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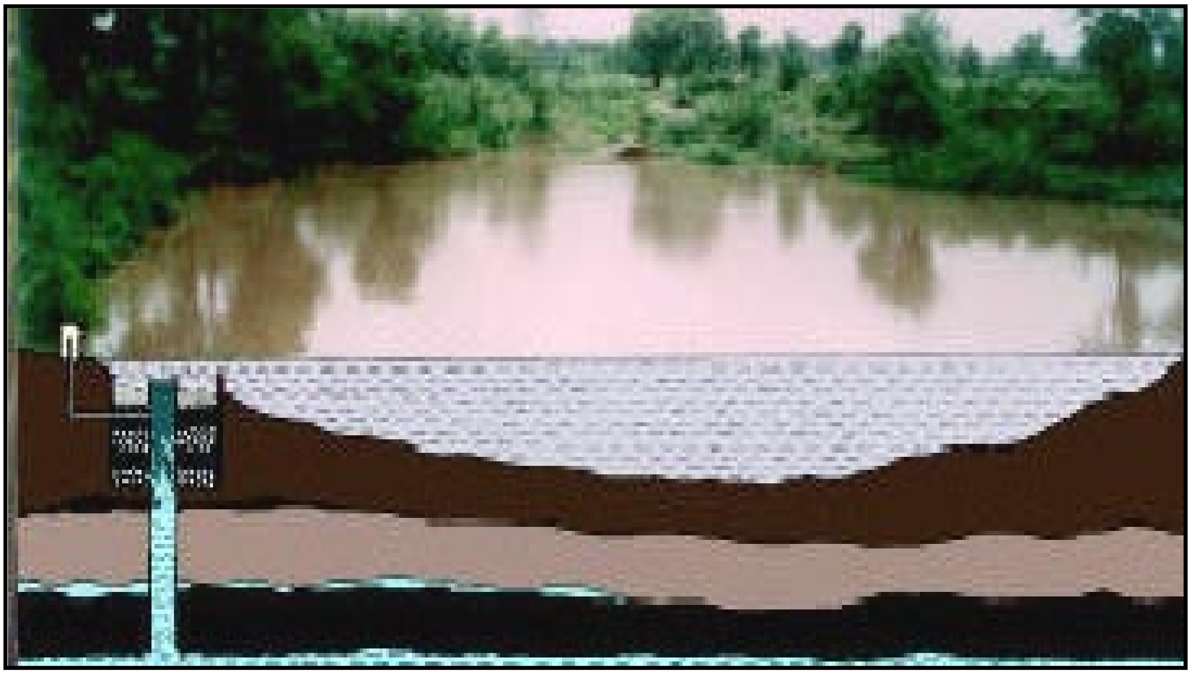
CLOSING THE DEMAND-SUPPLY GAP THROUGH RAINWATER HARVESTING:

A Case Study of Sargasan, Gujarat, India

Srinivas Mudrakartha and Shashikant Chopde



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Srinivas Mudrakartha[1] and Shashikant Chopde[2]

Abstract

Ground water as a dependable source and its increasing extraction for various uses in India is reflected in the drastic lowering of water levels leading to “local” draw downs. The efficacy of surface water bodies such as tanks, lakes and canals as a means of natural recharge to the ground water has drastically reduced simply because the local water levels are too deep. The need of the hour therefore is for artificial recharge systems that *convey* the fresh rainwater to the “aquifer”.

In Gujarat, VIKSAT experimented with the artificial recharge technique in various settings. One such experiment is located in a peri-urban area called *Sargasan* in Gandhinagar taluka. The experiment involved building social capital, setting up institutional norms and physical implementation.

The ground water level in Gandhinagar taluka has declined from around 30 meters to 80 meters below ground level over a period of two decades, with half of the decline occurring in the past 7 years. In other words, the dry aquifers above the present yielding zones offer opportunity for storing water. Underground storage of water, which has the additional advantage of avoiding evaporation losses as against surface water bodies, is increasingly seen as an option due to severe competition for land and changing land use.

The major objective of the experiment was to augment local supplies through the recharge route. The artificial recharge technique comprised developing an existing tank, drilling a borewell and facilitating rainwater recharge through a filter bed constructed with the borewell as the center.

Data on water levels was collected from 32 borewells located within a radius of 1.5 kilometer from the recharge borewell to understand the effect on the water level build up.

The experiment helped to establish the following :
A total of 23 (gross 33.2) million liters of rainwater has recharged into the ground with about 70% of the average annual rainfall incident in the area in the monsoon of 2001. Analysis of data from the 32 observation borewells revealed the presence of a mound around the recharging borewell which was observed to slope gradually towards southeast and southwest while it was steep towards northeast. The water level observations over a 4-month period (June-September 2001) indicated certain amount of dispersion, which is

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found to be due to some borewells under pumping. When the pumping was significant, the dispersion too was significant. However, interestingly, the mound did continue to be present throughout the 3 month-monsoon period and over a 600-800 meter distance from the recharging borewell, in particular along southeast and southwest directions. In other words, this represents the zone of influence of recharge which depends upon, *inter alia*, the piezometric gradient, pumping density and intensity, and also the direction of the ground water movement. This coincides well with the fact that the general direction of ground water movement in Gandhinagar is towards southeast.

The study estimates that recharge efforts, if properly planned, can effectively contribute to closing the existing gap between extraction and natural recharge. According to the Central Ground Water Board, Government of India, Gandhinagar taluka has an annual ground water draft of 130.35 MCM from 2382 borewells and a natural recharge of 111.57 MCM leaving a gap of about 19 MCM. This gap comprises approximately 15% of the extraction. Based on the field data, it is computed that the recharge system in Sargasan has absorbed a net 23 million litres when the incident rainfall was 70% of the annual average. Calculations show that the demand-supply gap can be closed by having about 700 "Sargasan" type of medium recharge systems. Larger catchment tanks would reduce the number proportionately. Thus, in principle, the gap can be effectively addressed as there are 520 tanks existing today in Gandhinagar taluka. Appropriate demand management, especially in the agriculture sector and domestic drinking sector, needs to be adopted simultaneously to utilize the natural resource sustainably.

Introduction

In the context of scarcity, groundwater accounts for a major portion of domestic and irrigation water in the State. The State has witnessed a whopping 104% increase in ground water extraction over two decades (1978-1997). Over extraction of groundwater has affected about 4.0 million ha (21% of the State) in 74 talukas of 14 districts of the State. The situation is set to worsen since about 87% of the municipal towns in the State depend on groundwater for drinking, domestic and other purposes. Groundwater accounted for 79% of the net irrigated area of the State in 1996-97 and 78% of the rural drinking water demand also continues to be met by groundwater. The groundwater level is declining at the rate of 2 to 3 metres per year in Gujarat.

To mitigate the drinking water scarcity, the Government of Gujarat in its Master Plan for the year 1999-2000, had estimated an expenditure of INR 3108.88 millions covering 6312 villages, 69 towns and 3 Municipal Corporations. The plan was to drill new bore wells, deep tube wells and rejuvenate individual and regional water schemes.

GUJARAT-THE DROUGHT PRONE STATE

The annual average rainfall in Gujarat ranges from 250 mm in its north-western part in Kachchh district to about 2000 mm in south-eastern area of Dangs district. The ten-fold difference is phenomenal within the 0.2 million sq. km. geographical spread of the State. The State is one of the most water scarce regions in India with an estimated annual per capita water availability of 1,137 Cu.M. compared with the corresponding national figure of 2,000 Cu.M. Gujarat is a drought prone state, with the exception of south Gujarat. Since 1999, the state has been suffering consecutive drought like conditions. It is stated that in the drought of 2000 AD, 25 million people in 9,500 villages, 4 metros and 79 towns were affected by drinking water scarcity.

During 1999-2000, Gandhinagar too was under the grip of unprecedented water scarcity, unknown in last thirty years. To meet the growing needs of water and considering the water problem, the government had to drill 40 tube wells on an emergency basis to meet the drinking water requirement of Gandhinagar city. One appreciates the massive effort of the government to tide over the crisis, but is this solution *sustainable*? This is what VIKSAT has been trying to address through promoting integrated water management.

VIKSAT strongly believes that participation of all stakeholders is the key to success of any natural resource management effort. More so for a critical resource such as water where both demand and supply sides are highly user-dependent and user-influenced. Therefore, for the past three years, VIKSAT has been promoting a Sabarmati Stakeholders Forum[3] to address various water related issues on a river basin level.

Looking at VIKSAT's efforts, Gandhinagar Urban Development Authority (GUDA) approached VIKSAT to help them in artificial recharge efforts. It was decided that recharge efforts would be made in four villages mutually identified. However, complete efforts could be made only in one village due to funding problems from GUDA.

Physical features of Gandhinagar District

Gandhinagar is a modern city planned to be capital of Gujarat. With wide roads, avenue plantation and well spread residential areas, the city houses all government departments, State Assembly, ministers bungalows and other residential buildings.

Gandhinagar is the second smallest district after Dangs in Gujarat with a geographical area of 2163.48 km^2. The urban area is 157.20 km^2 while the rural area is 2006.28 km^2. The district lies in the North Gujarat Plain generally devoid of relief features. There are no significant perennial water bodies except for the seasonal Sabarmati River. Originating in the Aravalli hills in south Rajasthan, river Sabarmati flows briefly for 48 kms in Rajasthan to enter (North) Gujarat and travel in a north-south direction to join the Gulf of Khambat. Out of a total length of 416 kms, the Sabarmati courses only 34 kms in the Gandhinagar district. The other significant river is Khari, which also flows in north-south direction. Out of its total length of 160 kms, the Khari flows for only 18 kms in the district.

[3] The Forum promoted by VIKSAT has been evolved after a year of working with stakeholder sub forums from across the Sabarmati river basin. It is an informal, unregistered forum, with active participation from government and non-government institutions and individuals. *For more details, visit website www.viksat.org.*

There are 208 tanks in Gandhinagar, 2382 tubewells and 117 dugwells. Around 3207 wells are not in use due to water level depletion (Taluka Level Ecological Profile, GEC).

The net groundwater draft is 70.6 MCM per year resulting in a water level depletion of 1.3 - 3.2 metres annually. Gandhinagar falls in the *grey category* as per the Central Groundwater Board (CGWB) classification for groundwater development. In view of this, the Central Ground Water Authority (CGWA) has recently notified *aquifers below 200 m depth of Gandhinagar taluka as protected zones, reserved for drinking water.*

Water use Pattern

Gandhinagar city, the capital of Gujarat, is the second planned state capital having 32 sectors. The entire water supply of the city is looked after by the Gujarat State Water Supply and Sewage Board (GSWSSB) having headquarters in Gandhinagar.

Gandhinagar city with a population of 123,359 (as per 1991 Census) uses 460 litres per capita per day (lpcd) for domestic purposes. Dependence on Groundwater as a source of supply is very high.

Earlier 92% of water supplied was through Radial wells and Intake wells located on the Sabarmati bed but due to the deteriorating water balance in the river presently only 25% is from radial wells and rest from bore wells (75%). Out of the 62 bore wells in the city, 20 are used for storage in tanks, 22 supply water directly, 5 to nearby villages and the remaining 15 for the Secretariat complexes, Minsters' Enclave, gardens and lawns of the city. The figures indicate that 24% of the city's supply, to the tune of 13.62 Mld, goes for the Secretariats and Minsters' enclave.

On the agricultural side, the cropping intensity is 116% with ground water being the only source of irrigation in the district. The livestock population has grown about 35% during 1977-1988 with the population in 1988 being 112649. The human and cattle population has exerted enormous stress on the natural resources of the district.

Sargasan village

Sargasan village is located in Gandhinagar taluka & district, about 25 kilometres from Ahmedabad along Sarkhej-Ahmedabad-Gandhinagar highway (NH 8). The population of Sargasan is 4000 comprising *Brahmin, Darbar, Thakore, Prajapati* and *Harijan* castes. The general land holding varies from 2 vighas[4] to 10 vighas. Sargasan represents a typical peri-urban village, influenced by the urban centers Ahmedabad and Gandhinagar. Thus, for the purpose of social activities, the conventional community based approach does not easily succeed because people are more self sufficient, having more than one occupation for income generation. The scope for multi source income is offered by the urban centers which are well connected.

Historical Development of Water Resources in Sargasan

During our PRAs, we tried to quickly trace the history of ground water development in Sargasan. Till the year 1945, the groundwater level was very shallow (10-20 feet) and

[4] 1 ha.= 4.32 vighas

was extracted through *kose*[5]. Gradually, by 1955, people started extracting water (from 20-40 feet) through pulley system both for drinking and irrigation purposes. While animals were used for irrigation water extraction, people themselves lifted water for drinking purpose. Early sixties saw the advent of diesel pumps which were used to lift water till 1973 from depths of (30-50 feet) when electricity connection arrived in the village and farmers started using electric pumps. With ease in extraction, the open wells went dry completely by the year 1988. In other words, the water level has gone beyond 20 metres below ground level. Around this time, the borewell technology arrived in the village and those farmers who could afford started drilling borewells energized with submersible pumpsets. Currently, the water level in the village stands at more than 65 m.

Table showing ground water development in brief

S.No.	Period	Source	Depth to Water Level in feet	Method of Extraction
01	Before 1945	Open well	10-20	*Kose*
02	1945-55	Open well	20-40	Pulley system
03	1955-60	Open well	20-40	Bucket & Rope; animal used for irrigation
04	1960-73	Open well	30-50	Diesel pumpset
05	1973-88	Open well (seasonal)	50-70	Electrical Pumpset
06	1988 onwards	Bore well	Below 70	Submersible pumpset

Current Water use pattern in Sargasan

VIKSAT conducted a survey for collecting baseline information using the stratified-random quota sampling method for understanding the water extraction and use pattern. The stratification was based on caste. From each caste, 3-4 households were randomly selected. All the samples indicated that irrigation water was sourced from borewells, either owned or on rented (Rs. 20/- to Rs. 30/- per hour). The depths of borewells ranged from 300-450 feet fitted with pumps of capacity ranging from 20-30 H.P. The water level ranged from 225-300 feet below ground level.

Major crops grown in winter are Wheat and *Jowar* (millets); hot weather crops are *Bajri* and *Jowar*. Among these, wheat consumes more water.

VIKSAT's Experience in Rainwater Harvesting

VIKSAT strongly believes that the goal of sustainable development and management of natural resource can be achieved only through decisive participation of local communities aided by an enabling role of the government agencies.

[5] A pole and leather bag contraction, manually operated to lift water from wells through leather bags.

VIKSAT implemented the Drought Relief programme in 2000 AD through *Gadhwada Jal Jameen Sanrakshan Sangh*[6] in Mehsana and in Kachchh districts. Several water harvesting structures were constructed through active participation of the community. These structures received water for the first time during the current monsoon (of 2001). The estimate of total water harvested by these structures till August 2001 is 100 million litres (www.viksat.org).

VIKSAT's Intervention in Sargasan village

VIKSAT adopted a systematic approach for planning and implementing artificial recharge in the four villages of *Sargasan*, *Por*, *Vavol* and *Tarapur* in Gandhinagar taluka. As the funds approval and release was delayed, it was decided to take up only one village to begin with (in the summer of 2001) before the onset of monsoon. The above four villages were selected based on the following norms :

Selection of tanks/villages

- The villages/tanks should be located within 1 km of each other to facilitate study of post-implementation impact;
- The villages/tanks should also serve as demonstration models. Therefore, they should be well accessible.
- The tanks should be free from inflow of waste water or sewage into the tank in order to avoid contamination of groundwater;
- The tank should have considerable drainage/catchment area;
- There should be users (that is, farmers having tubewells) within a radius of 1-1.5 kms so that the recharged water is tapped;
- The tanks should be free from current or potential conflict so that the basic objective of demonstration does not suffer.
- Other criteria considered included tank storage and frequency of filling over the past decade.

All the sites confirmed these criteria from both social and technical points of view.

Physical Implementation

The implementation comprised the following steps:

1. Social Preparation
2. Social & Technical Surveys
3. Implementation – Tank Excavation, Construction of Artificial Recharge Tubewell, Plantation & minor repair of tank inlet
4. Water Level Monitoring

1: Social Preparation

It is important to make the community feel the ownership of common assets created, especially from the Operation and Maintenance points of view. These villages are not

[6] a taluka level federation of Village Level Institutions

from among VIKSAT's regular project villages. The artificial recharge activity was taken up in order to develop a demonstration model so that the public could see and appreciate the potential of rainwater harvesting for scaling up appropriately.

As mentioned in the foregoing, the Sargasan village is highly urbanized and hence evolving community participation is very tricky. Hence, VIKSAT conducted a series of meetings with the *Panchayat leaders*, village elders and others to apprise them about the benefits of artificial recharge. The panchayat also gave a *No Objection Certificate* and passed a resolution to take care of maintenance of the recharge system. The village meeting also identified *local managers* for works implementation & monitoring.

2: Social and Technical Surveys

Appropriate structured questionnaires for collecting household level information related to water use pattern for domestic and irrigation purposes was prepared and data collected through PRAs, and interactions with groups and leaders.

People from Sargasan were present throughout night and day in shifts while the whole work was being implemented. They monitored the drilling for its depth, pipes, and other quality aspects. They have provided free electricity too.

The recharge tubewell (located in the tank) and all the observation borewells in a radius of 1.5 kms were mapped to scale on a cadastral map. The top of all the borewells were connected to the Mean Sea Level (MSL) by topographic surveys. This helped compare water levels in all the borewells.

Survey of the tank was carried out to help estimate storage capacities at various elevations. The tank is ellipsoidal with diagonals measuring 110m and 140 m, with a maximum depth from the bank of 6 m. Considering the location of the spill way, the effective depth of the tank is 5.2 m. The surface area of the tank is 1.35 ha with a storage capacity of 28 million litres. A gauge was installed in the tank to measure the tank water level. From the capacity-elevation curve, one could easily derive the volume of standing water in the tank. The community was trained to take the readings on the gauge and provide to VIKSAT.

3: Process of Implementation

Subsequent to the social preparation, implementation was taken up which involved the following steps:

1. As decided in the *panchayat* meetings and the village meetings, the excavated earth was used for landfills in common and private land (including farm lands). Under this arrangement, the private farmer paid Rs. 50/- for every tractor load of silt out of which Rs. 30/- was paid to the *panchayat*. Thus, a sum of Rs. 6223.50 was collected by the *panchayat* which as per *panchayat* resolution was earmarked for maintenance of the artificial recharge system. Care was taken to de-silt the bed in disaggregated patches and not extensively so that the micro-ecology is not lost. Similarly, low-lying areas in the village which used to get inundated during heavy spells causing

disruption of road movement were filled up. People were very happy that their inundation problem also got solved.

2. After deepening of the tank, an Artificial Recharge tubewell of 225 feet depth was constructed in a slightly elevated portion in the bed of the tank. The topmost 2 pipes (40 feet depth) were plain while the rest, 9 in number were slotted. A Filter pit 20' x 20' x 20' was constructed around the recharge tubewell. It was filled with filter material—pebbles of 60mm-90 mm, aggregate of 40 mm and sand of 0.6mm-1mm.
3. Often, in recharge structures, maintenance is neglected. In our designs, we tried to minimize the maintenance aspects. One of the aspects included placing a Plastic Pervious sheet (PPS) between the top sand & the aggregate layers to prevent sand compaction. Another sheet was similarly placed just 1 foot below the top of the sand. The PPS lining between layers prevents downward movement of the sand into the aggregate during recharging process. Further, a brick parapet wall of 2.5 feet height was constructed around the filter pit to reduce silt load into the recharge pit. Air release arrangement for recharge tubewell was also provided.
4. A few miscellaneous works were also carried out. For instance, the inlet was damaged and hence not functioning. This was repaired. Plantation was carried out along the tank bund to strengthen the bund**.** 495 saplings of *Jamun*, *Amla*, *Karanj*, Bamboo, Banyan and *Desi Baval* were planted. The saplings contain some fruit varieties so that children could pick them up whenever they wanted.
5. Continuous monitoring of water levels is done with the help of a Gauge-rod fixed in the tank. The inlet too was graduated to measure depth of inflows.

4: Water Level Monitoring

The following measurements were carried out to study the impact of the artificial recharge structure :

- Water level readings in the recharge tubewell were taken twice a day (morning and evening) to observe how the level was building up.
- The water levels in the 32 borewells around the recharge structure in 1.5 kms radius were measured once a day during monsoon. The readings were continued for 4 months till the difference between a few consecutive readings became negligible which in other words indicated that the water level has stabilized (see Figs. 3, 4, 5). The water levels were measured using a water level recorder.

Computations

The water from the catchment enters the tank through the inlet. Initial 2-4 spells of rain would normally fill up the dead storage of the tank. The subsequent rains help build the tank storage which then enters the recharge pit. In the recharge pit, the water seeps vertically down, as the top 20 feet is blind casing. Only after this depth will the water be able to enter the tubewell through its slotted casing pipe below. In other words, the design consideration was to provide maximum "filter area" to reduce contaminants.

Provision was also made to let the excess rainfall flow out of the tank through the spillway.

Figure 1 depicts the water level in the tank with time. The reduction in the water level in the tank is taken as the gross recharge to ground water. There are only two predominant losses here that need to be adjusted: the evaporation losses and the dead storage. For now, these corrections are made while computing the gross seasonal recharge in a season. No big reason for this but the limitation that this was not a purely research project. The magnitude of correction required is lowest in all these computations as the period under observation is monsoon. In the subject area, due to high humidity, the rate of evaporation is low as compared to non-monsoon period.

Scope and Limitations
It may be noted that the Sargasan experiment was not done as a research project. It was just an implementation project on artificial recharge which VIKSAT utilized to demonstrate the potential of enhancing the local supply option. The entire data collection, analysis and writing have been done without any funding support. Hence, there might be some shortcomings as compared to a strictly research oriented approach. For instance, one might argue on the accuracy of water levels measured by the water level recorder, or the figures used for correcting evaporation.

While the need for accuracy is not undermined, the authors exhort that the research approach and the insights that we sought to introduce into a normal implementation project be appreciated so that the data inaccuracy, data gaps and data insufficiency (which are one of the key research limitations in India) are reduced.

Discussions

Increasing water scarcity in both rural and urban areas, combined with increasing demand, degraded natural environment, changing landuse and “vagaries” of nature have led to knee-jerk solutions, which have often become unsustainable. Examples are the several piped water supply schemes transferring huge quantums of exogeneous water. Increasing urbanization has brought forth change in land use thus decreasing the net area available for natural recharge. Combined with deep water levels, the natural recharge has become less effective, thus increasing the demand-supply gap

Piped water supply schemes often impart a false sense of “water sufficiency” which soon turns out to be a myth. The water sufficiency tends to make people more indifferent to demand management upsetting the water balance. The schemes are generally not based upon any accurate, realistic estimates of the ground water reserves as the methods of estimation of components of water balance themselves are limiting. The limits include obsoleteness, insufficient equipment and data uncertainties. Thus, such schemes tend to become the key reason for failure of the schemes in the medium to long run.

The need of the hour therefore is for artificial recharge systems that *convey* the fresh rainwater to the “aquifer”.

Ensuring Drinking Water Security

VIKSAT artificial recharge experiment in Sargasan in Gujarat demonstrates that significant proportion of water requirement can be secured by storing it underground. Sargasan panchayat supplies 0.1 million litres per day to the village of 4000 population which works out to a per capita of 25 litres per day.

The Sargasan recharge system has recharged 23 million litres[7] even in a rainfall deficient year (2001). The top aquifers in this region are all dry. The water level is beyond 200 feet below ground level. If the water could be stored in a shallow aquifer, not tapped by the irrigation tubewells, then the wells would be rejuvenated and domestic and drinking water security for the entire year would be achieved even in a rainfall deficient year. During a good rainfall year, the tank would harvest equivalent to 2.5 times its capacity, which implies that a recharge of 57.5 million litres is possible. Every village traditionally has at least two tanks. Gandhinagar district has 520 tanks. Thus, the drinking water security is very much a possibility. Continuous recharge year after year is sure to lead from drinking water security to irrigation water security too.

It may be noted that such underground storage has minimum evaporation losses as against surface storage. Underground storage, further, goes a long way in addressing equity too.

Further, such a water security would also help tide over starvation deaths of animals, in particular, the livestock, which provides key supplemental livelihood support for the poor and the underprivileged, especially in drought conditions which occur with regular frequency in several states of India. Such “reservations” should be done considering the aquifer dispositions and the lithology.

Thus, there is a strong case for appropriate policy changes-policies that are made with suitable hydrogeological understanding. While this recharge “technology” can be adopted in alluvial areas, hard rocks do not present such a convenient scenario.

Raising the Water Level

It is seen from the Figures 3, 4 and 5 that there was a build up of mound around the recharge tubewell which tapered off at 600-800 metres depending upon the direction of ground water movement. This remained for 4 months. When several recharge structures are constructed, there will be a more or less continuous, raised regional water level which will remain for more than 3 months because the irrigation demand during monsoon is minimal. Hence, availability of ground water for *rabi* (winter crop) makes a tremendous difference for Gandhinagar as well as several other parts of India.

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[7] As per a study carried out by Dr. PP Patel (Head, Geology Department, MS University, Vadodara) the ratio of recharge to evaporation in case of percolation tanks and check dams ranges between 1.83 to 4.2. In other words, subtracting evaporation losses from the total recharge in the case of Sargasan tank, the conservative estimate of recharge ranges from 21.47 to 26.82 million litres.

The Question of Blocking Run-Off for Downstream

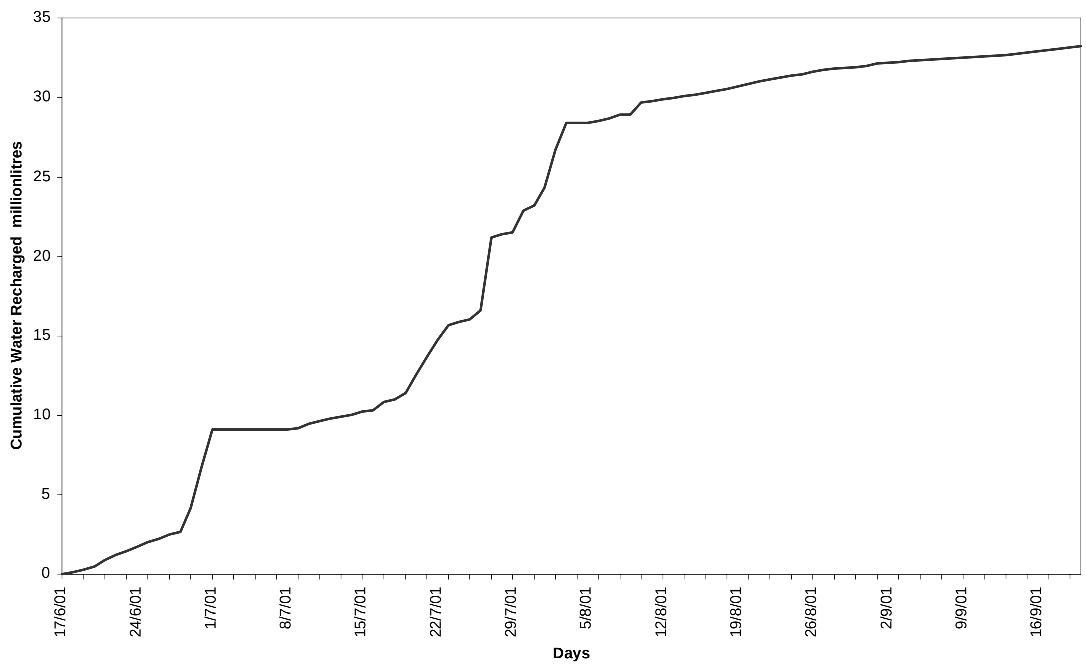
A question that can be raised is : are we not blocking off run-off water from reaching downstream? There are two explanations possible : One, in most of the peri-urban villages and urban areas, run-off water "goes down the drain" becoming contaminated and useless.

Two, as computed above, the potential annual recharge from all the tanks in Gandhinagar is 29,900 million litres as against 1,298,000 million litres (the district area times the average rainfall) in the district. In other words, the harvestable run off is just 2.4% of the rainfall. Thus, there is no question of totally blocking the run-off water nor there is a scope for "real" upstream-downstream conflicts.

Analysis

The figure given below constructed from the water level data from the Sargasan tank shows the cumulative values for the monsoon period. Gandhinagar taluka received 420 mm (i.e. 70%) of rainfall against an annual average of 596 mm.

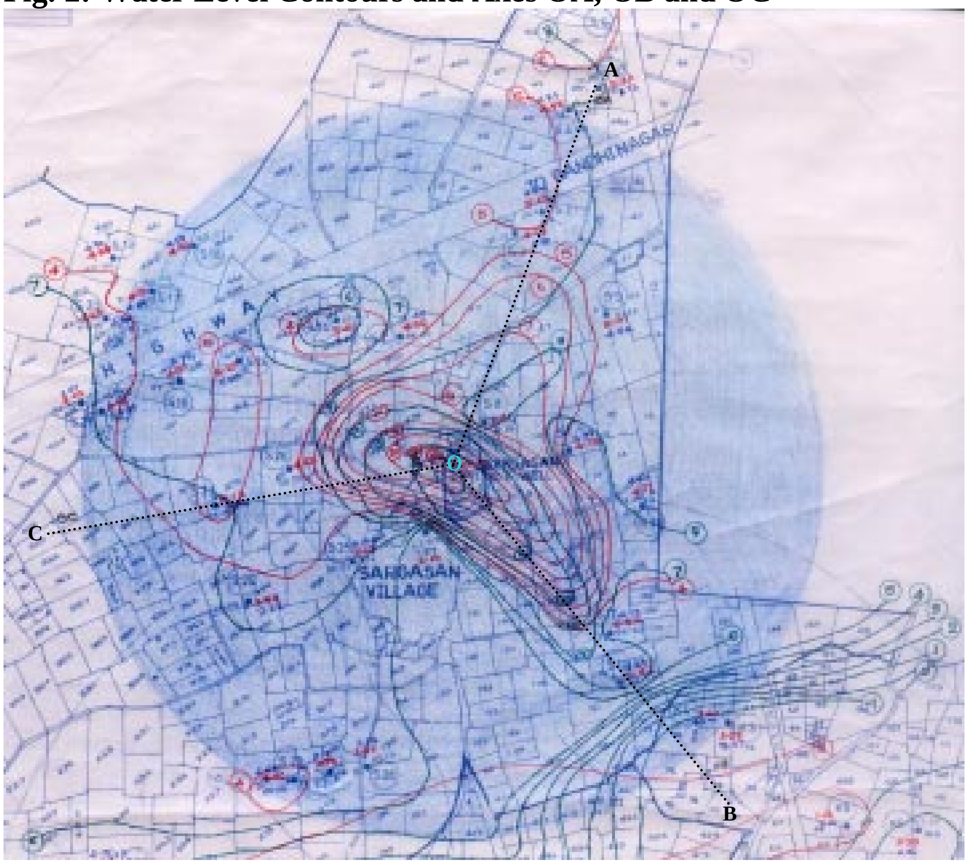
Fig. 1: Cumulative Water Recharged in Sargasan Tank



The above figure indicates that till September 20, 2001, with 70% of the average annual rainfall incident, a total of 33.2 million litres was harvested.

The water level data (in terms of reduced level) is drawn against chainage along three axes, OA, OB and OC separated from each other by 120 degrees. The point "O" represents the position of the Recharge Tubewell. Line OA, OB and OC are towards North, South West and South East with respect to Recharge Tubewell location.

Fig. 2: Water Level Contours and Axes OA, OB and OC



The following three figures are drawn from water level obtained from the recharge tubewell and the 32 surrounding borewells. Data was collected over 7 rounds between 7 August 2001 to 18 June 2002.

Fig. 3: Water Level Against Chainage Along Line OA

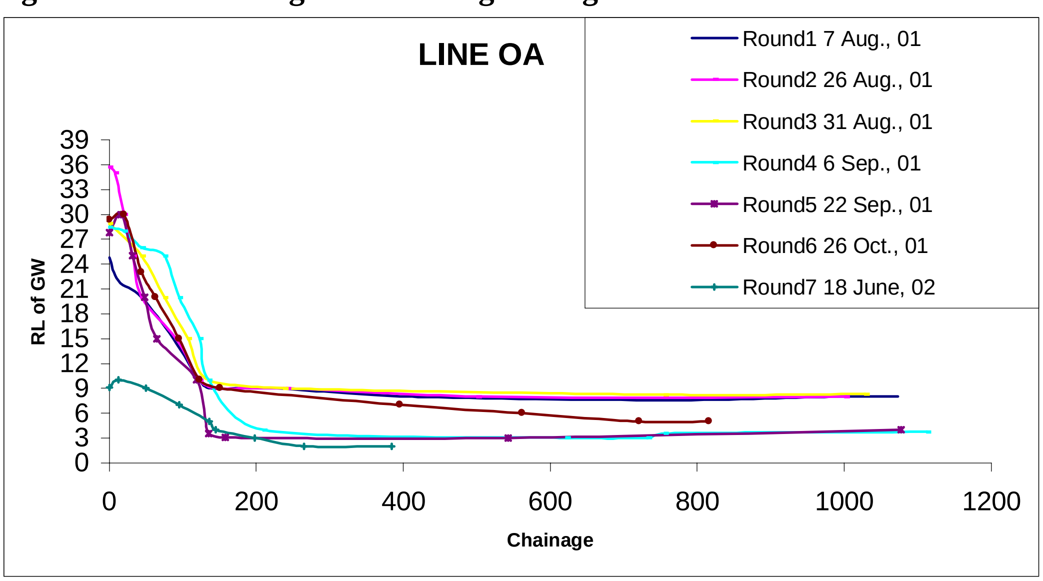


Fig. 4: Water Level Against Chainage Along Line OB

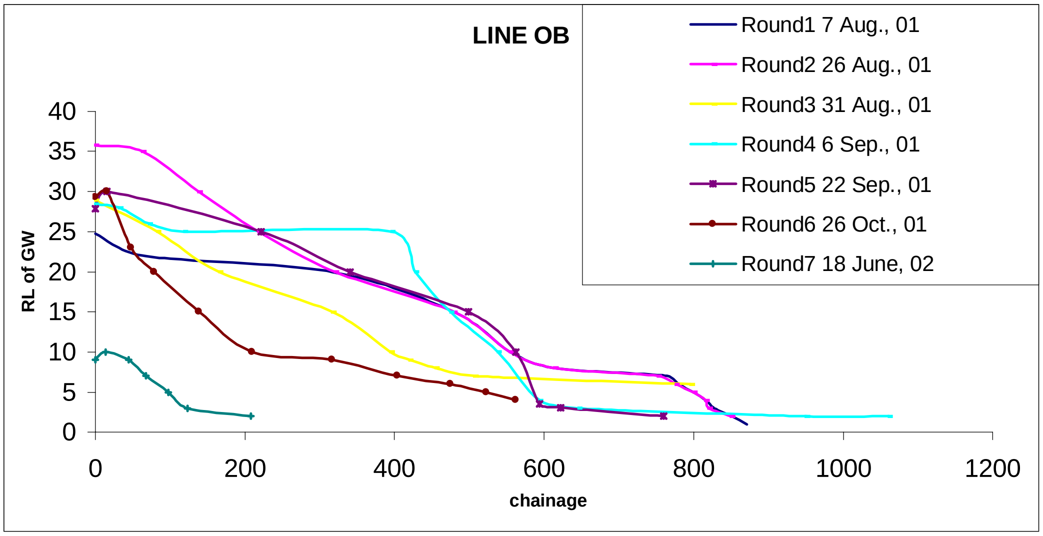
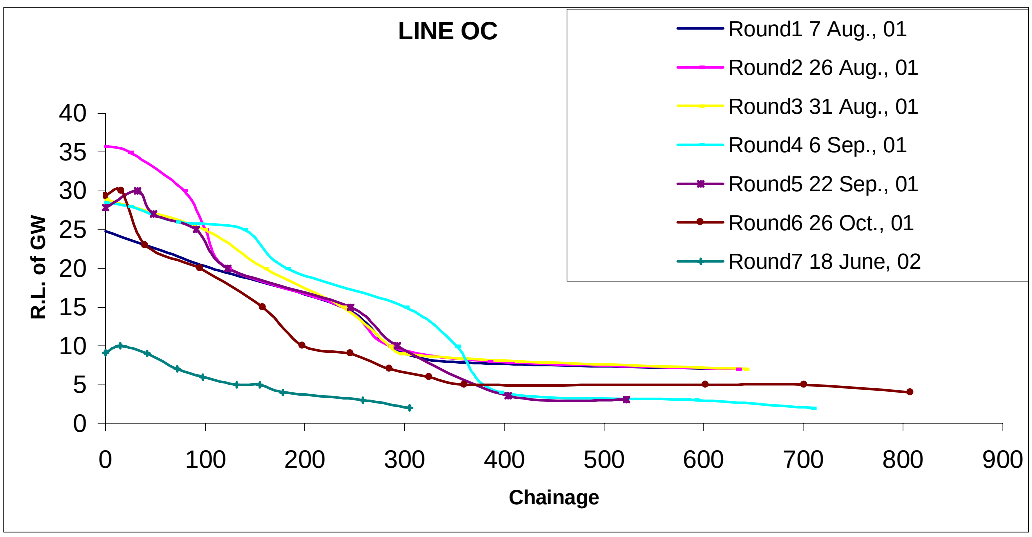


Fig. 5: Water Level Against Chainage Along Line OC

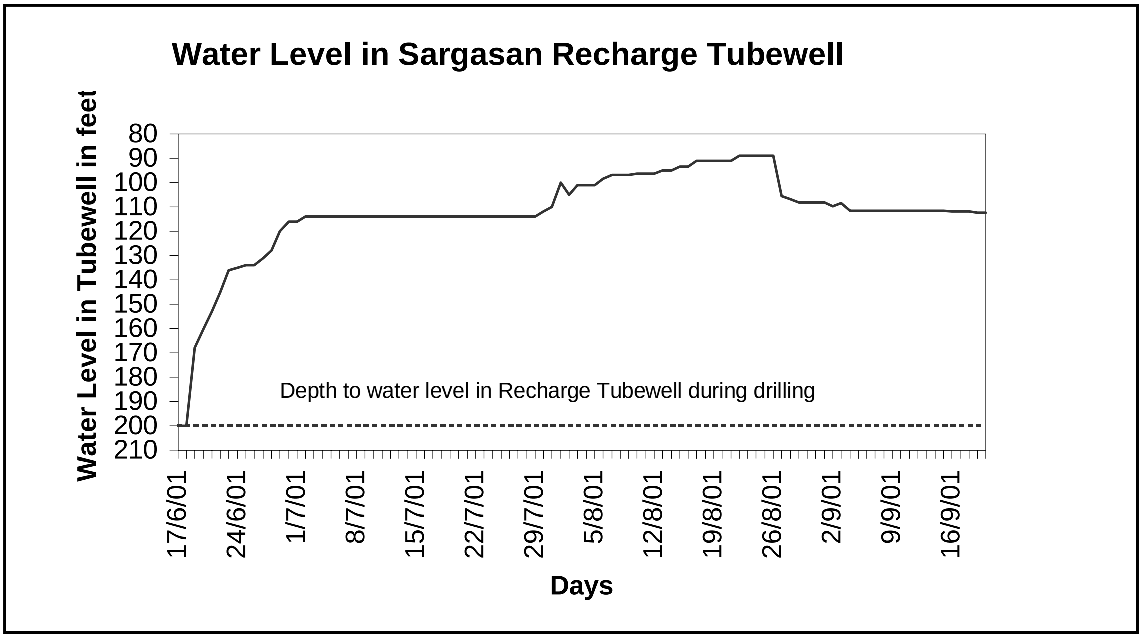


As can seen from the above figures, the dispersion of the mound is greatest along line OC (towards South East) coinciding with the general ground water movement direction[8].

The following figure shows the water level fluctuation *in the tank* and *in the Recharge Tubewell* separately from the start of monsoon 2001:

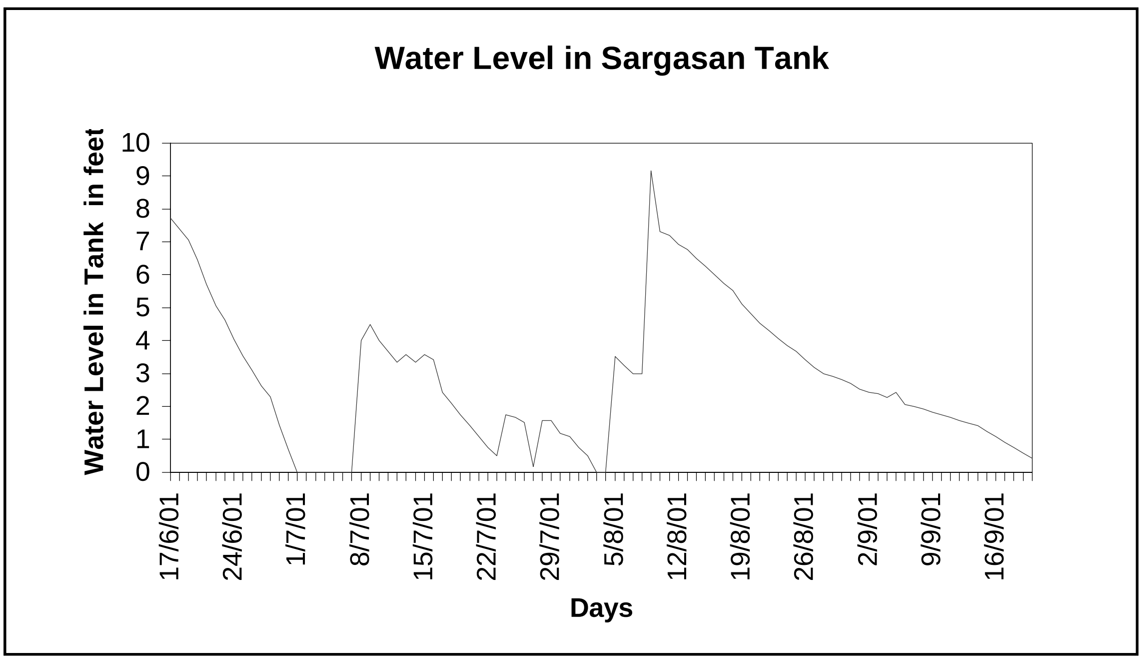
[8] Personal Communication with Dr. SC Sharma, Chairman & Managing Director (Retd.), Gujarat Water Resources Development Corporation Limited.

Fig. 6: Cumulative Water Level in Sargasan With Time



The following figure shows the water level in the tank along time axis. The figure clearly indicates the recharge into the ground indicating the function of the recharge tube well. However, when there is rainfall, there is a rise in the curve.

Fig. 7: Daily Residual Water Level in Sargasan Tank



Based on the post excavation capacity-elevation characteristic of the tank, estimate of water percolated was made which is shown in the following figure:

Fig. 7: Post Excavation Contours of the Tank

References:

1. *Gujarat Jal-Disha 2010 – A Vision of a Healthy and Equitable Future with Drinking Water, Hygiene and Sanitation for All, (December 2000)*. A report by a Working Group constituted by Gujarat State Drinking Water Infrastructure Co. Ltd.
2. India Water Partnership (1999), *India Water Vision 2025 – A report of the Vision Development Consultation.*
3. Government of Gujarat (1999), *Drinking Water Scarcity – Master Plan Gujarat 1999-2000.*
4. *Dynamics of Drinking Water in Rural Gujarat (May, 1994)*, Centre for Water Resources, Utthan, Ahmedabad.
5. Mudrakartha S. (1999), *Status and Policy Framework of Ground Water in India, VIKSAT Nehru Foundation for Development, Ahmedabad.*
6. Gujarat Ecology Commission, (?), Taluka Level Ecological Profile.

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