

On-farm reservoir to store groundwater

A water efficient system for managing irrigation supplies in arid region of Gujarat

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The development of agriculture in the arid areas as well as the use of groundwater has increased rapidly during the recent years. The traditional methods of irrigation are still prevalent in these areas at this modern age of technology. The storage of extracted groundwater is an integral part of irrigation water management in arid region of Gujarat. The need of such on-farm storage structures is discussed in this article. These storage tanks are classified based on location, material used and shape of the structure. The discharge of pumped (groundwater wells) and gravity flow (storage tanks) is measured separately and it is found more for storage tanks. Thus, the rate of water application for irrigation is modified through on-farm storage for the efficient management of available groundwater discharge. The farmers can decide for construction of different types of storage tanks based on their need and available facilities at their farms. It is also discussed about the efficient management of stored water with linkage of modern irrigation techniques so that it can be beneficial for conservation of natural resources with saving of both time and energy.

Key words: Arid region, Groundwater, Irrigation, On-farm reservoir, Water efficient system

TODAY, in the age of modern technology, the vast of area is still being irrigated by traditional methods. The most prominent traditional method of irrigation is flooding and this method is still prevalent because of its simplicity. In Kutch region, about 21% of the total cultivated land is irrigated, out of which 14% is covered by tube-well irrigation and the remaining through canal under minor irrigation schemes. In some parts, area under tube-well irrigation with new technologies such as micro-irrigation has also increased. There are no significant changes over the traditional methods of irrigation in tube-well command area. In the recent decades, the farming area has increased significantly in Kutch region and as a result, there has been a tremendous amount of groundwater exploitation. The depth of wells has increased over the years at high speed and it is declining the

discharge of irrigation wells day-by-day in arid region of Gujarat. The most of soils in arid area are of low in organic matter and water-holding capacity of such soils is less than that of other areas of Gujarat. Thus, the traditional method of flood irrigation is responsible for the huge decline in the application efficiency of irrigation water and it increases the water requirements of *rabi* crops (e.g. wheat crop requires 12 to 14 number of irrigations in this area) between 50 and 60%.

Need of on-farm storage of groundwater: With the present scenario of large groundwater withdrawal, the management is essential for its efficient use. There are following five major reasons which emphasize the need of on-farm storage of groundwater.

Irregular and restricted supply of electric power: It is revealed from the interaction with farmers that three-

phase electric power for running the motor attached with water pump is available for a limited time (on alternate day and night) and it discontinues suddenly at most of the time due to technical fault or maintenance of the electricity distribution system. The coverage of irrigated area declines significantly when irrigated during night in comparison to day while irrigating through traditional methods (border, check basin, furrow methods etc). The surface-stored groundwater is used for irrigation mostly in day time for efficient handling (minimum losses) and better management (no over-irrigation). Secondly, the sudden cutoff in electric supply reduces the water application efficiency when, groundwater is directly supplied for irrigating the crops. Any interruption in water supply reduces the area coverage by using traditional methods and more water is lost due



Fig. 1. Long border strips and practice of flood irrigation



Fig. 2. Exposure of groundwater with open air prior to irrigation

to disturbance in continuous advances in water front. It becomes more significant especially when irrigation is given through 100 to 150 m long border strips (Fig. 1). The continuous supply of irrigation water performs well with border (groundnut lucerne etc.), furrow (castor cotton etc) and check basin (orchard crops) irrigation methods which are still prevailing in arid areas.

Low-water holding capacity of soils: More than 80% of soils found in this arid area (Abdasa, Lakhpat, Nakhatrana, Bhachau and Rapartalukas) are low in organic carbon. These soils are less capable to hold water for a long time. Therefore, continuous supply of a certain amount of irrigation water is required to ensure the uniform water application. Otherwise, a large quantum of both water and time will be lost. In border or furrow irrigation methods, if electric power supply cuts after irrigating half or more land area, the already-irrigated area will receive water again and a large portion of irrigation water will be lost due to low water-holding capacity. Thus, it should be ensured to maintain the constant supply of irrigation water of certain amount to save both time and water while irrigating through traditional methods. The application rate of irrigation water depends upon the conveyance up to field and size of border, check basin and furrow to be irrigated. Therefore, it is emphasized to store the water and use it continuously with desired rate of application for increasing irrigation efficiency.

Continuously decreasing discharge of irrigation wells: In the recent past, it is observed that groundwater levels are

decreasing at faster rate in this arid region. At many places, it has declined up to 120 m or more below ground surface. Consequently, discharge of tube-wells in these areas has decreased substantially. It wastes both time and irrigation water in arid areas for irrigating sandy soils with less well discharge. For this reason, groundwater extracted from low discharge tube-wells can be stored at ground surface and used later as per need of desired water application rate.

Poor quality of groundwater: As groundwater level is declining continuously in arid Gujarat, the groundwater quality is becoming poor due to increasing amount of salts and other impurities. In many areas, the groundwater looks to be yellowish. In deeper wells (depth more than 150 m), abundant quantity of the water-soluble iron content (ferrous bicarbonate) is present. When this water is used for irrigation, ferrous bicarbonate directly comes in to contact with oxygen present in the air, it turns into insoluble iron element (ferric hydroxide). The ferric hydroxide deposits on the surface of irrigated land and its higher proportion in the soil adversely affects the quality of the soil along with hampered plant growth. Thus, emphasis is given on storing such type of groundwater at one place where it comes to in contact with oxygen so that most of insoluble iron is deposited at stored place and after that this water is used for irrigation. Some additional provisions are also made for increasing time of contact of groundwater with the air, Fig. 2. This water suits well for pressurized

irrigation methods which minimizes the choking risk of water application system.

Stored water for efficient irrigation

The stored water on the farm can be used for irrigation in two ways. In first method of irrigation the stored water is directly diverted in the crop fields, where it covers more area in less time when furrow method is used in place of border and check basin irrigation. In the second method, stored water is passed through filters for removing suspended materials. This filtered water is used in pressurized irrigation methods in different field, vegetables and orchard crops.

Groundwater storage tanks

The groundwater storage tanks are mainly classified based on three criteria, i.e. location, material used for construction and shape of structure.

Location of storage tanks: The location of groundwater storage tank is based on opted slope of the irrigated land and reach from the wells.

At the level of irrigated lands: In the areas where stored water is directly applied by gravity flow in the fields through furrows, check basin and border methods of flood irrigation, the bottom of storage tank is kept parallel or slightly above to irrigated lands. The care is taken for selecting the location of tank, so that water can reach at all places in irrigated field easily. This is mostly suitable for gentle and uniform sloppy fields where tank is situated at highest portion of field so that conveyance water losses can be minimized.

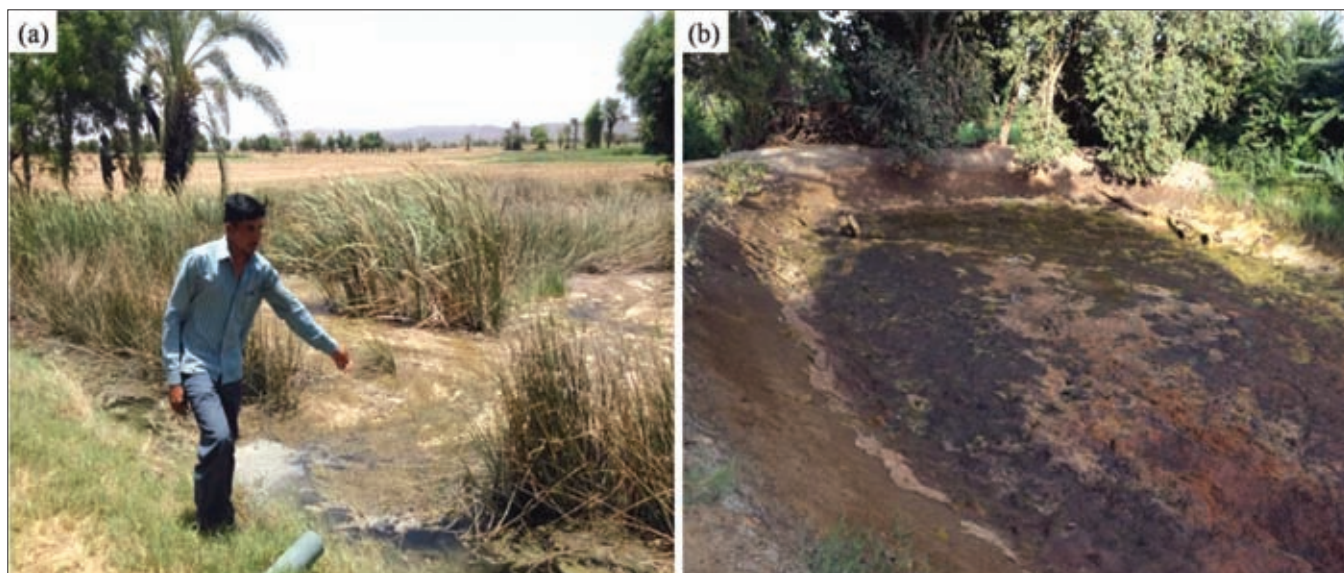


Fig. 3. Earthen storage tank having problem of (a) development of vegetation, and (b) opt 44 cm deposition of ferric hydroxide.

Above the level of irrigated lands: In this, the bottom of the storage tank is kept about 5 to 10 m above from the highest elevation of irrigated lands. This kind of situation is available at few places. The stored water can be used directly through gravity flow in drip irrigation method. The selection

of drippers depends upon the available pressure at inlet of irrigated field. Thus, it saves significant amounts of energy. In this method, approximately 0.25 ha of area can be irrigated at a time with 0.5 to 1.0 kg/cm² of pressure for on-line drippers. This irrigation method is easily linked

with pressurized irrigation techniques for improving water use efficiency in arid regions and for irrigating undulated fields efficiently.

Construction materials: Storage tanks are mostly divided into five types-based on the materials used in construction (Table 1).

Earthen tank: It is made of locally available soil which is comparatively less permeable. The clay soils are used for constructing core walls of the tank and rest of the portion is constructed through available local soils. This tank requires frequent periodic maintenance as it reduces its storage capacity due to slogging of side-walls or development of vegetation (Fig. 3 a) and deposition of ferric hydroxide (Fig. 3 b) inside the tank. One more thing that is important for selecting location of earthen storage tank is the availability of impermeable layer below the bottom of tank. The typical earthen storage tank is shown in Fig. 4(a).

Earthen tank pitching with loose boulders: The problem of vegetation development in earthen tanks is restricted through pitching of loose flat boulders of more than 5 cm thickness on side-walls and at bottom. It also solves the problem of slogging of loose soils from side-walls and development of vegetation inside the tank (Fig. 4 b). The cost of construction for such tanks is 25 to 30% more than earthen tanks. Sometimes, the pitching boulders are also joined by cement mortar for



Fig. 4. Different types of storage tanks (a) earthen; (b) stone pitching on earthen structure; (c) stone masonry back filled by soil; (d) plain cement concrete structure; and (e) reinforced cement concrete structure.

Table 1. Comparison of different types of storage tanks-based on construction material

Type of storage tank	Location of structure	Easiness of construction	Construction material	Cost (₹/m ³)	Maintenance	Average life (Years)
Earthen tank	Impermeable strata at the bottom	More easy	Local impermeable soils	65-75	More maintenance	5-8 (depends upon maintenance)
Earthen tank pitching with loose boulders		Easy	Local impermeable soils and flat boulders	100-120	Less than earthen tank	10-15
Stone masonry back filled by soil	Stable strata at bottom with no swelling and	Comparatively difficult	Boulder, cement, sand, stone chips and soil	400-650	Need to repair cracks developed in the bottom or walls	20-25
Plain cement concreted on earthen structure	contraction during filling and drying of tank		Cement, sand, stone chips, plastic sheet and soil	700-750	Less than stone masonry structure	25-30
Reinforced cement concrete structure	Any location from where water can easily reach to the fields	Difficult and requires more skills	Cement, sand, stone chips, plastic sheet, iron and soil	850-900	Very less maintenance	40-50

more stability and restricting water losses from comparatively permeable earthen walls.

Stone masonry back filled by soil: The permeable bottom of storage tank (such kind of structure) is constructed for storage of groundwater. The walls of stone masonry are backfilled with local soils for providing strength to walls against tension of stored water (Fig. 4 c). About 1 to 1.5 m long vertical walls are also constructed inside the tank for more strengthening of side-walls. These walls divide the long side-wall in different sections to withstand against water pressure. It requires less maintenance in comparison to earthen tanks. It should be maintained periodically in case of any cracks developed on side walls or in the bottom of the pond. These tanks can be constructed in rectangular, square, and triangular shapes as per availability of the area. It involves four-fold more cost than

that of earthen structure with loose boulder pitching.

Plain cement concreted on earthen structure: In place of loose stone boulders in earthen structure, a layer of about 5 to 8 cm thickness over side-walls and about 15 cm thickness in the bottom of tank is constructed with plain cement concreted. Sometimes, a layer of plastic sheet is also placed for restricting the loss of water from the tank in case of any leakage from the concrete. In such type of structures, clay soils should not be used for constructing walls of the tank as these soils can promote cracks in plain cement concreted due to frequent swelling and contraction. This structure costs somewhat more than that of stone masonry structures but requires less maintenance. It is always constructed in trapezoidal-shape (Fig. 4 d).

Reinforced cement concrete structure: to minimise the maintenance costs, reinforced cement concrete structures

are proposed. These structures are mostly suitable where the bottom of the tank is comparatively more permeable and unstable. It also suits over clay soils which create pressure over structure due to swelling and contraction. The reinforced cement concrete structure requires more skills and care during construction. It is constructed with reinforced iron in cement concrete (Fig. 4 e). The quantity of iron depends upon the desired strength of the structure. In the bottom, it requires more reinforcement in comparison to side walls. The thickness of side walls can be reduced from ground level to the maximum height of the structure. A plastic sheet is also placed behind the reinforced cement concrete structure to avoid any kind of water leakage in future. The bottom level of this structure can be constructed above the level of irrigated area for smooth movement of irrigation water in the entire field. This structure costs the highest among other kind of structures used for groundwater storage in this arid region. The reinforced cement concrete structure is mostly constructed in **Trapezoidal**: This kind of shape is common in earthen and PCC structures. The side slope of structure is kept minimum for sandy soils (3:1 to 2.5:1) and maximum for clay or murrum soils (2:1 to 1.5:1). The slope of structure should not be more than 1.5:1 in pitching and PCC inside the storage tank.

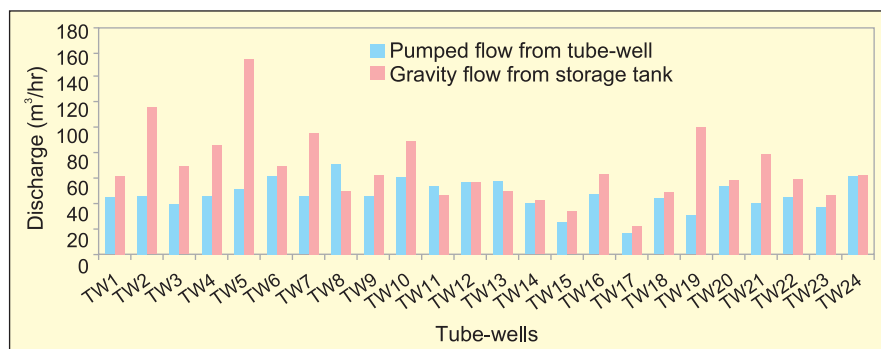


Fig. 5. Comparison of pump and tank discharge for randomly surveyed wells (Village- Sanyra, Taluka- Nakhatrana, Kachchh)

Rectangular: The rectangular-shaped structure is more common in stone masonry and reinforced cement concrete structure. It stores more capacity of water per unit surface area than trapezoidal-shaped structure.

Triangular: This structure is constructed at the corner location of the field and thus the available space is efficiently used for making tank. The shape of the tank is kept as triangular for utilizing all the corner area in less space available.

Circular: The circular shape is only constructed in reinforced cement concrete structures. The thickness of side wall is kept maximum at the bottom and minimum at highest end for minimizing the cost of construction. This shape provided more strength to reinforced cement concrete structure than other shapes. Thus, the circular shape is more suitable for constructing the structure with more height in comparison to other shapes.

IRRIGATION WATER MANAGEMENT THROUGH STORAGE TANK

Two methods of irrigation are prevailing in arid areas of Gujarat, one is surface irrigation and another is pressurized irrigation. In surface irrigation most common practices are check basin, border and furrows. In pressure irrigation, drip irrigation is being adopted mostly in vegetables and orchards in arid region of Gujarat.

Management of flood irrigation through storage tank

It is estimated that about 8 to 15 liters/ sec discharge rate is needed for irrigating 50 to 100 m² (for sandy soils) of small-sized check basins through traditional irrigation methods. The required rate increases with the increase in size of the border strips and the availability of this discharge rate from deeper tube-wells

Table 2. Pressure requirement of different water emitters used for irrigation.

Water emitting device	Pressure head (m)	Flow rate (litre/ hr)
Low pressure sprinkler	15-25	300-1500
Micro-sprinkler	20	150-250
Spitters, micro-jets and sprayers	15-20	150
Bubblers	10-30	110-250
Drippers	8-10	1-24
Drip-tapes	6-10	0.4-1

(After- <ftp://ftp.fao.org/agl/aglw/docs/pressirrig.pdf>, accessed on 04 October 2016)

is somewhat difficult. Most of the wells in this arid region yield 3 to 10 liters/sec of discharge, which is also further getting reduced over the years. The available discharge is not sufficient for maintaining continuous advances of water front for long border strips used for irrigating field crops. Therefore, stored water provides the desired rate of water application with available scarce water supply and it ultimately saves both time and quantity of irrigation water. The furrow method can also be practised efficiently using stored water for irrigating field crops such as cotton, castor etc., fruit trees such as mango, pomegranate, papaya etc. and vegetables in this arid area. The discharge through storage tank in comparison to pump discharge for randomly surveyed wells (24 nos.) in village Sanyra of Nakhtran Taluka, Kachchh is shown in Fig. 5. The significant improvement in water discharge as per need of water application rate proves the necessity of storage tank in the area. The discharge from tank is found to be more in mostly prevailing surface irrigation than for combined practices of both pressure and surface irrigation.

Low pressure irrigation: The drippers are selected based on the quality of stored water. In case of high amount of dissolved salts present in the stored water, inline dripper performs better than the inline drippers. Inline drippers can be used for medium to good quality water with proper care and

maintenance to minimize the risk of chocking. The pressure requirements of some common water emitters are discussed in Table 2.

SUMMARY

The system of irrigation by using these emitters can be designed in integration with groundwater storage tanks located above the cultivated lands. The selection of different emitters should be based on the available pressure head, irrigation requirement of crops, soil type and quality of groundwater. The drip-tapes require minimum operating pressure and it also has minimum risk of chocking. Thus, the on-farm storage of groundwater benefits to farmers in arid area of Gujarat for managing their irrigation needs independent to time of electric supply for running the pumps. It saves the time of irrigation in interrupted power supply and overcomes the problem of low discharge from wells. The storage tanks can manage variable discharge from multiple wells for irrigation. It provides the desired rate of discharge and farmer can decide the same as per need of crop, property of soil and method of irrigation.

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