Impact of Encroachment on Natural Drainage for Vadodara City

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Abstract
The city of Vadodara is prone to floods due to the combined impact of change in the precipitation patterns due to climate change and encroachments of waterways due to urbanisation. The river Vishwamitri flows through the heart of the city and there is a dam Ajwa on the upstream of the city. The present study deals with the GIS based mapping of slum and other encroachments on waterways and near water bodies of Vadodara and its effect on flash flooding by analysing two major flood events of the last two decades. During heavy rains under full reservoir conditions, water is released from the dams.

The encroachment within the city along the banks of the river Vishwamitri has caused reduction in the cross-sectional areas and the discharge carrying capacity of the river thus causing flooding in the low lying areas due to the water spilling over the banks. At times there are some places in the city which remain water logged in spite of rain having stopped before 48 hours. These sites are waterlogged because of people having encroached the entire storm water disposal system (Ponds and Lakes). The detailed study is carried out on the encroachments over the natural drainage system and its aftereffects by considering the Vadodara city as study area.

Keywords: Encroachment, Landfills, Flood, River, Low lying areas.

Introduction

Urban flash flood is a major threat to growing urban areas in Asia and Africa.[12] Huge proportions of low income group people are located near areas with recurrent and localized flooding.[9] Urban slum dwellers with low resources are most vulnerable to flood disaster.[13] Increased flood frequencies in urban areas are one of the foremost challenges for policymakers and national, regional and local government officials. Scientific studies confirm that extreme rainfall events in urban areas are rising,[7] though it is not the only reason for urban flooding. Change in catchment hydrology due to uncontrolled developments of concrete spaces, encroachment of natural drainage channels,[5] flinching of marshlands etc. result into high flood risk.[6]

Gupta et al[4] found that there is no major upward or downward trend of rainfall during past 200 years and even a decrease in last 20 years with a contrast record of increasing floods have been experienced. Land-use issues like decreased natural areas, loss of water bodies, encroachment of river, streams and drainages, uncontrolled construction activity have been identified as contributory factor to flood risk in Chennai.[1]

Apart from rapid rise of population, increase in built up area, increased rainfall and decreasing water bodies of Banglore, the major hurdle in flood mitigation and planning, as Ramachandra et al[11] pointed out that the local governance body has not adequate powers to plan, decide and administer the city. The State has created many parastatal organisations, each acting in its own geographic area, leading to complication in coordinating different activities.

Surat, mega city of Gujarat also faces similar problem.[10] Due to haphazard town planning, natural drainage is blocked by construction low lying areas. Illegal settlements are constructed in flood plain of Tapi river, hence a miniature flood event may result into a major disaster.

The findings showed about Dhaka Metropolitan Development Plan (DMDP) area that developers have significantly converted more than ten thousand hectare of lands in flood zones into housing projects on natural water retention ponds and violated the DMDP policy.[2] Such development projects contribute to the cumulatively increasing intensity of urban floods and subsequent damages in Greater Dhaka.

The present study deals with the GIS based preliminary mapping of slum and other encroachments on waterways and near water bodies of Vadodara and its effect on flash flooding by analysing two major flood events of the last two decades.

Material and Methods

Study Area: Vadodara is an important industrial City of Gujarat, situated on the broad gauge railway track on the Mumbai - Delhi and Mumbai – Ahmedabad routes. It is also well connected by road and airways to most parts of Western India. Located in the fertile plains between the rivers Narmada and Mahi and on the banks of River Vishwamitri, Vadodara lies on the 22º 17’ 59” N Latitude and 73º 15’ 18” E Longitude.

The topography of the city is generally flat with a gentle slope from the Northeast to Southwest following the basin of Vishwamitri. Vishwamitri – a meandering river, bifurcates the city centrally in two halves. The city is also dotted with many pretty lakes, which form part of the

catchment of Vishwamitri and another tributary known as Jambuva River, which flows on the southern outskirts of the city and merges with the River Vishwamitri. Length of Vishwamitri river within VUDA boundary is 27km and within VMC boundary is 16.5km. River length with branches within VMC boundary is 23.5 km approximate river width is 60m to 130m and river Depth is about 8-10 approximately.

The general ground level of the city varies from 20 m to 40 m above mean sea level. It has an average annual rainfall of 900 mm Monsoon is spread over the month of June to September. During the reign of Maharaja Sayajirao Gaekwad-III,(1881-1939) there was an all round development and due to his better vision he had planned the better and adequate system of storm water management, it includes the storm sewer in the walled city and system of interconnected lakes and ponds for discharge of storm water.

With the passage of time, due to unforeseen expansion and sudden boom in industrial development after 1960 coupled with lack of proper planning and management, there has been a haphazard growth of the city. Lack of proper vision for storm water disposal system, people have done encroachment on the natural system of river, ponds and lakes. Builders have developed the residential schemes in the flood plain of river Vishwamitri. Slums are created in the floodplain and on the ponds/lakes by filling of it.

Development of industries in Vadodara led to the influx of unskilled job seekers and daily-wagers besides skilled and educated workforce. The former has led to the growth of slums where poor working class people live. The initial increase in the slum population coincided with an increase in commercial and industrial activities leading to immigration and growth in the number of slums. From 192 slums in 1972, the number has gone up to 336 in 1996. The maximum number of slums i.e. 43% (146) slums is on the government land followed by 37% (124 slums) on private land and 20% (66 slums) on Municipal land.[3]

Ajwa reservoir is situated on the upstream of Vadodara city. Full reservoir level of Ajwa is marked as 212 feet, Spilled water is then disposed off in the river Vishwamitri. The river is gauged at Kalaghoda Bridge, in the heart of the city. High flood level at Kalaghoda Bridge is marked as 26 feet.

Over flow of the Ajwa reservoir due to high rainfall in the catchment area, high water level of Vishwamitri river due to discharge from the reservoir, high intensity rainfall in the city area, high runoff generation due to impervious surfaces and inadequate disposal system due to encroachment on natural drains and ponds are the major reasons for flood in Vadodara city. Studies show that the major climate change is indicated in the city with the drastic change in rainfall pattern after 2002.

Data Collection:

1. Water level data during flood events at Ajwa reservoir and Vishwamitri at Kalaghoda Bridge was collected from Vadodara Municipal Corporation.
2. Satellite images from Google Earth are processed for showing the Encroachment on the water way based on actual site investigation.
3. Some images of actual flood situation were taken by Er. Hiren Rathod and some were collected from social media platform www.facebook.com\Vadodara floods.
4. Rainfall data from 1961-2014 of Vadodara City was collected from State Water Data Centre (SWDC), Gandhi nagar.

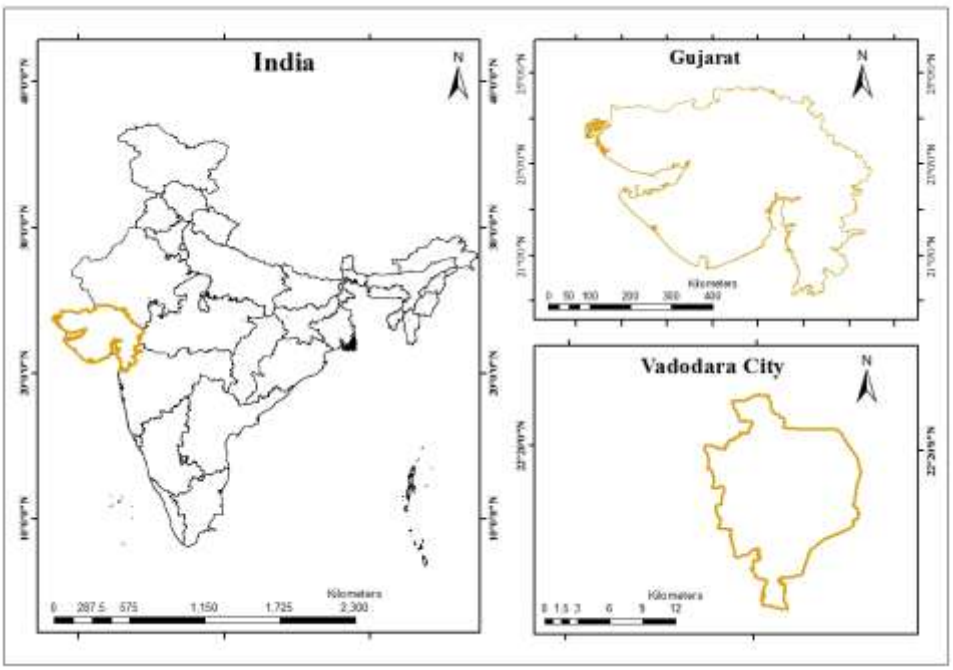


Fig. 1: Study Area of Vadodara

Analysis: Google Earth software is used for analysing encroachment on floodplains of river Vishwamitri, natural drains or rivulets and lakes of Vadodara city. Ground truthing was done by field visit. The impact of encroachment on two major flood events of the 21st century was analysed by flood water levels, visits and interview of residents at flood inundated sites.

Results and Discussion

Disturbed Waterways and Flood Plains: The development of the city is at rapid pace in the last two decades. Change in land use near flood plains of river and flood inundated areas in the city is done by comparing the oldest available Google earth image (28th October 2000) and the recent one (29th May 2019). High end bunglows near Amit nagar bridge (Fig. 2) are affected badly almost every time whenever there is a high water level in the river. High economic losses are observed during each flood. Another colony of bunglows (Fig. 3) at upstream of Munjmahuda bridge is facing the same difficulty.

Comparatively recent construction is developed near Bhimnath bridge (Fig. 4) on the land which was served as inundation pond during high floods. The outfall of Parshuram nagar rivulet also seems affected due to this construction. Impervious area is increased due to construction of food market (Fig. 5) and other buildings near EME bridge.

Slum near newly constructed Akota bridge is one of the oldest dense slum (Fig. 6). This slum is affected during high floods in the river. Slum at the downstream of Munjmahuda bridge (Fig. 7) is expanded over the space which previously served as inundation pond.

Slum rehabilitation programme is being executed by public private partnership. Under this scheme slum on the banks of river is evacuated. Slum dwellers are shifted to other places and provided with the basic facilities by private developers, in turn developer can develop evacuated land or get more FSI in other construction projects. Evacuation of slum on both the banks of river near Narhari Hospital Bridge can be seen in fig. 8. Slum near Mangal Pandey Bridge is removed and construction has been started by a private developer (Fig. 9). Construction on river flood plain is clearly visible in the figure.

The eastern part of Vadodara facing floods is not only due to local rainfall but also due to runoff from outside the urban boundary. Though slums are removed on the banks of rivulet (Fig. 10) at Varasiya, concrete built up has also increased on the floodplains of the rivulet. Slum encroachment was observed on the wetlands of Kishanwadi area (Fig. 11).

(a) (b)

Fig. 2: Built-up near Amitnagar bridge (a) 2000 (b) 2019

(a) (b)

Fig. 3: Built-up near Munjmahuda bridge (a) 2000 (b) 2019

(a) (b)

Fig. 4: Construction near Bhimnath bridge (a) 2000 (b) 2019

(a) (b)

Fig. 5: Construction near EME bridge (a) 2000 (b) 2019

(a) (b)

Fig. 6: Slum near Akota bridge (a) 2000 (b) 2019

(a) (b)

Fig. 7: Slum near Munjmahuda bridge (a) 2000 (b) 2019

(a) (b)

Fig. 8: Slum evacuation near Narhari Hospital Bridge (a) 2000 (b) 2019

(a) (b)

Fig. 9: Redevelopment near Mangal Pandey Bridge (a) 2000 (b) 2019

(a) (b)

Fig. 10: Construction on rivulet flood plain at Varasiya (a) 2000 (b) 2019

(a) (b)

Fig. 11: Construction on wetlands of Kishanwadi (a) 2000 (b) 2019

These wetlands were used for flood inundation and helped in reducing vulnerability in the area. Though slums were removed, permanent residential structures were constructed on the same land.

Lake revival project has been undertaken by local authority. It is the fact that urbanisation has affected natural slopes and drainage channels. Depletion of ground water has also affected undercurrents. Change in catchment topography has resulted in to drying of ponds. Khanderao Lake (Fig. 12) near Khanderaoo temple has dried and construction is done after filling up the land of the lake. Lake near Manjalpur funeral ground is also dried and road is constructed after land filling (Fig. 13). The remaining portion of the lake is rehabilitated.

Validity of the satellite images of flood prone areas against actual conditions is verified by conducting site investigations. Blockage of drains mainly occurred in the Bukhi rivulet drainage and its catchment in Sama area. Narrow river segments were blocked in the densely populated North-West part of the city because the major industrial zone is located in nearby area. Many small natural drains vanished in this area by illegal landfills and the accretion on both sides of river bank.

Flood in 2005: Vadodara city receives the rainfall in in mid-June to mid-September; annual average rainfall is about 903 mm. This moderate rain region of central Gujarat received unprecedented rainfall of around 1200 mm due to upper air cyclonic circulation during 24 June to 4 July 2005. The total rainfall observed in 11 days is about 30 percent higher than the average annual rainfall of Vadodara.

Heavy damages occurred in urban and rural areas causing loss of life and property in central Gujarat due to flood in July 2005. The heavy rains had left many of the major dams full while the medium and small dams were overflowing. The worst was the case of Pratap Pura lake in Vadodara district where nearly 100-feet long breach developed in check dam-cum-reservoir as it overflowed and water gushed out towards the villages downstream. Much of the overflowing water was drained into the Vishwamitri river flowing through the Baroda city.

The situation became dangerous when heavy rainfall in the catchments areas of Ajwa Dam compelled opening of the spillway gates to release water. Water level at the Kalaghoda Bridge on river Vishwamitri crossed high flood level 27.9 feet on 30th June 2005 at 12:00 a.m. Water level crossed 35.6 feet on 1st July 2005 at 2:00 p.m.

(a) (b)

Fig. 12: Khanderao lake (a) 2000 (b) 2019

(a) (b)

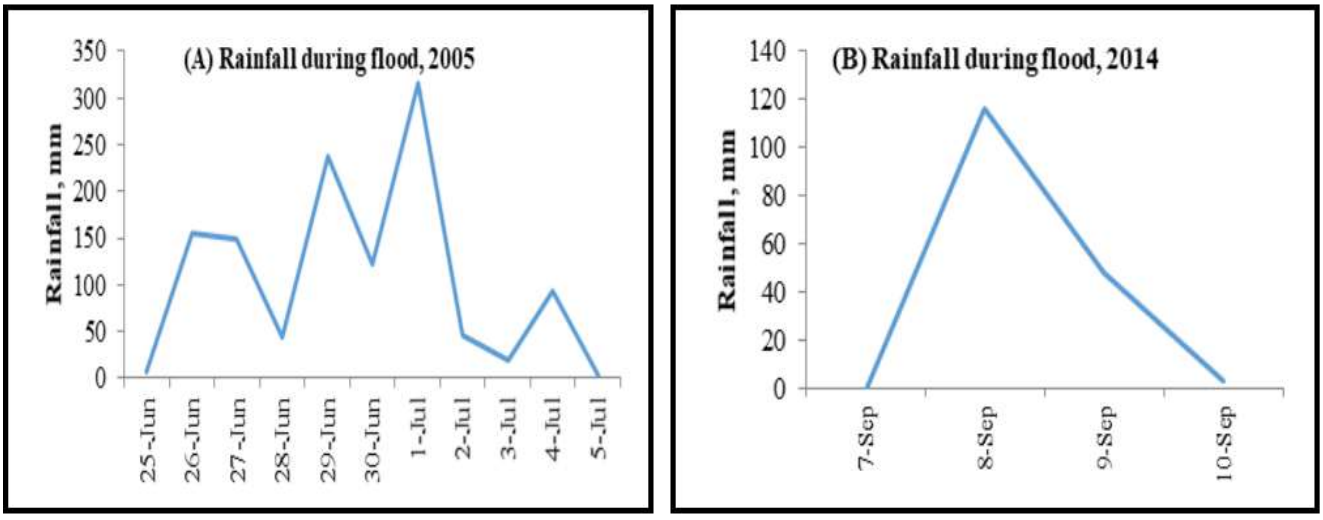
Fig. 13: Manjalpur lake (a) 2000 (b) 2019

The Northern areas of Bhukhi catchment like Nizampura, Channi, Sama and eastern area Kishanwadi were more affected. These areas remained waterlogged despite Vadodara did not receive any rain after 4th July 2005. Major reason of the flood water inundation as observed by local residents and news reports was obstruction caused by the illegal landfills and encroachment over the floodplain.

Flood in 2014: Vadodara faced flood during 9th and 10th September 2014. Vadodara received 116 mm rainfall on 8th September. Due to high continuous rainfall in catchment area, overflow from Pratappura reservoir and release from Ajwa reservoir, the city was flooded for 48 hours in 2014. Viswamitri crossed High Flood Level on 9th September 3:00 p.m. Peak flood level 34.00 feet was observed on 10th September at 2:00 p.m. River water level was back to below HFL on 11th September after 10:00 pm.

Severe water logging happened in Dandia Bazar, Kishanwadi and other flood prone areas. Overflow was observed from rivulet near Ayurvedic College, Key transport and health facilities like central Bus station (Fig. 15 a), SSG hospital Road, Railway Underpass (Fig. 15 b) etc. were also affected by flood. Many of such areas namely old city area, Kapurai, Ataladra, Gotri, Gorwa, Chhani, Subhanpura were flooded.

Flood in 2005 occurred due to unprecedented heavy rainfall in the city as well as in the catchment area of Ajwa reservoir while there was comparatively less rainfall in the city with respect to reservoir catchment area in the flood of 2014. The severity of the water logging in the flood affected area was more or less same in some areas during both the flood events. The major reason for water logging can be identified as (a) due to high water level in the river, low lying flood prone areas were water logged. (b) no disposal of urban runoff water in the river due to high water level (c) less detention capacity of ponds, less inundation capacity of natural rivulets and vanishing of natural drains due to encroachment and land filling.



(a) (b)

Fig. 14: Daily Rainfall during flood (a) 2005 (b) 2014

(a) (b)

Fig. 15: Water logging during 2014 flood (a) Central bus station (b) Railway station underpass

Table 1
Water Level Statistics during flood

Water Level Statistics (2005)			
Date	Time	Level (Ft) Ajwa	Level (Ft) Vishwamitri
30/6/2005	12:00	212.5	27.90
1/7/2005	2:00	213.39	35.60
4/7/2005	14:00	212.13	26.00
Water Level Statistics (2014)			
9/9/2014	15:00	214.85	26.00
10/9/2014	14:00	213.80	34.00
11/9/2014	22:00	213.85	26.00

Conclusion

The analysis of Google earth images shows that the new localities were built encroaching drainage ways and water disposing bodies in the course of urban development which ultimately resulted in flash flood events in most of the areas of Vadodara city.

Observations from Satellite images show the existing condition of water bodies of the Baroda city. It can be easily traced out that the city has number of lakes on both the sides of river and there was a system of interlinking of lakes through rivulets which vanished in the course of development.

There is a high risk of vulnerability due to flash floods in low lying encroached areas, taking this fact into consideration, the urban planner has to monitor the areas for checking the growth and expansion of the city; proper planning and management are required to mitigate the flood risk vulnerability in these areas. Remote sensing and GIS-based analysis can be useful to the authority in periodical monitoring of expansion and assessment of the city to identify and to remove the obstructions in the waterways and water bodies.

Bye-laws of the development must be followed by builders, developers and property buyers near the water bodies. Risk analysis should be carried out for the high flood condition at such particular sites before construction. The banks of the river and boundaries of water bodies should be protected by proper planning, management and enforcement of bye-laws. Dumping of garbage and other wastes in flood plains of the river should be prohibited.

Field observations of some sites point out the necessity of immediate action. The infrastructural pipelines are passing through the riverway (e.g. Nagarwada Bridge distributory) which obstructs the natural river flow, so the better alignment for these pipelines should be decided. The high growth of foreign vegetation was identified in the river way and ponds at some sites so it should be removed for unobstructed flow and more carrying capacity.

Analysis of two major flood events of the year 2005 and 2014 shows that continuous rainfall with high-intensity combined with the release of water from Ajwa reservoir resulted in the rise of water levels in the river and areas with low elevations. Encroachment and earth filling in the flood plain and natural drainage made the flood events more severe.

Spatial flood vulnerability based on the temporal satellite data should be analyzed. Long-term planning of land and water resources should be done by combining the conventional methods with the high-resolution satellite data which may be helpful to scale the risk of a flood hazard and disaster management to prevent damages.

Acknowledgement

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