Model Scheme For Water Harvesting in Industries

Contents

1. Introduction

One of the basic needs of an Engineering Industrial park is the requirement of water and the availability of water resources in the area. A study is carried out to estimate the total Storm water that would be available in the area and the water harvesting structures feasible so that the major requirement of water is met within the area it self.

A detailed hydro geological survey has been conducted in the area. The required secondary data from Government, Semi Government and various other agencies were collected and also the local information is collected from the discussions with local people. The area is covered by alluvial formations underlined by Deccan trap basalts. The alluvial formations have a depth of about 30 to 40 m below ground level, subsequently underlined by Deccan Basalts. The groundwater levels occur to a depth of 15 to 25 m in different seasons. The quality of groundwater is potable with an average of 1400 ppm.

The soils are mainly alluvial and texture of the soils fall in clayey loam where the permeability is very low of the order of about 0.05 mm/day and the infiltration rate is only 6.35 mm/ hr.

1.1 Physiography, Relief and Drainage

- Physiographically the area of *** taluka falls under the alluvium of Vishvamitri River and its tributaries. Erosion has caused several striking features in the landscape of this taluka. The process of deposition is observed on the river banks.
- The overall drainage pattern of the area is dendritic to sub-dendritic and the area is drained by the rivers Vishvamitri, Surwa, Dhadhar from east to west. The Sayaji Sarovar, from which water is distributed to Vadodara city, was excavated in the northeast of the taluka near Ajwa village on Surva River. The rivers passing through the area are not perennial and mostly serve as drainage outlet during monsoon. Ground water is inadequate and slightly saline. The rain water as surface run off in collected
- The project area is situated on the alluvial plain between Viswamitri and Dev rivers.

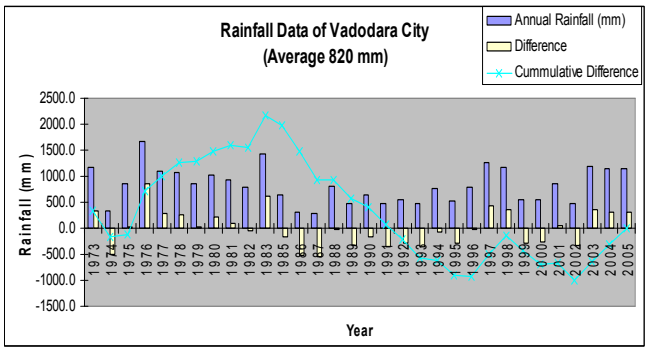
1.2. Climate

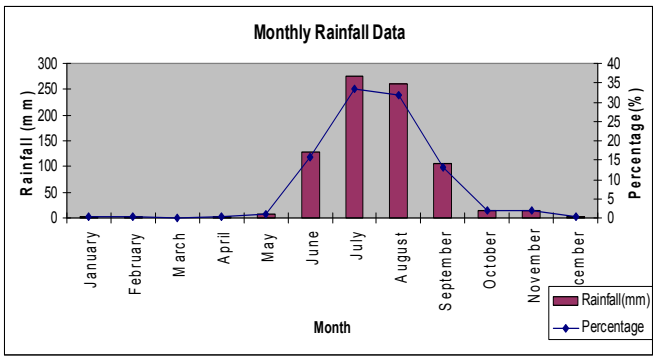
- The area experiences tropical humid to sub humid monsoon type climate characterized by three well defined season's viz. monsoon, winter and summer. The annual rainfall data of Vadodara for 30 years is collected. The weather data and monthly rainfall data of Vadodara have also been collected; the same is adopted for various analysis for water budget.

1.2.1 Rainfall data:

- The annual rainfall data of Vadodara is collected from 1973 to 2005. The monthly rainfall data for Vadodara is collected from 1973 to 2005.

- The annual and monthly rainfall data of Vadodara is plotted as above. The cumulative rainfall differences indicate that the rainfall is above normal from 1976 to 1990 and below normal since then. The average rainfall of Vadodara is about 820.0 mm.
- The monthly rainfall pattern indicates that the rainfall is only during June to September and the maximum rainfall falls in the months of July and August. The monthly rainfall data is given below.





Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Rainfall (mm)	Junto Jul
Rainfall (mm)	3.3	1.9	0.1	3.0	7.6	128.7	275.	260.	106.7	15.2	15.7	2.8	820.	770.4
Percentage	0.4	0.2	0.0	0.4	0.9	15.7	33.5	31.7	13.0	1.9	1.9	0.3		94.0
No of rainy days						2.0	10.0	11.0	9.0	1.0				32.0

- The maximum rain fall is in the months of June to September. About 94% of rainfall falls in this period with 32 days of rainfall out of total 33 days. The water conservation has to be done in these few days only.

2. Soil

2.1 Soil of Alluvial Plain of Mid Land

- The soil of these units is level to very gently sloping with slope gradient ranging from 1% to 3% and flat topography. The soils are deep to very deep, very dark grayish brown to dark yellowish brown and yellowish brown, poorly drained, alluvial clayey soils dominated by basaltic sediments and calcareous and non calcareous in nature. These soils are cracking and non-cracking in nature. Wide and deep cracking is due to high shrinking and swelling property of soils known as “Black cotton soils. They are generally non-porous.

2.2 Soils in the study area

The soil analysis of about 20 trial bores drilled indicate that the soil is Clayey loam, with a field density of 1.63 to 1.66 gm/cc for a depth of 3 m to 12 m. The soil moisture content

is gradually increasing from 11.6 to 21.6% from 3 m depth to 12 m depth. There is not much variation from 9 to 12 m depth below ground level. The specific gravity of soil is of soil is almost constant at 2.6. The sand content varies from 21 % to 34 % for different depths, but broadly the soil falls in the category of clayey loam.

- The permeability of the soils is very less and is in the order of 0.0518 mm /day for a depth up to 1.5 m and is 0.056 mm/day for a depth of 3m. The slight increase in permeability is due increase in sand content of soils beyond 3 m depth. The infiltration rate for installing drip and sprinkler irrigation systems for the soils is in the order of 0.25" /hour (6.35 mm / hour). If it is designed more than the above, there will be over flow conditions in the area.
- Major part of the soil fall in the category of clayey loam indicating that the infiltration is very less of the order of 6.35 mm/ hr and the permeability is of the order of 0.05 mm per day.
- The distribution of texture of soils in the area is also studied. The contours drawn in the area indicate that the major area has a sand percentage of about 20 %, except in the North East corner, where it is about 40%.

3. Drainage

3.1 Storm water (Rain Water) disposal system

- A centralized system for rain water disposal is required. The rain water collected on various buildings, open areas and roads to be collected and disposed off as per the standard engineering practice and local regulations.
- Rain water harvesting system including collection chambers, recharge bore wells and other components have to be considered while designing the system.
- If possible, recycling of rain water is to be considered in designing phase. The recharged water can be used for gardening purpose and/ or for use in toilet flush.
- Open areas shall be such designed that there is no water accumulation in any case and the water is automatically drained towards the discharge points.
- The system shall consist of all necessary underground piping network, chambers etc.
- The system shall be designed considering natural flow of water due to gravity.

4. Hydrogeology

4.1 Geology

- Major portion of Vadodara district in western part is covered by thick pile of alluvium.
- The geological map of the Gujarat indicates that the whole of Vadodara is consisting of alluvial formations except East of the Study area, where Deccan Trap formations are exposed. As such, the alluvial depth is very shallow in the order of 30 to 40 m resulting in poor aquifer material of clay and silty clay. The hard rock is exposed in the wells in the around a depth of 35 m.
- The depth of the various geological rock formations occurring at various depths is given below:

Sr. No	Formation	Thickness of layer
1	Alluvium, (Clayey loam)	0- 27 m
2	Weathered Basalt Mixed with sand	27- 33 m
3	Basalt (Hard and Jointed	33-50 m
4	Basalt (Hard & jointed)	50- 60 m
5	Basalt Hard Massive with occasional fractures	>60 m

4.2 Water Levels:

- The depth of water levels in the area is about 8 to 15 m in monsoon and about 15 to 25 m in summer. The same is shown below both in pre monsoon and post monsoon periods.
- A few bore wells have been drilled up to a depth of 20 m and collected various soil samples as well as depth to water level in these wells. Accordingly, the depth to water level map of this area is drawn. The same is shown in graphs below.

- The data indicates that the west and North east of the area is having shallow water table showing that the groundwater contours follow the topography.

4.3 Ground water Development

- The ground water potential of *** taluka is safe and categorized as White due. This indicates that groundwater can be exploited in the *** taluka. The details of the same are as well as critical and semi critical blocks indicating the groundwater development of Vadodara district is also shown below:

4.4 Aquifer Characteristics

- The data from the bore wells drilled for irrigation indicate that the depth of the wells range from about 48 to 54 m and the discharge of the wells are in the range of about 2.5 to 3.3 lps. The specific capacity of the wells is 2.5 lpm /m drawdown to 6.9 lpm/ m drawdown. This indicates low permeability of the aquifers. The Transmisivity of the aquifers range from 150 m2/day to about 300 m2/day with a specific yield ranging from 0.05 to 0.1. Looking into the hydro geological conditions of the area, the specific yield of the formations is considered at the lower end of the range of 0.05. The low specific yield values are considered as the overlying soil is mainly clayey loam and the underlying Deccan basalts are hard rock formations.

4.5. Geophysical Studies

- A geophysical study of the area has been done. The profile of the area is drawn by Vertical Electrical Sounding (VES) method by sending the electric current into the earth and receiving the same at specified intervals. This helps in estimating the resistivity of the soil and locating the bore wells both for recharge as well as for regular use. Based on the study, the following bore we ll sites were recommended at the different plots. The locations are as under. Bore wells can be drilled at Survey No 39, 189 (3A & 3B), 182 (3B, 3C), 19, 20, 231/A (2B). These bore wells can be drilled by the plot owners

subsequently. The depth of the bore wells would be about 60 m with a diameter of 200 mm. The expected yield is about 200 lpm for about 6 hours pumping.

5. Water Resources of the Area

5.1 Water Demand

- The water demand for the area is estimated to about 2000 cum/day that is 730000 cum (0.73 mcm) per annum for processing and domestic use.
- The total Maximum annual demand for landscape would be in the order of about 129613 cum /year @ 30" requirement for the 10 % of the area. This will be modified after the details of Landscaping are more clear. Thus the total requirement would be 858613 cum.

5.2 Supply side

- The total area of site is: 170 ha
- Average rainfall considered for vadodara: 820 mm
- The total rainfall falling in the area is: 1395000 cum
- The water harvested from roof top: 191141 cum (13.7 %)
- The water harvested in ponds: 177288 cum (12.7%)
- The groundwater recharge due to roof top and surface water pondage: 101547 cum (7.3 %)

The above data of demand and supply is analyzed vis-à-vis the total requirement and also the detailed water harvesting methods for storing and using and conserving the water.

The summary of the details are given in the following table. The detailed calculations are given in the annexure.

Summary of water harvesting				
Water requirement For processing and Domestic Use (cum)			720000.00	% of water saved
Water req For Landscape irrigation (cum)			129644.73	
Total water requirement (cum)			849644.73	
Cost of water @ Rs 8 /cum per year(Rs lakhs)			67.97	
Water saved from Roof top- A			191141.20	13.7
Water saved from surface storage- B			177288.68	12.7
Groundwater rech				
	Roof (cum)	39496		
	Surface (cum)	62051		
	Total Groundwater recharge (cum)	101547		7.3
	Recoverable rech -C		50774	33.7

	Total water saved (A+B+C)		419203.51	
	Saving of water @ Rs 8 /cum per year (Rs lakhs)		33.536281	
	Cost of investment @Rs 100/cum-(Rs lakhs)		419.20351	

5.3 Recycled water

- 18000 cum/year sewage will be generated at the project site, giving a daily average of 60 cum of wastewater considering 300 working days. This water would be used for landscape and other uses
- Water will be sourced from Narmada water from nearest canal
- The maximum demand for design of lift irrigation scheme for the Narmada canal would be about 3000 cum/day. The annual estimate is about 1095000 cum(1.095 mcm) per year

6. Water Harvesting

6.1 Water harvesting structures

The possible water harvesting structures both for roof and surface water harvesting are discussed and brief description of the same are indicated.

6.1.1 Series of Check dams/ Nalla bundings

- The area is drained by a stream coming from north West corner of the study area and flowing towards south of the area. The stream is meandering all the western part of the study area and has an approximate length of 3450 m. As the meandering is quite eating into the productive area of Industry, the management wants to train the stream to some extent and making as straight as possible, without in any way disturbing the ecology of the area. Accordingly, about 7 check dams were proposed to construct on the newly designed channel. The details of the same are shown below. The location of the check dams are shown in the Map (Annexure)

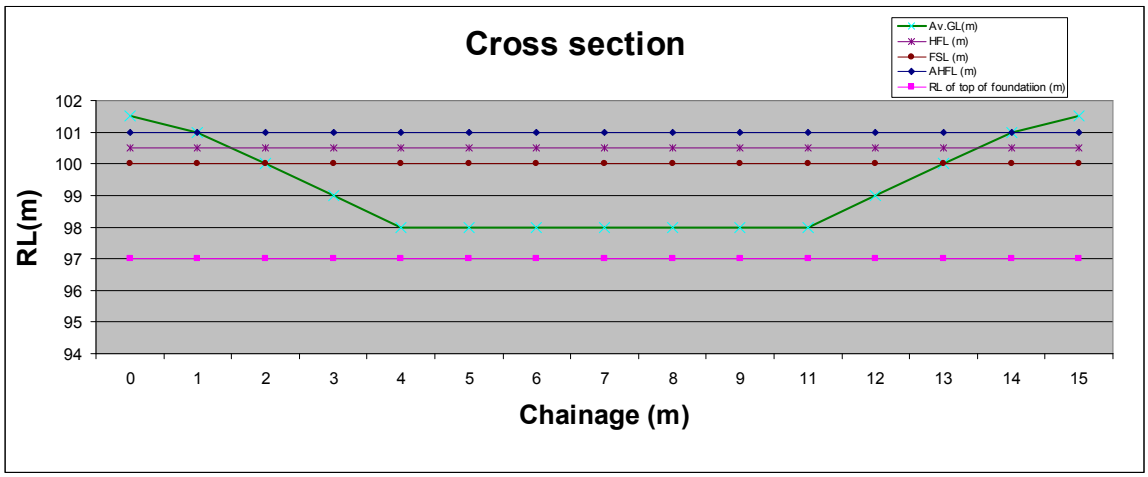
Catchment area(As estimated by Google map)-Sq.Km	1
Average Rainfall (mm)	820
Rainfall at 50 % dependability (mm)	807.6
Average flood reaching the site (cum/sec)	43.87
Design flood for 50 year return period (cum/sec)	30.71
Total water available at the dam site (mcm)	0.172
Height of dam (m)	1.5 to 2
Width (m)	0.5

Length (m)	10
No of check dams	7
Water Stored in Each check dam when the dam is full (cum)	3000
Total water stored in 7 check dams (cum)	21000
% of water stored from the total water available	12.20%
Slope of Nala bed	0.0067

- The flood estimation is very important for storing the water in the check dams as well as to know how flood is passing through the area. The maximum flood has been estimated by using various formulae and the same is shown below:

Maximum Flood with different Formulae (Cum/sec)	
MFD (Area velocity method)cum/sec (Q=A* V)	82.65
MFD at the site (Dickens)	25.00
Ingle's formula	36.43
MFD (Rainfall intensity method (C*I*A))- rational method	13.02
MFD at the site (GOG)-Standard Project flood method)	62.26
Average MFLD	43.87

- The flood estimation as well as well as the amount of water to be stored in the check dams depends on the cross section of the check dams. A tentative cross section is given in graph below. The actual cross section depends on the actual location and the actual levels which would be finalized at the time of tenders.
- The tentative cross section of the Stream is given in the graph below:



6.1 2. Recharge Bore well

- 3 Recharge bore wells at each tank site with a 200 mm diameter and 60 m depth is proposed. These bore wells would be used both for recharge as well as pumping when required. The location of the same are shown in the Map (Annexure)

6.1.3. Gabion structures in the middle of the roads in the green belt

- The rain falling on the roads even though not advisable to store in the ponds due to the possibility of pollution due to oil, grease etc due to traffic, the same can be recharged to groundwater to some extent by filtering. After filtering, the excess water can be taken out of the area by suitable drains. The water stored in the middle of the roads, where green belt is proposed would be useful for the irrigation of landscape and also groundwater recharge.
- Accordingly, suitable provision has to be made to design the curbs in such a way that water enters the green belt at suitable places and subsequently retained in the middle for some time, so that the water can percolate and filtered.
- Accordingly, about 8 Gabion structures were proposed at suitable places. The location of the same are indicated in the map. (Annexure)

6.1.4. Roof water structures that are suitable for the area

- Roof water is one of the clean and useful water that can be utilized for drinking as well as for other domestic purposes. The roof water tank designs vary depending on the area available roof catchments. About 25% of the factory area is considered for roof top. Out of this only 70% of the rain falling would be collected in the tanks. The tank designs vary from factory to factory which is given in the Annexure. However, average of 45*45*5 m tank size of two tanks is required for each factory site. This would store an amount of 16756 cum. Even though this appears to be very high, it is normal considering the average size of plot area of 11.68 ha. The two tanks occupy an area of 0.81 ha which is about 7% of the plot area. Considering the cost of the water, this is not high.
- Similarly two tanks of 29*29*5 m of roof water tanks are proposed in administrative building to conserve an amount 6625 cum.

6.1.5. Surface water tanks/ ponds

- Out of 170 hectares of total factory area, 75% is open area. At least 90% of the same can contribute to the surface over flow. Leaving the road structures for accumulation of water in ponds, an amount of 142186 cum in factory area and about 35102 in common area, totaling about 177288 cum is available for collection and storage in ponds. This is huge amount. A ponded area of about 0.4 ha per factory is required with a depth of 3 m. This would harvest about 12926 cum water per factory. The concerned factories should decide to construct the required pond if they want to harvest water.
- In case of common area, about 1.17 ha surface area with a depth of 3 m is required. This would harvest an amount of 35102 cum of water. In common area, the SIL would construct the required ponded area at the low lying areas so that the natural ecology is maintained and at the same time, the water could be collected and stored for regular use.
- Considering the drainage pattern and contour plan of the area, four suitable sites are suggested. Their locations are marked in Plan and the actual size and cost would depend on the levels of the area which would be given at the time of tenders.

No of tanks proposed: 3

Area of the tanks:

i. 3965
ii. 4250
iii. 4285

Total 11,500 sq.m

- Water stored in the tanks with a depth of 3 m (cum) = 34500(as per the available space). The maximum can be stored to the extent of about 35102 cum. The variation is very marginal as such; the actual figures can be accepted.

6.1.6 Other Recharge structures

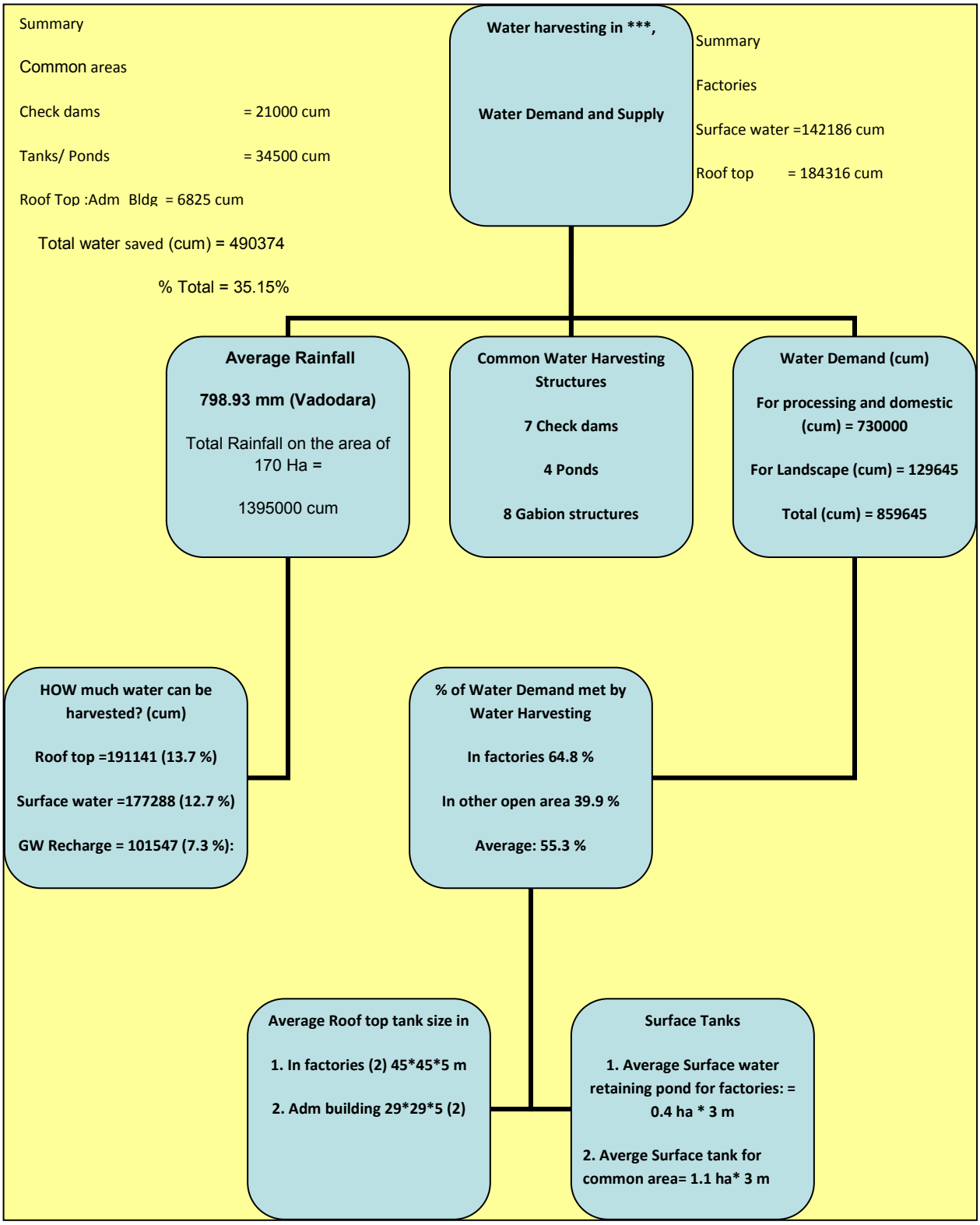
- The over flow running through gutters should not directly go to drainage pipes. They should pass through recharge pits, so that some water can recharge to the groundwater. Accordingly at least one recharge pit for each drainage pipe out let is recommended before the water reaches the drainage pipe.
- In addition Recharge trench all along the inside boundary of each factory is recommended along with plantation for recharging the groundwater.

6.2 Water Budget

The basic assumptions for estimating the scope of water harvesting in the area are as following:

Assumptions for Water Harvesting					
Rainfall (mm)	820	height of tank (m) from roof top water tank	5	GR. Recharge from Tanks	0.35
Total Rainfall (mcm)	1.395	Factor for GW Recharge (from roof)	0.15	Open area Available for Conservation (fra)	0.9
Fraction of roof area in the total area	0.25	Fraction of surface water flow from total rain	0.2	Landscape area (Fr)	0.1
Factor for roof catchment	0.7	Average surface water tank depth (m)	3	MAX Water demand for landscape (Inches / year)	30.0

A flow chart giving the total scope of water harvesting in the area is given in the following chart.


Summary
Common areas
Check dams = 21000 cum
Tanks/ Ponds = 34500 cum
Roof Top :Adm Bldg = 6825 cum
Total water saved (cum) = 490374
% Total = 35.15%
Water harvesting in ***,
Water Demand and Supply
Summary
Factories
Surface water =142186 cum
Roof top = 184316 cum
Average Rainfall
798.93 mm (Vadodara)
Total Rainfall on the area of 170 Ha =
1395000 cum
Common Water Harvesting Structures
7 Check dams
4 Ponds
8 Gabion structures
Water Demand (cum)
For processing and domestic (cum) = 730000
For Landscape (cum) = 129645
Total (cum) = 859645
HOW much water can be harvested? (cum)
Roof top =191141 (13.7 %)
Surface water =177288 (12.7 %)
GW Recharge = 101547 (7.3 %):
% of Water Demand met by Water Harvesting
In factories 64.8 %
In other open area 39.9 %
Average: 55.3 %
Average Roof top tank size in
1. In factories (2) 45*45*5 m
2. Adm building 29*29*5 (2)
Surface Tanks
1. Average Surface water retaining pond for factories: = 0.4 ha * 3 m
2. Averge Surface tank for common area= 1.1 ha* 3 m

7. Economics

7.1 Cost of the Investment and benefits in the Factory area

The total water harvested in the factory area would be 371133 cum (Including recoverable recharge from groundwater recharge. This would be about 50% of the requirement.

The cost of the water saved would be Rs 29.69 lakhs @ Rs 8 per cum. The capital cost for the same to construct the same @ Rs 100 cum is Rs 371.13 lakhs. Considering the life of the project as 25 years, the capital cost can be recovered @ 6% interest. The details are given below.

Water availability and consumption in factory area		
Water requirement For processing and Domestic (cum)		641428.2
Water req For Landscape irrigation (cum)		97873.6
Total (cum)		739301.8
Cost of water @ Rs 8 /cum per year (Rs in Lakhs		59.14414
Water saved from Roof top		184315.8
Water saved from surface storage		142186.4
Groundwater recharge (cum)		
Roof	39496.2	
Surface	49765.3	
50 % recoverable	89261.5	44630.75
Total water saved (cum)		371133
Cost of the water in Rs 8 per cum (Rs in Lakhs		29.69064
Capital cost for the water saved @ Rs 100/cum (Rs lakhs)		371.133
Life of the project in years		25
Equated installment for 25 year @ 6 % interest		(29.03)

7.2 Cost of the Investment and benefits in the common area

The total water harvested in the common area would be 69802 cum (Including recoverable recharge from groundwater recharge. This would be about 33 % of the water requirement of 208217 cum. The cost of the water saved would be Rs 5.58 lakhs @ Rs 8 per cum. The capital cost for the same to construct the same @ Rs 95 cum is Rs 66 lakhs. Considering the life of the project as 25 years, the capital cost can be recovered @ 6% interest. The details are given below:

Water availability and consumption in Common areas (cum)		
Check dams (cum)	21000	21000
Tanks (cum)		35102
Roof Top :Adm_Bldg (cum)		6825.4
Gw recharge in surface area	12286	
50% of GW is recoverable		6142.89
Total Water saved		69070.6
Cost of water saved @ 8 per cum (Rs in Lakhs)		5.53
Cost of investment (common area) (Rs in Lakhs)		69
Life of the project in years		25
Equated installment for 25 year @ 6 % interest (Rs in Lakhs)		(5.40)
Capital Cost per cum of water saved (Rs/cum)		100
Water Demand in the common area (cum)		208217
Percentage of water conserved to water requirement		33%

8. Unit cost of various structures

The cost of various structures varies from place to place and the site conditions. The average cost of the activities is indicated below. The detailed cost estimates would be considered at the time of execution and tenders.

Cost of investment (common area) Rs in Lakhs)	
7 check dams @ Rs 2 lakhs per CD	14
8 gabion 5 m length @ 0.25 Lakh per Gabion	2
3 bore wells (60 m) @ Rs 1lakh per Bore well	3
4 tanks (1.2 ha) @ Rs 66/cum of water stored	23
Adm - Roof Top @ 300 per cum of water stored	20
Recharge pits and trenches (LS)	7
Total cost	69
Capital Cost per cum of water saved (Rs /cum)	100

9. Conclusions

The factory plot owners and the Implementers of the scheme have to invest in water harvesting to the extent of Rs 375 Lakhs and Rs 70 Lakhs respectively for getting the benefits of water harvesting. If the individual plot owners do not attempt the water harvesting, the Implementers of the scheme would have to provide the drainage facilities to drain out the entire water. It may be costly for the Implementers of the scheme. In such circumstances, there will be two scenarios which the Implementers of the scheme has to consider for investing in water harvesting. They are briefly as under:

9.1 Scenario 1:

The Implementers of the scheme consider Total area as far as water supply is considered, and they will inform the Unit holders that they should save water where ever possible for their own requirement and discharge the excess water in the common drains. The Implementers of the scheme will arrange for storage, treatment and then supply the same back to Unit holders.

9.2 Scenario 2:

The Implementers of the scheme considers total area as far as water supply is considered but only provided harvesting for run off from common area only. The Unit holders will make their own arrangement for water harvesting in their factories.