Chapter - 5

Analysis & Impact of Check Dams on Bhadar(I) Major Irrigation Project

5 ANALYSIS OF IMPACT OF CHECK DAMS ON BHADAR-I MAJOR IRRIGATION PROJECT

5.1 SALIENT PARTICULARS OF BHADAR BASIN

5.1.1 Geographical description

Area of Bhadar basin is 7076 km^2 covering districts shown in Fig.5. Area of Bhadar-I basin is 2436 km^2. There are 27 sub basins in Bhadar-I as shown in Fig.5.2. The location of various sub-basins of Bhadar-I is depicted in Fig. 5.3.

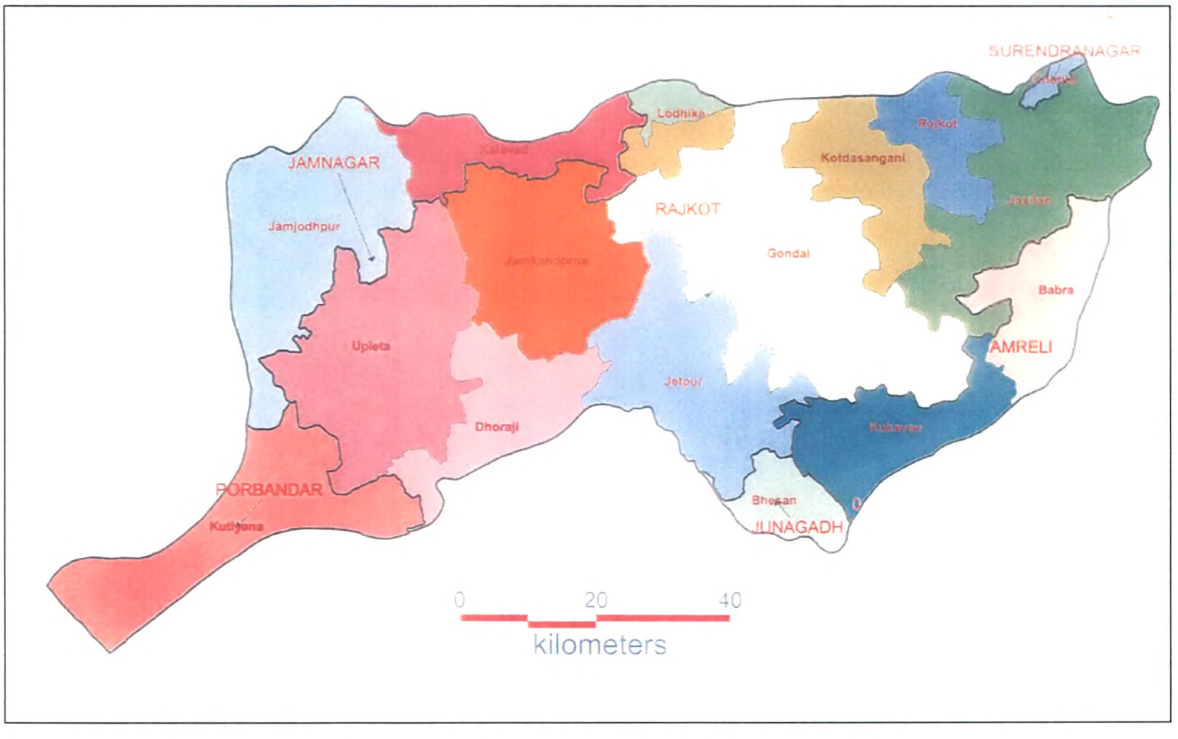


Figure 5.1 Districts in Bhadar basin

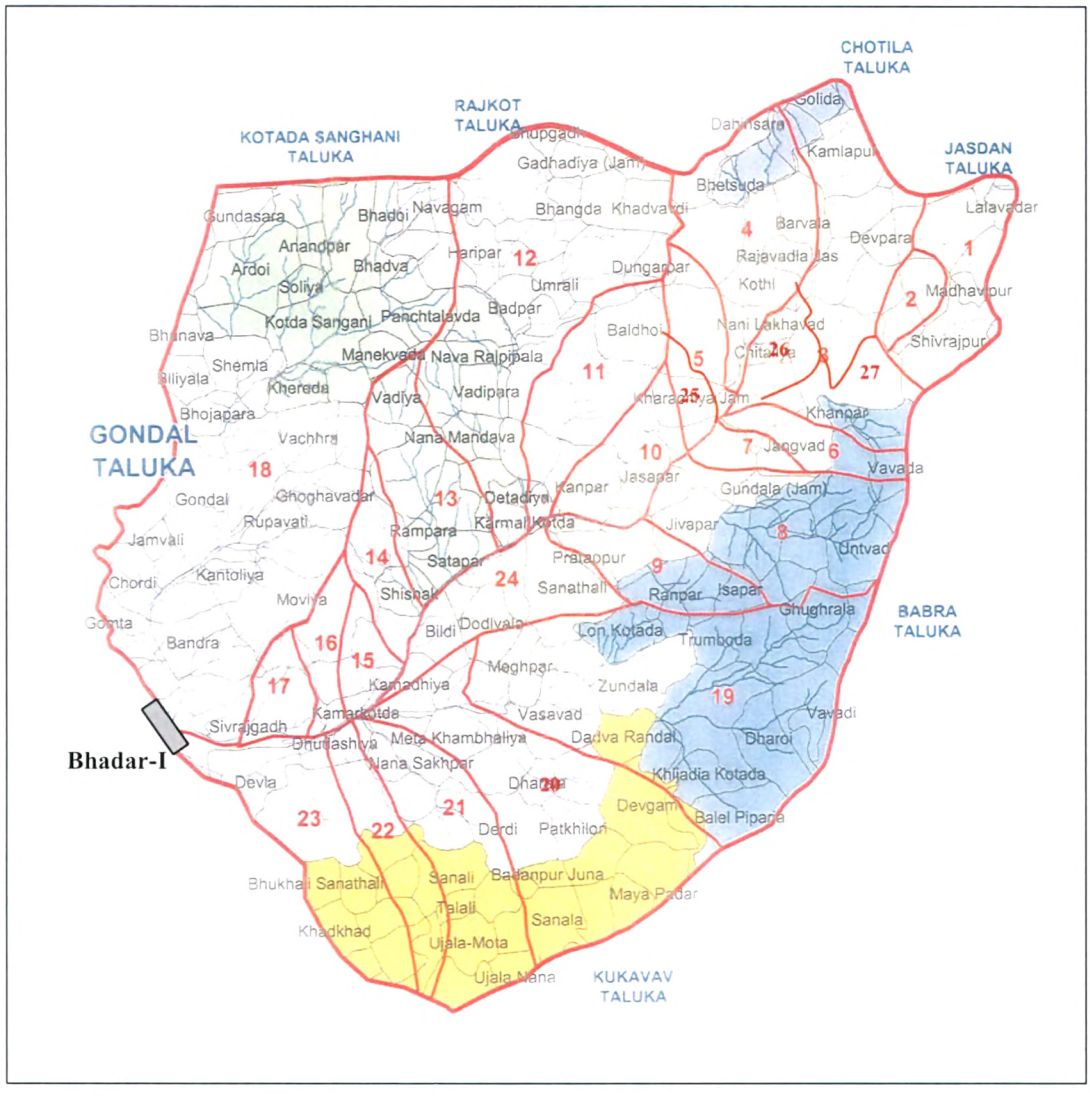
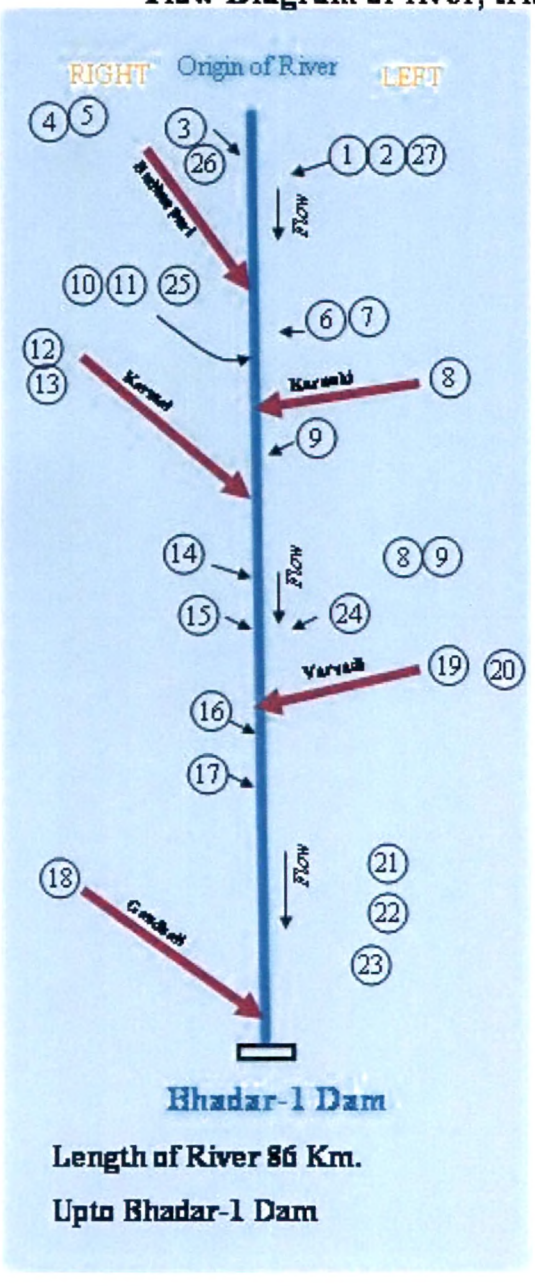


Figure 5.2 Bhadar-I sub basin

BHADAR-I Sub Basin

Flow Diagram of river, tributaries and check dams



Sub Basin	Check Dam Constructed	Storage Created
1	17	332
2	2	10
3	35	1003
4	40	1004
5	2	86
6	9	275
7	42	1125
8	15	153
9	7	66
10	25	1190
11	4	83
12	128	2225
13	58	1438
14	4	317
15	5	116
16	11	184
17	9	101
18	266	4913
19	45	1049
20	54	1054
21	38	417
22	26	54
23	38	711
24	22	5+5
25	1	28
26	1	27
27	1	27
Total	905	18596
		18.59 Mm^3

Symbol	Particular
	Bhadar River
	Tributary
	Sub Basin
	Origin of River
	End of River

FLOW DIAGRAM
BHADAR RIVER

Figure 5.3 Flow chart of Bhadar-I basin

5.1.2 Check dam related details

Description of sub-basin wise check dams is presented in Table 5.1.

Table 5.1 Sub basin wise check dams details

Sub Basin No.	Name of village	Nos. of check dams	Design storage capacity (10^3 m^3)	Surface area in (10^3 m^2)	Geographical area (Km^2)
1	**2**	**3**	**4**	**5**	**6**
1	Lalavadar	0	0.00	0.00	4.68
	Lilapur	0	0.00	0.00	22.34
	Madhavipur	8	141.02	182.72	6.10
	Mota Hadmatiya	9	191.14	256.13	8.8
	Shivrajpur	0	0.00	0.00	26.49
	Total	**17**	**332.15**	**438.85**	**73.14**
2	Kalasar	2	10.19	12.05	24.65
	Total	**2**	**10.19**	**12.05**	**24.65**
3	Bakhlvad	5	79.00	112.04	11.86
	Barvala	0	0.00	0.00	14.34
	Depara	0	0.00	0.00	9.81
	Jasdan	21	603.42	834.60	44.48
	Kamlapur	5	207.28	371.94	24.66
	Parewala	2	43.04	57.18	10.49
	Polarpar	2	70.51	118.03	6.05
	Total	**35**	**1003.25**	**1493.78**	**121.69**
4	Juna pipaliya	18	299.87	408.21	12.58
	Kanesara	8	282.88	336.55	23.43
	Kothi	2	70.22	57.27	11.18
	Kundani	0	0.00	0.00	8.66
	Nani Lakhavad	9	248.90	278.34	12.57
	Rajavadia Jas	3	101.94	112.93	3.29
	Total	**40**	**1003.82**	**1193.30**	**71.71**
5	Vimagar	2	85.80	90.98	27.84
	Total	**2**	**85.80**	**90.98**	**27.84**
6	Khanpar	8	272.13	425.95	10.34
	Kalorana	1	3.00	6.00	5.10
	Total	**9**	**275.13**	**431.94**	**15.44**
7	Atkot	14	183.77	254.89	21.90
	Jangvad	9	133.37	172.96	19.88
	Panchavada	19	807.87	1036.56	20.90
	Total	**42**	**1125.01**	**1464.41**	**62.68**

Sub Basin No.	Name of village	Nos. of check dams	Design storage capacity (10^3 m^3)	Surface area in (10^3 m^2)	Geographical area (Km^2)
	Gami	1	35.61	28.49	11.90
	Gandhiya Jas	3	66.26	78.79	5.25
	Jivapar	1	28.01	43.09	27.60
	Karnuki	0	0.00	0.00	8.12
8	Kotda Pitha	5	4.44	7.00	7.51
	Miya Khijadiya	0	0.00	0.00	10.32
	Navaniya	3	45.87	64.01	21.65
	Pansada	0	0.00	0.00	15.65
	Untvad	2	0.57	0.85	6.44
	Vavda	0	0.00	0.00	15.23
	Total	**15**	**152.75**	**179.14**	**129.67**
	Isapar	1	12.39	13.76	7.42
	Nadala	0	0.00	0.00	7.70
9	Thorkhan	6	53.24	98.78	10.28
	Total	**7**	**65.62**	**112.54**	**25.40**
10	Jasapar	25	1189.86	757.86	16.24
	Total	**25**	**1189.86**	**757.86**	**16.24**
11	Baldhol	4	82.68	100.92	19.00
	Total	**4**	**82.68**	**100.92**	**19.00**
	Badpar	6	222.57	147.61	8.36
	Bagdadiya	0	0.00	0.00	11.88
	Bhangda	2	64.31	98.92	10.43
	Bhupgadh	5	62.01	103.36	5.15
	Dungarpar	2	18.41	23.37	8.89
	Gandhiya (jam)	0	0.00	0.00	4.98
12	Haripar	20	144.10	210.13	3.39
	Helenda	13	237.89	315.66	11.56
	Hodhali	8	103.64	158.04	11.18
	Kamarkotda	2	7.08	10.38	6.89
	Karchachiya	11	217.84	318.39	5.39
	Khadvavdi	2	105.05	129.94	8.62
	Makanpar	3	95.88	123.64	13.46
	Mota mandava	8	299.59	441.52	13.26
	Nana mandava	7	207.84	339.63	7.15
	Nava Rajpipla	1	8.49	8.94	8.01
	Pipaliya karmal	0	0.00	0.00	5.42
	Ramaliya	7	56.63	73.80	31.81

Sub Basin No.	Name of village	Nos. of check dams	Design storage capacity (10^3 m^3)	Surface area in (10^3 m^2)	Geographical area (Km^2)
	Ramod	13	254.57	370.81	8.84
	Rampara	3	60.03	100.05	184.67
	Sandhavaya	3	11.89	25.58	7.23
	Sardhar	16	169.33	273.13	17.94
	Satapar	22	679.31	1344.14	23.60
	Total	**128**	**2225.03**	**3016.61**	**184.67**
13	Umrali	17	422.11	591.24	11.65
	Vadipara	8	88.91	100.82	16.04
	Vadiya	7	125.73	178.61	8.45
	Total	**58**	**1438.20**	**2471.09**	**92.36**
14	Bandhiya	4	317.34	260.15	13.90
	Shishak	0	0.00	0.00	9.36
	Total	**4**	**317.34**	**260.15**	**23.26**
15	Shrinathgadh	5	116.32	155.22	15.73
	Total	**5**	**116.32**	**155.22**	**15.73**
16	Madankundla	11	183.92	307.64	12.59
	Total	**11**	**183.92**	**307.64**	**12.59**
17	Shivrajgadh	9	100.72	189.03	52.4
	Total	**9**	**100.72**	**189.03**	**52.40**
	Anandpar	0	0.00	0.00	11.47
	Anida	13	325.92	596.50	8.52
	Ardoi	0	0.00	0.00	8.92
	Bandra	0	0.00	0.00	18.7
	Bhadoi	0	0.00	0.00	13.36
	Bhadva	0	0.00	0.00	18.07
	Bharudi	3	79.85	102.38	28.45
	Bhojpara	7	22.94	34.15	66.28
	Bhunava	4	16.99	26.14	12.2
	Biliyala	3	30.19	43.47	4.75
	Chitravav	6	57.74	78.69	8.95
	Chordi	8	104.71	141.49	8.71
	Detadiya	3	95.43	127.24	11.46
	Devachadi	4	61.16	110.15	66.54
	Devaliya	0	0.00	0.00	5.1
	Ghodavadar	7	258.50	498.98	11.05
	Gomata	11	147.64	253.46	6.24
	Gondal	12	129.72	178.79	8.15

Sub Basin No.	Name of village	Nos. of check dams	Design storage capacity (10^3 m^3)	Surface area in (10^3 m^2)	Geographical area (Km^2)
	Gundasara	10	48.28	68.30	7.03
	Hadamatala	11	268.16	411.73	8.17
	Jamvali	3	3.91	6.86	10.52
	Kantoliya	4	142.60	288.19	9.05
	Karmal Kotda	12	38.17	44.61	8.11
	Khandhar	0	0.00	0.00	9.32
	Khareda	13	187.46	327.90	12.76
	Khokhri	0	0.00	0.00	5.85
	Kotda Sangani	12	294.49	415.49	14.98
	Lilakha	9	529.52	1059.04	26.71
	Manekvada	1	20.95	27.94	5.64
18	Moviya	22	165.45	266.82	9.84
	Nagadka	7	73.54	145.36	5.38
	Naranka	0	0.00	0.00	5.61
	Navagam	5	26.76	42.17	11.32
	Navagam	5	56.35	81.16	9.43
	Panchiyavadar	3	22.43	42.82	10.25
	Panchtalavda	1	28.03	62.30	23.22
	Pipaliya	10	277.50	478.45	10.01
	Rajgadh	4	80.99	105.03	8.83
	Rajpara	5	182.08	319.94	9.97
	Rampara	14	783.26	1271.31	7.69
	Rupavati	7	132.97	234.71	19.03
	Sar	10	78.18	123.04	7.02
	Shemla	6	73.06	145.70	3.28
	Soliya	0	0.00	0.00	6.44
	Suki Sajadiali	9	37.43	60.06	1.64
	Vachhra	1	20.10	40.21	5.75
	Vorakotda	1	11.04	15.66	9.55
	Total	**266**	**4913.51**	**8276.19**	**599.32**
19	Balel Pipaliya	11	3.11	6.23	25.33
	Chamardi	10	16.42	25.86	28.04
	Charkha	8	6.80	9.00	16.6
	Dadva (Randal)	0	0.00	0.00	33.74
	Devaliya Mota	0	0.00	0.00	15.61
	Dharai	4	41.39	60.81	7.81
	Fuljhar	4	54.29	43.55	19.75

Sub Basin No.	Name of village	Nos. of check dams	Design storage capacity (10^3 m^3)	Surface area in (10^3 m^2)	Geographical area (Km^2)
	Gamapipaliya	8	47.82	74.54	16.95
	Ghughrala	4	78.99	128.43	3.75
	Jivapar	0	0.00	0.00	9.29
	Keshvala	1	353.96	707.91	12.54
	Khijadiya kotda	4	18.29	24.31	4.17
	Lonkotda	0	0.00	0.00	7.82
	Madhda	1	30.86	47.48	12.08
	Meghpar	4	56.63	74.84	13.9
	Nonhganvadar	3	22.89	27.15	24.28
	Ranpar	0	0.00	0.00	5.26
	Ranparda	5	47.01	93.13	8.88
	Tramboda	4	12.69	25.07	7.33
	Vasavad	3	284.01	470.39	12.96
	Zundala	0	0.00	0.00	12.14
	Total	**45**	**1048.83**	**1777.61**	**298.23**
20	Badanpur Juna	3	3.28	9.23	12.06
	Bambhaniya	3	11.04	14.98	10.51
	Derdi	9	150.11	220.09	31.69
	Devgam	8	14.05	19.50	6.87
	Ishvariya	5	34.63	48.11	15.47
	Moti Khiroli	4	453.35	827.73	6.46
	Nanikunkavav	4	9.91	16.52	17.68
	Badanpur Nava	0	0.00	0.00	7.68
	Bildi	2	170.32	310.92	9.35
	Dharala	0	0.00	0.00	4.32
	Ishvariya	3	14.44	31.90	2.62
	Kamadhiya	3	14.19	27.56	11.19
	Khambhalida	1	28.03	56.07	22.95
	Lakhapadar	3	17.85	18.05	9.36
	Maya Padar	0	0.00	0.00	8
	Megha-pipaliya	3	14.97	20.21	8.88
	Patkhilori	1	13.88	18.50	12.24
	Ravna	1	5.10	8.49	19
	Sanala	1	99.06	146.75	8.69
	Sarangpur	0	0.00	0.00	8.53
	Total	**54**	**1054.19**	**1794.61**	**233.55**
	Bhayavadar	0	0.00	0.00	7.34

Sub Basin No.	Name of village	Nos. of check dams	Design storage capacity (10^3 m^3)	Surface area in (10^3 m^2)	Geographical area (Km^2)
21	Mota Sakhpar	2	155.17	286.66	6.81
	Nana Sakhpur	0	0.00	0.00	9.96
	Ransiki	12	197.20	321.99	5.12
	Sajadiyali	0	0.00	0.00	7.68
	Sanali	5	19.69	27.68	9.68
	Talali	9	11.94	19.82	13.12
	Ujalal-Nana	0	0.00	0.00	5.45
	Ujala-Mota	0	0.00	0.00	7.45
	Vavdi	5	8.42	16.94	12.5
	Vinzivad	5	24.18	34.88	6.56
	Total	**38**	**416.60**	**707.96**	**91.67**
22	Anida	14	19.90	29.34	9.37
	Dhudashiya	0	0.00	0.00	9.34
	Khajuri-Pipaliya	4	7.29	10.05	8.82
	Targhari	8	26.81	42.48	6.69
	Total	**26**	**54.00**	**81.86**	**34.22**
23	Bhuki-Santhali	11	32.69	60.76	11.75
	Devla	0	0.00	0.00	46.26
	Khadkhad	9	226.32	386.90	7.66
	Khajuri	2	98.81	96.76	11.66
	Khakhariya	4	3.11	4.41	7.05
	Moti Kunkavav	2	16.71	23.87	4.46
	Sultanpur	10	333.65	623.12	37.77
	Surya Pratapgadh	0	0.00	0.00	8.19
	Total	**38**	**711.30**	**1195.82**	**134.80**
24	Dolatpar	2	69.94	69.94	8.03
	Pratappur	6	160.55	149.19	33.15
	Sanathali	14	344.33	402.76	8.67
	Total	**22**	**574.82**	**621.89**	**49.85**
25	Veraval Sanathali	1	28.32	56.63	5.46
	Total	**1**	**28.32**	**56.63**	**5.46**
26	Chitaliya	1	60.03	85.76	4.01
	Total	**1**	**60.03**	**85.76**	**4.01**
27	Jasdan	1	26.90	31.65	5.15
	Total	**1**	**26.90**	**31.65**	**5.15**
Grand Total		**905**	**18596.31**	**27272.45**	**2425.00**
			18.59Mm^3	**27.27Mm^2**	

There are total 188 villages covered under Bhadar-I basin, out of which in 43 villages check dams have not been constructed so far.

The design storage of 905 checkdams is 18.59 Mm^3. The filling of checkdams in sub basins depends on rainfall. To study the relation between the storage of water intercept in checkdams and the effect on Bhadar-I reservoir, the analysis of weekly rainfall pattern of Bhadar-I basin is necessary.

Based on the observations of the rain in each rain gauge stations in each sub basin, the average rainfall of each sub basin has been calculated & used for working out runoff, quantity of water storage (runoff) & quantity of water overflow on conservative estimate only. The rainfall of 100 mm spell in a week is considered. For less than 100 mm rainfall, runoff considered at check dam is nil. The Bhadar-I runoff 17% is taken from the Bhadar project report volume. Hence same is used for check dam runoff calculations. Overflow is considered only after designed full storage of check dams. The details for the years 2003, 2004 & 2005 are presented in Table 5.2, Table 5.3 and Table 5.4.

Table 5.2 Total quantity of water stored & over flow in check dams for year June 2003 to October 2003 in various sub-basins

3rd week of June 2003						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
14	23.26	200	4.652	0.791	0.317	0.474
15	15.73	200	3.146	0.535	0.116	0.419
16	12.59	200	2.518	0.428	0.184	0.244
18	599.32	148	88.400	15.028	4.913	10.115
19	298.23	200	59.646	10.140	1.048	9.092
20	233.55	200	46.710	7.941	1.054	6.887
21	91.67	200	18.334	3.117	0.416	2.701
24	49.85	139	6.929	1.178	0.574	0.604
Total			**230.33**	**39.157**	**8.622**	**30.535**

1st week of July 2003						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
17	52.40	129	6.760	1.149	0.100	1.049
22	34.22	129	4.414	0.750	0.054	0.696
23	134.80	129	17.389	2.956	0.711	2.245
Total			**28.56**	**4.856**	**0.865**	**3.991**

2nd week of July 2003						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
1	73.41	123	9.029	1.535	0.332	1.203
2	24.65	123	3.032	0.515	0.010	0.505
3	121.69	123	14.968	2.545	1.003	1.542
6	15.44	123	1.899	0.323	0.275	0.048
7	62.68	123	7.710	1.311	1.125	0.186
8	129.67	123	15.949	2.711	0.152	2.559
25	5.40	121	0.653	0.111	0.028	0.083
26	4.01	123	0.493	0.084	0.060	0.024
27	5.15	123	0.633	0.108	0.027	0.081
Total			**54.36**	**9.242**	**3.012**	**6.230**

4Th week of July 2003						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
9	25.40	123	2.616	0.445	0.065	0.38
10	16.24	123	1.673	1.190	1.190	
11	19.00	123	1.957	0.333	0.082	0.251
12	184.67	123	19.390	3.296	2.225	1.071
13	92.36	123	9.513	1.617	1.438	0.179
Total			**40.47**	**6.881**	**5.000**	**1.881**

1st week of August 2003						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
4	71.71	138	9.896	0.181	1.003	
5	27.84	138	3.842	0.014	0.085	
14	23.26	100	2.326	0.395	0.317	0.078
15	15.73	100	1.573	0.267	0.116	0.151
16	12.59	100	1.259	0.214	0.184	0.030
17	52.40	143	7.493	1.274	0.100	1.174
18	599.32	205	122.861	20.886	4.913	15.973
19	298.23	100	29.823	5.070	1.048	4.022
20	233.55	100	23.355	3.970	1.054	2.916
21	91.67	100	9.167	1.558	0.416	1.142
22	34.22	143	4.893	0.832	0.054	0.778
23	134.80	143	19.276	3.277	0.711	2.566
24	49.85	121	6.032	1.025	0.574	0.451
Total			**229.20**	**38.965**	**10.575**	**29.283**

2nd week of August 2003						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
1	73.41	136	9.984	1.697	0.332	1.365
2	24.65	136	3.352	0.570	0.010	0.560
3	121.69	136	16.550	2.813	1.003	1.810
6	15.44	136	2.100	0.357	0.275	0.082
7	62.68	136	8.524	1.449	1.125	0.324
8	129.67	136	17.635	2.998	0.152	2.846
25	5.40	136	0.734	0.125	0.028	0.097
26	4.01	136	0.545	0.093	0.060	0.033
27	5.15	136	0.734	0.125	0.028	0.097
Total			**60.12**	**10.221**	**3.012**	**7.209**

Table 5.3 Total Quantity of Water Stored & over flow in Check Dams for Year June 2004 to October 2004

3rd Week of June 2004						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
9	25.40	106	2.692	0.458	0.065	0.393
10	16.24	106	1.721	1.190	1.190	
11	19.00	106	2.014	0.342	0.082	0.260
13	58	1.438		1.438		
18	599.32	113	67.723	11.513	4.913	6.600
Total			**89.12**	**15.167**	**7.688**	**7.479**

1st week of July 2004						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
17	52.40	132	6.917	1.176	0.100	1.076
22	34.22	132	4.517	0.768	0.054	0.714
23	134.80	132	17.794	3.025	0.711	2.314
Total			**29.22**	**4.969**	**0.865**	**4.104**

1st week of August 2004						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
9	25.40	139	3.531	0.600	0.065	0.535
10	16.24	139	2.257	0.384	1.190	-0.806
11	19.00	139	2.641	0.449	0.082	0.367
12	184.67	130	24.007	4.081	2.225	1.856
13	92.36	139	12.838	2.182	1.438	0.744
17	52.40	261	13.676	2.325	0.100	2.225
18	599.32	178	106.679	18.135	4.913	13.222
22	34.22	261	8.931	1.518	0.054	1.464
23	134.80	261	35.183	5.981	0.711	5.270
24	49.85	155	7.727	1.314	0.574	0.740
25	5.40	156	0.842	0.143	0.028	0.115
Total (Mm^3)			**218.31**	**37.113**	**11.380**	**25.733**

2nd week of August 2004						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
1	73.41	120	8.809	1.498	0.332	1.166
2	24.65	120	2.958	0.503	0.010	0.493
3	121.69	120	14.603	2.482	1.003	1.479
6	15.44	120	1.853	0.315	0.275	0.040
7	62.68	120	7.522	1.279	1.125	0.154
8	129.67	120	15.560	2.645	0.152	2.493
26	4.01	120	0.481	0.082	0.060	0.022
27	5.15	120	0.618	0.105	0.027	0.078
Total			**52.40**	**8.909**	**2.984**	**5.925**
4th week of September 2004						
12	**184.67**	**100 mm**	**18.46**	**3.13**	**2.225**	**0.914**

Table 5.4 Total quantity of water Stored & over flow in check dams for year June 2005 to October 2005

4th Week of June 2005						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
1	**2**	**3**	**4**	**5**	**6**	**7**
1	73.41	125	9.176	1.560	0.332	1.228
2	24.65	125	3.081	0.524	0.010	0.514
3	121.69	125	15.211	2.586	1.003	1.583
4	71.71	250	17.928	3.048	1.003	2.045
5	27.84	250	6.960	1.183	0.085	1.098
6	15.44	125	1.930	0.328	0.275	0.053
7	62.68	125	7.835	1.332	1.125	0.207
8	129.67	125	16.209	2.755	0.152	2.603
9	25.40	347	8.814	1.498	0.065	1.433
10	16.24	347	5.635	0.958	1.190	-0.232

1	2	3	4	5	6	7
11	19.00	347	6.593	1.121	0.082	1.039
12	184.67	275	50.784	8.633	2.225	6.408
13	92.36	347	32.049	5.448	1.438	4.010
14	23.26	237	5.513	0.937	0.317	0.620
15	15.73	237	3.728	0.634	0.116	0.518
16	12.59	237	2.984	0.507	0.184	0.323
17	52.40	212	11.109	1.888	0.100	1.788
18	599.32	264	158.220	26.897	4.913	21.984
19	298.23	237	70.681	12.016	1.048	10.968
20	233.55	237	55.351	9.410	1.054	8.356
21	91.67	237	21.726	3.693	0.416	3.277
22	34.22	212	7.255	1.233	0.054	1.179
23	134.80	212	28.578	4.858	0.711	4.147
24	49.85	292	14.556	2.475	0.574	1.901
25	5.40	173	0.934	0.159	0.028	0.131
26	4.01	125	0.501	0.085	0.060	0.025
27	5.15	125	0.644	0.109	0.027	0.082
Total			**563.984**	**95.877**	**18.587**	**77.290**

1st week of August 2005

Sub basin No	Geo. area (km^2)	Average rainfall (mm)	Qty of rain water (Mm^3)	Runoff (17%) (Mm^3)	Qty stored in check dam (Mm^3)	Qty of overflow from check dam (Mm^3)
4	71.71	105	7.530	1.280	1.003	0.277
5	27.84	105	2.923	0.497	0.085	0.412
6	25.40	114	2.896	0.492	0.065	0.427
10	16.24	114	1.851	1.195	1.190	0.005
11	19.00	114	2.166	0.368	0.082	0.286
12	184.67	115	21.237	3.610	2.225	1.385
13	92.36	114	10.529	1.790	1.438	0.352
14	23.26	145	3.373	0.573	0.317	0.256
15	15.73	145	2.281	0.388	0.116	0.272
16	12.59	145	1.826	0.310	0.184	0.126
17	52.40	102	5.345	0.909	0.100	0.809
18	599.32	114	68.322	11.615	4.913	6.702
19	298.23	145	43.243	7.351	1.048	6.303
20	233.55	145	33.865	5.757	1.054	4.703
21	91.67	145	13.292	2.260	0.416	1.844
22	34.22	102	3.490	0.593	0.054	0.539
23	134.80	102	13.750	2.337	0.711	1.626
24	49.85	129	6.431	1.093	0.574	0.519
25	5.40	105	0.567	0.096	0.028	0.068
Total (Mm^3)			**250.09**	**42.516**	**15.690**	**26.826**

2nd week of September 2005						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
1	73.41	101	7.414	1.260	0.332	0.928
2	24.65	101	2.490	0.423	0.010	0.413
3	121.69	101	12.777	2.172	1.003	1.169
4	71.71	105	7.530	1.280	1.003	0.277
5	27.84	105	2.812	0.478	0.085	0.393
6	15.44	101	1.559	0.275	0.275	-
7	62.68	101	6.331	1.125	1.125	-
8	129.67	101	13.097	2.226	0.152	2.074
12	184.67	115	21.237	3.610	2.225	1.385
17	52.40	133	6.969	1.185	0.100	1.085
18	599.32	120	71.918	12.226	4.913	7.313
22	34.22	212	7.255	1.233	0.054	1.179
23	134.80	212	28.578	4.858	0.711	4.147
26	4.01	101	0.405	0.069	0.060	0.009
27	5.15	101	0.520	0.088	0.027	0.061
Total			**177.539**	**30.240**	**12.075**	**18.165**

3rd week of September 2005						
Sub basin No	**Geo. area (km^2)**	**Average rainfall (mm)**	**Qty of rain water (Mm^3)**	**Runoff (17%) (Mm^3)**	**Qty stored in check dam (Mm^3)**	**Qty of overflow from check dam (Mm^3)**
1	**2**	**3**	**4**	**5**	**6**	**7**
9	25.40	120	3.048	0.518	0.065	0.453
10	16.24	120	1.949	1.190	1.190	-
11	19.00	120	2.280	0.388	0.082	0.306
13	92.36	120	11.083	1.884	1.438	0.446
14	23.26	105	2.442	0.415	0.317	0.098
15	15.73	105	1.652	0.281	0.116	0.165
16	12.59	105	1.322	0.225	0.184	0.041
19	298.23	105	31.314	5.323	1.048	4.275
20	233.55	105	24.523	4.169	1.054	3.115
21	91.67	105	9.625	1.636	0.416	1.220
24	49.85	113	5.633	0.958	0.574	0.384
25	5.40	175	0.945	0.161	0.028	0.133

1	2	3	4	5	6	7
19	298.23	145	43.243	7.351	1.048	6.303
20	233.55	145	33.865	5.757	1.054	4.703
21	91.67	145	13.292	2.260	0.416	1.844
22	34.22	102	3.490	0.593	0.054	0.539
23	134.80	102	13.750	2.337	0.711	1.626
24	49.85	129	6.431	1.093	0.574	0.519
25	5.40	105	0.567	0.096	0.028	0.068
Total			**100.86**	**17.147**	**6.512**	**10.635**

The abstract of all the sub basin wise storage of water for the years 2003, 2004 & 2005 has been worked out as under (Table 5.6, Table 5.7 and Table 5.8):

Table 5.5 Details of filling of check dams for year 2003

Sub basin No	Nos. of check dams	3rd week of June	1st week of July	2nd week of July	4th week of July	1st week of August	2nd week of August
1	17			0.332			0.332
2	2			0.010			0.010
3	35			1.003			1.003
4	40					1.003	
5	2					0.085	
6	9			0.275			0.275
7	42			1.125			1.125
8	15			0.152			0.152
9	7				0.065		
10	25				1.190		
11	4				0.082		
12	128				2.225		
13	58				1.438		
14	4	0.317				0.317	
15	5	0.116				0.116	
16	11	0.184				0.184	
17	9		0.100			0.100	
18	266	4.913				4.913	
19	45	1.048				1.048	
20	54	1.054				1.054	
21	38	0.416				0.416	
22	26		0.054			0.054	
23	38		0.711			0.711	
24	22	0.574				0.574	
25	1			0.028			0.028
26	1			0.060			0.060
27	1			0.027			0.027
Total	**905**	**8.622 Mm^3**	**0.865 Mm^3**	**3.012 Mm^3**	**5.000 Mm^3**	**10.575 Mm^3**	**3.012 Mm^3**

Table 5.6 Details of filling of check dams for year 2004

Sub basin No	Nos. of check dams	3rd week of June	1st week of July	1st week of August	2nd week of August	4th week of September
1	17				0.332	
2	2				0.010	
3	35				1.003	
4	40					
5	2					
6	9				0.275	
7	42				1.125	
8	15				0.152	
9	7	0.065		0.065		
10	25	1.190		1.190		
11	4	0.082		0.082		
12	128			2.225		2.225
13	58	1.438		1.438		
14	4					
15	5					
16	11					
17	9		0.100	0.100		
18	266	4.913		4.913		
19	45					
20	54					
21	38					
22	26		0.054	0.054		
23	38		0.711	0.711		
24	22			0.574		
25	1			0.028		
26	1				0.060	
27	1				0.027	
Total	**905**	**7.688 Mm^3**	**0.865 Mm^3**	**11.380 Mm^3**	**2.984 Mm^3**	**2.225 Mm^3**

Table 5.7 Details of filling of check dams for year 2005

Sub basin No	Nos. of check dams	4th week of June	1st week of August	2nd week of September	3rd Week September
1	17	0.332		0.332	
2	2	0.010		0.010	
3	35	1.003		1.003	
4	40	1.003	1.003	1.003	
5	2	0.085	0.085	0.085	
6	9	0.275	0.065	0.275	
7	42	1.125		1.125	
8	15	0.152		0.152	
9	7	0.065			0.065
10	25	1.190	1.190		1.190
11	4	0.082	0.082		0.082
12	128	2.225	2.225	2.225	
13	58	1.438	1.438		1.438
14	4	0.317	0.317		0.317
15	5	0.116	0.116		0.116
16	11	0.184	0.184		0.184
17	9	0.100	0.100	0.100	
18	266	4.913	4.913	4.913	
19	45	1.048	1.048		1.048
20	54	1.054	1.054		1.054
21	38	0.416	0.416		0.416
22	26	0.054	0.054	0.054	
23	38	0.711	0.711	0.711	
24	22	0.574	0.574		0.574
25	1	0.028	0.028		0.028
26	1	0.060		0.060	
27	1	0.027		0.027	
Total	**905**	**18.587 Mm^3**	**15.690 Mm^3**	**12.075 Mm^3**	**6.512 Mm^3**

Table 5.8 Abstract of total water stored in check dams (Mm^3)

Month	Week	Year		
		2003	2004	2005
June	1st			
June	2nd			
June	3rd	8.622	7.688	
June	4th			18.587
July	1st	0.865	0.865	
July	2nd	3.012		
July	3rd			
July	4th	5.000		
August	1st	10.575	11.38	15.69
August	2nd	3.012	2.984	
August	3rd			
August	4th			
September	1st			
September	2nd			12.075
September	3rd			6.512
September	4th		2.225	
Total		**31.086**	**25.142**	**52.864**

To know the impact of water stored in Bhadar–I reservoir, it is first necessary to work out water storage without check dams scenario. The check dams store the water which is otherwise runoff to the reservoir, accordingly the additional yield of water at Bhadar-I reservoir has been worked out.

Now the data on rainfall- runoff & yield at Bhadar-I reservoir have been made available. The same data are used for deriving formula for each month rainfall-runoff relation has been worked out.

5.1.3 Analysis of rainfall - runoff formulas adopted.

5.1.3.1 Catchment area of Bhadar-I

The area of the watershed of the Bhadar river at the dam site is 2436 km^2. The catchment is partly hilly and partly plain and more or less devoid of

vegetation. The catchment is fan shaped. The hilly part of the catchment has very steep slopes. Which can be put in the category of an average catchment.

There are two existing tanks in the catchment area. The one on river Bhadar is near Jasdan, having a catchment area of 52.48 km^2. The second one of the river Gondli is near Gondal town and has a catchment of 233.57 km^2. The two tanks were constructed by the princely states of Jasdan and Gondal. There is also a third tank on river Gondli, near village Kotda-sangani. The catchment of this tank is 68.24 km^2 and is a part of the second catchment mentioned above. Thus total catchment of 2436 km^2 has already been tapped and necessary consideration for this area has been made in calculating the yield for the proposed reservoir. The maximum length of the catchment is about 68.04 km and the breadth is about 55.08 km.

5.1.3.2 Rainfall considered in design of Bhadar dam

There are six rain gauge stations in the catchment area. Such as, (1) Gondal (2) Amarnagar (3) Kotda-sangani (4) Jasdan (5) Vasavad (6) Kunavav. The rainfall figures for most of the stations are available for years 1935 to 1953, i.e. for a period of 18 years. There is more or less even distribution of rainfall all over the catchment. The average annual rainfall of the catchment as worked out from the average of all the six rain gauge stations, comes to 63.07 cm. The life of the Bhadar reservoir is considered as per the silt reserve provided is 80 years.

5.1.3.3 Run-off and yield calculation adopted during design of Bhadar reservoir

In the absence of actual observations near the dam site, various formula curves and tables were tried to get the possible results of percentage of run-off and annual yield from the catchment.

Method A:

Method is recommended in the annual irrigation report of the Central Board of Irrigation. This gives different percentage for different catchments depending on the annual rainfall. The formula does not provide for any consideration types of catchments, variation of soil, and the characteristics. The formula used is given below:

Percentage of run off =Rainfall - 7.

The percentage of run off for each zone of influence of each rain-gauge station has been considered separately to work out the annual yield. This works out to be 246.58 Mm^3. excluding the yield or capacities (whichever is less) for the existing tanks.

Method B:

W.L. Strange, in his book "INDIAN STORAGE RESERVOIR" gives a table of percentages of run-off for various values of rainfall and for three conditions of catchment viz. (1) good, (2) average and (3) bad.

In method B(1), all the zones of influences are considered as average catchment and in method B(2), the zones Jasdan and Kotada Sangani which are hilly are taken as good catchment and the remaining zones as average catchment. The annual yield works out to 210.73 Mm^3 according to method B(1), and 245.39 Mm^3 according to method B(2).

Method C:

The annual yield is computed by taking run-off of 17% of the replenishment for the whole catchment on individual stations. The annual yield calculated by this method works out to 235.71 Mm^3.

Method D:

In this method, percentages proportional to annual rainfall are taken and yield for the whole catchment is calculated for years 1935 to 1953.

Rainfall (cm)	Percentage
63.5 and above	1/5
50.8 to 63.5	1/6
38.1 to 50.8	1/7
25.4 to 38.1	1/8
Below 25.4	1/10

The yield from the catchment works out to 245.20 Mm^3.

The annual replenishment according to the various methods is as under : -

1) Method A : 246.58 Mm^3.
2) Method B(1) : 210.73 Mm^3.
3) Method B(2) : 245.39 Mm^3.
4) Method C : 235.71 Mm^3.
5) Method D : 245.20 Mm^3.

The observations on the existing tanks have so far indicated that the percentage of run-off works out between 17% to 20%. Hence in view of the topographical conditions in Saurashtra and the annual rainfall conditions, the annual yield of 235.71 Mm^3 as calculated by Method C is reasonable.

5.1.4 Analysis of rainfall-runoff formulas on the basis of actual observations

River gauging stations

In Bhadar-I river basin, there are 3 nos. of river gauge, discharge and sediment measurement sites.

The general methodology adopted for establishing rainfall runoff equations is on the basis of virgin flow condition of channel at particular site where the relation has been established. The virgin flow condition of channel is computed using reservoir performance details of Bhadar-I dam on the channel.

Bhadar-I dam is situated at the end of Bhadar-I sub basin. The monthly rainfall runoff relationship representative for that sub basin is developed for each month viz. June to October at Bhadar-I dam site. The monthly rainfall data of all 16 raingauge stations influencing the catchment area of Bhadar-I sub basin from 1960 to 1995 are taken into consideration. Average rainfall of 16 rain gauge stations covering the entire basin has been considered.

There are 6 medium existing projects on river Bhadar and its tributaries viz. Ishwaria, Karmal, Gondali, Veri, Vachhapari and Bhadar-I. From available fortnightly performance data of these existing projects, monthly observed run-off is computed for the year 1980 to 1995. The virgin flow at Bhadar-I dam site is computed by using the monthly reservoir performance of all the existing projects already constructed u/s of the Bhadar-I dam site between the year 1980 to 1995 (Table 5.9).

The rainfall-runoff relationships are developed at Bhadar-I dam site for each month from June to October for the year 1980 to 1995 and virgin flow at Bhadar-I dam site between the year 1980 to 1995 (Table 5.10 & Table 5.11). During analysis, it is found that data for the following years are not consistent and therefore not considered in the study.

Monthly relation for		**Data for the years not considered.**
June	:	1983
July	:	1980, 1983
August	:	1980, 1983
September	:	1983
October	:	1980, 1983

The rainfall data for post monsoon months (November to May) are available for long span of the years, while discharge gauging data are inadequate. Hence, run-off during post monsoon is worked out on the basis of the ratio of observed rainfall of post monsoon period to monsoon period. The post monsoon rainfall is 3.58 % to monsoon rainfall. The same percentage i.e. 3.58% is applied to work out the post monsoon runoff.

Using rainfall-runoff relationship for each month and arithmetic average rainfall of 16 rain gauge stations, yield series is computed for the period 1960 to 1995. The correlations have been worked out and the results have been expressed in terms of coefficient of correlation (r) and R values (Table 5.10, Table 5.11, Table 5.12, Table 5.13 & Table 5.14). Abstract of rainfall-runoff relation for Bhadar-I sub-basin is presented in Table 5.15.

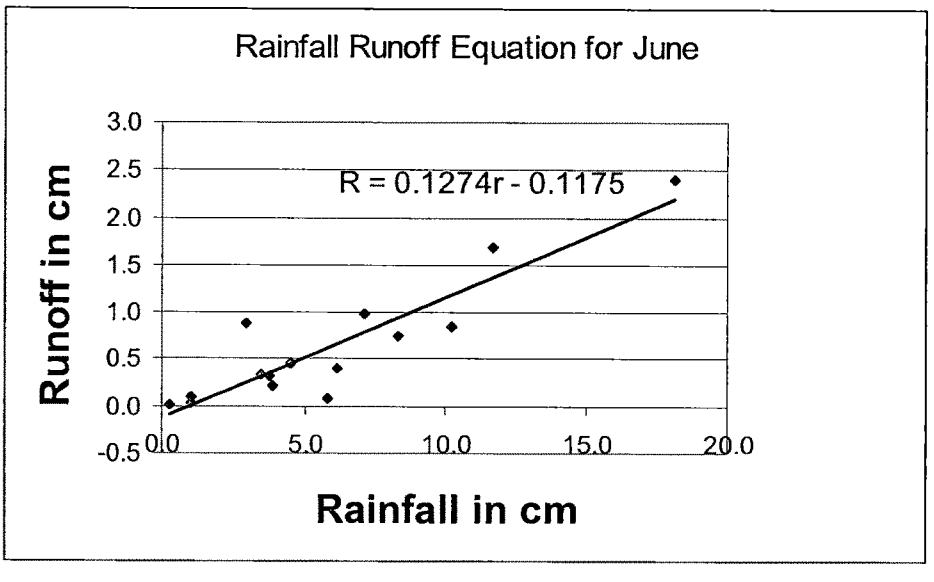
Table 5.9 Monthly runoff (cm) based on reservoir performance for Bhadar-I reservoir

Sr. No.	Year	June	July	August	September	October
1	1980	2.40	13.40	6.24	0.86	0.40
2	1981	0.75	7.00	5.25	2.14	0.65
3	1982	0.10	0.99	0.56	0.28	0.00
4	1983	13.91	14.73	15.91	6.16	2.55
5	1984	0.89	0.26	1.72	4.74	0.33
6	1985	0.03	0.12	0.32	0.18	0.00
7	1986	1.68	0.06	0.44	0.03	0.05
8	1987	0.46	0.12	0.78	0.03	0.00
9	1988	0.34	26.09	2.08	3.16	0.73
10	1989	0.40	2.10	0.49	1.01	0.12
11	1990	0.32	0.24	2.28	1.11	0.25
12	1991	0.21	5.12	0.46	0.24	0.06
13	1992	0.08	4.08	2.12	3.12	0.51
14	1993	0.99	2.52	0.06	0.63	0.22
15	1994	0.85	15.65	1.57	4.39	0.23
16	1995	0.01	1.14	1.05	0.31	0.04

Table 5.10 Rainfall -runoff correlation for month of June

Sr. No.	Year	Rainfall in cm (x)	Runoff in cm (y)
1	1980	18.16	2.40
2	1981	8.38	0.75
3	1982	1.03	0.10
4	1984	2.92	0.89
5	1985	1.03	0.03
6	1986	11.71	1.68
7	1987	4.49	0.46
8	1988	3.48	0.34
9	1989	6.15	0.40
10	1990	3.77	0.32
11	1991	3.88	0.21
12	1992	5.84	0.08
13	1993	7.12	0.99
14	1994	10.25	0.85
15	1995	0.28	0.01
Co-efficient of correlation = 0.904			
Relation is R= 0.1274r – 0.1175			

(Source: Rainfall and Runoff data RIC, Rajkot)

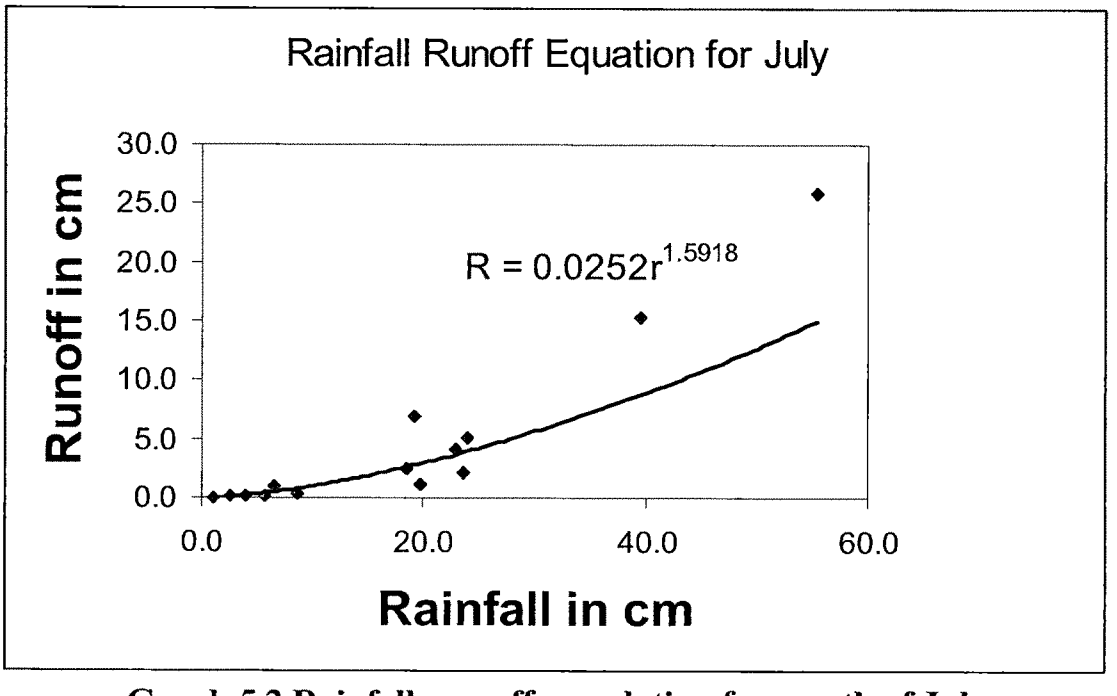


Graph-5.1 Rainfall -runoff correlation for month of June

Table 5.11 Rainfall -runoff correlation for month of July

Sr.	Year	Rainfall in cm (x)	Runoff in cm (y)
1	1981	19.27	7.00
2	1982	6.66	0.99
3	1984	8.76	0.26
4	1985	5.81	0.12
5	1986	0.99	0.06
6	1987	2.70	0.12
7	1988	55.39	26.09
8	1989	23.54	2.10
9	1990	4.11	0.24
10	1991	23.89	5.12
11	1992	22.89	4.08
12	1993	18.49	2.52
13	1994	39.60	15.65
14	1995	19.74	1.14
Co-efficient of correlation = 0.927			
Relation is R = 0.0252 $r^{1.5918}$			

(Source: Rainfall and Runoff data RIC, Rajkot)



Graph-5.2 Rainfall -runoff correlation for month of July

Table 5.12 Rainfall -runoff correlation for month of August

Sr. No.	Year	August rainfall in cm	August runoff in cm
1	1981	20.9	5.25
2	1982	7.2	0.56
3	1984	16.5	1.72
4	1985	6.4	0.32
5	1986	7.3	0.44
6	1987	7.4	0.78
7	1988	10.7	2.08
8	1989	5.3	0.49
9	1990	21	2.28
10	1991	7.1	0.46
11	1992	12.2	2.12
12	1993	0.1	0.06
13	1994	7.7	1.57
14	1995	6.7	1.05
Correlation coefficient		0.8834	
Relation is $R_{Aug} = -0.9783+0.026\ (r)_{july} +0.1928\ (r)_{Aug}$			

(Source: Rainfall and Runoff data RIC, Rajkot)

Table 5.13 Rainfall -runoff correlation for month of September

Sr. No.	Year	September rainfall in cm	September runoff in cm
1	1980	1.60	0.86
2	1981	13.90	2.14
3	1982	0.90	0.28
4	1984	16.80	4.74
5	1985	4.60	0.18
6	1986	0.10	0.03
7	1987	0.40	0.03
8	1988	12.40	3.16
9	1989	8.50	1.01
10	1990	6.20	1.11
11	1991	1.60	0.24
12	1992	11.60	3.12
13	1993	10.20	0.63
14	1994	11.30	4.39
15	1995	4.20	0.31
Correlation coefficient			0.8519
$R_{Sep} = -0.4592 + 0.0304(r)_{Aug} + 0.2361(r)_{Sep}$			

(Source: Rainfall and Runoff data RIC, Rajkot)

Table 5.14 Rainfall -runoff correlation for month of October

Sr. No.	Year	October rainfall (cm)	October runoff (cm)
1	1981	1.00	0.65
2	1982	0.10	0.00
3	1984	0.00	0.33
4	1985	0.10	0.00
5	1986	0.00	0.05
6	1987	0.10	0.00
7	1988	0.00	0.73
8	1989	0.40	0.12
9	1990	1.40	0.25
10	1991	0.00	0.06
11	1992	1.10	0.51
12	1993	4.30	0.22
13	1994	0.00	0.23
14	1995	1.60	0.04
Correlation coefficient			0.80
$R_{Oct.} = -0.0231 + 0.0355\ (r)_{Sep} - 0.0135\ (r)_{Oct}$			

(Source: Rainfall and Runoff data-RIC, Rajkot)

Table 5.15 Abstract of rainfall-runoff relation developed

Bhadar-I sub-basin		
1	Site at which relation developed	BHADAR-I Dam.
2	Period of data considered :	1980 to 1995.
3	Type of relation	Monthly Relation. (June to October)
4	Relation	
	June*	$R = 0.1273\ r - 0.1175$
	July*	$R = 0.0251 * (r)^{1.593}$
	August**	$R_{Aug} = -0.9783 + 0.026(r)_{July} + 0.1928(r)_{Aug}$
	September**	$R_{Sep} = -0.4592 + 0.0304(r)_{Aug} + 0.2361(r)_{Sep}$
	October**	$R_{Oct.} = -0.0231 + 0.0355\ (r)_{Sep} - 0.0135\ (r)_{Oct}$
	Where r = Rainfall in cm and R = Run-off in cm	
	* Rainfall runoff correlation are derived based on MS Excel ** Rainfall runoff correlation are derived from FORTRAN based Multivariate Program.	

The check dams are constructed on the catchment of Bhadar-I after year 2000. The total 905 concrete/ masonry check dams (not water sheds) are

constructed which have storage capacity of 18.59 Mm^3. The catchment area of Bhadar-I is 2436 km^2 which is intercepted partially. It is, however, important to know the effect of storage reduction if any on Bhadar-I and effect on irrigation reduction in the command of Bhadar-I.

5.1.5 Additional yield in Bhadar-I without check dam scenario

If there were no checkdams in catchment area, the water stored in different years at Bhadar-I reservoir is calculated. The quantity of water received every year in Bhadar – I reservoir is worked out considering runoff at (a) 17% rate and (b) new equation of rainfall-runoff. The details of which are presented in Table 5.16.

Table 5.16 Results of water received in Bhadar reservoir (without Check dam)

Week /Month	Qty of stored in check dams (Mm^3)	Check dam water available at Bhadar-I reservoir considering 17 % runoff (Mm^3)	Water available at Bhadar-I reservoir as per new formula (Mm^3)
Year 2003-2004			
3rd/ June	8.622	1.466	1.000
1 / July	0.865	0.147	0.160
2 / July	3.012	0.512	0.550
4 / July	5.000	0.850	0.920
1 / August	10.575	1.800	1.930
2 / August	3.012	0.510	0.550
Total	**31.086**	**5.285**	**5.11**
Year 2004-2005			
3/June	7.688	1.310	0.890
1/July	0.865	0.150	0.110
1/August	11.380	1.970	1.870
2/August	2.984	0.510	0.490
4 / September	2.225	0.380	0.580
Total	**25.145**	**4.32**	**3.94**
Year 2005-2006			
4 / June	18.587	3.160	2.286
1 / August	15.690	2.670	10.900
2 / September	12.075	2.050	2.790
3 / September	6.512	1.100	0.250
Total	**52.864**	**8.98**	**16.226**

5.1.6 Scenarios of water storage in Bhadar-I reservoir without check dam in catchment

In this study it is required to know what is the effect on water storage in Bhadar-I reservoir due to construction of check dams in the catchment area. The total 905 check dams have been constructed which are designed to overflow at 4" (10 cm) rainfall. If there are no check dams in the catchment, the water reaches to Bhadar-I reservoir. The runoff scenarios for the check dam water are adopted in two different types. (1) the water of check dam is considered as rainfall quantity and 17% runoff of this quantity is added in Bhadar-I reservoirs, and (2) as per actual observations and using the new rainfall runoff equation is being used and considering that runoff quantity of check dam water is added in Bhadar-I reservoir and same has been considered as additional canal release.

Table 5.17 The effect of check dam water on water level in Bhadar-I reservoir (Year 2001-02) (Actual reservoir performance)

Sr. No.	Month & Fort-night	Reservoir Level Beginning (m)	Reservoir Level End (m)	Capacity at Beginning (Mm^3)	Capacity at End (Mm^3)	Difference of Capacity (Mm^3)	Canal Releases (Mm^3)	Water Supply (Mm^3)	Flow Over the Waste Weir (Mm^3)	Other Losses (Mm^3)	Average RL (m)	Area at Average RL (Mm^2)	Evaporation Depth	Evapo-ration Losses (Mm^3)	Runoff (Mm^3)
1	JUL1	96.000	101.250	0.0000	18.5828	18.5828		0.3490			98.625	2.9069	0.1145	0.3328	19.2647
2	JUL2	101.250	101.100	18.5828	17.1269	-1.4559		0.8290			101.175	9.8929	0.1145	1.1327	0.5058
3	AUG1	101.100	101.350	17.1269	19.6509	2.5240		0.9730			101.225	10.0699	0.1015	1.0221	4.5191
4	AUG2	101.350	101.770	19.6509	24.9970	5.3461		0.9670			101.560	11.3008	0.1015	1.1470	7.4601
5	SEP1	101.770	101.620	24.9970	22.9170	-2.0800		1.0230			101.695	11.8449	0.1015	1.2023	0.1453
6	SEP2	101.620	101.410	22.9170	20.2917	-2.6253		1.0150		0.4230	101.515	11.1195	0.1015	1.1286	-0.0586
7	OCT1	101.410	101.190	20.2917	17.9420	-2.3497		0.9010		0.4380	101.300	10.3396	0.0890	0.9202	-0.0905
8	OCT2	101.190	100.920	17.9420	15.4967	-2.4453		1.0990		0.4240	101.055	9.4841	0.0890	0.8441	-0.0782
9	NOV1	100.920	100.640	15.4967	13.3306	-2.1661		1.0520		0.3300	100.780	8.4934	0.0760	0.6455	-0.1386
10	NOV2	100.640	100.370	13.3306	11.5488	-1.7818		1.1240		0.1000	100.505	7.5047	0.0760	0.5704	0.0125
11	DEC1	100.370	100.060	11.5488	9.7750	-1.7738		1.0590		0.2730	100.215	6.7017	0.0635	0.4256	-0.0163
12	DEC2	100.060	99.760	9.7750	7.8162	-1.9588		1.0950		0.4040	99.910	5.8922	0.0635	0.3742	-0.0856
13	JAN1	99.760	99.520	7.8162	6.4622	-1.3540		0.5900		0.3560	99.640	5.2251	0.0635	0.3318	-0.0762
14	JAN2	99.520	99.300	6.4622	5.3880	-1.0742		0.2890		0.3640	99.410	4.6738	0.0635	0.2968	-0.1244
15	FEB1	99.300	99.090	5.3880	4.3380	-1.0500		0.2140		0.4690	99.195	4.1959	0.0635	0.2664	-0.1006
16	FEB2	99.090	98.900	4.3380	3.6285	-0.7095		0.1230		0.3400	98.995	3.7608	0.0635	0.2388	-0.0077
17	MAR1	98.900	98.690	3.6285	2.9141	-0.7143		0.1490		0.2150	98.795	3.3231	0.1015	0.3373	-0.0130
18	MAR2	98.690	98.440	2.9141	2.2070	-0.7071		0.1590		0.2000	98.565	2.7477	0.1015	0.2789	-0.0693
19	APR1	98.440	98.200	2.2070	1.5958	-0.6112		0.1610		0.1990	98.320	2.1928	0.1145	0.2511	-0.0001
20	APR2	98.200	97.900	1.5958	0.8542	-0.7416		0.1430		0.3780	98.050	1.6909	0.1145	0.1936	-0.0270
21	MAY1	97.900	97.690	0.8542	0.4665	-0.3877		0.1410		0.0700	97.795	1.2173	0.1270	0.1546	-0.0221
22	MAY2	97.690	96.500	0.4665	0.0734	-0.3931		0.1070		0.2180	97.095	0.5283	0.1270	0.0671	-0.0010
23	JUN1	96.500	97.840	0.0734	0.7070	0.6336					97.170	0.5645	0.1145	0.0646	0.6983
24	JUN2	97.840	107.290	0.7070	161.7340	161.0270		0.0460	130.268		102.565	15.2880	0.1145	1.7505	293.091
				TOTAL		**161.7340**	**0.00**	**13.608**	**130.268**	**5.2010**				**13.977**	**324.788**

(Source : Rajkot Irrigation Circle, Rajkot)

Table 5.18 The effect of check dam water on water level in Bhadar-I reservoir (Year 2002-03) (Actual reservoir performance)

Sr. No.	Month & Fort-night	Reservoir Level Beginning (m)	Reservoir Level End (m)	Capacity at Beginning (Mm^3)	Capacity at End (Mm^3)	Difference of Capacity (Mm^3)	Canal Releases (Mm^3)	Water Supply (Mm^3)	Flow Over the Waste Weir (Mm^3)	Other Losses (Mm^3)	Average RL (m)	Area at Average RL (Mm^2)	Evaporation Depth	Evapo-ration Losses (Mm^3)	Runoff (Mm^3)
1	JUL1	107.290	107.130	161.7340	154.8570	-6.8770		0.5330		1.9340	107.210	38.4770	0.1145	4.4056	-0.0044
2	JUL2	107.130	107.010	154.8570	149.7858	-5.0712		0.7380		0.0180	107.070	37.8078	0.1145	4.3290	0.0138
3	AUG1	107.010	106.890	149.7858	145.5888	-4.1970		0.7800			106.950	37.1760	0.1015	3.7734	0.3564
4	AUG2	106.890	106.770	145.5888	141.6832	-3.9056	0.460	0.9390			106.830	36.4320	0.1015	3.6978	1.1912
5	SEP1	106.770	106.650	141.6832	137.8060	-3.8772	0.500	0.7900			106.710	35.6888	0.1015	3.6224	1.0352
6	SEP2	106.650	106.530	137.8060	134.0140	-3.7920		0.9330			106.590	34.9456	0.1015	3.5470	0.6880
7	OCT1	106.530	106.380	134.0140	128.9910	-5.0230		1.0730		0.9100	106.455	34.1090	0.0890	3.0357	-0.0043
8	OCT2	106.380	106.220	128.9910	123.6837	-5.3073		1.0490		1.3080	106.300	33.2725	0.0890	2.9613	0.0109
9	NOV1	106.220	105.690	123.6837	106.9278	-16.7559	10.710	1.0860		2.6600	105.955	31.4447	0.0760	2.3898	0.0899
10	NOV2	105.690	105.050	106.9278	87.6616	-19.2662	14.190	1.0180		1.8900	105.370	28.3652	0.0760	2.1558	-0.0125
11	DEC1	105.050	104.380	87.6616	70.8662	-16.7954	13.190	1.1180		0.9780	104.715	25.0744	0.0635	1.5922	0.0829
12	DEC2	104.380	103.330	70.8662	47.7700	-23.0962	19.842	1.0000		0.9170	103.855	20.9928	0.0635	1.3330	-0.0042
13	JAN1	103.330	101.942	47.7700	27.2525	-20.5175	18.023	1.0700		0.4710	102.636	15.6071	0.0635	0.9911	0.0376
14	JAN2	101.942	101.470	27.2525	20.9326	-6.3200	4.0800	1.1670		0.3180	101.706	11.8890	0.0635	0.7550	0.0000
15	FEB1	101.470	101.220	20.9326	18.2624	-2.6702		1.1340		0.8620	101.345	10.5015	0.0635	0.6668	-0.0073
16	FEB2	101.220	100.968	18.2624	15.9345	-2.3279		0.9120		0.8010	101.094	9.6175	0.0635	0.6107	-0.0042
17	MAR1	100.968	100.670	15.9345	13.5580	-2.3766		1.1200		0.3490	100.819	8.6460	0.1015	0.8776	-0.0300
18	MAR2	100.670	100.340	13.5580	11.3592	-2.1988		1.2140		0.2570	100.505	7.5047	0.1015	0.7617	0.0340
19	APR1	100.340	100.000	11.3592	9.4463	-1.9129		1.0000		0.1570	100.170	6.5804	0.1145	0.7535	-0.0024
20	APR2	100.000	99.730	9.4463	7.6068	-1.8395		0.9570		0.2180	99.865	5.7806	0.1145	0.6619	-0.0026
21	MAY1	99.730	99.330	7.6068	5.5360	-2.0708		0.9370		0.5020	99.530	4.9610	0.1270	0.6300	-0.0018
22	MAY2	99.330	98.812	5.5360	3.3213	-2.2147		1.0000		0.7160	99.071	3.9266	0.1270	0.4987	0.0000
23	JUN1	98.812	98.350	3.3213	1.9778	-1.3435		0.8310		0.1930	98.581	2.7904	0.1145	0.3195	0.0000
24	JUN2	98.350	102.660	1.9778	36.6240	34.6462		0.8330			100.505	7.5047	0.1145	0.8593	36.338
				TOTAL		**-125.1100**	**80.995**	**23.2320**	**0.0000**	**15.459**				**45.228**	**39.805**

(Source : Rajkot Irrigation Circle, Rajkot)

Table 5.19 The effect of check dam water on water level in Bhadar-I reservoir (Year 2003-04) (Actual reservoir performance)

Sr. No.	Month & fort-night	Reservoir level beginning (m)	Reservoir level End (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Runoff (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow over the waste weir (Mm^3)	Other Losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evapo-ration losses (Mm^3)
1	Jul-01	102.63	103.14	36.22	44.18	7.96	10.8		0.91			102.89	16.8	0.11	1.92
2	Jul-02	103.14	103.83	44.18	58.85	14.67	17.85		0.96			103.49	19.4	0.11	2.22
3	Aug-01	103.83	105.55	58.85	102.65	43.8	47.41		1.08			104.69	24.95	0.1	2.53
4	Aug-02	105.55	105.9	102.65	113.14	10.49	14.72		1.17			105.73	30.12	0.1	3.06
5	Sep-01	105.9	105.98	113.14	115.59	2.44	6.76		1.13			105.94	31.35	0.1	3.18
6	Sep-02	105.98	106.1	115.59	119.44	3.85	8.2		1.1			106.04	31.97	0.1	3.25
7	Oct-01	106.1	106.04	119.44	117.45	-1.99	1.9		1.03			106.07	32.16	0.09	2.86
8	Oct-02	106.04	105.92	117.45	113.72	-3.72	0.22		1.13			105.98	31.6	0.09	2.81
9	Nov-01	105.92	105.76	113.72	109.07	-4.66	0.01		1.05		1.28	105.84	30.76	0.08	2.34
10	Nov-02	105.76	105.12	109.07	89.56	-19.51	5.13	15.65	1.04		0.48	105.44	28.71	0.08	2.18
11	Dec-01	105.12	104.17	89.56	66.36	-23.2	0.11	18.8	1.12		1.82	104.65	24.73	0.06	1.57
12	Dec-02	104.17	103.34	66.36	47.98	-18.37	0.04	13.84	1.21		2.06	103.76	20.54	0.06	1.3
13	Jan-01	103.34	102.19	47.98	30.44	-17.54	-0.05	13.76	1.15		1.55	102.77	16.21	0.06	1.03
14	Jan-02	102.19	101.56	30.44	22.09	-8.36	0.06	5.15	1.21		1.26	101.88	12.54	0.06	0.8
15	Feb-01	101.56	100.83	22.09	14.77	-7.31	0.02	5.09	1.14		0.48	101.2	9.96	0.06	0.63
16	Feb-02	100.83	100.61	14.77	13.1	-1.67	-0.02		1.01		0.11	100.72	8.26	0.06	0.52
17	Mar-01	100.61	100.34	13.1	11.36	-1.74	0.01		1		0	100.48	7.42	0.1	0.75
18	Mar-02	100.34	100.03	11.36	9.61	-1.75	-0.02		1.02		0.04	100.19	6.62	0.1	0.67
19	Apr-01	100.03	99.76	9.61	7.82	-1.79	0.01		1.05		0.08	99.9	5.86	0.11	0.67
20	Apr-02	99.76	99.4	7.82	5.88	-1.93	0.04		1.1		0.3	99.58	5.08	0.11	0.58
21	May-01	99.4	102.96	5.88	41.02	35.14	37.46		1.07			101.18	9.91	0.13	1.26
22	May-02	102.96	102.72	41.02	37.44	-3.58	-0.04		1.01		0.42	102.84	16.58	0.13	2.11
23	Jun-01	102.72	102.87	37.44	39.68	2.24	4.89		0.78			102.8	16.36	0.11	1.87
24	Jun-02	102.87	102.81	39.68	38.78	-0.89	1.79		0.79			102.84	16.58	0.11	1.9
				TOTAL		**2.57**	**152.02**	**72.29**	**25.26**	**0**	**9.88**			**2.26**	**42.03**

Table 5.20 The effect of check dam water (considering 17%) on water level in Bhadar-I reservoir (year 2003-04)

Sr. No.	Month & fort-night	Reservoir level beginning (m)	Reservoir level End (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Runoff (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow over the waste weir (Mm^3)	Other Losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evapo-ration losses (Mm^3)
1	Jul-01	102.63	103.14	36.22	44.18	7.96	10.8	2.13*	0.91			102.89	16.8	0.11	1.92
2	Jul-02	103.14	103.83	44.18	58.85	14.67	17.85	0.85*	0.96			103.49	19.4	0.11	2.22
3	Aug-01	103.83	105.55	58.85	102.65	43.8	47.41	2.31*	1.08			104.69	24.95	0.1	2.53
4	Aug-02	105.55	105.9	102.65	113.14	10.49	14.72		1.17			105.73	30.12	0.1	3.06
5	Sep-01	105.9	105.98	113.14	115.59	2.44	6.76		1.13			105.94	31.35	0.1	3.18
6	Sep-02	105.98	106.1	115.59	119.44	3.85	8.2		1.1			106.04	31.97	0.1	3.25
7	Oct-01	106.1	106.04	119.44	117.45	-1.99	1.9		1.03			106.07	32.16	0.09	2.86
8	Oct-02	106.04	105.92	117.45	113.72	-3.72	0.22		1.13			105.98	31.6	0.09	2.81
9	Nov-01	105.92	105.76	113.72	109.07	-4.66	0.01		1.05		1.28	105.84	30.76	0.08	2.34
10	Nov-02	105.76	105.12	109.07	89.56	-19.51	5.13	15.65	1.04		0.48	105.44	28.71	0.08	2.18
11	Dec-01	105.12	104.17	89.56	66.36	-23.2	0.11	18.8	1.12		1.82	104.65	24.73	0.06	1.57
12	Dec-02	104.17	103.34	66.36	47.98	-18.37	0.04	13.84	1.21		2.06	103.76	20.54	0.06	1.3
13	Jan-01	103.34	102.19	47.98	30.44	-17.54	-0.05	13.76	1.15		1.55	102.77	16.21	0.06	1.03
14	Jan-02	102.19	101.56	30.44	22.09	-8.36	0.06	5.15	1.21		1.26	101.88	12.54	0.06	0.8
15	Feb-01	101.56	100.83	22.09	14.77	-7.31	0.02	5.09	1.14		0.48	101.2	9.96	0.06	0.63
16	Feb-02	100.83	100.61	14.77	13.1	-1.67	-0.02		1.01		0.11	100.72	8.26	0.06	0.52
17	Mar-01	100.61	100.34	13.1	11.36	-1.74	0.01		1		0	100.48	7.42	0.1	0.75
18	Mar-02	100.34	100.03	11.36	9.61	-1.75	-0.02		1.02		0.04	100.19	6.62	0.1	0.67
19	Apr-01	100.03	99.76	9.61	7.82	-1.79	0.01		1.05		0.08	99.9	5.86	0.11	0.67
20	Apr-02	99.76	99.4	7.82	5.88	-1.93	0.04		1.1		0.3	99.58	5.08	0.11	0.58
21	May-01	99.4	102.96	5.88	41.02	35.14	37.46		1.07			101.18	9.91	0.13	1.26
22	May-02	102.96	102.72	41.02	37.44	-3.58	-0.04		1.01		0.42	102.84	16.58	0.13	2.11
23	Jun-01	102.72	102.87	37.44	39.68	2.24	4.89		0.78			102.8	16.36	0.11	1.87
24	Jun-02	102.87	102.81	39.68	38.78	-0.89	1.79		0.79			102.84	16.58	0.11	1.9
				TOTAL		**2.57**	**152.02**	**77.58**	**25.26**	**0**	**9.88**			**2.26**	**42.03**

(* Canal release from check dams)

Table 5.21 The effect of check dam water on water level in Bhadar-I reservoir (year 2004-05) (Actual reservoir performance)

Sr. No.	Month & fort-night	Reservoir level beginning (m)	Reservoir level End (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Runoff (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow over the waste weir (Mm^3)	Other Losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evapo-ration losses (Mm^3)
1	Jul-01	102.81	103.17	38.49	44.62	6.13	9.13		1.02			102.94	17.32	0.11	1.98
2	Jul-02	103.17	103.08	44.62	42.86	-1.76	1.58		0.98			103.12	20.61	0.11	2.36
3	Aug-01	103.08	104.45	42.86	72.28	29.42	32.17		0.94			103.76	17.80	0.10	1.81
4	Aug-02	104.45	104.64	72.28	76.61	4.33	7.77		0.98			104.54	24.25	0.10	2.46
5	Sep-01	104.64	104.57	76.61	75.06	-1.55	1.97		1.03			104.60	24.51	0.10	2.49
6	Sep-02	104.57	104.70	75.06	78.15	3.09	6.66		1.07			104.63	24.60	0.10	2.50
7	Oct-01	104.70	104.64	78.15	76.61	-1.55	1.74		1.08			104.67	24.80	0.09	2.21
8	Oct-02	104.64	104.42	76.61	71.63	-4.98	-0.58		1.07		1.18	104.53	24.25	0.09	2.16
9	Nov-01	104.42	104.24	71.63	67.64	-3.99	0.00		1.13		1.10	104.33	23.15	0.08	1.76
10	Nov-02	104.24	103.96	67.64	61.70	-5.94	4.32	2.33	1.15		0.78	104.10	22.01	0.08	1.67
11	Dec-01	103.96	103.09	61.70	42.97	-18.73	0.00	15.57	1.16		0.90	103.52	17.36	0.06	1.10
12	Dec-02	103.09	101.92	42.97	26.75	-16.22	0.00	13.33	1.19		0.75	102.50	15.04	0.06	0.95
13	Jan-01	101.92	101.74	26.75	24.36	-2.39	-0.06	0.07	1.16		0.32	101.83	12.36	0.06	0.78
14	Jan-02	101.74	101.55	24.36	21.86	-2.50	-0.06		1.18		0.52	101.64	11.62	0.06	0.74
15	Feb-01	101.55	101.38	21.86	19.69	-2.17	0.00		1.05		0.42	101.46	10.95	0.06	0.70
16	Feb-02	101.38	101.19	19.69	17.72	-1.98	0.00		1.07		0.25	101.28	10.28	0.06	0.65
17	Mar-01	101.19	100.86	17.72	14.76	-2.95	0.00		1.13		0.87	101.02	9.37	0.10	0.95
18	Mar-02	100.86	100.56	14.76	12.65	-2.11	0.00		1.11		0.16	100.72	8.37	0.10	0.85
19	Apr-01	100.56	100.31	12.65	10.94	-1.71	0.91		0.95			100.44	7.25	0.11	0.76
20	Apr-02	100.31	100.00	10.94	9.23	-1.72	0.00		0.97			100.15	6.58	0.11	0.75
21	May-01	100.00	99.67	9.23	6.96	-2.26	0.00		1.18		0.37	94.86	5.67	0.13	0.72
22	May-02	99.67	99.30	6.96	5.16	-1.80	0.00		1.18			94.48	4.85	0.13	0.62
23	Jun-01	99.30	98.90	5.16	3.31	-1.85	-0.22		1.16			94.10	4.13	0.11	0.47
24	Jun-02	98.90	105.95	3.31	112.57	109.26	112.07		1.14			102.42	14.59	0.11	1.67
			TOTAL			**74.08**	**177.41**	**31.30**	**26.07**	**0.00**	**7.61**			**2.26**	**33.11**

Table 5.22 The effect of check dam water (considering 17%) on water level in Bhadar-I reservoir (year 2004-05)

Sr. No.	Month & fort-night	Reservoir level beginning (m)	Reservoir level End (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Runoff (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow over the waste weir (Mm^3)	Other Losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evapo-ration losses (Mm^3)
1	Jul-01	102.81	103.17	38.49	44.62	6.13	9.13	1.46*	1.02			102.94	17.32	0.11	1.98
2	Jul-02	103.17	103.08	44.62	42.86	-1.76	1.58		0.98			103.12	20.61	0.11	2.36
3	Aug-01	103.08	104.45	42.86	72.28	29.42	32.17	2.48*	0.94			103.76	17.80	0.10	1.81
4	Aug-02	104.45	104.64	72.28	76.61	4.33	7.77		0.98			104.54	24.25	0.10	2.46
5	Sep-01	104.64	104.57	76.61	75.06	-1.55	1.97		1.03			104.60	24.51	0.10	2.49
6	Sep-02	104.57	104.70	75.06	78.15	3.09	6.66	0.38*	1.07			104.63	24.60	0.10	2.50
7	Oct-01	104.70	104.64	78.15	76.61	-1.55	1.74		1.08			104.67	24.80	0.09	2.21
8	Oct-02	104.64	104.42	76.61	71.63	-4.98	-0.58		1.07		1.18	104.53	24.25	0.09	2.16
9	Nov-01	104.42	104.24	71.63	67.64	-3.99	0.00		1.13		1.10	104.33	23.15	0.08	1.76
10	Nov-02	104.24	103.96	67.64	61.70	-5.94	4.32	2.33	1.15		0.78	104.10	22.01	0.08	1.67
11	Dec-01	103.96	103.09	61.70	42.97	-18.73	0.00	15.57	1.16		0.90	103.52	17.36	0.06	1.10
12	Dec-02	103.09	101.92	42.97	26.75	-16.22	0.00	13.33	1.19		0.75	102.50	15.04	0.06	0.95
13	Jan-01	101.92	101.74	26.75	24.36	-2.39	-0.06	0.07	1.16		0.32	101.83	12.36	0.06	0.78
14	Jan-02	101.74	101.55	24.36	21.86	-2.50	-0.06		1.18		0.52	101.64	11.62	0.06	0.74
15	Feb-01	101.55	101.38	21.86	19.69	-2.17	0.00		1.05		0.42	101.46	10.95	0.06	0.70
16	Feb-02	101.38	101.19	19.69	17.72	-1.98	0.00		1.07		0.25	101.28	10.28	0.06	0.65
17	Mar-01	101.19	100.86	17.72	14.76	-2.95	0.00		1.13		0.87	101.02	9.37	0.10	0.95
18	Mar-02	100.86	100.56	14.76	12.65	-2.11	0.00		1.11		0.16	100.72	8.37	0.10	0.85
19	Apr-01	100.56	100.31	12.65	10.94	-1.71	0.91		0.95			100.44	7.25	0.11	0.76
20	Apr-02	100.31	100.00	10.94	9.23	-1.72	0.00		0.97			100.15	6.58	0.11	0.75
21	May-01	100.00	99.67	9.23	6.96	-2.26	0.00		1.18		0.37	94.86	5.67	0.13	0.72
22	May-02	99.67	99.30	6.96	5.16	-1.80	0.00		1.18			94.48	4.85	0.13	0.62
23	Jun-01	99.30	98.90	5.16	3.31	-1.85	-0.22		1.16			94.10	4.13	0.11	0.47
24	Jun-02	98.90	105.95	3.31	112.57	109.26	112.07		1.14			102.42	14.59	0.11	1.67
			TOTAL			**74.08**	**177.41**	**35.62**	**26.07**	**0.00**	**7.61**			**2.26**	**33.11**

(* Canal release from check dams)

Table 5.23 The effect of check dam water on water level in Bhadar-I reservoir (year 2005-06) (Actual reservoir performance)

Sr. No.	Month & fort-night	Reservoir level beginning (m)	Reservoir level End (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Runoff (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow over the waste weir (Mm^3)	Other Losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evapo-ration losses (Mm^3)
1	Jul-01	105.95	106.16	114.65	121.56	6.91	11.48		0.91			106.06	32.04	0.11	3.67
2	Jul-02	106.16	106.04	121.56	117.50	-4.06	0.70		1.06			106.10	32.31	0.11	3.70
3	Aug-01	106.04	106.68	117.50	138.80	21.30	25.54		0.84			106.36	33.58	0.10	3.41
4	Aug-02	106.68	106.77	138.80	141.68	2.89	7.53		1.01			106.73	35.78	0.10	3.63
5	Sep-01	106.77	107.07	141.68	152.32	10.64	15.32		0.92			106.92	36.99	0.10	3.75
6	Sep-02	107.07	107.90	152.32	188.14	35.82	45.68		0.89	4.92		107.49	39.88	0.10	4.05
7	Oct-01	107.90	107.90	188.14	188.14	0.00	14.98		0.91	10.31		107.90	42.25	0.09	3.76
8	Oct-02	107.90	107.80	188.14	184.15	-3.99	0.72		0.97			107.85	41.98	0.09	3.74
9	Nov-01	107.80	107.65	184.15	177.50	-6.65	0.17	0.75	0.96		1.98	107.73	41.28	0.08	3.14
10	Nov-02	107.65	107.42	177.50	167.41	-10.09	-0.18	4.51	0.92		1.42	107.54	40.18	0.08	3.05
11	Dec-01	107.42	106.86	167.41	144.61	-22.80	-0.26	16.39	0.98		2.75	107.14	38.15	0.06	2.42
12	Dec-02	106.86	106.25	144.61	124.75	-19.87	0.03	14.30	0.91		2.49	106.56	34.73	0.06	2.21
13	Jan-01	106.25	105.71	124.75	107.54	-17.20	-0.07	12.41	0.96		1.75	105.98	31.60	0.06	2.01
14	Jan-02	105.71	105.12	107.54	89.73	-17.82	0.04	15.11	0.93		0.01	105.42	28.60	0.06	1.82
15	Feb-01	105.12	104.23	89.73	67.66	-22.07	0.05	17.75	0.89		1.90	104.68	24.80	0.06	1.57
16	Feb-02	104.23	103.50	67.66	51.20	-16.46	-0.13	13.16	0.92		0.92	103.87	21.05	0.06	1.34
17	Mar-01	103.50	103.11	51.20	43.67	-7.53	0.11	3.89	0.97		0.89	103.31	18.64	0.10	1.89
18	Mar-02	103.11	102.96	43.67	40.97	-2.70	0.00		0.93			103.04	17.51	0.10	1.78
19	Apr-01	102.96	102.78	40.97	38.29	-2.68	0.00		0.76			102.87	16.73	0.11	1.92
20	Apr-02	102.78	102.60	38.29	35.89	-2.40	0.14		0.72			102.69	15.86	0.11	1.82
21	May-01	102.60	102.38	35.89	32.84	-3.05	-0.15		0.95		0.05	102.49	14.99	0.13	1.90
22	May-02	102.38	101.84	32.84	25.95	-6.90	0.04	2.96	0.93		1.34	102.11	13.39	0.13	1.70
23	Jun-01	101.84	101.28	25.95	18.93	-7.02	9.33	14.10	0.96			101.56	11.28	0.11	1.29
24	Jun-02	101.28	101.13	18.93	17.33	-1.60	3.84	3.32	0.98			101.21	10.00	0.11	1.14
		TOTAL				**-97.33**	**134.91**	**118.638**	**22.19**	**15.23**	**15.49**			**2.26**	**60.70**

Table 5.24 The effect of check dam water (considering 17%) on water level in Bhadar-I reservoir (year 2005-06)

Sr. No.	Month & fort-night	Reservoir level beginning (m)	Reservoir level End (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Runoff (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow over the waste weir (Mm^3)	Other Losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evapo-ration losses (Mm^3)
1	Jul-01	105.95	106.16	114.65	121.56	6.91	11.48	3.16*	0.91			106.06	32.04	0.11	3.67
2	Jul-02	106.16	106.04	121.56	117.50	-4.06	0.70		1.06			106.10	32.31	0.11	3.70
3	Aug-01	106.04	106.68	117.50	138.80	21.30	25.54	2.67*	0.84			106.36	33.58	0.10	3.41
4	Aug-02	106.68	106.77	138.80	141.68	2.89	7.53		1.01			106.73	35.78	0.10	3.63
5	Sep-01	106.77	107.07	141.68	152.32	10.64	15.32	2.05*	0.92			106.92	36.99	0.10	3.75
6	Sep-02	107.07	107.90	152.32	188.14	35.82	45.68	1.10*	0.89	4.92		107.49	39.88	0.10	4.05
7	Oct-01	107.90	107.90	188.14	188.14	0.00	14.98		0.91	10.31		107.90	42.25	0.09	3.76
8	Oct-02	107.90	107.80	188.14	184.15	-3.99	0.72		0.97			107.85	41.98	0.09	3.74
9	Nov-01	107.80	107.65	184.15	177.50	-6.65	9.15	0.75	0.96		1.98	107.73	41.28	0.08	3.14
10	Nov-02	107.65	107.42	177.50	167.41	-10.09	-0.18	4.51	0.92		1.42	107.54	40.18	0.08	3.05
11	Dec-01	107.42	106.86	167.41	144.61	-22.80	-0.26	16.39	0.98		2.75	107.14	38.15	0.06	2.42
12	Dec-02	106.86	106.25	144.61	124.75	-19.87	0.03	14.30	0.91		2.49	106.56	34.73	0.06	2.21
13	Jan-01	106.25	105.71	124.75	107.54	-17.20	-0.07	12.41	0.96		1.75	105.98	31.60	0.06	2.01
14	Jan-02	105.71	105.12	107.54	89.73	-17.82	0.04	15.11	0.93		0.01	105.42	28.60	0.06	1.82
15	Feb-01	105.12	104.23	89.73	67.66	-22.07	0.05	17.75	0.89		1.90	104.68	24.80	0.06	1.57
16	Feb-02	104.23	103.50	67.66	51.20	-16.46	-0.13	13.16	0.92		0.92	103.87	21.05	0.06	1.34
17	Mar-01	103.50	103.11	51.20	43.67	-7.53	0.11	3.89	0.97		0.89	103.31	18.64	0.10	1.89
18	Mar-02	103.11	102.96	43.67	40.97	-2.70	0.00		0.93			103.04	17.51	0.10	1.78
19	Apr-01	102.96	102.78	40.97	38.29	-2.68	0.00		0.76			102.87	16.73	0.11	1.92
20	Apr-02	102.78	102.60	38.29	35.89	-2.40	0.14		0.72			102.69	15.86	0.11	1.82
21	May-01	102.60	102.38	35.89	32.84	-3.05	-0.15		0.95		0.05	102.49	14.99	0.13	1.90
22	May-02	102.38	101.84	32.84	25.95	-6.90	0.04	2.96	0.93		1.34	102.11	13.39	0.13	1.70
23	Jun-01	101.84	101.28	25.95	18.93	-7.02	9.33	14.10	0.96			101.56	11.28	0.11	1.29
24	Jun-02	101.28	101.13	18.93	17.33	-1.60	3.84	3.32	0.98			101.21	10.00	0.11	1.14
		TOTAL				**-97.33**	**143.90**	**127.62**	**22.19**	**15.23**	**15.49**			**2.26**	**60.70**

(* Canal release from check dams)

Table 5.25 The effect of check dam water (as per formula) on water level in Bhadar-I reservoir (year 2003-04)

Sr. No.	Month & fort-night	Reservoir level beginning (m)	Reservoir level End (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Runoff (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow over the waste weir (Mm^3)	Other Losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evapo-ration losses (Mm^3)
1	Jul-01	102.63	103.14	36.22	44.18	7.96	10.8	1.71*	0.91			102.89	16.8	0.11	1.92
2	Jul-02	103.14	103.83	44.18	58.85	14.67	17.85	0.92*	0.96			103.49	19.4	0.11	2.22
3	Aug-01	103.83	105.55	58.85	102.65	43.8	47.41	2.48*	1.08			104.69	24.95	0.1	2.53
4	Aug-02	105.55	105.9	102.65	113.14	10.49	14.72		1.17			105.73	30.12	0.1	3.06
5	Sep-01	105.9	105.98	113.14	115.59	2.44	6.76		1.13			105.94	31.35	0.1	3.18
6	Sep-02	105.98	106.1	115.59	119.44	3.85	8.2		1.1			106.04	31.97	0.1	3.25
7	Oct-01	106.1	106.04	119.44	117.45	-1.99	1.9		1.03			106.07	32.16	0.09	2.86
8	Oct-02	106.04	105.92	117.45	113.72	-3.72	0.22		1.13			105.98	31.6	0.09	2.81
9	Nov-01	105.92	105.76	113.72	109.07	-4.66	0.01		1.05		1.28	105.84	30.76	0.08	2.34
10	Nov-02	105.76	105.12	109.07	89.56	-19.51	5.13	15.65	1.04		0.48	105.44	28.71	0.08	2.18
11	Dec-01	105.12	104.17	89.56	66.36	-23.2	0.11	18.8	1.12		1.82	104.65	24.73	0.06	1.57
12	Dec-02	104.17	103.34	66.36	47.98	-18.37	0.04	13.84	1.21		2.06	103.76	20.54	0.06	1.3
13	Jan-01	103.34	102.19	47.98	30.44	-17.54	-0.05	13.76	1.15		1.55	102.77	16.21	0.06	1.03
14	Jan-02	102.19	101.56	30.44	22.09	-8.36	0.06	5.15	1.21		1.26	101.88	12.54	0.06	0.8
15	Feb-01	101.56	100.83	22.09	14.77	-7.31	0.02	5.09	1.14		0.48	101.2	9.96	0.06	0.63
16	Feb-02	100.83	100.61	14.77	13.1	-1.67	-0.02		1.01		0.11	100.72	8.26	0.06	0.52
17	Mar-01	100.61	100.34	13.1	11.36	-1.74	0.01		1		0	100.48	7.42	0.1	0.75
18	Mar-02	100.34	100.03	11.36	9.61	-1.75	-0.02		1.02		0.04	100.19	6.62	0.1	0.67
19	Apr-01	100.03	99.76	9.61	7.82	-1.79	0.01		1.05		0.08	99.9	5.86	0.11	0.67
20	Apr-02	99.76	99.4	7.82	5.88	-1.93	0.04		1.1		0.3	99.58	5.08	0.11	0.58
21	May-01	99.4	102.96	5.88	41.02	35.14	37.46		1.07			101.18	9.91	0.13	1.26
22	May-02	102.96	102.72	41.02	37.44	-3.58	-0.04		1.01		0.42	102.84	16.58	0.13	2.11
23	Jun-01	102.72	102.87	37.44	39.68	2.24	4.89		0.78			102.8	16.36	0.11	1.87
24	Jun-02	102.87	102.81	39.68	38.78	-0.89	1.79		0.79			102.84	16.58	0.11	1.9
				TOTAL		**2.57**	**157.3**	**77.40**	**25.26**	**0**	**9.88**			**2.26**	**42.03**

(* Canal release from check dams)

Table 5.26 The effect of check dam water (as per formula) on water level in Bhadar-I reservoir (year 2004-05)

Sr. No.	Month & fort-night	Reservoir level beginning (m)	Reservoir level End (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Runoff (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow over the waste weir (Mm^3)	Other Losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evapo-ration losses (Mm^3)
1	Jul-01	102.81	103.17	38.49	44.62	6.13	9.13	1.00*	1.02			102.94	17.32	0.11	1.98
2	Jul-02	103.17	103.08	44.62	42.86	-1.76	1.58		0.98			103.12	20.61	0.11	2.36
3	Aug-01	103.08	104.45	42.86	72.28	29.42	32.17	2.36*	0.94			103.76	17.80	0.10	1.81
4	Aug-02	104.45	104.64	72.28	76.61	4.33	7.77		0.98			104.54	24.25	0.10	2.46
5	Sep-01	104.64	104.57	76.61	75.06	-1.55	1.97		1.03			104.60	24.51	0.10	2.49
6	Sep-02	104.57	104.70	75.06	78.15	3.09	6.66	0.58*	1.07			104.63	24.60	0.10	2.50
7	Oct-01	104.70	104.64	78.15	76.61	-1.55	1.74		1.08			104.67	24.80	0.09	2.21
8	Oct-02	104.64	104.42	76.61	71.63	-4.98	-0.58		1.07		1.18	104.53	24.25	0.09	2.16
9	Nov-01	104.42	104.24	71.63	67.64	-3.99	0.00		1.13		1.10	104.33	23.15	0.08	1.76
10	Nov-02	104.24	103.96	67.64	61.70	-5.94	3.94	2.33	1.15		0.78	104.10	22.01	0.08	1.67
11	Dec-01	103.96	103.09	61.70	42.97	-18.73	0.00	15.57	1.16		0.90	103.52	17.36	0.06	1.10
12	Dec-02	103.09	101.92	42.97	26.75	-16.22	0.00	13.33	1.19		0.75	102.50	15.04	0.06	0.95
13	Jan-01	101.92	101.74	26.75	24.36	-2.39	-0.06	0.07	1.16		0.32	101.83	12.36	0.06	0.78
14	Jan-02	101.74	101.55	24.36	21.86	-2.50	-0.06		1.18		0.52	101.64	11.62	0.06	0.74
15	Feb-01	101.55	101.38	21.86	19.69	-2.17	0.00		1.05		0.42	101.46	10.95	0.06	0.70
16	Feb-02	101.38	101.19	19.69	17.72	-1.98	0.00		1.07		0.25	101.28	10.28	0.06	0.65
17	Mar-01	101.19	100.86	17.72	14.76	-2.95	0.00		1.13		0.87	101.02	9.37	0.10	0.95
18	Mar-02	100.86	100.56	14.76	12.65	-2.11	0.00		1.11		0.16	100.72	8.37	0.10	0.85
19	Apr-01	100.56	100.31	12.65	10.94	-1.71	0.91		0.95			100.44	7.25	0.11	0.76
20	Apr-02	100.31	100.00	10.94	9.23	-1.72	0.00		0.97			100.15	6.58	0.11	0.75
21	May-01	100.00	99.67	9.23	6.96	-2.26	0.00		1.18		0.37	94.86	5.67	0.13	0.72
22	May-02	99.67	99.30	6.96	5.16	-1.80	0.00		1.18			94.48	4.85	0.13	0.62
23	Jun-01	99.30	98.90	5.16	3.31	-1.85	-0.22		1.16			94.10	4.13	0.11	0.47
24	Jun-02	98.90	105.95	3.31	112.57	109.26	112.07		1.14			102.42	14.59	0.11	1.67
			TOTAL			**74.08**	**177.41**	**35.24**	**26.07**	**0.00**	**7.61**			**2.26**	**33.11**

(* Canal release from check dams)

Table 5.27 The effect of check dam water (as per formula) on water level in Bhadar-I reservoir (year 2005-06)

Sr. No.	Month & fort-night	Reservoir level beginning (m)	Reservoir level End (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Runoff (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow over the waste weir (Mm^3)	Other Losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evapo-ration losses (Mm^3)
1	Jul-01	105.95	106.16	114.65	121.56	6.91	11.48	2.29*	0.91			106.06	32.04	0.11	3.67
2	Jul-02	106.16	106.04	121.56	117.50	-4.06	0.70		1.06			106.10	32.31	0.11	3.70
3	Aug-01	106.04	106.68	117.50	138.80	21.30	25.54	10.90*	0.84			106.36	33.58	0.10	3.41
4	Aug-02	106.68	106.77	138.80	141.68	2.89	7.53		1.01			106.73	35.78	0.10	3.63
5	Sep-01	106.77	107.07	141.68	152.32	10.64	15.32	2.79*	0.92			106.92	36.99	0.10	3.75
6	Sep-02	107.07	107.90	152.32	188.14	35.82	45.68	0.25*	0.89	4.92		107.49	39.88	0.10	4.05
7	Oct-01	107.90	107.90	188.14	188.14	0.00	14.98		0.91	10.31		107.90	42.25	0.09	3.76
8	Oct-02	107.90	107.80	188.14	184.15	-3.99	0.72		0.97			107.85	41.98	0.09	3.74
9	Nov-01	107.80	107.65	184.15	177.50	-6.65	16.40	0.75	0.96		1.98	107.73	41.28	0.08	3.14
10	Nov-02	107.65	107.42	177.50	167.41	-10.09	-0.18	4.51	0.92		1.42	107.54	40.18	0.08	3.05
11	Dec-01	107.42	106.86	167.41	144.61	-22.80	-0.26	16.39	0.98		2.75	107.14	38.15	0.06	2.42
12	Dec-02	106.86	106.25	144.61	124.75	-19.87	0.03	14.30	0.91		2.49	106.56	34.73	0.06	2.21
13	Jan-01	106.25	105.71	124.75	107.54	-17.20	-0.07	12.41	0.96		1.75	105.98	31.60	0.06	2.01
14	Jan-02	105.71	105.12	107.54	89.73	-17.82	0.04	15.11	0.93		0.01	105.42	28.60	0.06	1.82
15	Feb-01	105.12	104.23	89.73	67.66	-22.07	0.05	17.75	0.89		1.90	104.68	24.80	0.06	1.57
16	Feb-02	104.23	103.50	67.66	51.20	-16.46	-0.13	13.16	0.92		0.92	103.87	21.05	0.06	1.34
17	Mar-01	103.50	103.11	51.20	43.67	-7.53	0.11	3.89	0.97		0.89	103.31	18.64	0.10	1.89
18	Mar-02	103.11	102.96	43.67	40.97	-2.70	0.00		0.93			103.04	17.51	0.10	1.78
19	Apr-01	102.96	102.78	40.97	38.29	-2.68	0.00		0.76			102.87	16.73	0.11	1.92
20	Apr-02	102.78	102.60	38.29	35.89	-2.40	0.14		0.72			102.69	15.86	0.11	1.82
21	May-01	102.60	102.38	35.89	32.84	-3.05	-0.15		0.95		0.05	102.49	14.99	0.13	1.90
22	May-02	102.38	101.84	32.84	25.95	-6.90	0.04	2.96	0.93		1.34	102.11	13.39	0.13	1.70
23	Jun-01	101.84	101.28	25.95	18.93	-7.02	9.33	14.10	0.96			101.56	11.28	0.11	1.29
24	Jun-02	101.28	101.13	18.93	17.33	-1.60	3.84	3.32	0.98			101.21	10.00	0.11	1.14
		TOTAL				**-97.33**	**151.15**	**134.87**	**22.19**	**15.23**	**15.49**			**2.26**	**60.70**

(* Canal release from check dams)

It is seen that the additional quantity of check dam water does not substantially increase the surface area. The increase in surface water area is only 2% against 3 Mm^3 additional water at F.R.L. The evaporation loss of check dam water in the reservoir is not separately considered.

Additional coverage of area under irrigation in Bhadar-I command has been estimated using new formula scenario (Table 5.28) and 17% runoff scenario (Table 5.29), had there been no construction of check dams in the catchment area and the entire runoff would have reached the reservoir. The average value of the additional area under irrigation comes to 519 ha.

With the check dams constructed in the catchment, the check dams based irrigation coverage in the year 2003, 2004 and 2005 has been presented in Table 5.30. The average value of irrigated area comes to 17760 ha against the formal value of 519 ha i.e. about 31 times larger area.

Table 5.28 Additional irrigation with check dam water in Bhadar-I command (new formula scenario)

Sr. No.	Year	Actual storage (Mm3)	Actual canal releases (Mm^3)	% of canal release with respect to storage	Actual Irrigation (ha)	Estimated new storage (no check dam condition) adding new formula runoff (Mm^3)	Estimated new canal releases (Mm^3) w.r.t % as per column 5	Estimated New irrigation (no check dam condition) (ha)	Estimated Increase in irrigation by check dam water (ha) (no check dam condition)
1	2003-04	149.453	72.29	48.37	14686	154.5697	74.7651	15188.8	502.82
2	2004-05	99.002	31.304	31.62	5508	102.942	32.5498	5727.2	219.2
3	2005-06	232.244	118.64	51.08	18352	248.473	126.9283	19634.4	1282.42

Table 5.29 Additional irrigation with check dam water in Bhadar-I command (17 % Runoff scenario)

Sr. No.	Year	Actual storage (Mm^3)	Actual canal releases (Mm^3)	% of canal release with respect to storage	Actual Irrigation (ha)	Estimated new storage (no check dam condition) adding new formula runoff (Mm^3)	Estimated new canal releases (Mm^3) w.r.t % as per column 5	Estimated New irrigation (no check dam condition) (ha)	Estimated Increase in irrigation by check dam water (ha) (no check dam condition)
1	2003-04	149.453	72.29	48.37	14686	154.7377	74.8464	15205.33	519.33
2	2004-05	99.002	31.304	31.62	5508	103.32	32.67	5748.34	240.34
3	2005-06	232.244	118.64	51.08	18352	241.224	123.2253	19061.6	709.60

Table 5.30 Area irrigated due to check dams

Sr. No.	Year	Total storage in check dams (Mm^3)	Evaporation losses in check dams (Mm^3)	Net utilisation of check dam Storage (Mm^3)	Area irrigated by check dams (ha) (Five waterings)	Protective irrigation (ha) (Two waterings)
1	2003	31.086	7.633	23.453	5746	11720
2	2004	25.142	5.996	19.226	4710	9600
3	2005	52.864	12.37	40.49	9921	20240
	1. Duty 245 ha/ Mm^3 for five waterings					
	2. Duty 500 ha/ Mm^3 for two waterings					

5.2 IMPACT OF CHECKDAM IN SEDIMENTATION/SILTATION IN BHADAR RESERVOIR

5.2.1 Trend of sedimentation/ siltation in various regions

The life of reservoir of any dam is considered on the basis of siltation taken place every year. In Gujarat, the average sedimentation considered during planning/design stage is 3.37 ha.m/100 km^2/year. However after actual survey of 91 dams in Gujarat, the siltation rate is much higher than the design siltation rate (Table 5.31) and the data for Rajkot district are presented in Table 5.32.

Table 5.31 Analysis of region wise trend of reservoir Sedimentation actually surveyed in Gujarat

Sr. No.	Trend of reservoir	Region					
		Saurashtra	North Gujarat	Central	South	Kachchh	Total
A	No. of Reservoirs	55	10	10	8	8	91
1	Insignificant Nos.	1	1	-	-	1	3
2	Significant Nos.	15	3	3	3	4	28
3	Serious Nos.	39	6	7	4	4	60
B	Annual % loss in capacity						
	Maximum	3.22	4.19	2.23	3.38	1.91	
	Minimum	0.06	0.09	0.16	0.02	0.23	
C	Silt rate ham/100km^2/year						
	Maximum	18.6	61.03	64.07	123.68	15.54	
	Minimum	1.43	0.02	1.90	0.68	1.90	

(Source: GERI, Vadodara)

Note:

- Insignificant means annual less than 0.1 % loss in gross capacity.
- Significant means annual 0.1 to 0 .5% loss in gross capacity.
- Serious means annual more than 0.5 % loss in gross capacity.
- Design silt rate normally considered as 3.37 ham/100km^2/year

Table 5.32 Details of sedimentation survey analysis of reservoirs of Rajkot district

Sr. No.	Name of reservoir	Designed gross capacity (Mm^3)	Surveyed gross capacity (Mm^3)	Loss in capacity (Mm^3)	Annual % loss in capacity	Silt rate ha.m./ 100 km^2/Year
1	Gondali	11.36	10.11	1.25	0.37	6.06
2	Bhadar-I	237.86	202.08	35.78	0.376	3.717
3	Phophal	59.6	51.82	7.78	0.5	5.6
4	Ghelo(s)	8.13	6.09	2.04	1.09	15
5	Moj	53.01	38.94	14.07	0.86	10.34
6	Chhaparwadi	5.01	4.22	0.79	1.31	7.69
7	Vachhapari	6.6	6.13	0.47	0.37	5
8	Demi-1	21.52	16.65	4.87	0.91	11.45
9	Ghodadharoi	8.34	6.88	1.46	1.17	6.66
10	Aji-1	32.29	26.43	5.86	0.42	9.64
11	Bangavadi	4.91	4.26	0.65	0.88	6.95
12	Khodapipar	3.37	2.99	0.37	1.38	8.72
13	Motisar	2.69	2.58	0.11	0.46	3.65
14	Nyari-2	13	12.25	0.75	0.36	2.99
15	Machhu-1	83.13	75.09	8.04	0.22	3.06
16	Machhu-2	100.56	60.69	39.86	1.59	8.27
17	Venu-2	22.58	15.32	7.26	3.22	9.67
	Total	**676.96**	**546.53**	**136.41 (20.15%)**	**1.13%**	**7.32**

(Source: GERI, Vadodara)

5.2.2 Sedimentation survey analysis of Bhadar Basin-I

Bhadar-I basin has one major Irrigation scheme and other seven medium and minor irrigation schemes. Sedimentation survey for all the eight dams was carried out and data are presented in Table 5.33.

Table 5.33 Sedimentation in Bhadar-I basin

Sr. No.	Reservoir	Original gross capacity at FRL as per project (Mm^3)	Revised gross capacity at FRL (Mm^3)	Assumed rate of sedimentation as per project planning (ham/100km^2/ year)	Observed rate of sedimentation as per silt survey (ham/100km^2/ year)
1	Bhadar (I)	237.86	202.08	3.57	5.752 (Before check dams in C.A.) 3.717 (After check dams in C.A)
2	Sankroli	11.00	7.87	3.57	10.13
3	Phophal	59.60	52.82	3.57	5.60
4	Moj	53.01	36.69	3.57	8.6
5	Gondali	11.36	10.11	4.04	6.06
6	Veri	10.88	4.59	3.57	2.99
7	Chhaparwadi-1	5.01	4.22	1.78	7.69
8	Vachhapari	6.60	6.13	3.57	5.0
Total		**395.32**	**324.51**		

(Source: GERI, Vadodara)

The Bhadar Irrigation project was constructed in the year 1965. As per the project report, sedimentation was considered as 14.16 Mm^3 and accordingly sill level of the canal was fixed at RL 320 ft (97.56 m) and per year siltation at the time of project report was considered as 3.37ha.m/100 km^2/year.

In the year 1985-87, the entire Saurashtra region was affected by serious drought. The Bhadar reservoir was completely dried out in the year 1986. GERI

in consultation with field officers of Bhadar project carried out land level field survey using area capacity method. It is noticed that not only the dead storage of the reservoir but also the live storage of the reservoir started silting up (Table 5.34.

Table 5.34 Sedimentation in Bhadar reservoir in the year 1986

Survey	Dead storage Mm^3	Live storage Mm^3	Gross storage Mm^3
As per project report	14.16	223.70	237.86
As per actual survey	1.27	199.09	200.36

(Source: GERI, Vadodara)

Again in the year 2000, the Bhadar reservoir was completely dried out and land level field survey was carried out by GERI in consultation with field of officers. As per the survey, 49.82 Mm^3 silt was found to be deposited in the reservoir (13.93 Mm^3 in dead storage and 35.89 Mm^3 in live storage). In the year 2004 in Bhadar reservoir, water was available at RL 106.46 m (against FRL 107.90m). The new method of bathymetric survey was used first time for the survey up to RL 106.46m. Between reservoir water level 106.46m to RL 107.90 m , land level field survey was carried out. Result of the survey year 2004 indicated that the total sedimentation in Bhadar reservoir is of 35.78 Mm^3 (13.83 Mm^3 in dead storage and 21.95 Mm^3 in live storage).

As per the actual sedimentation survey conducted in the year 1986, 2000 and 2004, the comparison of sedimentation rate of the reservoir is presented in Table 5.35.

Table 5.35 Computation of sedimentation rate

Sr.No.	Year	Sedimentation rate/year
1	1986	7.085 ham/100km^2/year
2	2000	5.752 ham/100 km^2/year
3	2004	3.717 ham/100 km^2/year

The last survey was carried out in 2004 (after construction of check dam in catchment). The survey results of 1965 and 2004 with respect to area and capacity elevations are presented in Table 5.36.

Table 5.36 Original and revised elevation/ area/ capacity details of Bhadar I

RL (m)	1965- Original		2004- Survey	
	Area (km^2)	Capacity (Mm^3)	Area (km^2)	Capacity (Mm^3)
86.13	0	0	0	0
86.89	0.05	0.01	0	0
87.80	0.09	0.08	0	0
88.72	0.14	0.18	0	0
89.63	0.19	0.34	0	0
90.55	0.37	0.57	0	0
91.46	0.70	0.92	0	0
92.38	0.93	1.75	0	0
93.29	1.21	2.77	0	0
94.21	1.63	4.06	0	0
95.12	2.14	5.78	0	0
96.04	2.97	6.74	0	0
96.95	4.09	11.38	0.096	0.008
97.56 OSL	5.19	14.16	1.193	0.327
97.87	5.76	15.80	2.231	0.867
98.78	7.80	22.03	4.717	4.081
99.27	9.14	26.39	5.933	6.683
99.70	10.31	30.21	7.120	9.491
100.60	12.91	40.92	9.938	17.130
101.52	15.79	53.91	13.446	27.815
102.44	18.95	69.74	17.809	42.163
103.35	22.39	88.66	21.994	60.454

RL (m)	1965- Original		2004- Survey	
	Area (km^2)	Capacity (Mm^3)	Area (km^2)	Capacity (Mm^3)
104.27	26.01	110.89	25.084	82.189
104.50	27.09	117.35	25.860	88.071
104.99	29.40	131.09	27.535	101.214
05.18	30.29	136.42	28.193	106.538
106.10Crest	34.93	164.69	31.721	134.286
106.46	36.88	178.84	33.645	146.310
107.90 FSL	44.59	239.22	-	-

(Source: RIC, Rajkot)

As per 2004 survey, total area of reservoir at RL 106.46 m is 33.645 km^2 and corresponding storage capacity is 146.31 Mm^3. The original gross storage capacity at RL 106.46 m is 178.84 Mm^3. Rate of siltation in the reservoir during the period of 40 years, works out to 0.813 Mm^3 / year presented in Table 5.37.

Table 5.37 Rate of siltation in the reservoir

Original gross storage capacity at RL 106.46 m.	: 178.84 Mm^3
Revised gross storage capacity at RL 106.46 m.	: 146.31 Mm^3
Loss in capacity	: 32.53 Mm^3
Rate of Siltation	: 0.813 Mm^3/year
Average rate of siltation	: 3.379 ham / 100 km^2 / year

Table 5.38 Year wise sedimentation result of Bhadar- I reservoir

Year of survey	Capacity in Mm^3			Loss in Capacity in Mm^3			Silt rate ha. m./ 100 Km^2 /year	Annual % loss
	Dead	Live	Gross	Dead	Live	Gross		
1964(Original)	14.16	223.70	237.86	-	-	-	-	-
1986(DBS)	1.27	199.09	200.36	12.89	24.61	37.50	7.085	0.72
2000 (DBS) (FRL 107.90)	0.226	187.814	188.04	13.93	35.89	49.82	5.752	0.58
2004 (at RL 106.46)	0.327	145.983	146.31	13.833	18.697	32.53	3.379	0.455
	(without considering interception of 567 sq. km. C.A. of check dam)							
							4.25	
	(with considering interception of 567 sq. km. C.A. of check dam)							
2004 (FRL 107.90)	0.327	201.753	202.08	13.83	21.95	35.78	3.717	0.376

Note :-

1. The rate of siltation in earlier 22 years was 7.0 ham/100 km^2/year which stabilized at 5.75 ha.m / 100 km^2 /year in 14 years (1986 to 2000). After check dams in catchments the siltation rate got reduced from 5.75 to 3.7 ha.m/100 km^2/year.
2. Bhadar-I original gross storage was 237.86 Mm^3 which is now reduced to 202 Mm^3 (85 %).

5.2.3 Sedimentation/ siltation in check dams

The total 905 check dams have been constructed with peoples' participation in the catchment area of Bhadar I reservoir. Due to construction of the check dams, variation in siltation has been noticed. The actual siltation survey in the 120 check dams in 12 villages has been carried out by GERI staff in the year 2005. As per actual measurement, of the siltation in the 120 check dams is 0.1286 Mm^3, The original storage capacity of 120 check dams was 3.1818 Mm^3. Due to siltation, the revised storage capacity of check dams was found as 3.0533 Mm^3. The details are presented in Table 5.39.

Table 5.39 Sedimentation in check dams in Bhadar basin (year 2005)

Name of Taluka	Nos. of check dam	Catchment area (km^2)	Initital storage capacity (m^3)	Storage capacity at the time of survey (m^3)	Sedimentation (m^3)	Year for impounding	Siltation (m^3/year)	% sedimentation /year col.(8)/col.(4)
1	2	3	4	5	6	7	8	9
Gondal	12	7.79	259740	253800	5940	2002	1980	0.76
Gondal	7	0.67	22400	21812	588	2003	294	1.31
Gondal	4	1.07	35712	34902	810	2004	810	2.27
Gondal	11	1.89	63140	60665	2475	2003	1237.5	1.96
Gondal	7	0.65	21560	21140	420	2000	84	0.39
Gondal	3	12.96	431883	431545.5	337.5	2004	337.5	0.08
Gondal	9	1.51	50400	49738.5	661.5	2000	132.3	0.26
K.Sanghani	3	0.63	21000	20892	108	2003	54	0.26

Name of Taluka	Nos. of check dam	Catchment area (km^2)	Initital storage capacity (m^3)	Storage capacity at the time of survey (m^3)	Sedime Ntation (m^3)	Year for impou nding	Siltation (m^3/year)	% sedimentation /year col.(8)/col. (4)
K.Sangha ni	12	15.12	504000	502650	1350	2000	270	0.05
K.Sangha ni	13	19.5	650000	645125	4875	2000	975	0.15
K.Sangha ni	21	31.5	1050000	944412	105588	2003	52794	5.03
Jasdan	18	2.16	72000	66600	5400	2000	1080	1.50
Total	**120**	**95.45**	**3181835**	**3053282**	**128553**		**60048.3**	**1.88**

Sedimentation rate in check dams – 6.16 ha.m/ 100 km^2/year

As seen from the above data, siltation in check dams is 6.16 ha.m/100 km^2/year. As most of the check dams are on the steep hill of catchment area and because of retention of water in check dams, the velocity is reduced considerably and due to that sedimentation is found considerably less. Further all these check dams are just near to the beneficiary farmers' fields and these check dams are constructed by them; they are removing the silt from the bed of the check dam and using in their fields.

Out of total catchment area of 2436 km^2 of Bhadar-I reservoir, only 460 km^2 catchment is intercepted by construction of 905 check dams storage. There is ample scope of reduce sedimentation by construction of more check dams.

Gross storage of Bhadar Reservoir project was 238.86 Mm^3 which has now reduced to 202.08 Mm^3. To remove the silt from the bed of Bhadar reservoir, it was estimated by the Irrigation Department that for removal of one m^3 of silt, an approximate expenditure of Rs.200 will be incurred (lead of 20 to 30 km). For the removal of silt load of 35 Mm^3, the estimated cost works out to Rs. 700 crores against that the cost of check dam is only Rs. 27crores for the entire catchment. As the farmers takeout silt from check dams, there is no cost

of silt removal from the check dam. Hence, for enhancing the life of the reservoir, the option of constructing check dams in catchment area is most viable, economical and technically feasible solution.

5.3 COMPARISON OF EVAPORATION LOSSES IN BHADAR RESERVOIR AND CHECK DAMS

5.3.1 General

In hot climates, the loss of water by evaporation from the rivers, canal and open water storages, which form the major water supply systems, is a vital concern as evaporation removes a significant portion of all water supplies even before they arrive at the locations where they are used. This lost water, if saved, would be available for gainful utilization in several ways. It is significant that, while most of the water withdrawn for beneficial uses returns to streams and aquifers which can be reuse.

The main factors which affect the evaporation are: (a) the area of the exposed water surface, (b) the temperature of the water and the air above, (c) the wind effect, (d) the vapour pressure difference (the rate of evaporation depends upon the difference between the saturated vapour pressure at the water temperature and the dew point of air; and the evaporation continues till the differences become nil and (e) the quality of water (the salt content in the water influences the rate of evaporation, since the rate of evaporation decreases with increase in the salt content).

Artificial recharge can be described as a process through which water stored in surface reservoirs or flowing through streams can be transferred under ground to aquifers. Artificial recharge is useful in augmenting ground water reserves and water transferred under ground is not subject to evaporation losses. Artificial recharge needs to be practiced in the area where ground water is prime

source of water supply and evaporation losses are more. Artificial recharge methods include construction of check dams, percolation tanks, recharge pits or injection of water in bore wells.

Looking to the above, the analysis has been carried out to compute the evaporation losses in the Bhadar-I reservoir and the check dams constructed in Bhadar catchment.

5.3.2 Evaporation Losses Considered in Bhadar Reservoir at the Time of Design

As per Project Report, it is proposed to utilize almost all the water during Kharif and Rabi seasons only, and as the basin of the reservoir is very shallow, a depth of 6 ft of water over the average capacity of the tank between the sill of the tank and FSL of the tank is taken as the loss due to evaporation and absorption.

Capacity at the sill level of outlet R.L. 320 ft = 495 Mcft.

Capacity at FSL RL 354 ft = 8400 Mcft

Average capacity per feet height = (8400-495)/(354-320)

= 7905/34

= 232.20 Mcft (6.57 Mm^3)

Therefore, the loss due to evaporation that was considered at project report stage is 232.3 x 6 = 1393.20 Mcft Say 1400 Mcft. /year (40 Mm^3 /year)

Hence, the average evaporation losses were considered as 40 Mm^3 every year (19%).

The Net quantity of water available for irrigation:

Quantity available for irrigation = Capacity at FSL – Capacity at sill level – Losses due to evaporation

= 8400 – 495 – 1400 = 6505 Mcft (184 Mm^3)

Post monsoon flow of 60 cusecs discharge for a period of 6 months = 936 Mcft was considered at Design stage.

Therefore, net water availability considered = 6505 + 936 = 7441 Mcft.

Say 7400 Mcft.(210.73 Mm^3)

5.3.3 Actual evaporation losses of Bhadar-I dam year 2002-03 to 2005-06

The fortnightly evaporation losses adopted as per Narmada, Water Resources, Water Supply and Kalpasar Department, Government of Gujarat's circular as are presented in Table 5.40. The data of monthly/ yearly analysis are presented in Table 5.41, Table 5.42, Table 5.43 and Table 5.44.

Table 5.40 Depth of evaporation losses in each fortnight in Gujarat State

Sr. No.	Month	Kachchh Region (cm)	Saurashtra Region (cm)	Gujarat Region	
				North (cm)	South (cm)
1	June	26.70	22.90	27.90	20.30
2	July	22.90	22.90	22.90	20.30
3	August	20.30	20.30	20.30	15.20
4	September	22.90	20.30	20.30	15.20
5	October	15.20	17.80	17.80	11.40
6	November	15.20	15.20	15.20	11.40
7	December	11.40	12.70	11.40	10.20
8	January	11.40	12.70	11.40	11.40
9	February	12.70	12.70	14.00	14.00
10	March	20.30	20.30	20.30	17.80
11	April	20.30	22.90	26.70	20.30
12	May	25.40	25.40	31.80	22.90
	Total	**224.0**	**226.10**	**240.00**	**190.40**
	Average	**18.72**	**18.84**	**20.00**	**15.87**

(Source : N.W.R.W.S. and K. Department, GOG's circular)

Table 5.41 Analysis of evaporation losses in Bhadar-I reservoir July 2002 to June 2003

Sr. No.	Month & fort-night	Reservoir level beginning(m)	Reservoir level end (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Other losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evaporation losses (Mm^3)	Runoff (Mm^3)
1	JUL1	107.29	107.130	161.7340	154.8570	-6.8770		0.5330	1.9340	107.210	38.4770	0.1145	4.4056	-0.0044
2	JUL2	107.13	107.010	154.8570	149.7858	-5.0712		0.7380	0.0180	107.070	37.8078	0.1145	4.3290	0.0138
3	AUG1	107.01	106.890	149.7858	145.5888	-4.1970		0.7800		106.950	37.1760	0.1015	3.7734	0.3564
4	AUG2	106.89	106.770	145.5888	141.6832	-3.9056	0.4600	0.9390		106.830	36.4320	0.1015	3.6978	1.1912
5	SEP1	106.77	106.650	141.6832	137.8060	-3.8772	0.5000	0.7900		106.710	35.6888	0.1015	3.6224	1.0352
6	SEP2	106.65	106.530	137.8060	134.0140	-3.7920		0.9330		106.590	34.9456	0.1015	3.5470	0.6880
7	OCT1	106.53	106.380	134.0140	128.9910	-5.0230		1.0730	0.9100	106.455	34.1090	0.0890	3.0357	-0.0043
8	OCT2	106.38	106.220	128.9910	123.6837	-5.3073		1.0490	1.3080	106.300	33.2725	0.0890	2.9613	0.0109
9	NOV1	106.22	105.690	123.6837	106.9278	-16.7559	10.7100	1.0860	2.6600	105.955	31.4447	0.0760	2.3898	0.0899
10	NOV2	105.69	105.050	106.9278	87.6616	-19.2662	14.1900	1.0180	1.8900	105.370	28.3652	0.0760	2.1558	-0.0125
11	DEC1	105.05	104.380	87.6616	70.8662	-16.7954	13.1900	1.1180	0.9780	104.715	25.0744	0.0635	1.5922	0.0829
12	DEC2	104.38	103.330	70.8662	47.7700	-23.0962	19.8420	1.0000	0.9170	103.855	20.9928	0.0635	1.3330	-0.0042
13	JAN1	103.33	101.942	47.7700	27.2525	-20.5175	18.0230	1.0700	0.4710	102.636	15.6071	0.0635	0.9911	0.0376
14	JAN2	101.94	101.470	27.2525	20.9326	-6.3200	4.0800	1.1670	0.3180	101.706	11.8890	0.0635	0.7550	0.0000
15	FEB1	101.47	101.220	20.9326	18.2624	-2.6702		1.1340	0.8620	101.345	10.5015	0.0635	0.6668	-0.0073
16	FEB2	101.22	100.968	18.2624	15.9345	-2.3279		0.9120	0.8010	101.094	9.6175	0.0635	0.6107	-0.0042
17	MAR1	100.96	100.670	15.9345	13.5580	-2.3766		1.1200	0.3490	100.819	8.6460	0.1015	0.8776	-0.0300
18	MAR2	100.67	100.340	13.5580	11.3592	-2.1988		1.2140	0.2570	100.505	7.5047	0.1015	0.7617	0.0340
19	APR1	100.34	100.000	11.3592	9.4463	-1.9129		1.0000	0.1570	100.170	6.5804	0.1145	0.7535	-0.0024
20	APR2	100.00	99.730	9.4463	7.6068	-1.8395		0.9570	0.2180	99.865	5.7806	0.1145	0.6619	-0.0026
21	MAY1	99.73	99.330	7.6068	5.5360	-2.0708		0.9370	0.5020	99.530	4.9610	0.1270	0.6300	-0.0018
22	MAY2	99.33	98.812	5.5360	3.3213	-2.2147		1.0000	0.7160	99.071	3.9266	0.1270	0.4987	0.0000
23	JUN1	98.81	98.350	3.3213	1.9778	-1.3435		0.8310	0.1930	98.581	2.7904	0.1145	0.3195	0.0000
24	JUN2	98.35	102.660	1.9778	36.6240	34.6462		0.8330		100.505	7.5047	0.1145	0.8593	36.3385
				TOTAL		**-125.110**	**80.9950**	**23.2320**	**15.459**			**2.2610**	**45.2287**	**39.8047**

Table 5.42 Analysis of evaporation losses in Bhadar-I reservoir July 2003 to June 2004

Sr. No.	Month & fort-night	Reservoir level beginning (m)	Reservoir level end (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Other losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evaporation losses (Mm^3)	Runoff (Mm^3)
1	JUL1	102.630	103.140	36.2160	44.1796	7.9636		0.9100		102.885	16.8029	0.1145	1.9239	10.7975
2	JUL2	103.140	103.830	44.1796	58.8501	14.6705		0.9600		103.485	19.3971	0.1145	2.2210	17.8515
3	AUG1	103.830	105.550	58.8501	102.6490	43.7989		1.0800		104.690	24.9504	0.1015	2.5325	47.4113
4	AUG2	105.550	105.900	102.6490	113.1410	10.4920		1.1700		105.725	30.1246	0.1015	3.0577	14.7197
5	SEP1	105.900	105.980	113.1410	115.5850	2.4440		1.1300		105.940	31.3519	0.1015	3.1822	6.7562
6	SEP2	105.980	106.100	115.5850	119.4392	3.8542		1.1000		106.040	31.9712	0.1015	3.2451	8.1993
7	OCT1	106.100	106.040	119.4392	117.4470	-1.9922		1.0300		106.070	32.1570	0.0890	2.8620	1.8998
8	OCT2	106.040	105.920	117.4470	113.7230	-3.7240		1.1300		105.980	31.5996	0.0890	2.8124	0.2184
9	NOV1	105.920	105.760	113.7230	109.0670	-4.6560		1.0500	1.2760	105.840	30.7630	0.0760	2.3380	0.0080
10	NOV2	105.760	105.120	109.0670	89.5595	-19.5075	15.6490	1.0400	0.4790	105.440	28.7119	0.0760	2.1821	-0.1574
11	DEC1	105.120	104.170	89.5595	66.3575	-23.2020	18.8020	1.1200	1.8200	104.645	24.7272	0.0635	1.5702	0.1102
12	DEC2	104.170	103.340	66.3575	47.9841	-18.3734	13.8380	1.2100	2.0610	103.755	20.5431	0.0635	1.3045	0.0401
13	JAN1	103.340	102.190	47.9841	30.4425	-17.5417	13.7630	1.1500	1.5540	102.765	16.2081	0.0635	1.0292	-0.0455
14	JAN2	102.190	101.560	30.4425	22.0850	-8.3575	5.1500	1.2100	1.2630	101.875	12.5378	0.0635	0.7961	0.0617
15	FEB1	101.560	100.830	22.0850	14.7704	-7.3146	5.0880	1.1400	0.4760	101.195	9.9620	0.0635	0.6326	0.0219
16	FEB2	100.830	100.610	14.7704	13.1033	-1.6670		1.0100	0.1130	100.720	8.2595	0.0635	0.5245	-0.0196
17	MAR1	100.610	100.340	13.1033	11.3592	-1.7441		1.0000	0.0020	100.475	7.4210	0.1015	0.7532	0.0111
18	MAR2	100.340	100.030	11.3592	9.6106	-1.7486		1.0200	0.0380	100.185	6.6208	0.1015	0.6720	-0.0185
19	APR1	100.030	99.760	9.6106	7.8162	-1.7944		1.0500	0.0800	99.895	5.8550	0.1145	0.6704	0.0060
20	APR2	99.760	99.400	7.8162	5.8815	-1.9347		1.1000	0.2970	99.580	5.0813	0.1145	0.5818	0.0442
21	MAY1	99.400	102.960	5.8815	41.0176	35.1361		1.0700		101.180	9.9099	0.1270	1.2586	37.4646
22	MAY2	102.960	102.720	41.0176	37.4400	-3.5776		1.0100	0.4170	102.840	16.5798	0.1270	2.1056	-0.0450
23	JUN1	102.720	102.870	37.4400	39.6760	2.2360		0.7800		102.795	16.3568	0.1145	1.8728	4.8888
24	JUN2	102.870	102.810	39.6760	38.7816	-0.8944		0.7900		102.840	16.5798	0.1145	1.8984	1.7940
				TOTAL		**2.5656**	**72.2900**	**25.260**	**9.8760**			**2.2610**	**42.0267**	**152.0183**

Table 5.43 Analysis of evaporation losses in Bhadar-I reservoir July 2004 to June 2005

Sr. No.	Month & fort-night	Reservoir level beginning (m)	Reservoir level end (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Other losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evapo-ration losses (Mm^3)	Runoff (Mm^3)
1	JUL1	102.810	103.170	38.4880	44.6150	6.1270		1.0200		102.940	17.3200	0.1145	1.9830	9.1300
2	JUL2	103.170	103.080	44.6150	42.8570	-1.7580		0.9800		103.120	20.6100	0.1145	2.3590	1.5810
3	AUG1	103.080	104.450	42.8570	72.2780	29.4210		0.9400		103.760	17.8000	0.1015	1.8060	32.1670
4	AUG2	104.450	104.640	72.2780	76.6050	4.3270		0.9800		104.540	24.2500	0.1015	2.4610	7.7680
5	SEP1	104.640	104.570	76.6050	75.0600	-1.5450		1.0300		104.600	24.5100	0.1015	2.4870	1.9720
6	SEP2	104.570	104.700	75.0600	78.1500	3.0900		1.0700		104.630	24.6000	0.1015	2.5000	6.6600
7	OCT1	104.700	104.640	78.1500	76.6050	-1.5450		1.0800		104.670	24.8000	0.0890	2.2070	1.7420
8	OCT2	104.640	104.420	76.6050	71.6270	-4.9780		1.0700	1.1750	104.530	24.2500	0.0890	2.1580	
9	NOV1	104.420	104.240	71.6270	67.6370	-3.9900		1.1300	1.1000	104.330	23.1540	0.0760	1.7600	
10	NOV2	104.240	103.960	67.6370	61.7000	-5.9370	2.3300	1.1500	0.7840	104.100	22.0060	0.0760	1.6730	
11	DEC1	103.960	103.090	61.7000	42.9740	-18.7260	15.5700	1.1600	0.8980	103.520	17.3620	0.0635	1.0980	
12	DEC2	103.090	101.920	42.9740	26.7540	-16.2200	13.3300	1.1900	0.7460	102.500	15.0370	0.0635	0.9540	
13	JAN1	101.920	101.740	26.7540	24.3550	-2.3940	0.0740	1.1600	0.3210	101.830	12.3590	0.0635	0.7840	
14	JAN2	101.740	101.550	24.3550	21.8590	-2.4960		1.1800	0.5190	101.640	11.6170	0.0635	0.7370	
15	FEB1	101.550	101.380	21.8590	19.6910	-2.1680		1.0500	0.4230	101.460	10.9500	0.0635	0.6950	
16	FEB2	101.380	101.190	19.6910	17.7160	-1.9750		1.0700	0.2530	101.280	10.2790	0.0635	0.6520	
17	MAR1	101.190	100.860	17.7160	14.7640	-2.9520		1.1300	0.8720	101.020	9.3680	0.1015	0.9500	
18	MAR2	100.860	100.558	14.7640	12.6500	-2.1140		1.1100	0.1550	100.720	8.3650	0.1015	0.8490	
19	APR1	100.558	100.310	12.6500	10.9440	-1.7060		0.9460	0.9090	100.440	7.2490	0.1145	0.7600	
20	APR2	100.310	100.000	10.9440	9.2260	-1.7180		0.9650		100.150	6.5800	0.1145	0.7530	
21	MAY1	100.000	99.670	9.2260	6.9620	-2.2640		1.1800	0.3650	94.860	5.6690	0.1270	0.7190	
22	MAY2	99.670	99.300	6.9620	5.1620	-1.8000		1.1800		94.480	4.8510	0.1270	0.6200	
23	JUN1	99.300	98.900	5.1620	3.3110	-1.8510		1.1600		94.100	4.1260	0.1145	0.4720	
24	JUN2	98.900	105.950	3.3110	112.5660	109.2550		1.1400		102.420	14.5910	0.1145	1.6700	112.065
				TOTAL		**74.0830**	**31.3040**	**26.0710**	**8.5200**			**2.2610**	**33.1070**	**173.085**

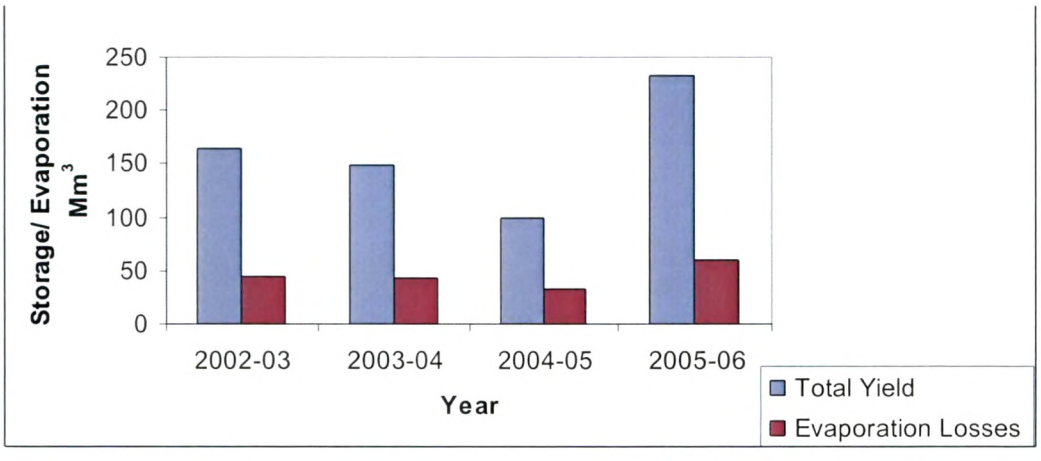
Table 5.44 Analysis of evaporation losses in Bhadar-I reservoir July 2005 to June 2006

Sr. No.	Month & fort-night	Reservoir level beginning (m)	Reserv oir level end (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Other losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporat ion depth	Evapo-ration losses (Mm^3)	Runoff (Mm^3)
1	2	3	4	5	6	7	8	9	11	12	13	14	15	16
1	JUL1	105.95	106.16	114.6545	121.5624	6.9079		0.906		106.055	32.04365	0.1145	3.6690	11.4829
2	JUL2	106.16	106.04	121.5624	117.4992	-4.0632		1.061		106.1	32.306	0.1145	3.6990	0.6968
3	AUG1	106.04	106.68	117.4992	138.7966	21.2974		0.836		106.36	33.5796	0.1015	3.4083	25.5417
4	AUG2	106.68	106.77	138.7966	141.6831	2.8865		1.011		106.725	35.782	0.1015	3.6319	7.5294
5	SEP1	106.77	107.07	141.6831	152.3215	10.6384		0.924		106.92	36.985	0.1015	3.7540	15.3164
6	SEP2	107.07	107.9	152.3215	188.138	35.8165		0.893		107.485	39.8803	0.1015	4.0479	45.6784
7	OCT1	107.9	107.9	188.138	188.138	0		0.911		107.9	42.25	0.089	3.7603	14.9843
8	OCT2	107.9	107.8	188.138	184.148	-3.99		0.973		107.85	41.9805	0.089	3.7363	0.7193
9	NOV1	107.8	107.65	184.148	177.4975	-6.6505	0.75	0.963	1.975	107.725	41.279	0.076	3.1372	0.1747
10	NOV2	107.65	107.42	177.4975	167.4124	-10.0851	4.513	0.921	1.415	107.535	40.17855	0.076	3.0536	-0.1825
11	DEC1	107.42	106.86	167.4124	144.6126	-22.7998	16.387	0.978	2.75	107.14	38.1544	0.0635	2.4228	-0.2620
12	DEC2	106.86	106.25	144.6126	124.7465	-19.8661	14.3	0.906	2.487	106.555	34.72845	0.0635	2.2053	0.0322
13	JAN1	106.25	105.71	124.7465	107.5425	-17.204	12.412	0.962	1.75	105.98	31.5992	0.0635	2.0065	-0.0735
14	JAN2	105.71	105.12	107.5425	89.727	-17.8155	15.107	0.925	0.01	105.415	28.59575	0.0635	1.8158	0.0423
15	FEB1	105.12	104.23	89.727	67.66	-22.067	17.748	0.893	1.901	104.675	24.7985	0.0635	1.5747	0.0497
16	FEB2	104.23	103.5	67.66	51.202	-16.458	13.157	0.916	0.919	103.865	21.0524	0.0635	1.3368	-0.1292
17	MAR1	103.5	103.11	51.202	43.6693	-7.5327	3.891	0.973	0.886	103.305	18.64445	0.1015	1.8924	0.1097
18	MAR2	103.11	102.96	43.6693	40.9678	-2.7015		0.929		103.035	17.5116	0.1015	1.7774	0.0049
19	APR1	102.96	102.78	40.9678	38.2894	-2.6784		0.763		102.87	16.7285	0.1145	1.9154	0.0000
20	APR2	102.78	102.6	38.2894	35.894	-2.3954		0.72		102.69	15.859	0.1145	1.8159	0.1405
21	MAY1	102.6	102.38	35.894	32.8442	-3.0498		0.952	0.049	102.49	14.9887	0.127	1.9036	-0.1452
22	MAY2	102.38	101.84	32.8442	25.9486	-6.8956	2.956	0.934	1.343	102.11	13.3878	0.127	1.7003	0.0377
23	JUN1	101.84	101.28	25.9486	18.9262	-7.0224	14.095	0.961		101.56	11.2822	0.1145	1.2918	9.3254
24	JUN2	101.28	101.13	18.9262	17.3265	-1.5997	3.322	0.975		101.205	9.9996	0.1145	1.1450	3.8423
				TOTAL		**-97.328**	**118.638**	**22.186**	**15.485**			**2.261**	**60.7010**	**134.9160**

The year wise evaporation losses are presented in Table 5.45. Graph 5.1 depicts the year wise storage and evaporation losses in the Bhadar reservoir.

Table 5.45 Evaporation losses in Bhadar-I reservoir

Sr. No.	Year	Total yield Mm^3	Evaporation losses Mm^3	% of Evaporation losses
1	2002-03	164.91	45.23	27.42
2	2003-04	149.45	42.0267	28.12
3	2004-05	99.02	33.105	33.44
4	2005-06	232.24	60.70	26.14
	Total	645.62	181.0617	28.05



Graph 5.3 Year wise storage and evaporation losses in Bhadar reservoir

5.3.4 Evaporation losses in check dams constructed in Bhadar catchment

In Bhadar catchment, total 905 check dams are constructed. The total storage of these check dams is 18.59 Mm^3 and the storage area 27.27 Mm^2.The evaporation losses in the monsoon season is less compared to winter and summer due to higher humidity. Further the surface area of the check dams compared to the reservoir is more. The ground water recharge will take faster because of exposed fractures, cracks, joints and permeable dykes. Further the siltation in the check dams is less compared to Bhadar-I reservoir. Total dead storage of Bhadat-I is silted up. The ground water recharge in check dams is

faster due to less sedimentation in check dams. The check dams are constructed just near the cultivable land. The farmers are desilting the check dams every year and utilized the silt material as a fertilizer. There are so many diesel pumps surrounding check dams. Hence in addition to ground water recharge direct lifting of water from check dams noticed at some places. The evaporation losses are calculated when the check dams are filled by rainfall (Table 5.46, Table 5.47 and Table 5.48) The check dam water generally gets utilized within 21 days by lifting or ground water recharge. The yearly evaporation losses for the years 2003-04, 2004-05 and 2005-06 are presented in Table 5.49 and also depicted graphically in Graph 5.2. The average for three years works out to be 23.8% of the storage in check dams.

Table 5.46 Evaporation losses calculated in check dams for the year June 2003 to October 03

Sub basin No	Total Surface Area (Mm^2)	Evaporation losses (2nd week of June to1st week of July)		Evaporation losses (1st week of July to last week of July)		Evaporation losses (last week of July to 2nd week of August)		Evaporation losses (1st week of August to 3rd week of August)	
		Depth (cm)	Losses (Mm^3)	Depth (cm)	Losses (Mm^3)	Depth (cm)	Losses (Mm^3)	Depth (cm)	Losses (Mm^3)
1	0.439			17.175	0.076			15.225	0.067
2	0.012			17.175	0.002			15.225	0.002
3	1.494			17.175	0.257			15.225	0.227
4	1.193							15.225	0.181
5	0.091							15.225	0.014
6	0.432			17.175	0.074			15.225	0.066
7	1.464			17.175	0.252			15.225	0.223
8	0.179			17.175	0.031			15.225	0.027
9	0.112					17.175	0.019		
10	0.758					17.175	0.130		
11	0.101					17.175	0.017		
12	3.017					17.175	0.519		
13	2.474					17.175	0.426		
14	0.260	17.175	0.045					15.225	0.040
15	0.155	17.175	0.027					15.225	0.024
16	0.308	17.175	0.053					15.225	0.047
17	0.189			17.175	0.033			15.225	0.029
18	8.272	17.175	1.423					15.225	1.257

Sub basin No	Total Surface Area (Mm^2)	Evaporation losses (2nd week of June to1st week of July)		Evaporation losses (1st week of July to last week of July)		Evaporation losses (last week of July to 2nd week of August)		Evaporation losses (1st week of August to 3rd week of August)	
		Depth (cm)	Losses (Mm^3)	Depth (cm)	Losses (Mm^3)	Depth (cm)	Losses (Mm^3)	Depth (cm)	Losses (Mm^3)
19	1.778	17.175	0.306					15.225	0.270
20	1.794	17.175	0.309					15.225	0.273
21	0.708	17.175	0.122					15.225	0.108
22	0.082			17.175	0.014			15.225	0.012
23	1.196			17.175	0.206			15.225	0.182
24	0.622	17.175	0.107					15.225	0.095
25	0.028			17.175	0.005			15.225	0.004
26	0.086			17.175	0.015			15.225	0.013
27	0.027			17.175	0.006			15.225	0.004
Total	**27.27**		**2.392**		**0.971**		**1.111**		**3.165**
					Total evaporation losses 7.633 Mm^3.				

Table 5.47 Evaporation losses calculated in check dams for the year June 2004 to October-2004

Sub basin No	Total surface area (Mm^2)	Evaporation losses (3rd week of June to 2nd week of July		Evaporation losses (1st week of August to last week of August)		Evaporation losses (last week of Sep to 2nd week of October)	
		Depth (cm)	Losses (Mm^3)	Depth (cm)	Losses (Mm^3)	Depth (cm)	Losses (Mm^3)
1	0.439			15.225	0.067		
2	0.012			15.225	0.002		
3	1.494			15.225	0.227		
4	1.193						
5	0.091						
6	0.432			15.225	0.066		
7	1.464			15.225	0.223		
8	0.179			15.225	0.027		
9	0.112	17.175	0.019	15.225	0.017		
10	0.758	17.175	0.130	15.225	0.115		
11	0.101	17.175	0.017	15.225	0.015		
12	3.017			15.225	0.459	15.225	0.459
13	2.474	17.175	0.426	15.225	0.376		
14	0.260	17.175					
15	0.155	17.175					

Sub basin No	Total surface area (Mm^2)	Evaporation losses (3rd week of June to 2nd week of July		Evaporation losses (1st week of August to last week of August)		Evaporation losses (last week of Sep to 2nd week of October)	
		Depth (cm)	Losses (Mm^3)	Depth (cm)	Losses (Mm^3)	Depth (cm)	Losses (Mm^3)
16	0.308	17.175					
17	0.189	17.175	0.033	15.225	0.029		
18	8.272	17.175	1.423	15.225	1.257		
19	1.778	17.175					
20	1.794	17.175					
21	0.708	17.175					
22	0.082	17.175	0.014	15.225	0.012		
23	1.196	17.175	0.206	15.225	0.182		
24	0.622	17.175		15.225	0.095		
25	0.028	17.175		15.225	0.004		
26	0.086	17.175		15.225	0.013		
27	0.027	17.175		15.225	0.004		
Total			**2.268**		**3.190**		**0.459**
		Total evaporation losses 5.916 Mm^3.					

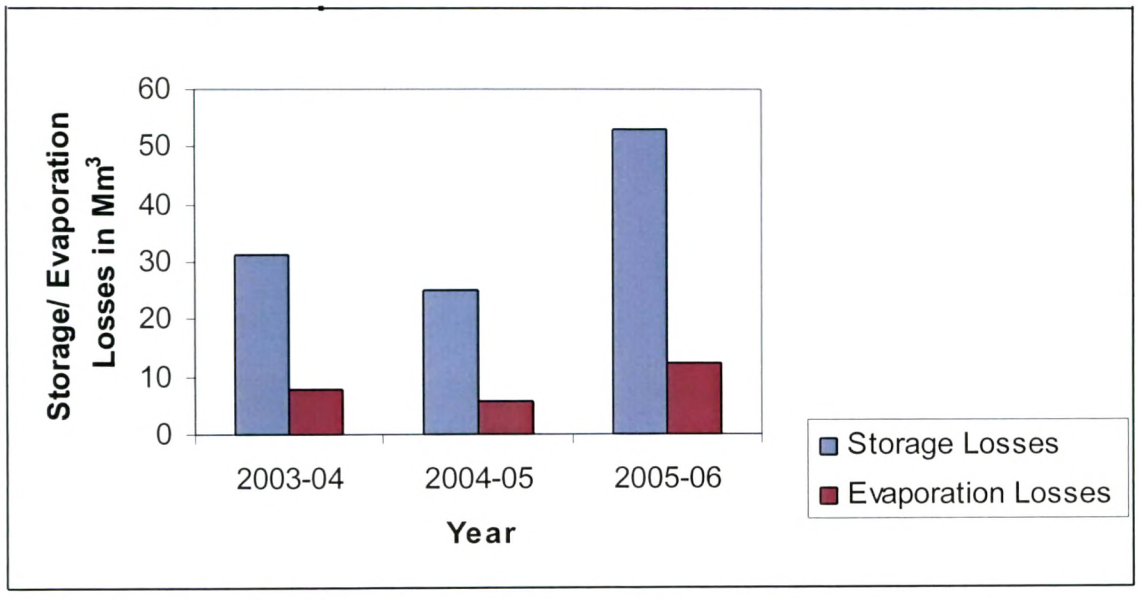
Table 5.48 Evaporation losses calculated in check dams for the year June 2005 to October 2005

Sub basin No	Total surface area (Mm^2)	Evaporation losses (last week of June to 2nd week of July		Evaporation losses (last week of August to 3rd week of August)		Evaporation losses (2nd week of Sep to 1st week of October)	
		Depth (cm)	Losses(Mm^3)	Depth (cm)	Losses(Mm^3)	Depth (cm)	Losses(Mm^3)
1	0.439	17.175	0.076			15.225	0.067
2	0.012	17.175	0.002			15.225	0.002
3	1.494	17.175	0.257			15.225	0.227
4	1.193	17.175	0.205	15.225	0.181	15.225	0.181
5	0.091	17.175	0.016	15.225	0.014	15.225	0.014
6	0.432	17.175	0.074			15.225	0.066
7	1.464	17.175	0.252			15.225	0.223
8	0.179	17.175	0.031			15.225	0.027
9	0.112	17.175	0.019	15.225	0.017	15.225	0.017
10	0.758	17.175	0.130	15.225	0.115	15.225	0.115
11	0.101	17.175	0.017	15.225	0.015	15.225	0.015
12	3.017	17.175	0.519	15.225	0.459	15.225	0.459
13	2.474	17.175	0.426	15.225	0.376	15.225	0.376
14	0.260	17.175	0.045	15.225	0.040	15.225	0.040
15	0.155	17.175	0.027	15.225	0.024	15.225	0.024

Sub basin No	Total surface area (Mm^2)	Evaporation losses (last week of June to 2nd week of July		Evaporation losses (last week of August to 3rd week of August)		Evaporation losses (2nd week of Sep to 1st week of October)	
		Depth (cm)	Losses(Mm^3)	Depth (cm)	Losses(Mm^3)	Depth (cm)	Losses(Mm^3)
16	0.308	17.175	0.053	15.225	0.047	15.225	0.047
17	0.189	17.175	0.033	15.225	0.029	15.225	0.029
18	8.272	17.175	1.423	15.225	1.257	15.225	1.257
19	1.778	17.175	0.306	15.225	0.270	15.225	0.270
20	1.794	17.175	0.309	15.225	0.273	15.225	0.273
21	0.708	17.175	0.122	15.225	0.108	15.225	0.108
22	0.082	17.175	0.014	15.225	0.012	15.225	0.012
23	1.196	17.175	0.206	15.225	0.182	15.225	0.182
24	0.622	17.175	0.107	15.225	0.095	15.225	0.095
25	0.028	17.175	0.005	15.225	0.004	15.225	0.004
26	0.086	17.175	0.015	15.225	0.013	15.225	0.013
27	0.027	17.175	0.005	15.225	0.004	15.225	0.004
Total			**4.691**		**3.534**		**4.145**
				Total Evaporation losses 12.37 Mm^3			

Table 5.49 Evaporation Losses in Check dams

Sr. No.	Year	Total Storage in check dam Mm^3	Total Evaporation Losses in Mm^3	% losses
1	2003-04	31.086	7.633	24.55
2	2004-05	25.142	5.916	23.53
3	2005-06	52.864	12.37	23.40
	Average	36.364	8.64	23.76



Graph 5.4 Evaporation losses in check dams

5.4 IMPACT ON CONTROLLING FLOOD ROUTING OF BHADAR DAM DUE TO CHECK DAMS

5.4.1 Bhadar design flood

The catchment area of the reservoir at the dam site is 2436 km^2. The maximum flood calculated according to several rational formulae are as under :

1) Dicken's formula 170,000 cusecs.
2) Ryves formula 96000 cusecs.
3) William Bransby's formula 1,62,000 cusecs.
4) Inglis formula 2,14,000 cusecs.

The spillway has been designed to discharge a maximum flood of 2,00,000 cusecs with a depth of 1.22 m over the spillway crest. It is proposed to keep flood lift of 4.27 m and to design the spillway to pass the maximum floods of the order of 2,00,000 cusecs. The F.S.L. of the reservoir is already fixed at R.L. 107.89 m. The capacity of the reservoir at F.S.L. (R.L. 107.89 m) works out 237.89 Mm^3.

The river Bhadar-I passes through semi-arid region where rainfall is scanty and erratic and therefore, most of the major tributaries are now having dam structures across them. The basin is also having a systematic network of flood forecasting arrangement. The rivers and tributaries of the basin are having very short length and therefore for incoming floods, the time lag available will not be helpful in speedy alerting and evacuation of affected people. Total 22 Nos. of wireless stations are established in the basin at dam sites to obtain the details about rainfall and discharge. Information on the occurrence of some heavy floods in river Bhadar and tributaries is presented in Table 5.50.

Table 5.50 Unprecedented floods in river Bhadar and its tributaries

Sr. No.	River/Tributary	Dam site	Maximum observed flood (cusecs)	Year of occurrence
1,	Bhadar	Bhadar	1,88,221	1979
2.	Saran	Ishwaria	48644	1983
3.	Karmal	Karmal	42500	1994
4.	Gondali	Gondali	31300	1983
5.	Veri	Veri	52000	1983
6.	Chhapaprwadi	Chhapaprwadi	48750	1983
7.	Chhhapparwadi	Chhaparwadi-II	88000	1994
8.	Vachhapari	Vachhapari	18700	1983.

Maximum observed flood recorded at Bhadar dam site is 1,88,221 cusecs in the year 1979. According to 1983 storm, design flood is revised and the revised design flood is worked out to 8.79 lakh cusecs.

Flood prone districts and talukas in Bhadar basin are given in Table 5.51.

Table 5.51 The Flood prone talukas and districts of entire Bhadar (s) basin

Sr. No.	District	Flood prone taluka with area		
		<10%	10 to 25 %	>25%
1.	Rajkot	Lodhika	Jam-Kandarna Rajkot	Jetpur, Dhoraji, Gondal, Upleta ,Kotada-Sangani, Jasadan
2.	Junagadh	Manavadar Bhesan Mangrol		Porbandar, Kutiyana
3.	Jamnagar	Kalavad		Jam-Jodhpur
4.	Surendranagar	Chotila		
5.	Amreli	Babra Vadia		

5.4.2 Impact of check dams on flood routing in June year 2006

Impact of flood on Bhadar-I reservoir is calculated on hourly basis rainfall-runoff methods. Even in this case reservoir performance statement of Bhadar-I are correlated with hourly rainfall-runoff computation. However in case of check dams in the catchment area, the storage & surface area etc. are so small that the check dams are filled up with 3 to 4 hours in case of good intensity of rainfall. The storage water of check dams without check dams scenario is used for calculating reduction in quantity of Bhadar-I reservoir storage. Where as on flood impact the actual performance of Bhadar-I reservoir with the same average rainfall for year 2002 andyear 2005 are used. In which hourly rainfall-runoff has been considered. The analysis of the rainfall-runoff and reservoir filling position of last five years, it is noticed that the same rainfall (10 inches) of June 2002 created a flood type situation whereas after construction of check dams in year 2005 in the same month June 2005 with the same amount of rainfall (10 inches) there was no flood effect in Bhadar

reservoir. The relevant data are presented in Table 5.52, Table 5.53, Table 5.54 and Table 5.55.

Table 5.52 Rain fall during June-2002 (mm)

Rain Gauge Station	June-I	June-II	June-III	June-IV	**Total JUNE**
Adiya	0	0	25	144	**169**
Amarnagar	0	0	0	296	**296**
Bhadar-I	0	7	0	263	**270**
Gondali	0	25	0	260	**285**
Ishvariya	0	19	14.5	381.5	**415**
Jasdan	0	7	8	190	**205**
K.Sanghani	0	0	8	219	**227**
Kamadhia	0	36	0	403	**439**
Rajwadala	0	0	12	133	**145**
Vachhapari	0	40	0	217	**257**
Total	**0**	**134**	**68**	**2507**	**2708**
Average	**0**	**13**	**7**	**251**	**271**

Table 5.53 Rain fall during June-2005 (mm)

Rain gauge station	June-I	June-II	June-III	June-IV	**JUNE**
Adiya	0	0	70	275	**345**
Amarnagar	0	10	67	212	**289**
Bhadar-I	0	0	14	248	**262**
Gondali	0	0	105	280	**385**
Ishvariya	0	0	5	347	**352**
Jasdan	0	0	0	0	**0**
Kamadhia	0	0	3	237	**240**
Rajwadala	0	0	85	250	**335**
Vachhapari	0	0	77	173.5	**250.5**
Total rainfall	**0**	**10**	**426**	**2023**	**2459**
Average	**0**	**1**	**47**	**225**	**273**

Table 5.54 Reservoir scenario of Bhadar reservoir for June-I and June-II fortnight for year 2002

Month & fort-night	Reservoir level beginning (m)	Reservoir level end (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow over the waste weir (Mm^3)	Other losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evapo-ration losses (Mm^3)	Runoff (Mm^3)
Jun1 2002	96.50	97.840	0.0734	0.707	0.6336					97.170	0.5645	0.1145	0.0646	0.6983
Jun2 2002	97.84	107.29	0.7070	161.734	161.027		0.046	130.268		102.565	15.2880	0.1145	1.7505	293.0915

Table 5.55 Reservoir scenario of Bhadar reservoir for June-I and June-II fortnight for year 2005

Month & fort-night	Reservoir level beginning (m)	Reservoir level end (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow over the waste weir (Mm^3)	Other losses (Mm^3)	Average RL (m)	Area at average RL (Mm^2)	Evaporation depth	Evapo-ration losses (Mm^3)	Runoff (Mm^3)
Jun1 2005	99.30	98.900	5.1620	3.3110	-1.8510		1.1600			94.100	4.126	0.1145	0.4720	
Jun2 2005	98.90	105.95	3.3110	112.5660	109.2550		1.1400			102.420	14.591	0.1145	1.6700	112.065

From the Tables 5.50 to Table 5.55 above, the following observations are noticed.

1. There was no significant rainfall in first three weeks of June-2002 and the storage in Bhadar reservoir was also insignificant.
2. In the last week of June-2002 average rainfall was 251 mm. Because of this rainfall in the catchment, the reservoir level increased from 97.84 m to 107.29 m (FRL). The dam was filled with storage of 161 Mm^3. There was release of 130.268 Mm^3 flood water from spillway in this week.

5.4.3 Impact of check dams on flood routing year 2005

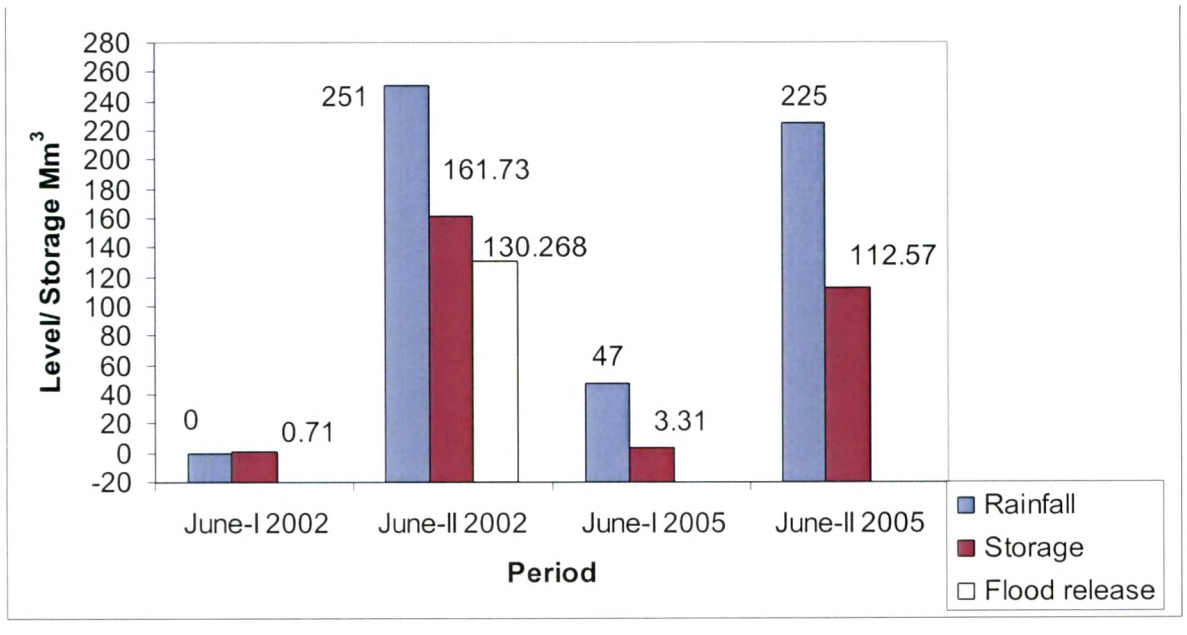
1. There was no rainfall in 1st and 2nd week of June-2005 (1 mm). The reservoir level was 98.90 m and the water storage in the reservoir was 3.31 Mm^3.
2. In the 3rd week of June-2005, the rainfall received was 47 mm while in the 4th week of June- 2005, the rainfall received was 225 mm. Hence in the 2nd fortnight, the rainfall received was 273 mm. Because of the rainfall of 273 mm in the catchment, the reservoir level increased from 98.90 m to 105.95 m (FRL 107.29 m), which is below FRL. There was no flood and no flow over the waste weir/ spillway.

As seen from the above after construction of the check dams in the catchment, the flood in Bhadar in June 2005 did not occur whereas for the same scenario in June 2002, the flood of the order of 135 Mm^3 was occurred (Table 5.56 and Graph 5.3).

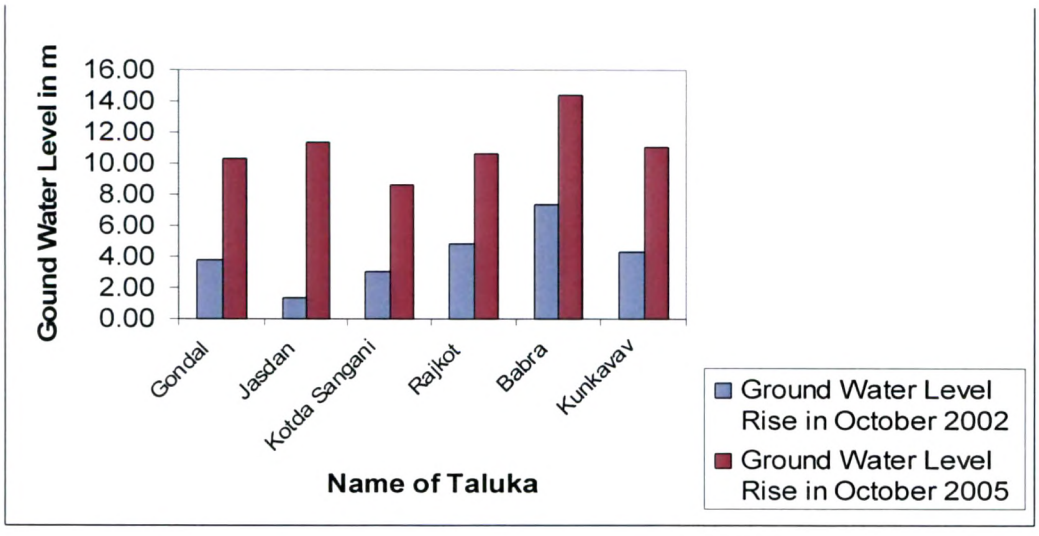
Table 5.56 Results of flood routing

	Average rainfall in	Qty. of water received	Spillway water	Initial storage
Year June 2002	271 mm	293 Mm^3	135 Mm^3	0.70 Mm^3
Year June 2005	273 mm	112 Mm^3	---	3.31 Mm^3

In the year 2005, flood routing could be achieved because of the construction of check dams which enabled the check dam stored water to entre underground and raise the ground water levels (Table 5.56 and Graph 5.4) instead of contributing to the flood water quantity as happened in the year 2002 without check dams.



Graph 5.5 Flood routing scenario



Graph 5.6 Ground water scenario in 2002 and 2005

In the Bhadar catchment Gondal, Jasdan, Rajkot, Kotda Sangani talukas of Rajkot district and Babra and Kunkavav talukas of Amreli district are falling. The ground water level of May 2002 to October 2002 and of May 2005 to October 2005, as obtained from GWRDC are presented in Table 5.57.

Table 5.57 Results of rise of ground water level in catchment of Bhadar during 2002 and 2005.

Sr. No.	Bhadar catchment taluka	District	Ground water level Rise in October 2002 (m)	Ground water level Rise in October 2005 (m)	Average rainfall 2002	Average rainfall 2005
1	Gondal	Rajkot	3.83	10.31		
2	Jasdan	Rajkot	1.39	11.34		
3	Kotda Sangani	Rajkot	3.05	8.67	391 mm	673 mm (172%)
4	Rajkot	Rajkot	4.81	10.63		
5	Babra	Amreli	7.34	14.46		
6	Kunkavav	Amreli	4.30	11.04		
		Average	**4.12**	**11.08 (268%)**		

The average rainfall year 2005 is 172% of average rainfall of year 2002. however due to check dams, the ground water rise in October 2005 is 268% higher in compared to October 2002. Hence due to increase in ground water recharge, the flood routing took place in June 2005.

5.5 ANALYSIS OF GROUND WATER RECHARGE IN BHADAR CATCHMENT DUE TO CHECKDAM

The catchment area of Bhadar dam is 2436 km^2. There are 4 talukas viz. Gondal, Jasdan, Rajkot & Kotdasangani in Rajkot district and Babra & Kukavav Taluka in Amreli district & a small portion of Chotila taluka of Surendranagar district. The total basin is highly weathered and fractured in top 30 to 40 m. depth. The geological formation is basalt trap with crisis cross dykes. The gradient is gentle to steep in the catchment. The run off is varying from 15% to 17% in the catchment. Due to rainfall, there is a monsoon recharge and thereafter during the winter there is non-monsoon recharge due to irrigation and storage in surface water reservoir. Generally, in Bhadar basin, most of the recharge ground water recharge takes place during the monsoon season. The ground water recharge rate mainly depends upon the intensity of the rainfall and retention of rain water. In Bhadar catchment, 905 checkdams are constructed. The ground water recharge estimation of six talukas for the year 1997 as well as for the year 2006 in the entire Bhadar catchment area has been presented in Table 5.58.

Table 5.58 Ground water recharge for year 2006 & 1997

Sr. No.	Taluka	Geographical area in km^2	Area falling in Bhadar basin (km^2)	Gross recharge (For entire taluka) (Mm^3)		Gross recharge (area falling in Bhadar Basin)(Mm^3)	
				1997	2006	1997	2006
1.	Jasdan	1321	495	118	254	94	96
2.	Gondal	1193	683	135	257	77	147
3.	Kotadasangani	447	326	58	62	42	45
4.	Rajkot	1005	146.50	108	222	16	32
5.	Kunkavav	546	400	124	84	91	62
6.	Babra	793	375	92	94	43	44
Total		**5304**	**2425**	**635**	**973**	**313**	**426 (136%)**

It can be seen from the above that the talukawise ground water recharge for 1997 was 635 Mm^3. In the year 2006, the ground water recharge in all these 6 talukas was 973 Mm^3. The ground water recharge exclusively in Bhadar catchment for all the 6 talukas has been analyzed and it is seen that in the year 1997, the ground water recharge in Bhadar catchment was 313 Mm^3, whereas in the year 2006, the ground water recharge was 426 Mm^3. Hence because of check dams, the ground water recharge has been increased by 36% more compared to that in year 1997. The details of average rainfall of the year 1997, 2006 & annual draft are presented in Table 5.59 and Table 5.60.

Table 5.59 Average rainfall of year 1997 and year 2006

Sr. No.	Taluka	Total rainfall (mm)		Weighted average rainfall (mm)	
		1997	2006	1997	2006
1.	Gondal	678	628	193	177
2.	Rajkot	595	882	36	53
3.	Jasdan	509	662	104	135
4.	Kotadasangani	625	681	84	92
5.	Babra	489	754	75	116
6.	Kankavav	596	677	98	111
			Total	**590**	**685 (116%)**

Table 5.60 Details of annual draft of year 1997 and year 2006

Sr. No.	Taluka	Taluka wise annual draft (mm)		Annual draft for area falling within Bhadar-I basin (mm)	
		Draft 1997	Draft 2006	Draft 1997	Draft 2006
1.	Gondal	81	69	46	40
2.	Rajkot	61	111	9	16
3.	Jasdan	73	96	27	36
4.	Kotadasangani	29	45	21	33
5.	Babra	40	53	19	25
6.	Kankavav	68	41	50	30
Total		**352**	**415**	**172**	**180**

It can be seen from the above that the average rainfall for the year 2006 is 685mm and for the year 1997, it is 590 mm. Whereas there was only 16% more rainfall in 2006, the ground water recharge was 36% higher in the year 2006. The ground water extraction in the year 2006 and the year 1997 are more or less similar.