CHAPTER 3

DATA COLLECTION AND INTERPRETATION

3 DATA COLLECTION AND INTERPRETATION

Data has been collected to fulfill the objectives of the study. Tapi River cross sections from Ukai to Hazira are used to find River carrying capacity. To understand methodology & limitations of existing model for Tapi river water surface profile, charima and distorted physical model data are obtained and used. To work on GIS & RS, image of study area is obtained and used. To know Tapi river system detail of tree structure on tributaries, base stations and flood forecasting stations was prepared. To revise Ukai Dam reservoir gate operation policy, existing rule level, manual, demand and losses data are collected and used. To understand sedimentation in Ukai Dam as well as in Tapi River sediment data like size, properties, distribution, sediment inflow hydrographs, armoring etc. are collected and analyzed. To study Tapi River past flood, long period historical flood data are used. To forecast flood probability peak flood data from the year 1939 & 2012 are collected and analyzed. To find the role of rainfall and tidal wave effect, rainfall data and tidal wave data are collected. To study diversion of Tapi River, contour level data, topographic data and drainage disposal data are used.

Data has been collected from the following offices for the academic purpose of this research study.

Sr. No.	Description of Data Collected	Name of Offices
1	Topographic data i.e. Channel cross sections, layout & connectivity, configuration of weirs.	Surat Irrigation Circle, Surat.
2	Hydrologic data i.e. Inflow hydrographs for upstream & downstream boundary condition, bed roughness, Deforestation and Historical change data.	Ukai Flood Control Cell, Ukai.
3	Sediment data i.e. size, properties, distributions, sediment inflow hydrographs by class.	Gujarat Engineering Research Institute (GERI), Gotri, Vadodara.
4	Calibration & verification data i.e. Discharge hydrographs, sediment transport rates by size class, observed changes in bed levels and composition.	Central Water Power Research Station (CWPRS), Khadakwasla, Pune.

Sr. No.	Description of Data Collected	Name of Offices
5	PAN-A/F (2.5m high resolution) Cartosat-1 image data from NRSC, in stereo pair path 93, raw 57, SOI Topo sheet 46C 15 and 16, UTM map projection, WGS84 datum, product no 4.2. Ortho kit in Geotiff file format.	National Remote Sensing Centre (NRSC), Hyderabad.
6	Distorted physical model data pilot project report.	Gujarat Engineering Research Institute (GERI), Gotri, Vadodara.
7	Gate reservoir operation data (up to year 2008.)	Ukai Flood Control Cell, Ukai.
8	Long span monthly inflows data, Irrigation-Industrial-drinking water demand, reservoir elevation-storage relationship, reservoir elevation- area, penstock numbers and capacity, Maximum Drawdown Level-Full Reservoir Level-Canal Bed Level.	Ukai Flood Control Cell, Ukai.
9	Tidal wave level data.	Magdalla port authority, Surat.
10	Drainage disposal and past flood data	Surat Municipal Corporation, Surat
11	Rainfall Data	State Water Data Centre (SWDC), Gandhinagar.
12	River cross sections from Ukai to Hazira in Auto Cad format.	Chetan Engineers, Gotri, Vadodara.
13	Hydropower generation and demand data.	Ukai Dam circle, GSECL – Unit, Ukai.

In this chapter collection of data from various agencies, offices are complied and enlisted. The large data scrutinize for different analysis in this research study. Among some of the data like Ukai Dam technical features, irrigation demand, hydropower generation, inflow, outflow, daily reservoir water level, existing gate operation policy rule levels, historical flood data are used for modification of rule level for Ukai reservoir. Tapi river cross section data are used for determination of flood carrying capacity in Surat City. Existing model data are thoroughly studied to identified drawbacks, disadvantages and limitations.

Below Table.No.3.1 shows Maximum flood water level at different location during flood in Tapi River and Table.No.3.2 shows Flood water mark on Hope/Nehru Bridge in Surat City for different flood frequency.

Table.3.1 Maximum Level at Different Location during Flood in Tapi River

Date	Flood in (Lac Cusecs)	Ukai Level (feet)	Kakrapar level (feet)	Kathor Level (meter)	Nehru Bridge Level (meter)	Singanpur Level (meter)	Magdalla Level (meter)
6-8-1968	15.60	-	181.50	-	12.38	-	-
6-9-1970	13.00	-	-	-	11.02	-	-
8-9-1994	5.25	345.24	175.80	14.97	10.10	-	6.20
16-9-1998	6.99	346.04	178.90	17.05	11.40	13.90	6.75
7-9-2002	3.30	341.21	172.30	-	8.10	10.64	-
9-8-2006	9.10	346.07	182.70	20.11	12.50	14.10	8.00

(Source: Surat Irrigation Circle)

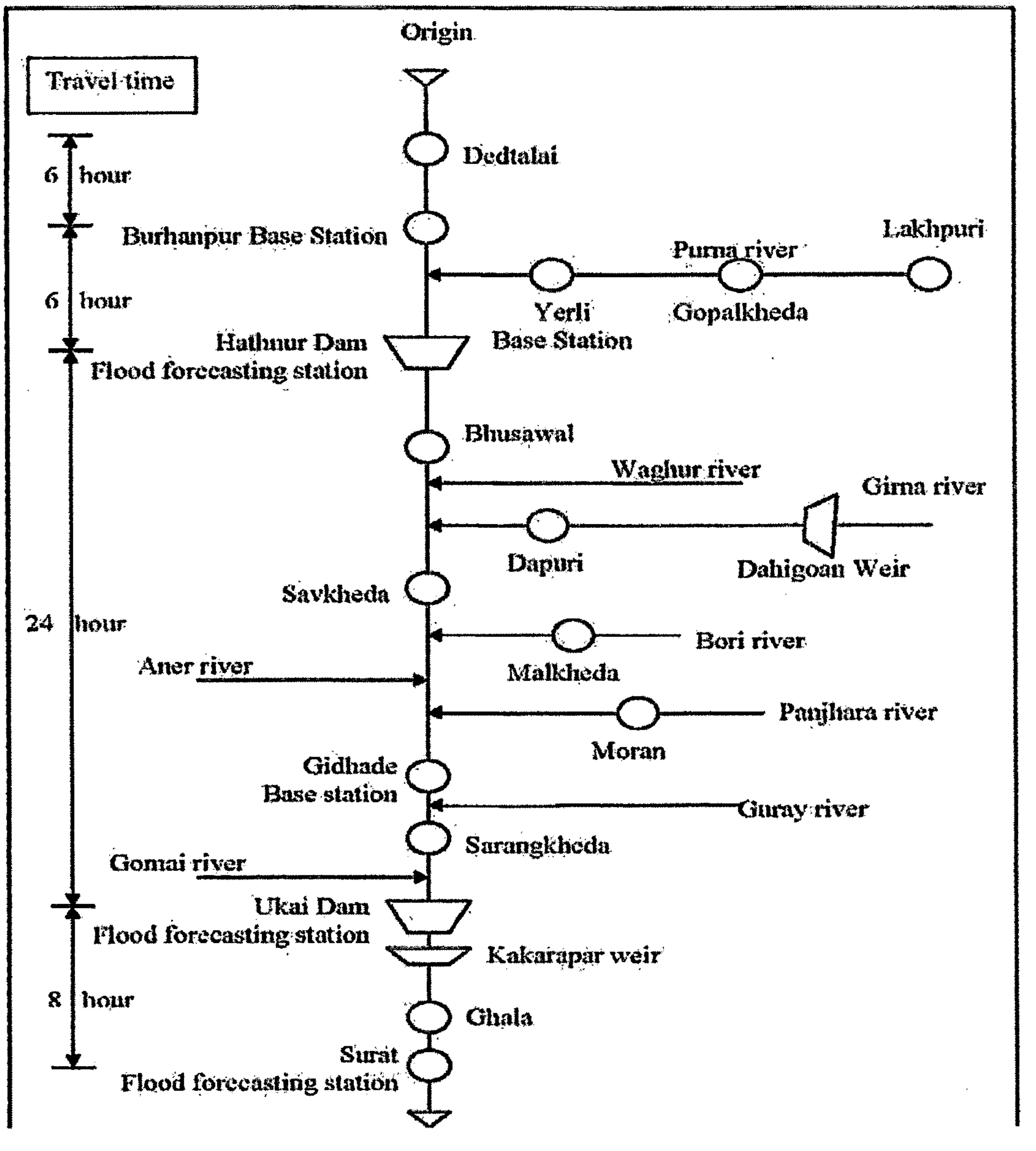
Table.3.2 Major Flood in Surat City

Year	Magnitude (Lacs Cusecs)	Flood Level (m)	Remarks
Sep. 17, 1959	12.94	11.55	Warning Level 8.50 meter
Aug. 06, 1968	15.60	12.38	
Sep. 08, 1969	08.56	9.96	
Sep. 08, 1994	05.25	10.10	Danger Level 9.50 meter
Sep. 16, 1998	07.00	11.40	
Aug. 08, 2006	09.10	12.50	

(Source: Surat Irrigation Circle)

3.1 Topographic Data

Channel cross sections, layout & connectivity, configuration of weirs are collected for topography data. The below Fig.No.3.1 shows tree structure of Tapi River i.e. from origin to Surat city travel time, base stations and Flood forecasting stations with its interconnections. Table.No.3.3 shows hydrometric network for flood forecast in Tapi basin. Time lag & Distance of various stations from the original of River Tapi Shown in Table.No.3.4. Table.No.3.5 shows drainage system in Surat District.



(Source: Surat Irrigation Circle)

Fig.3.1 Tree Structure of Tapi Tributaries, Base Stations and Flood Forecasting Stations

Table.3.3 Hydrometric Network for Flood Forecast in Tapi Basin

Sr. No.	River / Site	Length of river to site (Km)	Catchment area up to the site (Sq.Km)	Bank of station gauge	Type of observation / site	Common Calender Year
1	Chikaldhara	--	--	--	WR	1988
2	Amrawati	--	--	--	WR	1988
3	Tapi at Dedtalai	200	6660	Left	WGDRSQ	1977
4	Tapi at Burhanpur	241	8487	Right	WGDRSQ	1969
5	Purna at Gopalkheda	170	9500	Left	WGDRSQ	1977
6	Purna at Yerli	223	16517	Left	WGR	1971
7	Tapi at Hathnur	290	29430	Right	WGR	1979
8	Tapi at Bhusaval	306	32478	Left	WGR	1969
9	Girna at Girna Dam	110	4729	Right	WGR	1979
10	Girna at Dahigaon	202	8599	Left	WGR	1978
11	Tapi at Savkheda	388	48136	Left	WGDRSQ	1972
12	Panjra at Morane (Dhulia)	95	1933	Right	WGDRSQ	1978
13	Tapi at Gidhade	420	54750	Right	WGDR	1969
14	Tapi at Sarangkheda	488	58400	Right	WGDRSQ	1976
15	Tapi at Ukai	595	62225	Left	WGR	1969
16	Tapi at Kakrapar	624	62826	Left	WGR	1969
17	Tapi at Ghala	640	63325	Right	WGDRQ	1977
18	Tapi at Surat	708	63973	Bridge	WGR	1969

Note: W – Wireless; R – Rainfall; G – Gauge; D – Discharge; S – Silt; Q – Water quality

(Source: State Water Data Center (SWDC))

Table.3.4 Time Lag & Distance of Various Stations from Origin to the end of Tapi Basin

Sr. No.	Name of Site	Disaster from Origin (Km)	Time Leg in (Hrs)	Cumulative Time Lag (Hrs)
1	Teska (M.P.)(Betul)	76	5	5
2	Dedtalai (M.P)	200	11	16
3	Burhanpur (M.P)	241	4	20
4	Hathnur (Maharashtra)	290	4	24
5	Bhusaval (Maharashtra)	306	1	25
6	Gidhade (Maharashtra)	420	9	34
7	Ukai (Gujarat)	595	12	46
8	Kakarapar (Gujarat)	624	1	47
9	Ghala (Gujarat)	685	3	50
10	Surat (Gujarat) (up to Sea)	725	6	56

(Source: Surat Irrigation Circle)

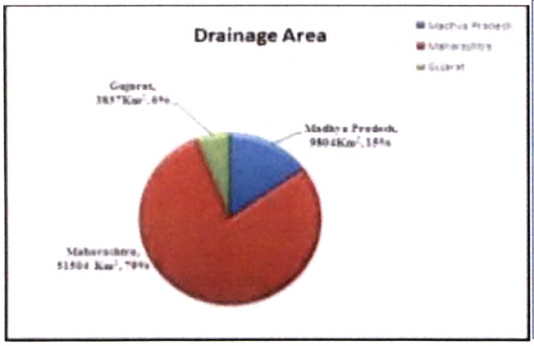
Table.3.5 Drainage System in Surat District

District	No. of Talukas	No. of Villages	Catagorywise Length of Drains (km.)					Total No. of Structures
			Main	Sub	Lateral	Sub-Lat	Total	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Surat	10	653	882	1715	1077	261	3935	1525
Total	**10**	**653**	**882**	**1715**	**1077**	**261**	**3935**	**1525**

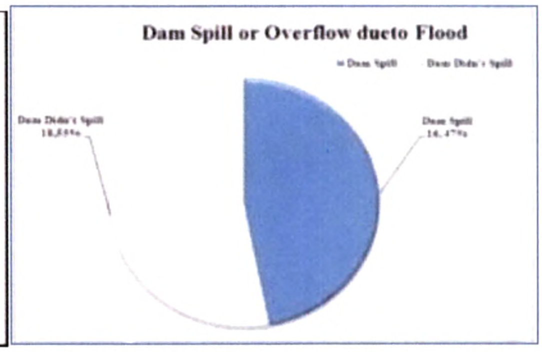
(Source: Surat Irrigation Circle)

3.2 Hydrologic Data

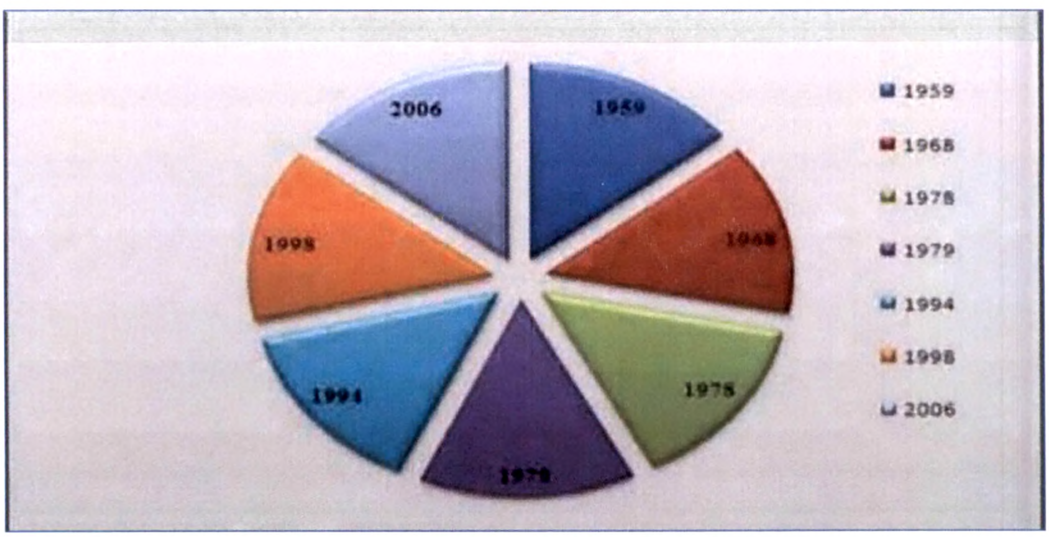
In hydrologic data inflow and outflow hydrographs of the year 1994, 1998 and 2006 for upstream & downstream boundary condition, bed roughness, drainage area distribution, behaviour of Ukai dam, water spill from dam, photograph during flood year 2006 are collected and used.



Pie Chart.3.1 Drainage Area Distribution



Pie Chart.3.2 Behaviour of Ukai Dam



Pie Chart.3.3 Disaster Flood Years

(Source: Surat Irrigation Circle)

Plate.3.1 Water Spill from Dam, Flood 2006

(Source: Surat Irrigation Circle)

Plate.3.2 Photograph During 2006 Flood

Comparison of Tapi River flood at Surat City for the year 1998 and 2006 is shown in below Table.No.3.6.

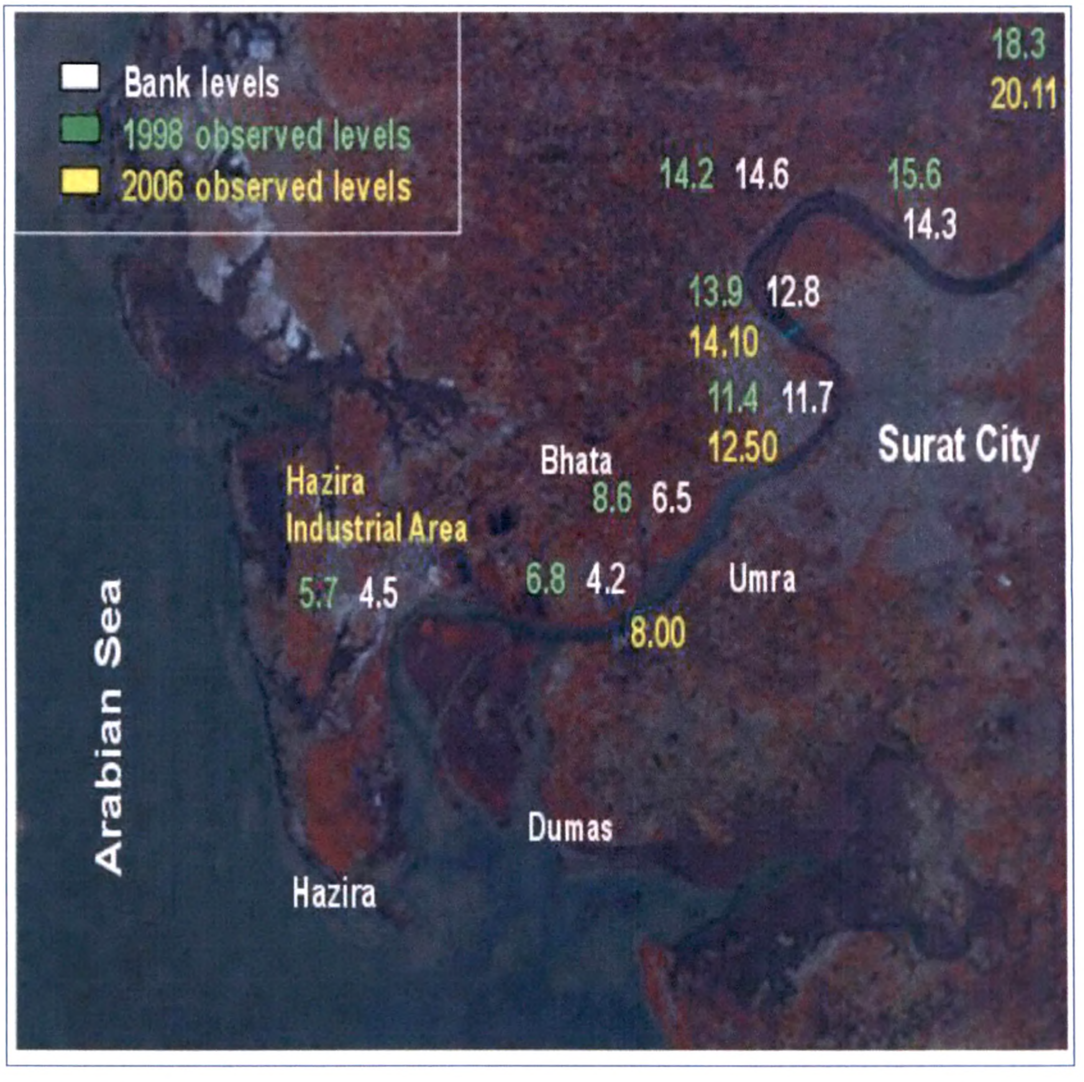
Table.No.3.6 Comparison of 1998 and 2006 Flood

Sr.No.	Detail	1998		2006	
1	Ukai Dam Discharge	6.99 Lac Cusecs for duration of 16 hrs.		6.00 to 7.5 Lac Cusecs for duration of 13 hrs. And 8.00 to 9.5 Lac Cusecs for a duration of 42 hrs.	
2	Area Under Submergence	Level (feet)	Area in Sq.Km (Old City Limit)	Level (feet)	Area in Sq.Km (Old City Limit)
		0'-2'	5.79	0'-3'	16.04
		2'-4'	6.89	3'-5'	14.55
		4'-6'	4.26	5'-10'	30.03
		> 6'	6.32	> 10'	20.82
		Total	23.26	Total	81.44
				Total of 46.99 sq.km. Area of new city limit under sub.	
3	Appro.Affected Population	400000		1900000	
4	Appro.Affected Area in sq.km)	23.5		128	
5	Rescue Operation (Persons Rescued)	1958	Defense Forces	11964	
			S.M.C	13867	
			Total	25831	
6	No. of Food Packets	314332		1951852	
7	Labors Deployed	6343		8227	
8	Solid Waste Disposed in MT	38888		239098	
9	Human Death	20		155	
10	Dead Animal Disposal				
	(a) Small	2089		2096	
	(b) Big	301		2378	
	Total	2390		4474	
11	Machinery Deployed				
	(a) Transportation	343		1176	
	(b) Loading Equipments	45		223	
11	Insecticides Sprayed				
	(a) Powder (mt)	300		2452	
	(b) Liquid (k.Lts.)	25		61	
12	Medical Teams	108		250	

(Source: Surat Municipal Corporation)

3.3 Hydraulic Data

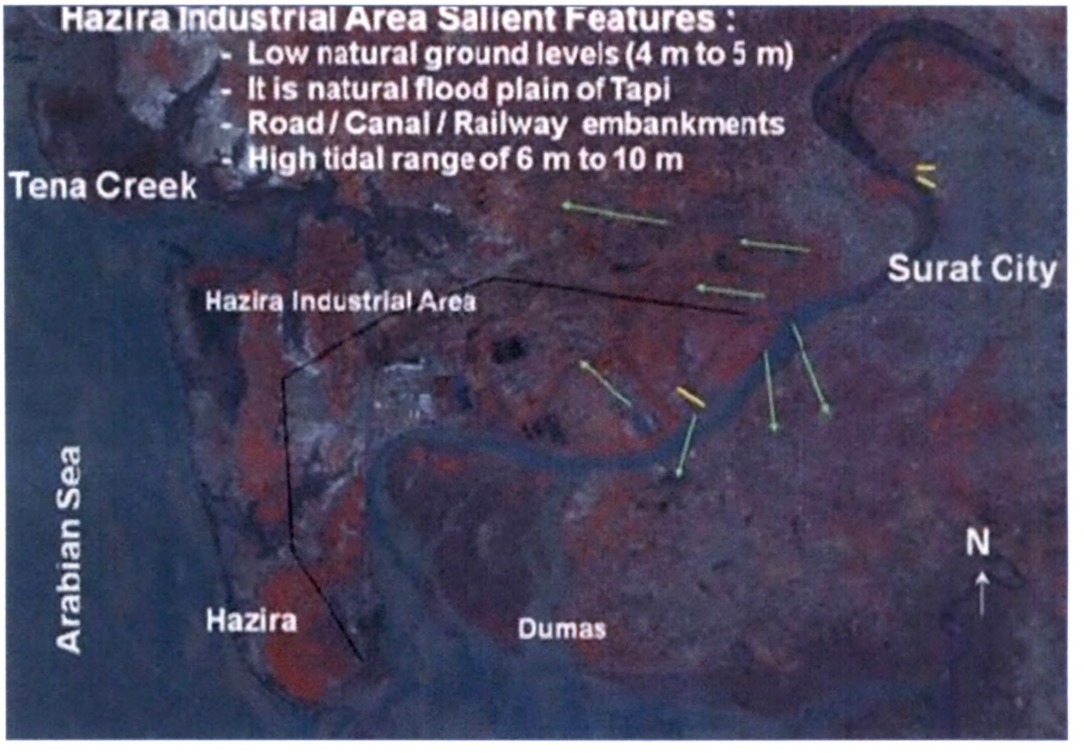
Following hydraulic data are collected i.e. Observed flood levels of the years 1998 and 2006 along Tapi River, records of Ukai flood release during year 1994, 1998 and 2006, tidal water level for a period of one month outside mouth of Tapi River at Magdalla Bridge and other locations, velocity data at four locations during spring/neap tide situation. This below image shows high meandering shape of Tapi River and observed flood water levels during year 1998 -2006 while passing through Surat.



(Source:Google Image)

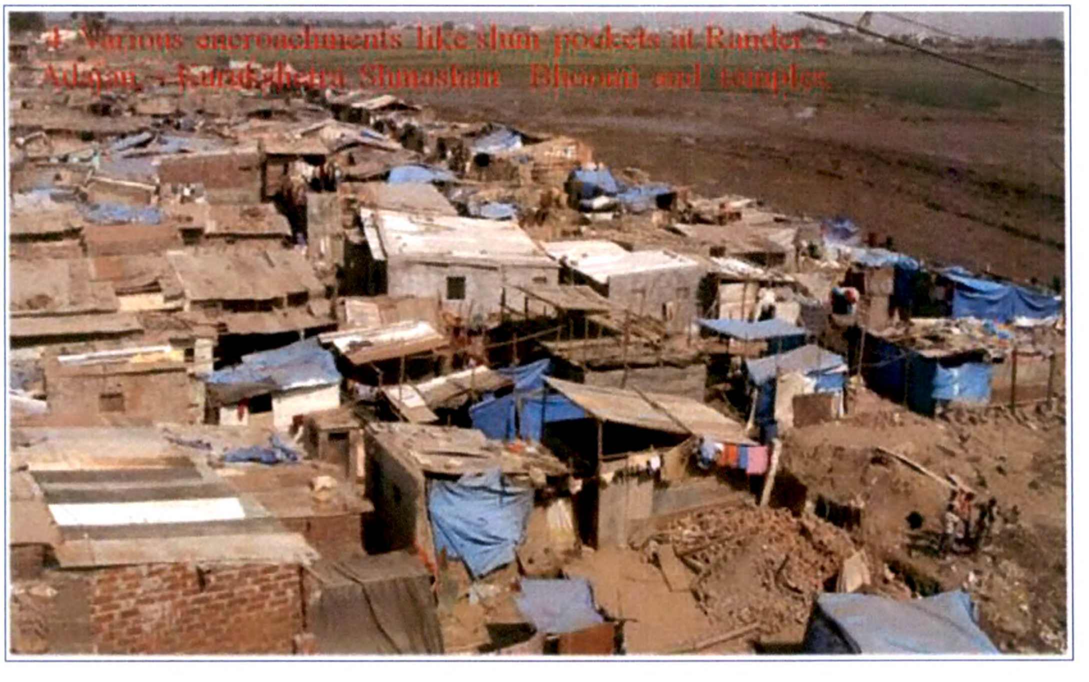
Plate.3.3 1998 & 2006 Flood Levels and Natural Right Bank Levels

Above image explain about development of Hazira twin city which is originally flood plain area at low height and slum pockets encroachments at Render- Adajan and U/S of Nehru Bridge Surat city.



(Source:Google Image)

Plate.3.4 Development of Industries of Hazira Area which is originally in Flood Plain Area



(Source: Surat Municipal Corporation)

Plate.3.5 Tapi R.H.S. Bank, U/S of Nehru Bridge Showing Slums Encroachment

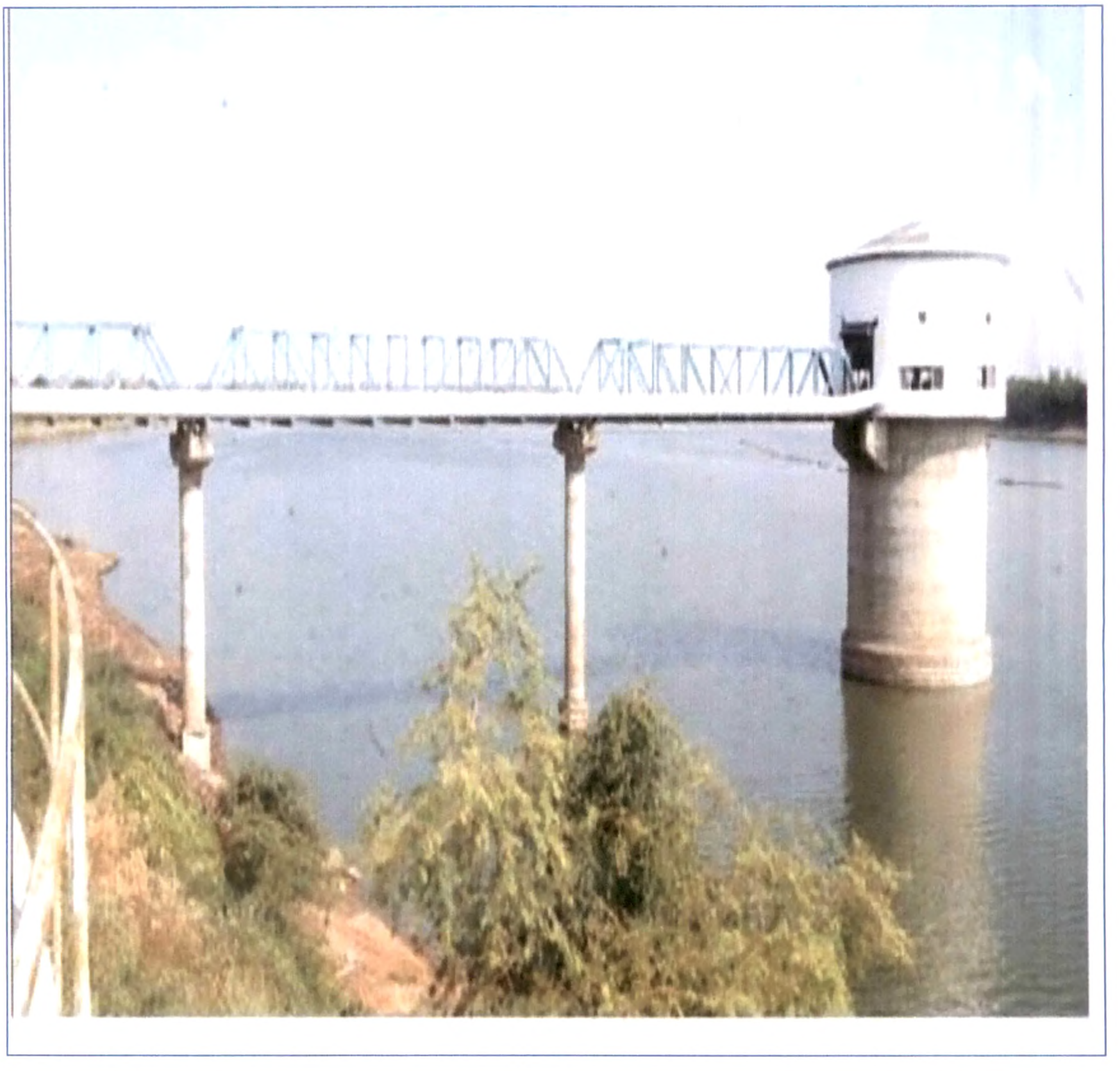
(Source: Surat Municipal Corporation)

Plate.3.6 Tapi L.H.S. Bank, Pataliya Hanuman Temple Encroachment

(Source: Surat Municipal Corporation)

Plate.3.7 Tapi L.H.S. Bank, Ramnath Washing Ghat @ Fulpada Area Surat

Below image shown construction of intake wells at Variav by industries and water supply intake wells of SMC (at Jahangirpura, Katargam & Nana Varachha) create obstruction to the Tapi River flow.



(Source: Surat Municipal Corporation)

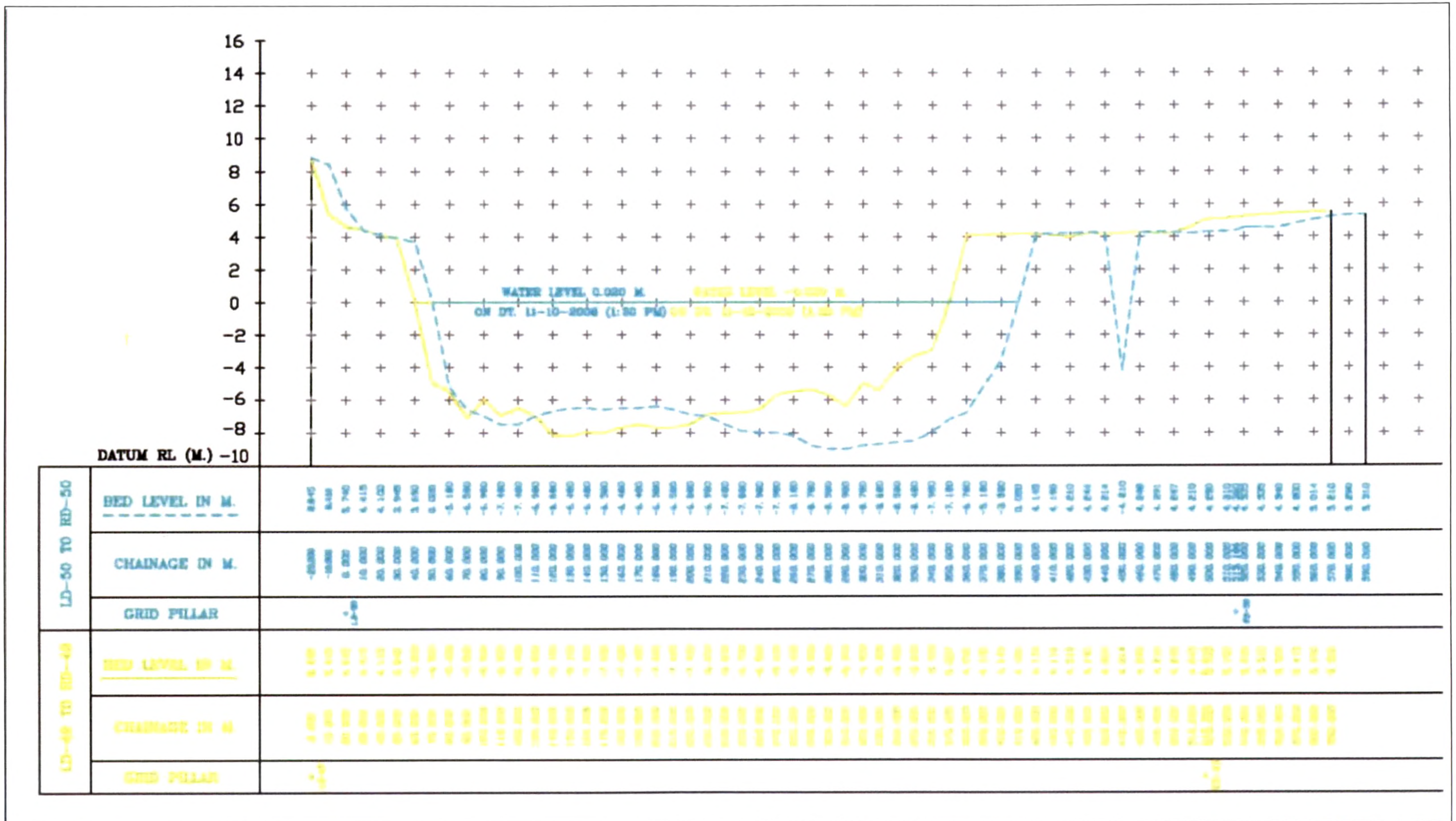
Plate.3.8 Variav Water Works [Intake-Well]

3.4 Sediment Data

Sediment data are collected from SEDI Department, GERI, Gotri, Vadodara i.e. size, properties, distributions, sediment inflow hydrographs by class from the Year 1972 to 2003. Moreover, reports of sedimentation survey are also collected. According to the report, authority have adopted integrated bathymetric system for survey by using GPS system (time, place). The grid of 100 sq.m. for reading along with boat (eco sound system) for the whole reservoir (for different years) at 5 year intervals, for different years was made.

3.5 Validation of Data

For verification of data, discharge hydrographs, sediment transport rates by size class, observed changes in bed levels and composition are collected. Below Fig.no.3.2 shows Tapi river cross section for year 2006.



(Source: Chetan Engineers, Gotri, Vadodara)

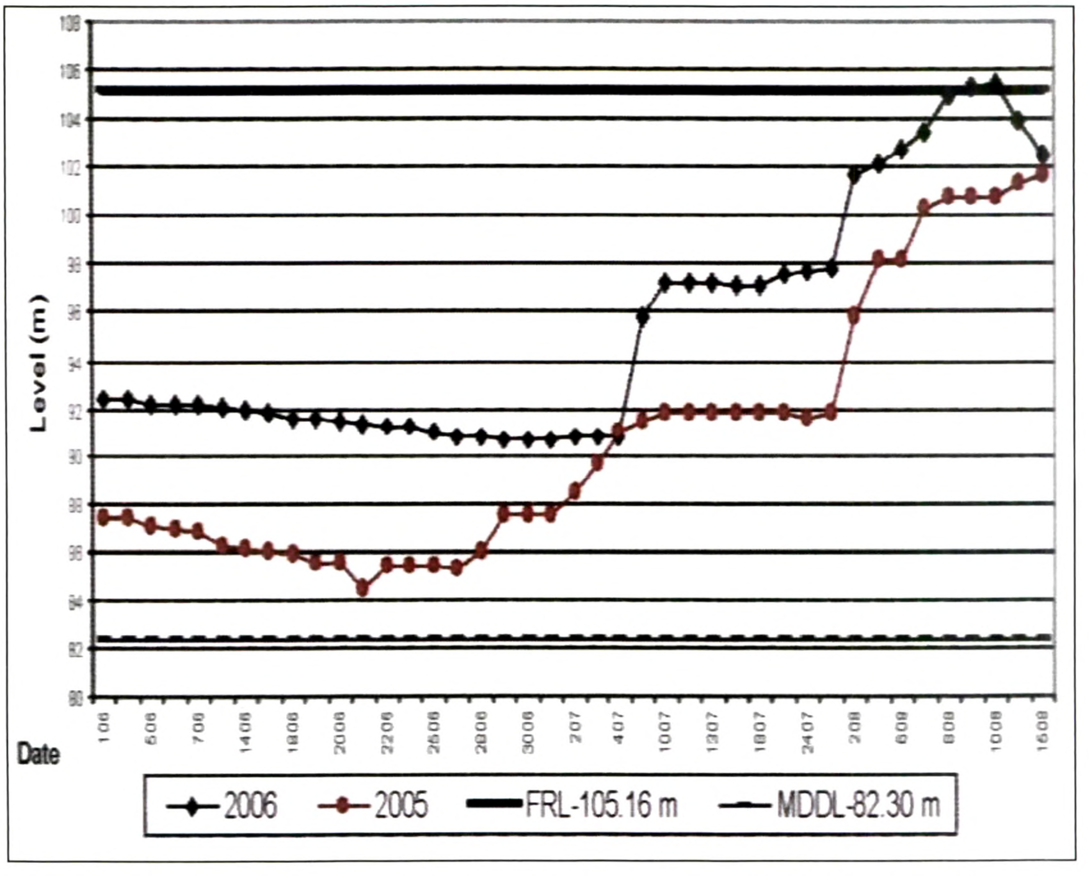
Fig.3.2 Tapi River Cross Section

Armoring Scheme

Most river beds consist of grains with a broad range of size fractions. In an erosion process, fine particles are entrained more easily and the bed surface will become progressively coarser. Ultimately, an armor coat of large particles forms, and that stops further degradation. During the aggradations process, layers of sediment will be deposited on the bed surface and the bed surface will be progressively finer. (International journal of Sediment Research, Vol.18, No.1, 2003, pp.32-49), (Ref.No.61).

Updating of sediment composition at every time step is necessary and crucial to a sediment routing model. Various techniques dealing with bed composition variation have been proposed. This model adopts the sorting and armoring techniques proposed by Benet and Nordin (1977). In that model the bed is divided into three layers and sediment composition computation is accomplished through the use of one or two layers depending on whether scouring or deposition occurs during that particular time step. According to this procedure the thickness of the active layer is set equal to a preselected parameter, N, times the geometric mean of the largest size class used in the simulation. The active layer is defined as the bed material layer that can be worked or sorted through by the action of the flowing water in the time step, to supply the volume of material necessary for erosion. Therefore, the parameter N is related to the duration of simulation time step. The value of parameter N should be increased for longer time steps. For the net deposition case, an inactive deposition layer is used. This layer is located beneath the active layer. When the deposition of a particle size fraction of certain thickness occurs, this thickness is added to the active layer. Also, an equal thickness of active layer is added to the inactive deposition layer. The size composition and the thickness of the inactive layer are recomputed. Finally, the size computation of the active layer is recomputed and the channel bottom elevation is updated.

It is clear from this below Graph.3.1 that Ukai Dam was going to get large inflows in the days to come and there was sufficient actionable information available with the Gujarat Water Resources Department to release water from Ukai Dam in July itself. This was all the more important considering the rapid rise in water level at Ukai dam. The compare is on of the Ukai reservoir levels just before the monsoon and at the end of July for the last four years (for which were obtained the data from Central Water Commission and Central Electricity Authority bulletins) the result shows that the levels at Ukai dam were the highest this year in last four years, both with respect to the level just before the monsoon and also at the end of July, as it is clear from the Table. No.3.7 below.



(Source: Central Water Commission, Central Electricity Authority, Govt of India, Bulletins of Various Dates)

Graph.3.1 Level at Ukai Dam Comparison Year 2005 and 2006

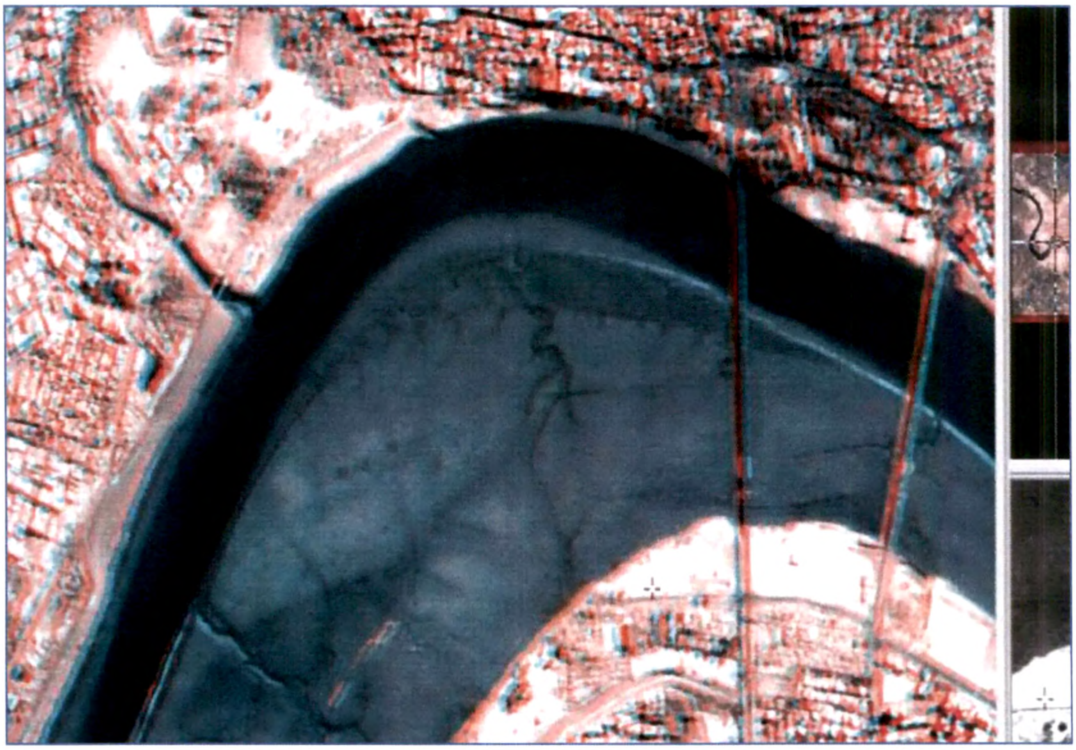
Table.3.7 Water Level Just before the Monsoon end of July

Year	Lowest level Before monsoon		Level (m) at the end of July
	Level (m)	Date	
2002	89.91	June 17	94.56
2003	88.02	June 25	88.16
2004	85.37	June 24	94.26
2005	90.71	June 29	97.8

(Source: Central Water Commission, Central Electricity Authority, Govt. of India, Bulletins of Various Dates)

3.6 Remote Sensing Cartosat-1 Image Data

PAN-A/F (2.5m high resolution) Cartosat-1 image data was collected from NRSC, Hyderabad in stereo pair path 93, raw 57, SOI Map sheet 46C 15 and 16, UTM map projection,WGS84 datum, product no 4.2, ortho kit in Geotiff file format. For DEM generation of Cartosat –1 data, data of Surat city were collected. Fore and after scenes of town, dated 12th January 2012 were used. After scenes are mentioned in below Plate.No.3.9.



(Source: NRSC, Hyderabad)

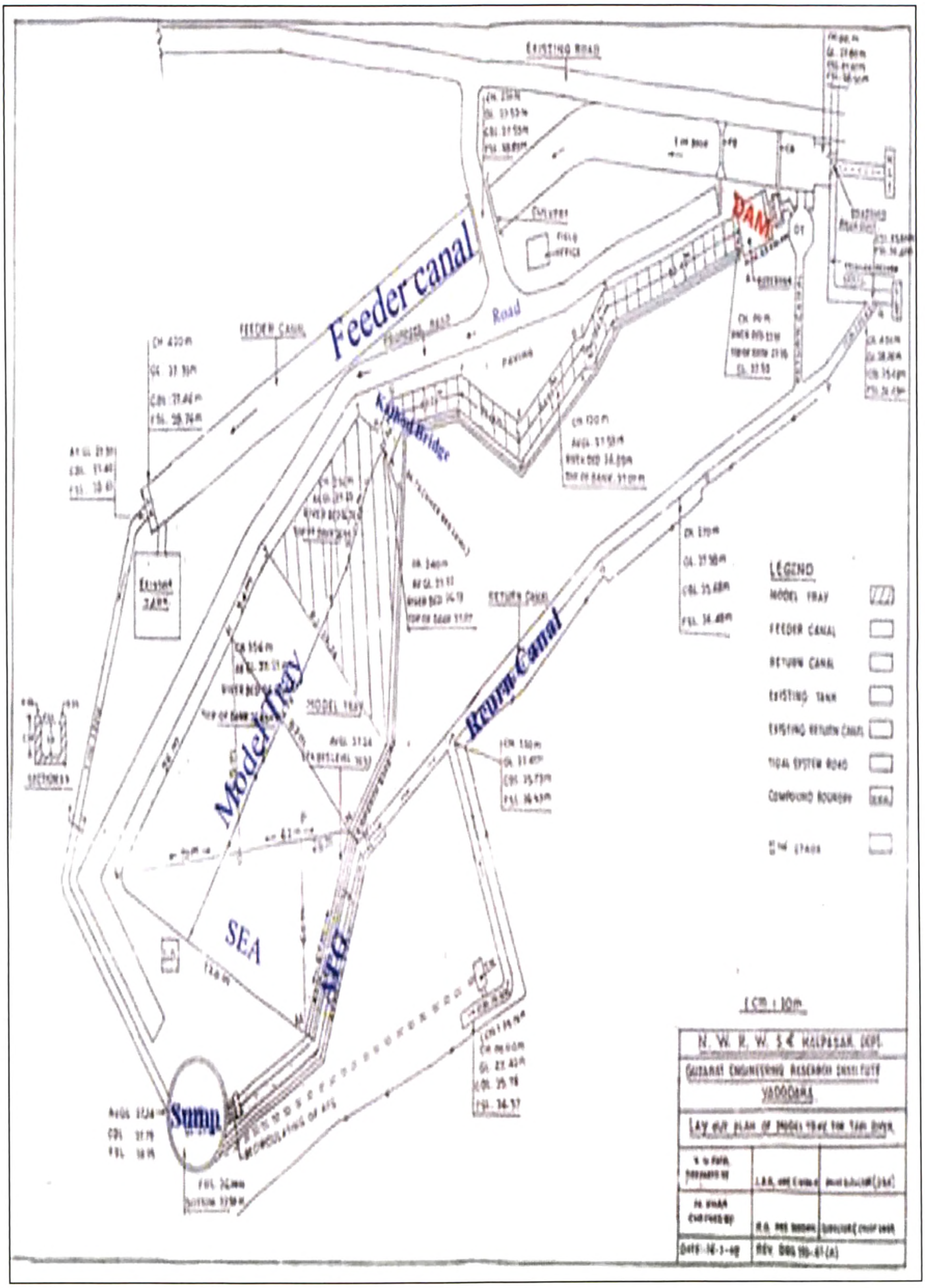
Plate.3.9 Y-Parallax in Typical CARTOSAT-1 Stereo Pair

3.7 Distorted Physical Model Data

Distorted physical model data from pilot project report of CWPRS and GERI, for construction and running of the model are as follow.

3.7.1 Topographical Data

Tapi river cross section from river mouth at Hazira to Ukai dam at an interval of 200 to 500 m, Topographical details/maps of Surat city area along both the banks including road, canal & railway embankment levels etc, Topographical details of Hazira industrial area, Bathymetry of sea portion between Mindhola creek to Tena creek for a distance 15 km are used as topographical data which are shown below Fig.No.3.3 and Plate.No.3.10 to 3.12.

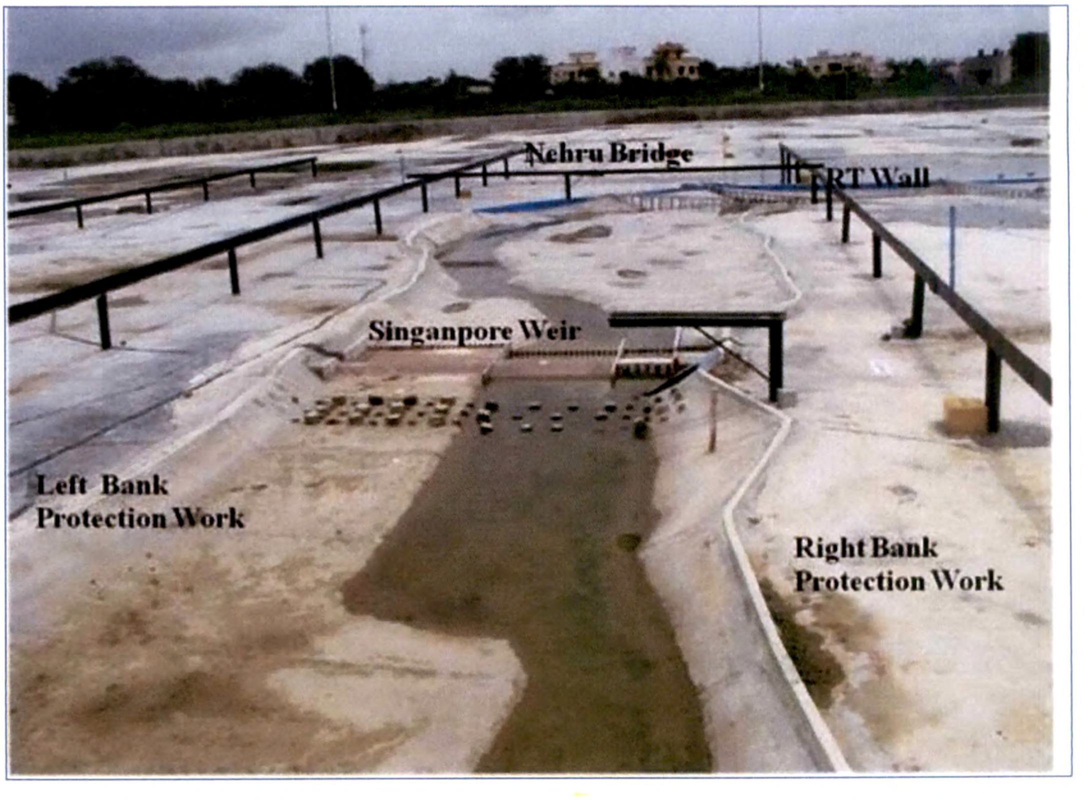


(Source: GERI, Gotri, Vadodara)

Fig.3.3 Plan of Tapi River Model

(Source: GERI, Gotri, Vadodara)

Plate.3.10 Google Image of Tapi River Model



(Source: GERI, Gotri, Vadodara)

Plate.3.11 Distorted Model of Tapi River

(Source: GERI, Gotri, Vadodara)

Plate.3.12 Photograph of Distorted Model at GERI, Gotri, Vadodara

3.7.2 Model Scale and Features

The physical model is constructed at GERI with horizontal scale 1:300 and vertical scale 1:80. The model covers the part of the Ukai reservoir and full Ukai dam length including spillway portion, non over flow portion and earthen dam, the tail channel, divide bund, power channel and TRC bund. Complete Tapi river topography from d/s of Ukai dam to its out fall at Hazira about 125 km and further 15 km extended portion of sea. Width of model from Ukai dam to Kathor Bridge is 10m and after Kathor Bridge the width of the model is widen considering the topography of developments of Surat city. Topography of entire Surat city is reproduced on the model. The width of the model at Surat city is 90m. The downstream boundary of the model is sea portion, considering 36 km width of the sea the model width at the D/S boundary is 120m. The flood embankments raised after flood 2006 on both the banks. All Bridges, weir structures, roads, canal embankments and railway tracks are reproduced on model. Automatic Tide Generating System of 67m is constructed to simulate tide.

3.7.3 Size of Model

Area covered by the model is 12 hactors. Length of the model is 500 m length of the feeder canal is 555 m. Length of the return canal is 540 m. Length of the feeder channel to sump is 200 m. The diameter of the sump is 35 m and depth is 5.5 m to create reservoir of 3000 m^3 for generating the tides. The length of Automatic Tide Generation (ATG) is 67 m provided with 44 Nos. of gates size 1.2m x 0.5m for generating 10 cm height of tide the ATG system needs 53 cusecs discharge. Control room for ATG is located at the middle length. The pump room houses 4 Nos. of 100 HP pumps for feeding the ATG.

3.7.4. Model Application

Model runs with 8494.97m^3/s (3 lac Cusecs), 14158.28 m^3/s (5 lac Cusecs), 19038.18 m^3/s (6.73 lac Cusecs), 22630.83 m^3/s (8 lac Cusecs), 25768.08 m^3/s (9.1 Lac Cusecs) and 28316.57 m^3/s (10 lac Cusecs) discharge of water. The flood levels at various locations in relation to present embankment levels were measured all along the reach between Kathor Bridge and Singanpore Weir. The vulnerable locations of possible flood spills for the above discharges were identified. The Tapi river physical model was approximately calibrated with available water level data for September 1998 flood discharge of 19075.96 m^3/s (6.73 lacs Cusecs). The model was approximately validated for the August 2006 flood of 9.1 lacs cusec discharge using the water level data. The predicted water levels on the physical model were in fair agreement with flood levels observed in the reach between Singanpure weir and Kathor Bridge. The Tapi river physical model was approximately calibrated with available water level data for September 1998 flood discharge of 19075.96 m^3/s (6.73 lacs Cusecs). The model was approximately validated for the August 2006 flood of 25793.65 m^3/s (9.1 lac Cusecs) discharge using the water level data. The predicted water levels on the physical model were in fair agreement with flood levels observed in the reach between Singanpure weir and Kathor Bridge. It is necessary to stop spilling of flood water on either banks especially in the reach between Amroli Bridge and Savji Korat Bridge as this flood spill finds its way towards main Surat city on left and right bank on downstream. If this spill is not controlled then the advantage of construction of the embankments between Nehru Bridge and Amroli Bridge is lost. The velocities for 28344.67 m^3/s (10 lacs Cusec) discharge will be in the range of 2.5 to 3.0 m/sec in general in the model reach under consideration. At Singanpure weir and Amroli Bridge the velocities will be of order of 3.5 m/sec and at Kathor Bridge 4 to 4.5 m/sec. For effective and efficient flood routing of reservoir dam operator must have understood the complete basin. Dam operation should be sensitive to the inhabitant likely to be affected and should be free of interference, pressure and threats.

3.8 Gate Reservoir Operation Register Data

Gate reservoir operation register data are collected from year 1973 to 2008 and are presented in below Table No.3.8.

Table.3.8 Existing Rule Levels

Date	Rule level in ft (m)
1st July	321.00 (97.85)
1st August	333.00 (101.50)
1st September	343.00 (104.55)
16th September	345.0 (105.15)

(Source: Flood control cell –Ukai dam)

3.9 Deforestation and Historical Change Data

Surat is usually affected by two types of floods: Tapi River flood and Khadi flood. Tapi river flood occurs due to heavy inflow of rainfall in Tapi basin while Khadi flood occur due to heavy rainfall in city and tidal effect of the sea. Table.No.3.9 shows information about major flood received in River Tapi and historical flood data for Ukai Reservoir is shown in Table.No.3.10.

Table.3.9 Details of Major Flood Received in River Tapi

Year	Month	Discharge in Lacs Cusecs
1883	JULY	10.05
1884	SEPTEMBER	08.46
1894	JULY	08.00
1942	AUGUST	08.60
1944	AUGUST	11.84
1945	AUGUST	10.24
1949	SEPTEMBER	08.42
1959	SEPTEMBER	12.94
1968	AUGUST	15.00
1970	SEPTEMBER	13.00
1998	SEPTEMBER	06.99
2006	AUGUST	09.10

(Source: Ukai Flood Control Cell)

Table.3.10 Historical Flood Data for Ukai Reservoir

Year	Post monsoon inflow Maft	Max. R.W.L in.Ft.	Date	Min. R.W.L in Ft.	Date	Total Inflow in Maft	Power Generation in MU (JAN-DEC)	Max. Flood Released			Max. Flood	
								Date	R.W.L	Lac cusecs	1876 To 1970 Date	Lac cusecs
1973	0.64	335.80	24/09/73	283.70	01/07/73	12.02	0	29/08/73	330.1	4.81	29/8/1876	7.5
1974	2.36	335.20	15/08/74	318.45	05/07/74	3.94	212.195	14/08/74	334.8	2.01	12/9/1882	7.7
1975	0.8	345.10	28/09/75	277.30	20/06/75	9.83	758.373	7/9/1975	342.8	2.99	3/7/1883	10.65
1976	0.85	343.99	27/09/76	293.85	05/06/76	13.09	1312.227	6/8/1976	338.67	3.48	9/9/1884	8.8
1977	0.62	344.77	08/10/77	284.74	15/06/77	8.98	1230.4	4/9/1977	340.28	1.02	22/7/1894	8.35
1978	0.44	341.83	31/08/78	273.10	15/06/78	10.18	1267.733	31/8/78	341.83	4.4	17/9/1914	7.7
1979	0.664	340.37	02/10/79	268.30	25/06/79	10.20	1175.735	12/8/1979	336.56	3.29	30/9/1930	8.00
1980	0.628	329.99	24/09/80	278.38	06/06/80	6.71	1045.203	0/0/0	0	0	18/9/1933	9.00
1981	0.295	345.24	04/10/81	269.84	25/06/81	8.56	1037.036	19/8/81	338.12	0.51	10/9/1937	7.05
1982	0.367	298.94	03/10/82	273.13	12/07/82	3.51	615.885	0/0/0	0	0	6/8/1942	7.9
1983	0.122	344.91	14/10/83	275.65	26/06/83	10.26	738.327	28/9/83	344.92	1.25	18/8/1944	10.34
1984	0.192	332.98	18/09/84	280.32	14/06/84	4.49	845.597	0/0/0	0	0	24/9/1945	8.55
1985	0.148	309.62	29/08/85	277.94	28/06/85	2.58	399.827	0/0/0	0	0	17/9/1949	6.47
1986	0.095	340.68	28/08/86	272.64	19/06/86	5.70	424.439	0/0/0	0	0	9/9/1958	6.93
1987	0.045	317.27	09/09/87	273.50	16/06/87	2.29	416.657	0/0/0	0	0	17/9/1959	13.16
1988	0.167	346.06	30/9/88	272.37	16/06/88	13.23	785.127	4/10/1988	345.7	3.39	15/9/1962	7.9
1989	0.23	345.94	07/09/89	289.90	27/06/89	7.43	1026.562	4/9/1989	345.64	0.44	6/8/1968	15.00
1990	0.22	346.17	08/10/90	293.65	20/06/90	13.21	1150.186	24/8/90	344.67	4.15	8/9/1969	8.46
1991	0.28	324.86	07/09/91	295.02	12/06/91	3.46	676.362	0/0/0	0	0	6/9/1970	14.96
1992	0.35	339.10	17/9/1992	275.12	20/06/92	5.045	336.466	0/0/0	0	0		
1993	0.46	343.75	05/10/93	298.41	23/06/93	6.40	873.493	0/0/0	0	0		
1994	0.42	345.77	08/09/94	298.98	06/07/94	13.93	826.192	8/9/1994	344.8	5.08		
1995	0.53	328.12	24/09/95	285.08	12/07/95	3.716	594.432	0/0/0	0	0		
1996	0.57	338.67	12/09/96	279.99	15/07/96	4.785	474.507	0/0/1	0	0		
1997	0.32	344.16	05/09/97	292.19	23/06/97	5.261	744.936	5/9/1997	344.16	0.23		
1998	0.41	346.04	17/9/98	294.20	10/07/98	10.655	913.093	17/9/98	346	6.99		
1999	0.49	344.53	17/10/99	294.90	19/06/99	5.629	874.424	0/0/0	0	0		
2000		322.75	26/7/00	301.46	04/06/00	2.041	527.085	0/0/0	0	0		
2001		322.54	17/10/01	272.11	08/06/01	2.089	224.99	0/0/0	0	0		
2002		341.20	07/09/02	280.95	05/06/02	7.086	504.609	7/9/2002	341.25	3.3	0.50 G.U	
2003		343.81	04/10/03	294.60	20/06/03	6.5811	714.582	25/8/03	337.08	1.26	0.50 G.U	
2004		331.95	03/09/04	288.76	26/07/04	3.3073	465.521	26/9/04	330.79	0	0.50 G.U	
2005		342.20	27/09/05	279.67	28/05/06	5.897	540.218	1/9/2005	338.32	0.6	0.60 G.U	
2006		346.07	10/08/06	297.56	01/07/06	18.870	884.86	9/8/2006	345.6	9.1		
2007		344.20	10/10/07	291.23	01/06/07	12.014	893.407	9/9/2007	315.9	2.48	0.70 G.U	
2008		335.46	12/10/08	292.92	31/07/08	3.412	451.46	0/0/0	0	0		
2009		326.71	17/09/09	288.50	09/07/09	2.768	361.052	0/0/0	0	0		

(Source: Ukai Flood Control Cell)

Below photograph in Plate.No.3.13 shows same flood water level in Gopipura, Kshetrapal sheri, Surat city for different flood intensity of 15 Lacs Cusecs before and 9.1 Lacs Cusecs after construction of major control point Ukai dam in the year 1968 and 2006 respectively as development and encroachment of land use.

City grows - vulnerability increases.

Compare the Flood in 1968 to the floods in 2006. Water level is almost the same,

"This gave rise to media cry: 2006 flood is biggest flood ever...

when the city was smaller- with water had more area to spread. 1968 was a bigger flood for water to have risen to the same level as August 2006 flood.

The fact that this flood was perceived as a larger disaster was because the area in which the flood could spread has shrunk. Multiple actions have contributed to this fact. Either one can link it to all the way to global warming , term it a natural phenomena. If one sit back or Review the fact that we have all contributed to the increase in the vulnerability of the region - since long...

1968 – the flood flow was 15.0 lac cusec. The level at hope bridge:12.36 m
1994 – 5.25 lac cusec : the level at hope bridge: 11.02m
1998 – 6.99 lac cusec : the level at hope bridge : 11.40 m
2006 –10 lac cusec. The level at hope bridge: 12.5 m.

[Source: Surat Municipal Corporation (Gujarat Samachar News Paper Cuting)]

Plate.3.13 Observed Flood Water Level Comparison Year 1968 and 2006

Data collected for Peak flood in Tapi River-Year 1939 to 2012 listed here in Table.No.3.11.

Table.3.11 Peak Flood in Ukai Reservoir Year (1939-2012)

SR.NO	YEARS	PEAK FLOOD IN LACS CUSECS
1	1939	5.15
2	1940	2.43
3	1941	4.81
4	1942	7.58
5	1943	1.79
6	1944	9
7	1945	7.22
8	1946	3
9	1947	2.91
10	1948	2.55
11	1949	6.62
12	1950	3.98
13	1951	1.62
14	1952	1.12
15	1953	3.6
16	1954	6.89
17	1955	2.36
18	1956	3.06
19	1957	1.58
20	1958	6.2
21	1959	13.16
22	1960	2.55
23	1961	7.36
24	1962	7.99
25	1963	2.7
26	1964	2.15
27	1965	1.55
28	1966	3.66
29	1967	4.55
30	1968	15
31	1969	8.56
32	1970	13.14
33	1971	0.66
34	1972	2.47
35	1973	5.29
36	1974	3.06
37	1975	4.56
38	1976	3.81
39	1977	3.09
40	1978	8.88
41	1979	8.58
42	1980	3.17
43	1981	5.73
44	1982	1.33
45	1983	3.4
46	1984	0.5
47	1985	0.5
48	1986	2.86
49	1987	0.5
50	1988	3.3
51	1989	3.1
52	1990	4.9
53	1991	3.68
54	1992	1.84
55	1993	3.35
56	1994	8.87
57	1995	4.01
58	1996	2.12
59	1997	4.94
60	1998	10.53
61	1999	3.3
62	2000	2.38
63	2001	3.09
64	2002	4.32
65	2003	3.32
66	2004	3.89
67	2005	4.68
68	2006	12.05
69	2007	6.37
70	2008	2.08
71	2009	2.15
72	2010	2.32
73	2011	2.31
74	2012	3.35

(Source: Ukai Flood Control Cell)

3.10 Existing Reservoir Operation Data

Following data collected for simulation of model for revised reservoir operation. e.g. long span monthly inflows data, irrigation-industrial-drinking water demand, reservoir elevation-storage relationship, reservoir elevation- area, penstock numbers and capacity, maximum drawdown level-full reservoir level-canal bed level. Table.No.3.12 gives information about monthly evaporation losses. Tapi river flood occur due to heavy inflow of rainfall in Tapi basin while Khadi flood occur due to heavy rainfall contribution in city as shown in Table.No.3.13.

Table.3.12 Monthly Evaporation Losses

Month	Evaporation Depth in		Month	Evaporation Depth in	
	Inches	mm		Inches	mm
July	4.0	101.60	Jan.	5.0	127.00
Aug.	4.0	101.60	Feb.	5.0	127.00
Sept.	6.0	152.40	Mar.	8.0	203.20
Oct.	8.0	203.20	Apr.	9.0	228.60
Nov.	6.0	152.40	May.	10.0	254.00
Dec.	5.0	127.00	Jun.	8.0	203.20
			Total	78.0	1981.20

(Source: Ukai Flood Control Cell)

Table.3.13 Contribution of Rainfall (in mm) at Tapi River Reservoir Stations

Sr. No.	Station Name	Date 1.8.06	Date 2.8.06	Date 3.8.06	Date 4.8.06	Date 5.8.6	Date 6.8.06	Date 7.8.06	Date 8.8.06
1	2	3	4	5	6	7	8	9	10
1	Teska	0.00	4.40	0.40	14.00	22.80	2.80	38.60	21.60
2	Chikhalda	19.40	0.00	12.80	65.20	61.00	49.20	43.20	22.00
3	Lacpuri	0.00	0.00	1.80	19.40	66.80	119.40	63.20	15.40
4	Gopalkheda	0.00	0.00	5.20	8.50	60.20	100.00	84.30	38.80
5	Dedatlai	9.20	0.00	14.20	22.00	49.80	35.10	40.20	59.40
6	Burhanpur	13.00	4.20	7.60	4.20	11.60	50.80	246.20	27.20
7	Yerli	0.00	0.00	5.40	4.60	33.40	68.80	279.60	59.00
8	Hathnur	3.20	5.00	1.90	5.60	18.40	141.50	227.40	66.20
9	Bhusaval	1.20	4.90	5.60	0.50	16.50	229.20	202.80	21.20
10	Girnadem	0.00	0.00	2.00	5.80	1.80	26.40	83.00	26.60
11	Dahigaon	0.60	1.20	7.00	9.80	13.40	119.20	180.40	11.80
12	Dhulia	0.00	0.00	13.20	3.30	8.00	29.40	68.80	41.60
13	Savakheda	0.00	1.80	3.20	6.60	16.40	82.00	105.60	29.70
14	Gidhade	3.80	8.20	4.80	5.40	16.40	42.80	117.20	30.20
15	Sarangkheda	4.40	32.60	0.00	4.00	7.20	39.80	121.60	30.20
16	Ukai	7.50	62.00	40.00	51.00	10.50	5.00	135.00	48.70
17	Ghala	10.20	28.60	46.80	19.40	25.60	6.60	78.60	51.20
18	Surat	18.70	20.70	6.40	8.60	10.90	4.60	69.60	0.00
	Average rain upto Hathnur Stn. (Sr.No.1 to 8)	5.60	1.70	6.12	17.94	40.50	70.95	127.84	38.30
	Average rain from Hathnur to Ukai Stn. (Sr.No.9 to 16)	2.19	13.84	9.48	10.80	11.28	71.73	126.80	
	Average rain upto Ukai (Sr.No.1 to 16)	3.89	7.77	7.86	14.37	25.89	71.34	127.32	
		Normal	Normal	Normal	Normal	Normal		Emergency	

(Source: Ukai Flood Control Cell)

Note: ☐ **Yellow color shows heavy rainfall in upper and lower Tapi river basin.**

■ **Blue colour shows Nomal condition.**

■ **Red colour shows Emergency.**

Hydraulic cycle occurred after 100 year but, 34 years inflow data (1975-2009) used for this research study shown in Table.No.3.14 so, perfect prediction is not possible. Even though one challenging exercise took in this direction. Table.No.3.15 gives information about Planned and Present Utilization of Ukai Reservoir Project for Ukai Left Bank Canal (ULBC) and D/S irrigation requirement.

Table.3.14. Year Wise Details of Monthly Inflow Summary at Ukai Dam Reservoir

Year	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1975	0	0	0	0	0	407	1380.03	4184.3	4094	406.51	106.96	182.06
1976	30	0	0	0	0	2013	3849.27	5321.86	5003	194.89	510.56	33.37
1977	0	0	0	0	0	1659	1714.61	2859.78	2976	411.18	216.21	158.04
1978	0	0	0	0	0	803	2645.95	5488.78	2577	149.14	0	0
1979	0	0	0	0	0	1061	1054.86	8658.87	1372	127.22	134.95	255.84
1980	4.8	1.2	0	0	0	1538	977.94	4522.66	1014	130.26	90.09	93.97
1981	2.1	0.7	0	0	0	57	1743.18	6403.82	2213	612.3	56.04	127.73
1982	8.8	3.1	0	0	0	527	1181.3	1261.36	791.3	205.24	94.85	35.64
1983	0	0	0	0	0	98	1304.95	4403.6	5337	1614.7	79.29	15.01
1984	6.1	4.9	1.2	0.5	0	83	662.4	3998.25	653.4	461.84	64.76	76.83
1985	5	0	0	0	0	330	505.71	1991.74	227.9	321.97	39.28	20.86
1986	0	0	0	0	0	314	2050.86	4515.22	158.8	90.76	19.58	18.22
1987	0.3	0	0	0	0	660	988.78	1137.95	257.2	100.32	59.94	6.94
1988	0	0	0	0	0	487	3795.65	3504.26	5339	3248.2	82.34	1.84
1989	0	0.2	0	0	0	181	1568.92	3847.06	920.4	110.97	31.34	0
1990	0	0	0	0	0	1057	2569.95	8336.36	3530	874.72	88.96	1.98
1991	0	0	0	0	0	393	1588.36	1892.98	279.2	99.92	31.4	8.75
1992	0	0	0	0	0	926	170.48	3308.44	2048	631.29	257.91	33.26
1993	0	0	0	0	0	40.11	3200.46	1800.48	2409	1107.44	29.09	7.07
1994	0	0	0	0	0	520.88	2937.46	4383.8	9694	245.75	17.11	48.87
1995	0	0	0	0	0	40.19	2003.02	621.85	2195	164.01	2.67	2.74
1996	0	0	0	0	0	176.53	1512.86	2010.72	2731	687.4	8.06	9.84
1997	0	0	0	0	0	519.64	106.03	4038	412	323	88.96	920.19
1998	0	0	0	0	42.2	75.4	1013.17	315.83	8792	1624.72	88.96	0
1999	0	0	0	0	0	1089.3	1016.42	2730.26	1453	1695.87	239.33	0
2000	0	0	0	0	0	684.82	2248.05	446.99	167.5	20.97	0	0
2001	0	0	0	0	0	889.08	485.33	2622.24	101.8	663.58	0	0
2002	0	0	0	0	0	1476.2	141.45	2599.72	5892	107.54	0	9.72
2003	0	0	0	0	0	910.49	2295.01	264.54	2288	828.61	1.83	11.48
2004	6.7	7.4	0	0	27.8	64.47	236.72	4089.75	445.8	267.44	0	93.7
2005	0	2.9		0	2.09	526.16	1746.69	3179.17	1881	306.52	5.79	4.51
2006	3.6	3.2	8.58	8.85	0	9.07	3508.84	13906	4091	1477.35	31.34	93.7
2007	6	3.1	0	0	0	81.31	7815.6	4013.13	3046	153.57	0	0.18
2008	0	4.6	0	0	0	86.33	240.18	1951	2417	237.27	237.27	5.08
2009	0	0	0	0	0	86.36	240.3	1950	2448	237.27	0	5.08

(Source: Ukai Flood Control Cell)

☐ **Yellow Colur Shows Cumulative RainFall causing Heavy Rainfall in month of July, August, September at Ukai Dam.**

Table.3.15 Planned and Present Utilization of Ukai Reservoir Project

Month	Planned Utilization				Present Utilization			
	ULBC Requirement		D/S irrigation Requirement		ULBC Requirement		D/S irri. Requirement	
	Maft.	MCM	Maft.	MCM	Maft.	MCM	Maft.	MCM
JULY	-	-	0.01	12.33	0.016	19.740	0.084	103.61
AUGUST	-	-	-	-	0.060	74.010	0.323	398.41
SEPTEMBER	0.03	37.00	0.15	185.02	0.050	61.670	0.252	310.83
OCTOBER	0.06	74.01	0.26	320.70	0.033	40.700	0.178	219.56
NOVEMBER	0.07	86.34	0.32	394.71	0.060	74.010	0.205	252.86
DECEMBER	0.07	86.34	0.33	407.50	0.045	55.510	0.238	293.57
JANUARY	0.07	86.34	0.29	357.71	0.070	86.340	0.258	318.24
FEBRUARY	0.06	74.01	0.27	333.04	0.069	85.110	0.291	358.94
MARCH	0.06	74.01	0.28	345.37	0.073	90.040	0.262	323.17
APRIL	0.06	74.01	0.28	345.37	0.072	88.810	0.282	347.84
MAY	0.07	86.34	0.30	370.04	0.073	90.040	0.308	379.91
JUNE	0.03	37.00	0.13	160.35	0.048	59.210	0.207	255.33
Total	0.58	715.40	2.62	3231.69	0.699	825.210	2.888	3562.27
Grand Total	**3.20 Maft (3947.10 MCM)**				**3.557 Maft (4387.45 MCM)**			

(Source: Ukai Flood Control Cell)

3.11 Tidal Wave Data

Tide effect during flood Year 2006 repotted at Magdalla port for Hazira inner and Hazira outer, among which one sample tide data is as shown in below Table.No.3.16.

Table.3.16 Tide Wave Data

Date	Magdalla		Hazira Inner		Hazira Outer	
	Time	Height	Time	Height	Time	Height
1/08/2006	01.38	0.63	0.39	1.21	4.51	6.04
	5.22	2.78	4.20	4.35	11.43	1.25
	13.03	0.28	12.35	0.89	17.06	7.32
	17.51	4.03	16.51	5.46		

(Source: Magdalla Port, Surat Authority)

Tidal Wave High Research

The research of the fifty year have made tremendous strides in the observation, analysis, and prediction of the tidal mystery, namely, stationary wave motion, resonance, and gyration, but it is still true that predictions must be based on reliable quantitative records of observed performance; for the frictional modifications of the primary wave are as yet, incalculable from fundamental postulates. Furthermore, the meteorological surge is often a major and unexpected feature of tidal perturbations and seismic surges "arrive" often without official warning. The tidal streams in the oceans await accurate observation at all depths and the surface currents shown on charts are often derived from the difference between the astronomical and dead reckoning positions of ships at sea—a method, even since the advent of gyroscopic compasses, fraught with much uncertainty and error and nearly always unrelated to tidal rhythms.

Tractive Forces

Whilst the forces that produce the ride are precisely known, the term "gravitational" is only a descriptive device to indicate the behavior of cosmic tensions, the ultimate nature of which we are as yet unable to understand.

To say that the mutual action of bodies over a distance varies as the product of their masses and inversely as the square of their distance, only describes the mode or degree of action. It is possible that new cosmic discoveries will reveal many features bearing upon the operation of those tractive forces which raise the tides.

Main Formulae for Tide Calculation

Attractive force between particles $Fx = \frac{mm1}{d2}$ .... (3.1)

Moon's attraction on particle of unit mass at centre of earth $- g.\frac{M}{E}.\frac{e^2}{x^2}$.................................. (3.2)

Tractive force $T = 1.5\ g.\frac{M}{E}.\frac{e^3}{r^3} Sin\ 2\theta$ .... (3.3)

Simple Standing Oscillation: T = $\frac{21}{gh}$ $\dot{-}$ (1, 2, 3...)

Formulae for free progressive wave:

Speed (fps) = $\sqrt{gh}$ .... (3.4)

Wave length in nautical miles = 8.25T $\sqrt{D}$ (approx.) .... (3.5)

Where, T= period in hours

D= depth in fathoms

Formulae for stationary waves:

Where l = length in nautical miles of gulf

D = mean depth in fathoms

T = period in hours

$l = 4.1\mathrm{T}\sqrt{D}$ .... (3.6)

$\mathrm{T} = \frac{l}{4.1}\sqrt{D}$ .... (3.7)

Gyroscopic effect of earth's rotation = 2m.w.sin latitude .... (3.8)

Height at any time of any harmonic constituent = H.Cos (NT – g) .... (3.9)

Formula for theoretical elevation for sea level resulting from a moving atmospheric pressure system:

$$y = \frac{13(29.8 - P)}{1 - \frac{k^2}{68}D}$$ .... (3.10)

Where,

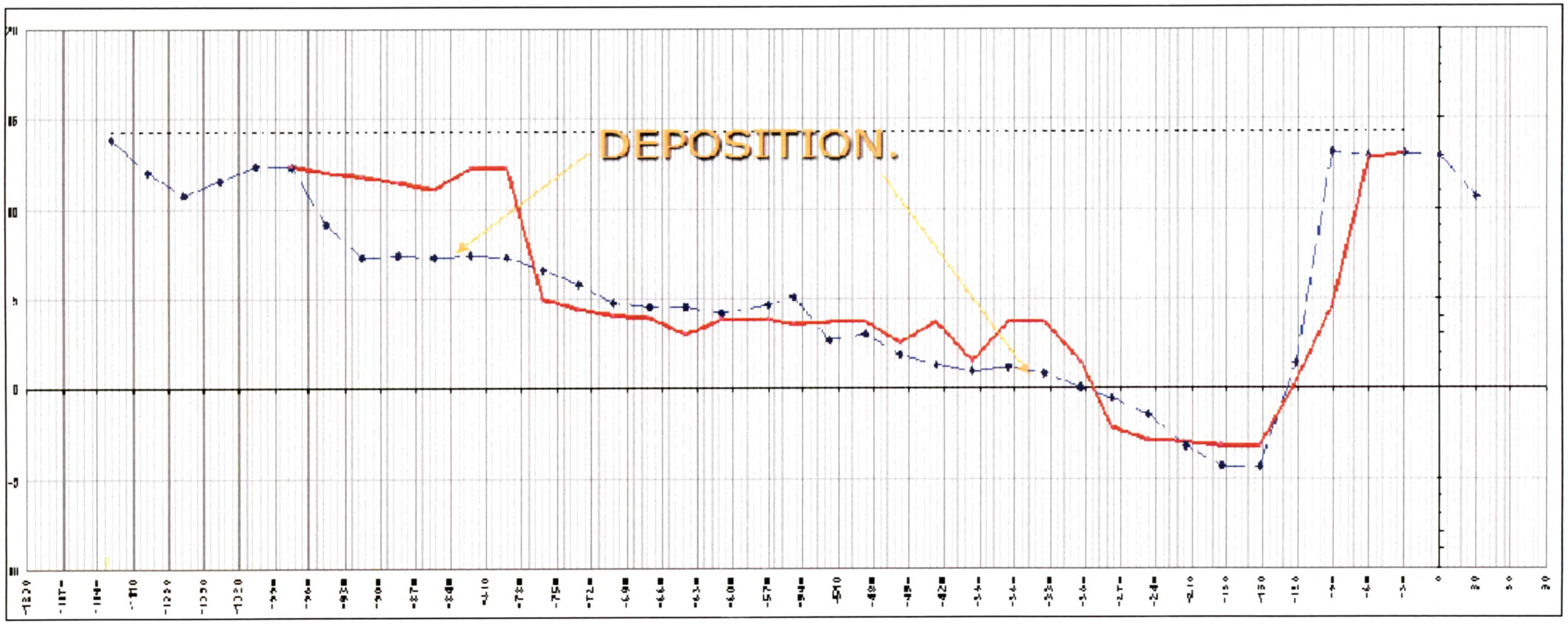
y = Elevation in feet

K = Speed in knots

D = Depth in fathoms.

3.12 Data Interpretation

Below Graph.No.3.2 Shows Tapi River Cross section of Year 1968 & 2000 are overlaid to find sediments deposition 1 km Upstream of Singanpure weir and change in cross section.

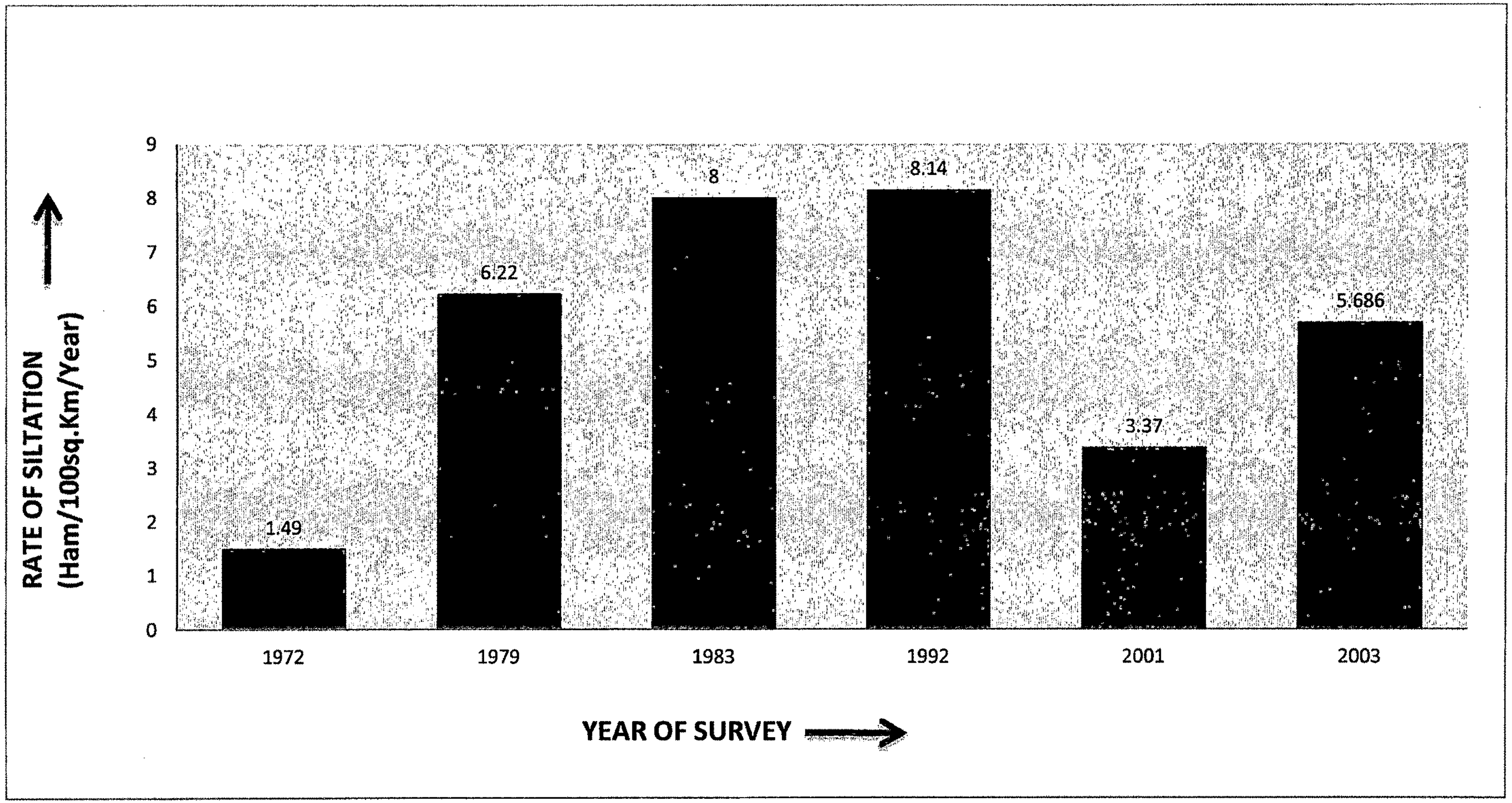


Graph.3.2 Cross Section of Tapi River 1 km Upstream of Singanpure weir bed Sediments Year (1968 & 2000)

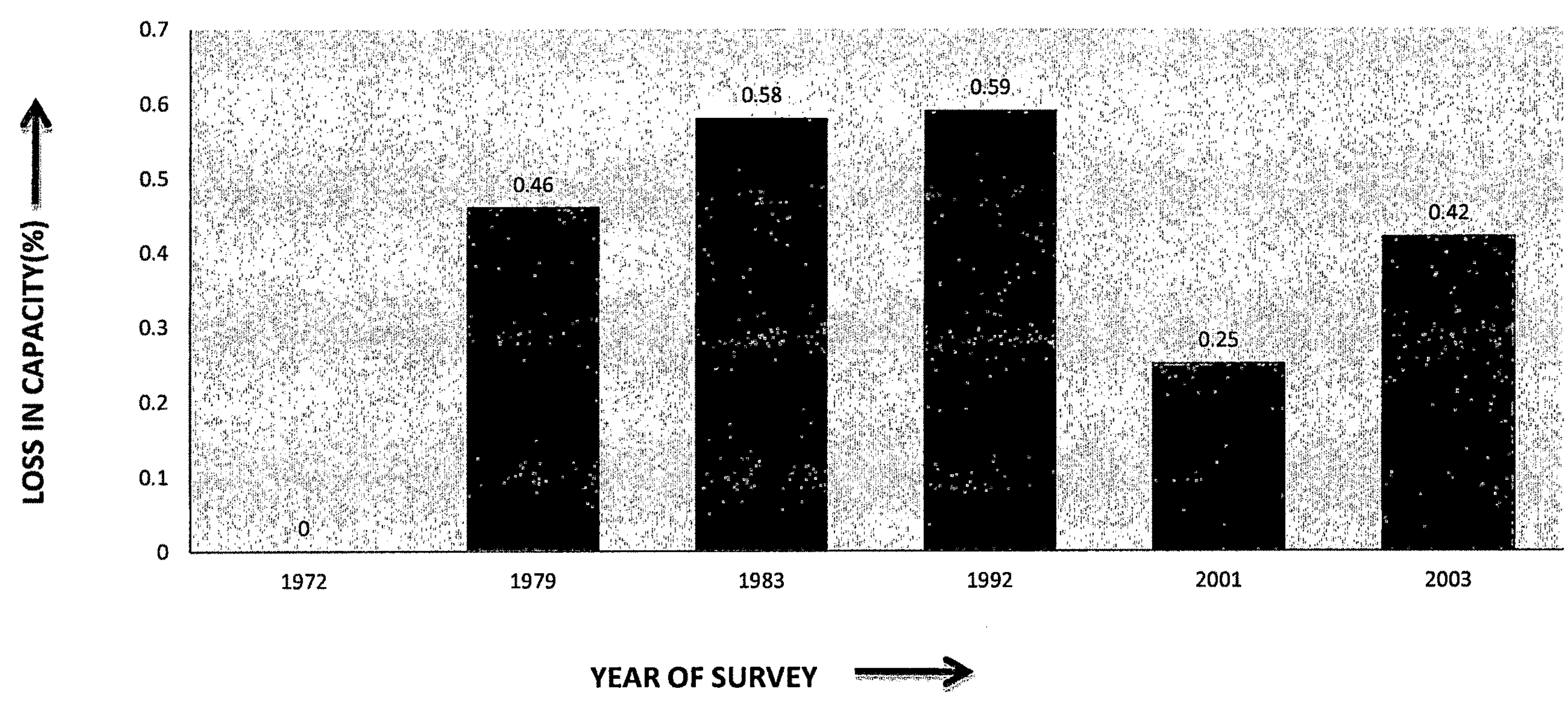
Red Line for 2006 Year River Bed Surface

Blue Line for 1968 Year River Bed Surface

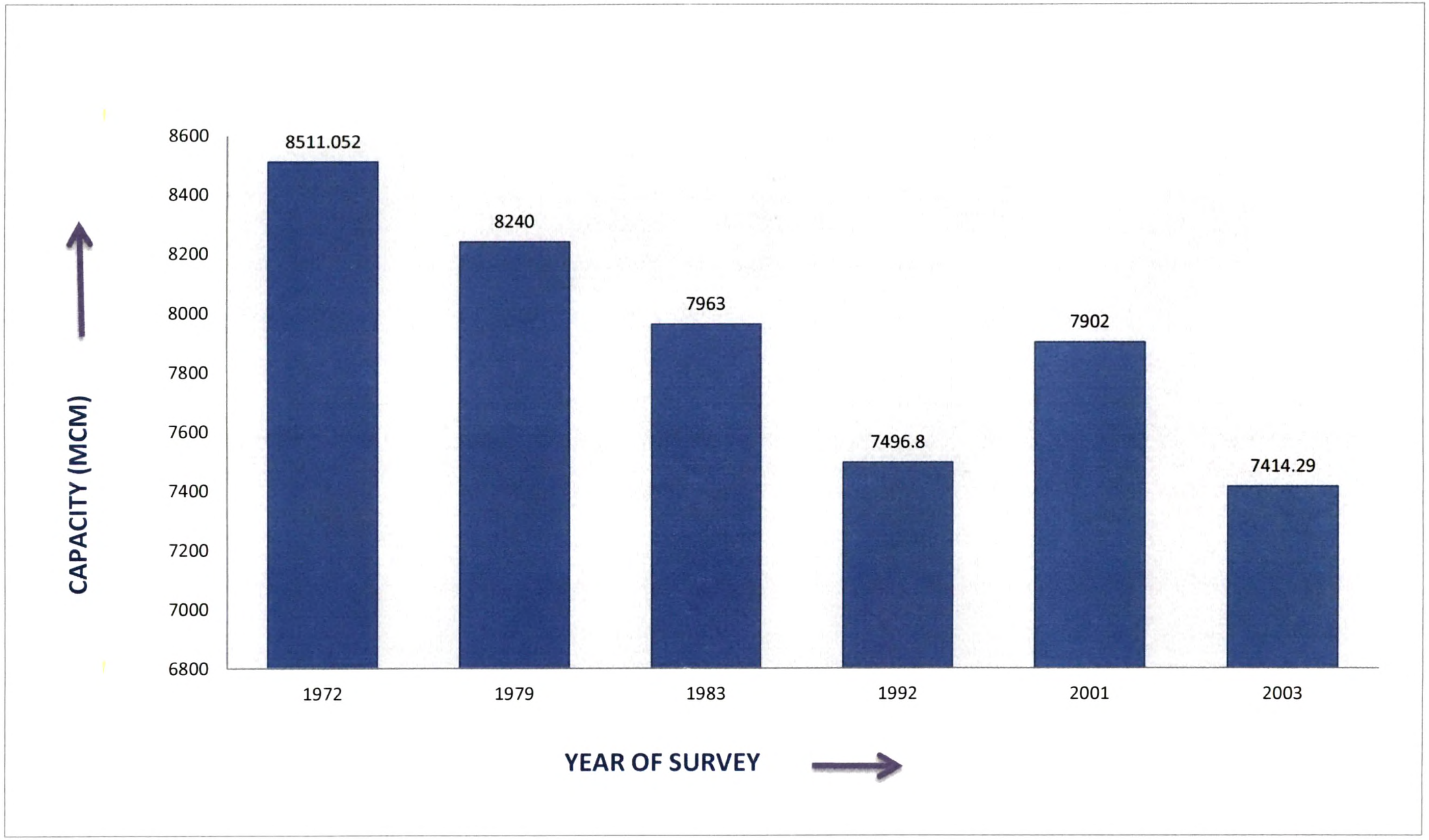
Graph.No.3.3 shows Silt index of Ukai reservoir, Graph.No.3.4 shows annual % loss in capacity of Ukai reservoir and Graph.No.3.5 shows capacity of Ukai reservoir at F.R.L



Graph.3.3 Silt Index of Ukai Reservoir

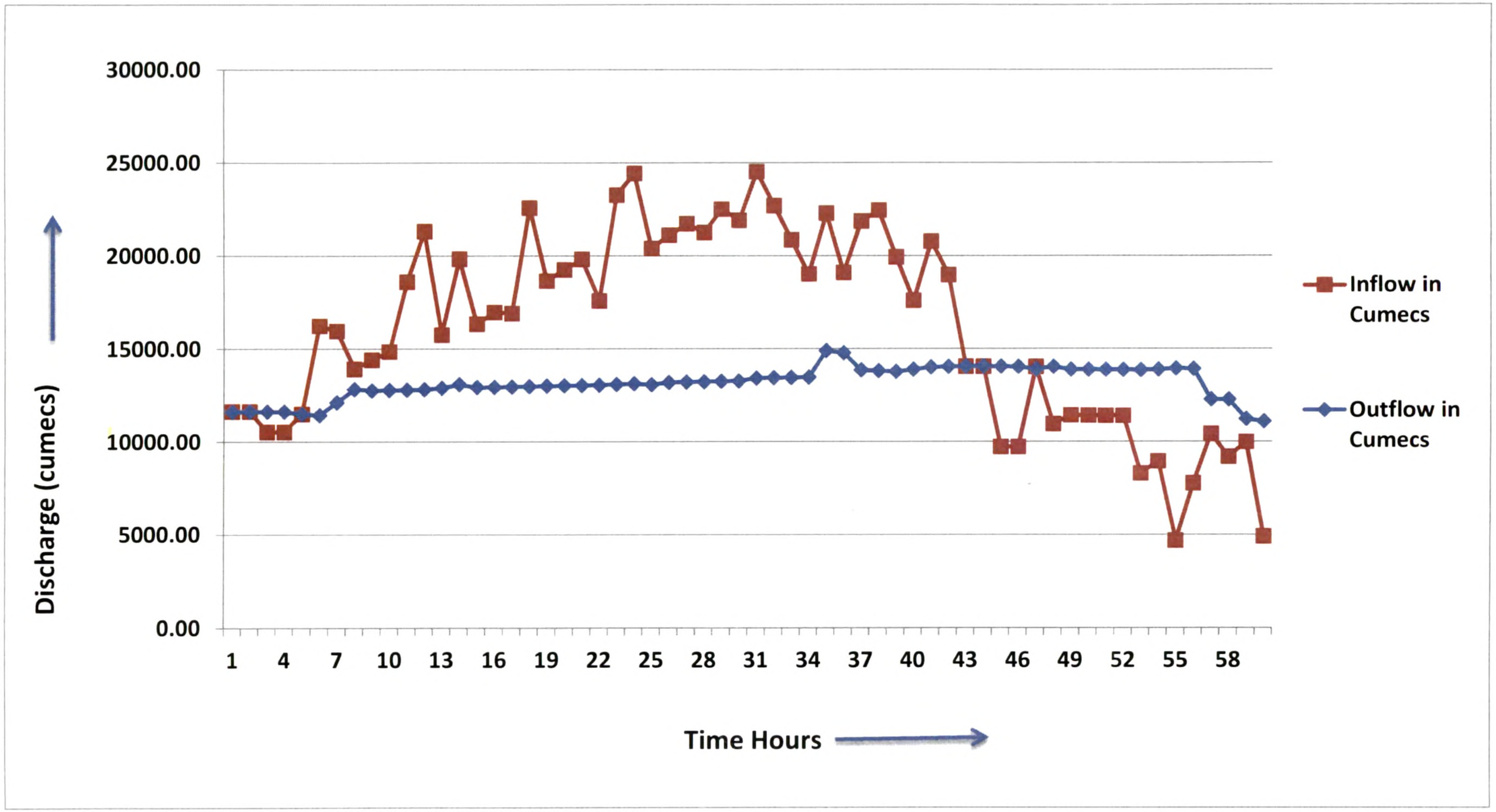


Graph.3.4 Annual % Loss in Capacity of Ukai Reservoir

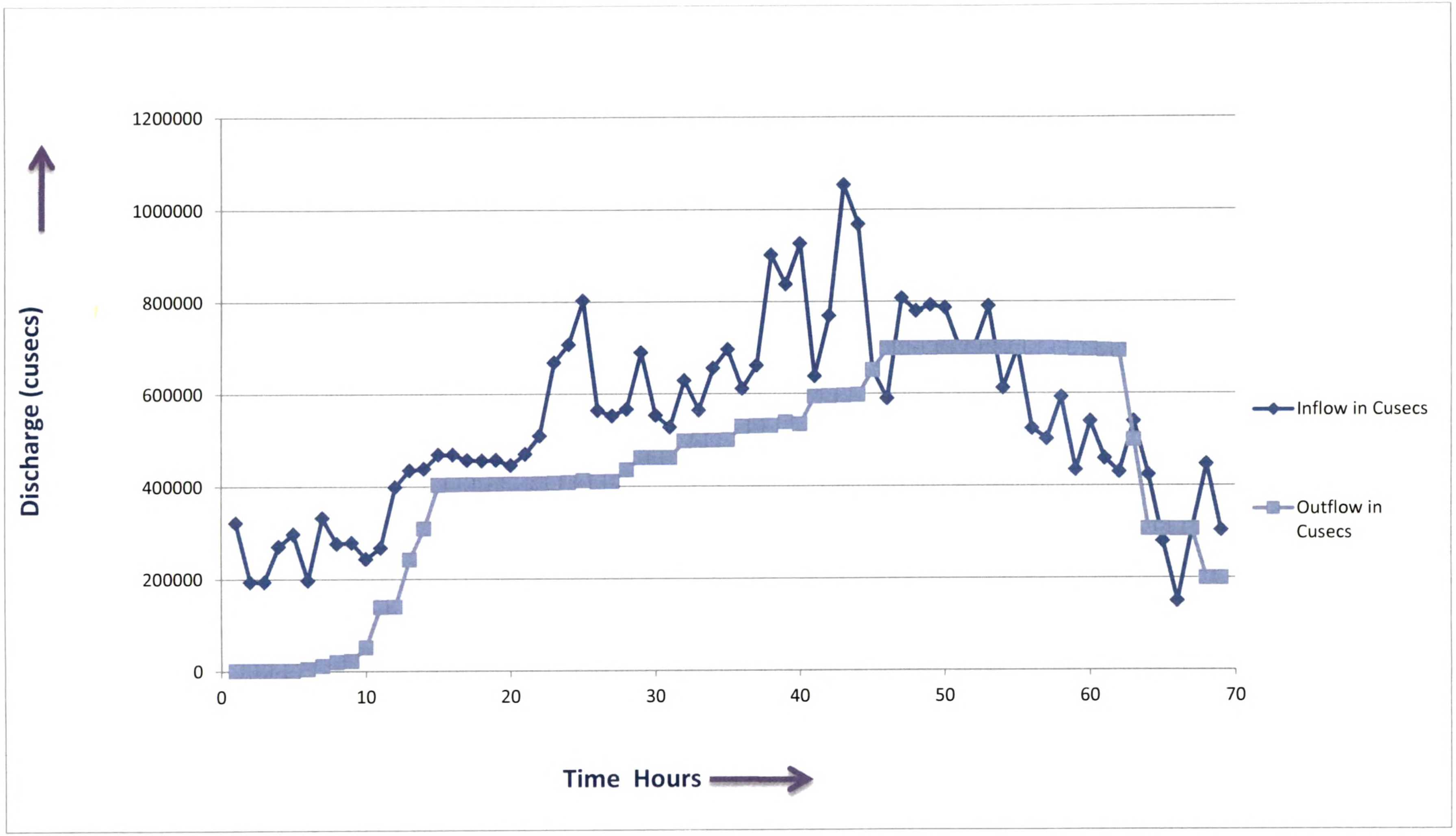


Graph.3.5 Capacity of Ukai Reservoir at F.R.L

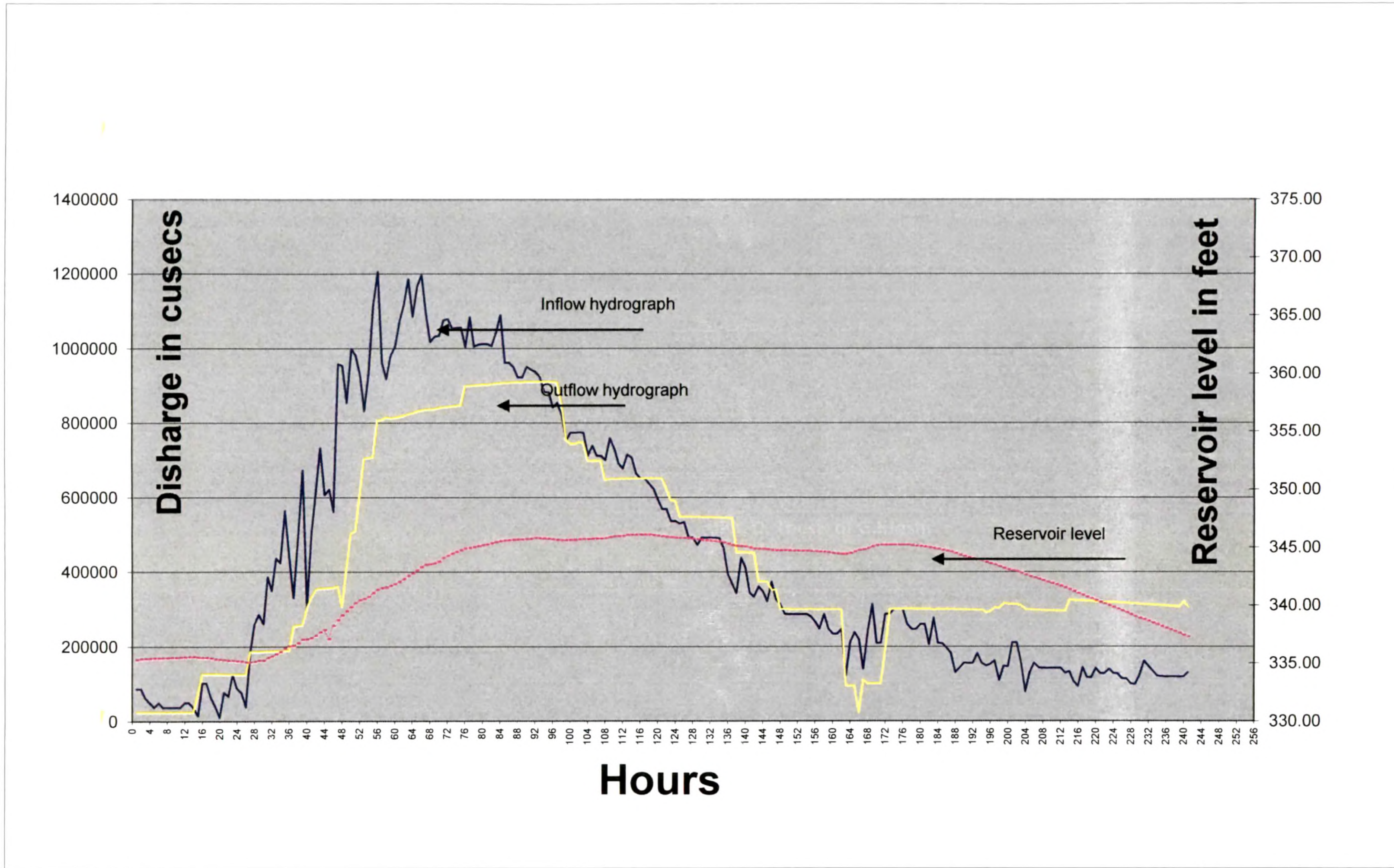
Graph.No3.6 shows flood hydrograph Year (1994), Graph.No.3.7 shows flood hydrograph year (1998) and Graph.No.3.8 shows Chart Showing Operation of Ukai Reservoir during August – 2006.



Graph.3.6 Flood Hydrograph Year (1994)

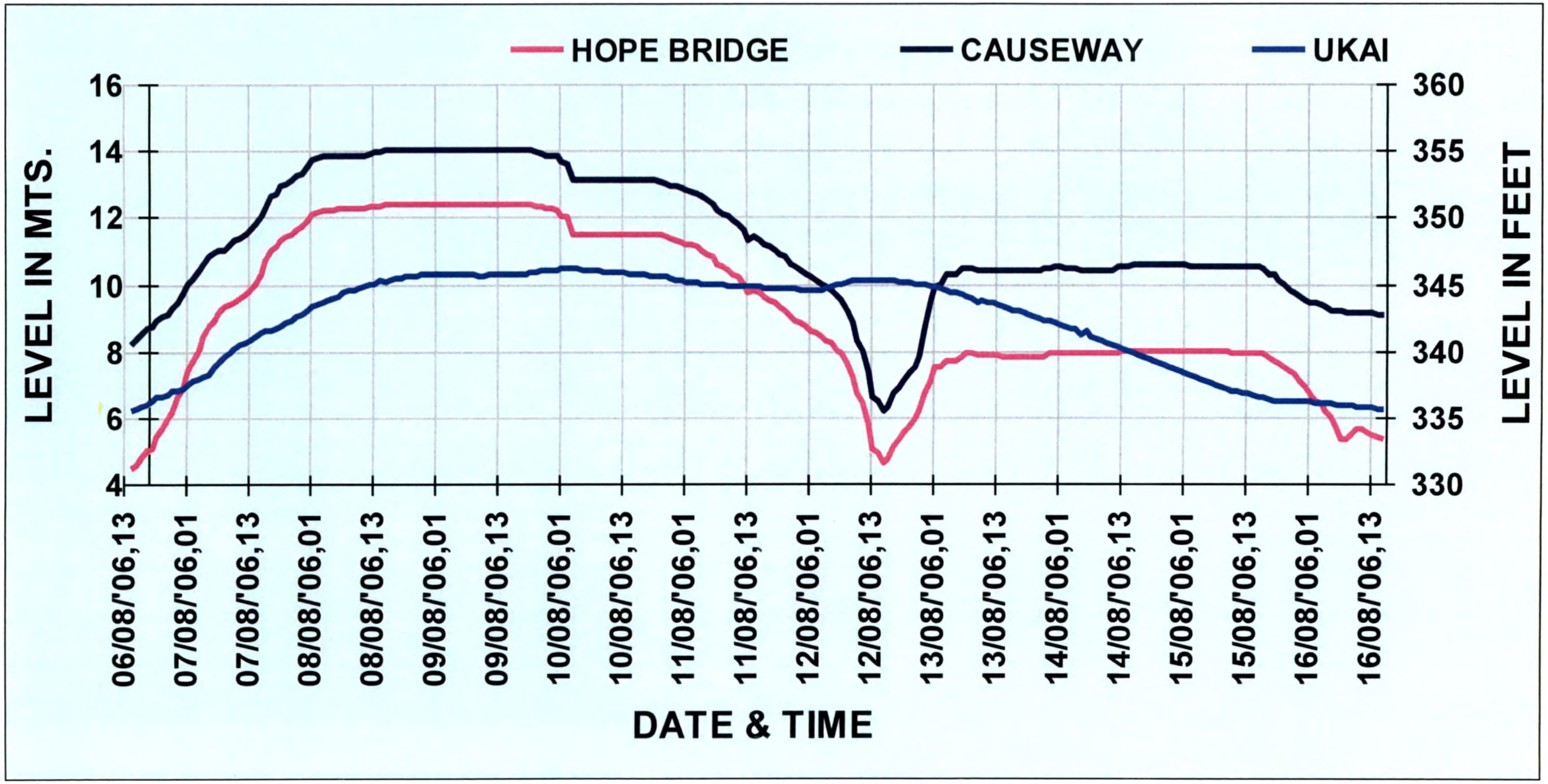


Graph.3.7 Flood Hydrograph Year (1998)

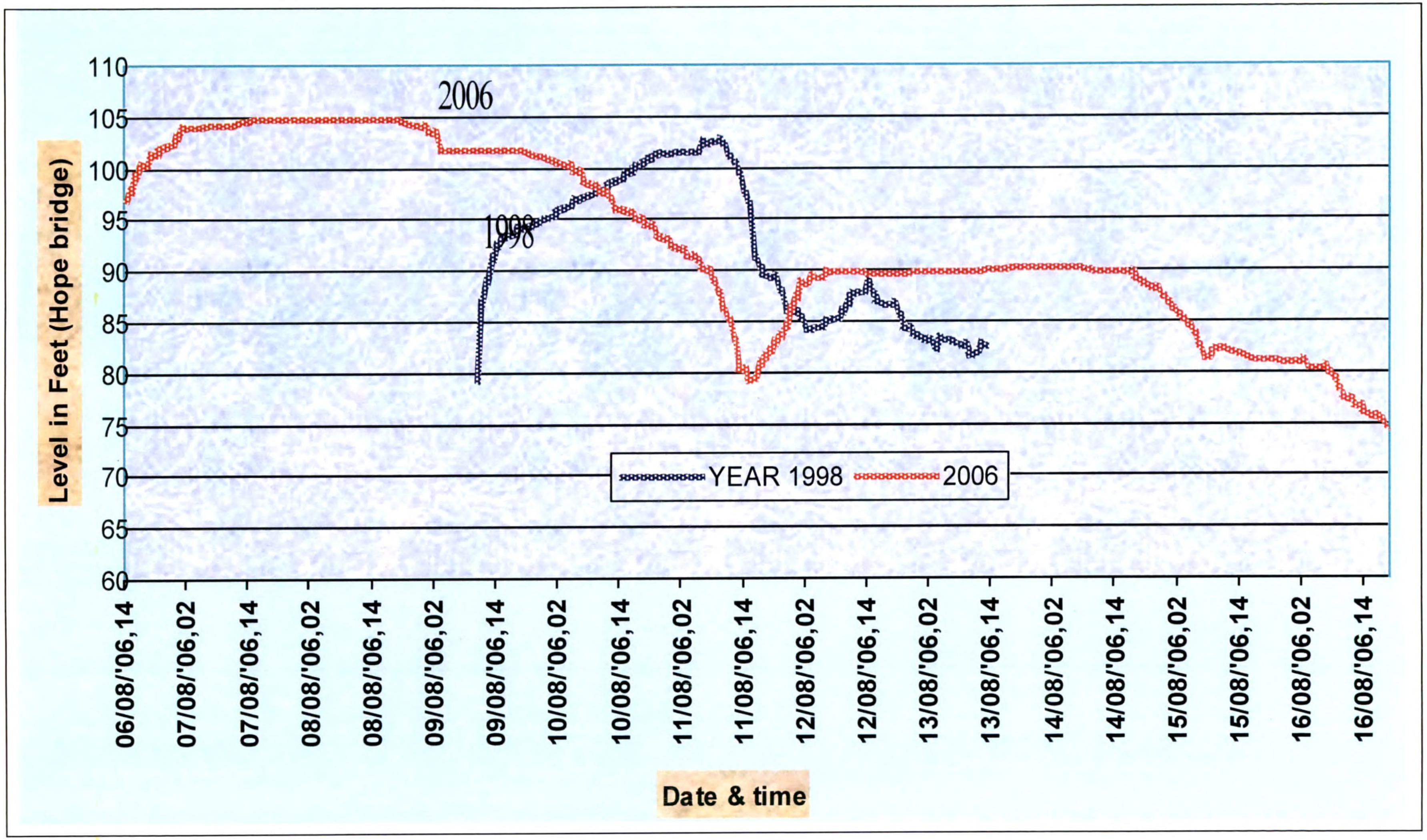


Graph.3.8 Chart Showing Operation of Ukai Reservoir during August - 2006

Graph.No.3.9 shows Tapi river flood water surface level at Hope Bridge, Causeway and Ukai (2006), Graph.No.3.10 shows comparative flood situation for the year 1998 and 2006 after construction of Ukai dam.

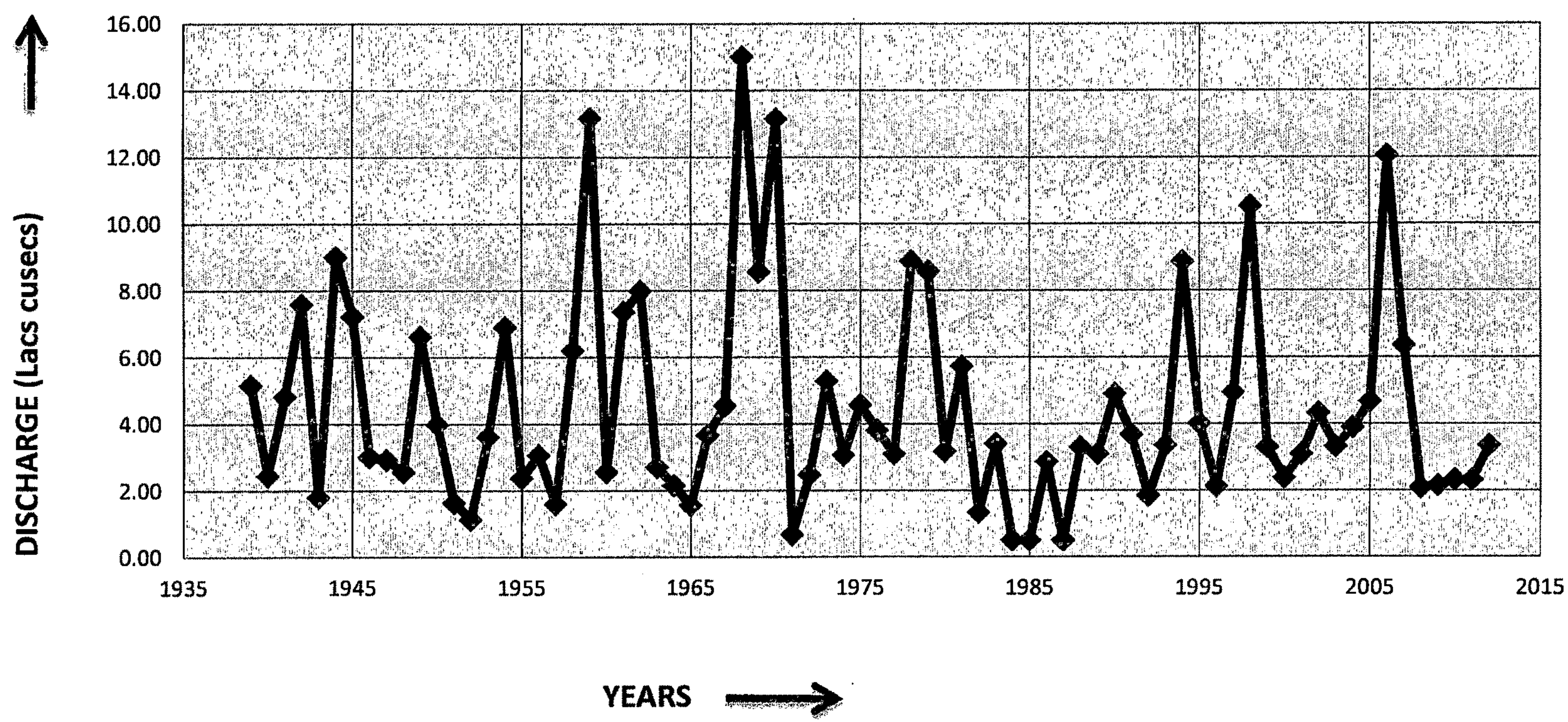


Graph.3.9 Tapi river flood water surface level at Hope Bridge, Causeway and Ukai (2006)



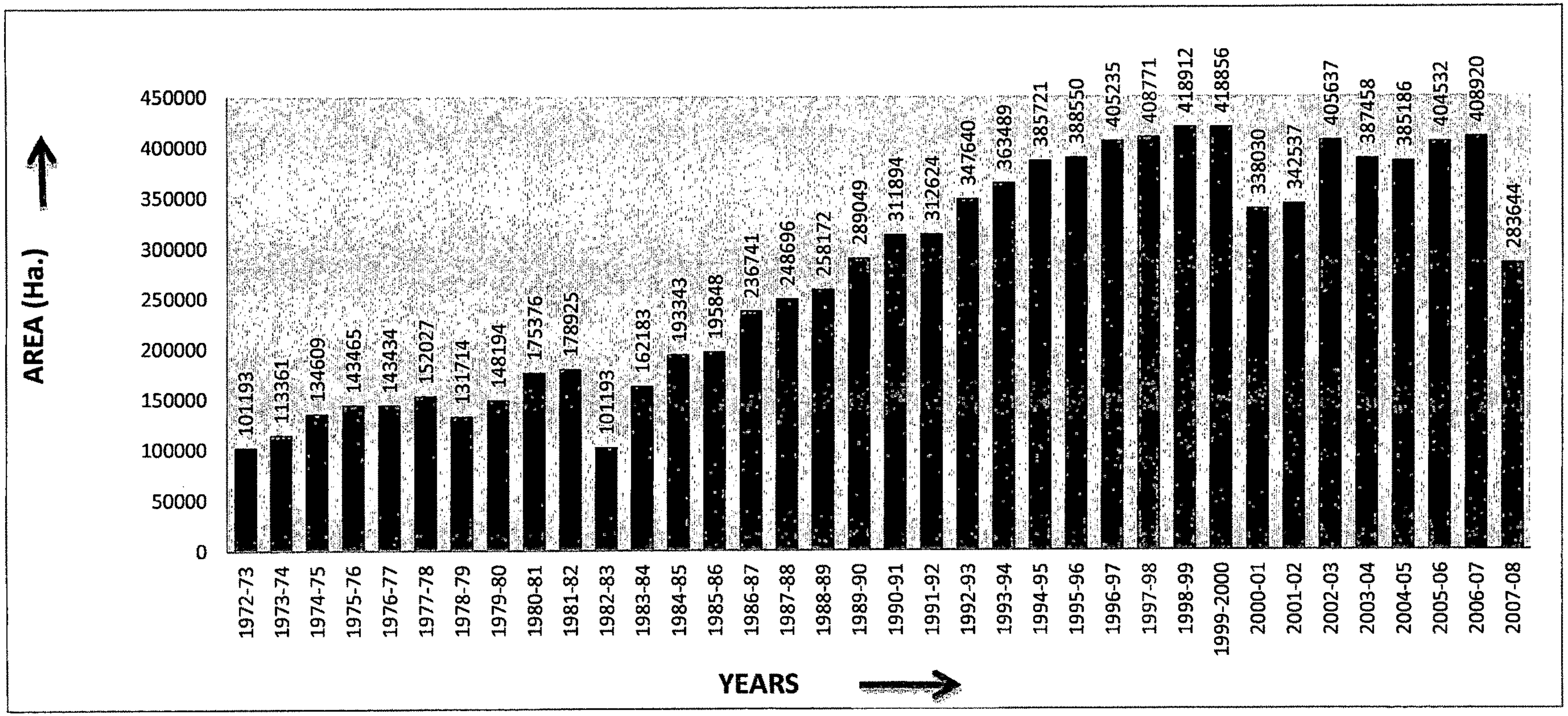
Graph.3.10 Comparative Flood Situation for the Year 1998 and 2006 after Construction of Ukai Dam

Peak flood pattern plotted in Graph.No.3.11.from year 1939 to 2012.

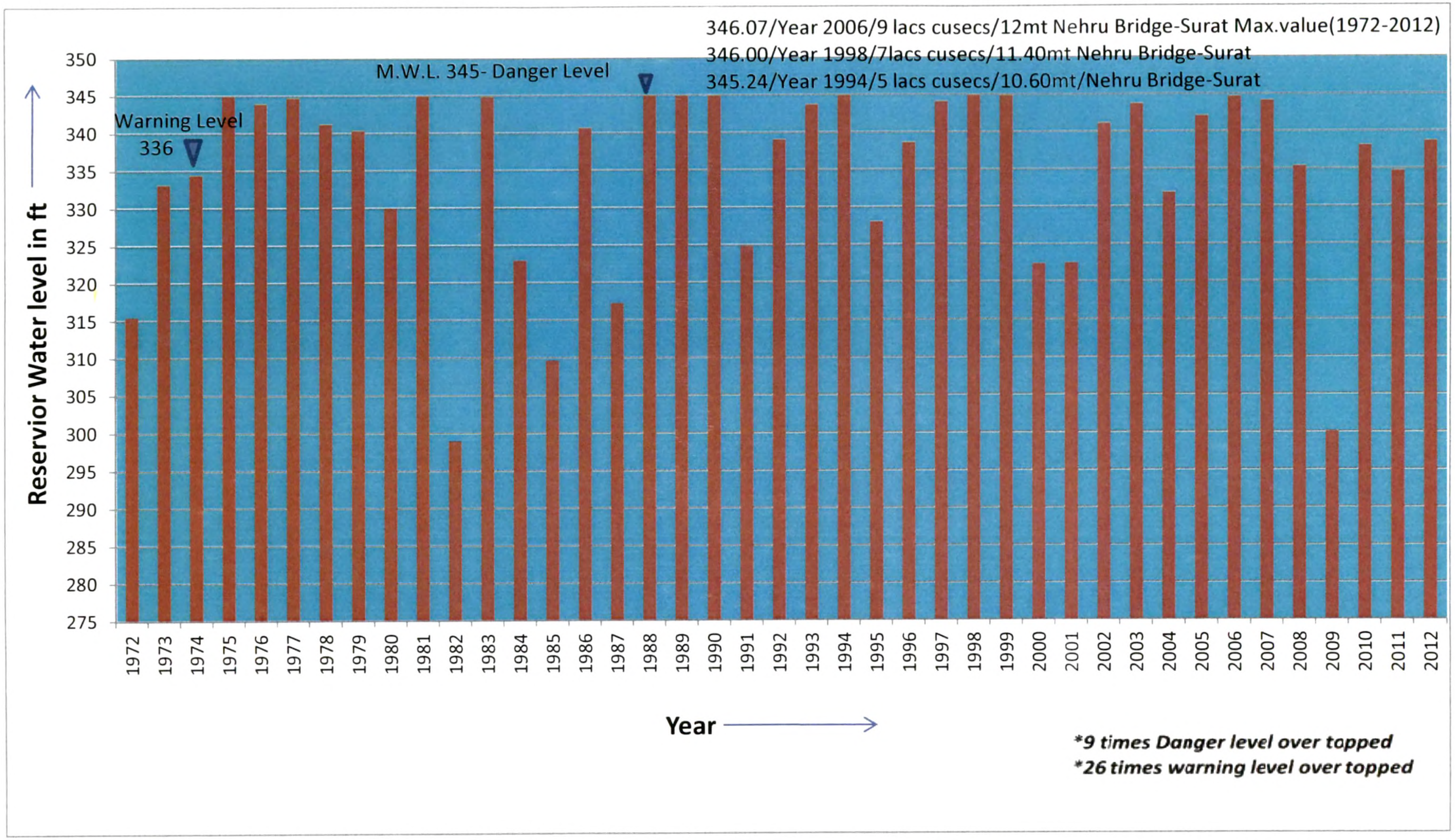


Graph.3.11 Peak Flood in Ukai Reservoir Year (1939-2012)

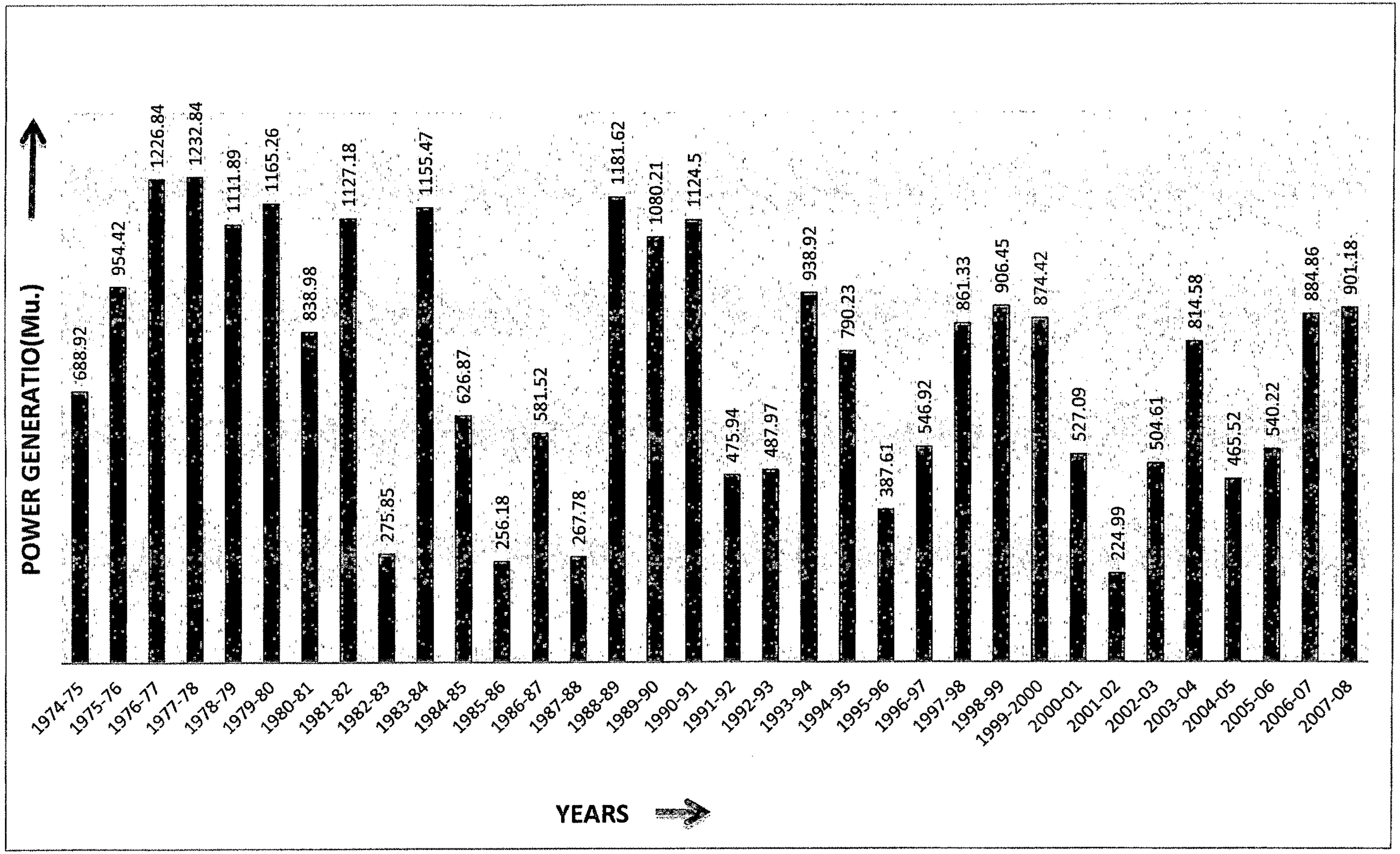
Interpretation done by using these data graph plotted and shown year wise area irrigated in Graph.No.3.12, ukai reservoir performance - MWL (1972 to 2012) in Graph.No.3.13, power generated in Ukai Reservoir in Graph.No.3.14, elevation v/s capacity curve of Ukai Reservoir in Graph.No.3.15, maximum and minimum RWL-August – September 2008 in Graph.No.3.16, Ukai reservoir performance – MWL (1972 to 2012) in Graph.No.3.17, maximum water level Ukai reservoir in Graph.No.3.18, monthly total Inflow detail - Ukai dam (1975-2009) in Graph.No3.19, inflow & outflow of Ukai reservoir (1973-2009) in Graph.No.3.20. respectively.



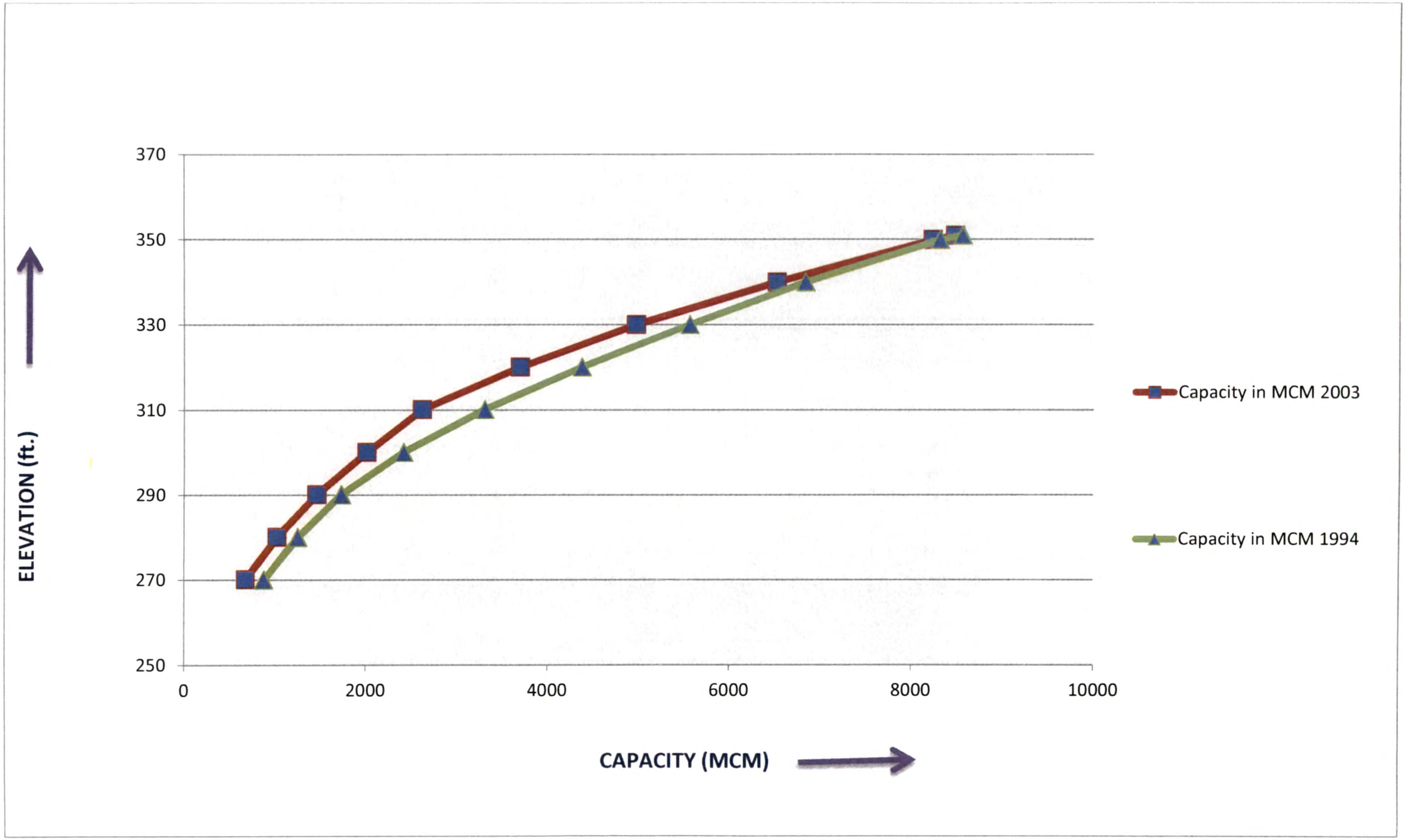
Graph.3.12 Year wise Area Irrigated



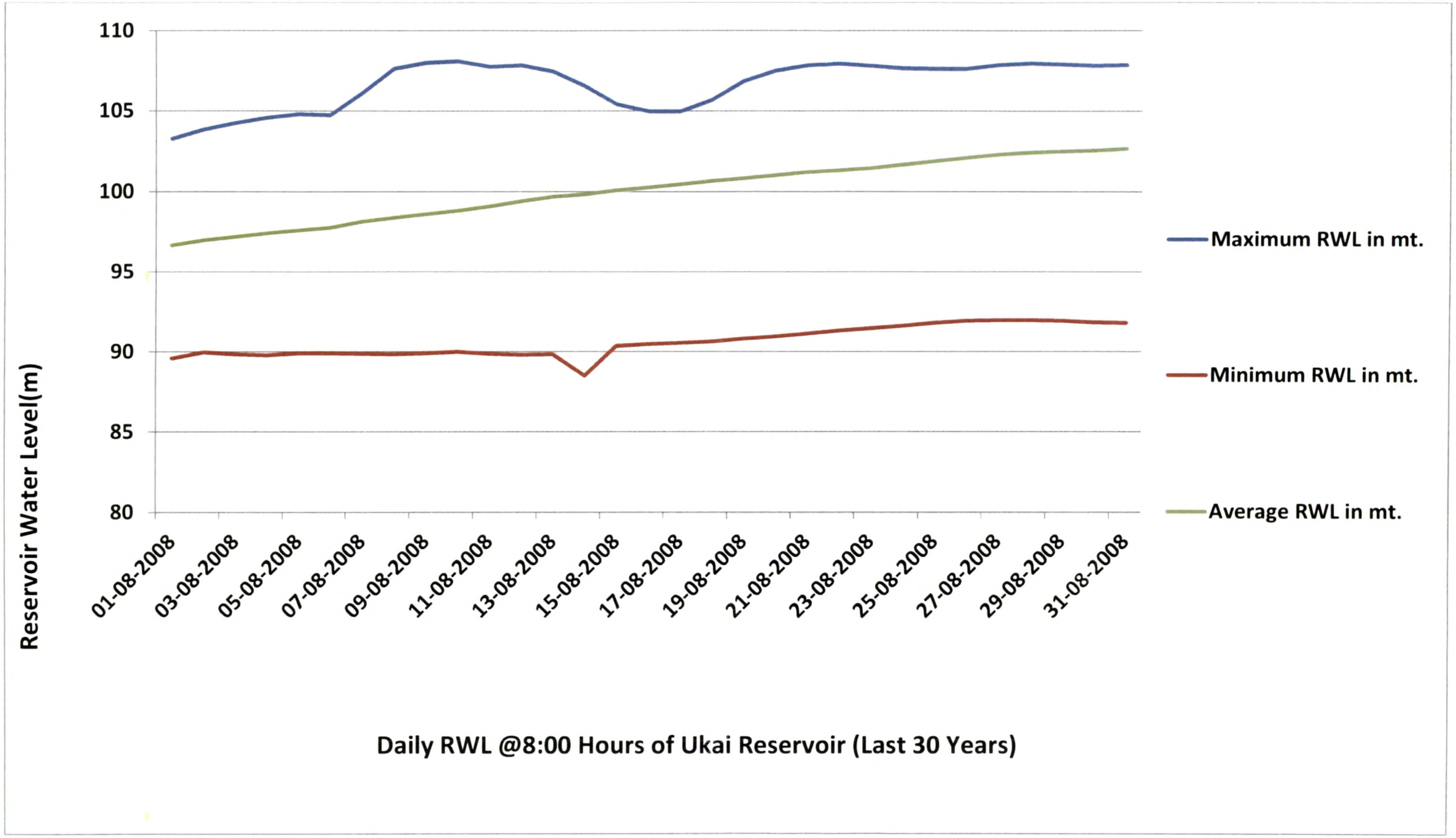
Graph.3.13 Ukai Reservoir Performance - MWL (1972 to 2012)



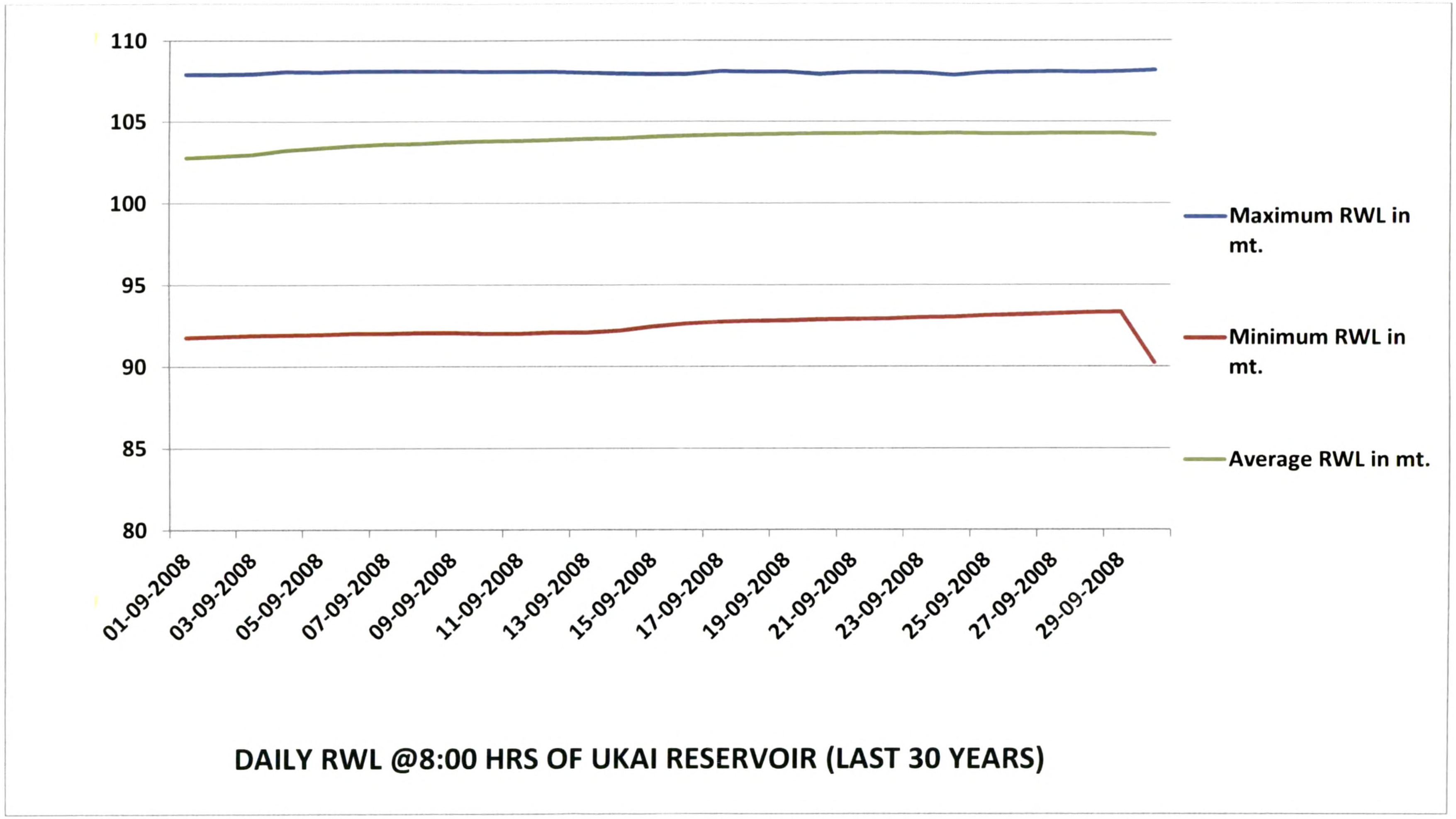
Graph.3.14 Power Generated in Ukai Reservoir



Graph.3.15 Elevation v/s Capacity Curve of Ukai Reservoir

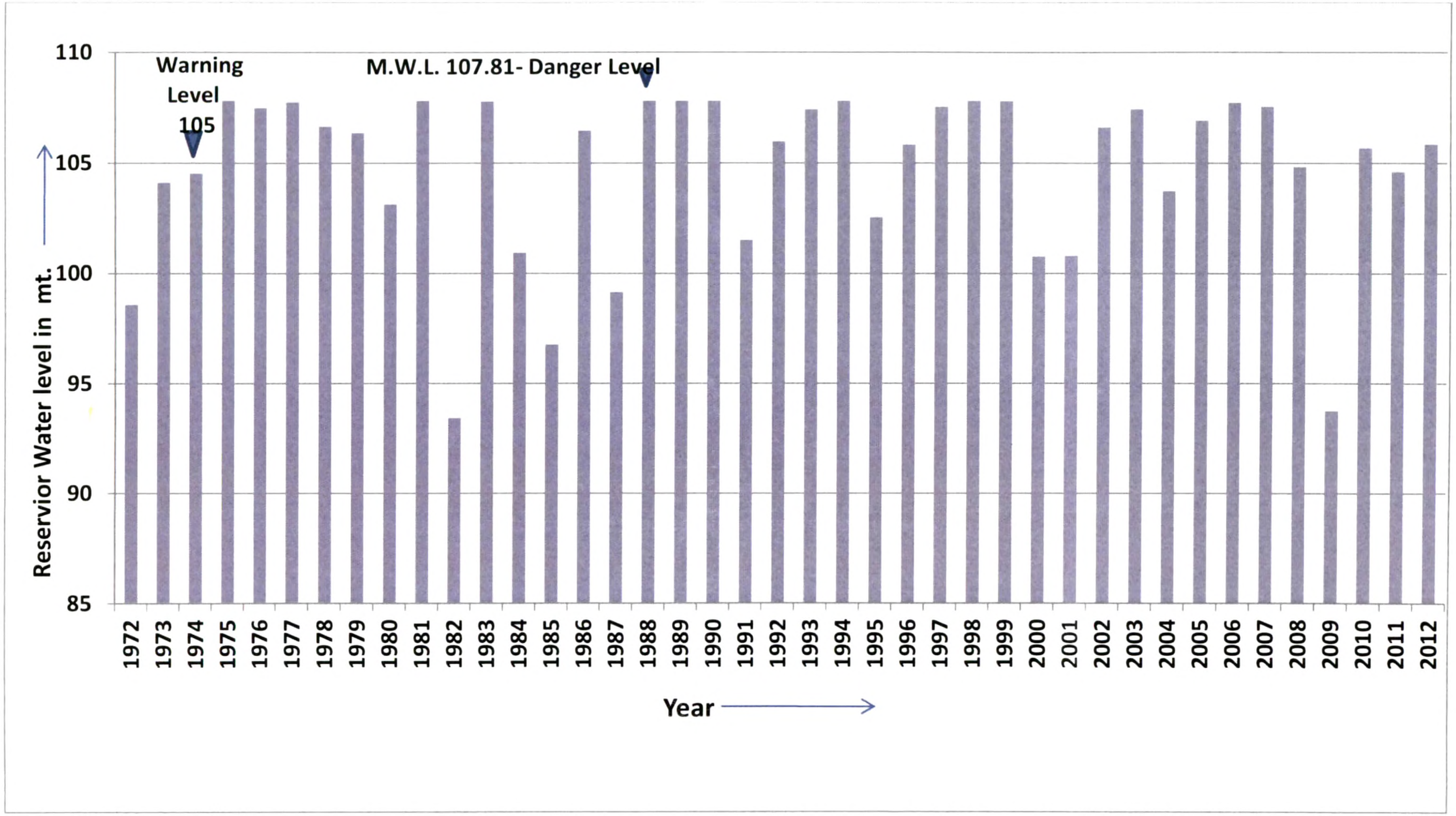


Graph.3.16 (A) Maximum and Minimum RWL-August – 2008

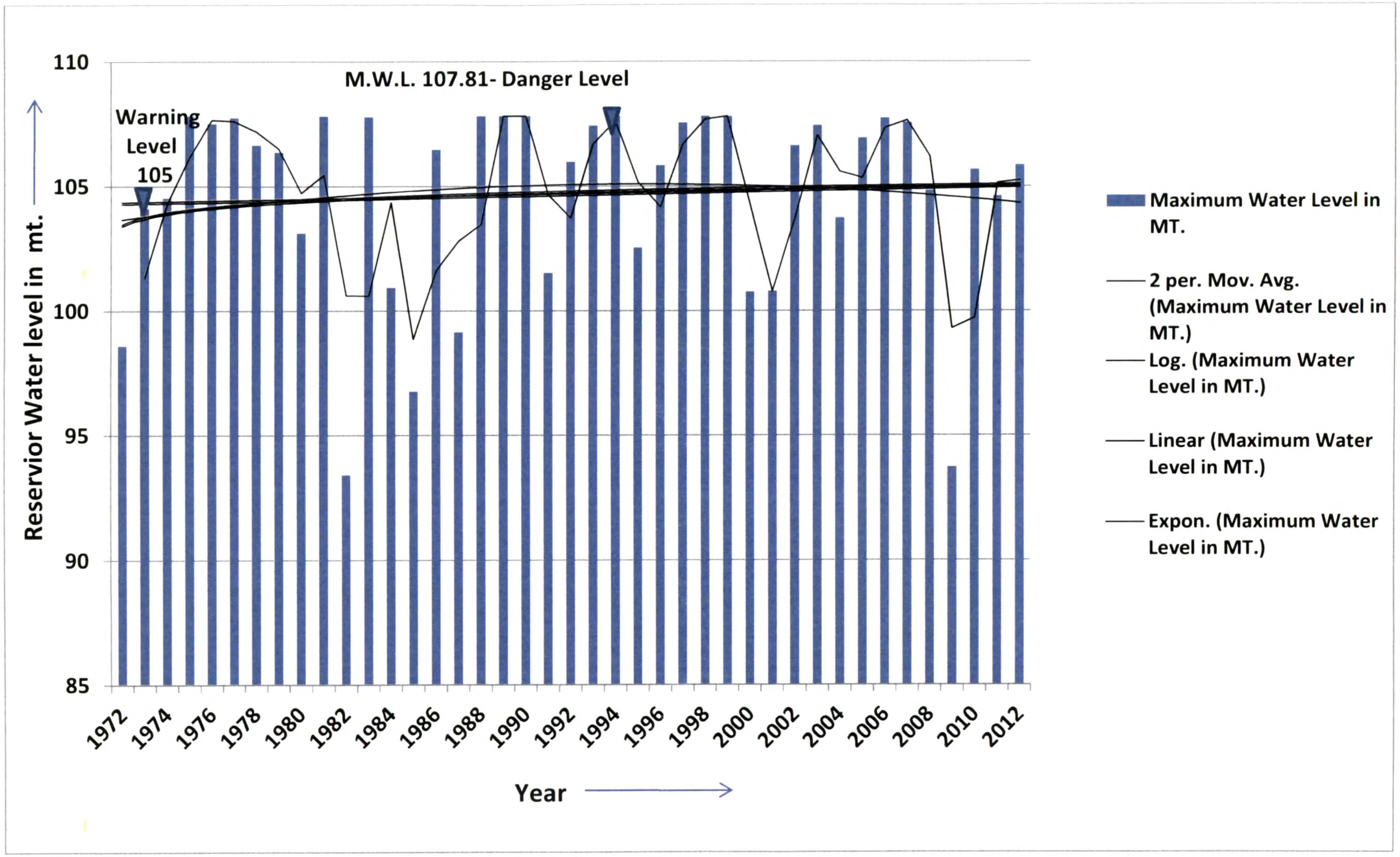


Graph.3.16 (B) Maximum and Minimum RWL-September– 2008

Below graph shows maximum water level 26 times over topped and 9 times danger level at Ukai reservoir

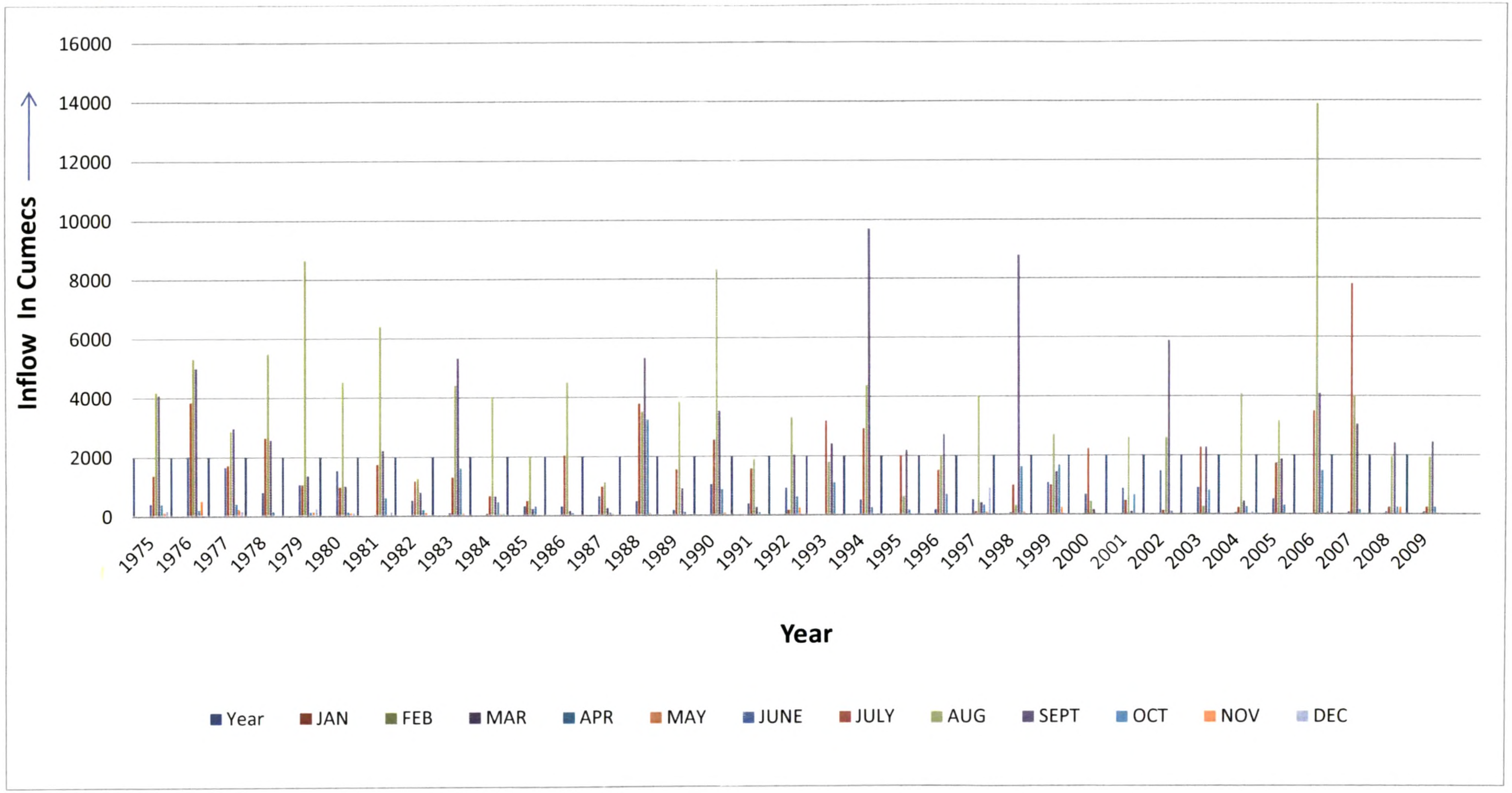


Graph.3.17 Ukai Reservoir Performance – MWL (1972 to 2012)

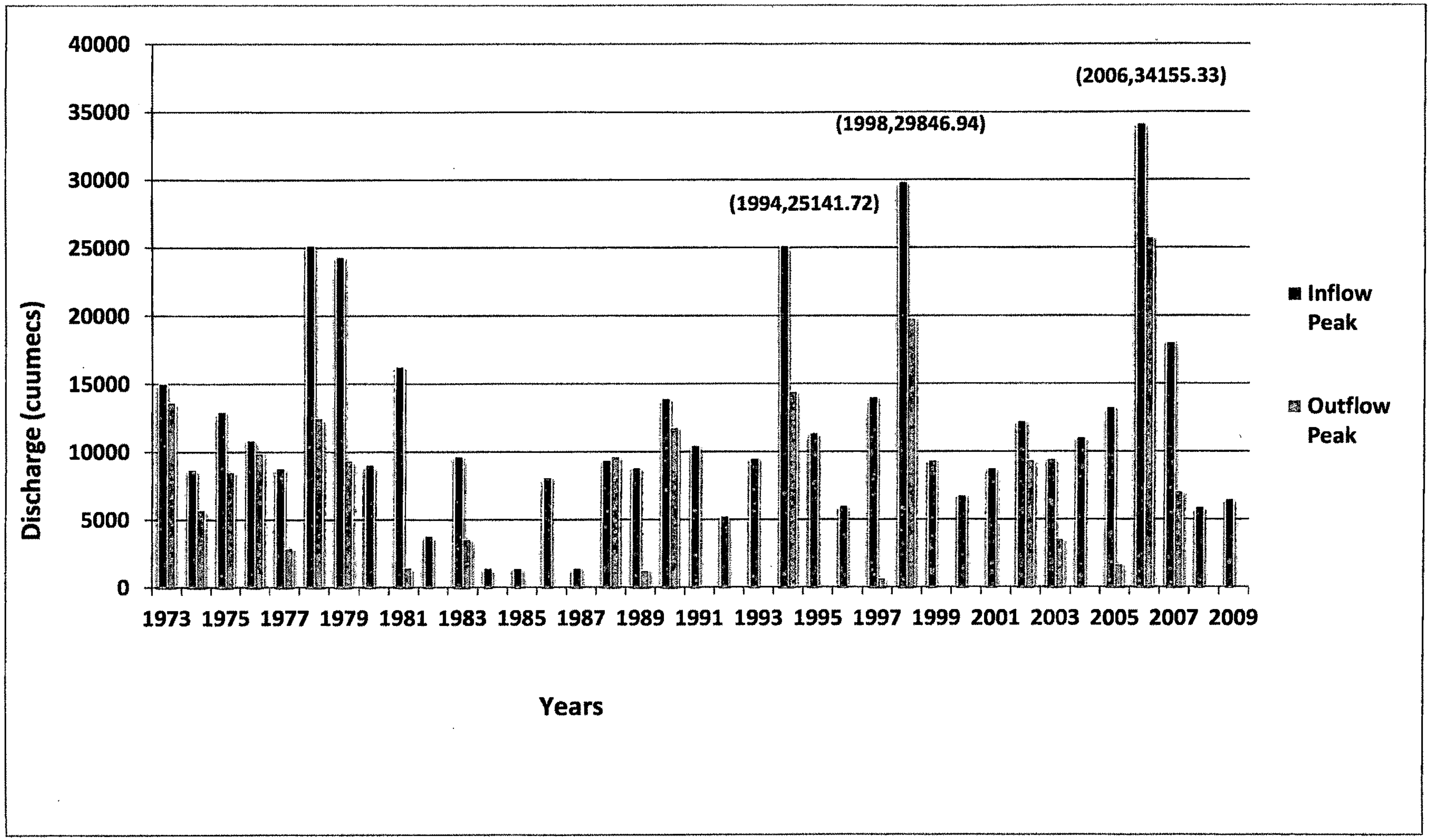


Graph.3.18 Maximum Water Level Ukai Reservoir

Below Graph.No.3.19 shows that in month of August and September during monsoon season inflow values very high which cause peak flood. Graph.No.3.20. Shows inflow and outflow comparison especially year 1994, 1998 and 2006.



Graph 3.19 Monthly Total Inflow Detail - Ukai Dam (1975-2009)



Graph.3.20 Inflow & Outflow of Ukai Reservoir (1973-2009)

Table.No.3.17 shows comparison of predicted water levels by CDO and CWPRS flood along with levels observed for their accuracy check. The table also shows that the flood level predicted by CWPRS is more accurate than the level predicted by CDO.

Table.3.17 Comparison of Flood Levels Predicted by CWPRS and CDO

Tapi Flood Discharge	Prediction by	Predicted Water at Various Locations (m)						
		Magdalla Bridge	Umra/ Bhata	Nehru Bridge	Singanpur Weir	Varivay	Amroli Bridge	Kathor Bridge
1998 Flood	CDO	7.80 (Reported at port)	8.80	11.50	12.81	14.31	14.87	18.40
19057 m³/s (7 lac cfs)	CWPRS	6.80	8.62	11.36	13.56	14.99	15.58	18.77
	Observed level In September 1998	6.80	8.55	11.40	13.90	14.23	14.77	18.29
28315 m³/s (10 lac cfs)	CDO	9.88	-	13.95	15.57	17.05	17.61	21.29
	With Sept. 1998 tide	7.86	10.63	12.90	15.24	17.34	18.17	21.55
	With highest Spring tide	7.92	10.66	12.93	15.24	17.43	18.29	21.76