GOVERNMENT OF ORISSA

WORKS DEPARTMENT

ORISSA STATE ROAD PROJECT

FINAL DETAILED ENGINEERING REPORT FOR PHASE-I ROADS

HYDROLOGY REPORT

(BHAWANIPATNA TO KHARIAR)

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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. ∑ 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 ∑ 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:3/050

1. Hydraulic calculations for Bridge of road Bhawanipatna-Khariar

1 Name of the Nala Pipal Nala/Jokapal Nala

Road No.:	S.H - 16
G.T S No :	65M/8,65 N/5
Nearest Village :	Bhawanipatna
RD :	Km.3.05
Latitude:	83^0 25' 00"
Long	19^0 05' 15"
Sub-Zone	4(a)

2 Discharge as per 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		44.250	sqkm
Q =	19*(44.25)^3/4	325.9782	Cumecs.

3 Discharge by Rational Formula

Catchment area		44.250 sqkm	4425.00	ha
Length of path from toposheet (L)			12.250	km
Difference in levels from toposheet (H)			810	m
(Ref: Index map)				
Maximum rain fall (F)			92.77	mm
Duaration of storm (T)			2	hrs
One hour rainfall (I_o)	Io = (F/T)*(T+1)/(1+1)		69.5775	mm/hr
Time of concentration (SP-13, page 12)	$t_c = (0.87*L^3/H)^{0.385}$		1.30	hrs.
Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$			60.52	mm/hr

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

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	4225.00	Hectares
I_c =	6.052	cm/hr
Q =	286.370	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		325.98	
Discharge by Rational Formula		286.37	
Discharge by SUG		339.00	
Maximum discharge		339.00	
Next maximum discharge		325.98	
The difference is within 50% of the next maximum discharge			
Hence adopt design discharge,		**339.00**	
Design discharge adopted	**Q =**		**339.00 Cumecs**

5 Linear Water Way

Regime width as per Lacey's theory $W = 4.8Q^{1/2}$ 88.38 m

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

6 Vertical Clearanace

Vertical clearance for opening of high level bridge, from the lowest point

0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 1.2 m

7 Afflux

HFL at site		265.615	m
Bed level at site		261.081	m
Cross-sectional area of flow (A)		144.87	sqm
Regime width of flow (W)		42.25	m
Total water way provided (L)		22.80	m
Design discharge (Q)		339.00	cum/sec
Depth of flow at d/s of bridge Dd = A/W		3.429	m
L/W		0.540	
(Refer SP-13, page 55-56)	Cofficient e	1.04	
	Cofficient Co	0.881	
	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+ 0.104 u^2 = 1.235 (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 = (8.024 / u) - 3.429 (ii)

Combining (i) & (ii)

u - 0.02230 u^3 = 1.72048 (iii)

by trial & error u = 1.865

LHS of the equation (iii) = 1.72020

Substituting u in equation (i), we get		
h=	0.874	m
The afflux as per Orifice formula	0.874	m

Since h>Dd/4, Weir formula will be applicable

By Weir formula, the discharge is given as

Q= 1.706 Cw L H3/2

H={Q/(1.706 Cw L)}2/3

(Refer SP-13, page 52)

Cw for wide bridge opening with no bed=	0.98	
H=	4.292	m
Also Du = H - u2/2g		
Assume Du = H =	4.292	m
u = Q/Wdu =	1.869	m/sec
Now Du = H - u2/2g =	4.114	m
Dd as above	3.429	m
Afflux h=Du-Dd	0.685	m

Since h<Dd/4, Orifice formula will be applicable

The afflux as per Weir formula	0.685	m
The afflux adopted	0.685	m

8 Deck level

HFL at proposed bridge site including afflux	265.615	m
Minimum vertical clearance (Table 12.1 of SP-13)	1.200	m
Depth of super structure including camber	0.670	m
Wearing coat	0.056	m
Minimum deck level required as per hydraulic conditions	267.541	m
Deck level of the existing bridge	267.510	m

9 Recommendation

The existing formation level of bridge is kept as 267.51m.

No additional waterway is reqd. as per site condition.The minimum vertical clearance is about (1.2-267.541+267.51=1.169 m), which is sufficient. Hence the structure is hydraulically adequate. No additional waterway is required.

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	339.00 cum/sec
HFL	265.615 m
Bed level	261.081 m
Maximum scour depth	7.82 m
Maximum scour level	257.795 m

Curtain wall shall be provided below maximum scour level

Bed level		261.081 m
Scour depth below bed		3.29 m
Minimum depth of curtan wall as per IRC:89-1997	u/s	2 m
	d/s	2.5 m
Provide depth of curtain wall	u/s	4.0 m
	d/s	4.5 m
Rigid apron as per IRC:89-1997	u/s	3.0 m
	d/s	5.0 m

		As per IRC:89	2xscour depth	Provided
Flexible apron	u/s	3.0	6.57	7.0 m
	d/s	6.0	6.57	7.0 m

CHAPTER-2

BRIDGE AT CH:4/450

2. Hydraulic calculations for Bridge of road Bhawanipatna-Khariar

1	**Name of the Nala :**	Bulat nalah
	Road No.:	S.H - 16
	G.T S No :	65M/8,65N/5
	Nearest Village :	Kamathana
	RD :	4.450km
	Latitude:	83^0 27' 00"
	Longitude	19^0 55' 30"
	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	48.000	sqkm
Q =	346.49	cum/s

3 Discharge by Rational Formula

Catchment area	48.000 sqkm		4800.00	hectares
Length of path from toposheet (L)			23.650	km
Difference in levels from toposheet (H)			830	m
(Ref: Index map)				
Maximum rain fall (F)			116.56	mm
Duaration of storm (T)			4	hrs
One hour rainfall (I_o)	$I_o = (F/T)*(T+1)/(1+1)$		72.85	mm/hr
Time of concentration (SP-13, page 12)		$t_c = (0.87*L^3/H)^{0.385}$	2.75	hrs.
Critical rainfall intensity $I_c = I_o*[(2/(1+t_c)]$			38.83	mm/hr
Discharge $Q = 0.028 * P*f* A* I_c$				
P = (for loam, lightly cultivated or covered)			0.400	
f =			1.00	
A =			4800.00	Hectares
I_c =			3.883	cm/hr
Q =			208.750	cum/sec

tc= 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-4.1,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 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	346.49 cum/sec
Discharge by Rational Formula	208.75 cum/sec
Discharge by SUG	257.00 cum/sec
Maximum discharge	346.49 cum/sec
Next maximum discharge	340.30 cum/sec
Hence design discharge	**346.49 cum/sec**
Design discharge adopted	**Q = 346.49 cum/sec**

5 Linear Water Way

Regime width as per Lacey'y theory $W = 4.8Q^{1/2}$ 89.35 m

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

6 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 1.2 m

7 Afflux

Cross-sectional area of flow (A)		307.89 sqm
Regime width of flow (W)		63.90 m
Total water way provided (L)		33.20 m
Design discharge (Q)		346.49 cum/sec
Depth of flow at d/s of bridge Dd=A/W		4.818 m
L/W		0.520
(Refer SP-13, page 55-56)	Cofficient e	1.05
	Cofficient Co	0.887
	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

$$h + 0.104\;u^2 = 0.304 \qquad \text{(i)}$$

Also at u/s of the bridge

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

Substituting values, we have .

$$h = (5.422\;/\;u) - 4.818 \qquad \text{(ii)}$$

Combining (i) & (ii)

$u - 0.02040\ u^3 = 1.05858$ (iii)

by trial & error u = 1.085

LHS of the equation (iii) = 1.05871

Substituting u in equation (i), we get

h= 0.180 m

The afflux as per Orifice formula 0.180 m

h<Dd/4, OK

The afflux adopted 0.180 m

8 Deck level

HFL at proposed bridge site including afflux	261.327	m
Minimum vertical clearance (Table 12.1 of SP-13)	1.200	m
Depth of super structure including camber	0.800	m
Wearing coat	0.056	m
Minimum deck level required as per hydraulic conditions	263.383	m
Deck level of the existing bridge	262.952	m

The existing formation level of bridge is 262.952m,however the deck level provided as per hydrology calculations is 263.383 i.e. 0.431 m below the proposed road level. The above bridge has been designed as submersible bridge and has never been overtopped till date. Keeping in view the structural soundness and vertical clearance I.e.(1.2-0.431=0.769 m), it is suggested to retain the above bridge without any increase in waterway.

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	346.49	cum/sec
HFL	261.327	m
Bed level	255.901	m
Maximum scour depth	7.88	m
Maximum scour level	253.447	m

As per site inspection, bed protection has not been proposed

CHAPTER-3

BRIDGE AT CH:8/600

3. Hydraulic calculations for Bridge of road Bhawanipatna-Khariar

1	**Name of the Nala :**	Sankharimal nala
	Road No.:	S.H-16
	G.T S No :	65M
	Nearest Village :	Dumala
	RD :	Km.8.60
	Latitude:	$83^{0}10^{'}00^{"}$
	Longitude	$19^{0}56^{'}00^{"}$
	Sub Zone	3(d)

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	4.700 sqkm
Q=	60.65 cum/s

3 Discharge by Rational formula

Catchment area	4.700 sqkm	470.00 hectares
Length of path from toposheet (L)		3.750 km
Difference in levels from toposheet (H)		30 m
(Ref: Index map)		
Maximum rain fall (F)		116.56 mm
Duaration of storm (T)		4 hrs
One hour rainfall (I_o)	$I_o=(F/T)*(T+1)/(1+1)$	72.85 mm/hr
Time of concentration (SP-13, page 12)	$t_c=(0.87*L^3/H)^{0.385}$	1.18 hrs.
Critical rainfall intensity , $I_c = I_o*(2/(1+t_c)$		66.91 mm/hr
Discharge $Q=0.028 * P*f* A* I_c$		
P = (for loam, lightly cultivated or covered)		0.400
f =		1.00
A =		470.00 Hectares
I_c =		6.691 cm/hr
Q=		35.219 cum/sec

- tc= 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 based on the catchment characteristics (Ref.Table-4.1,P-13, I.R.C.:SP:13-2004)
- A= Catchment area of Project in hectare
- Q= Maximum discharge in cumecs.
- L= Distance from the critical point to the structure site in Km.
- H= The fall in level from the critical point to the structure site in metre

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

Discharge by Dicken's Formula	60.65 cum/sec
Discharge by Rational formula	35.22 cum/sec

Maximum discharge	60.65 cum/sec	
Next maximum discharge	35.22 cum/sec	
The difference is beyond 50% of the next maximum discharge		
Hence design discharge of Project site	**60.65 cum/sec**	
Design discharge adopted	**Q=**	**60.65 cum/sec**

5 Linear Water Way

Regime width as per Lacey'y theory $W=4.8Q^{1/2}$ 37.38 m

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

6 Silt factor: Based on Geotechnical report of the site

Depth (m)	Silt factor		
0.75	1.276	0.957	
1.5	1.254	1.881	
3	1.386	4.158	
5.25		6.996	1.3325714 Say 1.33

7 Scour depth

For catchment area upto 3000 Sq.Km.

Increase in design discharge,as per IRC:78-2000,Clause 703.1.1,P-10 30%

Increased design discharge,Q_R 78.84 cum/sec

Mean depth of scour below H.F.L, as per IRC:78-2000, Clause 703.2

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

D_b = Design discharge per metre width 2.11 cum/sec/m

K_{sf} = Silt factor 1.33

d_{sf} = 2.00 m

Maximum scour depth below H.F.L., as per IRC:78-2000, Clause 703.3

For Pier $2\,d_{sf}$ 4.01 m

For Abutment $1.27\,d_{sf}$ 2.55 m

8 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9 m

9 Span arrangement

In proposed span arrangement, single span of 8.0 m has been proposed with bed protection.

10 Afflux

The existing structure is a balancing type structure and lies in submerged area. The road level has been raised by 1.5 m above HFL. The water way is proposed to be 8.0 m against 6.3 m waterway of existing structure. Some additional balancing type culvert shall also be introduced to take care additional waterway.

11 Deck level

HFL at existing bridge site including afflux	246.338 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900 m
Depth of super structure including camber	0.800 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	248.094 m
Deck level of the existing bridge	247.513 m

As per the proposed allignment, the formation level of bridge has been kept as 248.2m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	60.65 cum/sec
HFL	246.338 m
Bed level	244.814 m
Maximum scour depth	2.55 m
Maximum scour level	243.788 m

Curtain wall shall be provided below maximum scour level

Bed level		244.814 m
Scour depth below bed		1.03 m
Minimum depth of curtan wall as per IRC:89-1997	u/s	2 m
	d/s	2.5 m
Provide depth of curtain wall	u/s	2.0 m
	d/s	2.5 m
Rigid apron as per IRC:89-1997	u/s	3.0 m
	d/s	5.0 m

		As per IRC:89	2xscour depth	Provided
Flexible apron	u/s	3.0	2.05	3.0 m
	d/s	6.0	2.05	6.0 m

CHAPTER-4

BRIDGE AT CH:10/500

4. Hydraulic calculations for Bridge of road Bhawanipatna-Khariar

1	**Name of the Nala :**	Badakhermai nala
	Road No.:	S.H-16
	G.T S No :	65M
	Nearest Village :	Thuapadar
	RD :	Km.10.50
	Latitude:	$83^0 10' 00''$
	Longitude	$19^0 57' 00''$
	Sub-Z0ne	3(d)

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	4.900 sqkm
Q=	62.57 cum/s

3 Discharge by Rational Formula

Catchment area	4.900 sqkm	490.00 hectares
Length of path from toposheet (L)		4.000 km
Difference in levels from toposheet (H)		30 m
(Ref: Index map)		
Maximum rain fall (F)		116.56 mm
Duaration of storm (T)		4 hrs
One hour rainfall (I_o)	$I_o=(F/T)*(T+1)/(1+1)$	72.85 mm/hr
Time of concentration (SP-13, page 12)	$t_c=(0.87*L^3/H)^{0.385}$	1.27 hrs.
Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$		64.22 mm/hr
Discharge Q=0.028 * P*f* A* I_c		
P = (for loam, lightly cultivated or covered)		0.400
f =		1.00
A =		490.00 Hectares
I_c =		6.422 cm/hr
Q=		35.243 cum/sec

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-4.1,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 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	62.57 cum/sec
Discharge by Rational formula	35.24 cum/sec
Maximum discharge	62.57 cum/sec

Next maximum discharge		35.24 cum/sec	
The difference is beyond 50% of the next maximum discharge			
Hence design discharge		**62.57 cum/sec**	
Design discharge adopted		**Q=**	**62.57 cum/sec**

5 Linear Water Way

Regime width as per Lacey's theory $W=4.8Q^{1/2}$ 37.97 m

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

6 Silt factor Based on Geotechnical investigation report

Depth(m)	Silt factor		
0.75	1.462	1.0965	
3	1.412	4.236	
4.5	1.272	5.724	
8.25		11.0565	1.340182 Say 1.34

7 Scour depth

For catchment area upto 3000 Sq. Km.

Increase in design discharge, as per IRC:78-2000, Clause 703.1.1,P-10	30%	
Increased design discharge		81.35 cum/sec
Mean depth of scour below H.F.L, as per IRC:78-2000, Clause 703.2		
$d_{sf} = 1.34\ (D_b^2/K_{sf})^{1/3}$		
D_b = Design discharge per metre width		2.14 cum/sec/m
K_{sf} = Silt factor	1.34	
d_{sf} =		2.02 m
Maximum scour depth below H.F.L, as per IRC:78-2000, Clause 703.3		
For Abutment $1.27\ d_{sf}$		2.57 m

8 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point
0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9 m

9 Span arrangement

In proposed allignment, a single box type structure of 8.0 m span has been proposed with bed protection as discussed at site with PIU officials.

10 Afflux

The existing structure is a balancing type structure and lies in submerged area. The road level has been raised by 1.5 m above HFL. The water way is proposed to be 8.0 m against 6.4 m waterway of existing structure. Some additional balancing type culvert shall also be introduced to take care additional waterway.

11 Deck level

HFL at existing bridge site	239.276 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900 m
Depth of super structure including camber	0.800 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	241.032 m
Deck level of the existing bridge	239.426 m
Minimum deck level proposed	241.032 m

As per the proposed allignment, the formation level of bridge has been kept as 241.1m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	62.67	cum/sec
HFL	239.276	m
Bed level	236.149	m
Maximum scour depth	2.57	m
Maximum scour level	236.706	m

Curtain wall shall be provided below maximum scour level

Bed level				236.149	m
Scour depth below bed				0.00	m
Minimum depth of curtain wall as per IRC:89-1997			u/s	2	m
			d/s	2.5	m
Provide depth of curtain wall			u/s	2.0	m
			d/s	2.5	m
Rigid apron as per IRC:89-1997			u/s	3.0	m
			d/s	5.0	m
		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	0.00	3.0	m
	d/s	6.0	0.00	6.0	m

CHAPTER-5

BRIDGE AT CH:13/750

5. Hydraulic calculations for Bridge of road Bhawanipatna-Khariar

1 Name of the Nala : Bada Polia

Road No.:	S.H-16
G.T S No :	64P/4
Nearest Village :	Korlagurhab
RD :	Km.13.750
Latitude	83^0 7' oo"
Longitude	20^0 01'oo"
Sub Zone	3(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	7.750 sqkm
Q=	88.25 cum/s

3 Discharge by Rational formula

Catchment area	7.750 sqkm	775.00 hectares
Length of path from toposheet (L)		3.750 km
Difference in levels from toposheet (H)		20 m
(Ref: Index map)		
Maximum rain fall (F)		116.56 mm
Duaration of storm (T)		4 hrs
One hour rainfall (I_o)	$I_o=(F/T)*(T+1)/(1+1)$	72.85 mm/hr
Time of concentration (SP-13, page 12)	$t_c=(0.87*L^3/H)^{0.385}$	1.38 hrs.
Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$		61.30 mm/hr
Discharge $Q=0.028 * P*f* A* I_c$		
P = (for loam, lightly cultivated or covered)		0.400
f =		1.00
A =		775.00 Hectares
I_c =		6.130 cm/hr
Q=		53.212 cum/sec

tc= 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-4.1,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 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	88.25 cum/sec
Discharge by Rational Formula	53.21 cum/sec

Maximum discharge		88.25 cum/sec	
Next maximum discharge		53.21 cum/sec	
The difference is beyond 50% of the next maximum discharge			
Hence design discharge		**88.25 cum/sec**	
Design discharge adopted		**Q=**	**88.25 cum/sec**

5 Linear Water Way

Regime width as per Lacey's theory $W=4.8Q^{1/2}$ 45.09 m

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

6 Silt factor Based on Geotechnical investigation report

Depth(m)	Silt factor			
0.75	*1.296*	0.972		
1.5	1.701	2.5515		2.076666667
3	3.233	9.699		
5.25		13.2225	2.518571 Say 2.52	

7 Scour depth

For catchment area upto 3000 Sq. Km.

Increase in design discharge, as per IRC:78-2000, Clause 703.1.1,P-10	30%	
Increased design discharge		114.73 cum/sec
Mean depth of scour below H.F.L, as per IRC:78-2000, Clause 703.2		
$d_{sf} = 1.34\ (D_b^2/K_{sf})^{1/3}$		
D_b = Design discharge per metre width		2.54 cum/sec/m
K_{sf} = Silt factor	2.52	
d_{sf} =		1.84 m
Maximum scour depth below H.F.L., as per IRC:78-2000, Clause 703.3		
For Abutment 1.27 d_{sf}		2.33 m

8 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point
0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9 m

9 Span arrangement

In proposed span arrangement, single span of 14.0 m has been proposed .

10 Afflux

The existing structure is a balancing type structure and lies in submerged area. The road level has been raised by min. 1.5 m above HFL. The water way is proposed to be 14.0 m against 12.4 m waterway of existing structure. Some additional balancing type culvert shall also be introduced to take care additional waterway.

11 Deck level

HFL at existing bridge site including afflux	232.670 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900 m
Depth of super structure including camber	1.450 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	235.076 m
Deck level of the existing bridge	233.945 m
Minimum deck level proposed	235.076 m

The proposed road levels as per highway allignment is 235.1m.

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	88.25	cum/sec
HFL	232.670	m
Bed level	229.452	m
Maximum scour depth	2.33	
Maximum scour level	227.122	m

Foundation level adopted in design	225.824	m
Hard rock level	226.452	m
Depth of embedment of foundation in rock	0.628	m

The depth of embedment of foundation in hard rock is more than 0.6m, floor protection is not provided.

The foundation may be anchored with 25 mm dia tor bars of 2.0m in length @ 1m c/c in both directions. The 2/3rd length of bar may be embeded in rock and 1/3rd in foundation concrete.

CHAPTER-6

BRIDGE AT CH:17/120

6. Hydraulic calculations for Bridge of road Bhawanipatna-Khariar

1 Name of the Nala : Manigah nala

Road No.:	S.H-16
G.T S No :	64P/4
Nearest Village :	Ratanpur
RD :	Km.17.120
Latitude	83^0 7' 00"
Longitude	20^0 3'00"
Sub-Zone	3(d)

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	3.500	sqkm
Q=	48.62	cum/s

3 Discharge by Rational Formula

Catchment area	3.500 sqkm	350.00	hectares
Length of path from toposheet (L)		2.500	km
Difference in levels from toposheet (H)		20	m
(Ref: Index map)			
Maximum rain fall (F)		116.56	mm
Duaration of storm (T)		4	hrs
One hour rainfall (I_o)	$I_o=(F/T)*(T+1)/(1+1)$	72.85	mm/hr
Time of concentration (SP-13, page 12)	$t_C=(0.87*L^3/H)^{0.385}$	0.86	hrs.
Critical rainfall intensity $I_C = I_O*(2/(1+t_C)$		78.25	mm/hr

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

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	350.00	Hectares
I_C =	7.825	cm/hr
Q=	30.676	cum/sec

tc= 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-4.1,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 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	48.62	cum/sec
Discharge by Rational Formula	30.68	cum/sec
Maximum discharge	48.62	cum/sec
Next maximum discharge	30.68	cum/sec

The difference is beyond 50% of the next maximum discharge

Hence design discharge **48.62 cum/sec**

Design discharge adopted **Q= 48.62 cum/sec**

5 Linear Water Way

Regime width as per Lacey's theory $W=4.8Q^{1/2}$ 33.47 m

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

6 Silt factor Based on Geotechnical investigation report

Depth(m)	silt factor			
0.75	1.188	0.891		
1.5	1.513	2.2695		
3	1.661	4.983		
5.25		8.1435	1.551143	Say 1.55

7 Scour depth

For catchment area upto 3000 Sq. Km.

Increase in design discharge, as per IRC:78-2000, Clause 703.1.1,P-10 30%

Increased design discharge 63.20 cum/sec

Mean depth of scour below H.F.L, as per IRC:78-2000, Clause 703.2

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

D_b = Design discharge per metre width 1.89 cum/sec/m

K_{sf} = Silt factor 1.55

d_{sf} = 1.77 m

Maximum scour depth below H.F.L, as per IRC:78-2000, Clause 703.3

For Pier $2\ d_{sf}$ 3.54 m

For Abutment $1.27\ d_{sf}$ 2.25 m

8 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9 m

9 Span arrangement

In proposed span arrangement, single span of 8.0 m has been proposed .

10 Afflux

The existing structure is a balancing type structure and lies in submerged area. The road level has been raised by min. 1.5 m above HFL. The water way is proposed to be 8.0 m against 6.3 m waterway of existing structure. Some additional balancing type culvert shall also be introduced to take care additional waterway.

11 Deck level

HFL at existing bridge site including afflux	224.991	m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900	m
Depth of super structure including camber	0.800	m
Wearing coat	0.056	m
Minimum deck level required as per hydraulic conditions	226.747	m
Deck level of the existing bridge	225.986	m
Minimum deck level proposed	226.747	m

The proposed formation level of bridge as per highway allignment has been kept as 226.786m.

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	48.62	cum/sec
HFL	224.991	m
Bed level	222.855	m
Maximum scour depth	2.25	m
Maximum scour level	222.741	m

Curtain wall shall be provided below maximum scour level

Bed level	222.855	m
Scour depth below bed	0.11	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.0	m
	d/s	2.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	0.23	3.0	m
	d/s	6.0	0.23	6.0	m

CHAPTER-7

BRIDGE AT CH:21/000

7. Hydraulic calculations for Minor Bridge of road Bhawanipatna-Khariar

1 Name of the Nala : Karla Pada nala

Road No.:	S.H-16
G.T S No :	64P/4
Nearest Village :	Karlaparha
RD :	Km.21/000
Latitude:	83^0 6'00"
Longitude	20^0 2'00"
Sub Zone	3(d)

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	3.500	sqkm
Q=	48.62	cum/s

3 Discharge by Rational Formula

Catchment area	3.500 sqkm	350.00	hectares
Length of path from toposheet (L)		5.250	km
Difference in levels from toposheet (H)		200	m
(Ref: Index map)			
Maximum rain fall (F)		116.56	mm
Duaration of storm (T)		4	hrs
One hour rainfall (I_o)	I_o=(F/T)*(T+1)/(1+1)	72.85	mm/hr
Time of concentration (SP-13, page 12)	$t_c=(0.87*L^3/H)^{0.385}$	0.84	hrs.
Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$		79.32	mm/hr
Discharge Q=0.028 * P*f* A* I_c			
P = (for loam, lightly cultivated or covered)		0.400	
f =		1.00	
A =		350.00	Hectares
I_c =		7.932	cm/hr
Q=		31.095	cum/sec

tc=	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-4.1,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 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	48.62 cum/sec	
Discharge by Rational Formula	31.10 cum/sec	
Maximum discharge	48.62 cum/sec	
Next maximum discharge	31.10 cum/sec	
The difference is beyond 50% of the next maximum discharge		
Hence design discharge	**48.62 cum/sec**	
Design discharge adopted	**Q=**	**48.62 cum/sec**

5 Linear Water Way

Regime width as per Lacey's theory $W=4.8Q^{1/2}$ 33.47 m

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

6 Silt factor Based on Geotechnical investigation report

Depth(m)	Silt factor			
0.75	0.853	0.63975		
1.5	0.597	0.8955		
3.5	1.236	4.326		
4.5	0.84	3.78		
10.25		9.64125	0.94061	say 0.94

7 Scour depth

For catchment area upto 3000 Sq. Km.

Increase in design discharge, as per IRC:78-2000, Clause 703.1.1,P-10 30%

Increased design discharge 63.20 cum/sec

Mean depth of scour below H.F.L, as per IRC:78-2000, Clause 703.2

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

D_b = Design discharge per metre width 1.89 cum/sec/m

K_{sf} = Silt factor 0.94

d_{sf} = 2.09 m

Maximum scour depth below H.F.L, as per IRC:78-2000, Clause 703.3

For Pier $2\ d_{sf}$ 4.18 m

For Abutment $1.27\ d_{sf}$ 2.65 m

8 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9 m

9 Span arrangement

In proposed span arrangement, single span of 12.0 m has been proposed with bed protection.

10 Afflux

The existing bridge is vented causeway with 3 x 0.6 m dia pipe in one row and 7 x 1.2 m dia pipe in another row. As per site condition this structure is a balancing type as no well defined cross-section is there.Keeping in view the submergence of area, vented causeway has been replaced by a High level bridge of span 1 x 12 m.

However it has been assumed that by replacing it by a high level bridge, around 0.5 m water level will be reduced.

11 Deck level

HFL at proposed bridge including afflux	218.807 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900 m
Depth of super structure including camber	1.250 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	221.013 m
Deck level of the existing bridge	218.807 m
Minimum deck level proposed	221.013 m

The proposed formation level as per proposed verticle profile is 221.200 m.

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	48.62	cum/sec
HFL	218.807	m
Bed level	215.848	m
Maximum scour depth	4.18	m
Maximum scour level	214.627	m

Proposed foundation level	211.178	m
Depth of foundation below maximum scour level	3.449	m

The above depth is more than than 2m, hence floor protection is not required.

CHAPTER-8

BRIDGES ON TEL & TEL APPROACHES
(27/600,27/800,28/400,28/900 & 29/400)

8. Hydraulic calculations for Tel River Bridge at km 28/400
Including bridges in the approaches (27/600, 27/800, 27/850, 28/900 and 29/400)

1 General features of bridges on Tel river:

The main bridge over Tel river is a high level bridge having 480 m linear waterway. In addition to this, there are three bridges on Bhawanipatna side (right flank) and two bridges on Khariar side (left flank) have been provided. There exists total 6 nos. bridges at this location. The Tel river is a wide channel. During low floods, water flows in main channel and some local flow in the side channels. During high flood periods, the water spreads upto HFL and all the side channels attain the same level as that of the main channel. The bridges on the left and right side channels have much lower deck level as compared to bridge over main channel and get submerged during high floods. The HFL of the main bridge was 212.83 m in year 1990 which was crossed to 213.99 m in year 1992. In the current year flood i.e. during the year 2006, the HFL attained a level of 215.10 m, which is the highest level recorded so far after construction of bridge as per OWD records. This observed HFL is much higher than the designed HFL. This is on account of the fact that the waterway provided at these bridge sites are much less than the required. To pass the high floods, water level rises at upstream side to have more head i.e. the afflux is more under present conditions of flow. In case this HFL value is used to calculate discharge from Manning's formula, then it will give very high results. Therefore to have a reasonable value of HFL under normal conditions of flow i.e. without contraction of waterway due to bridge, it is essential first to calculate afflux under present conditions. The correct approach would be, is to first calculate normal HFL without afflux. This normal HFL obtained after deducting afflux from the HFL observed during last flood event shall be used to calculate flood discharge.

The total width of Tel river stream has been divided into 3 sections for discharge calculation purposes. The section-1 is towards Bhawanipatna (right) side, section-2 is main section in the middle (main stream) and section-3 is towards Khariar (left) side. Afflux has been calculated by trial and error. Initially some value of afflux is assumed. Normal HFL is calculated by deducting it from the observed HFL. Discharge is calculated by Manning's formula at upstream and downstream sections. After comparing the discharge calculated by different methods, design discharge is fixed. For this design discharge, afflux is calculated for the present existing waterway. This afflux is compared with the afflux initially assumed and modified till the assumed afflux and the calculated afflux are nearly the same. Detailed calculations have been presented in the following steps.

Name of stream	Tel River	
Location of proposed bridge	(Latitude-84°32' / Longitute-19°23')	
HFL at proposed bridge site with afflux(as observed)	215.100	m
Afflux by trial and error, which has been calculated in following steps.	2.613	m
Normal HFL at proposed bridge site	212.487	m

The hydrological calculations has been done at three sections I.e. at upstream side, downstream side and near existing bridge locations using Manning's formula

2 Discharge by Manning's Formula at existing location:

	Section-1	Section-2	Section-3	Total	
Cross-sectional area of flow	1381.76	2749.66	1053.36	5184.78	sqm
Width of flow	680.00	480.00	580.00	1740.00	m
Wetted perimeter perpendicular to direction of flow	680.83	480.35	580.38	1741.57	m
Hydraulic mean radius R=A/P	2.03	5.72	1.81		m
Longitudinal slope as calculated	0.0016	0.0016	0.0016		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	0.035	0.08		
Velocity V=	1.069	3.657	0.744		m/s
Discharge Q=A*V	**1476.62**	**10055.83**	**783.65**	**12316.10**	cum/s

3 Discharge by Manning's Formula at upstream location:

	Section-1	Section-2	Section-3	Total	
Distance of upstream section from centre				400.00	m
HFL at this section				213.49	m
Cross-sectional area of flow	1626.84	2851.28	847.66	5325.78	sqm
Width of flow	620.00	540.00	880.00	2040.00	m
Wetted perimeter perpendicular to direction of flow	620.12	540.63	880.01	2040.76	m
Hydraulic mean radius R=A/P	2.62	5.27	0.96		m
Longitudinal slope as calculated	0.0025	0.0025	0.0025	0.0025	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	0.035	0.08		
Velocity V=	1.585	4.328	0.610		m/s

	Discharge Q=A*V	**2578.76**	**12341.49**	**516.72**	**15436.97**	cum/s

4 Discharge by Manning's Formula at downstream location:

Distance of downstream section from centre				400.00	m
HFL at this section				211.77	m
Cross-sectional area of flow	2024.12	2961.16	1663.76	6649.04	sqm
Width of flow	660.00	680.00	580.00	1920.00	m
Wetted perimeter perpendicular to direction of flow	660.19	680.24	580.23	1920.65	m
Hydraulic mean radius R=A/P	3.07	4.35	2.87		m
Longitudinal slope as calculated	0.0020	0.0020	0.0020	0.0018	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	0.035	0.08		
Velocity V=	1.573	3.407	1.128		m/s
Discharge Q=A*V	**3184.04**	**10087.35**	**1877.20**	**15148.60**	cum/s

5 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 in Sq.km.	8150.00	sqkm
Q=	16297.53	cum/s

6 Discharge by Rational Formula

Catchment area	8150.00 sqkm		815000.00	hectares
Length of path from toposheet (L)			143.750	km
Difference in levels from toposheet (H)			662.79	m

(Ref: Index map)

The severest storm occurred in 50 years in the region adopted for this stream as under.

(Ref: SUG of Tel River

Maximum rain fall (F)		228.59	mm
Duaration of storm (T)		17	hrs
One hour rainfall (Io)	Io=(F/T)*(T+1)/(1+1)	121.018	mm/hr
Time of concentration (SP-13, page 12)	$tc=(0.87*L^3/H)^{0.385}$	24.13	hrs.
Critical rainfall intensity Ic = Io*(2/(1+tc)		9.63	mm/hr

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

P = (for loam, lightly cultivated or covered)	0.500	
f =	1.00	
A =	815000.00	Hectares
Ic =	0.963	cm/hr
Q=	10990.252	cum/sec

7 Comparison of discharge

(Refer SP-13, page 21)

Discharge by Manning's Formula at U/S	15436.97	cum/sec
Discharge by Manning's Formula at D/S	15148.60	cum/sec
Discharge by Manning's Formula at B/S	12316.10	cum/sec
Discharge by Dicken's Formula	16297.53	cum/sec
Discharge by Rational Formula	10990.25	cum/sec
Discharge based on regional hydrology (SUG)	27515.00	cum/sec
Maximum discharge	27515.00	cum/sec
Next maximum discharge (by Mannings formula, Dicken's not considered being empirical)	15436.97	cum/sec
Hence design discharge adopted for afflux calculations	15436.97	cum/sec

8 Existing Water Way

	Section-1	Section-2	Section-3	Total	
bridge 1	58.40	480.50	33.20		
bridge 2	12.00		16.40		
bridge 3	75.20				
total waterway provided	145.60	480.50	49.60	675.70	m

9 Afflux for Existing Waterway

Cross-sectional area of flow (A)		5184.78	sqm
Top width of flow (W)		1740.00	m
Total water way provided (L)		675.70	m
Design discharge (Q)		15436.97	cum/sec
average depth of flow at d/s of bridge Dd=A/W		2.980	m
L/W		0.39	
Area of flow under the bridge, total for 6 bridges (a)		3468.29	sqm
a/A		0.67	
(Refer SP-13, page 55-56)	Cofficient e	0.97	
	Cofficient Co	0.866	
	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+ 0.100 u^2 = 3.995 (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 = (8.872 / u) - 2.980 (ii)

Combining (i) & (ii)

u - 0.01436 u^3 = 1.27199 (iii)

by trial & error	u =	1.304	
LHS of the equation (iii) =		1.27199	
Substituting u in equation (i), we get			
h=		3.825	m
The afflux as per Orifice formula		3.825	m

Since h>Dd/4, Weir formula will be applicable

By Weir formula, the discharge is given as

$Q= 1.706\ Cw\ L\ H^{3/2}$

$H=\{Q/(1.706\ Cw\ L)\}^{2/3}$

(Refer SP-13, page 52)

Cw for wide bridge opening with no bed=	0.98	
H=	5.716	m
Also Du = H - u^2/2g		
Assume Du = H =	5.716	m
u = Q/Wdu =	1.552	m/sec
Now Du = H - u^2/2g =	5.593	m
Dd as above	2.980	m
Afflux h=Du-Dd	2.613	m

h>Dd/4, OK

The afflux as per Weir formula 2.613 m

The afflux adopted 2.613 m

The afflux adopted is equal to the initially assumed value, hence OK.

10 Design Discharge

The discharge calculated at u/s and d/s side by Manning's formula and by Dicken's formula are reasonably close to each other.
As per above calculations, the maximum discharge by mannings formula is 15,436.97cum/s
The design discharge may be adopted as above

	Section-1	Section-2	Section-3	Total	
Thus the design discharge adopted =	**2578.76**	**12341.49**	**516.72**	**15436.97**	**cum/sec**

11 Proposed Water Way

Regime width	(Refer IRC:5-1998, Clause 104.3 or SP-13, page 23)	$W=4.8Q^{1/2}$	596.38 m
Existing natural width			1740.00 m
Maximum contracted width, assuming contraction upto 2/3(permissble)			1148.40 m
Minimum waterway,which may be required based on hydraulic considerations			1148.40 m

In case of purely alluviam streams, the stream flows within regime width (Lace'stheory). Where in the present case the width of flow is much more than the regime width. This indicates that Tel river is quassi alluviam in nature. Under high flood conditions, the water spreads in larger width rather than scouring the bed upto maximum scour.

Although the waterway required is much more than the regime width, it should be decided carefully. The main stream is about 560 m wide in which average depth is of the order of 6 to 7m. The depth of river is having shallow section on both sides varies from 1 to 4 m. In shuch cases it adviseable to provide restricted waterway depending upon the natural stream section. But it should not be restricted to such an extent that heavy scour may occur during high flood period. A balance dimensions should be maintained based on experience looking to the natural section of Tel river.

Site visit was made to identify deeper section of river flow in which vents can be provided. Embankment with river protection works can be provided in shallow sections to divert the flow towards the deeper sections. Presently three independent bridges exists on Bhawanipatna side(right flank). The linear waterway for these are 58.4 m, 12.0 m and 75.2 m respectively from Bhawanipatna side. The bridge having 12.0 m and 75.2 m waterway are lying in relatively deeper sections and needs more waterway. Overall waterway of about 240 m seems to be reasonable on this side combining these two bridges excluding 58.5m bridge. This makes a total waterway of 58.4 + 8x30.7 = 304.0m on Bhawanipatna side.

On Khariar side (left flank), there exists two bridges having 33.2 m and 16.4 m waterway. These are located relatively at deeper sections but needs more waterway.The linear water way of second bridge i.e. 16.4m may be increased by adding 2 spans of same size on either side making additional waterway of 2x8.2+2x8.2=32.8m.
This makes total waterway of 33.2 +16.4+32.8 = 82.2m on Khariar side, which seems to be reasonable at these locations.

	Section-1	**Section-2**	**Section-3**	**Total**
Existing waterway used	58.40	480.50	49.60	588.50 m
Additional water way proposed	245.60	0.00	34.00	279.60 m
Total waterway proposed to be provided	304.00	480.50	83.60	868.10 m

12 Scour depth

Increase in design discharge, as per IRC:78-2000, Clause 703.1.1	22.6%	22.6%	22.6%	22.6%
Increased design discharge	3162.66	15135.95	633.72	18932.34 cum/sec

Mean depth of scour, for obstructed as per IRC:78-2000, cl 703.2
(as per IRC:78-2000, Clause 703.3)
$d_{sf} = 1.34\ (D_b^2/K_{sf})^{1/3}$

Db = Design discharge per metre width	10.40	31.50	7.58	21.81 cum/sec/m
K_{sf} = Silt factor (avaerage)	1.44	1.30	1.67	1.30
d_{sf} =	5.66	12.25	4.36	9.58 m

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

For Pier	11.31	24.49	8.72	19.17 m
For Abutment	7.18	15.55	5.54	12.17 m

This depth of scour will not be applicable if rock is available at shallow depths.

13 Foundation depth

Pile type of foundation is proposed for new bridge sections on both sides of main bridge
Depth of pile shall be provided as per recommendations of Geo-technical investigations
Actual foundation level will be decided as per Geo-technical investigations

14 Afflux for proposed waterway

Cross-sectional area of flow (A)	5184.78 sqm
Top width of flow (W)	1740.00 m
Total water way provided (L)	868.10 m
Design discharge (Q)	15436.97 cum/sec
Average depth of flow at d/s of bridge Dd=A/W	2.980 m
L/W	0.50

Area of flow under the bridge, total provided (a)		4044.60 sqm
a/A		0.78
(Refer SP-13, page 55-56)	Cofficient e	0.77
	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 u^2 = 2.382 (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 = (8.872 / u) - 2.980 (ii)

Combining (i) & (ii)

u - 0.01685 u^3 = 1.65473 (iii)

By trial & error	u =	1.7441
LHS of the equation (iii) =		1.65473
Substituting u in equation (i), we get		
h=		2.107 m
The afflux as per Orifice formula		2.107 m

Since h>Dd/4, Weir formula will be applicable

By Weir formula, the discharge is given as

$Q= 1.706\ Cw\ L\ H^{3/2}$

$H=\{Q/(1.706\ Cw\ L)\}^{2/3}$

(Refer SP-13, page 52)

Cw for wide bridge opening with no bed=	0.98
H=	4.836 m
Also Du = H - $u^2/2g$	
Assume Du = H =	4.836 m
u = Q/Wdu =	1.834 m/sec
Now Du = H - $u^2/2g$ =	4.665 m
Dd as above	2.980 m
Afflux h=Du-Dd	1.685 m
h>Dd/4, OK	
The afflux as per Weir formula	1.685 m
The afflux adopted	1.685 m

15 Deck level

	for 9.2m span	for 32.2m span
Normal HFL at proposed bridge site	212.487	212.487 m
Afflux	1.685	1.685 m
HFL with afflux	214.172	214.172 m
Minimum vertical clearance (Table 12.1 of SP-13)	1.200	1.500 m
Depth of super structure	0.700	2.350 m
Wearing coat	0.056	0.056 m
Minimum deck level required as per hydraulic conditions	216.128	218.078 m
Deck level of the existing bridge at the proposed location	214.417	213.702 m
Minimum deck level proposed	216.128	218.078 m
The deck level as per profile of approaching road alignment.	216.189	218.139

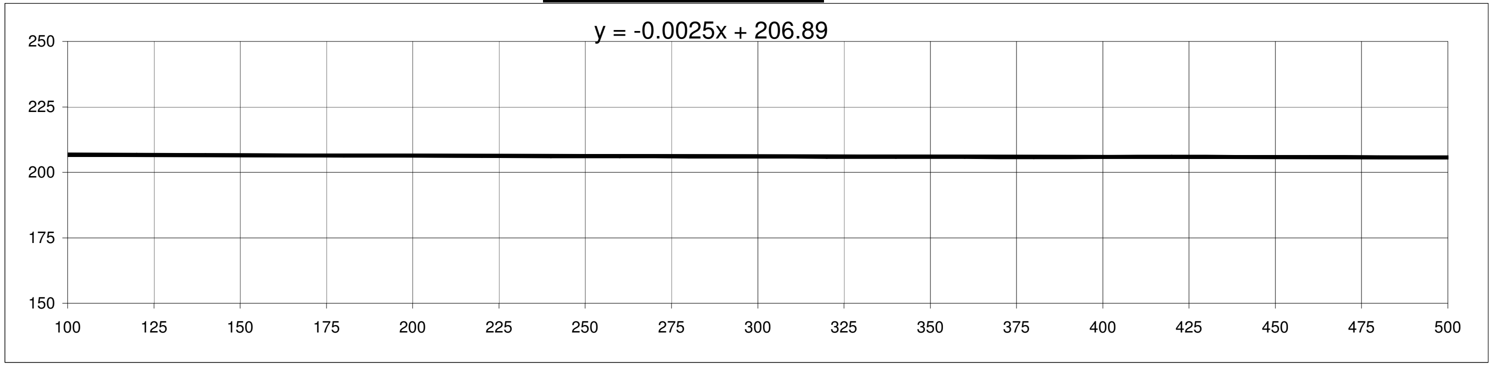
Existing main bridge

Existing deck level	219.183 m
Bearing level	214.513 m
Design HFL with afflux after proposed construction	214.172 m
Available free board for bearings	0.341 m
As per IRC:5-1998, required free board for metallic bearings	0.500 m

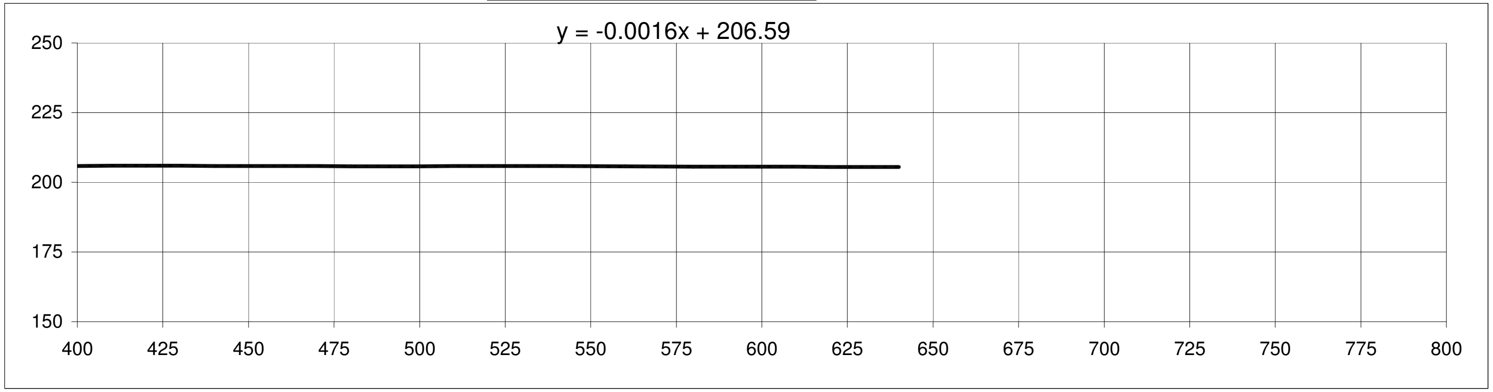
The available free board is marginally less than the required.

Note : Discharge calculations of Tel river at the existing site of bridges have been estimated using Dicken's empirical formula, Rational formula, Manning's formula and based on Regional Hydrological report of Maha nadi Sub-zone-3(d). There is a limitation to use Regional Flood estimation report for catchment area of a Project site having catchment area more than 3000 Sq.Km.and the design peak discharge estimated for the present site may not be reliable. On this river system there exists a Gauge-discharge site at Kesinage railway bridge site, about 16.25 Km downsream of the existing bridge sites, which are being regularly recorded by the Central Water Commission. In case yearly observed peak discharge data are made available, atleast for the past 20 to 25 years, then by making use of Statistical models, which involves flood frequency analysis in estimation of peak discharge for any return period, the design peak discharge at the Project site can be asessed. This approach has a universal recogination, reliable and acceptable for large catchment area of present site.

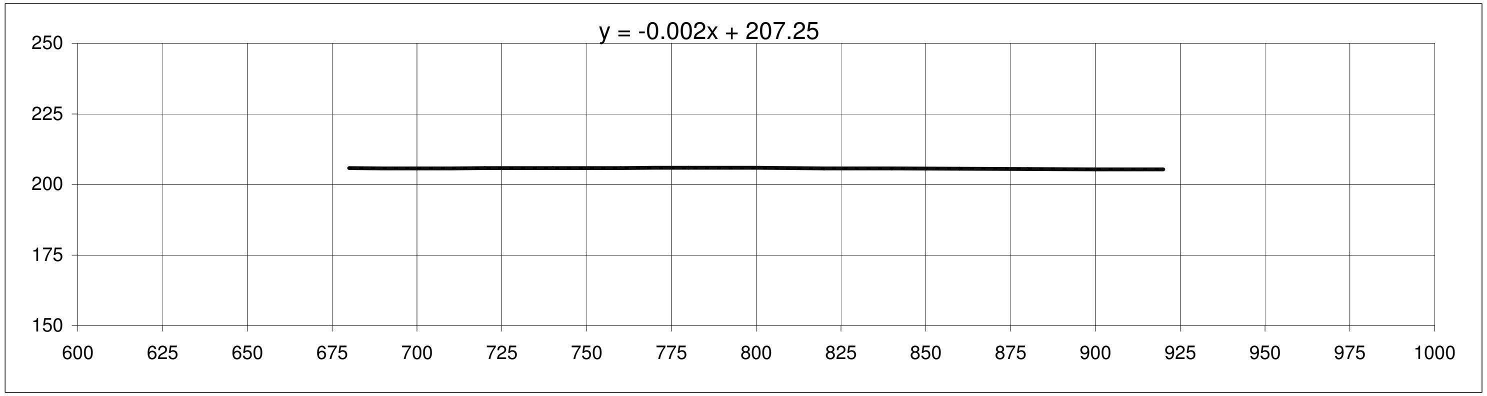
L-Section of River at U/S

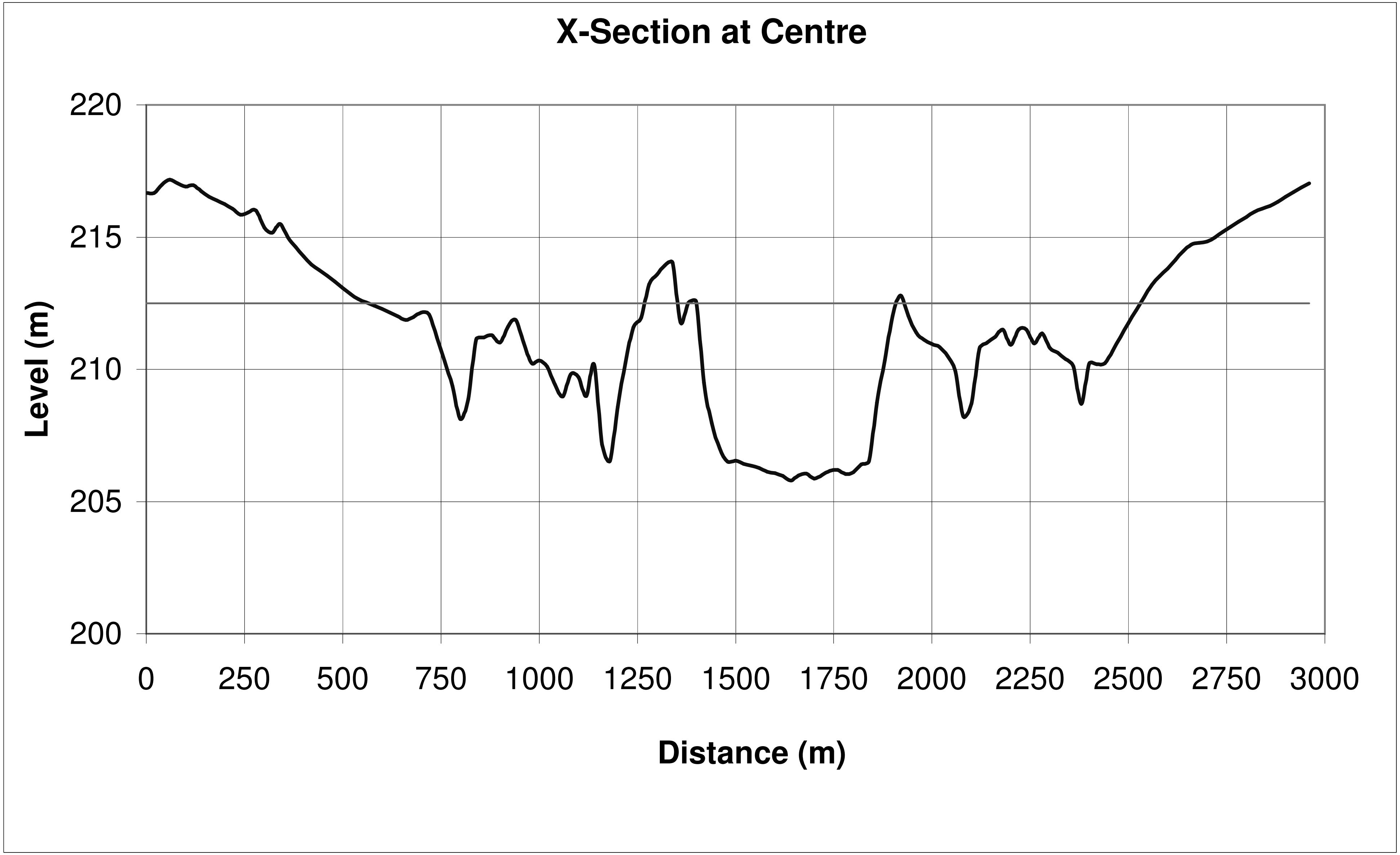


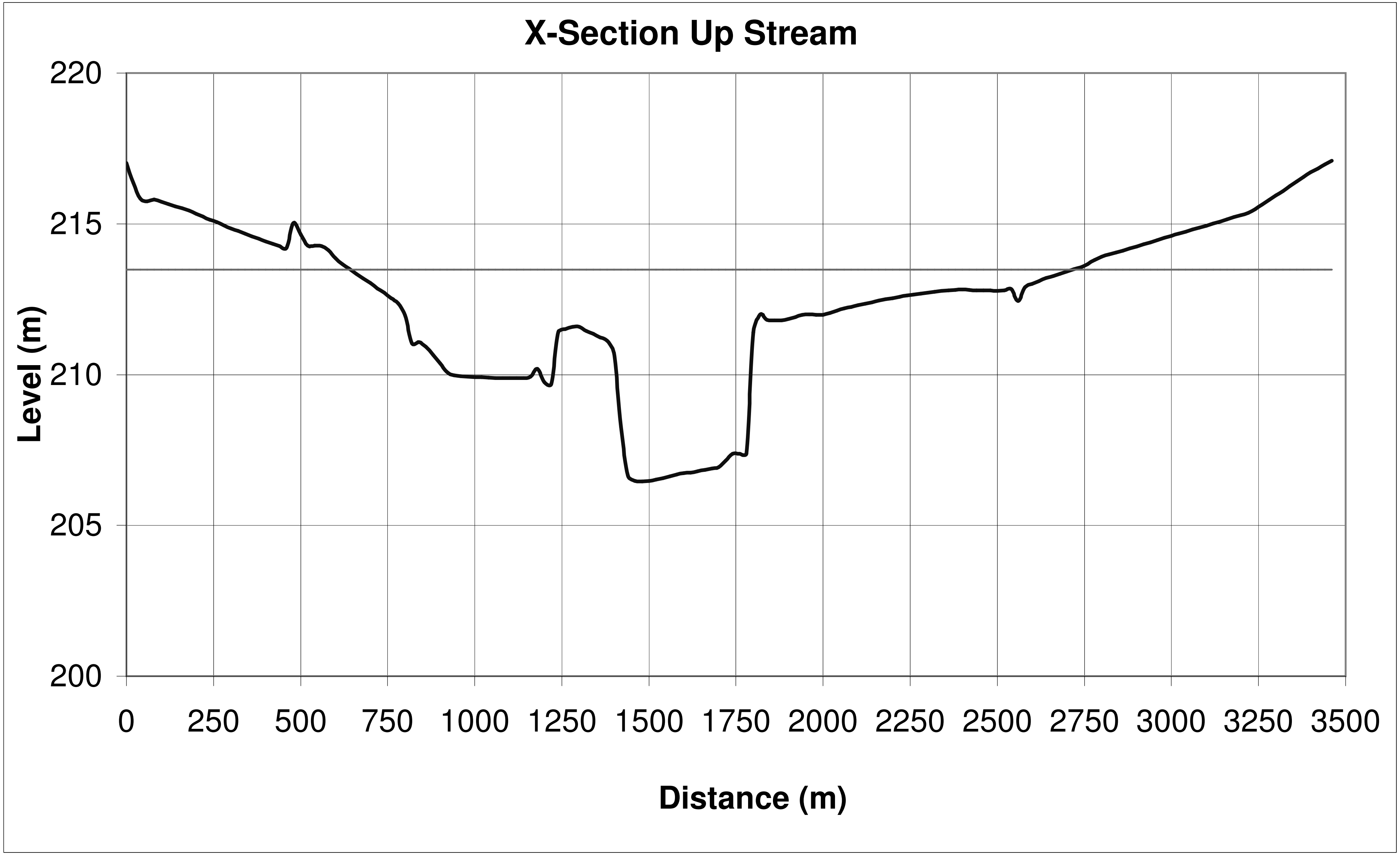
L-Section of Nallah at Centre

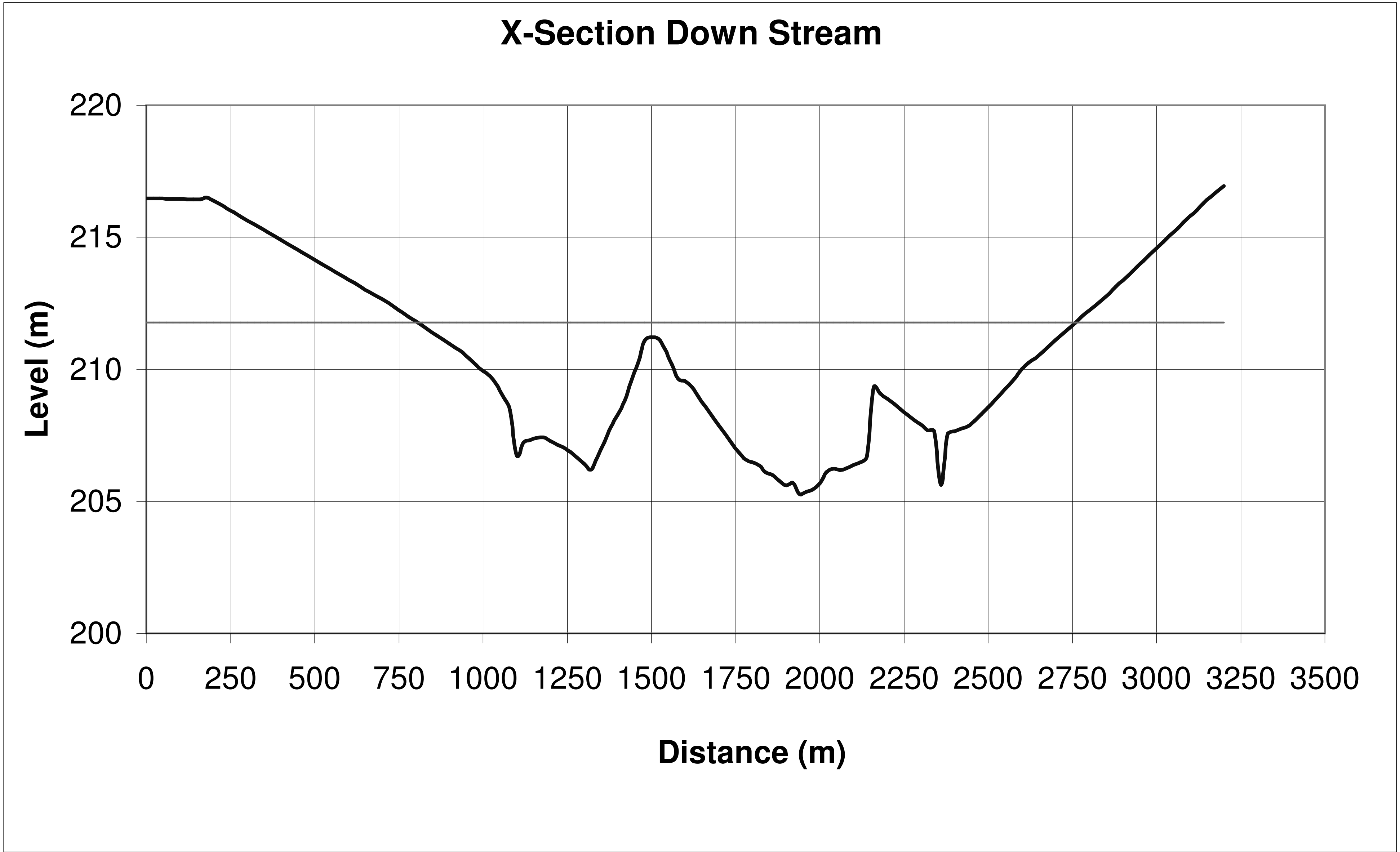


L-Section of Nallah at D/S




X-Section at Centre
220
215
210
205
200
Level (m)
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Distance (m)


X-Section Up Stream
Level (m)
220
215
210
205
200
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
Distance (m)


X-Section Down Stream
Level (m)
220
215
210
205
200
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
Distance (m)

ORISSA STATE ROAD PROJECT
HYDROLOGICAL STUDY

DEVELOPMENT OF DESIGN FLOOD HYDROGRAPH- BASED ON REGIONAL HYDROLOGY OF MAHA NADI SUB_BASIN

Road	: Bhawanipatna to Khariar
Name of River/Nallah/Stream	: Tel Nadi/River
Name of nearest Village/Town	:Sapasilat
RD	:Km.28.4
Latitude	:$82^0 55^' 00^"$
Longitude	:$19° 55^' 00^"$
GT Sheet No.	: 65 I, 64 L, 65M, 64P
Sub-Zone	Mahanadi-3(d)

Estimation of slope

S. No.	Reduced distance starting from gauging site (Point of study) (kms)	Reduced levels of river bed (m)	Length of each Segment- L_i (km)	Height above datum *(D_i Difference between the datum and the ith R.L.(m)	(D_{i-1} + D_i)	L_i (D_{i-1} + D_i) (4) x (6) (m x km)
1	2	3	4	5	6	7
1	0	161.32	0	0	0	0.00
2	24.75	361.32	24.75	200	200	4950.00
3	88.75	461.32	64	300	500	32000.00
4	101	561.32	12.25	400	700	8575.00
5	108.25	661.32	7.25	500	900	6525.00
6	129.75	761.32	21.5	600	1100	23650.00
7	143.75	824.11	14	662.79	1262.79	17679.06
					Σ Li (Di-1 + Di) =	93379.06

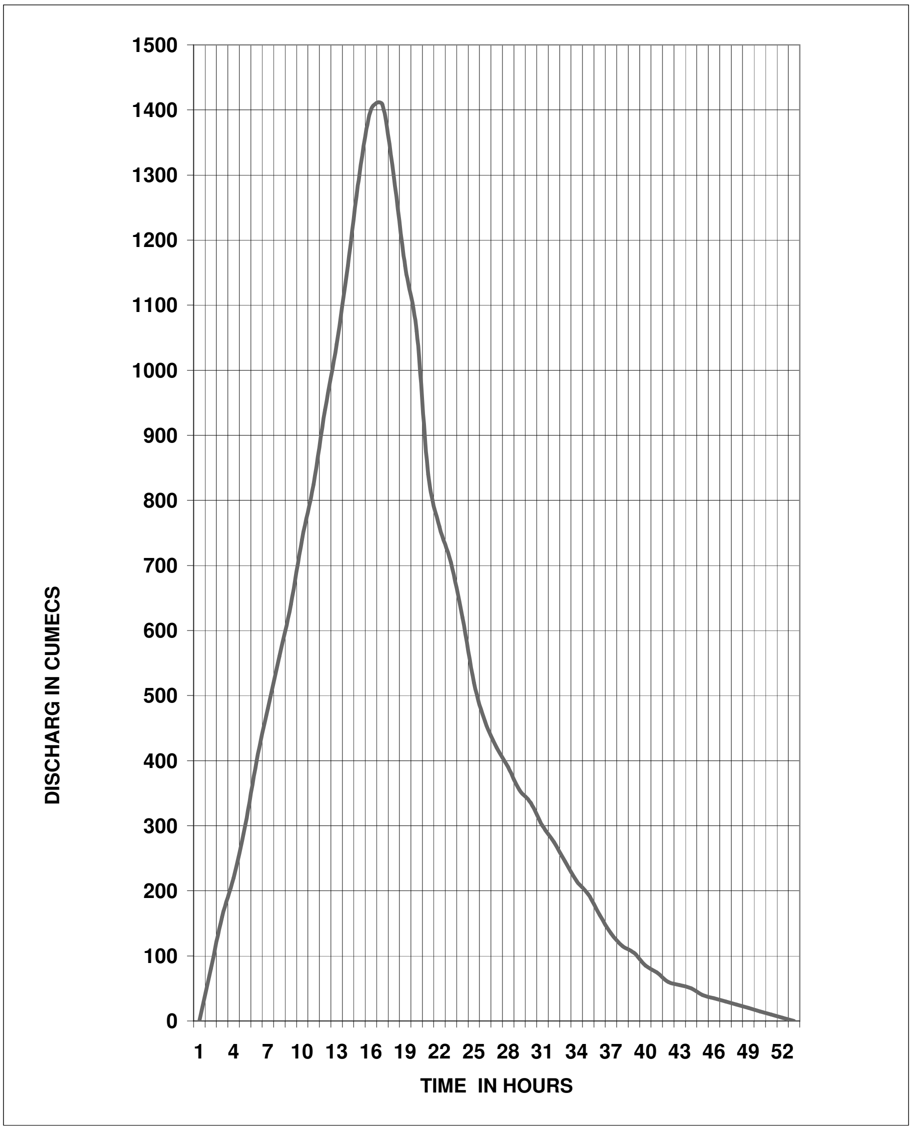
$$S = \frac{\Sigma L_i (D_{i-1} + D_i)}{L^2} = \mathbf{4.519\ m/km}$$

Synthetic Unitgraph

Base flow = 0.10 cumecs/ Sq.Km of catchment area
0.10*8150=815 cumecs

Catchment area =	8150.00 Sq.Km.
L =	143.75 km
Lc =	62.00 km
LxLc/(sqrt(s)) =	4192.55
t_p = 1.757((L X Lc)/sqrt(S))$^{0.261}$ =	15.50 hrs
Say	15.50 hrs
q_p = 1.260 (tp)$^{-0.725}$ =	0.17
Q_p = Catchment area x q_p =	1407.79 cumecs
W_{50} = 1.974 (q_p)$^{-1.104}$ =	13.72 hrs
W_{75} = 0.961 (q_p)$^{-1.125}$ =	6.93 hrs
W_{R50} = 1.150 (q_p)$^{-0.829}$ =	4.93 hrs
W_{R75} = 0.527 (q_p)$^{-0.932}$ =	2.71 hrs
Q_{50} = 0.5 x Q_p =	703.89 cumecs
Q_{75} = 0.75 x Q_p =	1055.84 cumecs
T_B = 5.411 (tp)$^{0.826}$ =	52.06 hrs
Storm duration ,t_r =	1 Hour

Unit Graph(1 cm 1 hour)				
S.N.	Time	Ordinate		
1	0	0		
2	1	80		
3	2	160		
4	3	220		
5	4	300		
6	5	400		
7	6	480		
8	7	560		
9	8	640		
10	9	740		
11	10	825		
12	11	940		
13	12	1040		
14	13	1160		
15	14	1300		
16	15	1400		
17	16	1407.79		
18	17	1300		
19	18	1160		
20	19	1060		
21	20	840		
22	21	760		
23	22	705		
24	23	620		
25	24	520		
26	25	460		
27	26	420		
28	27	390		
29	28	355		
30	29	335		
31	30	300		
32	31	275		
33	32	245		
34	33	215		
35	34	195		
36	35	163		
37	36	135		
38	37	115		
39	38	105		
40	39	85		
41	40	75		
42	41	60		
43	42	55		
44	43	50		
45	44	40		
46	45	35		
47	46	30		
48	47	25		
49	48	20		
50	49	15		
51	50	10		
52	51	5		
53	52	0		
		22830.8	cumec hours	
	=	10.0848	mm	



STORM DURATION Td = 1.1 t_p
= 1.1 X 15.5 = 17.1 say 17 Hrs

From Plate- 9 , the 50 -Year return period , 24 hour point rainfall = 280 mm (Based on Latitude & Longitude of Project site).
From Fig. 10, the 50 year return period ,17 hour point rainfall= 0.930*280 260 mm (Conversition ratio for 17 hour storm duration)

Areal Rainfall = 76.81 % of Point Rainfall Ref: Annexture-II
= 228.59 mm
Loss rate = 0.15 cm / hour (As per Fig.13)
Cumulative percentage

Hours	Storm Percentage	Storm Rainfall	Excess Rainfall	Incremental R.E.
0	0	0	0	0
1	22	50.290	48.790	48.790
2	41	93.722	92.222	43.432
3	48	109.723	108.223	16.001
4	55	125.725	124.225	16.001
5	64	146.298	144.798	20.573
6	68	155.441	153.941	9.144
7	71	162.299	160.799	6.858
8	77	176.014	174.514	13.715
9	79	180.586	179.086	4.572
10	82	187.444	185.944	6.858
11	86	196.587	195.087	9.144
12	90	205.731	204.231	9.144
13	93	212.589	211.089	6.858
14	95	217.161	215.661	4.572
15	96	219.446	217.946	2.286
16	98	224.018	222.518	4.572
17	100	228.590	227.090	4.572

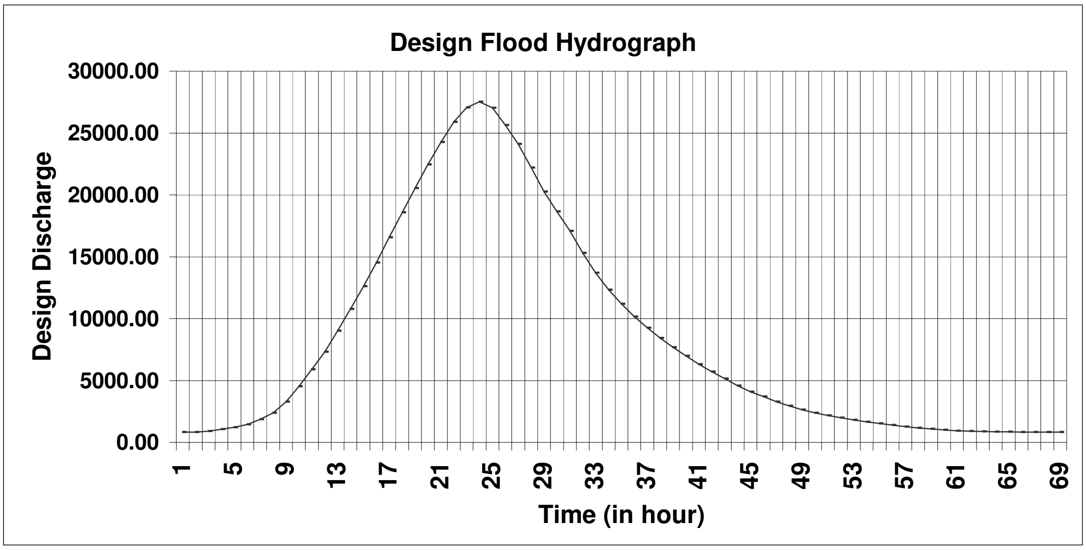
Estimation of Design Flood Hydrograph

Unit Graph(1 cm 1 hour)			R.E.	R.E.																		Base Flow	Design Flood Hydrograph
Sl. No	Time	Ordinate	Peak to Peak	Reverse order	0.229	0.686	0.914	0.457	0.686	2.057	1.600	4.879	4.343	1.600	0.914	1.372	0.686	0.914	0.457	0.457	0.457		
1	0	0			0																	815	815.00
2	1	80			18.29	0																815	833.29
3	2	160			36.57	54.86	0															815	906.44
4	3	220			50.29	109.72	73.15	0														815	1048.16
5	4	300			68.58	150.87	146.30	36.57	0													815	1217.32
6	5	400			91.44	205.73	201.16	73.15	54.86	0												815	1441.34
7	6	480	0		109.72	274.31	274.31	100.58	109.7	164.6	0											815	1848.23
8	7	560	4.57	2.29	128.01	329.17	365.74	137.15	150.9	329.2	128	0										815	2383.13
9	8	640	4.57	6.86	146.30	384.03	438.89	182.87	205.7	452.6	256	390.3	0									815	3271.77
10	9	740	4.57	9.14	169.16	438.89	512.04	219.45	274.3	617.2	352	780.6	347.5	0								815	4526.16
11	10	825	9.14	4.57	188.59	507.47	585.19	256.02	329.2	822.9	480	1073	694.9	128	0							815	5880.70
12	11	940	6.86	6.86	214.87	565.76	676.63	292.60	384	987.5	640.1	1464	955.5	256	73.15	0						815	7324.82
13	12	1040	13.72	20.57	237.73	644.62	754.35	338.31	438.9	1152	768.1	1952	1303	352	146.3	109.7	0					815	9011.67
14	13	1160	9.14	16.00	265.16	713.20	859.50	377.17	507.5	1317	896.1	2342	1737	480	201.2	219.4	54.86	0				815	10784.96
15	14	1300	16.00	48.79	297.17	795.49	950.93	429.75	565.8	1522	1024	2732	2085	640.1	274.3	301.7	109.7	73.15	0			815	12616.54
16	15	1400	43.43	43.43	320.03	891.50	1060.66	475.47	644.6	1697	1184	3123	2432	768.1	365.7	411.5	150.9	146.3	36.57	0		815	14522.41
17	16	1407.79	48.79	16.00	321.81	960.08	1188.67	530.33	713.2	1934	1320	3610	2780	896.1	438.9	548.6	205.7	201.2	73.15	36.57	0	815	16573.36
18	17	1300	16.00	9.14	297.17	965.42	1280.10	594.33	795.5	2140	1504	4025	3214	1024	512	658.3	274.3	274.3	100.6	73.15	36.57	815	18583.76
19	18	1160	20.57	13.72	265.16	891.50	1287.23	640.05	891.5	2386	1664	4586	3583	1184	585.2	768.1	329.2	365.7	137.2	100.58	73.15	815	20553.59
20	19	1060	6.86	6.86	242.31	795.49	1188.67	643.61	960.1	2675	1856	5074	4083	1320	676.6	877.8	384	438.9	182.9	137.15	100.6	815	22450.62
21	20	840	4.57	9.14	192.02	726.92	1060.66	594.33	965.4	2880	2080	5660	4517	1504	754.3	1015	438.9	512	219.4	182.87	137.2	815	24255.12
22	21	760	9.14	4.57	173.73	576.05	969.22	530.33	891.5	2896	2240	6343	5038	1664	859.5	1132	507.5	585.2	256	219.45	182.9	815	25879.22
23	22	705	6.86	4.57	161.16	521.19	768.06	484.61	795.5	2675	2253	6831	5646	1856	950.9	1289	565.8	676.6	292.6	256.02	219.4	815	27056.18
24	23	620	2.29	4.57	141.73	483.47	694.91	384.03	726.9	2386	2080	6869	6080	2080	1061	1426	644.6	754.3	338.3	292.60	256	815	27514.90
25	24	520			118.87	425.18	644.62	347.46	576	2181	1856	6343	6114	2240	1189	1591	713.2	859.5	377.2	338.31	292.6	815	27021.69
26	25	460			105.15	356.60	566.90	322.31	521.2	1728	1696	5660	5646	2253	1280	1783	795.5	950.9	429.7	377.17	338.3	815	25624.64
27	26	420			96.01	315.45	475.47	283.45	483.5	1564	1344	5172	5038	2080	1287	1920	891.5	1061	475.5	429.75	377.2	815	24108.46
28	27	390			89.15	288.02	420.61	237.73	425.2	1450	1216	4098	4604	1856	1189	1931	960.1	1189	530.3	475.47	429.7	815	22204.29
29	28	355			81.15	267.45	384.03	210.30	356.6	1276	1128	3708	3648	1696	1061	1783	965.4	1280	594.3	530.33	475.5	815	20259.93
30	29	335			76.58	243.45	356.60	192.02	315.5	1070	992.1	3440	3301	1344	969.2	1591	891.5	1287	640.1	594.33	530.3	815	18649.26
31	30	300			68.58	229.73	324.60	178.30	288	946.4	832.1	3025	3062	1216	768.1	1454	795.5	1189	643.6	640.05	594.3	815	17069.75
32	31	275			62.86	205.73	306.31	162.30	267.5	864.1	736.1	2537	2693	1128	694.9	1152	726.9	1061	594.3	643.61	640.1	815	15290.31
33	32	245			56.00	188.59	274.31	153.16	243.4	802.4	672.1	2244	2258	992.1	644.6	1042	576	969.2	530.3	594.33	643.6	815	13700.33
34	33	215			49.15	168.01	251.45	137.15	229.7	730.3	624.1	2049	1998	832.1	566.9	966.9	521.2	768.1	484.6	530.33	594.3	815	12316.37
35	34	195			44.58	147.44	224.02	125.72	205.7	689.2	568	1903	1824	736.1	475.5	850.4	483.5	694.9	384	484.61	530.3	815	11185.92
36	35	163			37.26	133.73	196.59	112.01	188.6	617.2	536	1732	1694	672.1	420.6	713.2	425.2	644.6	347.5	384.03	484.6	815	10154.06
37	36	135			30.86	111.78	178.30	98.29	168	565.8	480	1634	1542	624.1	384	630.9	356.6	566.9	322.3	347.46	384	815	9240.64
38	37	115			26.29	92.58	149.04	89.15	147.4	504	440	1464	1455	568	356.6	576	315.5	475.5	283.5	322.31	347.5	815	8427.08
39	38	105			24.00	78.86	123.44	74.52	133.7	442.3	392	1342	1303	536	324.6	534.9	288	420.6	237.7	283.45	322.3	815	7676.25
40	39	85			19.43	72.01	105.15	61.72	111.8	401.2	344	1195	1194	480	306.3	486.9	267.5	384	210.3	237.73	283.5	815	6976.24
41	40	75			17.14	58.29	96.01	52.58	92.58	335.3	312	1049	1064	440	274.3	459.5	243.4	356.6	192	210.30	237.7	815	6305.94
42	41	60			13.72	51.43	77.72	48.00	78.86	277.7	260.8	951.4	933.8	392	251.4	411.5	229.7	324.6	178.3	192.02	210.3	815	5698.38
43	42	55			12.57	41.15	68.58	38.86	72.01	236.6	216	795.3	846.9	344	224	377.2	205.7	306.3	162.3	178.30	192	815	5132.85
44	43	50			11.43	37.72	54.86	34.29	58.29	216	184	658.7	707.9	312	196.6	336	188.6	274.3	153.2	162.30	178.3	815	4579.51
45	44	40			9.14	34.29	50.29	27.43	51.43	174.9	168	561.1	586.3	260.8	178.3	294.9	168	251.4	137.2	153.16	162.3	815	4083.96
46	45	35			8.00	27.43	45.72	25.14	41.15	154.3	136	512.3	499.5	216	149	267.5	147.4	224	125.7	137.15	153.2	815	3684.51
47	46	30			6.86	24.00	36.57	22.86	37.72	123.4	120	414.7	456	184	123.4	223.6	133.7	196.6	112	125.72	137.2	815	3293.42
48	47	25			5.71	20.57	32.00	18.29	34.29	113.2	96.01	365.9	369.2	168	105.2	185.2	111.8	178.3	98.29	112.01	125.7	815	2954.55
49	48	20			4.57	17.14	27.43	16.00	27.43	102.9	88.01	292.7	325.7	136	96.01	157.7	92.58	149	89.15	98.29	112	815	2647.75
50	49	15			3.43	13.72	22.86	13.72	24	82.29	80.01	268.3	260.6	120	77.72	144	78.86	123.4	74.52	89.15	98.29	815	2389.96
51	50	10			2.29	10.29	18.29	11.43	20.57	72.01	64.01	243.9	238.9	96.01	68.58	116.6	72.01	105.2	61.72	74.52	89.15	815	2180.41
52	51	5			1.14	6.86	13.72	9.14	17.14	61.72	56	195.2	217.2	88.01	54.86	102.9	58.29	96.01	52.58	61.72	74.52	815	1981.90
53	52	0			0	3.43	9.14	6.86	13.72	51.43	48	170.8	173.7	80.01	50.29	82.29	51.43	77.72	48	52.58	61.72	815	1796.12
						0	4.57	4.57	10.29	41.15	40	146.4	152	64.01	45.72	75.43	41.15	68.58	38.86	48.00	52.58	815	1648.28
							0	2.29	6.858	30.86	32	122	130.3	56	36.57	68.58	37.72	54.86	34.29	38.86	48	815	1514.16
								0	3.429	20.57	24	97.58	108.6	48	32	54.86	34.29	50.29	27.43	34.29	38.86	815	1389.19
									0	10.29	16	73.18	86.86	40	27.43	48	27.43	45.72	25.14	27.43	34.29	815	1276.79
										0	8.001	48.79	65.15	32	22.86	41.15	24	36.57	22.86	25.14	27.43	815	1168.96
											0	24.39	43.43	24	18.29	34.29	20.57	32	18.29	22.86	25.14	815	1078.27
												0	21.72	16	13.72	27.43	17.14	27.43	16	18.29	22.86	815	995.59
													0	8.001	9.144	20.57	13.72	22.86	13.72	16.00	18.29	815	937.30
														0	4.572	13.72	10.29	18.29	11.43	13.72	16	815	903.01
															0	6.858	6.858	13.72	9.144	11.43	13.72	815	876.72
																0	3.429	9.144	6.858	9.14	11.43	815	855.00
																	0	4.572	4.572	6.86	9.144	815	840.14
																		0	2.286	4.57	6.858	815	828.72
																			0	2.29	4.572	815	821.86
																				0	2.286	815	817.29
																					0	815	815.00

Qp = 27515 Cumecs

C.A. = 8150 Sq. Kms.

Q=C*(M)^3/4
Dicken's C = Q/(8150)^3/4
32.08



Bridge at km 27+600 for Bhawanipatna - Khariar

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge of Tel River complete stream	15436.97	cum/sec
Design discharge for the part of stream on Bhawanipatna side	2578.76	cum/sec
HFL	214.172	m
Design velocity	1.59	m/s
Bed level	207.950	m
Maximum scour depth (2 d_{sf})	11.310	m
Maximum scour level	202.862	m

Curtain wall shall be provided below maximum scour level

Bed level		207.950	m
Scour depth below bed		5.09	m
Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	5.5	m
	d/s	6.0	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour deoth	Provided	
Flexible apron	u/s	3.0	10.18	10.5	m
	d/s	6.0	10.18	10.5	m

Floor Protection Works

At this location, one new major bridge is proposed in replacement of bridge at km 27+800 and 27+850.

As per hydrology report, the hydraulic parameters are as follows:

Design discharge of Tel River complete stream	15436.97	cum/sec
Design discharge for the part of stream on Bhawanipatna side	2578.76	cum/sec
HFL	214.172	m
Design velocity	1.59	m/s
Bed level	208.599	m
Maximum scour depth (2 d_{sf})	11.310	m
Maximum scour level	202.862	m

Type of foundation proposed	pile foundation
Pile cap top level	207.599
Pile cap bottom level	205.599

The piles are end bearing piles, resting on rock. There is no need of floor protection works.

Bridge at km 28+900 for Bhawani Patna - Khariar

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge of Tel River complete stream	15436.97	cum/sec
Design discharge for the part of stream on Khariar side	516.72	cum/sec
HFL	214.172	m
Design velocity	0.61	m/s
Bed level	208.432	m
Maximum scour depth (2 d_{sf})	8.720	m
Maximum scour level	205.452	m

Curtain wall shall be provided below maximum scour level

Bed level	208.432	m
Scour depth below bed	2.98	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2.0	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	3.5	m
	d/s	4.0	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour deoth	Provided	
Flexible apron	u/s	3.0	5.96	6.0	m
	d/s	6.0	5.96	6.0	m

Bridge at km 29+400 for Bhawani Patna - Khariar

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge of Tel River complete stream	15436.97	cum/sec
Design discharge for the part of stream on Khariar side	516.72	cum/sec
HFL	214.172	m
Design velocity	0.61	m/s
Bed level	209.300	m
Maximum scour depth (2 d_{sf})	8.720	m
Maximum scour level	205.452	m

Curtain wall shall be provided below maximum scour level

Bed level		209.300	m
Scour depth below bed		3.85	m
Minimum depth of curtan wall as per IRC:89-1997	u/s	2.0	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	4.5	m
	d/s	5.0	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour deoth	Provided	
Flexible apron	u/s	3.0	7.70	8.0	m
	d/s	6.0	7.70	8.0	m

CHAPTER-9

BRIDGE AT CH:45/700

9. Hydraulic calculations for Minor Bridge of road Bhawanipatna-Khariar

1 Name of the Nala : 45/700

Road No.:	S.H-16
G.T S No :	64L/16
Nearest Village :	Turuk bhata
RD :	Km.45.70
Latitude:	$82^0 57' 00''$
Longitude	$20^0 12' 00''$
Sub-Zone	3(d)

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	1.250	sqkm
Q=	22.46	cum/s

3 Discharge by Rational Formula

Catchment area	1.250	sqkm	125.00	hectares
Length of path from toposheet (L)			1.250	km
Difference in levels from toposheet (H)			10	m
(Ref: Index map)				
Maximum rain fall (F)			266.57	mm
Duaration of storm (T)			16	hrs
One hour rainfall (I_o)	$I_o=(F/T)*(T+1)/(1+1)$		141.615313	mm/hr
Time of concentration (SP-13, page 12)	$t_c=(0.87*L^3/H)^{0.385}$		0.51	hrs.
Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$			188.14	mm/hr

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

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	125.00	Hectares
I_c =	18.814	cm/hr
Q=	26.340	cum/sec

Here,

tc = 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-4.1,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 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	22.46 cum/sec		
Discharge by Rational Formula	26.34 cum/sec		
Maximum discharge	26.34 cum/sec		
Next maximum discharge	22.46 cum/sec		
The difference is within 50% of the next maximum discharge			
Hence design discharge	**26.34 cum/sec**		
Design discharge adopted	**Q=**	**26.34**	**cum/sec**

5 Linear Water Way

Regime width as per Lacey's theory $W=4.8Q^{1/2}$ 24.63 m

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

6 Silt factor

Depth(m)	Silt factor				
0.75	1.534	1.1505			
1.5	1.602	2.403		2.209	
4.5	2.328	10.476			
6.5	3.372	21.918			
13.25		35.9475	2.71301887 or say		2.71

7 Scour depth

For catchment area upto 3000 Sq. Km.

Increase in design discharge, as per IRC:78-2000, Clause 703.1.1,P.-10 30%

Increased design discharge 34.24 cum/sec

Mean depth of scour below H.F.L, as per IRC:78-2000, Clause 703.2

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

Db = Design discharge per metre width 1.39 cum/sec/m

K_{sf} = Silt factor 2.71

d_{sf} = 1.20 m

Maximum scour depth below H.F.L., as per IRC:78-2000, Clause 703.3

For Pier $2\ d_{sf}$ 2.39 m

for Abutment $1.27\ d_{sf}$ 1.52 m

8 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.60 m

9 Span arrangement

In proposed span arrangement, single span of 8.0 m has been proposed with bed protection.

10 Afflux

The existing structure is a balancing type structure and lies in submerged area. The road level has been raised by 1.5 m above HFL. The water way is proposed to be 8.0 m against 5.2 m waterway of existing structure. Some additional balancing type culvert shall also be introduced to take care additional waterway.

11 Deck level

HFL at existing bridge site including afflux	228.824 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.600 m
Depth of super structure including camber	0.800 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	230.280 m
Deck level of the existing bridge	229.649 m
Minimum deck level proposed	230.280 m

The formation level of proposed bridge has been kept 231.6m as the stretch lies in submerged portion and levels has been decided keeping in view the approaches on both side I.e. Bhawanipatna and Khariar side.

CHAPTER-10

BRIDGE AT CH:54/600

10. Hydraulic calculations for Minor Bridge of road Bhawanipatna-Khariar

1 Name of the Nala : Kana Nala

Road No :	S.H-16
G.T S No :	64L/16
Nearest Village :	Tureikela
RD :	Km.54.600
Latitude:	82^0 52'00"
Longitude	20^0 12'00"
Sub Zone	3(d)

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	27.750	sqkm
Q=	229.72	cum/s

3 Discharge by Rational Formula

Catchment area	27.750 sqkm	2775.00	hectares
Length of path from toposheet (L)		7.250	km
Difference in levels from toposheet (H)		100	m
(Ref: Index map)			
Maximum rain fall (F)		266.57	mm
Duaration of storm (T)		16	hrs
One hour rainfall (I_o)	I_o=(F/T)*(T+1)/(1+1)	141.6153125	mm/hr
Time of concentration (SP-13, page 12)	$t_c=(0.87*L^3/H)^{0.385}$	1.59	hrs.
Critical rainfall intensity $I_c = I_o*(2/(1+tc)$		109.51	mm/hr
Discharge Q=0.028 * P*f* A* I_c			
P = (for loam, lightly cultivated or covered)		0.400	
f =		1.00	
A =		2775.00	Hectares
I_c =		10.951	cm/hr
Q=		340.353	cum/sec

Here,

tc=	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-4.1,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 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	229.72	cum/sec
Discharge by Rational Formula	340.35	cum/sec
Maximum discharge	340.35	cum/sec
Next maximum discharge	229.72	cum/sec

The difference is within 50% of the next maximum discharge

Hence design discharge **340.35 cum/sec**

Design discharge adopted **Q= 340.35 cum/sec**

5 Linear Water Way

Regime width as per Lacey's theory $W=4.8Q^{1/2}$ 88.55 m

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

6 Silt factor

Depth(m)	Silt factor			
0.75	1.018	0.7635		
1.5	3.186	4.779		
3	2.879	8.637		
5.25		14.1795	2.700857	Say 2.70

7 Scour depth

For catchment area upto 3000 Sq. Km.

Increase in design discharge, as per IRC:78-2000, Clause 703.1.1,P.-10 30%

Increased design discharge 442.46 cum/sec

Mean depth of scour below H.F.L, as per IRC:78-2000, Clause 703.2

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

D_b = Design discharge per metre width 5.00 cum/sec/m

K_{sf} = Silt factor Based on Geotechnical investigation report 2.7

d_{sf} = 2.81 m

Maximum scour depth below H.F.L, as per IRC:78-2000, Clause 703.3

For Pier $2\ d_{sf}$ 5.63 m

For Abutment $1.27\ d_{sf}$ 3.57 m

8 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point

0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9 m

9 Foundation depth

Depth of foundation below max. scour, as per IRC:78-2000, cl 705.2	2.00 m
HFL at site	240.009 m
Max. Scour level	234.384 m
Desired foundation level	232.384 m
Bed level at site	236.941 m

10 Afflux

There is no well defined cross-section .The HFL noticed is including afflux.

11 Deck level

HFL at existing bridge site including afflux	240.009 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900 m
Depth of super structure including camber	0.925 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	241.890 m
Deck level of the existing bridge	239.701 m
Minimum deck level proposed	241.890 m

The proposed formation level has been kept as 241.909m.

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	340.35	cum/sec
HFL	240.009	m
Bed level	236.941	m
Maximum scour depth	5.63	m
Maximum scour level	234.379	m
Rock level	232.905	m
Applicable scour level	234.379	m

Proposed foundation level for pier	232.000	m
Depth of foundation below maximum scour level	2.379	m

The depth of foundation is more than 2.0m below maximum scour, hence floor protection not provided.

CHAPTER-11

BRIDGE AT CH:58/900

11. Hydraulic calculations for Minor Bridge of road Bhawanipatna-Khariar

1	**Name of the Nala :**	Chandel Nala
	Road No :	S.H-16
	G.T S No :	64L/16
	Nearest Village :	Bankapur
	RD :	Km.58.900
	Latitude:	$82^0 51' 00''$
	Longitude	$20^0 15' 00''$
	Sub Zone	3(d)

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	6.100	sqkm
Q=	**73.75**	**cum/sec**

3 Discharge by Rational Formula

Catchment area	6.100 sqkm	610.00	hectares
Length of path from toposheet (L)		4.750	km
Difference in levels from toposheet (H)		100	m
(Ref: Index map)			
Maximum rain fall (F)		266.57	mm
Duaration of storm (T)		16	hrs
One hour rainfall (I_o)	I_o=(F/T)*(T+1)/(1+1)	141.615313	mm/hr
Time of concentration (SP-13, page 12)	$t_c=(0.87*L^3/H)^{0.385}$	0.97	hrs.
Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$		143.52	mm/hr
Discharge Q=0.028 * P*f* A* I_c			
P = (for loam, lightly cultivated or covered)		0.400	
f =		1.00	
A =		610.00	Hectares
I_c =		14.352	cm/hr
Q=		**98.055**	**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-4.1,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 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	73.75 cum/sec		
	Discharge by Rational Formula	98.06 cum/sec		
	Maximum discharge	98.06 cum/sec		
	Next maximum discharge	73.75 cum/sec		
	The difference is within 50% of the next maximum discharge			
	Hence design discharge	**98.06 cum/sec**		
	Design discharge adopted	**Q=**	**98.06**	**cum/sec**

5 Linear Water Way

Regime width as per Lacey's theory $W = 4.8Q^{1/2}$ 47.53 m

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

6 Silt factor

Depth (m)	Silt factor			
0.75	1.461	1.09575		
1.5	1.551	2.3265		
2.25		3.42225	1.521	Say 1.52

7 Scour depth

For catchment area upto 3000 Sq. Km.

Increase in design discharge, as per IRC:78-2000, Clause 703.1.1,P.10	30%		
Increased design discharge		127.47	cum/sec

Mean depth of scour below H.F.L., as per IRC:78-2000, Clause 703.2

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

D_b = Design discharge per metre width		2.68	cum/sec/m
K_{sf} = Silt factor	1.52		
d_{sf} =		2.11	

Maximum scour depth below H.F.L, as per IRC:78-2000, Clause 703.3

For Pier	$2\ d_{sf}$	4.23	m
For Abutment	$1.27\ d_{sf}$	2.68	m

8 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9 m

9 Foundation depth

Depth of foundation below max. scour, as per IRC:78-2000, cl 705.2	2.00	m
HFL at site	242.295	m
Max. Scour level	238.068	m
Desired foundation level	236.068	m
Bed level at site	239.785	m

10 Afflux

There is no well defined stream and the structure is being used to pass surplus water of sunder river.

11 Deck level

HFL at proposed bridge site including afflux	242.295	m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900	m
Depth of super structure including camber	2.200	m
Wearing coat	0.056	m
Minimum deck level required as per hydraulic conditions	245.451	m
Deck level of the existing bridge	243.070	m
Minimum deck level proposed	245.451	m

The min. formation level shall be kept 245.451 m.

CHAPTER-12

BRIDGE AT CH:59/100

12. Hydraulic calculations for Major Bridge of road Bhawanipatna-Khariar

1	**Name of the Nala :**	Sunder Nadi	
	Road No :	S.H-16	
	G.T S No :	64L/15	
	Nearest Village :	Bankapur	
	RD :	Km.59.100	
	Latitude:	82^0 50' 00"	
	Longitude	20^0 31'00"	
	Sub Zone	3(d)	

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	1493.750	sqkm
Q=	4565.22	cum/s

3 Discharge by Rational Formula

Catchment area	1493.750 sqkm		149375.00	hectares
Length of path from toposheet (L)			81.250	km
Difference in levels from toposheet (H)			100	m
(Ref: Index map)				
Maximum rain fall (F)			266.57	mm
Duaration of storm (T)			16	hrs
One hour rainfall (I_o)	$I_o=(F/T)*(T+1)/(1+1)$		141.615313	mm/hr
Time of concentration (SP-13, page 12)	$t_c=(0.87*L^3/H)^{0.385}$		25.86	hrs.
Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$			10.55	mm/hr
Discharge $Q=0.028 * P*f* A* I_c$				
P = (for loam, lightly cultivated or covered)			0.400	
f =			1.00	
A =			149375.00	Hectares
I_c =			1.055	cm/hr
Q=			**1764.393**	**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-4.1,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 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	4565.22	cum/sec
Discharge by Rational Formula	1764.39	cum/sec
Discharge by SUG	5133.00	cum/sec
Maximum discharge	5133.00	cum/sec
Next maximum discharge	4565.22	cum/sec

The difference is within 50% of the next maximum discharge

Hence design discharge **5133.00 cum/sec**

Design discharge adopted **Q= 5133.00 cum/sec**

5 Linear Water Way

Regime width as per Lacey's theory $W=4.8Q^{1/2}$ 343.90 m

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

6 Scour depth

For catchment area upto 3000 Sq. Km.

Increase in design discharge, as per IRC:78-2000, Clause 703.1.1,P.-10 30%

Increased design discharge 6672.90 cum/sec

Mean depth of scour below H.f.L., as per IRC:78-2000, Clause 703.2

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

D_b = Design discharge per metre width 19.40 cum/sec/m

K_{sf} = Silt factor 1 assumed

d_{sf} = 9.68

Maximum scour depth below H.F.L, as per IRC:78-2000, Clause 703.3

For Pier $2\ d_{sf}$ 19.35 m

For Abutment $1.27\ d_{sf}$ 12.29 m

7 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 1.5 m

9 Afflux

Cross-sectional area of flow (A)		1821.78	sqm
Regime width of flow (W)		343.90	m
Total water way provided (L)		225.30	m
Design discharge (Q)		5133.00	cum/sec
Depth of flow at d/s of bridge Dd=A/W		5.297	m
L/W		0.655	
(Refer SP-13, page 55-56)	Cofficient e	0.97	
	Cofficient Co	0.863	
	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

$h + 0.100\ u^2 = 1.266$ (i)

Also at u/s of the bridge

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

Substituting values, we have

$h = (14.926\ / u) - 5.297$ (ii)

Combining (i) & (ii)

$u - 0.01530\ u^3 = 2.27416$ (iii)

by trial & error	u =	2.519
LHS of the equation (iii) =		2.27446

Substituting u in equation (i), we get

h= 0.628 m

The afflux as per Orifice formula 0.628 m

h<Dd/4, OK

The afflux adopted 0.628 m

10 Deck level

HFL at proposed bridge site including afflux	243.536 m
Minimum vertical clearance (Table 12.1 of SP-13)	1.500 m
Depth of super structure including camber	1.850 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	246.942 m
Deck level of the existing bridge	246.661 m

The bridge has sufficient margin of vertical clearance and in good condition from the structural point of view.
The vertical clearance available is (1.5-246.942+246.661) I.e. 1.219 m.
Hence it is recommended to retain the bridge without any additional waterway.

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	5133.00	cum/sec
HFL	243.536	m

This is a major bridge with well foundations (deep foundations), there is no need of floor protection.

CHAPTER-13

BRIDGE AT CH:59/400

13. Hydraulic calculations for Minor Bridge of road Bhawanipatna-Khariar

1 Name of the Nala : Tukulia nala-Indra Sunder nadi

Road No :	S.H-16
G.T S No :	64L/15
Nearest Village :	Malpara
RD :	Km.59.40
Latitude:	82^0 51' 30"
Longitude	20^0 15'00"
Sub-Zone	3(d)

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	4.100	sqkm
Q=	54.74	cum/s

3 Discharge by Rational Formula

Catchment area		4.100 sqkm	410.00	hectares
Length of path from toposheet (L)			2.050	km
Difference in levels from toposheet (H)			20	m
(Ref: Index map)				
Maximum rain fall (F)			266.57	mm
Duaration of storm (T)			16	hrs
One hour rainfall (I_o)	I_o=(F/T)*(T+1)/(1+1)		141.615313	mm/hr
Time of concentration (SP-13, page 12)	$t_c=(0.87*L^3/H)^{0.385}$		0.69	hrs.
Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$			168.06	mm/hr
Discharge Q=0.028 * P*f* A* I_c				
P = (for loam, lightly cultivated or covered)			0.400	
f =			1.00	
A =			410.00	Hectares
I_c =			16.806	cm/hr
Q=			77.172	cum/sec

tc= 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-4.1,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 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	54.74 cum/sec	
	Discharge by Rational Formula	77.17 cum/sec	
	Maximum discharge	77.17 cum/sec	
	Next maximum discharge	54.74 cum/sec	
	The difference is within 50% of the next maximum discharge		
	Hence design discharge	**77.17 cum/sec**	
	Design discharge adopted	**Q=**	**77.17 cum/sec**

5 Linear Water Way

Regime width as per Lacey's theory $W=4.8Q^{1/2}$ 42.17 m

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

6 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9 m

7 Afflux

There is no well defined cross-section .The HFL noticed is including afflux.

8 Deck level

HFL at existing bridge site including afflux	242.328 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900 m
Depth of super structure including camber	0.650 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	243.934 m
Deck level of the existing bridge	243.803 m

Keeping in view, the structural soundness and sufficient free board available and the site condition, it is suggested to retain the bridge without any increase in waterway or raising the existing road.

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	77.17	cum/sec
HFL	242.328	m
Bed level	239.050	m
Maximum scour depth	4.78	m
Maximum scour level	237.548	m

Curtain wall shall be provided below maximum scour level

Bed level		239.05	m
Scour depth below bed		1.50	m
Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.0	m
	d/s	2.5	m

Rigid apron as per IRC:89-1997 Upto the end of splayed wing walls on both sides.

Formation level	243.803	m
Width of bridge	8.6	m
Camber	2.50%	
Road top level at edge of bridge	243.696	m
Natural bed level	239.050	m
Floor level	238.750	m
Height of retained earth at high end	4.95	m
Height of retained earth at low end	1.00	m
Side slope, 1 V : H	2.0	
Length of rigid apron	7.9	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	3.00	3.0	m
	d/s	6.0	3.00	6.0	m

CHAPTER-14

BRIDGE AT CH:63/650

14. Hydraulic calculations for Minor Bridge of road Bhawanipatna-Khariar

1 **Name of the Nala :** Rasigaon nala

Road No :	S.H-16
G.T S No :	64L/15
Nearest Village :	Lachhipur
RD :	Km.63.65
Latitude	82^{0} 49' 00"
Longitude	20^{0} 16'00"
Sub Zone	3(d)

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	6.250	sqkm
Q=	**75.10**	**cum/sec**

3 **Discharge by Rational Formula**

Catchment area	6.250 sqkm		625.00	hectares
Length of path from toposheet (L)			3.750	km
Difference in levels from toposheet (H)			180	m
(Ref: Index map)				
Maximum rain fall (F)			266.57	mm
Duaration of storm (T)			16	hrs
One hour rainfall (I_o)	I_o=(F/T)*(T+1)/(1+1)		141.615	mm/hr
Time of concentration (SP-13, page 12)		$t_c=(0.87*L^3/H)^{0.385}$	0.59	hrs.
Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$			178.04	mm/hr

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

P = (for loam, lightly cultivated or covered)	0.400	
f =	1.00	
A =	625.00	Hectares
I_c =	17.804	cm/hr
Q=	**124.630**	**cum/sec**

tc= 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-4.1,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 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	75.10 cum/sec		
Discharge by Rational Formula	124.63 cum/sec		
Maximum discharge	124.63 cum/sec		
Next maximum discharge	75.10 cum/sec		
The difference is beyond 50% of the next maximum discharge			
Hence design discharge	**124.63 cum/sec**		
Design discharge adopted	**Q=**	**124.63**	**cum/sec**

5 Linear Water Way

Regime width as per Lacey's theory $W=4.8Q^{1/2}$ 53.59 m

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

6 Silt factor based on Geotechnical investigation report

Depth(m)	Silt factor			
0.75	1.124	0.843		
3	1.33	3.99		
3.75		4.833	1.2888	Say 1.29

7 Scour depth

For catchment area upto 3000 Sq. Km.

Increase in design discharge, as per IRC:78-2000, Clause 703.1.1,P.10 30%

Increased design discharge 162.02 cum/sec

Mean depth of scour below H.F.L, as per IRC:78-2000, Clause 703.2

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

D_b = Design discharge per metre width 3.02 cum/sec/m

K_{sf} = Silt factor 1.29

d_{sf} = 2.57 m

Maximum scour depth below H.F.L, as per IRC:78-2000, Clause 703.3

For Pier $2\ d_{sf}$ 5.15 m

For Abutment $1.27\ d_{sf}$ 3.27 m

8 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9 m

9 Span arrangement

In proposed span arrangement, single span of 8.0 m has been proposed with bed protection.

10 Afflux

The existing structure is a balancing type structure and lies in submerged area. The road level has been raised by 1.5 m above HFL. The water way is proposed to be 8.0 m against 6.6 m waterway of existing structure. Some additional balancing type culvert shall also be introduced to take care additional waterway.

11 Deck level

HFL at proposed bridge site including afflux	247.868 m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900 m
Depth of super structure including camber	0.800 m
Wearing coat	0.056 m
Minimum deck level required as per hydraulic conditions	249.624 m
Deck level of the existing bridge	248.643 m
Minimum deck level proposed	249.624 m

As per the proposed allignment, the formation level of bridge has been kept as 250.244m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	124.63	cum/sec
HFL	247.868	m
Bed level	247.279	m
Maximum scour depth	3.27	m
Maximum scour level	244.598	m

Curtain wall shall be provided below maximum scour level

Bed level		247.279	m
Scour depth below bed		2.68	m
Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	3.5	m
	d/s	4.0	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	5.36	5.5	m
	d/s	6.0	5.36	6.0	m

CHAPTER-15

BRIDGE AT CH:66/500

15. Hydraulic calculations for Minor Bridge of road Bhawanipatna-Khariar

1 Name of the Nala : Lachhipur Nala

Road No :	S.H-16
G.T S No :	64L/15
Nearest Village :	Lachhipur
RD :	Km.66.50
Latitude	82^0 47'00"
Longitude	20^0 16'00"
Sub Zone	3(d)

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	2.875	sqkm
Q=	41.95	cum/s

3 Discharge by Rational Formula

Catchment area	2.875 sqkm		287.50	hectares
Length of path from toposheet (L)			2.500	km
Difference in levels from toposheet (H)			170	m
(Ref: Index map)				
Maximum rain fall (F)			266.57	mm
Duaration of storm (T)			16	hrs
One hour rainfall (I_o)	$I_o=(F/T)*(T+1)/(1+1)$		141.61531	mm/hr
Time of concentration (SP-13, page 12)		$t_c=(0.87*L^3/H)^{0.385}$	0.38	hrs.
Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$			205.52	mm/hr
Discharge $Q=0.028 * P*f* A* I_c$				
P = (for loam, lightly cultivated or covered)			0.400	
f =			1.00	
A =			287.50	Hectares
I_c =			20.552	cm/hr
Q=			66.178	cum/sec

tc= 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-4.1,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 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	41.95	cum/sec	
Discharge by Rational Formula	66.18	cum/sec	
Maximum discharge	66.18	cum/sec	
Next maximum discharge	41.95	cum/sec	

The difference is beyond 50% of the next maximum discharge

Design discharge adopted Q= **66.18 cum/sec**

5 Linear Water Way

Regime width as per Lacey's theory $W=4.8Q^{1/2}$ **39.05 m**

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

6 Silt factor Based on Geotechnical investigation report

Depth(m)	Silt factor		
0.75	1.214	0.9105	
3	1.33	3.99	
3.75		4.9005	1.3068 or Say 1.31

7 Scour depth

For catchment area upto 3000 Sq. Km.

Increase in design discharge, as per IRC:78-2000, Clause 703.1.1,P.10 30%

Increased design discharge 86.03 cum/sec

Mean depth of scour below H.F.L., as per IRC:78-2000, Clause 703.2

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

D_b = Design discharge per metre width 2.20 cum/sec/m

K_{sf} = Silt factor 1.31

d_{sf} = 2.07 m

Maximum scour depth below H.F.L, as per IRC:78-2000, Clause 703.3

For Pier	$2\ d_{sf}$	4.15 m
For Abutment	$1.27\ d_{sf}$	2.63 m

8 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9 m

9 Span arrangement

In proposed span arrangement, single span of 8.0 m has been proposed with bed protection.

10 Afflux

The existing structure is a balancing type structure and lies in submerged area. The road level has been raised by 1.5 m above HFL. The water way is proposed to be 8.0 m against 6.4 m waterway of existing structure. Some additional balancing type culvert shall also be introduced to take care additional waterway.

11 Deck level

HFL at proposed bridge site including afflux	254.585	m
Minimum vertical clearance (Table 12.1 of SP-13)	0.900	m
Depth of super structure including camber	0.800	m
Wearing coat	0.056	m
Minimum deck level required as per hydraulic conditions	256.341	m
Deck level of the existing bridge	255.360	m
Minimum deck level proposed	256.341	m

As per the proposed allignment, the formation level of bridge has been kept as 256.657m

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	66.18	cum/sec
HFL	254.585	m
Bed level	253.692	m
Maximum scour depth	2.63	m
Maximum scour level	251.955	m

Curtain wall shall be provided below maximum scour level

Bed level		253.692	m
Scour depth below bed		1.74	m
Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	2.5	m
	d/s	3.0	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	3.47	3.5	m
	d/s	6.0	3.47	6.0	m

CHAPTER-16

BRIDGE AT CH:69/300

16. Hydraulic calculations for Minor Bridge of Bhawanipatna-Khariar

1	**Name of Nala :**	Tributary of Sundar-Bichhi nala
	Road No :	S.H-16
	G.T S No :	64L/15
	Nearest Village :	Khariar
	RD :	Km.69.30
	Latitude	82^0 46' 00"
	Longitude	20^0 17'00"
	Sub Zone	3(d)

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	6.750	sqkm
Q	79.57	Cumecs

3 Discharge by Rational Formula

Catchment area	6.750 sqkm		675.00	hectares
Length of path from toposheet (L)			3.500	km
Difference in levels from toposheet (H)			10	m
(Ref: Index map)				
Maximum rain fall (F)			266.57	mm
Duaration of storm (T)			16	hrs
One hour rainfall (I_o)	I_o=(F/T)*(T+1)/(1+1)		141.6153	mm/hr
Time of concentration (SP-13, page 12)	$t_c=(0.87*L^3/H)^{0.385}$		1.66	hrs.
Critical rainfall intensity $I_c = I_o*(2/(1+t_c)$			106.48	mm/hr
Discharge Q=0.028 * P*f* A* I_c				
P = (for loam, lightly cultivated or covered)			0.400	
f =			1.00	
A =			675.00	Hectares
I_c =			10.648	cm/hr
Q=			80.496	cum/sec

tc= 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-4.1,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 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	79.57	cum/sec
Discharge by Rational Formula	80.50	cum/sec
Maximum discharge	79.57	cum/sec
Next maximum discharge	80.50	cum/sec
Hence design discharge	**80.50**	**cum/sec**
Design discharge adopted **Q=**	**80.50**	**cum/sec**

5 Linear Water Way

Regime width as per Lacey's theory $W=4.8Q^{1/2}$ **43.07 m**

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

6 Silt factor Based on Geotechnical investigation report

Depth(m)	Silt factor			
0.75	0.853	0.63975		
1.5	0.913	1.3695		
3.5	1.401	4.9035		
4.5	1.721	7.7445		
10.25		14.65725	1.42997561	Say 1.43

7 Scour depth

For catchment area upto 3000 Sq. Km.

Increase in design discharge, as per IRC:78-2000, Clause 703.1.1,P.10 30%

Increased design discharge 104.65 cum/sec

Mean depth of scour below H.F.L., as per IRC:78-2000, Clause 703.2

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

Db = Design discharge per metre width 2.43 cum/sec/m

K_{sf} = Silt factor 1.43

d_{sf} = 2.15 m

Maximum scour depth below H.F.L., As per IRC:78-2000, Clause 703.3

For Pier	$2\ d_{sf}$	4.30 m
For Abutment	$1.27\ d_{sf}$	2.73 m

This depth of scour will not be applocable if rock is available at shallow depths.

8 Vertical clearance

Vertical clearance for opening of high level bridge, from the lowest point 0f deck structure (Ref.I.R.C.-5-1998,Clause-106.2.1,Page-16) 0.9

9 Span arrangement

In the draft report, looking to the structural condition of existing bridge having span 1x7.2m, it was proposed to construct a new bridge with 8.0m waterway and FRL to meet the requirements of vertical clearance to bridge and free board to approaches for high level bridge.

As per the decisions taken during site visit by Review Committee on date 22.01.07 (Inspection Note communicated vide letter no. 6839 dated 20.02.07), this bridge is to be retained and suitable rehabilitaion measures shall be taken up.

10 Afflux

The HFL observed includes afflux also.

11 Deck level

HFL at proposed bridge site including afflux	258.131	m
FRL of the existing bridge	259.006	m
Sofit level of the deck slab of existing bridge	258.431	m
Vertical clearance available	0.300	
Minimum vertical clearance required (Table 12.1 of IRC:SP-13)	0.900	m

Vertical clearance available is less than the required. This bridge is to be retained as discussed above. Hence the existing level shall be maintained in profile design.

Floor Protection Works

As per hydrology report, the hydraulic parameters are as follows

Design discharge	80.50	cum/sec
HFL	258.131	m
Bed level	257.529	m
Maximum scour depth	2.73	m
Maximum scour level	255.401	m

Curtain wall shall be provided below maximum scour level

Bed level	257.529	m
Scour depth below bed	2.13	m

Minimum depth of curtan wall as per IRC:89-1997	u/s	2	m
	d/s	2.5	m
Provide depth of curtain wall	u/s	3.0	m
	d/s	3.5	m
Rigid apron as per IRC:89-1997	u/s	3.0	m
	d/s	5.0	m

		As per IRC:89	2xscour depth	Provided	
Flexible apron	u/s	3.0	4.26	4.5	m
	d/s	6.0	4.26	6.0	m

APPENDIX

ORISSA STATE ROAD PROJECT
HYDROLOGICAL STUDY

Road	: Bhawanipatna-Khariar
Name of River/Nallah/Stream	: Jokapal Nala/Pipal Nala
Name of nearest Village/Town	: Bhawanipatna
RD	Km.: 3.05
Latitude	: 83^0 25' 00"
Longitude	: 19^0 5' 15"
GT Sheet No.	: 65 M/8, 65 N/5
Sub Basin	4(a)

Estimation of slope

S. No.	Reduced Distance Starting from Gauging Site (Point of Study) (kms)	Reduced Levels of River Bed (m)	Length of each Segment L_i (km)	Height Above Datum *(D_i Difference Between the Datum and the ith R.L. (m)	(D_{i-1}+ D_i)	L_i (D_{i-1} + D_i) (4) x (6) (m x km)
1	2	3	4	5	6	7
1	0	140	0	0	0	0
2	1.2	160	1.2	20	20	24
3	4.2	180	3	40	60	180
4	5.6	200	1.4	60	100	140
5	6.95	220	1.35	80	140	189
6	8.05	240	1.1	100	180	198
7	8.65	260	0.6	120	220	132
8	9.65	280	1	140	260	260
9	9.85	300	0.2	160	300	60
10	10.5	400	0.65	260	420	273
11	11	500	0.5	360	620	310
12	11.15	600	0.15	460	820	123
13	11.5	700	0.35	560	1020	357
14	11.7	800	0.2	660	1220	244
15	12	900	0.3	760	1420	426
16	12.15	950	0.15	810	1570	235.5
					$\Sigma L_i (D_{i-1} + D_i)$ =	3151.50

$$S = \frac{\Sigma L_i (D_{i-1} + D_i)}{L^2} = \quad 21.348 \text{ m/km}$$

Synthetic Unitgraph

Catchment area A =	44.25	Sq.Km.
d =	1	cm depth
t_i = t_r (the unit duration of the UG) =	1	hr
$\Sigma Q_i t_i = A \times d / (0.36 \times t_r)$ =	122.917	
L =	12.150	km
Lc =	6.500	km
LxLc/(sqrt(s)) =	17.093	
$t_p = 0.376((L \times Lc)/sqrt(S))^{0.434}$ =	1.289	hrs
Say	1.500	hrs
$q_p = 1.215 (tp)^{-0.691}$ =	0.918	
Q_p = Catchment area x q_p =	40.627	cumecs
$W_{50} = 2.211 (q_p)^{-1.07}$ =	2.423	hrs
$W_{75} = 1.312 (q_p)^{-1.003}$ =	1.429	hrs
$W_{R50} = 0.808 (q_p)^{-1.053}$ =	0.884	hrs
$W_{R75} = 0.542 (q_p)^{-0.965}$ =	0.589	hrs
$Q_{50} = 0.5 \times Q_p$ =	20.313	cumecs
$Q_{75} = 0.75 \times Q_p$ =	30.470	cumecs
$T_B = 7.621 (tp)^{0.623}$ =	9.811	hrs
$Tm = t_p + t_r/2 = 1.5 + 1/2$ =	2.000	hrs

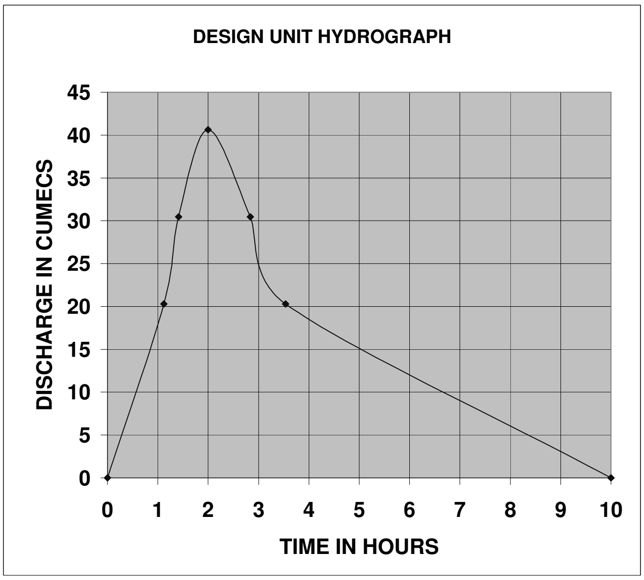
Base flow ,qb=0.536 /(A)0.523 cumecs./Sq.Km

Total base flow for the catchment = qb *A cumecs.

i.e.=0.536*44.25/(44.25)0.523=3.2678 cumecs.

Say 3.3 cumecs

	Unit Graph(1 cm 1 hour)			
Sl.	Time	Ordinate		
No				
1	0	0		
2	1	8.5		
3	2	40.63		
4	3	27.5		
5	4	16.5		
6	5	11		
7	6	7.75		
8	7	5.6		
9	8	3.5		
10	9	2		
11	10			
		122.98	cumec hours	
	=	10.00515254	mm	



STORM DURATION Td = 1.1 t_p

= 1.1 X 1.5 = 1.7 say 2 Hrs

From Plate 9.4 (a) , the 50 -Year return period , 24 hour point rainfall = 190 mm .

50 -Year return period , 2 hour point rainfall = 0.525*190 = 99.75 mm

Areal Rainfall = 93 % of Point Rainfall = 0.93*99.75 92.77 mm

Loss rate = 0.75 cm / hour i.e 7.5 mm /hour

Cumulative percentage

Hours	Storm Percentage	Storm Rainfall	Excess Rainfall	Incremental R.E.
0	0	0	0	0
1	86	85.785	78.285	78.285
2	100	99.75	84.75	6.465

Estimation of Design Flood Hydrograph

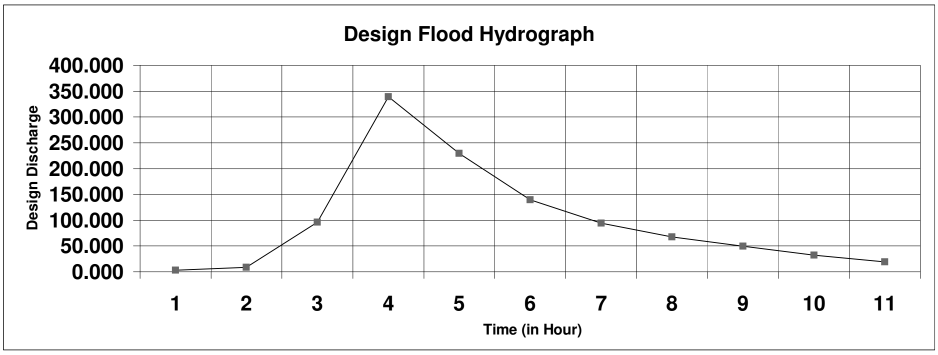
Unit Graph(1 cm 1 hour)			R.E.	R.E.			Base Flow	Design Flood Hydrograph
Sl.	Time	Ordinate	Peak to	Reverse				
No			Peak	order	0.647	7.829		
1	0	0			0		3.3	3.300
2	1	8.5			5.495	0	3.3	8.795
3	2	40.63	78.285	6.465	26.267	66.542	3.3	96.110
4	3	27.5	6.465	78.285	17.779	318.072	3.3	339.151
5	4	16.5			10.667	215.284	3.3	229.251
6	5	11			7.112	129.170	3.3	139.582
7	6	7.75			5.010	86.114	3.3	94.424
8	7	5.6			3.620	60.671	3.3	67.591
9	8	3.5			2.263	43.840	3.3	49.402
10	9	2			1.293	27.400	3.3	31.993
11	10	0			0	15.657	3.3	18.957
						0	3.3	3.300

Q = 339 Cumecs

C.A. = 44.25 Sq. Kms.

Q=C*(M)^3/4

C= 19.76



ORISSA STATE ROAD PROJECT
HYDROLOGICAL STUDY

Road	Bhawanipatna-Khariar,S.H.-16
Name of River/Nallah/Stream	: Harikani Nala/Bulat nala
Name of nearest Village/Town	: Kamathana
RD	Km 4.450km
Latitude	: 83^0 27' 00"
Longitude	: 18^0 58' 10"
GT Sheet No.	: 65 M/8, 65 N/5
Sub-Zone	4(a)

Estimation of slope

S. No.	Reduced Distance Starting from Gauging Site (Point of Study) (kms)	Reduced Levels of River Bed (m)	Length of each Segment L_i (km)	Height Above Datum *(D_i Difference Between the Datum and the ith R.L. (m)	$(D_{i-1}+ D_i)$	$L_i (D_{i-1} + D_i)$ (4) x (6) (m x km)
1	2	3	4	5	6	7
1	0	120	0	0	0	0.00
2	5	140	5	20	20	100.00
3	7.35	160	2.35	40	60	141.00
4	11	180	3.65	60	100	365.00
5	13.15	200	2.15	80	140	301.00
6	15.35	220	2.2	100	180	396.00
7	16.35	240	1	120	220	220.00
8	18.2	300	1.85	180	300	555.00
9	20.5	400	2.3	280	460	1058.00
10	21.35	500	0.85	380	660	561.00
11	22.1	600	0.75	480	860	645.00
12	22.65	700	0.55	580	1060	583.00
13	22.9	800	0.25	680	1260	315.00
14	23.1	900	0.2	780	1460	292.00
15	23.2	950	0.1	830	1610	161.00
					$\Sigma L_i (D_{i-1} + D_i)$ =	5693.00

$S = \frac{\Sigma L_i (D_{i-1} + D_i)}{L^2} =$ 10.577 m/km

Synthetic Unitgraph

Catchment area A = 48 Sq.Km.

d = 1 cm depth

$t_i = t_r$ (the unit duration of the UG) 1 hr

$\Sigma Q_i t_i = A \times d / (0.36 \times t_r) =$ 133.333

L = 23.200 km

Lc = 14.650 km

LxLc/(sqrt(s)) = 104.507

$t_p = 0.376((L X Lc)/sqrt(S))^{0.434} =$ 2.828 hrs

Say 3.000 hrs

$q_p = 1.215 (tp)^{-0.691} =$ 0.569

Q_p = Catchment area x q_p = 27.298 cumecs

$W_{50} = 2.211 (q_p)^{-1.07} =$ 4.044 hrs

$W_{75} = 1.312 (q_p)^{-1.003} =$ 2.311 hrs

$W_{R50} = 0.808 (q_p)^{-1.053} =$ 1.464 hrs

$W_{R75} = 0.542 (q_p)^{-0.965} =$ 0.934 hrs

$Q_{50} = 0.5 \times Q_p =$ 13.649 cumecs

$Q_{75} = 0.75 \times Q_p =$ 20.473 cumecs

$T_B = 7.621 (tp)^{0.623} =$ 15.110 hrs

$Tm = t_p + t_r/2 = 3 + 1/2 =$ 3.500 hrs

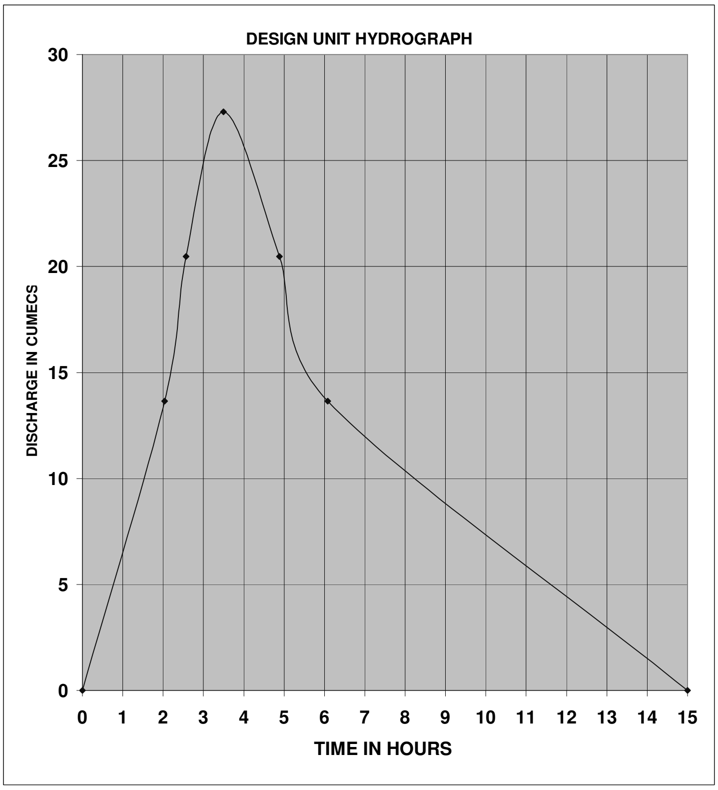
Base flow ,$qb=0.536 /(A)^{0.523}$ cumecs./Sq.Km

Total base flow for the catchment = qb *A cumecs.

i.e.=$0.536*48/(48)^{0.523}$=3.397 cumecs.

Say 3.4 cumecs

	Unit Graph(1 cm 1 hour)			
Sl.	**Time**	**Ordinate**		
No				
1	0	0		
2	1	3.5		
3	2	12.5		
4	3	25		
5	4	26		
6	5	20		
7	6	14		
8	7	10		
9	8	7.5		
10	9	5.5		
11	10	4		
12	11	3		
13	12	1.6		
14	13	0.85		
15	14	0.5		
16	15	0		
		133.95	cumec hours	
	=	10.04625	mm	



STORM DURATION Td = 1.1 t_p

= 1.1 X 3 = 3.3

say 4 Hrs

From Plate 9.4 (a) , the 50 -Year return period , 24 hour point rainfall = 200 mm . (Based on Isopluvial map 0f 50 year ,24 hour rainfall)

50 -Year return period , 4 hour point rainfall = 0.62*200 = 124.00 mm (Factor 0.62 is based on ratios of 24-hour point rainfall to shour duration rainfall i.e. 4 hour storm duration)

Areal Rainfall = 94 % of Point Rainfall ratio (Based on catchment area and storm duration)=0.94*124=116.56 mm

= 116.56 mm

Loss rate = 0.55cm / hour i.e. 5.5 mm /hour (Based on trail not to have negative incremental rainfall excess,the loss rate for this catchment has been assumed as 5.5 mm /hour)

Cumulative percentage

Hours	Storm Percentage	Storm Rainfall	Excess Rainfall	Incremental R.E.
0	0	0	0	0
1	66	76.930	71.430	76.560
2	86	100.242	89.242	17.812
3	95	110.732	94.232	4.990
4	100	116.560	94.560	0.328

Estimation of Design Flood Hydrograph

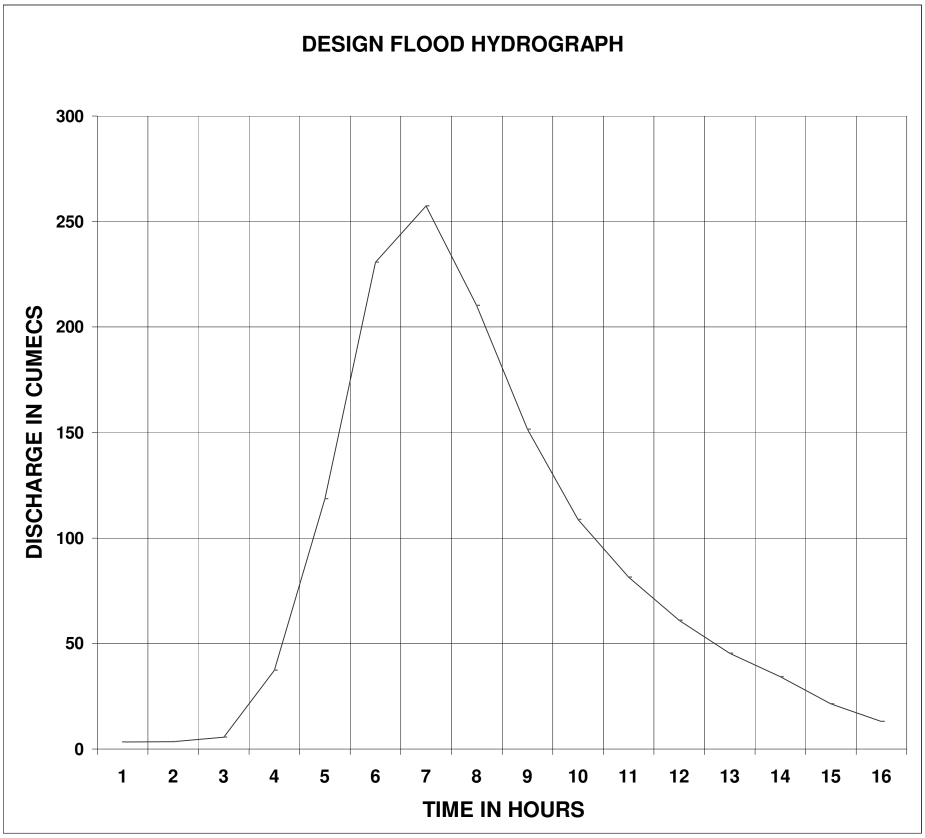
Unit Graph(1 cm 1 hour)			R.E.	R.E.					Base Flow	Design Flood Hydrograph
Sl.	Time	Ordinate	Peak to	Reverse						
No			Peak	order	0.033	0.49904	7.656	1.7812		
1	0	0			0				3.4	3.4
2	1	3.5			0.115	0			3.4	3.515
3	2	12.5			0.410	1.747	0		3.4	5.557
4	3	25	17.8	0.328	0.820	6.238	26.796	0	3.4	37.254
5	4	26	76.6	4.990	0.853	12.476	95.700	6.2342	3.4	118.663
6	5	20	4.99	76.560	0.656	12.975	191.400	22.265	3.4	230.696
7	6	14	0.33	17.812	0.459	9.981	199.056	44.53	3.4	257.426
8	7	10			0.328	6.987	153.120	46.311	3.4	210.146
9	8	7.5			0.246	4.990	107.184	35.624	3.4	151.444
10	9	5.5			0.180	3.743	76.560	24.937	3.4	108.820
11	10	4			0.131	2.745	57.420	17.812	3.4	81.508
12	11	3			0.098	1.996	42.108	13.359	3.4	60.962
13	12	1.6			0.052	1.497	30.624	9.7966	3.4	45.370
14	13	0.85			0.028	0.798	22.968	7.1248	3.4	34.319
15	14	0.5			0.016	0.424	12.250	5.3436	3.4	21.434
16	15	0			0	0.250	6.508	2.8499	3.4	13.007
						0	3.828	1.514	3.4	8.742
							0	0.8906	3.4	4.291
								0	3.4	3.4

Qp = 257 Cumecs

C.A. = 48 Sq. Kms.

Q=C*(M)^3/4

C=Q/(M)^ 3/4 14.1



ORISSA STATE ROAD PROJECT

HYDROLOGICAL STUDY

Road : Bhawanipatna-Khariar-SH-16
Name of River/Nallah/Stream : Sundar Nadi
Name of nearest Village/Town Bankapur
RD : Km. 59.10 Label1
Latitude : 82^0 50' 00"
Longitude : 20^0 31' 00"
GT Sheet No. : 64 L
Sub Zone 3(d)

Estimation of slope

S.	Reduced Distance Starting from gauging point of study(Km)	Reduced Levels of each segment(Km)	Length of each segment-Li(Km)	Height above datum(m)	$(D_{i-1} + D_i)$	$L_i*(D_{i-1}+D_i)$
1	2	3	4	5	6	7
1	0	300	0	0	0	0.00
2	81.25	400	81.25	100	100	8125.00

$\Sigma L_i (D_{i-1} + D_i) =$

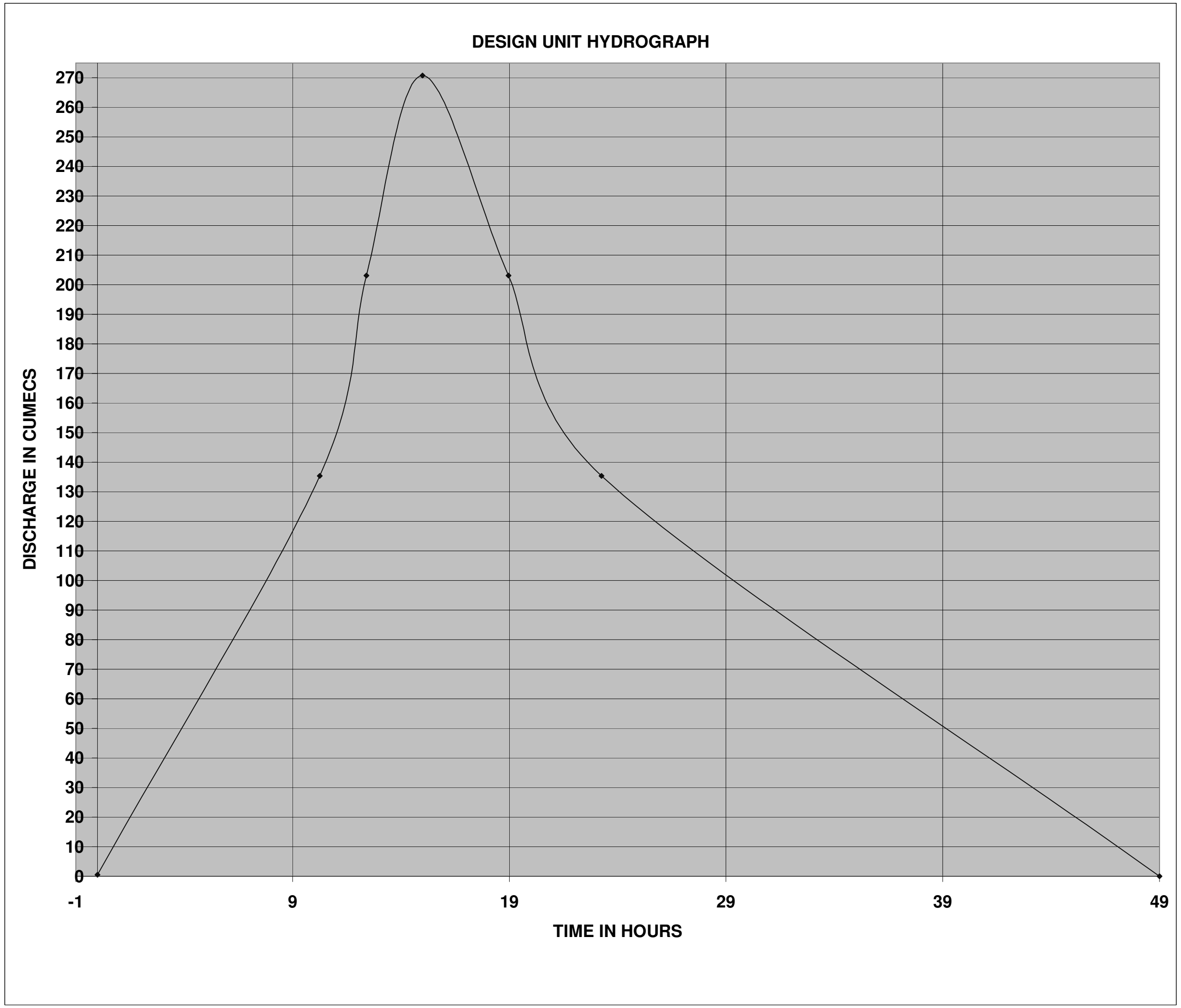
$S = \frac{\Sigma L_i (D_{i-1} + D_i)}{L^2}$ 1.231 Km/m

Synthetic Unitgraph

Catchment area = 1493.75 Sq.Km.
L = 81.25 km
Lc = 47.50 km
LxLc/(sqrt(s)) = 3478.47
$t_p = 1.757((L X Lc)/sqrt(S))^{0.261} =$ 14.76 hrs
Say 14.50 hrs
$q_p = 1.260 (tp)^{-0.725} =$ 0.18
Q_p = Catchment area x q_p = 270.80 cumecs
$W_{50} = 1.974 (q_p)^{-1.104} =$ 13.00 hrs
$W_{75} = 0.961 (q_p)^{-1.125} =$ 6.56 hrs
$W_{R50} = 1.150 (q_p)^{-0.829} =$ 4.74 hrs
$W_{R75} = 0.527 (q_p)^{-0.932} =$ 2.59 hrs
$Q_{50} = 0.5 \times Q_p =$ 135.40 cumecs
$Q_{75} = 0.75 \times Q_p =$ 203.10 cumecs
$T_B = 5.411 (tp)^{0.826} =$ 49.27 hrs
Storm duration ,t_r = 1 Hour
$Tm = t_p + t_r/2 = 14.5 + 1/2 =$ 15 hrs

Base flow = 0.10 cumecs/ Sq.Km of catchment area
0.10*1493.75=149.375 cumecs

	Unit Graph(1 cm 1 hour)			
Sl.	Time	Ordinate		
No				
	0	0		
1	1	5		
2	2	12.5		
3	3	20		
4	4	30		
5	5	37.5		
6	6	50		
7	7	60		
8	8	80		
9	9	100		
10	10	130		
11	11	155		
12	12	190		
13	13	225		
14	14	255		
15	15	270.8		
16	16	265		
17	17	245		
18	18	230		
19	19	202.5		
20	20	185		
21	21	170		
22	22	155		
23	23	135		
24	24	122.5		
25	25	107.5		
26	26	95		
27	27	80		
28	28	70		
29	29	62.5		
30	30	55		
31	31	47.5		
32	32	40		
33	33	35		
34	34	30		
35	35	27.5		
36	36	25		
37	37	22.5		
38	38	20		
39	39	17.5		
40	40	15		
41	41	13		
42	42	12.5		
43	43	11		
44	44	10		
45	45	8		
46	46	7.5		
47	47	6		
48	48	5		
49	49	0		
		4153.8	cumec hours	
	=	10.010832	mm	



STORM DURATION Td = 1.1 t_p
= 1.1 X 14.5 = 15.95 say 16 Hrs

From Plate 9 , the 50 -Year return period , 24 hour point rainfall = 380 mm .
Areal reduction factor= 76.25 %=0.7625*380=289.75 mm Based on catchment area and storm duration of 16 hours
Areal Rainfall =92 % of Point Rainfall =0.92*289.75=266.57 mı (Factor 0.92 is based on ratios of 24-hour point
= 266.57 rainfall to shour duration rainfall i.e. 16 hour storm duration)
Loss rate = 0.15 cm / hour i.e.1.5 mm /hour

Cumulative percentage

Hours	Storm Percentage	Storm Rainfall	Excess Rainfall	Incremental R.E.
0	0	0	0	0
1	15	39.99	38.49	38.49
2	29	77.31	74.31	35.82
3	37	98.63	94.13	19.83
4	46	122.62	116.62	22.49
5	56	149.28	141.78	25.16
6	61	162.61	153.61	11.83
7	68	181.27	170.77	17.16
8	74	197.26	185.26	14.49
9	78	207.92	194.42	9.16
10	83	221.25	206.25	11.83
11	86	229.25	212.75	6.50
12	88	234.58	216.58	3.83
13	94	250.58	231.08	14.49
14	97	258.57	237.57	6.50
15	99	263.90	241.40	3.83
16	100	266.57	242.57	1.17

Estimation of Design Flood Hydrograph

Unit Graph(1 cm 1 hour)			R.E. Peak to	R.E. Reverse Order																	Base Flow	Design Flood Hydrograph
Sl. No.	Time	Ordinate			0.12	0.38	1.45	0.38	1.18	0.92	1.72	2.52	1.98	3.58	3.85	2.25	#	1.45	0.65	0.65		
1	0	0			0																149.375	149.38
2	1	5			0.58	0															149.375	149.96
3	2	12.5			1.46	1.92	0														149.375	152.75
4	3	20			2.33	4.79	7.25	0													149.375	163.74
5	4	30			3.50	7.66	18.12	1.92	0												149.375	180.57
6	5	37.5			4.37	11.49	28.99	4.79	5.91	0											149.375	204.93
7	6	50			5.83	14.37	43.48	7.66	14.79	4.58	0										149.375	240.08
8	7	60			6.99	19.16	54.35	11.49	23.66	11.45	8.58	0									149.375	285.06
9	8	80			9.33	22.99	72.47	14.37	35.49	18.33	21.4	12.58	0								149.375	356.37
10	9	100			11.66	30.65	86.97	19.16	44.36	27.49	34.3	31.45	9.91	0							149.375	445.33
11	10	130	6.497	1.17	15.15	38.31	115.95	22.99	59.14	34.36	51.5	50.31	24.78	17.91	0						149.375	579.77
12	11	155	6.497	3.83	18.07	49.81	144.94	30.65	70.97	45.81	64.3	75.47	39.65	44.77	19.24	0					149.375	753.12
13	12	190	14.49	14.49	22.15	59.39	188.42	38.31	94.63	54.98	85.8	94.34	59.48	71.64	48.11	11.246	0				149.375	977.86
14	13	225	11.83	3.83	26.23	72.80	224.66	49.81	118.29	73.30	103	125.79	74.35	107.46	76.97	28.114	6	0			149.375	1236.01
15	14	255	22.49	11.83	29.73	86.21	275.39	59.39	153.77	91.63	137	150.94	99.13	134.32	115.46	44.983	#	7.2471	0		149.375	1549.63
16	15	270.8	38.49	9.16	31.57	97.70	326.12	72.80	183.34	119.12	172	201.26	118.95	179.10	144.32	67.474	#	18.118	3.2486	0	149.375	1907.74
17	16	265	35.82	17.16	30.89	103.75	369.60	86.21	224.74	142.02	223	251.57	158.61	214.92	192.43	84.342	#	28.988	8.1214	3.2486	149.375	2307.38
18	17	245	19.83	25.16	28.56	101.53	392.50	97.70	266.14	174.09	266	327.04	198.26	286.56	230.91	112.46	#	43.483	12.994	8.1214	149.375	2740.07
19	18	230	25.16	19.83	26.81	93.87	384.10	103.75	301.63	206.16	326	389.93	257.74	358.20	307.88	134.95	#	54.353	19.491	12.994	149.375	3186.41
20	19	202.5	17.16	35.82	23.61	88.12	355.11	101.53	320.32	233.65	386	477.98	307.30	465.66	384.86	179.93	#	72.471	24.364	19.491	149.375	3660.83
21	20	185	9.163	38.49	21.57	77.59	333.37	93.87	313.46	248.13	438	566.03	376.69	555.21	500.31	224.91	#	86.965	32.486	24.364	149.375	4136.52
22	21	170	11.83	22.49	19.82	70.88	293.51	88.12	289.80	242.81	465	641.50	446.08	680.58	596.53	292.39	#	115.95	38.983	32.486	149.375	4581.78
23	22	155	3.831	11.83	18.07	65.13	268.14	77.59	272.06	224.49	455	681.25	505.56	805.95	731.22	348.62	#	144.94	51.977	38.983	149.375	4991.85
24	23	135	14.49	14.49	15.74	59.39	246.40	70.88	239.53	210.74	420	666.66	536.88	913.40	865.92	427.33	#	188.42	64.971	51.977	149.375	5311.39
25	24	122.5	3.831	6.50	14.28	51.72	224.66	65.13	218.83	185.55	395	616.35	525.38	970.00	981.38	506.05	#	224.66	84.462	64.971	149.375	5502.22
26	25	107.5	1.166	6.50	12.53	46.93	195.67	59.39	201.08	169.51	347	578.61	485.73	949.22	1042.19	573.53	#	275.39	100.71	84.462	149.375	5537.97
27	26	95			11.07	41.19	177.55	51.72	183.34	155.77	317	509.43	455.99	877.59	1019.87	609.06	#	326.12	123.44	100.71	149.375	5411.32
28	27	80			9.33	36.40	155.81	46.93	159.68	142.02	292	465.40	401.47	823.86	942.89	596.02	#	369.6	146.18	123.44	149.375	5180.47
29	28	70			8.16	30.65	137.69	41.19	144.90	123.70	266	427.67	366.78	725.35	885.17	551.04	#	392.5	165.68	146.18	149.375	4875.46
30	29	62.5			7.29	26.82	115.95	36.40	127.16	112.24	232	389.93	337.04	662.67	779.33	517.3	#	384.1	175.94	165.68	149.375	4508.67
31	30	55			6.41	23.95	101.46	30.65	112.37	98.50	210	339.62	307.30	608.94	711.98	455.45	#	355.11	172.17	175.94	149.375	4131.49
32	31	47.5			5.54	21.07	90.59	26.82	94.63	87.05	184	308.17	267.65	555.21	654.25	416.09	#	333.37	159.18	172.17	149.375	3765.15
33	32	40			4.66	18.20	79.72	23.95	82.80	73.30	163	270.44	242.87	483.57	596.53	382.35	#	293.51	149.43	159.18	149.375	3391.72
34	33	35			4.08	15.33	68.85	21.07	73.93	64.14	137	238.99	213.13	438.79	519.55	348.62	#	268.14	131.57	149.43	149.375	3043.36
35	34	30			3.50	13.41	57.98	18.20	65.06	57.27	120	201.26	188.35	385.06	471.45	303.63	#	246.4	120.2	131.57	149.375	2716.15
36	35	27.5			3.21	11.49	50.73	15.33	56.19	50.40	107	176.10	158.61	340.29	413.72	275.52	#	224.66	110.45	120.2	149.375	2423.18
37	36	25			2.91	10.54	43.48	13.41	47.31	43.52	94.4	157.23	138.78	286.56	365.61	241.78	#	195.67	100.71	110.45	149.375	2146.63
38	37	22.5			2.62	9.58	39.86	11.49	41.40	36.65	81.5	138.36	123.91	250.74	307.88	213.67	#	177.55	87.711	100.71	149.375	1900.18
39	38	20			2.33	8.62	36.24	10.54	35.49	32.07	68.6	119.50	109.04	223.87	269.40	179.93	#	155.81	79.589	87.711	149.375	1680.52
40	39	17.5			2.04	7.66	32.61	9.58	32.53	27.49	60.1	100.63	94.17	197.01	240.53	157.44	#	137.69	69.844	79.589	149.375	1492.88
41	40	15			1.75	6.70	28.99	8.62	29.57	25.20	51.5	88.05	79.30	170.14	211.67	140.57	#	115.95	61.722	69.844	149.375	1321.74
42	41	13			1.52	5.75	25.36	7.66	26.61	22.91	47.2	75.47	69.39	143.28	182.81	123.7	#	101.46	51.977	61.722	149.375	1170.11
43	42	12.5			1.46	4.98	21.74	6.70	23.66	20.62	42.9	69.18	59.48	125.37	153.94	106.83	#	90.589	45.48	51.977	149.375	1039.34
44	43	11			1.28	4.79	18.84	5.75	20.70	18.33	38.6	62.89	54.52	107.46	134.70	89.965	#	79.718	40.607	45.48	149.375	929.20
45	44	10			1.17	4.21	18.12	4.98	17.74	16.03	34.3	56.60	49.56	98.50	115.46	78.72	#	68.847	35.734	40.607	149.375	837.30
46	45	8			0.93	3.83	15.94	4.79	15.38	13.74	30	50.31	44.61	89.55	105.84	67.474	#	57.977	30.861	35.734	149.375	757.78
47	46	7.5			0.87	3.07	14.49	4.21	14.79	11.91	25.7	44.02	39.65	80.59	96.21	61.851	#	50.73	25.988	30.861	149.375	689.86
48	47	6			0.70	2.87	11.60	3.83	13.01	11.45	22.3	37.74	34.70	71.64	86.59	56.228	#	43.483	22.74	25.988	149.375	626.78
49	48	5			0.58	2.30	10.87	3.07	11.83	10.08	21.4	32.70	29.74	62.68	76.97	50.605	#	39.859	19.491	22.74	149.375	573.92
50	49	0			0	1.92	8.70	2.87	9.46	9.16	18.9	31.45	25.77	53.73	67.35	44.983	#	36.236	17.867	19.491	149.375	523.85
						0	7.25	2.30	8.87	7.33	17.2	27.67	24.78	46.57	57.73	39.36	#	32.612	16.243	17.867	149.375	478.77
							0	1.92	7.10	6.87	13.7	25.16	21.81	44.77	50.03	33.737	#	28.988	14.618	16.243	149.375	435.05
								0	5.91	5.50	12.9	20.13	19.83	39.40	48.11	29.239	#	25.365	12.994	14.618	149.375	401.08
									0	4.58	10.3	18.87	15.86	35.82	42.33	28.114	#	21.741	11.37	12.994	149.375	366.73
										0	8.58	15.09	14.87	28.66	38.49	24.74	#	18.842	9.7457	11.37	149.375	334.54
											0	12.58	11.90	26.86	30.79	22.491	#	18.118	8.4462	9.7457	149.375	303.31
												0	9.91	21.49	28.86	17.993	#	15.944	8.1214	8.4462	149.375	271.98
													0	17.91	23.09	16.868	9	14.494	7.1468	8.1214	149.375	246.47
														0	19.24	13.495	9	11.595	6.4971	7.1468	149.375	216.22
															0	11.246	7	10.871	5.1977	6.4971	149.375	190.28
																0	6	8.6965	4.8728	5.1977	149.375	174.06
																	0	7.2471	3.8983	4.8728	149.375	165.39
																		0	3.2486	3.8983	149.375	156.52
																			0	3.2486	149.375	152.62
																				0	149.375	149.38

Qp = 5538 Cumecs
Q=C*(M)^3/4
C.A. = 1494 Sq. Kms.
C=Q/(M)3^4
Dicken's C = 23.05

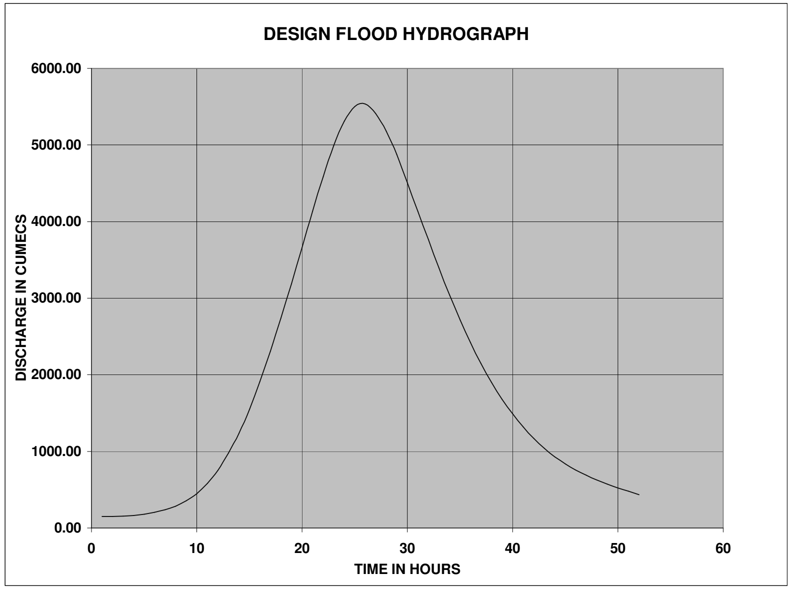


Figure - 4(a)

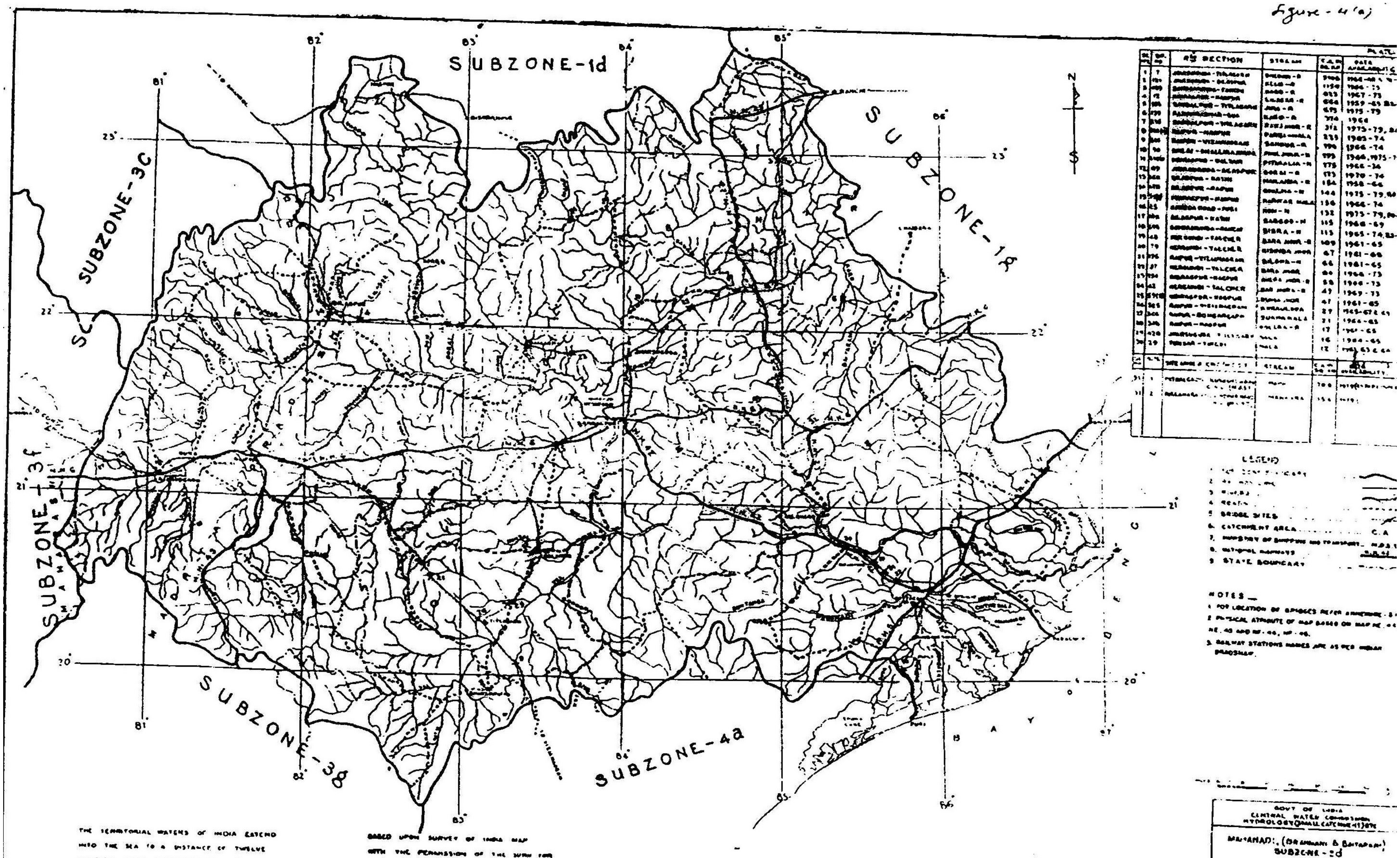
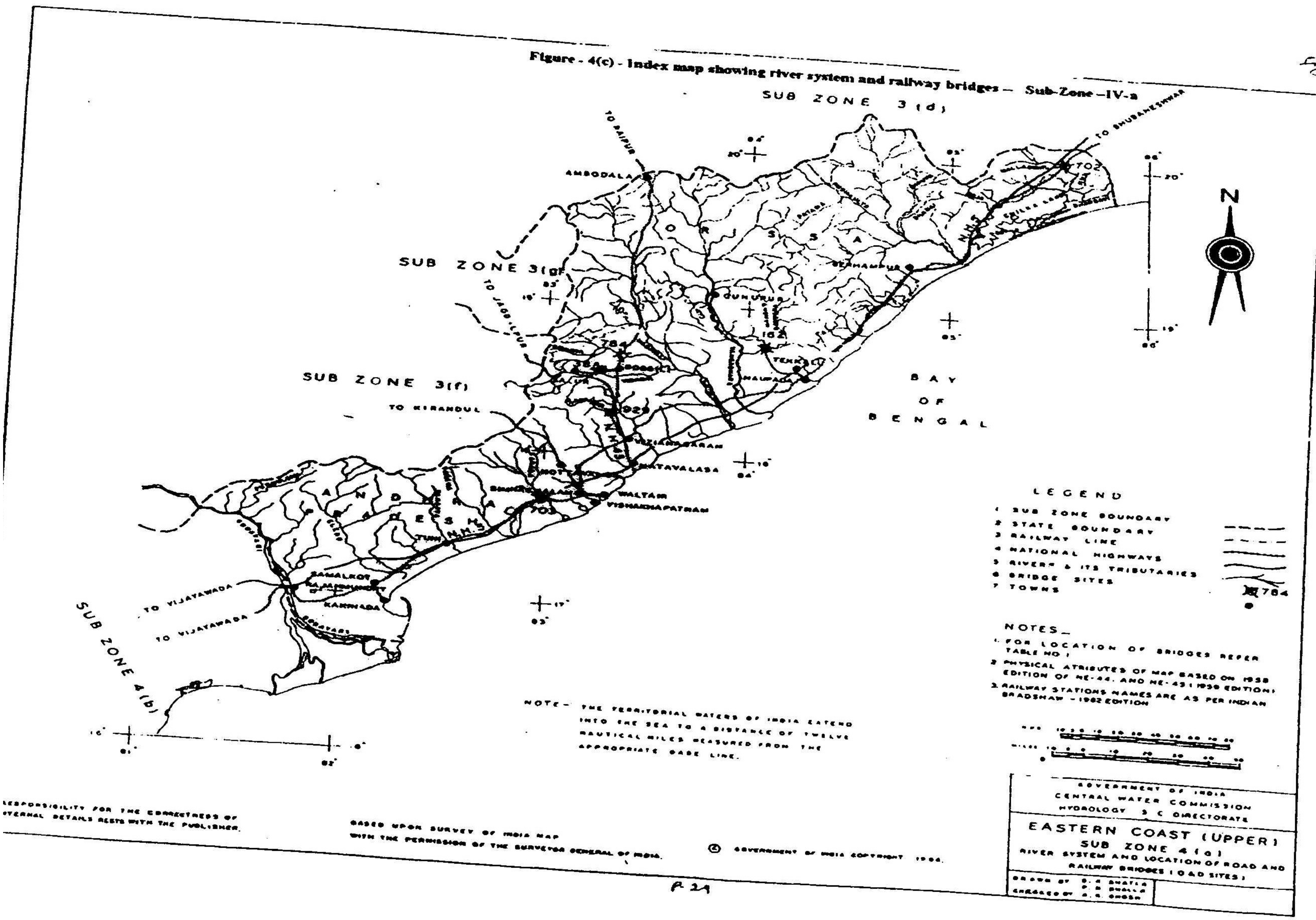


Figure - 4(a) - Index map showing river system and railway bridges – Sub-Zone-III-d

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

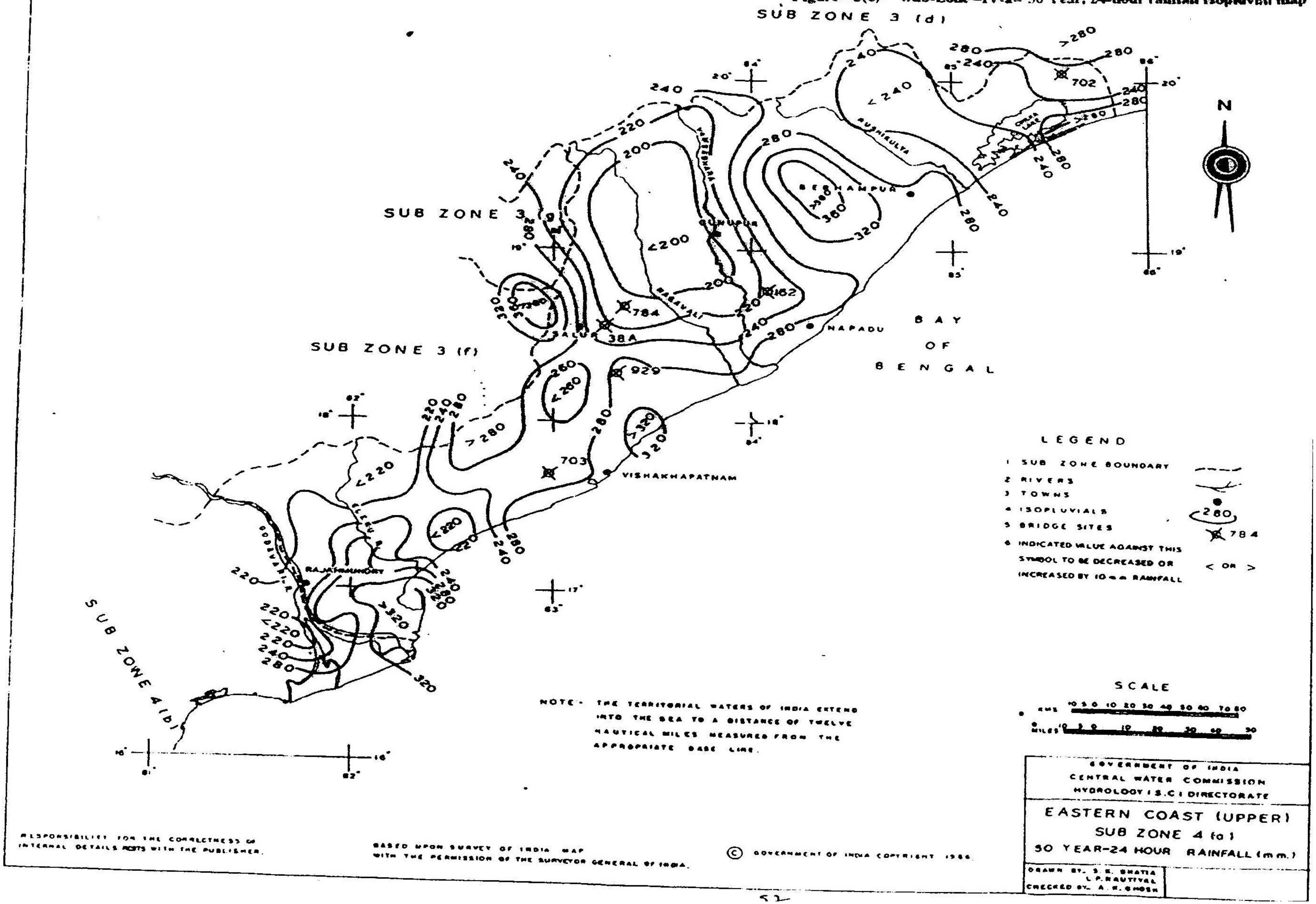
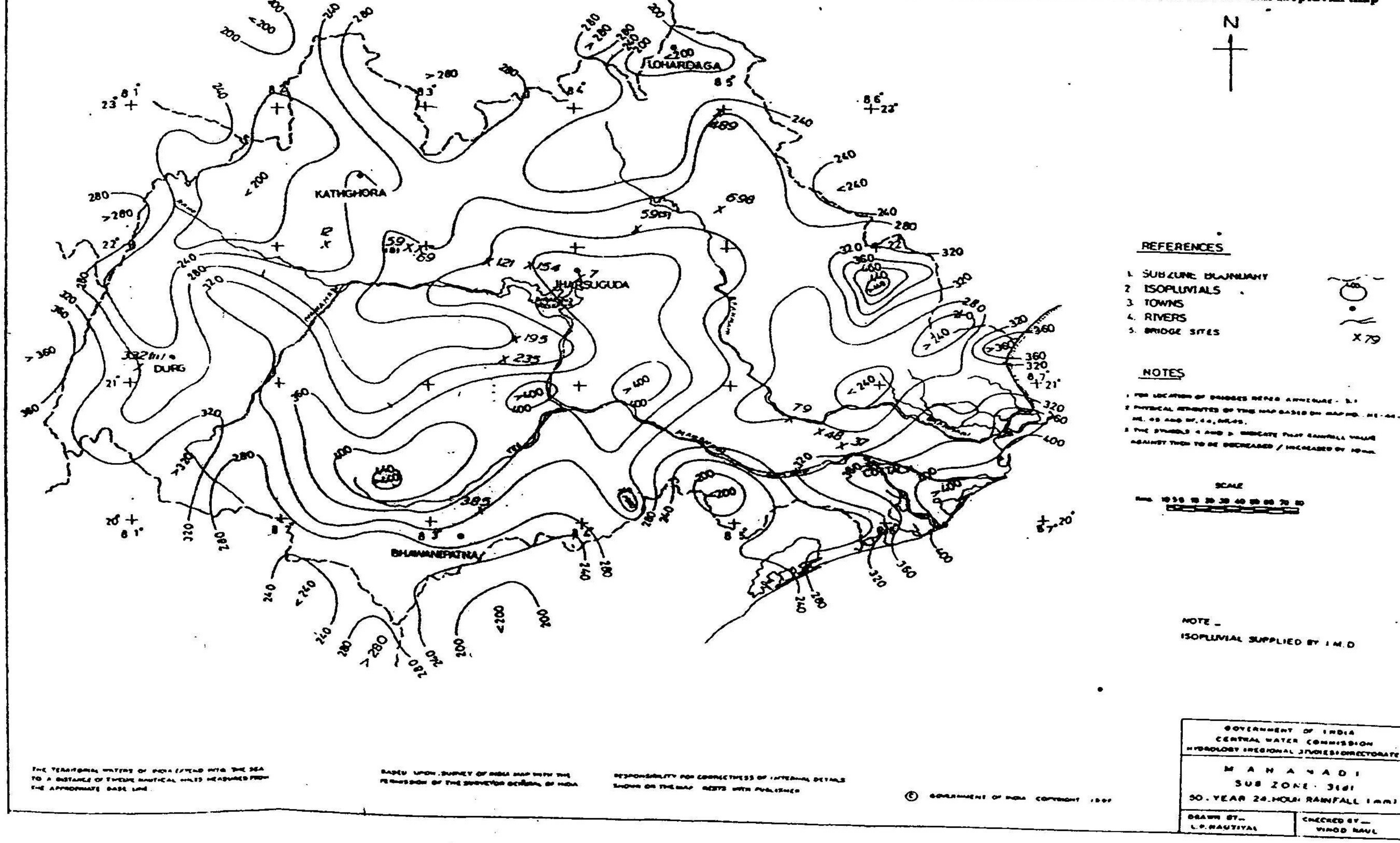
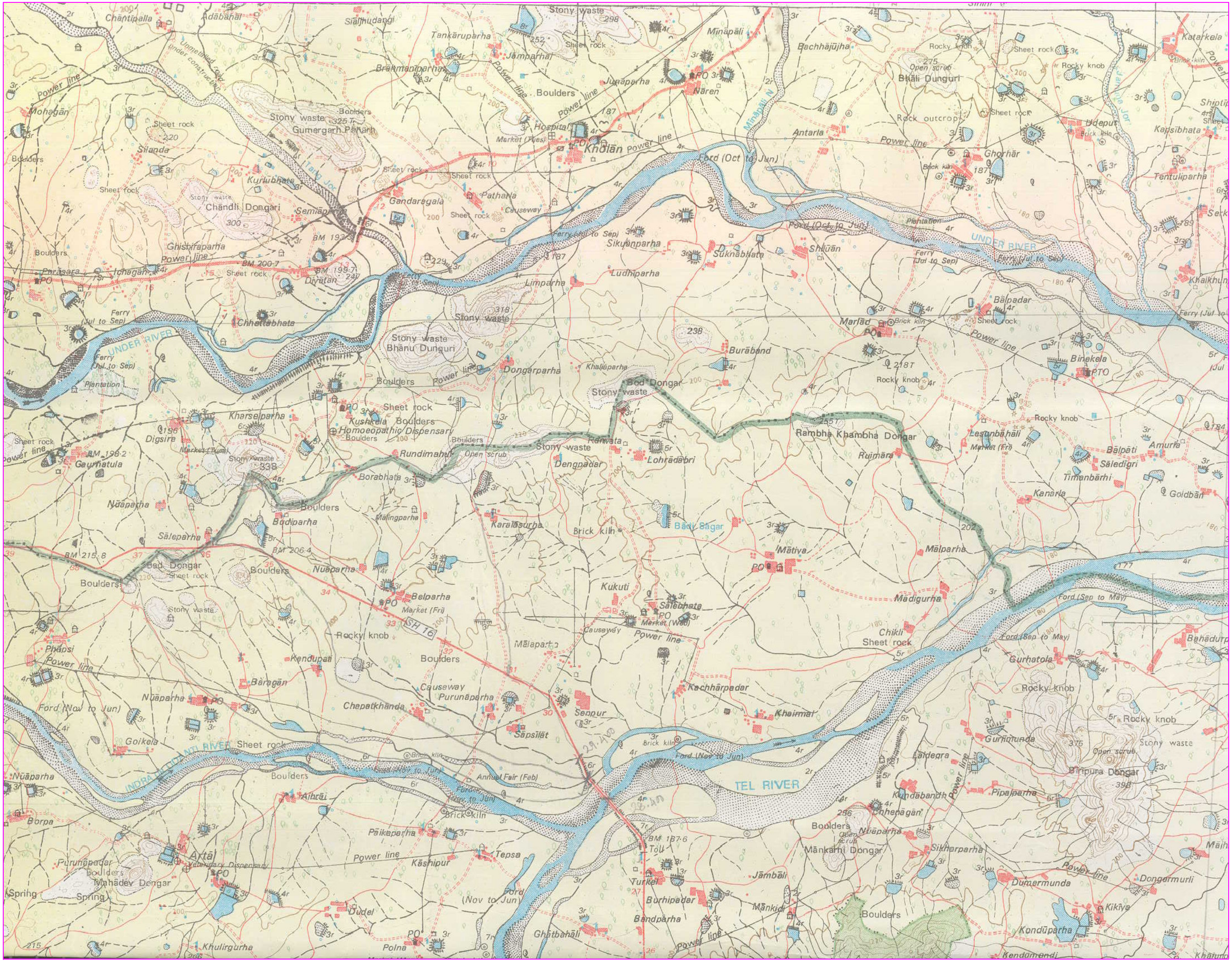
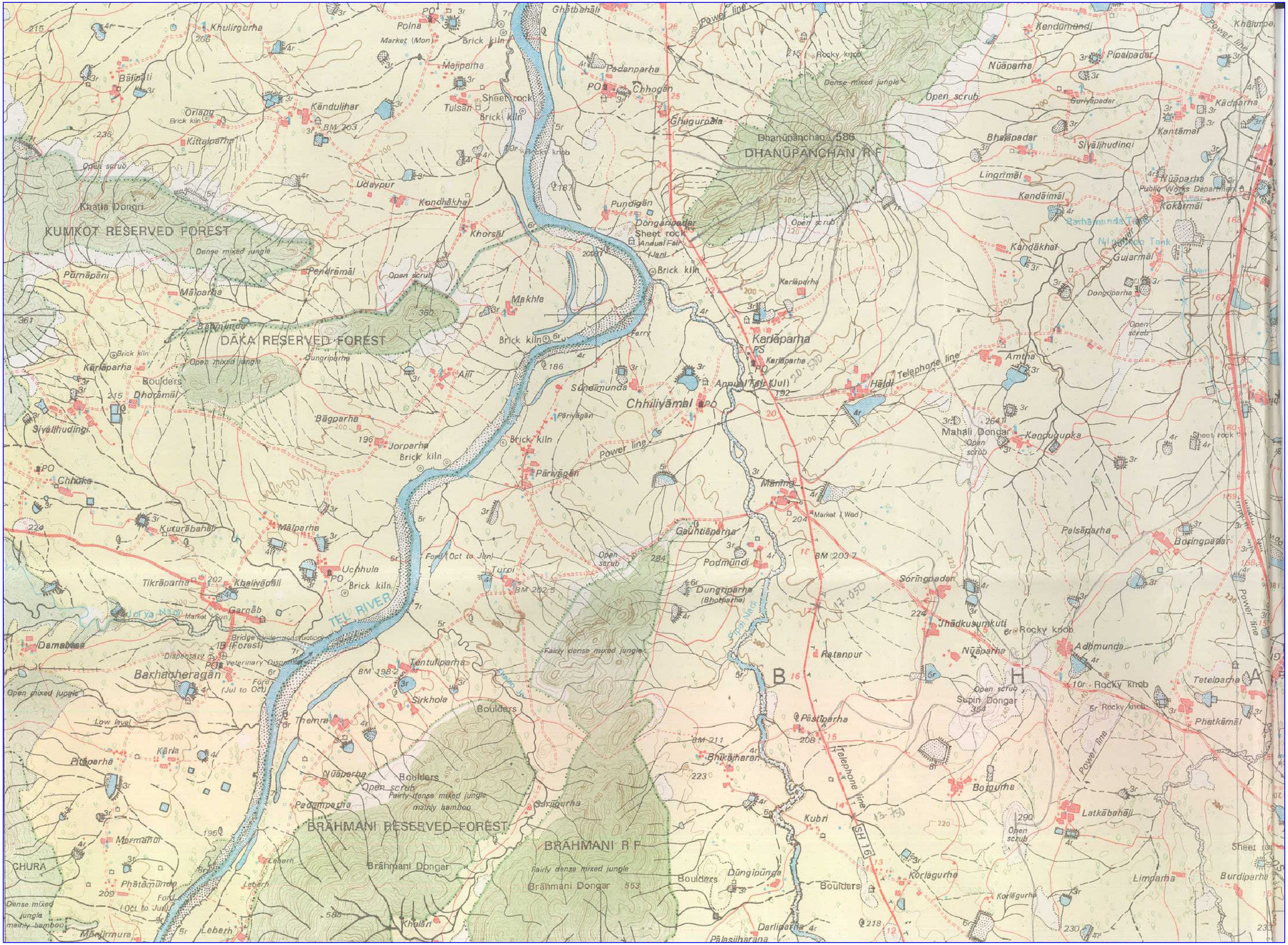


Figure –5(a) - Sub-Zone-III-d– 50 Year, 24-hour rainfall Isopluvial map

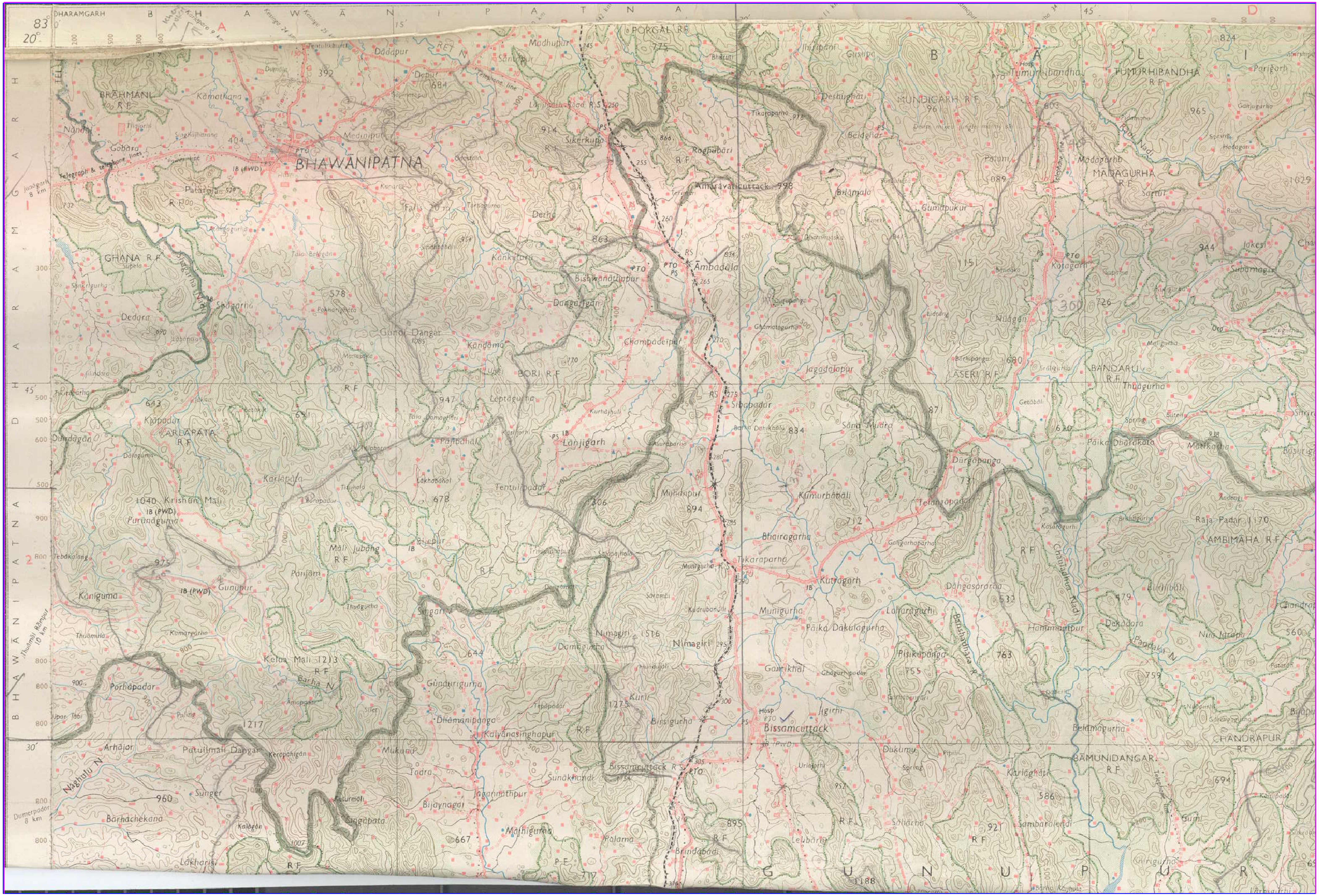




TEL RIVER
UNDER RIVER
Khariār
Chandli Dongari
Gumergarh Pahār
Stony waste
Bhānu Dunguri
Dongarparha
Bad Dongar
Rambha Khambha Dongar
Bāud Sāgar
Mātiva
Kukuti
Belparha
Chapatkhanda
Purunāparha
Sāpsilāt
Seopur
Kachhārpadar
Khairmal
Artāl
Mahādev Dongar
Kāshipur
Tepsa
Turkel
Burhipadar
Bandparha
Jambāli
Mānkarhi Dongar
Sikharparha
Dumermunda
Kondūparha
Biripura Dongar
Gurjimunda
Laideara
Kundābandh
Pipalparha
Gurhatola
Madigurha
Mālparha
Lohrādabri
Dengpadar
Rundimahal
Borabhata
Bodiparha
Nuāparha
Sāleparha
Kharselparha
Digsira
Gaurnatula
Binekela
Bālpāti
Sāledigri
Timanbarhi
Kanarla
Goldbāri
Marlad
Burābānd
Ludhiparha
Sikuānparha
Suknābhata
Shilūān
Ghorhār
Antarla
Bhāli Dunguri
Udepur
Kapsibhata
Tentuliparha
Nären
Junāparha
Minapāli
Bachhājūjha
Tankāruparha
Jamparhal
Silanda
Kurlubhata
Semāpadar
Gandaregala
Patharla
Chheliābhata
Ghishtiparha
Iohagān
Chantipalla
Adabahal
Sajhudangi
Homoeopathic Dispensary
Market (Fri)
Power line
Sheet rock
Boulders
Rocky knob
Brick kiln
Ford (Oct to Jun)
Ferry (Jul to Sep)
Causeway
Annual Fair (Feb)
SH 16


KUMKOT RESERVED FOREST
DAKA RESERVED FOREST
DHANUPANCHAN R F
BRAHMANI RESERVED FOREST
BRAHMANI R F
TEL RIVER
Chhiliyamal
Karlaparha
Haldi
Maning
Gargab
Barhacheragan
Uchhula
Parivagan
Sundimunda
Jorparha
Bagparha
Malparha
Kuturabahal
Tikraparha
Kandulihar
Udaypur
Kondhakha
Khorsal
Pundigan
Dongaripadar
Chhogan
Padanparha
Ghugurpala
Amtha
Mahali Dongar
Kendugupka
Soringpadar
Jhadkusumkuti
Nuaparha
Admunda
Ratanpur
Pastiparha
Bhikajharan
Kubri
Korlagurha
Bonguma
Latkabahali
Limparha
Burdiparha
Phatkamal
Tetelparha
Kokarmal
Kandakhal
Gujarmal
Kendamal
Lingrimal
Bhejapadar
Siyalihudingi
Kantamal
Kadparha
Pipalpadar
Kendumundi
Telephone line
Power line
SH 16


Khariār
TITLĀGARH
BUNDIA P F
Indra or Sundar Nadi
Bangomunda
Bhālumunda
Biripāli
Market (Thurs)
Tukla
Market (Mon)
Bhushlār
Market (Sat)
Bargumara
Market (Wed)
Bāgiharan Jhor
Telegraph & telephone lines
Power line
Dense scrub
Boulders
Sheet rock
Chimney
Rice mill
45' E. of GREENWICH
50'
20°
N A W Ā P Ā R A
Index to Sheets



BHAWANIPATNA
DHARAMGARH
BHAWANIPATNA
Bissamcuttack
Lanjigarh
Ambadola
BORI R F
ASERI R F
MUNDIGARH R F
TUMURHIBANDHA R F
MADAGURHA R F
BANDARU R F
AMBIMAHA R F
BAMUNIDANGAR R F
CHANDRAPUR R F
GHANA R F
BRAHMANI R F
ARLAPATA R F
PORGAL R F
Kelua Mali 1213
Krishan Mali
Raja Padar 1170
Telephone line
G U N U P U R


KHĀSBAHĀL PROTECTED FOREST
Khāsbahāl Dongri
Fairly dense mixed jungle mainly teak
Khāsbahāl
PF
Open teak
Open scrub
CHAURA PF
Fairly dense mixed jungle mainly teak
GUJIA RESERVED FOREST
Dense mixed jungle mainly teak
GUJIA RF
GHATUL RESERVED FOREST
Fairly dense mixed jungle mainly teak
GHATUL RF
Fairly dense teak
CHAURA RF
PROTECTED FOREST
Indra or Undare Nadi
Indra or Sundar Nadi
UDANTI NADI
Power line
Power line (under construction)
Telephone line
Canal
Siphon
Rānīmura
Anchalpur
Gurtola
Chondgiri
Bahalpadar
Chāndel
Srīrām
Dohelpāra Market (Tues)
Bankāpur
Gharla
Jāmkhunta
Tureikela Market (Thurs)
Barapāra
Gandharla
Sundhimura
Chatrābhāta
Jāmpāra
Koirbāri
Rājpur
Tiranpur
Kalkut
Sālemuranga
Jhinkipāra
Batharla
Mālpāra
Barkāni
Dābjhar
Gumah
Jaintpur
Open teak
Kurlubhāta
Bhurshāgura Market (Sun)
Titisilat
Sondhipāra
Bālipadar
Kāntāmāl
Kendumundi
Borguma
Kuhura Market (Fri)
Bordi
Masigaon
Kholapala
Makhan
Sālegaon
Gurjung
Dongāpokan
Karlapita
Paruābhādi
Jhalap
Purniāpāli
Sālebarat
Mainia
Bhānpur
Putupāra
Hospital
Market (Wed)
Sindhekela
Lohārapāli
Sālemuranga
Gidhora Pahār
Jarāmunda
Mungai Pahār RF
SINDHEKELA RF
Bhātāsar
Kurdiamunda
Arasātāla
Telsarāi
Chandotara
Kutmāra
Kandara
Suknābhāta
Turukbhāta
Ghantasara
Pipalpadar
Market Kurisuc (Sat)
Purāpāli
Dedhgaon
Boulders
Ford