IMPACT OF VARIOUS FACTORS CAUSING FLOOD SITUATION IN LOWER TAPI RIVER BASIN USING GEOSPATIAL TECHNOLOGY

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***ABSTRACT:** The Lower part of the Tapi basin is prone to flood hazards due to its geographical location. The excessive release of water from Ukai dam during rainy season results in the inundation of Lower Tapi Basin (LTB) including Surat city. The flood occurred in 2006 instead of vast property damage, animal live lost, killed 300 people. Beside rainfall intensity, high discharge from Ukai Dam and decreasing carrying capacity of Tapi River, change in land cover is also a factor causing flood situation. In this study, runoff contribution of change in land cover to flood in Lower Tapi Basin is focused. The methodology includes geospatial technology, in which of satellite images are used to develop LULC maps of LTB for years 2002 and 2016 in ArcGIS 10.1 environment. HEC-HMS software was used to generate a rainfall-runoff model of both the land covers using single hydrograph. The change in peak discharge was compared.*

***KEYWORDS:** Flood, Land Use Land Cover, Modelling, Peak discharge, Lower Tapi River Basin.*

INTRODUCTION

Flood is a type of natural disaster which can happen any time in flood prone area if the proper preventive setup is not available, may lead to loss of lives and property. Especially it is common in the areas having high rainfall in the monsoon season.

To model and estimate the flood magnitude in the specific region requires a lot of studies. These studies and modeling of flood become easier with use of geospatial technology. According to (Abrishamchi, Dashti et al. 2011) “In recent years, Remote Sensing and Geographic Information Systems have been used in the evaluation of the environmental hazards.”.

Before modeling the flow of flood it necessary to model the integrated terrain of the river and locate the obstacles in the river. According to (Merwade, Cook et al. 2008) “The key to overcoming most of the issues associated with analyzing river channel data in GIS including spatial interpolation is mapping data in channel fitted (s,n) coordinate systems.”.

Mapping flooded area is become easier by processing satellite images. But satellite images are available in deferent intervals. When developing flood map from a satellite image may have some error because of the time lag. To overcome this issue (Brivio, Colombo et al. 2002) “developed a new procedure to estimate the flooded area at the peak time by integrating the flooded area from SAR imagery with digital topographic data from a GIS technique.”

Lower Tapi Basin is also the area where high-intensity monsoon rainfall starts from mid-June to mid-September and is the flood-vulnerable area. Studies are being conducted on the flood situation in Lower Tapi Basin. According to (Singh and Sharma 2009) “For quantification of the flood-prone area, the thematic map based on Google-Earth and IRS-1D data reveal that more than 80% of the urban area in Surat City could be flooded by an event of 50-year return period.”.

Several flood preventive measures are taken in the Lower Tapi Basin to prevent Surat City and surrounding area from flooding. But on the passage of time, this measure will not be enough to control and prevent the flood. According to someone (Patel and Srivastava 2013) “Till the 1994 monsoon, the warning level and danger level of Surat city was 10.18 m and 11.18 m respectively, but in 1994 the maximum level attained was 10.2 m which caused heavy damages in the city. This level corresponded to a release of 14868 cumecs from Ukai.”

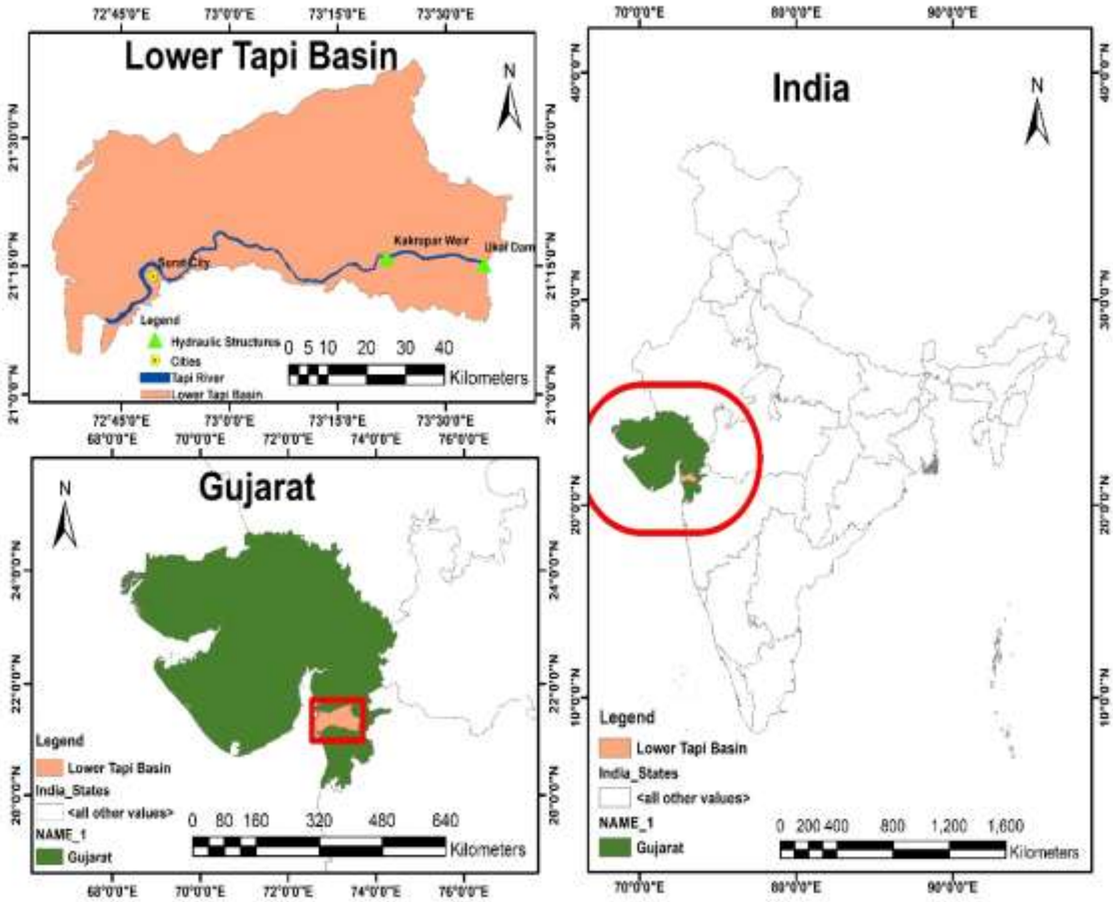
Due to several factor chances of flood satiation in Lower Tapi Basin increases by the passage of time. One of the main factors that contribute to the flooding is an increase in peak flow due to excess runoff due to change in land cover.

STUDY AREA

Lower Tapi river basin’s main river channel starts from Ukai dam to the Arabian Sea in the State of Gujarat. Length of Tapi river mainstream in Lower Tapi Basin is 129 Km. The total catchment area of Lower Tapi Basin is 3837 Km^2.

Figure 1: Map of the study area (Lower Tapi Basin)

On the mainstream of Tapi river downstream of Ukai dam there is another project, Kakrapar Weir. Kakrapar weir is an irrigation project which was constructed at a cost of rupees 20.61 crores. Length of Kakrapar weir is 621m and height is 14m. A couple of canals from both banks irrigate 2.28 lakh ha area.



Surat city is located 100 Km downstream of Ukai dam on the banks of Tapi river. Hazira city is located near the fall of Tapi River to the Arabian Sea. Both these cities are highly vulnerable to flooding. Flooding history shows that several times in the past these cities were inundated with floods, caused a huge human death and property damages.

DATA COLLECTION

The data required for this study includes satellite images covering study area, rainfall data recorded in the study area and soil data of the area. The required data was collected from different sources. The sources of data and acquisition methods are as follows:

Satellite Images:

United Nation Geological Survey (USGS), Earth Explorer website is providing satellite image free of cost. These free of cost satellite images have a resolution of 30x30 m, which is enough for this study. For this study, the required satellite images of Landsat 7 - 8 images of the years 2002 and 2016 respectively covering Lower Tapi Basin of the free monsoon season are downloaded from the USGS Earth Explorer website.

Rainfall data:

Rainfall data of the in Lower Tapi Basin is recorded in so many rain gauge. Historical rainfall data of these stations in Lower Tapi Basin was collected from Indian Meteorological Department, Surat.

Daily rainfall data recorded by Mandavi station in the month of August 2002 was used for the rainfall-runoff model in HEC-HMS.

Table 1: Daily Rainfall data for August 2002 recorded in Mandavi station Lower Tapi Basin

Daily Precipitation Recorded in Mandavi Station in the Month of August 2002					
Date	**RF in mm**	**Date**	**RF in mm**	**Date**	**RF in mm**
1	0	11	13	21	0
2	0	12	15	22	0
3	0	13	8	23	1
4	0	14	2	24	0
5	6	15	0	25	102
6	40	16	0	26	75

7	13	17	0	27	0
8	9	18	0	28	0
9	2	19	0	29	0
10	30	20	0	30	107
				31	23

Soil data:

World Digital Soil Map is free of cost available on the GeoNetwok website of United Nations Food and Agriculture Organization (UNFAO) free of cost. World Digital Soil Map was download shapefile format from GeoNework website. Shapefile format is easy to use in ArcGIS 10.1 software and crop the World Digital Map to the area under consideration.

DEVELOPMENT OF LAND USE LAND COVER MAPS

Due to increase in population with the passage of time the urbanization and other human activities increases, leads to the change land use and land cover, finally results increase the excess runoff. With the increase in excess runoff, chances of flooding also increase. Land cover is rapidly changing in Lower Tapi Basin due to increase in population and rapid change of vegetative areas into build-up area.

To compare the change in the land cover of the Lower Tapi Basin, satellite images from USGS Earth Explorer is an option which is more easy to use in ArcGIS environment. United States Geological Survey (USGS), Erath explorer website is providing Landsat image of 30x30m resolution free to download.

The change in land cover occurs in the long interval of time. The interval between two images selected for this study is 14 years

Fist Landsat 7 image selected is of the year 2002, covering the Lower Tapi Basin. The year 2002 was selected because Landsat 7 images later than 2002 have scanline gaps.

The second Landsat 8 image selected is of the year 2016, covering are under consideration. The gap between this two images is enough to know about the change in land cover.

The supervised Classification method in ArcGIS 10.1 software was used to classify the land cover of Lower Tapi Basin. Both images of 2002 and 2016 were supervised classified using Training Samples.

Both the image was classified into the same categories of land uses. The main land uses in the Lower Tapi Basin are buildup area, agricultural lands, vegetation, open lands, and water bodies and others. The four categories used in this study are buildup area, vegetative cover (agricultural land, forests and other vegetation), open lands and water bodies.

Following is the map showing Lower Tapi Basin Land Use Land Cover, developed from Landsat 7 satellite image of 2002 covering the Lower Tapi Basin, in ArcGIS 10.1 software.

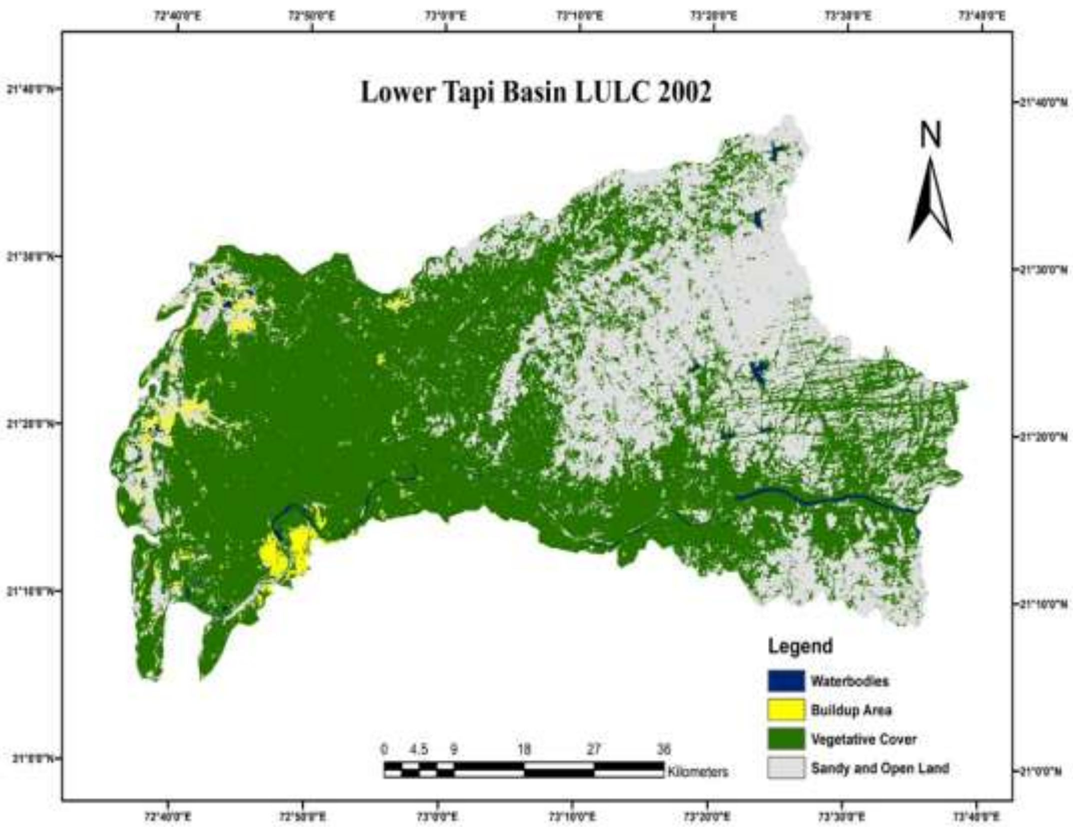


Figure 2: LULC of Lower Tapi Basin (2002)

Similarly, the Land Use Land Cover map of Lower Tapi Basin for the next year after a gap of 14 years is to be developed. Having Land Use Land Cover map of two different years give us capability to detect the change in different land covers.

Following is the map showing Lower Tapi Basin Land Use Land Cover of the year 2016, developed by processing Landsat 8 satellite image of 2016 and of the same season (pre-monsoon) covering the Lower Tapi Basin, in ArcGIS 10.1 software.

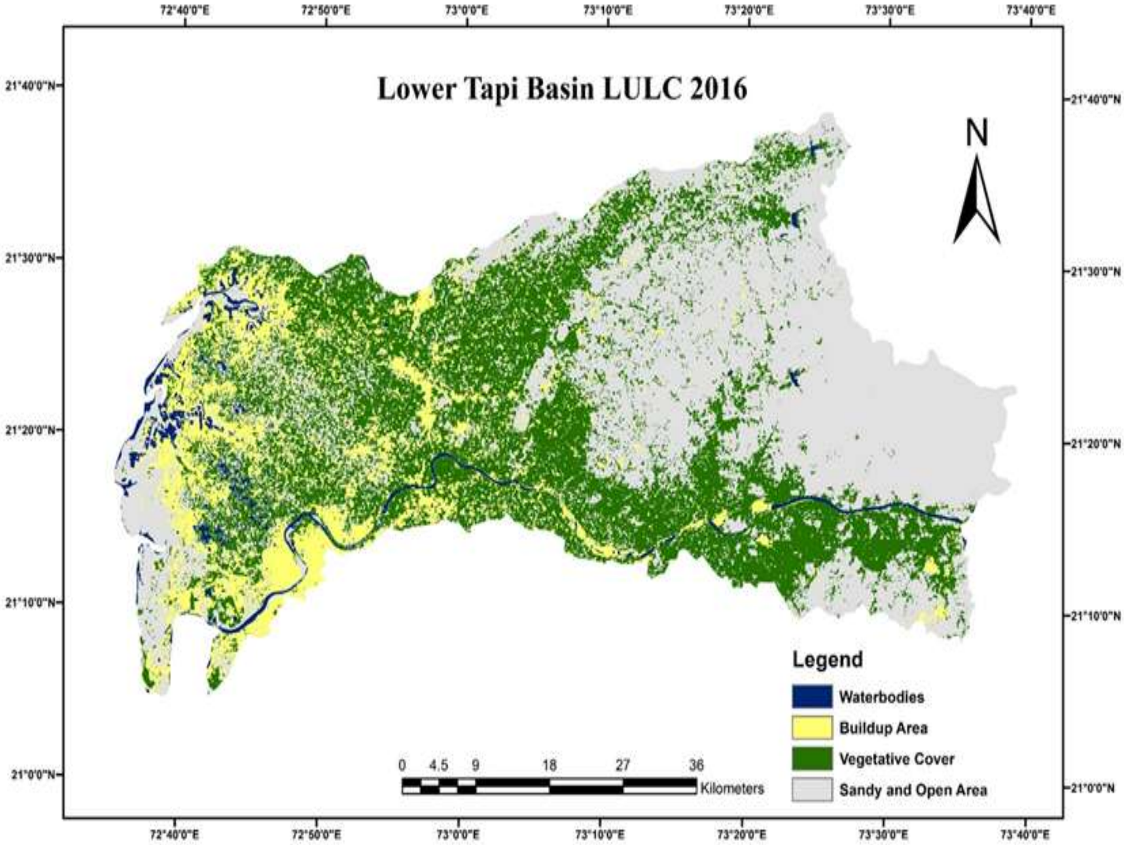


Figure 3: LULC of Lower Tapi Basin (2016)

DEVELOPING RAINFALL-RUNOFF MODEL

The Hydrologic Modeling System (HEC-HMS) is designed by US Army Corps to model rainfall and runoff of the watershed. Its open source software and easy to use.

To find the change in the peak discharge of the two land covers of the year 2002 and 2016, The Soil Conservation Service (SCS) method was used. This method introduces CN (Curve Number) for each type of land cover on A, B, C and D types of soil.

Soil map of Lower Tapi Basin was prepared from the World Digital Soil Map, available on United Nation Food and Agriculture Organization (UN-FAO) website. This soil data in conjugation with LULC maps were used to assign CN. (Te Chow, Maidment et al.)

Rainfall data of the August 2002, from the rainfall station Mandavi located in the Lower Tapi Basin, was selected. The assigned Curve Numbers were used to develop Rainfall-runoff models of both the land covers.

RESULTS AND ANALYSIS

Change in LULC:

In the result, the two Land Use Land Cover maps of Lower Tapi Basin developed for the years 2002 and 2016. The comparison of these Land Use Land Cover maps shows some changes in the Land Use Land Cover of Lower Tapi Basin. Among the four land covers studied (Water bodies, Buildup area, Vegetative Cover and Open land) only Vegetative Cover is decreased, all other covers including buildup area increased. The following table shows a change in LULC between years 2002 and 2016.

Table 2: Change in Land Cover of Lower Tapi Basin between years 2002 and 2016

Land Cover	LULC 2002 area in Sq Km	LULC 2016 area in Sq Km	Change in SQ Km	Increase/ Decrease
Waterbodies	30.82	83.55	52.7346	Increase
Buildup Area	65.83	497.45	431.6211	Increase
Vegetative Cover	2306.06	1315.33	-990.7245	Decrease
Sandy and open Land	1330.04	1836.38	506.3364	Increase

Change in Peak Discharge & other Hydrological Parameters due to change in LULC:

The change in land cover causes a change in runoff produced from the rainfall. The change in peak discharge due runoff produce in the result of same rainfall hyetograph recorded in the Mandavi rain gauge station in the Lower Tapi Basin in the month of August 2002, computed using HEC-HMS software is shown in the chart below.

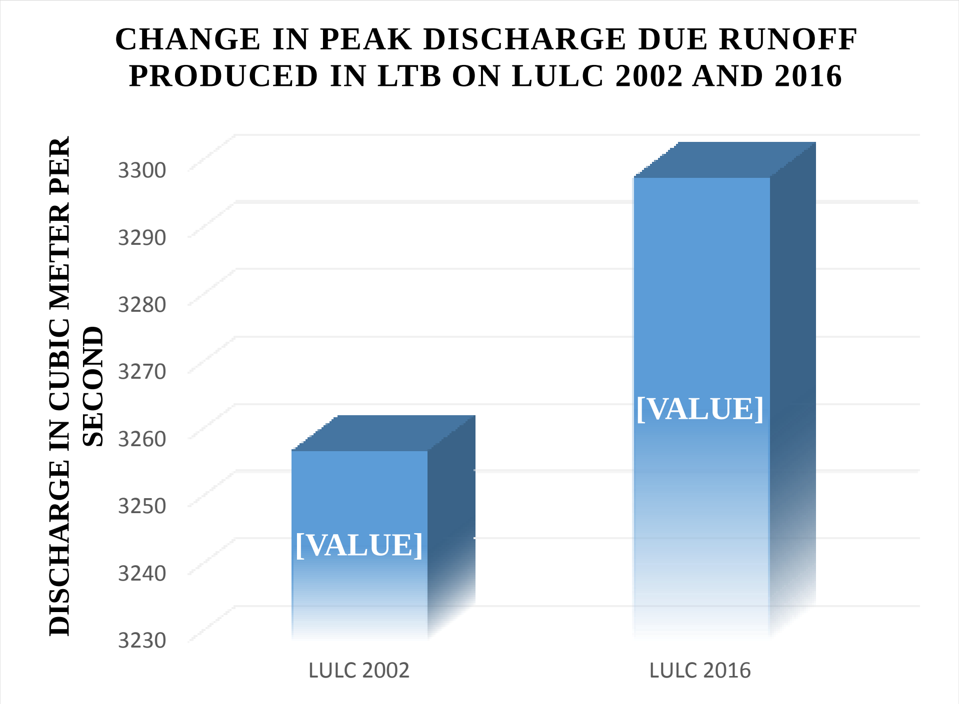


Fig 4: Change in Peak discharge due to runoff produced in LTB on LULC 2002 and 2016

The above chart shows that the peak discharge produced from the runoff of same rainfall hyetograph in the Lower Tapi Basin increased by 40.6 meter cubes per second.

The change in other hydrological parameters is also detected. Some of the parameters show an increase and some of them show a decrease due to change in LULC. Surface runoff produced after a change in LULC show an increase while the loss in precipitation shows a decrease in its quantity. Change in surface runoff and change in precipitation losses are shown in the table below.

Table 3: Change in Hydrological Parameters due to change in Land Cover of LTB between years 2002 and 2016

Parameters	Value for Land Cover of 2002	Value for Land Cover of 2016	Difference
Surface Runoff Depth in (mm)	315.40	327.95	+12.55
Precipitation Loss Depth in (mm)	102.16	89.48	-12.68

OHER MAJOR FACTORS CAUSING FLOOD SITUATION IN LOWER TAPI BASIN

Besides the discharge of runoff produced from the precipitation in Lower Tapi Basin, there are to other main causes of historical in the basin. These factors are huge discharge from Ukai dam during the rainy season of monsoon and decreasing carrying capacity of the main channel of Tapi River in Lower Tapi Basin.

The following graph shows the quantity of discharge from Ukai dam and stage level of the respected discharge in Hope Bridge.

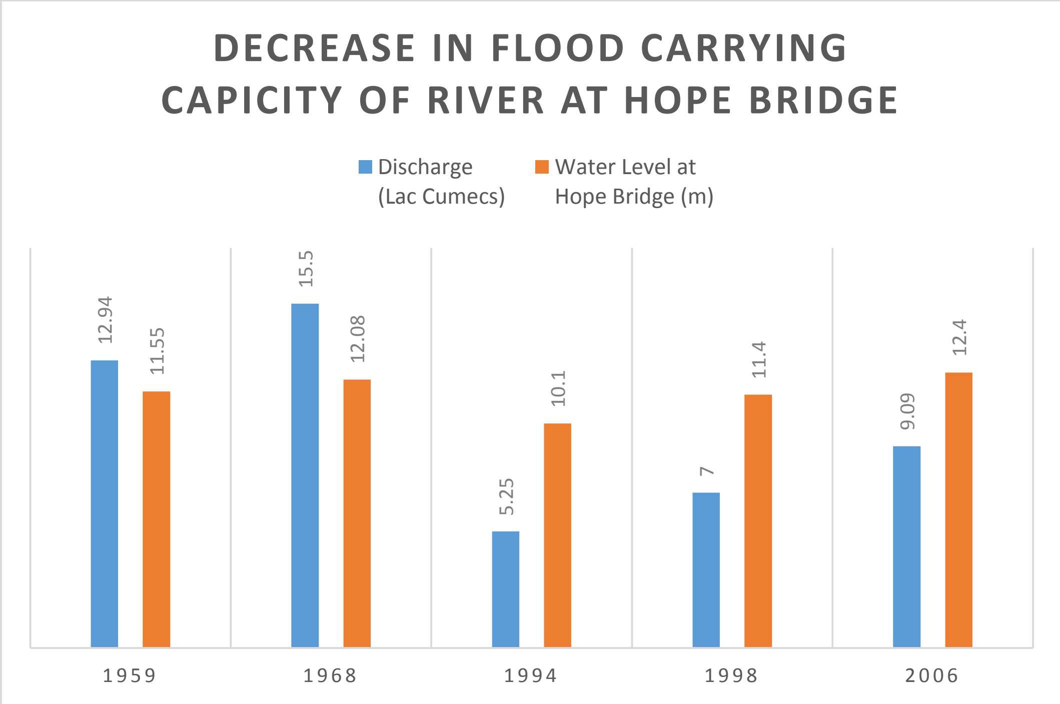


Figure 4: Chart showing historical flood water discharge and water level at Hope Bridge. (Agnihotri and Patel 2011)

The above chart shows that the discharge from Ukai dam during historical flood situation is in a very large quantity. Which is several times more as than the runoff produced due to precipitation in Lower Tapi Basin. From the chart, it's clear that 12.94 lac cumecs discharge from Ukai dam in the year 1959 created a water level of 11.55m in the Hope Bridge, but in the year 1998 only 7 Lac cumecs result in a water depth of 11.4 m in Hope Bridge in the Surat. It shows that the carrying capacity of Tapi River in Lower Tapi region decreased from one flooding event to another.

CONCLUSION

Land Use Land Cover (LULC) maps of the study area (for the years 2002 and 2016) are prepared using ArcGIS 10.1 software, by processing satellite images of the area under consideration. The method is accurate and consumes less time to evaluate the change in LULC.

In this study LULC change of Lower Tapi Basin detected and it reveals an increase in the buildup area. This increase in urbanization and buildup area is coupled with an increase in peak discharge produced from the runoff of the precipitation in the Lower Tapi Basin.

LULC mapping indicates that entire Lower Tapi Basin as single catchment is less responsible for flood situation rather than quick urbanization found in Surat city and surrounding area.

The Two major facts which cause flooding situation in Lower Tapi Basin are high discharge from Ukai dam and reduction in carrying capacity of Tapi River main channel in the Lower Tapi region. The runoff produced due to precipitation in Lower Tapi Basin is quite low.

As the population is increasing year to year, the need for build up area also increases. With the increase in the urbanization and buildup area, this contribution will increase with the passage of time.

This study is providing information to the planner, that during planning for the future, all factors causing a flood in Lower Tapi Basin should be taken into account, especially increase in buildup area. Because its contribution in flooding will increase year to year and long-term development planner must consider it as an issue.

A considerable increase in buildup area will help planners to estimate the future loss of lives and properties, according to that they must plan. This will decrease the risk of future investment to the natural disaster (Flood).

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