The study of Urban sprawl and its Effect on Flood plains of the Vishwamitri River, A Case study of Vadodara

Thesis submitted in
Partial Fulfilment for
The Award of the Degree of
Master of Urban and Regional Planning

By
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JULY 2021

CERTIFICATE

The study of Urban sprawl and its Effect on Flood plains of the Vishwamitri River, A Case study of Vadodara

The contents presented in this Thesis represent my original work and it Has not been submitted for the award of any other Degree or Diploma Anywhere else.

MISTRY VATSALI KAMLESHBHAI

This Thesis is submitted in partial fulfilment of the requirements for the Degree of Master of Urban and Regional Planning
At the Department of Architecture
Faculty of Technology and Engineering
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The present work has been carried out under our supervision and Guidance and it meets the standard for awarding the above stated degree.

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ABSTRACT

Due to global climate change, Frequent Occurrence of floods in the country has become a serious concern for the planners and policy makers. Irregular and varied spatial distribution of rainfall coupled with failure and mismanagement of human constructed water body reservoirs have resulted in reoccurring floods affecting large areas of population. Vadodara city has suffered from events of floods incurred due to such causality. The study focuses on evaluating the reasons of flooding and defining strategic solutions for a better flood management approach.

A river to basin network is prepared for better understanding the relationship of the river Vishwamitri and its connections to various water bodies present in its basin. This approach further deepens into study of different parameters related to flood events for Vadodara city. Frequency analysis is carried from the available hydro meteorological historical rainfall data series of past four decades for Vadodara city, Gujarat. A Hydrologic Model is prepared to understand the rainfall-runoff relationship by using GIS and ARCSWAT software which can act as a warning indicator for Vadodara city to cope up with future occurrences of floods.

The mixed Global probability distribution is adopted to explore the re-occurrence of rainfall events with certain return period. Analysis has also revealed the Flood reoccurrence Time duration is 25years. Statutory Recommendations and Policies are recommended for reducing the Rainfall runoff of Vadodara and to ensure the better flood management approach.

This thesis is dedicated to my parents, family and friends for patiently waiting for me to socialize with them. To all who believe in themselves and have followed their will to find the way.

ACKNOWLEDGEMENT

It is an impeccable fact that every vision needs a spirit of dedication and hard work but more than that it needs proper guidance. Therefore, first and foremost I would like to thank my department for letting me carry out this Study. I am extremely grateful to Head of the Department Dr. Bhawana Vasudeva, for providing me this platform to conduct the study.

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I am extremely grateful to my Family for their love, prayers and sacrifices for educating and preparing me for my future. I would like to thank all my friends and colleagues to help me whenever I needed them throughout the study. Finally, my thanks go to all the people who have supported me to complete the research work directly or indirectly.

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Abbreviations

BOD: Biochemical Oxygen Demand
CETP: Common Effluent Treatment Plant
CGWB: Central Ground Water Board
COD: Chemical Oxygen Demand
CPCB: Central Pollution Control Board
CWC: Central Water Commission
GOI: Government of India
GERI: Gujarat Engineering Research Institute
GIDC: Gujarat Industrial Development Corporation
GPCB: Gujarat Pollution Control Board
GSWSSB: Gujarat State Water Supply and Sewerage Board
IMA: Indian Medical Association
IMD: Indian Meteorological Department
IUCN: International Union for Conservation of Nature
JNNURM: Jawaharlal Nehru National Urban Renewal Mission
KM: Kilometer
LPCD: Liter per Capita per Day
MCM: Million Cubic Meter
MGD: Million Gallons per day
MLD: Million Liters per day
MoEF : Ministry of Environment and Forest PDS Purpose Driven Study
STP: Sewerage Treatment Plant
SWM: Solid Waste Management
TPD: Tonnes per Day
VMC: Vadodara Municipal Corporation
WTP: Water Treatment Plant
SWAT: Soil Water Assessment Tool

CHAPTER 1

1.Introduction

Floods are natural hazards occurring on regular basis in developed, developing, and underdeveloped countries. The effect of floods has an impact on livelihood systems, property, people, infrastructure, and public utilities. Recent trends have shown an increase in flood-related damages. This can be attributed to a steep increase in population, rapid urbanization, growing development and economical activities in flood plains coupled with global warming. (Natural Disaster Floods, 2014).

The carrying capacity of rivers has been constantly decreasing, mainly responsible for causing floods, drainage congestion, and erosion of river-banks. Cyclones, cyclonic circulations, and cloud bursts cause flash floods and further lead to huge losses. Large-scale loss of lives and damage to public and private property due to floods indicate that we are still to develop an effective response to floods. (Natural Disaster-Floods, 2014)

Change in Rainfall patterns is one of the effects of climate change. Every year rainfall occurs for three to four months in most of the districts of India. Floods affect vast areas of the country, sometimes transcending the state boundaries. Proper study should be conducted as prior planning, to manage the circumstance of floods which are essential at the National level. In the Vadodara district, the rainfall pattern is highly variable. Rainfall mainly occurs in July, August, September, and October. Heavy rainfall and flood cause severe damage to the livelihood and infrastructure of the town. Erroneous planning and construction near the drainage channel are additionally among the explanations for flooding in the Vadodara district.

1.1 What is Urban Flooding?

Flooding is an overflowing of water toward land that's normally dry and adjacent to water body. Floods can happen during heavy rains, when ocean waves come on shore, when snow melts quickly, or when dams or levees break. Damaging flooding may happen with only some inches of water, or it's going to cover a house to the rooftop. Floods can occur within minutes or over a protracted period, and will last days, weeks, or longer. Floods are the foremost common and widespread of all weather-related natural disasters.

Flash floods are the foremost dangerous reasonably floods, because they combine the destructive power of a flood with incredible speed. Flash floods occur when heavy rainfall exceeds the power of the bottom to soak up it. They also occur when water fills normally dry creeks or streams or enough water accumulates for streams to overtop their banks, causing rapid rises of water in an exceedingly short amount of your time. They'll happen within minutes of the causative rainfall, limiting the time available to warn and protect the general public.

1.1.1 What areas are at risk from flash floods?

Densely populated areas are at a high risk for flash floods. The construction of buildings, highways, driveways, and parking lots increases runoff by reducing the quantity of rain absorbed by the bottom. This runoff increases the flash flood potential. Sometimes, streams through cities and towns are routed underground into storm drains. During heavy rain, the storm drains can become overwhelmed or plugged by debris and flood the roads and buildings nearby. Low spots, like underpasses, underground parking garages, basements, and low tide crossings can become death traps.

Areas near rivers re at risk from floods. Embankments, referred to as levees, are often built along rivers and are wont to prevent high water from flooding bordering land. Dam failures can send a sudden destructive surge of water downstream.

Mountains and steep hills produce rapid runoff, which causes streams to rise quickly. Rocks and shallow, clayey soils don't allow much water to infiltrate into the bottom. Saturated soils also can cause rapid flash flooding. Camping or recreating along streams or rivers are often a risk if there are thunderstorms within the area. A creek only 6 inches deep in mountainous areas can swell to a 10-foot deep raging river in but an hour if a thunderstorm lingers over a neighbourhood for an extended period of time. Sometimes the thunderstorms that produce the heavy rainfall may happen well upstream from the impacted area, making it harder to acknowledge a dangerous situation.

1.1.2 Factor Causing Urban Floods in India

Majorly the factors causing urban floods are sub divided into three categories i.e.

1. Hydrological factors:

- Change in course of rivers
- Type of soil and water retention capacity
- Infiltration rate and Ground water level prior to floods
- Synchronization of runoffs from various parts of the watershed
- Channeled Storm water network. cross-sectional shape and roughness

2. Meteorological Factors :

- Unprecedented Rainfall
- Cyclones
- Heavy Thunderstorms
- Global warming
- Influence of Urban microclimate

3. Man-Made factors:

- Surface sealing due to urbanization and deforestation
- Building design without regard to flood risk
- Encroachment of floodplains and low-lying areas
- Lack of maintenance of infrastructure and drainage channels
- Siltation and improper solid waste disposal in Drainage channels
- Unplanned release of water from dams / lakes located upstream of cities and towns
- Absence of administrative framework & Lack of preparedness

Primary Losses	Loss of life & physical injury
	Damage to buildings, contents & infrastructures
	Disruptions to industrial production
	Loss of, or disruptions to utility supplies
	Loss of heritage or archaeological site
Secondary Losses	Increased stress; physical & psychological trauma
	Enhanced rate of property deterioration & decay
	Lost value added to IND
	Increased traffic congestion; disruption of flow of employees to work
	Contamination of water supplies; food and other shortages
	Loss of exports; Reduced national gross domestic product

Table 1 Primary and Secondary losses due to urban floods

1.1.3 Urban Flood: Man-Made Disaster

Overburdened drainage, unregulated construction, no regard to the natural topography and hydro-geomorphology all make urban floods a man-made disaster. Below is the diagram showing how heavy rains penetrate into the water bodies and its path.

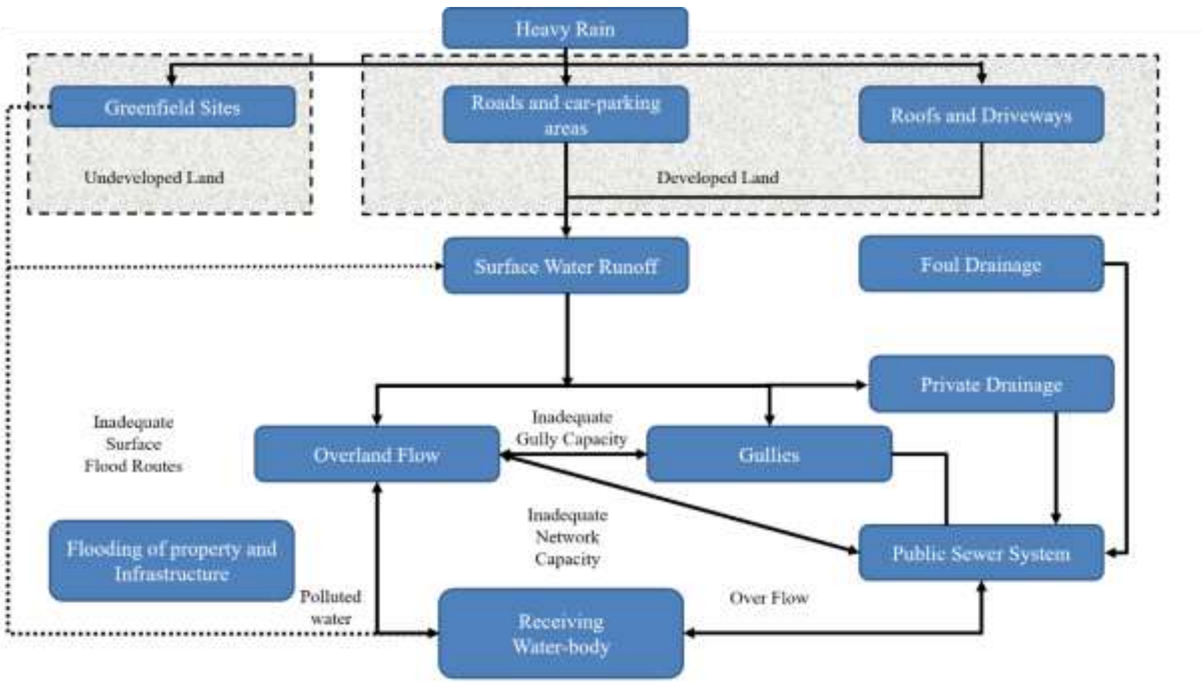


Figure 1 Systematic Diagram of Flooding

1.2 Literature Review

The literature review is done in two parts before finalizing aim and objectives and after. Depending upon the past flood history of Vadodara city, literature study has been categorized in the following manner:

1. Causes of floods
2. Geomorphology of watershed
3. Mitigation measures for flood control
4. Development of Flood model using ARC-SWAT and GIS

1.2.1 Causes of Flood

Shastri, H.K et. al (2010) studied the floods situation that occurred in Vadodara city in 2005 and concluded how natural disasters enhances due to improper planning of resources and gives importance of consideration of natural water bodies in any town-planning scheme as the same situation may be faced in all developing cities.

U.S. De, G. P. Singh* and D. M. Rase*(April 2013)** Urban flooding in recent decades in four mega cities of India

In this paper flood situations of the four most populated mega cities of India is discussed: Delhi, Kolkata, Mumbai and Chennai. Uncontrolled growth of mega cities has increased their vulnerability to flooding. Impacts can be reduced by various measures with help of

Doppler radars, Identification of vulnerable zones in and around the mega cities , Improvement of old drainage systems, Implementation of health and sanitation measures, Pollution control measures with planning of green cities, including urban reforestation

1.2.2 Geomorphology of Watershed

Patel, A. et. al (2014) has attempted in the present study to prioritized watersheds based on morphometric parameters derived from Indian Remote Sensing Satellite (IRS) Cartosat1 DEM-10m data and LISS-IV data covering Vishwamitri watershed in Vadodara and Panchmahals districts in Gujarat State. The morphometric parameters like stream length, bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circularity ratio and compactness coefficient and elongation ratio are considered for prioritization of all the mini watersheds in the study area.

Shah, S.D. et. al (2009) has done morphometric analysis and their relative parameters for the Vishwamitri river basin. The quantitative analyses of the morphmetric characteristics of the basin include stream order, stream length, bifurcation ratio, drainage density, drainage frequency; relief ratio, elongation ratio & circularity ratio etc. were computed in present study using Geographical Information System (GIS) Software (Geomedia Professional V 5.1).

1.2.3 Mitigation methods for Flood Control

Nehmat Khosla,(2019) Impact of urban floods on the community living in informal settlements: The case of VADODARA FLOODS

After Analyzing the situation and the recommendations which were made such as:

1. ERADICATING PHYSICAL VULNERABILITY: A suitable relocation policy is recommended for adversely affected settlements at appropriate high elevated areas with sufficient job centers.
2. REMOVING THE DILAPIDATED HOUSING CONDITIONS:

DEVISING JOB AND LIVELIHOOD OPPORTUNITIES

Stokkom, H.T. et. al (2005)has discussed about how the Dutch government is currently trying to achieve sustainable water and river management by developing and implementing a new approach to flood defense. New approaches includes Awareness, Three-step-strategy: Water by Restoring Rivulets, Temporarily Storing Water and Delaying Runoff, Spatial planning, Responsibilities

1.2.4 Development through ARC-SWAT model

Vikas Kumar Rana & Tallavajhala Maruthi Venkata Suryanarayana (2020) presents in their paper a case study of Godavari river flood modeling using SWAT software. The flood released for Gangapur dam, which is constructed on upstream of Nashik city at 14 km distance is considered for the modeling. The flood discharge is based on the worst discharge of 1969 flood. The runoff was calculated for the particular events. The model facilitates to locate the flood plain and its extent for effective flood mitigation measures

Sunil Kumar and N. K. Goel (2015) In the present study the hydro-meteorological data of Dhadhar river basin have been analysed in detail for the presence of any non-stationary like changes in mean, presence of short and long term dependence and presence of trend etc. For this purpose observed data of rainfall and temperature at various stations over Dhadhar basin have been analysed and results presented.

1.3 Problem Statement

Due to constant growth rate in urbanization, floods are most frequently occurring and causing natural disasters. In the past decade Vadodara city has witnessed floods several time which have resulted into loss of property and lives. Flooding in urban areas and has brought down city to halt. The city as well as the surrounding villages are prone to flood risk. Even with such frequent occurrences of floods in the city an effective flood management plan has not been worked out.

In order to provide a proper flood management plan first it is necessary to understand the relative causes of flood. So the main problem lies with understanding the causes of flood with respect to the city characteristic. Many governmental & nongovernmental agency are working to reduce the effects of flood which include construction of check dams, inter basin water exchange, channelizing & diversion of flood water, etc.

Being a citizen of Vadodara city and a student of Urban Planning is tremendous urge to find out why the city was still on the verge of flooding every year, in spite of having experienced the same situation before. Even with such occurrences, at present the city is lacking with a proper flood management strategy. This motivated to focus on research of the disaster management aspect of urban planning. This study also demanded to work on cross-platforms fields such as planning, engineering, hydrology and geology which are both, interesting and a challenging tasks.

1.4 Aim of the Study

To study the Urban flood Impacts & its causes on the Vadodara City and presenting a set of operative strategies and practical recommendations to increase the level of resilience in urban space with regards to flooding.

1.5 Research Objectives of the Study

This research would mainly focus on fact that how the flood impacts the Vadodara City, How the Rainfall and Surface water Runoff are interlinked.. The objectives of the study will be as following:

1. To study the occurrence, its causes and mismanagement of floods for Vadodara city.(Current and Past)
2. To Identify Features and Characteristics that hinder Main Natural flow of the water in Existing Urban Environment.
3. To develop a Hydrologic flood model using Software Database (GIS and ARC-SWAT model).
4. To assess the effects of land use/land cover change on the hydrological processes and the effects of human activity on it.

1.6 Research Questions of the Study

In order to achieve the above objectives, the research questions to be answered are:

1. What is the contemporary understanding regarding phenomenon of flood?

2. How the natural water bodies, including river Vishwamitri, its tributaries and water courses, have been responding to sudden heavy rainfall in the catchment areas?
3. What are the causes for occurrence of such Urban floods?
4. How are flooding adaptation measures being performed in the city in past?
5. Depending on the context, which measures that deal with urban flooding can be considered the most effective to manage floods in Vadodara?

1.7 Scope of the study

The scope of the study is focused on the parameters that have caused floods in Vadodara city.

- In context on the present study, the flood analysis is done for the situation emerged in the city along the banks of Vishwamitri river when it flows above its High Flood Level (H.F.L)
- Vishwamitri river basin which is part of Dhadhar river basin is delineated for the present study.

1.8 Limitations of the study

The study limits itself to Vishwamitri River and its streams existing within the city only. Flood analysis for the entire city is done and solution will be provided as statutory because Flood occurrence is an Act of God. Morphometric analysis of Vishwamitri sub-basin is done for specific parameters which are related to research objectives. The flood model would have been more accurate if specific data related to cross-section, discharge data of the catchment and local runoff were available. The meandering effect of river reach was not taken account.

1.9 Research Methodology

The methodology adopted during the study started with identification of issues for Vadodara city. From the various issues identified, frequent occurrence of flooding in Vadodara city that motivated to take up this particular topic.

The name of the topic was finalized which reflected a holistic approach towards the study. The next step was stating down the exact problem that was faced by the city due to floods. Flood management is a very broad aspect, so specific question related to the problem were scrutinized and a focus was created for the research topic. Based on the previous process research questions, aim and objective were finalized.

The aim and objectives helped the research not getting diverted into other aspects of flood management and focused study was maintained. The step followed study of literature. Literature review included books, journal papers, articles, reports, etc. which were categorized according to research objectives. Findings from literature review were written in the form of summary. The next step is data collection.

A detailed methodology is created in collecting the data and analysing it. Data is also further divided into various categories which helped in collection of precise and relevant data focusing to the research objectives. Analysis is carried out based on the data collected.

Final step includes deriving conclusions and recommendation for the study. The overall methodology is presented in Figure 2.

Research Methodology

Issues and SWOT Analysis

Floods	Flood impacts	Major Losses

↓

Literature Review

Floods	Flood modelling	Types of floods	Causes & Impacts of floods

↓

Study Area Delineation

Selection of study area	Delineation of watershed area	Rainfall analysis	Identification of Gaps

↓

Data Preparation

LULC Maps of 2001 2011,2021, 2005 & 2019	History of Flood patterns in the area	Generation of maps on GIS	SWAT Model for finding surface runoff

↓

Data Analysis

Stacking of LULC Maps of 2001 2011,2021	Study the impact of floods of 2005and 2019	Running Swat model and Calculation surface runoff	Comparing it with the data from Gage stations

↓

Development of Flood Model

Collecting data from SWC, India	Study the Storm water management in past and present conditions	Calibration and Validation for Hydro graph preparation	Comparing it with the data from Gage stations

↓

Formulation of Results

↓

Conclusions and Recommendations + Finances

Figure 2 Research Methodology

CHAPTER 2

2.Study Area

In this study the years which are considered to be base years are from 1980-2019 and on the basis of this calculations inventory forecasts are made for 2021, 2031, 2041 and 2051.

2.1 General Overview

The study area comprises of Vadodara city and Vishwamitri river sub-basin. In Vadodara city the study area for flood analysis is limited to area along the banks of Vishwamitri river and its streams which is flowing through the city and the flood accumulating spots. Flooding situation has occurred when the river has crossed its H.F.L. The entire city is taken up for flood analysis. Vishwamitri river sub-basin encompasses the origin of the river and major water bodies which have relationship with the city and flood hazard.

2.2 Vadodara City Profile

Vadodara is located in the middle east side of Gujarat state, India. It is the third largest city of Gujarat also known as the cultural city. The geographical location is 22°18'N 73°19'E . Total area of city within the municipal limits is about 159.95 sq.kms. The city has population of 16,66,495 people and is divided into 4 zones, 28 election wards and 12 administrative wards. The 15th largest city in India with the area of 260.33km2

Figure 3 Location map of Vadodara city

2.2.1 Climate

Vadodara features a tropical savanna climate under Koppen's climate classification. There are three main seasons: Summer, Monsoon and winter. The climate is dry. The weather is hot through the months of March to July — the average maximum summer is 36 °C, and the average minimum is 23 °C. From November to February, the average maximum temperature is 30 °C, the average minimum is 15 °C, and the climate is extremely dry. Cold northerly winds are responsible for a mild chill in January. The southwest monsoon brings a humid climate from mid-June to mid-September. The highest temperature recorded is 47 °C and the lowest is 15 °C

2.2.2 Rainfall

The average annual rainfall in Vadodara is 930 mm. The rainfall occurs almost entirely during the monsoon months of June, July, August and September.

2.3 Codification of Vishwamitri River Catchment Area

The study comprises of Vishwamitri sub-basin and Vishwamitri River. The catchment area of the Dhadhar basin is 3423 Sq.km. The Vishwamitri river is a major tributary of the Dhadhar river (It is a part of Lower Mahi Basin). The study area covers the Vishwamitri sub-basin. The catchment area of the basin is 624 Sq.km. Upper catchment produces approximately 5020 cubic meter runoff per second during peak rainfall. It is located in the north-east direction of Dhadhar river basin. Vadodara city is a part of the basin (Figure 4).

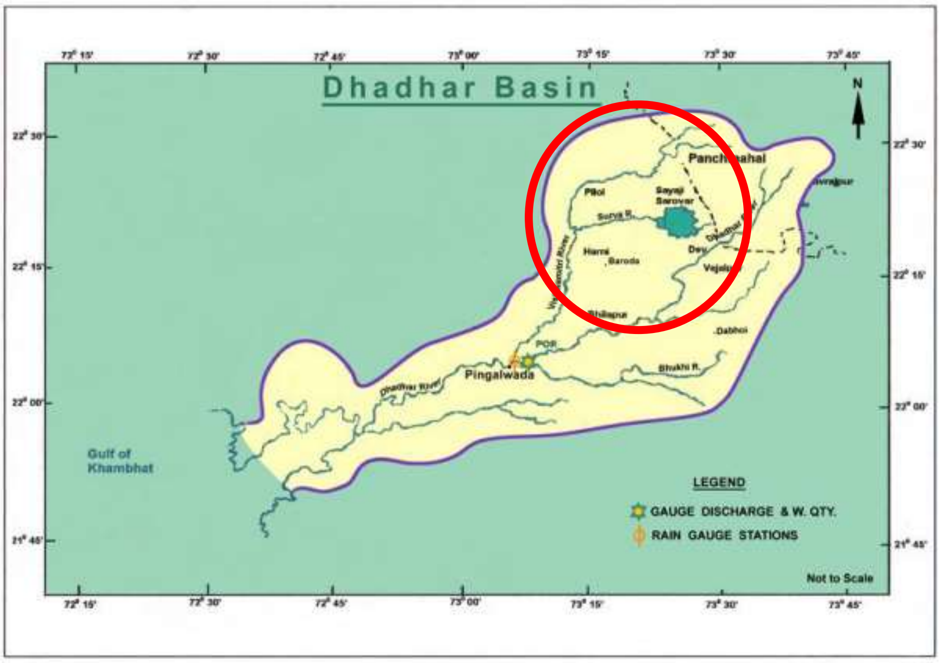


Figure 4 Dhadhar River Basin

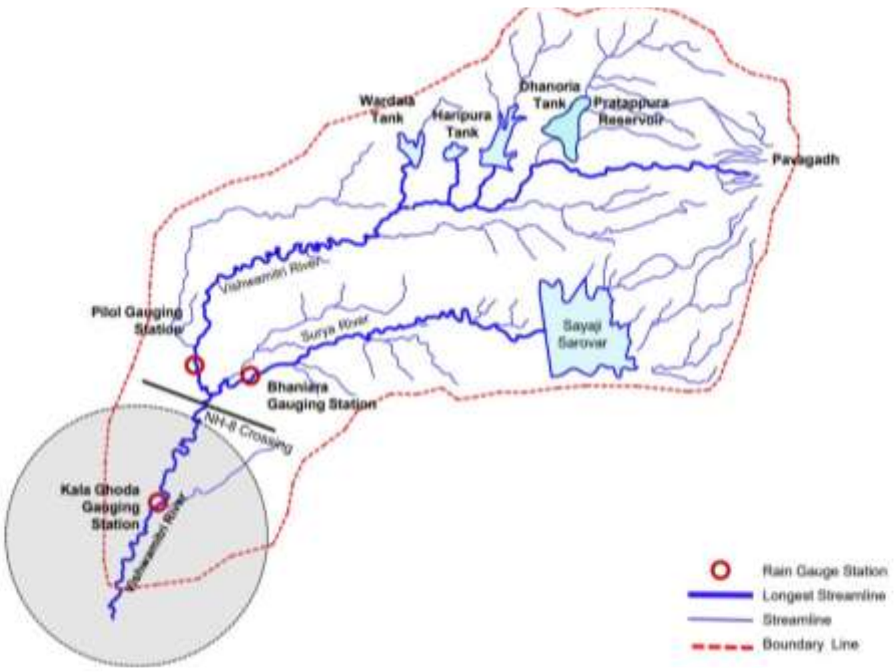


Figure 5 Vishwamitri River Catchment Area

The major water bodies in the basin are Ajwa sarovar, Pratapura lake, Dhanora lake and Dhansarvav lake. Ajwa Reservoir accounts for 40% of the watersupply. The climate of the basin is characterized by a hot dry summer, an moderate winter and humid monsoon.

There are total seven IMD (Indian Meteorological Department) stations in the catchment area where rainfall is recorded. They are Vadodara city (MS University, Observatory), Pilol, Bhaniara, Ajwa, Pratapura, Dhansarvav and Dhanora. The two rivers majorly receives water from rainfall in catchment and through these water bodies. Ajwa sarovar fulfils 40% need of water to the city.

2.3.1 Rainfall and Water level

The basin receives most of the rainfall from the south west monsoon from June to September. There are total seven IMD (Indian Meteorological Department) stations in the catchment area where rainfall is recorded. They are Vadodara city (MS University, Observatory), Ajwa, Pratapura, Dhansarvav, Dhanora, Pilol and Bhaniara. Presently there are only three stations in the catchment area where discharge/water level/discharge is recorded. They are at Vadodara City (Kalaghoda) Bridge, Pilol, Bhaniara.

2.3.2 River System and its Interconnection with lakes

Vishwamitri river originates from the Pavagadh hill which is located 40 K.m. in the north-east direction from the city.

Figure 6 Vishwamitri River Map passing through City

River length within VUDA boundary: 27 km

River length within VMC boundary: 16.5 km

River length with branches and loops: 23.5 km

River width: 60-80 m

River depth: 8-10 m

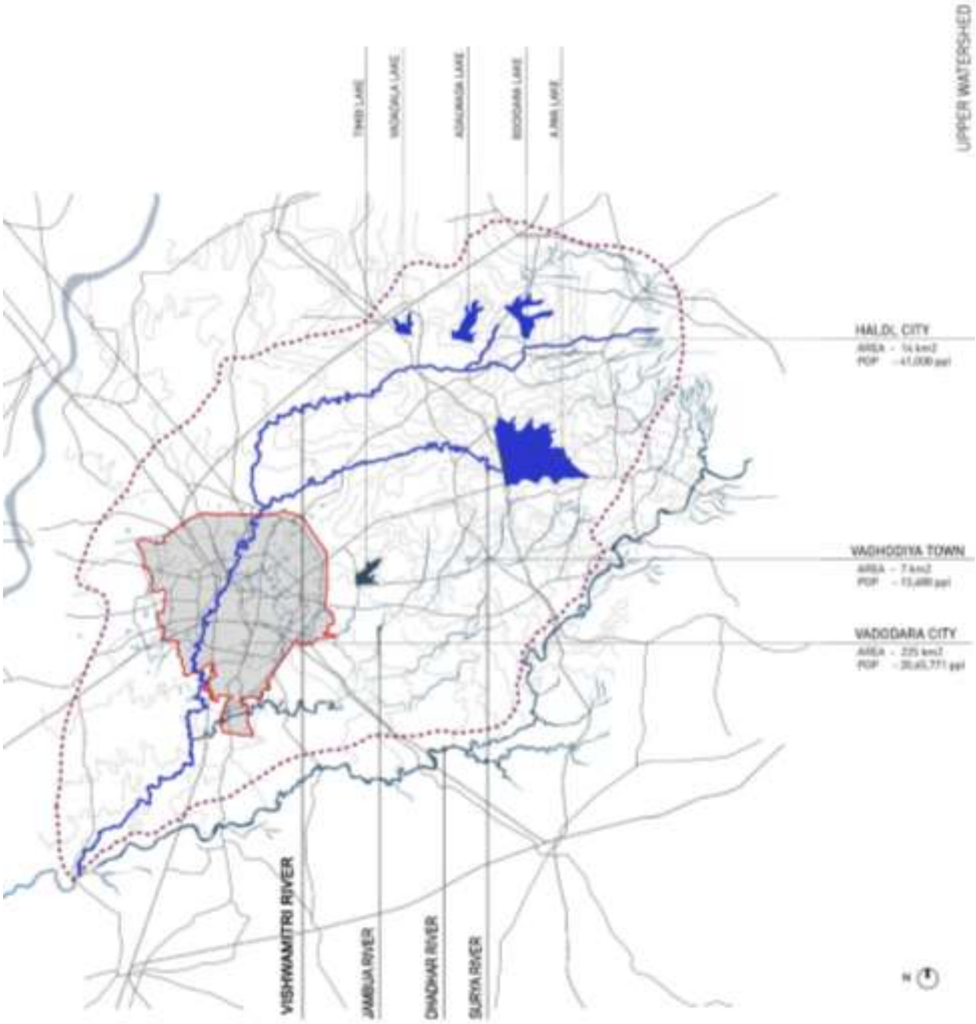


Figure 7 Watershed Area of Whole Vishwamitri Basin from Pavagadh to Gulf of Khambhat

It passes nearby Pratappura tank and passes through Vadodara City. 27 km stretch of the river divides Vadodara city in to two parts. The general slope of river within the city is from NE-SW direction (Figure 7). In the city river receives water from two major drains from east and west direction which meets the river at centre of the river reach. There are two main tributaries to the river Vishwamitri i.e. Surya river joins Vishwamitri at Dena Village and Jambua River joins at Jaas village near Khalipur village. In the course of river length Vishwamitri river receives a large number of sewage drains, storm water drains, industrial discharges and discharges from sewage treatment plants. The river ultimately meets river Dhadhar at Pingalwada. The water from Pratappura Sarovar, Haripura Tank, Dhanora Tank, Ajwa Sarovar and runoff generated due to rainfall in catchment area flows in the Vishwamitri river. The river Dhadhar finally joins the Gulf of Khambat. (Vyas & Fefar, 2014)

Past:

- There were 30 lakes and 1 river Vishwamitri in 1884.These water bodies had a planned network channel.
- ANCIENT BARODA, as we may call the region of the old tanks which run for about a mile and a half along the eastern margin of the city plan, from the Warashia and Sarshia tanks, past the Ajab and Rajah tanks to the Mahmad tank and even to minor ones southward.

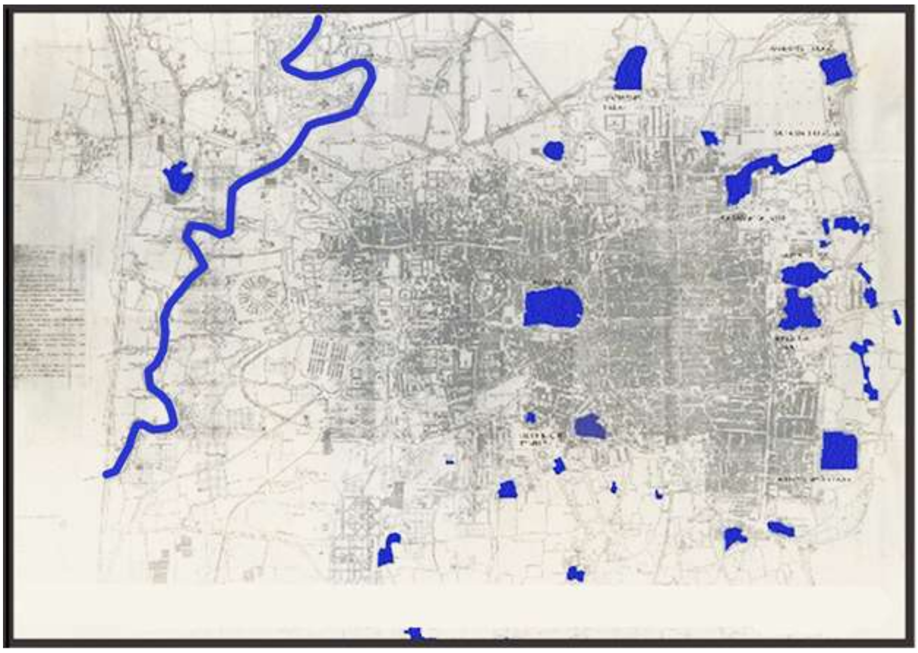


Figure 8 Map of Natural Water bodies Vadodara in 1884

Present:

75% of the bodies within the city limits are in eutrophic condition. The wetland areas are generally encroached upon by slum dwellers and they use the wetland area for various purposes. Close look into the environment of these water bodies indicate that these ponds are surrounded by densely populated slum areas.

The household sewage and domestic waste of these slum dwellers is directed into these water bodies resulting in high organic loading.

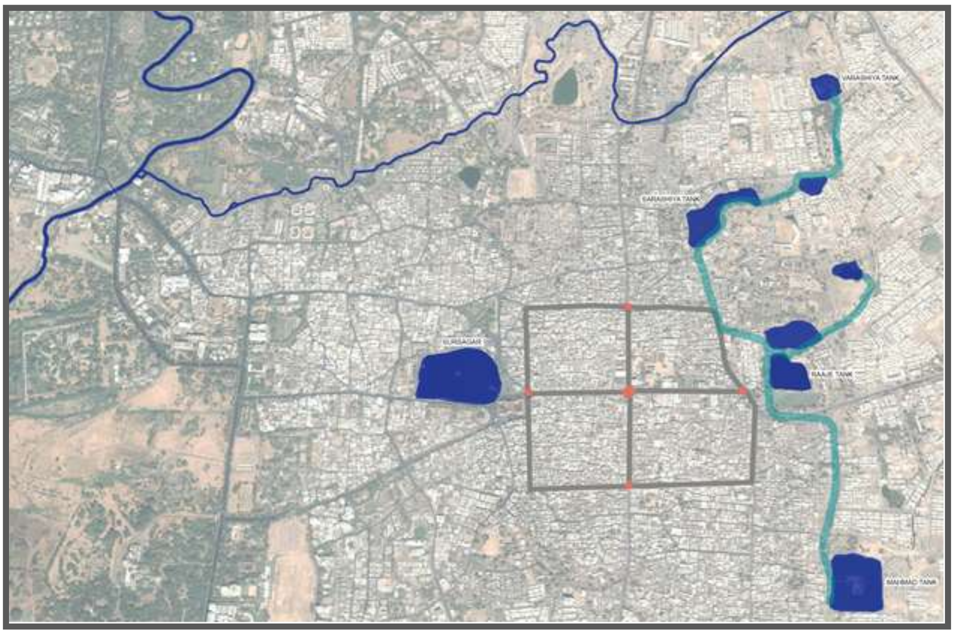
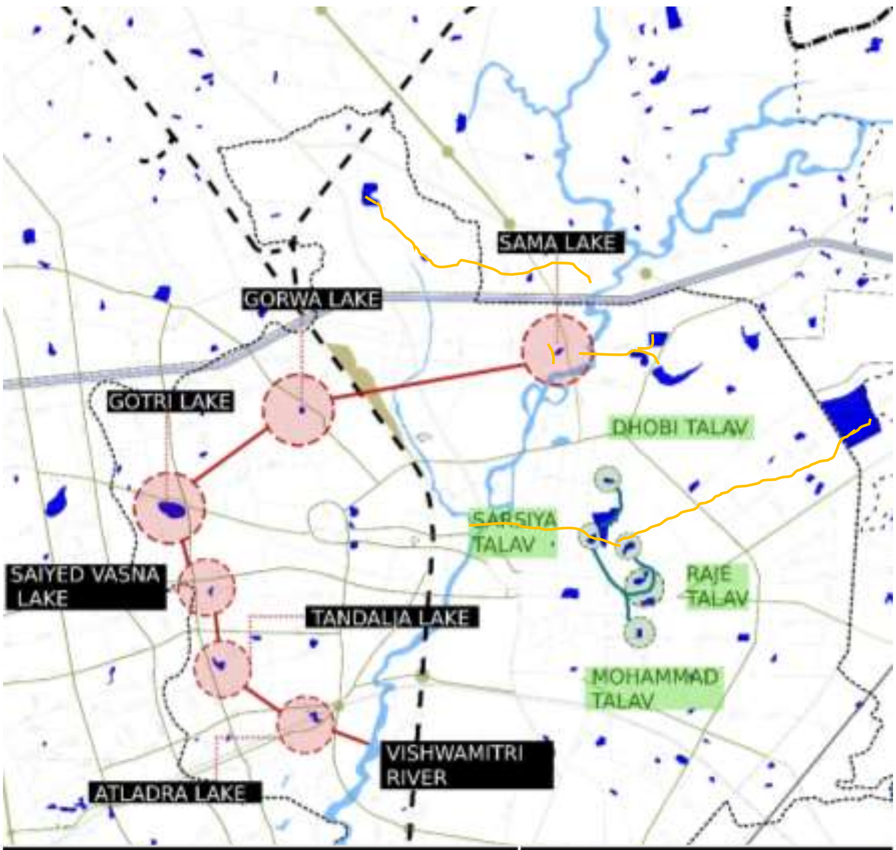


Figure 9 Connection of City areas Water bodies Vadodara in 1884



Lakes connection	Route Length (m)
Sama Lake to Gorwa Lake	6630
Gorwa Lake to Gotri Lake	4270
Gotri Lake to Saiyodvasna Lake	2180
Saiyodvasna Lake to Tandalja Lake	1420
Tandalja Lake to Atladra Lake	2550
Atladra Lake to Vishwamitri River outfall	2390

Figure 10 Connection and Distance of Lakes to one another

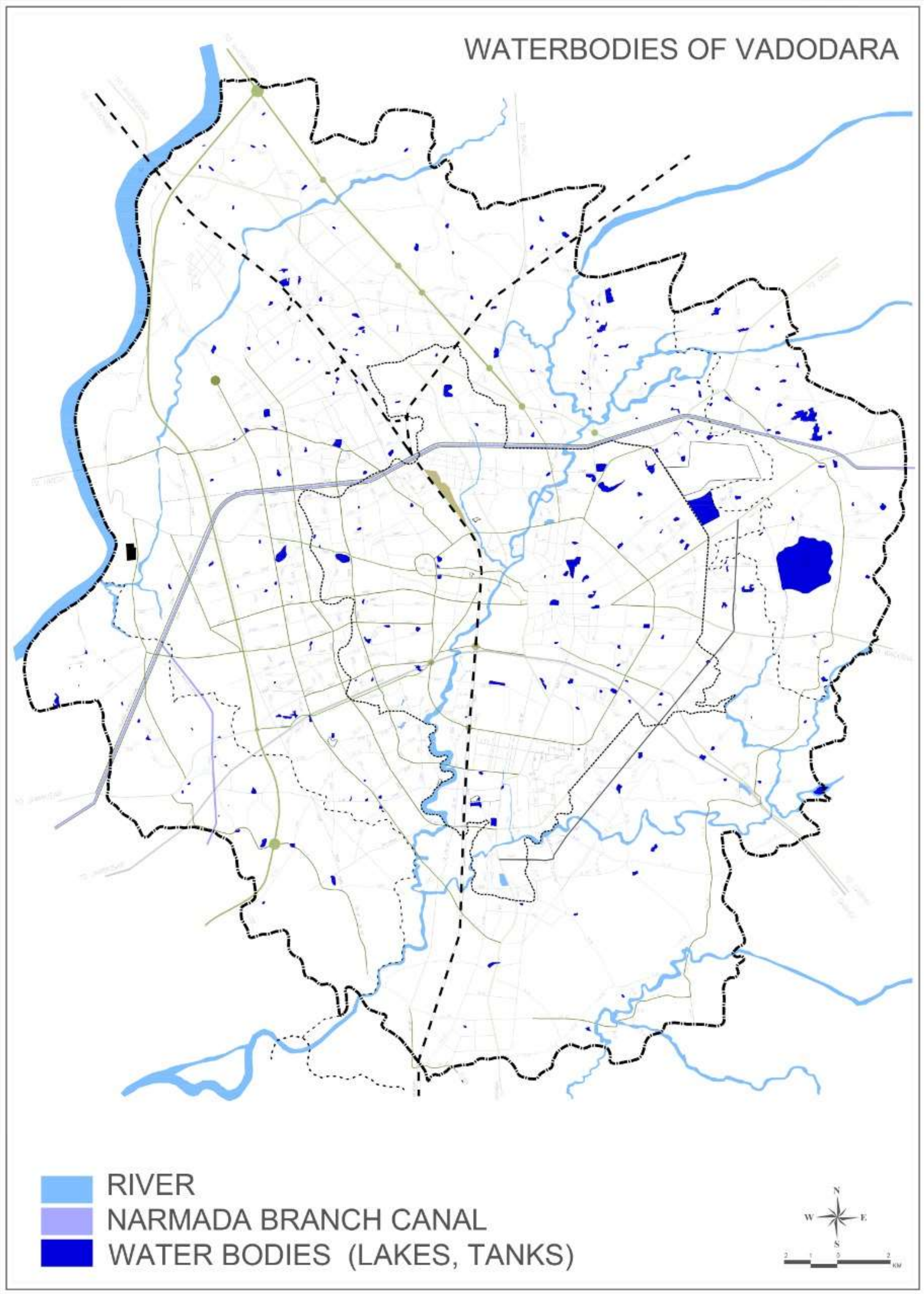


Figure 11 Present Water bodies map in 2021

2.3.3 Role and Interconnection of wetlands to River

Between 1970 and 2003, the VUDA region has lost 62 ha of wetland area (GES 2007). At present, there are 48 wetlands distributed among 13 administrative wards in the Vadodara city

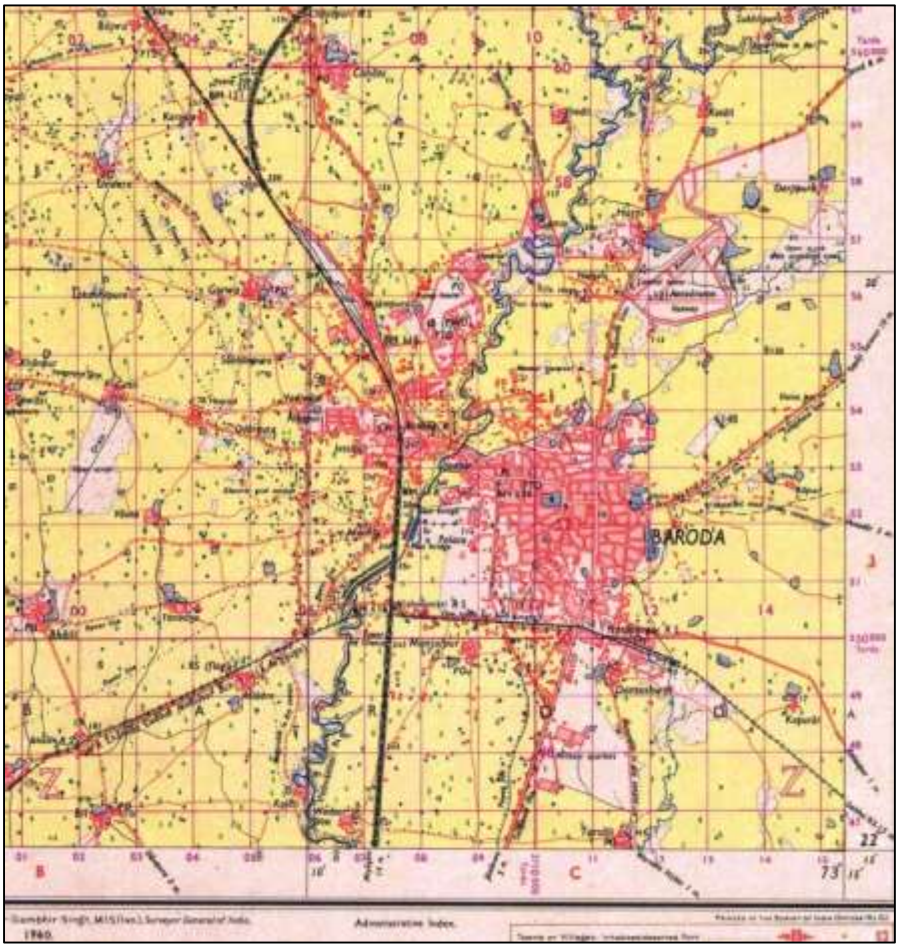


Figure 12 Original Mapping of Interconnection of water bodies of Vadodara

Loss of these wetlands are causing waterlogging problem every year during the monsoons. The wetlands need to be integrated in the urban development schemes and to link the role of wetlands in the Disaster Risk Management of a city.

Absence of a strong implementation of Wetland Policy and notification of the water body also lead to their loss from the urban area.

Ward No.	Name of the Ward	No. of wetlands	Area (ha)			% Loss (2005-2014)
			2005	2010	2014	
1	Old city area	2	10.2	9.53	9.8	4.08
2	Harni airport	3	15	11.15	11.6	2.74
3	Eastern city area	8	27.5	17.66	16.6	65.66
4	Manjalpur	6	7.56	7.1	7.1	6.48
5	Lalbaug	4	3.9	3.1	2.8	39.29
6	Atladra	3	2.16	1.78	1.7	27.06
7	Sama		5	5	5.9	2.04
8	Karelibaug		0	0	0	0.00
9	Bapod & Warasiya		26	14.76	14.2	83.10
10	Gorwa	3	4.05	3.95	4	1.25
11	Saiyad vasna	3	11.21	8.73	8.8	27.39
12	Makarpura	4	8.87	6.9	4.3	106.28
13	Channi	4	13	12.48	13	0.00
TOTAL		48	134.45	102.14	101.8	32.07

Table 2 Ward wise Demarcations of wetlands and its losses

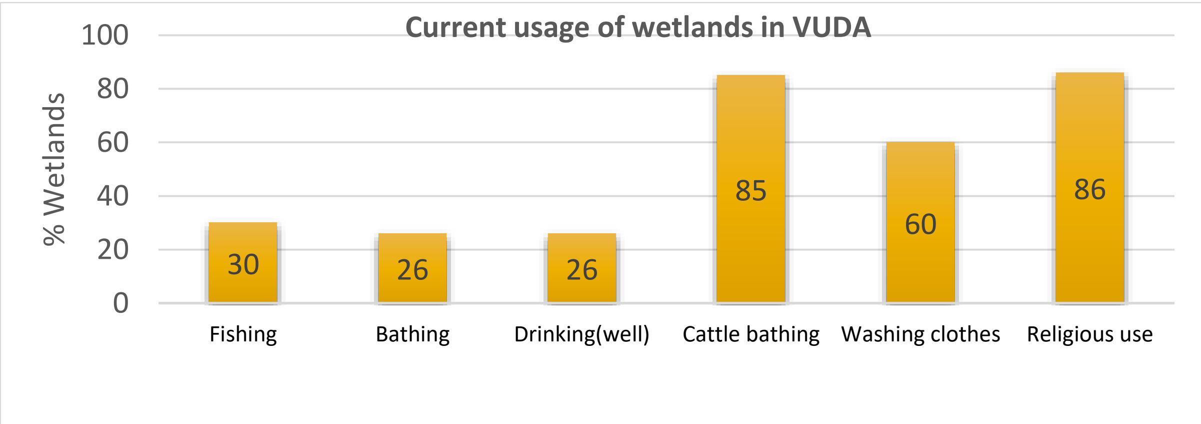


Figure 13 Current usage of Wetlands in VUDA Boundary

2.4 Impact of Urbanization on Water bodies

Every year 10% hard surface is increasing as per observation. The encroachment on riparian belts, filling of ravines, floodplains and water bodies has affected carrying capacity for rainwater causing urban floods. The concretization of storm water drains and increase in impervious surfaces has increased intensity of runoff and reduction in groundwater percolation. This is the map showing flood prone zone of Vadodara City

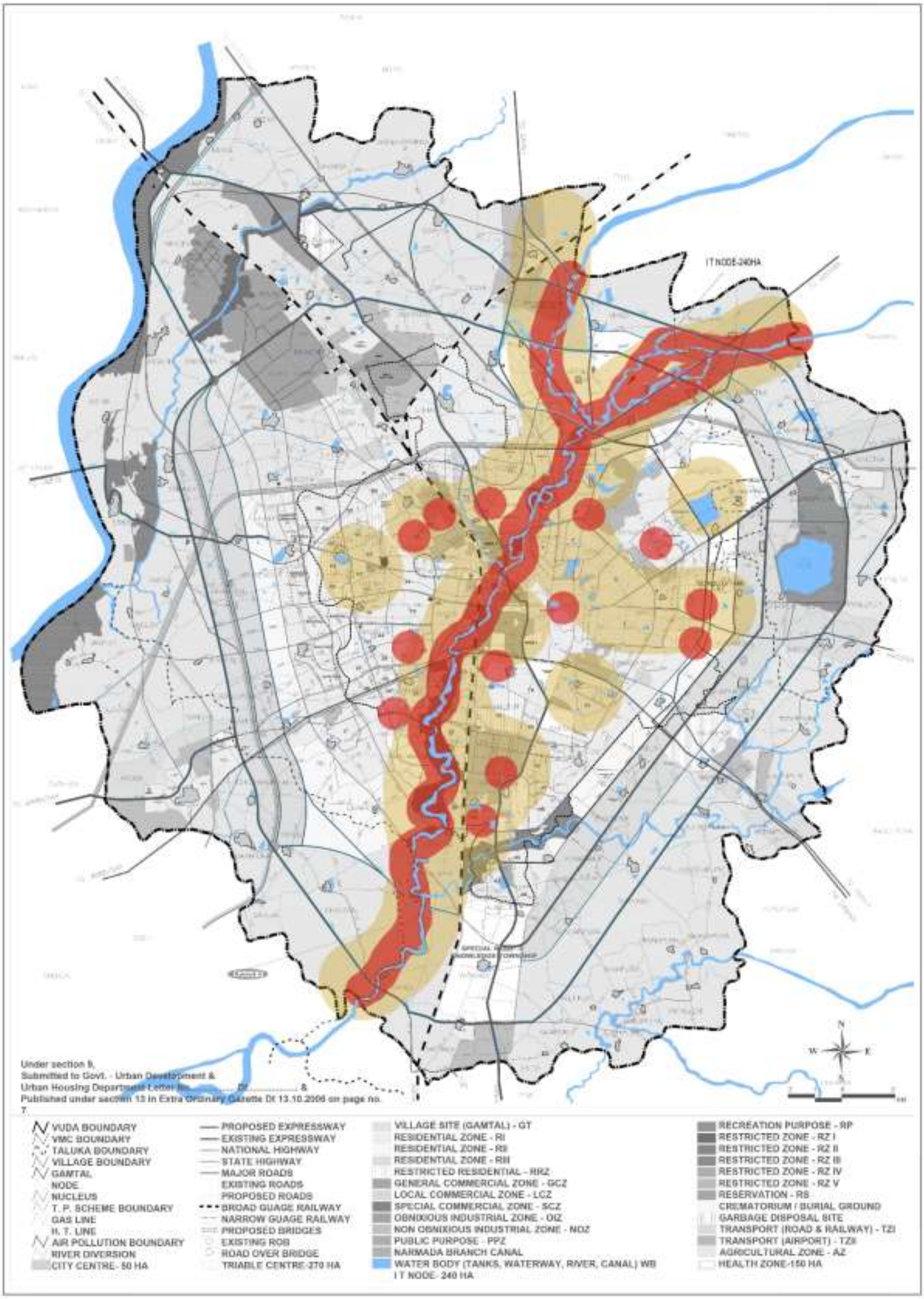


Figure 14 Flood prone Area of Vadodara City

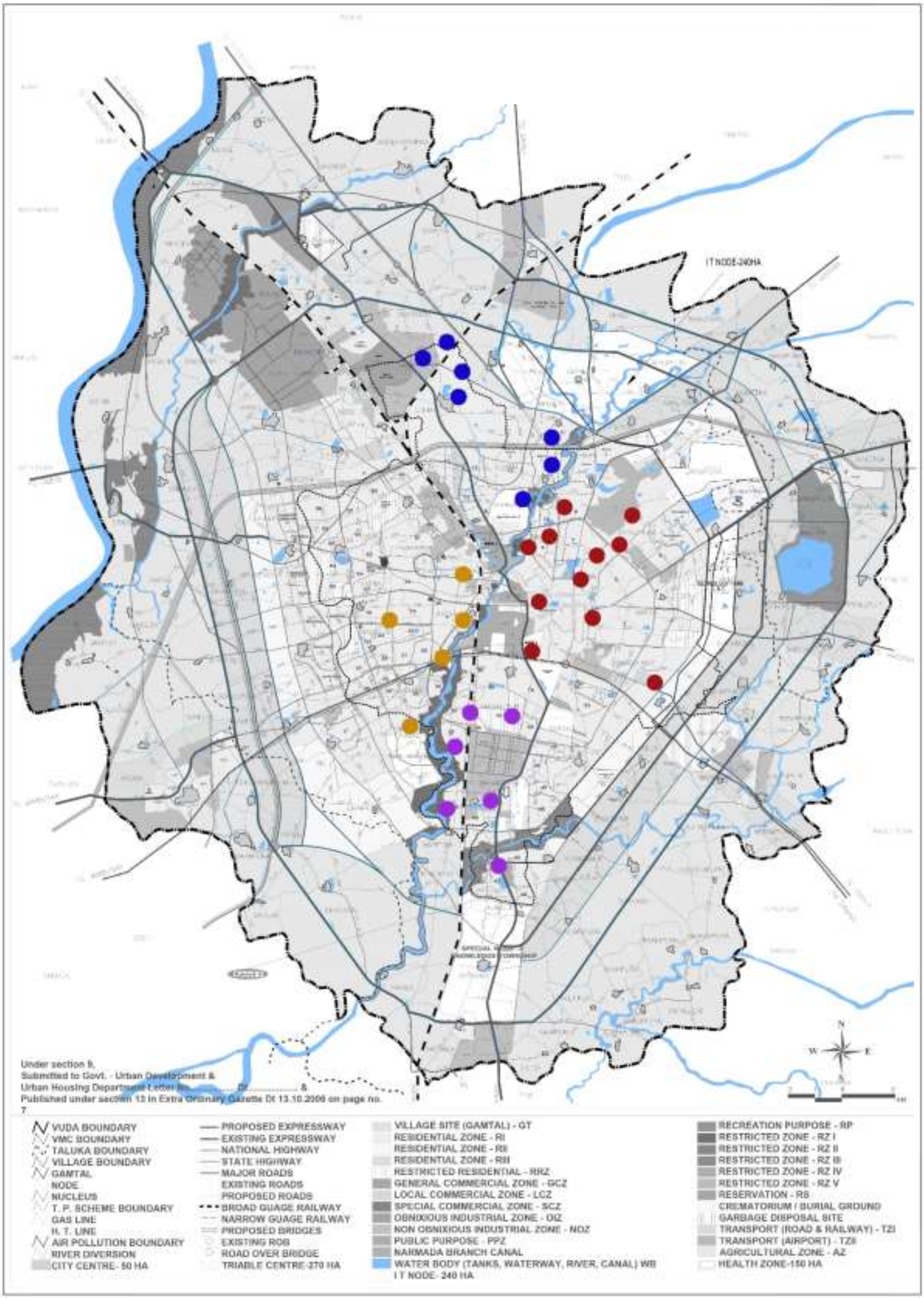


Figure 15 Ward wise Affected Areas

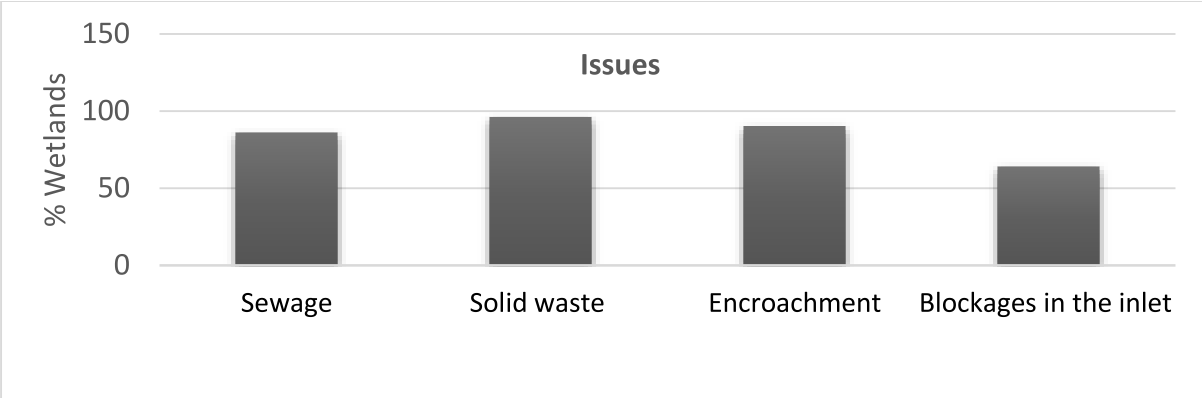


Figure 16 Issues that Degrade Water bodies and Wetlands in VUDA Boundary

Figure 17 Urbanization along River

CHAPTER 3

3. Flood Assessment of Vadodara City and Vishwamitri watershed

For this study, two main flood events are selected i.e. 2005 and 2019. Vadodara received the maximum no of rainfall in this year and the destruction in following years were not only just in Capital sector but more than 2000 people were severely affected due to it.

3.1 History of floods in Vadodara City

Floods are not totally new to Vadodara. The 2005 floods (Figure 18) have been assessed as the second worst after the 1927 devastating floods, called Ghoda Poor. The 1927 season witnessed the highest recorded rain levels - 2336mm - and swelled the Vishwamitri so much that flood water had touched the feet of Kala Ghoda statue near the river. Ghoda Poor had wiped off villages after villages and human lives. While average annual rain received in Vadodara is 930mm , it was 1955mm in 1878, 1752mm in 1917, and 2336mm in 1927.

Figure 18 Vadodara's situation in 2005 flood

It shows that there are total 7 episodes of flood that has happened in the city, in which the water in Vishwamitri reached more than 20 feet, which is a danger situation for the city. i.e. (2004, 2006, 2008, 2010, 2013, 2014, 2019.) The water level in river reached up to 34 feet in 2019.

Floods that occurred in 1970, 1974, 1976, 1994, 1996 and excessive rainfall was recorded in 1878 (1955mm), 1917 (1752mm), and 1927 (2336mm) respectively. (Flood Analysis 2005-UNDP & CDMP 20-21).

Figure 19 Vadodara's situation in 2019 Floods

The table and the graph represent the flood episodes taken place in Vadodara City.

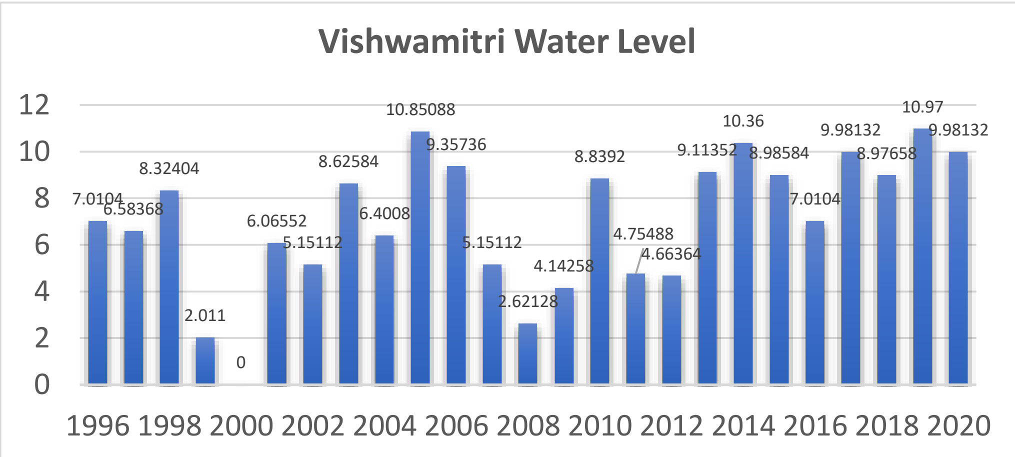


Figure 20 Rainfall data of last 15 Years

The above chart (Figure 20) shows peak water level details in Vishwamitri river from the year 1996 to 2020. The H.F.L or danger level for Vishwamitri river is 7.9m (26 ft). It is observed that in the past history Vishwamitri river has crossed its danger level 7 times and out of 7 times 4 times it has crossed in the last decade. The most devastating floods took place in the year 2005, 2014 and 2019 where river has reached levels up to 10.85m (35ft), 2.95m (9.6ft) above danger level and 10.36m (34ft), 2.46m (8.07ft) above the danger level respectively.

Year	Highest Level of Ajwa Lake (Feet)	Highest Level of Vishwamitri River (Feet)	Total Rain in Rainy Season in Vadodara City in (mm)	Vishwamitri River More Than 20 Feet
2004	212.14	21	1146.72	Aug-04
2005	**212.98**	**35.59**	**1783.6**	
2006	212.94	30.6	1708.3	Aug-06
2007	212.42	16.9	1210.3	
2008	205.12	28.6	379.3	Aug-08
2009	209.49	13.6	595	
2010	213.29	29	1549	Sep-10
2011	212.35	15.6	1140	
2012	212.1	15.3	934	
2013	213.4	29.9	1436	Jul-13
2014	215.1	34	1075	Jul-14
2015	210.45	6.8	450.3	
2016	210.85	13.3	714	
2017	211.6	16	916	
2018	210.45	12	802.8	
2019	**213.1**	**34.5**	**1921**	**Aug-19**

Table 3 Highest Water level mark in Ajwa dam and Vishwamitri River from 2004-2019

The rainfall statistics have been triangulated between data of waghodia halol and ajwa.

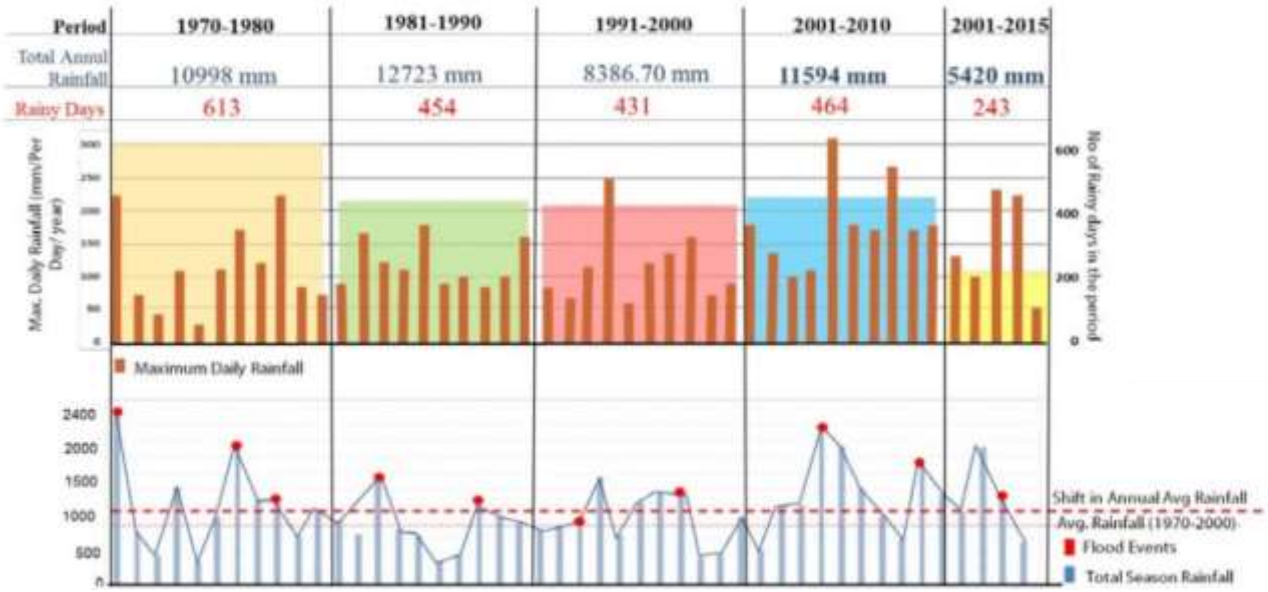


Figure 21 Maximum daily & Total Annual rainfall Chart from 1970-2015

The global climatic change has added to the woes of the city. It has decreased number of rainy days but increased peak intensity of rainfall which is unevenly distributed through the year as seen in the graph beside. In front of gradual decrease in total rainy days for particular monsoon season there is extensive increase in total monthly and per day peak rainfalls which contributes to maximum chances of flash floods.

3.2 Flood Management in Vadodara City

The flood forecasting system for Vishwamitri Basin is being looked after by the Superintending Engineer, Vadodara Irrigation Circle, Vadodara. Various wireless stations are established at the locations upstream of Vadodara from where gauge and rainfall data & spillway discharges from various tanks are obtained. The gauge and rainfall data are being communicated through wireless stations. (Disaster Management Plan, 2011-2012)

The flood forecasting & flood warning arrangements for following water supply projects under Vadodara Mahanagar Seva Sadan (VMSS) will be looked after by Municipal Commissioner, Vadodara. VMSS shall directly collect weather bulletin, Heavy Rainfall Warning (H.R.W) from Indian

Meteorological Department, Ahmedabad or Revenue Control Room of the concerned districts & shall formulate the flood forecast & convey to the concerned Collector regarding the area likely to be affected for alerting and evacuation of the people as warranted by flood, Simultaneously, they convey the flood forecast and action taken by them to the Flood Control Cell (Irrigation) nearest to them. (Disaster Management Plan, 2011-2012)

The City Engineer, Vadodara Municipal Corporation, Vadodara, Shall also give messages about the gauge levels at City Bridge and also rainfall observed at the M.S.University Observatory, Sayaji Ganj, Vadodara. Whenever the rainfall recorded at the observatory over the previous 24 Hours exceeds 50 mm, the hourly rainfall shall also be obtained by the City Engineer and transmitted together with gauges at City Bridge to the Flood Cell of the Vadodara Irrigation Circle, Vadodara. (Disaster Management Plan, 2020-2021)

When the water levels at the City Bridge is likely to cross the danger mark the message shall immediately be conveyed to the Flood Control Cell of the Collector, Vadodara for taking necessary measures by the City Engineer, Vadodara Municipal Corporation, Vadodara. (Disaster Management Plan, 2020-2021)

After 2014 flood the municipal corporation took an initiative and proposed a new reservoir adjacent to the existing Ajwa reservoir. The water from this reservoir will flow by gravity which already exist in Ajwa reservoir. This new reservoir will not only fulfill the demand water demand of Vadodara city but also will reduce the additional storage of water in Ajwa dam. The proposed area of the reservoir is about 100 acres. It is proposed at Adrian village.

3.3 Water Supply & Storm water distribution network of the City

On an average, Vadodara receives 930 mm rainfall every year. Vishwamitri River, a passes through the city and another river Jambuva flows from the south-east of the city to join Vishwamitri River further southwards. There are many watercourses called "Kaans" which form the main storm water drainage for the city.

There is 150 km of storm water drains and about 50 km of major kaans, which along with the River Vishwamitri crossing across the city covers about 25% of the municipal limits. The walled city has storm water drains below the footpath flowing from Mandvi gate to all the four gates viz. Lehripura gate, Champaner gate, Pani Gate and Gendi gate, with the catch drains provided on the kerb.

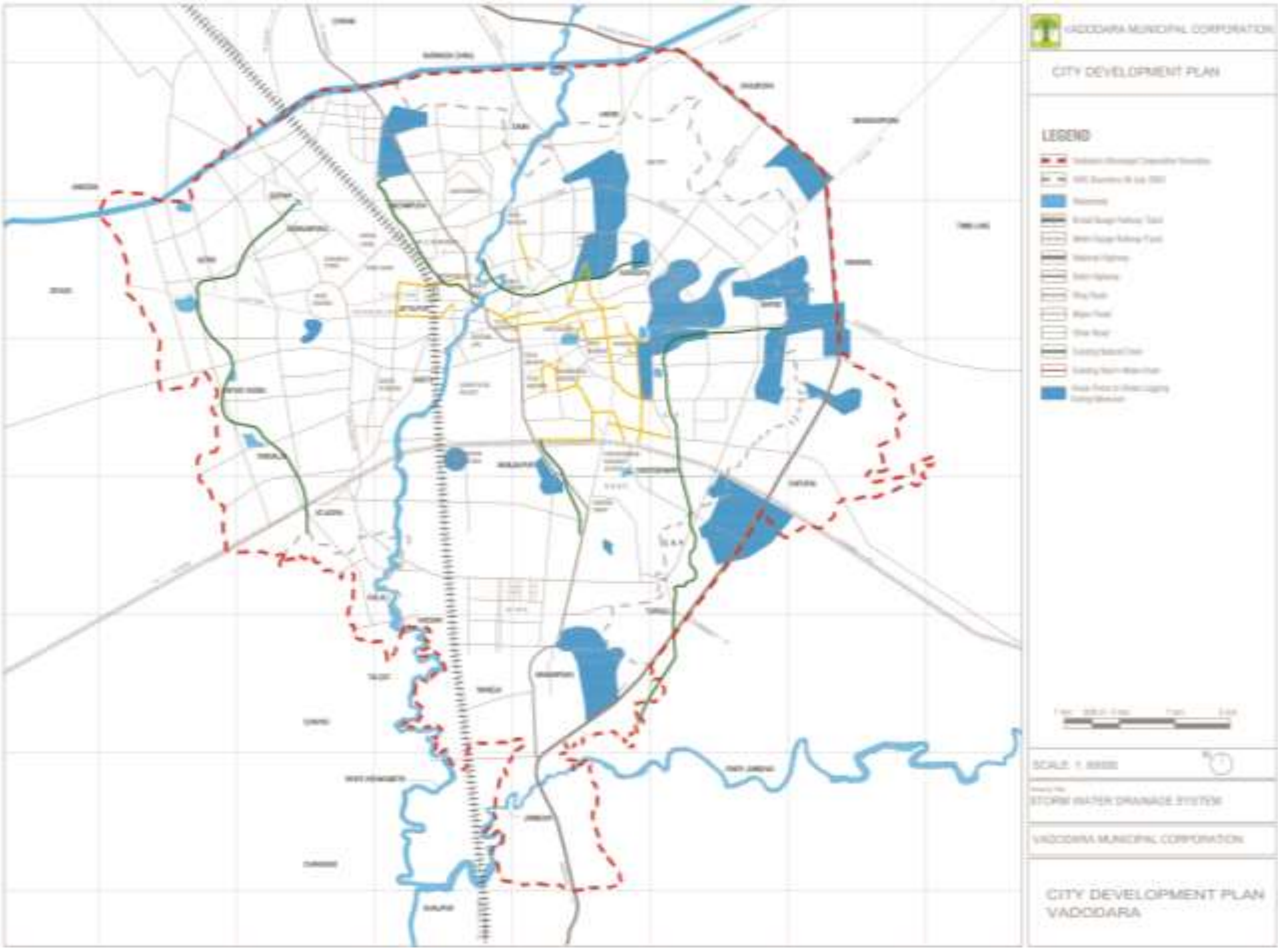


Figure 22 Map showing Existing Storm Water Drainage and Natural Drains

3.4 Development along the edges

The city has undergone lot of change in its natural Land Form, Land Cover, and Land Use to meet the demand of urbanization which has also altered the structure and function of the ecosystems of the urban area. These ecosystems provided many services for human well-being and sustainability like flood regulation, water quality and quantity control, vegetation, water logging, microclimate etc. With the impact of urbanization, there is a change in structure and function of these urban ecosystems affecting its service provisioning. This the city is undergoing many urban issues like Urban floods, water logging in many areas as road network does not consider the natural topography causing the disturbance in drainage pattern and hence rainwater drainage. Also in order to mitigate the demand of water for the industry and households, there is a lot of groundwater extraction of groundwater but no recharge because of increased impermeable surface adding to the severity of the issue causing the change in quantity and quality of water in aquifers within last decade.

Due to increasing urbanization, more and more people are migrating from nearby rural areas to the city of Vadodara in search of job opportunities. These people are not capable to afford the rents of the housing societies so they start to live in huts or tents on the edges of the water bodies nearby to their work places. Another reason for the settlement of slums on the edges of the water bodies is the availability of potable water.

Moreover many town planning schemes and housing schemes are also proposed and developed near the water bodies so as to provide houses with a view of scenic beauty. The prices of houses in these schemes are high. As a result only upper middle class and higher income group people can only afford those houses. The city is becoming more and more congested over the years.

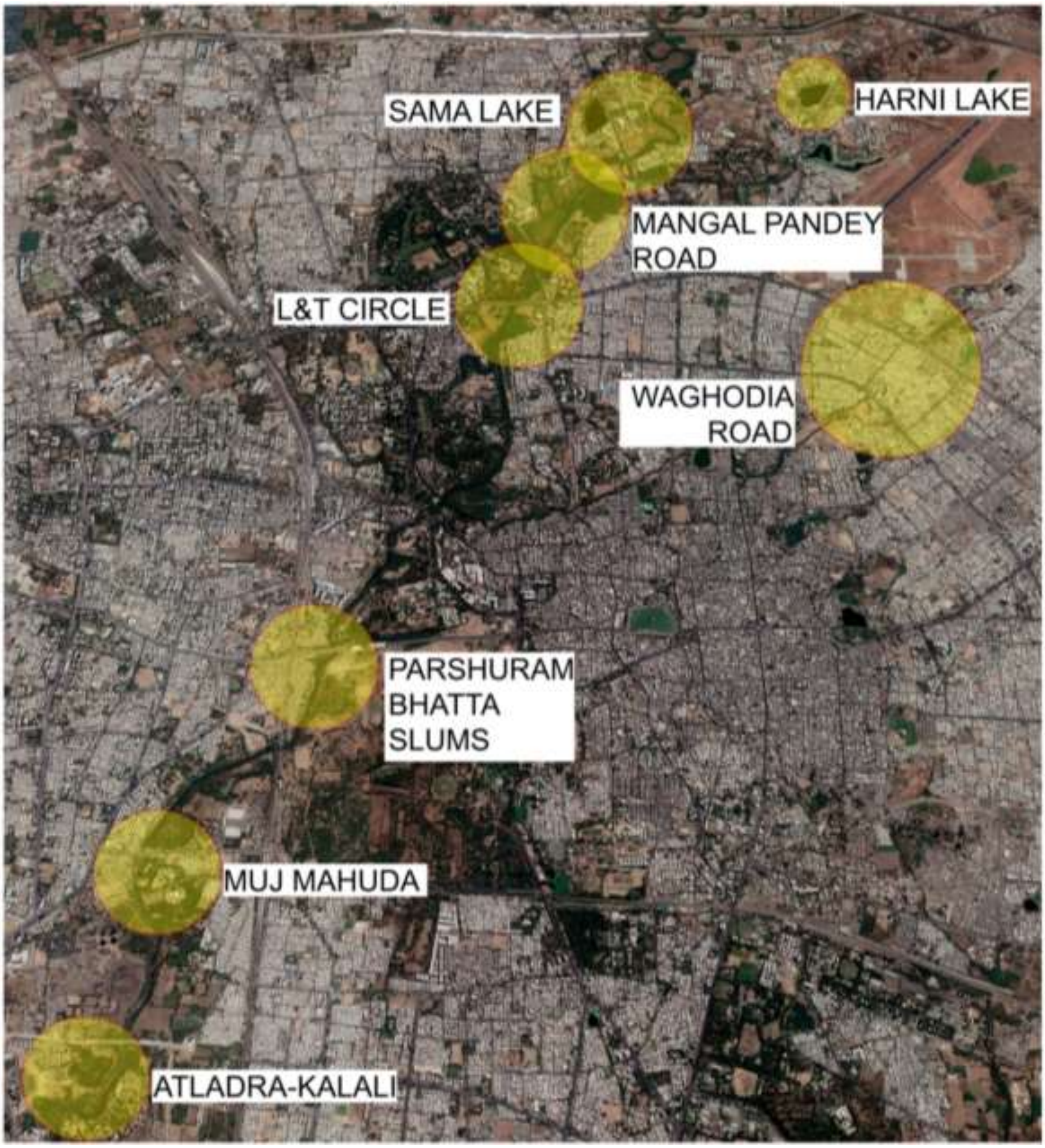


Figure 23 Development along the edges of water bodies

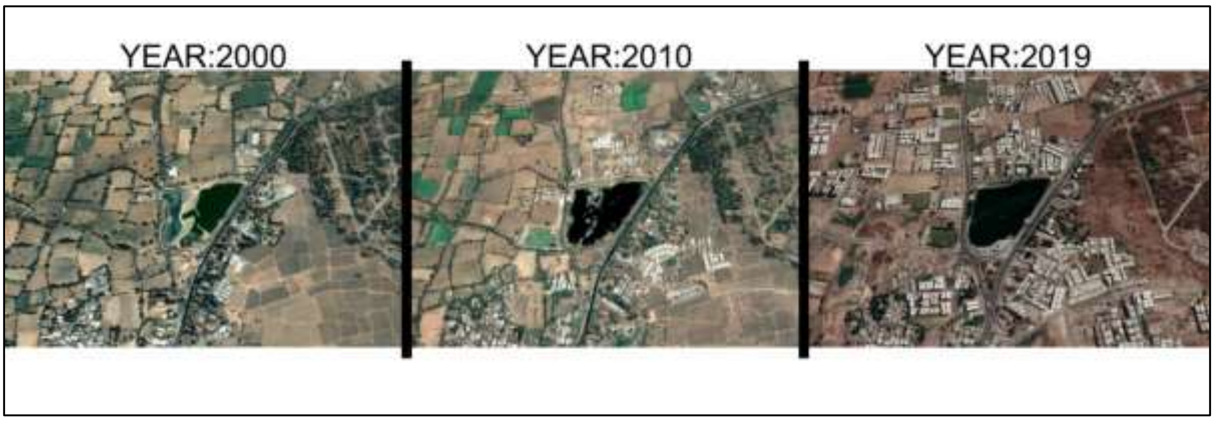


Figure 24 Evolution of Harni lake

Figure 25 Evolution of Sama lake

Figure 26 Evolution of Mangal Pandey Road

Figure 27 Evolution of LNT Circle

Figure 31 Evolution of Parshuram Bhatta Road

Figure 30 Evolution of Waghodia Road

Figure 29 Evolution of Mujmahuda Area

Figure 28 Evolution of Atladra Kalali Area

3.5 Obstructions in the flow of Vishwamitri River

Maximum flood level in Vishwamitri is higher than the banks of the river in heavy rains It is flooding the banks of the river. The highest flood level noted at Kala Ghoda is 36 ft. from the ma. While the danger line considered by VMC is at 26 ft the study done by NIH Roorkee has shown that to deal with such flooding scenario. It is necessary to build an embankment of 2-4 m height on the river bank to stop the river from flooding.

Carrying Capacity of the river gets affected due to above reasons which also includes dumping of 40% city's sewage water into Vishwamitri River in which 25% (215MLD) is treated and 15% (180 MLD) is not treated.

All Infrastructural Bridges & Old Sama Bridge gets totally submerged while Narhari Bridge, Kalaghoda Bridge & Bhimnath Bridge has flood water at soffit level for design flood of 660 cumecs in present natural condition. The required free board below soffit of the bridge is also not met with the requirement.

Longitudinal section of river through main river **(through Sayaji Baug)**

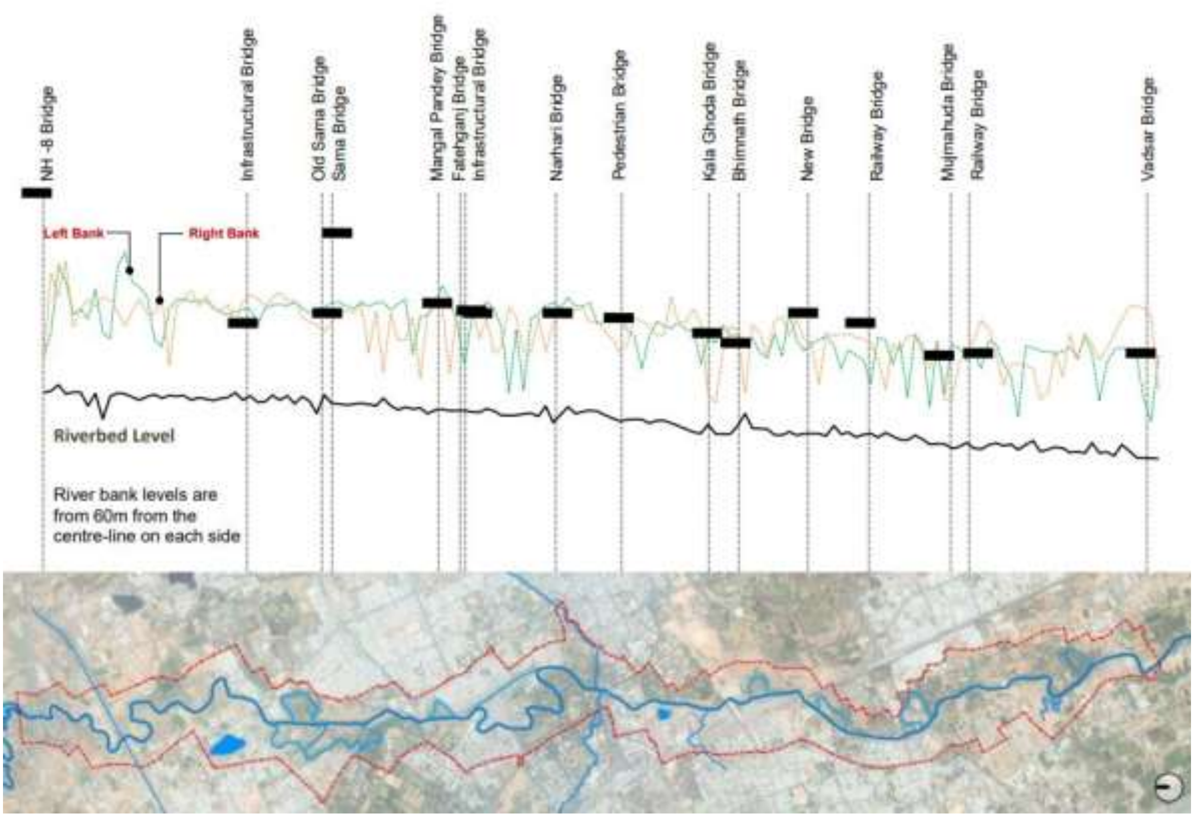


Figure 32 Longitudinal Section of River through Sayajibaug

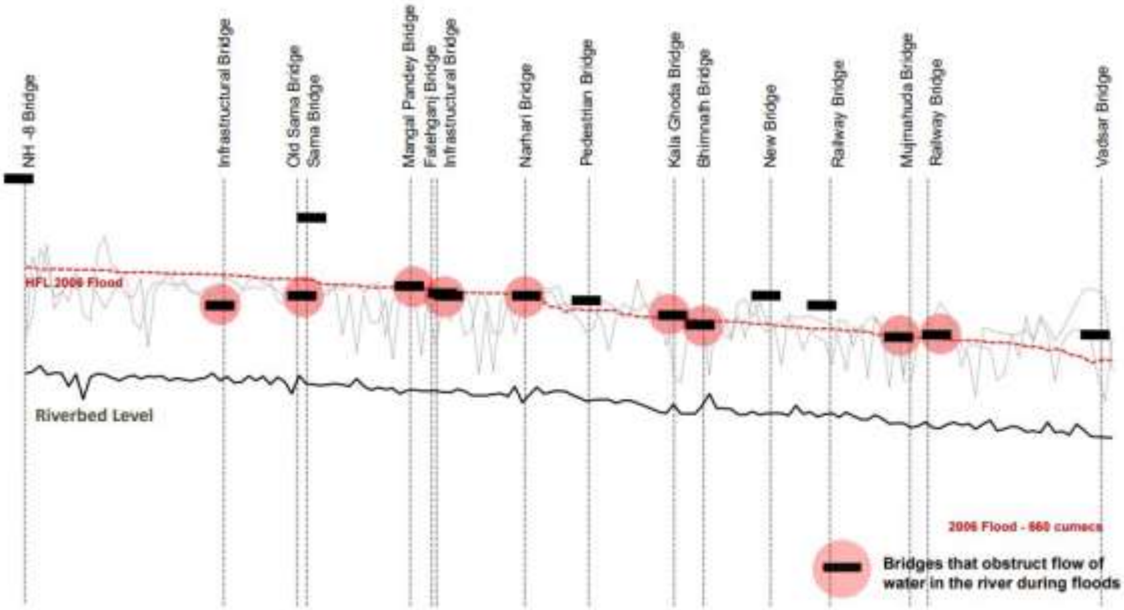


Figure 33 Map showing Bridges that obstruct the Flow of River during Monsoon

CHAPTER 4

4. SWAT Introduction

SWAT is a physically based continuous event hydrologic model developed by USDAARS, which operates on a daily time step and uses physiographical data such as elevation, land use, and soil properties as well as meteorological data. The model divides the study catchment into sub-catchments, which are further partitioned into HRUs (Hydrological Response Units). It includes a unique combination of land cover, soil and management combinations.

The SWAT model is mainly used to predict the impact of land-management practices on water, sediment etc. in large basins with varying soils, land use, and management over long periods of time. The hydrological processes included in the model are surface runoff, Potential evapotranspiration (PET), percolation, infiltration, Base flow etc. The model work on the principal of water balance. The SWAT model uses Natural Resource Conservation Service (NRCS) curve number method (SCS 1972) for estimating surface runoff (Quiff).

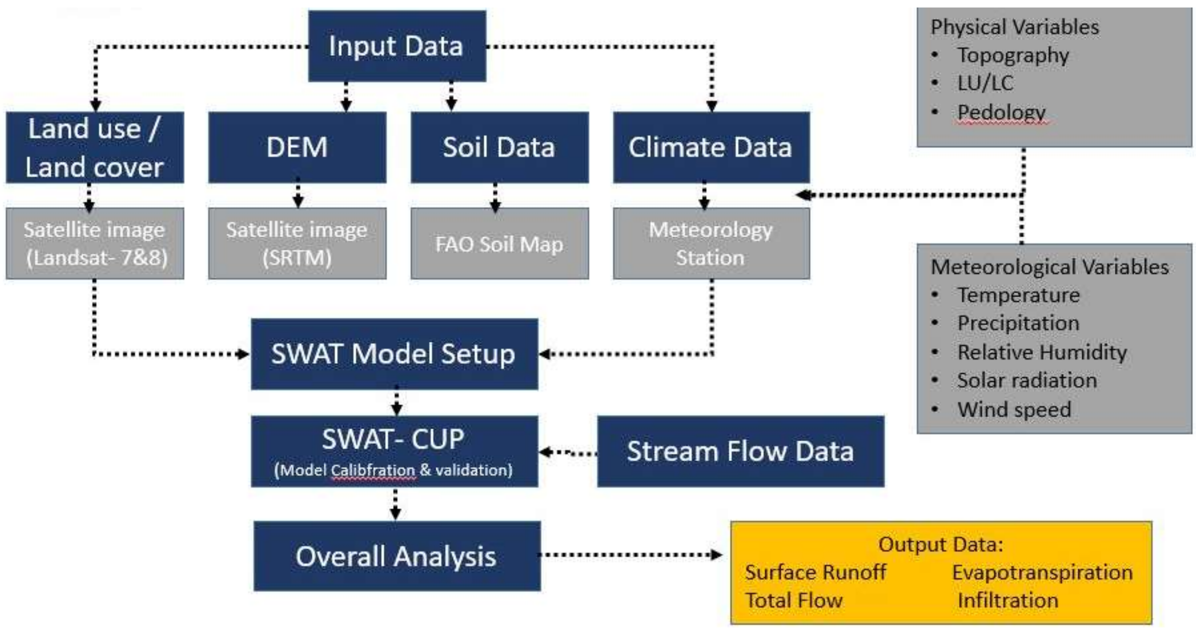


Figure 34 SWAT Methodology

4.1 Runoff Calculation by SWAT

SWAT uses the SCS curve number method (USDA Soil Conservation Service, 1972) to compute surface runoff volume for each

HRU. The SCS runoff equation is an empirical model that was developed to provide a consistent basis for estimating the amounts

of runoff under varying land use, soil types, and antecedent moisture conditions Rallison and Miler, 1981), The SCS curve number.

$$Q_{surf} = \frac{(Rday - 0.2S)^2}{(Rday + 0.8S)}$$

S= Retention Parameter in mm

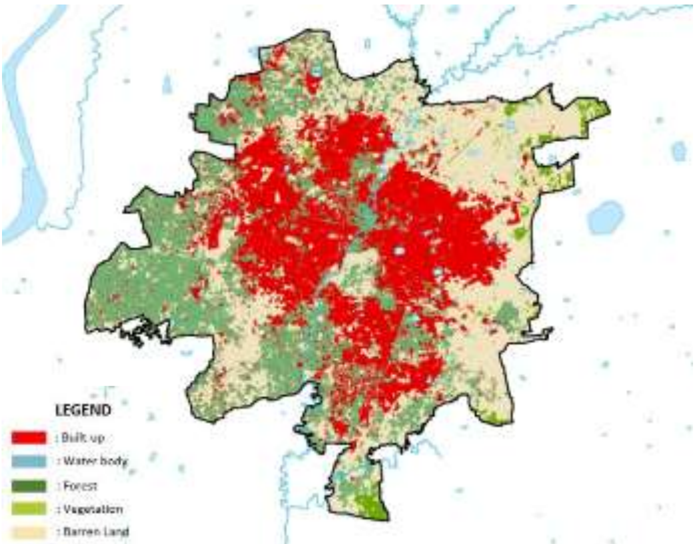
$$S = 25.4\left(\frac{1000}{CN} - 10\right)$$

CN has a range from 30 to 100; lower numbers indicate low runoff potential while larger numbers are for increasing runoff potential. The lower the curve number, the more permeable the soil is. As it can be seen in the curve number equation, runoff cannot begin until the initial abstraction has been met. The runoff curve number is based on the area's hydrologic soil group, landuse, treatment and hydrologic condition.

4.2 Input Data Preparation

Land use pattern of any watershed influences the runoff. To compute hydrological elements more accurately more accurate LULC map is required. By image-processing techniques, image can be produced, which depict some of the characteristics, notably the cover types such as areas with vegetation, water bodies, bare soils etc. The LULC pattern and rainfall have a significant influence on the hydrological response of the watershed.

For Land use/Landover Map preparation the satellite image of Landsat 4, 5, 6 and 8 are used. Maps used in Preparation of Swat model are classified as Built-up, water body, forest, farmlands and barren land



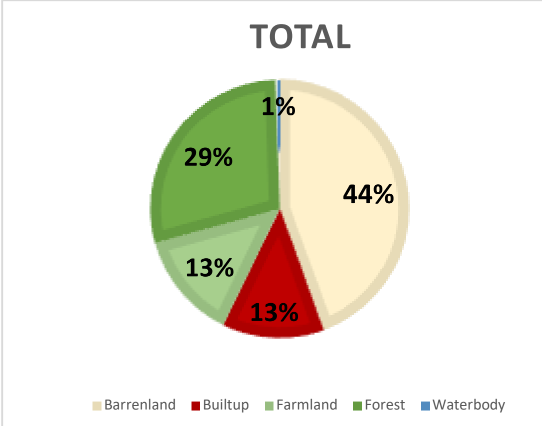
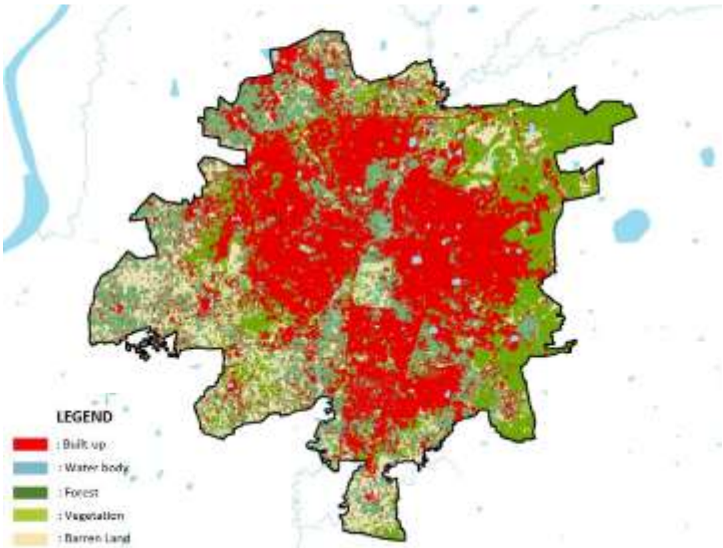


Figure 35 2001 LULC Map



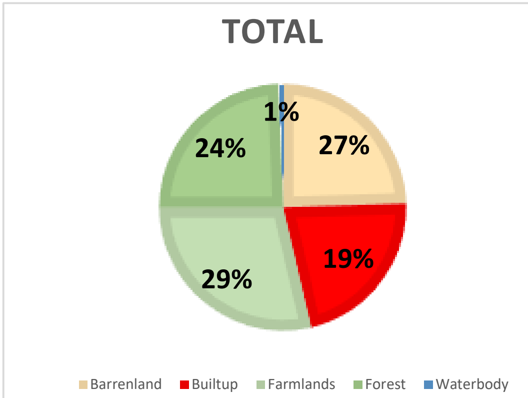
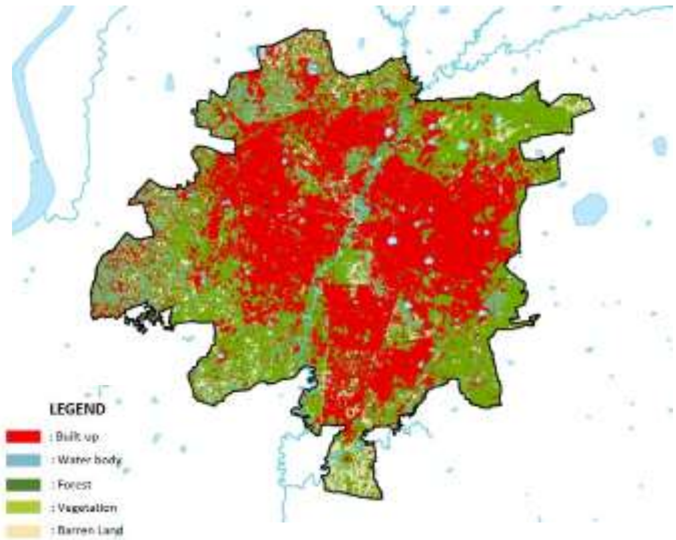


Figure 36 2005 LULC Map



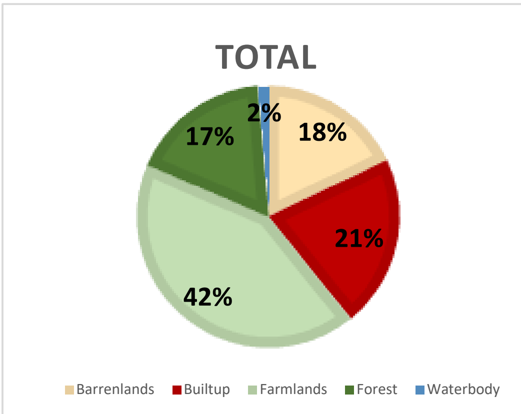
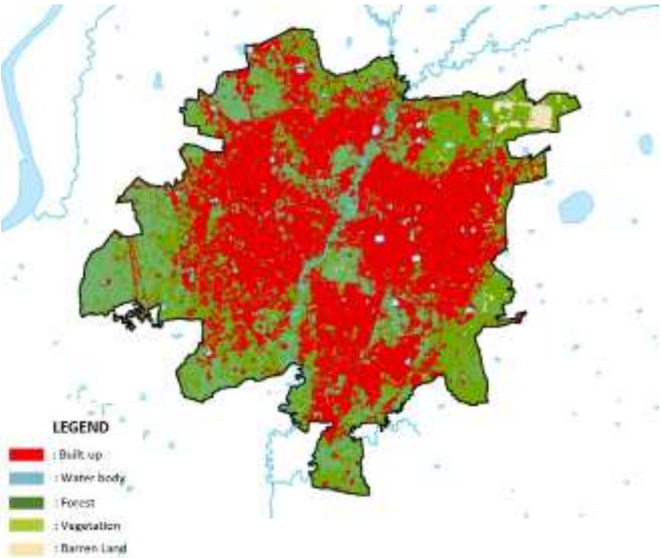


Figure 37 2011 LULC Map



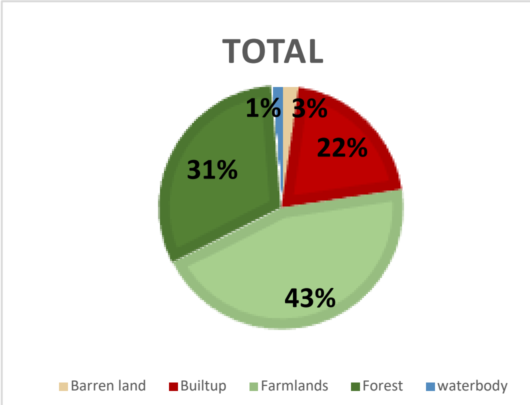
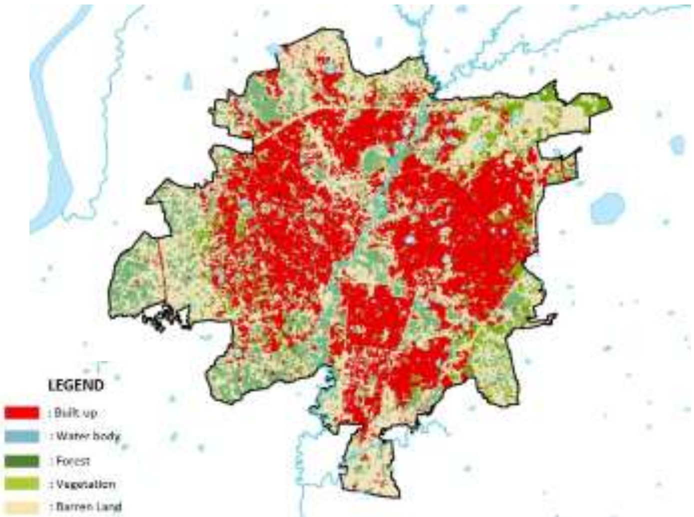


Figure 38 2019 LULC Map



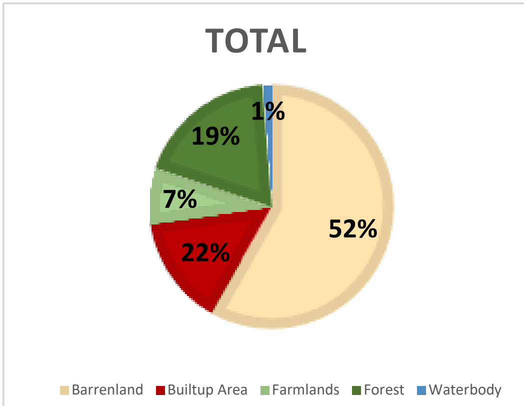


Figure 39 2021 LULC Map

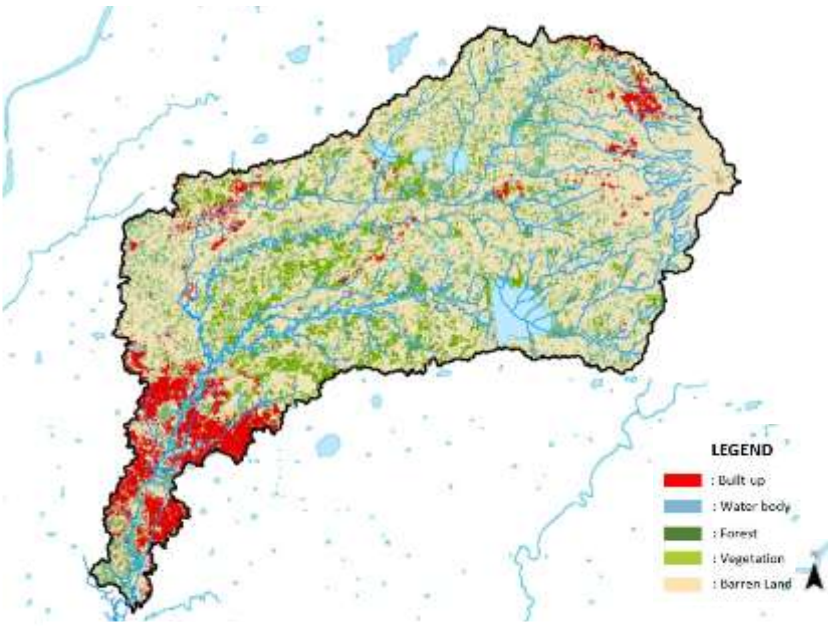


Figure 40 LULC map of Vishwamitri Catchment Watershed

4.2.1 Digital Elevation Method

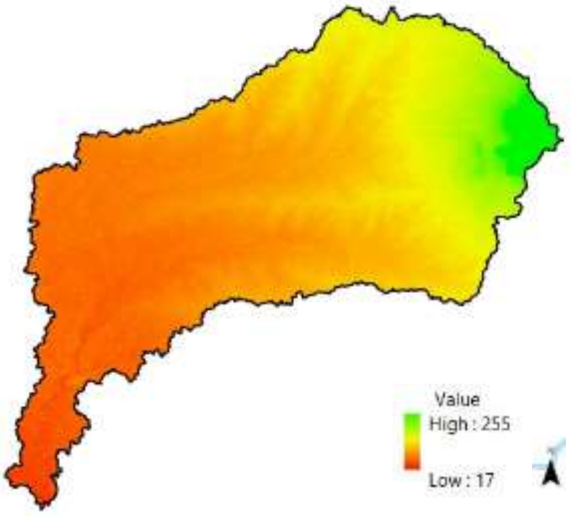


Figure 41 Digital Elevation Map of Vishwamitri Watershed

SRTM Data helps in making the digital elevation maps and by defining the hydrology and the Watershed Boundaries and Outlets.

The availability of the total quantity of surface water is proportional to the stream order and some particular structure are suitable at a particular drainage order only.

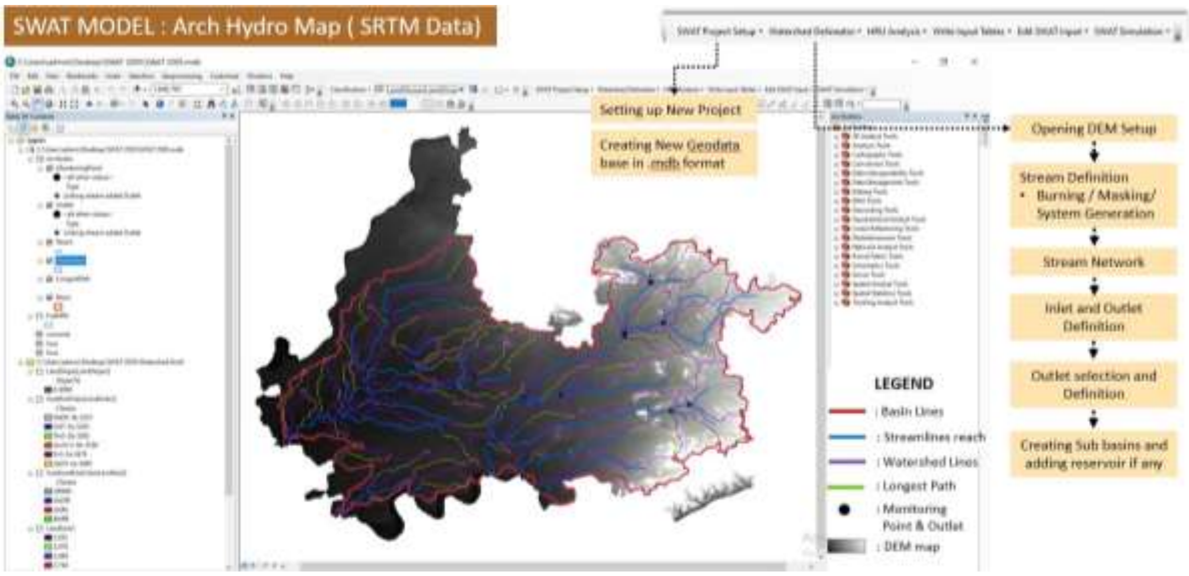


Figure 42 SRTM Method for SWAT Model in GIS

The stream order of the Vishwamitri watershed was assigned using the Strahler (1957) method. In the Strahler method, all streams without any tributaries are assigned an order of 1 and are referred to as first order. The stream segments starting from the confluence of two streams of the first order are called streams of second order and so on. The tail point of each stream is defined as the point from where a stream of higher order starts. Flow accumulation and flow direction rasters were used to generate stream network using hydrology toolset of ArcGIS. Stream ordering was done for proper planning of conservation measures in terms of storage and capacity.

4.2.2 Land use/ Land cover Map

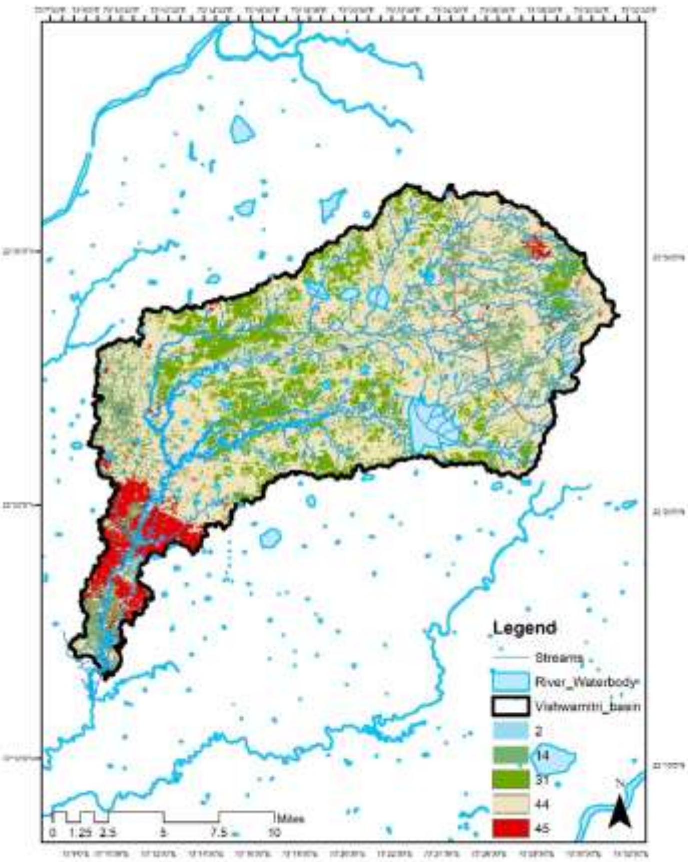


Figure 43 LULC map of Vishwamitri Watershed Catchment Area

LULC map is used in SWAT model for Creating HRU analysis of the Watershed Area By image-processing techniques, image can be produced, which depict some of the characteristics, notably the cover types such as areas with vegetation, water bodies, bare soils etc. The LULC pattern and rainfall have a significant influence on the hydrological response of the watershed.

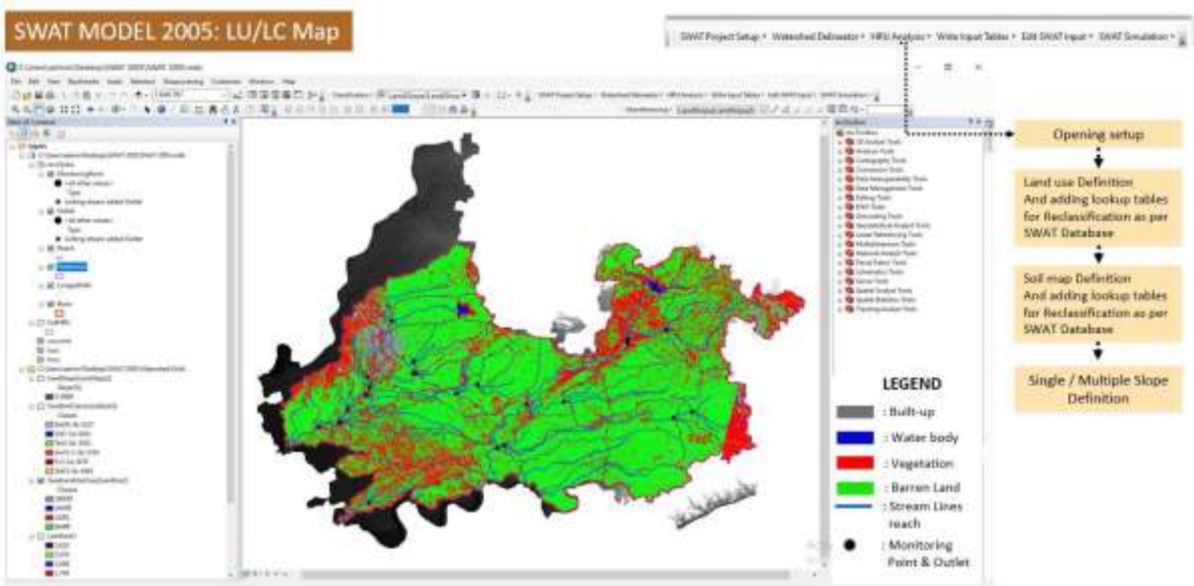


Figure 44 LULC Map input in SWAT Model Methodology

4.2.3 Soil Map

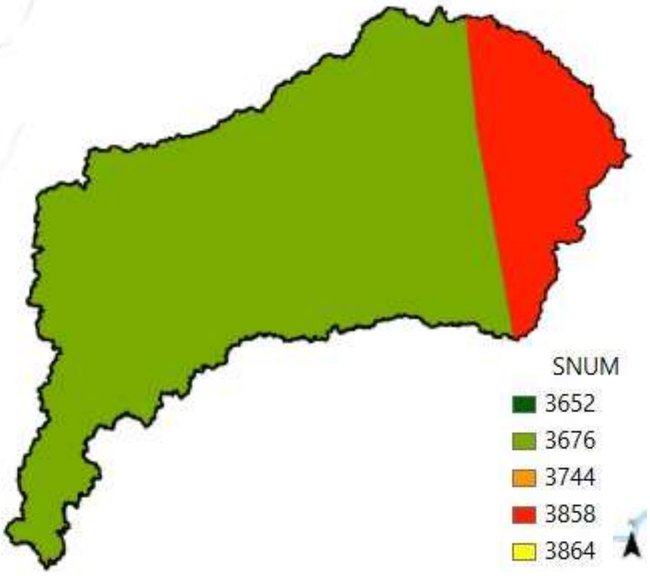


Figure 45 Soil Map of Vishwamitri Watershed Catchment

Soil texture refers to the relative proportion of clay, silt and sand. Soils containing large proportions of sand have relatively large pores through which water can drain freely. These soils produce less runoff. As the proportion of clay increases, the size of the pore space decreases. This restricts movement of water through the soil and increases the runoff.

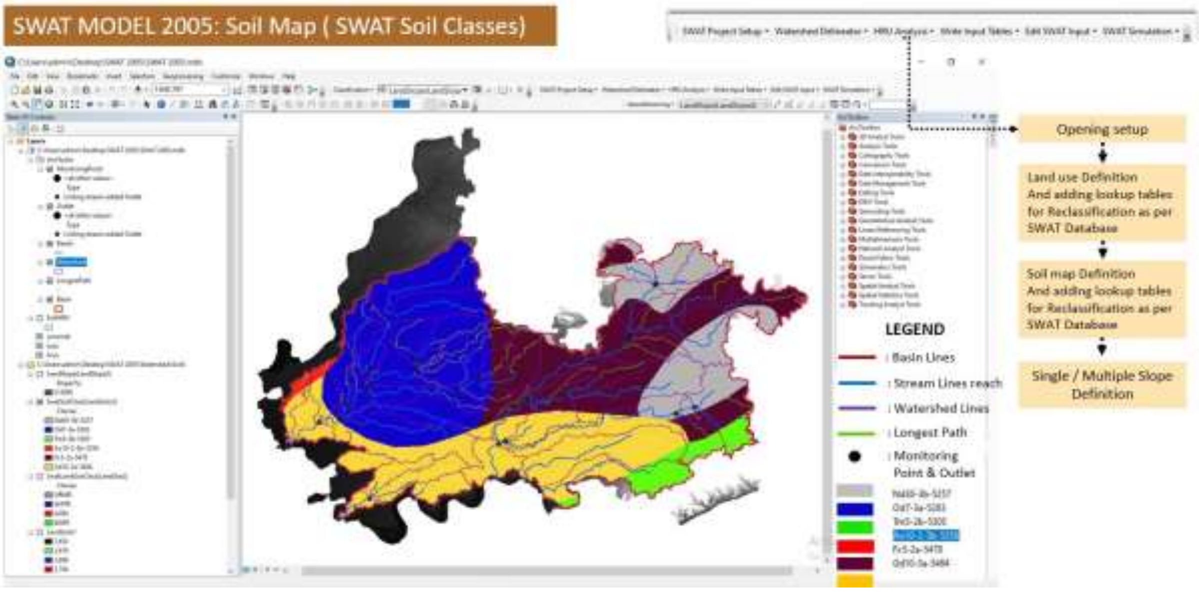


Figure 46 Soil Map input in SWAT Model Methodology

Soil data is based on soil texture collected from National Bureau of Soil Survey and Land Use Planning (NBSS & LUP). The land use and land cover maps were later used in ARC-SWAT Hydrologic Model for the integration of land use land cover and soil data for CN grid preparation. The ARC-SWAT is extension to ESRI's ArcGIS software that compute the Curve Number and other loss rate parameters based on various soil and land use and land cover databases.

4.2.4 Weather Input Data for Hydrological Simulation

The data set used for the present work are daily rainfall data, daily temperature data, daily relative humidity, Daily solar radiation and daily wind speed for years 1980 to 2019, These data corresponds to Bhaniyara and Pilol station located at latitude & longitude of 22°39 & 73°26 respectively, near to Vadodara city and are collected from State Water Data Centre (SWDC), Gandhinagar.

The model input data required for hydrological simulation of a River Basin is categorised broadly in two types-spatial data and non-spatial data, Hydrological simulation of the river basin requires certain type of data before simulation, The spatial data required by SWAT for hydrological simulation of basin are: DEM, LULC & SOIL MAP. On the same lines of Spatial Data, an extensive dataset is required for non-spatial data type, they are temperature, precipitation, relative humidity, solar radiation and wind speed.

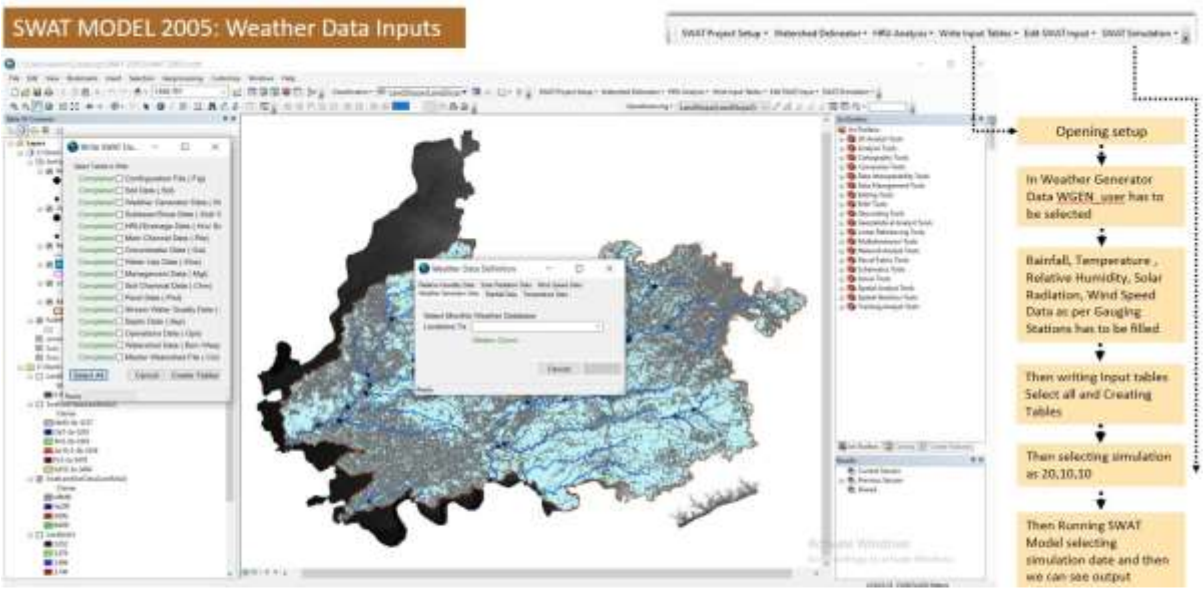
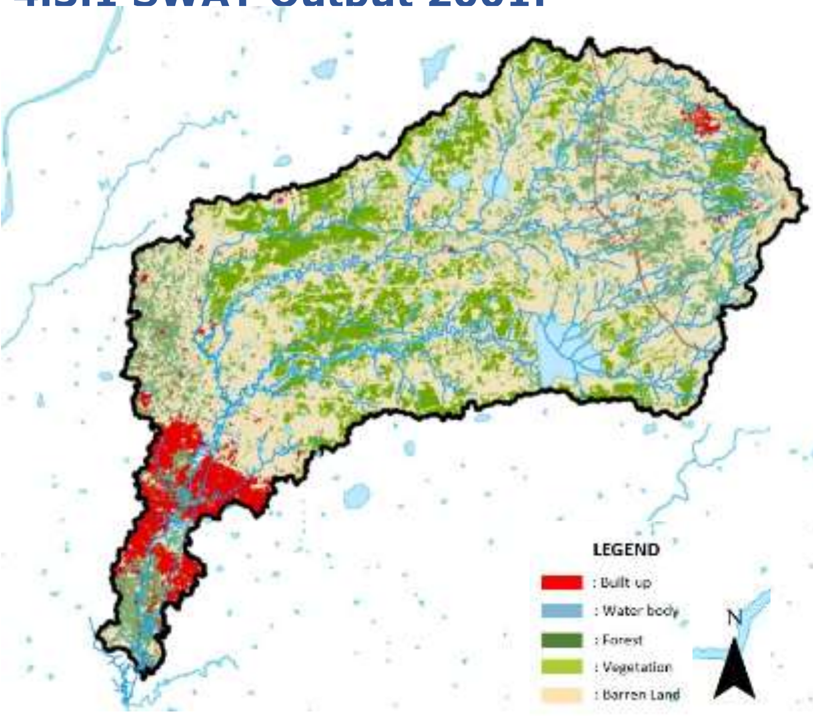


Figure 47 Weather data Inputs in SWAT Model Methodology

4.3 SWAT Output and Analysis

4.3.1 SWAT Output 2001:



The SWAT output for 2001 Hydrologic model Surface Runoff is 287.69mm and the input data of precipitation from Pilol gauging station is 710.5mm

Figure 48 LULC of 2001 for Vishwamitri Catchment Area

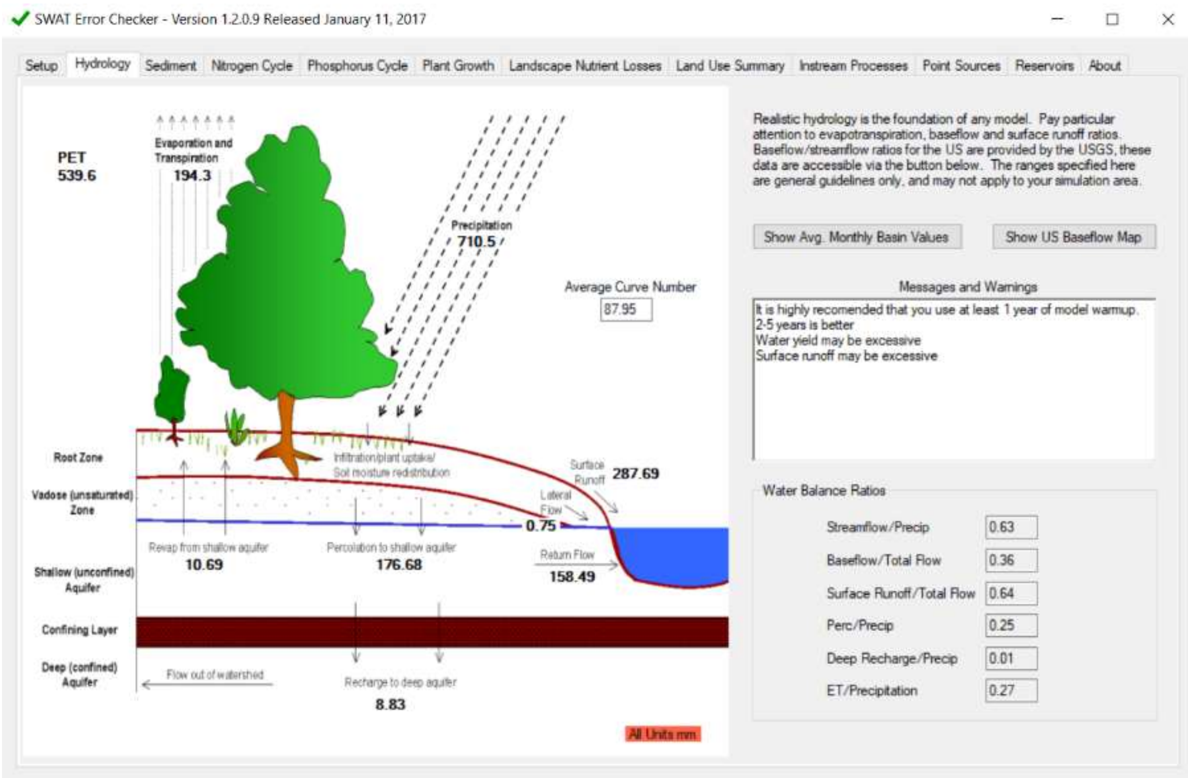


Figure 49 Output Analysis of SWAT for 2001

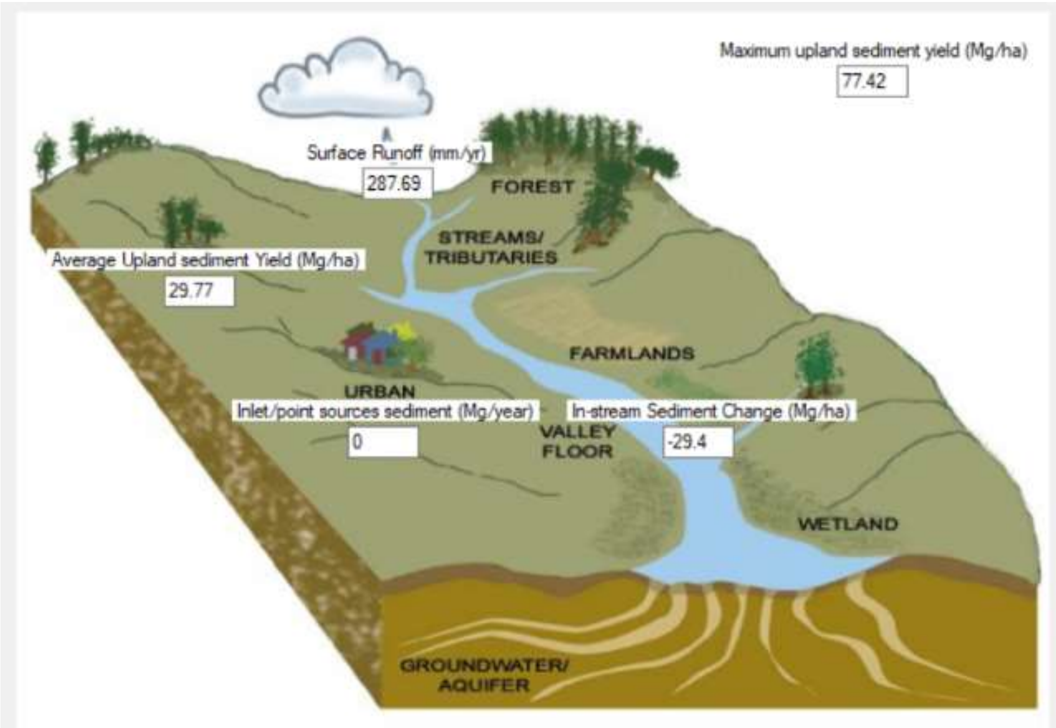
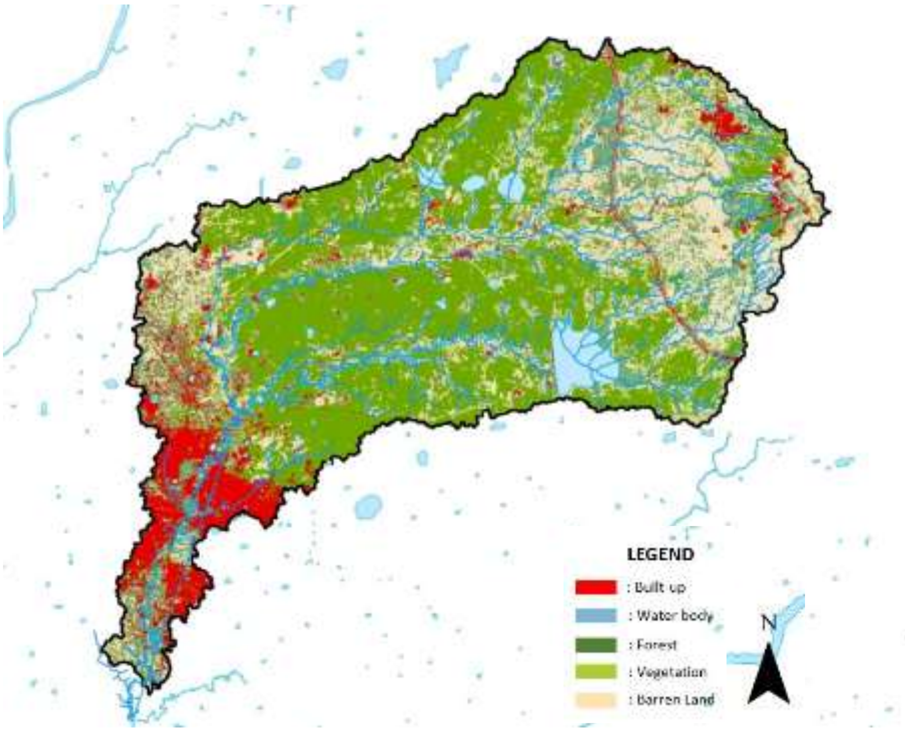


Figure 51 Runoff Analysis of SWAT 2001

Calibration for the Hydrological Model is done when the input data of precipitation and runoff from the model is checked with the authentic data from the gauging stations with the help of SWAT CUP software. In 2001 case data from the model is calibrated with the data of discharge from the Pilol,Bhaniara and Kalaghoda gauging Stations and the goodness level is marked when the value of R2≥0.50 , Here R2 value is 0.54 and value of P factor is 0.82

Figure 50 Calibration Output 2001

4.3.2 SWAT Output 2005: Flood Event



SWAT output for
5 Hydrologic model
ace Runoff is
.73mm and the
t data of
ipitation from Pilol
ging station is
4.9mm

Figure 53 LULC of 2005 for Vishwamitri watershed

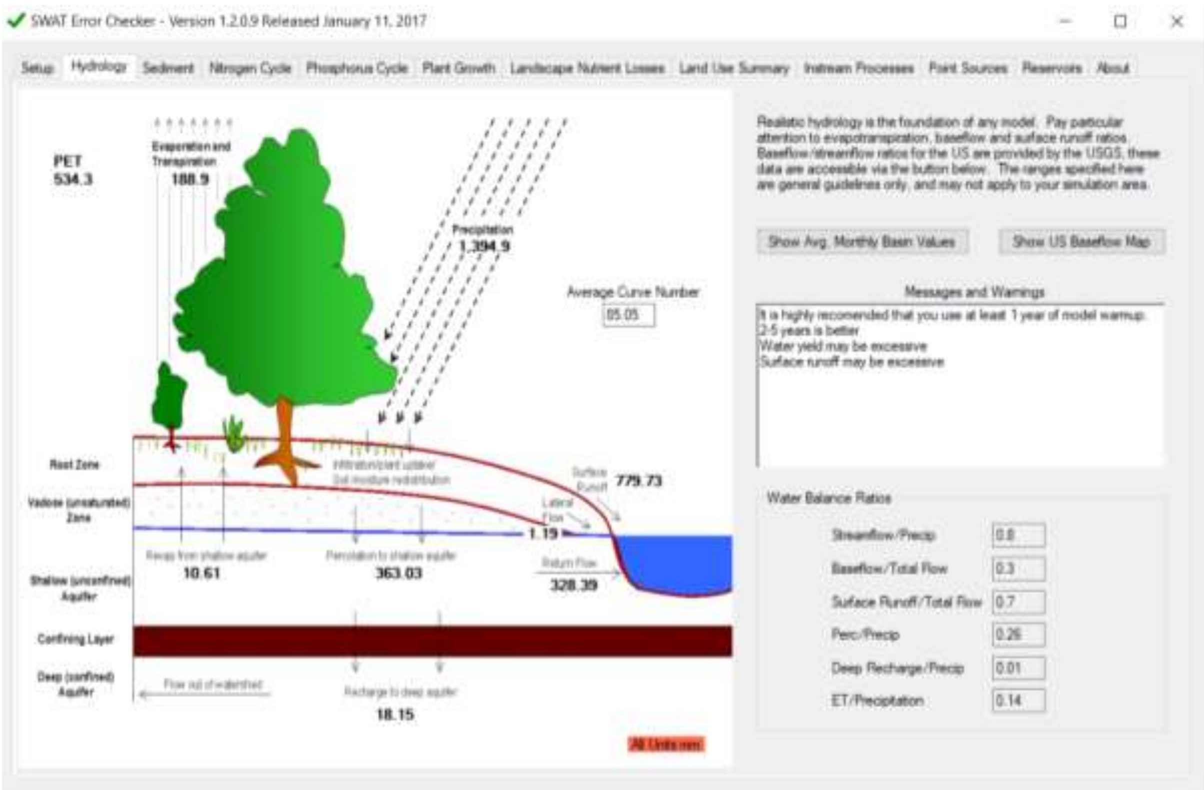


Figure 52 Output Analysis of SWAT for 2005

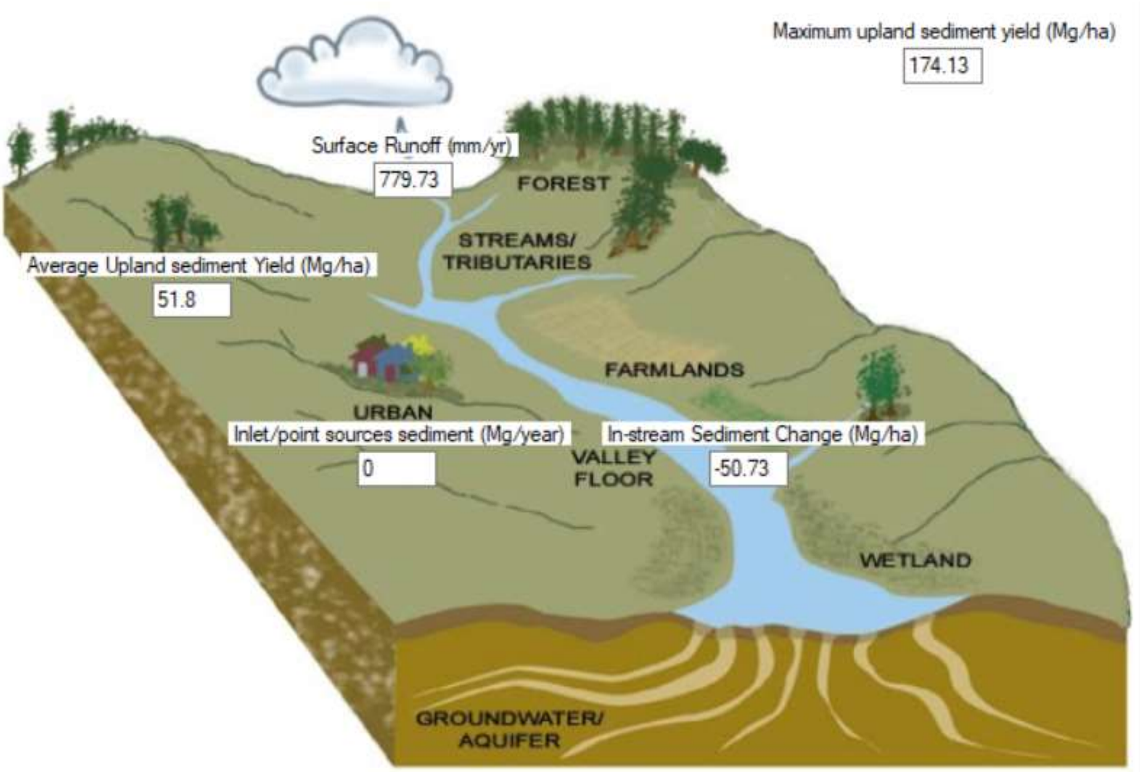


Figure 54 Surface Runoff output fro 2005

Calibration for the Hydrological Model is done when the input data of precipitation and runoff from the model is checked with the authentic data from the gauging stations with the help of SWAT CUP software. In 2005 case data from the model is calibrated with the data of discharge from the Pilol,Bhaniara and Kalaghoda gauging Stations and the goodness level is marked when the value of R2≥0.50 , Here R2 value is 0.42 and value of P factor is 0.52.

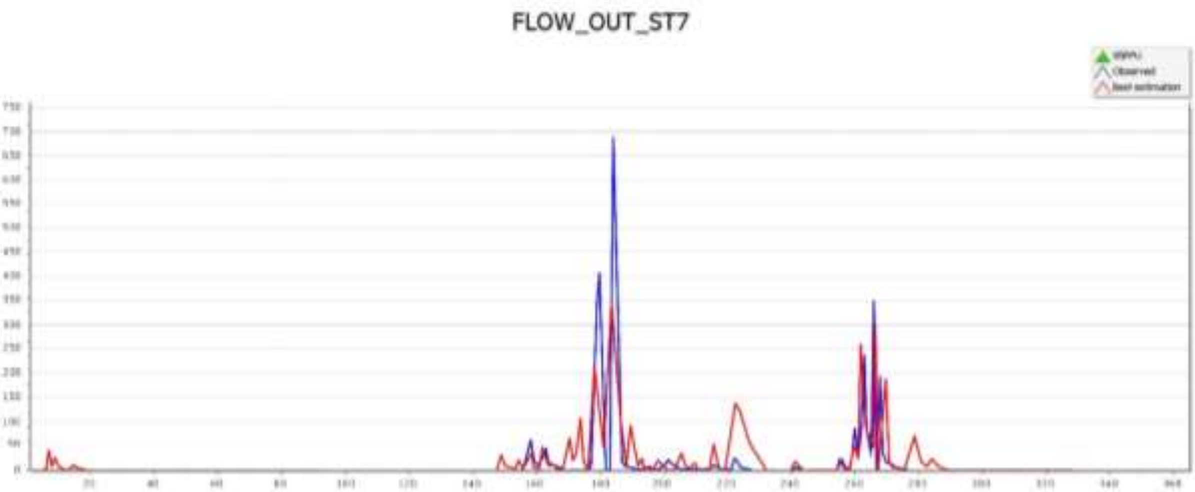
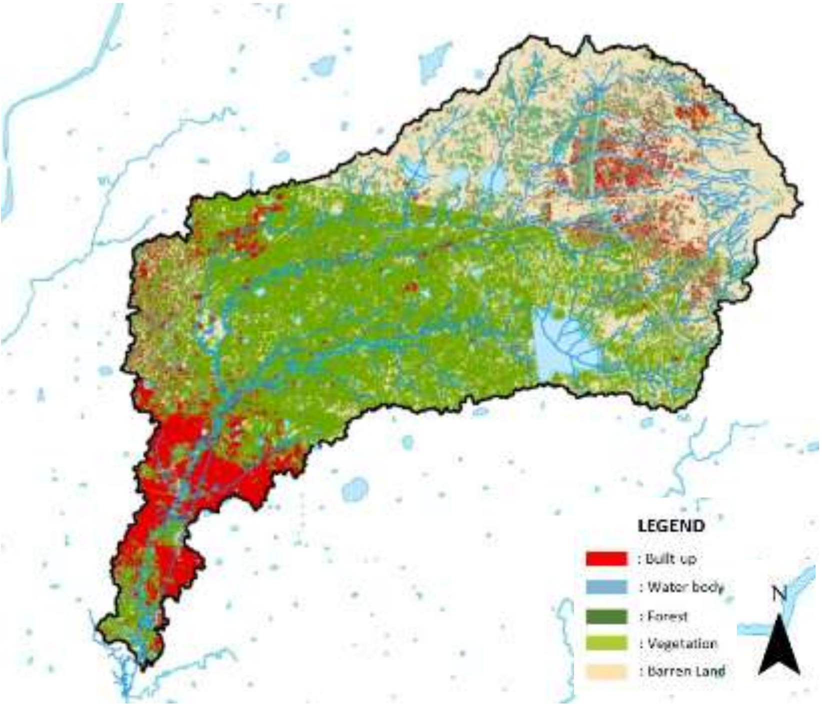


Figure 55 Calibration Output for 2005

4.3.3 SWAT Output 2011



The SWAT output for 2011 Hydrologic model Surface Runoff is 459.73mm and the input data of precipitation from Pilol gauging station is 1035.8mm

Figure 56 LULC map of 2011 For Vishwamitri watershed

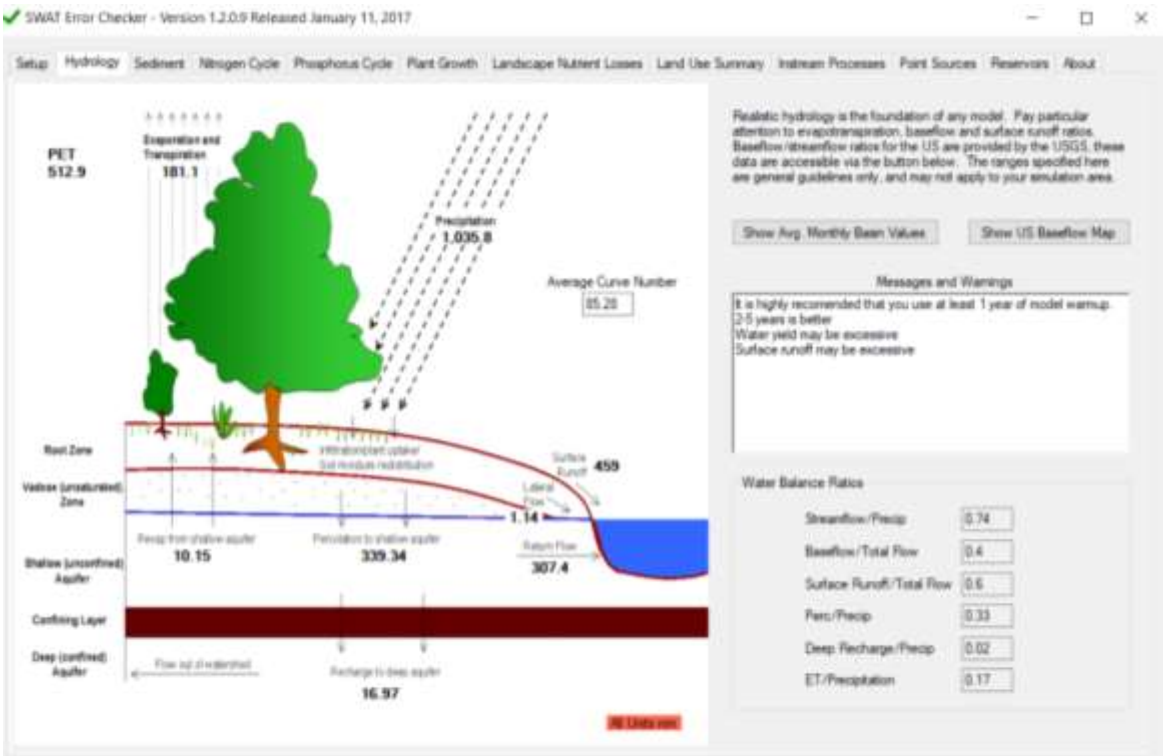


Figure 57 SWAT Output for 2011

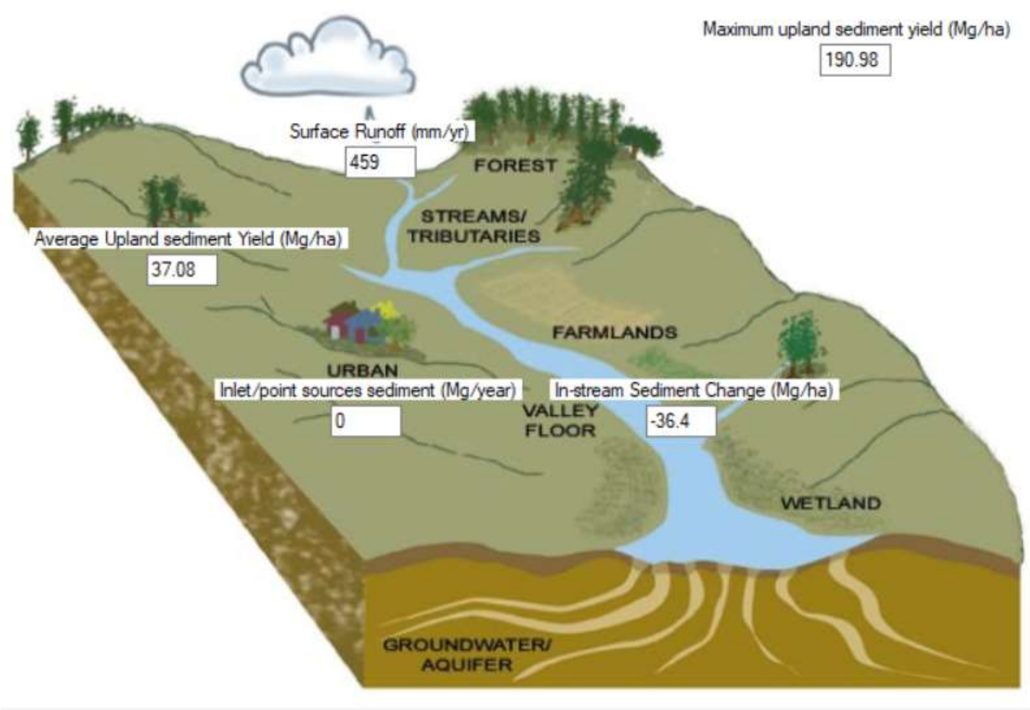


Figure 58 Surface Runoff of 2011

Calibration for the Hydrological Model is done when the input data of precipitation and runoff from the model is checked with the authentic data from the gauging stations with the help of SWAT CUP software. In 2005 case data from the model is calibrated with the data of discharge from the Pilol,Bhaniara and Kalaghoda gauging Stations and the goodness level is marked when the value of R2≥0.50 , Here R2 value is 0.63 and value of P factor is 0.67.

Figure 59 Calibration Output for 2011

4.3.4 SWAT Output 2019

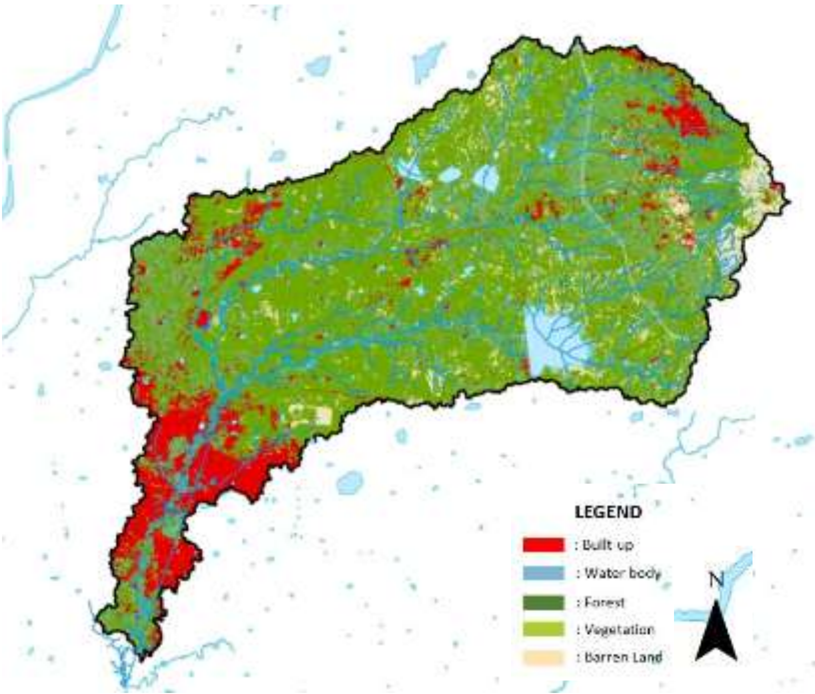


Figure 60 LULC of 2019 for Vishwamitri Watershed

The SWAT output for 2011 Hydrologic model Surface Runoff is 761.92mm and the input data of precipitation from Pilol gauging station is 1416.9mm

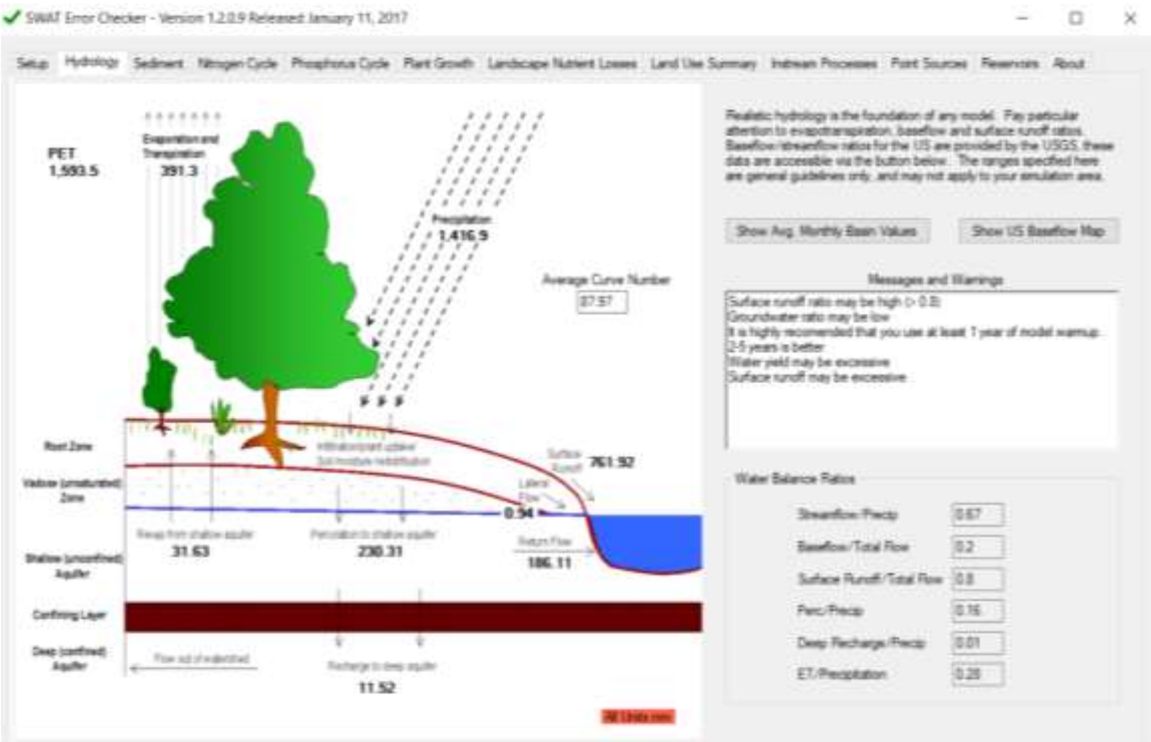


Figure 61 SWAT Output for 2019

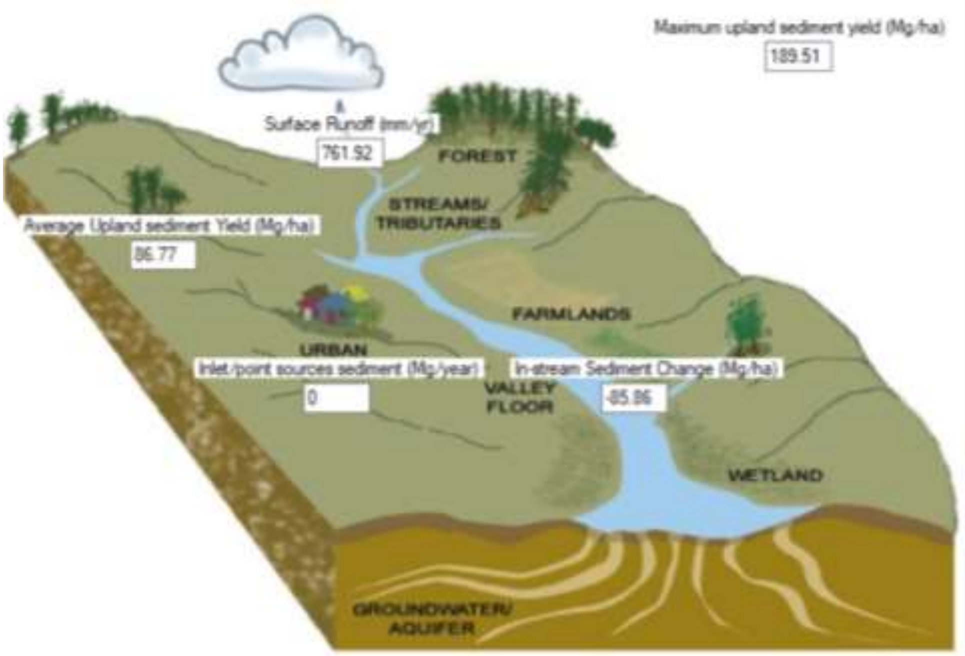


Figure 62 Surface runoff for 2019

Calibration for the Hydrological Model is done when the input data of precipitation and runoff from the model is checked with the authentic data from the gauging stations with the help of SWAT CUP software. In 2005 case data from the model is calibrated with the data of discharge from the Pilol,Bhaniara and Kalaghoda gauging Stations and the goodness level is marked when the value of R2≥0.50 , Here R2 value is 0.54 and value of P factor is 0.56.

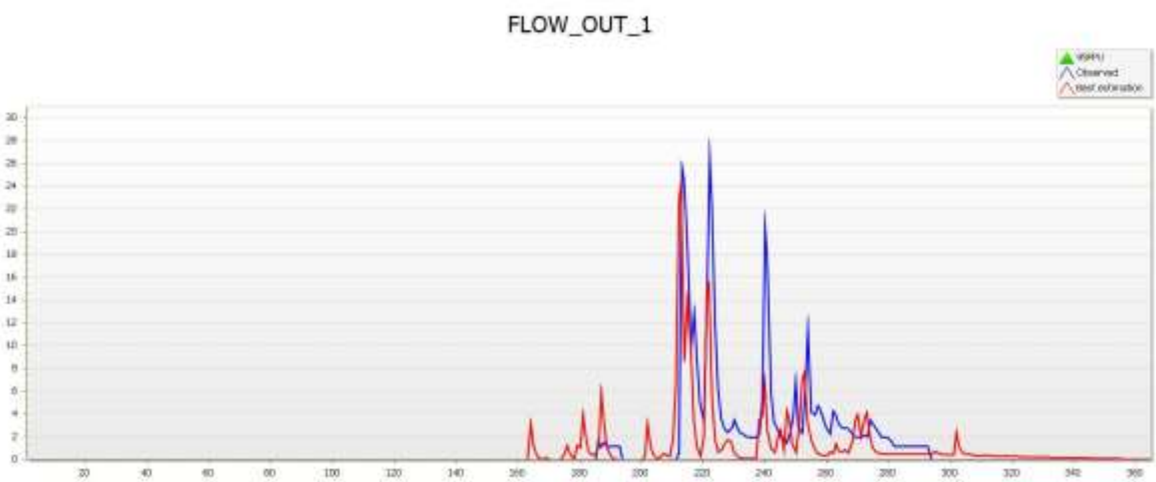


Figure 63 Calibration Output for 2019

4.3.5 SWAT Runoff Calculation from 1980-2019

Year	Rainfall (mm)	Runoff (mm)	Year	Rainfall (mm)	Runoff (mm)
1990	898.7	288.1	2005	1547.96	779.73
1991	676.7	223.6	2006	1357.3	548.6
1992	594.9	91.9	2007	899	252.2
1993	2170.2	603.5	2008	1012	261.1
1994	1220	390.4	2009	437.38	99.25
1995	582.62	332.01	2010	1036.6	340.2
1996	1078.9	407.7	2011	1106.1	459.1
1997	939.7	294	2012	775.08	242.06
1998	928.33	315.71	2013	1439	639.7
1999	336.28	49.49	2014	1075	365.32
2000	431.7	126.3	2015	528.97	261.1
2001	710.3	287.69	2016	722.52	289.4
2002	687.5	291.8	2017	788.58	390.8
2003	934.9	281.2	2018	667.65	340.2
2004	854.8	261.2	2019	1416.9	761.92

Table 4 Runoff Calculation from 1980-2019

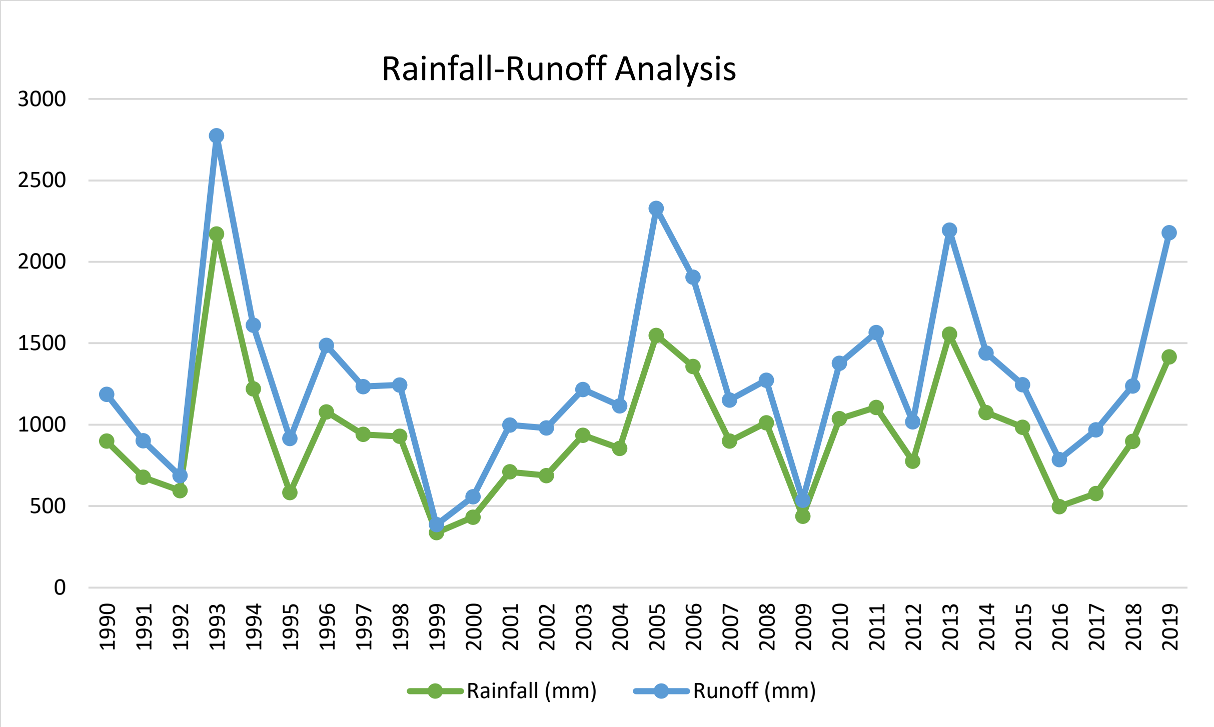


Figure 64 Rainfall-Runoff Analysis from 1980-2019

The computed values of minimum and maximum (a) Yearly average rainfall are 336.28 mm and 2170.2 mm respectively and (b) Yearly average runoff are 49.49 mm and 779.73 mm respectively.

Vadodara District rarely receives very intensive rainfall occurrences but once they happen the amount of rainfall is very high which can be one the major impacts of climate change. The mixed global probability distribution discussed by Haanis used to explore the re-occurrence of rainfall events with certain return period .Table 5 represents various rainfall events and their corresponding return period of re-occurrence.

Rainfall Event (in mm)	Return Periods (in Years)
881	02
1181	05
1377	10
1487	15
1564	20
1622	25
1803	50
1983	100

Table 5 Rainfall events and Re-occurrence Period

Recently severe flooding occurred in Vadodara District during 2013 and 2019 with annual rainfall of 1439 and 1427 mm respectively. Rainfall events causing such flooding have been predicted more frequent to occur. The analysis revealed that more than 1622 mm rainfall which can cause extreme flooding conditions in Vadodara City has frequency of 25 years to re-occur.

4.4 Land use Land cover Analysis

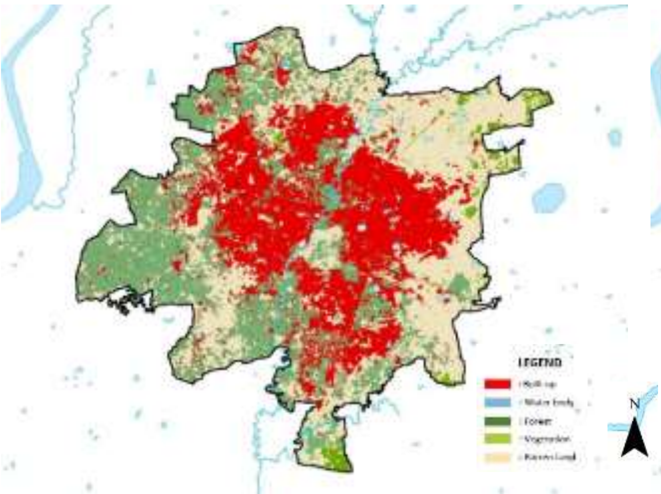


Figure 66 LULC 2001

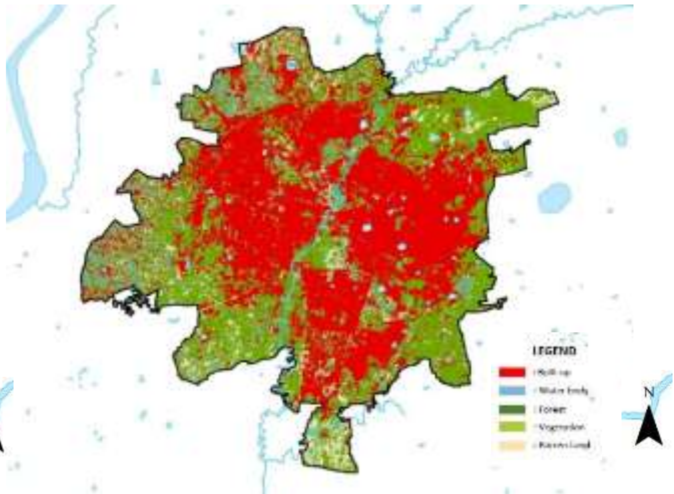


Figure 65 LULC 2011

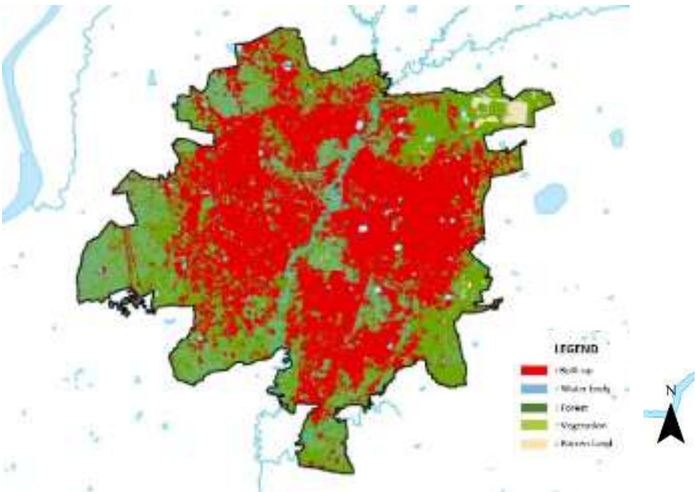


Figure 67 LULC 2021

Year	Area in Hectare	Growth Rate	Population
2001	14900	2.53%	15,02,000
2011	15995	2.00%	18,34,000
2021	22030	1.96%	22,32,521
2031	24771.67	2.22%	27,68,318
2041	28336.67	2.63%	28,94,505
2051	31901.67	2.32%	32,27,165

Table 6 Area Projections for Future LULC

4.5 Gap Analysis and Statutory Recommendations

Figure 68 Gap Analysis Found while Research Study

4.6 Gaps in Current legislatives and Governance structures

Name	ARCTICLE	Gaps
GTPUD ACT	12 (h) Preservation, conservation and development of areas of natural scenery and landscape	The understanding of eco-system needs to be incorporated in this article.
	12 (l) the filling or reclamation of low lying, swampy or unhealthy areas or levelling up of land	This allows to fill ravines and wetlands which affects drainage pattern of city
GDCR	Very generalized mention of restricted zoning	Doesn't include the mention of Relevant act and laws
	25.1 Minimum distance from water body	Doesn't include mention of Highest flood level
	25.2 Rain water management	Mention rain water disposal for building only what about site

Table 7 Gaps in Current Legeslatives and Governance Structures

: Amend : Replace

Legislation Gap	Strengthening of Legislative provision
Inclusion for consideration of Natural Systems in planning	Amendments in existing articles of GTPUD Act & GDCR
Integration of Environmental Solution based acts in developmental acts and laws	Inclusion of ES based Acts & Laws in GTPUD & GDCR
Strong political hold due to weak government structure as per act	Restriction on changes in TP/DP

Table 8 Gaps in Legislation

CHAPTER 5

5. Proposals and Statutory Recommendations

This chapter includes the policies and mitigation measures which can be taken to prevent Flood situations in the city. There are several policies and strategies through which Rainfall runoff can be decreased. Below are some policies and strategies to strengthen the Hydrology of Vishwamitri River.

5.1 Recommendations to take care of run-off water, local flooding and to rejuvenate water bodies

1. Widening of Cross Sections In Main River

Building embankments after leaving the Riparian Edge zone to protect Bio-diversities and using Low Impact Development Concept where development is yet to be planned

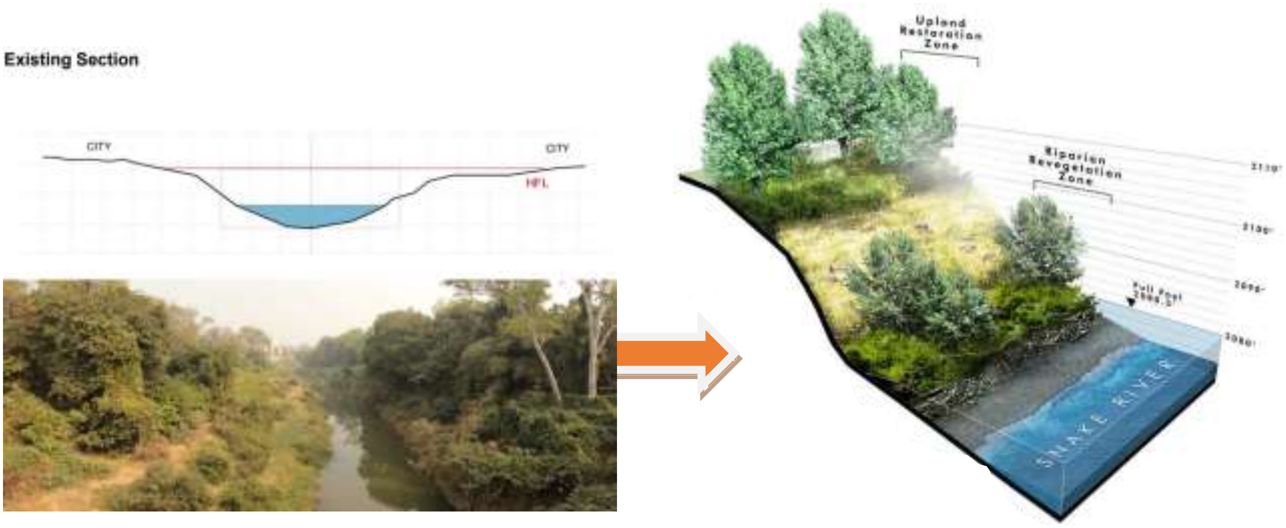


Figure 69 Existing Section of River Vishwamitri

By Building the River Edge with this strategy the less amount of concretization will be there in proposed VRDP. Every year 10% Concretization Increases. Guidelines to follow this

Transferable Development Rights for the Current plot owners in Riparian edge

Higher FSI for the plots adjacent to embankment

Compulsory Bylaws to be followed:

1. River side margin should be left as per size of the plot and height of the building.
2. River side margin should be developed as permeable surface

2\.

Relocation for Dumping of debris

Aluminum, plastic,Glass soft drink containers Steel cans Plastic laundry detergent bottles can be easily recycled into ashphalt for Paved Roads and Plastic can be recycled into Park benches and in Carpeting

Construction Debris and other garbage is being dumped in and along the edges of river Vishwamitri, rather than dumbing it in River if they are recycled there will be less amount of garbage and more amount of Cleanliness.

Figure 70 Recycling bins

3.

Restricting the new structures, Removal of slums around the River & Demolishing the old structures that Obstructs the natural flow of water and Low Impact Development Concept to be used in while planning new Areas and new TP Schemes.

Figure 71 Agora Site Comparison between 2000 & 2021

As the image on the left shows in 2000 the Agora site near Mangal pandey bridge was having a natural ravine passing through it and due to the landuse change allotment the area got completely concretized.

Planning Projects are given such permissions on what basis?

There is a lack of Environmental based planning in Vadodara and In VUDA it is highly recommended to have a Environmental Planning Commission and cell for permission

5.2 Demarcating Riparian edge zone with vegetation and forming Natural Boundaries

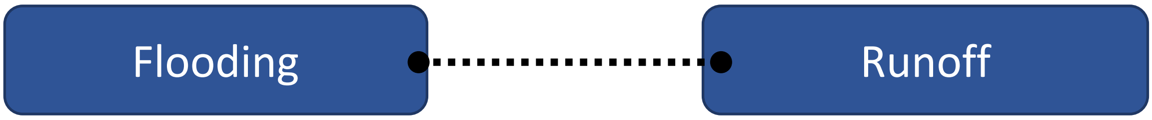
<u>Reestablishment of Eco sensitive Zones:</u>

- 50 mts of vegetation stretch developed alongside river as it covers the area of natural linkages.
- It will approximately accommodate around 55lakh trees.
- As VRDP project is again floated by Mr Vijay Rupani the finance and framework can fall under this.
- VMC can collaborate with VVA, Forest department and VUDA.
- Activities in this project will be Land clearance and preparation and tree planting

Figure 73 VUDA 2031 Development plan

Figure 72 River Vishwamitri

5.3 Revision of bylaws to make rainwater harvesting mandatory in all buildings and adoption of water conservation measures.(Statutory Solution)



2025 Water Demand = Water Supply

2030 Water Demand > Water Supply

1 person needs 20litres of Potable Water Daily

Calculating for the need for 1 society (200 people) on Neighborhood level as an example

400 people X 20 liters requirement of potable water (1day)

8000 liters requirement of potable water for 400 people (1day)

Calculating for 300 days

As per above calculation a Water Storage tank should be constructed combined for the Society and it should be a compulsory intervention to be added in Building Bylaws so the water scarcity can be dealt with.

<u>Policies:</u>

1. In urban areas, where water is provided through public stand posts, 40 lpcd should be considered.
2. Unaccounted-for Water (UFW) is the difference between the quantity of water supplied to a network and the metered quantity of water used by the customers. UFW has two components:
   (a) Physical losses due to leakage from pipes, and
   (b) Administrative losses due to illegal connections and under registration of water meters. The exculpation of UFW, which should Be limited to 15% for new proposed systems.
3. The water needs of the City will be partially met by making provision of Rain Harvesting Structures in all the buildings.
4. Piped water supplies should be designed on continuous 24 hours basis to distribute water to consumers at adequate pressure at all points (using grid supply system of a Smart city).
5. The consumption of water when supply is metered is less compared to that when the water charges on flat rate basis. Hence in order to achieve optimal utilization of water, metering is recommended.
6. In urban and industrial areas, rain water harvesting and desalinization where techno-economically feasible, should be encouraged to increase availability of utilizable water.

7. CPHEEO manual specifies design period for various components, broadly 30 years for civil works and 15 years for electro-mechanical works.
8. PPP should be encouraged and could be introduced in phases, either on Build, Operate and Own (BOO) or Build, Operate, Own and Transfer (BOOT) basis. Primarily, it is possible in two ways i.e. privatization of the existing water supply systems and secondly, privatization of systems in newly developed townships, housing colonies, business and commercial complexes, etc.

Year	Area (ha)	Population	Water Coverage	Per capita supply (lpcd)	Need of Potable water(lpcd)
2001	14900	1300000	55%	150	135
2011	15995	1670000	75%	180	145
2019	21563	2065000	79%	183	160

Table 9 WaterSupply Table

5.4 To manage water in Vishwamitri watershed catchment area before it enters the city

Diverting Water Flow

1. **Water Diversion channels** feeding into new reservoirs and these diversion channels can further lead into irrigation canals as well.
2. These can be planned with **water navigation mechanisms** and **controlled with safety gates**. During heavy monsoons, these gates can lead to branching channels that lead to micro irrigation and ponds(that are dried up) for agricultural purpose and ground water recharge also. Orissa has interlinked irrigation channels and flood drains that help in coping floods.

Increasing Reservoir Capacity

1. Existing reservoirs that feed water into Vishwamitri River have capacity of 96 ML Metric cube, In Last 56 years these reservoirs have not been distilled.
2. **Distillation** of these reservoirs and managing soil erosion into them can enhance their capacity to store water and limit discharge.
3. **Addition of new reservoir** at Indrad,Adrian and wadalda can help in enhancing reservoir capacity and act as artificial wetlands in times of drought. Actions to be taken into Considerations for new reservoir are land ownership and surface water conditions
4. **Micro level** : ponds can be ploted and located to help in irrigation.

Eco sensitive Planning

1. **Spatial tools** to be devised while managing land-use Land-cover and components like, roads, canals, reservoirs with incorporating water sensitivity principles.
2. Critical floods zones managed by watershed committees: Identifying flood risk zones and planning of such zones to be **'No development and Controlled Development Zones.**
3. Implementation of such guidelines needs legal support and micro management which can be supported by legal policies like:

- National Climate Change Policy,
- National Water Policy,
- Integrated Watershed Management Programme,
- Pradhanmantri Krishi Sinchayi Yojana.

Responsible Stakeholder Departments involved in various hierarchy for the given solution are:

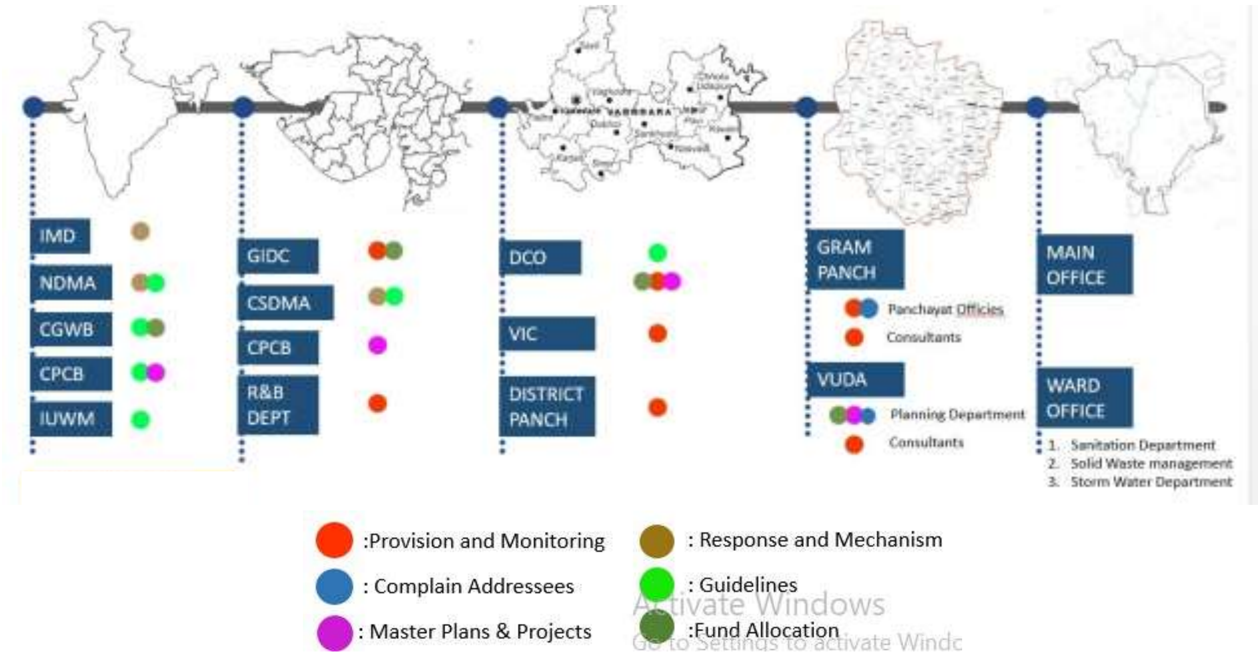
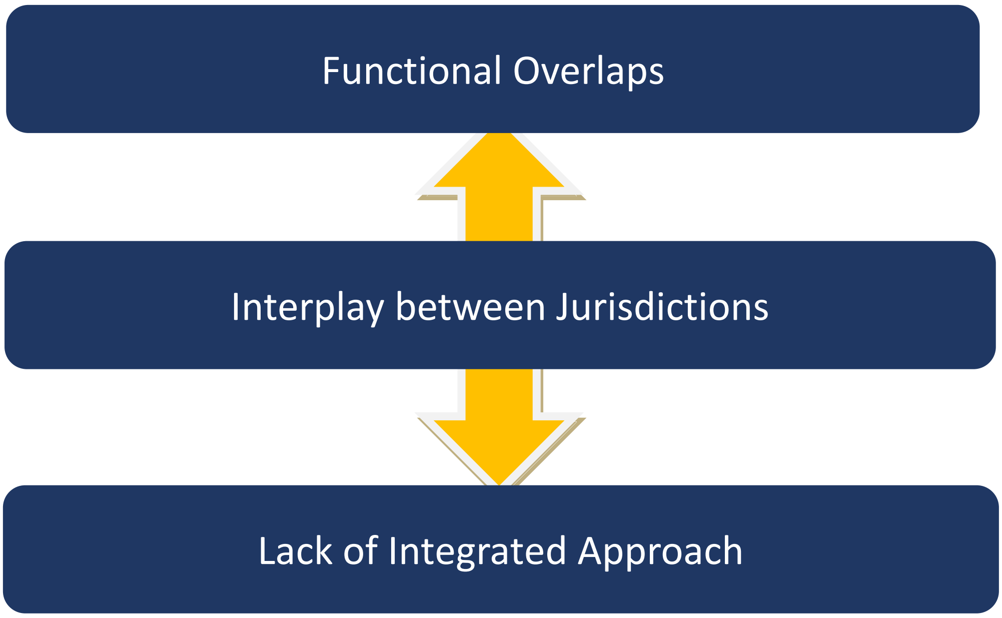


Figure 74 Stakeholder Identification at various Judicial Levels

Stakeholder Analysis:



5.5 Watershed Management by incorporating Flood Zones of Catchment area in Development plan as Flood Sensitive Zones with Eco sensitive Planning Bylaws

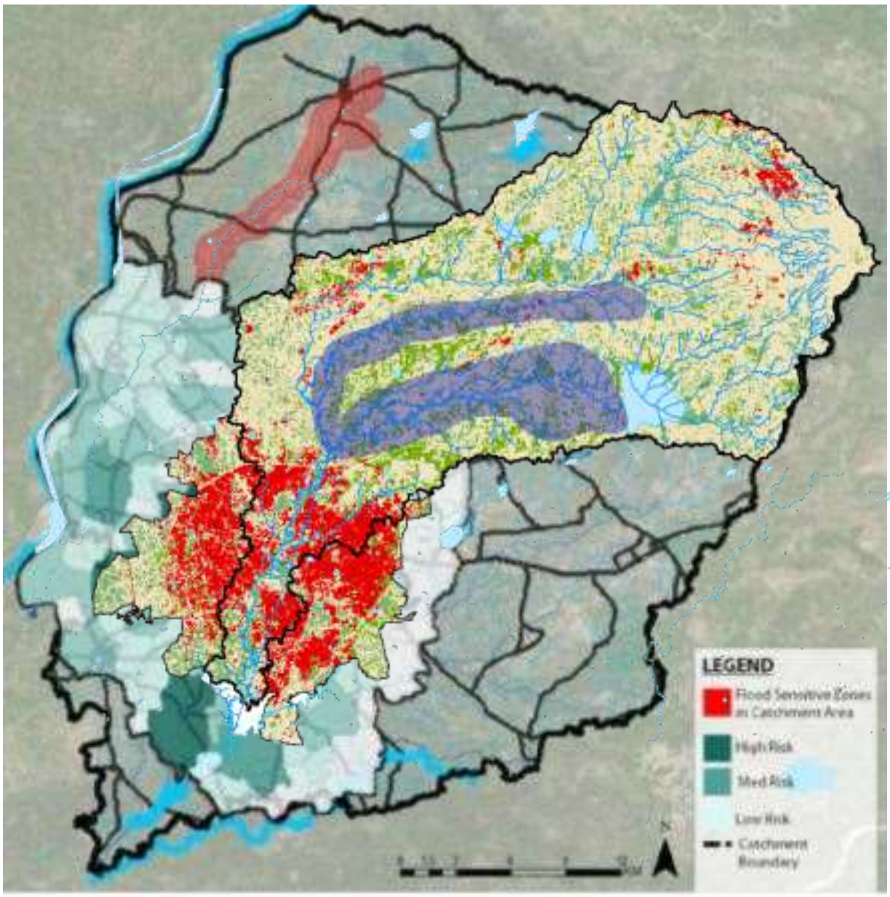


Figure 75 Map showing Flood Prone Zones in Vishwamitri Watershed Area

Watershed Committees for Flood sensitive Zones:

1. Vadodara district currently has four detailed projects under integrated watershed management program and other projects under MGNERA and PMIKSY in particular working for storm water infrastructure such as provision of pipe lines/ducts. roads, ponds, rainwater harvesting structures and resource plans for disaster management.
2. Such proposals planned for critical zones in watershed of Vishwamitri with support of watershed committees can notably reduce chances of floods.

3. Except technical DPR's these watershed committees & VMC can recognize immediate efforts as following and reduce the amount of water entering Vishwamitri river from the catchment.
4. **Using Software's for Calculation of The runoff and the Flood prone zones with help of DEM and Various Hydrological models.**
5. Ajwa dam falls under the VMC purview so the development along the reservoir should be controlled by VMC itself and the micro watersheds by the Watershed Committees as per IWMP DPR report with ULB's support and Funding.

CONCLUSION

1. From hydrological flood analysis the management and operation of Ajwa dam needs to be alter according to consideration of safety of Vadodara City.
2. Encroachment along the river reach causes obstruction to the natural flow of the river which has resulted in intensifying the flood effect.
3. Morphometry analysis shows that due typical characteristic of Vishwamitri basin, which is a natural setup often facilitates the flood situation.
4. Presently there is no flood forecasting model which can act as a warning indicator.
5. With the help of available data, and rainfall forecast using SWAT flood model, the water level at Kalaghoda bridge at Vadodara can be predicted.
6. If we manage the Water in watershed Catchment area by diverting the flow then the impact of Discharge will not result into Flood and the water will not Cross HFL of Vishwamitri river
7. Degradation of Wetlands and Natural Ravine system has played a major Role in Flooding Situation.
8. We should learn from the past.

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