5.4 ARTIFICIAL RECHARGE OF GROUNDWATER

INTRODUCTION

The artificial recharge to ground water aims at augmentation of ground water reservoir by modifying the natural movement of surface water utilizing suitable civil construction techniques. Artificial recharge techniques normally address to following issues –

(i) To enhance the sustainable yield in areas where over-development has depleted the aquifer.

(ii) Conservation and storage of excess surface water for future requirements, since these requirements often changes within a season or a period.

(ii) To improve the quality of existing ground water through dilution.

(iv) To remove bacteriological and other impurities from sewage and waste water so that water is suitable for re-use. The basic purpose of artificial recharge of ground water is to restore supplies from aquifers depleted due to excessive ground water development.

Basic Requirement for Artificial Recharge Projects

a) Availability of non-committed surplus monsoon run off in space and time.

b) Identification of suitable hydrogeological environment and sites for creating subsurface reservoir through cost effective artificial recharge techniques.

ARTIFICIAL RECHARGE TECHNIQUES AND DESIGNS

A wide spectrum of techniques are in vogue to recharge ground water reservoir. Similar to the variations in hydrogeological framework, the artificial recharge techniques too vary widely. The artificial recharge techniques can be broadly categorised as follows:-

a. Direct surface techniques

- Flooding
- Basins or percolation tanks

• Stream augmentation

• Ditch and furrow system

• Over irrigation

b. Direct sub surface techniques

• Injection wells or recharge wells

• Recharge pits and shafts

• Dug well recharge

• Bore hole flooding

• Natural openings, cavity fillings.

c. Combination surface – sub-surface techniques

• Basin or percolation tanks with pit shaft or wells.

d. Indirect Techniques

• Induced recharge from surface water source.

• Aquifer modification.

Besides above, the ground water conservation structures like ground water dams, sub-surface dykes or locally termed as Bandharas, are quite prevalent to arrest sub-surface flows. Similarly in hard rock areas rock fracturing techniques including sectional blasting of boreholes with suitable techniques has been applied to inter-connect the fractures and increase recharge. Cement sealing of fractures, through specially constructed bore well has been utilised in Maharashtra to conserve sub-surface flow and augment bore well yield. (A schematic diagram of these is given in Fig. 1).

Artificial Recharge Structures

1 Ditch and Furrow Method: In areas with irregular topography, shallow, flat bottomed and closely spaced ditches or furrows provide maximum water contact area for recharge water from source stream or canal. This technique requires less soil preparation than the recharge basins and is less sensitive to silting.

Generally three patterns of ditch and furrow system are adopted.

Lateral Ditch Pattern

The water from stream is diverted to the feeder canal/ditch from which smaller ditches are made at right angles. The rate of flow of water from the feeder canal to these ditches is controlled by gate valves. The furrow depth is kept according to the topography and also with the aim that maximum wetted surface is available along with maintenance of uniform velocity. The excess water is routed to the main stream through a return canal along with residual silt.

Dendritic Pattern

The water from stream can be diverted from the main canal to a series of smaller ditches spread in a dendritic pattern. The bifurcation of ditches continues until practically all the water is infiltrated in the ground

Contour Pattern

The ditches are excavated following the ground surface contour of the area. When the ditch comes closer to the stream a switch back is made and thus the ditch is made to meander back and forth to traverse the spread are repeatedly. At the lowest point down stream, the ditch joins the main stream, thus returning the excess water to it.

Site Characteristics and Design Guidelines

a. Although this method is adaptable to irregular terrain, the water contact area seldom exceeds 10 percent of the total recharge area.

b. Ditches should have slope to maintain flow velocity and minimum deposition of sediments.

c. Ditches should be shallow, flat-bottomed, and closely spaced to obtain.

Maximum water contact area. Width of 0.3 to 1.8 m. are typical d.

A collecting ditch to convey the excess water back to the main stream channel should be provided. 3.1.2 Percolation Tanks (PT) / Spreading Basin

These are the most prevalent structures in India as a measure to recharge the ground water reservoir both in alluvial as well as hard rock formations. The efficacy and feasibility of these structures is more in hard rock formation where the rocks are highly fractured and weathered.

In the States of Maharashtra, Andhra Pradesh, Madhya Pradesh, Karnataka and Gujarat, the percolation tanks have been constructed in plenty in basaltic lava flows and crystalline rocks. A typical design of PT .

The percolation tanks are however also feasible in mountain fronts occupied by talus scree deposits. These are found to be very effective in Satpura Mountain front area in Maharashtra. The percolation tanks can also be constructed in the Bhabar zone. Percolation tanks with wells and shafts Percolation tanks are also constructed to recharge deeper aquifers where shallow or superficial formations are highly impermeable or clayey with certain modification. Recharge wells with filter are constructed in the Percolation Tanks and the stored water is Moti Ranjan and Bhujpur, Mandvi Kutch district, Gujarat.

Important Aspects of Percolation Tanks:

a. A detailed analysis of rainfall pattern, number of rainy days, dry spells, and evaporation rate and detailed hydrogeological studies to demarcate suitable percolation tank sites.

b. In Peninsular India with semi arid climate, the storage capacity of percolation tank be designed such that the water percolates to ground water reservoir by January since the evaporation losses would be high subsequently.

c. Percolation tanks be normally constructed on second to third order stream since the catchment so also the submergence area would be smaller.

d. The submergence area should be in uncultivable land as far as possible.

e. Percolation tank be located on highly fractured and weathered rock for speedy recharge. In case of alluvium, the bouldary formations are ideal for locating Percolation Tanks.

f. The aquifer to be recharge should have sufficient thickness of permeable vadose zone to accommodate recharge.

g. The benefitted area should have sufficient number of wells and cultivable land to develop the recharge water.

h. Detailed hydrological studies for run off assessment be done and design capacity should not normally be more than 50% of total quantum of rainfall in catchment.

i. Waste weir or spillway be suitably designed to allow flow of surplus water based on single day maximum rainfall after the rank is filled to its maximum capacity.

j. Cut off trench be provided to minimise seepage losses both below and above nalla bed.

k. To avoid erosion of embankment due to ripple action stone pitching be provided upstream upto HFL.

l. Monitoring mechanism in benefitted as well as catchment area using observation well and staff gauges be provided to assess the impact and benefits of percolation tank.

Check Dams Cement Plug nala bunds

Check dams are constructed across small streams having gentle slope and are feasible both in hard rock as well as alluvial formation. The site selected for check dam should have sufficient thickness of permeable bed or weathered formation to facilitate recharge of stored water within short span of time. The water stored in these structures is mostly confined to 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 run off, water cushions are provided at down streamside. To harness the maximum run off in the stream, series of such check dams can be constructed to have recharge on regional scale. A series of small bunds or weirs are made across selected nala sections such that the flow of surface water in the stream channel is impeded and water is retained on pervious soil/tock surface for longer body. Nala bunds are constructed across bigger nalas of second order streams in areas having gentler slopes. A nala bund acts like a mini percolation tank.

Site Characteristic and Design Guidelines :

For selecting a site for Check Dams/Nala bunds the following conditions may be observed.

1. The total catchment of the nala should normally be between 40 to 100 Hectares. though the local situations can be guiding factor in this.

2. The rainfall in the catchment should be less than 1000 mm/annum.

3. The width of nala bed should be atleast 5 metres and not exceed 15 metres and the depth of bed should not be less than 1 metre.

4. The soil down stream of the bund should not be prone to water logging and should have pH between 6.5 to 8.

5. The lands downstream of Check Dam/bund should have irrigable land under well irrigation.

6. The Nala bunds should be preferable located in area where contour or graded bunding or lands have been carried out.

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

8. Nala bund is generally a small earthen dam, with a cut off core wall of brick work, though cement bunds/plugs are now prevalent.

9. For the foundation for core wall a trench is dug 0.6 m wide in hard rock or 1.2 metres in soft rock of impervious nature. A core brick cement wall is erected 0.6 m wide to stand atleast 2.5 metres above nala bed and the remaining portion of trench is 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 on the upstream face, stone pitching is done.

10. Normally the final dimensions of the Nala bund are; length 10 to 15 metres, height 2 to 3 metres and width 1 to 3 metres, generally constructed in a trapezoidal form. If the bedrock is highly fractured, cement grouting is done to make the foundation leakage free. The check dams are also popular and feasible in Bhabar, Kandi and talus scree areas of Uttar Pradesh, Punjab, and Maharashtra and have substantial impact on augmentation of ground water.

Gabion Structure

This is a kind of check dam being commonly constructed across small stream to conserve stream flows with practically no submergence beyond stream course. The boulders locally available are stored in a steel wire. This is put up across the stream's mesh to make it as a small dam by anchoring it to the streamside. The height of such structures is around 0.5 m and is normally used in the streams with width of about 10 to 15 m. The cost of such structures is around Rs.10 to 15000/-. The excess water overflows this structure storing some water to serve as source of recharge. The silt content of stream water in due course is deposited in the interstices of the boulders to make it more impermeable. These structures are common in the State of Maharashtra, Madhya Pradesh, Andhra Pradesh etc.

Modification of Village tanks as recharge structure

The existing village tanks which are normally silted and damaged can be modified to serve as recharge structure. In general no "Cut Off Trench" (COT) and Waste Weir is provided for village tanks. Desilting, coupled with providing proper waste weir and C.O.T. on the upstream side, the village tanks can be converted into recharge structure. Several such tanks are available which can be modified for enhancing ground water recharge. Some of the tanks in Maharashtra and Karnataka have been converted.

Inter Watershed Transfer

The percolation tanks in a watershed may not have enough catchment discharge though a high capacity tank is possible as per site conditions. In such situations stream from nearby watershed can be diverted with some additional cost and the tank can be made more efficient. Such an effort was made in Satpura Mountain front area at Nagadevi Jalgaon district, Maharashtra. The existing capacity of the tank of 350 TMC was never utilised after its construction. This could however be filled by stream diversion from adjacent watershed.

Dug Well Recharge

In alluvial as well as hard rock areas, there are thousands of dug wells which have either gone dry or the water levels have declined considerably. These dug wells can be used as structures to recharge. The ground water reservoir, storm water, tank water, canal water etc. can be diverted into these structures to directly recharge the dried aquifer. By doing so the soil moisture losses during the normal process of artificial recharge, are reduced. The recharge water is guided through a pipe to the bottom of well, below the water level to avoid scoring of bottom and entrapment of air bubbles in the aquifer. The quality of source water including the silt content should be such that the quality of ground water reservoir is not deteriorated.

Recharge Shaft

These are the most efficient and cost effective structures to recharge the aquifer directly. In the areas where source of water is available either for some time or perennially e.g. base flow, springs etc. the recharge shaft can be constructed.

Following are site characteristics and design guidelines: -

(i) To be dug manually of the strata is non-caving nature.

(ii) If the strata is caving, proper permeable lining in the form of open work, boulder lining are should be provided.

(iii) The diameter of shaft should normally be more than 2 m to accommodate more water and to avoid eddies in the well.

(iv) In the areas where source water is having silt, the shaft should be filled with boulder, good and sand from bottom to have inverted filler. The upper most sandy layer has to be removed and cleaned periodically. A filter be provided before the source water enters the shaft.

(iv) When water is put into the recharge shaft directly through pipes, air bubbles are also sucked into the shaft through the pipe which can choke the aquifer. The injection pipe should therefore be lowered below the water level, to avoid this

The main advantages of this technique are as follows: -

* It does not require acquisition of large piece of land like percolation tanks.

* There are practically no losses of water in the form of soil moisture and evaporation, which normally occur when the source water has to traverse the vadose zone

* Disused or even operational dugwells can be converted into recharge shafts, which does not involve additional investment for recharge structure.

* Technology and design of the recharge shaft is simple and can be applied even where baseflow is available for a limited period.

* The recharge is fast and immediately delivers the benefit. In highly permeable formation, the recharge shaft are comparable to percolation tanks with no submergence and hence no land compensation to local farmers. The recharge shafts can be constructed in two different ways viz. Vertical and lateral.

Vertical Recharge Shaft - The vertical recharge shaft can be further improvised with injection well at the bottom of the shaft.

(a) Without Injection well

- Ideally suited for deep water levels (up to 15 metres b.g.l.)
- Presence of clay is encountered within 15 m.
- Effective in the areas of less vertical natural recharge
- Copious water available can be effectively recharged.
- Effective with silt water also (using inverted filter consisting of layers of sand, gravel and boulder)
- Depth and diameter depends upon the depth of aquifer and volume of water to be recharged.
- The rate of recharge depends on the aquifer material and silt content in the water.
- The rate of recharge with inverted filter ranges from 7 - 14 lps for 2 - 3 meter diameter. This type of shaft has been constructed at the following places.
- Brahm Sarovar, Kurukshetra district, Haryana - Silt free water
- Dhuri drain, Sangrur district, Punjab - surface run off with heavy silt
- Dhuri link drain, Sangrur district, Punjab - surface run off with heavy silt
- President Estate, New Delhi - Roof Top and Surface Run Off
- Nurmahal Block, Jalandhar district, Punjab
- Kirmich and Samastipur, Kurukshetra distrtict - surface water from depression (b) With Injection Well In this technique at the bottom of recharge shaft a injection well of 100 - 150

mm diameter is constructed piercing through the layers of impermeable horizon to the potential aquifers to be reached about 3 to 5 meter below the water level.

• Ideally suitable for very deep water levels (more than 15 meters)

• Aquifer is over lain by impervious thick clay beds

• Injection well can be with or without assembly

• The injection well with assembly should have screen in the potential aquifer at least 3 – 5 meter below the water level.

• The injection well without assembly is filled with gravel to provide hydraulic continuity so that water is directly recharged into the aquifer

• The injection well without assembly is very cost effective.

• Depending upon volume of water to be injected, number of injection wells, can be increased to enhance the recharge rate.

• The efficiency is very high and rate of recharge goes even up to 15 lps at certain places. These structures have been constructed at following places.

♦ **Injection Well Without Assembly**

• Dhuri drain, Sangrur district, Punjab

• Issru, Khanna block, Ludhiana district, Punjab

• Lodi Garden, New Delhi

• Dhaneta, Samana Block, Patiala district, Punjab

♦ **Injection Well With Assembly**

• Dhuri drain, Sangrur district, Punjab •

Dhuri Link drain, Sangrur district, Punjab

• Kalasinghian, Jalandhar district, Punjab

Lateral Recharge Shaft

• Ideally suited for areas where permeable sandy horizon is within 3 meter below ground level and continues upto the water level - under unconfined

• Copious water available can be easily recharged due to large storage and recharge potential.

• Silt water can be easily recharged

• 2 to 3 meter wide and 2 to 3 meter deep trench is excavated, length of which depends on the volume of water to be handled.

• With and without injection well

(Details of structures already described in Section 3.1.8.1) This structure has been constructed at following places.

• Dhuri drain, Sangrur district, Punjab - 300 meters (with 6 injection wells)

• Dhuri Link drain, Sangrur district, Punjab - 250 meter (with 3 injection wells)

• Garhi Kangran, Baghpat district, U. P. - 15 meter (with 2 injection wells)

• Shram Shakti Bhawan, New Delhi - 15 meter (3 lateral shafts with 2 injection well in each) • Dhanetha, Samana block, Patiala district, Punjab - 4 lateral shaft with injection wells

• The injection wells are advantageous when land is scarce.

This techniques was successfully adopted at temple town of Bhadrachallam in A.P. during 1987 to provide safe drinking water to about 2 to 3 lakh pilgrims on the festival of Shriramanawami. The ground water aquifer had meager reserve and had to be necessarily replenished through induced recharge from Godavari River. The surface water could not be directly pumped to the distribution system due to turbidity and bacteriological contaminations. A water supply scheme was successfully executed by construction of 30 filter point wells of 90 cm dia which yielded about 60 cubic metre/ha of potable water, mainly the induced recharge from river with phreatic alluvial aquifer acting as filtering medium.

Hydraulically the effectiveness of induction of water in injection well is determined by:

- (a) Pumping Rate

(b) Permeability of aquifer

(c) Distance from stream

(d) Natural ground water gradient

(e) Type of well In alluvial areas injection well recharging a single aquifer or multiple aquifers can be constructed to normal gravel packed pumping well. An injection pipe with opening against the aquifer to be recharged may be sufficient. However, in case of number of permeable zones separated by impervious rocks, a properly designed injection well with inlet pipe against each aquifer to be recharged need to be constructed. The injection wells as a means of artificial recharge are comparatively costlier and require specialised techniques of tubewell constructed supported by operation and maintenance to protect the recharge well from clogging.

It is an indirect met

Induced Recharge:

hod of artificial recharge involving pumping from aquifer hydraulically connected with surface water, to induce recharge to the ground water reservoir. When the cone of depression intercepts river recharge boundary a hydraulic connection gets established with surface source which starts providing part of the pumpage yield. In such methods there is actually no artificial build up of ground water storage but only passage of surface water to the pump through an aquifer. In this sense, it is more a pumpage augmentation rather than artificial recharge measure. (Fig. 11). In hardrock areas the abandoned channels often provide good sites for induced recharge. Check weir in stream channel, at location up stream of the channel bifurcation, can help in high infiltration from surface reservoir to the abandoned channel when heavy pumping is carried out in wells located in the burried channel. The greatest advantage of this method is that under favourable hydrogeological situations the quality of surface water generally improves due to its path through the aquifer material before it is discharged from the pumping well. For obtaining very large water supplies from river bed lake bed deposits or waterlogged areas, collector wells are constructed. In India such wells have been installed in Yamuna Bed at Delhi and other places in Gujarat, Tamil Nadu and Orissa. The large discharges and lower lift heads make these wells economical even if initial capital cost is higher as compared to tube well. In areas where the phreatic aquifer adjacent to the river is of limited thickness, horizontal wells may be more appropriate than vertical wells. Collector well with horizontal laterals and infiltration galleries can get more induced recharge from the stream collector wells constructed in seasonal nala beds these can be effective as induced recharge structures for short periods only.

Site Characteristics and Design Guidelines:

1. A collector well is a large diameter (4 to 8 m) well from which laterals are driven/drilled near the bottom at one or two levels into permeable strata. The central well is a vertical concrete cassion in precast rings, (wall thickness 0.45 m) sunk upto the bottom of aquifer horizon. The bottom of cassion is sealed by thick concrete plugs. Slotted steel pipes, 9 mm thick, 15 to 50 cm in diameter having open area above 15% and a tapered leading are driven laterally through port holes at appropriate places in the cassion. The successive slotted pipes are welded and driven using special hydraulic jacks installed at the bottom of the cassion. The number of laterals is usually less than 16 thus permitting minimum angle of 22 30", between two laterals. The maximum length of lateral reported is 132 m. and the total length of laterals from 120 to 900 m. depending upon requirement of yield. 2. The laterals are developed by flushing and if entrance velocity of water is kept less than 6-9 mm/sec, these do not get filled by sand. The effective radius of a collector well is 75 to 85% of the individual lateral length.

Ground Water Dams Or Sub-Surface Dykes Or Underground Bandharas (UGB): These are basically ground water conservation structures and are effective to provide sustainability to ground w ater structures by arresting sub surface flow. A ground water dam is a sub-surface barrier across stream which retards the natural ground water flow of the system and stores water below ground surface to meet the demands during the period of need. The main purpose of ground water dam is to arrest the flow of ground water out of the sub-basin and increase the storage within the aquifer. By downing so the water levels in upstream part of ground water dam rises saturating the otherwise dry part of aquifer.

The underground dam has following advantages: -

* Since the water is stored within the aquifer, submergence of land can be avoided and land above reservoir can be utilised even after the construction of the dam.

* No evaporation loss from the reservoir takes place.

* No siltation in the reservoir takes place.

* The potential disaster like collapse of dams can be avoided The aquifer to be replenished is generally one which is already over exploited by tube well pumpage and the declining trend of water levels in the aquifer has set in. Because of the confining layers of low

permeability the aquifer can not get natural replenishment from the surface and needs direct injection through recharge wells. Artificial recharge of aquifers by injection well is also done in coastal regions to arrest the ingress of sea water and to combat the problems of land subsidence in areas where confined aquifers are heavily pumped. In alluvial areas injection well recharging a single aquifer or multiple aquifers can be constructed in a fashion similar to normal gravel packed pumping well. The only difference is that cement sealing of the upper section of the well is done in order to prevent the injection pressures from forcing leakage of water through the annular space of bore hole and well assembly. In hard rock areas casing and well screens may not be required. An injection pipe with opening against the aquifer to be recharged may be sufficient. However, in case of number of permeable horizons separated by impervious rocks like vesicular basalts or cavernous limestones, a properly designed injection well may be constructed with slotted pipe against the aquifer to be recharged. In practice the injection rates are limited by the physical characteristics of the aquifer. In the vicinity of well, the speed of groundwater flow may increase to the point that the aquifer is eroded, specially if it is made up of unconsolidated or semi-consolidated rocks. In confined aquifer confining layers may fail if too great pressure is created under them. If this occurs, the aquifer will become clogged in the vicinity of the borehole and/or may collapse

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