RAIN WATER HARVESTING FOR URBAN FLOOD PEAK REDUCTION

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INTRODUCTION

- Guwahati, the gateway to the North Eastern Region of India is situated in the zone of heavy rainfall.
- It has witnessed large population growth, huge construction activities and unplanned urbanisation in the last few decades.
- **Outcomes:**
  - denudation of surrounding hills
    - soil erosion and sedimentation in the drains
  - filling-up of low-lying areas
    - water logging
  - throwing of garbage to the rivers and drains
    - congestion of the drains, and flood during rainy season
  - Rapid and huge withdrawal of ground water
    - water shortage in many parts, particularly during winter

Why Rain Water Harvesting (RWH)?

- RWH can lead to
  - Reduction of Peak flow & Flood
  - Increased ground water recharge & Reduction of Water Shortage Problem
  - Partial Reduction of Soil erosion

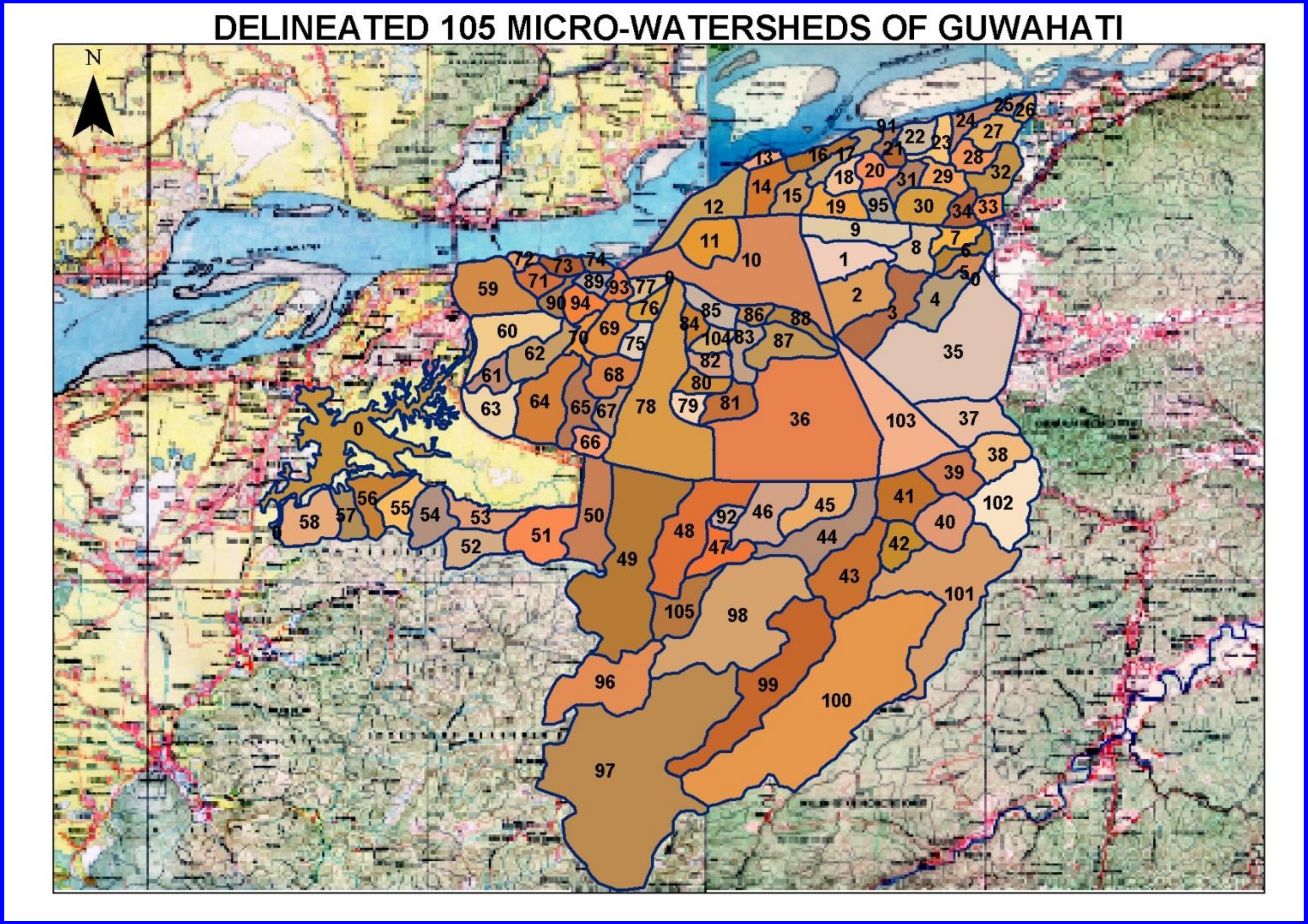
Study Area

- To evaluate efficacy of Rain Water Harvesting Scheme
  - as a possible solution of the flood and water shortage problem of Guwahati, a

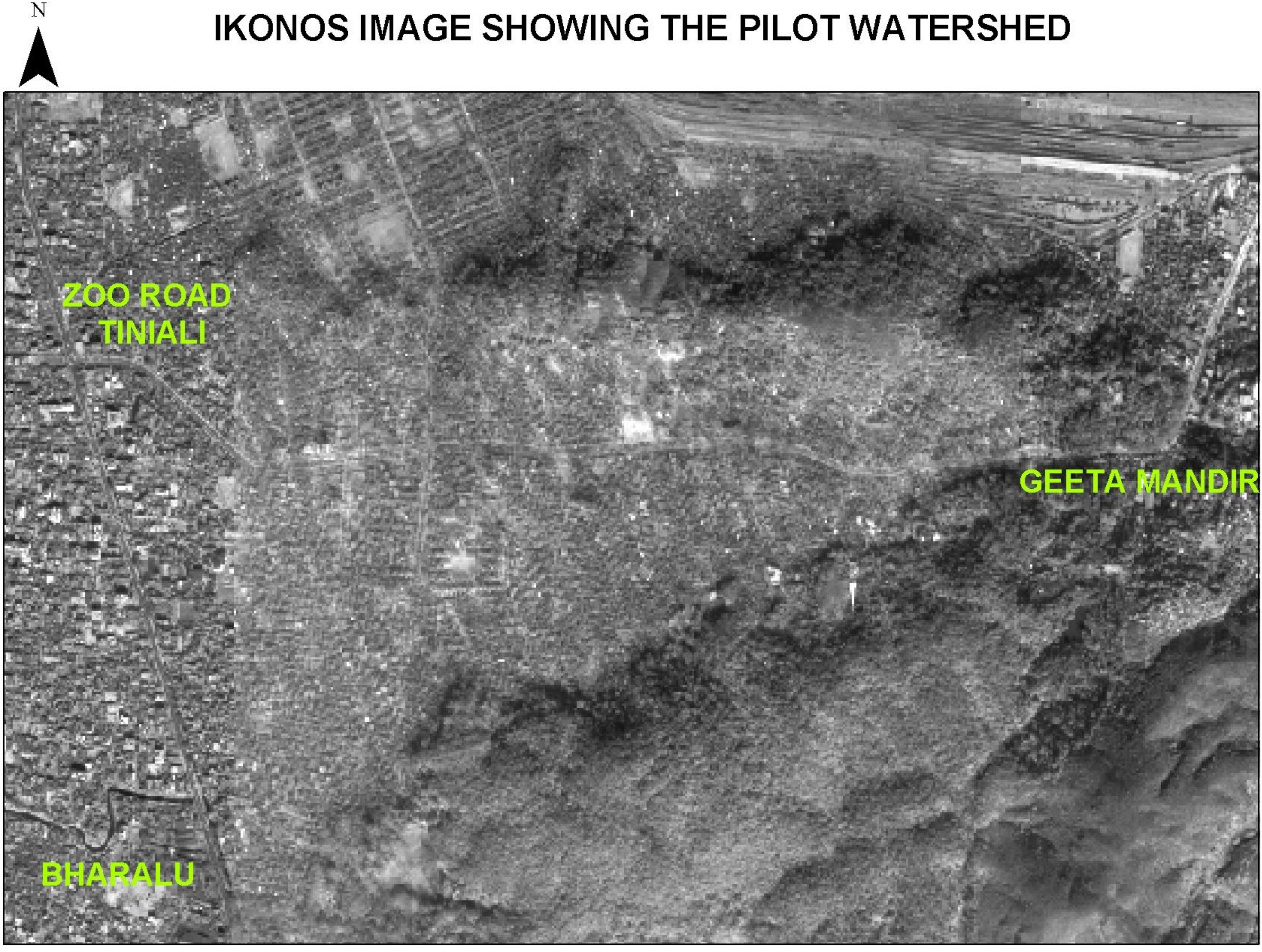
    study has been conducted in the Pilot Watershed of Hatigarh Chariali area of Guwahati
  - Watershed Delineation of the City was carried out using a DEM developed for the purpose

Development of DEM

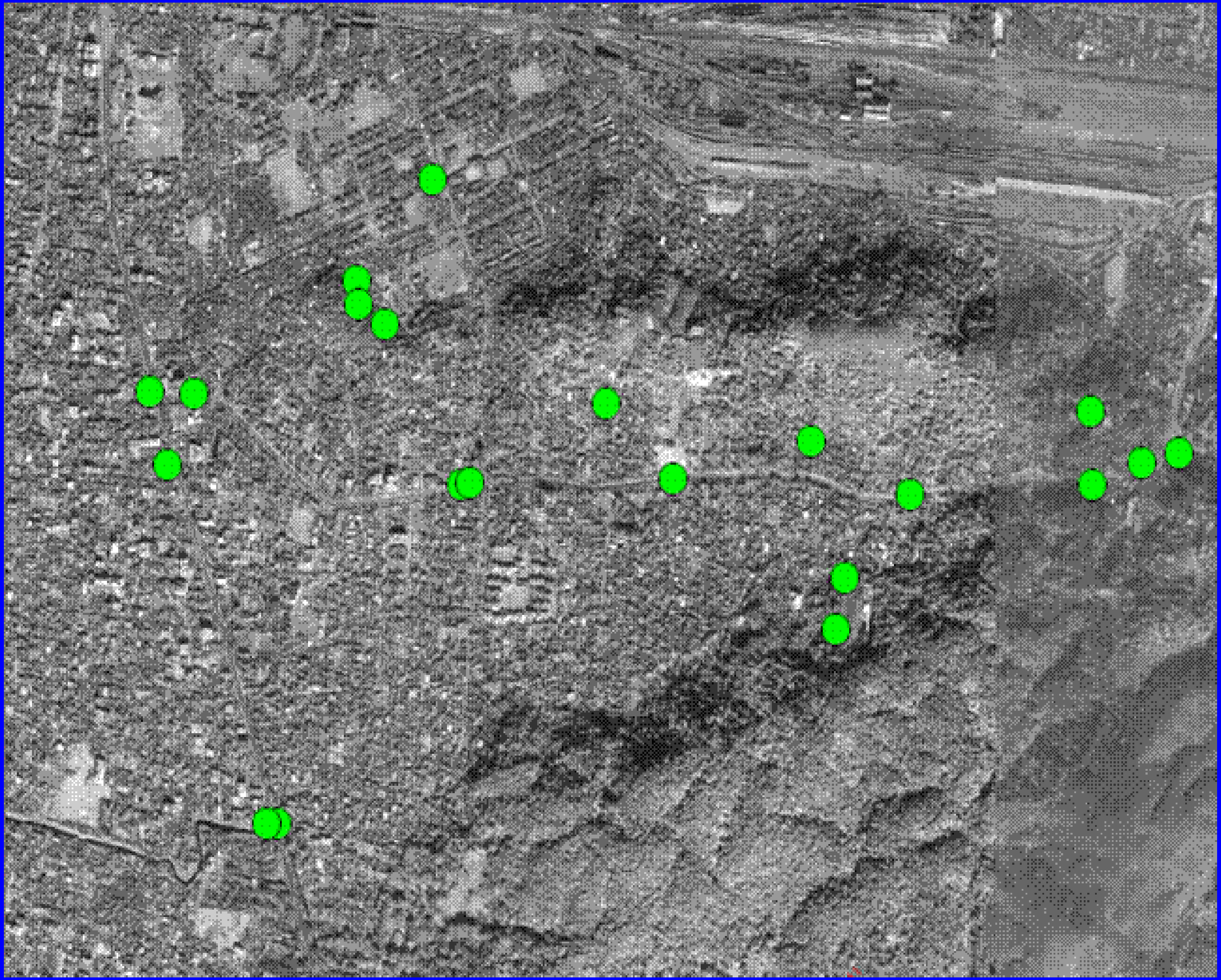
Watershed delineation



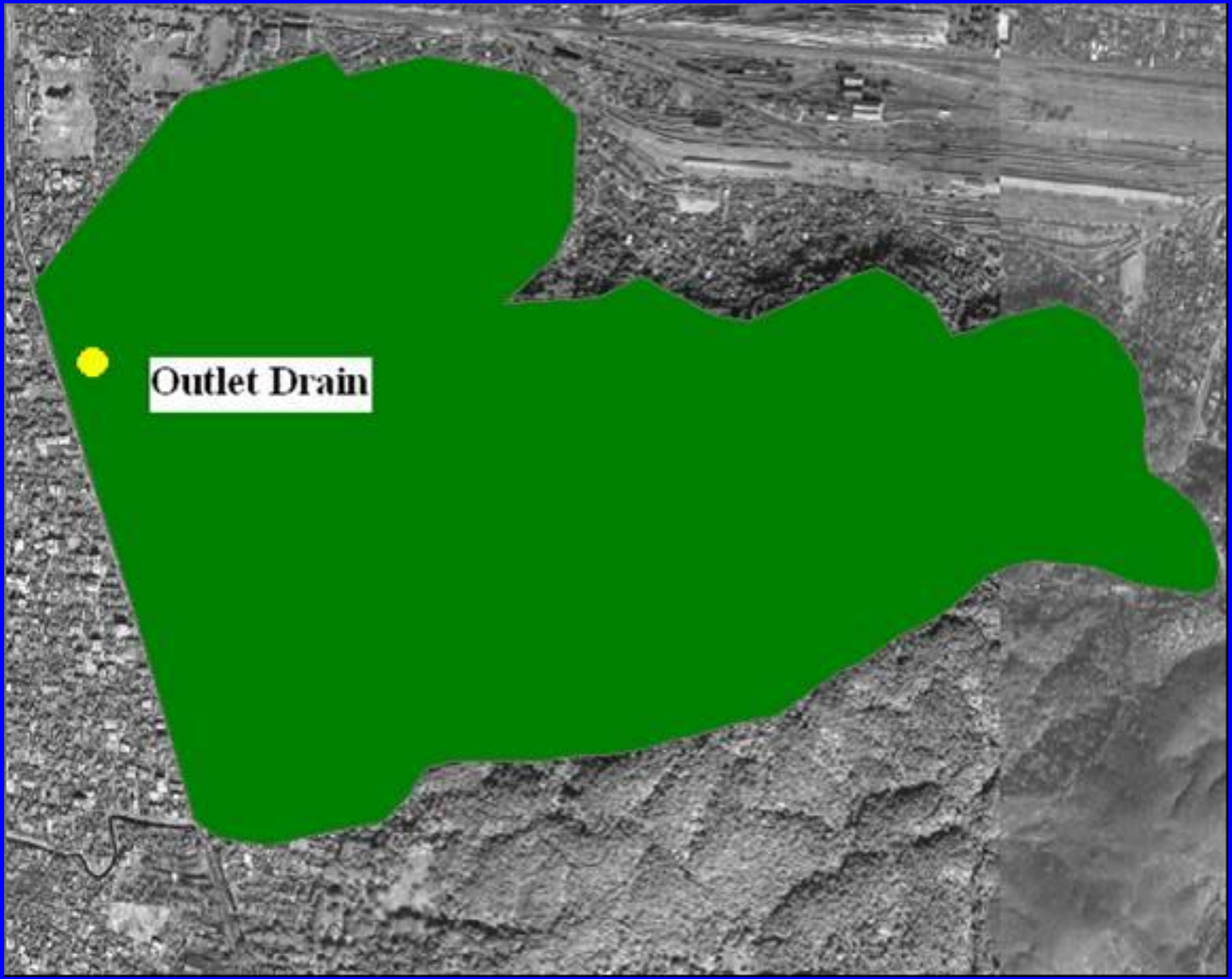
IKONOS IMAGE SHOWING THE PILOT WATERSHED



GPS points on Georeferenced Image

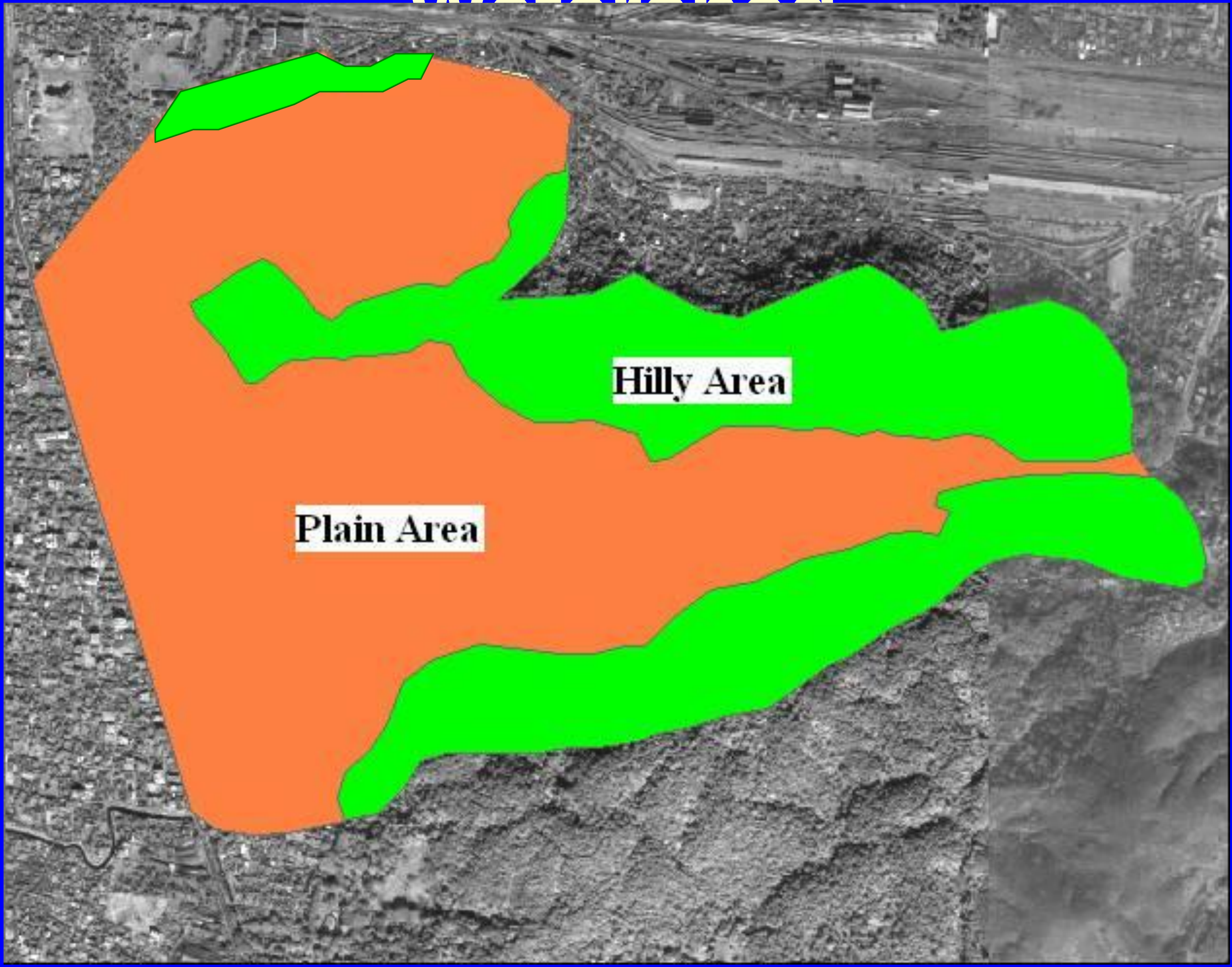


Hatigarh Chariali Watershed



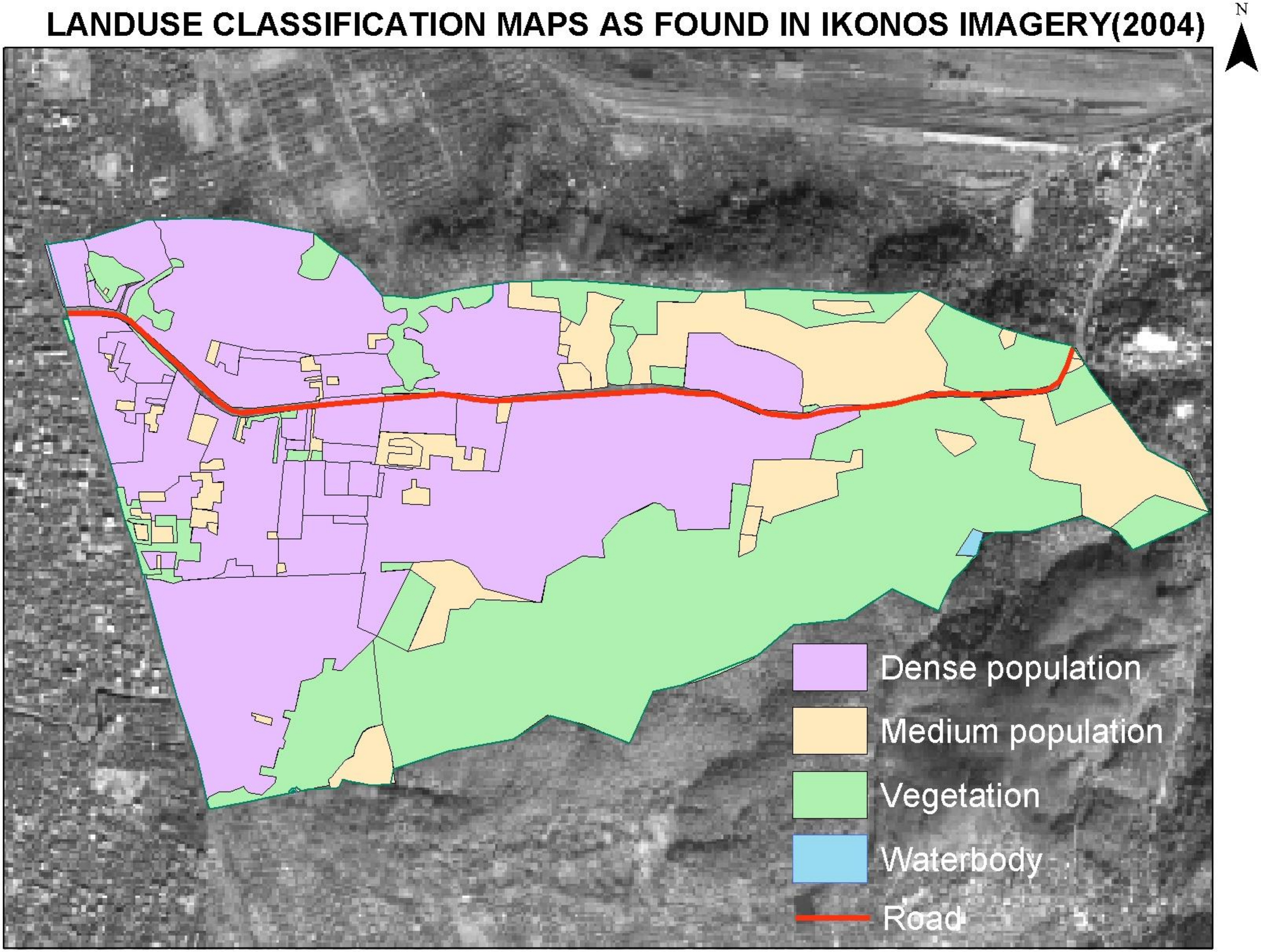
Delineation of Total Watershed with Location of Outlet Drain

Hilly and Plain Areas of Hatigarh Watershed



Buildings and Drains in Hatigarh Watershed

LANDUSE CLASSIFICATION MAPS AS FOUND IN IKONOS IMAGERY(2004)



Summary of GIS Analysis

Relevant Data of GIS Analysis of Watershed

Particulars	**Length (km)**	**Area (ha)**
Total Watershed	-	280
Plain part	-	175
Hill part	-	105
Total Drains	17.6	-
Total Roof Area	-	21.3
Roof area as % of plain area		12.2

Computation of peak discharge by Rational method

- Peak Discharge from a watershed is given by

$$Q = CiA \ / \ 36,00,000$$

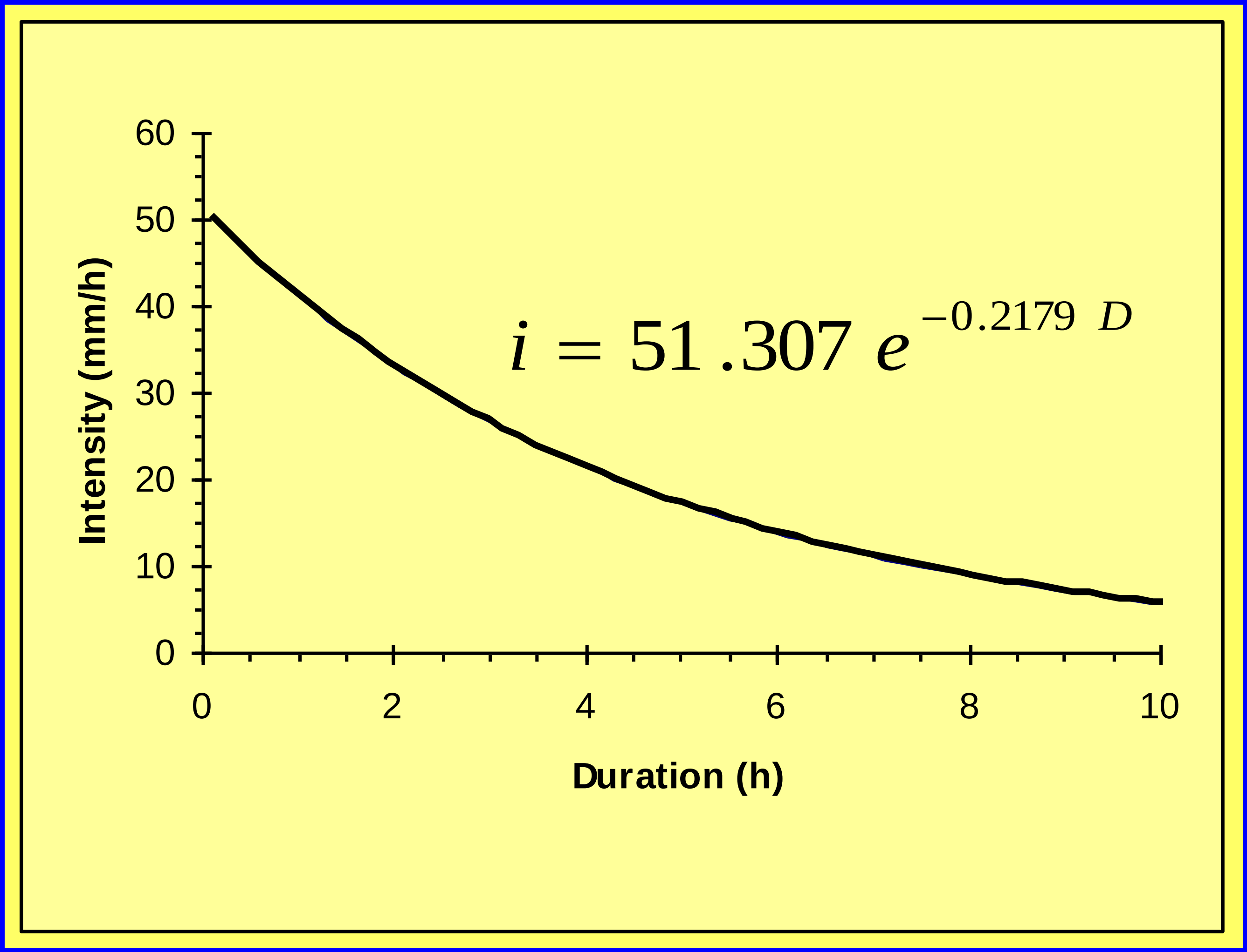
Where, Q = Peak Discharge or rate of Runoff (Cumec),

C = Runoff Coefficient,

i = Maximum intensity of runoff for the time of concentration of the selected design storm (mm/hr), and

A = Area of watershed in m^2

Intensity-Duration Relationship

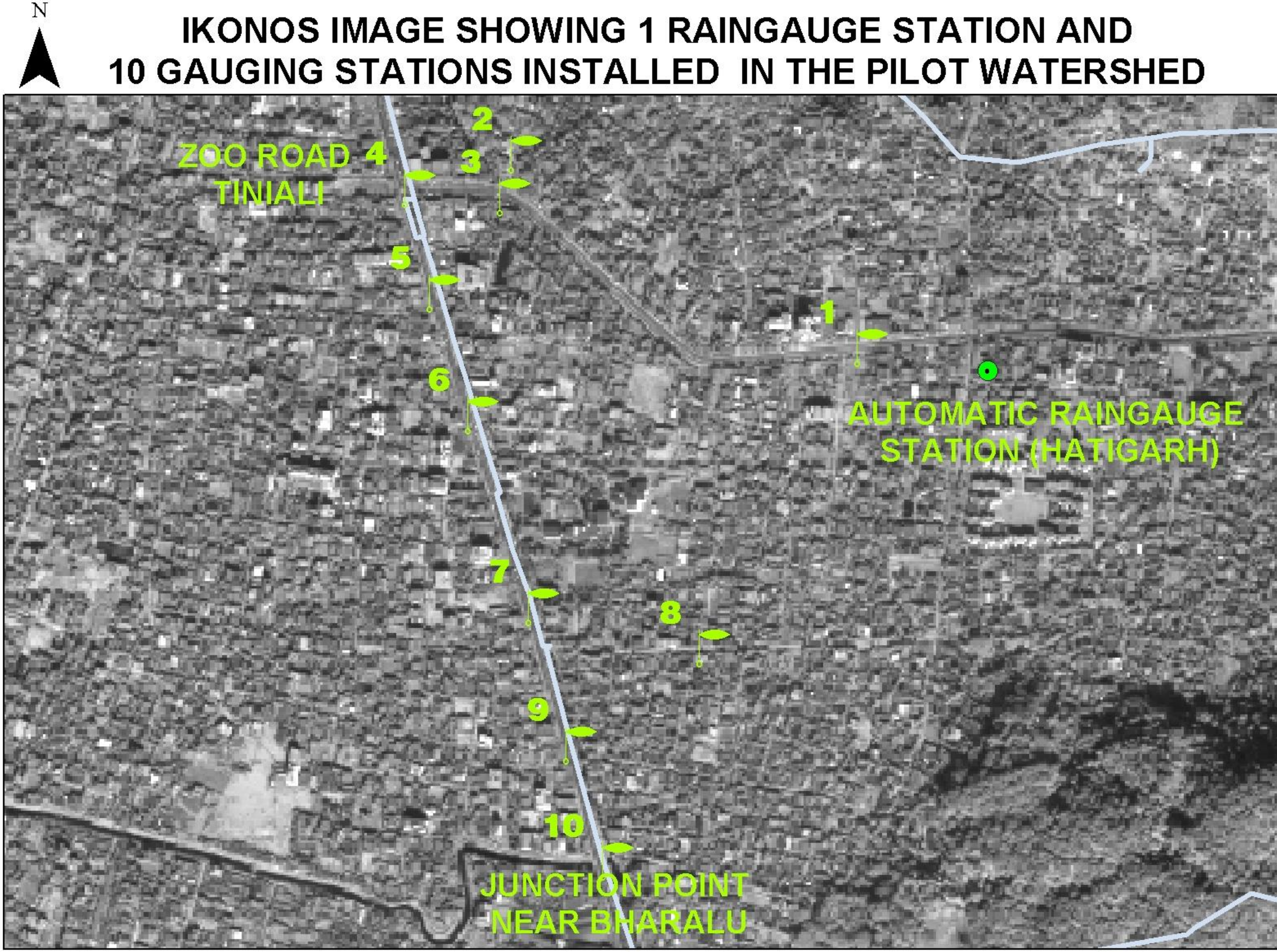


After Sarma and Goswami (2004)

Special Considerations for Urban Watershed

- The land use pattern in urban watershed is different from usual watersheds.
- This results in modification of the values of empirical factors to be used in the hydrological models.
- Presence of manmade structures modifies the drainage pattern of the watershed, compared to an ordinary watershed
- These points are duly considered while applying hydrological models in urban areas like Guwahati.

IKONOS IMAGE SHOWING 1 RAINGAUGE STATION AND 10 GAUGING STATIONS INSTALLED IN THE PILOT WATERSHED



Standard Values of *C* for Urban Watershed (Sarma et. al., 2005)

Sl. No	**Land Use Type**	***C*-Values**
1	High Residential	0.21
2	Medium Residential	0.22
3	Low Residential	0.22
4	Open Mix Forest (slope> 30%)	0.25
5	Open Mix Forest (slope< 30%)	0.20
6	Dense Mix Forest (slope> 30%)	0.15
7	Dense Mix Forest (slope< 30%)	0.10
8	Agricultural land (Scrubland)	0.40
9	Beel (swampy)	0.36
10	Light Industrial	0.20
11	Heavy Industrial	0.25
12	Mixed Built-up	0.30
13	Transportation (Railways/yards)	0.35
14	Public, Semipublic & Educational Institute	0.29

Time of Concentration

Flow	Notation	Time of Concentration (min)
Overland	T_o	7.22
Shallow Concentrated	T_{sc}	7.23
Channel	T_d	39.52
Total	$\boldsymbol{T_c}$	**53.97 $\approx$ 54.00**

Design storm producing peak discharge at the outlet

Parameters	Values
Duration of rainfall producing Peak Runoff Volume (min)	54
Intensity corresponding to Peak Runoff Volume (mm/h)	42.17
Runoff Coefficient of the Watershed (*C*)	0.212
Discharge *Q* (m^3/s)	6.93 m3/s

Computation of Normal Depth

- Computation of Normal Depth needs iterative solution of Manning's Equation.
- To avoid iterative solution Barr and Das Equations are used
- For rectangular channels,

$$Q_N = \frac{nQ}{s_b^{1/2} B^{8/3}}$$

$$Y_N = Q_N \left(1 + 0.855\, Q_N^{3/5}\right)$$

$$y_n = BY_N$$

Computation of Water Levels in Drains

- Based on Peak Discharge of the watershed & Manning's Equation
- Sediment Depth taken from a concurrent study (Sarma and Bracht, 2005)

Parameters	**Values**
Duration of rainfall (h)	0.9
Intensity of rainfall (mm/h)	42.17
Runoff Coefficient (*C*)	0.212
Peak Discharge Q (m^3/s)	6.93
Manning's Coefficient, *n*	0.015
Width of the drain (m)	3.0
Bed slope of the drain (%)	0.05
Depth of water in the drain (m)	1.78
Sediment depth in the drain (m)	0.5
Depth of the outlet drain (m)	1.5
Flood with sedimentation (m)	0.78
Flood without sedimentation (m)	0.28

HYDROLOGICAL ANALYSIS

- From the above analysis it may be concluded that
  - the peak discharge from the watershed cannot be carried by the drains of the watershed without creation of flood, even when there is no sedimentation.
  - Thus, the solution of the flood problem calls for the reduction of peak discharge by some means
  - Rain Water Harvesting (RWH) scheme is one option

Socio-Economic Survey

- Preceding the analysis, a *Socio-economic questionnaire survey* is carried out to
  - understand the current situation in a better way and
  - to study the acceptability of the proposed RWH scheme among the people.

Socio-economic Study

PRESENT SOURCE OF WATER		
	WELL	WATER SUPPLY & WELL
IN GENERAL	57%	43%
HIGH LAND	100%	0%
LOW LAND	35%	65%

OCCURRENCE OF FLOODS DURING RAINY PERIOD		
	Occurs	Does not Occur
IN GENERAL	44%	56%
HIGH LAND	10%	90%
LOW LAND	60%	40%

Socioeconomic Data (Contd.)

WATER SCARCITY DURING WINTER		
	Present	Absent
IN GENERAL	40%	60%
HIGH LAND	40%	60%
LOW LAND	40%	60%

WILLINGNESS TO INVEST IN RAINWATER HARVESTING		
	Willing	Unwilling
IN GENERAL	52%	48%
HIGH LAND	50%	50%
LOW LAND	55%	45%

Socioeconomic Data (Contd.)

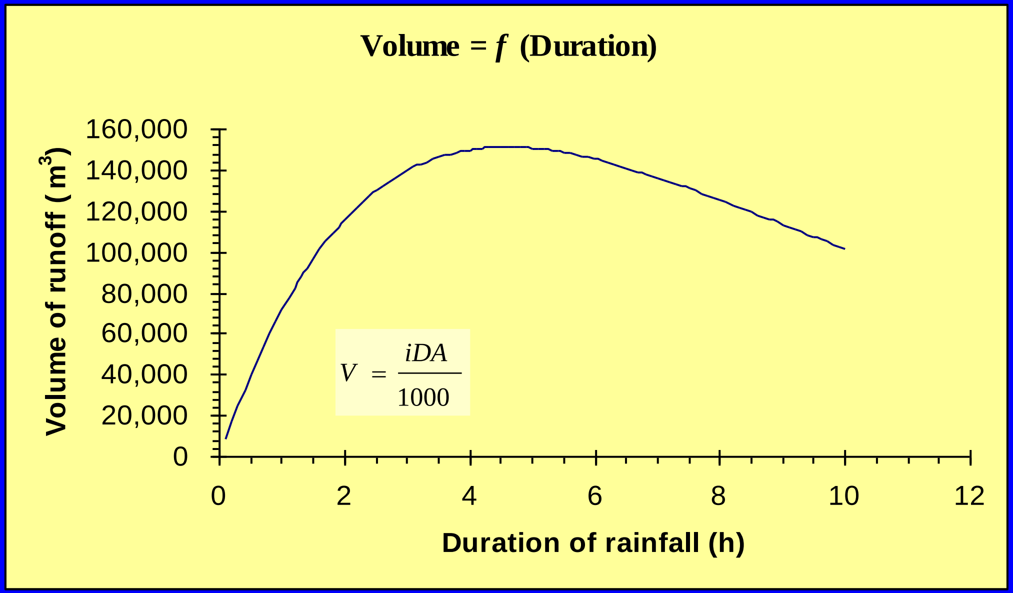
PREFERRED TYPE OF INVESTMENT			
	INDIVIDUAL	COMMUNITY BASED	COMMUNITY& PRIVATE PARTNERSHIP
IN GENERAL	48%	46%	6%
HIGH LAND	60%	40%	0%
LOW LAND	36%	55%	9%

PREFERRED USE OF HARVESTED WATER			
	IMMEDIATE USE	USE DURING DRY PERIOD	USE FOR GROUND WATER RECHARGE
IN GENERAL	27%	32%	41%
HIGH LAND	43%	14%	43%
LOW LAND	20%	40%	40%

DESIGN OF RAIN WATER HARVESTING (RWH) SYSTEMS

- Two options for RWH are proposed and their Layout and Designs are discussed
  - Roof Top RWH(RTRWH)
    - Rain water harvesting from roof top
  - Flood Well RWH (FWRWH)
    - Rain water infiltration through flood wells.
- They are independent options
  - may be used individually or in combination depending on the hydrological needs for Flood Peak Reduction

Design storm for maximum total volume



Volume of runoff (m^3)of a rain of duration D hr is given by

Parameters	Values
Duration of rainfall producing Maximum Total Volume (h)	5
Intensity corresponding maximum Runoff Volume (mm/h)	17.26
Runoff Coefficient of the Watershed (*C*)	0.212
Discharge *Q* (m^3/s)	1.775
Peak Runoff Volume *V* (m^3)	1,50,670

Design Summary of Roof Top Rain Water Harvesting Systems

Sl. No.	PARAMETERS	FORMULAE Or NOTATION	Values
1	Intensity (mm/h)	i	17.26
2	Duration (h)	D	5
3	Runoff Vol Collected from Roof Top Area A (m^3)	$V = iAD/1000$	18,385
4	Runoff Volume Collected per unit area of Roof (m^3/m^2)	$\overline{V} = iD/1000$	0.086≈ 0.10
5	Area of tank required for a 1m depth tank		10% of the roof area

Layout of RTRWH Systems

RTRWH Scheme 1

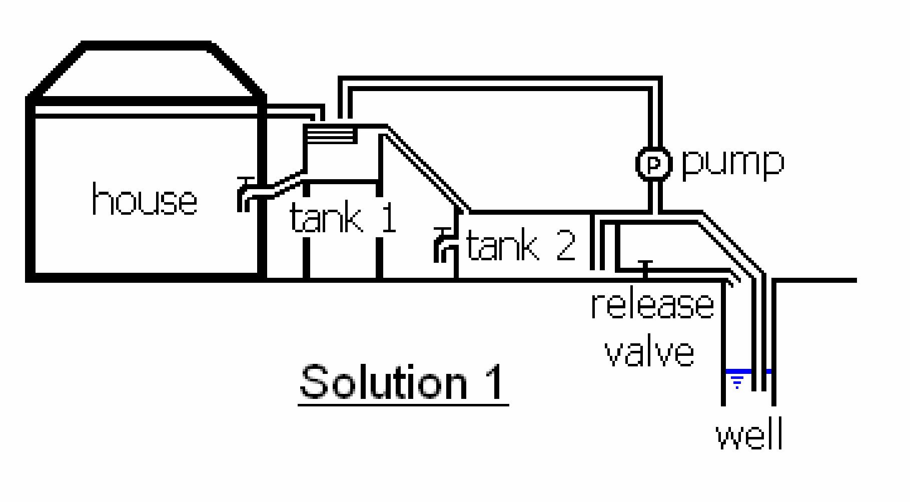


Table 5.1a Advantages and Disadvantages of RWH Scheme 1

Advantages	**Disadvantages**
Reduction of peak flow	Initial cost is more
Free use of water	
Reduction in pumping costs	
Recharge of ground water table	

Layout of RTRWH Systems

RTRWH Scheme 2

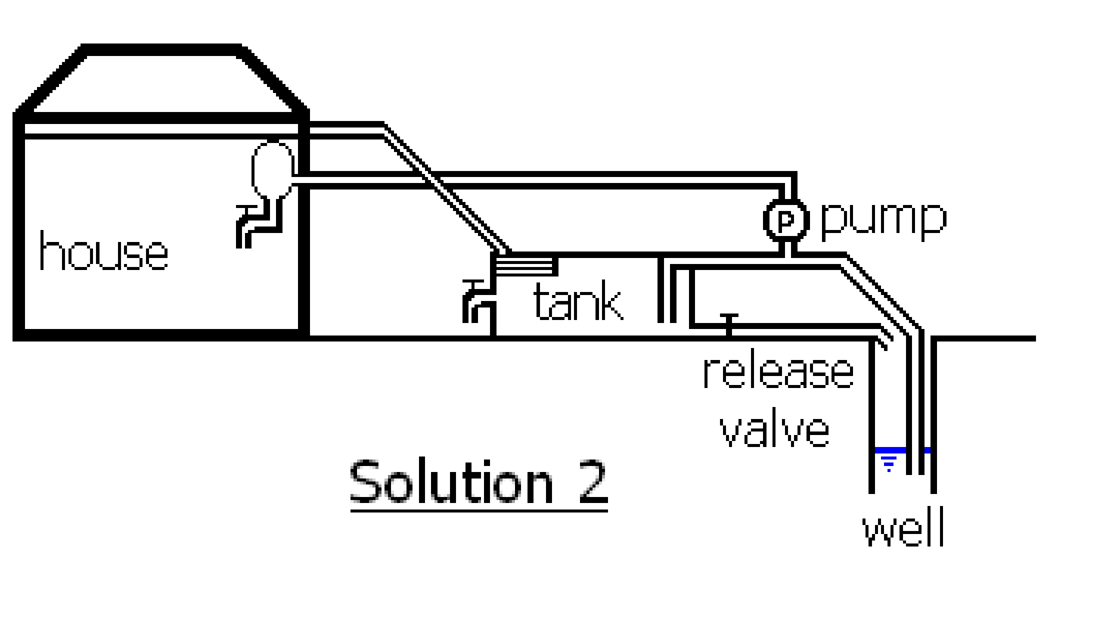


Table 5.1 b Advantages and Disadvantages of RWH Scheme 2

Advantages	**Disadvantages**
Reduction of peak flow	Pumping provision must be present.
Recharge of the ground water table	
Partial reduction in pumping costs	

Layout of RTRWH Systems

RTRWH Scheme 3

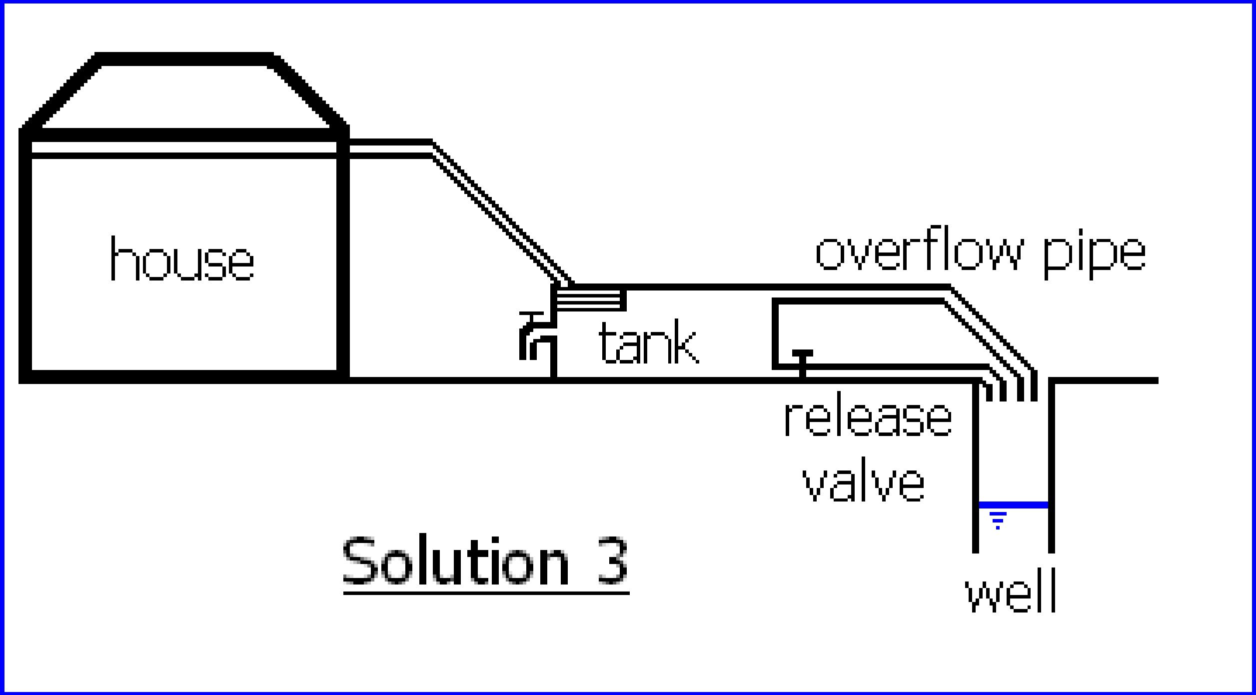
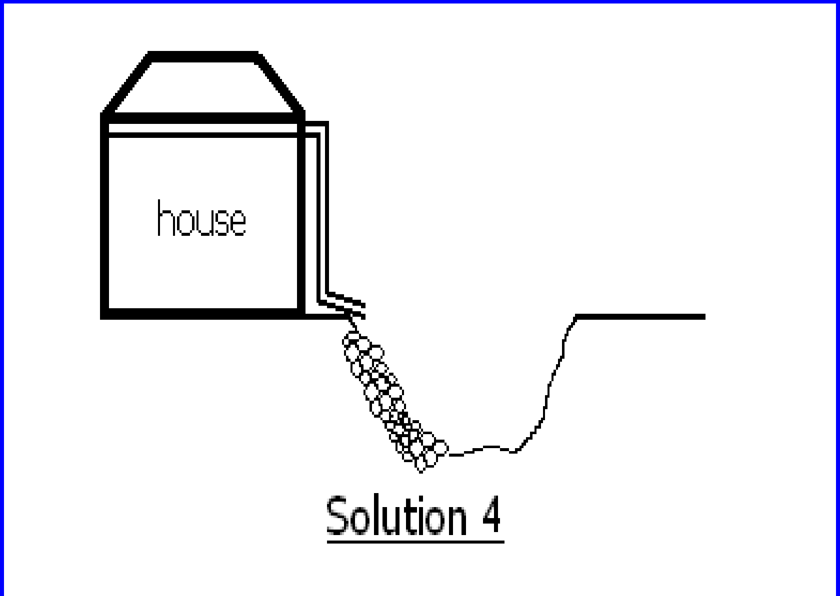
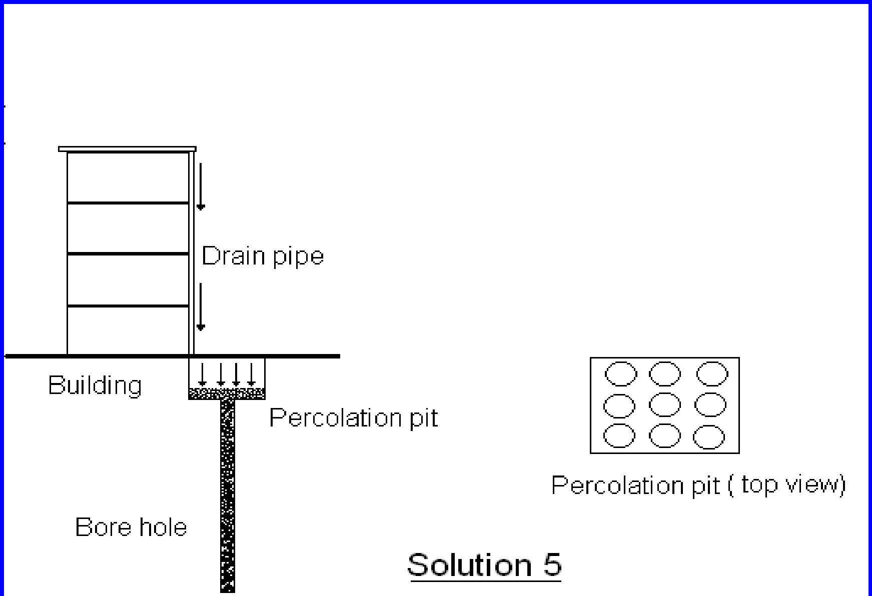


Table 5.1 c Advantages and Disadvantages of RWH Scheme 3

Advantages	Disadvantages
Reduction of peak flow	No inside supply
Recharge of the ground water table	
Free use of water without pumping	

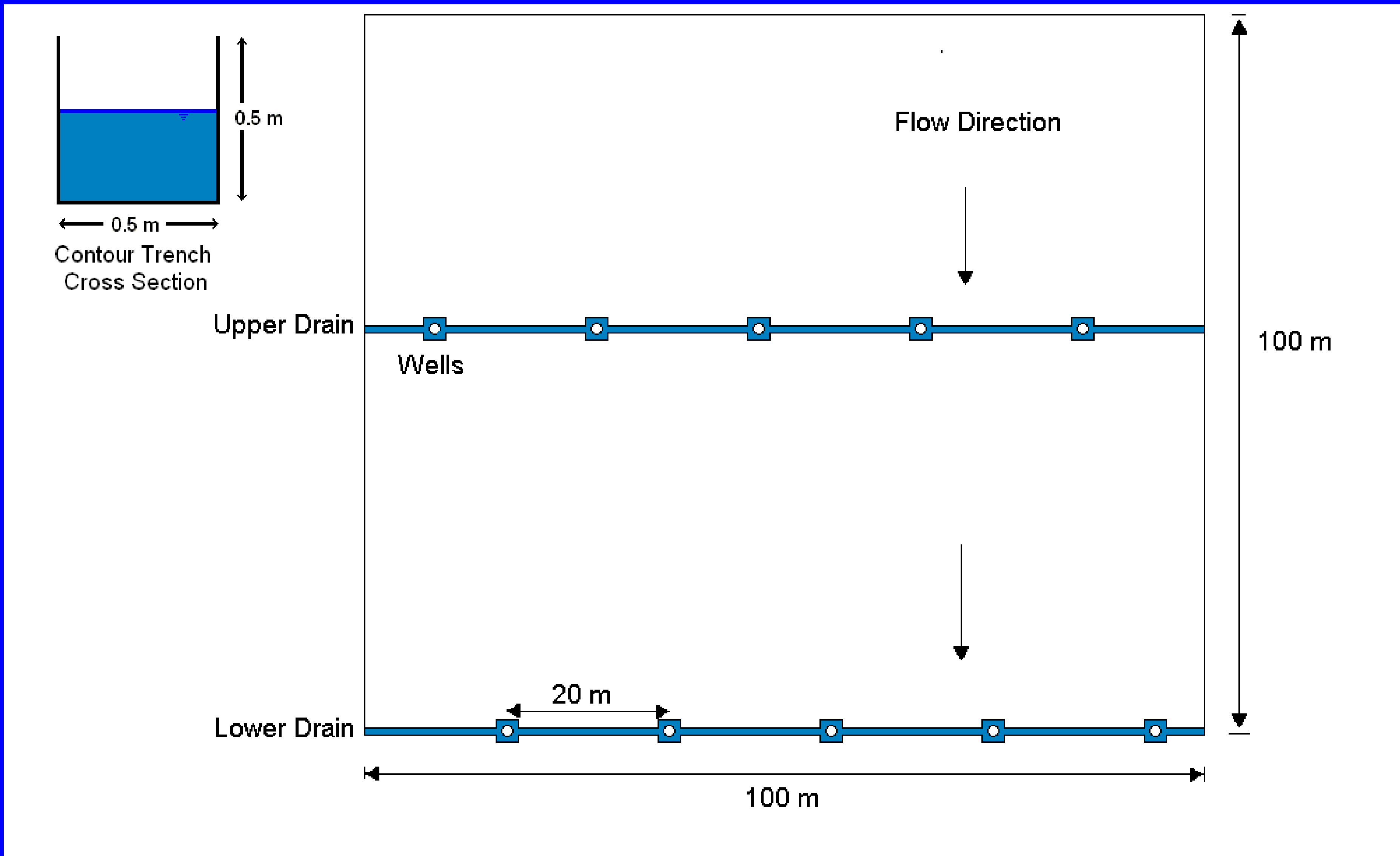
Scheme 4





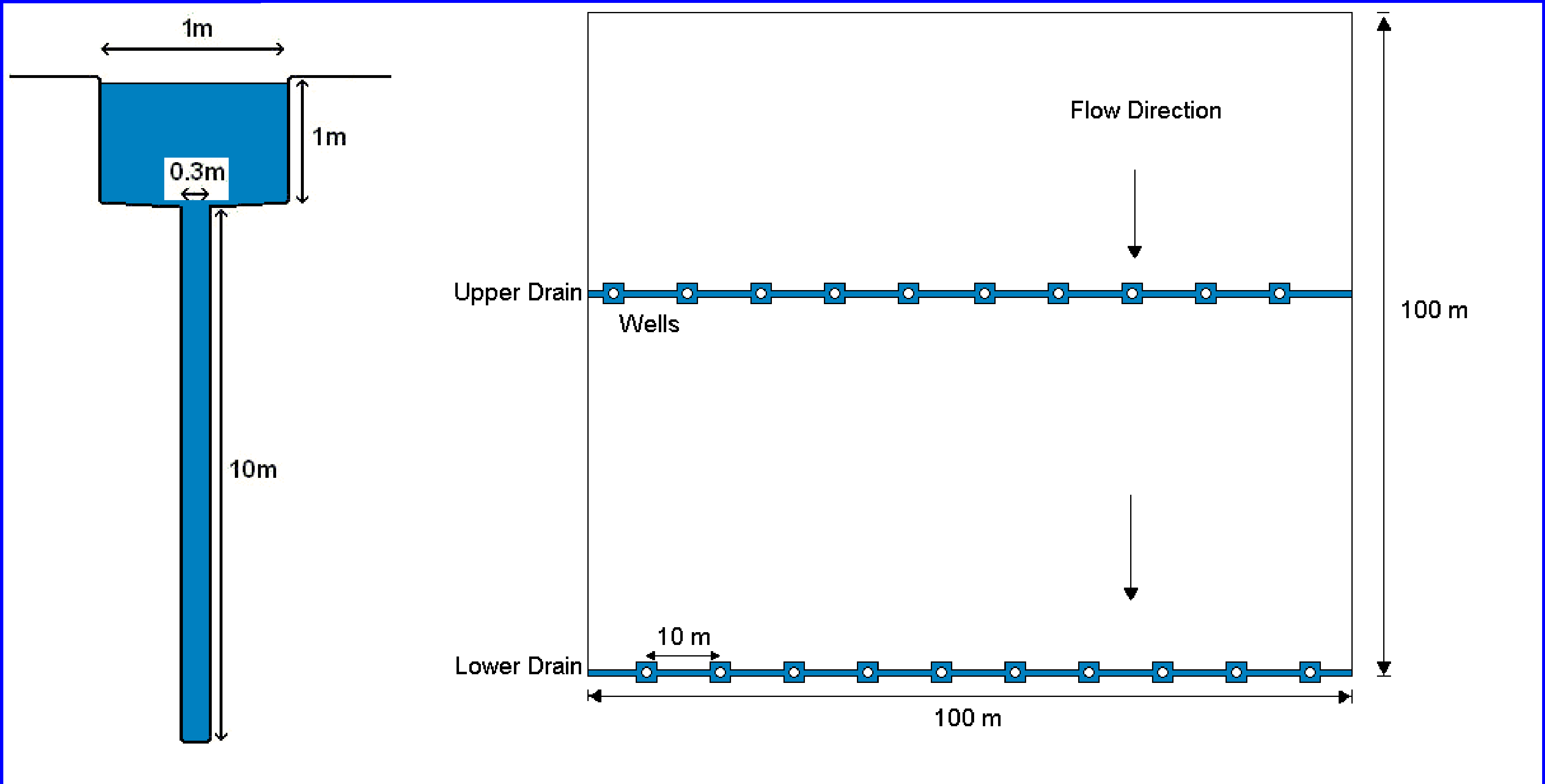
Advantages	Disadvantages
Reduction of peak flow	No possibility to use rain water
Recharge of ground water table	

Layout of Flood Well RWH System



10 Flood Wells per ha Scheme

Layout of Flood Well RWH System (Contd.)



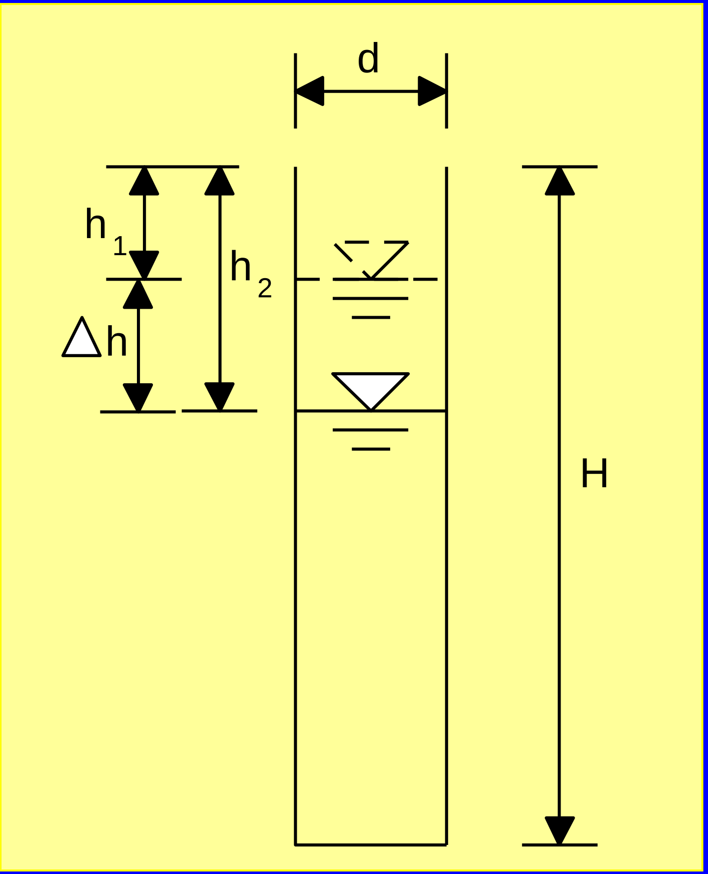
20 Flood Wells per ha Scheme with X-Sectional Details

Estimation of Field Infiltration Rate

- Field Infiltration rate is estimated by conducting a infiltration test in a dug bore hole in a foot hill and noting the lowering depth of water with time
- Average Surface velocity of water over the infiltration area may be expressed as

$$v = \frac{\Delta h d}{4 \Delta t \left(H - \frac{h_1 + h_2}{2} \right)} = \frac{\Delta h d}{4 \Delta t \left(H - h_1 + \frac{\Delta h}{2} \right)}$$

- This velocity is plotted as a function of Head at the bottom of the hole and logarithmic best fit equation is devised to obtain infiltration rate in Flood Wells

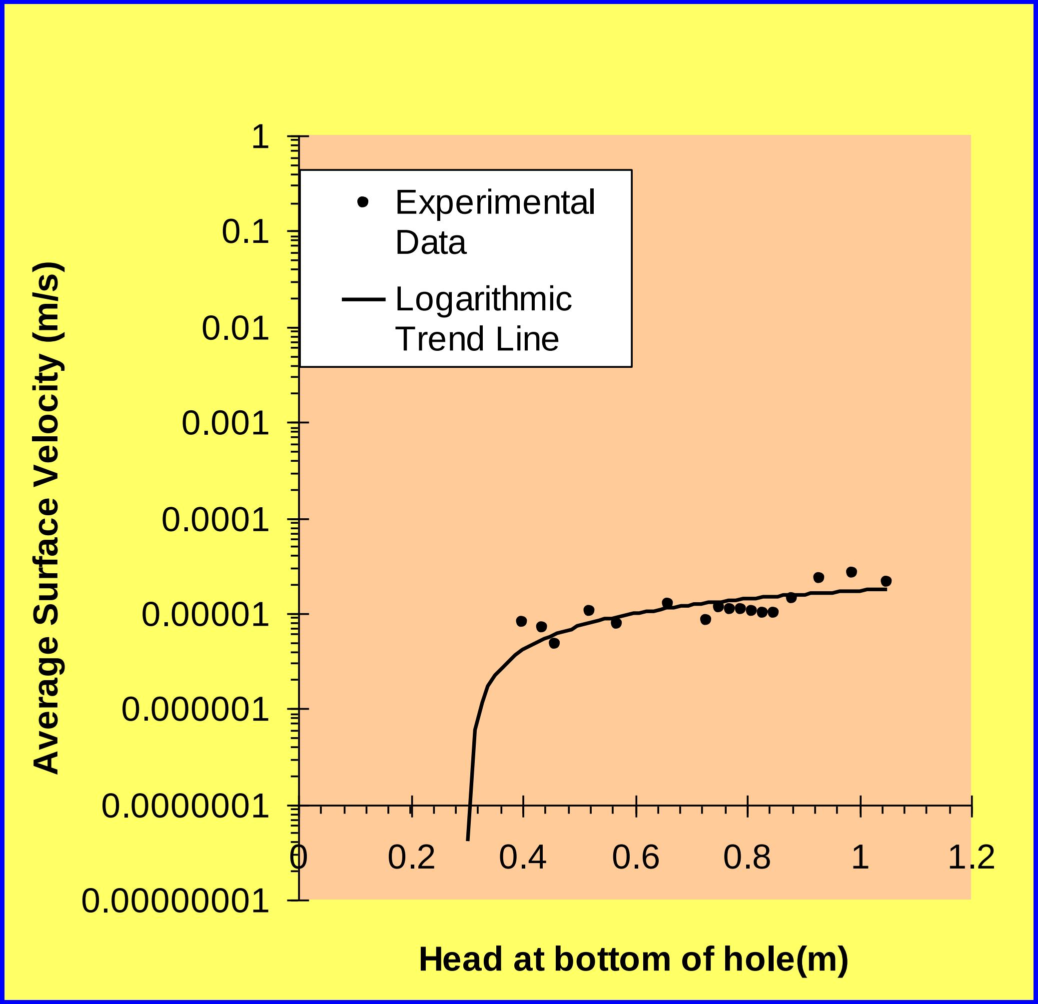


Estimation of Field Infiltration Rate (Contd.)

- The equation of the trend line is obtained as

$$v = 10^{-5}\left[\ln(h) + 2\right]$$

- The trend line shape appears to be logical from the physical point of view
  - Therefore used to calculate infiltration rate under an average head of 5 m at the bottom of Flood Well
  - The value obtained is 0.12 m/s
- Keeping in view the size difference between flood well and the test well Infiltration rate of 0.15 m/s is taken as a realistic value for Flood Wells



Summarised Details of Flood Wells

Design Parameters of Flood Wells

Serial No.	Depth of Flood Wells (m)	Volume (m^3)	Total Infiltration area (m^2)	Surface Velocity of Infiltration (m/h)
1	10	1.71	13.42	0.15[a]
2	6	1.42	9.65	

[a] The infiltration rate is estimated on the basis of field test

Summary of Flood Well Schemes

No of Well per hectare	Total No of Wells in Watershed	Total volume of wells (m^3)	Total infiltration area (m^2)	Volume of water infiltrated (5 h rain) (m^3)	% Reduction of the peak flood volume
10	1400	2198	16150	11871	9.3
20	2880	4396	32312	23749	18.7

ANALYSIS OF MODIFIED PEAK DISCHARGE AND FLOOD LEVEL IN DRAINS

- Following methodology is used
  - Determination of Retained Rainfall Volume in 10 Flood Wells/ha System
    - Total retention volume of contour trench and flood well = 8494 m^3
    - Calculation of Modified Time of Concentration
  - Time needed to store 8494m^3 volume of rain at an intensity of 42.17mm/h
    - = 8494/ 59038.50 = 0.144 h = 8.63 min.
  - Increased time of concentration = (54 + 8.63) = 62.63 min
- Calculation of Modified Discharge
  - Modified discharge corresponding to this time of concentration = $CiA/(36\times10^5)$ = 0.212 x 40.9 x 279.144/ (360×10^5) = 6.723 m^3/s
- Calculation of Infiltration Loss
  - Total Infiltration from 1400 wells = 2421.3 m^3/h = 0.67 m^3/s

ANALYSIS OF MODIFIED PEAK DISCHARGE AND FLOOD LEVEL IN DRAINS (Contd.)

- Net modified discharge considering infiltration
  - = (6.723 – 0.67)m3/s = 6.053 m3/s
- Percentage reduction of discharge due to implementation of FWRWH system
  - = (1-6.053/6.932) 100% = 12.68%
- Calculation of Modified Discharge due Roof top RWH System
  - Reduction in peak discharge due to RTRWH system is 12.2%.
  - Combined Reduction in peak discharge due to RTRWH & FWRWH = 12.68 %+12.20 % = 24.88 %
- Analysis of Modified Flood Level in Drains
  - Based on Modified Peak Discharge, Geometry of Drains and Manning’s Equation
  - Barr and Das Formulae (1986) are used

Table 5.4 Summary of RWH Analysis

Parameters	**Before Solution**	**After solution**		
		Only RTRWH	**RTRWH +10 FW/ha**	**RTRWH +20 FW/ha**
Rainfall Duration (h)	0.9	0.9	1.04	1.07
Intensity (mm/h)	42.17	42.17	40.9	40.64
Runoff Coefficient *C*	0.212	0.212	0.212	0.212
Manning's Coeff. (*n*)	0.015	0.015	0.015	0.015
Discharge Q (m^3/s)	**6.93**	**6.08**	**5.21**	**4.49**
Width of drain (m)	3	3	3	3
Drain-Bed slope (%)	0.05	0.05	0.05	0.05

(Continued in the next Slide)

Summary of RWH Analysis (Contd.)

Parameters	Before Solution	After solution		
		Only RTRWH	RTRWH +10 FW/ha	RTRWH +20 FW/ha
Water level in drains (m)	**1.78**	**1.62**	**1.44**	**1.29**
Sediment in drain (m)	0.5	0.5	0.18	0.18
Depth of outlet drain (m)	1.5	1.5	1.5	1.5
Flood with sediment control(m)	**0.78**	**0.62**	**0.11**	**0.00**
% Reduction in Maximum Runoff Volume	**-**	**12.2**	**21.54**	**30.87**
% Peak Discharge Reduction	**-**	**12.20**	**12.70**	**22.9**
% Flood Reduction in Drains (without Sediment Control)	**-**	**20.5**	**43.6**	**62.8**
% Flood Reduction in drains (With Sediment Control, Studyed by Bracht and Sarma)	**-**	**20.5**	**85**	**100**

SUMMARY & CONCLUSIONS

- Hydrological study has shown that the proposed schemes will reduce the flood problem significantly in the Pilot watershed.
- Socio-economic study has shown positive sign towards acceptability of such scheme by the community.
- While house owner will have to implement the Roof RWH scheme, Government will have to implement the Flood well harvesting scheme.
- Sediment control scheme must be implemented in parallel
- Possible adverse affects such as landslide etc. need to be analyzed.

THANK YOU