

# Remedial Solution of Waterlogged Area by Application of GIS

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**ABSTRACT:** Urban run-off increases significantly due to reduced drainage network and increased impervious area. The assessment of land use in urban area plays a vital role as input to the estimation of runoff. The hydrological design standard for water resources planning and management is commonly based on the frequency of occurrence of heavy rainfall events. In the area of Kalyan-Vithalwadi (Maharashtra, India) the life and properties are under the threat of flooding due to heavy rainfall within frequent time interval. In the present study, the occurrence of most frequent heavy rainfall event is investigated for Katimanavli area, located near the Vithalwadi railway station in the State of Maharashtra, India and used for estimation of run-off depth. By integration of GIS and remote sensing the land use detail for the study area was obtained. The spatial variation of event rainfall is taken into account with certain percentage of deviation from base rainfall for each triangle area that contributes to the run-off. The results of the analysis indicate that the study area can produce the run-off volume more than the present condition for water management at an average seasonal rainfall the canal already present, by maintaining the velocity of flow throughout the canal and drain out water into Ulhasriver.

**KEYWORDS:** Urban flooding, Application of GIS, Water logging, topography analysis.

## I. INTRODUCTION

Stormwater is the water that originates from precipitation events, it can soak into the soil (infiltrate), be stored on the land surface in ponds and puddles, evaporate, or runoff. Most runoff is conveyed directly to nearby streams, rivers, or other water bodies (surface water) without treatment conveyances such as ditches and storm sewers quickly transport runoff away from commercial and residential areas into nearby water bodies. Storm water management is that the effort to scale back runoff of rainwater or melted snow into streets, lawns and other sites and also the improvement of water quality. In urban and developed areas, impervious surfaces like pavement and roofs prevent precipitation from naturally soaking into the bottom. Instead, water runs rapidly into storm drains, sewer systems and drainage ditches and can cause flooding, erosion, turbidity, storm and sanitary sewer system overflow, and infrastructure damage. Adequate storm water drainage is extremely essential within the modern infrastructure of the city since it effects the roadway serviceability and usable life. Storm water is a significant component of the urban water cycle, and its improved management offers potentially significant environmental, economic and social benefits. Urban storm water management objectives now pursue the goal of ecological sustainable development and better environmental outcomes. Water logging is caused by a combination of excess rainfall, poor external drainage (runoff), poor internal drainage (water movement in the soil profile) and the inability of the soil to store much water.

In the Katimanavli area, located near the Vithalwadi railway station in the State of Maharashtra, India, occurrence of most frequent heavy rainfall event is investigated. The land use detail for the study area was obtained by integration of remote sensing and GIS.

Remote Sensing is the technique of gathering information about objects without being in physical contact with them. Information is acquired by detecting and measuring changes that the object imposes on the field by it on electromagnetic, acoustic or potential field. Geographical Information Systems is a powerful tool for collecting, storing, retrieval and manipulation of spatial data. It allows integration of spatial and aspatial data and also overlay of layered information that are beyond the capability of manual methods. GIS made it possible to map, model, query and analyse large quantities of data, all held together within a single database.

## II. OBJECTIVE

- To analyze drainage data of vitthalvadi areas with help of rainfall and terrain maps.
- To find solution for waterlogging in vitthalvadi railway station area.
- To understand functioning of QGIS software and its application in management of storm water.
- To minimise the loss of property.

## III. STUDY AREA

Vitthalwadi, Ulhasnagar is a Locality in Kalyan City in Maharashtra State, India. It belongs to Konkan region. It belongs to Konkan Division (19.2244° N, 73.1546° E). The 22 study area belongs to Pune Link Road, Vitthalwadi and chawls nearby locality Katemanivali road. There is natural open drainage line which is across the link roads which is connected to Ulhas River. The chawls gets affected every year in rainy season as the storm water gets Logged. Chawls consist of nearby 900 homes, as per survey done by us we get to know that ever year average loss from each home is 10-12 thousand rupees that is total cost of damage is 90 lakh. Every year KDMC does cleaning of drainage line but due to inefficient work, the region gets affected of 87448 m<sup>2</sup>.



Fig 1 : Natural drainage line



Fig 2 : Affected waterlogged area

## IV. METHODOLOGY

1. Collection of meteorological data and administrative maps from Municipal Corporation.
2. Create digital Elevation Map
3. Extract contours to identify the terrain of study area.
4. Analysis of Rainfall Data.
5. Spatial data.
6. Estimation of Peak discharge using rational method.
7. Creation of modified Storm water drainage system.

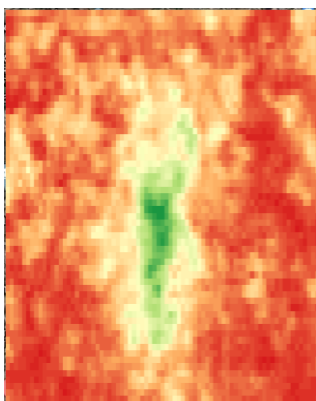


Fig3 : DEM created using QGIS

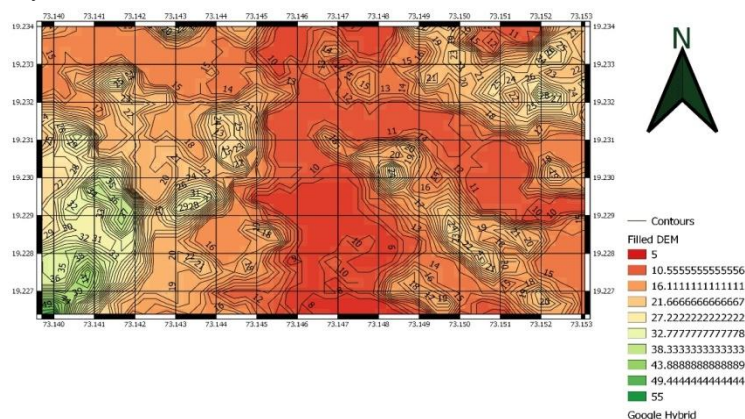
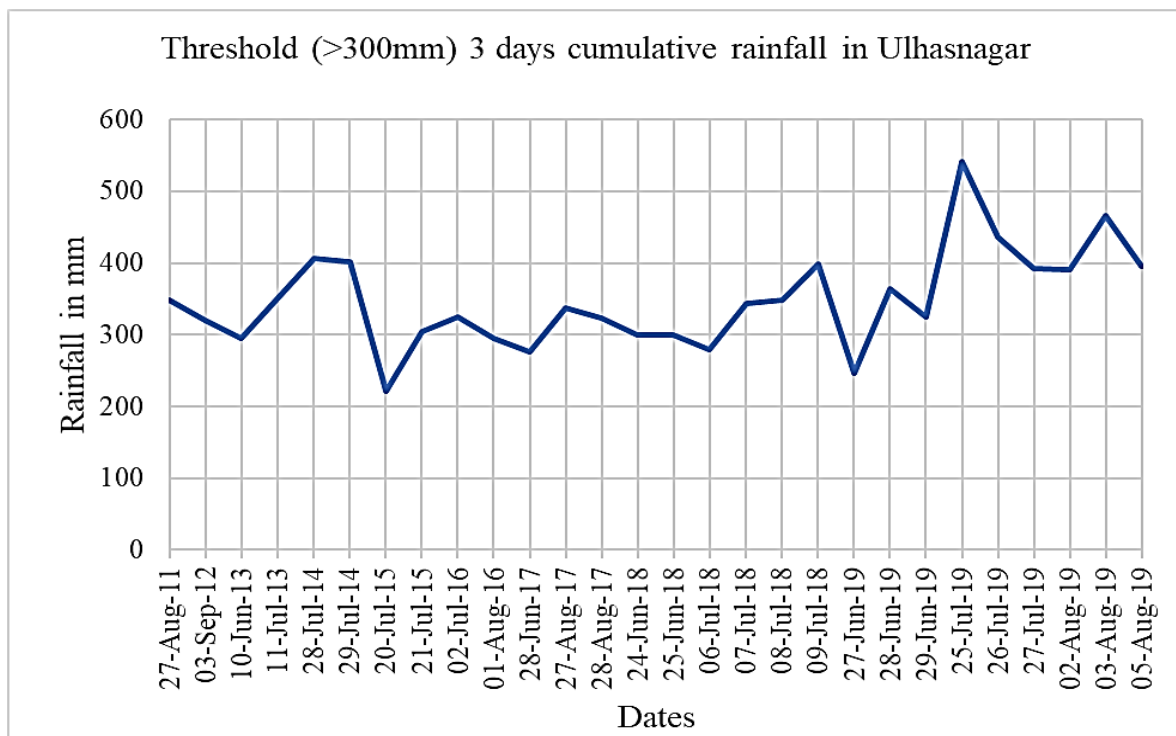
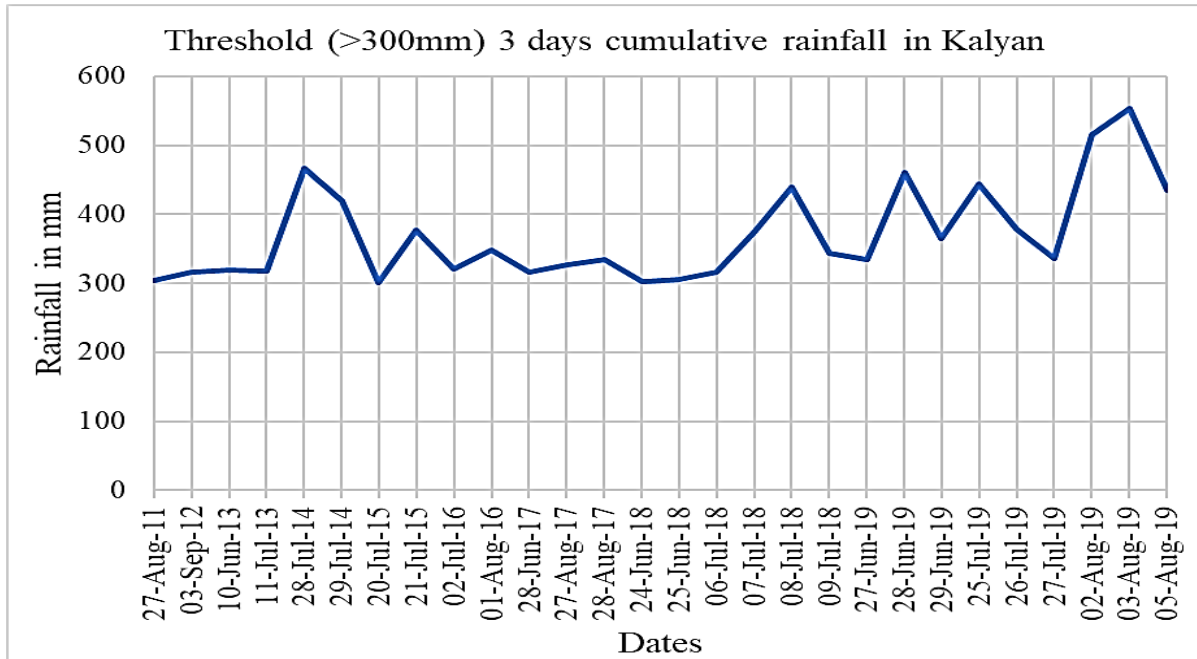


Fig 4 : Contours created using QGIS

## Analysis of Rainfall Data

The rainfall data is key component of this project. In order to calculate the rainfall intensity and flood estimation of study area. As the data of the location was not available the data for the three location is gathered and calculated the rainfall data for the area using QGIS. After pre-processing of rainfall data, by survey the date (3-8-19) was obtained of the waterlogging occurred in the year (2019). The peak rainfall intensity is 552.6 mm so therefore considering 300 mm as a threshold value as the rainfall intensity of 300 mm was occurring multiple times hence values more than 300mm in total 3 days rainfall data were gathered.

Rainfall data more than threshold value ( 300mm ) from 2009 to 2019			
Sr no.	Dates	Kalyan (mm)	Ulhasnagar (mm)
1	27-Aug-11	303.4	348.4
2	03-Sep-12	315.6	319.4
3	10-Jun-13	319.1	295.6
4	11-Jul-13	317.4	349.4
5	28-Jul-14	467.4	406
6	29-Jul-14	419.6	401.2
7	20-Jul-15	301.4	221
8	21-Jul-15	376.4	304
9	02-Jul-16	320	324.2
10	01-Aug-16	348	295
11	28-Jun-17	316	276
12	27-Aug-17	327	338
13	28-Aug-17	335	323
14	24-Jun-18	303	299
15	25-Jun-18	305	299
16	06-Jul-18	316	280
17	07-Jul-18	374	343
18	08-Jul-18	439	348
19	09-Jul-18	344	399
20	27-Jun-19	334	247
21	28-Jun-19	461	364
22	29-Jun-19	365.2	325
23	25-Jul-19	443.1	541
24	26-Jul-19	379.2	436
25	27-Jul-19	336.6	393
26	02-Aug-19	514.8	390
27	03-Aug-19	552.6	466
28	05-Aug-19	435.4	395



Analysis of spatial and non-spatial data

Spatial analysis is the process of manipulating spatial information to extract new information and meaning from the original data. A GIS usually provides spatial analysis tools for calculating feature statistics and carrying out geoprocessing activities as data interpolation. The field measurements are taken at various points along the surface and the intermediate values are inferred by a process called 'interpolation'. In QGIS, interpolation is achieved using the built-in Interpolation Plugin. Spatial interpolation is the process of using points with known values to estimate values at other unknown points.



Estimation of Peak discharge using rational method.

Rational method :The rational method represents a steady inflow-outflow condition of the watershed during the peak intensity of the design storm.The rational formula estimates the peak rate of runoff at a specific location in a watershed as a function of the drainage area, runoff coefficient, and mean rainfall intensity for a duration equal to the time of concentration. The rational formula is:

$$Q = \frac{CIA}{Z}$$

Where:Q = maximum rate of runoff (cfs or m3/sec.)      C = runoff coefficient  
 I = average rainfall intensity (in./hr. or mm/hr.)      A = drainage area (ac or ha)  
 Z = conversion factor

Procedure for using the Rational Method

**Time of Concentration**

The Kerby Method

For small watersheds where overland flow is an important component of overall travel time, the Kerby method can be used. The Kerby equation is

$$Toc = K(L \times N)^{0.467} S^{-0.235}$$

Where:toc= overland flow time of concentration, in minutes  
 K = a units conversion coefficient, K = 0.828 for traditional units and K = 1.44 for SI units  
 L = the overland-flow length, in feet or meters as dictated by K  
 N = a dimensionless retardance coefficient  
 S = the dimensionless slope of terrain conveying the overland flow



**Rainfall Intensity**

The rainfall intensity (I) is the average rainfall rate in in./hr. for a specific rainfall duration and a selected frequency

$$I = \frac{b}{(Toc + d)^e}$$

Where : I = design rainfall intensity (in./hr.) toc = time of concentration (min)  
 e, b, d = coefficients based on rainfall IDF data.



**Discharge**

$$Q = \frac{CIA}{Z}$$

Discharge (Q) is obtained as 12.55 m<sup>3</sup>/sec.



### Creation of modified Storm water drainage system

For design of Storm drainage system in katemanavli road, vitthalwadi region, The lined canals are not designed making use of Lacey or Kennedy Theory because the section is rigid. Generally Manning's equation is used in design. To carry a certain discharge number of channel sections may be designed with different bed widths and side slopes. But it is clear that each section is not equally good for the purpose. The section to be adopted should be economical and at the same time it should be functionally efficient. It has been found that the most suitable cross-section of a lined canal mentioned in IS code 10430-2000 as:

- trapezoidal with or without rounded corners - This section can be used for all types of lined canals.
  - cup shaped - It may be used for distributaries/minors for discharge up to 3m<sup>3</sup>/s as far as possible.
- As far, our Discharge by Rational Method = 12.67 m<sup>3</sup>/sec so we must consider different parameters for design purpose.

### Cross-Section, Discharge and Velocity

The cross-section of lined canal may be

- trapezoidal with or without rounded corners. This section can be used for all types of lined canals.
- cup shaped. It may be used for distributaries/minors for discharge up to 3m/s as far as possible.

The discharge that can pass through a canal section is calculated by

$$Q = A \times V_{\text{mean}} \text{ (m}^3\text{/s)}$$

Where A - area of cross-section in m<sup>2</sup>       $V_{\text{mean}}$  - mean velocity in m/s.

The mean velocity  $V_{\text{mean}}$  is given by:  $V_{\text{mean}} = \frac{R^{2/3} \times S^{1/2}}{n}$  m/s

Where: R= hydraulic mean depth (= A/P) (m);      A= cross sectional area (m<sup>2</sup>);

P= wetted perimeter (m);      S= longitudinal slope of water surface

n= rugosity coefficient as given in Table below:

The critical velocity ratio should be aimed at higher than unity or by any other method, it should be ensured that silting will not take place in the lined canal. The minimum average velocity is between 0.6 m/s to 0.9 m/s. In this range it will prevent growth of vegetation that might decrease flow carrying capacities.

Limiting Velocities in Different Types of Lining:

The maximum permissible velocities for some types of lining are given below:

- Stone-pitched lining 1.5 m/s
- Burnt clay tile or brick lining 1.8 m/s
- Cement concrete lining 2.7 m/s

Now, as per the design of canal the channel is nonstable and non regime because silt which is entered the channel is not carried by suspension. For sandy loamy soil which is 7 to 20% clay, more than 52% sand therefore silty factor will be for 0.45mm mean diameter of soil will be as follows,

According to lacey's factor,  $f = 1.76\sqrt{m_d} = 1.2$

Taking the Value of n = 0.018 from IS 10430.2000

Therefore, mean velocity of flow  $V_{\text{mean}} = \frac{R^{2/3} \times S^{1/2}}{n}$  m/s

$$V = 0.556 \times R^{2/3} \times S^{1/2}$$

The discharge is given by  $Q = A \times V$

$$12.67 = 0.725 \times r^{3/8} \times S^{1/2}$$

$$f = 0.603 \times r^{1/3} \times S^{1/2}$$

$$1.2 = 0.603 \times r^{1/3} \times S^{1/2}$$

$$S = \frac{1.2}{0.603} \times \frac{1}{r^{1/3}} = \frac{1.99}{r^{1/3}}$$

$$r = 2.737\text{m}$$

$$S = \frac{1.99}{2.737^{1/3}} = 1.423\text{m in } 10000\text{m}$$

Hydraulic mean Radius, R= 0.5r

$$V = 0.81 \text{ m/s}$$

The maximum permissible velocity for cement concrete lining is 2.7 m/s > 0.81 m/s

Therefore, safe.

$$\text{Area of canal} = \frac{(B + 3D + B)}{2} \times D$$

Fixation of B/D ratio using Wood's Table, For discharge of 12.67 cumecs, the B/D ratio will be 5.45 by interpolation of data. Put, B= 5.45 D, A = 7.45 D<sup>2</sup>

$$Q = A \times V$$

$$12.67 = 7.45 D^2 \times 0.81$$

D = 1.45 m ~ Take D = 2m

B = 7.89 m ~ Take B = 8.5m

Therefore, Provide Freeboard = 0.5m from IS 10430:2000

As the Discharge capacity is greater than 10 cumecs. According to IS 10430:2000, Provide berms = 4m.

Provide dowels on the canal side of the service road, Width of coping should be 550mm.

Provide Inspection Bank/ wider Bank to satisfy minimum Bank top width = 5.55m.

For Minimum Radius ( $R_m$ ) of the curve allowable would be in following cases

In loose soil,  $R_m = 30$  to  $50 \times$  bed width in meter Therefore, Minimum Radius or curve of canal ( $R_m$ ) =  $30 \times 8.5 = 255m$

## V. CONCLUSION

Reliable assessment of waterlogged areas forms a crucial element in the urbanized area. The present study was successfully employed for assessment of spatially and temporally distributed waterlogged areas in order to evaluate the impact on urban area of Vithalvadi. With the help of GIS technology the acquisition of recent information about water logging studies aimed at solving urban problem. The region of Vithalvadi ( $19.228793^\circ N$   $73.148610^\circ E$ ) was experiencing losses during heavy rainfall in recent years frequently. The quantification of the area vulnerable to water logging of different frequency of occurrence has been studied. The study conducted includes application of **geographic information system** (GIS) systems for estimating the runoff and region affected. With the help of these data, it has been concluded that the region affected requires drainage channel of size  $8.5 \times 2.5m$ . The use of QGIS has proved beneficial and to carry the work smoothly. As a result of proposed RCC canal, the water logging, silting, the maintenance cost can be significantly decreased consequently flow velocity, conveyance efficiency can be increased. Total runoff of the study area has been calculated based on the topography and rainfall data. Total length and width of the canal has been proposed using manning's formula. The proposed modified drainage system using GIS technology will help in proper draining out of storm water from the study area. This study can be applied for the designing of the storm water system of other cities.

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