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# The Estimation of Flood and Its Control by Section Modification in Mithi and Kankara Tributaries at Surat

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## Abstract

**The southern part of Surat city drains its storm drainage through Mithi, Kankara, Khajod, Koyali, Bhedwad, Sonari and Varachcha tributaries(creek) which ultimately drains into Mindhola river. In early past there was hardly any incident of creek flood due to sparse development and enough space for flood plains. But in few decades, due to developmental activities like buildings, roads, bridges etc and slum encroachments along and across the drains resulted in restricted waterway and reduction in flood plains. Mithi and Kankara tributary is more vulnerable to flood due to large catchment and large human settlements on their banks. In this paper, study of hydrology and survey data carried out for hydraulic design of tributaries by modification in the channel section and boundary condition in most vulnerable stretch for flood control. The peak flood is estimated from hydrological and catchment data using rational formula and accordingly tributary cross sections were designed to contain estimated peak flood.**

**Keywords-** Flood, Hydraulic design, Hydrology, Runoff, Tributary

## 1. Introduction

Mindhola is a state river flowing within state boundary of Gujarat and considerable part of its catchment in Surat city area. The Mindhola river system with in Surat city comprises of 7 natural tributaries (creeks) namely Koyali, Mithi, Kankara, Khajod, Bhedwad, Sonari and Varacha. The tributary wise length and catchment area is given in TABLE.

**Table: 1 Tributary Wise Length and Catchment**

| Location | Length from origin (km) | Catchment area from the origin (sq.km.) |
|---|---|---|
| Koyali | 8.35 | 13.45 |
| Mithi | 53.28 | 148.71 |
| Kankara | 61.43 | 172.15 |
| Khajod | 71.58 | 297.92 |
| Bhedwad | 15.00 | 38.00 |
| Sonari | 21.18 | 71.77 |
| Varachha | 24.57 | 85.82 |

**Area**

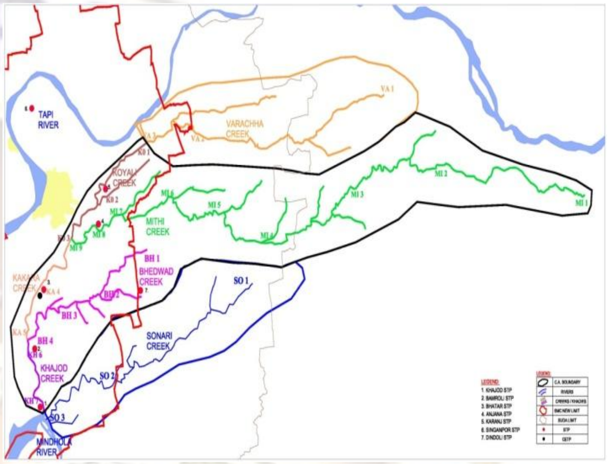


**Figure1: catchment area of Minhola river tributaries**

## 2. Rainfall Data

The monsoon season is generally confined between July to October. The annual rainfall and maximum one-day rainfall for Surat city from 1984 to 2010 are available from the Fire brigade station, Surat Municipal Corporation. It is seen from the available data that the average annual rainfall of the last 27 year is 1362.76mm. The one-day maximum rainfall intensity is 406.56 mm on 27.06.1988. The maximum rainfall is 2459.18mm in year 1988 and minimum rainfall is 666.25mm in year 1987.

## 3. Floods in Tributaries

In the early past, hardly any incident of flood was reported because of no development of surrounding areas. But in last 10 to 15 years developmental activities took place which resulted in construction of roads, buildings and bridges near or across tributaries. Moreover some of the slum also developed near tributaries which resulted in the encroachment in the water body, thus reducing the water way of stream. More over Villages, Colonies, slums also discharge their effluent and refuge directly in the creek, leads to obstruction and blockage to creek flow. This leads to frequent creek flood in the event of heavy rain in the catchment.

Surat witnessed highest creek flood in year 2004 & again in year 2005 which caused heavy damages to slums, residence and industries surrounding the drain. Every year there is a chance of creek flood in the incidence of heavy rain in the catchment area. There is no control on the creek flood as rain water directly flows in the drain in absence of any water retaining structure.

Though Mithi, Kankara and Khajod tributaries are different parts of one river system, the problem is more severe in Mithi and Kankara tributary because of large human settlement and development on its bank. More over Mithi drain has very large catchment area compared to other drains which make it more vulnerable to flood. Whereas, Khajod tributary passes through undeveloped area mostly and there is availability of flood plains which makes it less vulnerable. Owing to this fact, only Mith and Kankara tributaries are covered under present study.

### 3.1 Causes of Flood

The flooding could be attributed to many natural and man-made obstacles to the flow of water through the creeks.

#### 3.1.1 Man Made Obstacles

Some of the prominent man made obstacles causing constriction to flow are listed below.

(a) Reclamation of land along the banks of the creeks
(b) Constructions of bridges / culverts on the creek including roads in embankment

(c) Additions of untreated industrial effluent from the industry
(d) Suspended materials and non-degradable solids in the city Affluent.
(e) Encroachments by Huts and building constructions along the creeks, reducing flow area.

#### 3.1.2 Natural Causes

The natural phenomena affecting the flow in creeks could be

(a) Rainfall pattern and its intensity.
(b) Topography of the Catchments.
(c) Cross sectional Area available for flow.
(d) Bed gradients.
(e) Transfer of flow from Tapi river to Koyali/ Varachha and vice-versa.

## 4. Hydrology of Mithi and Kankara Tributary

Hydrological study is important aspect to plan for the re-sectioning of existing Streams. Hydrology deals with surface water, and its occurrences, circulation, distribution, reactions to environment, are concerned for the study. During the process of planning and the re-sectioning of existing Streams, required inputs will be given by this study. The tributaries are divided into number of reaches to calculate the hydrology and to carry out hydraulic design according to the length and catchment area.

### 4.1Estimation of Storm Water Runoff

Out of the different methods for estimation of runoff, the rational method is more commonly used and the same is being used for Design of Mithi and Kankara Tributary.

$$Q = \frac{CIA}{36}$$

Where, Q = runoff in $m^3$/sec
C = coefficient of runoff
I = intensity of rainfall in cm / hour
A = area of drainage basin in hectares

The storm frequency has been adopted as “Once a Two Year” for the design of storm water drains of Mithi and Kankara Tributary, considering the commercial, Industrial and high priced area

For the design of the Mithi and Kankara Tributary, the intensity of rainfall is considered as 378 mm/hour (i.e. 1.5 inch/hour) as per the record available.

The runoff coefficient is worked out depending upon the imperviousness of the catchment area and time of concentration. From Homer’s table, the runoff coefficient for duration‘t’ equals to 60 minutes are described in TABLE.

| Tributary | Chainage | Land Use | Imperviousness | Runoff Coeff |
|---|---|---|---|---|
| Mithi | 0 to 43280 | Agriculture | Pervious | 0.371 |
| | 43280 to 48280 | Sparsely Developed | 30% Impervious | 0.502 |
| | 48280 to 53280 | Fully Developed | Impervious | 0.808 |
| Koyali | 0 to 8350 | Fully Developed | Impervious | 0.808 |
| Kankara | 53280 to 57280 | Fully Developed | Impervious | 0.808 |
| | 57280 to 61430 | Sparsely Developed | 30% Impervious | 0.502 |

**Table 2: Runoff coefficient**

#### 4.1.1 Estimation of Peak Discharge for Mithi Tributary

The calculation for estimation of peak discharge for Mithi tributary is given in TABLE.

**Table 3: Estimated Discharge at Different Sections**

of Mithi Tributary

| Chainage In meter | Area of catchment in hector | Run-off coefficient | Est.Discharge in $m^3$ / Sec | Design Discharge in $m^3$ / Sec | Cumulative Discharge in $m^3$/sec |
|---|---|---|---|---|---|
| 0 to 13280 | 2790 | 0.371 | 108.68 | 130.42 | **130.42** |
| 13280 to 23280 | 2907 | 0.371 | 113.24 | 135.89 | **266.31** |
| 23280 to 33280 | 3050 | 0.371 | 118.81 | 142.57 | **408.88** |
| 33280 to 38230 | 1608 | 0.371 | 62.64 | 75.17 | **484.05** |
| 38280 to 43280 | 1891 | 0.371 | 73.66 | 88.39 | **572.44** |
| 43280 to 48280 | 1598 | 0.502 | 84.23 | 101.08 | **673.52** |
| 48280 to 51280 | 558 | 0.808 | 47.34 | 56.81 | **730.33** |
| 51280 to 53280 | 469 | 0.808 | 39.79 | 47.75 | **778.08** |

### 4.1.2 Estimation of Peak Discharge For Koyali Tributary

The calculation for estimation of peak discharge for Koyali tributary is given in TABLE.

**Table 4: Estimated Discharge at Different Sections of Koyali Tributary**

| Chainage In meter | Area of catchment in hector | Run-off coefficient | Est. Discharge $m^3$ / Sec | Design Discharge in $m^3$ /Sec | Cumulative Discharge in $m^3$/sec |
|---|---|---|---|---|---|
| 0 to 3000 | 782 | 0.808 | 66.34 | 79.61 | 79.61 |
| 3000 to 8350 | 563 | 0.808 | 47.76 | 57.31 | 136.92 |

### 4.1.3Estimation of Peak Discharge for Kankara Tributary

The Kankara tributary emerges after confluence of Mithi and Koyali tributary. Hence, peak discharge at the starting point of Kankara tributary will be summation of peak discharge of Mithi and Koyali tributary.

**Table 5: Estimated Discharge at Different Sections of Kankara Tributary**

| Chainage In meter | Area of catchment In hector | Run-off coefficient | Est. Discharge In $m^3$ / Sec | Design Discharge In $m^3$ / Sec | Cumulative Discharge In $m^3$/sec |
|---|---|---|---|---|---|
| Sum of cumulative flow of Mithi and Koyali Creek | | | | | **915.00** |
| 53280 to 57280 | 499 | 0.808 | 42.33 | 50.80 | **965.80** |
| 57280 to 61430 | 500 | 0.502 | 30.97 | 37.16 | **1002.96** |

## 5. Hydraulic Design For Tributary Section

### 5.1 Estimating Velocity

The design of channels will be based on a mean velocity determined from the Manning formula as given below.

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

The coefficient 'N' is known as Manning's rugosity coefficient contains the effect of all the retarding factors influences the flow.

The stretch of Mithi and Kankara tributaries under study passes through urban areas having large settlements and development on their banks. The designed section without any lining would be resulted in larger section which would not be feasible. Only feasible option would be to change boundary condition by means of lining. Therefore, for the design of section of Mithi and Kankara tributary cement concrete lining is proposed. In this case,the manning's coefficient 'N' is taken as 0.012.

From length of section and fall in reduced level of bed of the drain the falling gradient of bed is found out. The trapezoidal section is most economical section owing to the fact that with the increase in the discharge available section for the flow will be more. Hence, sections are designed considering trapezoidal section having side slope of 1:1. From available parameters the sections are designed from following equation in TABLE.

**Table 6: Equations Used For Design**

| Parameters | Equations |
|---|---|
| Area of Channel (A) = | $BD + nD^2$ |
| Wetted Perimeter (P)= | $B + 2D \times \sqrt{(n^2+1)}$ |
| Hydraulic Mean Depth (R)= | A/P |
| Constant( K)= | $\sqrt{S}/N$ |
| Velocity of Flow (V)= | $KR^{2/3}$ |
| Discharge (Q)= | AV |

## 5.2 The Profile of Mithi Tributary

For design of sections for Mithi tributary topographical survey has been carried out from chainage 44880 to chainage 53280. From survey data cross sections at the interval of 50m has been prepared. Moreover, longitudinal section of the Mithi tributary for chainage 44880 to chainage 53280 is also prepared. The average RL of the invert level at chainage 44880 is 5.125 m and the same at chainage 53280 is 3.655 m. Hence, for 8400 m length of tributary the total reduction in the RL is 1.47m. The gradient of the Mithi tributary for the portion under consideration has been worked out as 1 in 5715 (0.000175). From topographical survey, the available depth is 5.0m and after deducting free board of 0.3 m, the available depth for flow is 4.70m. Hence, sections are designed for the flow depth of 4.70m.The section is redesign as per the discharge calculated.

### 5.2.1 Design Calculations

For reasonable efficient and economical design of the Mithi Tributary alongwith the consideration of existing topography and physical feature of Mithi Tributary, the design parameters for different sections from chainage 44880 to chainage 53280 is given in TABLE.

**Table 7: Design Parameters for Mithi Tributary**

| | |
|---|---|
| Chainage | 44280 to 53280 |
| Length | 8400m |
| RL at chainage 53280 | 5.125 m |
| RL at chainage 59630 | 3.655 m |
| Fall in RL | 1.470m |
| Gradient | 1 in 5715 (0.000175) |
| Available depth for flow | 5.0 |
| Manning Coefficient (N) | 0.012 |

The hydraulic design calculation of Mithi tributary is given in TABLE

**Table 8: Hydraulic Design Calculations of Mithi Tributary**

| Design Parameters | Ch. 44880 To 46280 | Ch. 46280 To 47280 | Ch. 47280 To 48280 | Ch. 48280 To 49280 | Ch. 49280 To 50280 | Ch. 50280 To 51280 | Ch. 51280 To 52280 | Ch. 52280 To 53280 |
|---|---|---|---|---|---|---|---|---|
| Design Discharge ($m^3/s$) | 527.6 | 544.4 | 561.3 | 577.0 | 592.8 | 608.6 | 628.5 | 648.4 |
| Peak flow ($m^3/s$) | 633.1 | 653.3 | 673.5 | 692.5 | 711.4 | 730.3 | 754.2 | 778.1 |
| Length of section (m) | 1400 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| R.L. of bed at Starting (m) | 5.125 | 4.880 | 4.705 | 4.530 | 4.355 | 4.180 | 4.005 | 3.830 |
| R.L. of bed at Ending (m) | 4.880 | 4.705 | 4.530 | 4.355 | 4.180 | 4.005 | 3.830 | 3.655 |
| Fall in gradient (m) | 0.245 | 0.175 | 0.175 | 0.175 | 0.175 | 0.175 | 0.175 | 0.175 |
| Considering Width (B) | **44.0** | **46.0** | **47.0** | **48.0** | **50.0** | **51.0** | **53.0** | **54.0** |
| Area of Channel (A) ($m^2$) | 228.9 | 238.3 | 243.0 | 247.7 | 257.1 | 264.8 | 271.2 | 275.9 |
| Wetted Perimeter (P ) | 57.29 | 59.29 | 60.29 | 61.29 | 63.29 | 64.29 | 66.29 | 67.29 |
| Hyd. Mean Depth (R) | 3.99 | 4.019 | 4.030 | 4.041 | 4.062 | 4.072 | 4.091 | 4.100 |
| Constant ( K) | 1.102 | 1.102 | 1.102 | 1.102 | 1.102 | 1.102 | 1.102 | 1.102 |
| Velocity of Flow (m/s) | 2.77 | 2.787 | 2.792 | 2.797 | 2.806 | 2.811 | 2.815 | 2.824 |
| Discharge (Q) ($m^3/s$) | 635.3 | 664.0 | 678.4 | 692.7 | 721.5 | 735.9 | 764.7 | 779.1 |
| **Top Width (T) (m)** | **54.0** | **56.0** | **57.0** | **58.0** | **60.0** | **61.0** | **63.0** | **64.0** |

## 5.3 The Profile of Kankara Tributary

For design of sections for Kankara tributary, topographical survey has been carried out from chainage 53280 to Chainage 59630. From survey data cross sections at the interval of 50m has been prepared. Moreover, longitudinal section of the Kankara tributary for Chainage 53280 to Chainage 59630 is also prepared. The average RL of the invert level at chainage 53280 is 3.655 and the same at chainage 59630 is 1.508 m. Hence, for 6350m length of tributary the total reduction in the RL is 2.147m. The gradient of the Kankara tributary for the portion under consideration has been worked out as 1 in 2935 (0.00034).

From topographical survey, it can be derived that on the upstream side of the tributary available depth is more whereas on the downstream side it is less. The available depth is 4.6m at chainage 54280 and after deducting free board of 0.3 m; the available depth for flow is 4.30m. The available depth is continuously reducing on the downstream side and ultimately it is reduced to only 1.508m at chainage 59630. Moreover the difference of RL of the ground level of two banks of tributary is more in Kankara tributary. The width of designed section will be very large in case where available depth for flow is less. But such sections having larger width will not be feasible because of unavailability of land due to large human settlements and developmental activity. In such cases the tributary sections are designed in the filling taking at most care of balancing cutting and filling.

### 5.3.1 Design Calculations

For reasonable efficient and economical design of the Kankara Tributary alongwith the consideration of existing topography and physical feature of Kankara Tributary, the design parameters for different sections from chainage 53280 to chainage 59630 is given in TABLE.

**Table 9: Design Parameters for Kankara Tributary**

| Chainage | 53280 to 59630 |
|---|---|
| Length | 6350m |
| RL at chainage 53280 | 3.655 m |
| RL at chainage 59630 | 1.508 m |
| Fall in RL | 2.147m |
| Gradient | 1 in 2935(0.00034) |
| Available depth for flow | 4.60 m to 3.70m |
| Manning Coefficient (N) | 0.012 |

The hydraulic design calculation of Kankara tributary is given in TABLE

**Table 10: Hydraulic Design Calculations of Kankara Tributary**

| **Design Parameters** | **Ch. 53280 To 54280** | **Ch. 54280 To 55280** | **Ch. 55280 To 56280** | **Ch. 56280 To 57280** | **Ch. 57280 To 58280** | **Ch. 58280 To 59280** | **Ch. 59280 To 59630** |
|---|---|---|---|---|---|---|---|
| Design Discharge ($m^3$/s) | 773.1 | 783.7 | 794.2 | 804.0 | 812.3 | 819.7 | 827.2 |
| Peak flow ($m^3$/s) | 927.7 | 940.4 | 953.1 | 965.8 | 974.7 | 983.7 | 992.6 |
| Total length of the Drain (m) | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 350 |
| R.L. of bed at Starting (m) | 3.655 | 3.317 | 2.979 | 2.641 | 2.303 | 1.965 | 1.627 |
| R.L. of bed at Ending (m) | 3.317 | 2.979 | 2.641 | 2.303 | 1.965 | 1.627 | 1.508 |
| Fall in gradient (m) | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.119 |
| Availabe Depth (D) | **4.30** | **4.00** | **3.70** | **3.40** | **3.40** | **3.40** | **3.40** |
| Considering Width (B) | **54.0** | **62.0** | **71.0** | **83.0** | **83.0** | **84.0** | **85.0** |
| Area of Channel (A) ($m^2$) | 250.7 | 264.0 | 276.4 | 293.8 | 293.7 | 297.2 | 300.6 |
| Wetted Perimeter (P ) (m) | 66.16 | 73.31 | 81.46 | 92.62 | 92.62 | 93.62 | 94.62 |
| Hydraulic Mean Depth (R)(m) | 3.789 | 3.601 | 3.393 | 3.172 | 3.172 | 3.314 | 3.177 |
| Constant ( K) | 1.537 | 1.537 | 1.537 | 1.537 | 1.537 | 1.537 | 1.537 |
| Velocity of Flow (V) (m/s) | 3.734 | 3.610 | 3.469 | 3.317 | 3.317 | 3.319 | 3.320 |
| Discharge (Q) ($m^3$/s) | 936.2 | 953.0 | 958.9 | 974.4 | 974.4 | 986.2 | 998.0 |
| **Top Width (T) (m)** | **63.2** | **70.6** | **79.0** | **90.4** | **90.4** | **91.4** | **92.4** |

## 6. Advantages of Section Modification

The main advantages can be summarized as below.

(i) Restoration of carrying capacity of tributaries, thus easy and prompt disposal of floods and dry weather flow without causing any damage and nuisance.

(ii) Control of unauthorized disposal of untreated sewage by adjoining areas.

(iii) Protection of ground water thus prevention of quality of drinking water resources.

(iv) The surrounding land can be reclaimed which can be used for plantation and service roads.

(v) Protection of tributary banks in sustainable manner.

(vi) More approachable banks for cleaning

## 7. Conclusions

The southern part of Surat city discharges its storm water through tributaries to Mindhola river. Due to absence of any controlling structure, the adjoining areas are vulnerable to the floods every year. The Mithi and Kankara tributaries had witnessed frequent floods due to their large catchment. This paper describes method of flood control by channel section modification in most vulnerable stretch of Mithi and Kankara tributary in Surat city. Due to higher rainfall in this area, the only section modification without any lining would be resulted in large sections which would not be feasible looking at the present development along the banks. Owing to this reason it would be necessary to change boundary condition of tributary by means of cement concrete lining. The designed section with suggested cement concrete lining will effectively pass designed flood due to rainfall in the catchment. Apart from flood control the other advantages would be water pollution control, restoration of carrying capacity, protection of banks, reclamation of land etc. The care should be taken to leave sufficient space for flood plains on the downstream side of study area while preparation of town planning schemes of this surrounding area adjoining tributary.

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