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Study of Storm Water Drainage Problem of Surat City & Its Solutions Due To Flood in River Tapi

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Abstract: **This paper shows that the storm water back flow problem under high flood situation in river Tapi is the major storm water drainage problem, when drainage outlets are closed for Surat city. It indicates that storm water drainage system of Surat city during flooding condition is not much effective at some low lying areas of Surat city. The feasible solution of this problem is achieved in this case study by designing some general as well as systematic drainage solution & also appropriate design of storm water drainage system of desire working objective. Aim of the research is begins by examining the performance of current storm water drainage system & the conditions that lead flooding problem at some low lying critical areas of Surat city. It is important that all storm water drainage system are designed to a set of criteria that are subjected to economic, social & environmental point of view. One of the most factor in designing sustainable storm water drainage system is the physical storage & also conveyance within drainage outlets. That needs to be provide to achieve flood control & minimize the pollution impact of urban storm water runoff of Surat city, including solution of water logging problem at critical locations of Surat city during peak rainfall days. The study shows some appropriate solution of this problem with the new drainage system which is sustainable as well as capable to drain storm water from the low lying areas of Surat city.**

Keywords: **Surat city, water drainage system, flooding, storm, problem,**

1. INTRODUCTION

Adequate storm water drainage is very essential in the modern infrastructure of the city since it effects the roadway serviceability & usable life. If storm water logging at the some critical low lying areas occurs Hydroplaning becomes an important safety concern. Storm water drainage design for the peak rainy days involves providing facility that collect, transport & remove storm water from the low lying critical areas of Surat city. The design must also consider the storm water reaching in the lower critical level areas through natural stream flow on manmade ditches.

In Surat city some critical location flooding occurs during monsoon season. It is that interval of time in which river Tapi flows under high flood condition also. According to location there are some types of flood occurs in city like arroyos flooding, river flooding & urban flooding.

Mainly the urban area is paved with roads etc. & the discharge of heavy rain cannot absorbed into the ground due to drainage constraints leads to flooding of streets, underpasses, low lying areas & storm drains when flood gates of river Tapi are closed. Critical locational storm water backflow from drains results serious traffic at intersection of the road and affects daily life of local public of this particular area.

Figure.1 Construction of Storm water drainage line, Surat (Patel 2009)

Currently for storm water drainage adopted pumping system is less effective now a days so that by this case study we give some general & technical solution for storm water drainage system in Surat city. This solution is especially for that type of water logging at some critical city areas when river Tapi flows at high flooding situation& drainage outlets are closed.

2. BACKGROUND OF THE PROBLEM

Surat is situated in south Gujarat, 250 Km north of Bombay, on the banks of river Tapi. Total area of Surat city is 334.29 sq.km including 7 no. of zones, annual average rainfall of the city is 1894 mm. Major River is Tapi & major dams Ukai and Kakrapar constructed on river Tapi. River Tapi flows through the city and meets the Arabian Sea at about 16 km west from Surat. Surat is 90 km in downstream of Ukai Dam over river Tapi. Five main and several minor creeks pass through the city and meet river Mindhola in south of Surat.

Figure.2 Hopebridge, Adajan & LIC building HFL, Rander branch, Surat flood (River flood Hazard modeling 2008)

The average annual flood, with a recurrence interval of 2.33 years, on the Tapi (at Ukai) is 14,323 m^3/s. The flood in 2006 alone had caused total damage city was flooded in 2006, with a peak discharge of approximately 25,780 m^3/s (P. G. Patel 2007) from the Ukai Dam.

The flow capacity of the Tapi River has been reduced in Surat city due to rapid urbanizations/industrialization and severe encroachment of the floodplain. For example, a discharge of rarely 25,780 m^3/s during the flood in 2006 had attained a level of 12.5 m at the Nehru Bridge in Surat city compared to the level of 12.9 m attained by the historically maximum flood of discharge 42,500 m^3/s in 1968.

Apart from all that some manmade causes responsible for urban flooding condition also. As we know rigid pavements are increasing day by day due to more & more infrastructure development in Surat city. High infrastructure development leads more & more congestion of the area and its results lack of serviceability of existing routine facilities such as transportation, drainage and health etc.

It causes storm water runoff in some low lying urban areas which leads the problem of some location flooding in low lying areas like kadarshah Ni nal & hodi bungalow of the central zone of Surat city. Especially when the flood gates of this area are closed due to flooding condition of river Tapi storm water backflow problem is take place & it causes some serious water logging in this areas.

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3. PRESENT SITUATION OF THE PROBLEM IN SURAT CITY

Today, proper storm water system is increasingly becoming a key component of any developing urban area especially for Surat city. Sufficient & proper storm water drainage system is one of the big & important aspect for their development now a days.

The study area has been frequently affected by flood in river Tapi. Surat is situated on bank of river Tapi & is having coastline of Arabian sea on its wasted at a distance about 19.4 km. Due to increased industrialization in & around Surat also the population is increased. Surat has experienced three major flood events in recent past in year 1994, 1998 & 2006.

As per passing some decades over Surat city the natural flow of river Tapi is absolutely changes during this silting process of river is also increased so, that the natural path of river is become narrow year by year. The main problem is that the storm water drainage system is become more & more insufficient day by day because of some natural & artificial changes of Surat city.

According to that all aspects some critical locations flooding problem is occurs at some lower level areas of Surat city especially at central zone of city. Now a days the current drainage system is not sufficient during peak rainfall days & high flood situation in river Tapi when flood gates are closed.

It resulting no more discharge possible to the river & no proper conveyance of additional rainfall water. That is why flooding situation occurs in lower level areas of Surat city.

Some major creeks also not much sufficient to drain the access storm water because of the path of this creeks is obstructed by some manmade obstruction & it is becoming narrow due to silting. Some location flood is occurs by overflowing of this major creeks of central zone of Surat city.

At present during flooding condition in Surat city the pumping drainage system is working but it is not much effective for the high flooding situation of Surat city especially when drainage outlets are closed. Just because of it is necessary to new provision of some modern storm water drainage system.

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Figure.3 Critical water logging due to storm water back flow(2013)

Table.1 Flood history in Surat (P. G. Patel 2007)

Sr. No.	Flood Event	Discharge (Lac Cusecs)	Water Level at Hop Bridge(m)	Period
1.	1883	10.05	11.05	July
2.	1884	8.46	10.05	September
3.	1894	8.01	10.33	July
4.	1942	8.60	10.56	August
5.	1944	11.84	11.32	August
6.	1945	10.24	11.09	August
7.	1949	8.42	10.49	September
8.	1959	12.94	11.55	September
9.	1968	15.5	12.08	August
10.	1994	5.25	10.10	Aug.-Sept.
11.	1998	7.00	11.40	September
12.	2006	9.09	12.40	August

4. DATA COLLECTION & FIELD SURVEY SURAT CITY

Surat, the study area, is one of the cities of state Gujarat, India and has been frequently affected by flood in river Tapi. Surat is situated on bank of river Tapi and is having coastline of Arabian Sea on its west at a distance of about 19.4 km. Surat receives an annual rainfall ranging between 950-1200 mm. About 90% of the rainfall occurs in period between Junes to September. The GCM (Global Climate Model) and RCM (Remote Carrier Module) results indicate a high probability of increased precipitation in the future. This predicted increase, from different models and scenarios, ranges from 200 mm to 450 mm annually (by 2070)

Similar changes are expected in the upper catchment areas of Tapi basin also. Due to increased industrialization in and around Surat, the population had increased up to 68809 m³/s (24.34 lakh cusecs) in year 2001. Surat has experienced three major flood events in recent past in year 1994, 1998 and 2006. These events caused heavy loss of property and human lives. In 1998, 60% area of city was severally affected while in year 2006, large amount of water spilled from low rise river sections resulted in to flood and 90-95 % Surat city was under submerge up to 4-5 m. This unprecedented flood in Surat caused damages of over Rs. 2100 crores.

4.1 Flood Gates Locations:

There are total 34 flood gates provided to drain storm water of Surat city. This all floodgates distributed over entire city according to zones of the city. Central zone is affected by storm water logging frequently that is why the locations of flood gates of central zone area are given below.

Table.2 Locations of Flood gates (Drainage department, Rander, Surat 2014)

SR. NO.	NAME	LOCATION	DIMENSION (mm)
1.	L3	Bharimata Kotar-7	1000Φ
2.	L4	Nr. Dhastipura	1500 x 1200
3.	L5	Nr. Gandhi baug	1800 x 2100
4.	L6	U/S of Makkai bridge	2200Φ
5.	L8	D/S of Sardar bridge	2400 x 2400 (Double drain)

Figure.4 Location of Critical flood gates of central zone

The local civic body claims to have taken a series of steps to prevent entry of Tapi waters in the city. The steps include closing of flood gates at all the low lying areas and placing de-watering pumps at specific locations. Sources at SMC (Surat Municipal Corporation) said that no shifting of residents has taken place in any part of the city till now. Four outlets to Tapi River located at Bharimata, Chapra Bhatha and Amroli Bridge have been closed. A flood gate at Hanuman Tekri at Rander village has also been closed and dewatering exercise has been started there. When river Tapi flows at its high flood level this four flood gates are kept close during this time interval of monsoon season. So, that its causes critical locational water logging in some areas of central zone.

4.2 Critical Flood Gate Location:

Figure.5 L5 Flood gate, Nr. Gandhi Baug

- It is the outlet of the drainage line which coming from beneath of Gandhi baug.
- Size of this flood gate is 1800 mm x 2100 mm box drain.
- R.L. of this flood gate is well below about 2.385 m.

Figure.6 L6 Flood gate, U/S of Makkai Bridge

- It is the drainage outlet located on U/S of Makkai bridge portion.
- Size of this flood gate is 2200 mm Ø circular drain.
- R.L. of this flood gate is well below about 2.905 m.

Figure.7 L7 flood gate, D/S of Makkai Bridge

- It is the drainage outlet located on D/S of Makkai bridge portion.
- Size of this flood gate is 1800 mm x 2100 mm double drain having box shape.
- R.L. of this flood gate is well below about 3.135 m.

4.3 Rainfall data of Surat city:

Table: 3

SR. NO.	YEAR	MONTH						TOTAL (mm)
		JUNE (mm)	JULY (mm)	AUG. (mm)	SEPT. (mm)	NOVE. (mm)	DEC. (mm)	
1	1991	33	577	199	3	0	0	812
2	1992	604	433	402	460	41	0	1940
3	1993	425	516	40	323	84	0	1388
4	1994	132	934	160	82	1	0	1309
5	1995	13	894	48	145	10	0	1110
6	1996	196	600	204	60	78	0	1138
7	1997	410	172	311	108	0	0	1001
8	1998	63	636	262	163	26	15	1165
9	1999	178	460	81	78	125	0	922
10	2000	109	418	152	2	37	0	718
11	2001	393	344	222	13	0	0	972
12	2002	860	51	408	97	0	0	1416
13	2003	520	928	356	78	0	0	1882
14	2004	853	547	707	25	38	0	2170
15	2005	872	385	355	379	0	0	1991
16	2006	342	700	212	49	5	0	1308
17	2007	189	470	625	504	0	0	1788
18	2008	399	341	322	214	17	0	1293
19	2009	57	10	242	0	0	0	309
20	2010	65	475	436	590	0	0	1566
21	2011	31	325	563	234	0	0	1153
22	2012	63	299	111	434	7	0	914
23	2013	648	606	291	538	52	0	2135

4.4 Water Quantity Calculation:

- Maximum rainfall in one day :- 330.2 mm/day within 326 km² area of Surat city.
- Catchment area of all this critical flood gate :- 3.96 km².
- Rainfall within catchment area :- 4.0046 mm/day.

326 km 330.2 mm/day

3.96 4.0046 mm/day

- By using Rational method :
- $Q = \frac{1}{3.6}$ CiA

Where, Q :- Total water Quantity

C :- Runoff co-efficient (0.7 to 0.95 for pavement)

i :- Rainfall amount in mm/day

A :- Catchment area in m²

- $Q = \frac{1}{3.6}$ x 0.95 x 4.0046 x 3960

= 20,750.38 lit/min.

5. SOLUTION OF THIS PROBLEM

5.1 Hydraulic Ram pump:

5.1.1 Introduction:

Once upon a time a Frenchman named Joseph Michel Montgolfier (1796) (he and his brother were best known for being the first to send livestock aloft in a hot air balloon; it takes all kinds...) rigged up a couple of valves to automate a process. As flow developed, it would slam a ball against a seat, forcing the pressure through a check valve and into an air chamber.

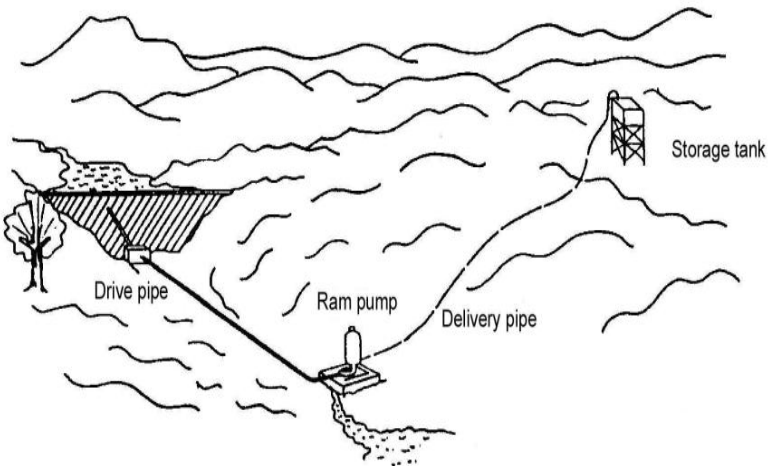

Figure.8 The hydraulic ram pump system

It were also the Montgolfier Brothers who invented the first self-acting ram pump for rising water in his paper mill at Voiron. His friend Matthew B lt t Boulton took out a British patent on his behalf in 1797. The sons of Montgolfier obtained an English patent for an improved version in 1816, and this was acquired, together with Whitehurst's design, in 1820. Altogether the ram pump designs changes after the centuries and a hundreds of different types were manufactured all over the world. Until now some of the old ram pumps are still doing their jobs as well as time stood still. If you are lucky enough you can see them all over the world mostly in farming areas. But also in some museums there are some antique pieces. (below an old ram in the German museum in Munich).

Figure.9 The hydraulic ram pump (Old model)

Its mode of operation depends on the use of the phenomenon called water hammer and the overall efficiency can be quite good under favorable circumstances. More than 50% of the energy of the driving flow can be transferred to the delivery flow.

5.2.1 Parts & Functions of the Ram pump

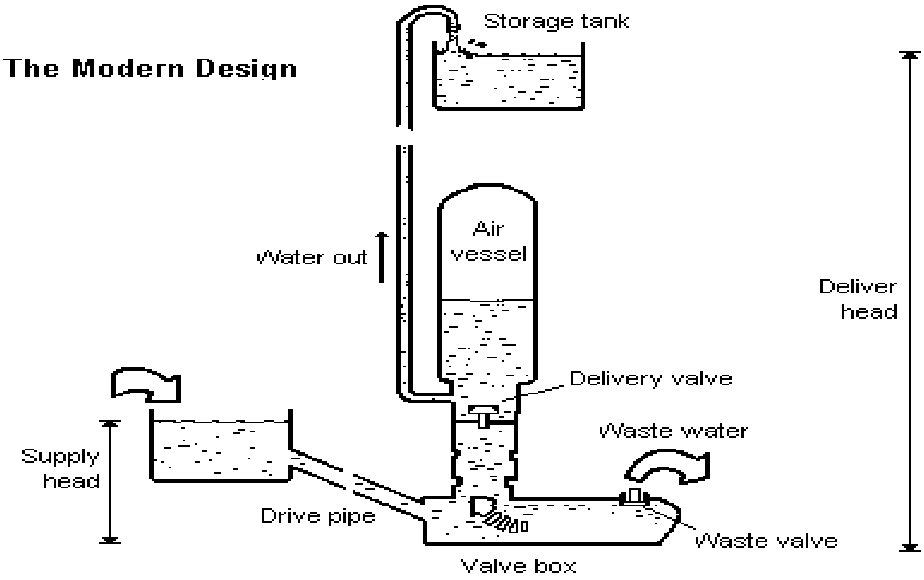

Figure.10 Parts of Ram pump

❖ **Drive Pipe:**

Drive pipe is made up of G.I or cast iron having diameter varies from 1 to 10 inch. The drive pipe serves the water coming from the sources available to the pump. Drive pipe must be capable to supply the water to the ram pump for proper operation.

❖ **Pressure Valve:**

Pressure valve is also iron metallic body fixed for the valve operation in the ram pump. Pressure valve catch up the water enters to the ram pump from drive pipe as a part of pumping function.

❖ **Pressure vessel or Air chamber:**

Pressure vessel is very important component of this whole assembly. Pressure vessel serves as to catch up the water pressure. It also works as a buffer space for the water in the ram pump. It is also known as air chamber.

❖ **Waste water valve:**

Waste water valve is the core component of the ram pump. It stops the inrushing water during the pumping operation. It is mainly responsible for over pressure so that the ram pump can deliver the water at the higher elevation.

❖ **Delivery Pipe:**

As the name explain its role in the pump it is the pipe which is deliver the pumped water to the collection tank or discharging location. A delivery pipe taking a portion of the water that comes through the drive pipe to an elevation higher than the source.

5.2.2 Design characteristics:

➢ **D = S x F x E / L**

Where, D = Amount Delivered in lit/min.

S = Quantity of water supplied in lit/min.

F = the fall or height of the source above the ram in m.

E = Efficiency Of the ram (for comm.- 66% & for home use- 33%)

L = Lift height of the point of use above the ram in m.

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Table.4 Ram Performance Data for a Supply of 1 liter/minute

Working Fall (m)	**Lift - Vertical Height to which Water is Raised Above the Ram (m)**											
	5	**7.5**	**10**	**15**	**20**	**30**	**40**	**50**	**60**	**80**	**100**	**125**
1.0	144	77	65	33	29	19.5	12.5					
1.5		135	96.5	70	54	36	19	15				
2.0		**220**	156	105	79	53	33	25	19.5	12.5		
2.5		**280**	**200**	125	100	66	40.5	32.5	24	15.5	12	
3.0			**260**	180	130	87	65	51	40	27	17.5	12
3.5				**215**	150	100	75	60	46	31.5	20	14
4.0				**255**	173	115	86	69	53	36	23	16
5.0				**310**	**236**	155	118	94	71.5	50	36	23
6.0					**282**	185	140	112	93.5	64.5	47.5	34.5
7.0						**216**	163	130	109	82	60	48
8.0							187	149	125	94	69	55
9.0							**212**	168	140	105	84	62
10.0							**245**	187	156	117	93	69
12.0							**295**	**225**	187	140	113	83
14.0								**265**	**218**	167	132	97
16.0									**250**	187	150	110
18.0									**280**	**210**	169	124
20.0										**237**	188	140

- **Characteristics Curves of the Prototype:**

The following characteristic curves of the Hydram prototype were drawn for a constant supply head (H) of 2 m, impulse valve weight of 2.2 kg and a drive pipe diameter of 1 1/4".

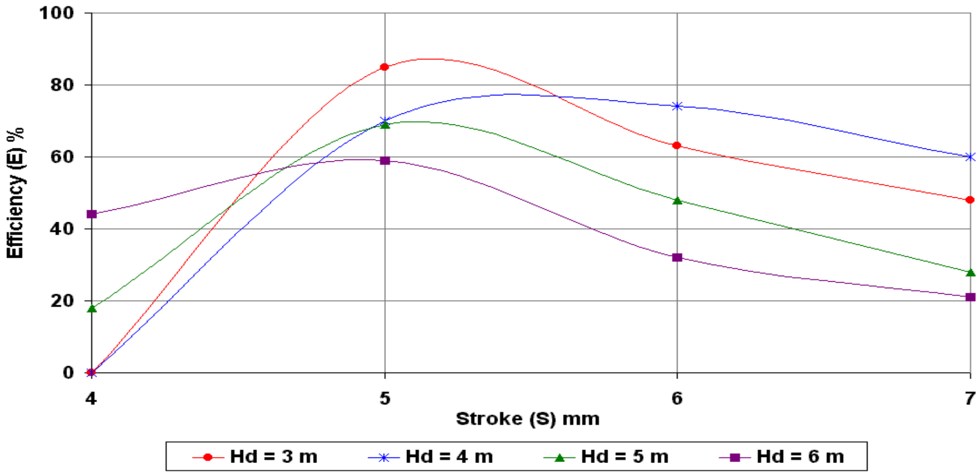


Figure.11 Stroke vs. Efficiency

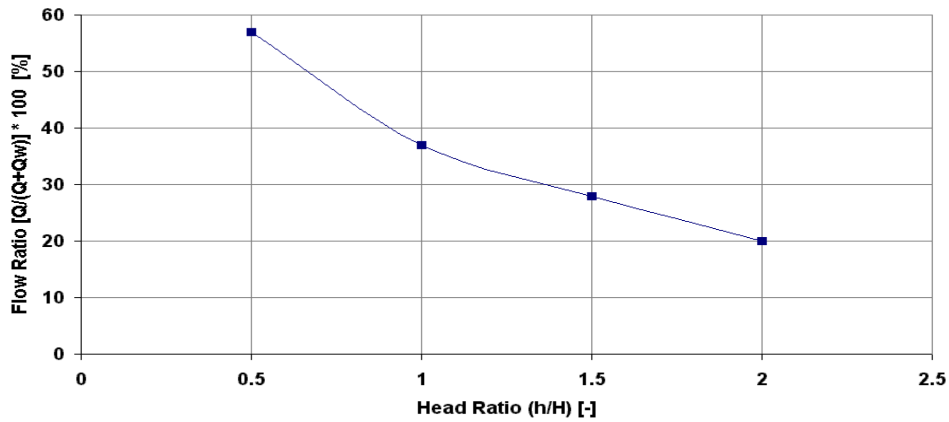
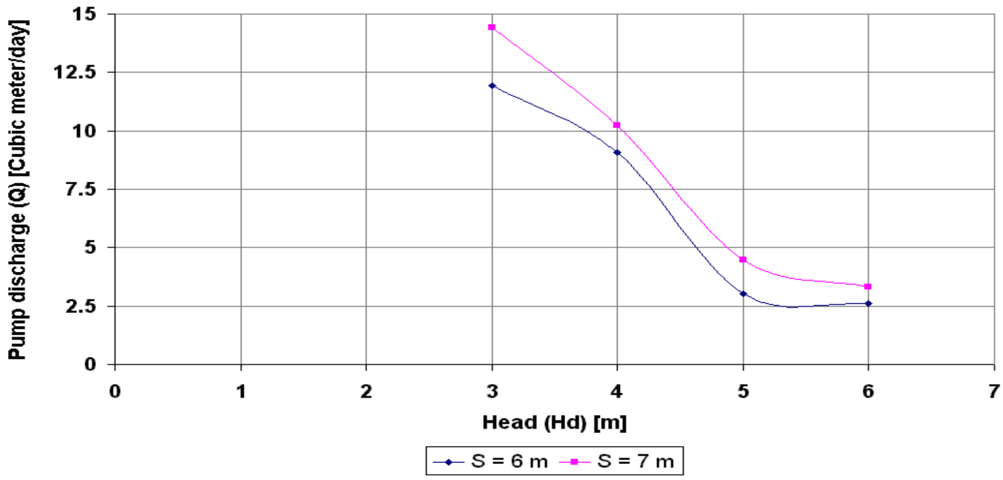


Figure.12 Head Ratio vs. Flow Ratio



Figure,13 Head vs. Pump Discharge

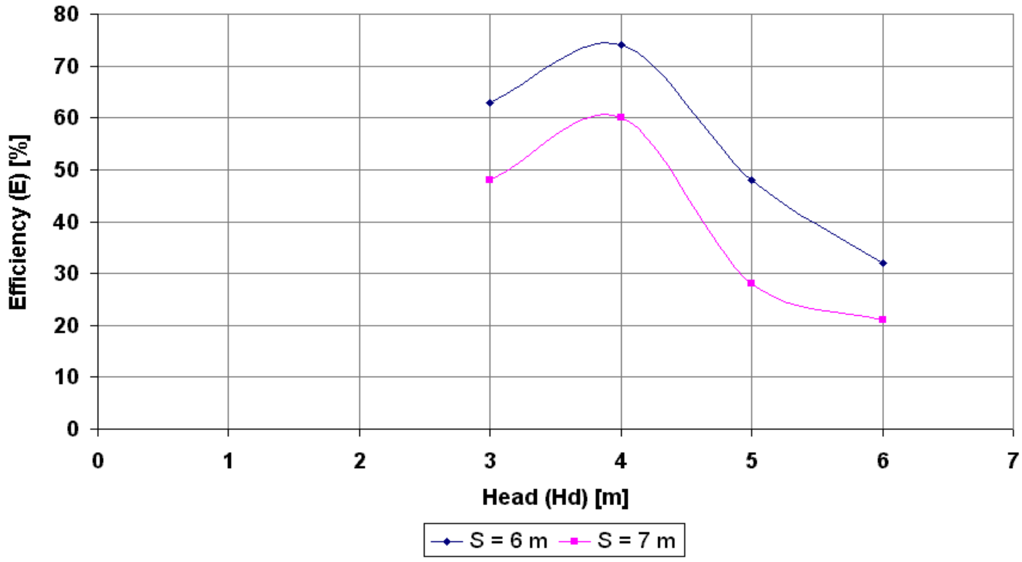


Figure.14 Head vs. Efficiency

5.2.3 Design calculation:

- Total Quantity of water :- **20,750.38 lit/min.**
- From the analytical formulae :-
- **D = S x F x E / L** Where,

S = Water supplied to the pump in lit/min.

F = vertical fall in m.

E = Eff. Of pump (0.105 for comm./ large model).

L = Vertical lift required in m.

D = Delivery give by the ram in lit/min.

- **D =** $\frac{20,750.38 \ x \ 8 \ x \ 0.105}{12}$

= 1,452.52 lit/min.

- No. of pump required = Total quantity / Delivery of one pump

= 20,750.38 / 1,452.52

= **13.79 Nos.**

- There are **14 no.** of pumps required in parallel assembly to dispose that much water quantity.

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5.2.4 Selection of hydraulic ram pump:

Table.5 "Universal Heavy Duty" Rams allow for a Max. Fall of 15 m & a Max Vertical Elevation of 150 m.

Model	Drive pipe (inch)	Deli. Pipe (inch)	Min. intake (l/m)	Max. intake (l/m)	Min. fall (m)	Price (Rs.)
10 HDU	1.25"	0.75"	11.54	38.47	0.9	1,480
20 HDU	2"	1"	38.47	96.18	0.9	2,590
25 HDU	2.5"	1"	57.70	173.12	1.22	4,320
30 HDU	3"	1.25"	96.18	269.31	1.22	6,600
40 HDU	4"	2"	134.65	577.09	1.52	10,675
60 HDU	6"	3"	288.54	1538.92	1.52	11,41,450
80 HDU	**8"**	**4"**	**1538.92**	**3077.84**	**1.52**	**26,53,100**

- 14 no. of 80 HDU heavy duty ram pump is preferable for the water quantity that need to be drain out from the water logging area during monsoon season.
- Drive pipe having 8" dia. & delivery pipe having 4" required.

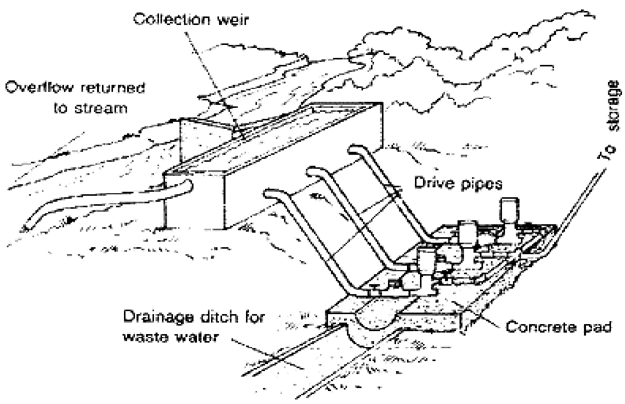

Figure 3. Multiple Rams with Common Delivery Pipe

Figure.15 80HDU ram pumps & multiple rams with common delivery pipe

5.2.5 Quantity calculation:

Table.6 Material quantity calculation for the ram pump system

Item No.	Item Description	No	L (m)	W (m)	H / T (m)	Qty.	Total Quantity
1.	**Excavation for pump assembly in ordinary soil**						
	Excavation up to 1.5 m with lead & lift up to 30m & 1.5 m respectively	1	15	10	1.5	225 m³	
	Excavation for next 1.5 to 5 m	1	15	10	3.5	525 m³	
	Excavation for next 5m to 8m	1	15	10	3.0	450 m³	
							1200 m³
2.	**C.C base (1:2:4) including centering & shuttering, finishing & curing**						
	Cement concrete base for pump installation	14	3.0	1.0	0.5	21 m³	**21 m³**
3.	**R.C.C Stand basin for temporary storage R.C.C work (1:1.5:3) including centering & shuttering, smoothing, finishing & curing but excluding reinforcement etc. complete.**						
	R.C.C base	1	5.0	5.0	0.3	7.5 m³	
	R.C.C Side walls	4	5.0	0.3	4.7	7.05 m³	
	R.C.C top slab	1	5.0	5.0	0.3	7.5 m³	
	Total						**22.05 m³**

4.	**Reinforcement Including cutting & bending, binding etc. complete**					
	Top of the base distribution steel 12 Ø @ 110 mm c/c bent up bar	46	5.25	@ 0.888 kg/m	214.45 kg	
	Top of the base main steel 12 Ø @ 190 mm c/c straight bar	27	5.17	@ 0.888 kg/m	119.84kg	
	Top of the slab main steel 10 Ø @ 250 mm c/c straight bars	21	5.25	@ 0.62 kg/m	68.65 kg	
	Top of the slab distribution steel 10 Ø @ 190 mm c/c straight bars	27	5.17	@ 0.62 kg/m	86.54 kg	
	Main reinforcement for side walls 16 Ø @ 190 mm c/c L- shape bars	108	6.13	@ 1.58 kg/m	1046.02kg	
	Distribution steel for walls 16 Ø @ 170 mm c/c straight bars	116	5.25	@ 1.58 kg/m	962.22 kg	
	Total					**2,497.72 kg**
5.	**Ground water recharge well for drainage of waste water**					
	Circular drill of 0.2 m dia. up to 25 m in rocky soil	1	$\Pi/4 \times (0.2)^2 = 0.0314\ m^2$	25	0.785 m^3	**0.785 m^3**

5.2.6 Cost estimation

Table.7 Cost estimation of hydraulic ram pump installation

Item No.	Description	Qty.	Per	Rate (Rs.)	Amount (Rs.)
1.	Ram pump	14 No.	No.	26,53,100	**3,71,43,400**
2.	R.C.C supply pipe of 0.3 m in dia.	3200 m	m	1,720	**55,04,000**
3.	G.I drive pipe of 8" in dia.	196 m	m	1,630	**3,19,480**
4.	G.I delivery pipe of 4" in dia.	60 m	m	1,280	**76,800**
5.	Reinforcement	2,497.22 kg	kg	46	**1,14,872**
6.	Excavation for installation				
	Up to 1.5 m	225	m^3	80	**18,000**
	1.5 to 5 m	525	m^3	110	**57,750**
	5 to 8 m	450	m^3	140	**63,000**
7.	R.C.C pipe for recharge well of 0.2 m in dia.	25 m	m	1,540	**38,500**
8.	R.C.C work	22.5 m^3	m^3	7,000	**1,57,500**
9.	C.C base for pump	21 m^3	m^3	6,200	**1,30,200**
10.	Aggregate for recharge well	3.125 m^3	m^3	1,600	**5,000**
11.	Hole drilling for well	25 m	m	2,150	**53,750**
12.	Nylon mesh for well	6.25 m^2	m^2	450	**2,800**
Total					**4,36,86,000**

5.2.7 Advantages:

- Ram pumps can runs without any kind of external energy like power, mechanical thrust required.
- Hydraulic ram pump can works for very long time that of 100 years.
- Operation cost is very low since it has only two moving parts.
- Ram pump has a unique ability of water lifting up to 150 m.

Figure.16 Hydraulic ram pump

5.2.8 Disadvantages:

- If we looking for this system we need to big compromise with its efficiency that of it is only 10.5 %. We can consider one tenth of total water supply only.
- Waste water coming from the impulse valve is the major disadvantages of this system because it is very difficult for disposal.
- As its capital cost it gives very less output so it can be consider as expensive system.
- It occupies large space at ground as well as underground on river bank.

5.3 Ground water recharge well:

5.3.1 Introduction:

Groundwater recharge or deep drainage or deep percolation is a hydrologic process where water moves downward from surface water to groundwater. This process usually occurs in the vadose zone below plant roots and is often expressed as a flux to the water table surface.

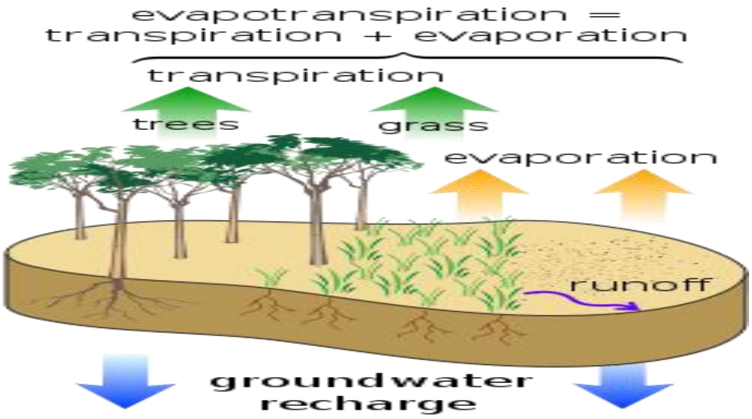

Figure.17 Ground water recharge phenomenon

Groundwater is recharged naturally by rain and snow melt and to a smaller extent by surface water (rivers and lakes). Recharge may be impeded somewhat by human activities including paving, development, or logging. These activities can result in loss of topsoil resulting in reduced water infiltration, enhanced surface runoff and reduction in recharge. Use of ground waters, especially for irrigation, may also lower the water tables. Groundwater recharge is an important process for sustainable groundwater management, since the volume-rate abstracted from an aquifer in the long term should be less than or equal to the volume-rate that is recharged.

Recharge can help move excess salts that accumulate in the root zone to deeper soil layers, or into the groundwater system. Tree roots increase water saturation into groundwater reducing water runoff. Flooding temporarily increases river bed permeability by moving clay soils downstream, and this increases aquifer recharge.

Figure.18 Ground water recharge well

Artificial groundwater recharge is becoming increasingly important in India, where over-pumping of groundwater by farmers has led to underground resources becoming depleted. In 2007, on the recommendations of the International Water Management Institute, the Indian government allocated Rs 1800 crore (US$400million) to fund dug-well recharge projects (a dug-well is a wide, shallow well, often lined with concrete) in 100 districts within seven states where water stored in hard-rock aquifers had been over-exploited. Another environmental issue is the disposal of waste through the water flux such as dairy farms, industrial, and urban runoff.

Generally, it recharge wells are used for water harvesting purpose for future scarcity. But we take this system as storm water drainage in some low lying areas of Surat city where flooding conditions takes place. Due to this solution we can solve water scarcity problem indirectly.

5.3.2 Suitability of recharge well in Surat city

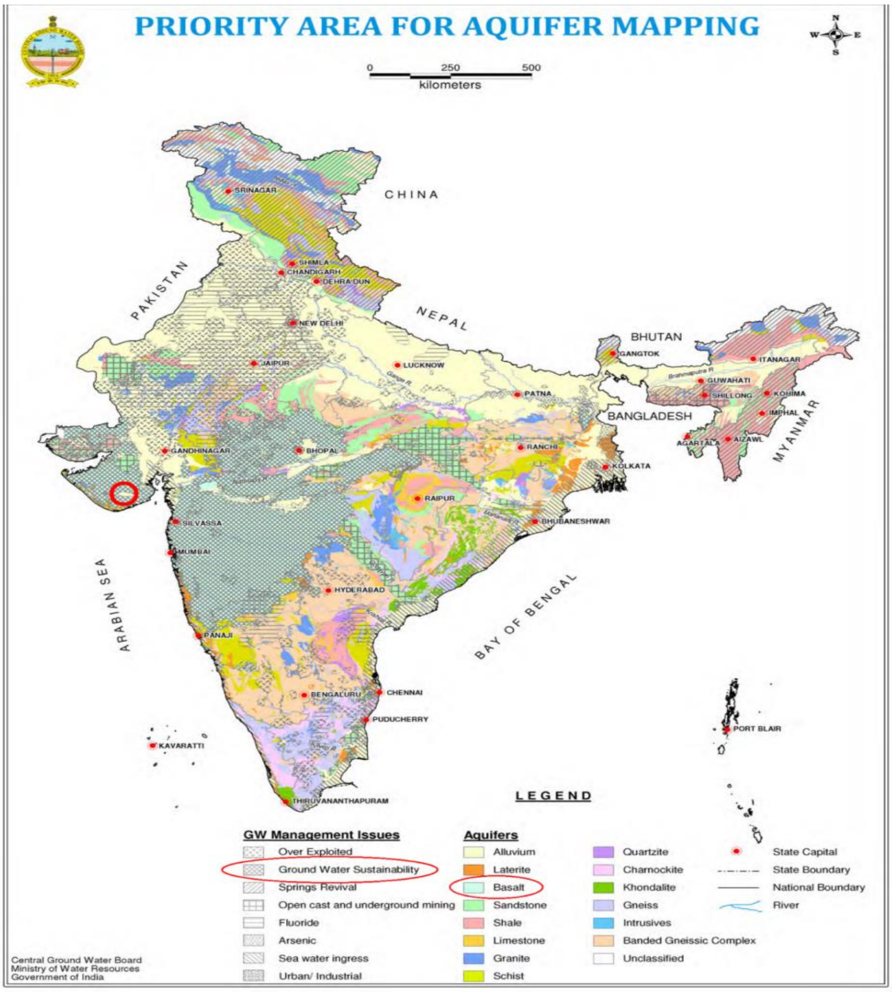

Figure.19 Aquifer system in India

5.3.3 Design consideration:

- Recharge capacity formulae

The recharge capacity of the well is depend upon permeability of the strata, diameter of recharge well & its depth up to available aquifer. Recharge well already constructed at SVNIT College & Panas Krushifarm in Surat city. On the basis of the results of this recharge wells appropriate analytical formulae is carried out that is,

Q = 55 x D x K

Where, Q = Recharge capacity of well in m^3/hr.

D = Diameter of well in m.

K = Co-eff. of permeability in m/hr.

- After the analysis of the recharge capacity of existing wells graph can be carried out on the basis of the formulae given above.

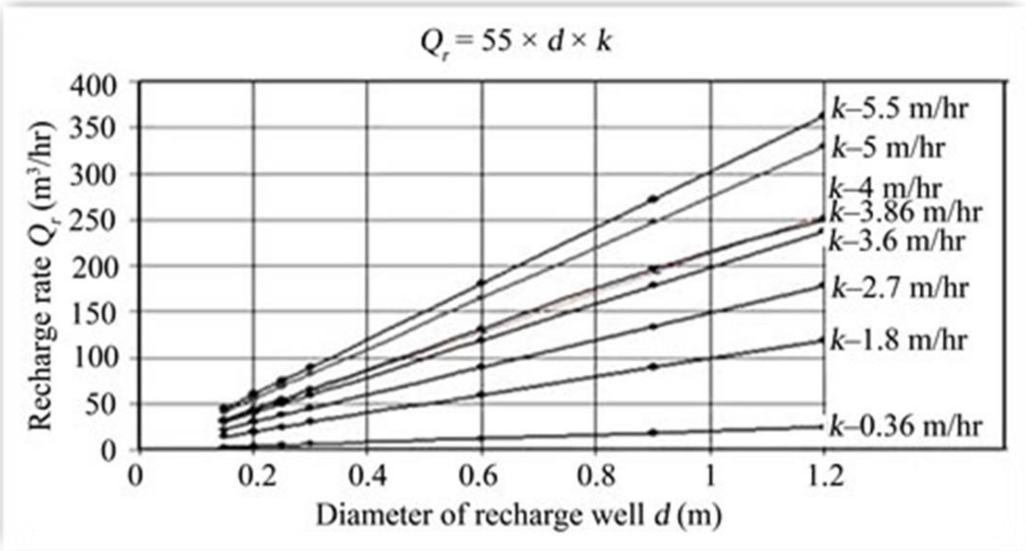

Figure.20 Ground water recharge well capacity

- The capacity of the well is also depends upon permeability characteristics of the material available in strata.

Table.8 Characteristics of Aquifer Materials

Material	**Porosity**	**Specific yield %**	**Permeability km/sec**
Clay	0.45 to 0.55	1 to 10	10-10 to10-6
Sand	0.35 to 0.40	10 to 30	10-5 to 10-3
Gravel	0.30 to 0.40	15 to 30	10-4 to 10-3
Sandstone	0.10 to 0.20	5 to 15	10-11 to 10-8

Table.9 Coefficient of Permeability for Various Sands (USBR Earth manual, I.S. Code 1498)

Type of sand	**Particle size**	**Permeability (km/s)**
Sandy silt	< 75 micron	2 x 10-6
Silty sand	< 75 micron	5 x 10-5
Very fine sand	425 micron	2 x 10-4
Fine sand	425 micron –75 micron	5 x 10-4
Fine to medium sand	2 mm – 425 micron	**1 x 10-3**
Medium to coarse sand	< 4.75 mm	**2 x 10-3**
Coarse sand and gravel	20 mm – 4.75 mm	5 x 10-3

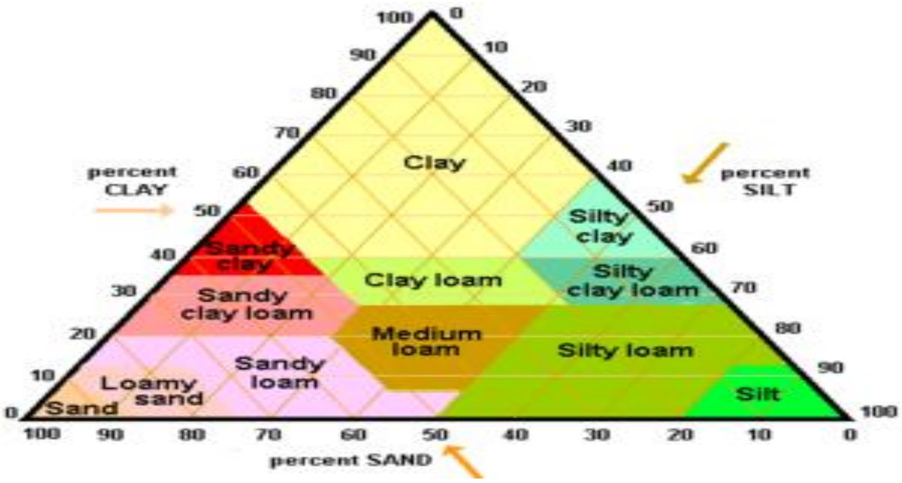

Figure.21 Soil classification

5.3.4 Design calculation:

➢ Locations of the ground recharge well

- Near Dada Bhai Pandya swimming pool, Makkai Bridge.
- Near Chowk Bazar, Chowk Bazar petrol pump.
- Sai temple, rustampura road.
- Kadarshah ni nal, Nanpura.
- Hodi Bungalow, Variyavi Bhagol, Ved road.
- Kshetrapal dada temple, Kailash Nagar.
- Gandhi Baug or Althan garden.

Table.10 Depth of Sand below Water Table located surrounding site

Name of site	**Depth of Sand Strata (m)**	**Depth of Water Table (m)**
Chowk Bazar	28	10
Nanpura	**23**	**11**
Adajan	**15**	**10**
Varachha Road	25	13
Athwalines	21	16
Ring road, Station	32	20
Althan Garden	**21**	**13**
Weir cum Cause way	24	8
Essar – Hazira	30	5
Tapi river - Amroli	30	6
Bhagol, Ved road	**31**	**10**

➢ Total water quantity need to be drain = 20,750.38 lit/min.

➢ Discharge capacity of the well

➢ **Q = 55 x D x K**

= 55 x 0.2 x 1.8

= 19.8 m^3/hr. (Each)

Where, Q = Recharge capacity of well in m^3/hr.

D = Diameter of well in m. (0.2 m)

K = Co-eff. of permeability in m/hr. (Avg. 1.8 m/hr.)

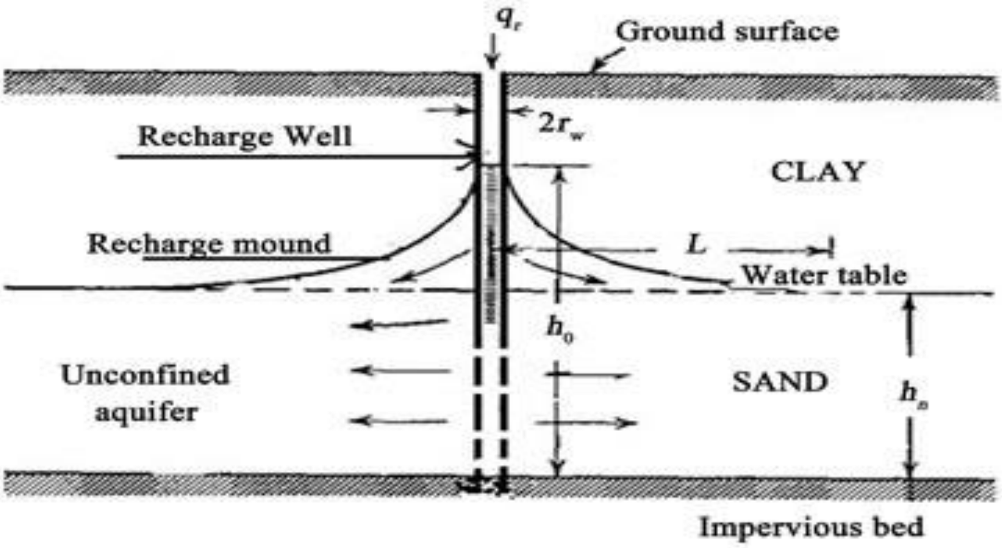

Figure.22 Ground water recharge well with open bottom

- ➢ Dimensions
- Diameter of the well 0.2 m
- Avg. depth of well 40 m
- Cap size 2.5 x 2.5 m

5.3.5 Quantity calculation one recharge well:

Table.11 Material quantity calculation of one recharge well

Item No.	**Description**	**No.**	**L (m)**	**B (m)**	**H / T (m)**	**Qty.**	**Total Qty.**
1.	Drilling a hole for well using reverse rotary drill machine	1	Hole of 0.2 m in dia. Π/4 x $(0.2)^2$ = 0.0314 m^2		40	1.256 m^3	**1.256 m^3**
2.	Brickwork for boundary wall	4	2.5	0.15	0.75	1.125 m^3	**1.125^3**
3.	Gravel layer at top	1	2.5	2.5	0.5	3.125 m^3	**3.125 m^3**
4.	R.C.C pipe of 0.2 m dia. Up to 10 m	1			10 m	10 m	**10 m**
5.	R.C.C perforated pipe of 0.2 m dia. for remaining 30 m	1			30 m	30 m	**30 m**
6.	G.I wire mesh	1	2.5	2.5	-	6.25 m^2	**6.25 m^2**
7.	Nylon mesh	1	2.5	2.5	-	6.25 m^2	**6.25 m^2**

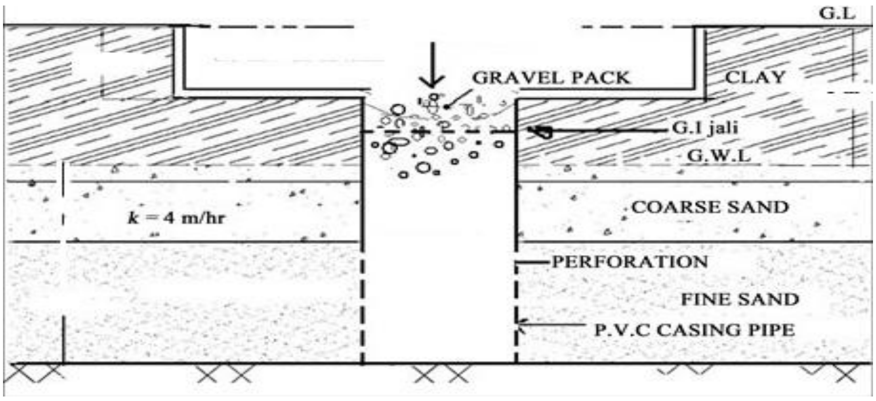

Figure.23 Components of ground water recharge well

5.3.6 Cost estimation of one recharge well:

Table.12 Cost estimation of one recharge well

Item No.	Description	Qty.	Rate (Rs.)	Per	Amount (Rs.)
1.	Hole Drilling	40 m	3,800	m	**1,52,000**
2.	10 m R.C.C pipe of 0.2 m dia.	10 m	1,720	m	**17,200**
3.	30 m Perforated R.C.C pipe of 0.2 m dia.	30 m	2,000	m	**60,000**
4.	First class Brickwork for boundary wall in 1:4 cement mortar	1.125 m^3	2,400	m^3	**2,700**
5.	Gravel layer	3.125 m^3	1,800	m^3	**5,625**
6.	G.I wire mesh	6.25 m^2	1,200	m^2	**7,500**
7.	Nylon mesh	6.25 m^2	900	m^2	**5,625**
Total					**2,50,650**

Figure.24 Construction of ground recharge well

5.3.7 Advantages:

- Artificial groundwater recharge well have the advantage that they can produce water that is hygienically safe and fit for reuse, without requiring extensive provisions for water treatment.
- Recharge well schemes involve measures for infiltration of water into pervious underground formations which can be a major advantage of ground water level improvement.
- Recharge schemes are economically attractive, and worth consideration in some area.
- It can play major role towards water scarcity in future time passage.
- Capital cost is very less in efficiency & capacity point of view.

Figure.25 Ground water recharge well for domestic use

5.3.8 Disadvantages:

- It requires frequent maintenance because of bacterial growth, blockage & other problems.
- There is a potential for contamination of the groundwater from injected surface-water run-off, especially from agricultural fields and road surfaces. In most cases, the surface-water run-off is not pre-treated before injection.

5.3.9 Operation & Maintenance:

Figure.26 Ground water recharge well at public recreation center

Periodic maintenance of artificial recharge structures is essential because infiltration capacity is rapidly reduced because of silting, chemical precipitation, and accumulation of organic matter. In the case of injection wells and connector wells, periodic maintenance of the system consists of pumping and / or flushing with a mildly acidic solution to remove encrusting chemical precipitates and bacterial growths on the well tube slots. By converting the injection or connector wells into dual-purpose wells, the time interval between one cleansing and another can be extended, but, in the case of spreading structures, except for sub-surface dykes constructed with an overflow or outlet, annual de-silting is necessary. Unfortunately, because the structures are installed as a drought-relief measure, periodic maintenance is often neglected until a drought occurs, at which time the structures must be restored (the 5 to 7 year frequency of droughts, however, means that some maintenance does take place). Several agencies and individuals normally carry out structural maintenance.

5.4 Underground pipe network as temporary storage:

5.4.1 Introduction:

The hidden advantage of large dia. R.C.C drainage pipe is that it can play a role of storage of additional storm water also. We can provide more than one pipe network in parallel under the ground. It should be connected with regular drainage line with little more elevation than the regular drainage line. At the junction of drainage line & storage line provision of valve system is must.

Figure.27 storm water storage line

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When additional rainfall occurs the storm water stored in this temporary storage system in case of flood gates are closed. This system is very useful for additional waterlogging, blockage of existing drainage line, repairing of existing drainage system etc.

5.4.2 Design calculation

- Distance available between Hodi bungalow & Makkai Bridge = **3.2 km**
- Diameter of pipe = **2,200 mm**
- No. of line to be laid in parallel = 3
- Valve operation = Ball valve sluice gates are used
- Capacity of storage network,

Volume of pipe = N x A x L Where, N = No. of pipe network

A = Area of pipe

L = Length of pipe

$= 3 \times (\Pi/4 \times 2.2^2) \times 3.2$

$\mathbf{= 36.492\ m^3}$

5.4.3 Quantity calculation:

Table.13 Material calculation of pipe storage system

Item No.	Description	No.	L (m)	W (m)	H/ T (m)	Qty.	Total Qty.
1.	Trench for pipe installation	3	9,600	2.5	3.0	72,000 m^3	**72,000 m^3**
2.	R.C.C pipe of 2200 in dia.	1	9,600			9,600 m	**9,600 m**
3.	Sluice valve	3					**3 No.**
4.	Jointing material Plain cement mortar	9,608	$\Pi/4 \times 2.2^2 = 3.80\ m^2$	-	0.02	730.20 m^3	**730.20 m^3**

5.4.4 Cost estimation of pipe storage system:

Table.14 Cost estimation of R.C.C pipe network

Item No.	Description	Qty.	Rate (Rs.)	Per	Amount (Rs.)
1.	Excavation of trench	72,000 m^3	60	m^3	**4,32,000**
2.	R.C.C pipe of 2.2 m in dia.	9,600 m	8,700	m	**8,35,20,000**
3.	Sluice valve	3 No.	10,51,255	No.	**31,53,765**
4.	Jointing material 1:4 cement mortar	730.20 m^3	1,800	m^3	**13,14,360**
5.	**Total**				**8,84,20,125**

Figure.28 R.C.C pipe of 2.2 m in diameter

5.4.5 Advantages:

- It is very useful when no extra space available at ground surface.
- It can works as stand by drainage system in case of emergency.
- We can divert this stored water to water treatment plant by using of diversion section.

Figure.29 Storm water pipe installation

5.4.6 Disadvantages:

- Capital cost is more.
- In case of improper joint between pipes cause very problematic condition.
- Leakage can creates danger problem
- It can be use only one time because after it fully filled with water no disposal can be possible of additional rainwater.

6. DISCUSSION & FUTURE SCOPE

6.1 Discussion:

In current situation if storm waterlogging from drains takes place it leads traffic on roadways, inflection, and obstruction to routine life of general public etc. Currently during storm water backflow problem pumping systems are used for disposal of excess storm water from low lying area of Surat city. But pumping system is not sufficient to pump large amount of water from at any location also in economical manner it is very costly in purchasing or hiring both. So, current pumping system need some improvements which results permanent solution of storm water drainage system. Hence, we conclude from the study of this problem, storm water backflow needs permanent solution, better storm water drainage facility in any urban area which leads better facility in transportation and routine life of habitants.

In other hand we need to solve this problem by improving existing storm water drainage system. Such as instead of provision of high capacity pump at low lying areas this water is divert to the river bank & than at this location we can provide moderate capacity pump which pump storm water continuously at river bank. We can increase working of this system by providing 24 hour holding tank at particular this location of Tapi to moderate sudden variances in flow of storm water.

We carried out general as well as technical solutions which is most appropriate & feasible for this problem. Some comparison between this three solutions in cost, feasibility, maintenance etc. are as under,

6.2 Comprehensive comparison of all three solutions:

Table.15 Comparison of the solutions

Criteria	Ram pumps	Recharge well	Storage pipe network
Capital Cost	**Rs. 4,36,86,000**	**Rs. 2,50,650**	**Rs.8,84,20,125**
	Moderate	Very Low	High
Feasibility	Fair	Good	Fair
Space Required	Very Large	Small	Large
Operation Cost	Moderate	Negligible	Moderate
Components	More	Less	Less
Size	More	Less	More

As per this comparison conclusion may be appear is that ground water recharge well is the most preferable solution for this problem. Hydraulic ram pump is likely adoptable but it have some serious disadvantages that about of its efficiency, wastewater drainage etc. On the other hand pipe storage network is very expensive for adoption since it is one time useable system. Only the groundwater recharge well have more feasibility in cost, maintenance, size point of vie

6.3 Run offPattern:

Prima facie, the rainfall pattern, storm intensity, days of rainfall, characteristics of catchments such as forest - land use, construction of dams / check dams on tributaries in past 5 years due to severe draught in central Maharastra do not follow trends adopted by Ukai project planners based on data of pre 1968. Pending a total studies of hydrology and storms, effect of number of reservoir, old model must be stayed from forecasting runoff and pattern of daily inflow.

The total 25,000 sq.miles drainage basin with range of 30" to 96" per year rainfall in average 60 rain days per year indicate minimum of 600 to maximum 1700 MCM runoff per day. For August first week with rainfall of 60 mm/day on average in East & West Khandesh (23360 sq.miles catchment) predicts 2500 MCM runoff.

The detailed analysis of sub-basin model for Tapti catchment on day today basis with travel time to Ukai from 24 to 12 hrs can be worked out and calibrated for factual data of past floods. (1972 – 2006) In short, commonsense simple assessment with factor of safety, gave 2000 MCM inflow in August 4 – 5th 2006. Monsoon 2006 was predicted as Normal by IMD hence to assume no rains in Aug, Sept, Oct is illogical and unscientific. The SW monsoon was late by 2 weeks. Data base of Meteorological Storm of 1968 Aug 2 – 7th (P.S. Pant 1968) predicts heavy inflow.

7. RESERVOIR DATA

7.1 Large 8.5 Lac ha.m (almost same capacity as Bhakra) extending 112 km from dam has spread of 614 sq.km area. The storage for power for tail dam will be available till Maharastra utilized its quota. Some relevant approximate data is tabled below to understand characteristics and operations.

Table.16 Showing total storage capacity (Dead storage 860 MCM)

RL (Ft.)	Capacity (MCM)
331	5690
333	5940
340	6840
345	7500
351	8270

Table.17 Showing approximate flood cushion between different reservoir levels

Range	Flood Cushion (in MCM)
331'-345'	1800
331'-349'	2320
345'-351'	770
329.5'-345'	2000
336.5'-351'	2000

The Ukai Reservoir Level (URL) 330'and 334' are adequate for irrigation and power production for the year (CWC – Hydrology Organization, 2000). As per design estimates minimum level required in 1st week of Aug for irrigation and power needs is 324.7' only.

7.2 The reservoir operations have been dictated by a mannual giving storage level on each week considering irrigation & power requirements. This secret rule book prepared & revised since 1980 has following principles:Before Aug 31st – URL below 339'

31 Aug to 30 Sept raise URL by 0.2' per day to reach 345'. It is understood that MWL in high floods will be 351' (designed). The press conference report shows that filling to 345' ill be attained after 1st Oct (PIL 1998 floods).

The partial flood protection to downstream areas the releases are to be moderated to 8.7 Lac cusecs (24620 cumecs) and in very high floods URL will be allowed to MWL 351' for short period. The data analyzed in Table below for 1998, 2001, 2002, 2006 shows clearly breaches of rule book to conserve more water thereby increase probability of floods downstream.

7.3 The data available for floods of 1998 is analyzed as under:

Table.18

Date	Max. URL* as per Rule Level (1979)	Actual observed URL*	Outflow (not more than 7 L cusecs)	Inflow	Flood Level at Weir (Surat)	Flood Level at Hope Bridge (Surat)
	in ft.	**in ft.**	**in Cusecs**	**in Cusecs**	**in mt.**	**in mt.**
15.09.1998 (2.00 pm)	342.00	**342.50**	4,00,000	4,84,000	-	1.8
16.09.1998 (2.00 pm)	342.20	**345.08**	5,30,974	9,01,234	12.1	9.6 (> 9.5)
16.09.1998 (11.00 pm)	342.20	**345.88**	6,98,200	-	12.5	**10.3 (> 9.5)**
17.09.1998 (6.00 pm)	342.40	**345.03**	3,05,864	1,49,774	13.8	**11.5 (> 9.5)**
21.09.1998 (11.00 am)	343.20	**345.49**	21,820	35,000	7.0	2.4
23.09.1998 (11.00 am)	343.60	**344.80**	2,30,130	2,95,000	9.2	5.3

* URL: Ukai Reservoir Level

The rule book level for data available shows:

a) Rule book is ignored in operations

b) Tendency is to conserve extra water even risking Ukai maximum RL 345' and Surat protection, Hope Bridge safe level 9.5 m.

c) If anticipating rainfall trends on 13 – 14 - 15.09.1998, rule level was violated to lower flood level by releasing floods upto 7 L cusecs gradually, Ukai reservoir will not touch 345'. Surat, Hope Bridge will also not exceeded danger level 9.5 m ± 0.5 m.

7.4 The rule level for year 2001 as per flood memorandum 2001 (NWR & WSD) (Pg - 26) flood control cell is as under:

Table.19

S.No.	Name	FRL	Tentative Levels as on				
			01/07/01	**01/08/01**	**01/09/01**	**16/09/01**	**01/10/2001**
		in mt. (in ft.)	**in mt. (in ft.)**	**in mt. (in ft.)**	**in mt. (in ft.)**	**in mt. (in ft.)**	**in mt. (in ft.)**
34	Ukai	105.15	97.85	101.5	103.63	103.63	105.15
		(345)	(321)	(333)	(340)	(340)	(345)

(This reduced level may be result of PIL in High Court during 1998-99)

Following table is for year 2002 flood (Reservoir operation rule level 2001)

Table.20

Date	**Max. URL* as per Rule Level (2001)**	**Actual observed URL***	**Outflow**	**Inflow**	**Flood Level at Weir**	**Flood Level at Hope Bridge**
	in ft.	**in ft.**	**in Cusecs**	**in Cusecs**	**in mt.**	**In mt.**
03.09.2002	340.00	333.20	16,695	3,57,858	4.73	-
07.09.2002	340.00	**341.07** **	2,34,061	2,34,061	10.64	8.10
17.09.2002	340.20	**340.80** **	22,444	12,850	6.54	1.50

* URL: Ukai Reservoir Level

** Rule book violated for extra storage.

Here again rule book is not followed to conserve extra water. Ofcourse, the operations did not encounter high flood and hence Ukai level was less than 345' and level at Hope Bridge for flood protection was below danger.

7.5 Rule book memorandum 2003 is cited by some authorities, we could not lay over hands to the document. The rule level s prescribed for 1st July to 10th of Oct (daily) for conservation of flood. It does not prima-facie, consider safety of Surat Maximum hope bridge level, RL: 9.5 m). Thus on 3rd Aug, a rule level of 333.45 is prescribed on basis of water requirements of irrigation & power and conservation.

The following table will indicate that even this rule book was not operative in 2006.

Table.21

Date	**Reservoir level as per rule book 2003**	**Reservoir level as per rule book* as operation manual cited by CWC**	**Actual Reservoir level in 2006**
	in ft	**in ft (in mt)**	**in ft**
31st July 06	332.61	-	-
1st Aug. 06	333.00	333.00 (101.50)	331.54
3rd Aug. 06	333.45	-	**334.44**
5th Aug. 06	333.90	-	**335.42**
7th Aug. 06	334.35	334.85 (102.06)	**342.98**
10th Aug. 06	335.03	-	**345.17**
15th Aug. 06	336.15	338.30 (103.11)	336.14
20th Aug. 06	337.27	-	331.00
1st Sep. 06	340.00	343.00 (104.55)	-
1st Oct. 06	345.00	-	-

* The level prescribed by Chapter 9, Pg 137 – 215 of operation manual July 2000 as refered by CWC. It appears that this rule levels were probably revised to account for reduced flood capacity of river at Surat. These levels are also shown in table. In both cases of rule level, whatsoever is applied / valid on 3rd Aug. onwards, the tendency was to fill above prescribed level to store more water. Outflow could have been increased over the inflow to keep URL lower than rule book (333' / 332') as a special case when high storm intensity rain fall was reported in catchment by press on 3rd – 4th Aug. 06. Such advance release could have kept URL to be below 345' and floods released suddenly on 10.08.2006 to Surat would be nearer to safe limits (Hope level 10.0 to 11.0 m)

7.6 Though emphatically stated by Gov. in special petition 190/1974, Para 13 / pg 7 and Para 13 / pg 7 the 1235 MCM flood cushion for flood between FRL 345' and

351' has never been availed by releasing all incoming flow even higher than 8.7 L with Pala to Surat. Thus officially though, there is no danger to dam, MWL is now 345' only.

There are 28 years when Ukai reservoir never touched 345' out of 36 years and hence following rule book may not create crisis for irrigation and water supply. The state has to be prepared for non-availability of storage even for power with upstream use of allotment of resources (by say 2010 – 12).

The rule book with slight conservative approach, with storage loss for power, would have prevented disaster to Surat as explained latter. As rule book is not followed nor made transparent and operation since 1998 of reservoir indicates non-consideration of constraints of not releasing more than 6.5 L cusecs (Pala incomplete), it needs to be scrapped. The divided responsibilities of gauging, measuring inflow, forecasting of next day inflow, interpreting of direct rains in reservoir, deciding the outflow by project authorities with approval of ministers (as per press reports) needs to be streamlined. The operations have to be transparent and responsibility assigned to a specific, say "Tapti Valley Authority". Authority will be decide and will be working with team of advisors of IMD, CWC, District Administrator of Disaster, Flood management local experts, representatives of affected citizens, HADA industries etc. During flood, video conferencing, open to public view by media, daily is recommended. This only can reestablish confidence in operative system. This approach can permit consideration of National economic loss against gains of irrigation & power by more storage by authority.

8. UKAIRESERVOIRLEVELHISTORY

Last 5 years levels of Ukai reservoirs are:

Table.22

Year	Max. URL (Ft.)	Min. URL (Ft.)
2001	322.44	272.11
2002	341.26	280.95
2003	343.81	294.60
2004	331.95	288.76
2005	342.20	276.68
2006	346.30	

The URL maximum and minimum are 346.3' and 320' for years 2006 and 1985 respectively.

Thus URL not reaching FRL is common and likely to be permanent in future with upstream utilization by Khandesh of their quota.

9. OPERATIONS OF RESERVOIR DURING FLOODS

As explained in functions of dam the inflow is moderated for flood by restricting out flow to 8.5 L cusecs and allowing FRL to touch MWL 351' (Para 3.0). Though 1970 flood of 15 lac cusecs operation, has protected Surat from floods (Para 3.0), system has failed to protect areas downstream in 1998 & 2006. The primary analysis shows overall intension to store more water for irrigation, power & water supply in recent years. Dam authorities tend to keep high storages at dams like Ukai for maximizing power generation (Indian express, News)

The flood cushion with MWL - 351' has never been availed by the project. The officials confirmed that dam is safe for design flood level. The panicky release high flood on URL touching 345' is unexplained and has led to phobia that dam is unsafe if flood level touches design maximum level of 351'. This revised mode of operation results in loss of 770 MCM of flood cushion. The rule book seems to have ignored this and guidelines of not filling reservoir above 340' till end of monsoon by Gov. High court (PIL 1998 flood – press conference report)

10. FLOODS2006

The flood moderation requires following estimates / data,

(a) Initial reservoir level,

(b) Expected rainy days and expected runoff in catchment,

(c) Constraints of maximum outflow for flood control at Surat with Pala's incomplete,

(d) Minimum storage for committed irrigation & power,

(e) Powers to decide sacrificing one or two functions for overall socio- economical national interest,

(f) Maximum water level for the reservoir designed, safe and operational, (g) Changes in hydraulics of flood channel since construction of dam,

(h) Changes in the environment of catchment basin – rain period, intensity of storms, deforestation of basin, land use and activities of storage / check dams,

(i) Loss of storage by silting.

In 36 years since completion of dam many of above parameters have been drastically changing irregularly every year. These parameters need continuous monitoring and analysis to evolve strategy of flood control. Thus guidelines with critical data, daily in monsoon, in standard format will be monitored and reviewed by experts on video conference to arrive at best timely economical plan of operation for each flood cycle. This cannot be done by divided authorities bound by static rules laid down for data pre 1970-75, in time available.

For Ukai 2006, Ukai Reservoir Level on 1st Aug was 331.54'. The river in flood plane has been seriously constrained as seen from Table below for safe flood of 8 Lac cusecs.

Table.23

Period (Activity)	Hope Gauge level for 8 L cusecs flood (in m)	Hope Gauge level for 10 L cusecs flood (in m)
Pre 1970 (no dam)	9.7	10.5
1970 – 1980 (Dam + Partial Pala)	10.8	11.8-12.0
1994 (Singanpore Weir + More Pala + Rly Embankments + HADA land development, Urban Growth)	11.6 to 12.0	13.5 to 14.0
1998 (Actual)	11.5	-
2006 Regulators on drains + some more Pala	12.0	

The earlier floods of July now tends to Aug – Sept period, with upstream water use it may shift to Sept – Oct. The rule book was violated to store more; not allowing MWL beyond 345', is seen from the flood outflow to Surat on 07.08.2006, 8.00 hrs exceed 8.5 L cusecs limit.

The options would be to a) allow flood flow storage to 351' and pray to god for rains to stop or b) release inflow totally to maintain 345' for 8th to 10th. The 10 L suddenly released at Surat on 08.08.2006 against safe flow of 7.5 cusecs (8.5 L with Pala, 6.5 no Pala) with partial Palas caused affluxed flood level of

12.0 m (Safe 9.5 m) to 13.0 m at Surat. This level toppled flood protections designed & under execution. Even banks spilled the water at Jahangirpua, Ved, Katargam, Variav, Bhatha, Magdalla etc. This unexpected fast flow of spills caused severe damages to city and surrounding.

This back water, through rivulets or storm drains manholes to Tapti entered city areas never flooded in the past. The unpredicted flood level breached walls and Palas near Dutch gardens. Water found entry into city posh area through storm water drains.

11. RESERVOIR OPERATIONS (FEASIBILITY OF CONTROLLING FLOODS AUG - 2006)

11.1 Rainfall:

The data of news 4th, 5th, 6th Aug. web site, gauging of CWC shows second cycle of heavy rainfall with storms / local rains as high as 200 mm/day in some districts of catchment basin of Maharastra.

The data of 04.08.2006 for Maharastra basin is predicted as 700 – 800

MCM. This will be reaching Ukai reservoir on 05.80.2006. The forecasts of IMD, BBC Setellites observed indicate trend of continued heavy rains. The anticipated inflow in Ukai was 1400, 3300, 800 MCM on safer side.

Table.24

Date	Rainfall recorded in basin in Maharastra Estimated Rains (mm/day)	Runoff to Ukai Reservoir	Date of reach at Ukai Reservoir
04.08.2006	30-40	700	05.08.2006
05.08.2006	80	1400	06.08.2006
06.08.2006	140	3300	07.08.2006
08.08.2006	30-40	700	08.08.2006

In Aug 1968 similar heavy rainfall pattern was recorded

11.2 Based on the data with conservative inflow predictions the reservoir operation is worked out. For a total run, our estimate of flood cushion for changed topography, river regime & flood vagaries, of 2000 MCM has been adopted. Thus the reservoir on 3rd Aug will be kept at 330' maximum by releasing extra inflow.

The table is worked out for Ukai MWL 346', as authorities have never availed MWL design 351' in past. It was presumed that Sept rains are good.

11.3 The table below is official record of flood 2006 with URL and uncontrolled out flow to Surat to control URL to 345' as MWL.

Ukai dam Regulation Aug 2006 flood (official reports)

Table.25

Sr. No	**Date**	**Inflow per day (MCM)**	**Outflow Per day (MCM)**	**Total Storage at 24.00 hr (MCM)**	**Flood Cushion (MCM)**	**Reservoir Level (Feet)**
1	04/08/06	137	59	6204	1294	335.06
2	05/08/06	128	82	6250	1248	335.42
3	06/08/06	662	445	6467	1031	337.12
4	07/08/06	2274	1511	7230	268	342.98
5	08/08/06	2516	2158	7588	-90	**345.65**
6	09/08/06	1951	1891	7648	-150	**346.05**
7	10/08/06	1315	1441	7522	-24	**345.17**
8	11/08/06	753	850	7425	73	344.45
9	12/08/06	589	545	7469	29	344.78

Remarks:- Outflow: 8.5 L cusecs, URL > 345', Hope bridge Max. Flood Level: 13.0 m

Note:- FRL: 345', MWL: 351', Storage at FRL: 7498 MCM (gross)

11.4 If advance prediction of rainfall (Para 10.1) as proposed by authors is used the operation of advance release, etc. is illustrated in table below

Table.26

Sr. No	Date	Inflow per day (MCM)	Outflow Per day (MCM)	Storage Per day (MCM)	Total Storage at 24.00 hr (MCM)	Flood Cushion (MCM)	Proposed Reservoir Level (Feet)
1	04/08/06	Collect data, analyze and decide for 3 - 4 rainy days entering Ukai on 5th, 6th, 7th, 8th Aug			6204.0	1294	335.06
2	05/08/06	700	1000 #	-300.0	5904.0	1594	332.69
3	06/08/06	1500	1500 #	0.0	5904.0	1594	332.69
4	07/08/06	2600	2000 ##	600.0	6504.0	994	337.44
5	08/08/06	2600	2000	600.0	7104.0	394	342.19
6	09/08/06	700 ###	1500	-800.0	6304.0	1194	335.85
7	10/08/06	700	1000	-300.0	6004.0	1494	333.48
8	11/08/06	700	700	0.0	6004.0	1494	333.48
9	12/08/06	700	700	0.0	6004.0	1494	333.48

Advance releases to accommodate inflow watching URL TO 333’

Restricting outflow to maximum 8.5 L cusecs

Decreased inflow (rainfall 7 - 8th) decrease outflow to maintain URL 333’

All the design obligations could be fulfilled with minimum disaster by flood.

The requirements of anticipating the rainfall and runoff, 3 - 4 days in advance was achieved by using the weather forecasts of IMD, BBC, CNN etc. & judgment. The process will have to be continued till end of monsoon (21st Oct 2006) for every cycle of the rain.

12. ACTIONS TO PREVENT FUTURE FLOODS

12.1 The present system of CWC and Ukai management Authority in operating the reservoir has failed in 1998, 2006 to,

a) Ensure URL below 345’ FRL (= MWL),

b) Protect the promised 1057 sq.mile from floods by outflow not more than 7 L cusecs (for incomplete Pala),

c) Construct complete Pala yojana inaugurated in 1971 and ensure safety by maintenance and inspections every monsoon,

d) Provide disaster management and scientific specific warning in time to flood prone areas.

Thus present system and its interpretation failed repeatedly. There is enough ground therefore for rethinking.

12.2 The revised procedure with transparency and flexibility, coupled with specific responsibility, is possible by delegating powers to a Valley Authority with team of advisors on Video conference. The team shall include Hydrologist, IMD expert on rain-forecast based on settelite images, CWC - gauging & discharge data collector or with better auto non-power dependent quick communication system, disaster and warning management authority at Surat, Socio-economic experts to assess financial impact etc. This authority, can, in National interest decide against conservation or power needs of water as well as control all parameters influencing drainage of flood of river valley.

12.3 If the trend of reduction in flood drainage capacity is uncontrolled, it could, over years, make flood moderation to impossible stage. Valley authority will have to freeze flood plane and develop schemes of diversion, conserve for desalinization of coast-lands and future sweet water requirements.

12.4 The dredging of mined river for sand and raising of flood bank for partial flood protection downstream are illusions.Back water & breaches of raised bunds in alluvial deposits by piping cannot be prevented economically.

12.5 The R & D studies have lot of scope to evolve strategy for availing more time say preferably 4 days before flood enters the URL to plan advanced safe release to attain minimum required URL of 330'. This seems feasible with use of weather forecasting and special fast communication systems, when losses runs to tens of thousands crores & more, such tools become inevitable & viable.

12.6 In technologically advanced era 2006 rule book, non-application of mind to facts of rains expected and releasing suddenly all floods to city of 30 Lac as URL touched FRL is non engineering and illogical. The individual authority even if the desires has no powers to act in National interest or economic evaluation of benefits of power & conservation of storage in August vis-à-vis torture to 30 Lac citizens, individual loss of 30,000 per capita on average. Losses to industry Hajira, Textile, Diamond etc. in terms of assets and production loss runs into twenty of thousands crores. A need therefore arises to evolve an authority to manage river valley floods, flood plane and drainage of flood areas.

12.7 For projects in extended city and industrial zones, including 2020 development plans for city, extensive study was referred to CWPRS (2000) to examine Ukai moderation and flood diversion. Urban planning and flood warning to downstream area including city can be developed to make every individual to decide flood problem for himself. Release of 6, 8, 10 L cusecs at Ukai can give warning sirens (non power dependent) with flood mark of expected level on electronic / phone pole near by. Mock pre-monsoon practice can minimize losses and panic. It helps disaster management much better. I.T. / Remote sensing / ISRO settelite images & forecasts can revolutionize flood management.Warning like go upto 20' for safety is no warning for city with 0 to 20' depth of flood.

12.8 Rethinking on storm drains - overall drainage of city & flood plane is need of the hour. The flow from breaches and backflow from the end of embankment for protection can spread to all unexpected areas in city.