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Effects of Urbanization on Floodplains of Streams

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Abstract: Stream flow regimes are determined by watershed characteristics: climate, geology, topography, soil, vegetation and human activities. To meet the demands of growing populations, there has been increasing urbanization and associated developments in the watersheds of a number of streams. The commonly observed hydrological responses of the watershed to urbanization are increased volume and peak of floodwaters. Flooding is a hazard with serious socioeconomic consequences for all activities and infrastructure within an affected floodplain. Determining the extent of flooding is an important role of the hydrological research community and provides a vital service to planners and engineers (Hudson et al., 2003). This study focuses on the analysis of increase in water surface elevations of stream Patiali Ki Rao within Chandigarh due to urbanization. The study has undertaken hydraulic modeling of Patiali Ki Rao using United States Army Corps of Engineers Hydraulic Engineering Centre River Analysis System (USACOE HEC-RAS) to understand the urgent need of onsite control of stormwater runoff to deal with flooding issues of the city. It has been concluded from this study that the condition of the stream has been deteriorating from existing to present to future condition of development and the predicted HEC-RAS water surface elevations can be put into effect to plan further development in the city.

Keywords: *Urbanization, Rational Method, HEC-RAS, Patiali Ki Rao, Delineation.*

1. Introduction

Building new towns or increasing the size of urban areas makes more of the land impermeable. It increases the amount of runoff by removing topsoil for construction and compacting the ground with earth moving machinery, building roads which increase the impermeable surface area, building drains and sewers that introduce a rapid means of transport of the water to river channels. This reduces the lag time and straightening river channels and lining them with concrete to enable building plans to proceed. This leads to faster delivery of water downstream of urban area increasing the risk of flooding in those areas. Urbanization alters the shape of the storm hydrograph reducing the lag time and increasing the peak discharge (Bowen et al., 2000). Land use changes associated with urbanization in the watershed are invariably reflected in the stream flow regime and flooding becomes an inevitable problem (Suriya et al., 2012).

International flood commission on Irrigation and Drainage had defined flood as markedly high discharge or stage in the river and inundation of adjoining low lying areas (Ramashastri et al., 1998). Floodplain Inundation Mapping is an important tool for engineers, planners, and government agencies used for municipal and urban growth planning and ecological studies. When conducting hydraulic studies or floodplain analysis two of the more time-consuming processes are setting up the hydraulic model and delineating the floodplain zones. The integration of widely available computational tools with hydrologic and hydraulic modeling and floodplain mapping improves accuracy, effectiveness, and quality (Hernandez et al., 2007). The Hydrologic Engineering Center's River Analysis System (HEC-RAS) is a software package that is well-suited for developing floodplain delineation maps for a variety of applications. An HEC-RAS model can be used for both steady and unsteady flow, and subcritical and supercritical flow Regimes.

The city Chandigarh is a Union Territory (UT) and is located at about 250 km north of New Delhi, capital of India. The surrounding districts are of Mohali, Patiala and Roopnagar in Punjab and Panchkula and Ambala in Haryana. The boundary of the state of Himachal Pradesh is also minutes away from its north border. The area of Union Territory of Chandigarh is 114 sq. km. which includes the nearly fully developed 70 sq km of the area planned by Le Corbusier and his team and the 44 sq km periphery controlled area with 26 villages. The present urban land use of Chandigarh has been further classified into residential, commercial, transport, industrial, public, recreational, agricultural, infrastructure and vacant land uses. In the periphery there are other present land uses which are classified as defense area, railways and forests.

Furthermore there are two major streams, Sukhna Choe and Patiali Rao that form the natural drainage of the city. The Sukhna Choe flows north to south drains the eastern part of Chandigarh and joins the Ghaggar River and Patiali Rao, which flows northeast to southwest and drains the northern parts of the city. Both these streams are seasonal in nature and carry high flows during monsoons. This study has focused on HEC-RAS analysis of the Patiali Rao stream to develop its 25-yr floodplain delineation map. The Figure 1 shows the map of Chandigarh and the location of Patiali Ki Rao within its periphery.

For the purpose of analysis in this study, the development pattern of the city has been viewed through following conditions which has been considered to significantly impact the floodplain of the stream:

1. Existing Condition (Year 1952)
2. Present Condition (Year 2014)
3. Future Condition (Year 2031)

2. River Analysis Model Development

The HEC-RAS model is used to perform one-dimensional steady flow analysis for the entire span of the stream Patiali Rao located within periphery of Chandigarh for computing the water surface profiles.

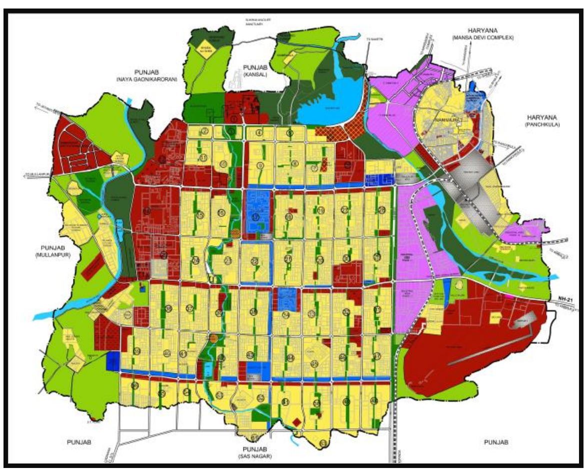

Figure 1: *Map of Chandigarh (Present Condition) and location of Patiali Ki Rao*

Water surface profiles are computed from one cross-section to the next by solving the Energy equation with an iterative procedure called the standard step method. The energy head losses between two cross-sections consist of friction and contraction or expansion losses. The total conveyance for a cross-section is calculated by subdividing the entire cross-section into three units termed as left overbank, main channel and right overbank on the basis of their Manning's coefficients and then summing the three subdivision conveyances. The effects of various obstructions such as bridges, culverts, etc. in the floodplain are also considered in the computations. The discharge during existing, present and future condition of city's watershed is calculated using the rational formula which estimates the peak rate of runoff at a specific location in a watershed as a function of the drainage area, runoff coefficient, and rainfall intensity for duration equal to the time of concentration.

2.1. Model Parameters

The function of the HEC-RAS program is to determine water surface elevations at all locations of interest. The data needed to perform these computations are separated into geometric data and steady flow data (boundary conditions).

The data needed to perform analysis is divided into two categories namely geometric data and steady flow data. The basic geometric data consist of river system schematic, cross-section data, reach lengths, energy loss coefficients and stream junction information. Hydraulic structure data for bridges and culverts is also considered in the geometric data. The steady flow data consist of subcritical flow regime, boundary conditions and peak discharge information. For subcritical flow regime, boundary conditions are only necessary at the downstream ends of the river system. The discharge information is required at each cross section in order to compute the water surface profile. Cross sections are requires at locations where changes occur in discharge, slope, shape or roughness; at locations where levees begin or end and at bridges or control structures such as weirs. Figure 2 shows locations of few HEC-RAS cross-sections within the stream.

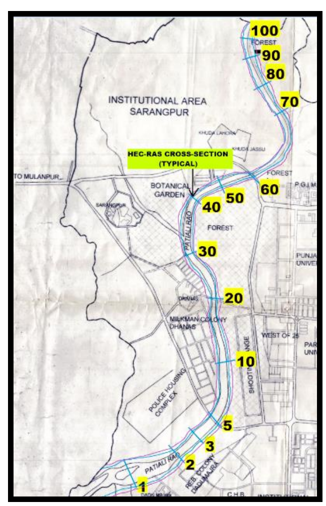

Figure 2: *Cross-sections of Patiali Ki Rao*

Once the geometry is complete, the hydrology can be entered into the model. HEC-RAS requires flows to be entered at all upstream boundaries. In addition, flow changes can be specified along any of the streams. Flows were provided to the model for the 25-yr and 100-yr recurrence interval storm events for existing, present and future condition are presented in Table 1, Table 2 and Table 3 respectively and are summarized graphically in Figure 3. For steady flow analysis, upstream boundary conditions are input as discharges. Downstream boundary conditions can be set to normal depth, a rating curve, a known water surface elevation, or critical depth. Since no gage data information was available at the downstream end of the model, normal depth was selected for the Patiali Ki Rao model downstream boundary condition. The normal depth option requires an energy slope be entered by the user and the program then back-calculates a starting water surface elevation using Manning's equation.

Table 1: *Peak Runoff from Sub-watersheds of Patiali Rao (Existing Condition)*

Basin Name	I	Q	I	Q
	mm/hr	m3/s	mm/hr	m3/s
	25 YR		100 YR	
ONPKR1	64.8	32.4	79.2	39.6
ONPKR2	80.8	13.5	98.8	16.5
ONPKR3	92.6	23.2	113.2	28.3
ONPKR4	80.8	37.0	98.8	45.3
OFFPKR	51.9	164.4	63.5	201.0

Table 2: *Peak Runoff from Sub-watersheds of Patiali Rao (Present Condition)*

Basin Name	I	Q	I	Q
	mm/hr	m3/s	mm/hr	m3/s
	25 YR		100 YR	
DBCHPKR1A	64.8	36.0	79.2	44.0
DBCHPKR1B	126.1	35.0	154.1	42.8
DBCHPKR2	80.8	22.4	98.8	27.4
DBCHPKR3A	109.9	22.9	134.4	28.0
DBCHPKR3B	109.9	16.0	134.4	19.6
ONPKR4	80.8	37.0	98.8	45.3
OFFPKR	51.9	164.4	63.5	201.0

Table 3: *Peak Runoff from Sub-watersheds of Patiali Rao (Future Condition)*

Basin Name	I	Q	I	Q
	mm/hr	m3/s	mm/hr	m3/s
	25 YR		100YR	
DBCHPKR1A	64.8	50.4	79.2	61.6
DBCHPKR1B	112.3	43.7	137.3	53.4
DBCHPKR2	80.8	31.4	98.8	38.4
DBCHPKR3A	109.9	22.9	134.4	28.0
DBCHPKR3B	109.9	16.0	134.4	19.6
ONPKR4	80.8	37.0	98.8	45.3
OFFPKR	51.9	164.4	63.5	201.0

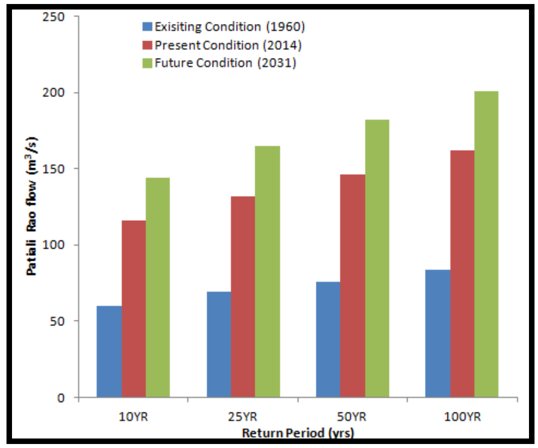

Figure 3: *Flow in Patiali Ki Rao during Existing, Present and Future Condition*

2.2. Model Calibration (Existing Condition)

The calibration of the model was done using the existing condition of the stream and considering the fact that based on the stormwater runoff generated from the city's watershed the runoff is well contained within the various cross-sections of the stream as obtained from the topography maps, UT administration reports and the field reconnaissance.

2.3. Model Validation (Present Condition)

The validation of the model was done using the present condition of the stream and considering the stormwater runoff generated from the city's present condition watershed and the built up of various obstructions such as bridges, spillways, culverts etc. within the span of the stream in lieu of the development. The results of the model were compared for existing and present condition for the calibration and validation of the model.

2.4. Model Prediction (Future Condition)

The model was used to simulate the future condition of the stream within the city for the period of 2015 to 2031.

3. Results and Discussions

The existing condition of the stream did not include any bridges and culverts as shown in Figure 3(a). The present and future condition has obstructions all along its course within the city as shown in Figure 3(b). The stream flow is overtopping the culverts at both the upstream and downstream ends of the stream in present condition of the study. The plan view of Patiali Rao during existing and present condition, in Figure 3(c) and (d) respectively, also shows variation of alignment of stream at the downstream end. The variation is due to urbanization of the floodplains located at downstream end of the stream. The future condition of the stream in terms of obstructions and alignment has been considered to be the same as present condition. Therefore, Figures 3(b) and (d) represents the future condition of the streams too. The stream flow in future condition has been increased due to proposed changes of green cover to impervious cover by 2031.

After adding geometric and steady flow data in the HEC-RAS model, the stream was analyzed for sub-critical flow regime. The Table 4 shows the results of the analysis in terms of water surface elevations for 25-yr return period for existing, present and future condition of the stream.

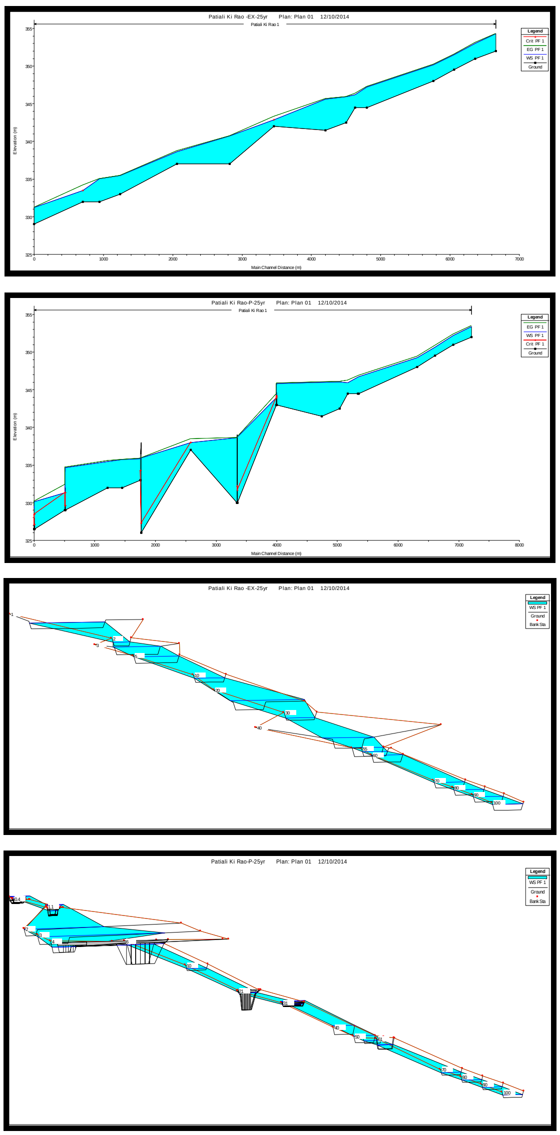

Figure 3: *(a) Course of Patiali Rao from upstream to downstream during Existing condition; (b) Course of Patiali Rao from upstream to downstream during Present/Future Condition; (c) Plan View of Patiali Rao during Existing Condition and (d) Plan View of Patiali Rao during Present/Future Condition.*

Table 4: *Water Surface Elevations of Patiali Rao*

Cross-Section Label	Existing Condition	Present Condition	Future Condition
	25 yr Water Surface Elevation (m)		
100.0	352.0	353.4	353.4
90.0	351.0	352.2	352.2
80.0	349.5	350.7	350.6
70.0	348.0	349.2	349.3
60.0	344.5	346.7	346.8
55.0	344.5	345.9	345.9
50.0	342.5	346.0	346.0
40.0	341.5	346.0	346.0
30.0	342.0	345.8	345.8
20.0	337.0	338.7	338.8
10.0	337.0	338.0	338.0
5.0	333.0	335.9	336.0
3.0	332.0	335.7	335.7
2.0	332.0	335.5	335.4
1.0	329.0	334.6	334.8

The water surface elevations as shown in Table 4 have increased clearly significantly from existing to present condition. The increase in flows in the future condition are visible but not significant difference from present condition which clearly implies that the adjacent floodplains have been almost completely converted to impervious areas in present condition only. The upstream locations of the streams have bridges above the HEC-RAS water surface elevations and the stream flow is contained within the stream but for downstream locations the stream flow is overtopping the access roads, flooding the low-lying floodplains which cause damage to the fields and inconvenience to the residents with threat to their life and property.

4. Conclusions

HECRAS is a powerful, yet easy-to-use software package for determining water surface profiles in a wide variety of streams.

It has been seen from the analysis that the development has increased peak flows draining to the stream. Consequently the HEC-RAS water surface elevations at various x-sections within the stream have increased from existing to present to future condition. The need of future development is the necessity of the time and the adequate stormwater infrastructure is required in coordination with the development. The major findings are that the urbanization had led to flooding from existing to present condition but due to construction of bridges at upstream locations the situation of flooding has been mitigated from existing to present condition. To eliminate flooding at downstream locations, the already existing stormwater management features can be put in effect. The stream needs maintenance in terms of removal of encroachments such as debris, trees etc., erosion control, maintaining lining, rip rap etc and control of water quality of runoff. The development can be allowed outside and above the 100 yr floodplain elevations of the stream. This study can assist in setting floodplain regulations which will protect life, health and property, minimize public expenditures for costly flood control projects, minimize damage to public facilities, discourage the encroachments in floodplains and prevent increases in the regional flood from occurring.

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References

[1] Bowen, A., Pallister, J. (2000). “AS Level Geography”. Heinemann, 296 Pages.

[2] Chandigarh Administration, 2013. *Draft Chandigarh Master Plan-2031*. Prepared by Chandigarh Administration.

[3] Hernandez, T. and Zhang, B. (2007). “Floodplain Analysis Using Computational Tools”. World Environmental and Water Resources Congress 2007: Page Nos. 1-13.

[4] Hudson, P.F., Colditz, R.R., (2003). “Flood delineation in a large and complex alluvial valley, lower Pánuco basin, Mexico”. Journal of Hydrology, Volume 280 Issue: 1-4, Page Nos: 229-245.

[5] Munoz, R.M., (2012) “River Flow 2012”. CRC Press, 1380 Pages.

[6] Suriya, S., Mudgal, B.V., (2012). “Impact of urbanization on flooding: The Thirusoolam sub watershed – A case study”. Journal of Hydrology, Volume 412-413, Page Nos: 210-219.

[7] Ramasastri, K.S., Brar, A.K., Rathore, D.S., (1998). “Flood Studies in Satluj Basin”. National Institute of Hydrology, Roorkee, India.

[8] U.S. Army Corps of Engineers HEC-RAS, Version 4.1.0, Jan 2010.