IWMI-TATA WATER POLICY RESEARCH PROGRAM

ANNUAL PARTNERS' MEET 2002

IWMI-TATA
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Impact of Groundwater Recharge Activities in Saurashtra

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Abstract

The ever-increasing demand for water and the deteriorating quality of available groundwater resources have already precipitated a major water crisis in the Saurashtra region of Gujarat. The region receives approximately 500 mm average annual rainfall, lion's share of which is received during the monsoon season (Mid-June to September). Due to the high year-to-year variation in the annual rainfalls, the region is heavily prone to droughts.

Over the past few years, local water harvesting and groundwater recharge have emerged as a major strategy in Saurashtra to mitigate the impact of the recurring droughts, which are manifested by severe shortage of water for irrigation and drinking, and fodder scarcity. Many NGOs in the region and government agencies had constructed nearly fourteen hundred percolation tanks in the region. It is important to analyze the impacts of these interventions, before advocating them as a viable approach for addressing water scarcity, and drought proofing.

A study was undertaken to analyze the hydrological impacts of the local recharge were selected for detailed keeping in view the unique geological settings of the areas where these structures are located. Water levels in the percolation tanks, check dams, A.S.R. wells, and surrounding observation wells were taken at fifteen-day intervals. Based on the data gathered, recharge rates and efficiency of percolation tanks are calculated. Based on the recharge rate estimates, performance indicators for the recharge systems were estimated. The paper presents the results of the study with regard to the following: [1] maximum rise in the water mount and the duration of rise; [2] radius of influence of percolation tanks; and [3] recharge rate and the recharge rate equation.

1.0 Introduction

Water is a prime natural resource, a basic human need and a precious national asset. The extent to which water is abundant or scarce, clean or polluted, beneficial or destructive has a major influence on our planet in its rapidly changing face brought about by rapid development on all fronts, ever increasing population and fast rate of scientific and technological advancements.

With an average annual rainfall of approximately 500 mm, lion's share of which is received during the monsoon season (Mid-June to September), Saurashtra region is one of the water scarce regions of Gujarat. Due to the high year-to-year variation in the annual rainfalls, the region is heavily prone to droughts. The demand for water in the region is growing due to rapid urbanization, increasing preference for water intensive crops, and industrial growth. On the other hand, freshwater supplies are dwindling due to the fast rate of depletion of groundwater resources, increasing level of salinity of available groundwater in the coastal areas, and the depleting surface reservoirs. This had already precipitated a major crisis in the Saurashtra region of Gujarat. During droughts, the crisis deepens, when all the reservoirs and most of the wells in the region dry up; while water for water for drinking and irrigation increases.

In the recent past, local water harvesting and groundwater recharge have emerged as a major strategy to deal with the perennial water problems of Saurashtra and to mitigate the impact of the recurring droughts. Many NGOs in the region and government agencies had constructed water-harvesting structures that include nearly 13,000 check dams, 1,400 percolation tanks in the region. So far, there have been no scientific assessments of these initiatives. It is important to analyze the impacts of these interventions, before advocating them as a "viable approach" for tackling water problems, and drought proofing.

2.0 Methodology Adopted

(1) Selection of suitable sites for recharge installations
(2) Monitoring water levels of source area and observation wells falling under the influenced area.
(3) Collection of evaporation data from nearby station.
(4) Calculation of recharge rates from water level fluctuations and evaporation data.
(5) Preparation of dimensionless graph to study nature of water mound developed.
(6) Preparation of recharge rate graph and to find recharge rate equation from log-log graph.

3.0 Percolation Tanks

General Introduction

Four ponds were selected for the study keeping in view the unique geology of the areas where the structures were located (Refer Table-1):

(1) Pichhvi Percolation Tank

Significant work has been done by NGOs in Saurashtra region for local recharging of groundwater. More than thousand percolation ponds have been constructed. To capture the vast magnitude of the work done on recharging, a percolation tank constructed by the Swadhyay Pariwar, known as the Pichhvi Percolation Tank was studied. The evaporation data for the tank was collected from the irrigation department. Water level fluctuation data were noted in weekly intervals. To study the effect of water mound developed, water levels in the surrounding wells are observed.

(2) Hamirpura Percolation Tank

This is located in the native place of Shri O. R. Patel of Orpat. Mr. O. R. Patel has handed over whole of his business to his sons and at the age of 60 year and has come to stay at his native village. With the cooperation of the villagers, he got this tank constructed in 1995. After seeing the encouraging results from the tank in 1998, he developed Hamirpura Watershed Programmed for the village Hamirpura and surrounding villages. It was really credible for an industrialist of his calibre to come out with such a detailed plan for watershed development. With the use of six bulldozers constantly for 15 days, the villagers built about 300 earthen bunds called para in local parlance. This is facilitating more percolation of water, in spite of the fact that the rainfall received in a day was of the order of 300 mm.

(3) Shingoda Percolation Tank

This village of Paddhari taluka is located at about 8 km away from Hamirpura. Drinking water is scarce in the village. By 15th March the drinking water source of the village gets dried up. As a result District Panchayat tankers would have to supply water to the village during March, April, May by tankers. Swadhyay Parivar came together and constructed a tank in village wasteland (*Gauchar*), adjoining the drinking water well. Nearly 430 persons worked for fifteen days continuously. Thirty tractors were also employed for the work. In 1995 spillway portion was constructed by using free stones available from the village and cement worth Rs.12, 000. Every year in April-May, villagers carry out de-silting of the tank. While in adjoining Hamirpura village, the tank is not de-silted. This tank has been selected for monitoring to study the effect of silting on recharge rate.

(4) Chhalla Rupavati Percolation Tank

Population of the village is 1088. The Swadhyayees are very active in the village. The work of construction of the percolation tank was started on 20/4/96, and completed on 27/5/96. The earthwork was of the order of 30,500 cubic meters. Two hundred and eighty persons were involved in this work. As a result of this good quality of water is available in adjoining wells. Local stones, which were available free of cost, and cement worth Rs.16, 000 were used for the construction. Thirty-five tractors were employed for 2092 hours. Six of non-Swadhyayee families, whose holdings were going under submergence of the proposed tank, happily agreed to the construction. One of the Swadhyayee came for the work, on the next day of his marriage along with his wife to offer Shrambhakti. This reflected the sense of devotion and dignity of labour among the people, and to what extent they are committed for such social activities.

4.0 Check Dams

General Introduction

For the present study five check dams have been presented. (Refer Table-2)

(1) Chokli Check Dam

Constructed in 1993 in Junagadh district, Swadhyayees of the village and surrounding five other villages have worked together for the construction this structure. After seeing the results of this check dam, in Mendarda taluka alone, 32 more check dams have been constructed. During the last three years, at every fifteen days interval, water levels of the wells surrounding the check dam have been monitored.

(2) Arnhi Check Dam

This is one of the 135 check dams built by tree lover Premjibhai in Upleta taluka of Rajkot. According to a Gujarat proverb, which when translated into English, mean father of the universe, will not sit idle waiting for someone to help. With these explanations taking help of all people and their carts, the dam was constructed. Premjibhai's Vruksh Premi Sewa Trust provided only cement.

(3) Sutrapada Check Dam

This check dam is located at distance of 2 km from the seashore. The water in all the wells in the village is salty due to intrusion of seawater. Total population of the village is 18,800. A group of businessmen of the village felt that the water of the village should be pure (*Nirmal Neer*) to fulfill their obligation to the land. They took the responsibility of constructing a check dam in the village. With the use of freely available limestone and using cement of Rs.12, 000/- the spillover portion was constructed. Two hundred and seventeen members of 70 families jointly worked for 27 days for the construction of the structure. This was built on Nagni storm water drain. For the past three years, this group of businessmen also does de-silting and raising the level of the earthen bund with excavated silt. There is no farm of any Swadhyayee in and around these wells. One can see green farming of chilly and groundnut even in summer in this area. More over, the drinking water well started yielding sweet water.

(4) Bhiyal Check Dam

The Swadhyay volunteers are engaged in collecting water related data from the Check dam constructed by the Government. No periodic de-silting work is carried out on this check dam. Therefore, the effects of silting on the performance of the recharge system can be analyzed by comparing the data for this check dam with that for Chokli check dam located in the same taluka of Mendarda.

(5) Hathigadh-Khara Check Dam:

In Liliya taluka of Amreli district, the problem of high level of fluorides in groundwater is very severe. Several thousand of rural people in this taluka suffer from skeletal fluorosis. There is no cure for fluorosis in modern medical science. In collaboration with the Government of Netherlands, Government of Gujarat had set up a de-fluorination plant. But due to the problem of effluent disposal, the plant is lying idle. This check dam has been selected with a purpose to study the effects of recharging on fluoride content in groundwater from the surrounding wells.

5.0 Aquifer Storage Recovery (A.S.R.) Wells

General Introduction

Here four cases are selected for data collection and analysis. (Refer Table-3)

(1) A well recharged from farm runoff at Khadvanthli.
(2) A well recharged from the reservoir created by a check dam constructed on Madhuvanti river at Mithapur.
(3) A well in Goraj village of Mangrol taluka, where Warabandhi for recharging wells is practiced.
(4) A well in fluoride affected area village Sajantimba, Taluka: Leliya or Amreli district.

All these wells are irrigation wells. They are recharged by rainfall during monsoon (July, Aug, Sept) and are discharged when water is withdrawn during needy periods. So these wells are called A.S.R. (Aquifer Storage Recovery) wells. As they are dual-purpose wells, due to surveying and de-silting effect, their discharging rate is not reduced considerably. The quality of water is improved due to recharging. This improves the quality of soils also. As a result, many farmers have earned addition income Rs.20, 000 per annum each.

(1) Khadvanthli A.S.R. Well

Mr. Kanjibhai K. Kachadiya is a progressive farmer of this village. He has made a channel of 2.0 m width and 0.8 m depth along the fencing. He collects the runoff water from his and the surrounding fields in this channel. This water has low turbidity. It passes through a 1.5m x 1.5m x 1.5m gravel pit. This well is getting recharged during rain since 1993. As a result, Kanjibhai is able to grow onion and garlic in summer season also, and earns Rs.1.0 lakh additional income every year.

(2) Mithapur A.S.R. Well

This village is on the bank of Madhuvanti river. One farmer laid out a pipeline by excavating more than 8.0 m deep in the rocky formation (using explosives) and recharged his well. The district Panchayat constructed one check dam in the upper catchment. The well gets recharged till the month of February from this reservoir. Due to this continuous recharge, the quality of water in the surrounding wells improved considerably, apart from water table conditions. Formally, the well used to get dry in the month of February. Now water is available throughout the year and farmer is able to take three crops.

(3) Goraj A.S.R. Well

This village is located 8.0 km away from the coast. More than 200 dug wells had been constructed by the farmers of this village. Nearly all wells are recharged during monsoon. In the case of the well under study, water is diverted from the tributary of a river. The porosity of calcareous limestone in this region is high. As a result, intake capacity of wells is excellent. The farmers here had agreed for Warabandhi for diverting stream water in to their wells. Such a system of recharging must have been practiced for the first time in the history.

(4) Sajantimba A.R.S. Well

This village is in Liliya taluka, a fluoride affected area of Amreli district. To study the effect of recharge on fluoride content in groundwater, water samples of the surrounding wells and the recharge wells are collected and analyzed in the laboratory of the Gujarat State Water Supply and Sewerage Board at Bhavnagar, for different water quality parameters.

6.0 Summary And Conclusions

From the forgoing discussion, following conclusions emerge.

(i) The maximum height of water mound observed for percolation tank at 200 m upstream of the bund of the tank is 6.2 m for milliolite limestone formations, 2.3 m for weathered basalt, and 4.45 m for Gaj limestone. Similarly maximum height of the water mound on downstream side at a distance of 200 m is 8 m for milliolite limestone, 3 m for weathered basalt rock and 5.1 m for Gaj limestone.

The height of water mound developed in A.S.R. wells in miliolite limestone is 8.4 m as compared to 6.1 m for A.S.R. wells in weathered trap. But the radius of influence is 530 m and 570 m, respectively. The period of development of water mound is 100 days and 120 days, where as period for decay is 200 and 220 days respectively. This indicates the fact that miliolite limestone has greater permeability. The height of the water mound in limestone is higher as compared to that in other formation, but the hydraulic diffusivity is very high, and the mound decays fast.

(ii) Silting in percolation tanks and check dams not only decreases the storage capacity but also reduces recharge rate. Reduction in recharge rates increases the recharge evaporation ratio as seen from the following results.

Table 1: Recharge rates at a glance

	Average Recharge. Rate (mm/day)	Recharge Rate Equations	Recharge Evaporation Ratio
Normal Percolation Tank	7.87	$I = 13\ T^{-0.111}$	1.83
De-silted Percolation Tank	20.40	$I = 34.67\ T^{-0.089}$	4.20
Normal Check Dam	30.05	$I = 57.67\ T^{-0.205}$	2.48
De-silted Check Dam	47.94	$I = 67.33\ T^{-0.086}$	3.08

(iii) Recharge structures have greater effects on the down stream as compared to upstream as seen from following results.

Table 2: Comparison of effect downstream and Upstream

		Radius of Influence (m)	
		U/S	D/S
Percolation Tank	Miliolite limestone	1100	1300
	Gaj limestone	780	1000
	Weathered basalt	720	1100
Check Dam	Weathered basalt	430	550

(iv) The TDS of water is remarkably less at the vicinity of recharge structure and increases as the distance from the structure increases. This is due to dilution caused by recharge.

(v) Monitoring one check dam and one aquifer storage recovery well in fluoride-affected area indicated a significant decrease in fluoride content, which proves that recharge methods are effective in reducing effects of fluoride.

(vi) The life of percolation tanks and check dams depend on de-silting.

From the above, one can deduce that the success of recharge structures in Saurashtra region can be assessed in relation to the following performance indicators.

(a) Height of water mound formed
(b) Areal extent of water spread both upstream and downstream of the structure.
(c) Water quality parameters such as TDS and fluoride

As more and more recharge structures are coming up, there is a necessity to systematically evaluate the success of such structures. Here, an attempt is made to project the above indicators to gauge the performance of such structures.

Annexes

Table-3: Location, Soils, Topography and Geology for Percolation Tank

Sr. No.	Village, Taluka, District	Dist. Km	Location Latitude North	Location Longitude East	Soils / Topography	Geology	Remark
1.	Pichhvi Kodinar Amreli	 20 100	20°59'	70°44'30"	Moderate salinity, clayey, montmorillonitic (calcareous), hyperthermic lithic ustochrepts. Very gently sloping coastal plain with moderate erosion	Miliolite limestone, 7 to 14 m thick, highly carveneous in nature forms local aquifer. The quality of ground water is good.	Constructed by Govt. before 50 years reno-vated and desilted by Swadhyay Parivar in 1994
2.	Hamirpura Morbi Rajkot	 18 35	20°26'	70°35'	Clayey, montmorillonitic, hyperthermic lithic ustochrepts. Well drained, gently sloping, dissected alluvial plain with moderate erosion	Deccan trap of cretaceoecocene age volcanic in nature having thickness of 10 to 26 m. Below it compact trap is encountered.	Constructed by ORPAT in 1995
3.	Chhalla-Rupavati Dhrol Jamnagar	 27 63	22°28'	70°27'	Moderate salinity, clayey, montmorillonitic (calcareous), hyperthermic lithic ustochrepts. Very gently sloping coastal plain with moderate erosion	Gaj limestone having thickness 10 to 20 m acts as a local aquifer	Constructed by Swadhyay Parivar in 1995. Desilting carried out every year
4.	Singhoda Padadhari Rajkot	 8 32	22°25'	70°32'	Moderate salinity, clayey, montmorillonitic (calcareous), hyperthermic lithic ustochrepts. Very gently sloping coastal plain with moderate erosion	Deccan trap of cretaceoecocene age volcanic in nature having thickness of 8 to 20 m. Below it compact trap is encountered.	Constructed by Swadhyay Parivar in 1995. Desilting carried out every year

Table-4 : Location, Soils, Topography and Geology for Check Dams

Sr. No.	Village Taluka, District	Location			Soils / Topography	Geology	Remark
		Dist. Km	Latitude North	Longitude East			
1.	Chokli Mendarda Junagadh	 10 22	20°0'30"	70°15'	Fine, montmorillonitic (calcareous), hyperthermic vertic ustochrepts. Moderately shallow, fine soil on very gently sloping alluvial plain (with mounds)	Deccan trap of cretaceoecocene age volcanic in nature having thickness of 7 to 26 m. Below it compact trap is encountered.	Constructed by Swadhyay Parivar in 1993. Desilting carried out every year
2.	Arnhi Upleta Rajkot	 22 95	20°50'	70°10'10"	Clayey, montmorillonitic (calcare-ous), hyperthermic, paralithic vertic ustochrepts. Well drained, gently sloping, dissected alluvial plain	Deccan trap of cretaceoecocene age volcanic in nature having thickness of 9 to 19 m. Below it compact trap is encountered.	Constructed by Premjibhai in 1996
3.	Sutrapada Veraval (Patan) Jamnagar	 22 120	22°50'	70°20'	Fine, loamy, mix (calcareous) isohyperthermic typic ustochrepts. Well drained, fine clayey soils on very gently coastal plains.	Miliolite limestone, 15 to 40 m depth are highly carveneous in nature forms local aquifer. Yielding saline quality of water.	3 km from Arabian sea cost constructed by Swadhyay Parivar
4.	Bhiyal Mendarda Junagadh	 26 57	20°30'	70°20'	Fine, montmorillonitic (calcareous), hyperthermic vertic ustochrepts. Moderately shallow, fine soils on very gently sloping alluvial plain (with mounds)	Miliolite limestone, 10 to 20 m depth are highly carveneous in nature forms local aquifer. Yielding saline quality of water.	Constructed by Government on tributary of Madhuvanti river
5.	Hathigadh-Khara Leliya Amreli	 10 57	21°45'	71°29'	Fine, montmorillonitic (calcareous), hyperthermic typic chromusterts. Moderately deep well drained, fine soils, on gently sloping ground plains with slight salinity	Deccan trap of cretaceoecocene of 15 to 20 m depth becomes compact at depth having max. depth more than 150 m contains fluoride contents	Constructed by Swadhyay Parivar

Table-5 : Location, Soils, Topography and Geology for A.S.R. Wells

Sr. No.	Village Taluka, District	Location			Soils / Topography	Geology	Remark
		Dist. Km	Latitude North	Longitude East			
1.	Khadvanthli Gondal Rajkot	 23 55	22°0'30"	70°30'	Clayey, montmorillonitic (calcareous), hyperthermic paralithic vertic ustochrepts. Very gently sloping dissected alluvial plain with moderate erosion	Deccan trap of cretaceoecocene age volcanic in nature having thickness of 9 to 20 m. Below it compact trap is encountered.	A open well recharge from farm runoff since 1993
2.	Mithapur Mendarda Junagadh	 12 43	21°30'	70°20'	Montmorillonitic (calcareous), hyperthermic vertic ustochrepts. Moderately shallow, well drained, calcareous, fine soils on very gently sloping alluvial plain with moderate erosion	Deccan trap of cretaceoecocene age volcanic in nature having thickness of 8 to 25 m. Below it compact trap is encountered.	A well recharge from the river Madhuvanti directly by laying 30cm dia. pipeline
3.	Goraj Mangrol Junagadh	 8 64	21°15'	70°0'30"	Fine loamy, mixed (calcareous), isohyperthermic typic ustochrepts. Moderately shallow, well drained, calcareous, fine loamy soils on very gently sloping coastal plain with moderate erosion	Miliolite limestone, 10 to 45 m depth are highly carveneous in nature forms local aquifer, yielding saline quality of water.	Warabandhi for recharging wells from storm water drains.
4.	Sajantimba Lilya Amreli	 10 57	21°48'	71°27'	Fine montmorillonitic (calcareous), hyperthermic typic chromusterts. Moderately deep, well drained, calcareous, fine soils on very gently sloping alluvial plain (with mounds)	Deccan trap of cretaceoecocene of 15 to 20 m depth becomes compact at depth having max. depth more than 150 m contains fluoride contents	Located on tributory of Shetrunji river. Fluoride affected area.

Results Of Percolation Tanks

Effect of Percolation Tanks on Surrounding Wells

Table-6: Maximum Water Mound Rise at Different Distances in Observation Wells

Name of Percolation Tank	Upstream Side (m)						Downstream Side (m)						
	200	400	600	800	1000	1200	200	400	600	800	1000	1200	1400
Pichhvi (Miliolite limestone, Desilted)	6.2	4.4	3.0	1.8	1	0	8	6.6	5.4	3.8	1	0.8	0
Hamirpura (Weathered basalt rock)	2.3	1.7	0.9	0	--	--	3	2.1	1.4	1.1	0.9	0	--
Chhalla Rupavati (Gaj limestone, Desilted)	4.45	3.05	1.45	0	--	--	5.1	3.9	3.2	0.9	0	--	--

Radius of Influence and Duration of Water Mound

Table-7: Radius of Influence and Duration of Water Mound

Name of Percolation Tank	Radius of Influence (m)		Duration of Water Mound (days)		Total Duration (days)	Duration of water stored in PT (days)
	U/S	D/S	Develop.	Decay		
Pichhvi (Miliolite limestone, Desilted)	1100	1300	165	100	265	270
Hamirpura (Weathered basalt rock)	720	1100	170	120	290	300
Chhalla Rupavati (Gaj limestone, Desilted)	780	1000	170	90	260	220

Recharge Rate of Percolation Tanks

Table-8: Recharge Rate of Percolation Tanks

Name of Percolation Tank	Recharge Rate (mm/day)									Ave-rage
	Maximum			Minimum			Yearly Average			
	1996	1997	1998	1996	1997	1998	1996	1997	1998	
Pichhvi (Miliolite limestone, Desilted)	95.84	74.29	--	27.46	26.86	--	30.05	30.0	--	30.02
Hamirpura (Weathered basalt rock)	43.1	18.0	39.76	7.0	6.28	6.85	8.0	7.8	7.8	7.87
Singhoda (Weathered basalt rock, Desilted)	29.71	34.29	36.43	17.57	18.57	20.57	18.5	20.7	22.0	20.40
Chhalla Rupavati (Gaj limestone, Desilted)	31.43	31.84	31.86	22.57	23.29	21.71	24.0	24.8	24.6	24.47

Recharge Rate Equations from Log-Log Graph

Table-9: Recharge Rate Equations from Log-Log Graph Cumulative Days v/s Recharge Rate

Name of Percolation tank	Intercept on y-axis (Recharge rate), α			Slope of graph, β			Average		Equation
	1996	1997	1998	1996	1997	1998	α	β	
Pichhvi (Miliolite limestone, Desilted)	78	95	--	-0.13	-0.12	--	86.5	-0.125	$I = 86.5\ T^{-0.125}$
Hamirpura (Weathered basalt rock)	13	13	13	-0.09	-0.114	-0.13	13	-0.111	$I = 13\ T^{-0.111}$
Singhoda (Weathered basalt rock, Desilted)	38	39	27	-0.13	-0.11	-0.026	34.67	-0.089	$I = 34.67\ T^{-0.089}$
Chhalla Rupavati (Gaj limestone, Desilted)	40	42	40	-0.11	-0.118	-0.11	41	-0.113	$I = 41\ T^{-0.113}$

Comparison of Recharge and Evaporation Volumes

Table-10: Comparison of Recharge and Evaporation Volumes

Name of Percolation Tank	Recharge Volume m^3/season			Evaporation Volume m^3/season			Average m^3/season		Rech. Evapo-ration Ratio
	96-97	97-98	98-99	96-97	97-98	98-99	Rech. Vol.	Evap. Vol.	
Pichhvi (Miliolite limestone, Desilted)	989514	922762	--	115344	98649	--	956138	106997	8.94
Hamirpura (Weathered basalt rock)	33753	43203	46254	17916	26219	23079	41070	22405	1.83
Singhoda (Weathered basalt rock, Desilted)	170409	218741	257000	41106	50107	62748	215383	51320	4.20
Chhalla Rupavati (Gaj limestone, Desilted)	181135	309600	242741	39571	73937	71001	244492	61503	3.98

Results of check dams

Effect of Check Dams on Surrounding Wells

Table-11: Maximum Water Mound Rise at Different Distances in Observation Wells for Chokli Check Dam (1996-98)

	Upstream Side (m)				Downstream Side (m)					
Dist. from C.D. (m)	150	200	300	400	100	150	200	300	400	500
Mound height developed (m)	1.2	1.1	0.87	0.1	4.2	4	3.6	1.5	0.5	0.2

Radius of Influence on upstream is 430 m and on down stream 550 m.

Recharge Rate of Check Dams

Table-12: Recharge Rate of Check Dams

Name of Check Dam	Recharge Rate (mm/day)									Ave-rage
	Maximum			Minimum			Yearly Average			
	1996	1997	1998	1996	1997	1998	1996	1997	1998	
Chokli (Weathered basalt rock, Desilted)	113.84	62.49	69.23	39.18	26.85	26.28	55.19	44.85	43.79	47.94
Arnhi (Weathered basalt rock)	38.54	41.73	38.82	22.25	20.23	18.74	29.17	30.98	30.0	30.05
Bhiyal (Weathered basalt rock)	44.9	45.8	61.5	38.2	34.7	27.2	40.2	38.82	24.9	34.64

Comparison of Recharge and Evaporation Volumes

Table-13: Comparison of Recharge and Evaporation Volumes

Name of Check Dam	Recharge Volume m^3/season			Evaporation Volume m^3/season			Average m^3/season		Rech. Evapo-ration ratio
	96-97	97-98	98-99	96-97	97-98	98-99	Rech. Vol.	Evap. Vol.	
Chokli (Weathered basalt rock, Desilted)	17015	16783	16593	5235	5553	5564	16797	5451	3.08
Arnhi (Weathered basalt rock)	7009	11421	21029	3002	4731	8144	13153	5292	2.48
Bhiyal (Weathered basalt rock)	16414	16024	14702	6856	6272	5947	15713	6358	2.47

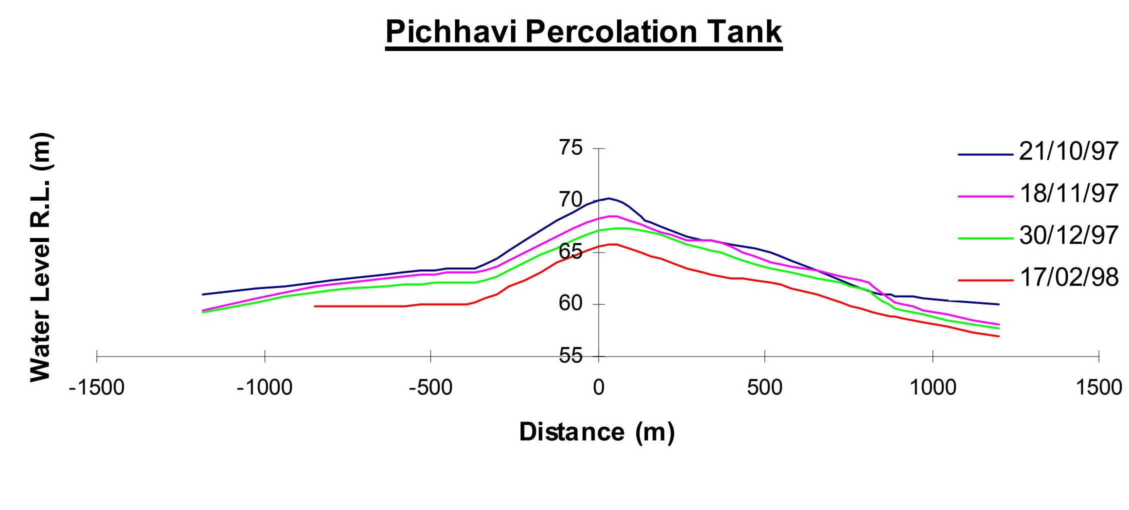
Results of aquifer storage recovery wells

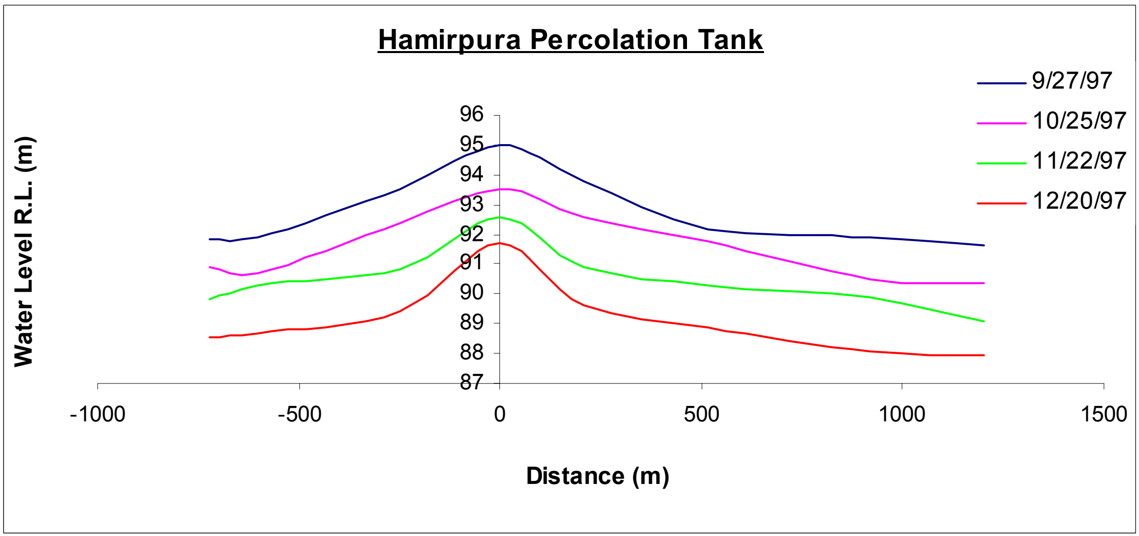
Development of Water Mound

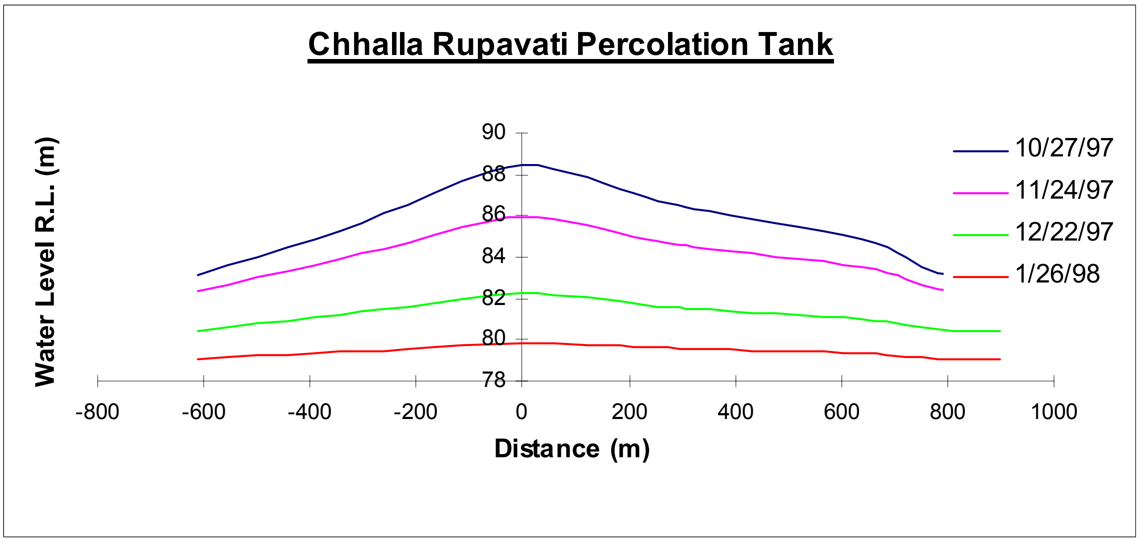
Table-14: Development of water Mound

Name of Well	Height of Water Mound (m)		Radius of Influence (m)	Period of Development (days)	Period of Decay (days)	Month of Maximum Height
	1997	1998				
Khadvanthli (Weathered basalt rock)	6.13	6.03	570	120	220	Middle Oct.
Goraj (Miliolite limestone)	8.67	8.14	530	100	200	Middle Nov.

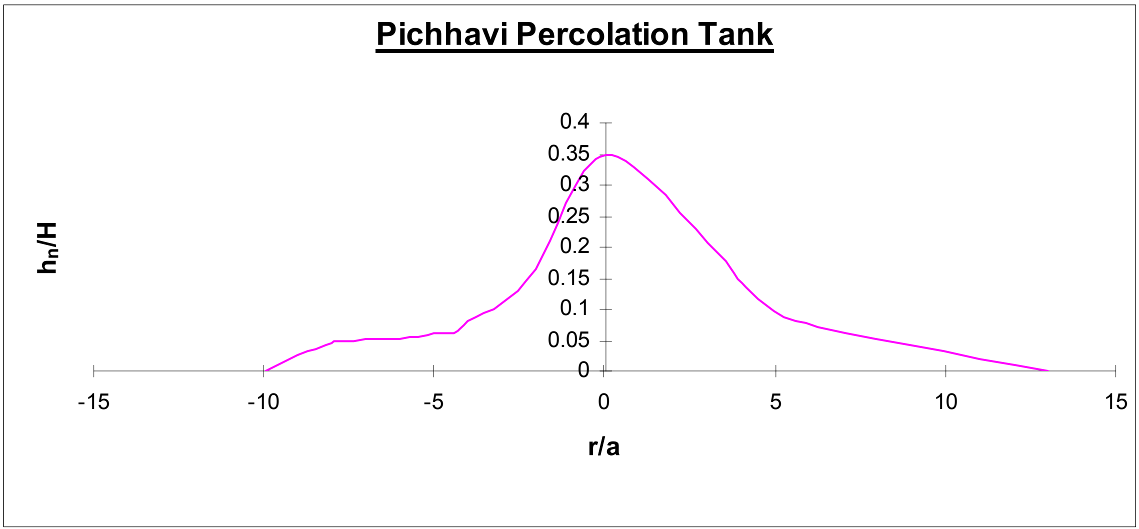
Water Mound Decay For Percolation Tanks

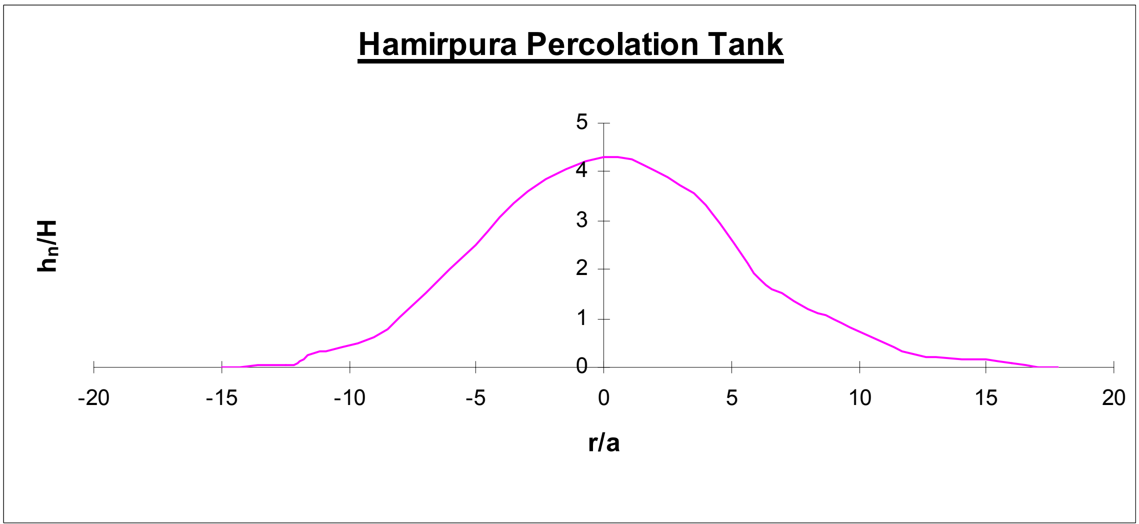


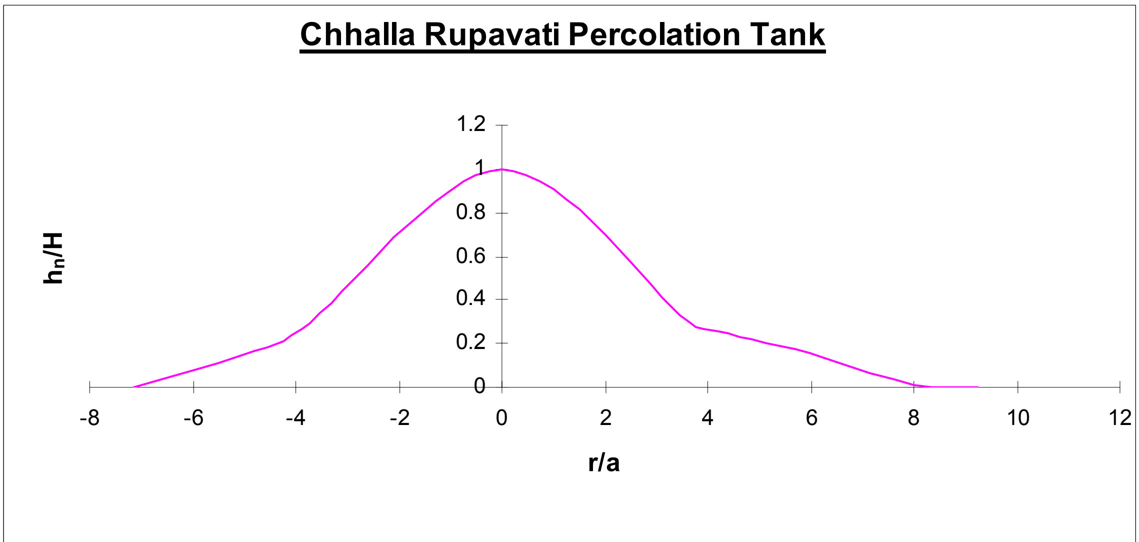




Non Dimensional Graphs For Percolation Tanks

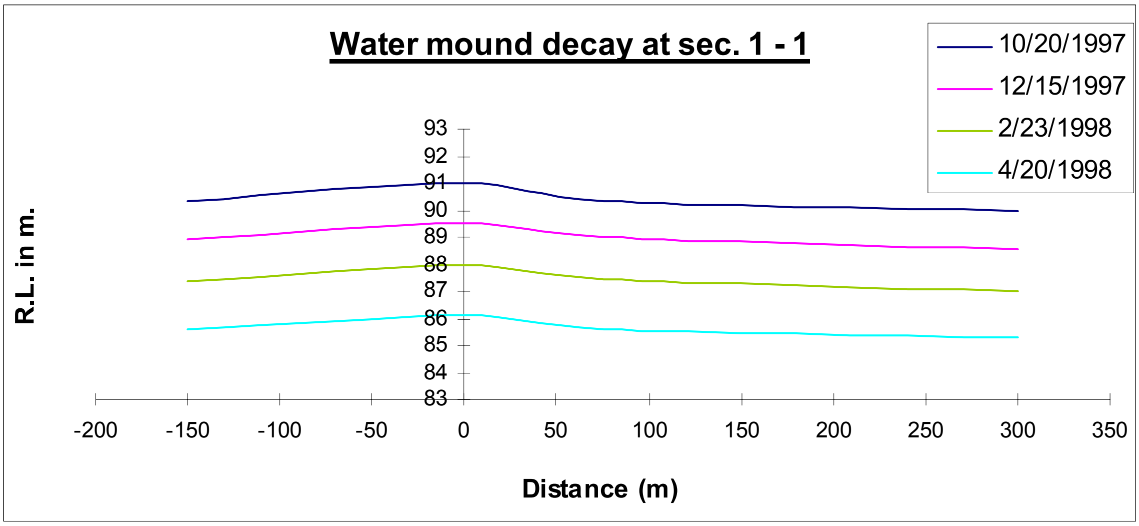


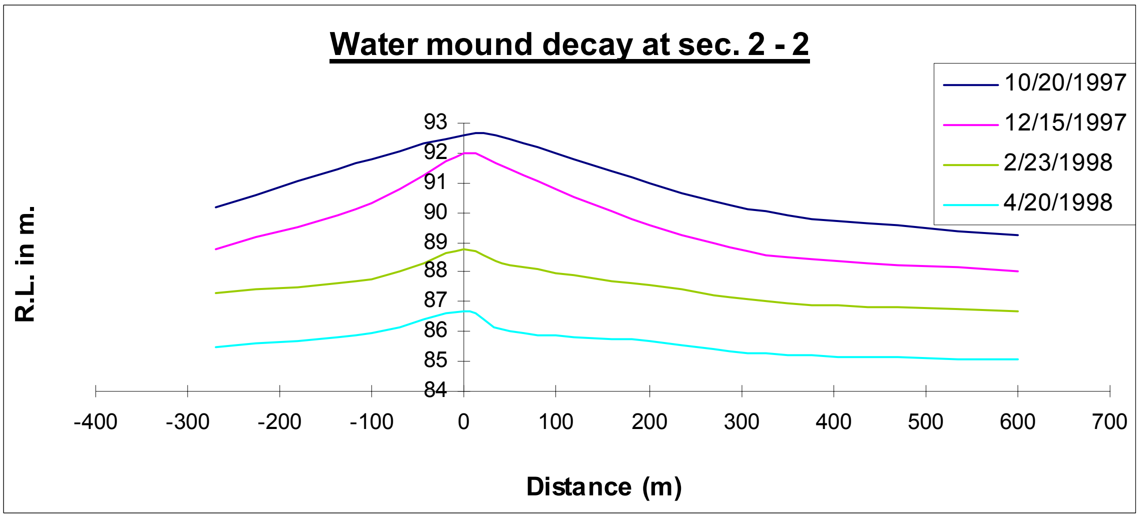


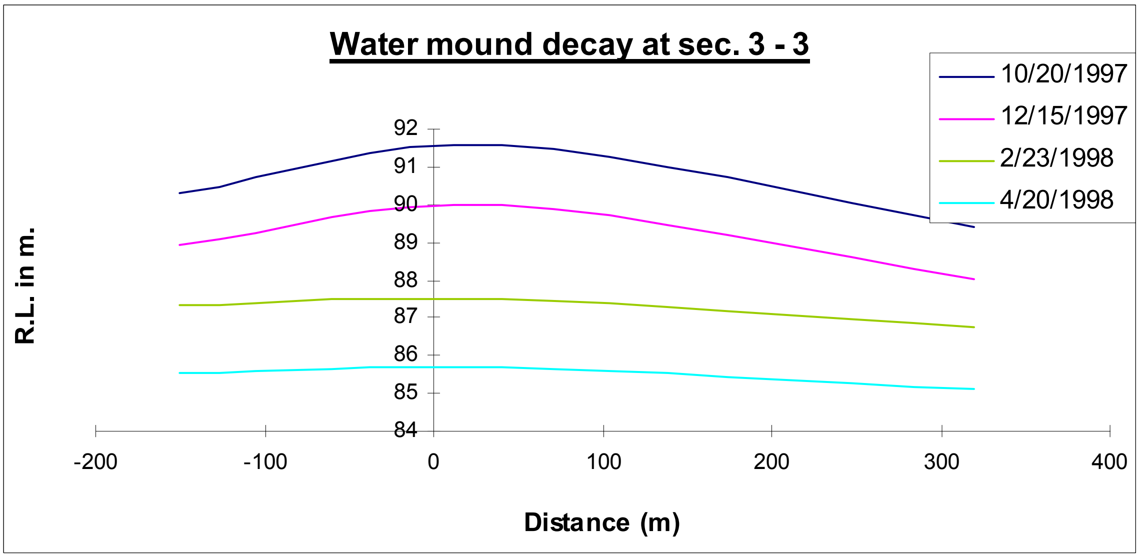


Chockli Vheck Dam

Village :- **Chockli** Ta. :- **Mendarda** Dist. :- **Junagadh**

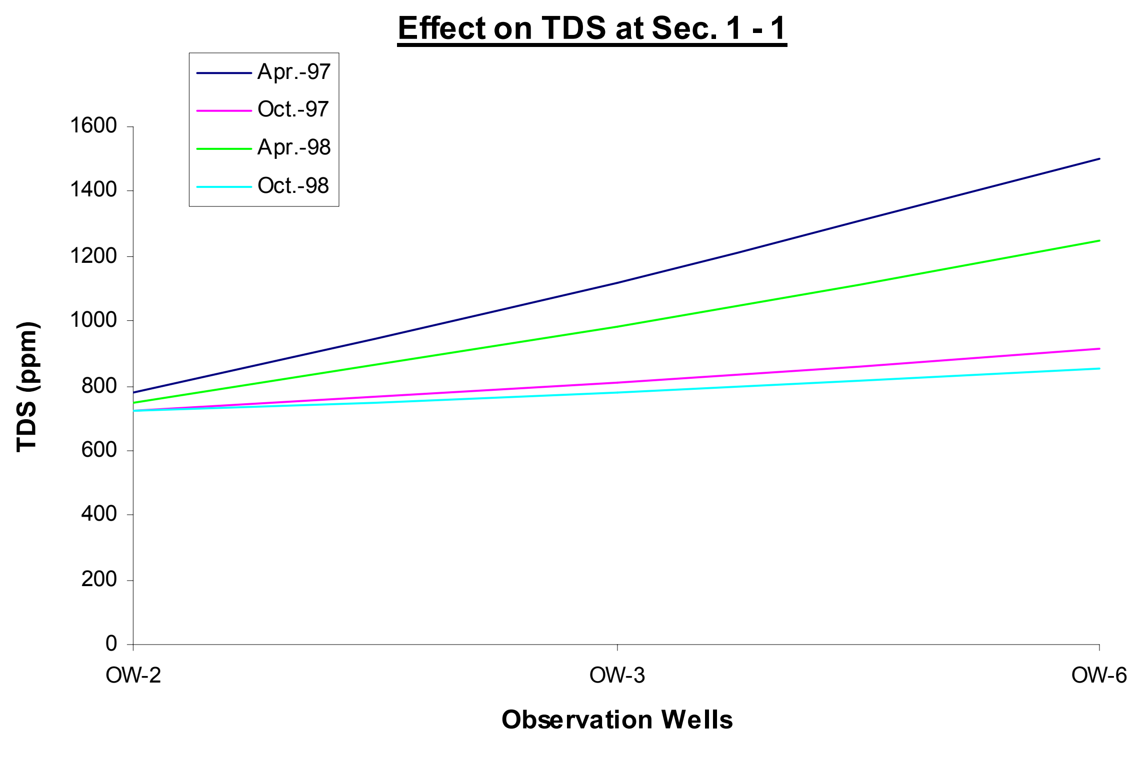


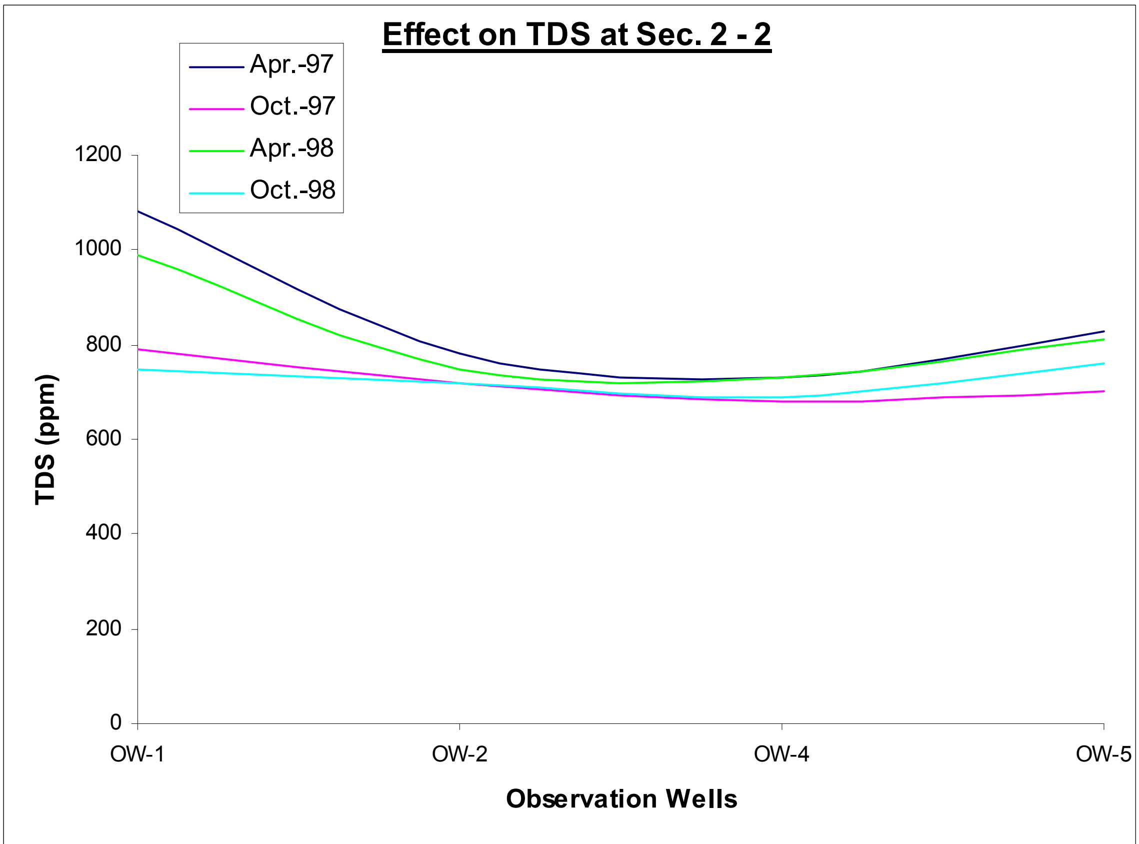




Sutrapada Check Dam

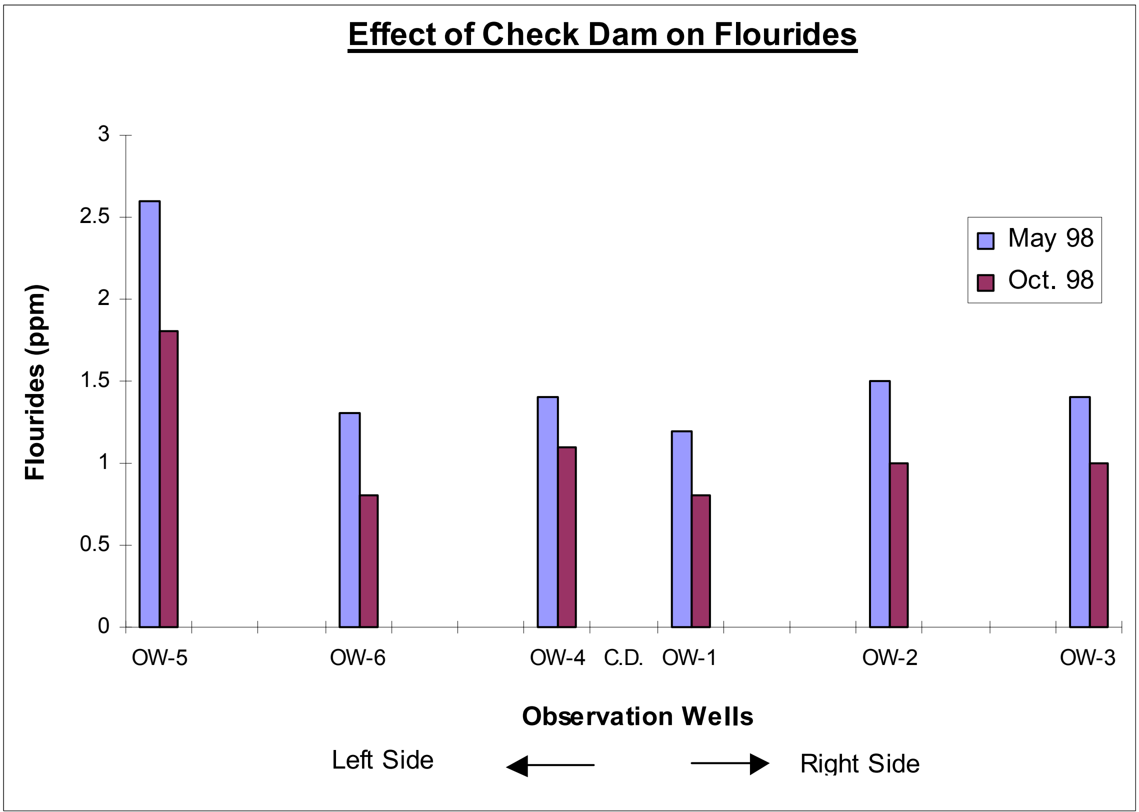
Village :- **Sutrapada** Ta. :- **Veraval** Dist. :- **Junagadh**

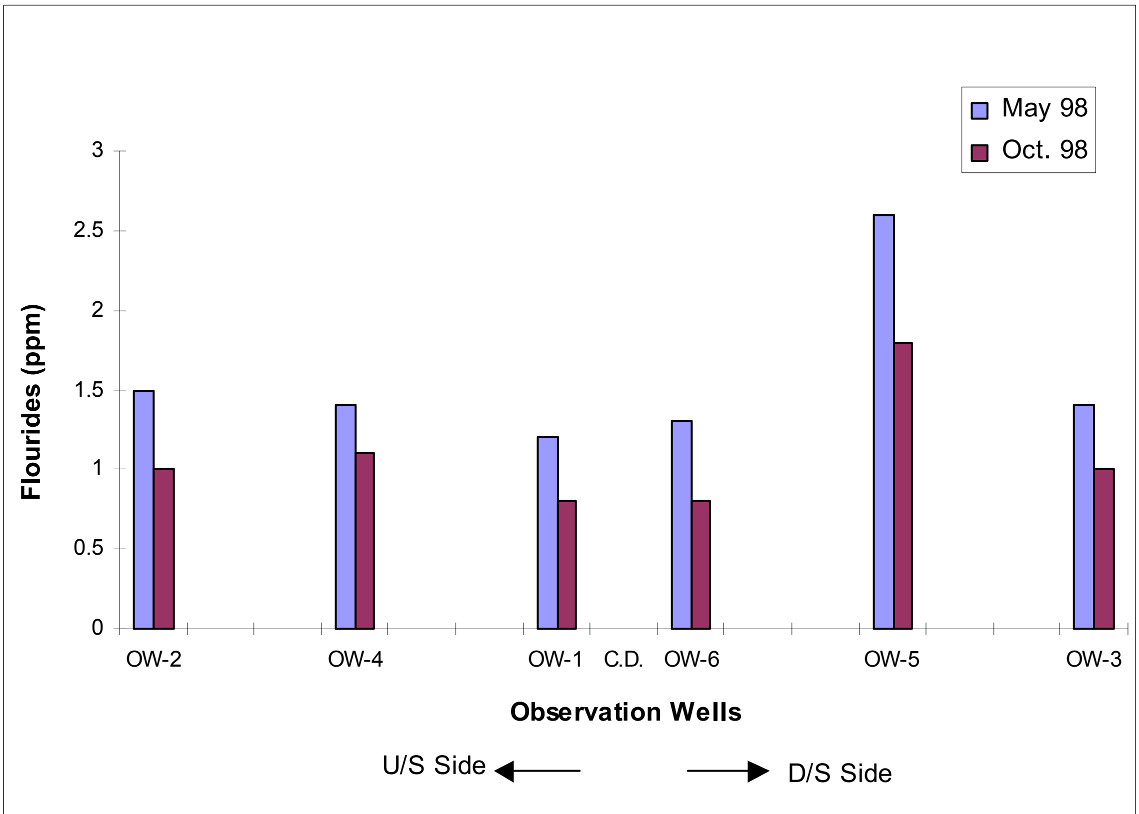




Hathigadh Khara Check Dam

Village :- **Hathigadh Khara** Ta. :- **Leliya** Dist. :- **Amreli**

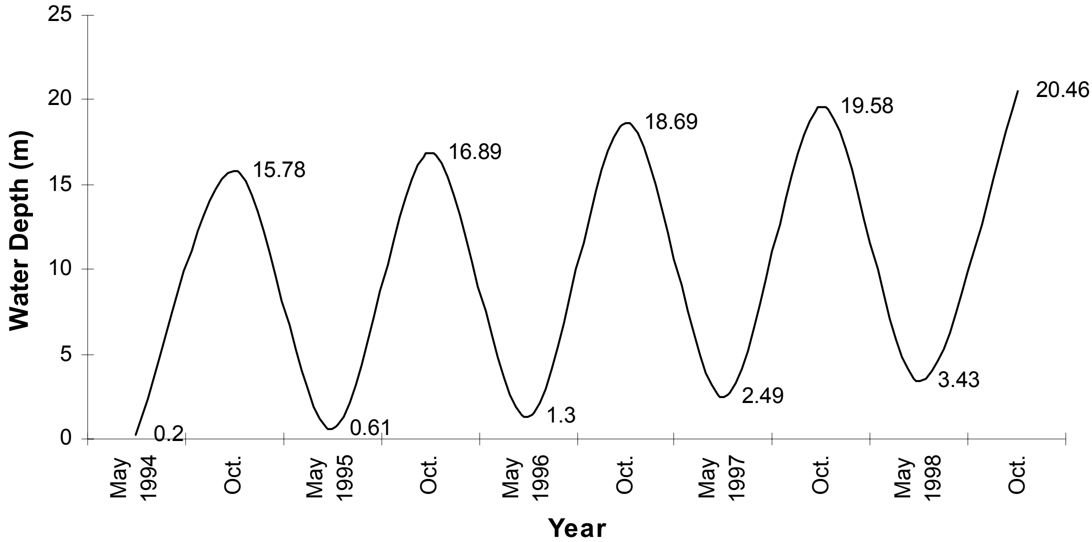




Rise and Fall of Water Level in A.S.R. Well

For Khadvanthali A.S.R. Well

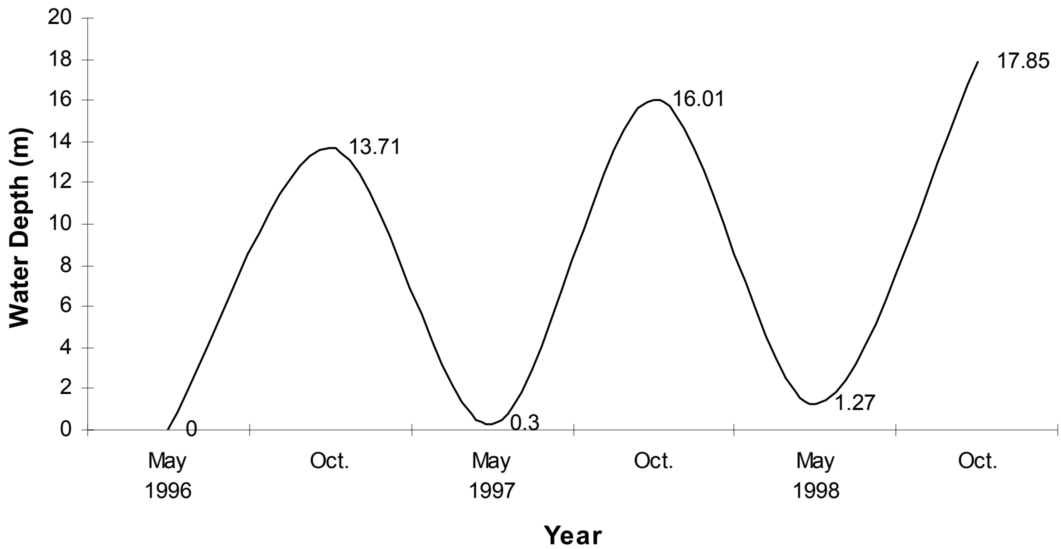
Village : **Khadvanthali** Tal. : **Gondal** Dist. : **Rajkot**



Note:-Well is Recharged Since 1993

For Goraj A.S.R. Well

Village **: Goraj** Tal. **: Mangrol** Dist. **: Veraval**



Not :- Well is Recharged Since 1994

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