsurface hydrogeological conditions economically, adequately and unambiguously. Generally, the prime task is to compliment the exploratory programme. Mostly it is employed to narrow down the target zone, pinpoint the probable site for artificial recharge structure and its proper design.

b) Nevertheless, the application of geophysical methods is to bring out a comparative picture of the sub-surface litho environment, surface manifestation of such structures, and correlate them with the hydrogeological setting.

c) Besides defining the sub-surface structure and lithology, it can identify the brackish/fresh ground water interface, contaminated zone (saline) and the area prone to seawater intrusion.

vi. **Chemical Quality of Source Water:**

Problem which arise as a result of recharge to ground water are mainly related to the quality of raw waters that are available for recharge and which are generally require some sort of treatment before being used is 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 brought to the environmental conditions. The chemical and bacteriological analysis of source water besides that of ground water is therefore essential. [13]

5. **ADVANTAGES OF ARTIFICIAL RECHARGE STRUCTURES**

Artificial recharge is becoming increasingly necessary to ensure sustainable groundwater supplies to satisfy the needs of a growing population. The benefits of artificial recharge can be both tangible and intangible. The important advantages of artificial recharge are:

- Evaporation losses are negligible.
- Subsurface storage space is available free of cost and inundation is avoided.
- Quality improvement by infiltration through the permeable media.
- Biological purity is very high.
- Temperature variations are minimum.
- Water stored underground is relatively immune to natural and man-made catastrophes. [14]
6. CASE HISTORIES OF ARTIFICIAL RECHARGE IN INDIA

A. Artificial recharge to ground water from runoff in Kushak Nala, New Delhi
   In the Kushak Nala which is having a catchment of 3.5 sq.km., about 0.142 mcm water is going as runoff. This excess water is being recharged to ground through 2 Gabion bunds and 2 nala bunds. It is anticipated that a net rise of 0.21 m in ground water level will occur in about 3.5 sq.km. area.

B. Artificial recharge to ground water from Brahm Sarovar, Kurukshetra, Haryana
   The Kirmich and Samaspur villages of Kurukshetra district are surrounded by the accumulated rainwater in depressions round the year. Ground water level is very deep i.e. more than 11 m and area is experiencing continuous decline of water level at the rate of 30 cm/yr. The presence of clay at shallow depths does not allow surface water to seep naturally into ground water reservoir. To artificially recharge stagnant water in depressions recharge shafts piercing through impermeable clay horizons are being constructed. Rise in water level in 500 ha is expected to be around 1.12 m. [15]

C. Artificial Recharge to ground water at Link Road connecting NH-8 to Dwarka, New Delhi:
   Delhi Development Authority has constructed 60 m wide road to connect Dwarka with N.H.-8. The runoff generated from the road is being collected in a drain constructed adjacent to the road. A series of shafts were constructed to recharge the runoff generated from the road. The shafts were constructed at a spacing of 250 to 300 m distance on both sides of the road.

D. Rain Water Harvesting and Artificial Recharge to Ground Water at Bungalow No. 78, Lodhi Estate, New Delhi:
   The main objective of this particular project is to propagate the concept of rainwater harvesting through a live demonstration project. The total area of the bungalow is 2810 sq m. The complex consists of main building, guesthouse, servant quarters, paved areas, roads and green lawns. Out of the total area of 2810 sq m, 2500 sq.m has been considered for effective rainwater harvesting through artificial recharge to ground water. [16]

E. Groundwater Recharge in Pulakuntlapalle Micro Hydrological Unit, Andhra Pradesh:
   Pulakuntlapalle micro hydrological unit is located in primary catchment area of Dighuvetigadda Hydrological Unit in Ramasamudrmandal, Chittoor dist (Figure.3). The study area (322 Ha) lies between 130 27’ 32” N to 130 26’ 12” N latitude and 780 23’ 18” E to 780 24’ 10” E longitude. Recharge techniques executed are described below:
   De-siltation of the tanks done fully of depth where the fracture system/ weathered granite system is traversing. Desilted material was used for both tank bund strengthening and application in catchment area fields. The water stored in the pit after rain infiltrates into the aquifer zone as recharge. The stored water spreads into the aquifer zone to all directions and recharging the groundwater. Three injection wells at Utlavani Cheruvu, Bayya Reddy Cheruvu and Kothakunta drilled to a depth of 400 feet at pre-defined location based on the Geophysical Investigations. Recharge shaft constructed to ensure the higher rate of good quality recharge to the deeper aquifers. One check dam was constructed to conserve the soil moisture and to maintain the ecological balance to some extent in the vicinity. [17]

7. REFERENCES