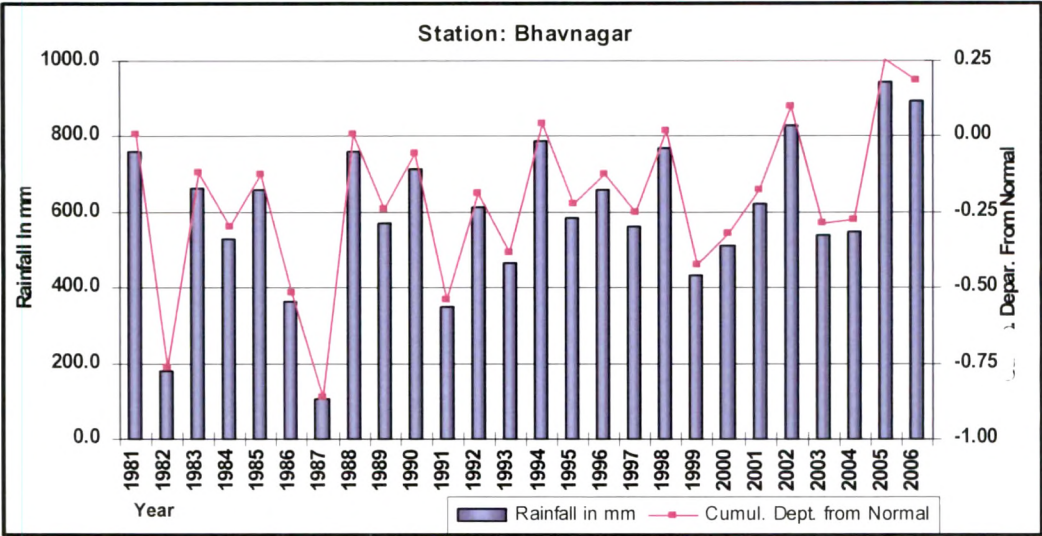


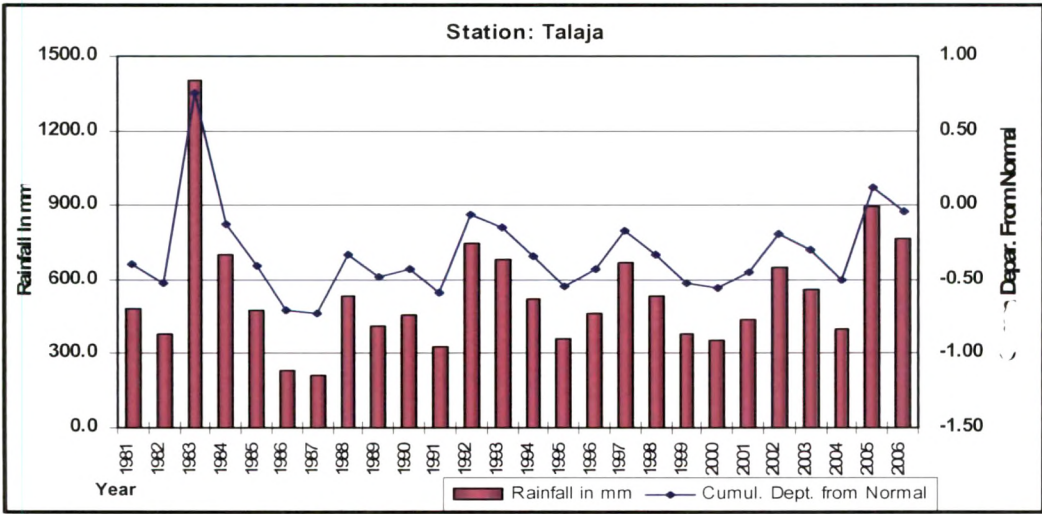
5 Analysis of SIP Structures

5.1 Analysis of Rainfall & Taluka-wise Affected Area

Data for rainfall of 26 years for Bhavnagar, Talaja, Mahuva, Rajula & Jafrabad is collected and analyze in the table 5.1. Following graphs are plotted to study the departure from normal rainfall. (Refer graph 5.1 to 5.5)



Graph 5.1: Rainfall & Cumulative Departure from Normal for Bhavnagar



Graph 5.2: Rainfall & Cumulative Departure from Normal for Talaja

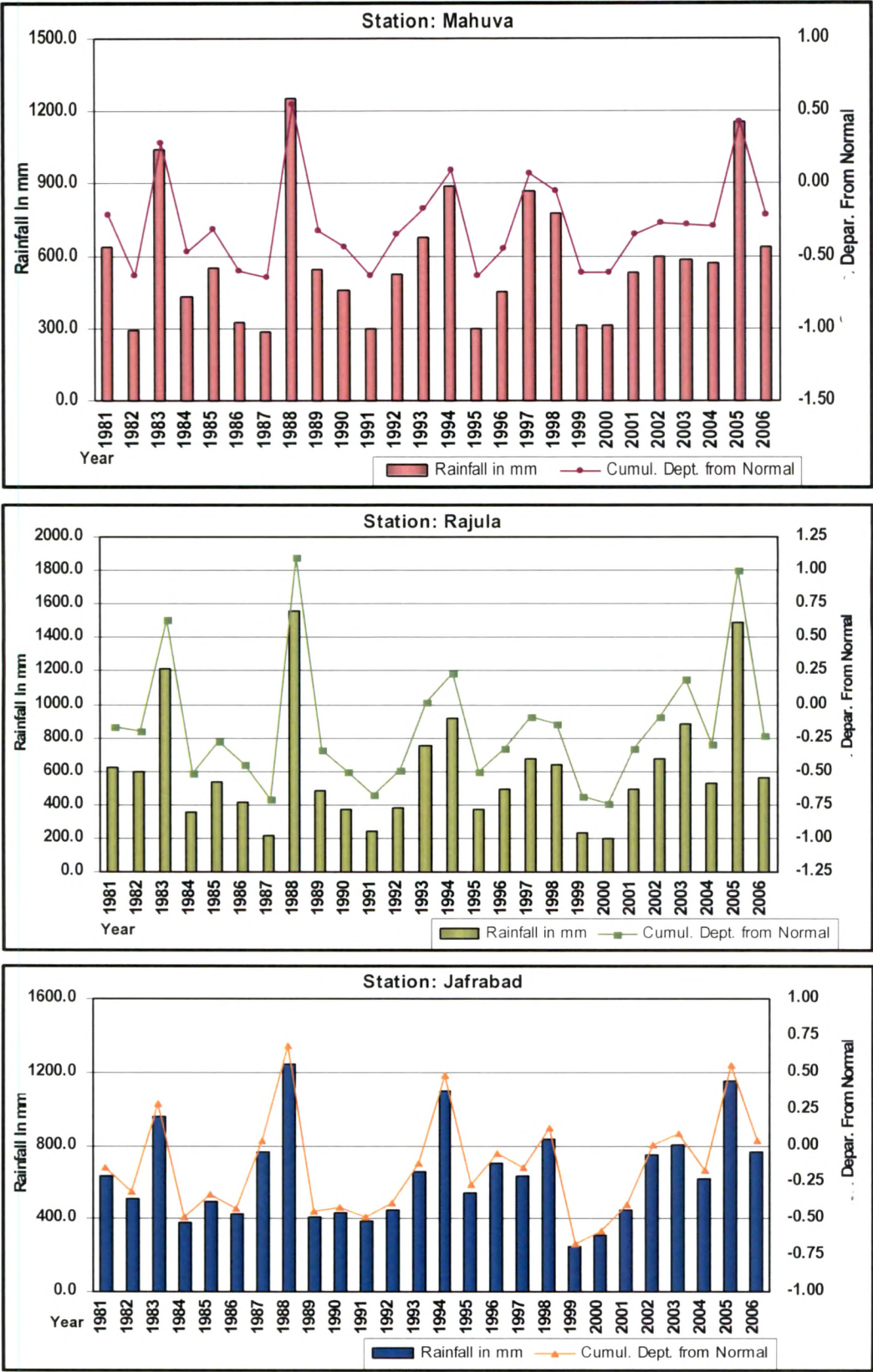
5.1.1 Bhavnagar – Una Coast

STATEMENT OF RAINFALL AND DEPARTURE FROM NORMAL FOR BAHVNAGAR TO UNA REACH FOR THE YEARS 1981 - 2006														
Station	Una		Jafrabad		Rajula		Mahuva		Talala		Ghogha		Bhavnagar	
Year	Rainfall In mm	Departure from NRL	Rainfall In mm	Departure from NRL	Rainfall In mm	Departure from NRL	Rainfall In mm	Departure from NRL	Rainfall In mm	Departure from NRL	Rainfall In mm	Departure from NRL	Rainfall In mm	Departure from NRL
1981	853.0	-0.11	634.0	-0.15	621.0	-0.16	640.0	-0.21	485.0	-0.39	500.0	-0.34	762.0	0.01
1982	784.0	-0.18	512.0	-0.31	597.0	-0.20	293.0	-0.64	380.0	-0.53	175.0	-0.77	178.0	-0.76
1983	1202.0	0.25	957.5	0.29	1210.0	0.63	1043.0	0.28	1401.0	0.75	780.0	0.03	665.0	-0.12
1984	1021.0	0.06	381.0	-0.49	358.0	-0.52	432.0	-0.47	699.0	-0.13	480.0	-0.36	530.0	-0.30
1985	516.0	-0.46	496.0	-0.33	538.0	-0.28	553.0	-0.32	474.0	-0.41	644.0	-0.15	659.0	-0.13
1986	517.1	-0.46	424.0	-0.43	413.0	-0.44	322.0	-0.60	232.0	-0.71	335.0	-0.56	364.0	-0.52
1987	345.7	-0.64	767.0	0.03	220.0	-0.70	285.0	-0.65	214.0	-0.73	141.0	-0.81	105.0	-0.86
1988	1086.0	0.13	1248.0	0.68	1562.0	1.10	1256.0	0.55	535.0	-0.33	623.0	-0.17	761.0	0.01
1989	526.0	-0.45	410.0	-0.45	489.0	-0.34	546.0	-0.33	413.0	-0.48	544.0	-0.28	573.0	-0.24
1990	741.0	-0.23	431.0	-0.42	373.0	-0.50	455.0	-0.44	460.0	-0.43	851.0	0.13	712.0	-0.06
1991	513.0	-0.47	383.0	-0.48	240.0	-0.68	298.0	-0.63	327.0	-0.59	380.0	-0.50	348.0	-0.54
1992	582.0	-0.39	452.0	-0.39	381.0	-0.49	525.0	-0.35	747.0	-0.07	590.0	-0.22	612.0	-0.19
1993	696.0	-0.28	655.0	-0.12	753.0	0.01	677.0	-0.17	683.0	-0.15	490.0	-0.35	466.0	-0.38
1994	1048.0	0.09	1097.0	0.48	915.0	0.23	887.0	0.09	524.0	-0.35	675.0	-0.11	788.0	0.04
1995	874.0	-0.09	543.0	-0.27	370.0	-0.50	297.0	-0.63	360.0	-0.55	600.0	-0.20	585.0	-0.22
1996	883.0	-0.08	707.0	-0.05	496.0	-0.33	451.0	-0.45	463.0	-0.42	581.0	-0.23	659.0	-0.13
1997	782.0	-0.19	630.0	-0.15	672.0	-0.10	871.0	0.07	667.0	-0.17	467.0	-0.38	563.0	-0.25
1998	671.0	-0.30	833.0	0.12	637.0	-0.14	774.0	-0.05	536.0	-0.33	624.0	-0.17	770.0	0.02
1999	1332.0	0.39	244.0	-0.67	232.0	-0.69	310.0	-0.62	383.0	-0.52	515.0	-0.32	433.0	-0.43
2000	341.0	-0.64	312.0	-0.58	195.0	-0.74	315.0	-0.61	357.0	-0.55	340.0	-0.55	173.0	-0.77
2001	716.0	-0.25	448.0	-0.40	496.0	-0.33	532.0	-0.35	439.0	-0.45	541.0	-0.28	622.0	-0.18
2002	735.0	-0.23	746.0	0.00	672.0	-0.10	596.0	-0.27	649.0	-0.19	767.0	0.02	831.0	0.10
2003	991.0	0.03	805.0	0.08	884.0	0.19	585.0	-0.28	559.0	-0.30	797.0	0.06	537.0	-0.29

STATEMENT OF RAINFALL AND DEPARTURE FROM NORMAL FOR BAHVNAGAR TO UNA REACH FOR THE YEARS 1981 - 2006														
Station	Una		Jafrabad		Rajula		Mahuva		Talala		Ghogha		Bhavnagar	
Year	Rainfall In mm	Departure from NRL	Rainfall In mm	Departure from NRL	Rainfall In mm	Departure from NRL	Rainfall In mm	Departure from NRL	Rainfall In mm	Departure from NRL	Rainfall In mm	Departure from NRL	Rainfall In mm	Departure from NRL
2004	794.0	-0.17	616.0	-0.17	524.0	-0.30	574.0	-0.29	400.0	-0.50	718.0	-0.05	549.0	-0.27
2005	1260.0	0.31	1148.0	0.54	1490.0	1.00	1157.0	0.42	898.0	0.12	927.0	0.23	947.0	0.26
2006	1111.0	0.16	766.0	0.03	567.0	-0.24	635.0	-0.22	764.0	-0.05	579.0	-0.23	893.0	0.18
Average Rainfall (In mm)														
	804.65		640.21		611.73		588.81		540.35		564.00		593.27	
IMD Average Annual Rainfall (In mm)														
	960.10		743.30		743.30		812.80		800.60		754.30		754.30	
Average Rainfall (In mm) For 1971 -1980														
	786.72		619.61		574.79		602.42		518.17		570.07		582.17	
Cumulative Departure From Normal														
		-4.21		-3.61		-4.60		-7.17		-8.45		-6.56		-5.55

Table 5.1: Rainfall Details and Cumulative Departure from Normal for Bhavnagar to Una Reach for the Years 1981 – 2006

Refer Graph 5.1 to 5.5



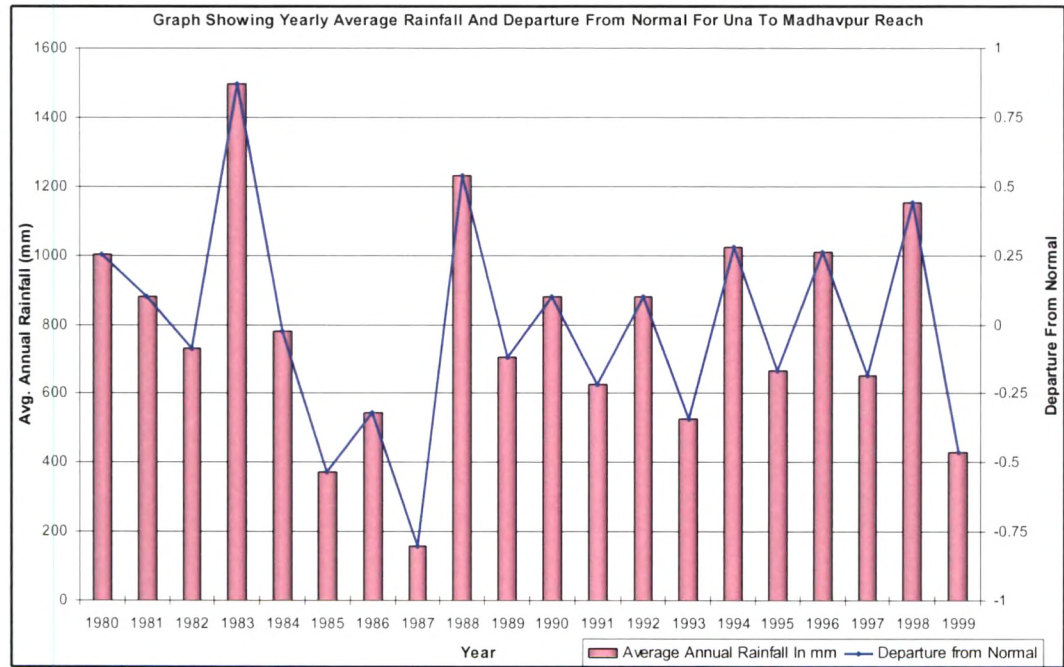
Graph 5.3 to 5.5: Rainfall & Cumulative Departure from Normal for Mahuva, Rajula & Jafrabad

5.1.2 Una – Madhavpur Coast

Data for rainfall of 20 years for Una to Madhavpur is collected and analyze in the table 5.2. Following graph is plotted to study the departure from normal rainfall.

Year	Average Annual Rainfall In mm	Departure from Normal	Year	Average Annual Rainfall In mm	Departure from Normal
1980	1002.90	0.254	1990	878.80	0.099
1981	881.60	0.102	1991	627.00	-0.216
1982	729.00	-0.089	1992	880.12	0.100
1983	1497.00	0.871	1993	526.00	-0.343
1984	781.00	-0.024	1994	1022.60	0.278
1985	373.00	-0.534	1995	666.20	-0.167
1986	543.00	-0.321	1996	1010.00	0.263
1987	157.00	-0.804	1997	651.00	-0.186
1988	1232.50	0.541	1998	1152.00	0.440
1989	705.46	-0.118	1999	430.50	-0.462
Average Annual Rainfall from 1980 to 1999 (In mm)				787.33	
IMD Avg. Annual Rainfall (In mm)				800.00	

Table 5.2: Details of Rainfall for Una to Madhavpur Reach for the Years 1980 – 1999.



Graph 5.6: Rainfall & Departure from Normal for Una – Madhavpur

5.1.3 Madhavpur – Malia Coast

Data for rainfall of 21 years for Madhavpur to Malia is collected and analyze in the table 5.3. Following graph is plotted to study the departure from normal rainfall.

STATEMENT OF RAINFALL AND DEPARTURE FROM NORMAL FOR MADHAVPUR TO MALIA COAST FOR THE YEARS 1985 - 2005															
Station	Mangrol			Porbandar			Ranavav			Okha			Kaiyanpur		
	Rainfall	Departure		Rainfall	Departure		Rainfall	Departure		Rainfall	Departure		Rainfall	Departure	
Year	In mm	from NRL	In mm	In mm	from NRL	In mm	In mm	from NRL	In mm	In mm	from NRL	In mm	In mm	from NRL	from NRL
1985	389.00	-0.55	249.00	-0.58	-0.58	229.00	-0.61	-0.61	201.00	-0.60	-0.60	207.00	-0.66	-0.66	-0.46
1986	853.00	-0.01	527.00	-0.11	-0.11	462.00	-0.22	-0.22	156.00	-0.69	-0.69	271.00	-0.55	-0.55	-0.25
1987	126.00	-0.85	21.00	-0.96	-0.96	16.00	-0.97	-0.97	36.00	-0.93	-0.93	15.00	-0.98	-0.98	-0.90
1988	2032.00	1.35	774.00	0.30	0.30	862.00	0.45	0.45	457.00	-0.08	-0.08	449.00	-0.26	-0.26	0.53
1989	1065.00	0.23	643.00	0.08	0.08	727.00	0.22	0.22	336.00	-0.33	-0.33	572.00	-0.05	-0.05	-0.17
1990	857.00	-0.01	218.00	-0.63	-0.63	238.00	-0.60	-0.60	150.00	-0.70	-0.70	260.00	-0.57	-0.57	0.27
1991	351.00	-0.59	338.00	-0.43	-0.43	318.00	-0.46	-0.46	88.00	-0.82	-0.82	423.00	-0.30	-0.30	-0.48
1992	954.00	0.10	549.00	-0.08	-0.08	470.00	-0.21	-0.21	558.00	0.12	0.12	498.00	-0.18	-0.18	-0.03
1993	349.00	-0.60	156.00	-0.74	-0.74	216.00	-0.64	-0.64	108.00	-0.78	-0.78	181.00	-0.70	-0.70	-0.74
1994	874.00	0.01	1444.00	1.43	1.43	867.00	0.46	0.46	408.00	-0.18	-0.18	488.00	-0.19	-0.19	0.22
1995	575.00	-0.33	548.00	-0.08	-0.08	537.00	-0.10	-0.10	141.00	-0.72	-0.72	441.00	-0.27	-0.27	-0.55
1996	836.00	-0.03	449.00	-0.24	-0.24	487.00	-0.18	-0.18	199.00	-0.60	-0.60	341.00	-0.44	-0.44	-0.24
1997	530.00	-0.39	841.00	0.42	0.42	662.00	0.11	0.11	426.00	-0.15	-0.15	628.00	0.04	0.04	0.15
1998	1372.00	0.59	1111.00	0.87	0.87	908.00	0.53	0.53	731.00	0.46	0.46	1274.00	1.11	1.11	0.82
1999	807.00	-0.07	201.00	-0.66	-0.66	314.00	-0.47	-0.47	203.00	-0.59	-0.59	624.00	0.03	0.03	-0.69
2000	664.00	-0.23	432.00	-0.27	-0.27	427.00	-0.28	-0.28	484.00	-0.03	-0.03	517.00	-0.14	-0.14	-0.08
2001	771.00	-0.11	623.00	0.05	0.05	787.00	0.32	0.32	346.00	-0.31	-0.31	1196.00	0.98	0.98	0.39
2002	221.00	-0.74	271.00	-0.54	-0.54	270.00	-0.55	-0.55	136.00	-0.73	-0.73	371.00	-0.39	-0.39	-0.60
2003	690.00	-0.20	666.00	0.12	0.12	912.00	0.54	0.54	437.00	-0.13	-0.13	882.00	0.461	0.461	0.07
2004	1072.00	0.24	477.00	-0.20	-0.20	546.00	-0.08	-0.08	274.00	-0.45	-0.45	574.00	-0.05	-0.05	-0.36
2005	913.00	0.06	903.00	0.52	0.52	735.00	0.24	0.24	413.00	-0.17	-0.17	353.00	-0.42	-0.42	0.23
#	818.19		620.92			605.92			327.04			584.96			
##	863.60		594.30			594.30			499.40			603.80			
###		-1.81		-0.50	-0.50		-0.50	-0.50		-8.64	-8.64		-1.86	-1.86	-0.15
# - Average Annual Rainfall (In mm)				# - IMD Average Annual Rainfall (In mm) Last 50 Years				### - Cumulative Departure From Normal							

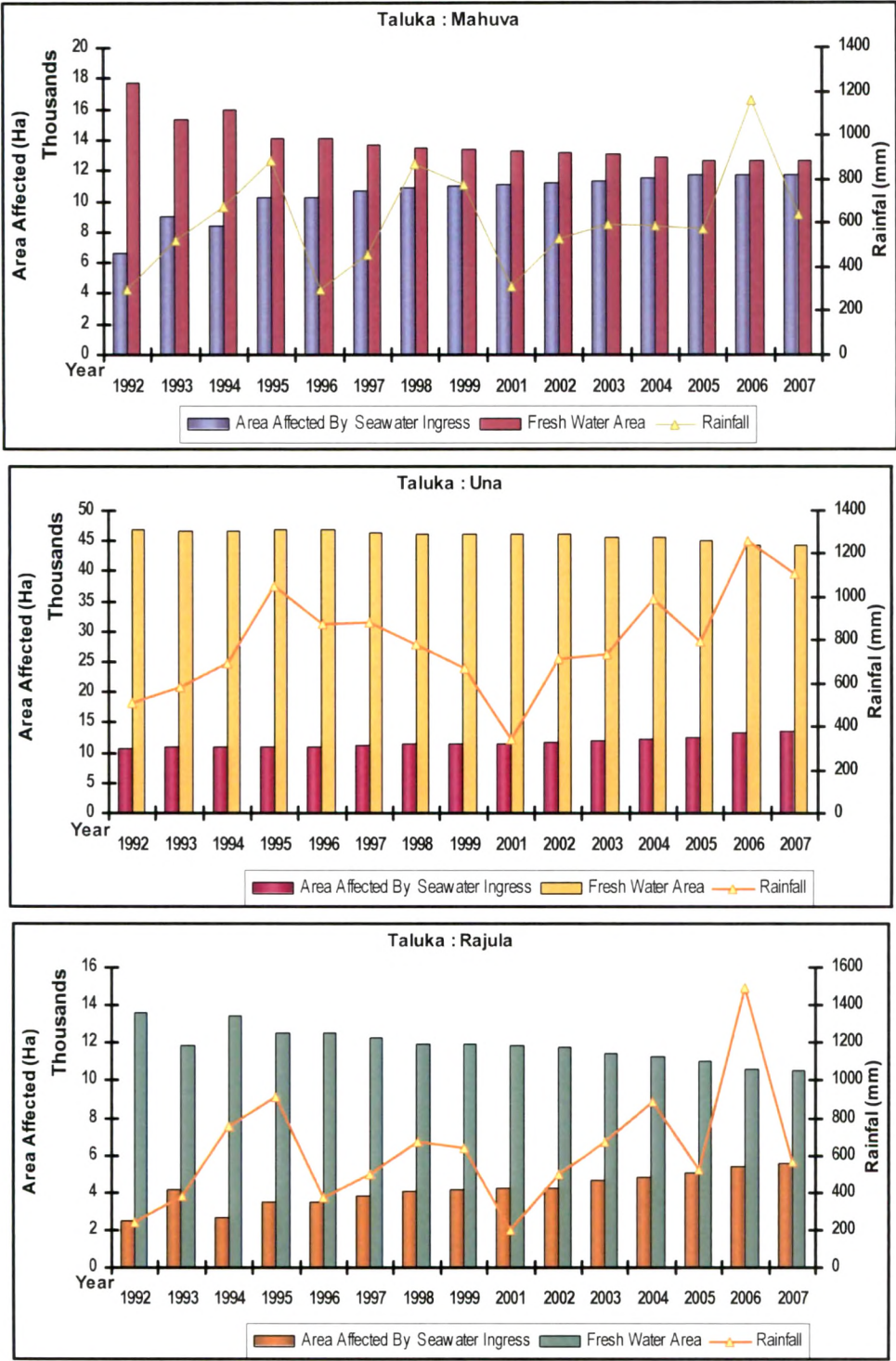
Table Contd....

STATEMENT OF RAINFALL AND DEPARTURE FROM NORMAL FOR MADHAVPUR TO MALIA COAST FOR THE YEARS 1985 - 2004													
Station	Lalpur			Jamnagar			Dhrol			Jodiya			Maliya
	Rainfall	Departure		Rainfall	Departure		Rainfall	Departure		Rainfall	Departure		Departure
Year	In mm	From NRL.		In mm	from NRL.		In mm	from NRL.		In mm	from NRL.	In mm	from NRL.
1985	223.00	-0.57		208.00	-0.68		278.00	-0.61		352.00	-0.44	324.00	-0.47
1986	438.00	-0.16		189.00	-0.71		266.00	-0.62		323.00	-0.49	374.00	-0.39
1987	62.00	-0.88		36.00	-0.94		139.00	-0.80		28.00	-0.96	53.00	-0.91
1988	962.00	0.85		492.00	-0.25		1314.00	0.86		984.00	0.56	571.00	-0.06
1989	540.00	0.04		286.00	-0.56		508.00	-0.28		329.00	-0.48	394.00	-0.35
1990	520.00	0.00		239.00	-0.63		205.00	-0.71		304.00	-0.52	283.00	-0.54
1991	430.00	-0.17		275.00	-0.58		231.00	-0.67		145.00	-0.77	345.00	-0.43
1992	617.00	0.18		446.00	-0.32		493.00	-0.30		528.00	-0.16	460.00	-0.25
1993	232.00	-0.55		194.00	-0.70		283.00	-0.60		239.00	-0.62	98.00	-0.84
1994	636.00	0.22		1050.00	0.61		1148.00	0.63		1373.00	1.18	692.00	0.14
1995	257.00	-0.51		267.00	-0.59		300.00	-0.58		476.00	-0.25	304.00	-0.50
1996	543.00	0.04		394.00	-0.40		588.00	-0.17		440.00	-0.30	270.00	-0.56
1997	654.00	0.26		977.00	0.50		891.00	0.26		645.00	0.02	470.00	-0.23
1998	743.00	0.43		463.00	-0.29		467.00	-0.34		400.00	-0.37	392.00	-0.36
1999	252.00	-0.52		239.00	-0.63		242.00	-0.66		305.00	-0.52	279.00	-0.54
2000	535.00	0.03		252.00	-0.61		340.00	-0.52		238.00	-0.62	191.00	-0.69
2001	641.00	0.23		583.00	-0.11		453.00	-0.36		371.00	-0.41	509.00	-0.17
2002	390.00	-0.25		433.00	-0.34		354.00	-0.50		275.00	-0.54	180.00	-0.55
2003	1095.00	1.10		1362.00	1.09		755.00	0.07		772.00	0.28	542.00	0.35
2004	642.00	0.23		852.00	0.31		500.00	-0.29		468.00	-0.22	428.00	0.07
#	589.70			563.00			569.50			470.00		373.70	
##	520.70			652.15			706.12			630.78		609.60	
###		-0.01			-2.30			-6.19			-5.11		-1.36
# - Average Annual Rainfall (In mm)				# # - IMD Average Annual Rainfall (In mm) Last 50 Years				# # # - Cumulative Departure From Normal					

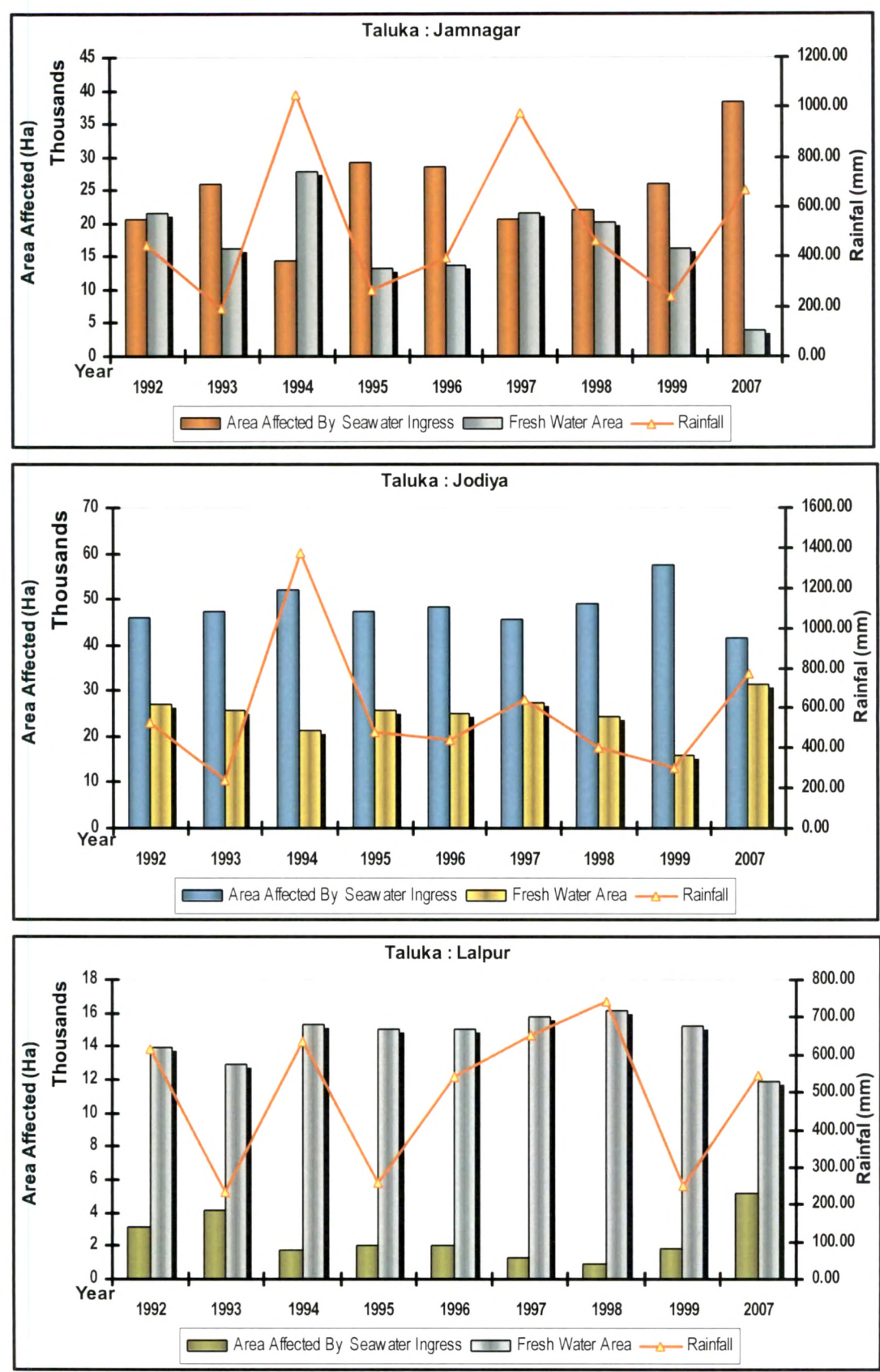
Table 5.3: Rainfall Details and Cumulative Departure from Normal for Madhavpur to Malia Coast for the Years 1985 – 2005

5.1.4 Taluka-wise Area Affected by Seawater Ingress, Fresh water & Rainfall

Taluka-wise data collected for rainfall, freshwater area and area affected due to seawater intrusion 1992 – 2007 (table 4.9) and graphs are plotted to show relationship between these parameters.



Graph 5.7, 5.8, 5.9: Area Affected by Seawater Ingress, Freshwater Area & Rainfall

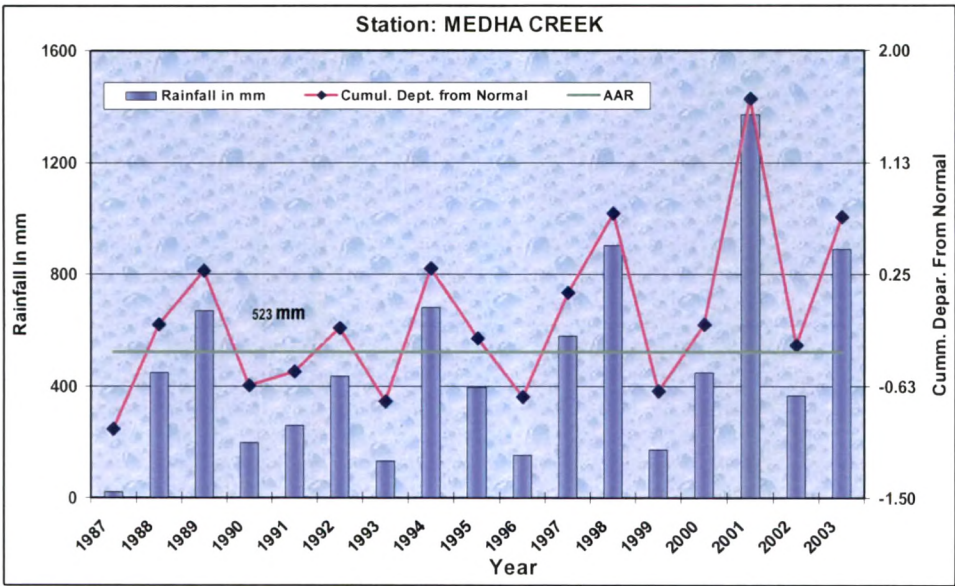


Graph 5.10, 5.11& 5.12: Area Affected by Seawater Ingress, Freshwater Area & Rainfall

5.2 Analysis of Medha Creek TR

5.2.1 Analysis of Rainfall in Medha Creek TR Area

Rainfall data from 1987 to 2003 is collected (table 4.10) and a graph 5.13 showing relationship between Rainfall, Cumulative departure from normal and Average Rainfall is plotted.



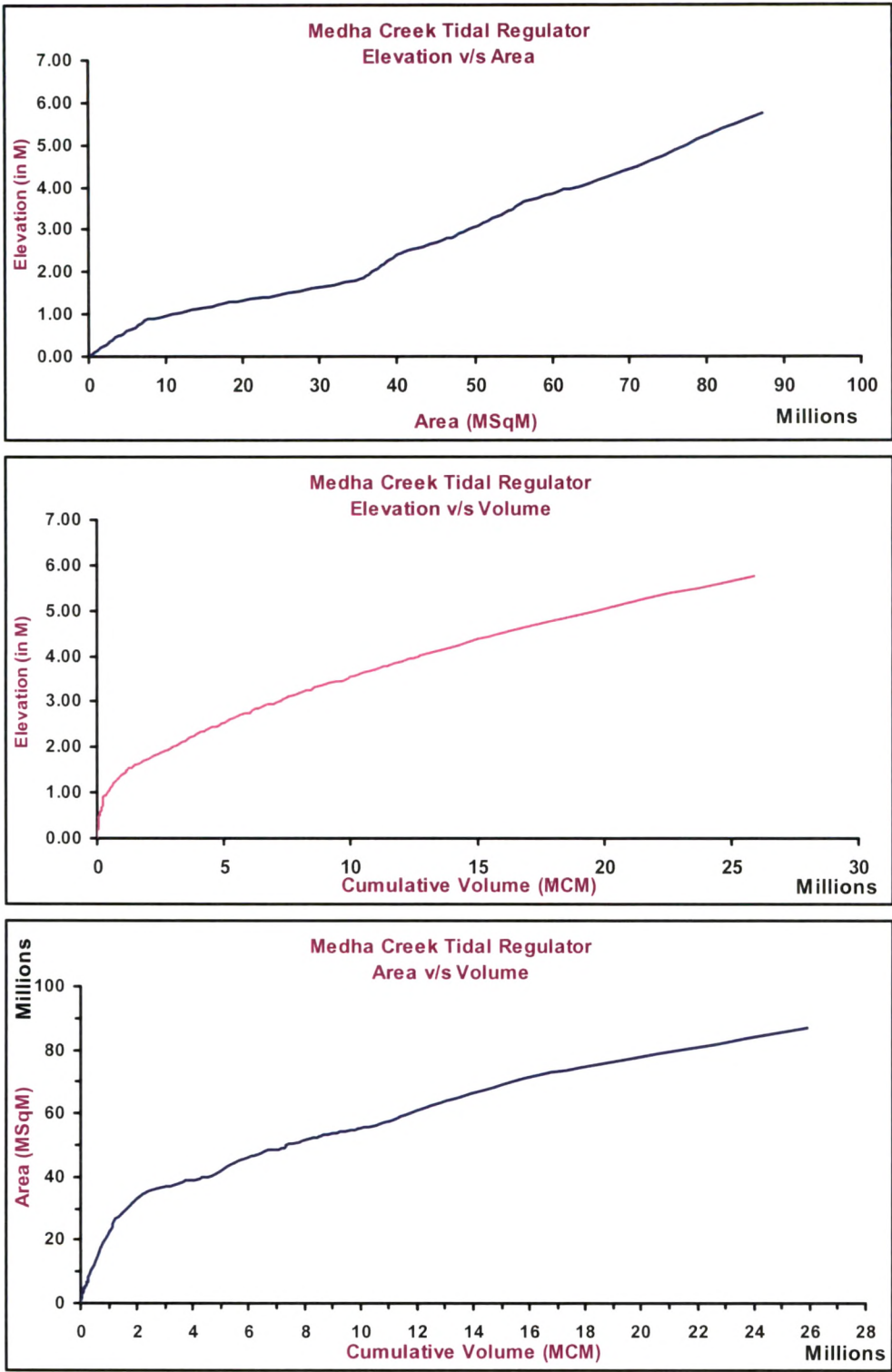
Graph 5.13: Graph Showing Rainfall, Departure from Normal Rainfall & Average Annual Rainfall



Radial canals are constructed from reservoir formed due to construction of structure in the coastal belt and progresses inland from its starting. The initial depth of such canal is nominal (sometimes less than 45 cm) and as it progress inland its depth increases with distance (upto 5 to 10 m depending upon gradient). Farmers irrigate their fields from these canals. Because of porous geological formation the percolation rate from canals and fields is very high. Due to deep percolation in entire area set back of saline water takes place. The above photograph is of radial canal constructed from reservoir of Medha Creek TR.

Plate 5.1 View of Radial Canal Constructed in Medha Creek TR area

5.2.2 **Graphs Showing Relation between Elevation, Area and Cumulative Volume Stored for Medha Creek TR**



Graph 5.14 to 5.16: Graphs Showing Relation between Elevation, Area & Cumulative Volume
(Refer Table 4.12)

5.2.3 Analysis of Pumping Test at Village Ambarama

Pumping test for a well situated in village Ambarama was carried out and aquifer parameters like Permeability (K), Transmissibility (T) and Specific Capacity (C) has been calculated.

5.2.3.1 Time – Drawdown Analysis

Sr. No.	Time H:M	Water Level (m)	Draw-down (m)	Sr. No.	Time H:M	Water Level (m)	Draw-down (m)	Sr. No.	Time H:M	Water Level (m)	Draw-down (m)
1	09:00	10.82	0.00	14	09:16	11.46	0.64	27	09:45	12.38	1.56
2	09:01	10.87	0.05	15	09:18	11.53	0.71	28	09:50	12.47	1.65
3	09:02	10.91	0.09	16	09:20	11.59	0.77	29	09:55	12.53	1.71
4	09:03	10.95	0.13	17	09:22	11.66	0.84	30	10:00	12.6	1.78
5	09:04	10.99	0.17	18	09:24	11.72	0.90	31	10:05	12.68	1.86
6	09:05	11.03	0.21	19	09:26	11.79	0.97	32	10:10	12.74	1.92
7	09:06	11.07	0.25	20	09:28	11.86	1.04	33	10:15	12.8	1.98
8	09:07	11.11	0.29	21	09:30	11.93	1.11	34	10:20	12.86	2.04
9	09:08	11.15	0.33	22	09:32	11.99	1.17	35	10:25	12.91	2.09
10	09:09	11.19	0.37	23	09:34	12.05	1.23	36	10:30	12.97	2.15
11	09:10	11.23	0.41	24	09:36	12.11	1.29	37	10:35	13.01	2.19
12	09:12	11.31	0.49	25	09:38	12.17	1.35	38	10:40	13.05	2.23
13	09:14	11.39	0.57	26	09:40	12.23	1.41	39	10:45	13.09	2.27
								40	10:50	13.13	2.31

Table 5.4: Time – Drawdown Analysis for the Pumping Test at Vill. Ambarama near Medha Creek TR

(Refer Graph 5.17)

5.2.3.2 Recuperation Analysis

Maximum Drawdown $S_1 = 2.31\text{m}$ (Refer Graph 5.18)

Sr. No.	Time Hr:Min:Sec	Time since Pumping Stopped (min)	Water Level (m)	Residual Drawdown S_2 (m)	$(t+\Delta t/\Delta t)$	S_1/S_2
1	09:00	---	10.82	---	---	---
2	10:50	0	13.13	2.310	---	---
3	10:51	1	13.13	2.310	111.00000	1.000000
4	10:52	2	13.13	2.305	56.000000	1.002169
5	10:53	3	13.13	2.305	37.666667	1.002169
6	10:54	4	13.12	2.300	28.500000	1.004348
7	10:55	5	13.12	2.300	23.000000	1.004348
8	10:56	6	13.12	2.295	19.333333	1.006536
9	10:57	7	13.12	2.295	16.714286	1.006536
10	10:58	8	13.11	2.290	14.750000	1.008734
11	10:59	9	13.11	2.290	13.222222	1.008734
12	11:00	10	13.11	2.285	12.000000	1.010941
13	11:02	12	13.10	2.280	10.166667	1.013158
14	11:04	14	13.10	2.275	8.8571429	1.015385
15	11:06	16	13.09	2.270	7.8750000	1.017621

Sr. No.	Time Hr:Min:Sec	Time since Pumping Stopped (min)	Water Level (m)	Residual Drawdown S2 (m)	(t+Δt/Δt)	S1/S2
16	11:08	18	13.09	2.265	7.1111111	1.019868
17	11:10	20	13.08	2.260	6.5000000	1.022124
18	11:12	22	13.08	2.255	6.0000000	1.024390
19	11:14	24	13.07	2.250	5.5833333	1.026667
20	11:16	26	13.07	2.245	5.2307692	1.028953
21	11:18	28	13.06	2.240	4.9285714	1.031250
22	11:20	30	13.06	2.235	4.6666667	1.033557
23	11:22	32	13.05	2.230	4.4375000	1.035874
24	11:24	34	13.05	2.225	4.2352941	1.038202
25	11:26	36	13.04	2.220	4.0555556	1.040541
26	11:28	38	13.04	2.215	3.8947368	1.042889
27	11:30	40	13.03	2.210	3.7500000	1.045249
28	11:35	45	13.02	2.200	3.4444444	1.050000
29	11:40	50	13.01	2.190	3.2000000	1.054795
30	11:45	55	13.00	2.180	3.0000000	1.059633
31	11:50	60	12.99	2.170	2.8333333	1.064516
32	11:55	65	12.98	2.160	2.6923077	1.069444
33	12:00	70	12.97	2.150	2.5714286	1.074419
34	12:05	75	12.96	2.140	2.4666667	1.079439
35	12:10	80	12.95	2.130	2.3750000	1.084507
36	12:15	85	12.94	2.120	2.2941176	1.089623
37	12:20	90	12.93	2.110	2.2222222	1.094787
38	12:25	95	12.92	2.100	2.1578947	1.100000
39	12:30	100	12.91	2.090	2.1000000	1.105263
40	12:50	120	12.87	2.050	1.9166667	1.126829
41	13:10	140	12.83	2.010	1.7857143	1.149254
42	13:30	160	12.79	1.970	1.6875000	1.172589
43	13:50	180	12.75	1.930	1.6111111	1.196891
44	14:10	200	12.71	1.890	1.5500000	1.222222
45	14:30	220	12.67	1.850	1.5000000	1.248649
46	14:50	240	12.63	1.810	1.4583333	1.276243
47	15:10	260	12.59	1.770	1.4230769	1.305085
48	15:30	280	12.55	1.730	1.3928571	1.335260
49	15:50	300	12.51	1.690	1.3666667	1.366864
50	16:10	320	12.47	1.650	1.3437500	1.400000
51	16:30	340	12.43	1.610	1.3235294	1.434783
52	16:50	360	12.39	1.570	1.3055556	1.471338

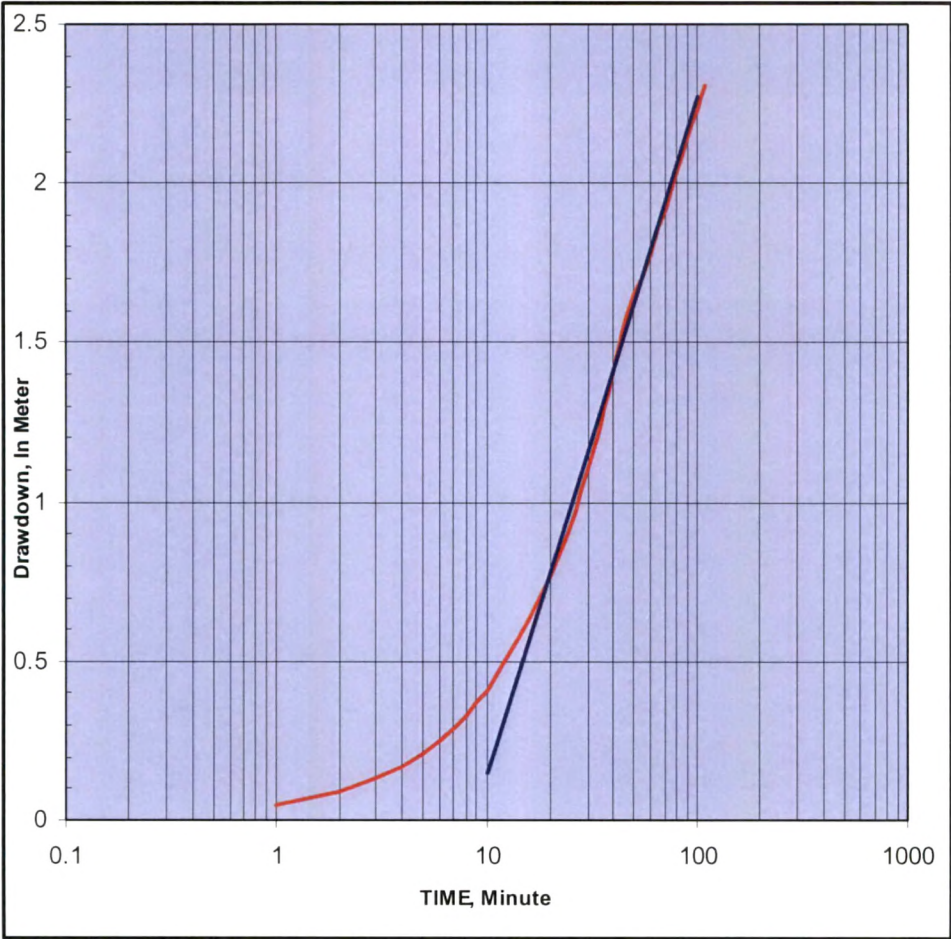
Table 5.5: Analysis for the Recuperation Test at Vill. Ambarama

5.2.3.3 Results for Pumping Test

	Pumping Test	Recuperation Test
Transmissibility	27.32485 m ² /day	27.6111 m ² /day
Permeability	6.537045 m/day	6.6055 m/day

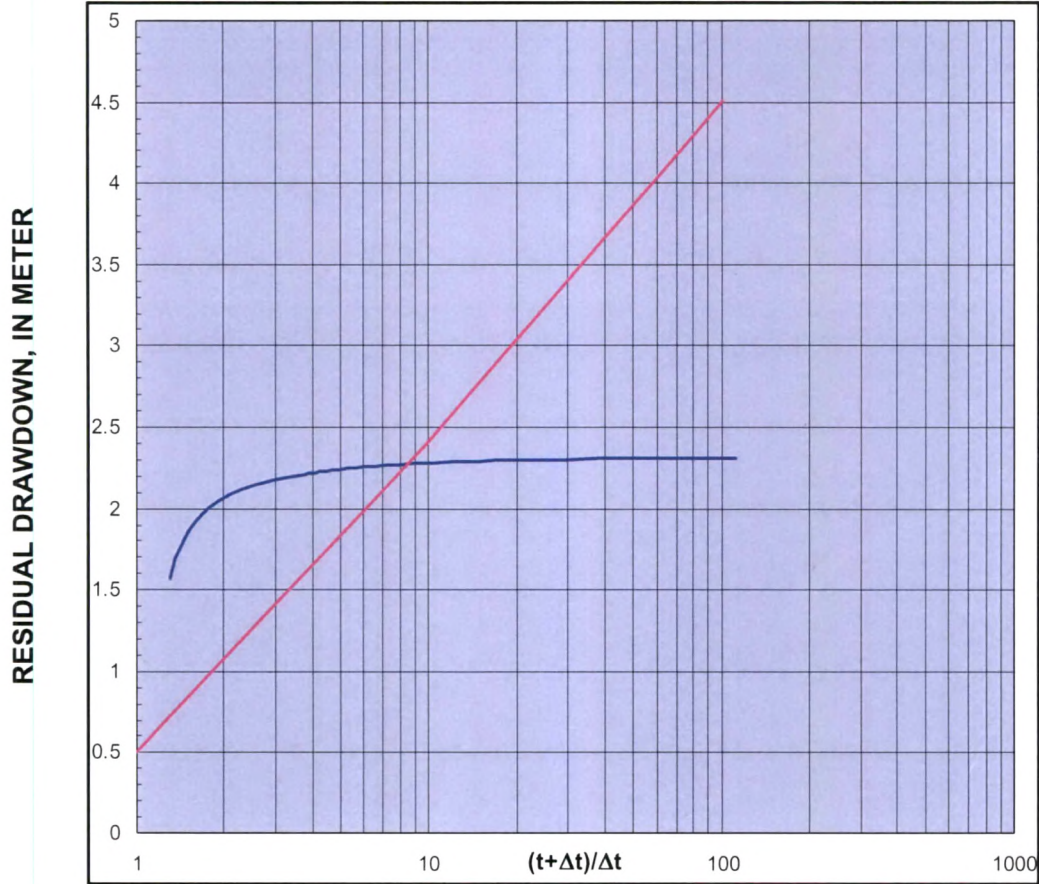
Table 5.6: Results of Pumping Test at Vill. Ambarama

Well located at village Ambarama	
INPUT Dimensions: Diameter of Well (d_c) = 3.95 Meter Area of Well (A) = 12.25417 Sq. Meter Depths to: water level (DTW) = 10.82 Meter Base of Aquifer = 15.00 Meter Type of Well: Open Well Aquifer Material -- Weathered Basalt FLOW RATE = 316.8 m³/d	Date: 05/01/2002 Time: 09:00
	Aquifer thickness = 4.18 Meter Slope = 2.1220 Meter/log10
	K = 6.53704514 Meter/Day T = 27.3248487 Meter²/Day



Graph 5.17 Cooper-Jacob's Log-Log Graph for Pumping Test Carried out at Village Ambarama

Well located at village Ambarama	
INPUT Dimensions: Diameter of Well (d_c) = 3.95 Meter Area of Well (A) = 12.25417 Sq. Meter Depths to: water level (DTW) = 10.82 Meter Base of Aquifer = 15.00 Meter Type of Well: Open Well Aquifer Material -- Weathered Basalt FLOW RATE = 316.8 m³/d	Date: 05/01/2002 Time: 09:00
	Aquifer thickness = 4.18 Meter Slope = 2.10 Meter/log10
	K = 6.6055285 Meter/Day T = 27.611109 Meter²/Day



Graph 5.18 Cooper-Jacob's Log-Log Graph for Recuperation Test Carried out at Village Ambarama

5.2.4 Calculation of Recharge Rate, Volume of Water Stored & Volume of Water Recharged for Medha Creek TR

Rainfall, Water-level fluctuation and evaporation rate for every week at Medha Creek TR was observed for four years and tabulated in table 4.15. Using these data in conjunction with elevation storage data, recharge rate in mm/day is worked out (Table 5.7 to 5.10). From the results obtained graph of Recharge rate v/s time (5.19) is drawn and Cumulative days v/s recharge rate graph for each year is plotted on log-log graph (5.20 to 5.23) to get recharge rate equation.

Date	Rainfall mm/ week	Water level RL (m)	Vol. of Water stored (M ³)	Vol. of water Loss (M3)	Evapo cm/week	Surface Area Of Water (M ²)	Vol. Of Evaporation (M ³)	Vol. Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
23/6/99	21	1.30	8160000	-	-	19180323	-	-	19754198	-
Jun 30	Nil	1.11	5416000	2744000	5.0	13581346	97010	2646990	13989982	27.029
7	3	0.98	3724000	1692000	5.0	10137711	506886	1185114	10443657	16.211
14	60	1.65	16610000	-	-	30358000	-	-	31257811	-
21	Nil	1.50	12000000	4610000	3.7	25879142	957528	3652472	26649823	19.579
28	Nil	1.37	9504000	2496000	3.9	21524909	839471	1656529	22167880	10.675
Aug 4	Nil	1.25	7200000	2304000	4.0	17505618	700225	1603775	18029999	12.707
11	Nil	1.13	5668000	1532000	4.0	14111136	564445	967555	14535515	9.509
18	Nil	1.04	4464000	1204000	3.9	11727081	457356	746644	12080500	8.829
25	Nil	0.96	3448000	1016000	3.8	9607921	365101	650899	9898013	9.394
Sep 1	Nil	0.91	2659664	788336	3.4	7980605	271341	516995	8222736	8.982
8	15	1.35	9120000	-	-	20855028	-	-	21478280	-
15	Nil	1.25	7200000	1920000	3.3	17505618	577685	1342315	18029999	10.636
22	Nil	1.14	5794000	1406000	3.3	14376031	474409	931591	14808276	8.987
29	5	1.05	4580000	1214000	3.1	11991976	371751	842249	12353295	9.740
Oct 6	12	1.01	4116000	464000	2.8	10932396	306107	157893	11262096	2.003
	153		109663664	23390336.00			6489315	16901020	Avg. = 11.868	

Table 5.7: Recharge Rate Calculation for Medha Creek Tr - Year 1999

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
08/07/2000	110	1.30	8160000	-	2.2	19180323	-	-	19754198	-
Jul 15	76	1.40	10080000	-	2.4	22529732	540714	-	23202245	-
22	Nil	1.18	6304000	3776000	3.3	15435612	509375	3266625	15899282	29.351
29	Nil	1.04	4464000	1840000	3.4	11727081	398721	1441279	12080500	17.044
Aug 5	Nil	0.95	3310000	1154000	3.7	9343026	345692	808308	9625186	11.997
13	176	1.85	23980000	-	2.2	35725323	785957	-	36777969	-
Aug 20	Nil	1.70	18230000	5750000	3.5	31816333	1113572	4636428	32758256	23.589
27	100	1.99	29610000	-	2.4	36731228	881549	-	37809914	-
Sep 3	5	1.85	23980000	5630000	3.5	35725323	1250386	4379614	36777969	17.012
10	Nil	1.74	19646000	4334000	3.5	32983000	1154405	3179595	33958538	13.376
Sep 17	Nil	1.62	15644000	4002000	3.6	29483000	1061388	2940612	30357495	13.838
24	Nil	1.53	12912000	2732000	3.6	26816457	965392	1766608	27613924	9.139
Oct 1	Nil	1.41	10272000	2640000	3.7	22864673	845993	1794007	23547024	10.884
8	Nil	1.32	8544000	1728000	3.7	19850205	734458	993542	20443845	6.943
Oct 15	Nil	1.25	7200000	1344000	3.7	17505618	647708	696292	18029999	5.517
22	Nil	1.17	6176000	1024000	3.8	15170717	576487	447513	15626536	4.091
	467		208512000	35954000			11811797	26350423	Avg. = 13.565	

Table 5.8: Recharge Rate Calculation for Medha Creek TR – Year 2000

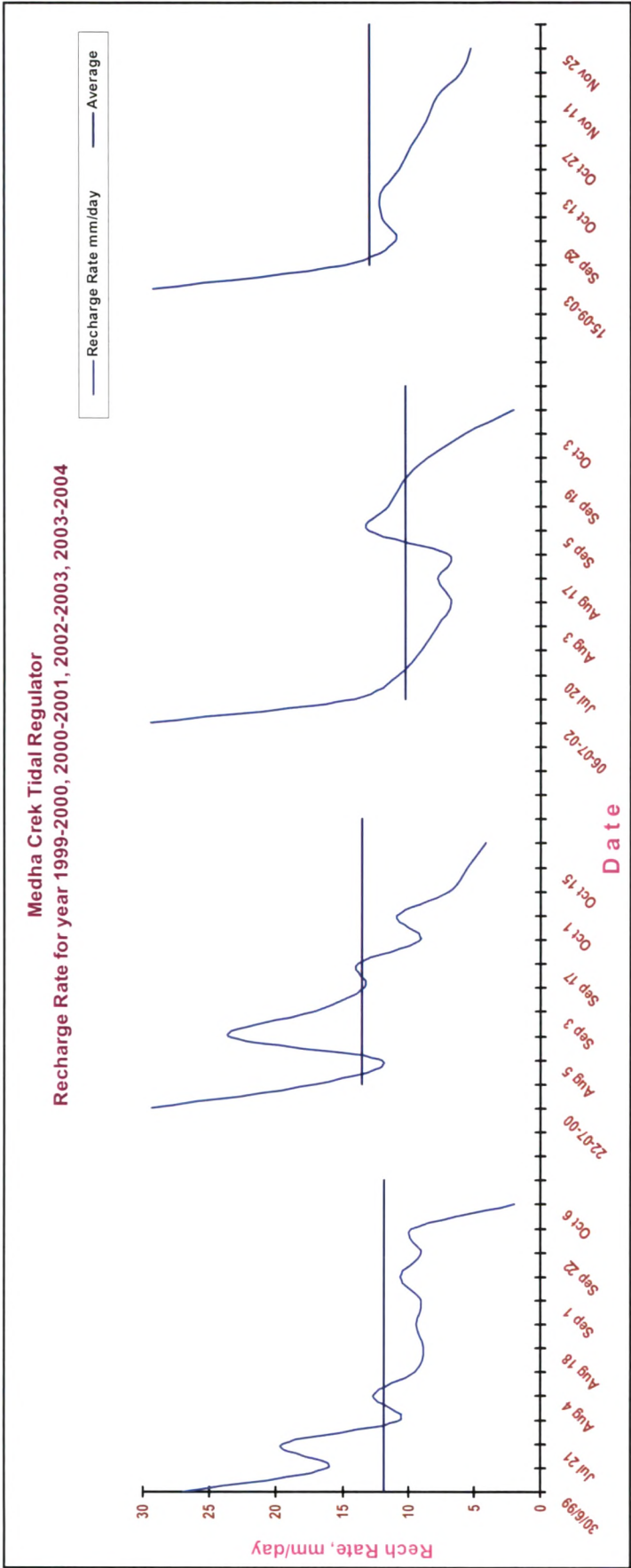
Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M3)	Volume of water Loss (M3)	Evapo cm/week	Surface Area Of Water (M2)	Volume Of Evaporation (M3)	Volume Of Recharge (M3)	Wetted Area (M2)	Recharge Rate mm/day
28/6/02	40	0.55	1280000	-	3.2	4420000	-	-	4559672	-
29	90	0.70	2120000	-	2.2	5980000	-	-	6165829	-
Jul 6	-	0.52	1112000	1008000	3.3	4108000	135564	872436	4238244	29.407
13	-	0.38	712000	400000	3.4	2940000	99960	300040	3034653	14.124
20	-	0.28	472000	240000	3.4	2140000	72760	167240	2209646	10.812
27	-	0.20	320000	152000	3.5	1520000	53200	98800	1569894	8.991
Aug 3	5	0.14	224000	96000	3.4	1064000	36176	59824	1099149	7.775
10	10	0.10	160000	64000	3.5	760000	26600	37400	785213	6.804
17	-	0.07	112000	48000	3.4	532000	18088	29912	549705	7.774
24	-	0.05	80000	32000	3.4	380000	12920	19080	392673	6.941
29	220	1.35	9120000	-	-	20855028	-	-	21478280	
Sep 5	-	1.24	7072000	2048000	2.5	17197575	429939	1618061	17712969	13.050
12	-	1.12	5542000	1530000	2.7	13846241	373849	1156151	14262750	11.580
19	-	1.03	4348000	1194000	2.9	11462186	332403	861597	11807702	10.424
26	-	0.96	3448000	900000	3.2	9607921	307453	592547	9898013	8.552
Oct 3	-	0.92	2822248	625752	3.4	8321210	282921	342831	8573385	5.713
10	-	0.85	2464720	357528	3.4	7260000	246840	110688	7481793	2.113
	365		41408968	8695280			2428674	6266606	Avg. =	10.290

Table 5.9: Recharge Rate Calculation for Medha Creek TR – Year 2002

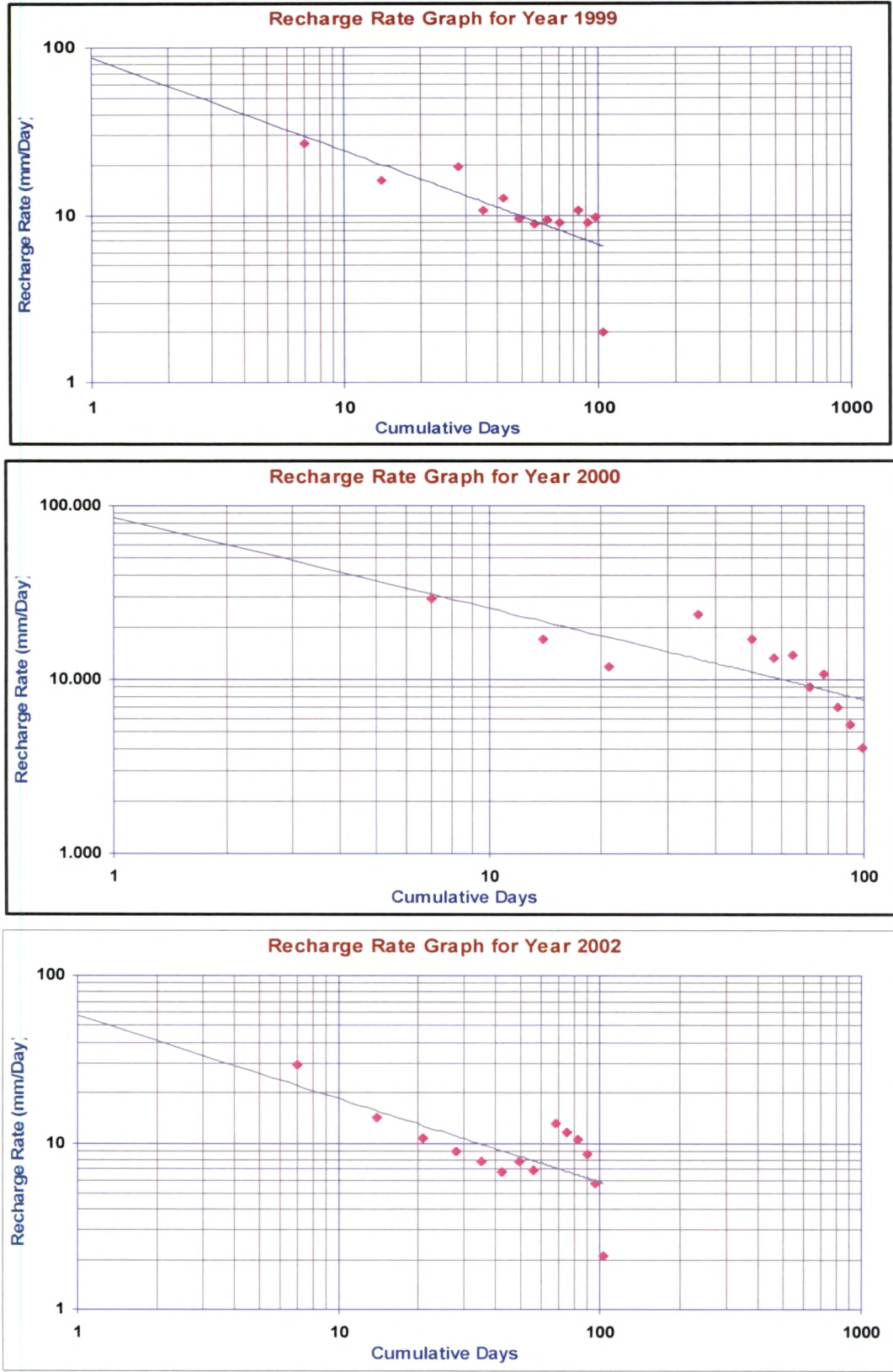
Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M3)	Volume of water Loss (M3)	Evapo cm/week	Surface Area Of Water (M2)	Volume Of Evaporation (M3)	Volume Of Recharge (M3)	Wetted Area (M2)	Recharge Rate mm/day
10/07/2003	219	1.65	16610000	-	-	30358000	-	-	31257811	-
17	275	2.50	49000000	-	-	41446430	-	-	42645890	-
Aug 4	140	2.55	50550000	-	-	42355059	-	-	43579332	-
11	125	2.55	50550000	-	-	42355059	-	-	43579332	-
18	Nil	2.50	49000000	-	-	41446430	-	-	42645890	-
25	Nil	2.50	49000000	-	-	41446430	-	-	42645890	-
Sep 1	45	2.50	49000000	-	-	41446430	-	-	42645890	-
8	Nil	2.50	49000000	-	-	41446430	-	-	42645890	-
15	5	2.29	39718000	9282000	2.7	39078648	1055124	8226876	40216697	29.223
22	Nil	2.14	34596000	5122000	2.9	37825083	1096927	4025073	38930861	14.770
29	Nil	2.02	30636000	3960000	2.8	36946780	1034510	2925490	38031020	10.989
Oct 6	Nil	1.91	26426000	4210000	3.0	36156425	1084693	3125307	37220256	11.995
13	Nil	1.81	22356000	4070000	2.9	34931465	1013012	3056988	35962676	12.143
20	Nil	1.72	18938000	3418000	2.8	32399667	907191	2510809	33358405	10.753
27	Nil	1.63	15966000	2972000	2.9	29774667	863465	2108535	30657605	9.825
Nov 4	Nil	1.55	13520000	2446000	2.7	27441333	740916	1705084	28256615	8.620
11	Nil	1.46	11232000	2288000	3.7	24539378	907957	1380043	25270848	7.801
18	Nil	1.36	9312000	1920000	4.7	21189969	995929	924071	21823082	6.049
25	Nil	1.27	7584000	1728000	5.7	18175500	1036004	691997	18719693	5.281
	809		592994000	41416000			10735727	30680273	Avg. = 11.590	

Table 5.10: Recharge Rate Calculation for Medha Creek TR – Year 2003

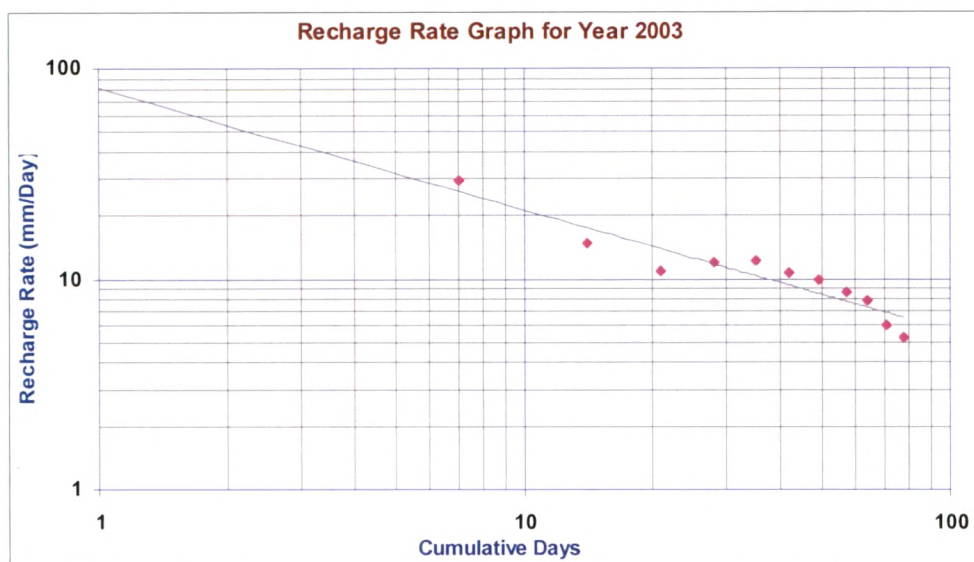
5.2.4.1 Recharge Rate Graphs and Equations for Medha Creek TR



Graph 5.19: Recharge Rate Graph for Medha Creek TR (Refer Table 5.7 to 5.10)



Graph 5.20 to 5.22: Log-Log Graph for Recharge Rate v/s Cumulative Days for Medha Creek TR – Year 1999, 2000 & 2002



Graph 5.23: Log-Log Graph for Recharge Rate v/s Cumulative Days for Medha Creek TR – Year 2003

General equation for recharge rate is $I = \alpha T^{\beta}$

Recharge rate Formula for Medha Creek Tidal Regulator

Year	Intercept on Y axis (Rech. Rate)	Slope of graph
	α	β
1999	87.39	-0.5584
2000	86.349	-0.5259
2002	57.71	-0.4964
2003	80.444	-0.577
Average	77.973	-0.5394

Table 5.11: Recharge Rate Equation for Medha Creek TR

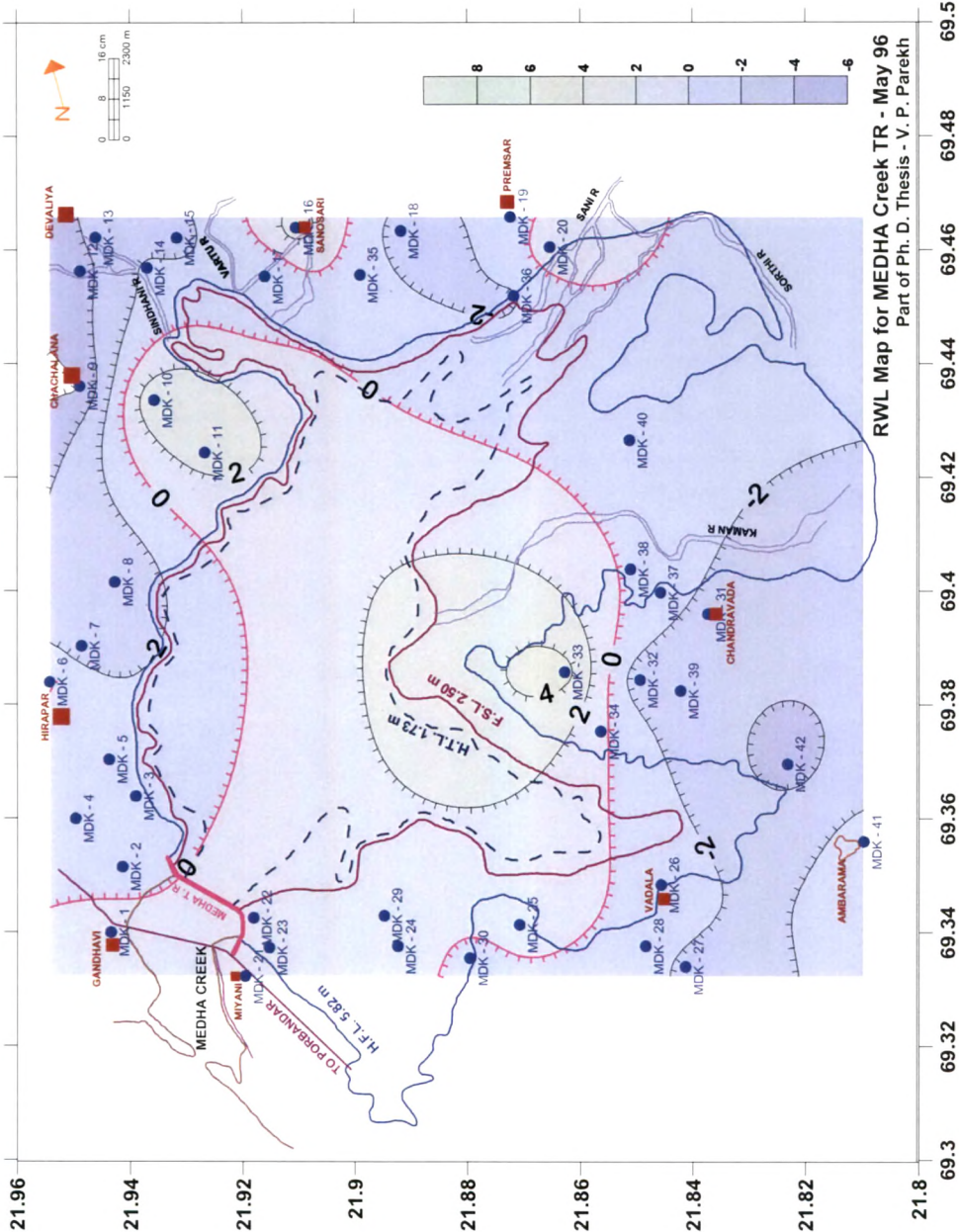
So Recharge Rate Equation, $I = 77.973 T^{0.5394}$

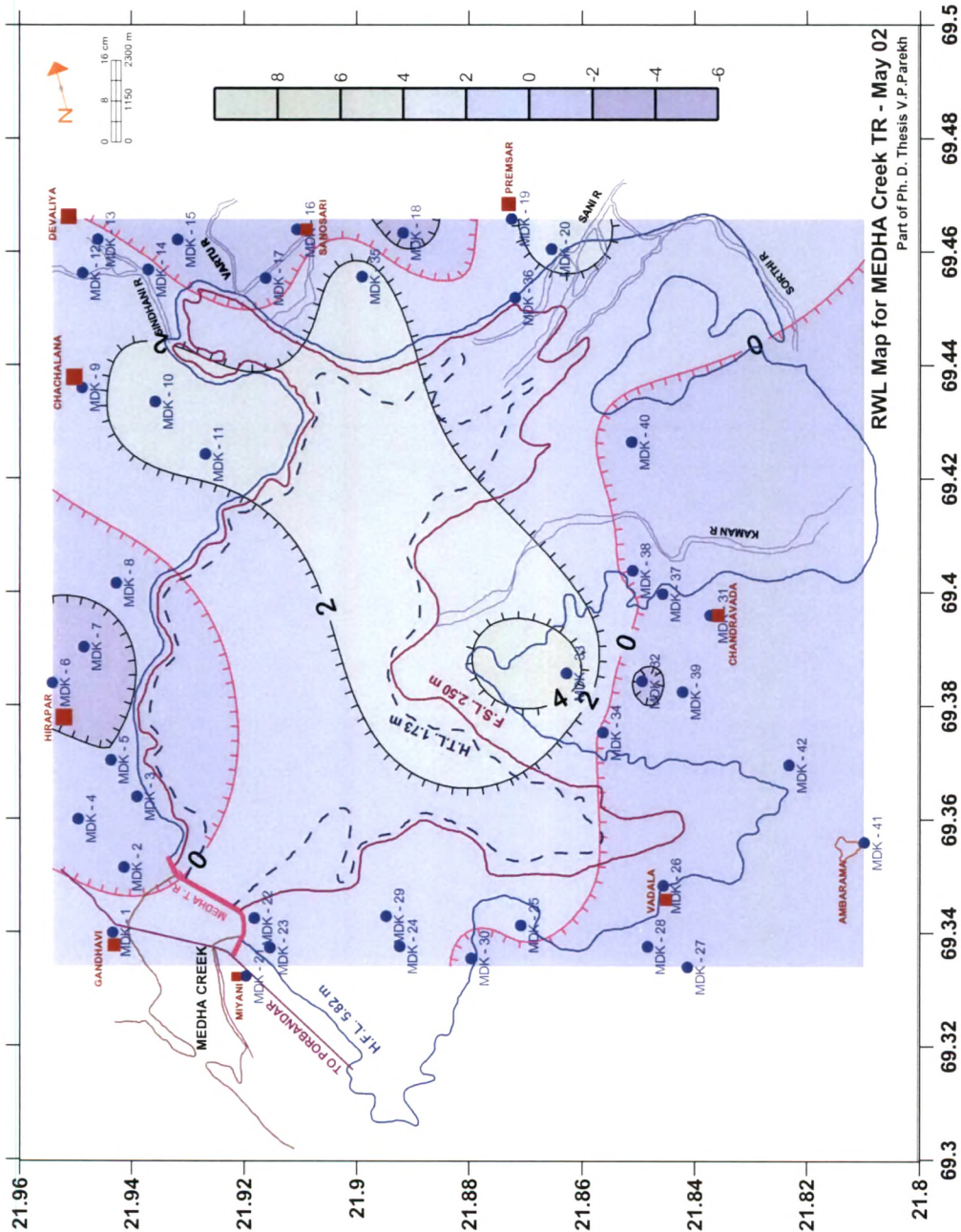
Where I = Recharge Rate mm/Day

T = Time in Days

5.2.5 Geohydrological & Geochemical Analysis for Medha Creek TR

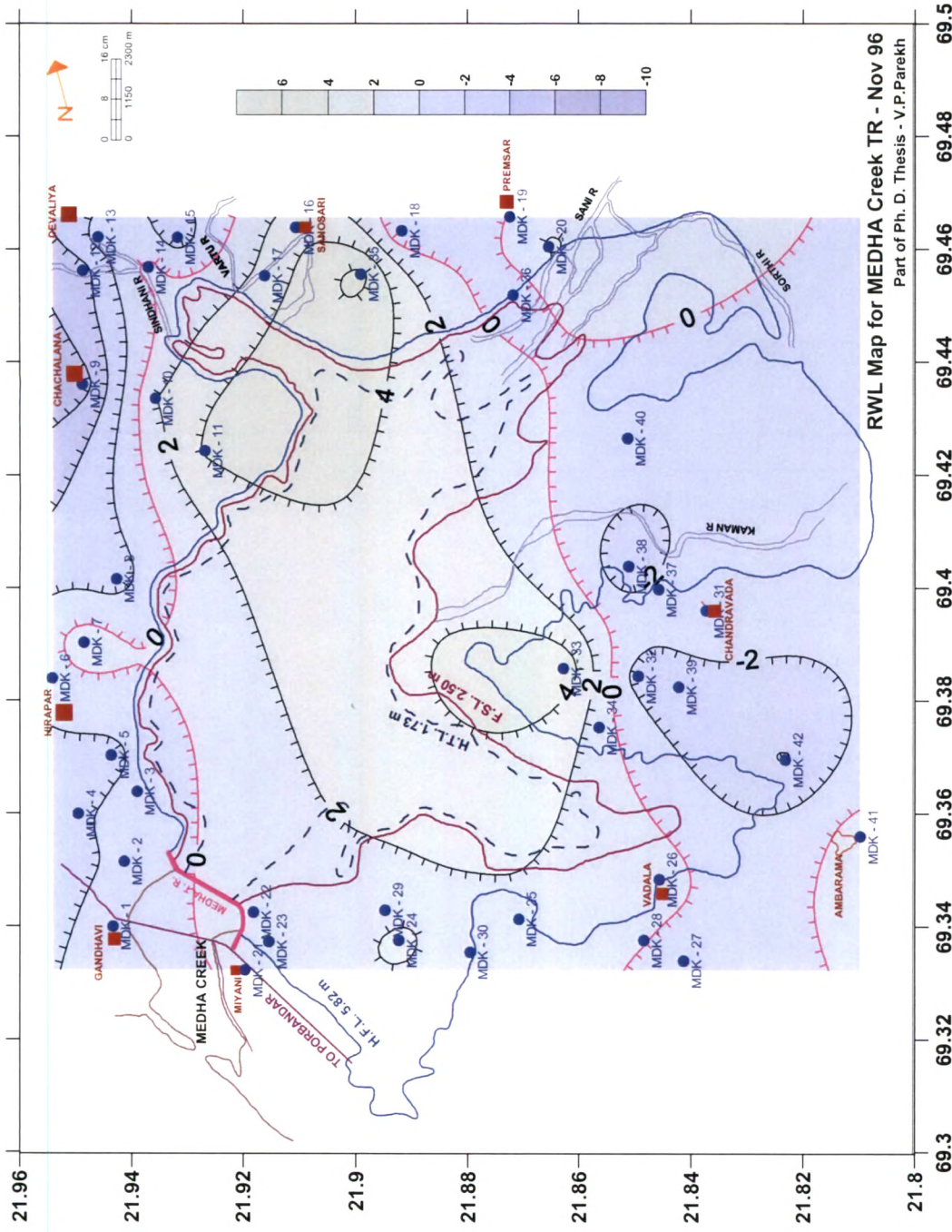
From the Geohydrological data collected from 42 wells surrounding the Medha Creek TR, RWL maps (Map 5.1 to 5.5) are plotted to study the pre-monsoon & post-monsoon groundwater flow pattern. Similarly from analyzed geochemical parameters IsoChlor Map 5.6 to 5.10 are prepared to study the variation of chloride in the study area. To study about fresh seawater intrusion in recent years ion ratio maps of Na^+/Cl^- (Map 5.11 to 5.12) and $Cl^-/(CO_3^{2-}+HCO_3^-)$ Map 5.13 to 5.15 is plotted. A section passing through the wells MDK-01, 02, 03, 04, 05, 06, 07, 08, 10, 11, 17, 16, 35 and 18 is plotted in map 5.16 to locate zone of transition between freshwater and saline water.



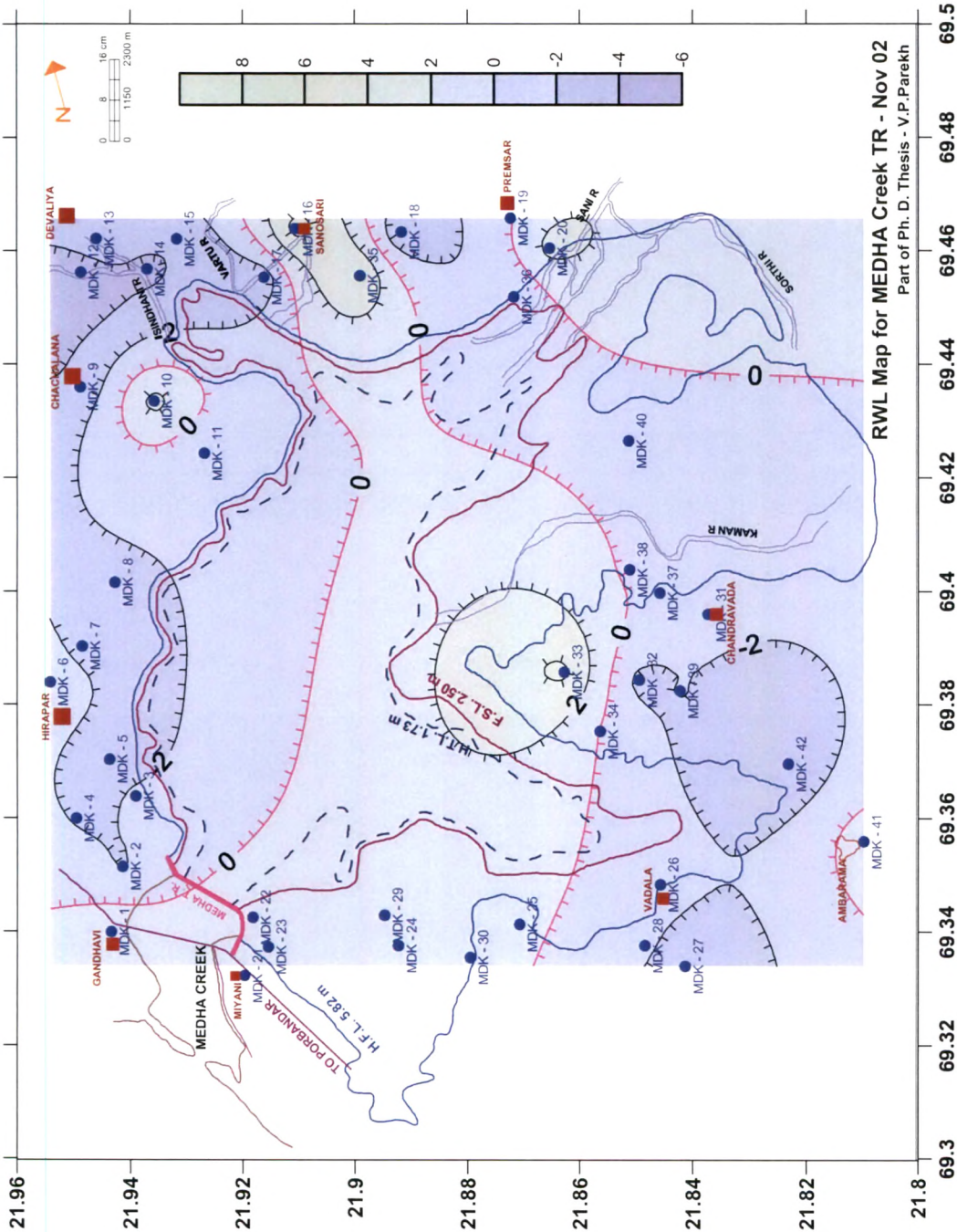


RWL Map for MEDHA Creek TR - May 02
Part of Ph. D. Thesis V.P.Parekh

Map 5.2 : RWL Map for Medha Creek TR – May 2002

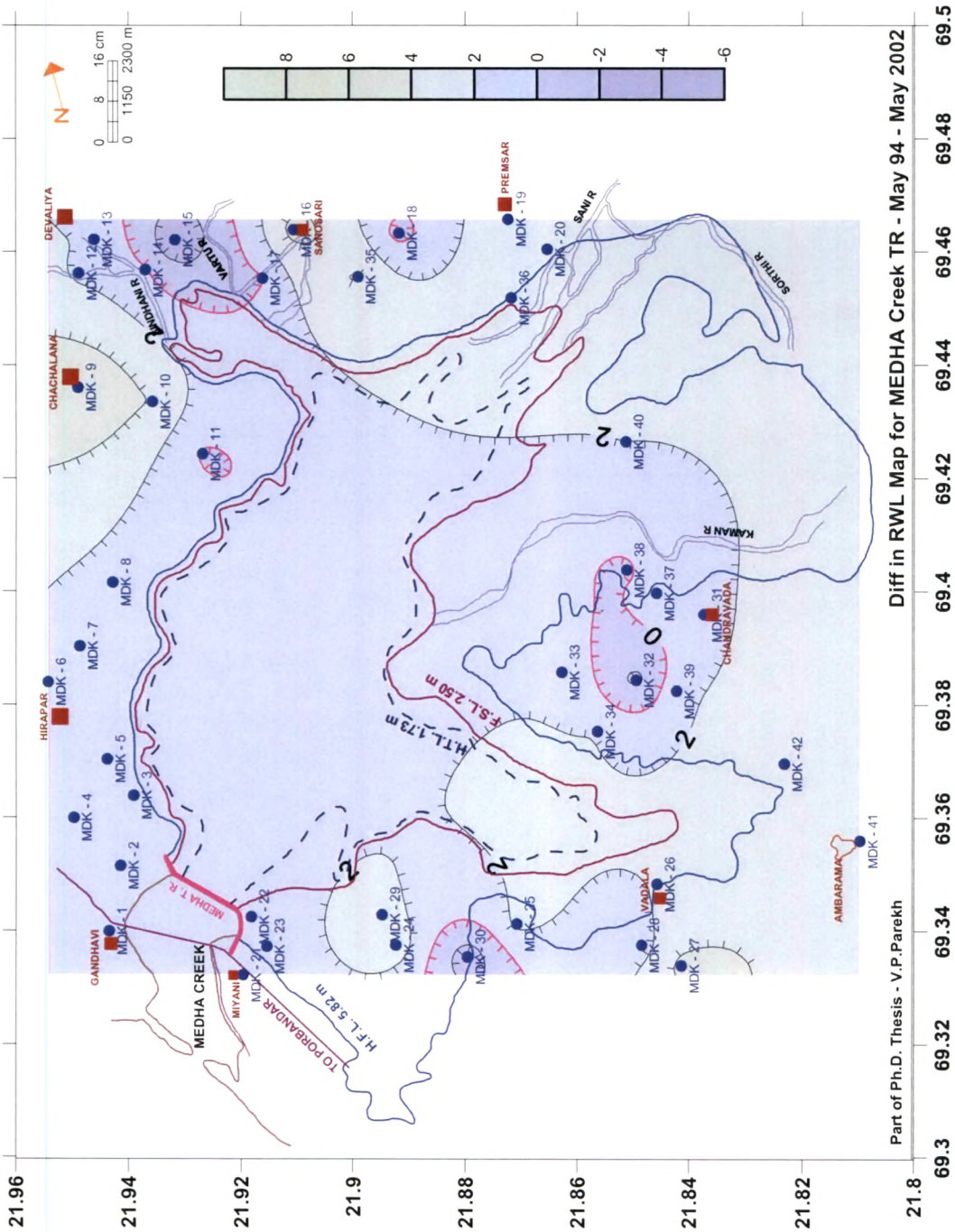


Map 5.3 : RWL Map for Medha Creek TR – November 1996

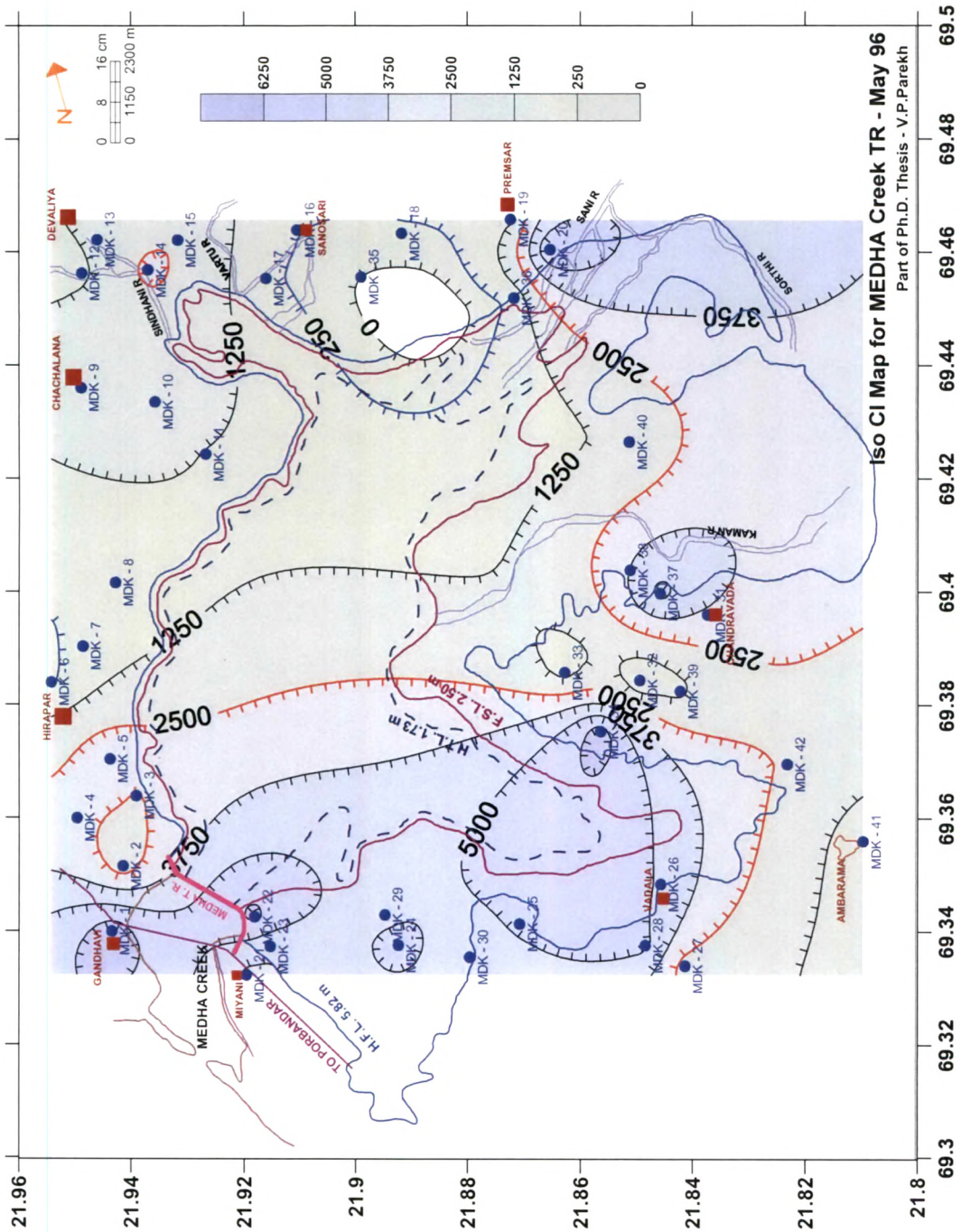


RWL Map for MEDHA Creek TR - Nov 02
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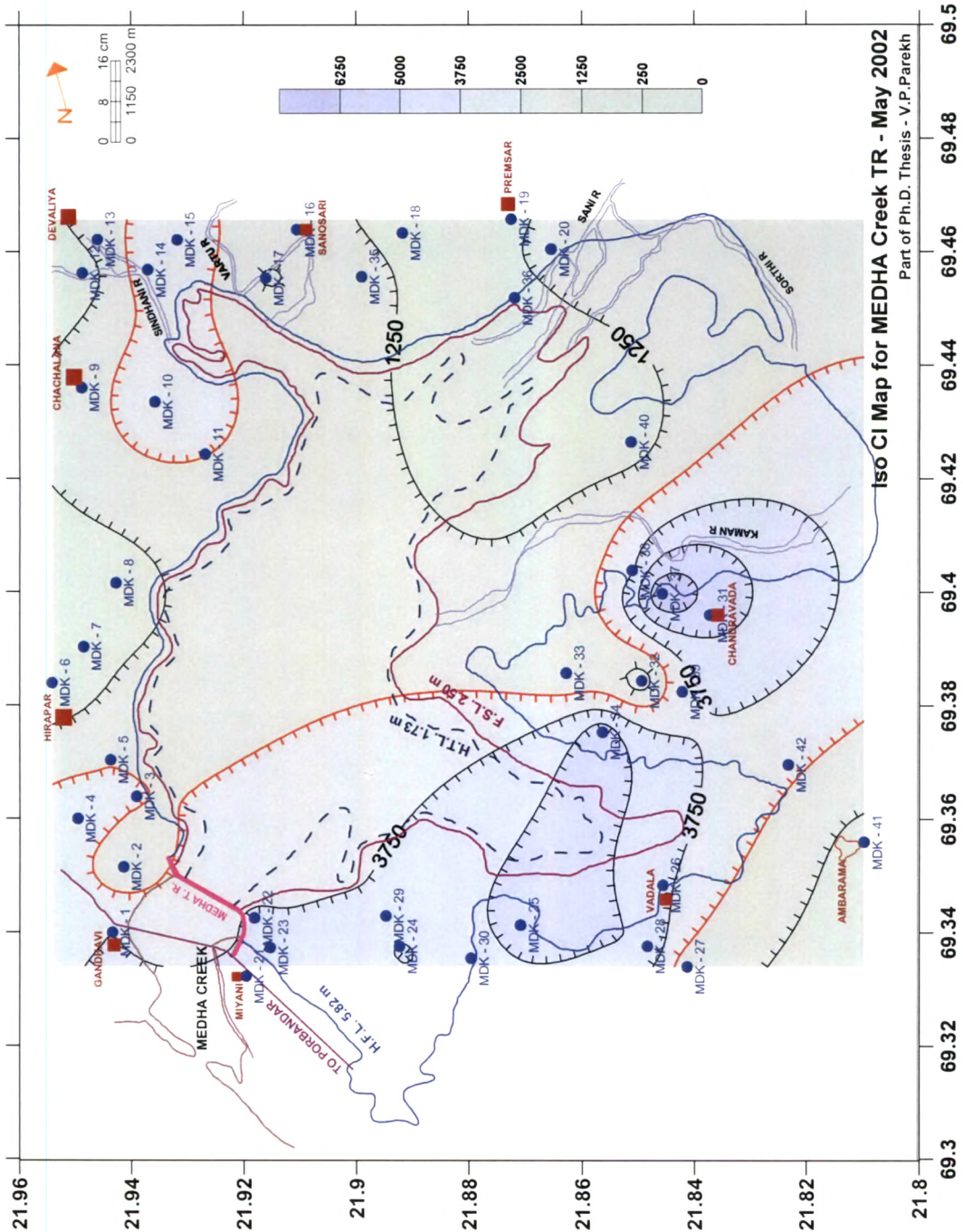
Map 5.4 : RWL Map for Medha Creek TR – November 2002



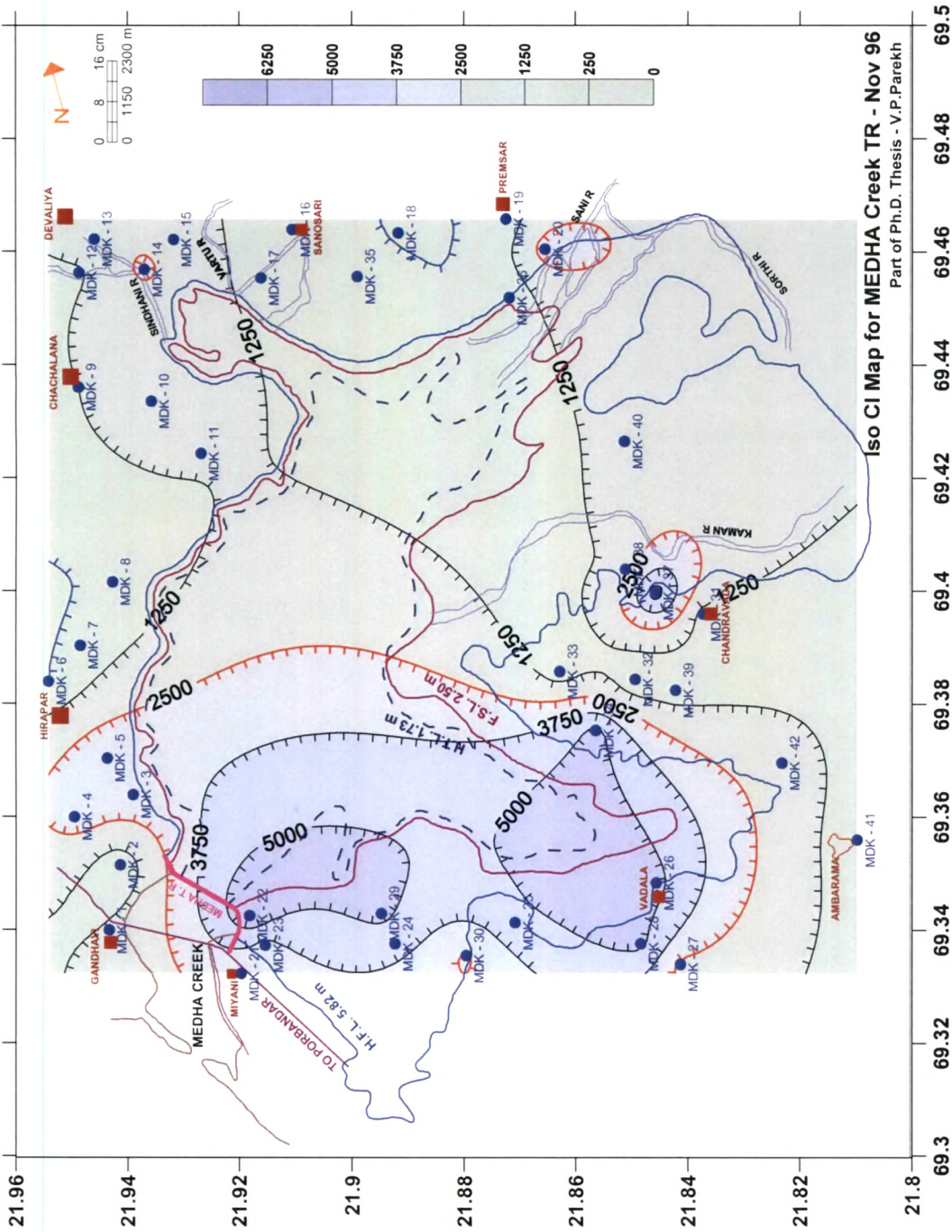
Map 5.5 : Difference in RWL Map for Medha Creek TR – May 1994 to May 2002



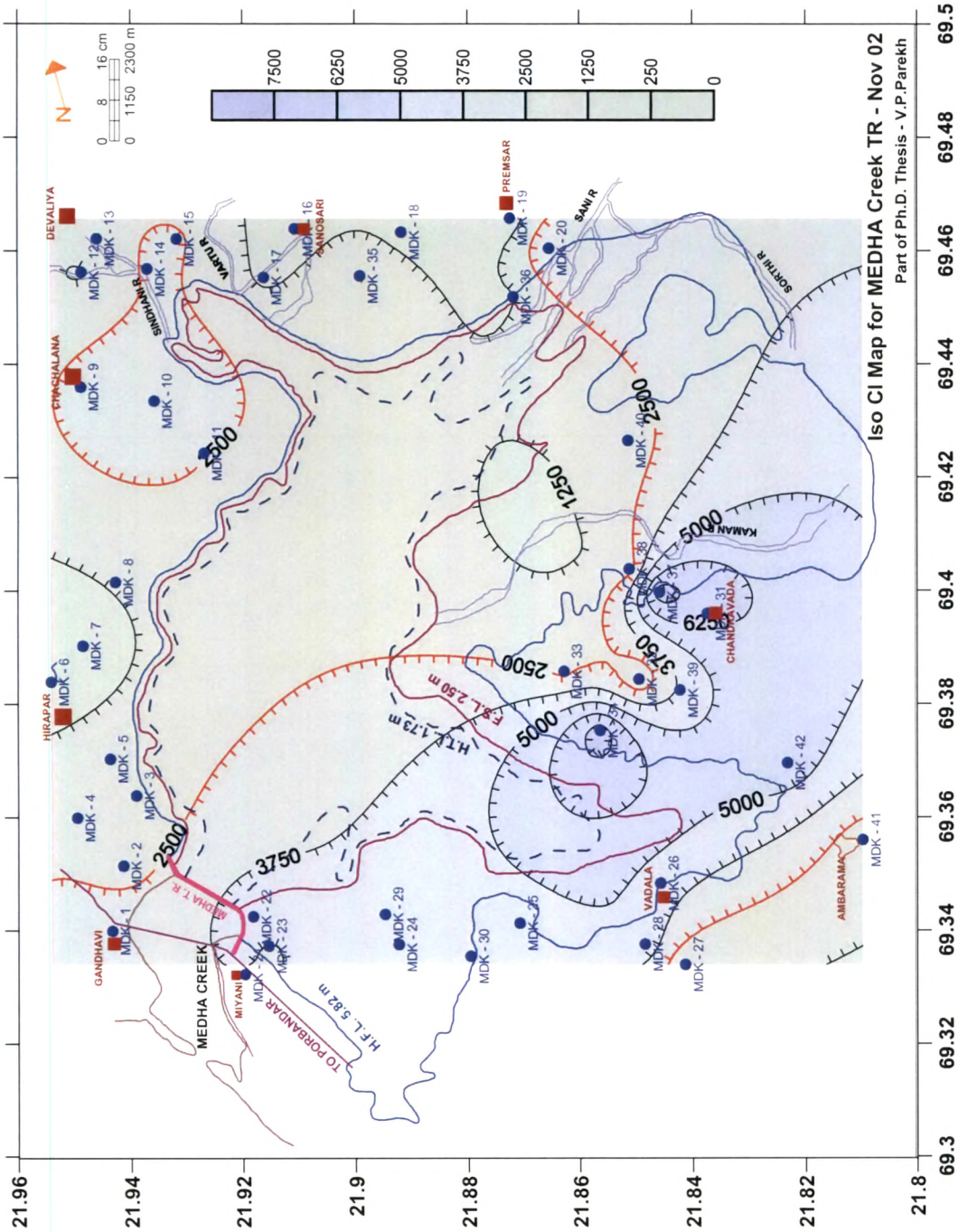
Map 5.6 : Iso CI Map for Medha Creek TR - May 1996



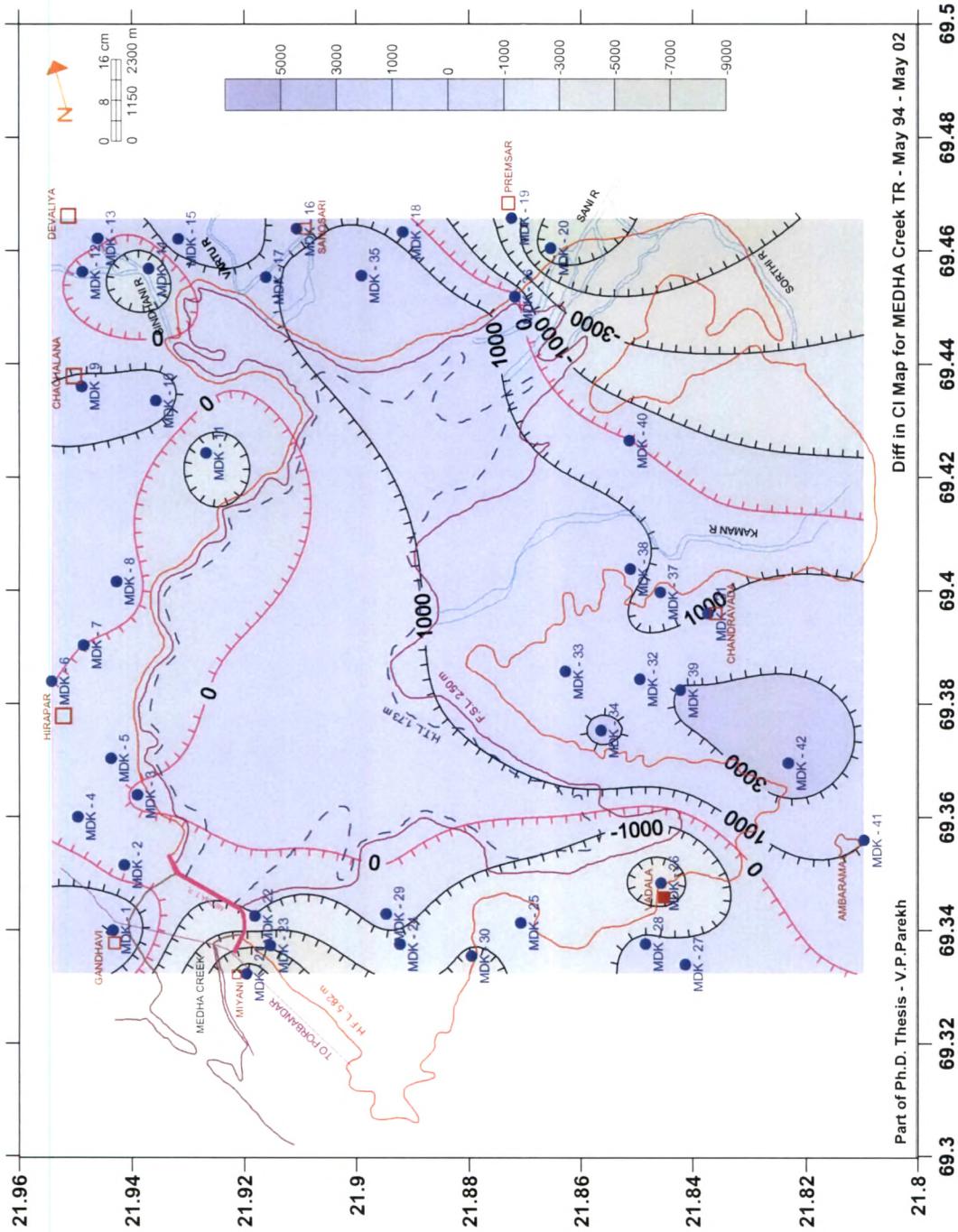
Map 5.7 : Iso CI Map for Medha Creek TR – May 2002



Map 5.8 : Iso CI Map for Medha Creek TR – November 1996



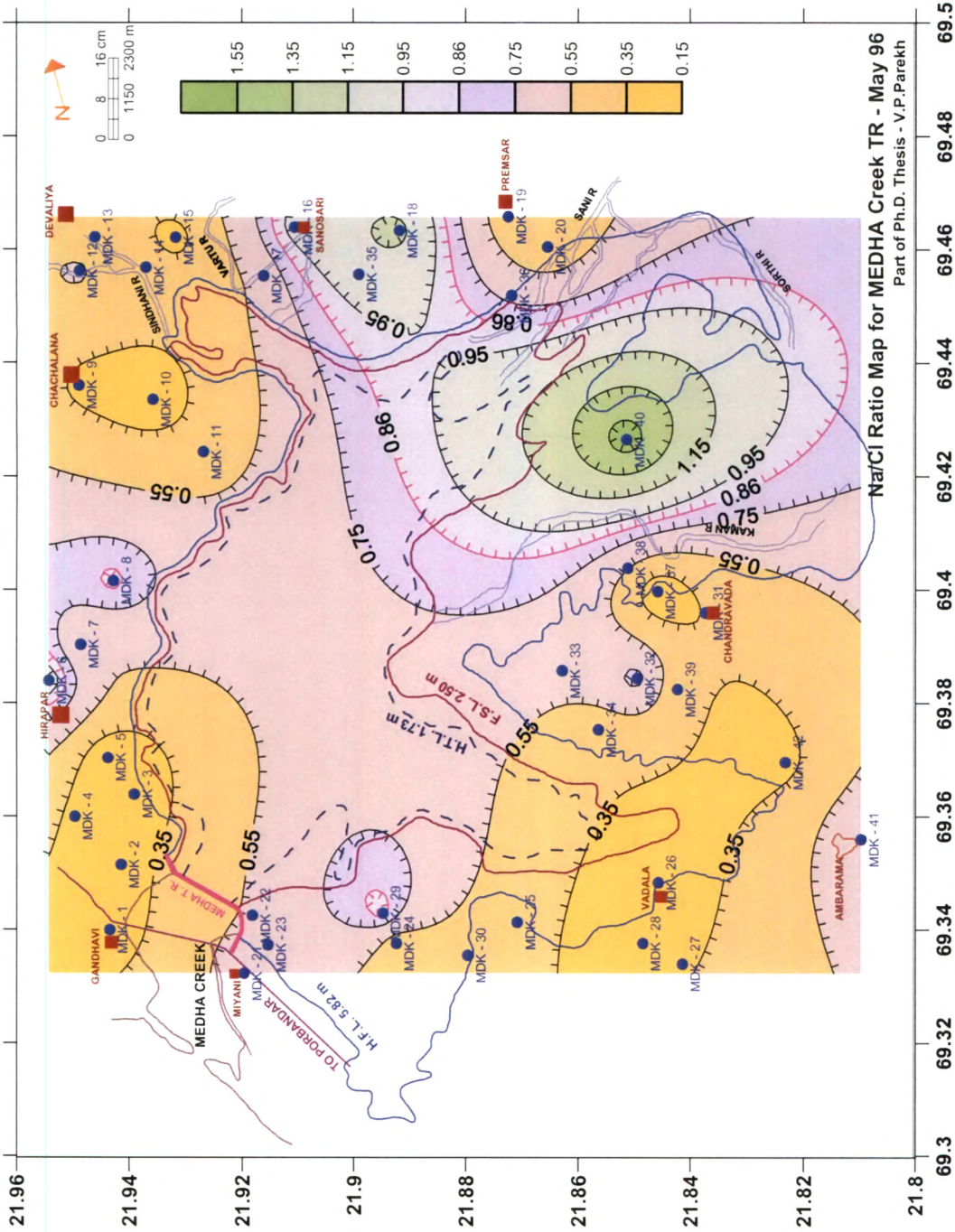
Map 5.9 : Iso CI Map for Medha Creek TR – November 2002



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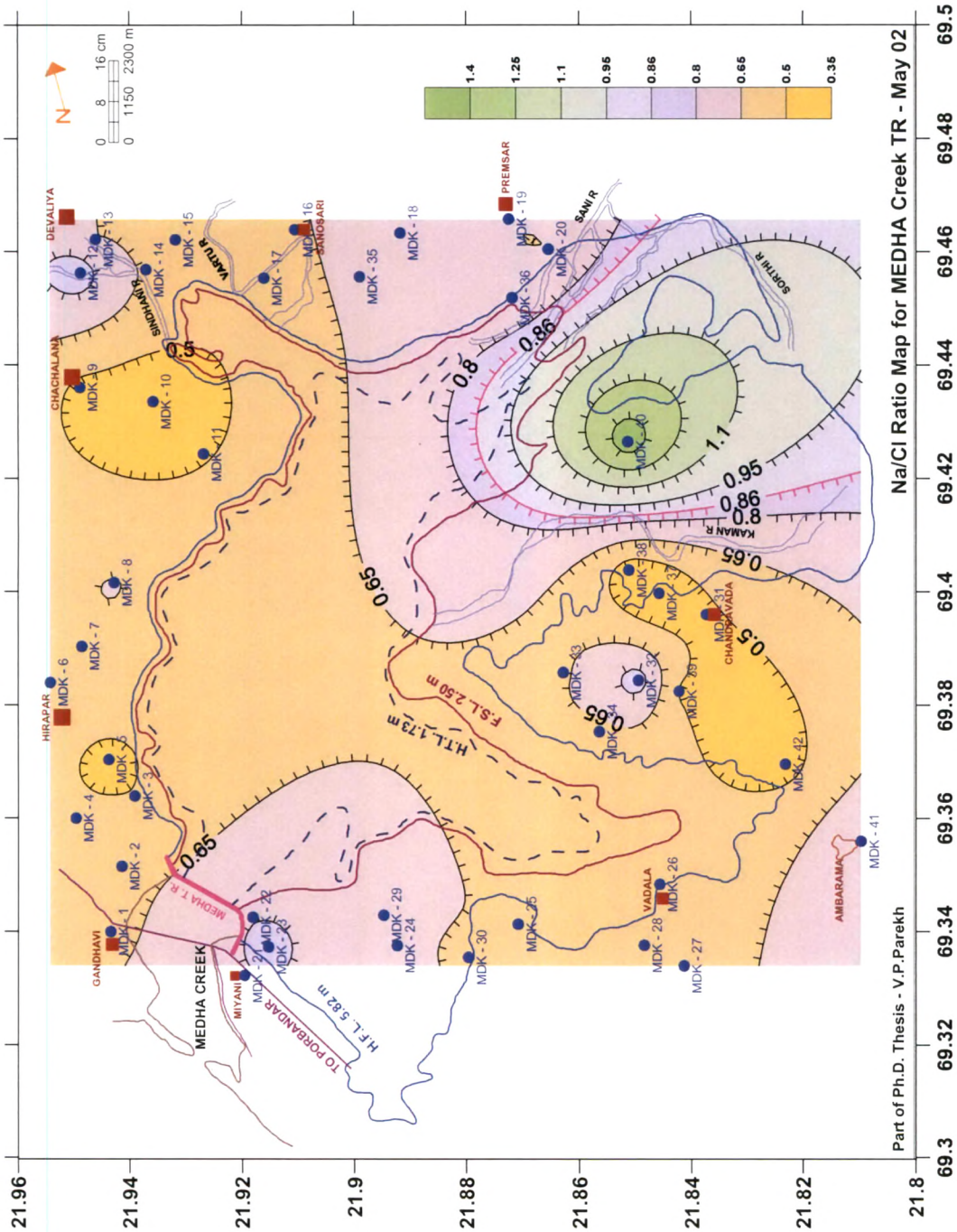
Diff in CI Map for MEDHA Creek TR - May 94 - May 02

Map 5.10 : Difference in CI Map for Medha Creek TR – May 1994 to May 2002

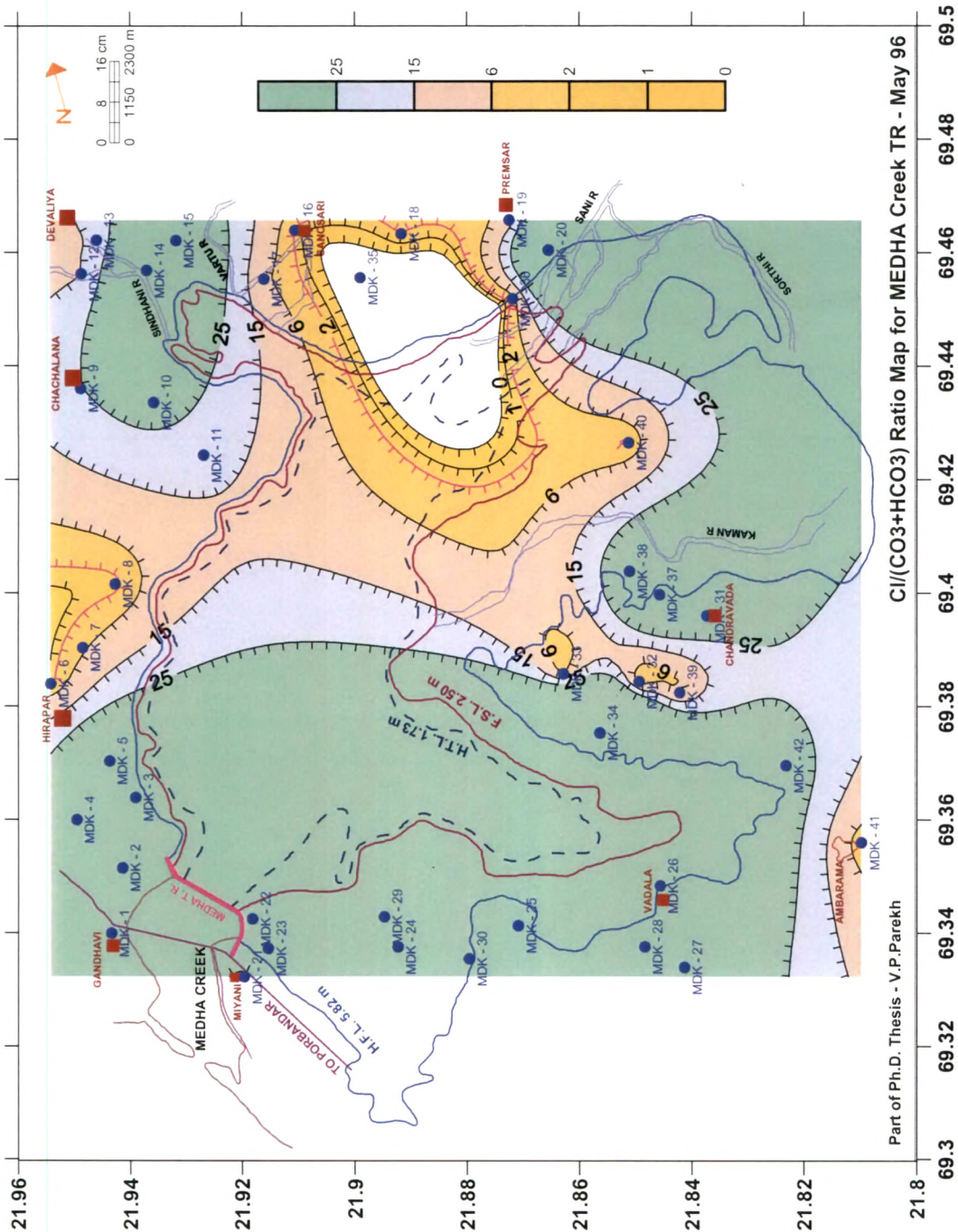


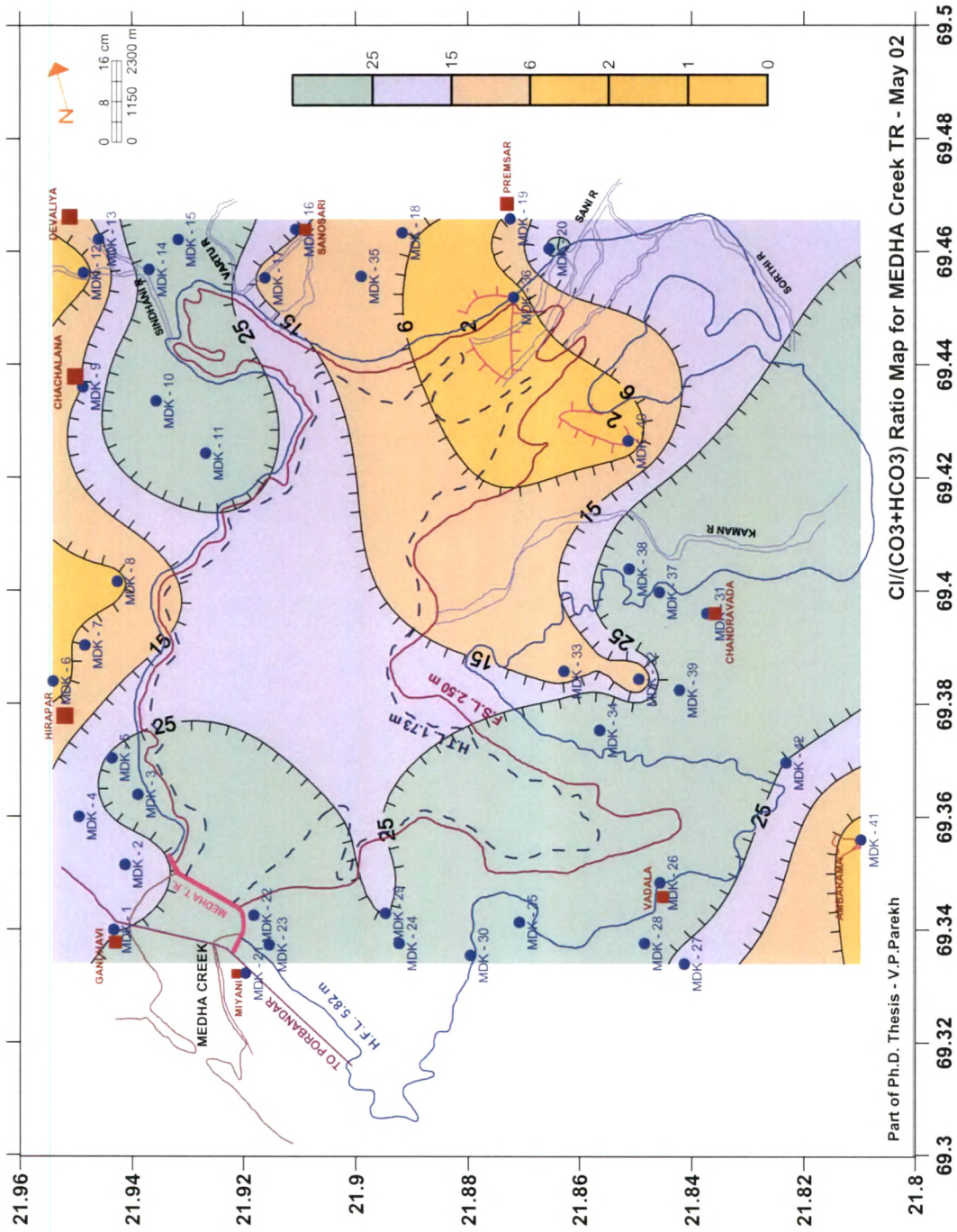
Na/Cl Ratio Map for MEDHA Creek TR - May 96
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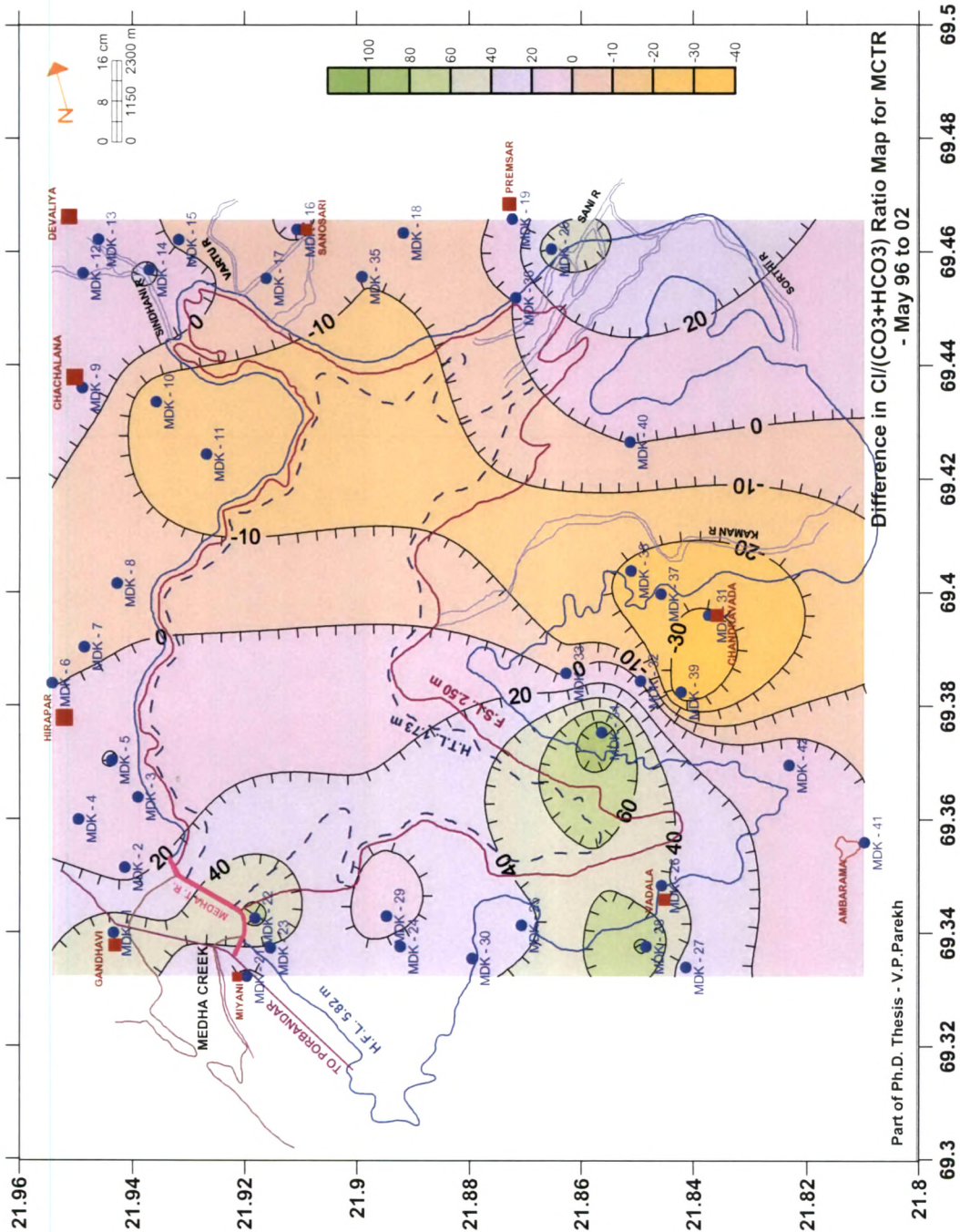
Map 5.11 : Na/Cl Ion Ratio Map for Medha Creek TR – May 1996



Map 5.12 : Na/Cl Ion Ratio Map for Medha Creek TR – May 2002







5.2.6 Interpretation of Geohydrological & Geochemical Maps for Medha Creek TR

5.2.6.1 Water Levels (Map 5.1 to 5.5)

Total rainfall of year 1995 was 393 mm and 2001 was 1372 mm. On the left bank and lower reaches of the right bank of the creek, Miliolite Limestone which is highly cavernous in nature, occurs with thin alluvium cover. From Pumping test permeability of the Miliolite Limestone in this area is calculated as 6.537045 m/day.

In RWL Map for the May 1996, water level surrounding the reservoir area is below MSL in the range of 0 to (-4) m. that means there is a flow from reservoir to inland. Also it is seen that RWL on north end of TR is at MSL and in far north end it is below MSL. The wells located very close to reservoir shows high RWL. During monsoon visit of the site it was observed that some wells were filled upto GL. As compared to 1995 monsoon, 2001 monsoon was very good and rainfall was also 62% above normal. The reservoir was also remaining full for 251 days of year. RWL map of the year May 2002 is almost of the same pattern in general. GW flow is from reservoir to surrounding. So there might be a chance of reversal of hydraulic gradient during low rainfall or drought years. To get aggregate view difference in RWL for the seasons May 1994 & May 2002 is prepared. This map shows an increase in RWL of 2 to 4m surrounding the reservoir area, which shows effect of TR on building up of freshwater cushion in the coastal area by arresting the GW flow.

5.2.6.2 Water Quality

Chloride (Map 5.6 to 5.10)

Isochlor map of Medha Creek TR for the season May 1996 shows zone of transition (i.e Chloride ranges between 250 mg/l to 2500 mg/l) from NW to NE part. On East side the Chloride content is high; more than 3750 mg/l. The area nearer to coast shows very high Chloride content. There are two separate high Chloride pockets. In May 2002 season, despite of very good preceding monsoon the well no. MDK-42 and MDK-39 turns to be saline and both the pockets of high Chloride in May 1996 get merged. So Chloride content has been increased from SW to nearly East side of the structure. To get aggregate view difference in Chloride for the seasons May 1994 & May 2002 is prepared. This map shows an increase in Chloride content in northern and SE part by 1000 mg/l, While the East side of the reservoir shows an improvement in Chloride content and the Chloride content has been reduced by more than 7000 mg/l.

Ion Ratios

When sea water intrusion occurs, some of the sodium cations are exchanged for calcium or magnesium in the aquifer sediments. This process lowers the sodium-to-chloride ratio below sea water values (<0.86 molar) while enriching calcium and magnesium.

Map 5.11 & 5.12 shows the sodium-to-chloride molar ratio for the seasons May 1996 & May 2002 respectively. Map 5.11 shows that entire area except east side is having ratio below the sea water value. The same was the situation in Map 5.12, which indicates the stagnant situation. Sea water is the only suspected source of salinity in the area that would cause the sodium-to-chloride ratio to drop below approximately 0.86 molar.

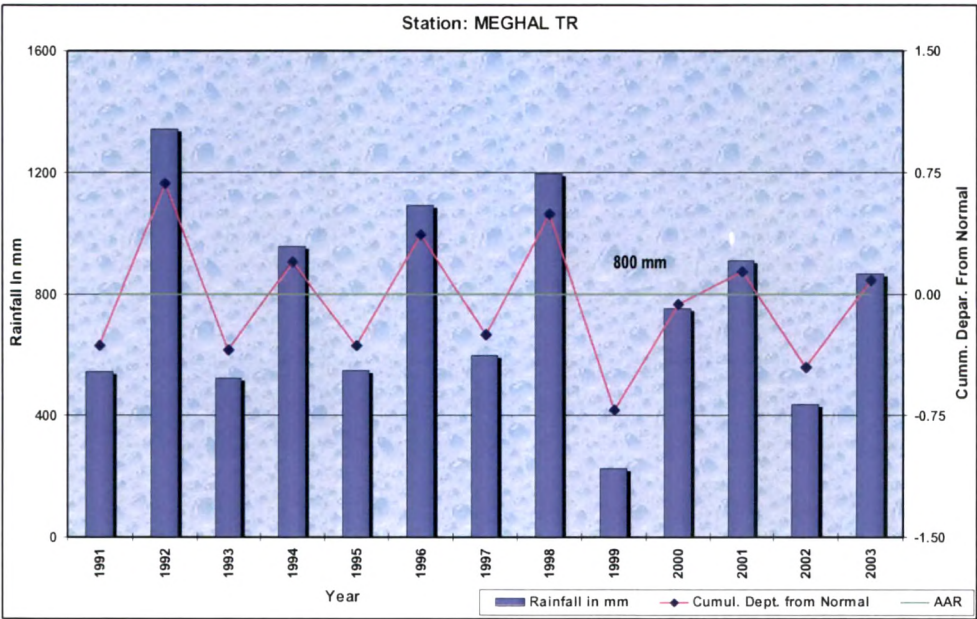
The chloride-to-bicarbonate ratio is useful in differentiating sea water intrusion from salinity increases due to other sources. Sea water has a much higher concentration of chloride and a lower concentration of bicarbonate than aquifer fresh water. When the two waters mix, the ratio of chloride to bicarbonate in the transition zone increases compared to the fresh water value. Map 5.13 to 5.15 shows the chloride-to-bicarbonate molar ratio across the Medha Creek TR area. A significant increase in the ratio occurs in 2002 on the SE side of the area as compared to 1996 situation. There is some fresh water area located on NE portion of the area, but it also shows reducing trend. Map 5.15 shows difference in chloride-to-bicarbonate ratio for the seasons May 1994 & May 2002, which shows improvement (decrease in the ratio upto 40) in the chloride-to-bicarbonate ratio for the area located in the upper reaches. But nearer to coast it increases by 60 ^{units} that might be due to localized pumping of well.

Zone of Transition and Interface line for the Medha Creek TR area is demarcated in the sectional view (Map 5.16). Well MDK-18 ($\text{Cl}^- = 192 \text{ mg/l}$) is located 5.9 km inland from coast. Well MDK-05 ($\text{Cl}^- > 2500 \text{ mg/l}$) is located 1.9 km inland from coast. From sectional view it is visualize that zone of transition ranges from 1.9 km to 5.9 km. The area having $\text{Cl}^- > 2500 \text{ mg/l}$ is referred as seawater intruded zone that lies from coast to 1.9 km inland and contour line of 2500 mg/l in sectional view indicates probable seawater-freshwater interface.

5.3 Analysis of Meghal Tidal Regulator

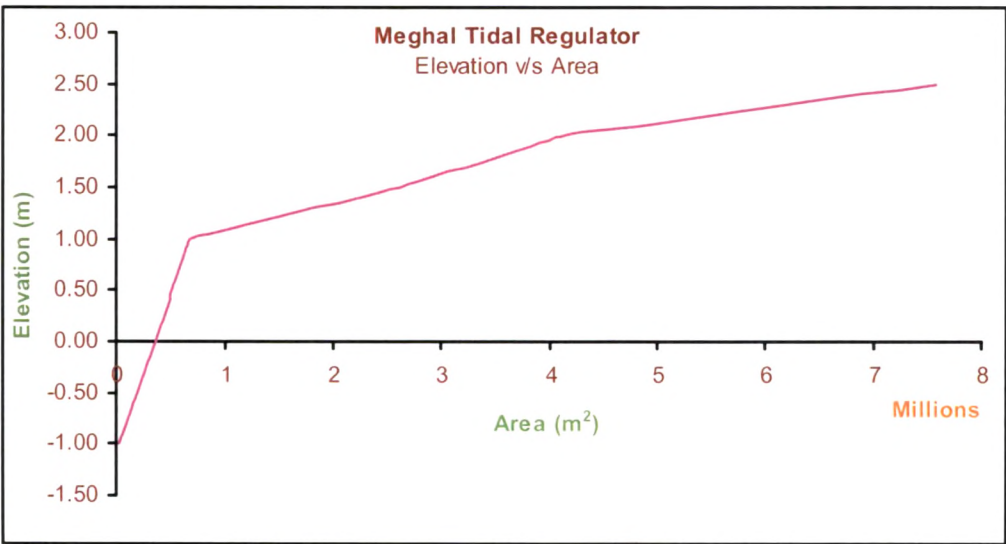
5.3.1 Analysis of Rainfall in Meghal TR Area

Rainfall data from 1991 to 2003 is collected (table 4.19) and a graph 5.24 showing relationship between Rainfall, Cumulative departure from normal and Average Rainfall is plotted.

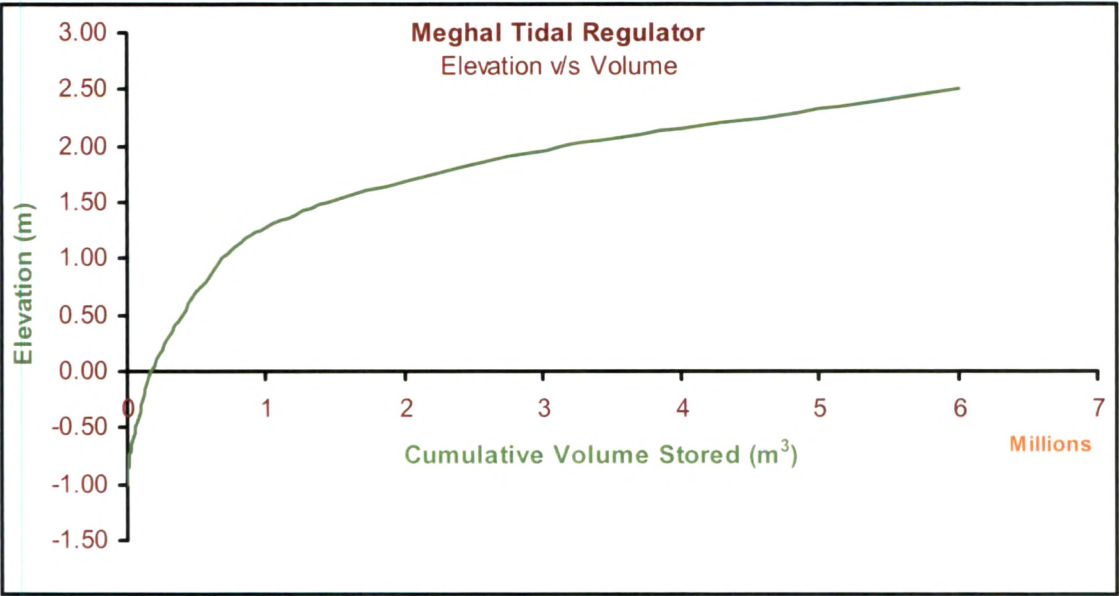


Graph 5.24: Graph Showing Rainfall, Departure from Normal rainfall & Avg. Annual Rainfall

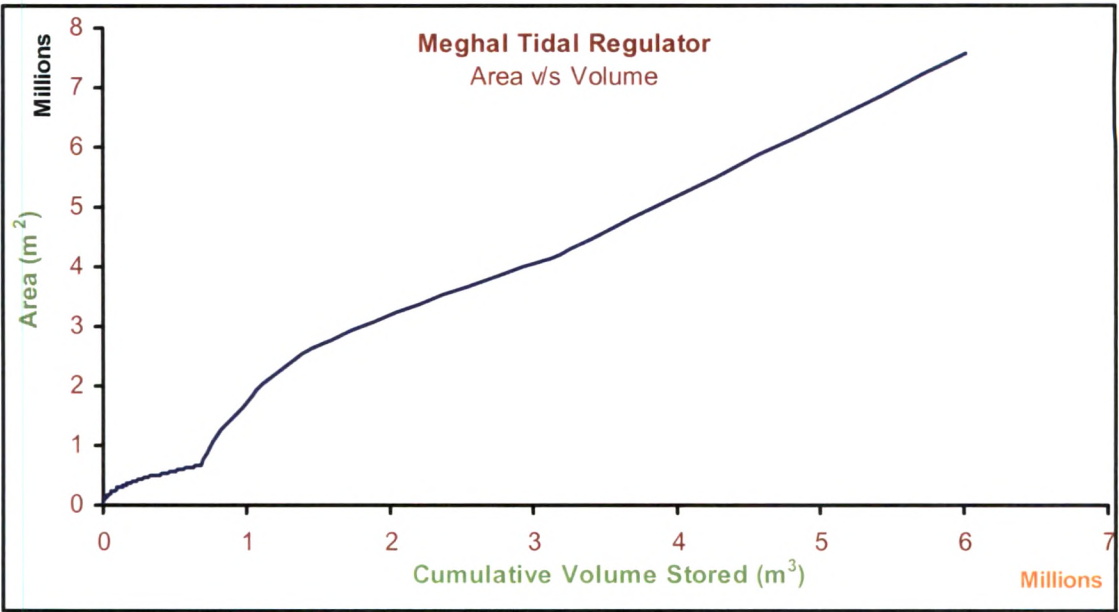
5.3.2 Graphs Showing Relation between Elevation, Area and Cumulative Volume Stored for Meghal TR



Graph 5.25: Relation between Elevation v/s Area for Meghal TR (Table 4.22)



Graph 5.26: Relation between Elevation v/s Volume for Meghal TR (Table 4.22)



Graph 5.27: Relation between Area v/s Volume for Meghal TR (Table 4.22)

5.3.3 Analysis of Pumping Test at Village Visanvel

Pumping test for a well situated in village Visanvel was carried out and aquifer parameters like Permeability (K), Transmissibility (T) and Specific Capacity (C) has been calculated.

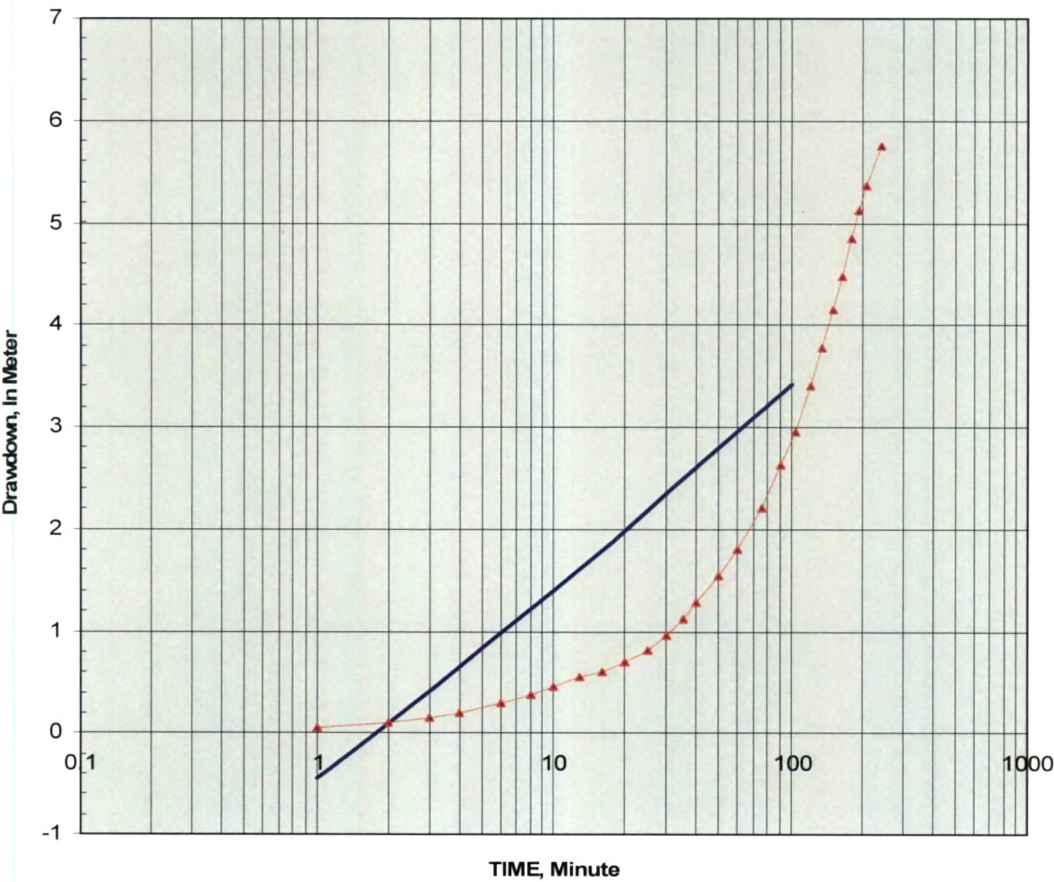
5.3.3.1 Time – Drawdown Analysis

Refer Graph 5.28

Sr. No.	Time Hr:Min:Sec	Water Level (m)	Drawdown (m)
1	9:00	22.15	0.000
2	9:01	22.20	0.050
3	9:02	22.25	0.100
4	9:03	22.30	0.150
5	9:04	22.35	0.200
6	9:06	22.45	0.300
7	9:08	22.53	0.380
8	9:10	22.61	0.460
9	9:13	22.70	0.550
10	9:16	22.76	0.610
11	9:20	22.85	0.700
12	9:25	22.97	0.820
13	9:30	23.11	0.960
14	9:35	23.27	1.120
15	9:40	23.43	1.280
16	9:50	23.70	1.550
17	10:00	23.95	1.800
18	10:15	24.35	2.200
19	10:30	24.77	2.620
20	10:45	25.10	2.950
21	11:00	25.55	3.400
22	11:15	25.93	3.780
23	11:30	26.30	4.150
24	11:45	26.63	4.480
25	12:00	26.99	4.840
26	12:15	27.27	5.120
27	12:30	27.51	5.360
28	13:00	27.91	5.760

Table 5.12: Time – Drawdown Analysis for the Pumping Test at Vill. Visanvel near Meghal TR

Well located at village Visanvel	
INPUT Dimensions: Diameter of Well (d _c) = 4.20 Meter Area of Well (A) = 13.85442 Sq. Meter Depths to: water level (DTW) = 22.15 Meter Base of Aquifer = 28.25 Meter Type of Well: Open Well Aquifer Material -- Gaj Limestone FLOW RATE = 475 m ³ /d	Date: 19/04/2002 Time: 09:00
	Aquifer thickness = 6.10 Meter Slope = 2.02 Meter/log10
	K = 7.1138522 Meter/Day T = 43.038806 Meter ² /Day



Graph 5.28 Cooper-Jacob's Log-Log Graph for Pumping Test Carried out at Village Visanvel

5.3.3.2 **Recuperation Analysis**

(Maximum Drawdown $S_1 = 5.76\text{m}$ - Refer Graph 5.29)

Sr. No.	Time Hr:Min	Time since Pumping Stopped (min)	Water Level (m)	Residual Drawdown S_2 (m)	$(t+\Delta t/\Delta t)$	S_1/S_2
1	09:00	---	22.15	---	---	---
2	13:00	0	27.91	---	---	---
3	13:01	1	27.85	5.700	241.00	1.010526
4	13:02	2	27.82	5.670	121.00	1.015873
5	13:03	3	27.78	5.630	81.00	1.023091
6	13:04	4	27.75	5.600	61.00	1.028571
7	13:05	5	27.72	5.570	49.00	1.034111
8	13:06	6	27.70	5.550	41.00	1.037838
9	13:07	7	27.68	5.530	35.29	1.041591
10	13:08	8	27.66	5.510	31.00	1.045372
11	13:10	10	27.63	5.480	25.00	1.051095
12	13:12	12	27.60	5.450	21.00	1.056881
13	13:15	15	27.56	5.410	17.00	1.064695
14	13:20	20	27.53	5.380	13.00	1.070632
15	13:25	25	27.51	5.360	10.60	1.074627
16	13:30	30	27.49	5.340	9.00	1.078652
17	13:40	40	27.41	5.260	7.00	1.095057
18	13:50	50	27.33	5.180	5.80	1.111969
19	14:00	60	27.26	5.110	5.00	1.127202
20	14:15	75	27.11	4.960	4.20	1.161290
21	14:30	90	27.00	4.850	3.67	1.187629
22	14:45	105	26.91	4.760	3.29	1.210084
23	15:00	120	26.82	4.670	3.00	1.233405
24	15:15	135	26.70	4.550	2.78	1.265934
25	15:30	150	26.58	4.430	2.60	1.300226
26	15:45	165	26.48	4.330	2.45	1.330254
27	16:00	180	26.38	4.230	2.33	1.361702
28	16:15	195	26.28	4.130	2.23	1.394673
29	16:30	210	26.17	4.020	2.14	1.432836
30	17:00	240	26.00	3.850	2.00	1.496104
31	17:30	270	25.83	3.680	1.89	1.565217
32	18:00	300	25.67	3.520	1.80	1.636364

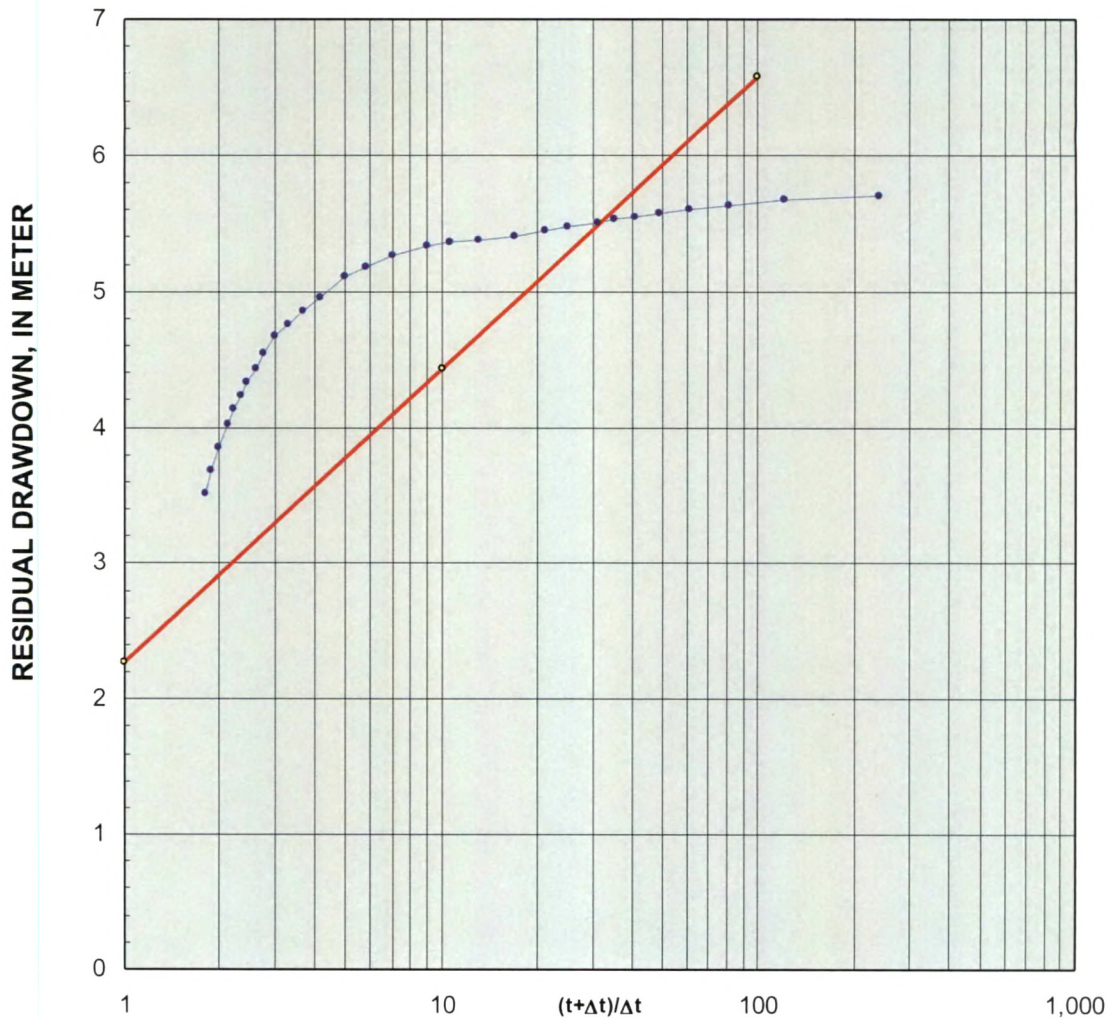
Table 5.13: Time – Recovery Analysis for the Recuperation Test at Vill. Visanvel near Meghal TR

5.3.3.3 **Results for Pumping Test**

	Pumping Test	Recuperation Test
Transmissibility	43.0389 m ² /day	40.4365 m ² /day
Permeability	7.1139 m/day	6.6837 m/day

Table 5.14: Results of Pumping Test at Vill. Visanvel

Well located at village Visanvel	
INPUT Dimensions: Diameter of Well (d_c) = 4.20 Meter Area of Well (A) = 13.85442 Sq. Meter Depths to: water level (DTW) = 22.15 Meter Base of Aquifer = 28.25 Meter Type of Well: Open Well Aquifer Material -- Gaj Limestone FLOW RATE = 475 m³/d	Date: 19/04/2002 Time: 09:00
	Aquifer thickness = 6.10 Meter Slope = 2.15 Meter/log10
	K = 6.683712 Meter/Day T = 40.43646 Meter²/Day



Graph 5.29 Cooper-Jacob's Log-Log Graph for Recuperation Test Carried out at Village Visanvel

5.3.4 Calculation of Recharge Rate, Volume of water Stored & Volume of Water Recharged for Meghal TR

Rainfall, Water-level fluctuation and evaporation rate for every week at Meghal TR was observed for four years and tabulated in table 4.25. Using these data in conjunction with elevation storage data, recharge rate in mm/day is worked out (Table 5.15 to 5.18). From the results obtained, graph of Recharge rate v/s time (5.30) is drawn and Cumulative day's v/s recharge rate graph for each year is plotted on log-log graph (5.31 to 5.34) to get recharge rate equation.

Date	Rainfall mm/ week	Water level RL (m)	Vol. of Water stored (M ³)	Vol. of water Loss (M ³)	Evapo. cm/week	Surface Area (M ²)	Vol. Of Evaporation (M ³)	Vol. Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
3/7/98	750	2.50	6009978	-	-	7566680	-	-	7763081	-
Jul 10	27	2.15	3991715	2018263	3.5	5166207	180817	1837446	5304134	49.488
17	3	2.50	6009978	-	-	7566680	-	-	7763081	-
Nov 20	419	2.50	6009978	-	-	7566680	-	-	7763081	-
Nov 27	Nil	2.25	4568362	1441617	3.4	5852057	198970	1242647	6007054	29.552
Dec 4	Nil	2.05	3415068	1153293	3.3	4480358	147852	1005441	4600924	31.219
Dec 12	Nil	1.87	2629625	785443	3.1	3743410	116046	669397	3845570	21.759
Dec 20	Nil	1.72	2102253	527372	3.1	3288768	101952	425421	3379566	15.735
Dec 27	Nil	1.60	1728551	373702	3.2	2925055	93602	280100	3006558	13.309
3/1/1999	Nil	1.46	1354247	374304	3.3	2465496	81361	292943	2534923	16.509
Jan 10	Nil	1.34	1100000	254247	3.3	1996102	65871	188376	2052818	13.109
Jan 17	Nil	1.22	919200	180800	3.4	1526709	51908	128892	1570474	11.725
Jan 24	Nil	1.10	768934	150266	3.5	1057315	37006	113260	1087897	14.873
Feb 1	Nil	1.01	690567	78367	3.7	705270	26095	52272	725801	10.289
Feb 8	Nil	0.89	619067	71500	3.9	632965	24686	46814	651555	10.264
Feb 15	Nil	0.77	545316	73751	4.0	596760	23870	49881	614438	11.597
Feb 22	Nil	0.64	470259	75057	4.1	557537	22859	52198	574207	12.986
Mar 1	Nil	0.52	405559	64700	4.2	521331	21896	42804	537051	11.386
	1196		145508284	7622682.30			1194791	6427891	Avg =	18.253

Table 5.15: Recharge Rate Calculation for Meghal TR – Year 1998 (Graph 5.30)

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
5/7/00	286	2.50	6009978	-	-	7566680	-	-	7763081	-
Jul 15	180	2.00	3126745	2883233	6.4	4137433	264796	2618437	4249210	61.622
22	3	1.71	2069217	1057528	4.4	3258459	143372	914156	3348490	39.001
29	Nil	1.50	1451235	617982	4.6	2621960	120610	497371	2695574	26.359
Aug 5	Nil	1.34	1100000	351235	4.7	1996102	93817	257418	2052818	17.914
11	Nil	1.20	888000	212000	3.8	1448476	55042	156958	1490065	17.556
13	196	2.50	6009978	-	-	7566680	-	-	7763081	-
20	1	2.25	4568362	1441617	4.1	5852057	205658	1235959	6007054	29.393
27	64	2.06	3472733	1095629	4.2	4548943	191056	904573	4671252	27.664
Sep 3	9	1.88	2667208	805524	4.2	3773719	158496	647028	3876626	23.844
10	Nil	1.70	2036180	631028	4.3	3228149	138810	492218	3317414	21.196
17	Nil	1.54	1559130	477050	4.3	2743198	117958	359093	2819981	18.191
24	Nil	1.38	1179600	379530	4.2	2152567	90408	289122	2213545	18.659
Oct 1	Nil	1.23	934800	244800	4.3	1565825	67330	177470	1610678	15.740
8	Nil	1.08	749777	185023	4.1	979083	40142	144880	1007438	20.544
15	12	0.92	638222	111555	4.1	642017	26323	85233	660831	18.425
22	Nil	0.75	533351	104871	4.0	590726	23629	81242	608250	19.081
29	Nil	0.59	442760	90591	4.0	542451	21698	68893	558727	17.615
Nov 5	Nil	0.44	364789	77971	3.9	497194	19391	58580	512270	16.336
	751		38902065	10767167			1778536	8988631	Aveg.	24.067

Table 5.16: Recharge Rate Calculation for Meghal TR – Year 2000 (Graph 5.30)

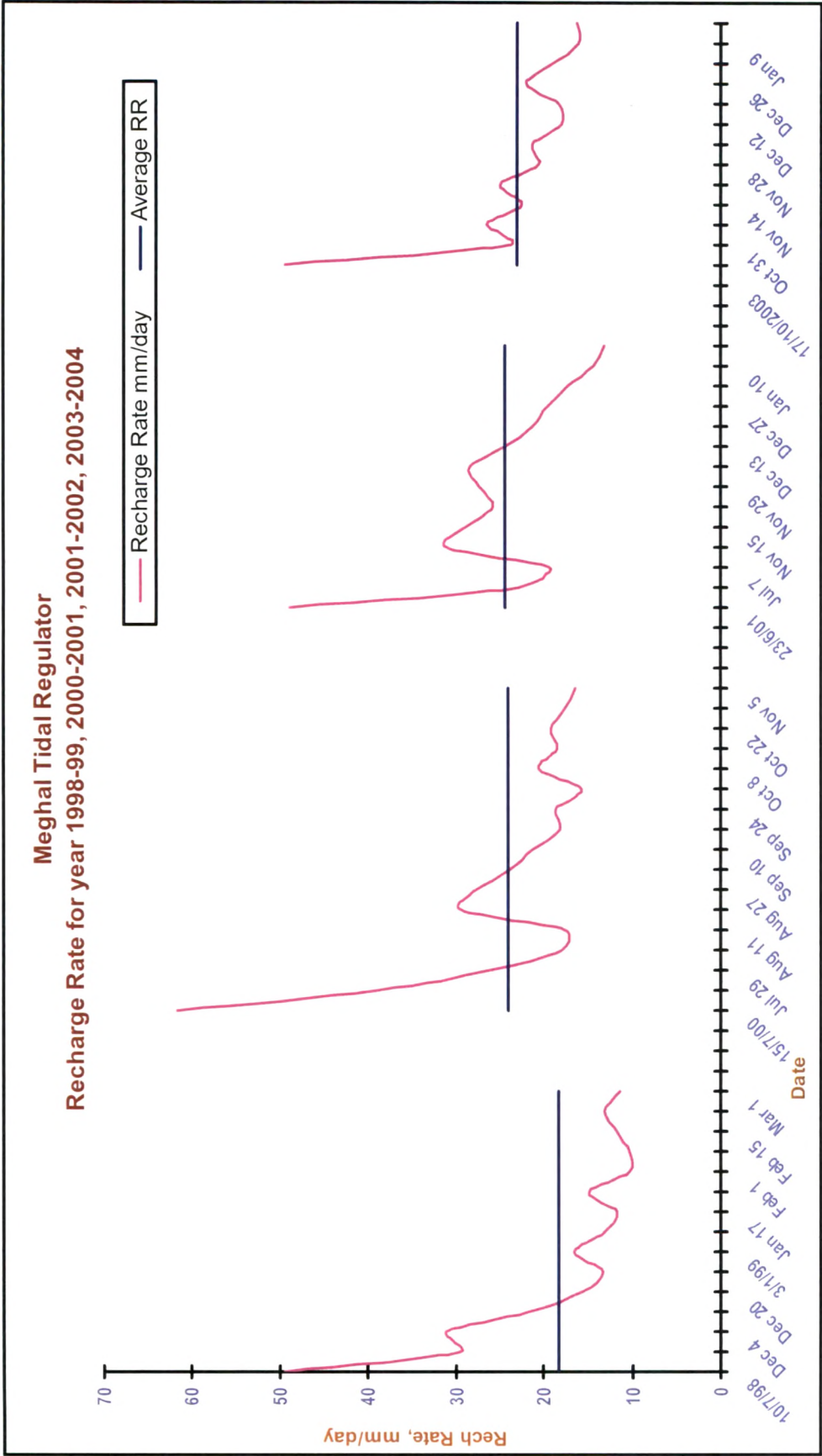
Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
16/6/01	325	2.50	6009978	-	-	7566680	-	-	7763081	-
23	77	2.15	3991715	2018263	4.0	5166207	206648	1811615	5304134	48.793
30	4	2.00	3126745	864970	4.5	4137433	186184	678785	4249210	22.821
Jul 7	114	1.83	2482324	644421	3.9	3622172	141265	503156	3721330	19.316
9	130	2.50	6009978	-	-	7566680	-	-	7763081	-
Nov 1	259	2.50	6009978	-	-	7566680	-	-	7763081	-
8	Nil	2.24	4510697	1499281	3.6	5783472	208205	1291076	5936769	31.067
15.	Nil	2.05	3415068	1095629	3.7	4480358	165773	929855	4600924	28.872
22	Nil	1.86	2592042	823026	3.6	3713101	133672	689354	3814513	25.817
29	Nil	1.65	1878577	713466	3.5	3076602	107681	605785	3162002	27.369
Dec 6	Nil	1.44	1308400	570177	3.4	2387263	81167	489010	2454588	28.460
13	Nil	1.25	966000	342400	3.3	1644057	54254	288146	1691087	24.342
20	Nil	1.10	768934	197066	3.3	1057315	34891	162174	1087897	21.296
27	Nil	0.95	657527	111407	3.1	651068	20183	91224	670107	19.448
03/01/02	Nil	0.80	563264	94264	3.1	605811	18780	75484	623719	17.289
10	Nil	0.67	487150	76113	3.1	566588	17564	58549	583493	14.335
17	Nil	0.55	421243	65907	3.0	530383	15911	49995	546342	13.073
	909		135349291	9116388			1392180	7724209	Aveg.	24.450

Table 5.17: Recharge Rate Calculation for Meghal TR – Year 2001 (Graph 5.30)

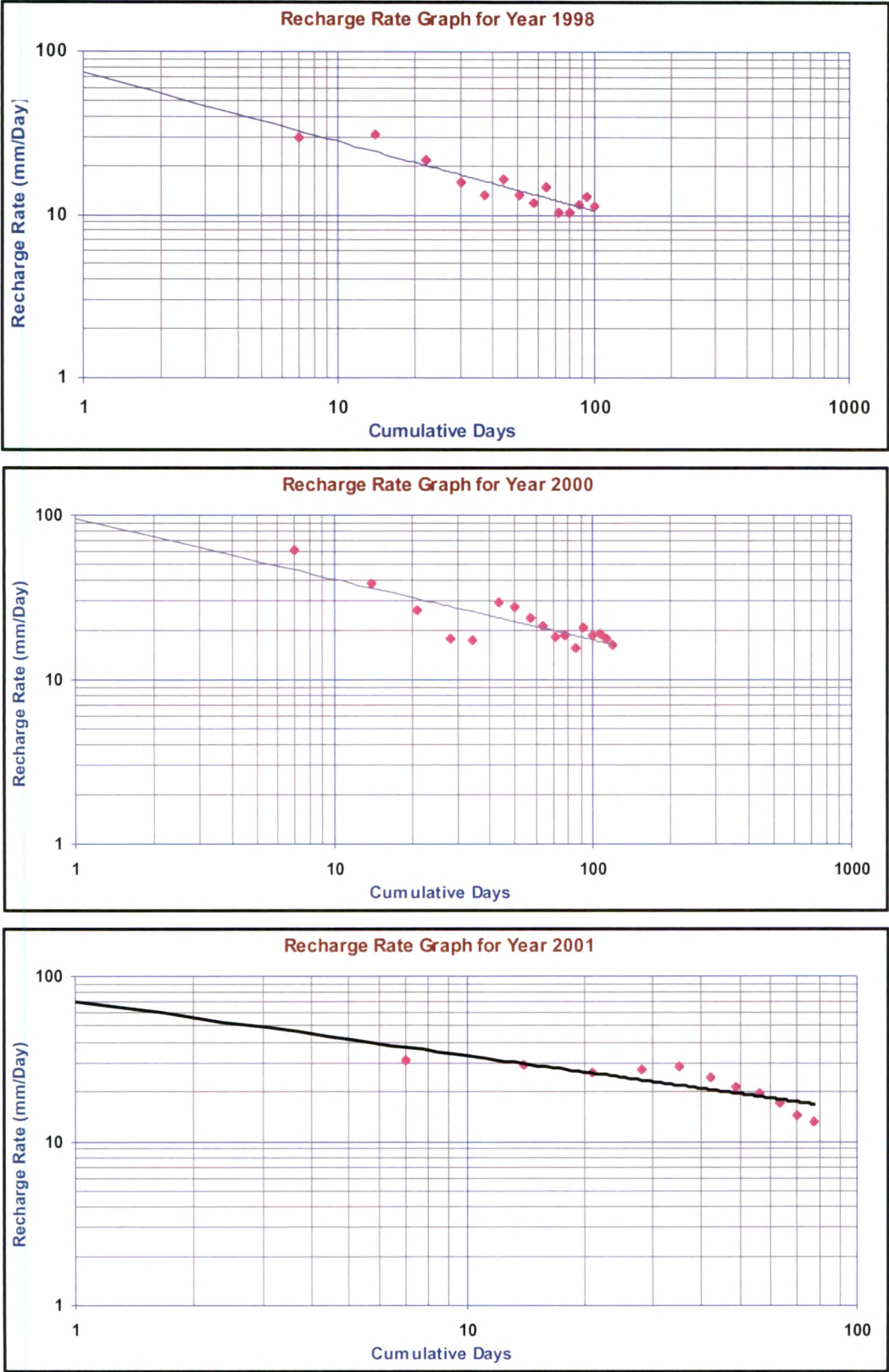
Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
21/07/2003	445	1.20	888000	-	-	1448476	-	-	1490065	-
28	46	0.90	625352	262648	4.8	635983	30527	232121	654647	50.653
Aug 4	13	0.65	475789	149563	4.7	560554	26346	123217	577302	30.491
8	195	2.50	6009978	-	-	7566680	-	-	7763081	-
17/10/03	Nil	2.50	6009978	-	-	7566680	-	-	7763081	-
24	Nil	2.19	3991715	2018263	3.7	5166207	191150	1827113	5304134	49.210
31	Nil	2.00	3126745	864970	3.7	4137433	153085	711885	4249210	23.933
Nov 7	Nil	1.79	2339570	787175	3.5	3500934	122533	664643	3597072	26.396
14	Nil	1.61	1758556	581013	3.5	2955364	103438	477576	3037647	22.460
21	Nil	1.42	1265200	493356	3.4	2309031	78507	414849	2374246	24.961
28	Nil	1.25	966000	299200	3.4	1644057	55898	243302	1691087	20.553
Dec 5	Nil	1.10	768934	197066	3.3	1057315	34891	162174	1087897	21.296
12	Nil	0.96	662612	106323	3.3	654085	21585	84738	673198	17.982
19	Nil	0.80	563264	99348	3.2	605811	19386	79962	623719	18.315
26	Nil	0.62	459199	104065	3.1	551503	17097	86968	568015	21.873
02/01/2004	Nil	0.46	374793	84406	3.1	503228	15600	68806	518466	18.959
9	Nil	0.32	307331	67462	3.1	460988	14291	53172	475084	15.989
16	Nil	0.18	245752	61579	3.0	418749	12562	49016	431677	16.221
	866		84928568	6176437			896895	5279542	Aveg.	22.93

Table 5.18: Recharge Rate Calculation for Meghal TR – Year 2003 (Graph 5.30)

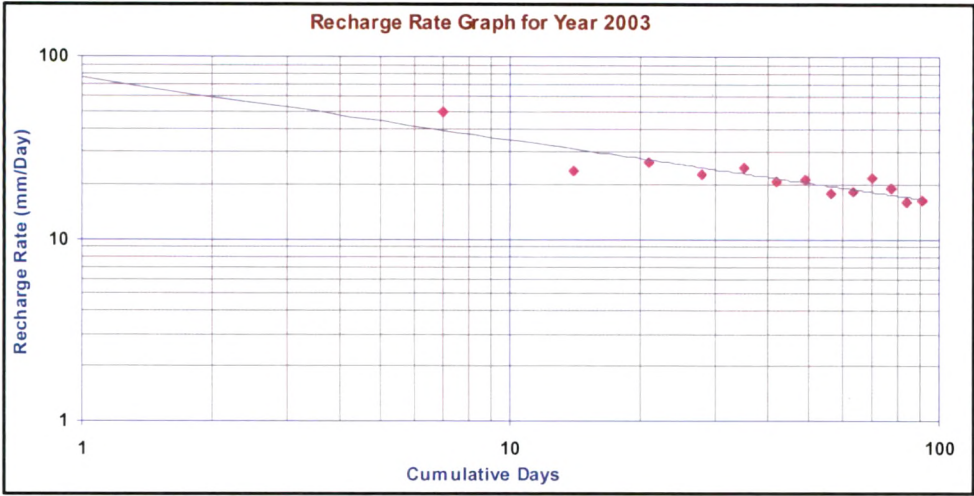
5.3.4.1 Recharge Rate Graphs and Equations for Meghal TR



Graph 5.30: Recharge Rate Graph for Meghal Tidal Regulator (Table 5.15 to 5.18)



Graph 5.31 to 5.33: Log-Log Graph for Recharge Rate v/s Cumulative Days for Meghal TR – Year 1998, 2000 & 2001



Graph 5.34: Log-Log Graph for Recharge Rate v/s Cumulative Days for Meghal TR – Year 2003

General equation for recharge rate is $I = \alpha T^\beta$

Recharge rate Formula for Meghal Tidal Regulator

Year	Intercept on Y axis (Rech. Rate)	Slope of graph
	α	β
1998	74.317	-0.4235
2000	95.194	-0.3685
2001	70.835	-0.3304
2003	76.315	-0.3389
Average	79.165	-0.3653

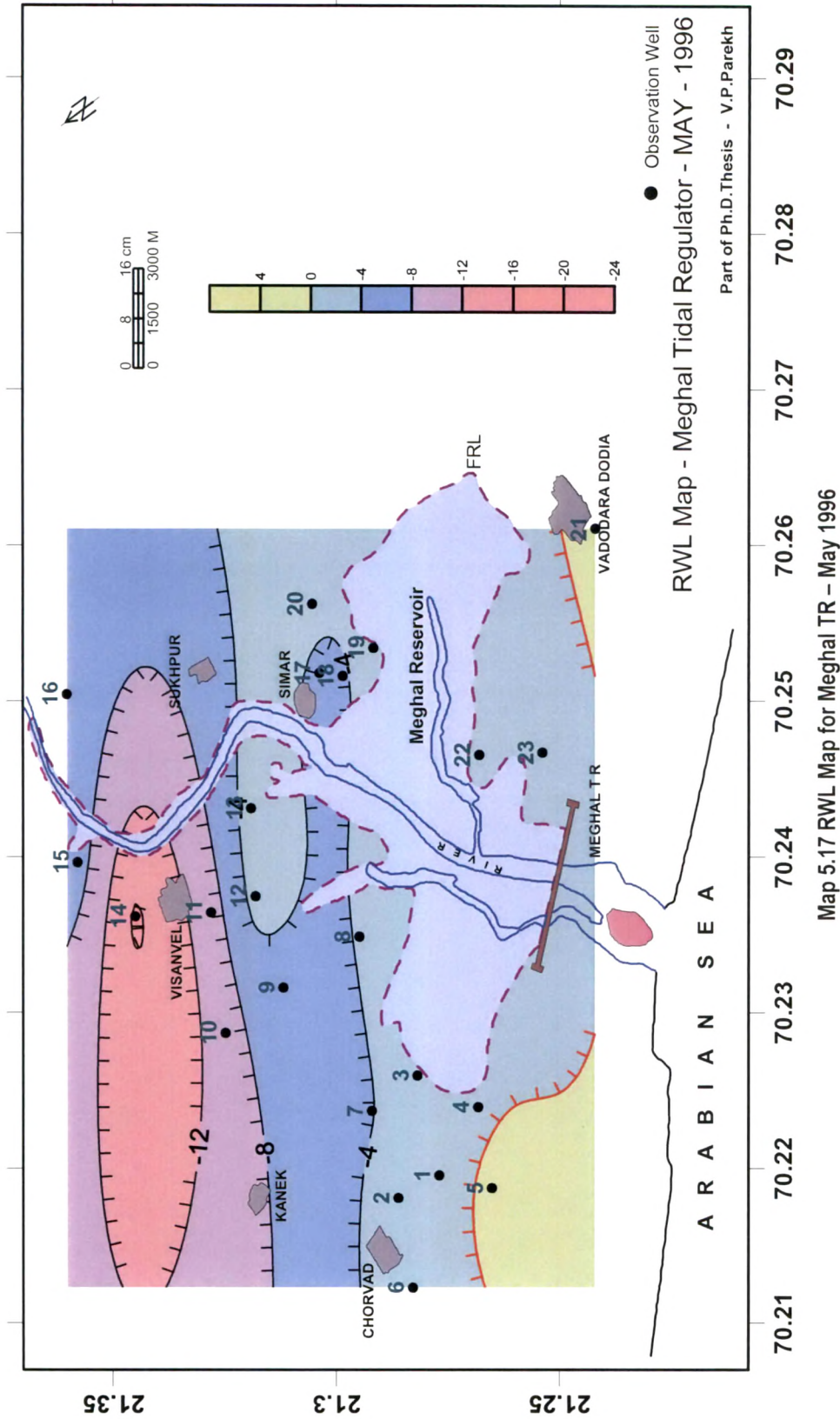
Table 5.19: Recharge Rate Equation for Meghal TR

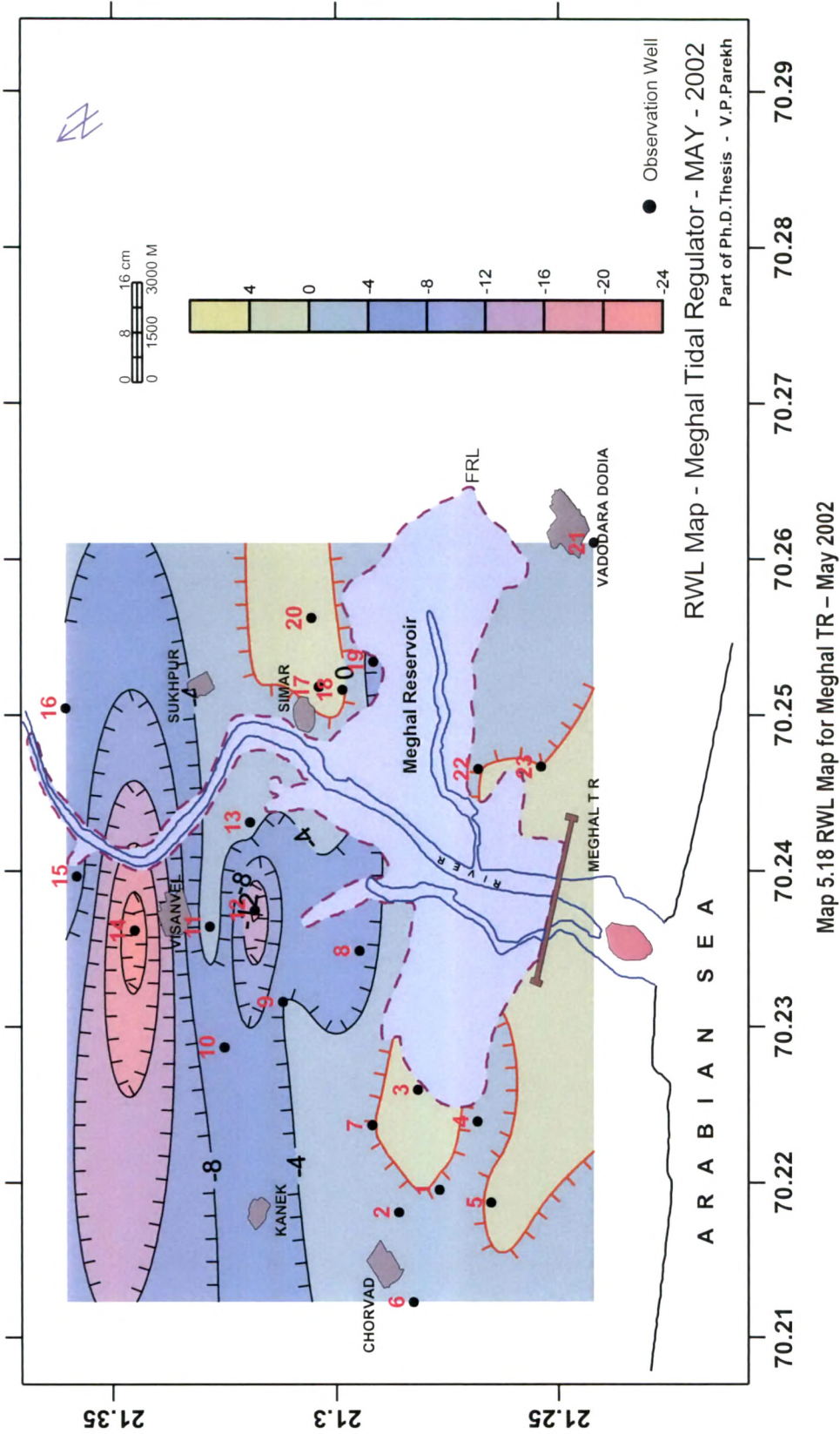
So Recharge Rate Equation, $I = 79.165 T^{-0.3653}$

Where I = Recharge Rate mm/Day
 T = Time in Days

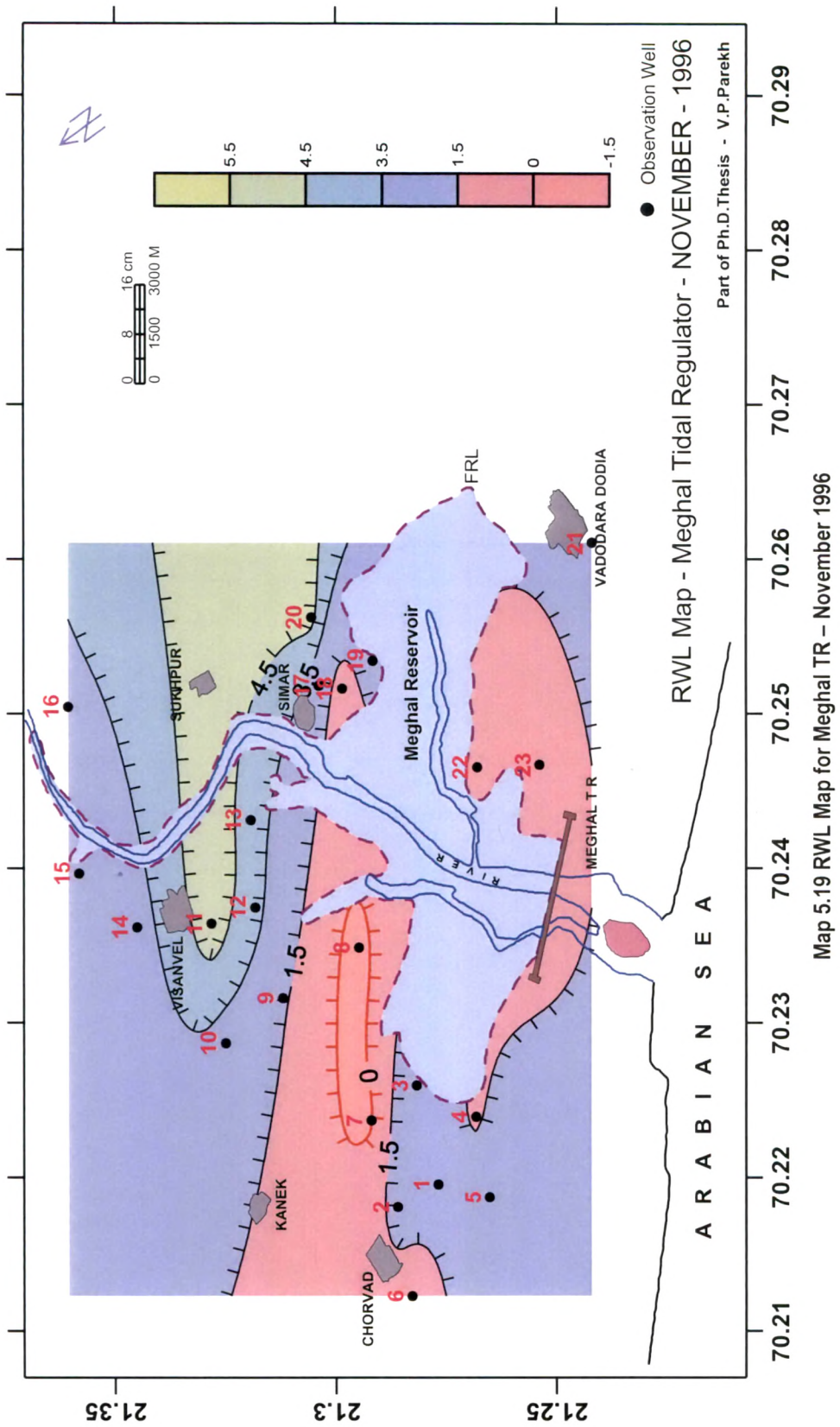
5.3.5 Geohydrological & Geochemical Analysis for Meghal TR

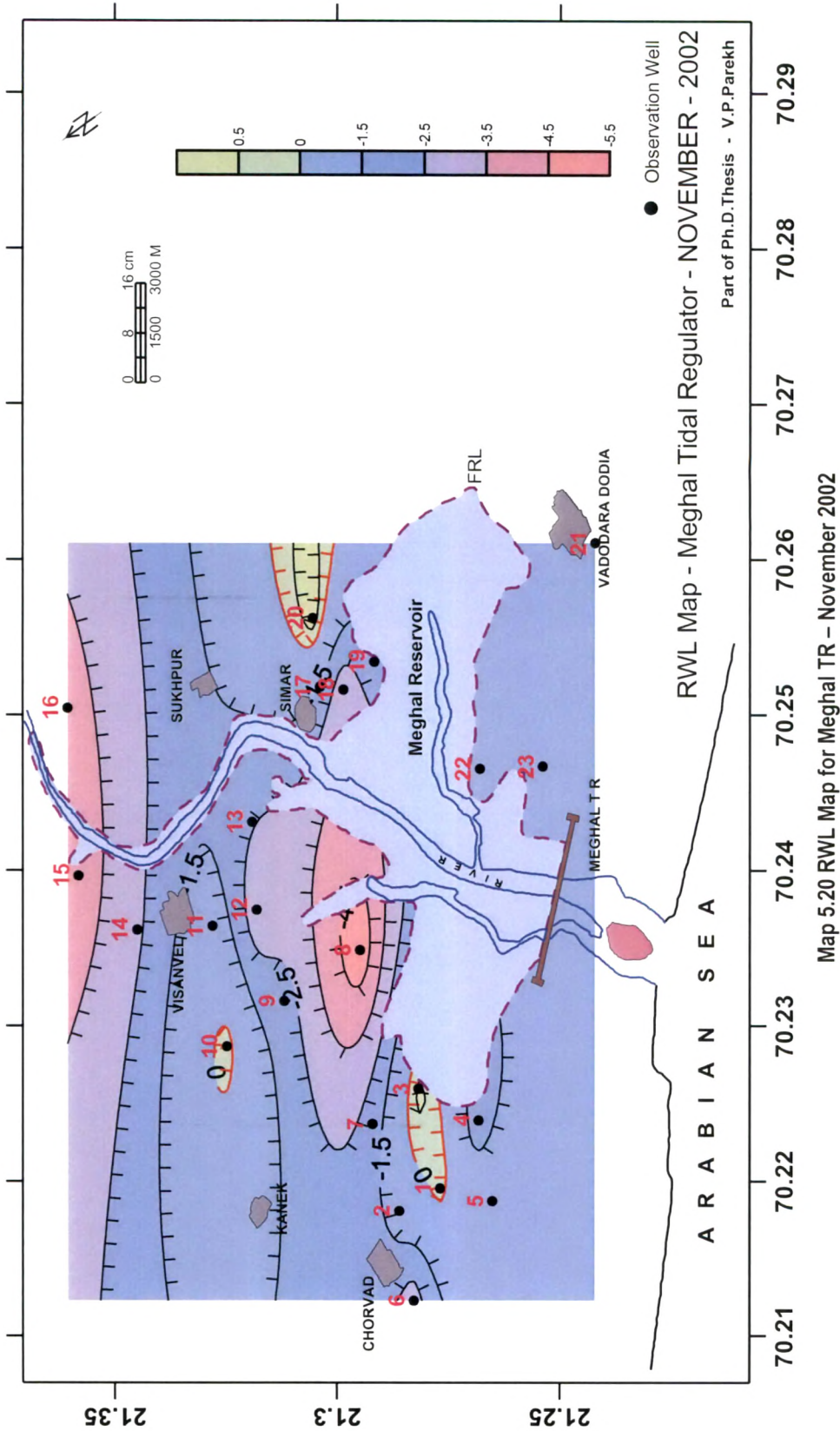
From the Geohydrological data collected from 23 wells surrounding the Mehal TR, RWL maps (Map 5.17 to 5.20) are plotted to study the pre-monsoon & post-monsoon groundwater flow pattern. Similarly from analyzed geochemical parameters IsoChlor Map 5.21 to 5.24 and IsoTDS Map 5.25 to 5.26 are prepared to study the variation of chloride and TDS in the study area. To study about fresh seawater intrusion or any leaching process in recent years ion ratio maps of Na^+/Cl^- (Map 5.27 to 5.29); $(Mg^{+}+Ca^{+})/Cl^-$ (Map 5.30 to 5.33); and $Cl^-/(CO_3^- + HCO_3^-)$ Map 5.34 to 5.35 are plotted. A section passing through the wells 06, 02, 07, 09, 10, 11, 14 and 16 is plotted in map 5.36 to locate zone of transition between freshwater and saline water.

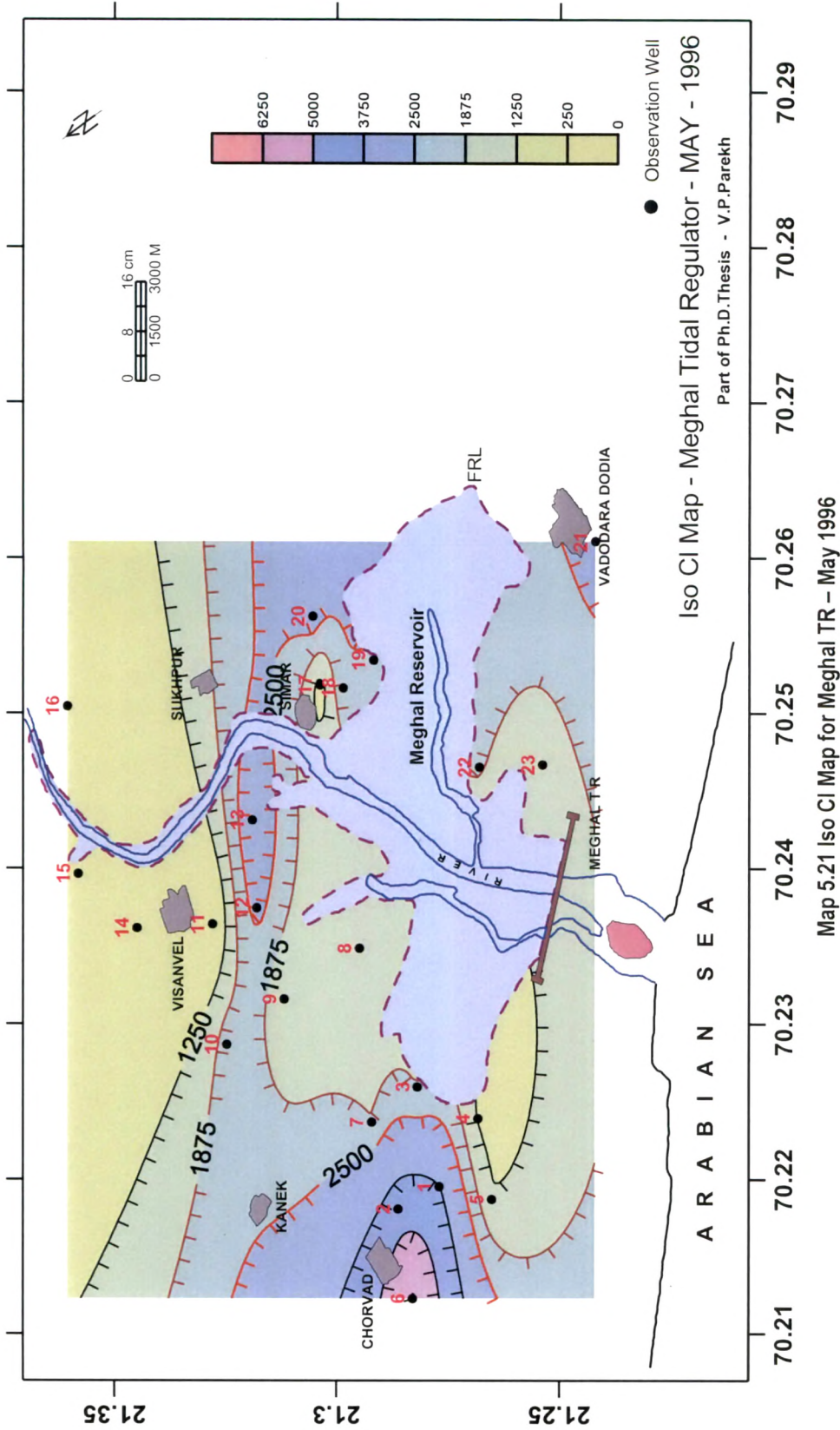


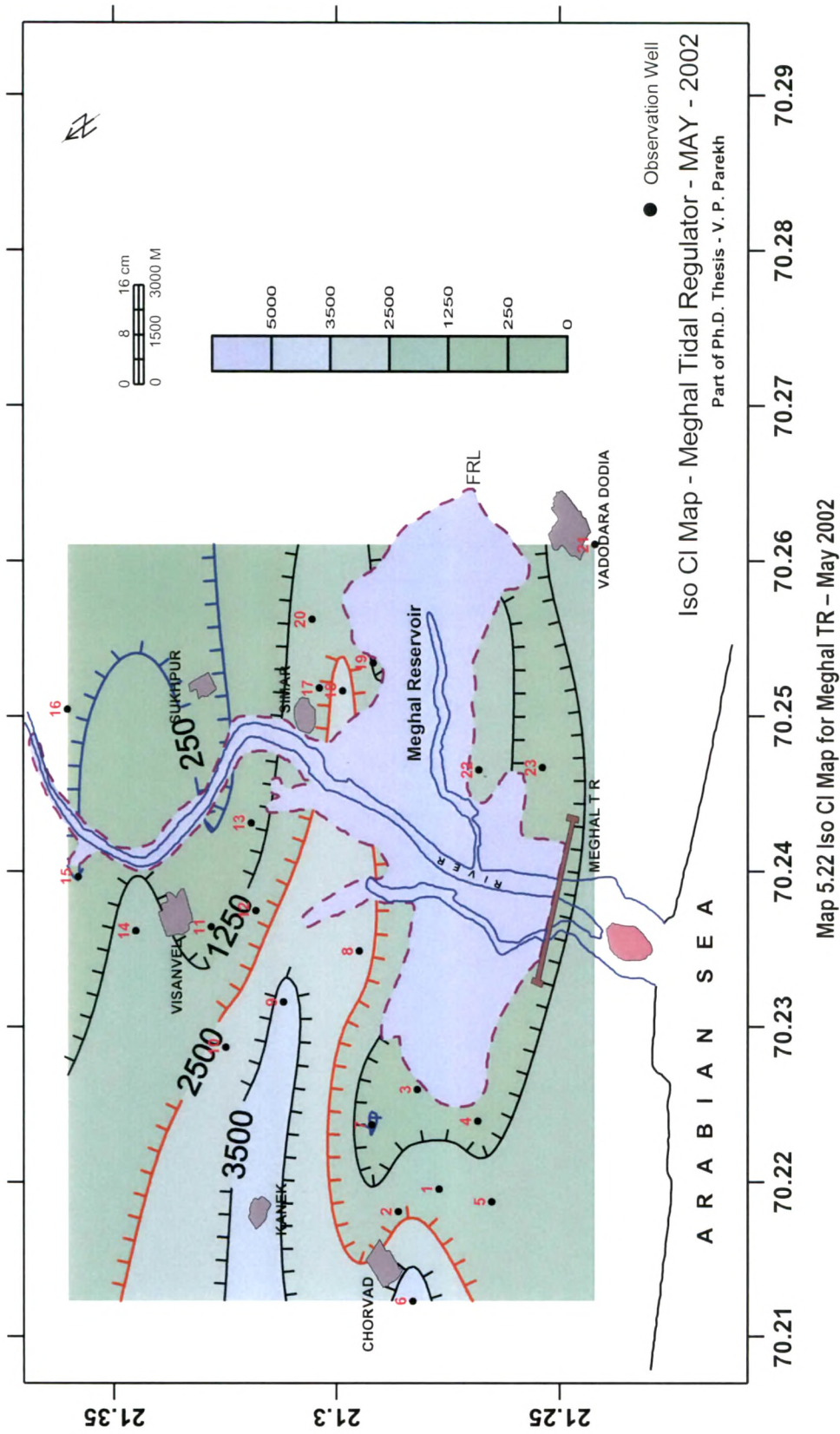


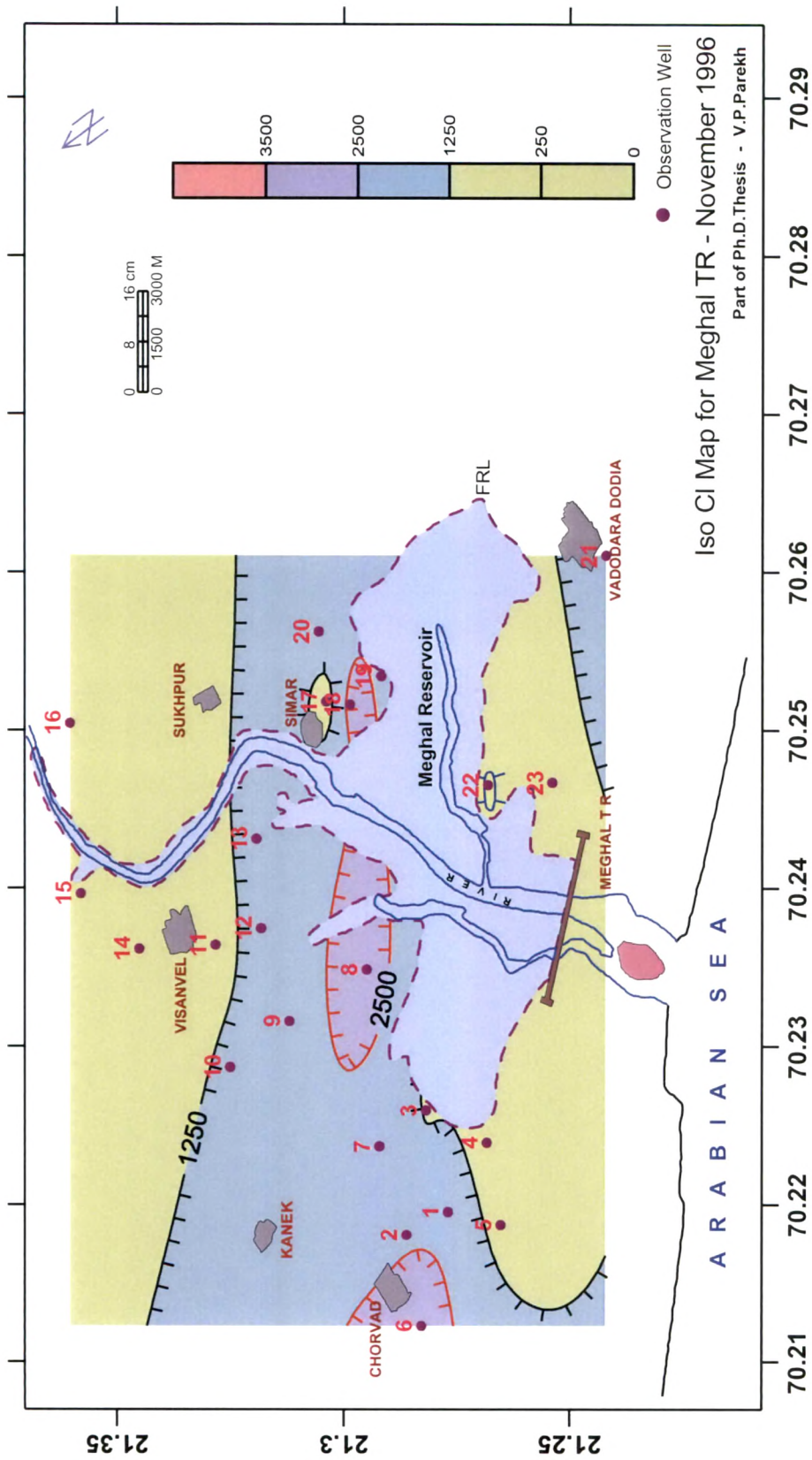
Map 5.18 RWL Map for Meghal TR – May 2002



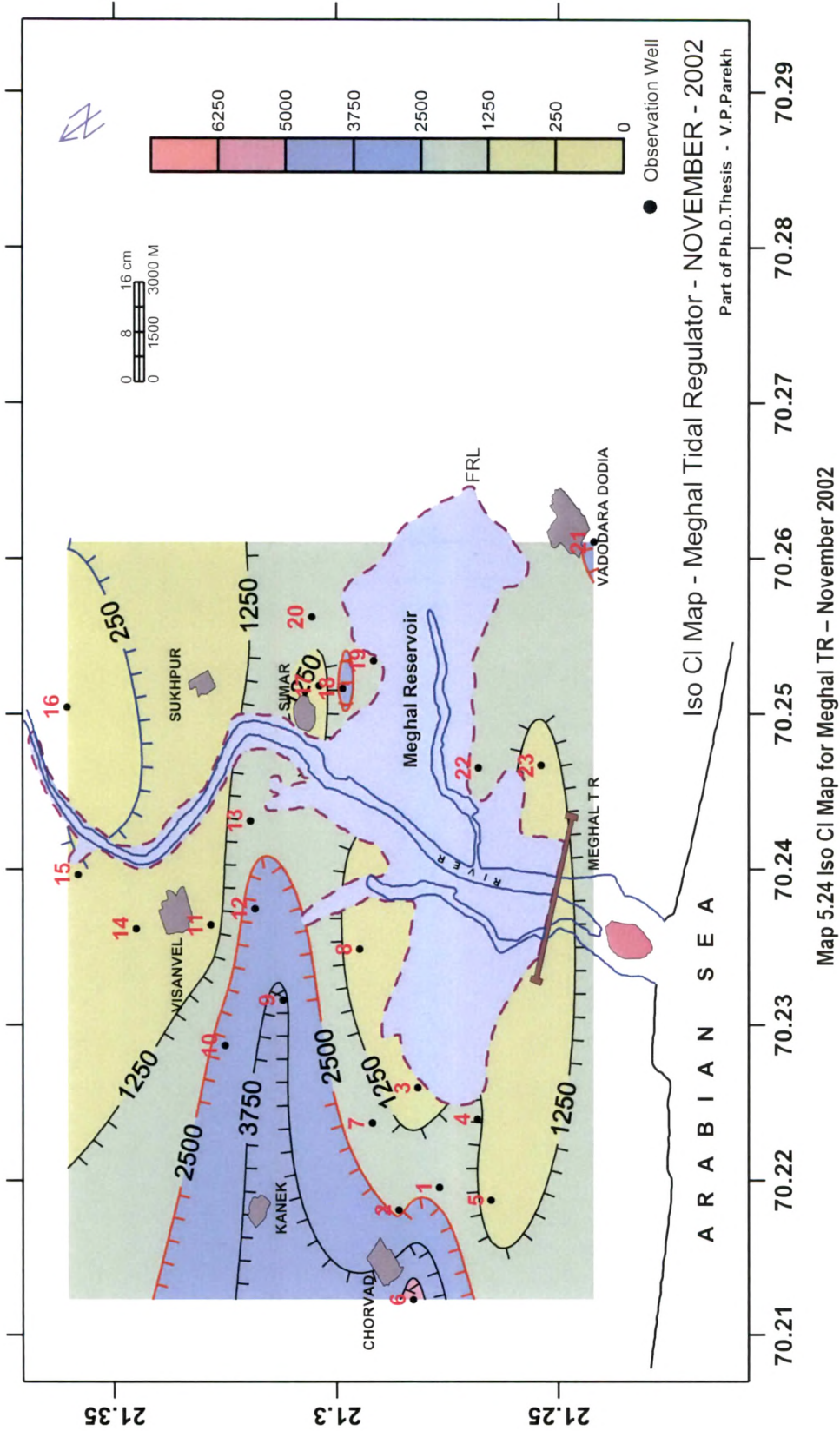


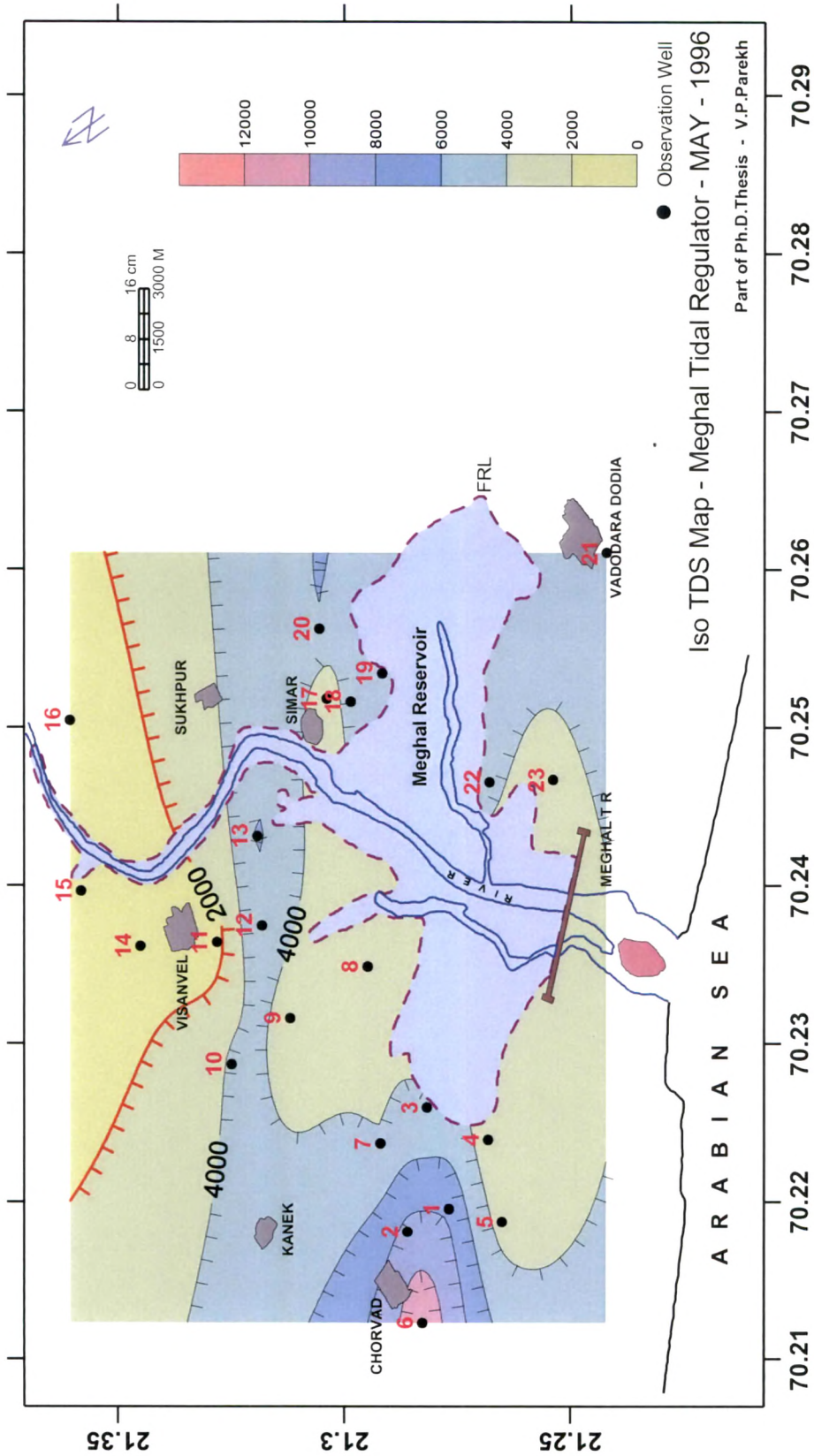




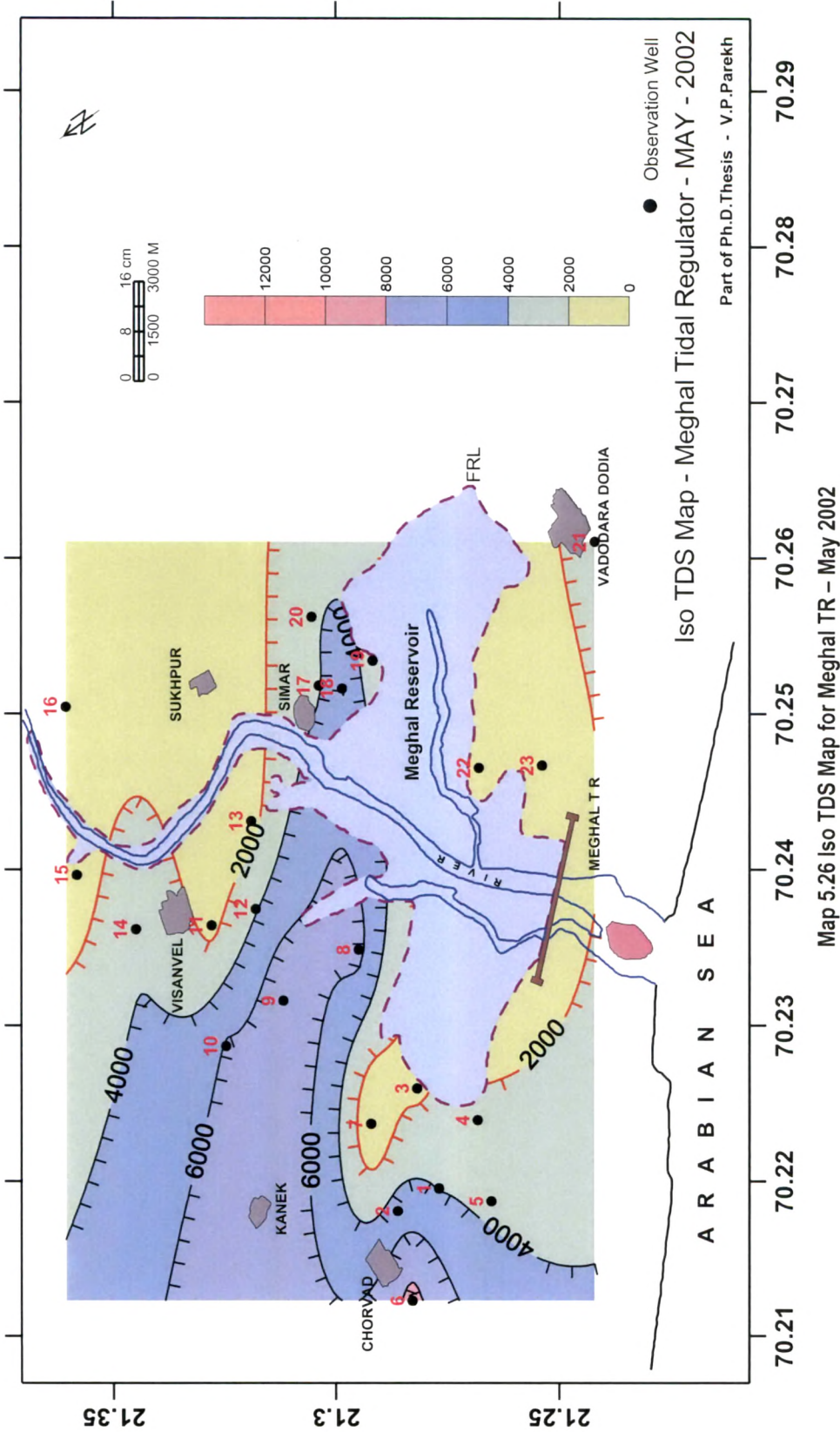


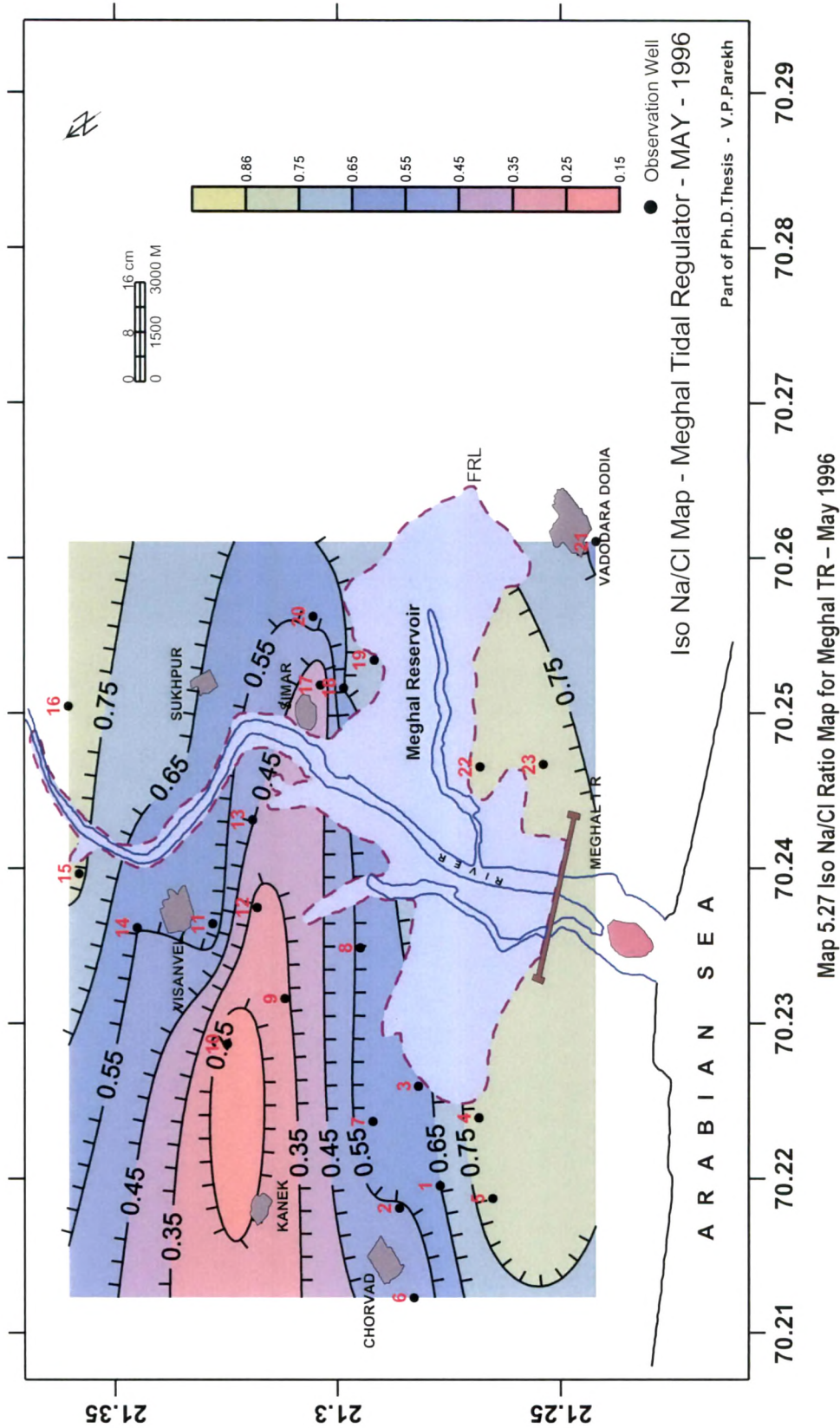
Map 5.23 Iso CI Map for Meghal TR – November 1996

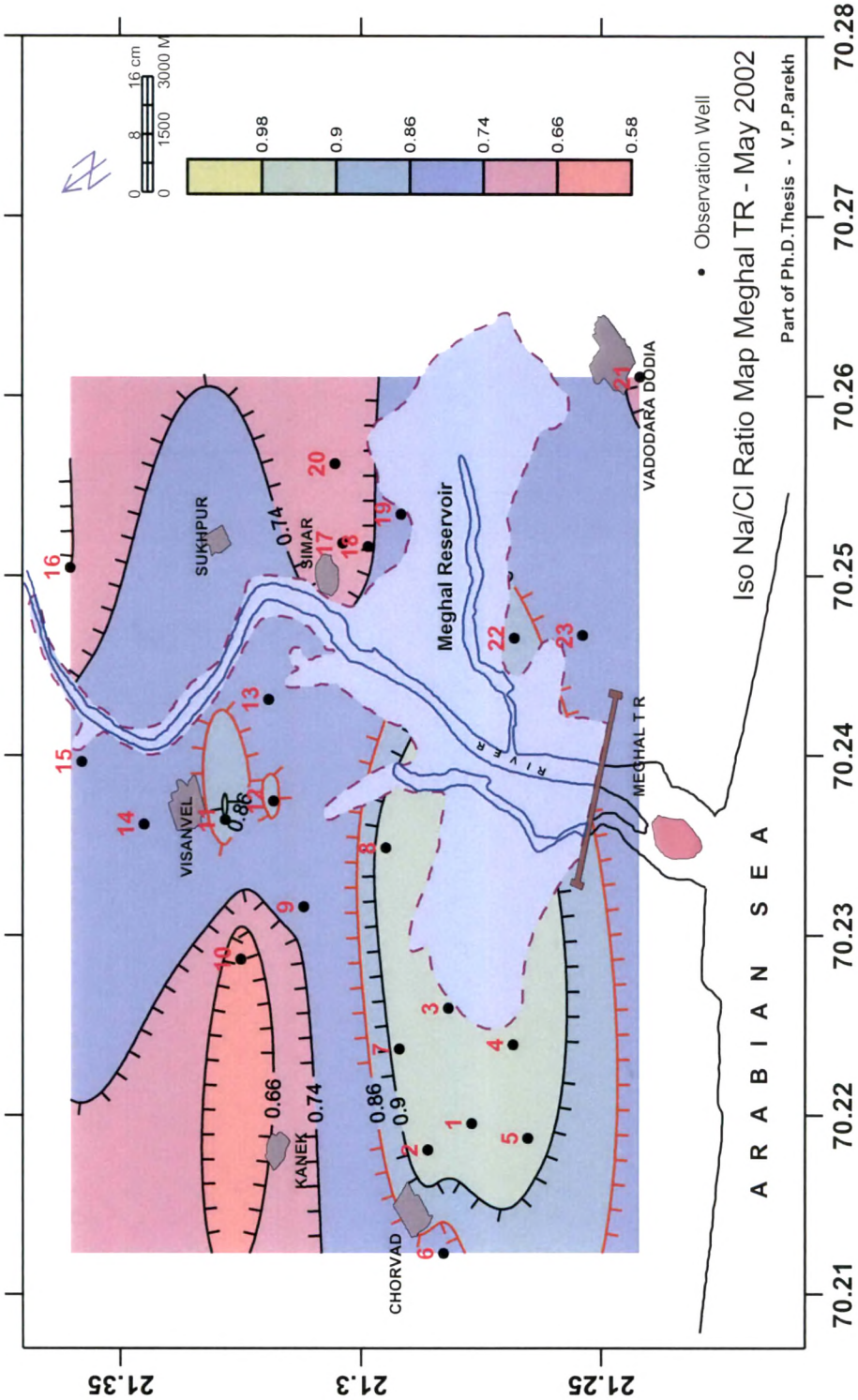




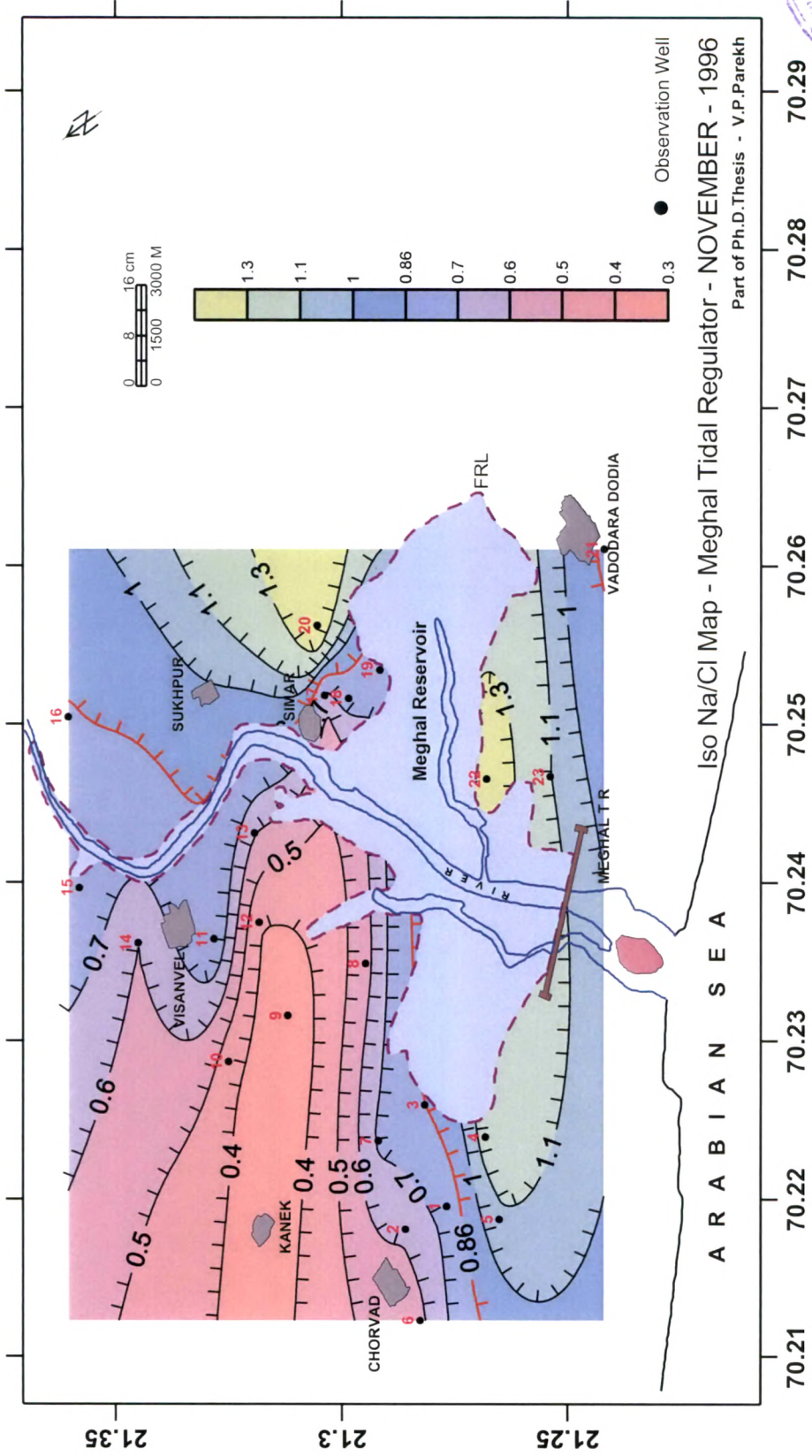
Map 5.25 Iso TDS Map for Meghal TR – May 1996



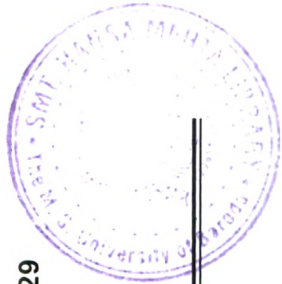


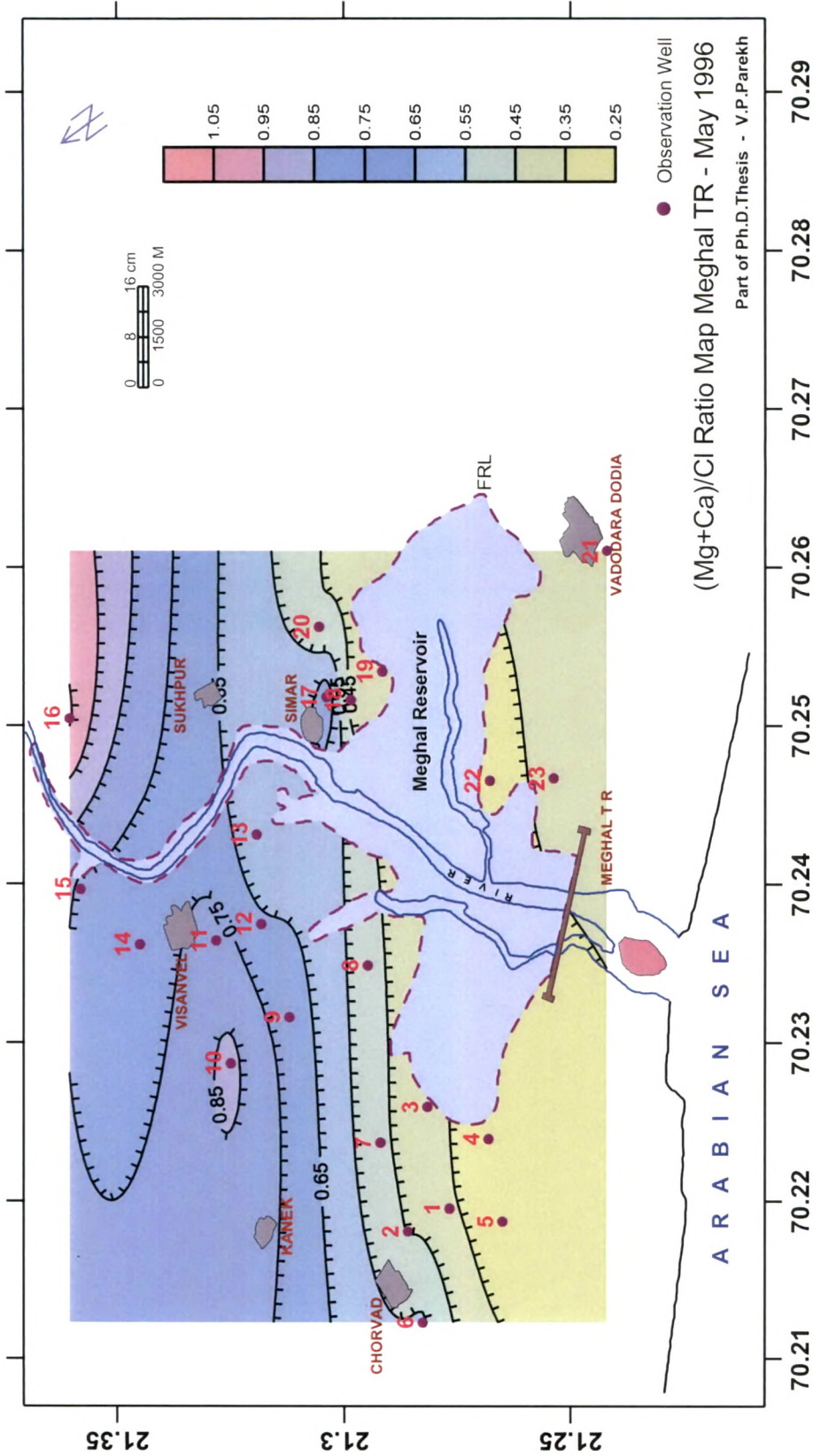


Map 5.28 Iso Na/Cl Ratio Map for Meghal TR - May 2002

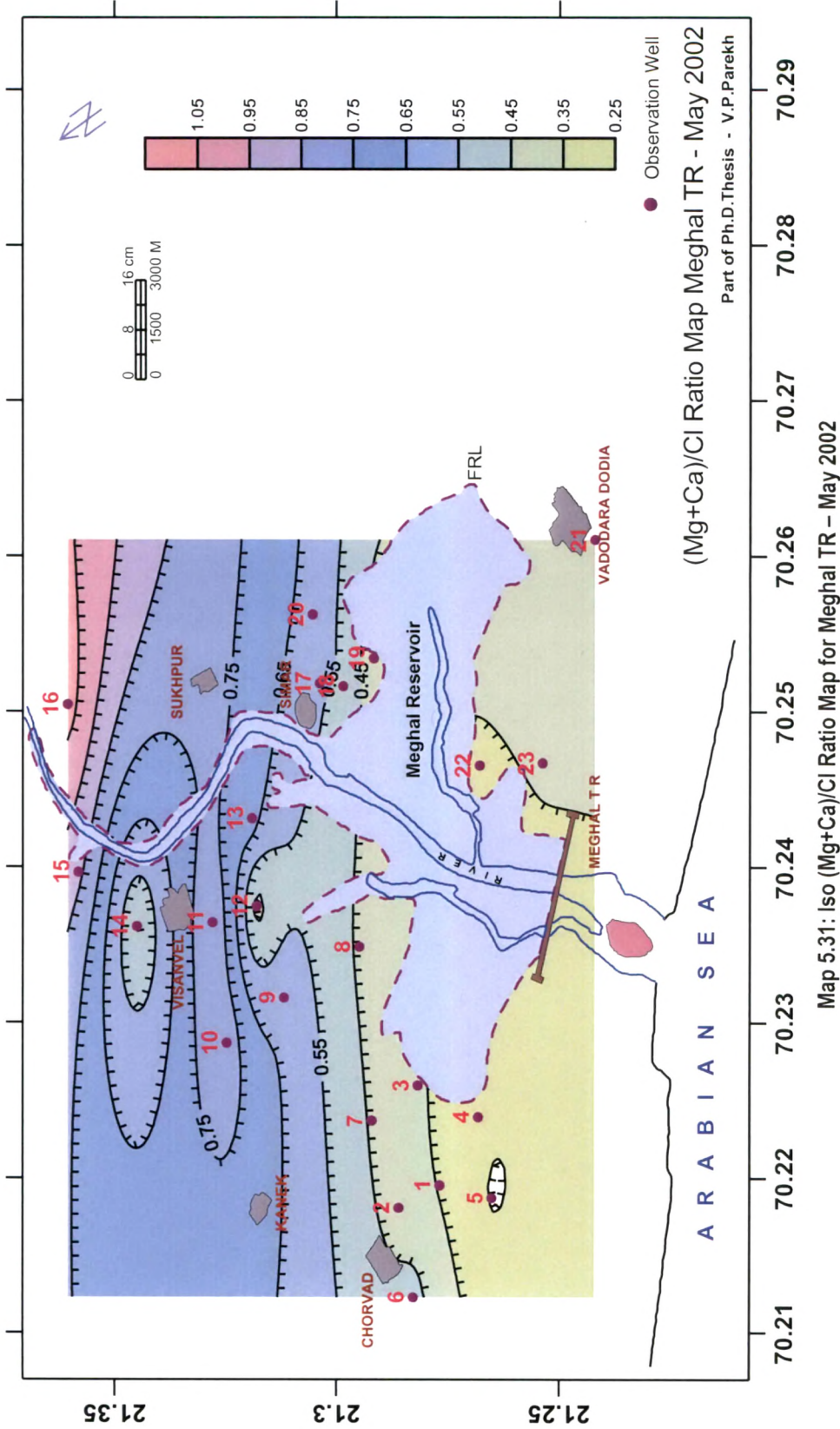


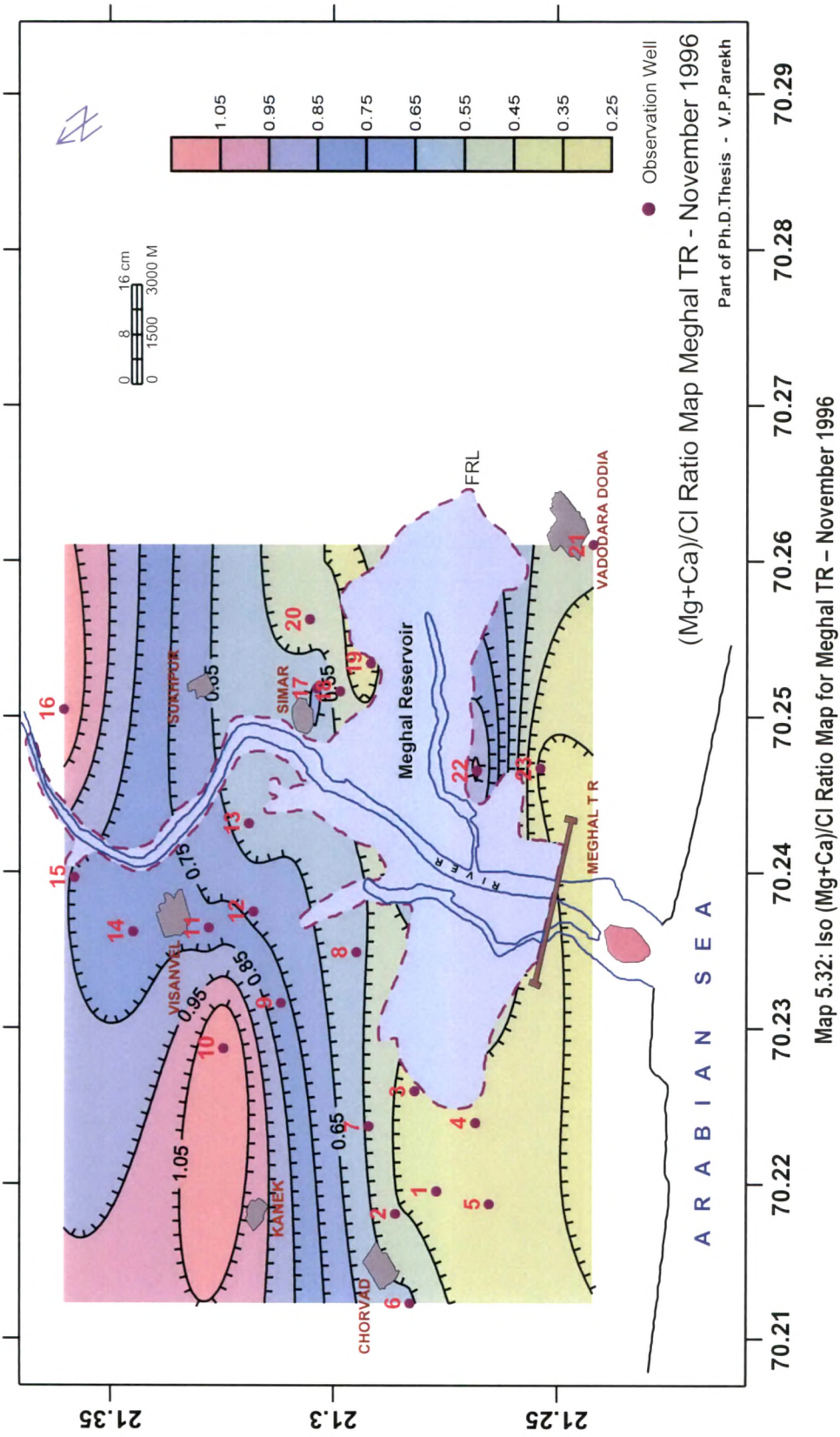
Map 5.29: Iso Na/Cl Ratio Map for Meghal TR – November 1996

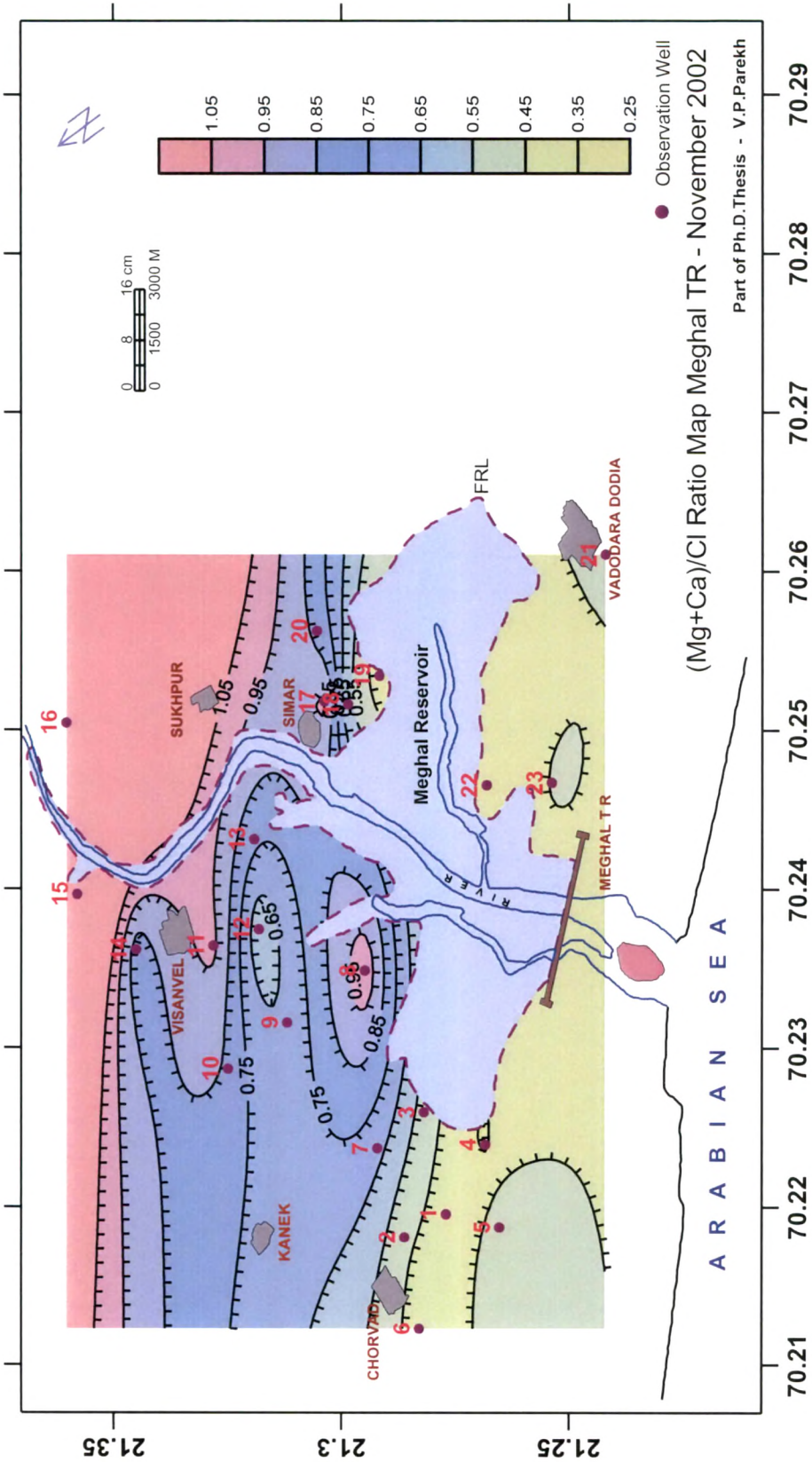




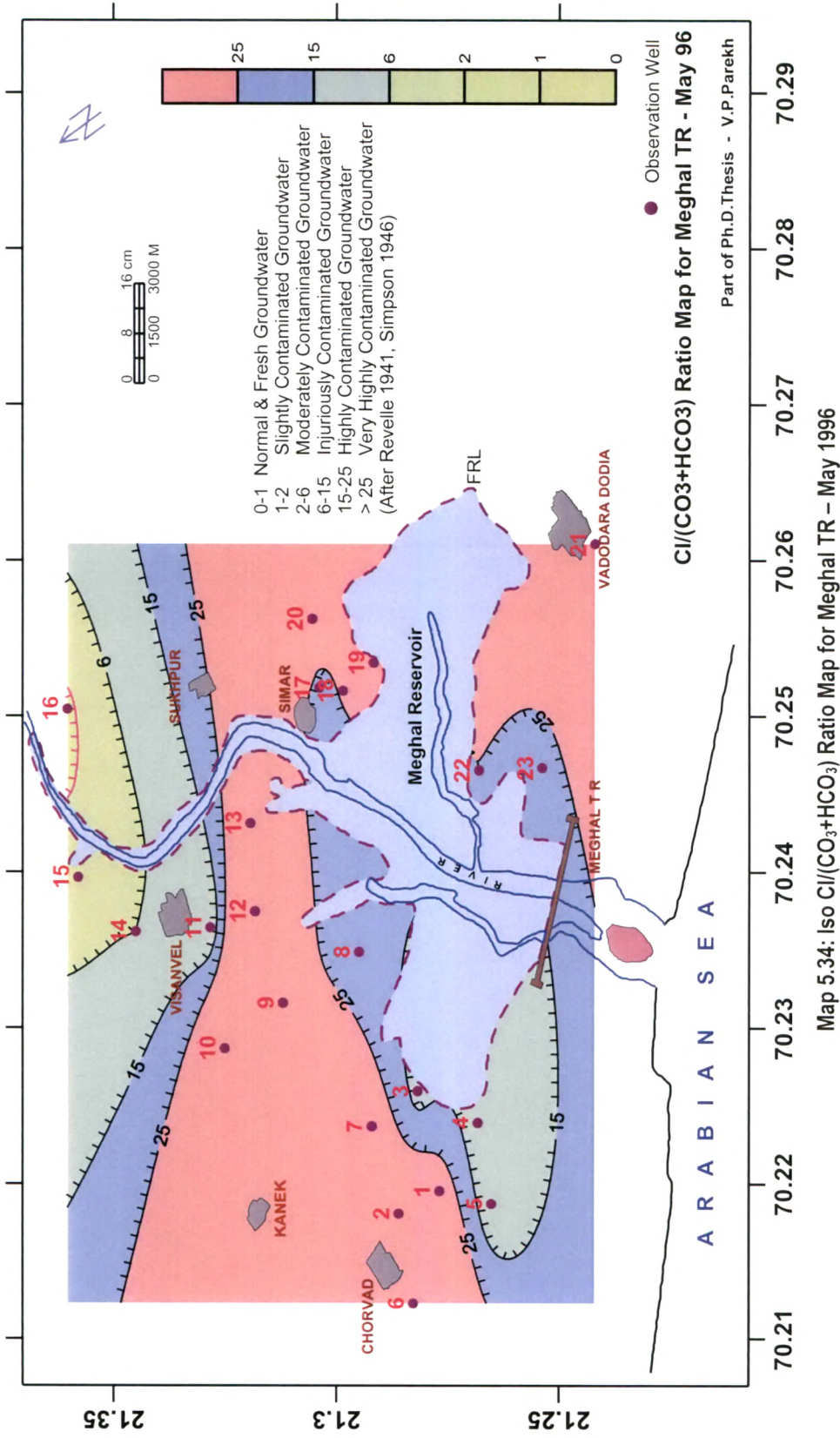
Map 5.30: Iso (Mg+Ca)/Cl Ratio Map for Meghal TR - May 1996



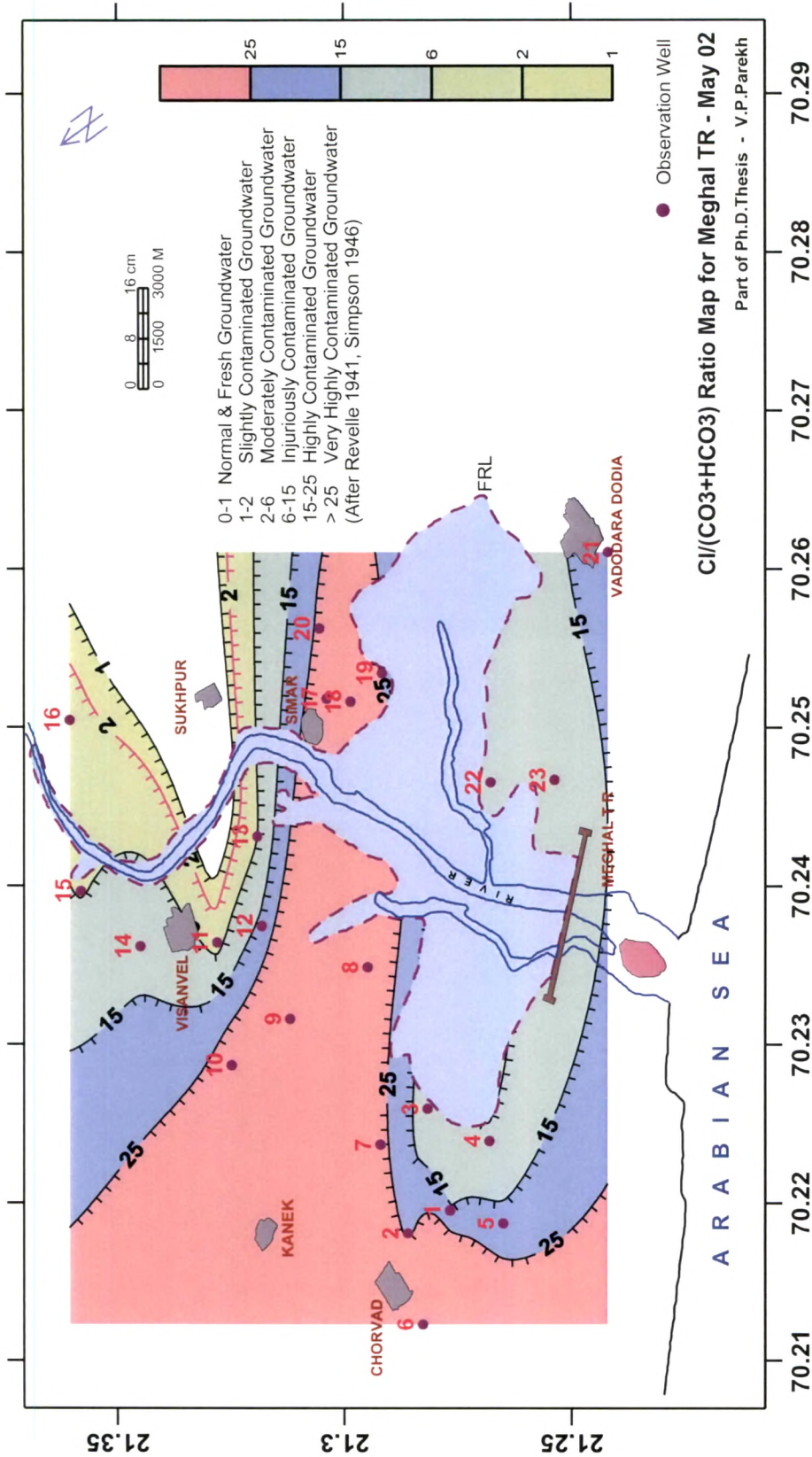




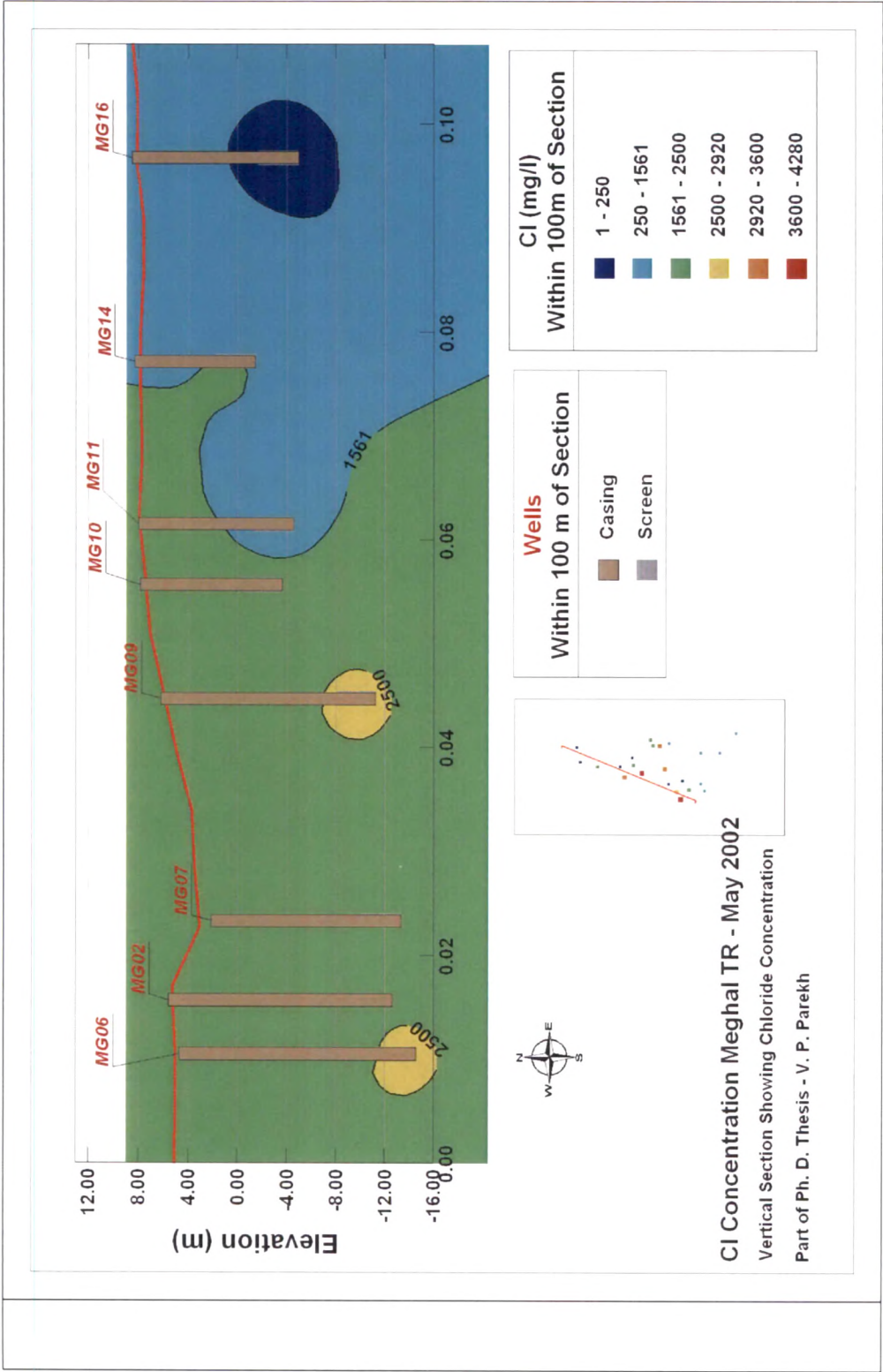
Map 5.33 Iso (Mg+Ca)/Cl Ratio Map for Meghal TR - November 2002



Map 5.34: Iso CI/(CO₃+HCO₃) Ratio Map for Meghal TR - May 1996



Map 5.35: Iso Cl/(CO₃+HCO₃) Ratio Map for Meghal TR – May 2002



Map 5.36: Section Showing Cl- Concentration at Meghal TR for May 2002

5.3.6 Interpretation of Geohydrological & Geochemical Maps for Meghal TR

5.3.6.1 Water Levels (Map 5.17 to 5.20)

Total rainfall of year 1995 was 546 mm and 2001 was 909 mm. The rock formation below the foundation of the structure is Miliolite Limestone. The Miliolite Limestone is cavernous and pervious in nature. The thickness of this formation is 25m near the coast and 2m inland. From Pumping test permeability of the Gaj Limestone in this area found to be 3.1856 m/day.

Map 5.17, RWL for the May 1996, water level is found below MSL in the range of 0 to (-12) m. that means there is a flow from sea to inland or reverse hydraulic gradient condition exists. Major decline is observed near the village Kanek and Visanvel which falls under the Gaj Limestone geology. These villages were famous for their Coconut productions before the intrusion of seawater. As compared to 1995 monsoon, 2001 monsoon was very good and rainfall was also 14% above normal. RWL map of the year May 2002 Map 5.18 is almost of the same pattern in general. In the year 2002 situation is more deteriorating. There is centralized pumping (too high than other wells) observed surrounding the wells 12 and 14. RWL in the area goes 17 m below MSL near the village Visanvel. In Post monsoon maps 5.19 & 5.20 this well shows quite good improvement. The RWL of this well in November 2002 was found to be (-2.5 m) as compared to pre-monsoon observation May 2002. (-23.89m) which indicates an improvement of about 21.40 m. It shows this well recharge and discharge at very fast rate.

5.3.6.2 Water Quality

Chloride (Map 5.21 to 5.24)

Isochlor map of Meghal TR for the season May 1996 shows chloride content more than 2500 mg/l on both the sides of TR. While the water quality in the area surrounding the village Visanvel is better as compare to coast. Well no. 14 which shows very low RWL in May 1996 is having reasonable good water quality. The area nearer to coast shows very high chloride content. Particularly from left region of the structure intrusion takes place i.e. from Chorvad village side. This is also visualizing in May 2002 map. May 2002 season shows improvement in water quality as far as chloride in concerned. Area near the right bank of the TR is quite improving. Moreover water quality inland the coast neat well 15 and 16 is also improving and goes below 250 mg/l. In November 2002 also same pattern is observed.

Also the same pattern is observed in Iso TDS and Sodium to Chloride ratio maps. Generally, where the SIP structure is located, seawater is not invading the freshwater aquifer. But here for this case on the left bank region the seawater intrusion is taking place through the cavernous Miliolite Limestone geology. This

can be stopped by construction of subsurface barrier parallel to coast so that seawater can not intrude the freshwater aquifer.

From Iso TDS map (5.25 & 5.26) it is observed that 2000 mg/l TDS line is around well no 13 which located at a distance of 1300 m from the MEGHAL TR. It indicates that beyond well no.13 some freshwater zone starts or it indicates limit of seawater intrusion inland. This is also revealed in subsequent analysis.

Ion Ratios

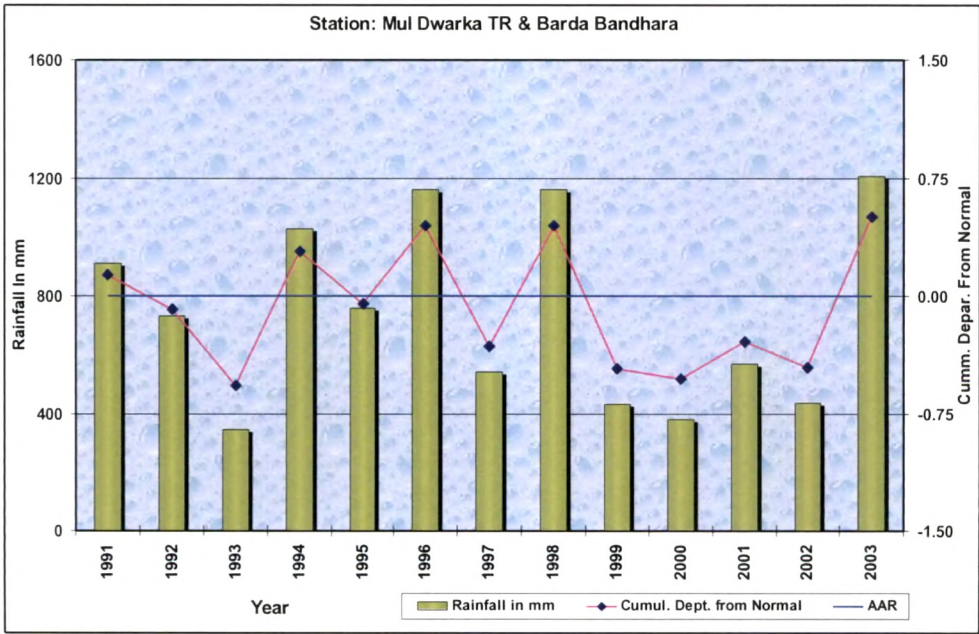
Map 5.34 to 5.35 shows the chloride-to-carbonate & bicarbonate molar ratio across the Meghal TR area. A significant in the ratio occurs in 2002 on the upper reaches of the area near the wells 15 and 16. In these maps also high chloride to carbonate & bicarbonate ratio observed on left region near village Chorvad.

Zone of Transition: The entire Meghal TR area is falling in this zone for the season May 2002. This zone extends upto well no 16 which is located at a distance of 2.15 km from structure. (Map 5.36).

5.4 Analysis of Mul Dwarka TR

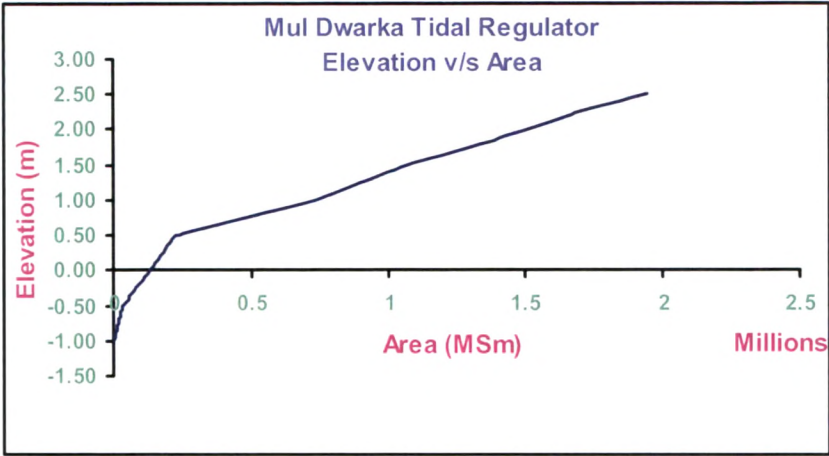
5.4.1 Analysis of Rainfall in Mul Dwarka TR area

Rainfall data from 1991 to 2003 is collected (table 4.28) and a graph 5.35 showing relationship between Rainfall, Cumulative departure from normal and Average Rainfall is plotted.

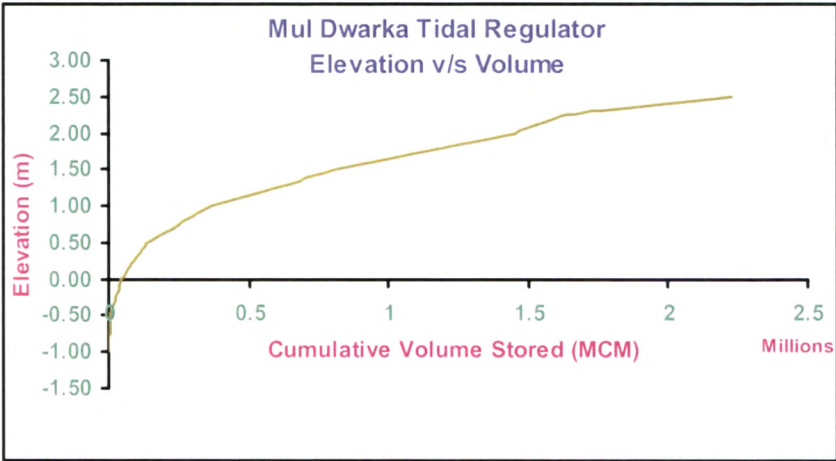


Graph 5.35: Graph Showing Rainfall, Departure from Normal rainfall & Avg. Annual Rainfall

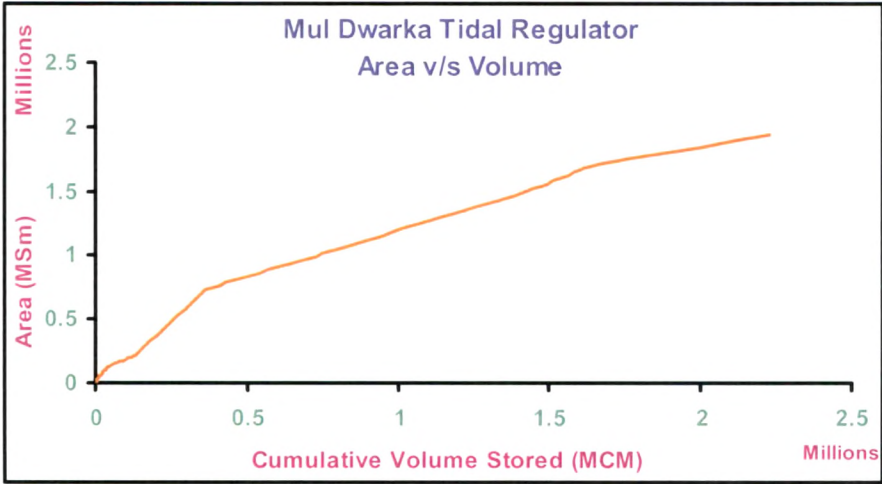
5.4.2 Graphs Showing Relation between Elevation, Area and Cumulative Volume Stored for Mul Dwarka TR



Graph 5.36: Relation between Elevation v/s Area for Mul Dwarka TR (Table 4.30)



Graph 5.37: Relation between Elevation v/s Volume for Mul Dwarka TR (Table 4.30)



Graph 5.38: Relation between Area v/s Volume for Mul Dwarka TR (Table 4.30)

5.4.3 Analysis of Pumping Test at Village Math

Pumping test for a well situated in village Math was carried out and aquifer parameters like Permeability (K), Transmissibility (T) has been calculated.

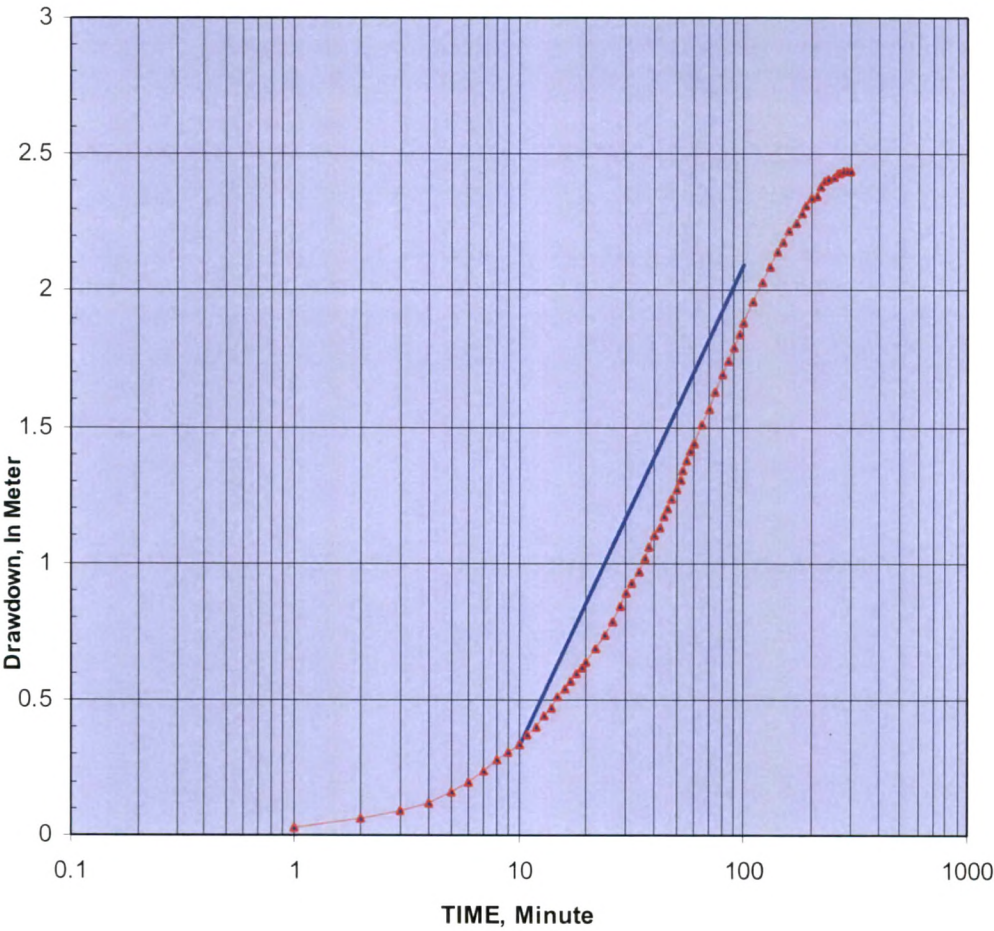
5.4.3.1 Time – Drawdown Analysis

Refer Graph 5.39

Sr. No.	Time Hr:Min	Water Level (m)	Drawdown (m)	Sr. No.	Time Hr:Min	Water Level (m)	Drawdown (m)
1	9:00	3.90	0.000	33	9:50	5.17	1.270
2	9:01	3.93	0.030	34	9:52	5.21	1.310
3	9:02	3.96	0.060	35	9:54	5.24	1.340
4	9:03	3.99	0.090	36	9:56	5.28	1.380
5	9:04	4.02	0.120	37	9:58	5.31	1.410
6	9:05	4.06	0.160	38	10:00	5.34	1.440
7	9:06	4.10	0.200	39	10:05	5.41	1.510
8	9:07	4.14	0.240	40	10:10	5.47	1.570
9	9:08	4.18	0.280	41	10:15	5.53	1.630
10	9:09	4.21	0.310	42	10:20	5.59	1.690
11	9:10	4.24	0.340	43	10:25	5.64	1.740
12	9:11	4.27	0.370	44	10:30	5.69	1.790
13	9:12	4.30	0.400	45	10:35	5.74	1.840
14	9:13	4.34	0.440	46	10:40	5.78	1.880
15	9:14	4.37	0.470	47	10:50	5.86	1.960
16	9:15	4.41	0.510	48	11:00	5.93	2.030
17	9:16	4.44	0.540	49	11:10	5.99	2.090
18	9:17	4.47	0.570	50	11:20	6.04	2.140
19	9:18	4.50	0.600	51	11:30	6.08	2.180
20	9:19	4.52	0.620	52	11:40	6.12	2.220
21	9:20	4.54	0.640	53	11:50	6.15	2.250
22	9:22	4.59	0.690	54	12:00	6.18	2.280
23	9:24	4.64	0.740	55	12:10	6.21	2.310
24	9:26	4.69	0.790	56	12:20	6.24	2.340
25	9:28	4.74	0.840	57	12:30	6.25	2.350
26	9:30	4.79	0.890	58	12:40	6.28	2.380
27	9:32	4.83	0.930	59	12:50	6.30	2.400
28	9:34	4.87	0.970	60	13:00	6.31	2.410
29	9:36	4.92	1.020	61	13:10	6.32	2.420
30	9:38	4.96	1.060	62	13:20	6.33	2.430
31	9:40	5.00	1.100	63	13:30	6.33	2.430
32	9:42	5.03	1.130		13:40	6.34	2.440

Table 5.20: Time – Drawdown Analysis for the Pumping Test at Vill. MATH near Mul Dwarka TR

Well located at village Math	
INPUT Dimensions: Diameter of Well (d_c) = 3.65 Meter Area of Well (A) = 10.46347 Sq. Meter Depths to: water level (DTW) = 3.90 Meter Base of Aquifer = 7.60 Meter Type of Well: Open Well Aquifer Material -- Milliolite Limestone (Cavernous) FLOW RATE = 496 m³/d	Date: 21/04/2002 Time: 09:00
	Aquifer thickness = 3.70 Meter Slope = 1.7630 Meter/log10
	K = 13.9169995 Meter/Day T = 51.4928982 Meter²/Day



Graph 5.39 Cooper-Jacob's Log-Log Graph for Pumping Test Carried out at Village Math

5.4.3.2 Recuperation Analysis

Maximum Drawdown $S_1 = 2.440$ m (Refer Graph 5.40)

Sr. No.	Time Hr:Min	Time since Pumping Stopped (min)	Water Level (m)	Residual Drawdown S_2 (m)	$(t+\Delta t/\Delta t)$	S_1/S_2
1	9:00	---	3.90	---	---	---
2	14:00	0	6.34	---	---	---
3	14:01	1	6.31	2.410	301.00	1.012448
4	14:02	2	6.29	2.390	151.00	1.020921
5	14:03	3	6.27	2.365	101.00	1.031712
6	14:04	4	6.25	2.345	76.00	1.040512
7	14:05	5	6.22	2.315	61.00	1.053996
8	14:06	6	6.19	2.290	51.00	1.065502
9	14:07	7	6.16	2.260	43.86	1.079646
10	14:08	8	6.14	2.240	38.50	1.089286
11	14:09	9	6.11	2.210	34.33	1.104072
12	14:10	10	6.09	2.190	31.00	1.114155
13	14:11	11	6.07	2.165	28.27	1.127021
14	14:12	12	6.04	2.140	26.00	1.140187
15	14:13	13	6.01	2.110	24.08	1.156398
16	14:14	14	5.99	2.090	22.43	1.167464
17	14:15	15	5.95	2.050	21.00	1.190244
18	14:16	16	5.93	2.030	19.75	1.201970
19	14:17	17	5.90	2.000	18.65	1.220000
20	14:18	18	5.88	1.980	17.67	1.232323
21	14:19	19	5.86	1.960	16.79	1.244898
22	14:20	20	5.84	1.940	16.00	1.257732
23	14:22	22	5.79	1.890	14.64	1.291005
24	14:24	24	5.73	1.830	13.50	1.333333
25	14:26	26	5.70	1.800	12.54	1.355556
26	14:28	28	5.66	1.760	11.71	1.386364
27	14:30	30	5.62	1.720	11.00	1.418605
28	14:32	32	5.58	1.680	10.38	1.452381
29	14:34	34	5.54	1.640	9.82	1.487805
30	14:36	36	5.50	1.600	9.33	1.525000
31	14:38	38	5.47	1.570	8.89	1.554140
32	14:40	40	5.43	1.530	8.50	1.594771
33	14:42	42	5.40	1.500	8.14	1.626667
34	14:44	44	5.36	1.460	7.82	1.671233
35	14:46	46	5.33	1.430	7.52	1.706294
36	14:48	48	5.29	1.390	7.25	1.755396
37	14:50	50	5.27	1.365	7.00	1.787546
38	14:52	52	5.24	1.335	6.77	1.827715
39	14:54	54	5.21	1.305	6.56	1.869732
40	14:56	56	5.19	1.285	6.36	1.898833
41	14:58	58	5.15	1.250	6.17	1.952000
42	15:00	60	5.13	1.230	6.00	1.983740
43	15:05	65	5.05	1.150	5.62	2.121739

Sr. No.	Time Hr:Min	Time since Pumping Stopped (min)	Water Level (m)	Residual Drawdown S_2 (m)	$(t+\Delta t/\Delta t)$	S_1/S_2
44	15:10	70	4.98	1.080	5.29	2.259259
45	15:15	75	4.93	1.030	5.00	2.368932
46	15:20	80	4.89	0.990	4.75	2.464646
47	15:25	85	4.84	0.935	4.53	2.609626
48	15:30	90	4.79	0.885	4.33	2.757062
49	15:35	95	4.74	0.840	4.16	2.904762
50	15:40	100	4.70	0.800	4.00	3.050000
51	15:50	110	4.62	0.720	3.73	3.388889
52	16:00	120	4.55	0.650	3.50	3.753846
53	16:10	130	4.50	0.600	3.31	4.066667
54	16:20	140	4.45	0.550	3.14	4.436364
55	16:30	150	4.40	0.500	3.00	4.880000
56	16:40	160	4.36	0.460	2.88	5.304348
57	16:50	170	4.32	0.420	2.76	5.809524
58	17:00	180	4.29	0.390	2.67	6.256410
59	17:10	190	4.26	0.360	2.58	6.777778
60	17:20	200	4.24	0.335	2.50	7.283582
61	17:30	210	4.21	0.310	2.43	7.870968
62	17:40	220	4.19	0.290	2.36	8.413793
63	17:50	230	4.18	0.280	2.30	8.714286

Table 5.21: Time – Recovery Analysis for the Recuperation Test at Vill. MATH near Mul Dwarka TR

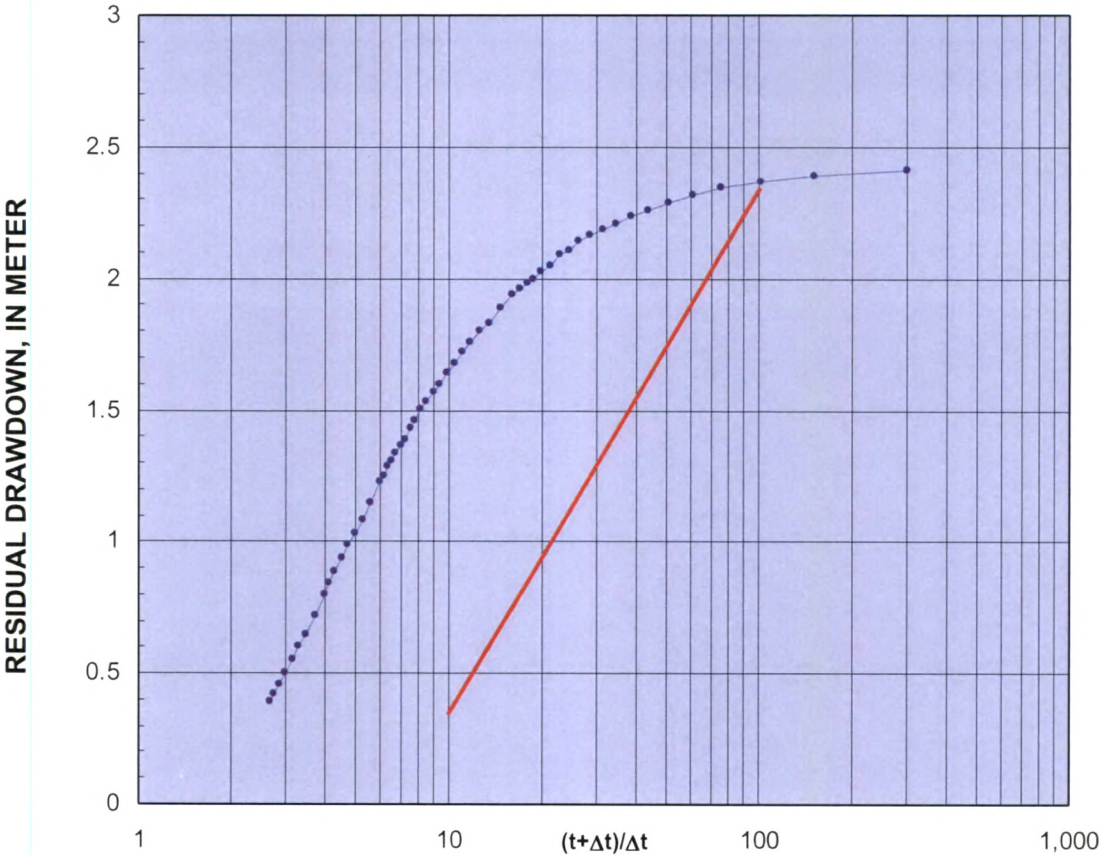
5.4.3.3 Results for Pumping Test

From the Pumping test following results were derived.

	Pumping Test	Recuperation Test
Transmissibility	51.4930 m ² /day	45.6191 m ² /day
Permeability	13.9170 m/day	12.3295 m/day

Table 5.22: Results of Pumping Test at Vill. Math

Well located at village Math	
INPUT Dimensions: Diameter of Well (d_c) = 3.65 Meter Area of Well (A) = 10.46347 Sq. Meter Depths to: water level (DTW) = 3.90 Meter Base of Aquifer = 7.60 Meter Type of Well: Open Well Aquifer Material -- Milliolite Limestone (Cavernous) FLOW RATE = 496 m ³ /d	Date: 21/04/2002 Time: 09:00
	Aquifer thickness = 3.70 Meter Slope = 1.990 Meter/log10
	K = 12.329482 Meter/Day T = 45.619085 Meter ² /Day



Graph 5.40 Cooper-Jacob's Log-Log Graph for Recuperation Test Carried out at Village Math

5.4.4 Calculation of Recharge Rate, Volume of water Stored & Volume of Water Recharged for Mul Dwarka TR

Rainfall, Water-level fluctuation and evaporation rate for every week at Mul Dwarka TR was observed for four years and tabulated in table 4.33. Using these data in conjunction with elevation storage data, recharge rate in mm/day is worked out (Table 5.23 to 5.26). From the results obtained graph 5.4.1 of Recharge rate v/s time is drawn and Cumulative days v/s recharge rate graph for each year is plotted on log-log graph (5.4.2 to 5.4.5) to get recharge rate equation.

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Vol of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Vol. Of Evaporation (M ³)	Vol. Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
23/6/99	203	1.00	363423	-	-	732617	-	-	753186	
30	0	0.67	213722	149700	4.0	396829	15873	133827	408248	46.830
Jul 7	0	0.53	150213	63509	4.3	254373	10938	52571	261769	28.690
14	32	0.38	114919	35294	4.2	202180	8492	26803	208122	18.398
21	140	0.98	354350		3.6	712266			732294	
28	Nil	0.72	236404	117946	4.0	447706	17908	100037	460542	31.031
Aug 4	Nil	0.58	172895	63509	4.0	305250	12210	51299	314092	23.332
11	Nil	0.44	125761	47133	4.1	213014	8734	38400	219247	25.021
18	Nil	0.24	89620	36142	4.0	176901	7076	29066	182153	22.795
25	Nil	0.10	64321	25299	4.2	151623	6368	18931	156169	17.317
Sep 1	7	0.00	46250	18071	3.9	133566	5209	12862	137599	13.353
8	Nil	-0.17	32902	13348	4.0	99830	3993	9355	102881	12.989
15	Nil	-0.30	22695	10207	4.1	74032	3035	7172	76315	13.425
	432		1987474	580158			99836	480322	Avg. =	23.017

Table 5.23: Recharge Rate Calculation for Mul Dwarka TR – Year 1999 (Refer Graph 5.41)

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored; (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
18/6/01	216	1.25	591705	-	-	898624	-	-	923377	-
25	Nil	0.92	327132	264574	4.0	651214	26048.55	238525.01	669608	50.888
Jul 2	10	0.73	240940	86191	4.1	457881	18773.14	67417.95	470999	20.448
9	262	1.50	819988	-	-	1064630	-	-	1093392	-
16	16	2.10	1525742	-	-	1590815	-	-	1631769	-
23	Nil	1.78	1173917	351825	3.9	1318429	51418.73	300405.98	1353265	31.712
30	7	1.64	996953	176965	4.1	1191530	48852.71	128112.17	1223366	14.960
Aug 6	2	1.49	810856	186096	4.1	1057990	43377.59	142718.61	1086595	18.764
13	29	1.35	683018	127838	4.0	965026	38601.05	89237.20	991404	12.859
20	20	2.40	1992403	-	-	1845732	-	-	1892075	-
27	Nil	2.25	1636348	356055	3.9	1700273	66310.65	289744.35	1743504	23.741
Sep 3	Nil	1.95	1388803	247544	4.0	1472521	58901	188643	1510898	17.836
10	Nil	1.79	1186558	202246	4.0	1327493	53100	149146	1362541	15.637
17	Nil	1.62	971672	214886	4.1	1173401	48109	166776	1204803	19.775
24	3	1.50	819988	151684	3.9	1064630	41521	110164	1093392	14.393
Oct 1	Nil	1.33	664756	155232	3.9	951746	37118	118114	977801	17.257
8	Nil	1.19	536917	127838	3.8	858782	32634	95205	882547	15.411
15	3	1.05	409079	127838	3.9	765818	29867	97971	787238	17.778
22	Nil	0.90	318059	91020	3.8	630863	23973	67047	648709	14.765
29	Nil	0.76	254550	63509	3.8	488408	18559	44950	502369	12.782
Nov 5	Nil	0.63	195577	58973	3.7	356127	13177	45796	366405	17.855
12	Nil	0.53	150213	45364	3.6	254373	9157	36206	261769	19.759
19	Nil	0.41	120340	29873	3.7	207597	7681	22192	213685	14.836

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
26	Nil	0.28	96848	23492	3.6	184124	6628	16864	189574	12.708
Dec 3	Nil	0.16	75163	21685	3.4	162456	5524	16161	167307	13.800
10	Nil	0.06	57092	18071	3.3	144400	4765	13306	148742	12.779
17	Nil	-0.08	39968	17124	3.3	117691	3884	13240	121264	15.598
24	Nil	-0.22	28976	10992	3.1	89908	2787	8205	92665	12.649
31	Nil	-0.32	21125	7852	3.3	70063	2312	5540	72227	10.957
07/01/2002	Nil	-0.39	15629	5496	3.1	56172	1741	3755	57915	9.262
	568		18150315	3170263			694821	2475442		Avg. = 17.662

Table 5.24: Recharge Rate Calculation for Mul Dwarka TR – Year 2001 (Refer Graph 5.41)

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
26/8/02	402	1.00	363423	-	-	732617	-	-	753186	
Sep 2	6	0.68	218259	145164	4.1	407004	16687	128477	418708	43.834
9	Nil	0.55	159286	58973	4.1	274724	11264	47709	282699	24.109
16	Nil	0.40	118533	40753	4.2	205791	8643	32109	211831	21.654
23	29	0.24	89620	28913	4.1	176901	7253	21660	182153	16.988
30	Nil	0.08	60706	28913	4.0	148011	5920	22993	152456	21.545
Oct 7	Nil	-0.07	40754	19953	3.9	119675	4667	15285	123307	17.709
	437		1050580	322669			54435	268234		Avg. = 24.307

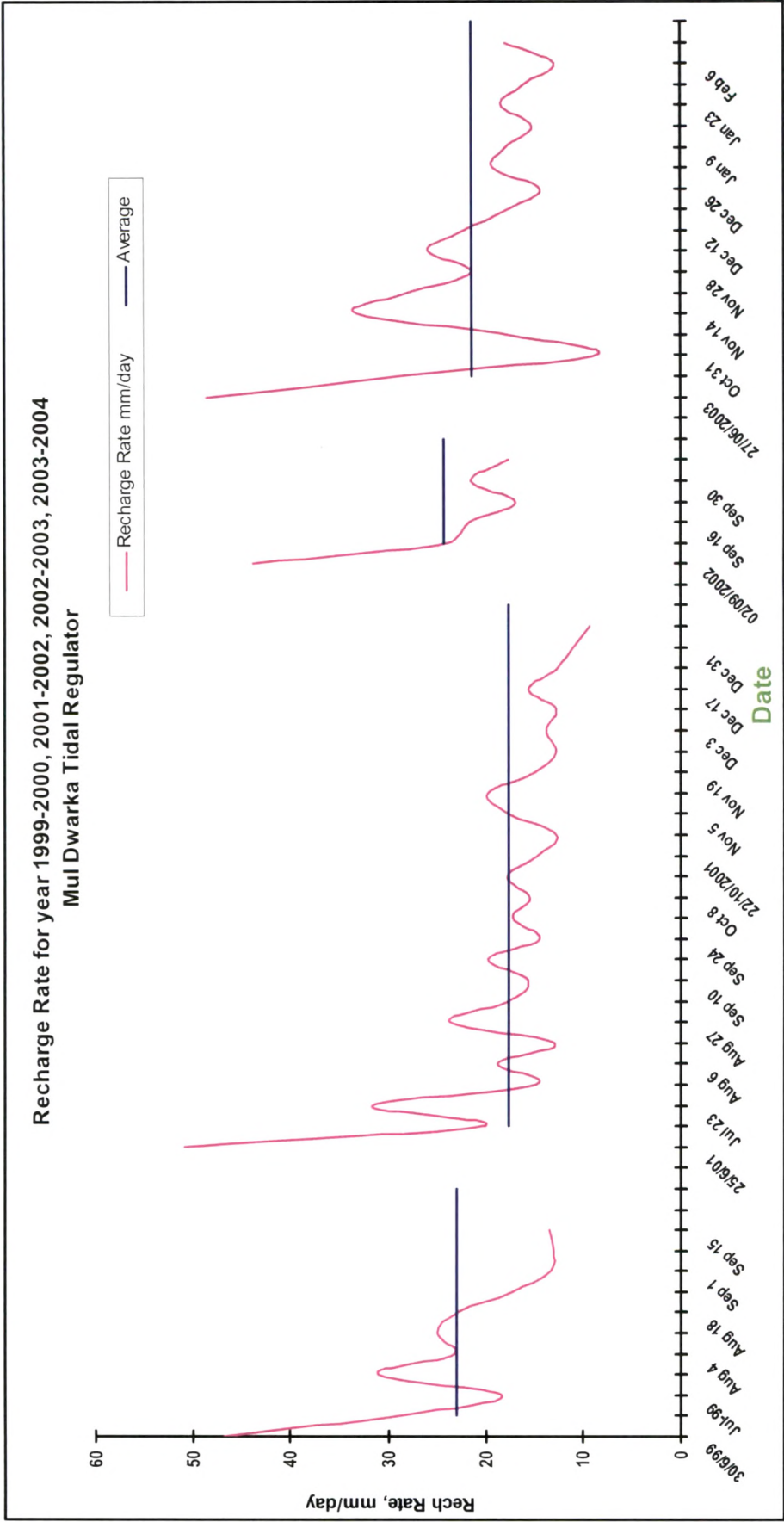
Table 5.25: Recharge Rate Calculation for Mul Dwarka TR – Year 2002 (Refer Graph 5.41)

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
20/6/03	264	1.55	883189	-	-	1109951	-	-	1139820	-
27	Nil	1.20	546049	337141	4.0	865422	34617	302524	889353	48.595
Jul 4	21	1.00	363423	182626	4.1	732617	30037	152589	753186	28.942
11	119	1.50	819988	-	-	1064630	-	-	1093392	-
18	64	2.25	1636348	-	-	1700273	-	-	1743504	-
25	70	2.25	1636348	-	-	1700273	-	-	1743504	-
Aug 1	29	2.25	1636348	-	-	1700273	-	-	1743504	-
8	388	2.25	1636348	-	-	1700273	-	-	1743504	-
15	15	2.25	1636348	-	-	1700273	-	-	1743504	-
22	3	2.25	1636348	-	-	1700273	-	-	1743504	-
29	77	2.25	1636348	-	-	1700273	-	-	1743504	-
Sep 5	55	2.25	1636348	-	-	1700273	-	-	1743504	-
12	6	2.25	1636348	-	-	1700273	-	-	1743504	-
19	Nil	2.25	1636348	-	-	1700273	-	-	1743504	-
26	Nil	2.25	1636348	-	-	1700273	-	-	1743504	-
Oct 3	94	2.25	1636348	-	-	1700273	-	-	1743504	-
10	Nil	2.25	1636348	-	-	1700273	-	-	1743504	-
17	Nil	2.25	1636348	-	3.5	1700273	-	-	1743504	-
24	Nil	2.25	1636348	-	3.4	1700273	-	-	1743504	-
31	Nil	2.05	1488874	147474	3.4	1554329	52847	94627	1594508	8.478
Nov 7	Nil	1.85	1262400	226474	3.7	1381879	51130	175344	1418186	17.663
14	Nil	1.60	946391	316009	3.6	1155273	41590	274419	1186239	33.048
21	Nil	1.38	710412	235979	3.7	984947	36443	199536	1011807	28.173

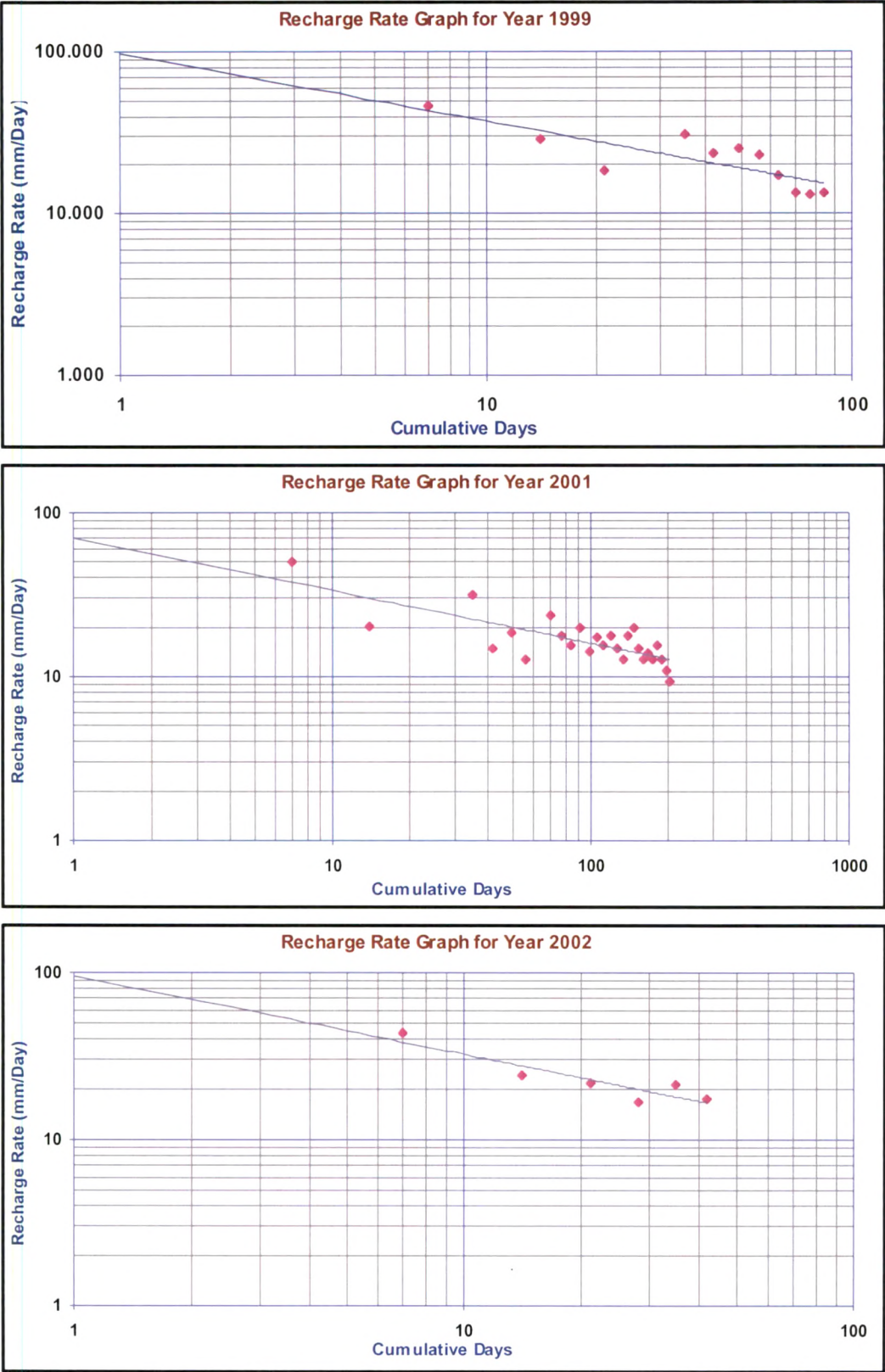
Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
28	Nil	1.20	546049	164363	3.6	865422	31155	133208	889353	21.397
Dec 5	Nil	1.02	381685	164363	3.4	745898	25361	139003	766808	25.896
12	Nil	0.81	277231	104454	3.3	539285	17796	86657	554643	22.320
19	Nil	0.67	213722	63509	3.3	396829	13095	50414	408248	17.641
26	Nil	0.58	172895	40827	3.1	305250	9463	31365	314092	14.265
02/01/2004	Nil	0.49	134797	38098	3.3	222042	7327	30771	228516	19.236
9	Nil	0.32	104076	30720	3.1	191346	5932	24789	196994	17.976
16	Nil	0.19	80584	23492	3.1	167873	5204	18288	172875	15.113
23	Nil	0.06	57092	23492	3.1	144400	4419	19073	148742	18.319
30	Nil	-0.08	39968	17124	3.0	117691	3554	13570	121264	15.986
06/02/2004	Nil	-0.22	28976	10992	3.0	89908	2679	8313	92665	12.816
13	Nil	-0.35	18769	10207	2.9	64110	1885	8322	66093	17.988
	1205		33621788	2137346			374534	1762811	Avg. = 21.325	

Table 5.26: Recharge Rate Calculation for Mul Dwarka TR – Year 2003 (Refer Graph 5.41)

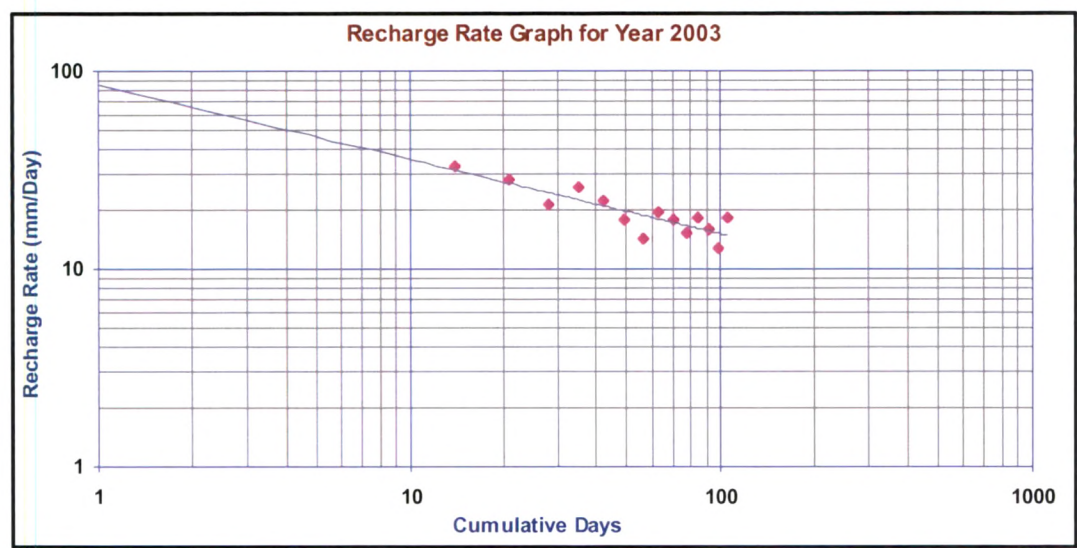
5.4.4.1 Recharge Rate Graphs and Equations for Mul Dwarka TR



Graph 5.41: Recharge Rate Graph for Mul Dwarka Tidal Regulator (Table 5.23 to 5.26)



Graph 5.42 to 5.44: Log-Log Graph for Recharge Rate v/s Cumulative Days for Mul Dwarka TR – Year 1999, 2001 & 2002



Graph 5.45: Log-Log Graph for Recharge Rate v/s Cumulative Days for Mul Dwarka TR – Year 2003

General equation for recharge rate is $I = \alpha T^\beta$

Recharge rate Formula for Mul Dwarka Tidal Regulator

Year	Intercept on Y axis (Rech. Rate)	Slope of graph
	α	β
1999	98.143	-0.4199
2001	70.582	-0.3222
2002	95.803	-0.4689
2003	85.633	-0.3778
Average	87.540	-0.3972

Table 5.27: Recharge Rate Equation for Mul Dwarka TR

So Recharge Rate Equation,

$$I = 84.54 T^{-0.3972}$$

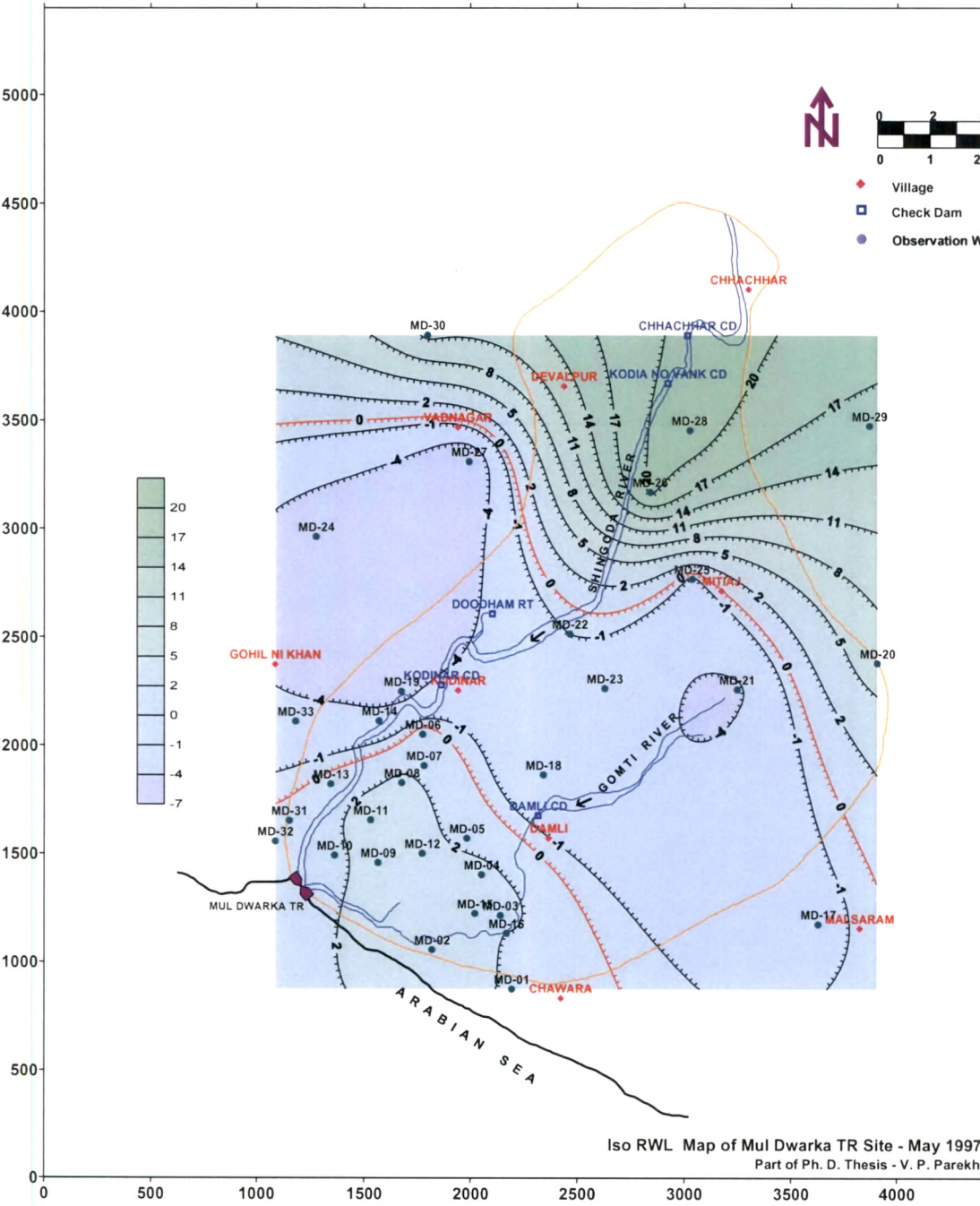
Where I = Recharge Rate mm/Day

T = Time in Days

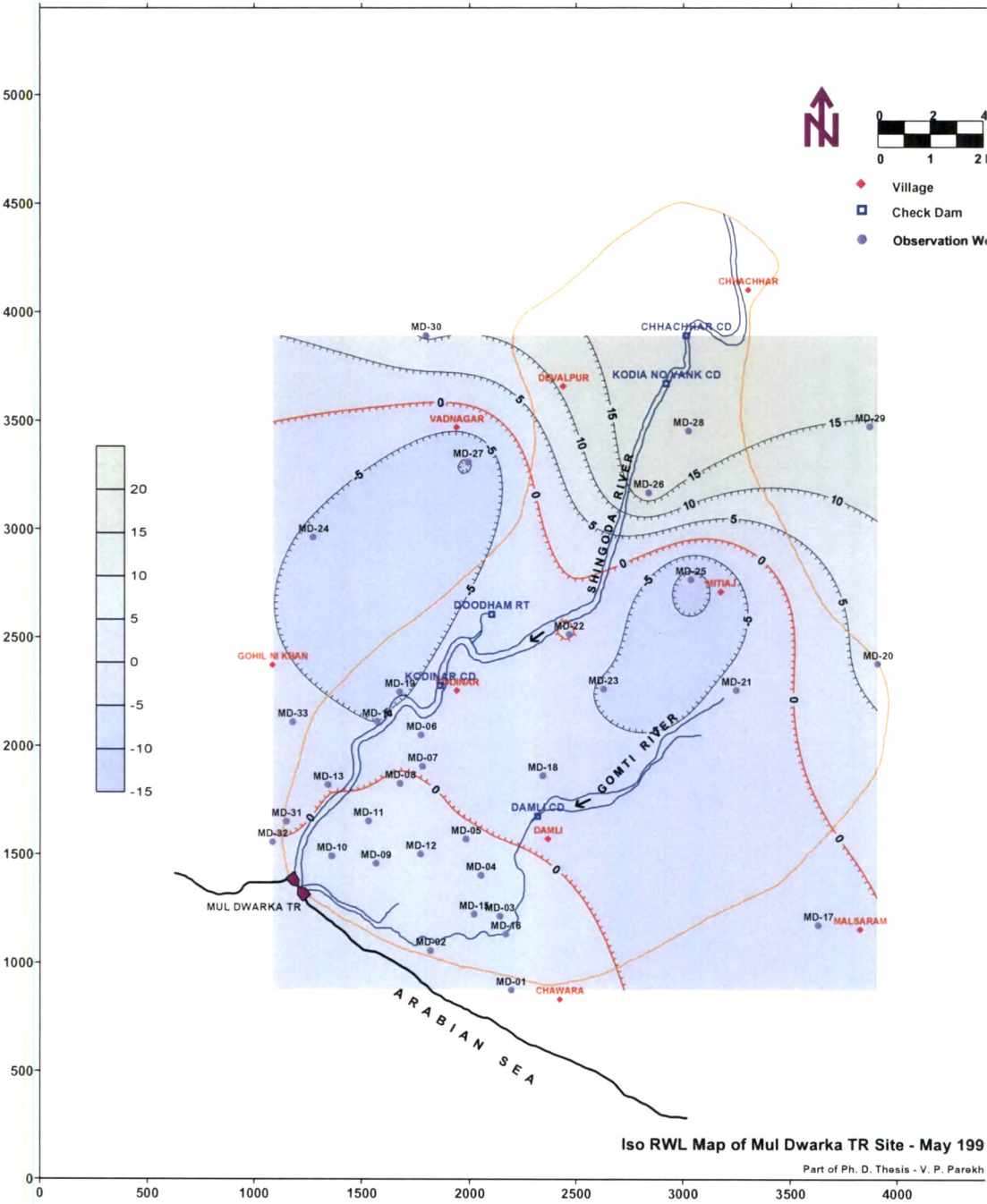
5.4.5 Geohydrological & Geochemical Analysis of Data Collected for Mul Dwarka TR

From the Geohydrological data collected from 33 wells surrounding the Mul Dwarka TR, RWL maps (Map 5.37 to 5.40) are plotted to study the pre-monsoon & post-monsoon groundwater flow pattern. Similarly from analyzed geochemical parameters IsoChlor Map 5.41 to 5.44 and IsoTDS Map 5.45 to 5.47 are prepared to study the variation of chloride and TDS in the study area. To study about fresh seawater intrusion or any leaching process in recent years, ion ratio maps of Na^+/Cl^- (Map 5.48 to 5.50) and $(Mg^{+}+Ca^{+})/Cl^-$ (Map 5.51 to 5.52) are

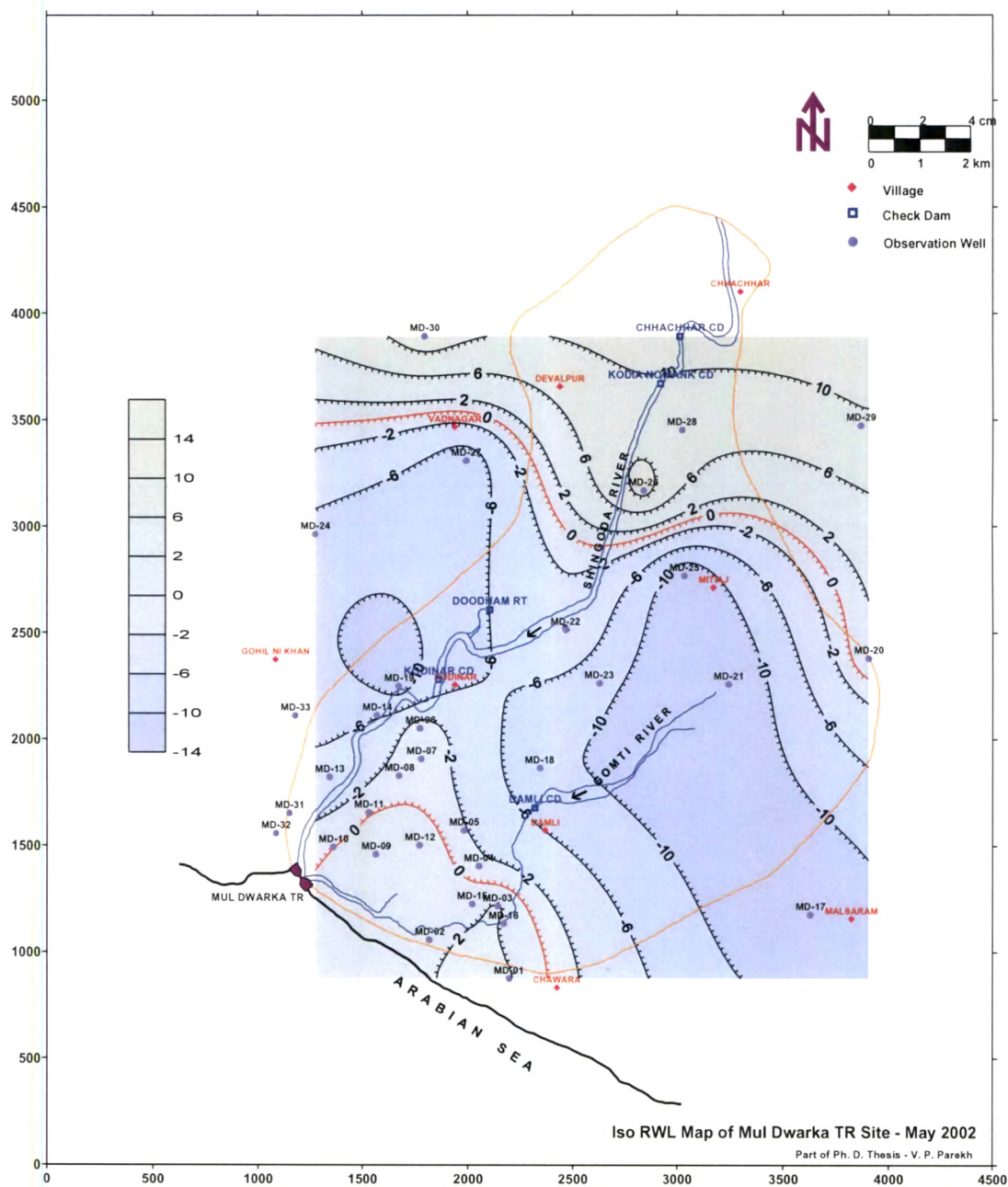
plotted. A section passing through the wells MD-01, 02, 03, 15, 16, 04, 05, 12, 07, 08, 18, 06, 19, 22, 27 and 30 is plotted in map 5.53 to locate zone of transition between freshwater and saline water.



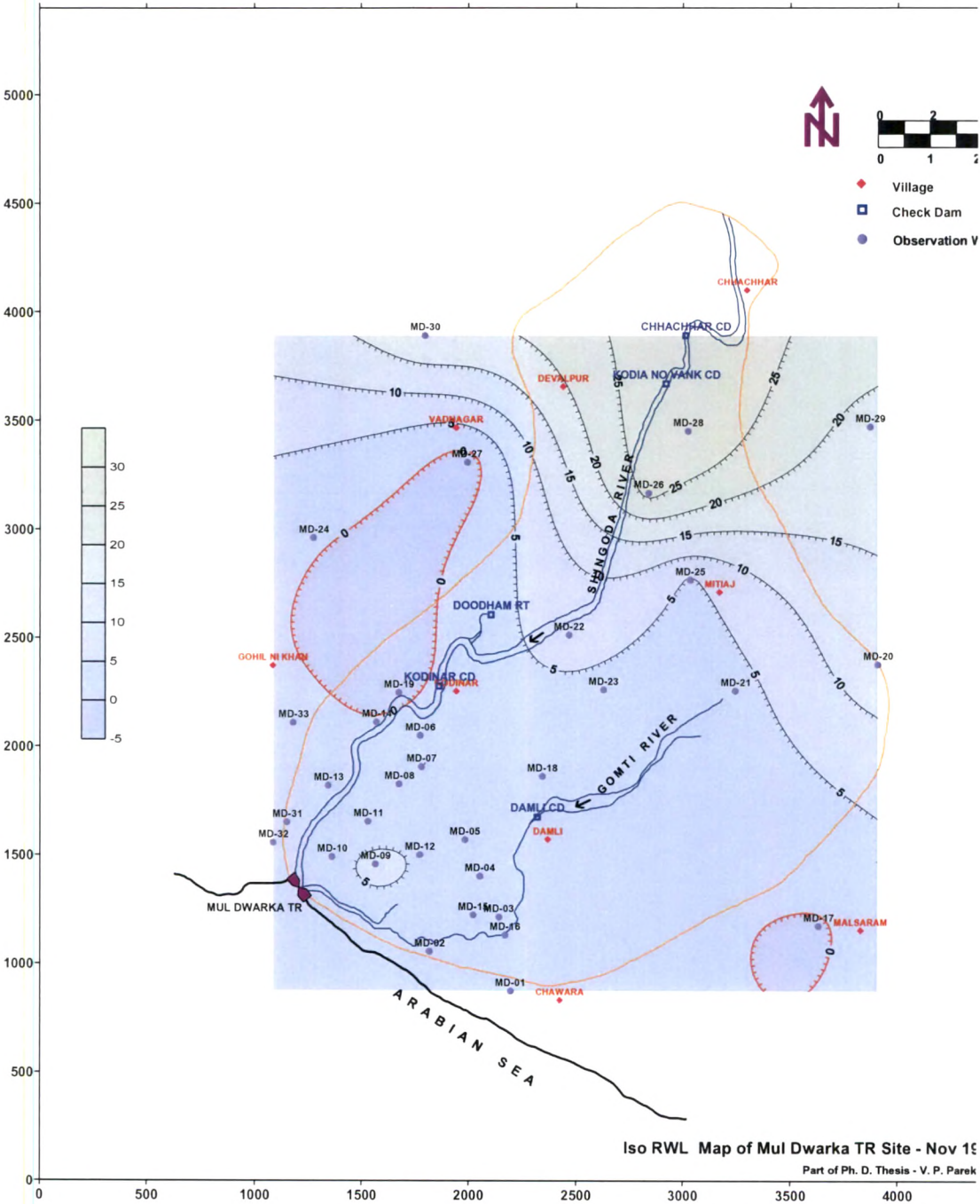
Map 5.37: RWL Map for Mul Dwarka TR – May 1997



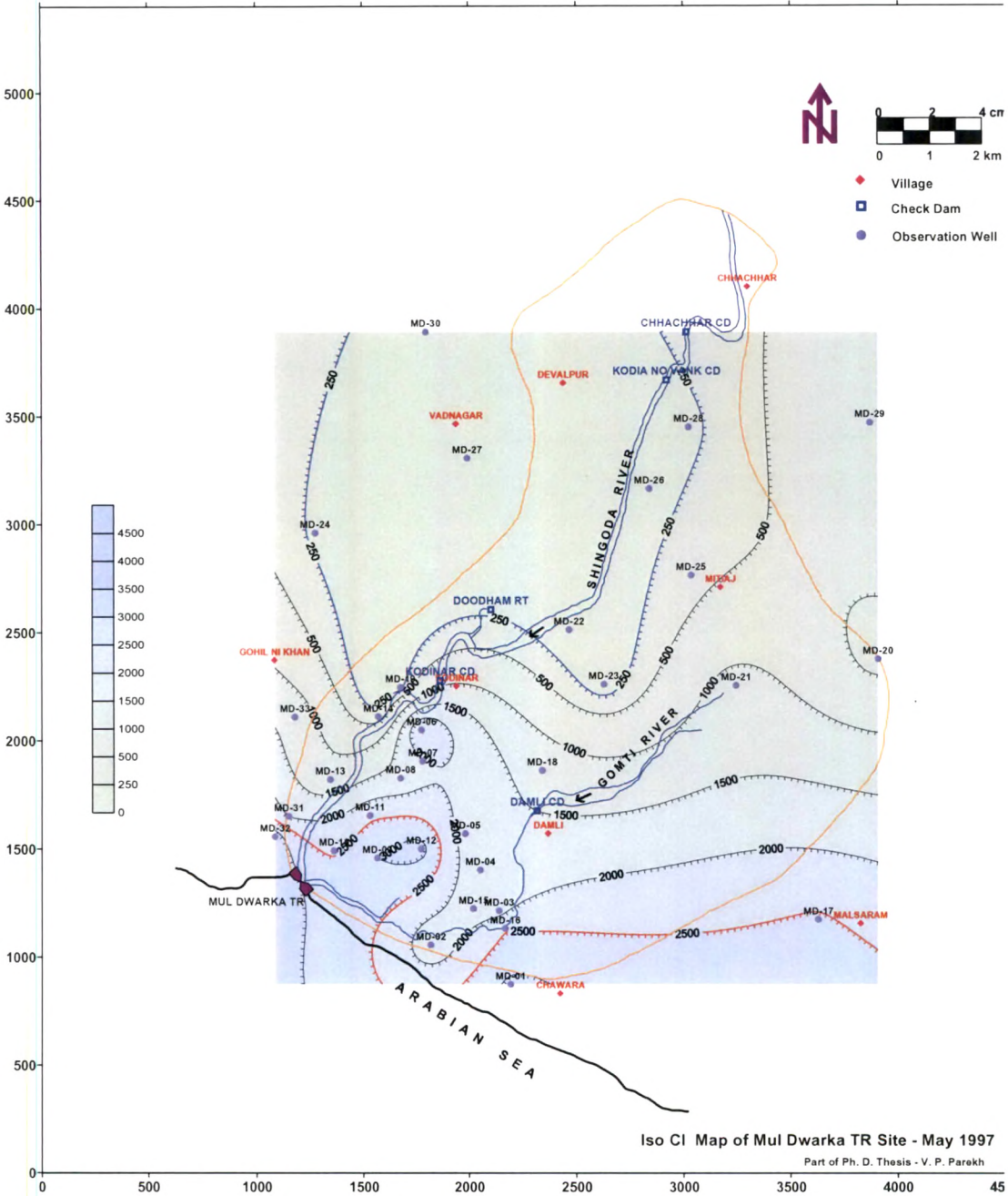
Map 5.38: RWL Map for Mul Dwarka TR – May 1999



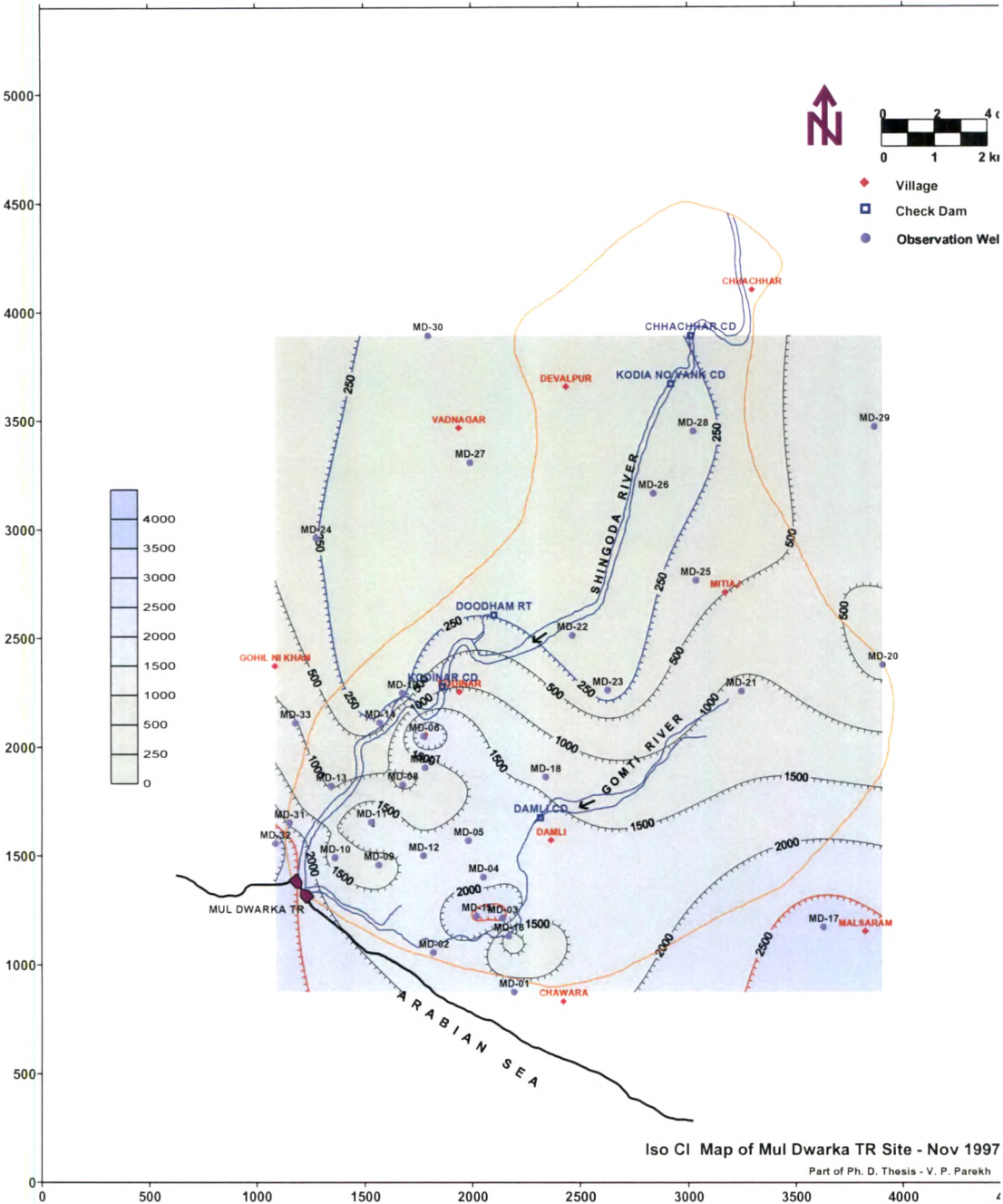
Map 5.39: RWL Map for Mul Dwarka TR – May 2002



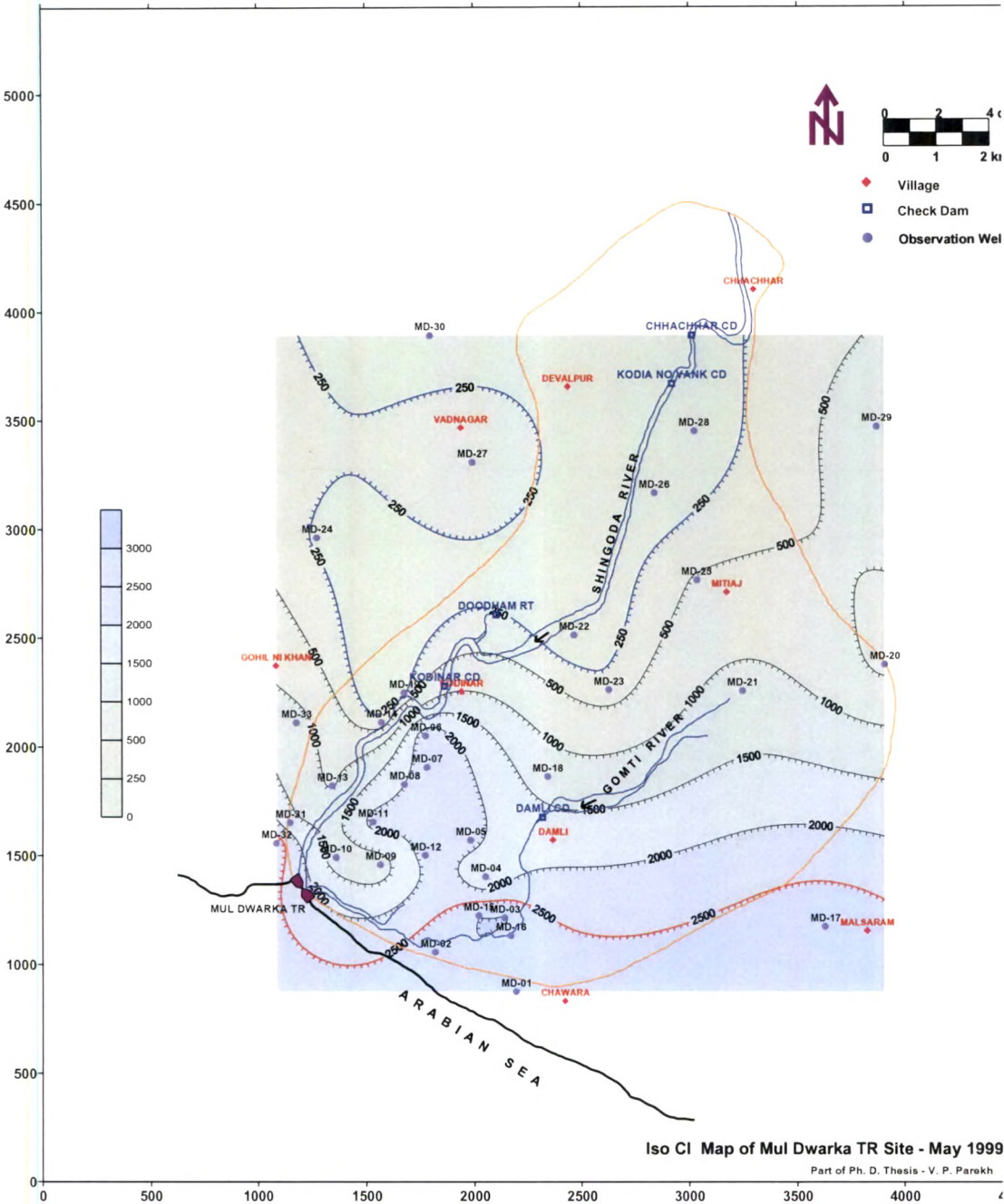
Map 5.40: RWL Map for Mul Dwarka TR – November 1997



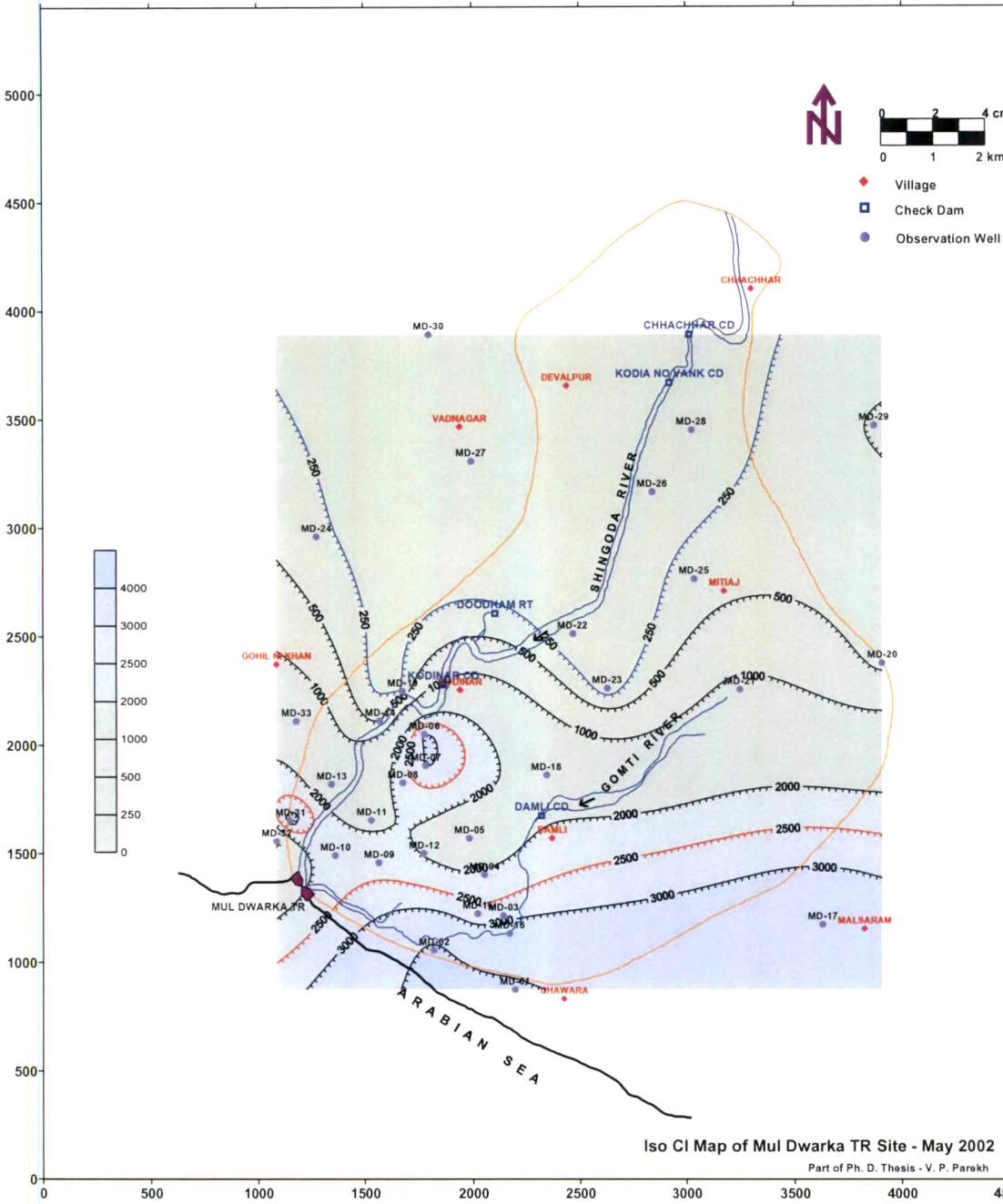
Map 5.41: Iso CI Map for Mul Dwarka TR – May 1997



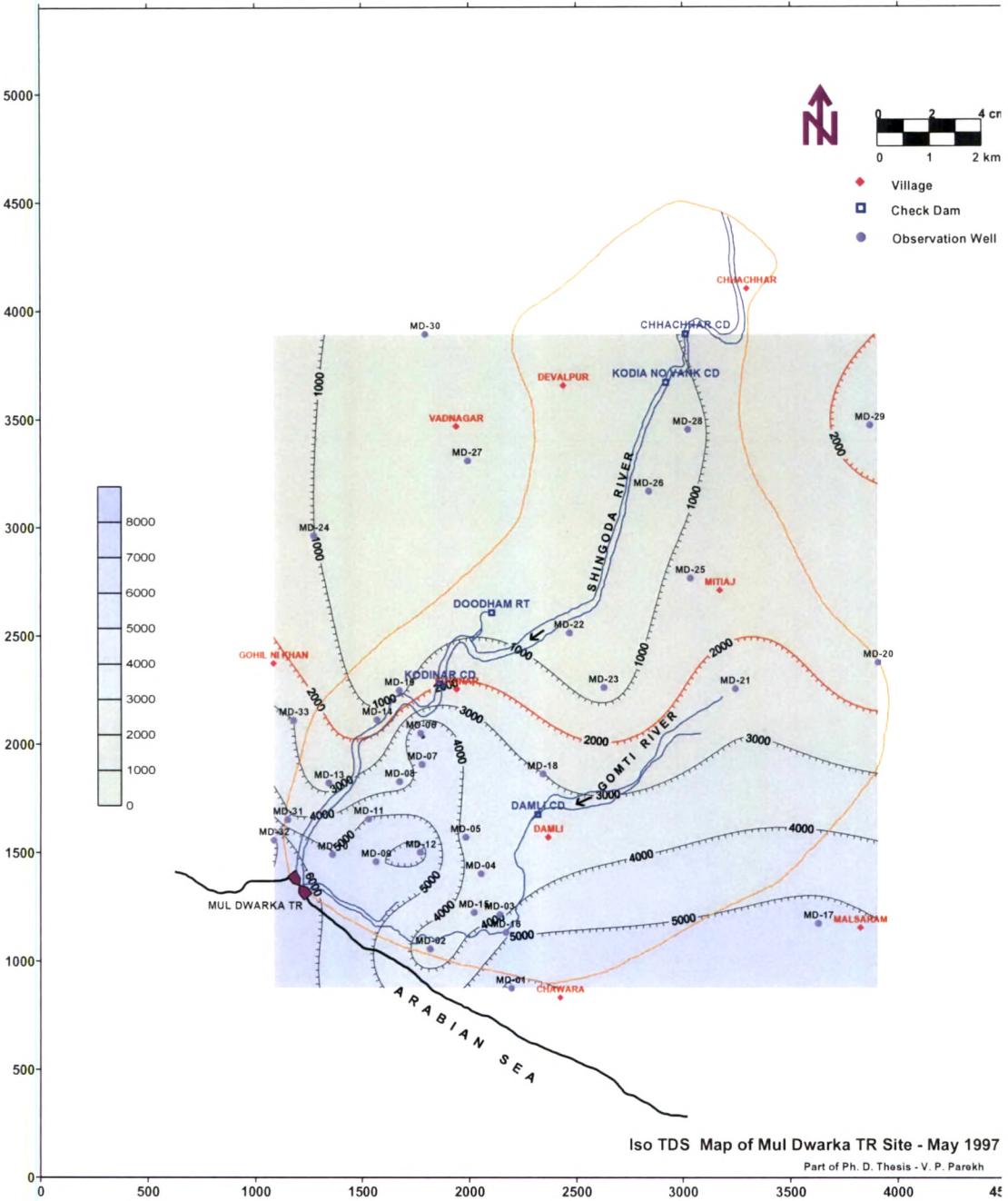
Map 5.42: Iso CI Map for Mul Dwarka TR – November 1997



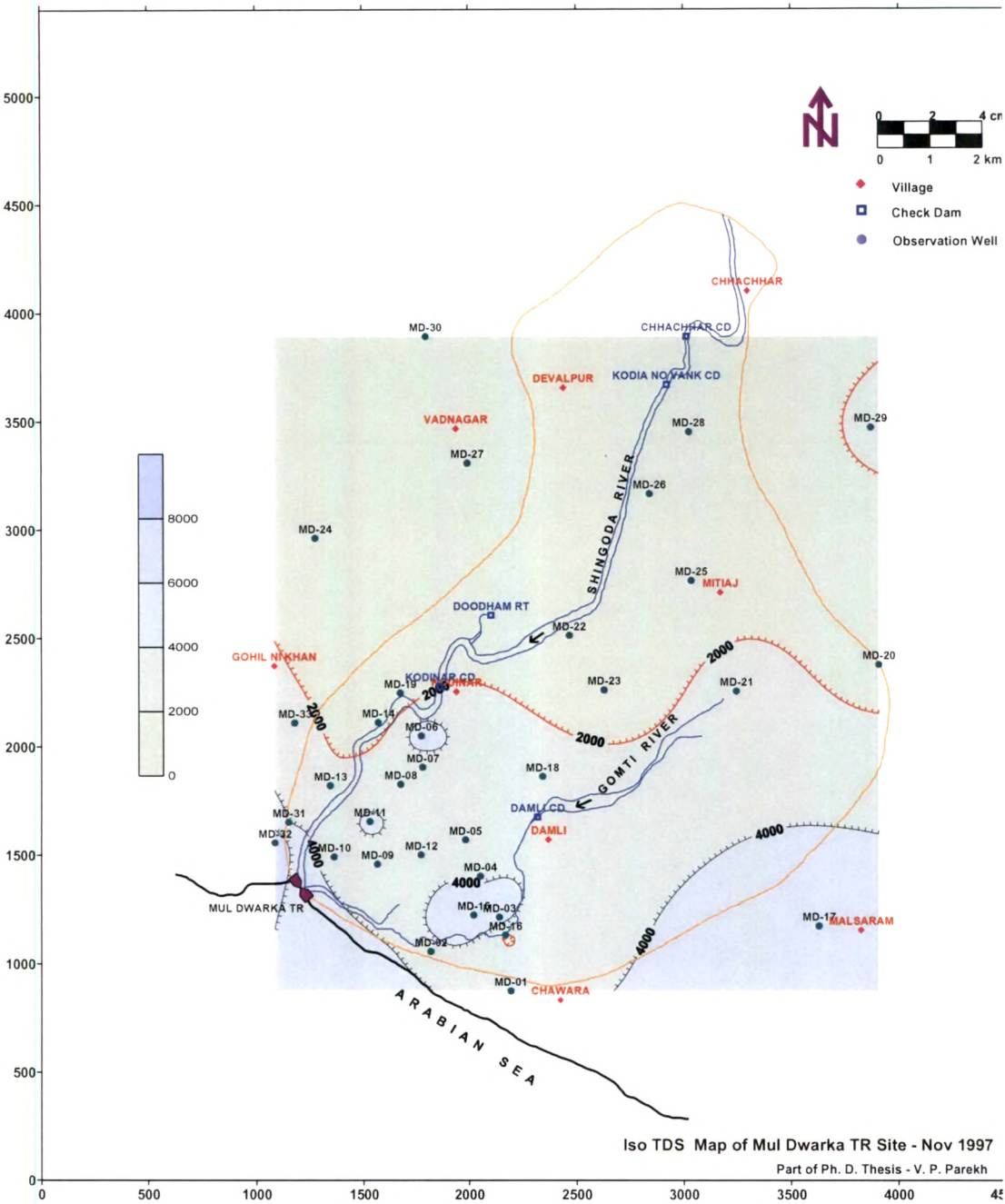
Map 5.43: Iso CI Map for Mul Dwarka TR – May 1999



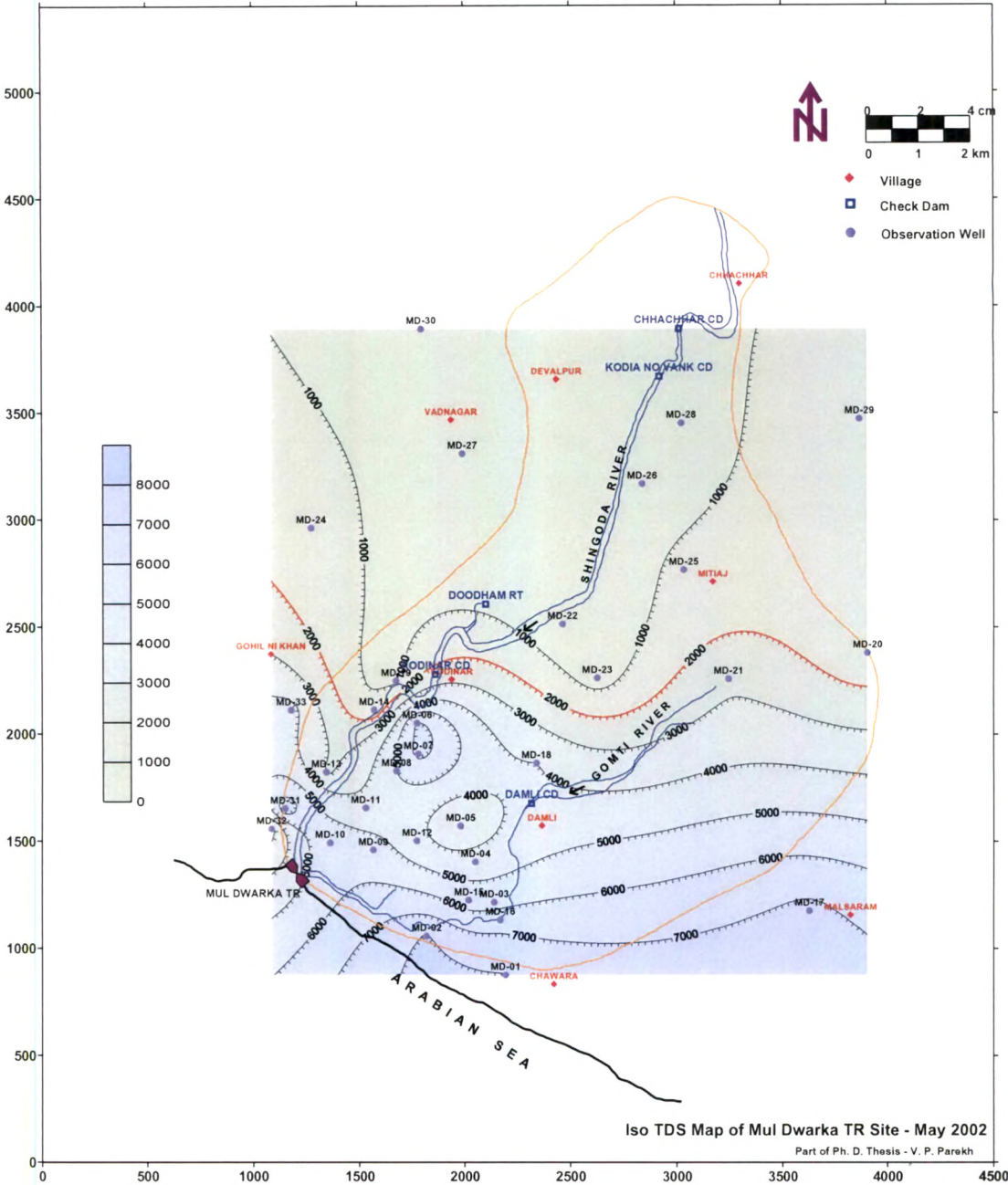
Map 5.44: Iso CI Map for Mul Dwarka TR – May 2002



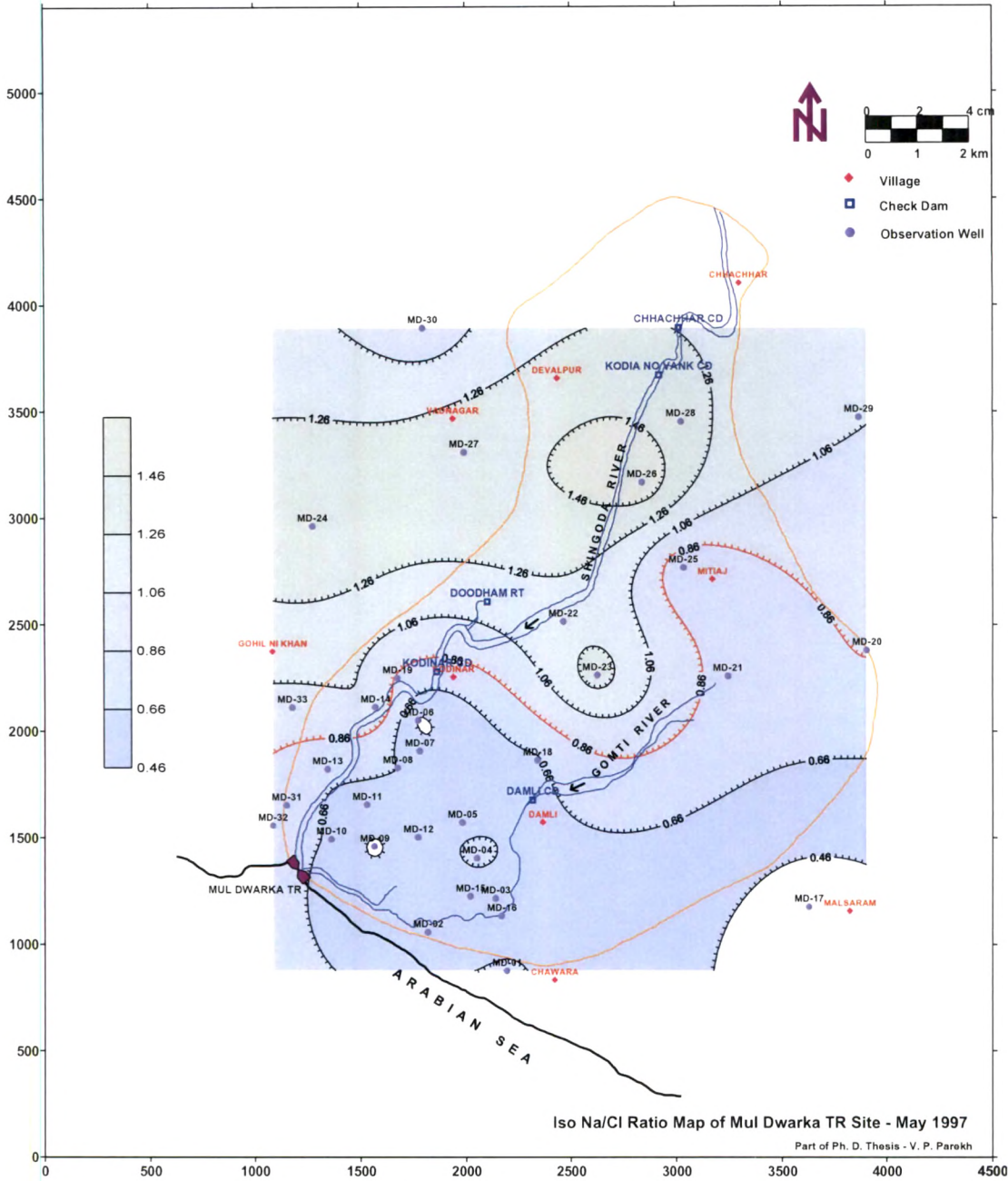
Map 5.45: Iso TDS Map for Mul Dwarka TR – May 1997



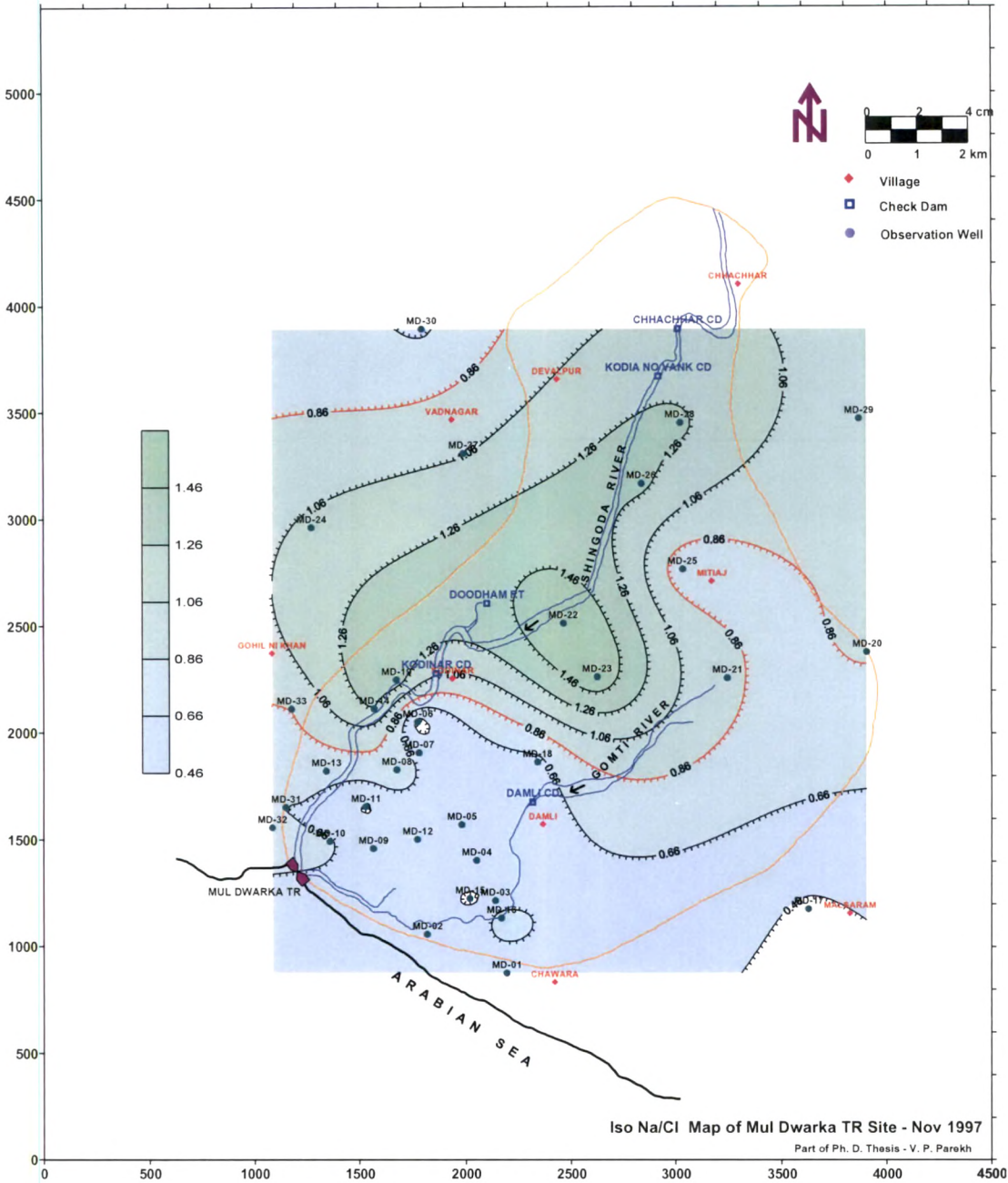
Map 5.46: Iso TDS Map for Mul Dwarka TR – November 1997



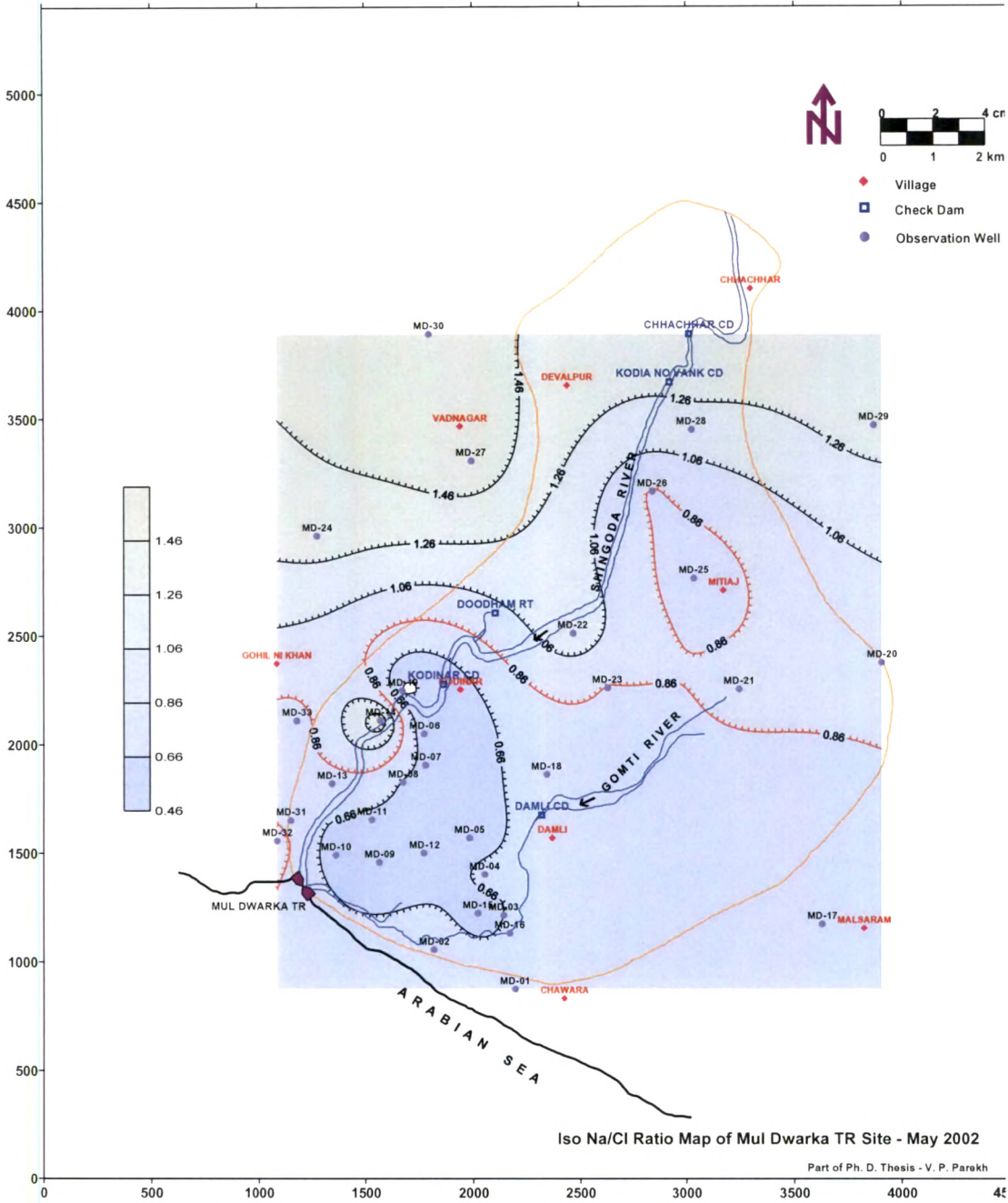
Map 5.47: Iso TDS Map for Mul Dwarka TR – May 2002

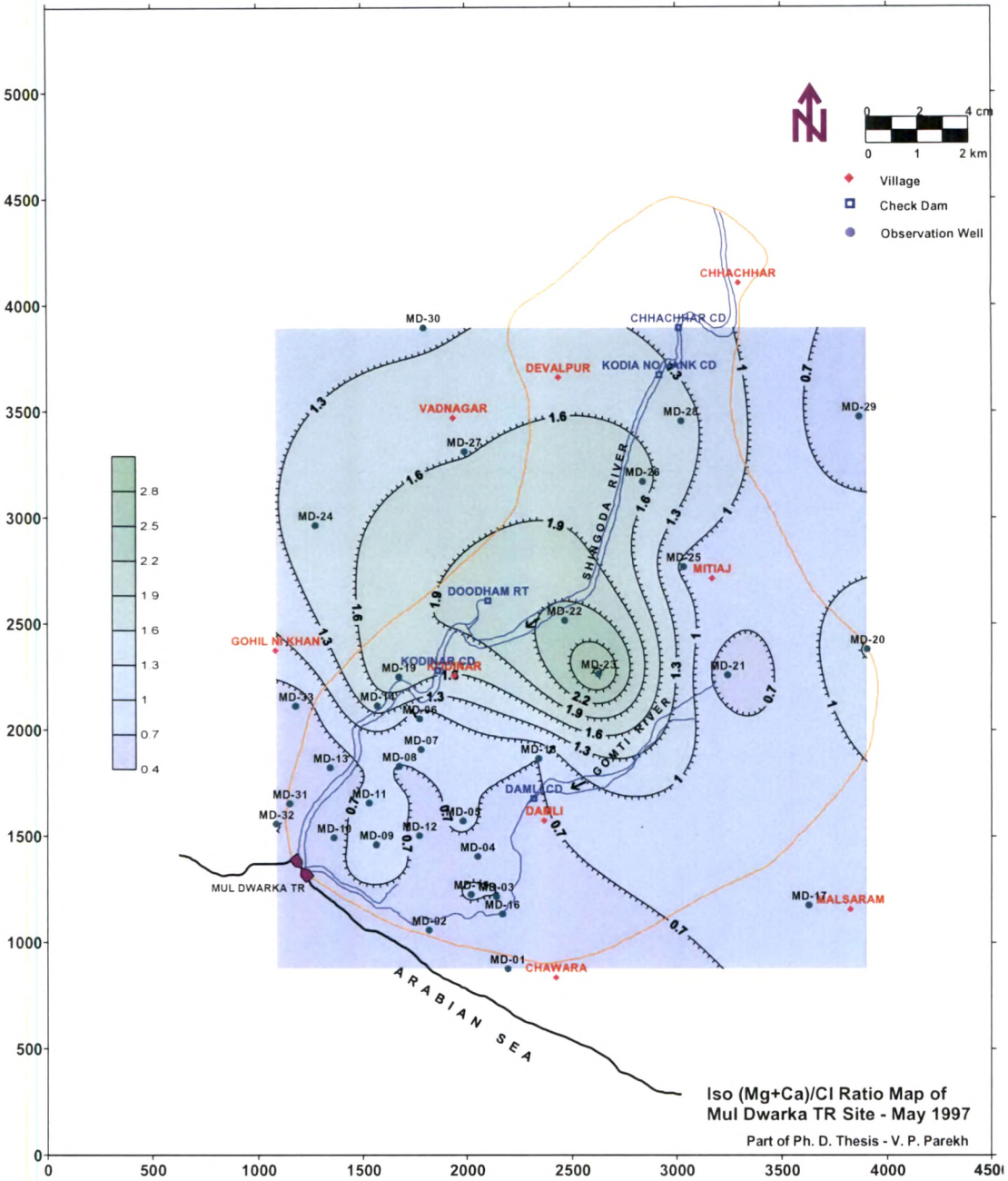


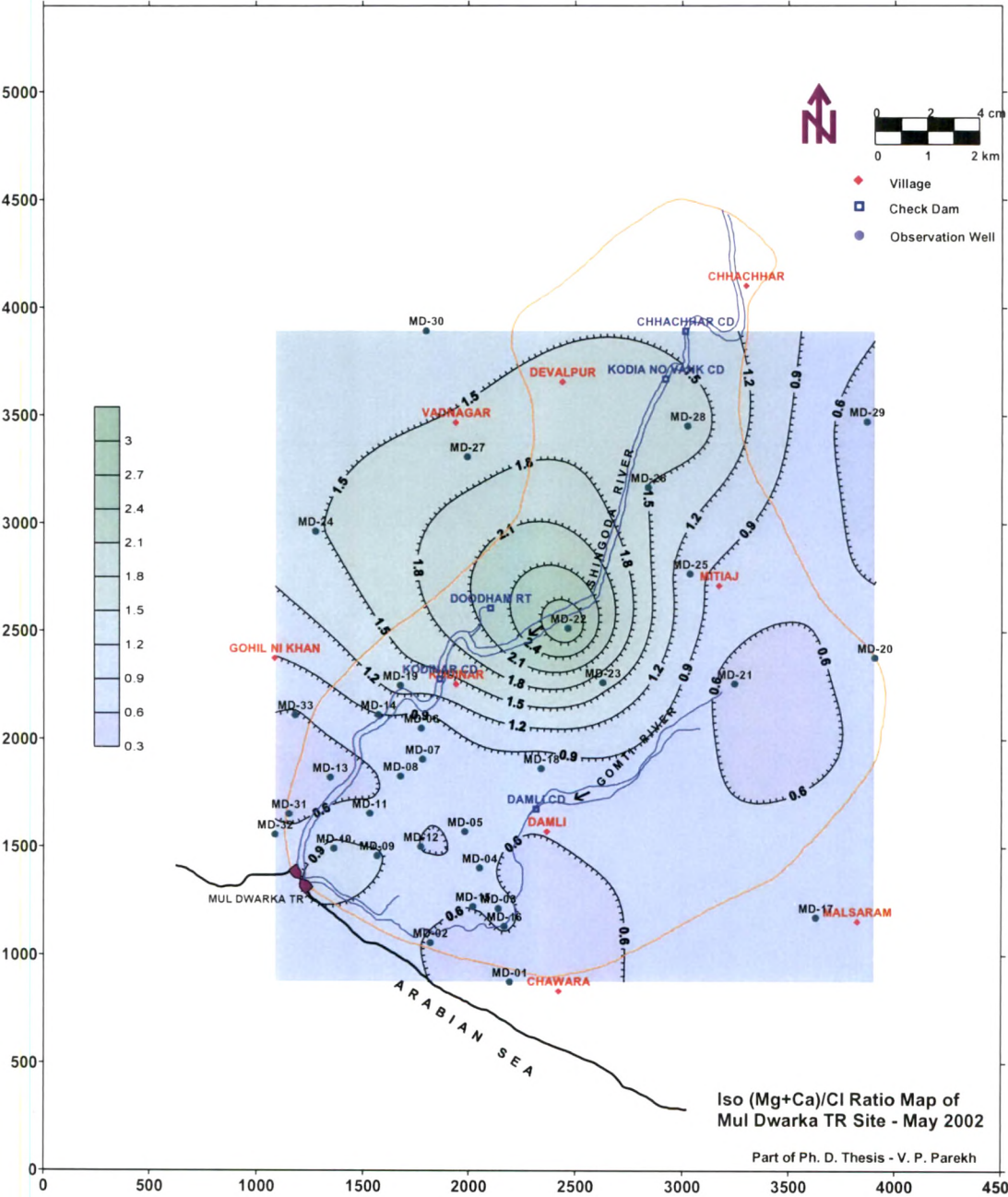
Map 5.48: Iso Na/Cl Ratio Map for Mul Dwarka TR – May 1997



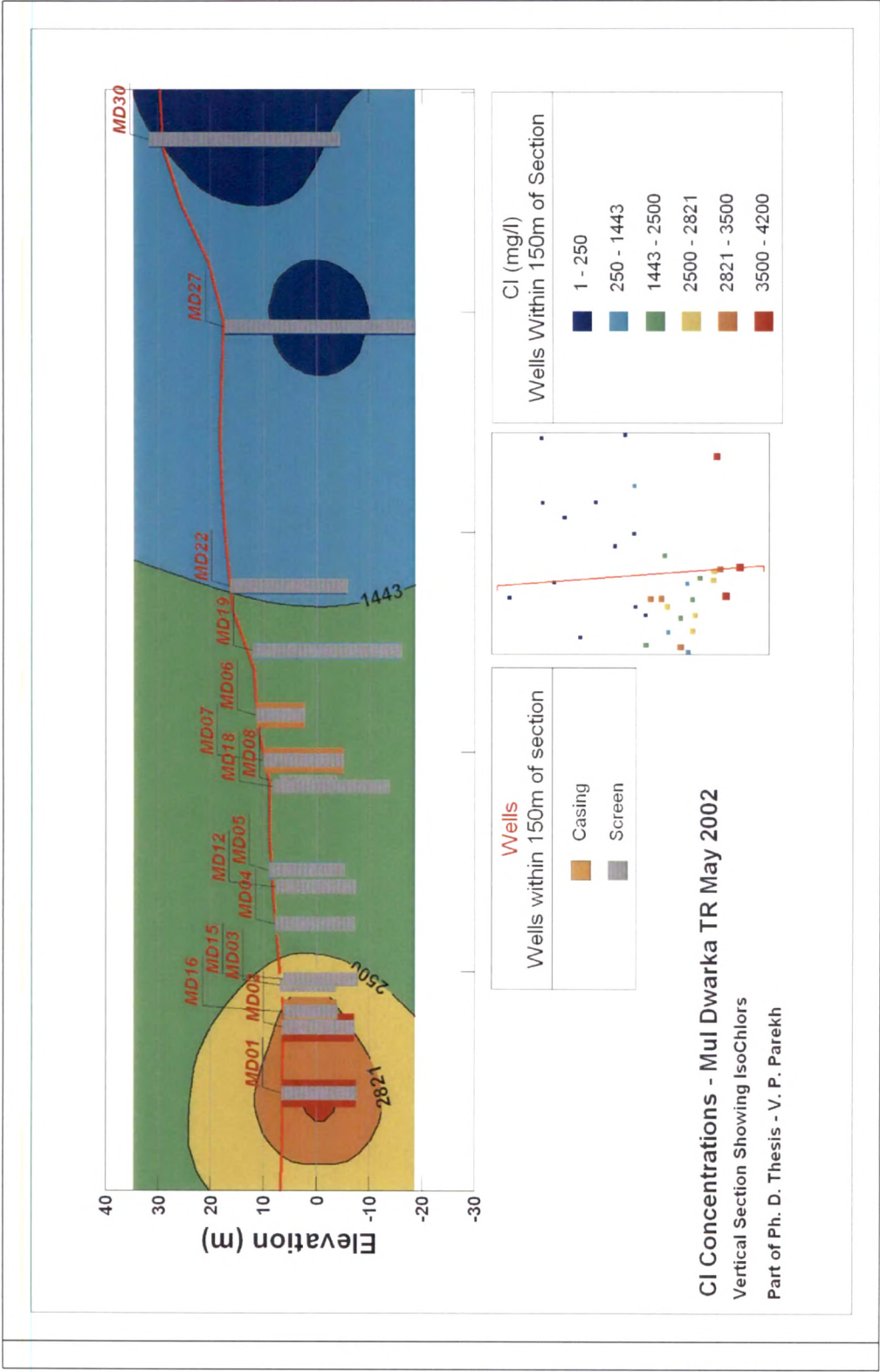
Map 5.49: Iso Na/Cl Ratio Map for Mul Dwarka TR – November 1997







Map 5.52: Iso (Mg+Ca)/CI Ratio Map for Mul Dwarka TR – May 2002



Map 5.53: Section Showing Cl- Concentration at Mul Dwarka TR for May 2002

5.4.6 Interpretation of Geohydrological & Geochemical Maps for Mul Dwarka TR

5.4.6.1 Water Levels

Total rainfall of year 1996 was 1160 mm and 2001 was 568 mm. Outcrops of highly cavernous Miliolite Limestone occur near the site. From Pumping test permeability of the Miliolite Limestone in this area found to be 13.917 m/day.

(Map 5.37 to 5.40) In RWL Map for the May 1997, almost closed contour of MSL (0 m) is observed. Its distance from structure varies from 3900 m to 7300 m inland. It indicates that upto approximately 5.0 km inland there is reversal of hydraulic gradient. However on the both side TR this distance is very less. The distance maximizes near the town Kodinar. One of the reasons is heavy withdrawal of groundwater in and around the Kodinar town. It should be noted that very famous Ambuja Cement Works factory and Kodinar Sugar Factory is situated in the vicinity of Kodinar town. Jetty of Ambuja Cement Works is located in the village Mul Dwarka itself in the vicinity of Mul Dwarka TR on left bank. Moreover farmers of Kodinar and surrounding talukas are growing Sugarcane, which requires ample irrigation water to grow and groundwater is the only handy resource for all the above activities. The situation after monsoon season is quite improving and watertable ranges between 0 to 5m nearer to the coasts shown in map 5.40. In May 2002 the situation went more deteriorating and the line of MSL (0 m) move further inland and approaches a distance of approximately 9500m. Less rainfall in preceding season and high requirement of freshwater is the main reason for this. On both the side of river there is declining of watertable by 8 to 10m below MSL.

5.4.6.2 Water Quality

Chloride (Map 5.41 to 5.44)

Isochlor map of Mul Dwarka TR for the season May 1997 and 2002 shows zone of transition (i.e Cl⁻ ranges between 250 mg/l to 2500 mg/l) from well MD-22 to MD-03. Well MD-03 is at distance of 4600m from structure but from coast it is located at a distance of 2000m, while well MD-22 is located at a distance of 7500m from coast. It means that transition zone extends between 2000m to 7500m from coast. There is no much more difference in water quality is observed from 1997 to 2002, which reflects the efficacy of Mul Dwarka TR as far as seawater intrusion is concern and this structure succeeds in maintaining the stagnant situation despite of variable & erratic rainfall. The same pattern is also observed in IsoTDS map for the season may 1997 and May 2000. Line of 2000 mg/l TDS is passing almost at the same distance from coast, which indicated no variation in water quality.

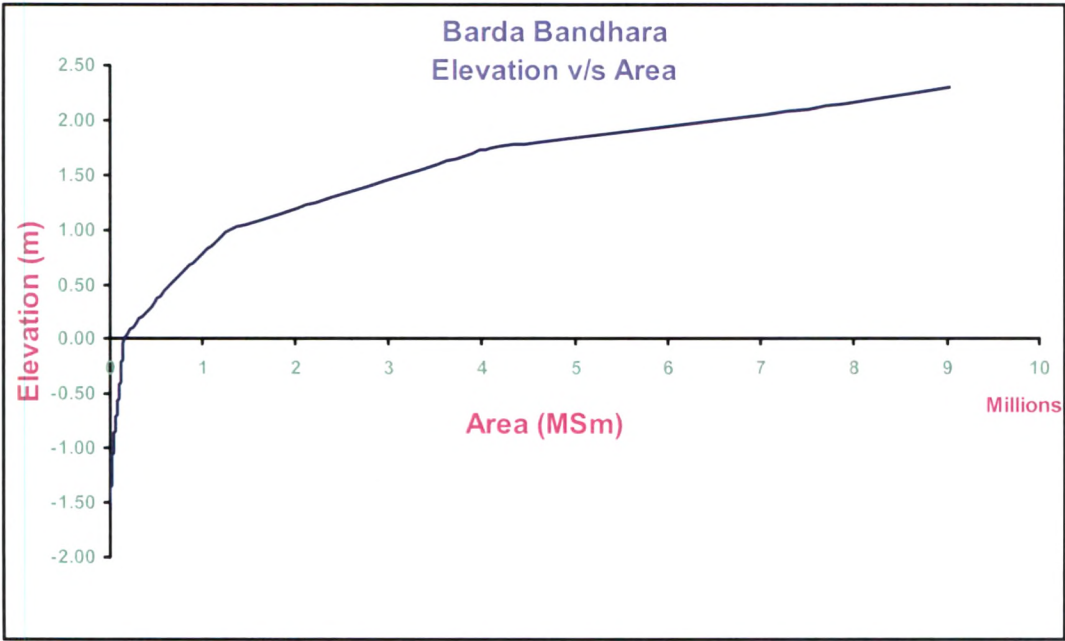
Ion Ratios

Map 5.48 to 5.50 shows the sodium-to-chloride molar ratio for the seasons May 1997 to May 2002. These maps show no change in pattern of 0.86 molar line for sodium-to-chloride ratio. The ratio is not found to be decreasing as compared to 1997. It indicates that there is no new seawater intrusion has taken place. However in the upper reaches the sodium content is found to be very high. In arid and semi-arid regions, as soil solution becomes concentrated through evaporation or transpiration, the solubility limits of calcium carbonate and magnesium carbonate are exceeded, with a corresponding increase in the relative proportion of sodium in the soil solution. Hence, a part of exchangeable calcium and magnesium is replaced by sodium, increasing the sodium content.

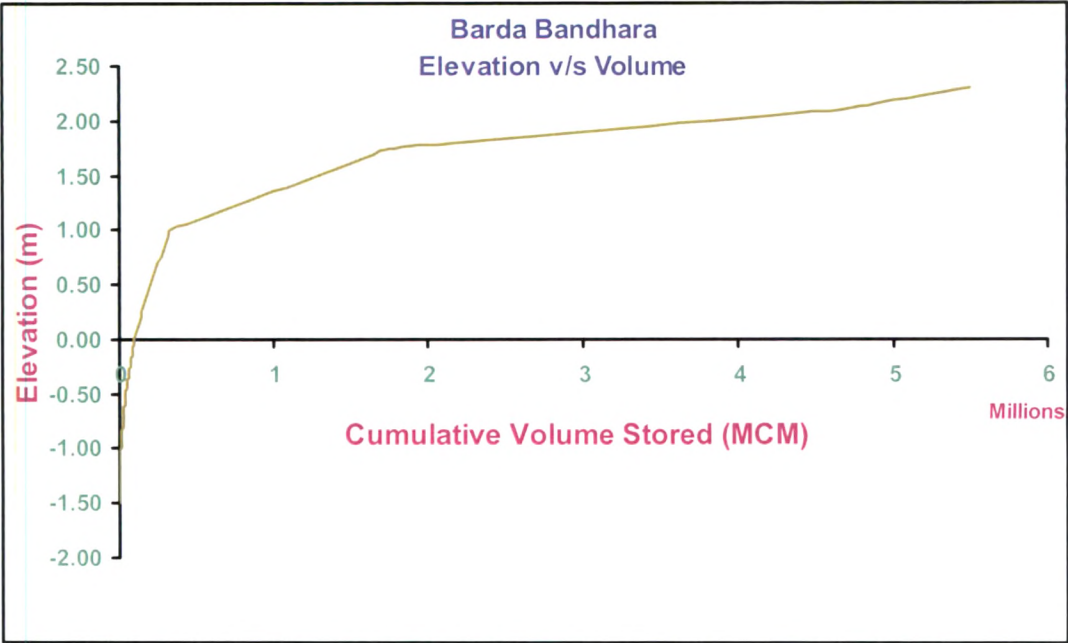
Zone of Transition and Interface line for the Mul Dwarka TR area is developed in the Map 5.53 Well MD-27 (Cl = 192 mg/l) is located 9 km inland from coast. Well MD-03, MD-04 & MD-15 (Cl > 2500 mg/l) are located at an average distance of 2.0 km inland from coast. From sectional view it is visualized that zone of transition ranges from 2.0 km to 9 km. The area having Cl > 2500 mg/l is termed as seawater intruded zone that lies from coast to 2 km inland and contour line of 2500 mg/l in sectional view indicates probable seawater-freshwater interface.

5.5 Analysis of Barda Bandhara

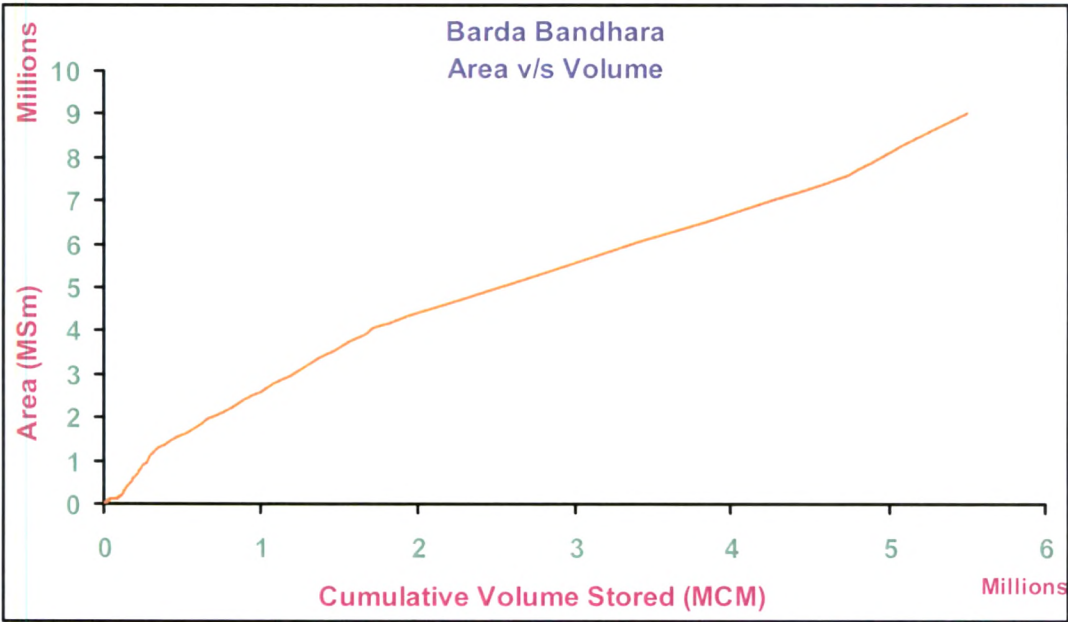
5.5.1 Graphs Showing Relation between Elevation, Area and Cumulative Volume Stored for Barda Bandhara



Graph 5.46: Relation between Elevation v/s Area for Barda Bandhara (Table 4.36)



Graph 5.47: Relation between Elevation v/s Volume for Barda Bandhara (Table 4.36)



Graph 5.48: Relation between Area v/s Volume for Barda Bandhara (Table 4.36)

5.5.2 Calculation of Recharge Rate, Volume of water Stored & Volume of Water Recharged for Barda Bandhara

Rainfall, Water-level fluctuation and evaporation rate for every week at Barda Bandhara site was observed for four years and tabulated in table 4.37 Using these data in conjunction with elevation storage data, recharge rate in mm/day is worked out (Table 5.28 to 5.31). From the results obtained graph of Recharge rate v/s time (5.49) is drawn and Cumulative days v/s recharge rate graph for each year is plotted on log-log graph (5.50 to 5.53) to get recharge rate equation.

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Vol of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Vol. Of Evaporation (M ³)	Vol. Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
23/6/99	203	1.30	899846	-	-	2406304	-	-	2470803	
30	0	1.03	391009	508837	4.0	1393566	55743	453094	1431717	45.210
Jul 7	0	0.60	222240	168769	4.3	763182	32817	135953	784770	24.748
14	32	0.31	158132	64108	4.2	449498	18879	45229	462490	13.971
21	140	1.00	334472		3.6	1281040			1316192	
28	Nil	0.50	194182	140290	4.0	633717	25349	114941	651778	25.193
Aug 4	Nil	0.20	137261	56921	4.0	342845	13714	43208	352834	17.494
11	Nil	0.06	110697	26563	4.1	207104	8491	18072	213200	12.109
18	Nil	-0.10	86989	23709	4.0	138991	5560	18149	143129	18.115
25	Nil	-0.25	68502	18487	4.2	124084	5212	13275	127817	14.838
Sep 1	7	-0.36	54944	13557	3.9	113151	4413	9144	116582	11.205
8	Nil	-0.49	38922	16022	4.0	100231	4009	12013	103298	16.613
15	Nil	-0.65	28273	10649	4.1	79685	3267	7382	82150	12.838
22	50	-0.77	20739	7534	4.1	64043	2626	4908	66040	10.617
	432		1846364	1055447			180078	875369	Avg. =	18.579

Table 5.28: Recharge Rate Calculation for Barda Bandhara – Year 1999 (Refer Graph 5.49)

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
18/6/01	216	1.35	994075	-	-	2593848	-	-	2663099	
25	Nil	1.05	428701	565374	4.0	1468584	58743	506631	1508726	47.971
Jul 2	10	0.75	264327	164374	4.1	957378	39253	125121	984156	18.162
9	262	1.40	1088304	-	-	2781392	-	-	2855355	
16	16	1.75	1747907	-	-	4094200	-	-	4200035	
23	Nil	1.45	1182533	565374	3.9	2968936	115789	449585	3047571	21.075
30	7	1.25	805617	376916	4.1	2218760	90969	285947	2278467	17.929
Aug 6	2	1.09	504084	301533	4.1	1618619	66363	235169	1662725	20.205
13	29	0.95	320443	183641	4.0	1216308	48652	134989	1249812	15.430
20	20	1.40	1088304	-	-	2781392	-	-	2855355	
27	Nil	1.18	673696	414608	3.9	1956198	76292	338316	2009130	24.056
Sep 3	Nil	1.02	372164	301533	4.0	1356058	54242	247290	1393210	25.357
10	Nil	0.62	227852	144312	4.0	789075	31563	112749	811362	19.852
17	Nil	0.32	160029	67822	4.1	459194	18827	48995	472456	14.815
24	3	0.11	120184	39845	3.9	255583	9968	29877	263079	16.224
Oct 1	Nil	0.00	99313	20871	3.9	148930	5808	15063	153332	14.034
8	Nil	-0.13	83291	16022	3.8	136010	5168	10854	140068	11.070
15	3	-0.25	68502	14790	3.9	124084	4839	9950	127817	11.121
22	Nil	-0.38	52480	16022	3.8	111163	4224	11798	114539	14.715
29	Nil	-0.50	37690	14790	3.8	99237	3771	11019	102276	15.391
Nov 5	Nil	-0.65	28273	9417	3.7	79685	2948	6469	82150	11.249
12	Nil	-0.78	20112	8161	3.6	62739	2259	5903	64697	13.034
	568		10367882	3225404			639679	2585725	Avg. = 18.427	

Table 5.29: Recharge Rate Calculation for Barda Bandhara – Year 2001 (Refer Graph 5.49)

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
26/8/02	402	1.14	598313	-	-	1806163	-	-	1855188	
Sep 2	6	0.79	275550	322763	4.1	1009164	41376	281387	1037305	38.753
9	Nil	0.39	173311	102239	4.1	527064	21610	80630	542208	21.244
16	Nil	0.10	118287	55024	4.2	245887	10327	44697	253104	25.228
23	29	-0.05	93151	25136	4.1	143961	5902	19234	148231	18.536
30	Nil	-0.25	68502	24649	4.0	124084	4963	19686	127817	22.002
Oct 7	Nil	-0.40	50015	18487	3.9	109176	4258	14229	112495	18.069
	437		1377129	548299			88436	459862	Avg. = 23.972	

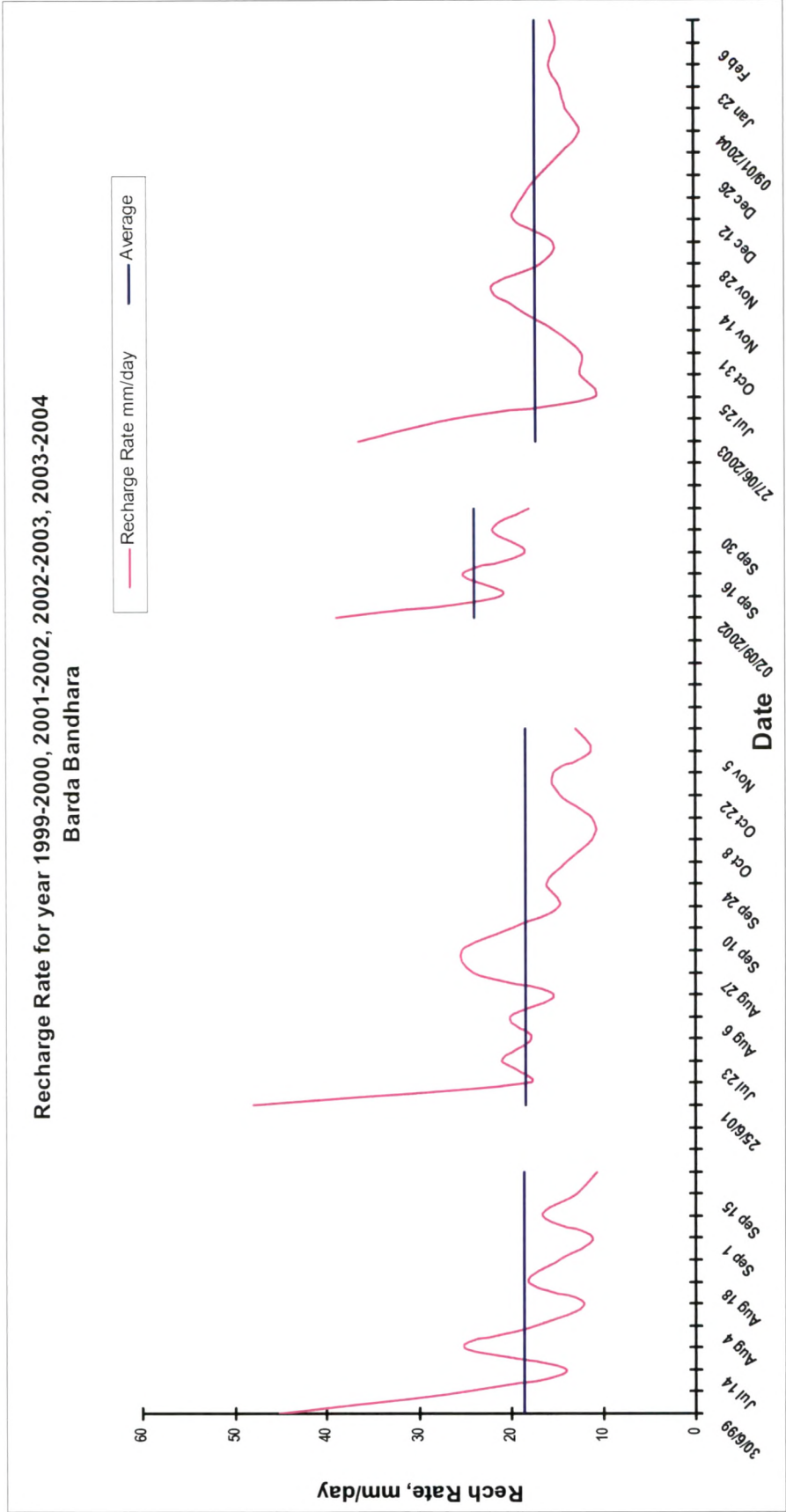
Table 5.30: Recharge Rate Calculation for Barda Bandhara – Year 2002 (Refer Graph 5.49)

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
20/6/03	264	2.10	4672467	-	-	7508450	-	-	7696972	
27	Nil	1.90	3001290	1671177	4.0	5557450	222298.00	1448879.14	5699343	36.317
Jul 4	21	1.78	1998584	1002706	4.1	4386850	179860.85	822845.44	4499971	26.122
11	119	1.85	2583496	-	-	5069700	-	-	5199677	-
18	64	2.20	5083332	-	-	8267875	-	-	8473712	-
25	70	2.05	4254673	828659	4.0	7020700	280828.00	547830.79	7197720	10.873
Aug 1	29	1.95	3419084	835589	5.0	6045200	302260.00	533328.57	6198905	12.291
8	388	2.30	5494196	-	-	9027300	-	-	9250130	
15	15	2.30	5494196	-	-	9027300	-	-	9250130	
22	3	2.30	5494196	-	-	9027300	-	-	9250130	-
29	77	2.30	5494196	-	-	9027300	-	-	9250130	-

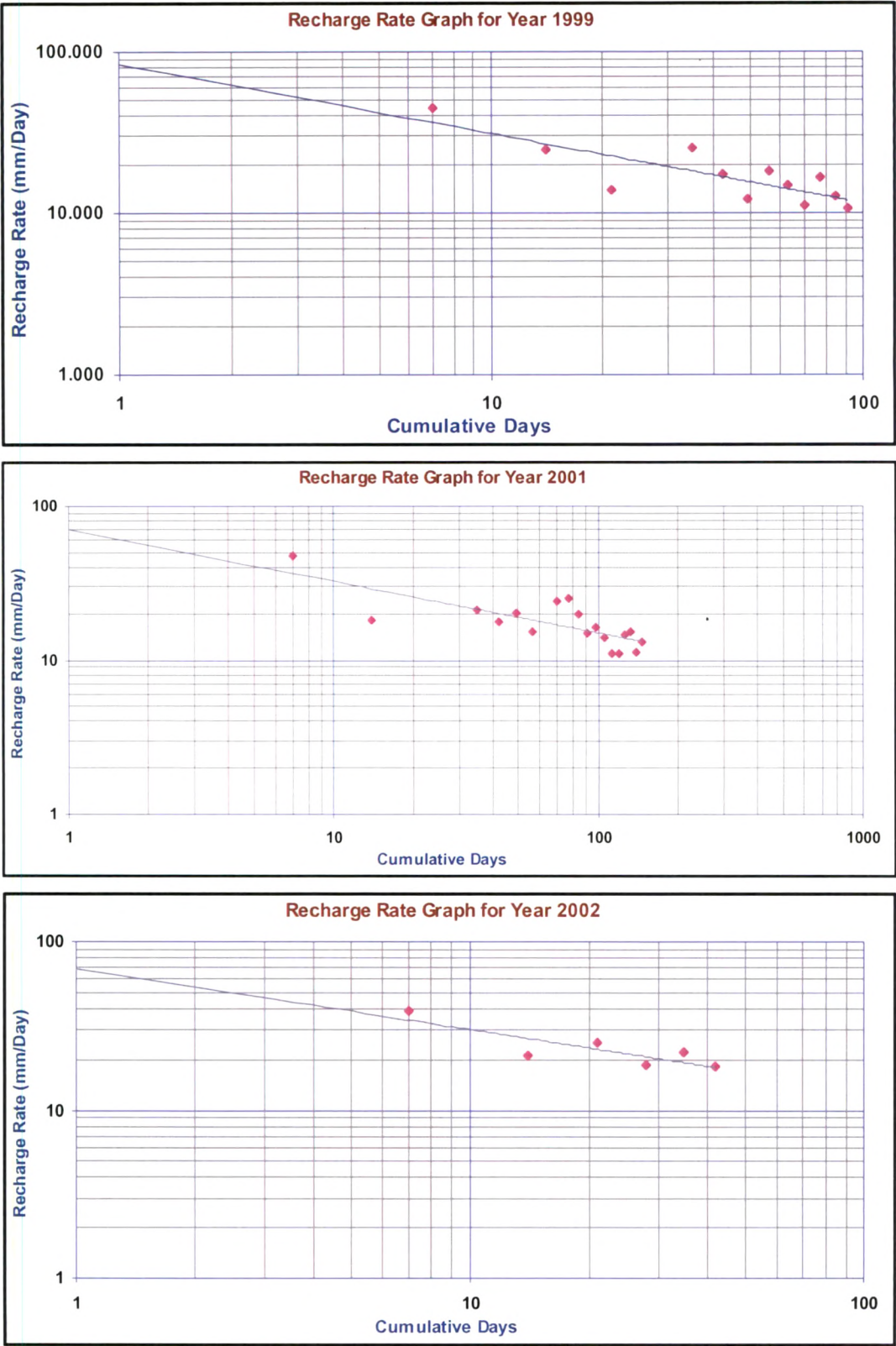
Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
Sep 5	55	2.30	5494196	-	-	9027300	-	-	9250130	-
12	6	2.30	5494196	-	-	9027300	-	-	9250130	-
19	Nil	2.30	5494196	-	-	9027300	-	-	9250130	-
26	Nil	2.30	5494196	-	-	9027300	-	-	9250130	-
Oct 3	94	2.30	5494196	-	-	9027300	-	-	9250130	-
10	Nil	2.30	5494196	-	-	9027300	-	-	9250130	-
17	Nil	2.30	5494196	-	-	9027300	-	-	9250130	-
24	Nil	2.30	5494196	-	-	9027300	-	-	9250130	-
31	Nil	2.09	4588908	905288	3.4	7410900	251970.60	653317.26	7597130	12.285
Nov 7	Nil	1.98	3669761	919147	3.7	6337850	234500.45	684646.98	6498593	15.050
14	Nil	1.87	2750613	919147	3.6	5264800	189532.80	729614.63	5399556	19.304
21	Nil	1.77	1915025	835589	3.7	4289300	158704.10	676884.47	4399997	21.977
28	Nil	1.56	1389837	525188	3.6	3381533	121735.18	403452.71	3470308	16.608
Dec 5	Nil	1.36	1012921	376916	3.4	2631357	89466.13	287449.84	2701609	15.200
12	Nil	1.18	673696	339224	3.3	1956198	64554.55	274669.83	2009130	19.530
19	Nil	1.05	428701	244995	3.3	1468584	48463.27	196532.11	1508726	18.609
26	Nil	0.75	264327	164374	3.1	957378	29678.73	134695.21	984156	19.552
02/01/04	Nil	0.45	184695	79632	3.3	585238	19312.86	60318.99	601980	14.314
9	Nil	0.22	141056	43640	3.1	362236	11229.32	32410.42	372775	12.421
16	Nil	0.07	112595	28461	3.1	216800	6720.81	21739.89	223177	13.916
23	Nil	-0.05	93151	19444	3.1	143961	4405.20	15038.78	148231	14.494
30	Nil	-0.20	74664	18487	3.0	129053	3897.39	14589.57	132922	15.680
	1205		108345720	9788474			2225943	7562532	Avg. = 17.257	

Table 5.31: Recharge Rate Calculation for Barda Bandhara – Year 2003 (Refer Graph 5.49)

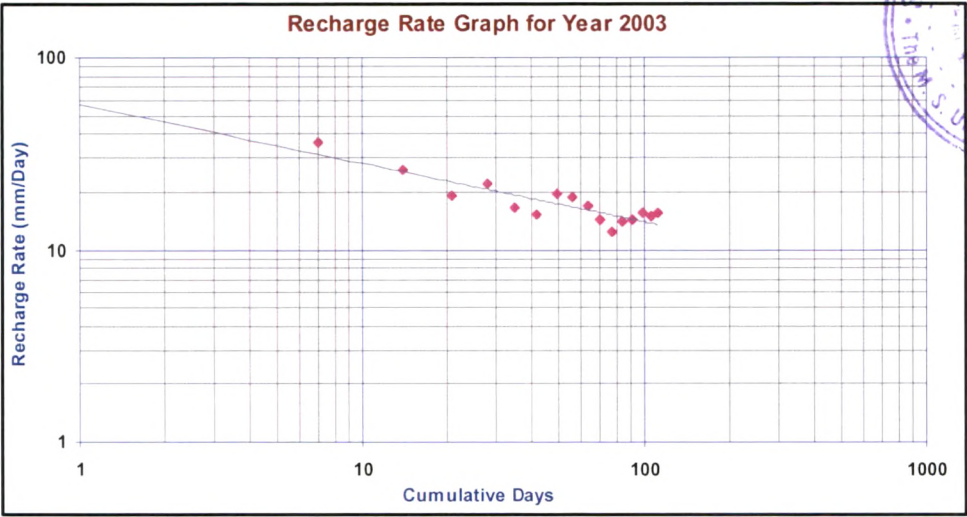
5.5.2.1 Recharge Rate Graphs and Equations for Barda Bandhara



Graph 5.49: Recharge Rate Graph for Barda Bandhara (Table 5.28 to 5.31)



Graph 5.50 to 5.52: Log-Log Graph for Recharge Rate v/s Cumulative Days for Barda Bandhara – Year 1999, 2001 & 2002



Graph 5.53: Log-Log Graph for Recharge Rate v/s Cumulative Days for Barda Bandhara – Year 2003

General equation for recharge rate is $I = \alpha T^\beta$

Recharge rate Formula for Barda Bandhara

Year	Intercept on Y axis (Rech. Rate)	Slope of graph
	α	β
1999	84.059	-0.4314
2001	69.995	-0.3338
2002	69.391	-0.3611
2003	57.051	-0.305
Average	70.124	-0.3578

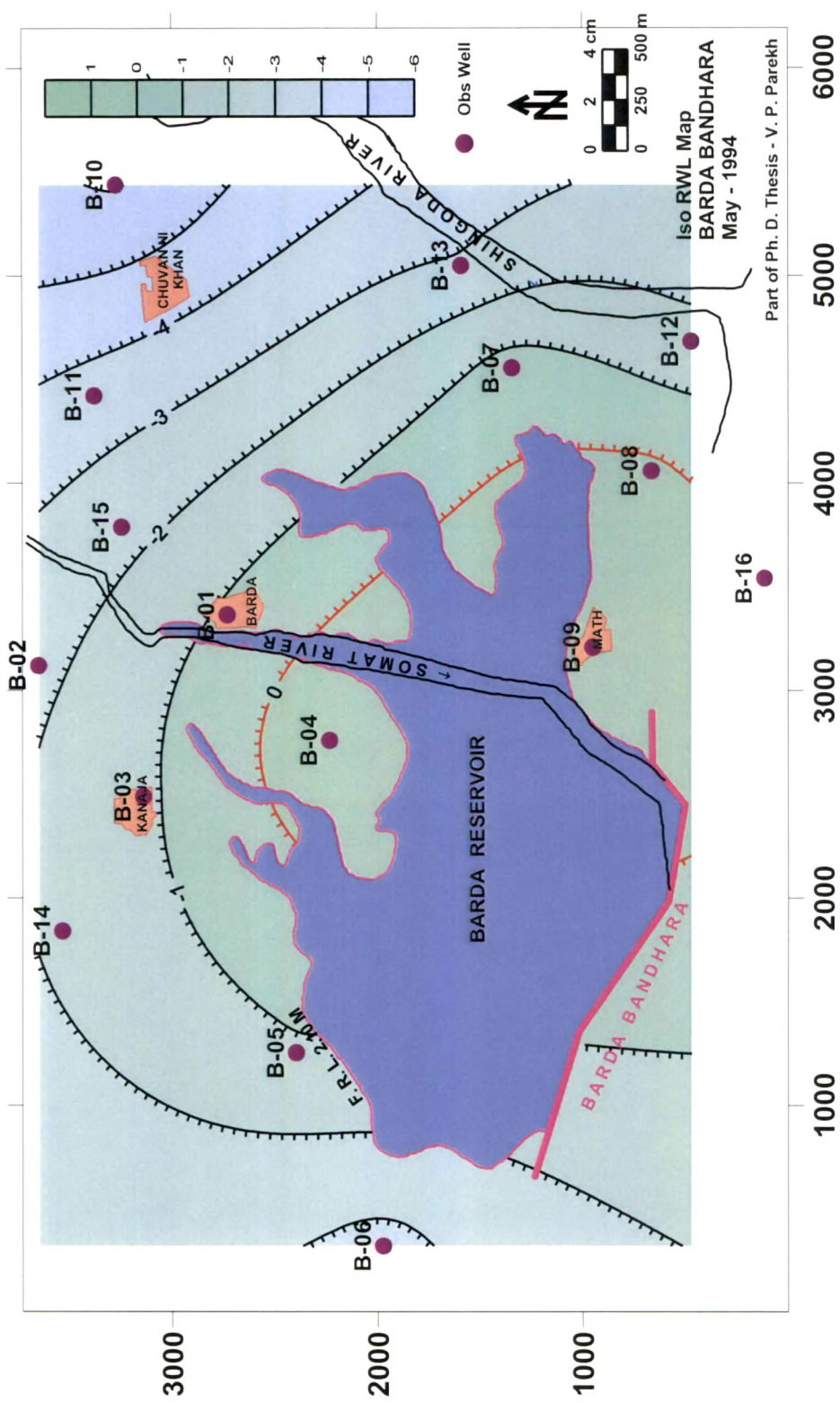
Table 5.32: Recharge Rate Equation for Barda Bandhara

So Recharge Rate Equation, $I = 70.124 T^{-0.3578}$

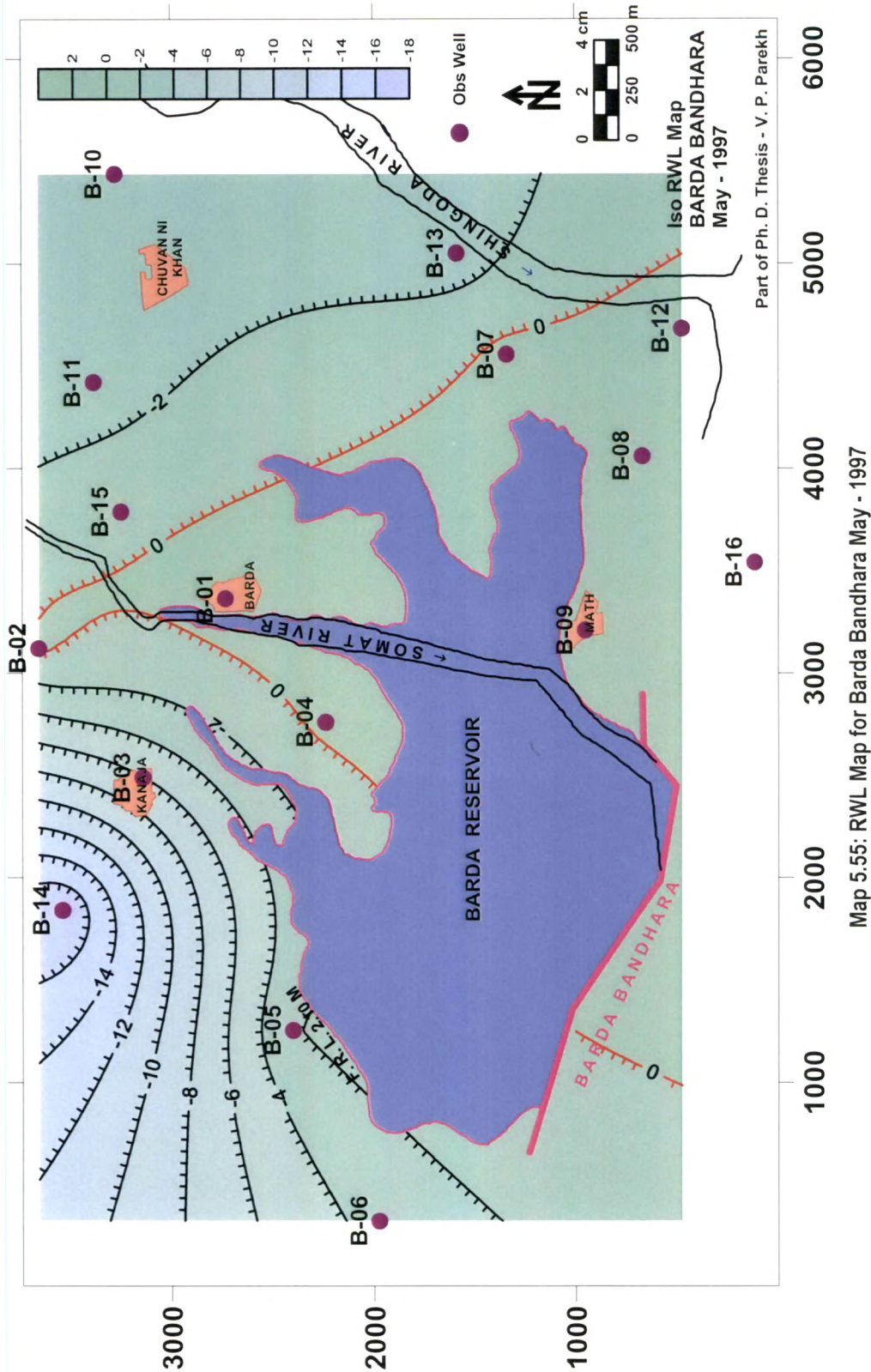
Where I = Recharge Rate mm/Day
 T = Time in Days

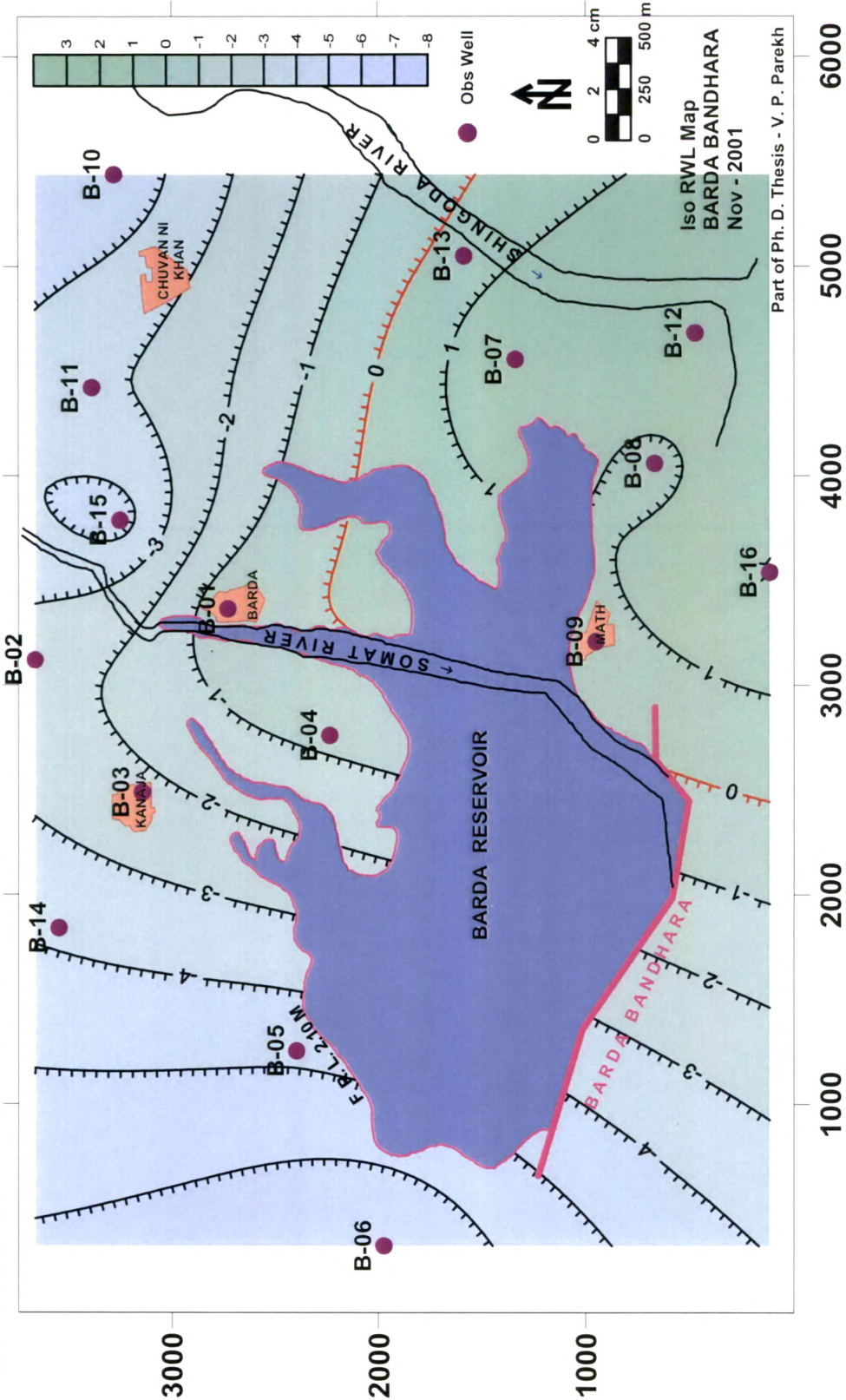
5.5.3 Geohydrological & Geochemical Analysis of Data Collected for Barda Bandhara

From the Geohydrological data collected from 16 observation wells surrounding the Barda Bandhara, RWL maps (Map 5.54 to 5.56) are plotted to study the pre-monsoon & post-monsoon groundwater flow pattern. Similarly from analyzed geochemical parameters IsoChlor Map 5.57 to 5.59 and IsoTDS Map 5.60 to 5.62 are prepared to study the variation of chloride and TDS in the study area. To study about fresh seawater intrusion or any leaching process in recent years, ion ratio maps of Na^+/Cl^- (Map 5.63 to 5.65) and $(Mg^{+}+Ca^{+})/Cl^-$ (Map 5.66 to 5.68) are plotted.

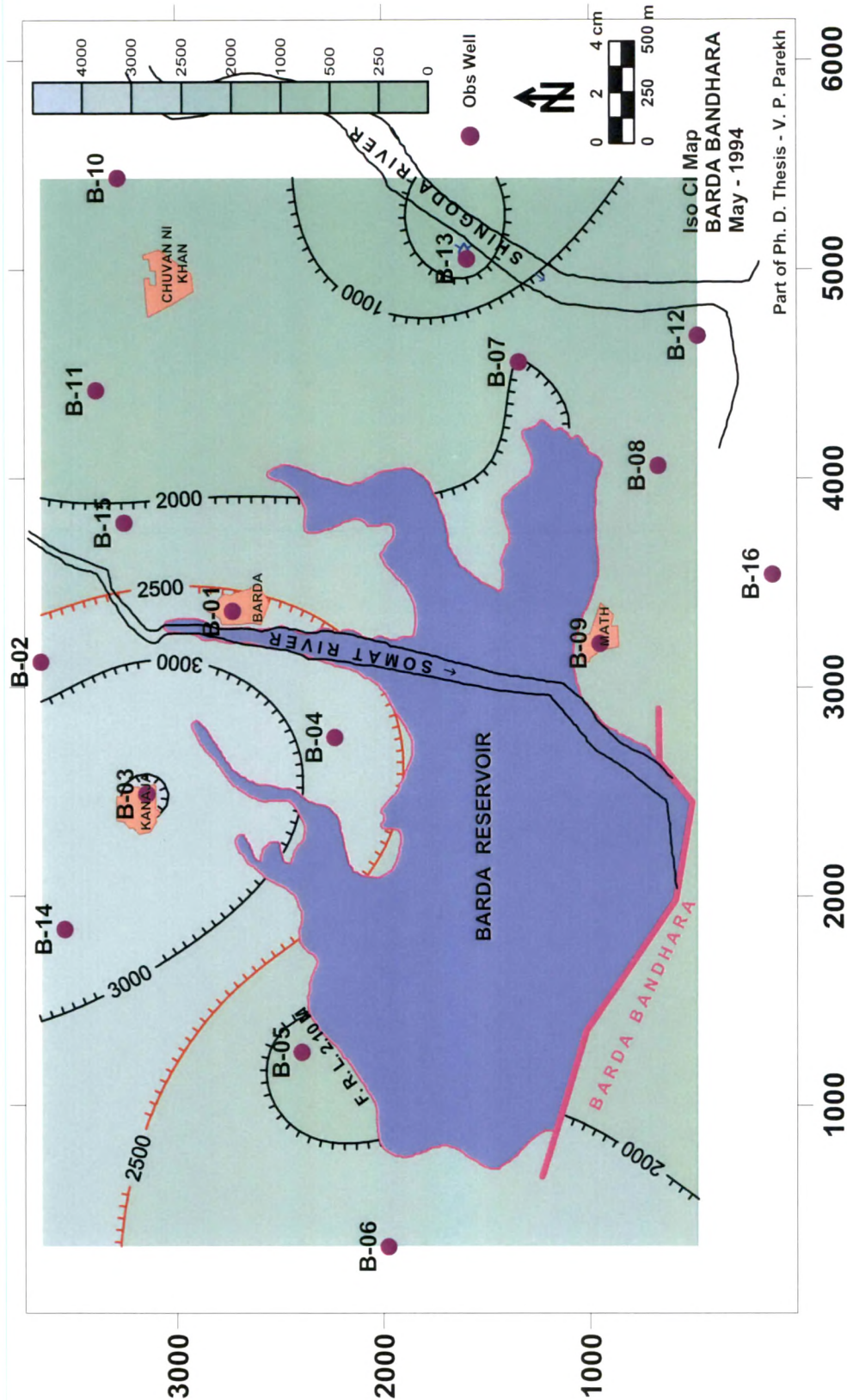


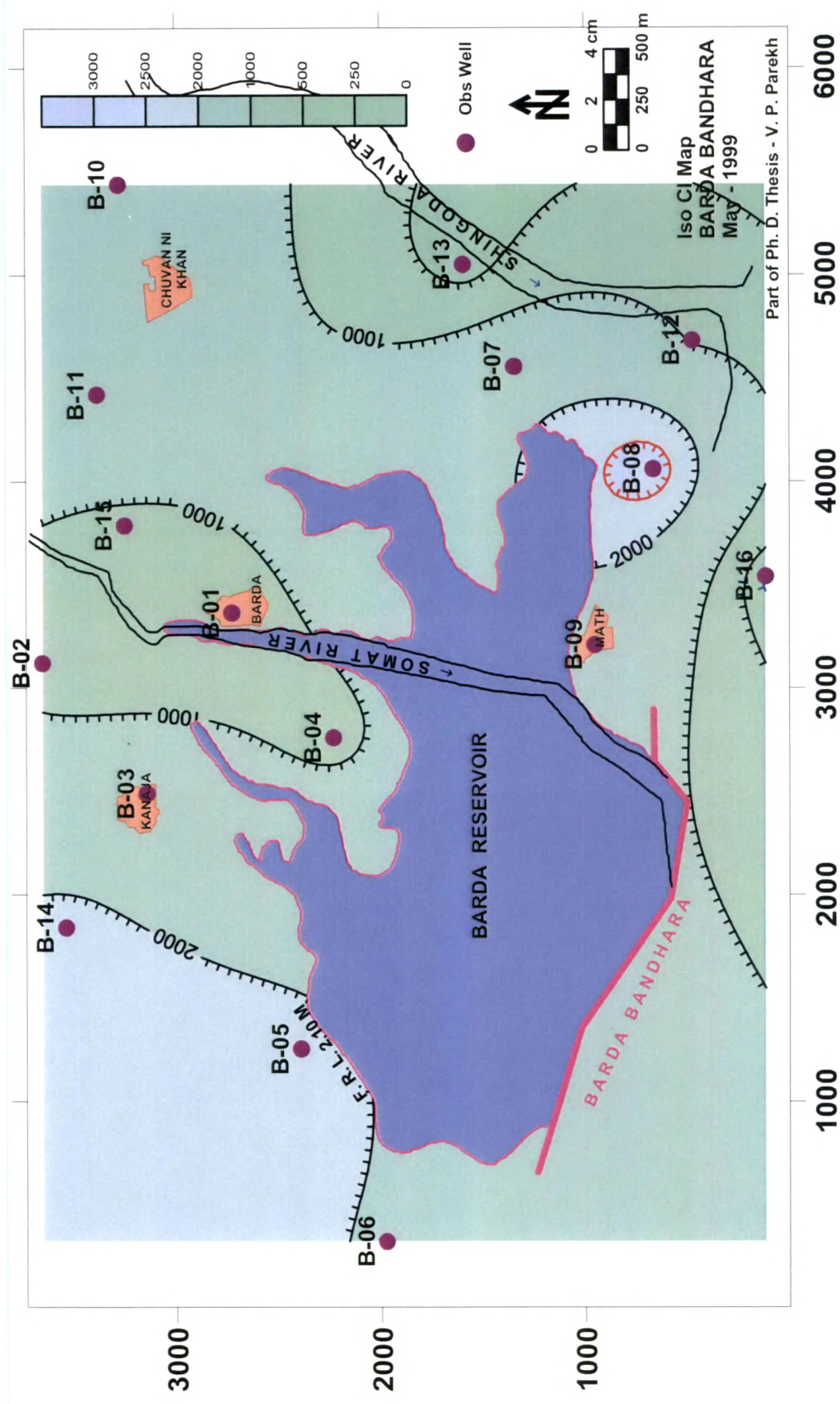
Map 5.54: RWL Map for Barda Bandhara May - 1994



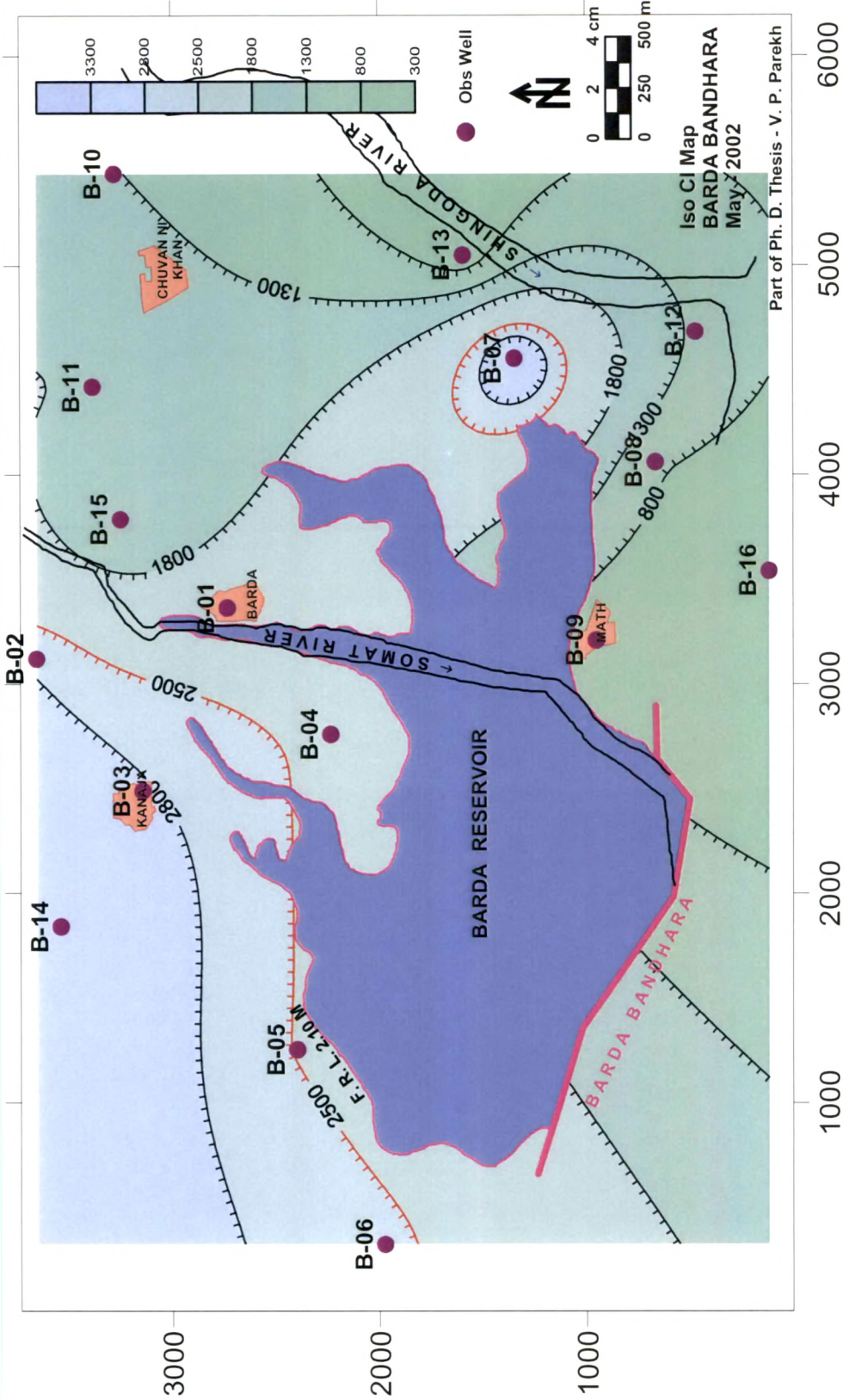


Map 5.56: RWL Map for Barda Bandhara November - 2001

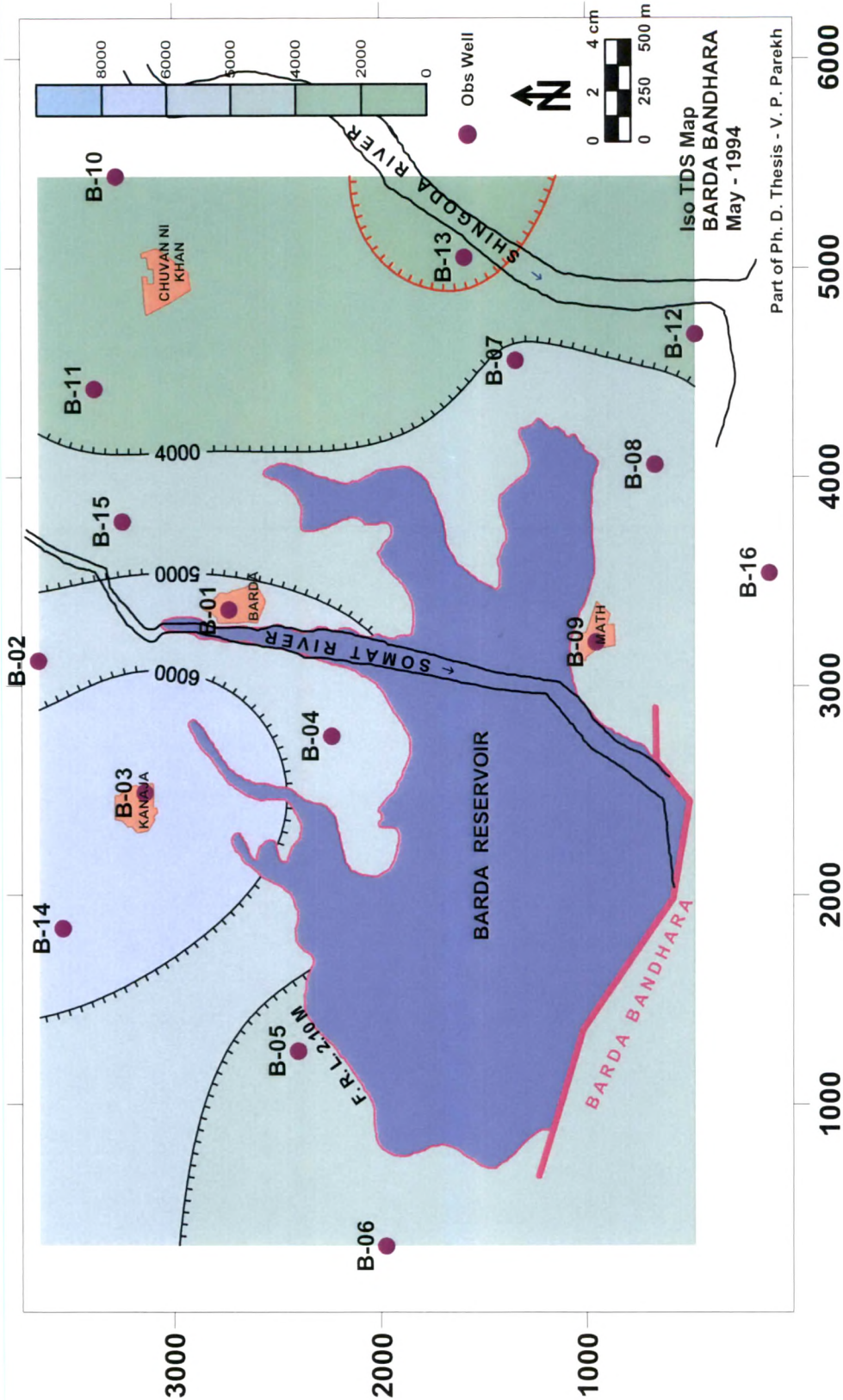




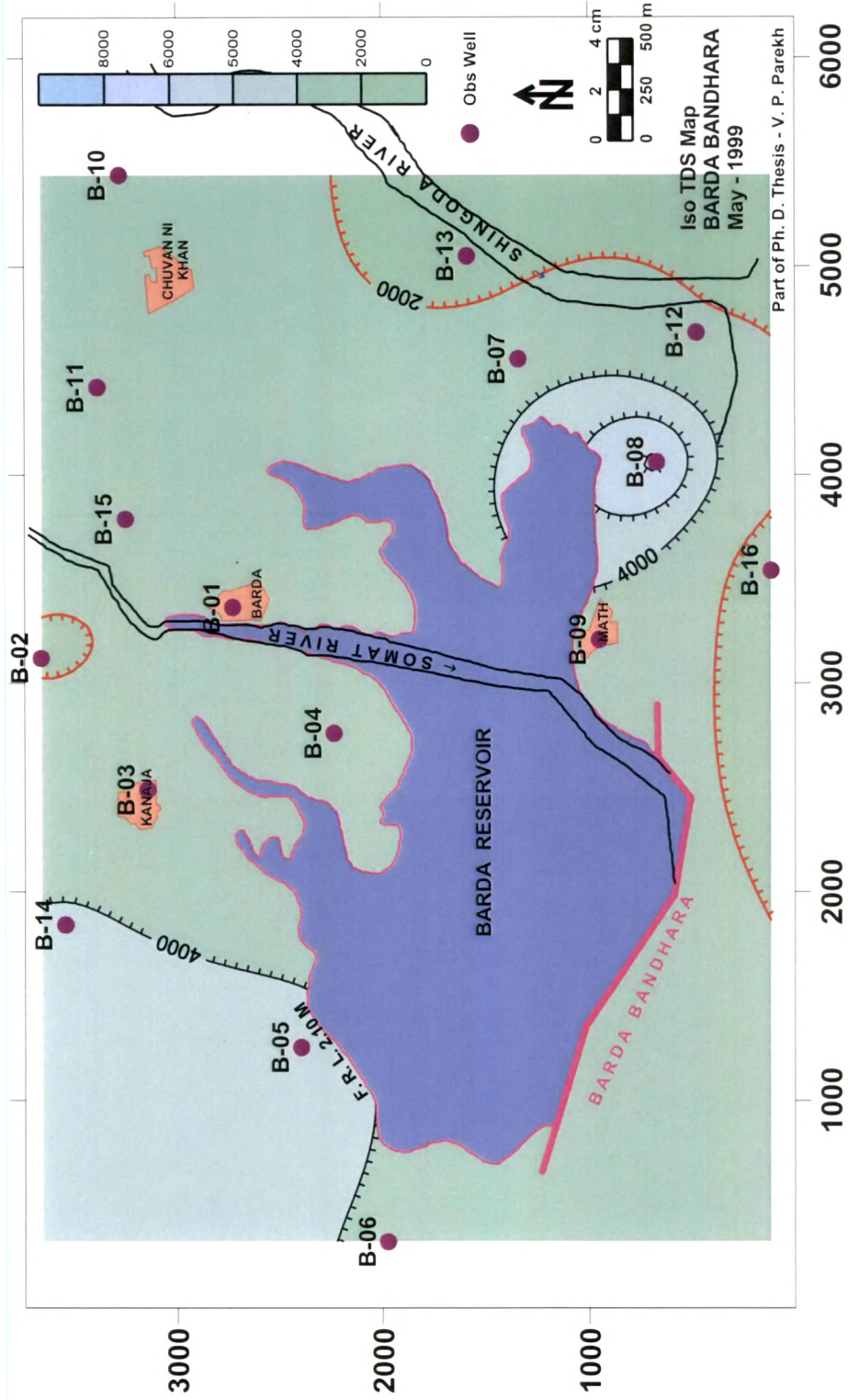
Map 5.58: Iso CI Map for Barda Bandhara May - 1999



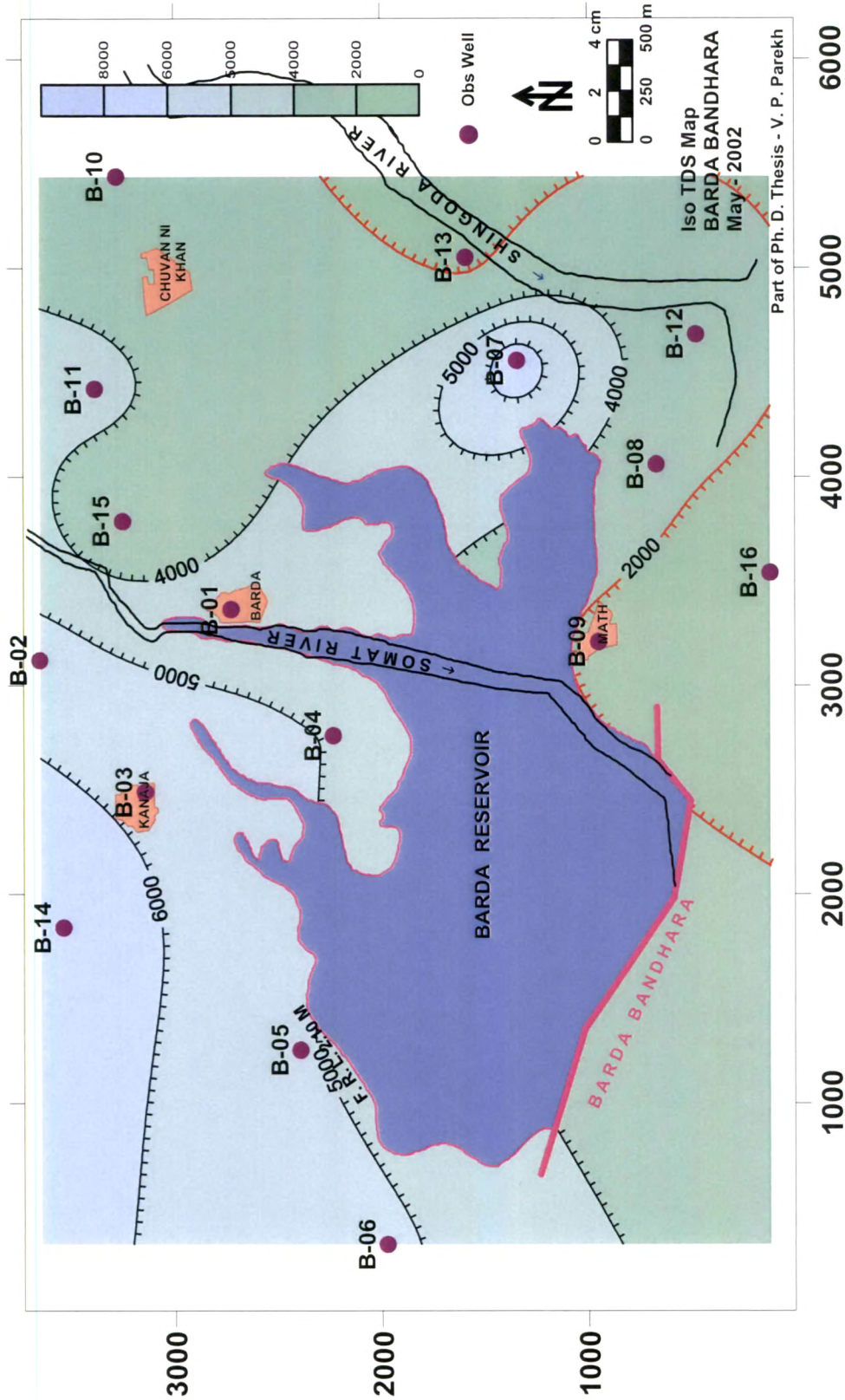
Map 5.59: Iso CI Map for Barda Bandhara May - 2002



Map 5.60: Iso TDS Map for Barda Bandhara May - 1994

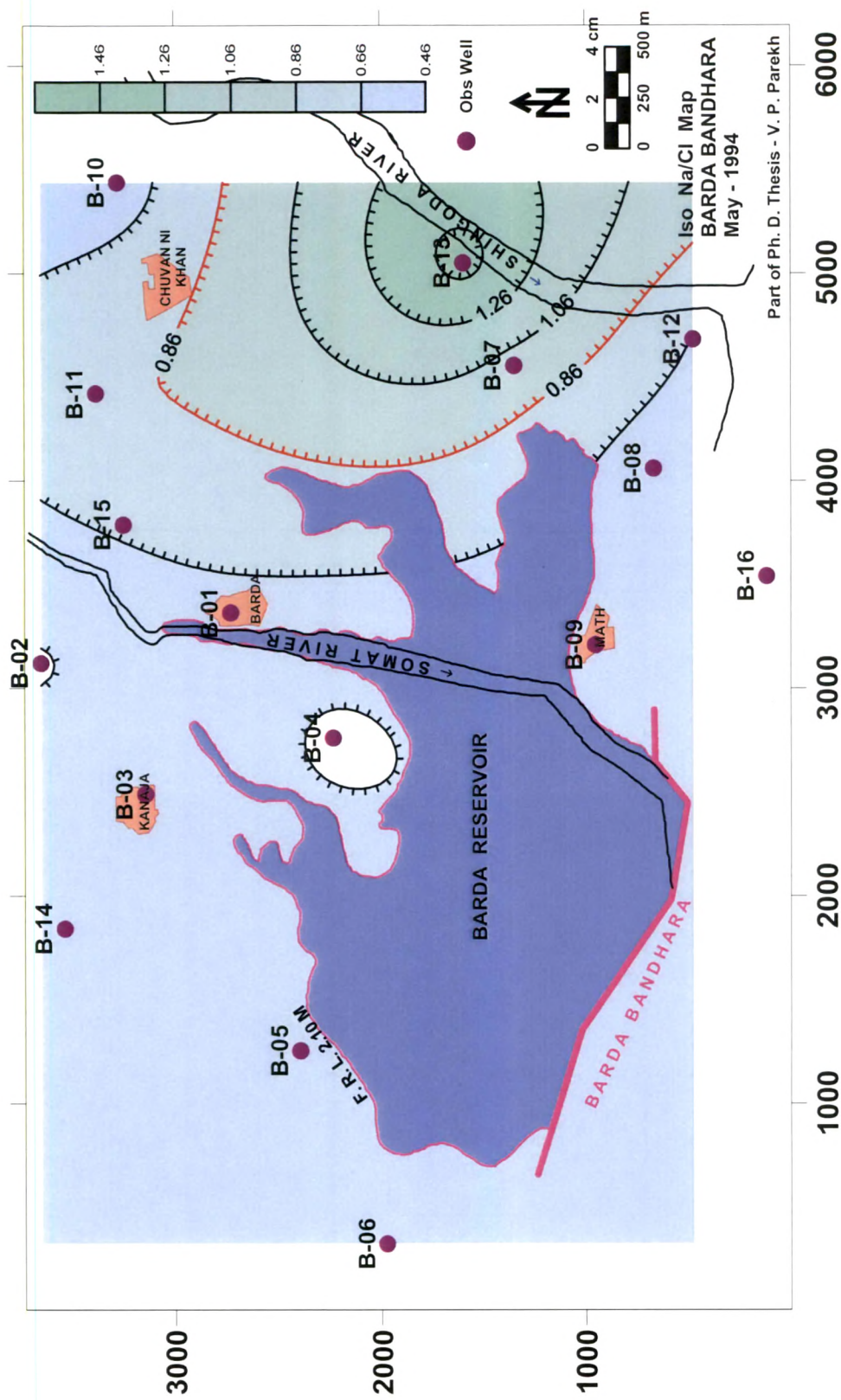


Map 5.61: Iso TDS Map for Barda Bandhara May - 1999

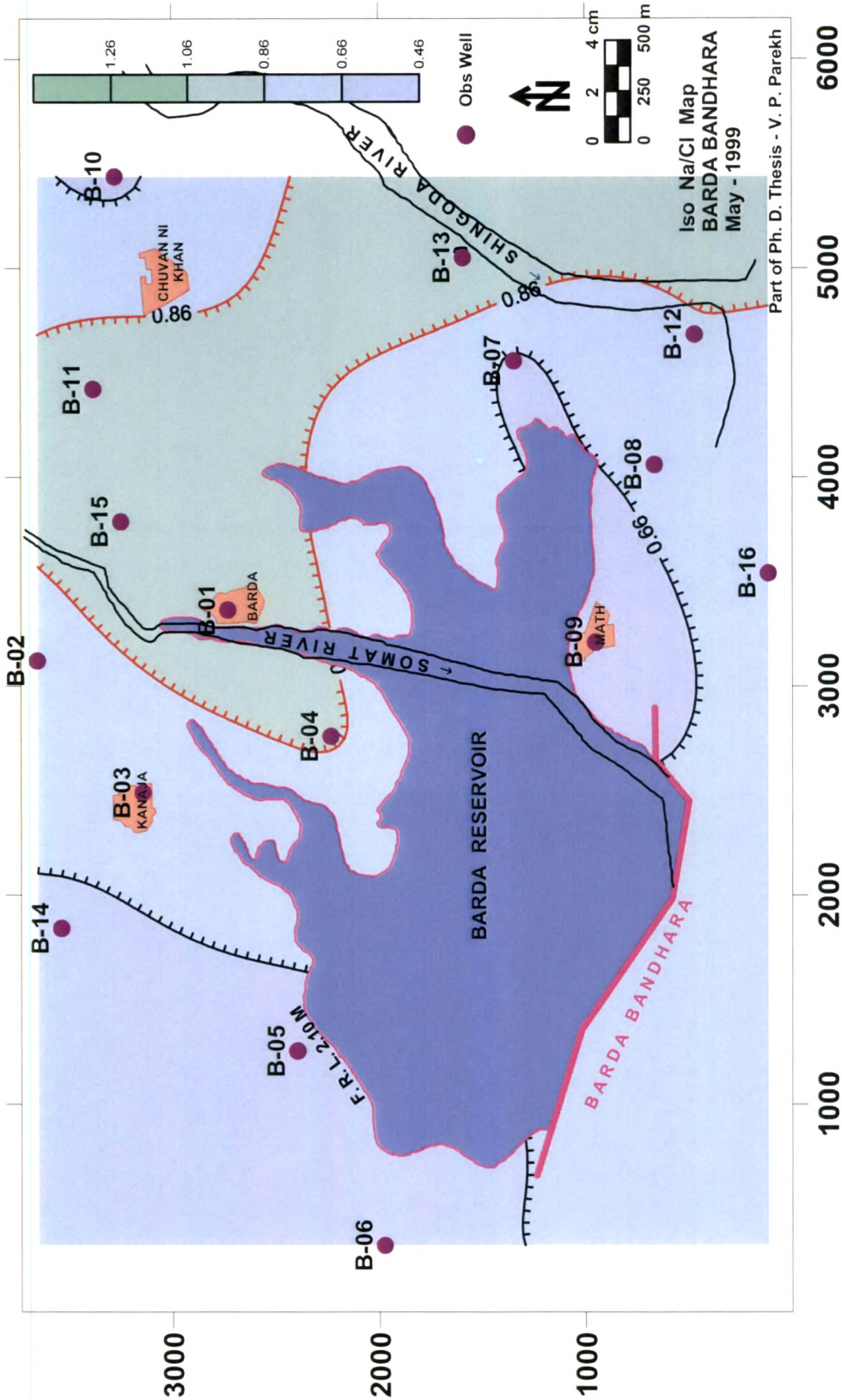


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Map 5.62: Iso TDS Map for Barda Bandhara May - 2002

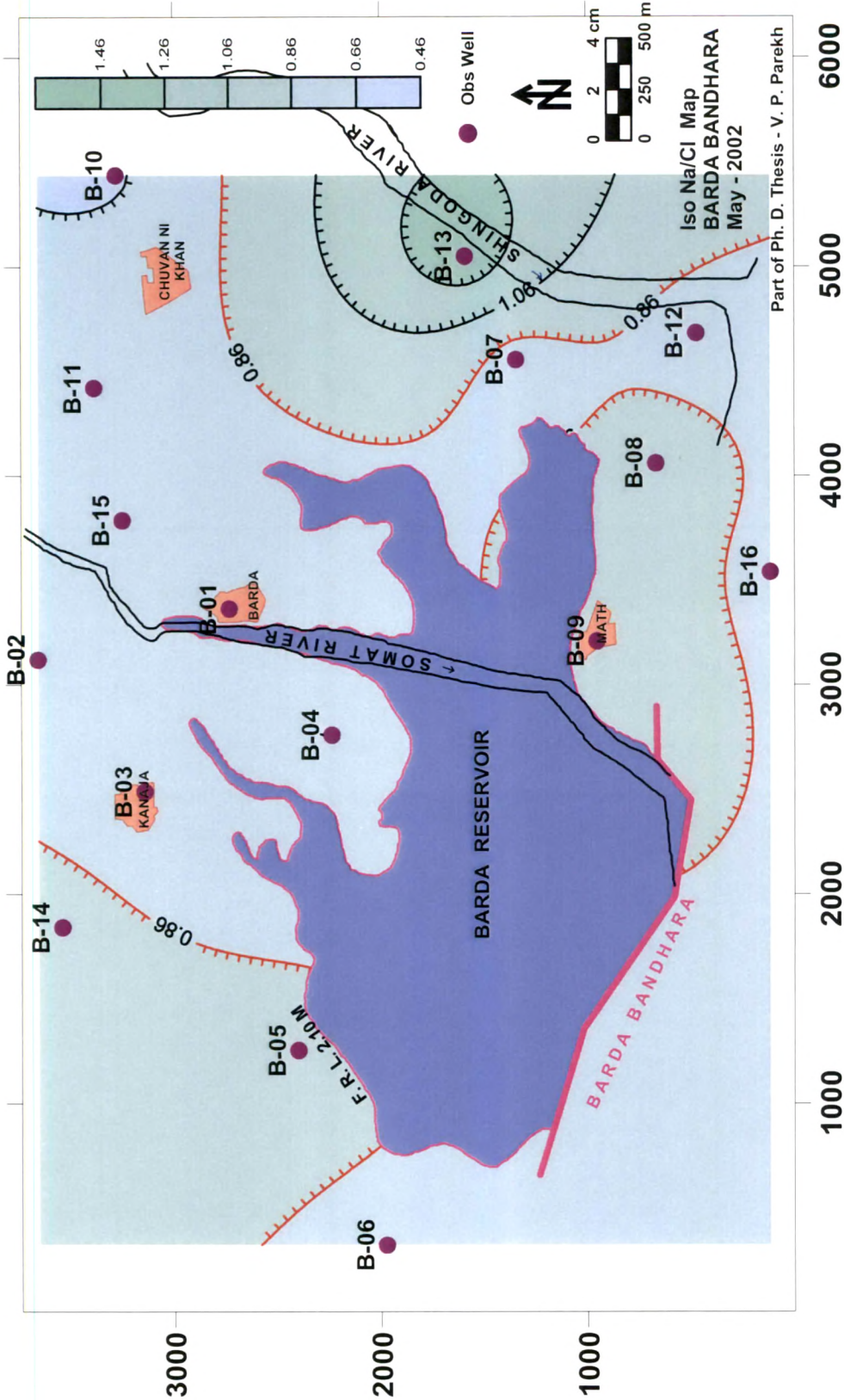


Map 5.63: Iso Na/Cl Ratio Map for Barda Bandhara May - 1994



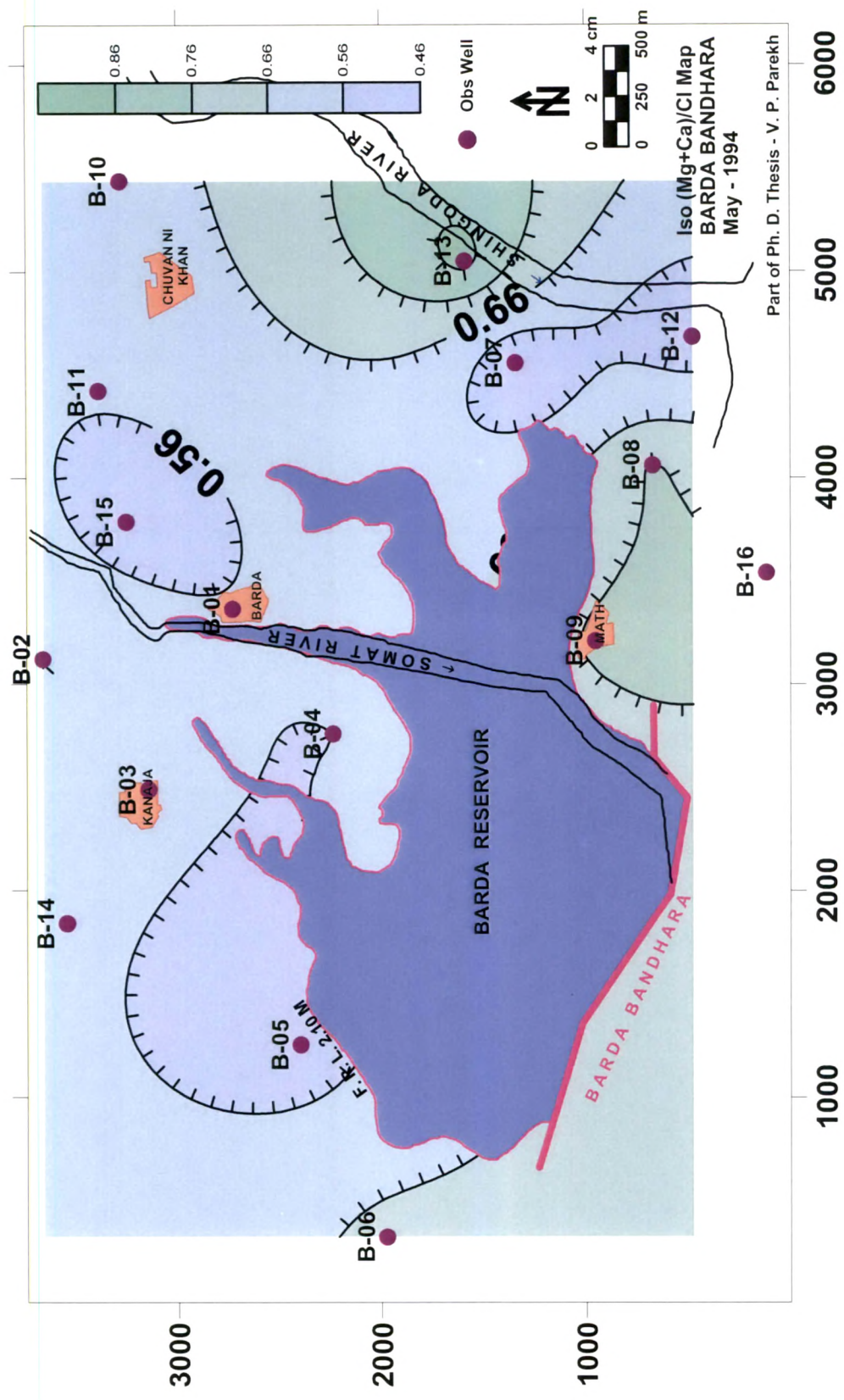
Map 5.64: Iso Na/Cl Ratio Map for Barda Bandhara May - 1999

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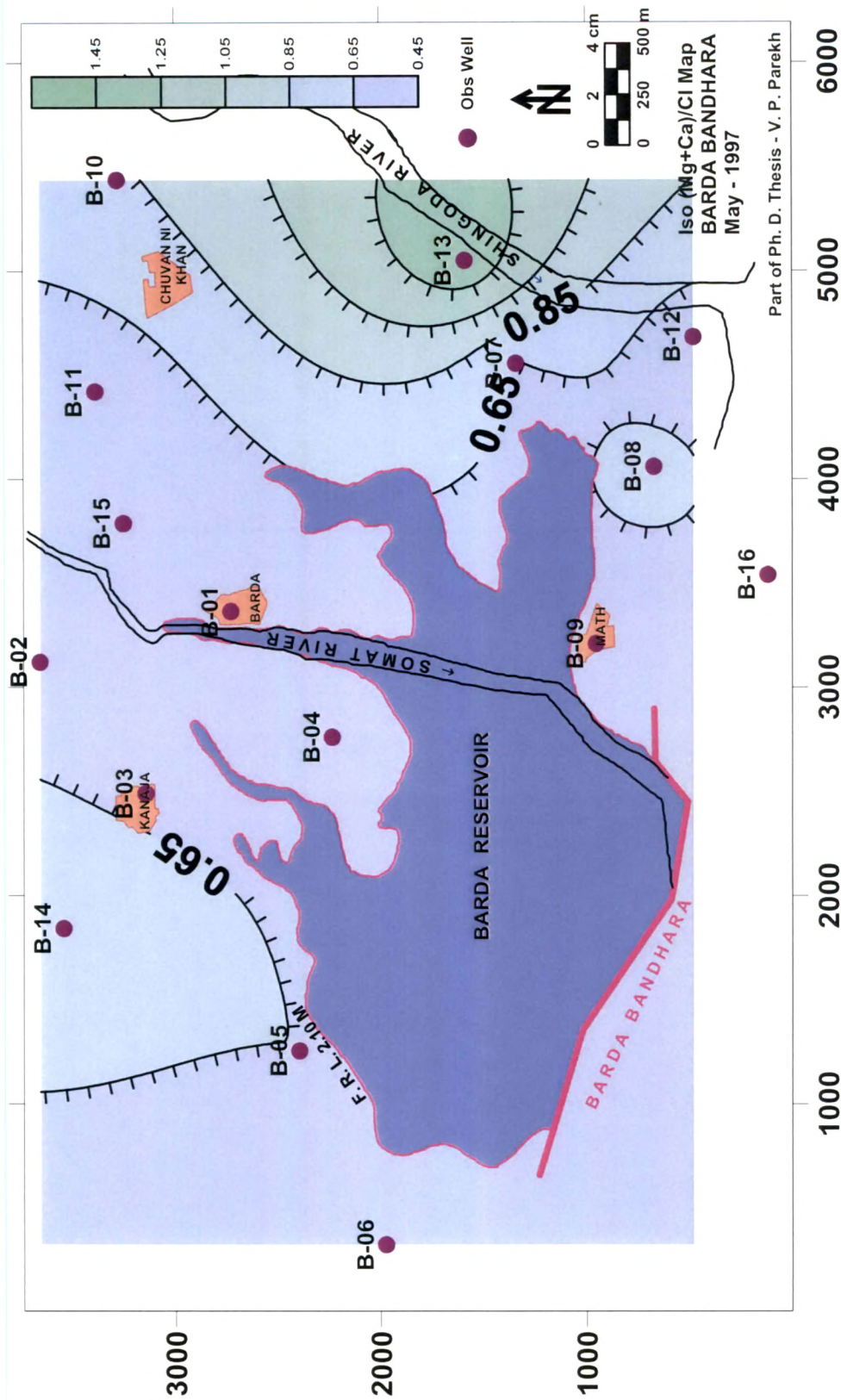


Map 5.65: Iso Na/Cl Ratio Map for Barda Bandhara May - 2002

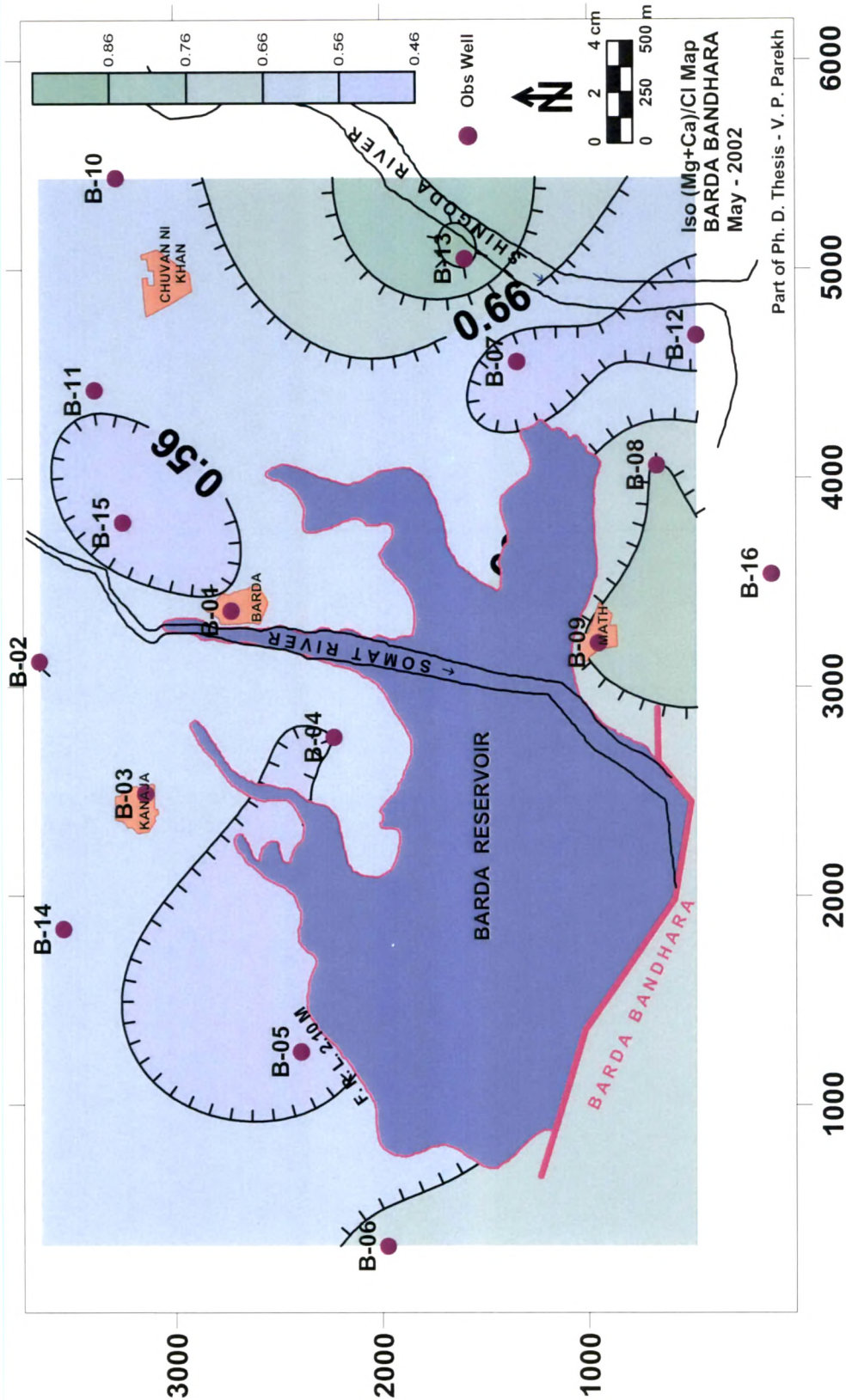
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Map 5.66: Iso (Mg+Ca)/Cl Ratio Map for Barda Bandhara May - 1994



Map 5.67: Iso (Mg+Ca)/Cl Ratio Map for Barda Bandhara May - 1997



Map 5.68: Iso (Mg+Ca)/Cl Ratio Map for Barda Bandhara May - 2002

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5.5.4 Interpretation of Geohydrological & Geochemical Maps for Barda Bandhara

5.5.4.1 Water Levels

Total rainfall of year 1996 was 1160 mm and 2001 was 568 mm. Outcrops of highly cavernous Miliolite Limestone occur near the site. From Pumping test permeability of the Miliolite Limestone in this area found to be 13.917 m/day.

Basically Bandhara structures are constructed on small local rivers, streams or creeks. Observation wells surrounding these structures covers very small area and seawater intrusion is far beyond the area covered.

The RWL Map for the May 1997 to November 2001 the trend shows reversal of hydraulic gradient. Even after the monsoon this trend is observed which indicates heavy withdrawal of groundwater from aquifers. Barda Bandhara is located just 6 km on left hand (West) side of Mul Dwarka TR. So here also heavy withdrawal of groundwater takes place due to industries and irrigation.

5.5.4.2 Water Quality

Chloride

Situation with reference to Chloride content in the freshwater is deteriorating in November 2001 as compare to May 1997. Well B-13 and B-12 has low Chloride content because of its vicinity to river Shingoda. Similar pattern is observed for IsoTDS map Nearer to river Shingoda the TDS is seen in limit but as the distance on West side of river Shingoda increases TDS is also increases.

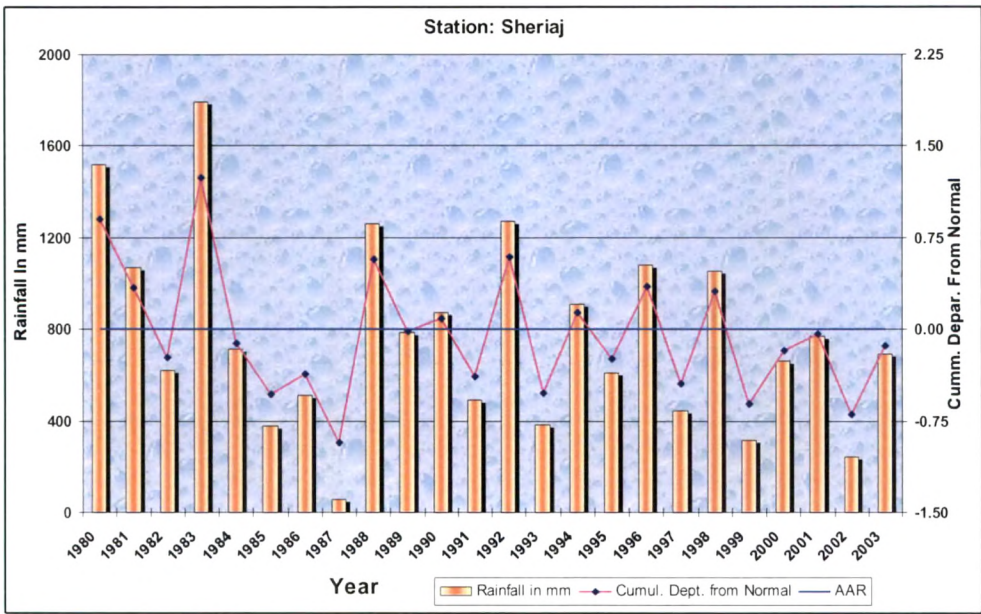
Ion Ratios

Map 5.63 to 5.68 shows ionic ratio maps for sodium-to-chloride molar ratio and (Magnesium + Calcium) to Chloride molar ratio. In this map positive sign that although it is observed that Chloride is increasing as compare to 1997 these ratios are also observed to be increasing in 2002 as compare to 1997 which indicates that process of marine sediments leaching is going on.

5.6 Analysis of Shardagram Bandhara

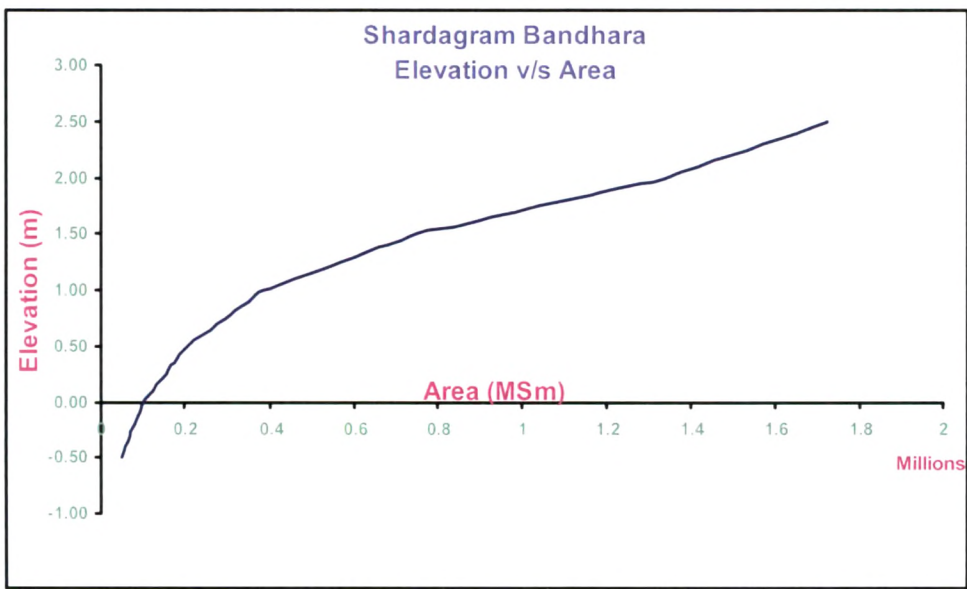
5.6.1 Analysis of Rainfall in Shardagram Bandhara Area

Rainfall data from 1980 to 2003 is collected (table 4.40) and a graph 5.54 showing relationship between Rainfall, Cumulative departure from normal and Average Rainfall is plotted.

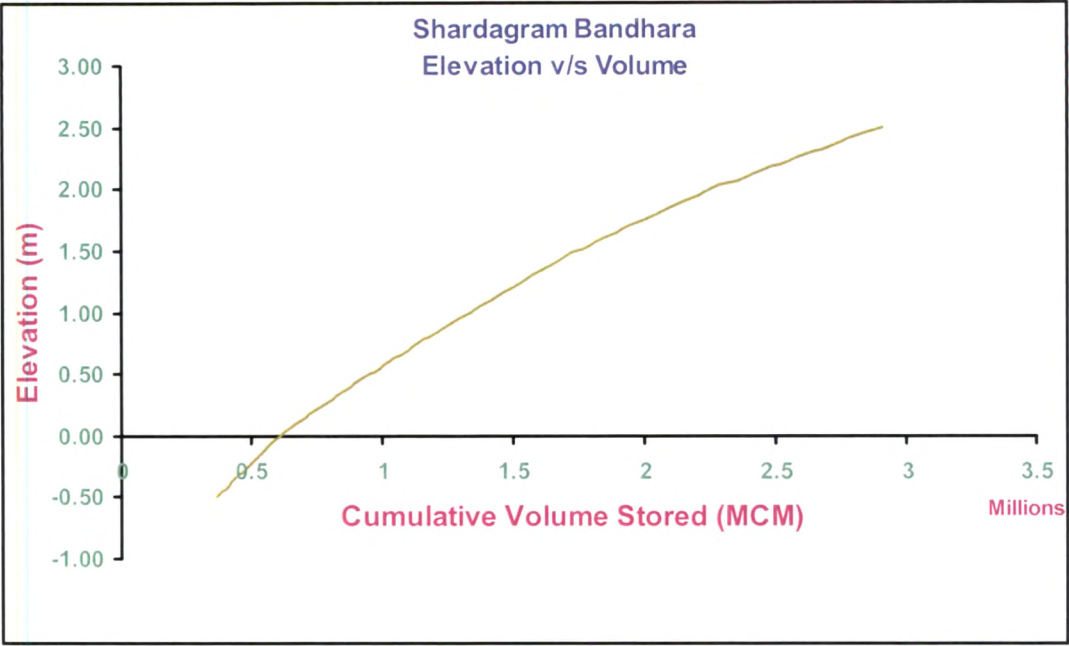


Graph 5.54: Graph Showing Rainfall, Departure from Normal rainfall & Avg. Annual Rainfall

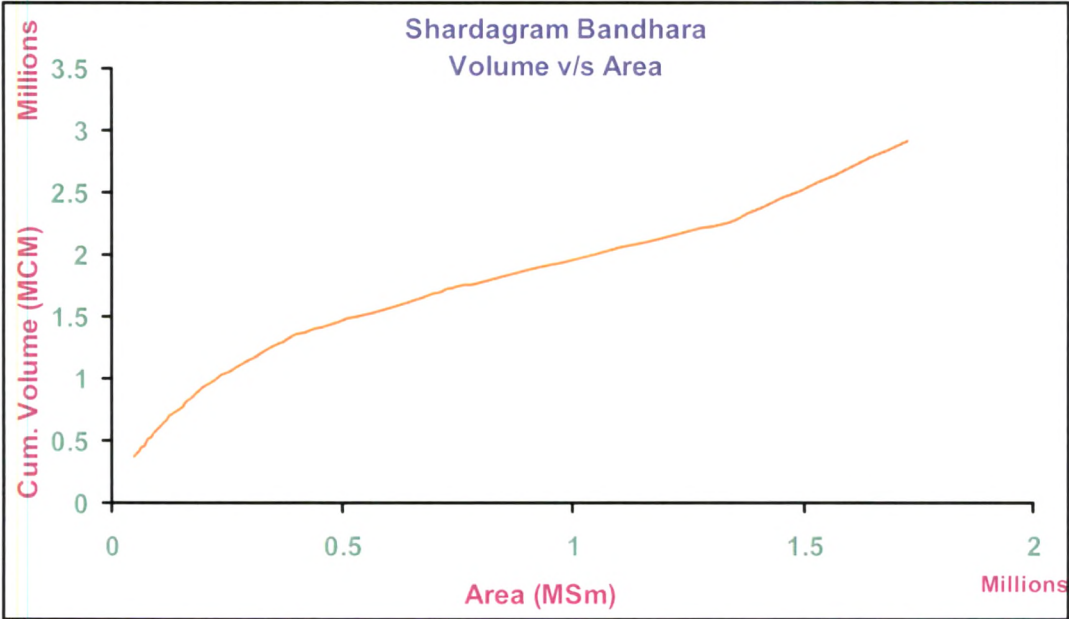
5.6.2 Graphs Showing Relation between Elevation, Area and Cumulative Volume Stored for Shardagram Bandhara



Graph 5.55: Relation between Elevation v/s Area for Shardagram Bandhara (Table 4.42)



Graph 5.56: Relation between Elevation v/s Volume for Shardagram Bandhara (Table 4.42)



Graph 5.57: Relation between Volume v/s Area for Shardagram Bandhara (Table 4.42)

5.6.3 Analysis of Pumping Test at Village Langodra

Pumping test for a well situated in village Langodra was carried out and aquifer parameters like Permeability (K), Transmissibility (T) has been calculated.

5.6.3.1 Time – Drawdown Analysis

Sr. No.	Time Hr:Min	Water Level (m)	Drawdown (m)	Sr. No.	Time Hr:Min	Water Level (m)	Drawdown (m)
1	10:10	10.82	0.000	17	10:32	11.66	0.840
2	10:11	10.87	0.050	18	10:34	11.72	0.900
3	10:12	10.91	0.090	19	10:36	11.79	0.970
4	10:13	10.95	0.130	20	10:38	11.86	1.040
5	10:14	10.99	0.170	21	10:40	11.93	1.110
6	10:15	11.03	0.210	22	10:42	11.99	1.170
7	10:16	11.07	0.250	23	10:44	12.05	1.230
8	10:17	11.11	0.290	24	10:46	12.11	1.290
9	10:18	11.15	0.330	25	10:48	12.17	1.350
10	10:19	11.19	0.370	26	10:50	12.23	1.410
11	10:20	11.23	0.410	27	10:55	12.38	1.560
12	10:22	11.31	0.490	28	11:00	12.53	1.710
13	10:24	11.39	0.570	29	11:05	12.68	1.860
14	10:26	11.46	0.640	30	11:10	12.83	2.010
15	10:28	11.53	0.710	31	11:15	12.98	2.160
16	10:30	11.59	0.770	32	11:20	13.13	2.310

Table 5.33: Time – Drawdown Analysis for the Pumping Test at Vill. Langodra near Shardagram Bandhara (Refer Graph 5.58)

5.6.3.2 Results for Pumping Test

From the Pumping test following results were derived.

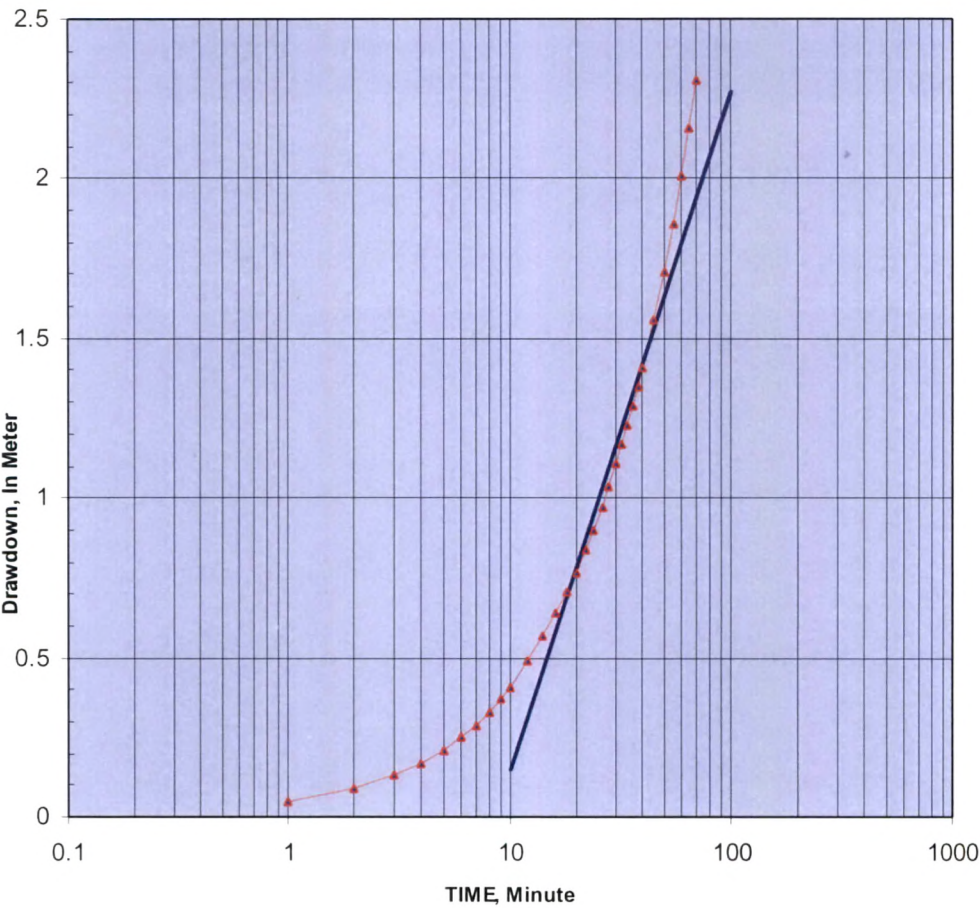
	Pumping Test
Transmissibility	52.911 m ² /day
Permeability	9.8347 m/day

Table 5.34: Results of Pumping Test at Vill. Langodra

5.6.4 Calculation of Recharge Rate, Volume of water Stored & Volume of Water Recharged for Shardagram Bandhara

Rainfall, Water-level fluctuation and evaporation rate for every week at Shardagram Bandhara was observed for four years and tabulated in table 4.44 Using these data in conjunction with elevation storage data, recharge rate in mm/day is worked out (Table 5.35 to 5.38). From the results obtained, graph 5.59 of Recharge rate v/s time is drawn and Cumulative days v/s recharge rate graph for each year is plotted on log-log graph (5.60 to 5.63) to get recharge rate equation.

Well at Village: Langodra, Tal: Mangrol	
INPUT Dimensions: Diameter of Well (d _c) = 3.95 Meter Area of Well (A) = 12.25417 Sq. Meter Depths to: water level (DTW) = 10.82 Meter Base of Aquifer = 16.20 Meter Type of Well: Open Well Aquifer Material -- Milliolite Limestone (Cavernous) FLOW RATE = 613.44 m ³ /d	Date: 03/01/2002 Time: 10:10
	Aquifer thickness = 5.38 Meter Slope = 2.1220 Meter/log10
	K = 9.8347292 Meter/Day T = 52.910843 Meter ² /Day



Graph 5.58 Cooper-Jacob's Log-Log Graph for Pumping Test Carried out at Village Langodra

Calculation of Recharge Rate, Volume of water Stored & Volume of Water Recharged for Shardagram Bandhara

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, M ³	Vol of water Loss (M ³)	Evapo cm/week	Surface Area Of Water M ²	Vol. Of Evaporation (M ³)	Vol. Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
17/8/98	1052	2.50	2910000	-	-	1725000	-	-	1770506	
Aug 24	Nil	1.87	2124800	785200	5.4	1184750	63977	721224	1217586	84.620
31	Nil	1.59	1833600	291200	5.3	855750	45355	245845	879976	39.911
Sep 7	Nil	1.33	1600600	233000	5.0	626240	31312	201688	644314	44.718
14	Nil	1.16	1461200	139400	3.7	502480	18592	120808	517163	33.371
21	Nil	1.00	1330000	131200	4.2	386000	16212	114988	397410	41.335
28	Nil	0.84	1208400	121600	4.2	328080	13779	107821	337889	45.586
Oct 5	Nil	0.70	1102000	106400	4.3	277400	11928	94472	285776	47.226
12	Nil	0.57	1003200	98800	4.3	230340	9905	88895	237359	53.503
19	Nil	0.47	929420	73780	4.2	198880	8353	65427	204982	45.598
26	Nil	0.37	860820	68600	4.3	178480	7675	60925	183994	47.304
Nov 2	Nil	0.29	805940	54880	4.0	162160	6486	48394	167198	41.349
9	Nil	0.22	757920	48020	4.3	147880	6359	41661	152496	39.028
16	Nil	0.16	716760	41160	4.2	135640	5697	35463	139894	36.214
23	Nil	0.10	675600	41160	4.1	123400	5059	36101	127290	40.516
30	Nil	0.05	641300	34300	4.0	113200	4528	29772	116783	36.419
Dec 7	Nil	0.00	607000	34300	4.0	103000	4120	30180	106274	40.569
14	Nil	-0.06	578080	28920	4.1	96520	3957	24963	99603	35.803
21	Nil	-0.11	553980	24100	4.0	91120	3645	20455	94043	31.073
28	Nil	-0.15	534700	19280	4.2	86800	3646	15634	89594	24.929
4/1/99	Nil	-0.18	520240	14460	3.9	83560	3259	11201	86256	18.551
	1052		Total	2389760			273843	2115917	Avg. = 41.381	

Table 5.35: Recharge Rate Calculation for Shardagram Bandhara – Year 1998 (Refer Graph 5.59)

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, M ³	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water(M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
12/7/00	475	2.50	2910000	-	-	1725000	-	-	1770506	
Jul 19	5	1.92	2176800	733200	5.0	1243500	62175	671025	1277833	75.018
26	Nil	1.56	1802400	374400	5.4	820500	44307	330093	843780	55.887
Aug 2	Nil	1.29	1567800	234600	5.4	597120	32244	202356	614404	47.050
9	Nil	1.10	1412000	155800	5.3	458800	24316	131484	472265	39.773
16	119	1.70	1948000	-	-	985000	-	-	1012655	
23	Nil	1.33	1600600	347400	5.0	626240	31312	316088	644314	70.083
30	65	1.05	1371000	229600	4.5	422400	19008	210592	434841	69.185
Sep 6	Nil	0.85	1216000	155000	4.2	331700	13931	141069	341611	58.993
13	Nil	0.70	1102000	114000	4.3	277400	11928	102072	285776	51.025
20	Nil	0.58	1010800	91200	4.3	233960	10060	81140	241084	48.080
27	Nil	0.48	936280	74520	4.2	200920	8439	66081	207081	45.587
Oct 4	Nil	0.37	860820	75460	4.1	178480	7318	68142	183994	52.907
11	Nil	0.29	805940	54880	4.0	162160	6486	48394	167198	41.349
18	Nil	0.22	757920	48020	4.0	147880	5915	42105	152496	39.444
25	Nil	0.15	709900	48020	4.1	133600	5478	42542	137794	44.106
Nov 1	Nil	0.09	668740	41160	4.0	121360	4854	36306	125189	41.430
8	Nil	0.04	634440	34300	4.2	111160	4669	29631	114682	36.911
15	Nil	0.00	607000	27440	3.9	103000	4017	23423	106274	31.486
22	Nil	-0.05	582900	24100	4.0	97600	3904	20196	100715	28.647
29	Nil	-0.10	558800	24100	3.9	92200	3596	20504	95155	30.783
Dec 6	Nil	-0.14	539520	19280	3.9	87880	3427	15853	90706	24.967
13	Nil	-0.17	525060	14460	3.8	84640	3216	11244	87368	18.385
	664		Total	2920940			310602	2610338	Avg =	45.290

Table 5.36: Recharge Rate Calculation for Shardagram Bandhara – Year 2000 (Refer Graph 5.59)

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
18/6/01	418	2.50	2910000	-	-	1725000	-	-	1770506	
25	Nil	1.95	2208000	702000	5.0	1278750	63938	638063	1313974	69.371
Jul 2	18	1.58	1823200	384800	4.1	844000	34604	350196	867911	57.642
9	92	2.50	2910000	-	-	1725000	-	-	1770506	
16	36	2.00	2260000	650000	4.0	1337500	53500	596500	1374201	62.010
23	Nil	1.60	1844000	416000	3.9	867500	33833	382168	892040	61.203
30	Nil	1.33	1600600	243400	4.1	626240	25676	217724	644314	48.274
Aug 6	Nil	1.10	1412000	188600	4.1	458800	18811	169789	472265	51.360
13	135	2.50	2910000	-	-	1725000	-	-	1770506	
20	8	2.10	2390000	520000	3.9	1415000	55185	464815	1453528	45.683
27	Nil	1.70	1948000	442000	3.9	985000	38415	403585	1012655	56.935
Sep 3	40	1.45	1699000	249000	4.0	713600	28544	220456	734013	42.906
10	Nil	1.20	1494000	205000	4.0	531600	21264	183736	547089	47.978
17	5	1.02	1346400	147600	4.1	400560	16423	131177	412384	45.442
24	8	0.88	1238800	107600	3.9	342560	13360	94240	352773	38.163
Oct 1	Nil	0.74	1132400	106400	3.9	291880	11383	95017	300669	45.145
8	6	0.63	1048800	83600	3.8	252060	9578	74022	259709	40.717
15	5	0.53	972800	76000	3.9	215860	8419	67581	222456	43.400
22	Nil	0.42	895120	77680	3.8	188680	7170	70510	194489	51.791
29	Nil	0.33	833380	61740	3.8	170320	6472	55268	175597	44.963
Nov 5	Nil	0.25	778500	54880	3.7	154000	5698	49182	158797	44.245
12	Nil	0.18	730480	48020	3.6	139720	5030	42990	144094	42.621
19	Nil	0.12	689320	41160	4.6	127480	5864	35296	131492	38.347

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
26	Nil	0.06	648160	41160	5.6	115240	6453	34707	118885	41.705
Dec 3	Nil	0.01	613860	34300	6.6	105040	6933	27367	108376	36.075
10	Nil	-0.05	582900	30960	7.6	97600	7418	23542	100715	33.393
17	Nil	-0.11	553980	28920	8.6	91120	7836	21084	94043	32.027
24	Nil	-0.16	529880	24100	9.6	85720	8229	15871	88481	25.624
31	Nil	-0.20	510600	19280	10.6	81400	8628	10652	84031	18.108
	771		Total	4984200			508663	4475537	Avg = 44.813	

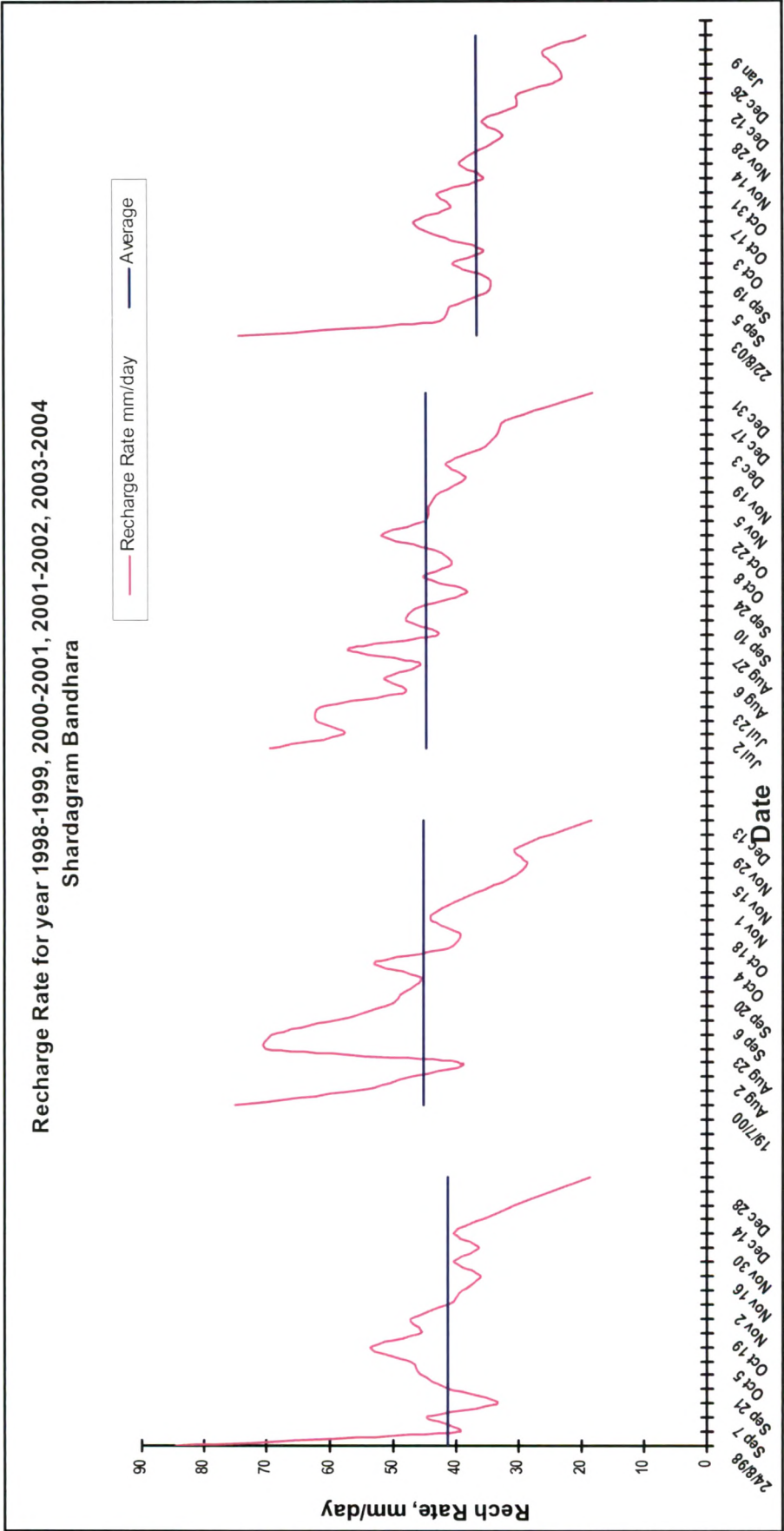
Table 5.37: Recharge Rate Calculation for Shardaigram Bandhara – Year 2001 (Refer Graph 5.59)

Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
8/8/03	603	2.50	2910000	-	-	1725000	-	-	1770506	-
15	Nil	2.50	2910000	0	-	1725000	-	-	1770506	-
22	Nil	1.93	2187200	722800	4.1	1255250	51465	671335	1289880	74.352
29	17	1.63	1875200	312000	3.9	902750	35207	276793	928230	42.599
Sep 5	30	1.39	1649800	225400	4.1	669920	27467	197933	689169	41.029
12	Nil	1.20	1494000	155800	4.1	531600	21796	134004	547089	34.992
19	22	1.05	1371000	123000	4.0	422400	16896	106104	434841	34.858
26	Nil	0.90	1254000	117000	4.2	349800	14692	102308	360214	40.574
Oct 3	18	0.78	1162800	91200	4.1	306360	12561	78639	315559	35.601
10	Nil	0.66	1071600	91200	4.0	262920	10517	80683	270881	42.551

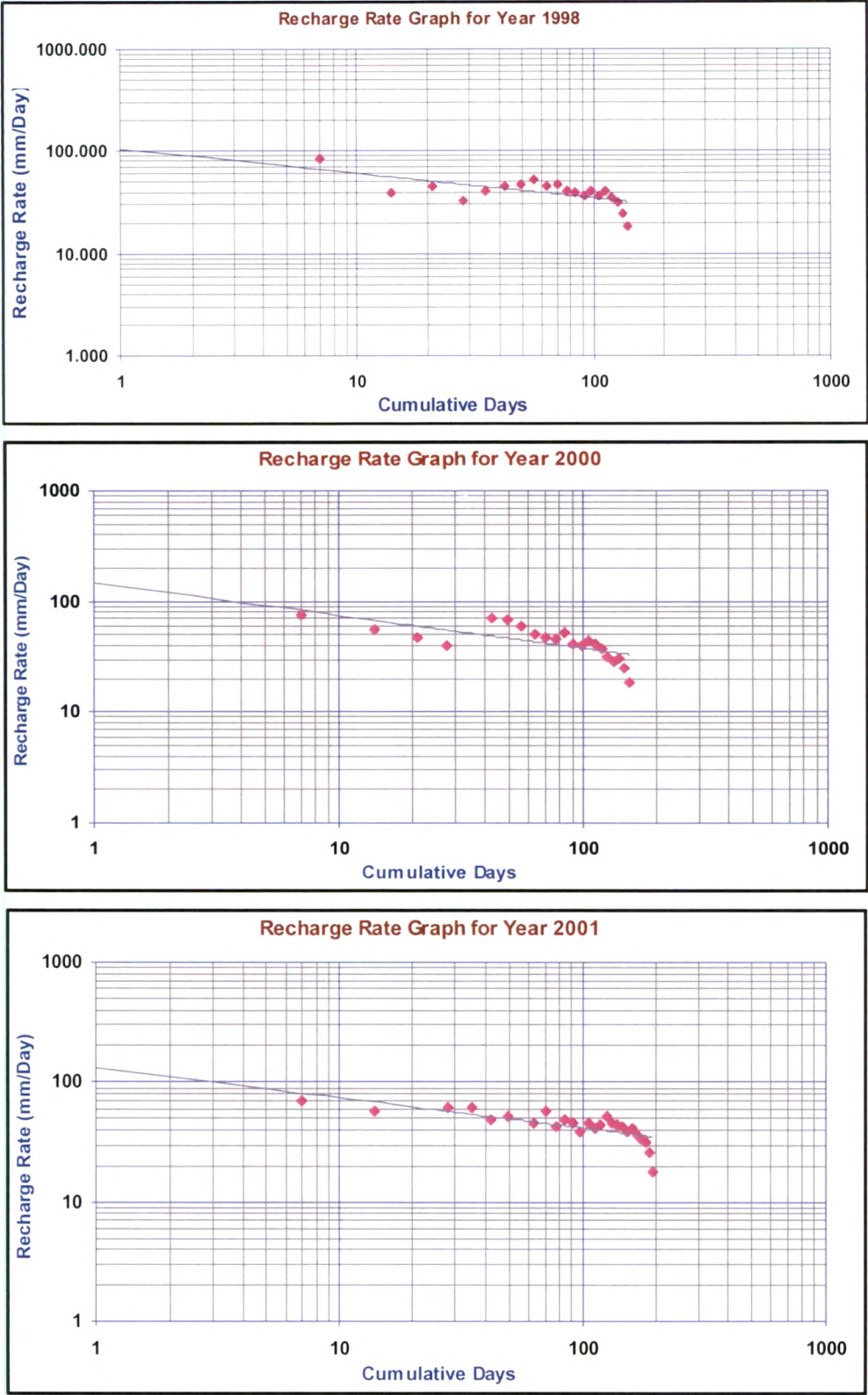
Date	Rainfall mm/ week	Water level RL (m)	Vol of Water stored, (M ³)	Volume of water Loss (M ³)	Evapo cm/week	Surface Area Of Water (M ²)	Volume Of Evaporation (M ³)	Volume Of Recharge (M ³)	Wetted Area (M ²)	Recharge Rate mm/day
17	Nil	0.55	988000	83600	3.9	223100	8701	74899	229908	46.540
24	Nil	0.46	922560	65440	3.8	196840	7480	57960	202884	40.812
31	Nil	0.37	860820	61740	3.7	178480	6604	55136	183994	42.809
Nov 7	Nil	0.30	812800	48020	3.7	164200	6075	41945	169297	35.394
14	Nil	0.23	764780	48020	3.6	149920	5397	42623	154596	39.386
21	Nil	0.17	723620	41160	3.7	137680	5094	36066	141994	36.285
28	Nil	0.12	689320	34300	3.6	127480	4589	29711	131492	32.279
Dec 5	Nil	0.07	655020	34300	3.4	117280	3988	30312	120986	35.792
12	Nil	0.03	627580	27440	3.3	109120	3601	23839	112580	30.250
19	Nil	-0.01	602180	25400	3.3	101920	3363	22037	105162	29.936
26	Nil	-0.05	582900	19280	3.1	97600	3026	16254	100715	23.056
02/01/04	Nil	-0.09	563620	19280	3.3	93280	3078	16202	96267	24.043
9	Nil	-0.13	544340	19280	3.1	88960	2758	16522	91818	25.706
16	Nil	-0.16	529880	14460	3.1	85720	2657	11803	88481	19.056
	690		Total	2380120			257011	2123109	Avg = 36.723	

Table 5.38: Recharge Rate Calculation for Shardagram Bandhara -- Year 2003 (Refer Graph 5.59)

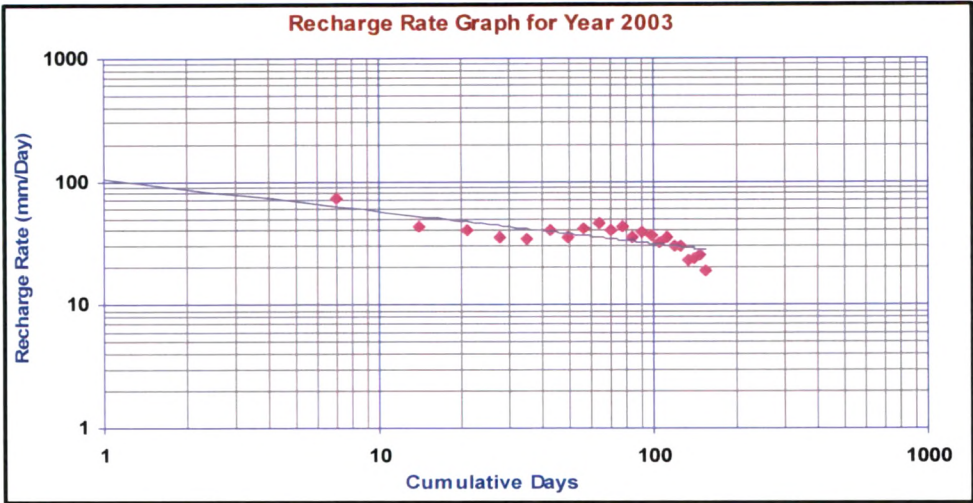
5.6.4.1 Recharge Rate Graphs and Equations for Shardagram Bandhara



Graph 5.59: Recharge Rate Graph for Shardagram Bandhara (Table 5.35 to 5.38)



Graph 5.60 to 5.62: Log-Log Graph for Recharge Rate v/s Cumulative Days for Shardagram Bandhara – Year 1998, 2000 & 2001



Graph 5.63: Log-Log Graph for Recharge Rate v/s Cumulative Days for Shardagram Bandhara - Year 2003

General equation for recharge rate is $I = \alpha T^\beta$

Recharge rate Formula for Shardgram Bandhara

Year	Intercept on Y axis (Rech. Rate)	Slope of graph
	α	β
1998	106.34	-0.2427
2000	147.27	-0.2956
2001	132.5	-0.2523
2003	105.34	-0.2634
Average	122.8625	-0.2635

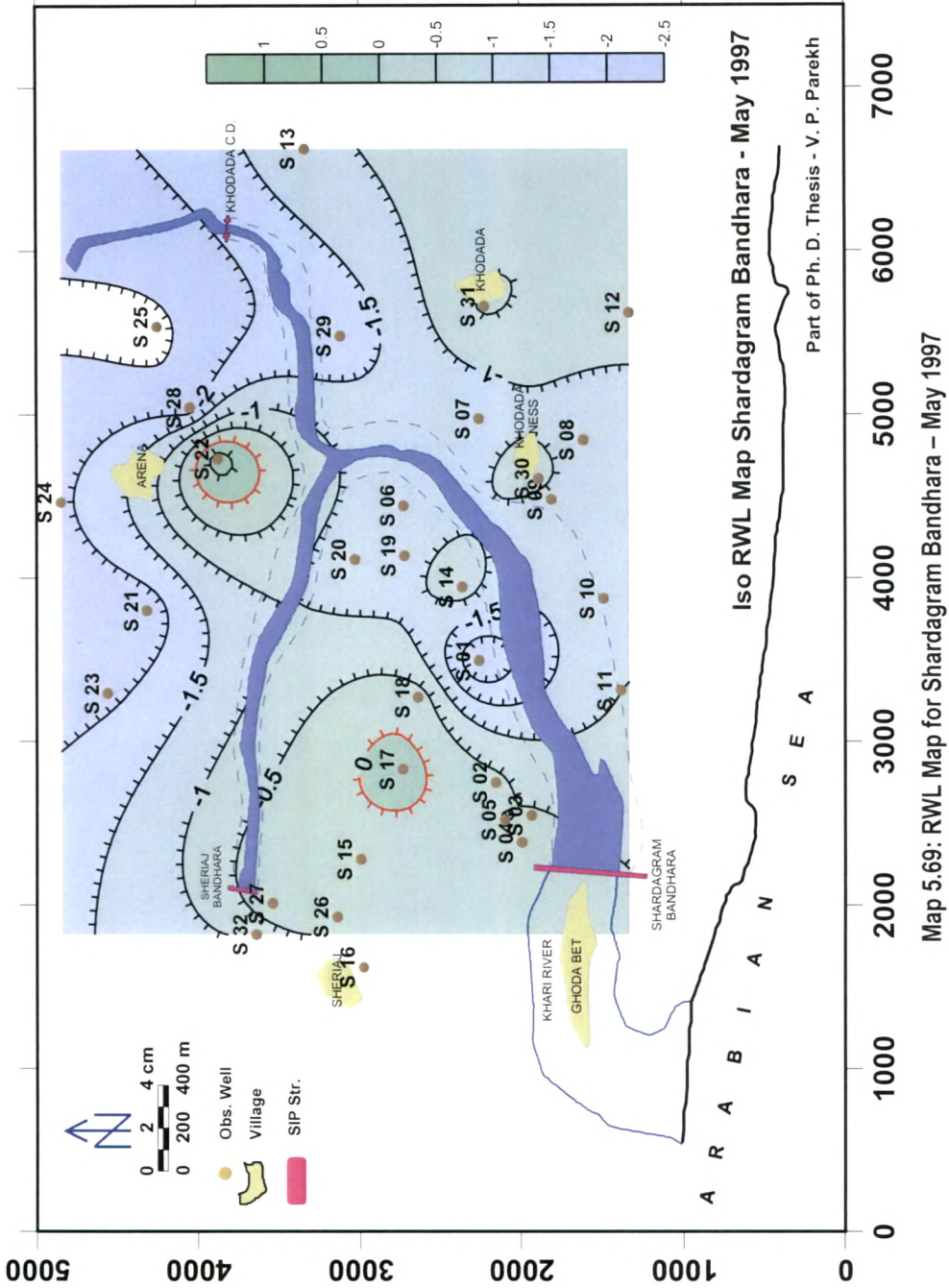
Table 5.39: Recharge Rate Equation for Shardagram Bandhara

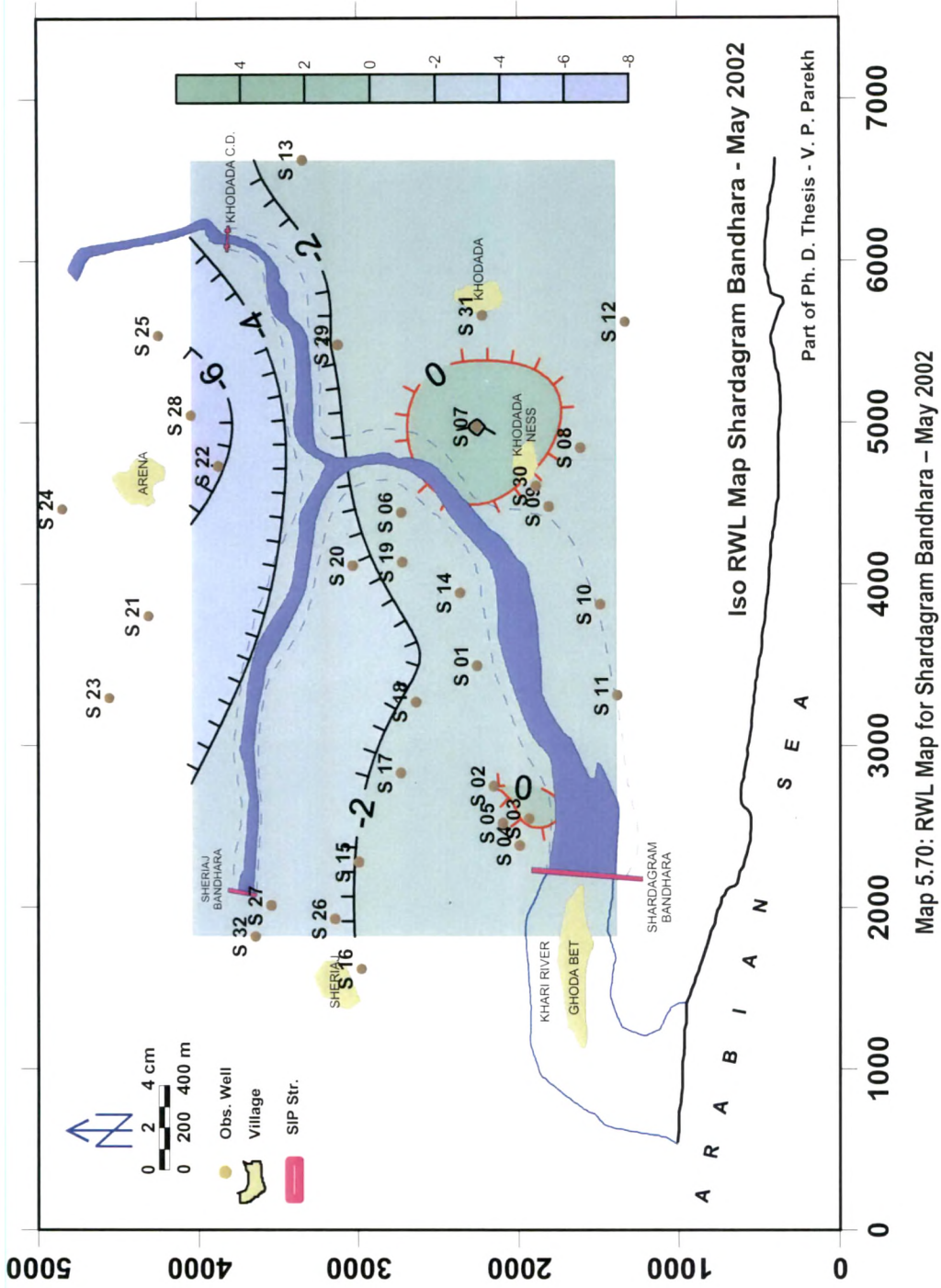
So Recharge Rate Equation $I = 122.8625 T^{-0.2635}$

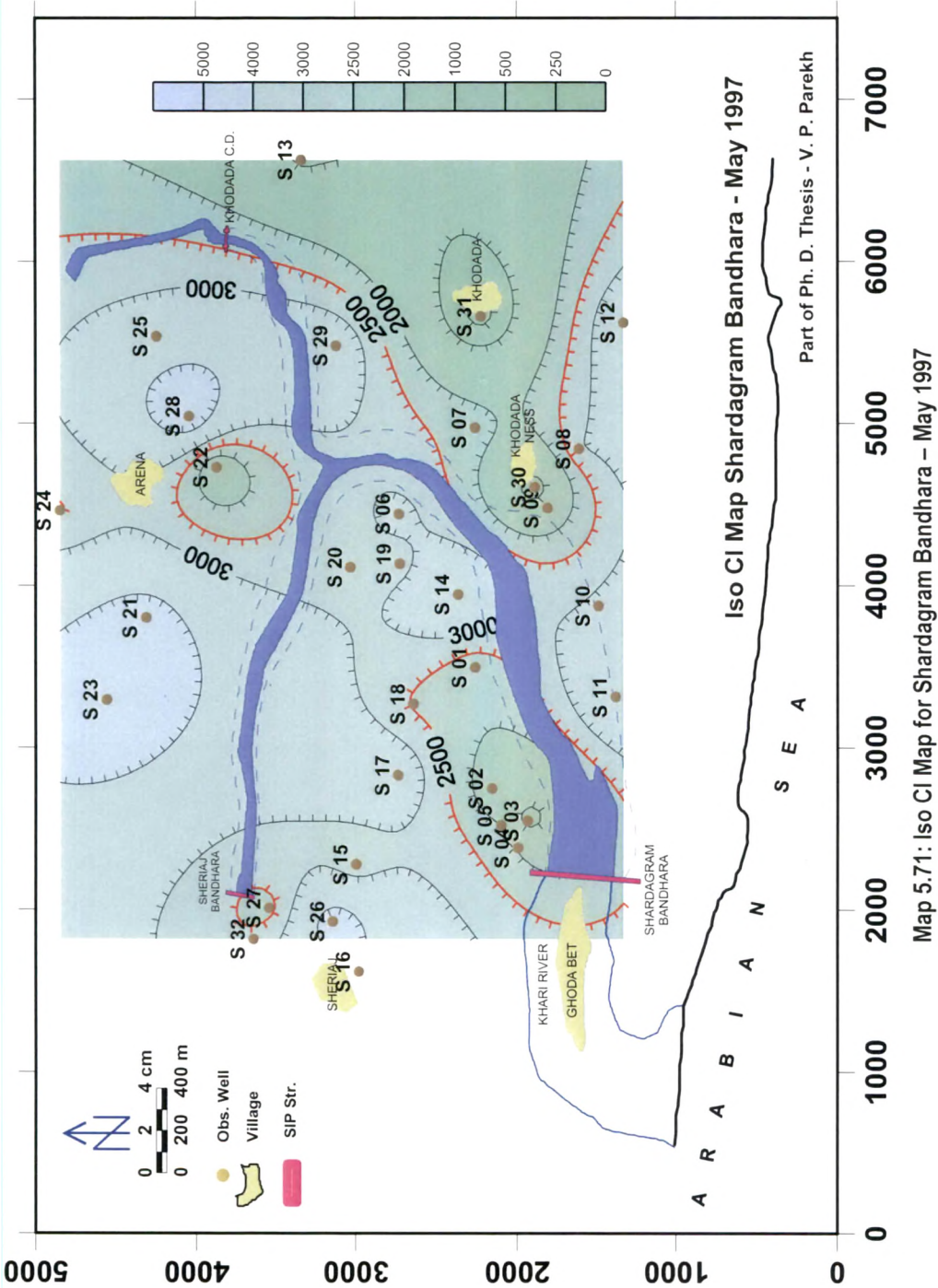
Where I = Recharge Rate mm/Day
 T = Time in Days

5.6.5 Geohydrological & Geochemical Analysis of Data Collected for Shardagram Bandhara

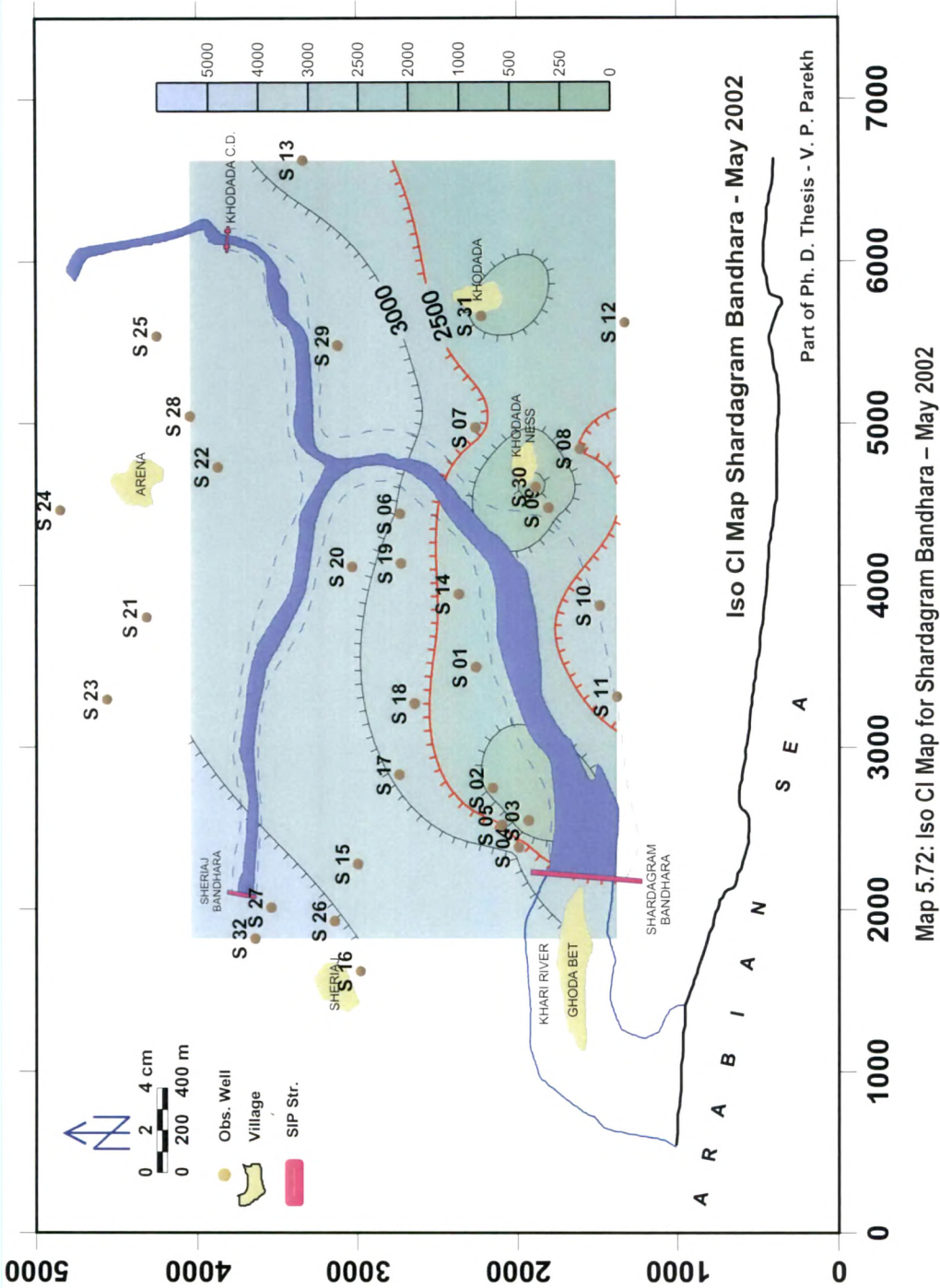
From the Geohydrological data collected from 32 observation wells surrounding the Shardagram Bandhara, RWL maps (Map 5.69 & 5.70) are plotted to study the pre-monsoon & post-monsoon groundwater flow pattern. Similarly from analyzed geochemical parameters IsoChlor Map 5.71 to 5.72 and IsoTDS Map 5.73 to 5.74 are prepared to study the variation of chloride and TDS in the study area. To study about fresh seawater intrusion or any leaching process in recent years, ion ratio maps of Na^+/Cl^- (Map 5.75 to 5.76) are plotted.



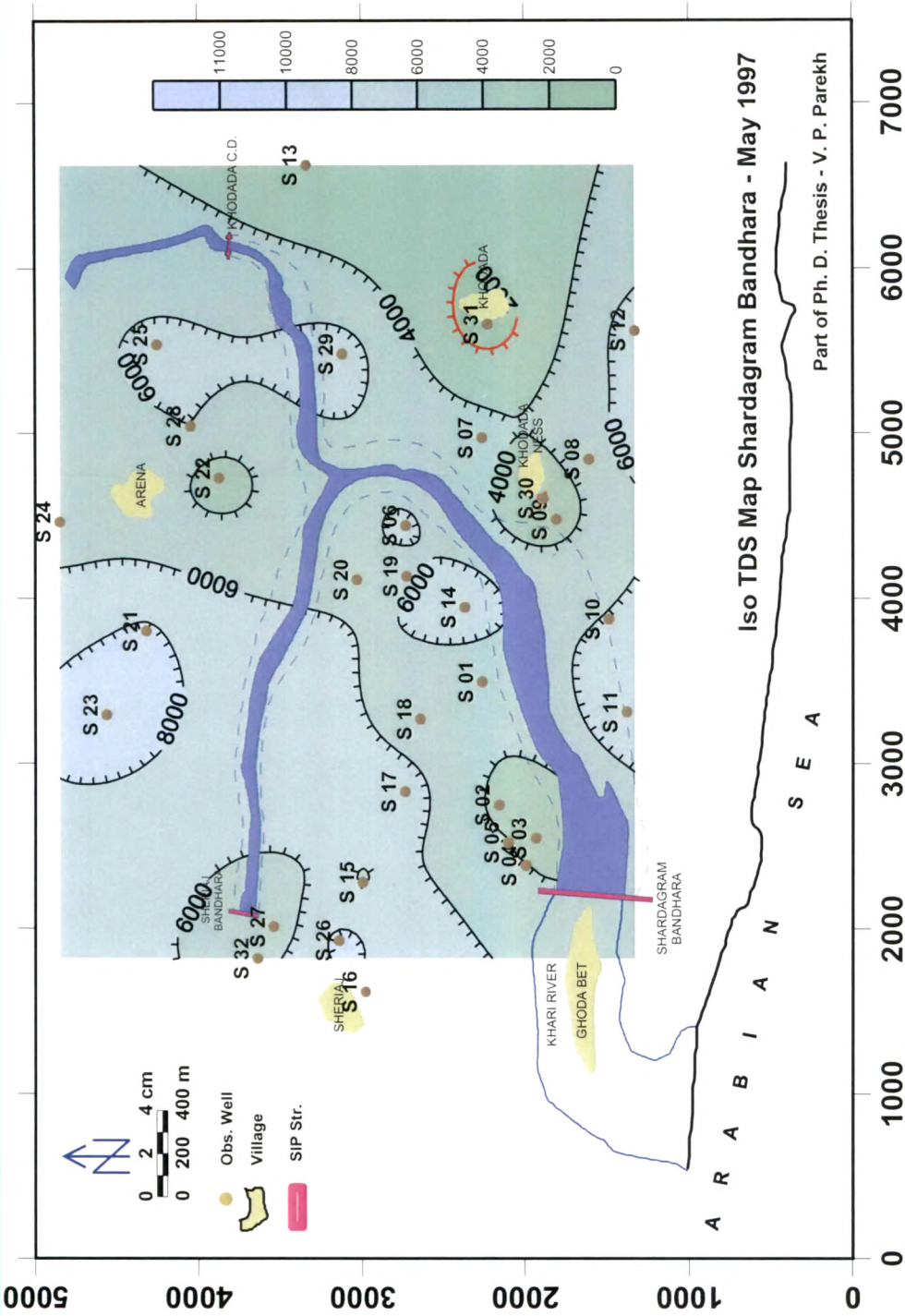




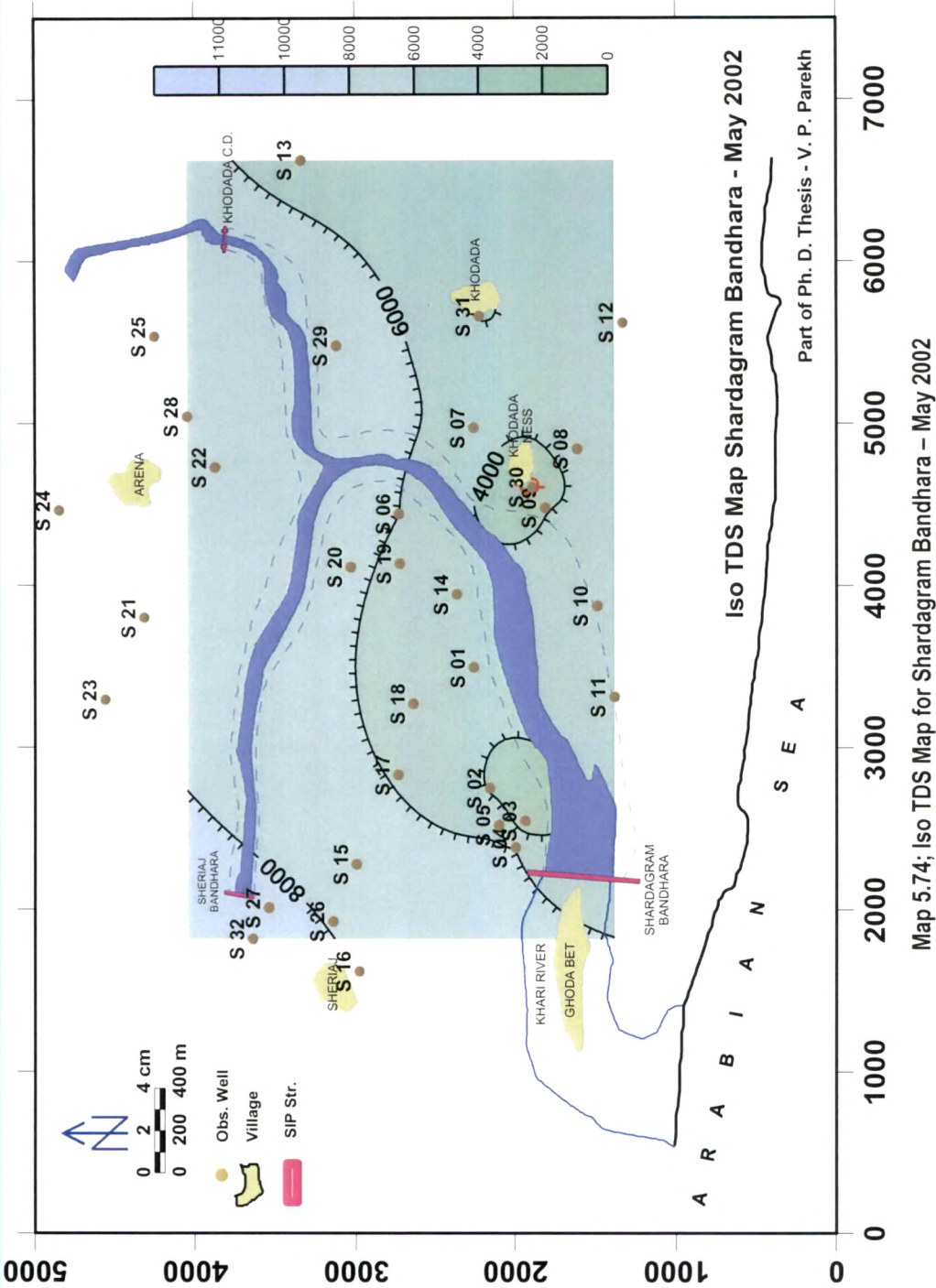
Map 5.71: Iso CI Map for Shardagram Bandhara - May 1997

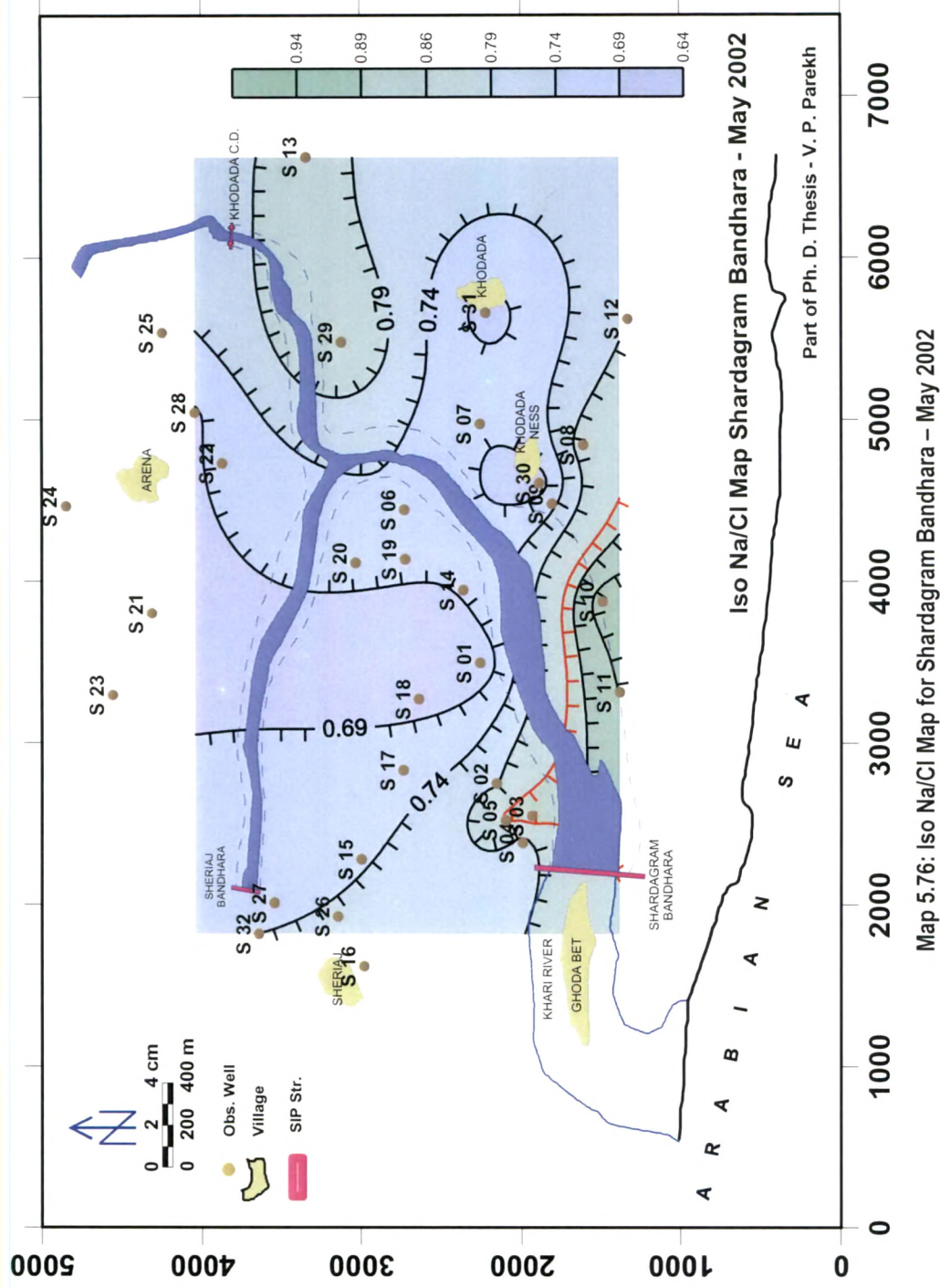


Map 5.72: Iso CI Map for Shardagram Bandhara - May 2002



Map 5.73; Iso TDS Map for Shardagram Bandhara - May 1997





5.6.6 Interpretation of Geohydrological & Geochemical Maps for Shardagram Bandhara

5.6.6.1 Water Levels (Map 5.69 to 5.70)

Total rainfall of year 1996 was 1078 mm and 2001 was 771 mm. Coastal sand is deposited in the form of sand dunes, occurring along the sea-coast which extends upto Khodada - Nes village on left bank of the bandhara. The Miliolite Limestone which is highly cavernous in nature is the major geological formation encountered underlying the thin soil cover and the sand dunes. From Pumping test permeability of the Miliolite Limestone in this area found to be 9.8347 m/day.

As compared to RWL Map for the May 1996, water level in May 2002 is decreasing by 3 to 4m inland. In May 1997 there is reversal of hydraulic gradient while in May 2002 increased more. This Bandhara is located on western side of Meghal TR. The geographic distance between these two structures is nearly 11 km. In Meghal TR analysis, it has been observed that on western side intrusion is more. In this patch in Miliolite Limestone is found to be highly cavernous so rate of intrusion will also increase.

5.6.6.2 Water Quality

Chloride (Map 5.71 to 5.72)

Situation with reference to Chloride content in the freshwater is deteriorating in May 2002 as compare to May 1997. Similar pattern is observed for IsoTDS map (Map 5.73 to 5.74)

Map 5.75 to 5.76 shows ionic ratio maps for sodium-to-chloride molar ratio. In this map positive sign that although it is observed that Chloride is increasing as compare to 1997 these ratios are also observed to be increasing in 2002 as compare to 1997 which indicates that process of marine sediments leaching is going on.

5.7 Interpretation of Geochemical Data with Graphs

According to Revelle’s Classification (1941) if Chloride to carbonate and bicarbonate ratio in value is found below 2.0 it will be slightly contaminated groundwater. (ion concentration expressed in meq/l).

If the value is above 25 it is considered as highly contaminated groundwater. Between 2 to 25 there are various categories of contaminated groundwater.

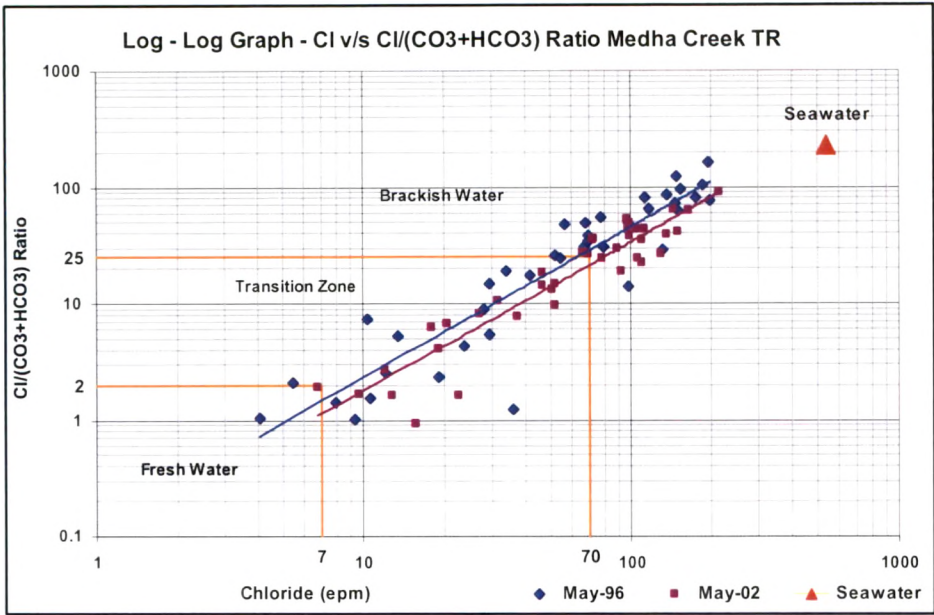
If we consider about chloride content in a water sample than, if in a groundwater sample $Cl^- < 250\text{ mg/l}$ (i.e. $Cl^- < 7\text{ meq/l}$) it will be a fresh groundwater. If in a groundwater sample $Cl^- > 2500\text{ mg/l}$ ($Cl^- > 70\text{ meq/l}$) it will be considered as highly contaminated groundwater.

So groundwater samples can be broadly classified as follows.

	Chloride content (Cl ⁻ in meq/l)			
Cl ⁻ / (CO ₃ +HCO ₃)	Values	Cl ⁻ < 7 meq/l	7 meq/l < Cl ⁻ < 70 meq/l	Cl ⁻ > 70 meq/l
	Ratio < 2	Fresh Water	Water sample in transition zone	Brackish water samples
	2 < Ratio < 25	Water sample in transition zone	Water sample in transition zone	
	Ratio > 25	Brackish water samples		

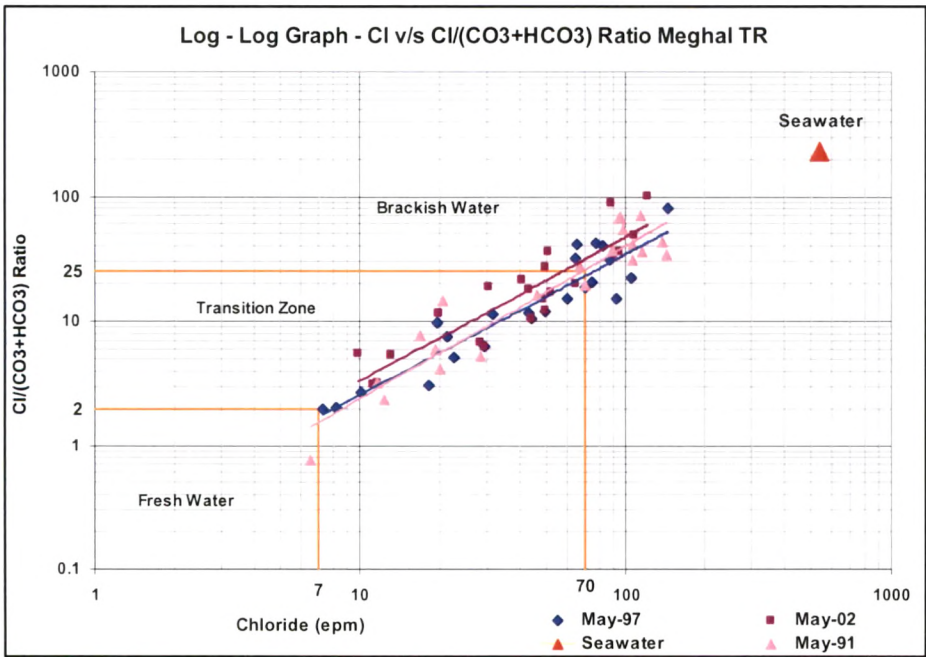
Table 5.40: Classification of Groundwater Samples on the Basis of Chloride to Carbonate and Bicarbonate Ratio and Cl^- (in meq/l)

On the basis of above explanation I have plotted Log-Log graph of Chloride to carbonate and bicarbonate ratio v/s Cl^- (in meq/l). On this graph I have plotted water samples for two different years and tried to show the trend of improvement/deterioration in quality of water sample with reference to previous year. Also on this graph I have plotted value of seawater for Chloride to carbonate and bicarbonate ratio v/s Cl^- (in meq/l). I have shown a trend lines for different years of data plotted which shows direction towards seawater point. Refer graph 5.64 to 5.68. With the help of this graph instantaneous judgment of groundwater quality in coastal area with reference to any other previous sample taken on the same well can easily be made without preparing any geochemical maps of entire area.



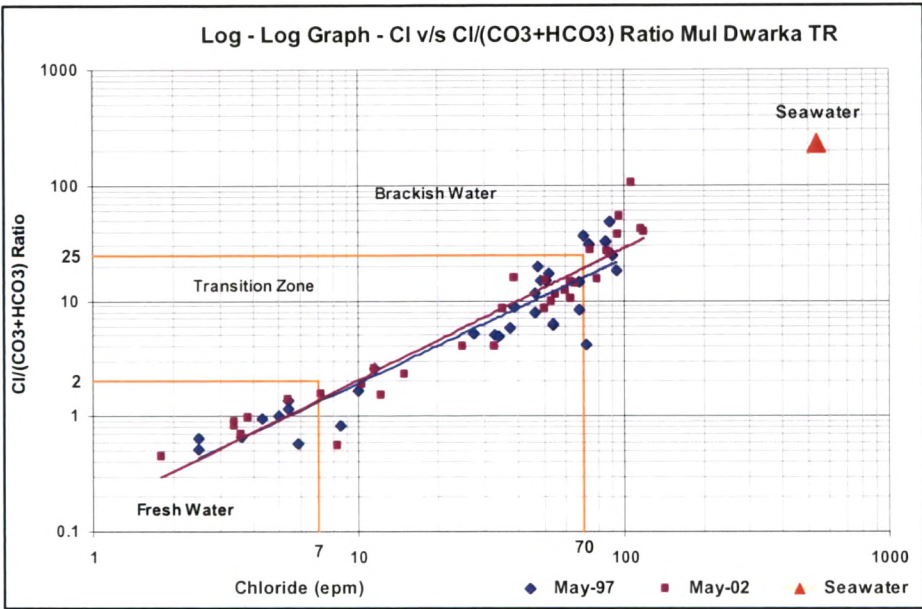
Graph 5.64: Log – Log Graph of Chloride to Carbonate and Bicarbonate Ratio v/s Cl⁻ (in meq/l) – for Medha creek TR Area

In graph 5.64 for Medha Creek TR the blue dots plotted is water samples collected from the observation wells for the year 1996 with a blue trend line, while violet colour dots plotted are water samples collected from the observation wells for the year 2002 with violet trend line. It is observed from the graph that more violet dots are moving downwards which shows quality improvement. Also the trend line is shifted downwards. The trend of shifting water samples in transition zone is observed.



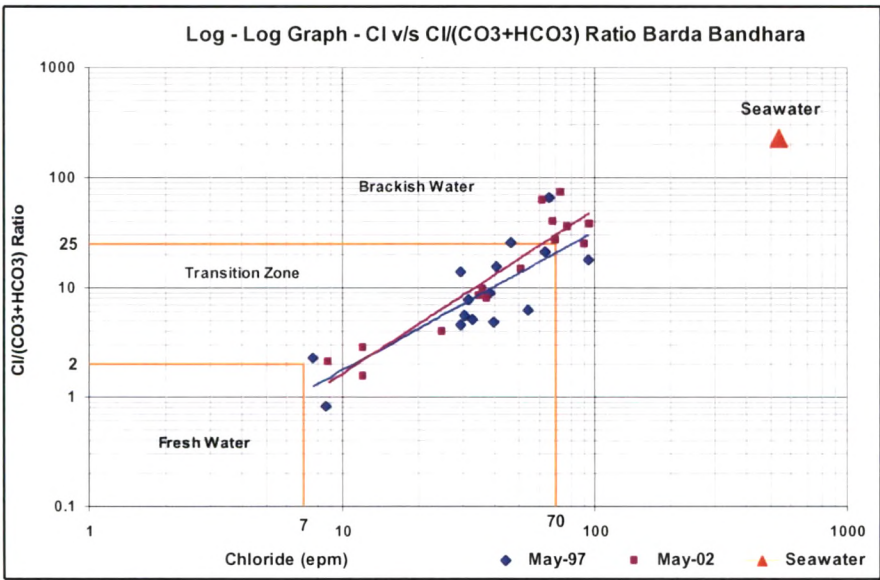
Graph 5.65: Log – Log Graph of Chloride to Carbonate and Bicarbonate Ratio v/s Cl⁻ (in meq/l) – for Meghal TR Area

From graph 5.65 for Meghal TR it is observed that more violet dots are moving upwards which shows quality deterioration. Also the trend line in 2002 is shifted upwards as compared to 1991 and 1997.



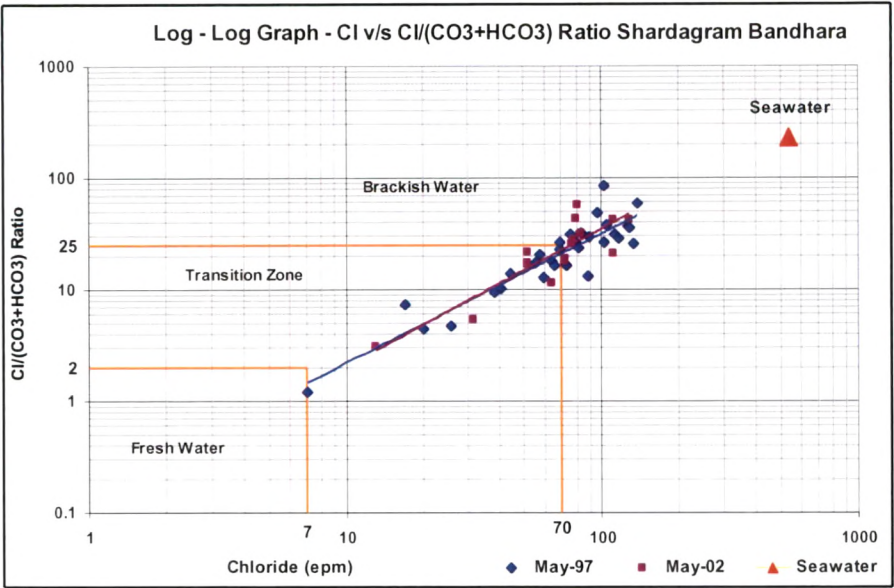
Graph 5.66: Log – Log Graph of Chloride to Carbonate and Bicarbonate Ratio v/s Cl⁻ (in meq/l) – for Mul Dwarka TR Area

From graph 5.66 for Mul Dwarka TR it is observed that more violet dots are moving downwards in the transition and freshwater zone which is positive impact of Mul Dwarka TR. It shows quality improvement. Also the trend line in 2002 is same as it was in 1997 that indicates stagnant situation with quality improvement in certain wells.



Graph 5.67: Log – Log Graph of Chloride to Carbonate and Bicarbonate Ratio v/s Cl⁻ (in meq/l) – for Barda Bandhara Area

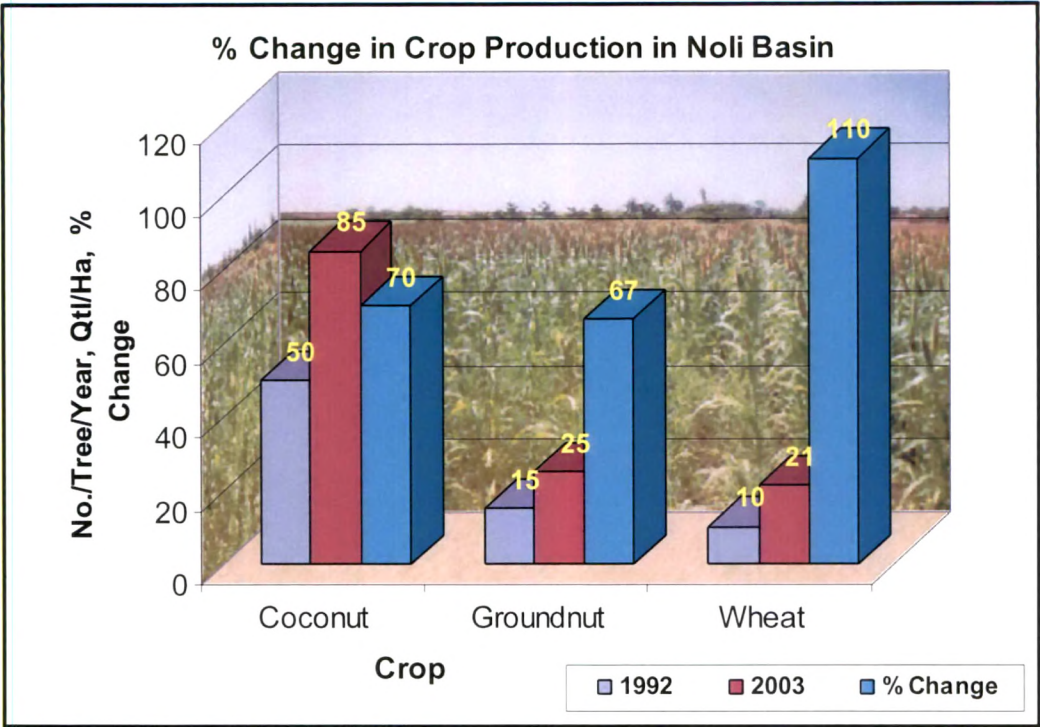
From graph 5.67 for Barda Bandhara it is observed that more violet dots are moving upwards which shows quality deterioration. Also the trend line in 2002 is shifted upwards as compared to 1997.



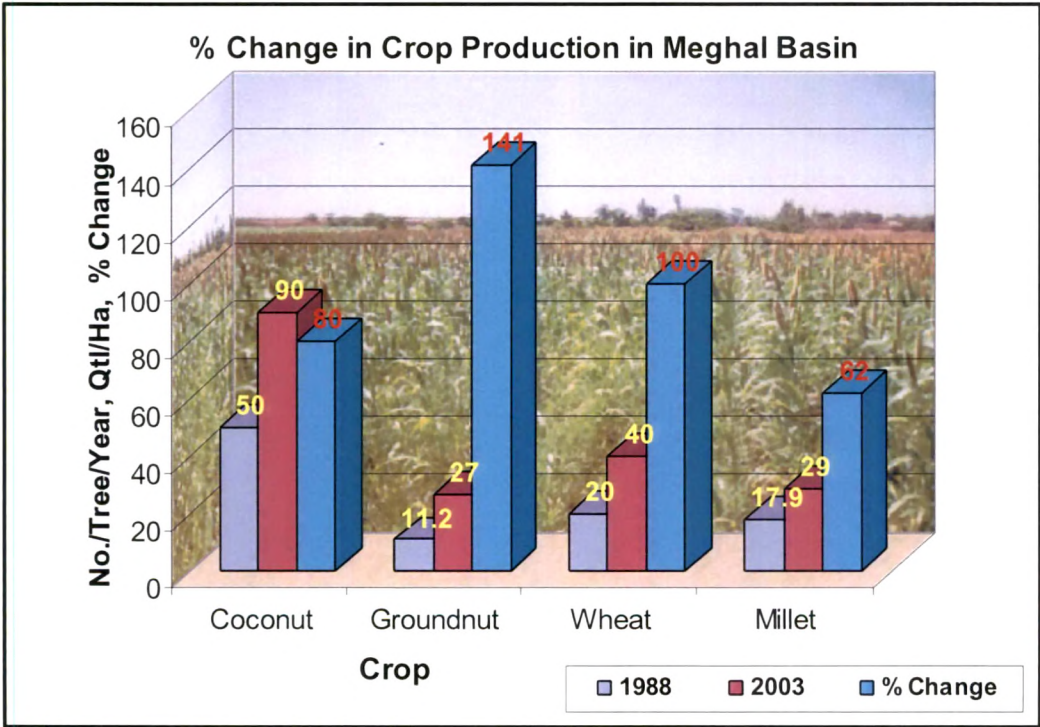
Graph 5.68: Log – Log Graph of Chloride to Carbonate and Bicarbonate Ratio v/s Cl⁻ (in meq/l) – for Shardagram Bandhara Area

From graph 5.68 for Shardagram Bandhara it is observed stagnant situation with in reference to year 1997. Both the trend lines are overlapping each other which indicates no improvement no deterioration condition. The structure is able to maintain the 1997 condition which is consider as positive impact of the structure.

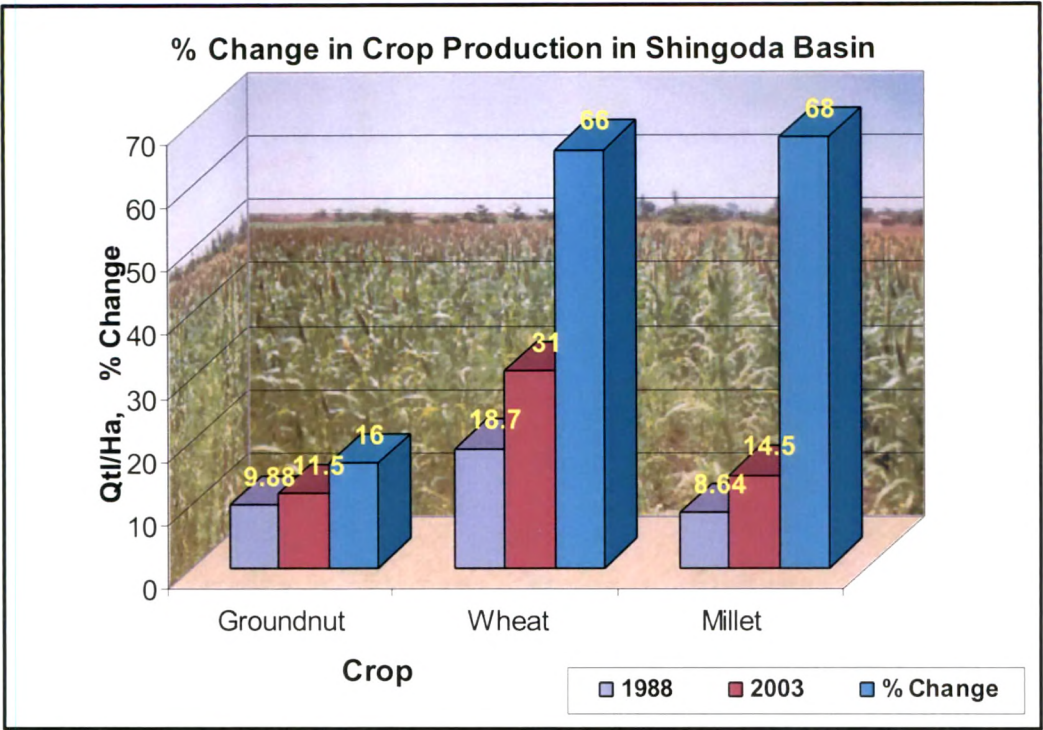
5.8 Effect on Crop Production



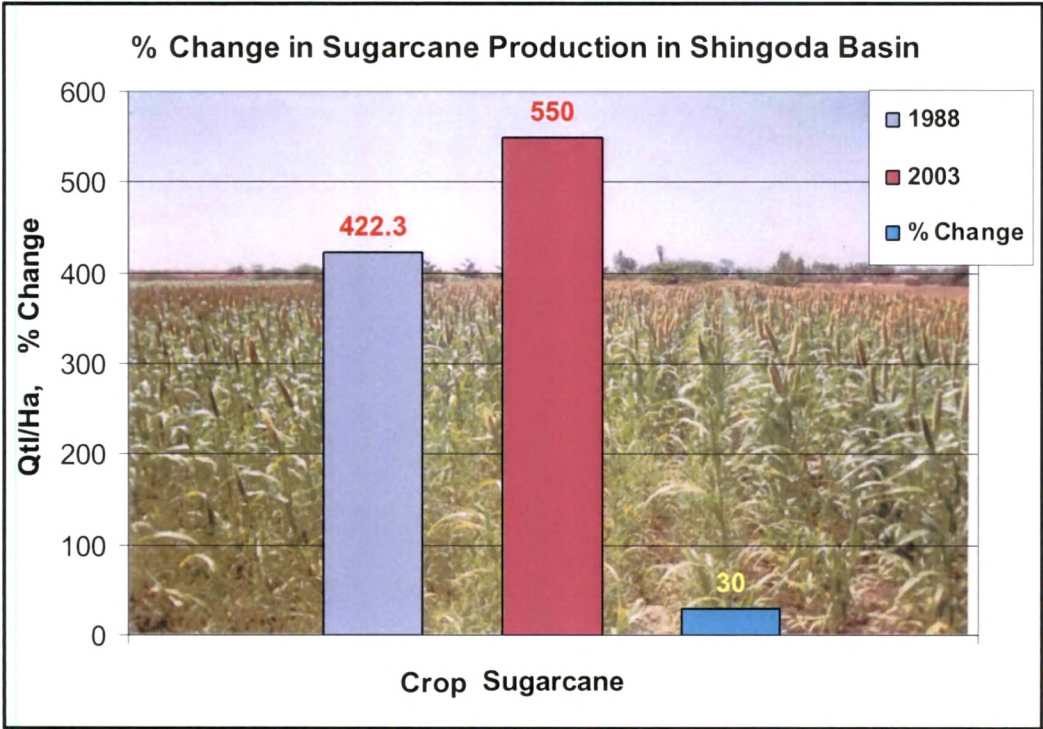
Graph 5.69: % Change in Crop Production in Noli Basin



Graph 5.70: % Change in Crop Production in Meghal Basin



Graph 5.71: % Change in Crop Production in Shingoda Basin



Graph 5.72: % Change in Sugarcane Production in Shingoda Basin