GOVERNMENT OF ORISSA

WORKS DEPARTMENT

ORISSA STATE ROAD PROJECT

FINAL DETAILED ENGINEERING REPORT FOR PHASE-I ROADS

HYDROLOGY REPORT
(BERHAMPUR TO BANGI JUNCTION)
(0.0 TO 41.0)

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INTRODUCTION

HYDROLOGICAL STUDIES RELATED TO ORRISA STATE HIGHWAY NET WORK

1. General:

Hydrological inputs play a very vital role in planning, execution and operation of any water related structure. Hydrological studies are carried out at all the stages of project development starting from the pre-feasibility stage and are continued even during operation of the project. A casual approach may lead in extreme case to loss and destruction of structure due to higher flood than the expected floods; where as over-designed structure may lead to very costly and uneconomical ones Proper selection of design value is of great importance. The Highway net work in a project area crosses a number of rivers/ tributaries / streams / nallahs with small, medium or large catchment and therefore for design of bridges and other structures, hydrological parameters of these structures are essentially required. It is an admitted fact that generally in most of the cases, the river net work does no have sufficient hydrological & meteorological records and most of the structure sites are ungauged. Though for determination of waterway, design flood at desired frequency for such structures are required, but economic constraints do not justify detailed hydrological and meteorological investigations at every such site on large scale and on long term basis for estimation of design flood with a desired return period. The system need to be based on a specific return period for fixing the water-way vis-à-vis the design highest flood level (HFL) and foundation depth of structure depending upon their life and importance to ensure safety as well as economy.

2. Criteria and standards in regard to design flood of structures of small and medium catchments

Khosla Committee of Engineers, appointed by the Government of India, had recommended a design flood of 50-Year return period for fixing the water ways of the structures/bridges. The Committee had also recommended designing the foundation and protection works for larger discharge by increasing the design flood for water ways by 30 % for small catchments and up to 500 Sq. km. by 25 to 20% for medium catchments up to 500 to 5000 Sq.km., by 20 to 10 % for large catchments up to 5000 Sq. km.to 25,000 Sq. km. and by less than 10% for very large catchments above 25,000 Sq. km.IRC 5-1985, clause 103 of Section-I,"General features of design" specifies that the water way of a bridge is to be designed from a maximum flood of 50-Year return period. To provide for adequate margin of safety, the foundation and protection works should be designed for larger discharges. The percentage increase over the design discharge recommended in this code is the same as suggested by the Committee of Engineers.

3. Methods /Models estimation of design flood peak

Depending upon the size of Project catchment, availability of field data and other primary data of Project area and the purpose for which it to be used ,various methods are available for design flood peak estimation such as,

(a) Empirical formulae
(b) Rational formula
(c) Hydro-meteorological model
(d) Statistical methods

3.1 Use of empirical formulae

During the past decade, number of inventers/scientists has evolved many empirical formulae, to be utilized in different zones across the World.I.R.C: SP: 13-2004, though have recommended using empirical formulae like Dicken's, Ryves and Inglis.Wherever hydrological records are inadequate, empirical formulae developed for the region is used. The common type of formula makes the flow function of catchment area i.e.M=C*(M)n. The important formulae used in India are Dicken's, Ryve and Inglis.The exponent 'n' assigned the value of 3/4,2/3 and1/2 respectively in Dicken,Ryve and Inglis formulae. Most popular formula in the region is Dicken's formula and is adopted for catchment area up to 25- 30 sq. Km.

However for small catchment area, the peak flood may be estimated using most popular Dicken's empirical formula can be adopted for catchment area up to 25-30 Sq.Km.

$$Q = C * (M)^{3/4}$$

Where, Q = Peak runoff in cumecs
M = Catchment area in Sq.km.
C= Dicken's constant
= 11-14 where the annual rainfall is 600 mm to 1200 mm
= 14- 19 where the annual rainfall is more than 1200 mm
=22 in Western Ghats

3.2 Rational formulae

The rational formula for assessment of peak discharge from project catchment takes into account rainfall, runoff under various circumstances, time of concentration and critical intensity of rainfall. Basic formulae are as under:

One hour rainfall (I_o), $I_o = (F/T)*(T+1)/(1+1)$

Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$

Discharge $Q=0.028 * P*f* A* I_c$

Time of concentration (SP-13, page 12), $t_c= (0.87*L^3/H)^{0.385}$
Where,
t_c= Time of concentration i.e time taken by runoff from farthest point on the periphery of catchment (hrs)
I_o= One hour rainfall in cm.
I_c= Critical intensity of rainfall in cm per hour

P= Coefficient of runoff for the catchment characteristics
(Ref.Table-4.1, P-13, I.R.C. SP: 13-2004)
A= Catchment area in hectare
Q= Maximum discharge in cumecs.
L= Distance from the critical point to the structure (Length of path) in Km.
H= The difference in level from the critical point to the structure in metre

F= Maximum rain fall in mm
T = Duration of storm in hours
f = A fraction of maximum point intensity at the centre of he storm and related with the catchment area (Determined from Fig.4.2, Page-14, I.R.C.: SP: 13-2004.)

In the present study, storm rainfall and storm duration data of 50 –Year return period have been utilized from design flood hydrograph of near by project sites, developed on the basis of Hydro-meteorological studies as per Flood estimation reports of Mahanadi & Upper eastern coast sub-zones.

3.3 Hydro-meteorological methods-- Use of Unit Hydrograph

3.3.1 General

The regional flood estimation reports under long term plan of 26 Sub-Zones in India are available. The reports pertaining to Orrisa State, of various Corridors which cover under the present consultancy are as under:

(a) Sub-zone-III-d-Mahanadi basin: The sub-zone comprises of Mahanadi, Mahanadi and Baitarani are peninsular rivers, out falling into Bay of Bengal. The basin boundaries are located between
Longitudes 80 0 25 ‘to 87 0 East and Latitudes 19 0 to 23 0 35 ‘North.

(b) Sub-zone- IV-a- Upper Eastern coast: This sub-zone comprises of east flowing coastal rivers between deltas of Mahanadi and Godavari rivers. The Godavari delta falls in the sub-zone. A part the Sub-Zone lies in the Orrisa State approximately in between
Longitudes 84 0 to 85 045‘East and Latitudes 18 0 30’ to 20 0 05 ‘.North

These reports have been formulated as a joint venture by the Ministry of Water resources through Central Water Commission, Research, and Designs & Standards Organization (RDSO) of Ministry of Railways, Ministry of Shipping & Transport (MOST) and India Meteorological Department (IMD) of Government of India.

The approach consists of working out regional Synthetic Unit hydrograph (SUG) parameters with pertinent physiographic characteristics from the recommended formulae in the particular Sub Zone flood estimation report, drawing and adjusting SUG , computation of design storm duration and point rainfall & areal rainfall, distribution of areal rainfall during design storm duration to obtain rainfall increments for unit duration intervals, assessment of effective rainfall units after subtraction of prescribed loss rate from rainfall increments ,estimation of hourly rainfall excess

,estimation of base flow and computation of 50-year peak flood and 50-year design flood hydrograph.

3.3.2 Approach for development of flood hydrograph (on regional basis)

3.3.2.1 Determination of physiographic parameters

Step 1: Preparation of Catchment area plan
The structure site point under study is located on the Survey of India map (G.T. sheet) and catchment/water shed boundary is marked.

Step 2: Determination of physiographic parameters from catchment area plan:
(i) Catchment area: **(A):** The area enclosed in the catchment area boundary up to structure site is referred as the catchment area and measured.

(ii) Length of longest stream (L): Length of the longest main stream in Km. from the farthest point of catchment /water shed boundary to the point of study of structure site is marked and measured on catchment area plan.

(**iii) Length of the longest main stream** (L_c): From a point opposite/near to centre of gravity of catchment to point of study

(iv) Centre of gravity of catchment area: Determination of center of gravity of the catchment.

(v) Stream slope: Equivalent stream slope (S_{eq}): Equivalent slope can be computed by the formula: Longitudinal section is broadly divided into 3 to 4 segments and the following formula is used to calculate the Equivalent slope of main stream.

$$S_{eq} = \frac{\Sigma L_I * [D_I - D_{i-1}]}{L^2}$$

Where, L_i = Length of the ith segment in Km.

D_I, D_{i-1} = Heights of successive bed location at the contour points and intersections (Elevations of the river/nallah bed at ith intersections points of contours are reckoned from the bed elevation at the point of study point/structure site considered as datum)

L = Length of the longest main stream, Km.

3.3.2.2 Determination of Synthetic Unit graph parameters

Step-3: The following SUG relationships are used to compute 1-hour SUG parameters for each structure site of different sub-zones pertaining to Orrisa State.

Recommended relations for determination of Synthetic Unit Hydrograph
(a) Synthetic relation between basin lag tp and physiographic parameters: tp-Time from the centre of unit rainfall duration to the peak of unit hydrograph in hours, tp =a1*[(L*Lc)* (S)1/2]b1

(b)Synthetic relation between unit peak rate (qp) of the unit hydrograph and basin lag (tp): qp- Peak discharge of unit hydrograph per unit area in cmecs./Sq.Km, qp =a2 / (tp) b2

(c) Qp-Peak discharge of unit hydrograph in cumecs. = qp *A

(d) Synthetic relation between unit discharge (qp) and W50- Width of unit graph measured in hours at discharge ordinate equal to 50 % of Qp , W50 =a3 / (qp)b3

(e) Synthetic relation between unit discharge (qp) and W75- Width of unit hydrograph measured in hours at discharge ordinate equal to 75 % of Qp, W75 =a4 / (qp)b4

(f) Synthetic relation between unit discharge (qp) and WR-50- Width of the rising limb side of unit hydrograph measured in hours at discharge ordinate equal to 50% of Qp, WR-50 =a5 / (qp) b5

(g) Synthetic relation between unit discharge (qp) and WR-75-Width of the rising limb side of unit hydrograph measured in hours at discharge ordinate equal to 75 % of Qp , WR-75 = a6 / (qp) b6

(h) Synthetic relation between the basin lag (tp) and base width of unit hydrograph- TB –Base width of unit hydrograph in Hours, TB = a7 *(tp) b7

(i) Tm- Time from start of rise to the peak of the unit hydrograph in hours = tp + tr / 2

(j) TD- Design storm duration in hours = 1.

Values of constants 'a ' and 'b ' for various Synthetic hydrograph parameters are as under

S.No.	**Unit hydrograph Parameter**	**Mahanadi basin-III(d)**	**Upper Eastern Coast-VI(A)**
(1)	(2)	(3)	(4)
1	**t r**	**1**	**1**
2	t_p **– a1**	**1.757**	**0.376**
	-b1	**0.261**	**0.434**
3	q_p **- a_2**	**1.260**	**1.215**
	- b_2	**0.725**	**0.691**
4	W_{50} **-- a_3**	**1.974**	**2.211**

	-- b_3	1.104	1.070
5	W_{75} -- a_4	0.961	1.312
	-- b_4	1.125	1.003
6	W_{R-50}- a_5	1.150	0.808
	- b_5	0.829	1.053
7	W_{R-75}- a_6	0.527	0.542
	- b_6	0.932	0.965
8	T_B . a_7	5.411	7.621
	- b_7	0.826	0.623
9	T_m	t_p + tr/2	t_p + tr/2
10	Qp	A * q_p	A * q_p
11	T_D	1.1*t_P	1.1*t_P

Step-4-The steps for derivation of 1-hour unit graph are as under

(i) Obtain unit graph parameters viz. t_p, q_p, W_{50}, W_{75}, W_{R-50}, W_{R-75} and T_B by substituting appropriate basin/unit graph parameters given in the above equation.

(ii) The above estimated parameters of unit graph are plotted on a natural graph paper and the plotted points are joined to draw synthetic unit graph. Suitable adjustment is made to ensure that volume of unit graph is 1 cm. depth of effective rainfall over the catchment.The discharge ordinates (Qi) of the unit graph at ti=tr =1 hr interval is summed up i.e. $\sum$ Qi * ti (cumecs./hr.) and compared with the volume of 1.0 cm. direct runoff depth over the catchment with the formula . $\sum Qi * t_i = 2.78*A*d / t_i$

Where, A= Catchment area in Sq.Km.
d=1.0 cm. depth
t_i = t_r (the unit duration of the UG) =1.0 hr.
$\sum Q_i * t_i = A *d / 0.36 * t_r = A *1 /0.36 *1$ (cumecs./ hr.)

In case the $\sum$ Qi * ti for the unit graph drawn is higher or lower than the volume worked out by the above formula ,then the falling limb and / or rising limb(preferably falling limb) may be suitably modified to get the correct volume under the hydrograph, taking care not to disturb the smooth shape of the unit graph.

3.3.2.3 Step 5: Design loss rate: The loss rate is an index of all the hydrologic abstractions like infiltration and evapotranspiration etc. Different loss rate and procedures are applicable for different sub-zones:

(a) For Mahanadi sub basin –Sub-zone -III-d: Estimation of loss rate for this sub zone is calculated as per the prescribed design loss rate curve. With t_p less than 5 hours, design loss rate of 0.26 cm. /hour is recommended. Between storm durations of 5 to 13 hours, the loss rates vary between 0.26 cm. / hr to 0.15 cm. / hr.For a storm duration of more than 13 hours, it remains constant at 0.15 cm. /hour.

(b) For Eastern coast region sub-zone-IV-a: Design loss rate of 0.75 cm /hour is recommended for adoption in this sub-zone.

3.3.2.4 Step-6 -Design Base flow: The base flow is separated through the normal procedure to obtain direct run off hydrograph and direct runoff depth over the catchment for each flood event.

(a) For Mahanadi sub basin (III-d): Estimation of design base flow for this sub zone is recommended to calculate at the rate of 0.10 cumecs./ Sq.Km.

(b) For eastern Coast region sub-zone-IV-a: The base flow q_b in cumecs./Sq.Km. is calculated for this sub-zone : $q_b = 0.536 / (A)^{0.523}$

3.3.2.5 Procedure for estimation of design storm rainfall: The areal distribution and time distribution of rainfall of a given duration are two main meteorological factors deciding the design flood peak and the shape of the hydrograph. This input has to be converted into effective rainfall and applied to the transfer function (Synthetic unit hydrograph) to obtain the response (flood hydrograph).

(a) Isopluvial maps:.. The isopluvial maps of 50- Year, 24- hour rainfall are available, which can be used to derive 24-hour rainfall estimates for 50-year return period at any desired location in the sub-zone

Procedure: Locate project site / structure site, with the help of their Latitude and Longitude, under study on 50-Year, 24-hour isopluvial map and obtain the 50-Year, 24-hour point rainfall value in cm. For a catchment covering more than one isopluvial, compute the average point rainfall.

(b) Short duration ratios:.

Procedure- Read the conversion ratio for particular storm duration T_D from the available Table/Figure and multiply the 50-Year .24-hour point rain fall values in Step 8 (a) to obtain 50-Year T_D hour point rainfall.

(c) Areal reduction factor (ARF):

Procedure-Read the areal reduction factor corresponding to storm duration T_D and the given catchment area of Project site in the available Table / Figure and multiply the 50- Year, T_D-hour rainfall in Step-8(b) by this factor to obtain the 50-Year , T_D-hour areal rain fall over the catchment.

(d) Time distribution factor:.

Procedure- Read the time distribution co-efficients for 1,2,-------(T_D-1) hours corresponding to storm duration T_D from the relevant graph/Table and multiply the 50- Year T_D-hour areal rainfall in Step -8(C) by these coefficients to obtain cumulative depths of 1, 2,------(T_D-1) hour catchment rainfall.

(e) Depth of storm rainfall -Obtain the depths of storm rain fall occurring every hour in the structure site catchment by subtracting (d) of the successive depths of 1,2 ,-------(T_D-1) and T_D hours in Step -8(d).

3.3.2.6 Estimation of design flood:

Step-9-Effective rain fall increments:

i. Obtain design storm rain fall and hourly areal rain fall units as per Step-8(e).
ii. Obtain hourly effective rainfall increments by subtracting the design loss rate.

Step-10: Estimation of 50-yr. flood (Peak only):

i. Arrange 1-hour effective areal rainfall values against the 1-hour Unit graph ordinates such that the maximum value of effective rainfall is positioned against the maximum ordinate of Unit graph, the next lower of effective rainfall against the next lower Unit graph ordinate and so on up to TD hour duration.

ii. Obtain the base flow for the catchment area under study.

iii. Obtain total surface runoff by summing the product of unit hydrograph ordinate and the effective rainfall increments give the total direct run-off peak.

(iv)By adding base flow, 50-year flood peak is obtained.

3.3.2.7 Design flood hydrograph:

Step-11: Computation of design flood hydrograph:

For computation of design flood hydrograph, carry out the following additional steps;

iv. Reverse the sequence of effective rainfall units obtained in the above step-10(i) to get the critical sequence of the effective rainfall units.

v. Multiply the first 1-hour effective rainfall with the ordinates of Unit graph to get the corresponding direct run off ordinate. Like wise, repeat the procedure with the rest of the hourly effective rainfall values giving a lag of 1-hour to successive direct runoff ordinate.

vi. Add the direct runoff ordinates at 1-hour interval to get the total direct runoff hydrograph.

vii. Add the base flow to the direct runoff ordinates at 1-hour interval to get 50-Year flood hydrograph.

4.0 Linear Water way of the bridge

4.1 The linear water way/regime width (W) of a bridge across a purely alluvial stream in regime state according to Lacey's formula,

$W = C (Q)^{1/2}$

Where, W= Liner water way in metre
C = A coefficient varying according to local conditions, the usual value adopted being 4.5 to 6.3 (for regime channel). I.R.C.-13 recommends to adopt value of C = 4.8
and Q = Design flood discharge in cumecs.

4.2 Criteria and standard for design flood: Indian Road Congress (I.R.C-5) specifies * That water way for a highway bridge needs to be designed for a maximum peak flood discharge of 50-year return period.

* Foundation and protection works of the structure should be designed for larger discharge by increasing design flood

a) Waterways may be increased by 30% to 25% for small catchments up to 500 sq.km

b) Waterways may be increased by 25% to 20% for medium catchments up to 500 to 5000 sq.km.

c) Waterways may be increased by 20% to 10% for large catchments up to 5000 to 25000 sq.km. and

d) Waterways may be increased by 10% for very large catchments, above 25000 sq.km.

4.3 Scour depth:
As per I.R.C.:78-2000, Clause: 703.1.1
Scour depth in metre,

$$d_{sf} = 1.34 * [(D_b)^2] / (K_{sf})^{1/3}$$

D_b= Unit discharge in cu.mecs/ metre
Q_R= Total discharge in cu.mecs

Design discharge per metre width at effective linear water way over scourable bed
D_b = Increase design discharge (Q_R) /Regime width (W)

4.4 Silt factor: For the regime characteristics of an alluvial channel, Lacey suggested a silt factor and its value depends upon the size and looseness of the grains of the alluvium. The value of silt factor (K_{sf}) is given by the relation,

$K_{sf} = 1.76 (d_m)^{1/2}$
Where**,** d_m is the weighted mean diameter of the particles in mm.

In design calculations value of silt factor based on geotechnical investigation of a particular or near by site by taking value at average depth has been considered.

4.5 Regime velocity of flow: $V = 0.44 * (Q)^{1/6} / (K_{sf})^{1/3}$

4.6 Maximum scour depth: The maximum depth of scour below the highest flood Level (HFL) at obstructions and configurations of the channel should be estimated from the value of 'd_{sf}'on the following basis:

(a) For the design of piers and abutments located in a straight reach and having individual foundations without any floor protection works

(i) In the vicinity of piers = 2.0 * dsf

(ii) Near abutments = 1.27 * dsf

4.7 Vertical clearance and other parameters as per I.R.C. standard

Discharge in cumecs.	Vertical clearance / Free board (metre)
Below 0.30	0.15
0.30 -- 3.00	0.30
3.00 –30.0	0.60
30.0—300.0	0.90
300.0—3,000.0	1.20
Above 3,000.0	1.50

4.8 Manning's formula: For estimation of design flood based on field data, knowing the slope of the stream (S) , Velocity as per Manning's formula is given by the relation,

Velocity of flow in a channel

$$V = 1 / \eta * (R)^{2/3} * (S)^{1/2}$$

Where, V = Mean velocity of flow in m/sec.

R= Hydraulic radius in metre = A/P,

A = Water area i.e. area of flow in Sq.m.

P =Wetted perimeter in metre

S = Slope of the energy line (When flow is uniform, energy slope gradient may become parallel to the water surface slope and bed of the channel)

η = Coefficient of roughness

Discharge, Q = A* V , in cumecs.= $A * 1 / \eta * (R)^{2/3} * (S)^{1/2}$

$= 1 / \eta * W *(R)^{2/3} * (S)^{1/2}$

R =A/P

$Q = A * (A/P)^{2/3} * [1 / \eta * (S)^{1/2}]$

or $Q =1 / \eta * (S)^{1/2}* [(A)^5 /(P)^2]^{1/3}$

Knowing Q, W and S, D can be calculated.

4.9 Afflux: When a bridge is constructed across a contracted stream, water on the upstream will rise up. Afflux is the rise or heading up of water level, above the normal, on the upstream side of a structure caused by an obstruction across the channel (abutments and piers of structure). Since the downstream depth is not affected by the bridge, as the same is governed by the hydraulic characteristics (conveyance factor and slope of the channel below the bridge), of the downstream channel, it can be safely assumed that the upstream depth which prevailed before the bridge construction is the same as the downstream depth (D_d) that prevails after the bridge construction. Hence, D_d is the depth that prevailed at bridge site before the construction of the bridge. To estimate, it is essential to know D_d. This can be calculated by the hydraulic parameters of the channel.

4.9.1 Broad Crested Weir formula:

$Q = 1.706 * C_w * L * H^{3/2}$

Where, Q =Discharge through the opening in cumecs.

C_w = Coefficient of discharge accounting for losses in friction.

L = Linear water way in metre

H = Total energy head upstream of the obstruction in metre = $D_u + V^2 / 2 * g$

D_u = Depth of flow upstream in metre

$V^2 / 2 * g$ = Velocity head, where V is the average velocity in the approach section worked out from the known width (W) of the unobstructed section.

W = Width of unobstructed section

So long as the afflux (D_u-D_d) is not less than 1/4 *D_d , Weir formula is applies ,i.e. Q depends on D_u and independent of D_d. The fact that the downstream depth D_d has no effect on the discharge Q **,** nor on the upstream depth D_u when the afflux is not less than 1/4*D_d is due to the formation of the standing wave.

4.9.2 Orifice formula: When the downstream depth is more than 80 % of the upstream depth i.e. the afflux is less than 1/4D_d , the weir formula is not valid as the performance of the Bridge opening gets affected by the downstream depth(D_u). In such a case, the discharge can be calculated by using the Orifice formula given by the relation,

$Q = C_0 *(2 * g)^{1/2} * L * D_d * [h + (1+e)* V^2 / 2 * g]^{1/2}$

Where, Q = Discharge through the opening in cu.mecs.

C_0= Coefficient of discharge

g = Acceleration due to gravity

L = Linear water way in metre

D_d = Depth downstream of the obstruction in metre

h = Afflux in metre

e = A factor accounting for recovery of some velocity as potential head on emergence from the cross drainage openings, and V = Average velocity in approach section in metre/sec.

The value of 'C_0 'and 'e 'to be adopted are given in I.R.C .The afflux can be calculated knowing (i) Discharge, (ii) the unobstructed width of the stream and (iii) the average depth downstream of the cross drainage work opening.

5.0 Present study: Detailed hydrological studies of bridge structures located on Bhawanipatna-Kheriar, State Highway-16 has been carried out. Physiographic parameters of various structure sites have assessed on the basis of G.T. sheets of the area as available on scale 1: 50,000 & 1: 2, 50,000.Inputs in the study includes the field surveys data, road inventory records, geo-technical investigations and informations gathered during field visit. Presently this corridor has 14 minor bridges at independent locations, one major bridge on river Sunder and one major bridge on river Tel including another five minor bridges at nearby locations on Tel River. Design discharge at each structure site has been estimated through various available approaches. Use of IRC-5-1998, IRC-SP-13-2004, I.R.C-78- 2000 and Regional Hydro meteorological Flood Estimation Reports prepared by Hydrology Organization, Central Water Commission, Government of India for Mahanadi Subzone-3(d) and East Coast region Sub-Zone Report-4(a).The detailed hydrological parameters of various structures are given in the report.

CHAPTER-1

BRIDGE AT CH:1/915

1. Hydraulic calculations for Minor Bridge of road Berhampur-Bangi-Rayagada

1 Name of the Nala : Ambagada Nala

Road No.:	S.H-17
G.T S No :	74A/11
Nearest Village :	Ambagada
RD :	Km.1.915
Latitude	85^0 01' 00'
Longitude	19^0 22' 00"
Sub-Zone	4(a)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q=CM^{3/4}$

C=14-19 where annual rainfall is more than 120 cm

=11-14 where annual rainfall is 60-120 cm

=22 in western Ghats

C adopted (Since Rain fall is more than 120 cm)	19	
M=catchment area	0.430	sqkm
Q=	10.09	cum/s

3 Discharge by Rational Formula Ref.SUG of Ghodahada Nala

Catchment area	0.430 sqkm	43.00	hectares
Length of path from toposheet (L)		0.600	km
Difference in levels from toposheet (H)		15	m
(Ref: Index map)			
Maximum rain fall (F)		208.4	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io=(F/T)*(T+1)/(1+1)	125.04	mm/hr
Time of concentration (I.R.C. SP-13, Page 12)	$tc=(0.87*L^3/H)^{0.385}$	0.19	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		211.00	mm/hr
Discharge Q=0.028 * P*f* A* Ic			
P = (for loam, lightly cultivated or covered)		0.400	
f =		1.00	
A =		43.00	Hectares
Ic =		21.100	cm/hr
Q=		10.162	cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A **=** Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge

(Refer I.R.C.SP-13, page 21)

Discharge by Dicken's Formula	10.09 cum/sec
Discharge by Rational Formula	10.16 cum/sec
Maximum discharge	10.16 cum/sec
Next maximum discharge	10.09 cum/sec
Hence design discharge	**10.16 cum/sec**

5 Linear Water Way

Regime width $W=4.8*Q^{1/2}$ 15.30 m

(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)

Waterway provided 12.00 m

The waterway provided is within $2/3^{rd}$ of the required. As per local enquary, the bridge was not observd to be overtopped. Hence the linear waterway of existing bridge is adequate.

6 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point of deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.60 m

Formation level	58.344 m
Bottom of deck level	57.769 m
HFL	57.169 m
Vertical clearance available	0.60 m

Hence OK

7 Velocity

Linear waterway	12.000	m
Average depth of flow	1.416	m
Cross sectional area of flow	16.992	sqm
Design discharge	10.162	cum/s
Design velocity	0.60	m/s

8 Scour depth

Increase in design discharge, as per IRC:78-2000, cl 703.1.1	30%	
Increased design discharge	13.21	cum/sec

Mean depth of scour, as per IRC:78-2000, cl 703.2

$d_{sf} = 1.34\ (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width	1.10	cum/sec/m
K_{sf} = Silt factor	1.000	
d_{sf} =	1.43	m

Maximum scour depth, as per IRC:78-2000, cl 703.3

for Abutment	1.81	m
for Pier	2.86	m

9 Foundation depth

	for abutment	for pier	
Depth of foundation below max. scour, as per IRC:78-2000, cl 705.2	2.00	2.00	m
Depth of foundation below HFL	3.81	4.86	m
HFL at site	57.169	57.169	m
Max. Scour level	55.355	54.312	m
Desired foundation level	53.355	52.312	m
Bed level at site	55.753	55.753	m

Existing foundation level

The existing foundation level is above the desired foundation level, hence floor protection work shall be provided.

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	10.162	cum/sec
HFL	57.169	m
Design velocity	0.6	m/s
Bed level	55.753	m
Maximum scour level	54.312	m

Desired foundation level (2m below scour level)	52.312	m
Existing foundation level	53.000	m
Depth of foundation below max scour level	1.312	m

The existing foundation level is above the desired foundation level, hence provide floor protection works.

Foundation level of existing curtain wall	52.953	m
Depth of foundation of curtain wall below scour level	1.359	m
Depth of existing curtain wall from bed level	2.8	m

Widening is to be carried out on u/s side

	u/s	**d/s**	
Minimum depth of curtain wall required as per IRC:89-1997	2.0	2.5	m
Provide depth as	3.0	3.0	m
Width of rigid floor	3.0	5.0	m
Width of flexible apron	3.0	6.0	m

CHAPTER-2

BRIDGE AT CH:4/400

2. Hydraulic calculations for Minor Bridge of road Berhampur-Bangi-Rayagada

1	**Name of the Nala :**	Canal
	Road No.:	S.H-17
	Km :	Km 4.400

This bridge is across the irrigation canal. Hence there is no need of hydraulic calculations.

This bridge has been retained.

CHAPTER-3

BRIDGE AT CH:11/270

3. Hydraulic calculations for Minor Bridge of road Berhampur-Bangi-Rayagada

1 General details

Name of the Nala :	Baliparha
Road No.:	S.H. No. 17
G.T S No :	74A/11
Nearest Village :	Baliparha
Location :	Km.11.270
Latitude	$84^0$41'15"
Longitude	$19^0$22'00"
Sub-Zone	4(a)

2 Discharge by Manning's Formula

HFL at proposed bridge site	80.100 m
Cross-section of the stream at different locations are as follows	

Discharge by Manning's Formula at existing location

Cross-sectional area of flow	5.19 sqm
Width of flow	7.00 m
Wetted perimeter perpendicular to direction of flow	7.28 m
Hydraulic mean radius R=A/P	0.71 m
Longitudinal slope as calculated	0.0075 m per m
Velocity by Manning's formula	
$V=1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)	
For slugish type bed (Table 5.1)	
n=	0.06
Velocity V=	1.152 m/s
Discharge Q=A*V	5.98 cum/s

Discharge by Manning's Formula at U/S location

Cross-sectional area of flow	8.39 sqm
Width of flow	7.00 m
Wetted perimeter perpendicular to direction of flow	7.55 m
Hydraulic mean radius R=A/P	1.11 m
Longitudinal slope as calculated	0.0019 m per m
Velocity by Manning's formula	
$V=1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)	
For sluugish type bed (Table 5.1)	
n=	0.06
Velocity V=	0.780 m/s
Discharge Q=A*V	6.55 cum/s

Discharge by Manning's Formula at D/S location

Cross-sectional area of flow	7.73 sqm
Width of flow	7.00 m
Wetted perimeter perpendicular to direction of flow	7.63 m

Hydraulic mean radius R=A/P	1.01	m
Longitudinal slope as calculated	0.0053	m per m
Velocity by Manning's formula		
$V=1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n=	0.08	
Velocity V=	0.918	m/s
Discharge Q=A*V	7.09	cum/s

The hydrological calculations has been done at three sections i.e. at upstream side, downstream side and near proposed bridge location

By comparision of upstream and downstream side and existing bridge location, the design discharge may be taken as 6.55 cum/s

3 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q=CM^{3/4}$

C=14-19 where annual rainfall is more than 120 cm

=11-14 where annual rainfall is 60-120 cm

=22 in western Ghats

C adopted (Since Rain fall is more than 120 cm)	19	
M=catchment area	0.125	sqkm
Q=	3.99	cum/s

5 Discharge by Rational Formula

Catchment area	0.125 sqkm	12.50	hectares
Length of path from toposheet (L)		0.650	km
Difference in levels from toposheet (H)		10	m
(Ref: Index map)			

The severest storm occurred in 50 years adopted for Ghoda Hada River at RD 29.230 km which is in the same region as calculated by synthetic unit hydrograph method. Hence the same rainfall is adopted for this Nallah.

Maximum rain fall (F)		208.4	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io=(F/T)*(T+1)/(1+1)	125.04	mm/hr
Time of concentration (SP-13, page 12)	$tc=(0.87*L^3/H)^{0.385}$	0.24	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		202.09	mm/hr

Discharge Q=0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	12.50	Hectares
Ic =	20.209	cm/hr
Q=	2.829	cum/sec

6 Design Discharge

(Refer SP-13, page 21)

Discharge by Manning's Formula	6.55	cum/sec
Discharge by Dicken's Formula	3.99	cum/sec
Discharge by Rational Formula	2.83	cum/sec
Maximum discharge	6.55	cum/sec
Next maximum discharge	3.99	cum/sec

The difference is beyond 50% of the next maximum discharge

Hence design discharge 5.99 cum/sec

7 Water Way

Regime width		$W=4.8Q^{1/2}$	11.75 m
(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)			
Provide	clear span		10 m
	no. of spans		1 no.
	total waterway provided L		10.00 m

8 Scour depth

Increase in design discharge, as per IRC:78-2000, cl 703.1.1	30%
Increased design discharge	7.79 cum/sec
Mean depth of scour, as per IRC:78-2000, cl 703.2	
$d_{sf} = 1.34\ (D_b^2/K_{sf})^{1/3}$	
Db = Design discharge per metre width	0.78 cum/sec/m
K_{sf} = Silt factor	

Silt factor has been calculated according to data collected from site

	Depth	Silt factor		
	0.75	1.187	0.890	
	1.5	0.901	1.352	
Weighted average	2.25		2.242	0.996

d_{sf} = 1.14 m

Maximum scour depth, as per IRC:78-2000, cl 703.3

for Abutment 1.44 m

9 Foundation depth

	for abutment
Depth of foundation below max. scour, as per IRC:78-2000, cl 705.2	2.00 m
Depth of foundation below HFL	3.44 m
HFL at site	80.100 m
Max. Scour level	78.658 m
Desired foundation level	76.658 m
Bed level at site	78.893 m

Actual foundation level will be decided as per Geo-Technical investigations

10 Afflux

Cross-sectional area of flow (A)		5.19 sqm
Width of flow (W)		11.75 m
Total water way provided (L)		10.00 m
Design discharge (Q)		5.99 cum/sec
Depth of flow at d/s of bridge Dd=A/W		0.442 m
L/W		0.851
(Refer SP-13, page 55-56)	Cofficient e	0.5
	Cofficient Co	0.898
	g	9.81 m/sec/sec

If the afflux h < Dd/4, the Orifice formula is applicable

By Orifice formula, the discharge is given as

$Q=C_0\ (2g)^{0.5}\ L\ D_d\ \{h+(1+e)u^2/2g\}^{0.5}$

or $\{h+(1+e)u^2/2g\}^{0.5} = Q / \{C_0\ (2g)^{0.5}\ L\ D_d\}$

or $\{h+(1+e)u^2/2g\} = [Q / \{C_0\ (2g)^{0.5}\ L\ D_d\}]^2$

Substituting values, we have

$h + 0.076\ u^2 = 0.116$ (i)

Also at u/s of the bridge

$Q=W\ (D_d+h)\ u$ or $h=Q/Wu - D_d$

Substituting values, we have

$h = (0.510\ /\ u) - 0.442$ (ii)

Combining (i) & (ii)

$u - 0.13699\ u^3 = 0.91377$ (iii)

by trial & error	u =	1.092
LHS of the equation (iii) =		0.91377
Substituting u in equation (i), we get		
h=		0.025 m
The afflux as per Orifice formula		0.025 m

h<Dd/4, OK

The afflux adopted 0.025 m

11 Deck level

HFL at proposed bridge site	80.100 m
Afflux	0.025 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure	0.925 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	81.706 m
Deck level of the existing bridge	82.335 m
Minimum deck level proposed	82.335 m

The deck level will also depend on the profile of approaching road alignment.

The existing bridge has 6.5m linear water way which, as per local enquary, was not observed to be overtopped. The bridge is to be reconstructed as per poor structural condition. As per above calculations, it is recommended to provide a waterway of 10.0m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

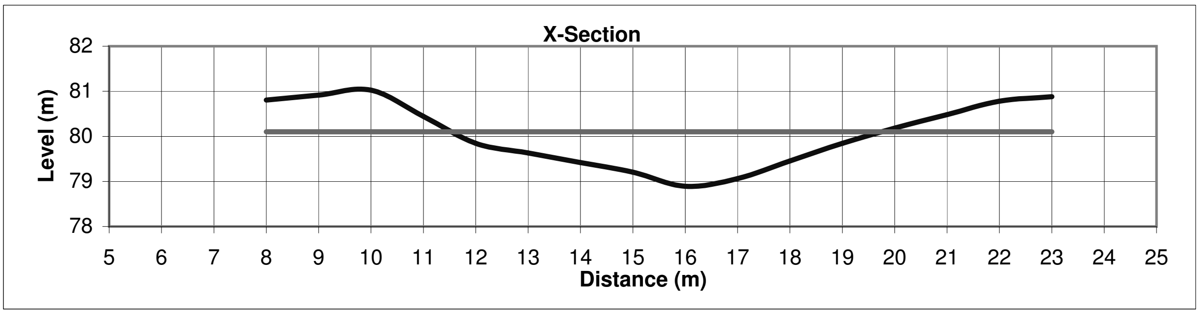
Design discharge	5.99	cum/sec
HFL	80.100	m
Design velocity	1.15	m/s
Bed level	79.717	m
Maximum scour level	78.658	m

Foundation level	76.019	m
Depth of foundation below max scour level	2.639	m

The depth of foundation is more than 2m below maximum scour level, floor protection is not provided.

Cross-sectional area of nallah at proposed bridge site is as follows:

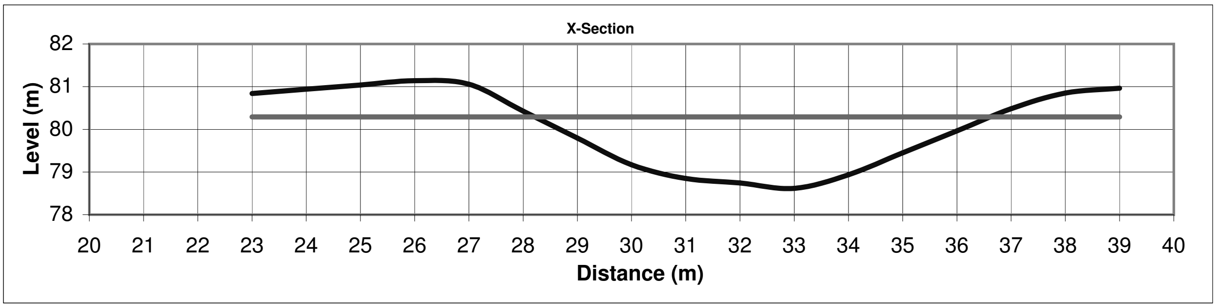
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
8	80.804	80.100					
9	80.915	80.100					
10	81.026	80.100					
11	80.441	80.100					
12	79.845	80.100	0.255				
13	79.631	80.100	0.469	0.362	0.362	1.023	1.000
14	79.418	80.100	0.682	0.575	0.575	1.022	1.000
15	79.204	80.100	0.896	0.789	0.789	1.023	1.000
16	78.893	80.100	1.207	1.052	1.052	1.047	1.000
17	79.064	80.100	1.036	1.122	1.122	1.015	1.000
18	79.454	80.100	0.646	0.841	0.841	1.073	1.000
19	79.844	80.100	0.256	0.451	0.451	1.073	1.000
20	80.183	80.100					
21	80.481	80.100					
22	80.779	80.100					
23	80.880	80.100					
Total					**5.19**	**7.28**	**7.00**



Cross-sectional area of nallah at u/s of the proposed bridge is as follows:

Distance from proposed bridge	100	m
Longitudinal slope u/s side	0.0019	
HFL at this location	80.290	m

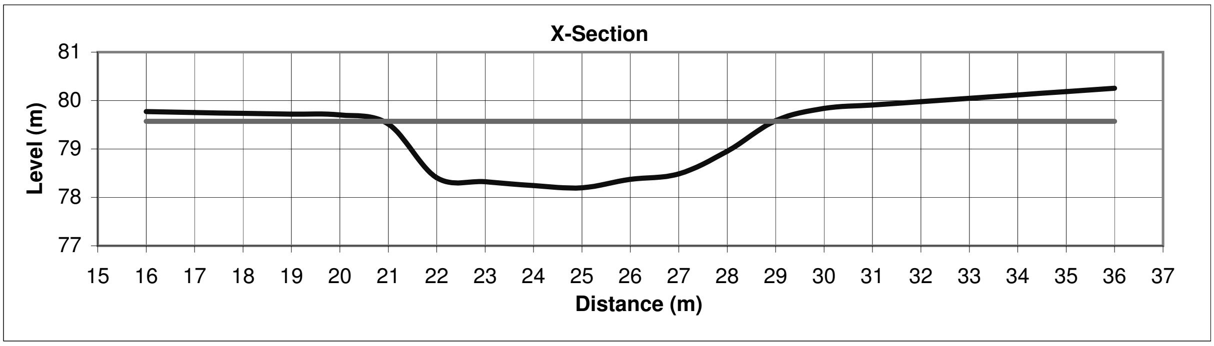
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
23	80.840	80.290					
24	80.940	80.290					
25	81.040	80.290					
26	81.139	80.290					
27	81.058	80.290					
28	80.428	80.290					
29	79.797	80.290	0.493				
30	79.167	80.290	1.123	0.808	0.808	1.182	1.000
31	78.847	80.290	1.443	1.283	1.283	1.050	1.000
32	78.744	80.290	1.546	1.495	1.495	1.005	1.000
33	78.615	80.290	1.675	1.610	1.610	1.008	1.000
34	78.934	80.290	1.356	1.516	1.516	1.050	1.000
35	79.449	80.290	0.841	1.098	1.098	1.125	1.000
36	79.965	80.290	0.325	0.583	0.583	1.125	1.000
37	80.481	80.290					
38	80.851	80.290					
39	80.964	80.290					
Total					**8.39**	**7.55**	**7.00**



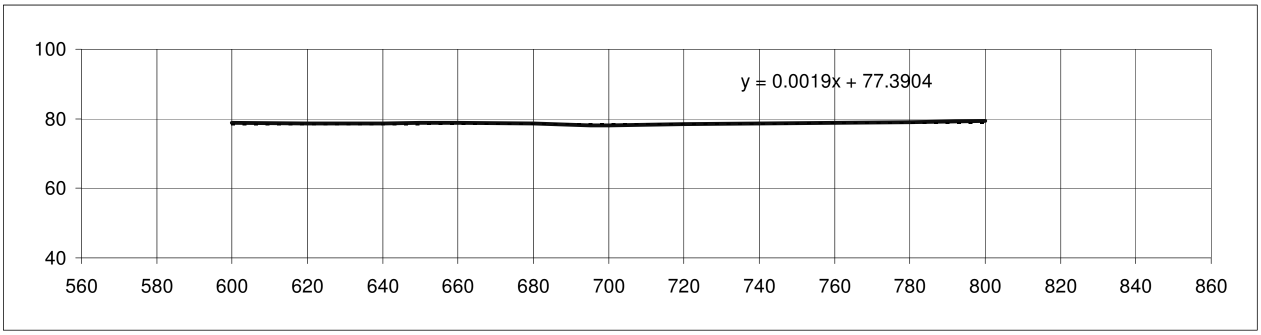
Cross-sectional area of nallah at d/s of proposed bridge is as follows:

Distance from proposed bridge 100 m
Longitudinal slope d/s side 0.0053
HFL at this location 79.570 m

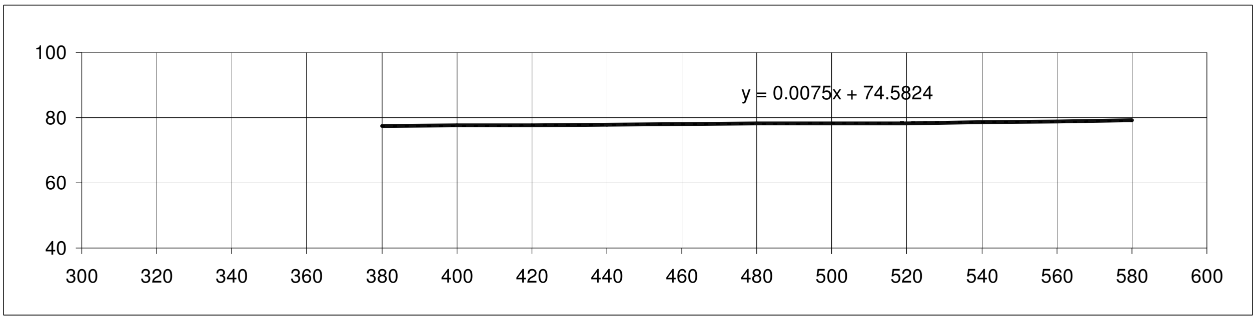
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
16	79.771	79.570					
17	79.754	79.570					
18	79.737	79.570					
19	79.721	79.570					
20	79.704	79.570					
21	79.514	79.570	0.056				
22	78.406	79.570	1.164	0.610	0.610	1.493	1.000
23	78.324	79.570	1.246	1.205	1.205	1.003	1.000
24	78.243	79.570	1.327	1.287	1.287	1.003	1.000
25	78.197	79.570	1.373	1.350	1.350	1.001	1.000
26	78.374	79.570	1.196	1.284	1.284	1.016	1.000
27	78.485	79.570	1.085	1.141	1.141	1.006	1.000
28	78.953	79.570	0.617	0.851	0.851	1.104	1.000
29	79.584	79.570					
30	79.839	79.570					
31	79.908	79.570					
32	79.978	79.570					
33	80.047	79.570					
34	80.116	79.570					
35	80.185	79.570					
36	80.254	79.570					
Total					**7.73**	**7.63**	**7.00**



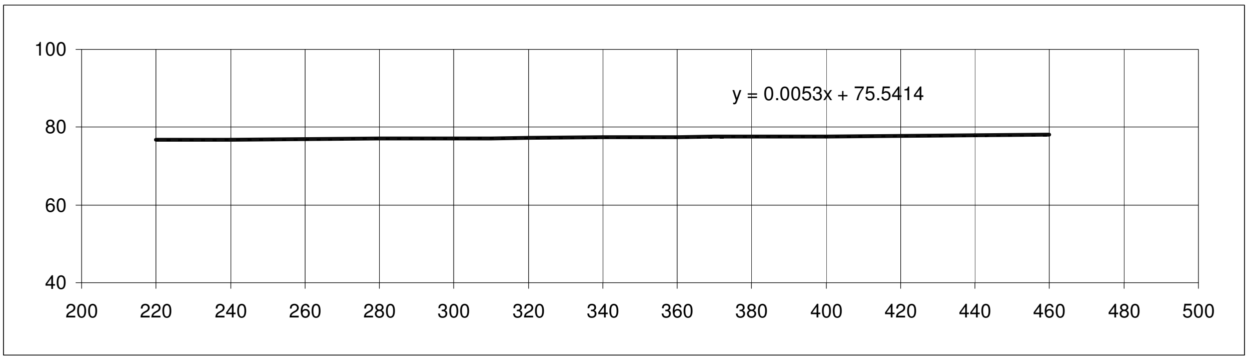
L-Section of Nallah at U/S



L-Section of Nallah at Existing Bridge



L-Section of Nallah at D/S



CHAPTER-4

BRIDGE AT CH:11/600

4. Hydraulic calculations for Minor Bridge of road Berhampur-Bangi-Rayagada

1 General details

Name of the Nala :	Dengapadar
Road No.:	S.H.No 17
G.T S No :	74A/11
Nearest Village :	Dengapadar
RD :	Km.11.660
Latitude	84^0 41' 00"
Longitude	19^0 22' 00"
Sub-Zone	4(a)

2 Discharge by Manning's Formula

HFL at proposed bridge site	81.699	m
Cross-section of the stream at different locations are as follows		

Discharge by Manning's Formula at existing location

Cross-sectional area of flow	57.07	sqm
Width of flow	22.00	m
Wetted perimeter perpendicular to direction of flow	23.71	m
Hydraulic mean radius R=A/P	2.41	m
Longitudinal slope as calculated	0.0076	m per m
Velocity by Manning's formula		
$V=1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n=	0.08	
Velocity V=	1.957	m/s
Discharge Q=A*V	111.70	cum/s

Discharge by Manning's Formula at U/S location

Cross-sectional area of flow	35.78	sqm
Width of flow	17.00	m
Wetted perimeter perpendicular to direction of flow	17.92	m
Hydraulic mean radius R=A/P	2.00	m
Longitudinal slope as calculated	0.0067	m per m
Velocity by Manning's formula		
$V=1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n=	0.08	
Velocity V=	1.623	m/s
Discharge Q=A*V	58.06	cum/s

Discharge by Manning's Formula at D/S location

Cross-sectional area of flow	59.84	sqm
Width of flow	22.00	m
Wetted perimeter perpendicular to direction of flow	23.78	m
Hydraulic mean radius R=A/P	2.52	m
Longitudinal slope as calculated	0.0072	m per m
Velocity by Manning's formula		
$V=1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sluugish type bed (Table 5.1)		
n=	0.08	
Velocity V=	1.962	m/s
Discharge Q=A*V	117.42	cum/s

The hydrological calculations has been done at three sections I.e. at upstream side, downstream side and near proposed bridge location
By comparision of upstream and downstream side and existing bridge location,
The design discharge may be taken as 111.70 cum/s

3 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q=CM^{3/4}$

C=14-19 where annual rainfall is more than 120 cm
=11-14 where annual rainfall is 60-120 cm
=22 in western Ghats

C adopted (Since Rain fall is more than 120 cm)	19	
M=catchment area	0.630	sqkm
Q=	13.44	cum/s

4 Discharge by Rational Formula

Catchment area	0.630	sqkm	63.00	hectares
Length of path from toposheet (L)			1.100	km
Difference in levels from toposheet (H)			20	m

(Ref: Index map)

The severest storm occurred in 50 years adopted for Ghoda Hada River at RD 29.230 km which is in the same region as calculated by synthetic unit hydrograph method. Hence the same rainfall is adopted for this Nallah.

Maximum rain fall (F)		208.4	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io=(F/T)*(T+1)/(1+1)	125.04	mm/hr
Time of concentration (SP-13, page 12)	$tc=(0.87*L^3/H)^{0.385}$	0.33	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		187.48	mm/hr

Discharge Q=0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	63.00	Hectares
Ic =	18.748	cm/hr
Q=	13.229	cum/sec

5 Design Discharge

(Refer SP-13, page 21)

Discharge by Manning's Formula	111.70	cum/sec
Discharge by Dicken's Formula	13.44	cum/sec
Discharge by Rational Formula	13.23	cum/sec
Maximum discharge	111.70	cum/sec
Next maximum discharge	13.44	cum/sec

The difference is beyond 50% of the next maximum discharge

Hence design discharge 20.15 cum/sec

6 Water Way

Regime width $W=4.8Q^{1/2}$ 21.55 m

(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)

Provide	clear span	6	m
	no. of spans	3	no.
	total waterway provided L	18.00	m

The waterway is within 2/3rd of waterway required and the bridge was not observed to be overtopped.
Hence the waterway of existing bridge is adequate.

6 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point of deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.60 m

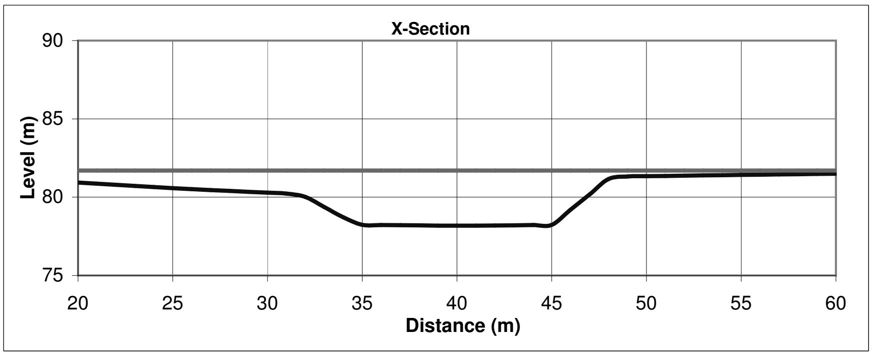
Vertical clearance available 0.605 m

Hence OK

Cross-sectional area of nallah at proposed bridge site is as follows:

HFL at this location 81.699 m

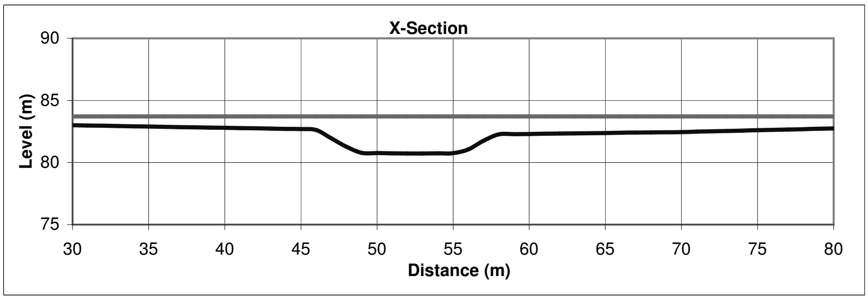
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
20	80.938	81.699	0.761				
21	80.866	81.699	0.833				
22	80.795	81.699	0.904				
23	80.723	81.699	0.976				
24	80.652	81.699	1.047	1.012	1.012	1.003	1.000
25	80.58	81.699	1.119	1.083	1.083	1.003	1.000
26	80.515	81.699	1.184	1.152	1.152	1.002	1.000
27	80.458	81.699	1.241	1.213	1.213	1.002	1.000
28	80.401	81.699	1.298	1.270	1.270	1.002	1.000
29	80.344	81.699	1.355	1.327	1.327	1.002	1.000
30	80.287	81.699	1.412	1.384	1.384	1.002	1.000
31	80.23	81.699	1.469	1.440	1.440	1.002	1.000
32	80.013	81.699	1.686	1.577	1.577	1.023	1.000
33	79.366	81.699	2.333	2.010	2.010	1.191	1.000
34	78.719	81.699	2.980	2.657	2.657	1.191	1.000
35	78.232	81.699	3.467	3.224	3.224	1.112	1.000
36	78.222	81.699	3.477	3.472	3.472	1.000	1.000
37	78.212	81.699	3.487	3.482	3.482	1.000	1.000
38	78.201	81.699	3.498	3.493	3.493	1.000	1.000
39	78.184	81.699	3.515	3.507	3.507	1.000	1.000
40	78.181	81.699	3.518	3.517	3.517	1.000	1.000
41	78.178	81.699	3.521	3.520	3.520	1.000	1.000
42	78.193	81.699	3.506	3.514	3.514	1.000	1.000
43	78.207	81.699	3.492	3.499	3.499	1.000	1.000
44	78.221	81.699	3.478	3.485	3.485	1.000	1.000
45	78.236	81.699	3.463	3.470	3.470	1.000	1.000
46	79.206	81.699	2.493	2.978	2.978	1.393	1.000
47	80.18	81.699	1.519	2.006	2.006	1.396	1.000
48	81.155	81.699	0.544	1.031	1.031	1.397	1.000
49	81.325	81.699	0.374				
50	81.342	81.699	0.357				
51	81.359	81.699	0.340				
52	81.376	81.699	0.323				
53	81.392	81.699	0.307				
54	81.407	81.699	0.292				
55	81.422	81.699	0.277				
56	81.437	81.699	0.262				
57	81.452	81.699	0.247				
58	81.467	81.699	0.232				
59	81.482	81.699	0.217				
60	81.498	81.699	0.201				
Total					**57.07**	**23.71**	**22.00**



Cross-sectional area of nallah at u/s of the proposed bridge is as follows:

Distance from proposed bridge	300	m
Longitudinal slope u/s side	0.0067	
HFL at this location	83.709	m

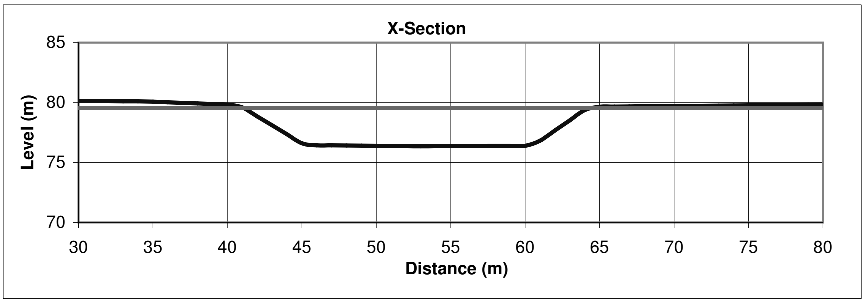
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
30	82.999	83.709					
31	82.978	83.709					
32	82.957	83.709					
33	82.936	83.709					
34	82.915	83.709					
35	82.894	83.709					
36	82.873	83.709					
37	82.852	83.709					
38	82.831	83.709					
39	82.810	83.709					
40	82.790	83.709					
41	82.771	83.709					
42	82.751	83.709					
43	82.732	83.709	0.977	0.489	0.489	1.000	1.000
44	82.712	83.709	0.997	0.987	0.987	1.000	1.000
45	82.693	83.709	1.016	1.007	1.007	1.000	1.000
46	82.622	83.709	1.087	1.052	1.052	1.003	1.000
47	81.947	83.709	1.762	1.425	1.425	1.206	1.000
48	81.271	83.709	2.438	2.100	2.100	1.207	1.000
49	80.778	83.709	2.931	2.685	2.685	1.115	1.000
50	80.758	83.709	2.951	2.941	2.941	1.000	1.000
51	80.739	83.709	2.970	2.961	2.961	1.000	1.000
52	80.723	83.709	2.986	2.978	2.978	1.000	1.000
53	80.729	83.709	2.980	2.983	2.983	1.000	1.000
54	80.742	83.709	2.967	2.974	2.974	1.000	1.000
55	80.754	83.709	2.955	2.961	2.961	1.000	1.000
56	81.057	83.709	2.652	2.804	2.804	1.045	1.000
57	81.749	83.709	1.960	2.306	2.306	1.216	1.000
58	82.267	83.709	1.442	1.701	1.701	1.126	1.000
59	82.283	83.709	1.426	1.434	1.434	1.000	1.000
60	82.298	83.709					
61	82.314	83.709					
62	82.329	83.709					
63	82.345	83.709					
64	82.360	83.709					
65	82.376	83.709					
66	82.391	83.709					
67	82.407	83.709					
68	82.422	83.709					
69	82.438	83.709					
70	82.453	83.709					
71	82.481	83.709					
72	82.510	83.709					
73	82.539	83.709					
74	82.568	83.709					
75	82.597	83.709					
76	82.626	83.709					
77	82.655	83.709					
78	82.684	83.709					
79	82.713	83.709					
80	82.741	83.709					
Total					**35.78**	**17.92**	**17.00**



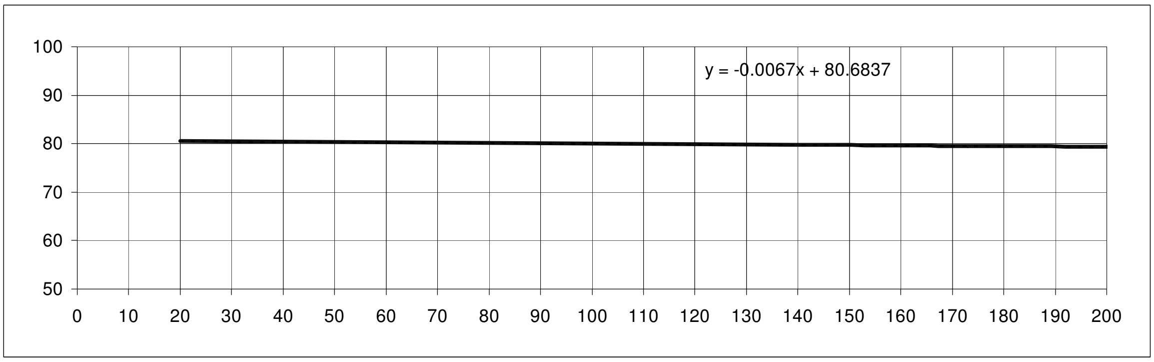
Cross-sectional area of nallah at d/s of proposed bridge is as follows:

Distance from proposed bridge	300	m
Longitudinal slope d/s side	0.0072	
HFL at this location	79.539	m

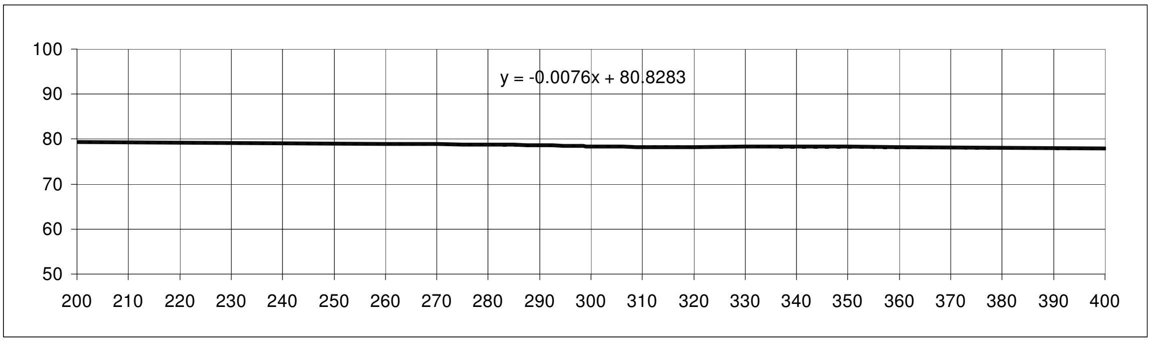
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
30	80.137	79.539					
31	80.127	79.539					
32	80.117	79.539					
33	80.107	79.539					
34	80.097	79.539					
35	80.074	79.539					
36	80.024	79.539					
37	79.975	79.539					
38	79.926	79.539					
39	79.876	79.539					
40	79.827	79.539					
41	79.598	79.539					
42	78.850	79.539	0.689				
43	78.103	79.539	1.436	1.063	1.063	1.248	1.000
44	77.355	79.539	2.184	1.810	1.810	1.249	1.000
45	76.608	79.539	2.931	2.558	2.558	1.248	1.000
46	76.439	79.539	3.100	3.016	3.016	1.014	1.000
47	76.427	79.539	3.112	3.106	3.106	1.000	1.000
48	76.414	79.539	3.125	3.119	3.119	1.000	1.000
49	76.401	79.539	3.138	3.132	3.132	1.000	1.000
50	76.388	79.539	3.151	3.145	3.145	1.000	1.000
51	76.376	79.539	3.163	3.157	3.157	1.000	1.000
52	76.363	79.539	3.176	3.170	3.170	1.000	1.000
53	76.356	79.539	3.183	3.180	3.180	1.000	1.000
54	76.364	79.539	3.175	3.179	3.179	1.000	1.000
55	76.370	79.539	3.169	3.172	3.172	1.000	1.000
56	76.376	79.539	3.163	3.166	3.166	1.000	1.000
57	76.381	79.539	3.158	3.161	3.161	1.000	1.000
58	76.387	79.539	3.152	3.155	3.155	1.000	1.000
59	76.393	79.539	3.146	3.149	3.149	1.000	1.000
60	76.398	79.539	3.141	3.144	3.144	1.000	1.000
61	76.825	79.539	2.714	2.928	2.928	1.087	1.000
62	77.672	79.539	1.867	2.291	2.291	1.310	1.000
63	78.518	79.539	1.021	1.444	1.444	1.310	1.000
64	79.365	79.539	0.174	0.598	0.598	1.310	1.000
65	79.650	79.539					
66	79.662	79.539					
67	79.673	79.539					
68	79.685	79.539					
69	79.697	79.539					
70	79.709	79.539					
71	79.720	79.539					
72	79.733	79.539					
73	79.746	79.539					
74	79.759	79.539					
75	79.772	79.539					
76	79.785	79.539					
77	79.798	79.539					
78	79.811	79.539					
79	79.824	79.539					
80	79.837	79.539					
Total					**59.84**	**23.78**	**22.00**



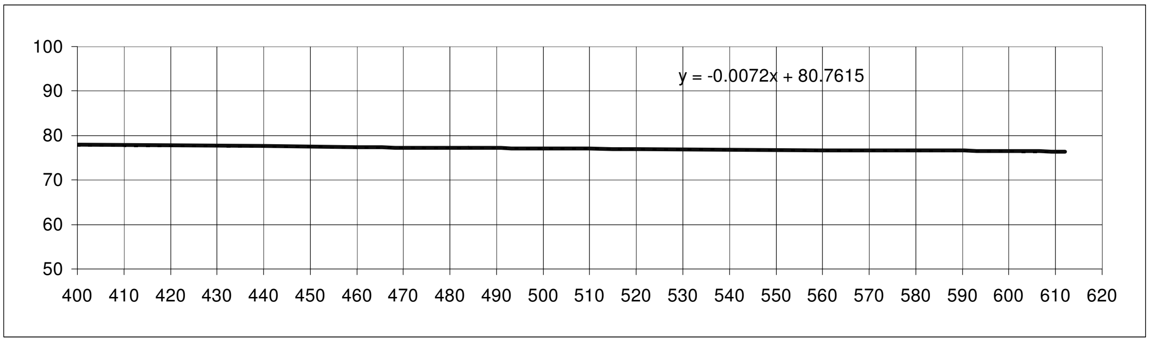
L-Section of Nallah at U/S



L-Section of Nallah at Existing Bridge



L-Section of Nallah at D/S



CHAPTER-5

BRIDGE AT CH:15/185

5. Hydraulic calculations for Minor Bridge of road Berhampur-Bangi-Rayagada

1 General details

Name of the Nala :	Khari Nala
Road No.:	S.H.No-17
G.T S No :	74A/11
Nearest Village :	Pitambarpur
RD :	Km.15.185
Latitude	84^0 39' 30"
Longitude	19^0 22' 00"
Sub-Zone	4(a)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q=CM^{3/4}$

C=14-19 where annual rainfall is more than 120 cm

=11-14 where annual rainfall is 60-120 cm

=22 in western Ghats

C adopted (Since Rain fall is more than 120 cm)	19	
M=catchment area	1.020	sqkm
Q=	19.28	cum/s

3 Discharge by Rational Formula

Catchment area	1.020 sqkm	102.00	hectares
Length of path from toposheet (L)		0.350	km
Difference in levels from toposheet (H)		10	m
(Ref: Index map)			

The severest storm occurred in 50 years adopted for Ghoda Hada River at RD 29.230 km which is in the same region as calculated by synthetic unit hydrograph method. Hence the same rainfall is adopted for this Nallah.

Maximum rain fall (F)		208.4	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io=(F/T)*(T+1)/(1+1)	125.04	mm/hr
Time of concentration (SP-13, page 12)	$tc=(0.87*L^3/H)^{0.385}$	0.12	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		224.05	mm/hr

Discharge Q=0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	102.00	Hectares
Ic =	22.405	cm/hr
Q=	25.596	cum/sec

4 Design Discharge

(Refer SP-13, page 21)

Discharge by Dicken's Formula	19.28	cum/sec
Discharge by Rational Formula	25.60	cum/sec
Maximum discharge	25.60	cum/sec
Next maximum discharge	19.28	cum/sec

The difference is within 50% of the next maximum discharge

Hence design discharge	25.60	cum/sec

5 Water Way

Regime width		$W=4.8Q^{1/2}$	24.28 m
(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)			
Provided	clear span		6 m
	no. of spans		2 no.
	total waterway provided L		12.00 m

The waterway available for existing bridge is about half of the waterway required for regime channel. The waterway available is less than the required, but as per local enquary, the bridge was not observd to be overtopped. Hence the linear waterway of existing bridge is adequate.

6 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point of deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16)		0.60 m
Formation level		90.350
Bottom of deck level		89.675
HFL		89.075
Vertical clearance available		0.60 m
	Hence OK	

CHAPTER-6

BRIDGE AT CH:15/680

6. Hydraulic calculations for Minor Bridge of road Berhampur-Bangi-Rayagada

1 Name of the Nala : Gania Nala

Road No.:	S.H.No 17
G.T S No :	74A/11
Nearest Village :	Gopalpur/Narayanpur
RD :	Km.15.680
Latitude	84^0 39' 00"
Longitude	19^0 22' 00"
Sub-Zone	4(a)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (Refer I.R.C. SP-13, page 7)

$Q=CM^{3/4}$

C=14-19 where annual rainfall is more than 120 cm

=11-14 where annual rainfall is 60-120 cm

=22 in western Ghats

C adopted	(Since Rain fall is more than 120 cm)	19	
M=catchment area		17.000	sqkm
Q=		159.07	cum/s

3 Discharge by Rational Formula Ref.SUG of Ghodahada River

Catchment area	17.000 sqkm	1700.00	hectares
Length of path from toposheet (L)		21.000	km
Difference in levels from toposheet (H)		20	m
(Ref: Index map)			
Maximum rain fall (F)		208.4	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io=(F/T)*(T+1)/(1+1)	125.04	mm/hr
Time of concentration (I.R.C.SP-13, Page 12)	$tc=(0.87*L^3/H)^{0.385}$	10.07	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		22.59	mm/hr
Discharge Q=0.028 * P*f* A* Ic			
P = (for loam, lightly cultivated or covered)		0.400	
f =		1.00	
A =		1700.00	Hectares
Ic =		2.259	cm/hr
Q=		43.017	cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge

(Refer I.R.C. SP-13, page 21)

Discharge by Dicken's Formula	159.07 cum/sec
Discharge by Rational Formula	43.02 cum/sec
Maximum discharge	159.07 cum/sec
Next maximum discharge	43.02 cum/sec
The difference is beyond 50% of the next maximum discharge	
Hence design discharge	**64.53 cum/sec**

5 Linear Water Way

Regime width		$W=4.8Q^{1/2}$	38.56 m
(Refer IRC:5-1998, Clause 104.3 or SP-13, page 23)			
Provided	clear span		6 m
	no. of spans		4 no.
	total waterway provided L		24.00 m

The waterway available for existing bridge is about 2/3rd of the waterway required for regime channel. As per local enquary, the bridge was not observd to be overtopped. Hence the linear waterway of existing bridge is adequate.

6 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point of deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.90 m

Formation level	92.049 m
Bottom of deck level	91.374 m
HFL	90.774 m
Vertical clearance available	0.60 m

Although the vertical clearance is less than the required, but looking to the hydraulic performance of the existing bridge, it is recommended to retain the existing bridge. Raising is not suggested.

CHAPTER-7

BRIDGE AT CH:17/900

7. Hydraulic calculations for Minor Bridge of road Berhampur-Bangi-Rayagada

1 General details

Name of the Nala :	Sagar Nadi
Road No.:	S.H.NO-17
G.T S No :	74A/11
Nearest Village :	Pitambarpur/Bajipalli
RD :	Km.17.900
Latitude	84^0 37' 00"
Longitude	19^0 22' 00"
Sub-Zone	4(a)

2 Discharge by Manning's Formula

HFL at proposed bridge site 82.736 m

Cross-section of the stream at different locations are as follows

Discharge by Manning's Formula at existing location

Cross-sectional area of flow	82.89	sqm
Width of flow	37.00	m
Wetted perimeter perpendicular to direction of flow	37.47	m
Hydraulic mean radius R=A/P	2.21	m
Longitudinal slope as calculated	0.0017	m per m
Velocity by Manning's formula		
$V=1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sreams with some pools & shoals (Table 5.1)		
n=	0.05	
Velocity V=	1.400	m/s
Discharge Q=A*V	116.05	cum/s

Discharge by Manning's Formula at U/S location

Cross-sectional area of flow	51.24	sqm
Width of flow	31.00	m
Wetted perimeter perpendicular to direction of flow	32.05	m
Hydraulic mean radius R=A/P	1.60	m
Longitudinal slope as calculated	0.0048	m per m
Velocity by Manning's formula		
$V=1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sreams with some pools & shoals (Table 5.1)		
n=	0.05	
Velocity V=	1.895	m/s
Discharge Q=A*V	97.07	cum/s

Discharge by Manning's Formula at D/S location

Cross-sectional area of flow	53.10	sqm
Width of flow	34.00	m
Wetted perimeter perpendicular to direction of flow	34.84	m
Hydraulic mean radius R=A/P	1.52	m
Longitudinal slope as calculated	0.0033	m per m
Velocity by Manning's formula		
$V=1/n\ R^{2/3}\ S^{1/2}$ (refer SP-13, page 17)		
For sreams with some pools & shoals (Table 5.1)		
n=	0.05	
Velocity V=	1.522	m/s
Discharge Q=A*V	80.80	cum/s

The hydrological calculations has been done at three sections I.e. at upstream side, downstream side and near proposed bridge location

By comparision of upstream and downstream side and Existing bridge location.

Hence the design discharge may be taken as 116.05 cum/s

3 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q=CM^{3/4}$

C=14-19 where annual rainfall is more than 120 cm
=11-14 where annual rainfall is 60-120 cm
=22 in western Ghats

C adopted (Since Rain fall is more than 120 cm)	19	
M=catchment area	10.000	sqkm
Q=	106.84	cum/s

4 Discharge by Rational Formula

Catchment area	10.000	sqkm	1000.00	hectares
Length of path from toposheet (L)			6.250	km
Difference in levels from toposheet (H)			300	m

(Ref: Index map)

The severest storm occurred in 50 years adopted for Ghoda Hada River at RD 29.230 km which is in the same region as calculated by synthetic unit hydrograph method. Hence the same rainfall is adopted for this Nallah.

Maximum rain fall (F)		208.4	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io=(F/T)*(T+1)/(1+1)	125.04	mm/hr
Time of concentration (SP-13, page 12)	$tc=(0.87*L^3/H)^{0.385}$	0.88	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		133.34	mm/hr

Discharge Q=0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	1000.00	Hectares
Ic =	13.334	cm/hr
Q=	149.340	cum/sec

5 Design Discharge

(Refer SP-13, page 21)

Discharge by Manning's Formula	116.05	cum/sec
Discharge by Dicken's Formula	106.84	cum/sec
Discharge by Rational Formula	149.34	cum/sec
Maximum discharge	149.34	cum/sec
Next maximum discharge	106.84	cum/sec
The difference is within 50% of the next maximum discharge		
Hence design discharge	149.34	cum/sec

6 Water Way

Regime width	$W=4.8Q^{1/2}$	58.66	m
(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)			
Provided clear span		6	m
no. of spans		4	no.
total waterway provided L		24.00	m

The waterway available for existing bridge is less than half of the waterway required for regime channel and needs more waterway. But as per local enquary, the bridge was not observd to be overtopped. Looking to the performance of existing bridge, the linear waterway seems to adequate.

7 Vertical Clearance

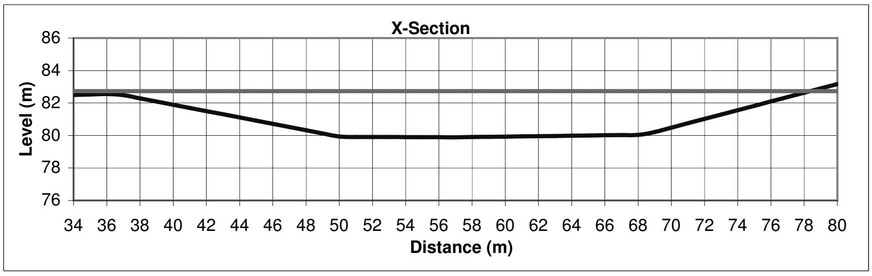
Vertical clearance for opening of high level bridge, from the lowest point of deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16)	0.90	m
Formation level	84.011	m
Bottom of deck level	83.336	m
HFL	82.736	m
Vertical clearance available	0.60	m

Although the vertical clearance is less than the required, but looking to the hydraulic performance of the existing bridge, it is recommended to retain the existing bridge. Raising is not suggested.

Cross-sectional area of nallah at proposed bridge site is as follows:

HFL at this location 82.736 m

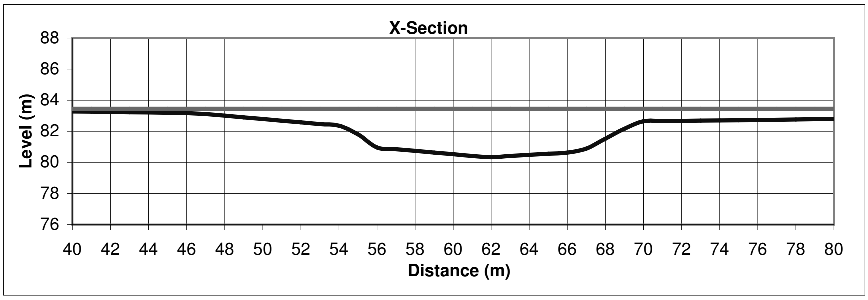
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
30	82.375	82.736					
31	82.408	82.736					
32	82.44	82.736					
33	82.469	82.736					
34	82.497	82.736					
35	82.525	82.736					
36	82.553	82.736					
37	82.482	82.736					
38	82.287	82.736					
39	82.091	82.736	0.645				
40	81.895	82.736	0.841	0.743	0.743	1.019	1.000
41	81.699	82.736	1.037	0.939	0.939	1.019	1.000
42	81.503	82.736	1.233	1.135	1.135	1.019	1.000
43	81.307	82.736	1.429	1.331	1.331	1.019	1.000
44	81.111	82.736	1.625	1.527	1.527	1.019	1.000
45	80.915	82.736	1.821	1.723	1.723	1.019	1.000
46	80.719	82.736	2.017	1.919	1.919	1.019	1.000
47	80.523	82.736	2.213	2.115	2.115	1.019	1.000
48	80.327	82.736	2.409	2.311	2.311	1.019	1.000
49	80.131	82.736	2.605	2.507	2.507	1.019	1.000
50	79.935	82.736	2.801	2.703	2.703	1.019	1.000
51	79.912	82.736	2.824	2.813	2.813	1.000	1.000
52	79.909	82.736	2.827	2.826	2.826	1.000	1.000
53	79.906	82.736	2.830	2.829	2.829	1.000	1.000
54	79.903	82.736	2.833	2.832	2.832	1.000	1.000
55	79.9	82.736	2.836	2.835	2.835	1.000	1.000
56	79.897	82.736	2.839	2.838	2.838	1.000	1.000
57	79.894	82.736	2.842	2.841	2.841	1.000	1.000
58	79.906	82.736	2.830	2.836	2.836	1.000	1.000
59	79.919	82.736	2.817	2.824	2.824	1.000	1.000
60	79.933	82.736	2.803	2.810	2.810	1.000	1.000
61	79.946	82.736	2.790	2.797	2.797	1.000	1.000
62	79.959	82.736	2.777	2.784	2.784	1.000	1.000
63	79.973	82.736	2.763	2.770	2.770	1.000	1.000
64	79.986	82.736	2.750	2.757	2.757	1.000	1.000
65	79.999	82.736	2.737	2.744	2.744	1.000	1.000
66	80.013	82.736	2.723	2.730	2.730	1.000	1.000
67	80.026	82.736	2.710	2.717	2.717	1.000	1.000
68	80.039	82.736	2.697	2.704	2.704	1.000	1.000
69	80.218	82.736	2.518	2.608	2.608	1.016	1.000
70	80.486	82.736	2.250	2.384	2.384	1.035	1.000
71	80.755	82.736	1.981	2.116	2.116	1.036	1.000
72	81.023	82.736	1.713	1.847	1.847	1.035	1.000
73	81.291	82.736	1.445	1.579	1.579	1.035	1.000
74	81.559	82.736	1.177	1.311	1.311	1.035	1.000
75	81.828	82.736	0.908	1.043	1.043	1.036	1.000
76	82.096	82.736	0.640	0.774	0.774	1.035	1.000
77	82.364	82.736					
78	82.632	82.736					
79	82.901	82.736					
80	83.169	82.736					
Total					**82.89**	**37.47**	**37.00**



Cross-sectional area of nallah at u/s of the proposed bridge is as follows:

Distance from proposed bridge 150 m
Longitudinal slope u/s side 0.0048
HFL at this location 83.456 m

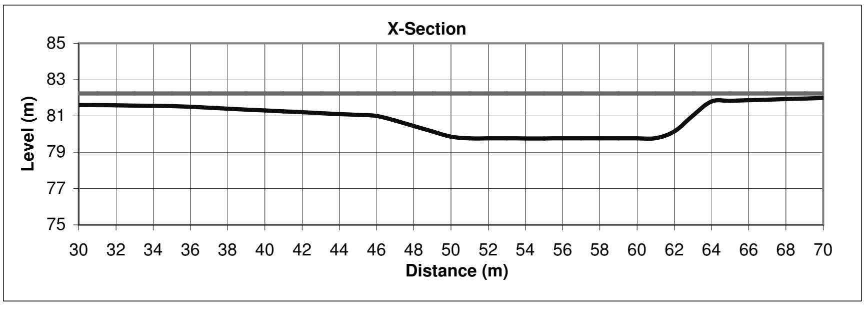
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
40	83.28	83.456					
41	83.263	83.456					
42	83.246	83.456					
43	83.229	83.456					
44	83.212	83.456					
45	83.194	83.456					
46	83.177	83.456					
47	83.112	83.456					
48	83.004	83.456	0.452				
49	82.896	83.456	0.560	0.506	0.506	1.006	1.000
50	82.789	83.456	0.667	0.614	0.614	1.006	1.000
51	82.681	83.456	0.775	0.721	0.721	1.006	1.000
52	82.573	83.456	0.883	0.829	0.829	1.006	1.000
53	82.465	83.456	0.991	0.937	0.937	1.006	1.000
54	82.357	83.456	1.099	1.045	1.045	1.006	1.000
55	81.806	83.456	1.650	1.375	1.375	1.142	1.000
56	80.957	83.456	2.499	2.075	2.075	1.312	1.000
57	80.849	83.456	2.607	2.553	2.553	1.006	1.000
58	80.741	83.456	2.715	2.661	2.661	1.006	1.000
59	80.633	83.456	2.823	2.769	2.769	1.006	1.000
60	80.525	83.456	2.931	2.877	2.877	1.006	1.000
61	80.417	83.456	3.039	2.985	2.985	1.006	1.000
62	80.332	83.456	3.124	3.082	3.082	1.004	1.000
63	80.419	83.456	3.037	3.081	3.081	1.004	1.000
64	80.491	83.456	2.965	3.001	3.001	1.003	1.000
65	80.563	83.456	2.893	2.929	2.929	1.003	1.000
66	80.635	83.456	2.821	2.857	2.857	1.003	1.000
67	80.888	83.456	2.568	2.695	2.695	1.032	1.000
68	81.524	83.456	1.932	2.250	2.250	1.185	1.000
69	82.16	83.456	1.296	1.614	1.614	1.185	1.000
70	82.647	83.456	0.809	1.053	1.053	1.112	1.000
71	82.66	83.456	0.796	0.803	0.803	1.000	1.000
72	82.673	83.456	0.783	0.790	0.790	1.000	1.000
73	82.686	83.456	0.770	0.776	0.776	1.000	1.000
74	82.699	83.456	0.757	0.764	0.764	1.000	1.000
75	82.712	83.456	0.744	0.751	0.751	1.000	1.000
76	82.725	83.456	0.731	0.738	0.738	1.000	1.000
77	82.742	83.456	0.714	0.723	0.723	1.000	1.000
78	82.761	83.456	0.695	0.705	0.705	1.000	1.000
79	82.781	83.456	0.675	0.685	0.685	1.000	1.000
80	82.801	83.456	0.655				
Total					**51.24**	**32.05**	**31.00**



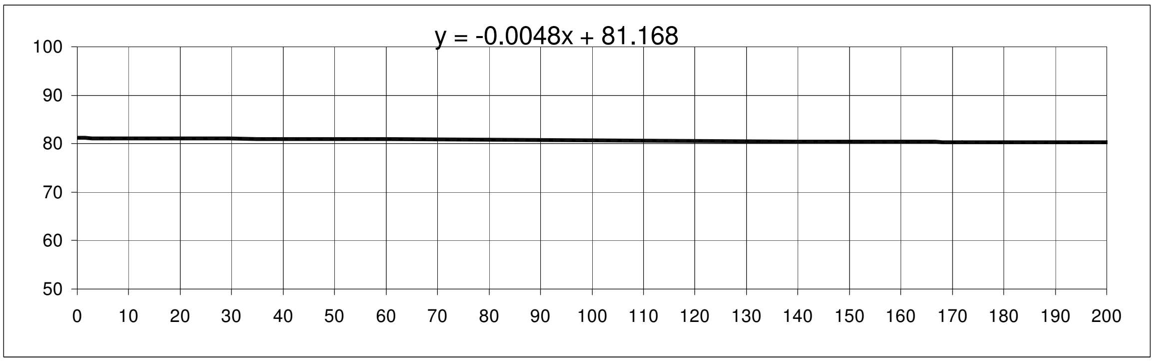
Cross-sectional area of nallah at d/s of proposed bridge is as follows:

Distance from proposed bridge 150 m
Longitudinal slope d/s side 0.0033
HFL at this location 82.241 m

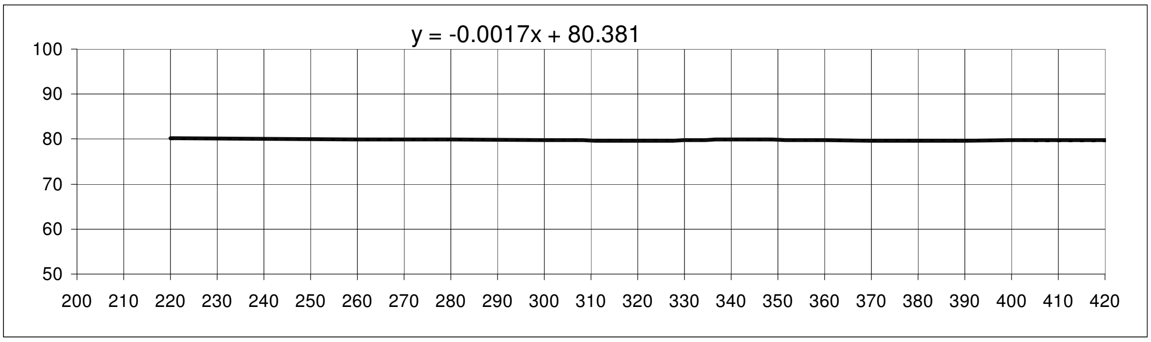
Distance (m)	Level (m)	HFL (m)	Depth (m)	Av depth (m)	Area (sqm)	Perimeter (m)	Top width of flow (m)
30	81.605	82.241	0.636				
31	81.593	82.241	0.648	0.642	0.642	1.000	1.000
32	81.581	82.241	0.660	0.654	0.654	1.000	1.000
33	81.568	82.241	0.673	0.666	0.666	1.000	1.000
34	81.556	82.241	0.685	0.679	0.679	1.000	1.000
35	81.544	82.241	0.697	0.691	0.691	1.000	1.000
36	81.501	82.241	0.740	0.718	0.718	1.001	1.000
37	81.45	82.241	0.791	0.765	0.765	1.001	1.000
38	81.4	82.241	0.841	0.816	0.816	1.001	1.000
39	81.349	82.241	0.892	0.866	0.866	1.001	1.000
40	81.299	82.241	0.942	0.917	0.917	1.001	1.000
41	81.25	82.241	0.991	0.966	0.966	1.001	1.000
42	81.201	82.241	1.040	1.016	1.016	1.001	1.000
43	81.152	82.241	1.089	1.065	1.065	1.001	1.000
44	81.103	82.241	1.138	1.114	1.114	1.001	1.000
45	81.054	82.241	1.187	1.163	1.163	1.001	1.000
46	81.006	82.241	1.235	1.211	1.211	1.001	1.000
47	80.75	82.241	1.491	1.363	1.363	1.032	1.000
48	80.45	82.241	1.791	1.641	1.641	1.044	1.000
49	80.15	82.241	2.091	1.941	1.941	1.044	1.000
50	79.85	82.241	2.391	2.241	2.241	1.044	1.000
51	79.766	82.241	2.475	2.433	2.433	1.004	1.000
52	79.764	82.241	2.477	2.476	2.476	1.000	1.000
53	79.762	82.241	2.479	2.478	2.478	1.000	1.000
54	79.76	82.241	2.481	2.480	2.480	1.000	1.000
55	79.76	82.241	2.481	2.481	2.481	1.000	1.000
56	79.762	82.241	2.479	2.480	2.480	1.000	1.000
57	79.764	82.241	2.477	2.478	2.478	1.000	1.000
58	79.766	82.241	2.475	2.476	2.476	1.000	1.000
59	79.768	82.241	2.473	2.474	2.474	1.000	1.000
60	79.77	82.241	2.471	2.472	2.472	1.000	1.000
61	79.772	82.241	2.469	2.470	2.470	1.000	1.000
62	80.147	82.241	2.094	2.281	2.281	1.068	1.000
63	81.02	82.241	1.221	1.658	1.658	1.327	1.000
64	81.798	82.241	0.443	0.832	0.832	1.267	1.000
65	81.83	82.241					
66	81.863	82.241					
67	81.895	82.241					
68	81.927	82.241					
69	81.959	82.241					
70	81.991	82.241					
Total					**53.10**	**34.84**	**34.00**



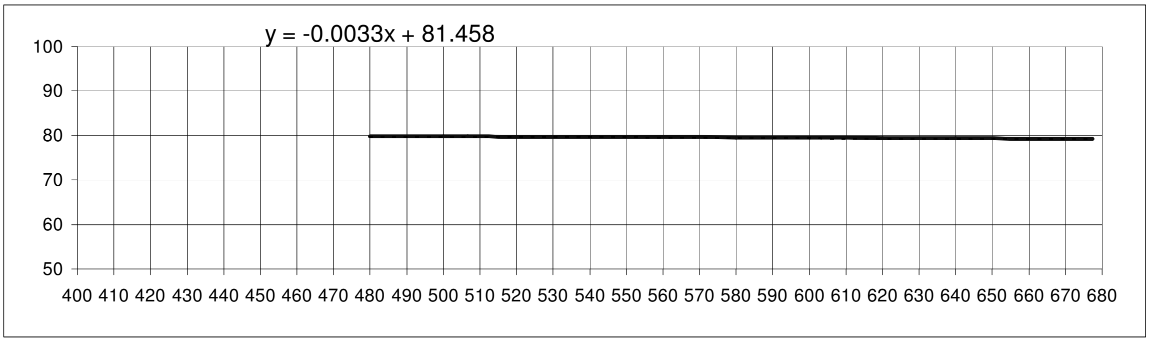
L-Section of Nallah at U/S



L-Section of Nallah at Existing Bridge



L-Section of Nallah at D/S



CHAPTER-8

BRIDGE AT CH:21/850

8. Hydraulic calculations for Minor Bridge of road Berhampur-Bangi-Rayagada

1 General details

Name of the Nala :	Anangpur
Road No.:	S.H.No 17
G.T S No :	74A/11
Nearest Village :	Digpahandi/Anangpur
RD :	Km.21.850
Latitude	84^0 36' 00"
Longitude	19^0 22' 00"
Sub-Zone	4(a)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q=CM^{3/4}$

C=14-19 where annual rainfall is more than 120 cm
=11-14 where annual rainfall is 60-120 cm
=22 in western Ghats

C adopted (Since Rain fall is more than 120 cm)	19	
M=catchment area	8.500	sqkm
Q=	94.58	cum/s

3 Discharge by Rational Formula

Catchment area	8.500 sqkm	850.00	hectares
Length of path from toposheet (L)		7.150	km
Difference in levels from toposheet (H)		70	m

(Ref: Index map)

The severest storm occurred in 50 years adopted for Ghoda Hada River at RD 29.230 km which is in the same region as calculated by synthetic unit hydrograph method. Hence the same rainfall is adopted for this Nallah.

Maximum rain fall (F)		208.4	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io=(F/T)*(T+1)/(1+1)	125.04	mm/hr
Time of concentration (SP-13, page 12)	$tc=(0.87*L^3/H)^{0.385}$	1.79	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		89.60	mm/hr

Discharge Q=0.028 * P*f* A* Ic

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	850.00	Hectares
Ic =	8.960	cm/hr
Q=	85.304	cum/sec

4 Design Discharge

(Refer SP-13, page 21)

Discharge by Dicken's Formula	94.58	cum/sec
Discharge by Rational Formula	85.30	cum/sec
Maximum discharge	94.58	cum/sec
Next maximum discharge	85.30	cum/sec

The difference is within 50% of the next maximum discharge

Hence design discharge	94.58	cum/sec

5 Water Way

Regime width		$W=4.8Q^{1/2}$	46.68 m
(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)			
Provide	clear span		10 m
	no. of spans		3 no.
	total waterway provided L		30.00 m

The waterway available for existing bridge is about 2/3rd of the waterway required for regime channel. As per local enquary, the bridge was not observd to be overtopped.
Looking to the performance of existing bridge, the linear waterway seems to adequate.

6 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point of deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16)	0.90 m
Formation level	83.332 m
Bottom of deck level	82.357 m
HFL	81.757 m
Vertical clearance available	0.600 m

Although the vertical clearance is less than the required, but looking to the hydraulic performance of the existing bridge, it is recommended to retain the existing bridge. Raising is not suggested.

CHAPTER-9

BRIDGE AT CH:29/230

9. Hydraulic calculations for Minor Bridge of road Berhampur-Bangi-Rayagada

1	**Name of the Nala :**	Ghodahada River		
	Road No.:	S.H.NO 17		
	G.T S No :	74A/11		
	Nearest Village :	Digpahandi/Malabhanja		
	RD :	Km.29.230		
	Latitude	84^0 32' 00"		
	Longitude	19^0 23' 00"		
	Sub-Zone	4(a)		

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (Refer I.R.C. SP-13, Page 7)

$Q=CM^{3/4}$

C=14-19 where annual rainfall is more than 120 cm

=11-14 where annual rainfall is 60-120 cm

=22 in western Ghats

C adopted (Since Rain fall is more than 120 cm)	19	
M=catchment area	377.750	sqkm
Q=	1628.01	cum/s

3 Discharge by Rational Formula Ref.SUG of Ghodahada River

Catchment area	377.750 sqkm	37775.00	hectares
Length of path from toposheet (L)		35.750	km
Difference in levels from toposheet (H)		600	m
(Ref: Index map)			
Maximum rain fall (F)		208.4	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io=(F/T)*(T+1)/(1+1)	125.04	mm/hr
Time of concentration (I.R.C.SP-13, Page 12)	$tc=(0.87*L^3/H)^{0.385}$	5.03	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		41.51	mm/hr
Discharge Q=0.028 * P*f* A* Ic			
P = (for loam, lightly cultivated or covered)		0.400	
f =		1.00	
A =		37775.00	Hectares
Ic =		4.151	cm/hr
Q=		1755.998	cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge

(Refer I.R.C.SP-13, Page 21)

Discharge by SUG (calculated separately)	2664.00	cum/sec
Discharge by Dicken's Formula	1628.01	cum/sec
Discharge by Rational Formula	1756.00	cum/sec
Maximum discharge	2664.00	cum/sec
Next maximum discharge	1628.01	cum/sec
The difference is beyond 50% of the next maximum discharge		
Hence design discharge	2442.01	**cum/sec**

5 Linear Water Way

Regime width		$W=4.8Q^{1/2}$	237.20 m
(Refer IRC:5-1998, Clause 104.3 or SP-13, Page 23)			
Provided	clear span		40 m
	no. of spans		3 no.
	total waterway provided L		120.00 m

The waterway available for existing bridge is about half of the waterway required for regime channel. As per local enquary, the bridge was not observd to be overtopped.
Looking to the performance of existing bridge, the linear waterway seems to adequate.

6 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point of deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16)	1.20 m
Formation level	100.100 m
Bottom of deck level	97.225 m
HFL	95.975 m
Vertical clearance available	1.250 m

The vertical clearance provided is OK.

DISCHARGE BY SYNTHETIC UNIT HYDROGRAPH

Road Berhampur-Bangli Jn.-Rayagada -S.H.No.-17
Name of River/Nallah/Stream : Ghodahada Nadi
Name of nearest Village/Town : Digapahandi(Malabhanja)
RD : Km 29.230
Lattitude : 84^0 32'00"
Longitude : 19^0 23'00"
GT Sheet No. : 74 A
Sub Zone 4(a)

Estimation of slope

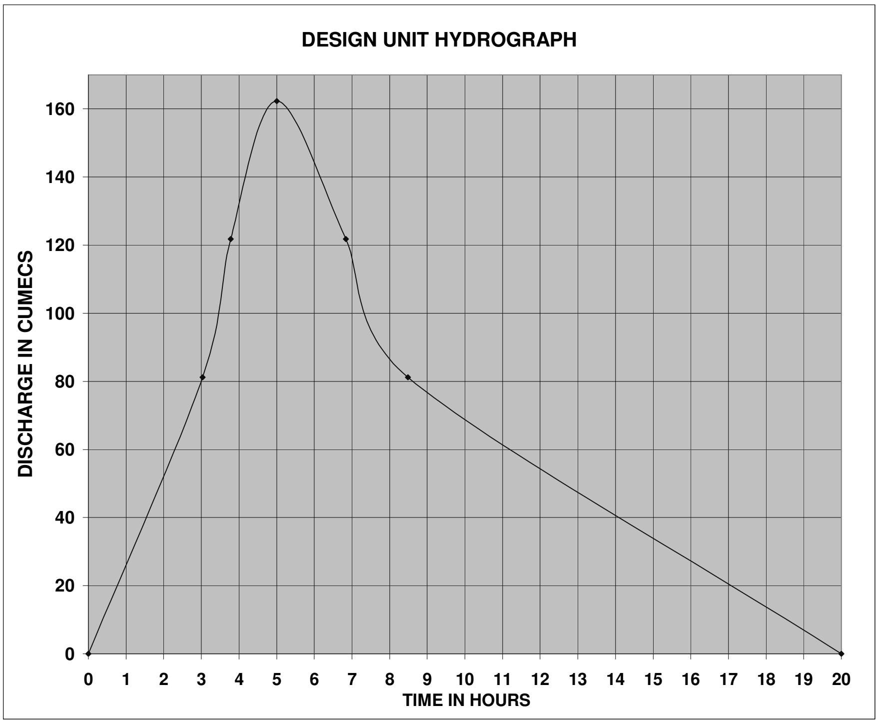
S.	Reduced Distance Starting	Reduced Levels	Length of	Height Above Datum	$(D_{i-1}+D_i)$	$L_i(D_{i-1}+D_i)$
1	2	3	4	5	6	7
1	0	100	0	0	0	0.00
2	29.25	200	29.25	100	100	2925.00
3	31.75	300	2.5	200	300	750.00
4	32.75	400	1	300	500	500.00
5	34	500	1.25	400	700	875.00
6	34.75	600	0.75	500	900	675.00
7	35.75	700	1	600	1100	1100.00
					$\Sigma L_i(D_{i-1}+D_i)$ =	6825.00

$S = \frac{\Sigma L_i (D_{i-1} + D_i)}{l^2}$ = 5.34 m/km

Synthetic Unitgraph

Catchment area A = 377.75 Sq.Km.
d = 1 cm depth
$t_i = t_r$ (the unit duration of the UG) = 1 hr
$\Sigma Q_i t_i = A \times d / (0.36 \times t_r)$ = 1049.31
L = 35.75 km
Lc = 16.25 km
LxLc/(sqrt(s)) = 251.40
$t_p = 0.376((L \times Lc)/\text{sqrt}(S))^{0.434}$ = 4.14 hrs
Say 4.5 hrs
$q_p = 1.215\ (tp)^{-0.691}$ = 0.430
Q_p = Catchment area x q_p = 162.335 cumecs
$W_{50} = 2.211\ (q_p)^{-1.07}$ = 5.458 hrs
$W_{75} = 1.312\ (q_p)^{-1.003}$ = 3.061 hrs
$W_{R50} = 0.808\ (q_p)^{-1.053}$ = 1.966 hrs
$W_{R75} = 0.542\ (q_p)^{-0.965}$ = 1.224 hrs
$Q_{50} = 0.5 \times Q_p$ = 81.167 cumecs
$Q_{75} = 0.75 \times Q_p$ = 121.751 cumecs
$T_B = 7.621\ (tp)^{0.623}$ = 19.452 hrs
$Tm = t_p + t_r/2 = 4.5 + 1/2$ = 5 hrs

Sl. No	Unit Graph(1 cm 1 hour) Time	Ordinate
1	0	0
2	1	21
3	2	42
4	3	78
5	4	126
6	5	162.33
7	6	144
8	7	111
9	8	90
10	9	72
11	10	60
12	11	45
13	12	33
14	13	21
15	14	15
16	15	10
17	16	8
18	17	6
19	18	4.5
20	19	2.9
21	20	0
		1051.73 cumec hours
	=	10.02 mm



STORM DURATION Td = 1.1 t_p
= 1.1 X 4.5 = 4.95
say 5 Hrs

From Plate 9.4 (a) , the 50 -Year return period , 24 hour point rainfall : 320 mm Based on Latitude&Longitude of site

50 -Year return period , 5 hour point rainfal 0.78 249.60 mm Based on Storm duration&Catchment area of Project site

Areal Rainfall =0.835 of Point Rainfall 0.835 208.4 mm
=

Loss rate = 0.75 cm / hour 7.5 mm/hour

Cumulative percentage

Base flow,qb=0.536/(A)0.523 0.024
Total base flow= A *qb 9.088
say 9.1

Hours	Storm Percentage	Storm Rainfall	Excess Rainfall	Incremental R.E.
0	0	0	0	0
1	61	127.12	119.624	119.624
2	81	168.8	153.804	34.18
3	90	187.56	165.06	11.256
4	97	202.148	172.148	7.088
5	100	208.4	170.9	-1.248

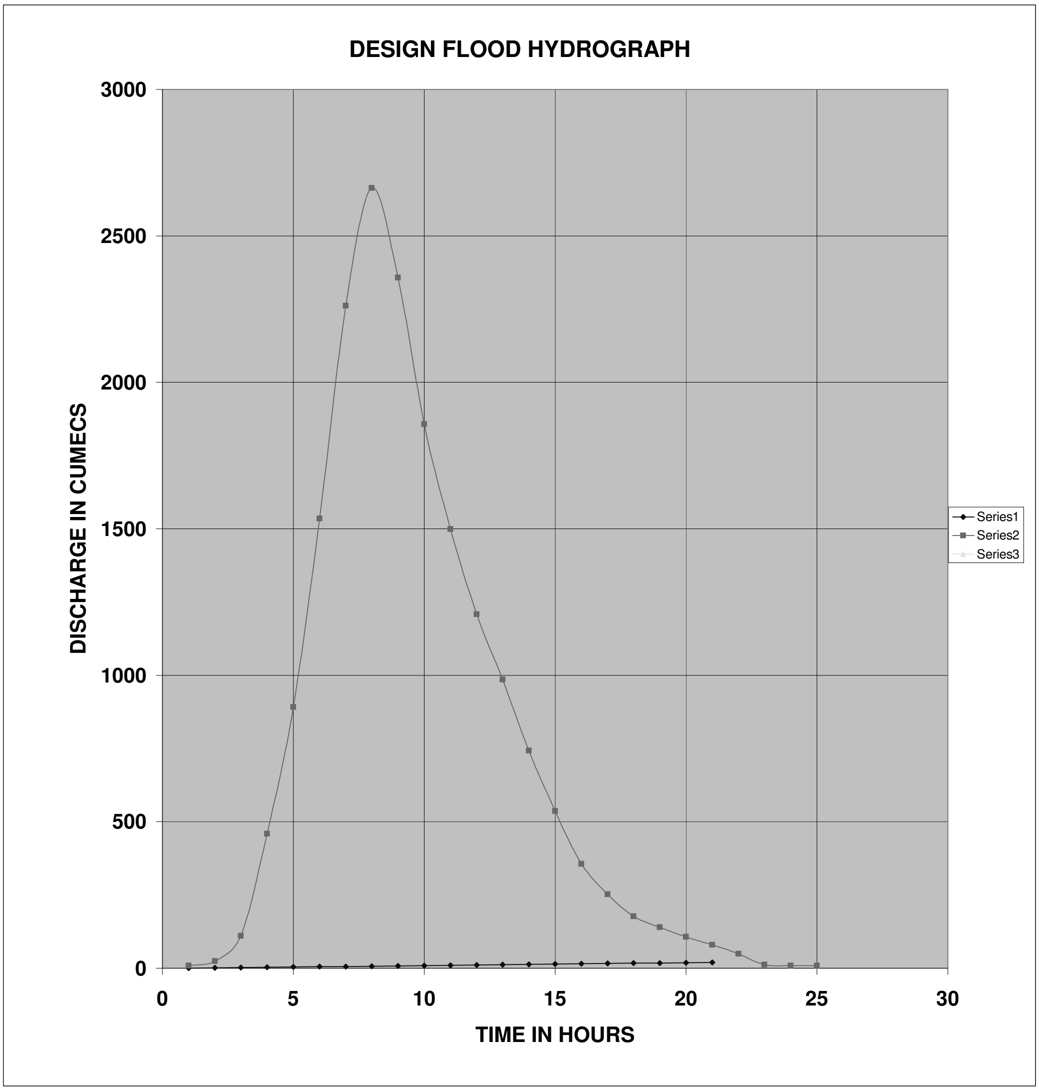
Estimation of Design Flood Hydrograph

Unit Graph(1 cm 1 hour)			R.E.	R.E.						Base Flow	Design Flood Hydrograph
Sl.	**Time**	**Ordinate**	**Peak to**	**Reverse**							
No			**Peak**	**order**	0.7088	3.418	11.9624	1.126	0		
1	0	0			0					9.1	9.1
2	1	21			14.88	0				9.1	23.98
3	2	42			29.77	71.78	0			9.1	110.65
4	3	78			55.29	143.56	251.21	0		9.1	459.15
5	4	126	11.256	7.088	89.31	266.60	502.42	23.64	0	9.1	891.07
6	5	162.33	119.624	34.18	115.06	430.67	933.07	47.28	0.00	9.1	1535.17
7	6	144	34.18	119.62	102.07	554.84	1507.26	87.8	0.00	9.1	2261.07
8	7	111	7.088	11.256	78.68	492.19	1941.86	141.8	0.00	9.1	2663.65
9	8	90			63.79	379.40	1722.59	182.7	0.00	9.1	2357.59
10	9	72			51.03	307.62	1327.83	162.1	0.00	9.1	1857.67
11	10	60			42.53	246.10	1076.62	124.9	0.00	9.1	1499.28
12	11	45			31.90	205.08	861.29	101.3	0.00	9.1	1208.67
13	12	33			23.39	153.81	717.74	81.04	0.00	9.1	985.09
14	13	21			14.88	112.79	538.31	67.54	0.00	9.1	742.62
15	14	15			10.63	71.78	394.76	50.65	0.00	9.1	536.92
16	15	10			7.09	51.27	251.21	37.14	0.00	9.1	355.81
17	16	8			5.67	34.18	179.44	23.64	0.00	9.1	252.02
18	17	6			4.25	27.34	119.62	16.88	0.00	9.1	177.20
19	18	4.5			3.19	20.51	95.70	11.26	0.00	9.1	139.75
20	19	2.9			2.06	15.38	71.77	9.005	0.00	9.1	107.32
21	20	0			0.00	9.91	53.83	6.754	0.00	9.1	79.60
						0	34.69	5.065	0.00	9.1	48.86
							0	3.264	0.00	9.1	12.36
								0	0.00	9.1	9.10
									0	9.1	9.10

Qp = 2664 Cumecs

C.A. = 377.75 Sq. Kms.

Dicken's C = Q/(M)^3/4 31.09



CHAPTER-10

BRIDGE AT CH:29/500

10. Hydraulic calculations for Minor Bridge of road Berhampur-Bangi-Rayagada

1 Name of the Nala : Ram Nadi

Road No.:	S.H.N0 17
G.T S No :	74A/11
Nearest Village :	Digpahandi/Malabhanja
RD :	29.500km
Latitude:	84^0 32' 15"
Longitude	19^0 23' 15"
Sub Zone	4(a)

2 Discharge by Dicken's Formula

Discharge as per Dicken's formula (refer SP-13, page 7)

$Q=CM^{3/4}$

C=14-19 where annual rainfall is more than 120 cm

=11-14 where annual rainfall is 60-120 cm

=22 in western Ghats

C adopted (Since Rainfall is more than 120 cm)	19	
M=catchment area	1.620	sqkm
Q=	27.28	cum/s

3 Discharge by Rational Formula (Ref.SUG of Ghodahada River)

Catchment area	1.620 sqkm	162.00	hectares
Length of path from toposheet (L)		1.850	km
Difference in levels from toposheet (H)		20	m
(Ref: Index map)			
Maximum rain fall (F)		208.4	mm
Duaration of storm (T)		5	hrs
One hour rainfall (Io)	Io=(F/T)*(T+1)/(1+1)	125.04	mm/hr
Time of concentration (SP-13, page 12)	$tc=(0.87*L^3/H)^{0.385}$	0.61	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		155.45	mm/hr
Discharge Q=0.028 * P*f* A* Ic			
P = (for loam, lightly cultivated or covered)		0.400	
f =		1.00	
A =		162.00	Hectares
Ic =		15.545	cm/hr
Q=		28.206	cum/sec

Here,

t_c= Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchment

I_o= One hour rainfall in cm.

I_c= Critical intensity of rainfall in cm per hour

P = Coefficient of runoff for the catchment characteristics (Ref.Table-4.1P-13,I.R.C.:SP:13-2004)

A = Catchment area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in metre

4 Design Discharge

(Refer SP-13, page 21)

Discharge by Dicken's Formula	27.28	cum/sec
Discharge by Rational Formula	28.21	cum/sec
Maximum discharge	28.21	cum/sec
Next maximum discharge	28.21	cum/sec
The difference is within 50% of the next maximum discharge		
Hence design discharge	**28.21**	**cum/sec**

5 Linear Water Way

Regime width $W=4.8Q^{1/2}$ 25.49 m

(Refer IRC:5-1998, cl 104.3 or SP-13, page 23)

Provide	clear span	20	m
	no. of spans	1	no.
	total waterway provided L	20.00	m

The proposed waterway is within 2/3rd of the waterway required for regime channel

6 Scour depth

Increase in design discharge, as per IRC:78-2000, cl 703.1.1 30%

Increased design discharge 33.14 cum/sec

Mean depth of scour, as per IRC:78-2000, cl 703.2

$d_{sf} = 1.34\ (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width 1.66 cum/sec/m

K_{sf} = Silt factor

	Depth	Silt factor		
	1.5	0.916	1.374	
	3.0	1.362	4.086	
Weighted average	4.5		5.460	1.213

$d_{sf} =$ 3.76 m

Maximum scour depth, as per IRC:78-2000, cl 703.3

for Abutment 1.27 d_{sf} 4.77 m

7 Vertical Clearance

Vertical clearance for opening of high level bridge, from the lowest point of deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.6 m

8 Foundation depth

Depth of foundation below max. scour, as per IRC:78-2000, cl 705.2	2.00	m
Depth of foundation below HFL	6.77	m
HFL at site	94.609	m
Max. Scour level	89.835	m
Desired foundation level	87.835	m
Bed level at site	90.145	m

Actual foundation level will be decided as per Geo-Technical investigations

9 Afflux

Cross-sectional area of flow (A)		104.28	sqm
Regime width of flow (W)		25.49	m
Total water way provided (L)		20.00	m
Design discharge (Q)		28.21	cum/sec
Depth of flow at d/s of bridge Dd=A/W		4.091	m
L/W		0.785	
(Refer SP-13, page 55-56)	Cofficient e	0.772	
	Cofficient Co	0.873	
	g	9.81	m/sec/sec

If the afflux h < Dd/4, the Orifice formula is applicable

By Orifice formula, the discharge is given as

$Q=C_0\ (2g)^{0.5}\ L\ D_d\ \{h+(1+e)u^2/2g\}^{0.5}$

or $\{h+(1+e)u^2/2g\}^{0.5} = Q / \{C_0\ (2g)^{0.5}\ L\ D_d\}$

or $\{h+(1+e)u^2/2g\} = [Q / \{C_0\ (2g)^{0.5}\ L\ D_d\}]^2$

Substituting values, we have

h+ 0.090 u² = 0.008 (i)

$h + 0.090\ u^2 = 0.008$ (i)

Also at u/s of the bridge

$Q=W\ (D_d+h)\ u$ or $h=Q/Wu - D_d$

Substituting values, we have

$h = (1.106\ / u) - 4.091$ (ii)

Combining (i) & (ii)

$u - 0.02204\ u^3 = 0.26996$ (iii)

by trial & error	u =	0.270	
LHS of the equation (iii) =		0.26996	
Substituting u in equation (i), we get			
h=		0.001	m
The afflux as per Orifice formula		0.001	m
	h<Dd/4, OK		
The afflux adopted		0.001	m

10 Deck level

HFL at proposed bridge site	94.609	m
Afflux of proposed bridge as per SP-13	0.001	m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600	m
Depth of super structure	2.200	m
Wearing coat	0.056	m
Minimum deck level required as per hydraulic conditions	97.465	m
Deck level of the existing bridge	96.334	m
Minimum deck level proposed	97.465	m

11 Velocity

Linear waterway	20.000	m
Average depth of flow	2.232	m
Cross sectional area of flow	44.640	sqm
Design discharge	28.206	cum/s
Design velocity	0.63	m/s

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	28.21	cum/sec
HFL	94.609	m
Design velocity	0.54	m/s
Bed level	90.145	m
Maximum scour level	89.835	m

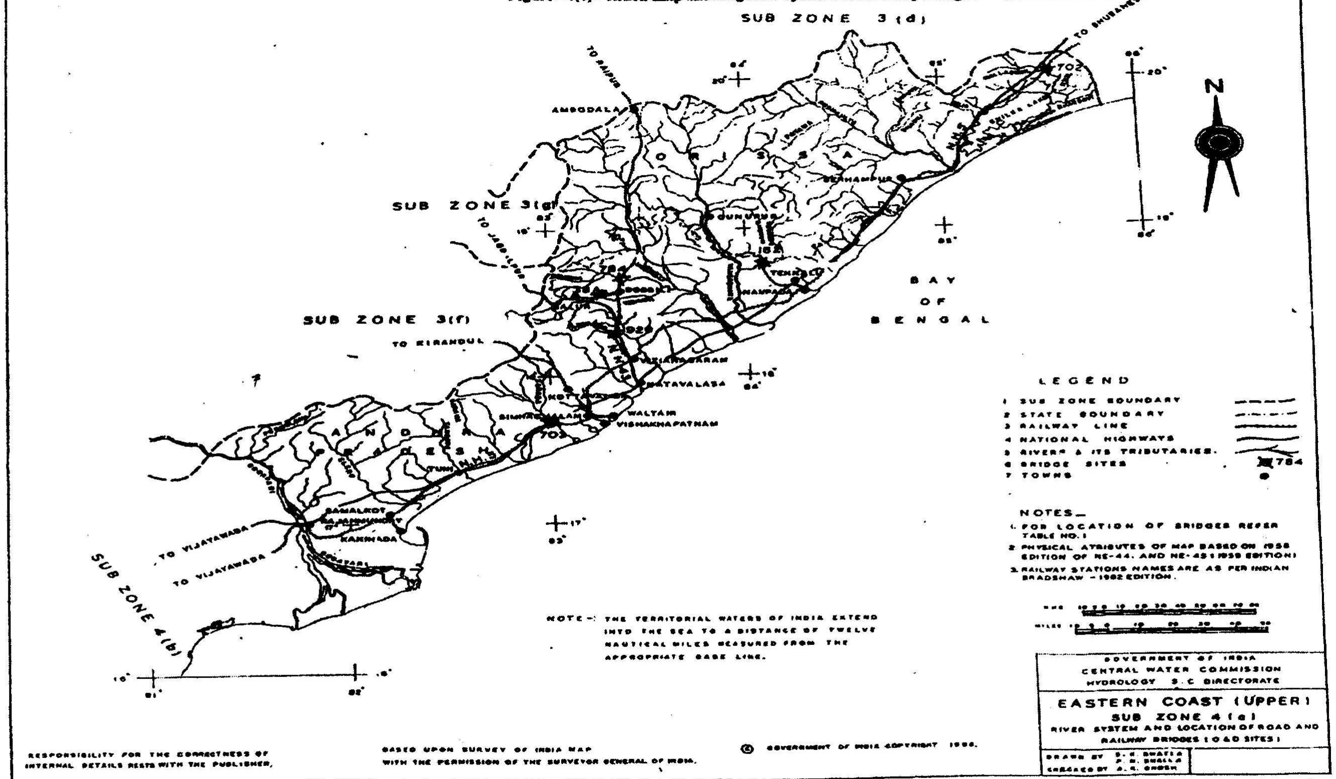
Type of foundation	pile foundation	
Bottom of pile cap	87.345	m
Foundation level	73.895	m

The foundation is deep foundation (pile type) and the piles are below the scour level.
There is no need of floor protection works.

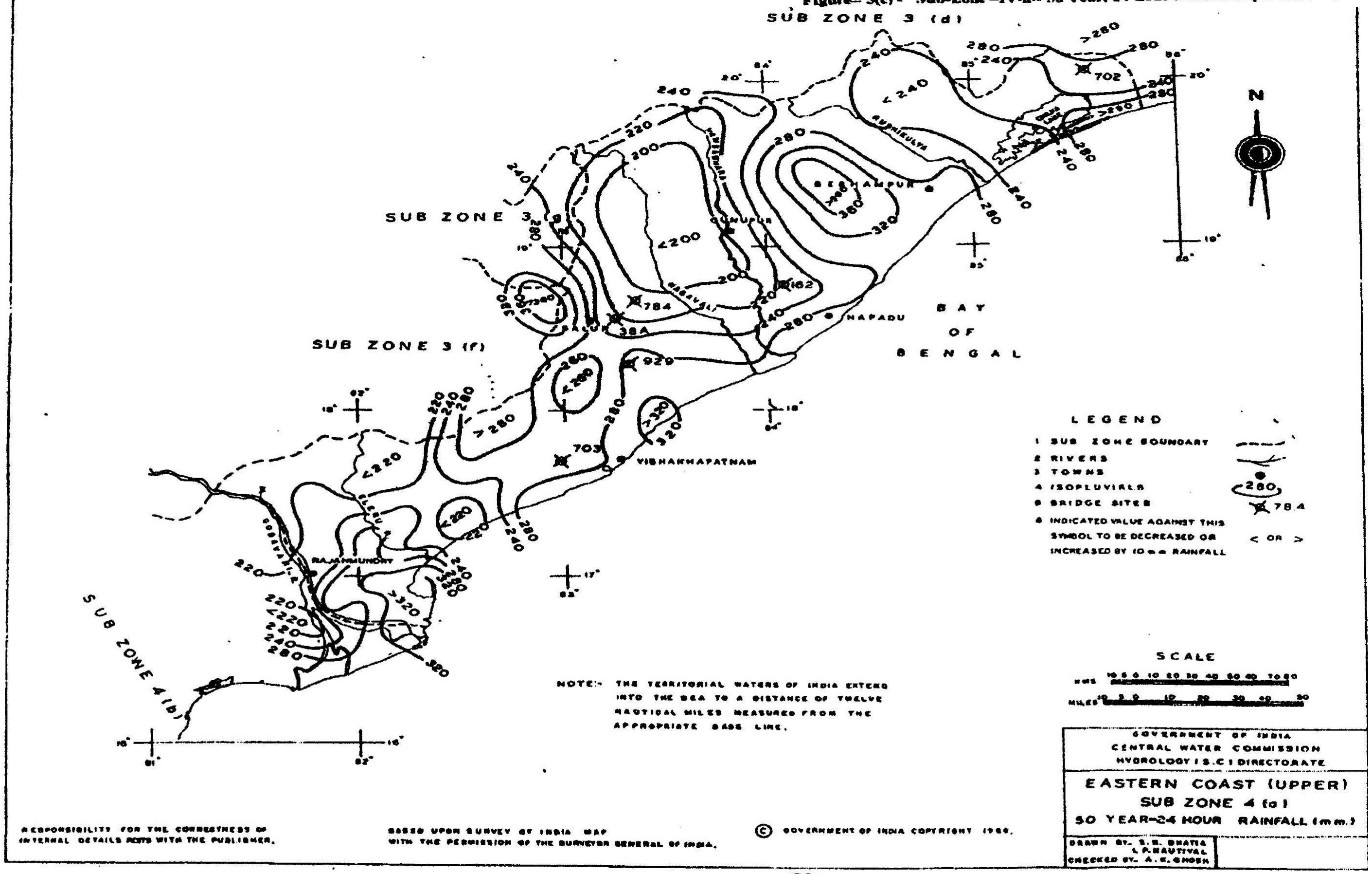
APPENDIX

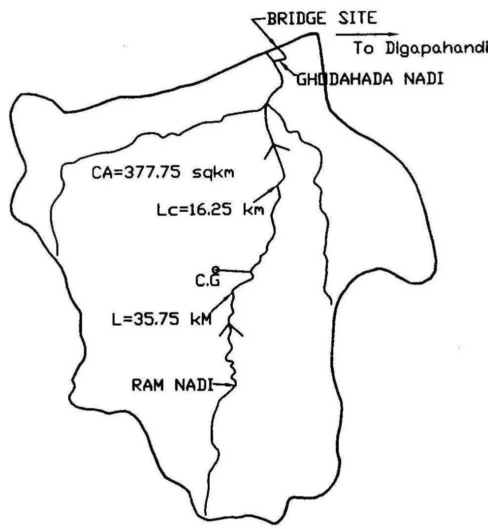
Figure 4-C

Figure - 4(c) - Index map showing river system and railway bridges – Sub-Zone –IV-a



Figure– 5(c) - Sub-Zone -IV-a-- 50 Year, 24-hour rainfall Isopluvial map





REFERENCES:-

1. CATCHMENT BOUNDARY
2. RIVER AND ITS TRIBUTARIES
3. ROADS
4. NEAREST VILLAGE/TOWN-Digapahandi
5. G.T SHEET NO.74A
   (SCALE-1:2,50.000)

DETAILS OF THE CATCHMENT

1. CATCHMENT AREA = 377.75 sqkm
2. LONGITUDE = 84° 32′
3. LATITUDE = 19° 23′
4. L = 35.75 km
5. Lc = 16.25 km

G.T.Sheet No.-73A/11