Using SWAT Module in the Design of Submerged Weir on narrow rivers having high flood discharge

Presented by

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INNOVATION , INNOVATION , INNOVATION !
INNOVATION IN APPLICATION OF SWAT MODULES

APPLICATIONS AREA OF SWAT MODEL

1.AGRICULTURE – Best management practices, Irrigation schedules, impact assessment,----, Simulations of scenarios with different cropping patterns, Developing SDSS for adaptation of best option----

2. DRAINAGE – Mapping/delineating drainage areas and planning development strategies

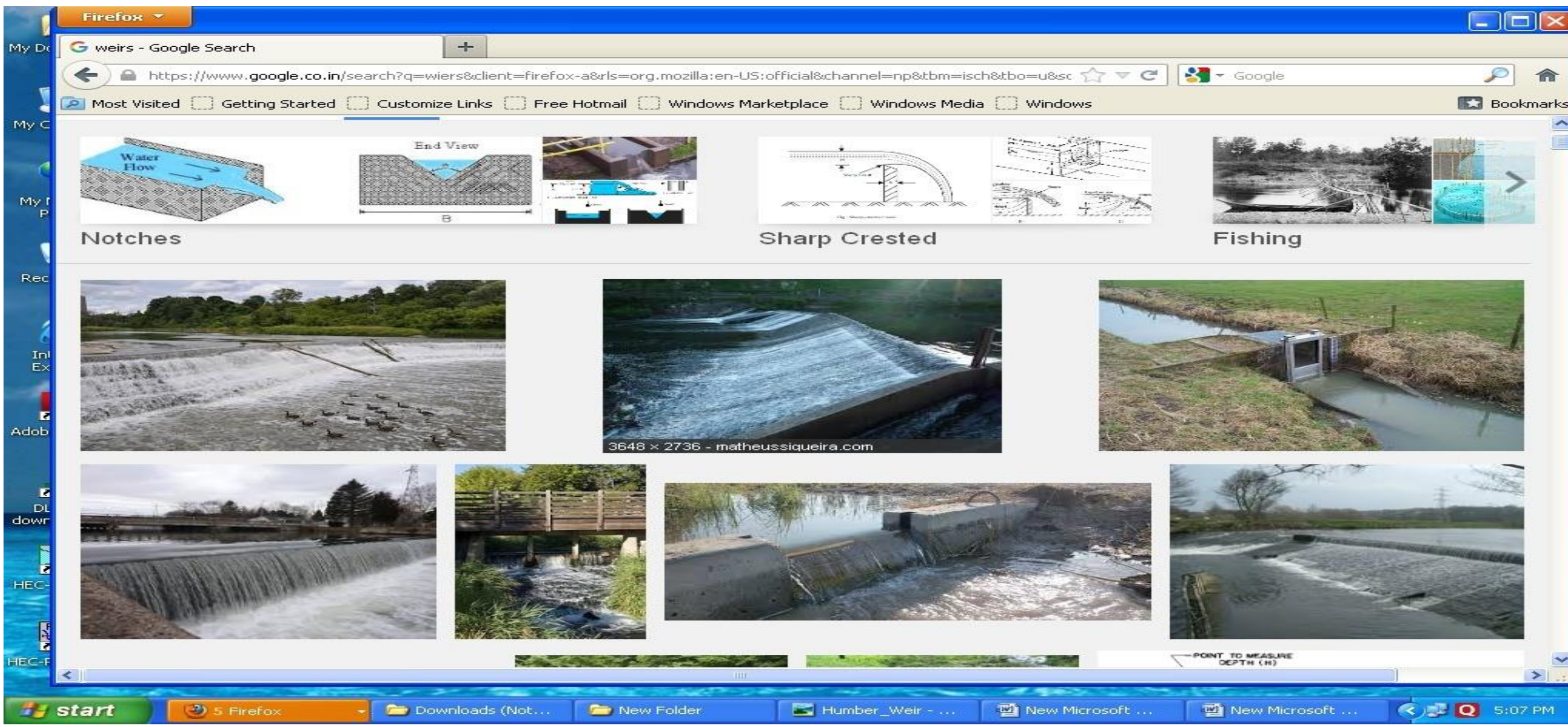
3.CLIMATE CHANGE APPLICATIONS

4.FLOOD FORECASTING, INUNDATION MAPPING, FLOOD HAZARD MAPPIND, FLOOD RISK MANAGEMENT, DAMAGE ASSESSMENT, AND FLOOD INSURANCE

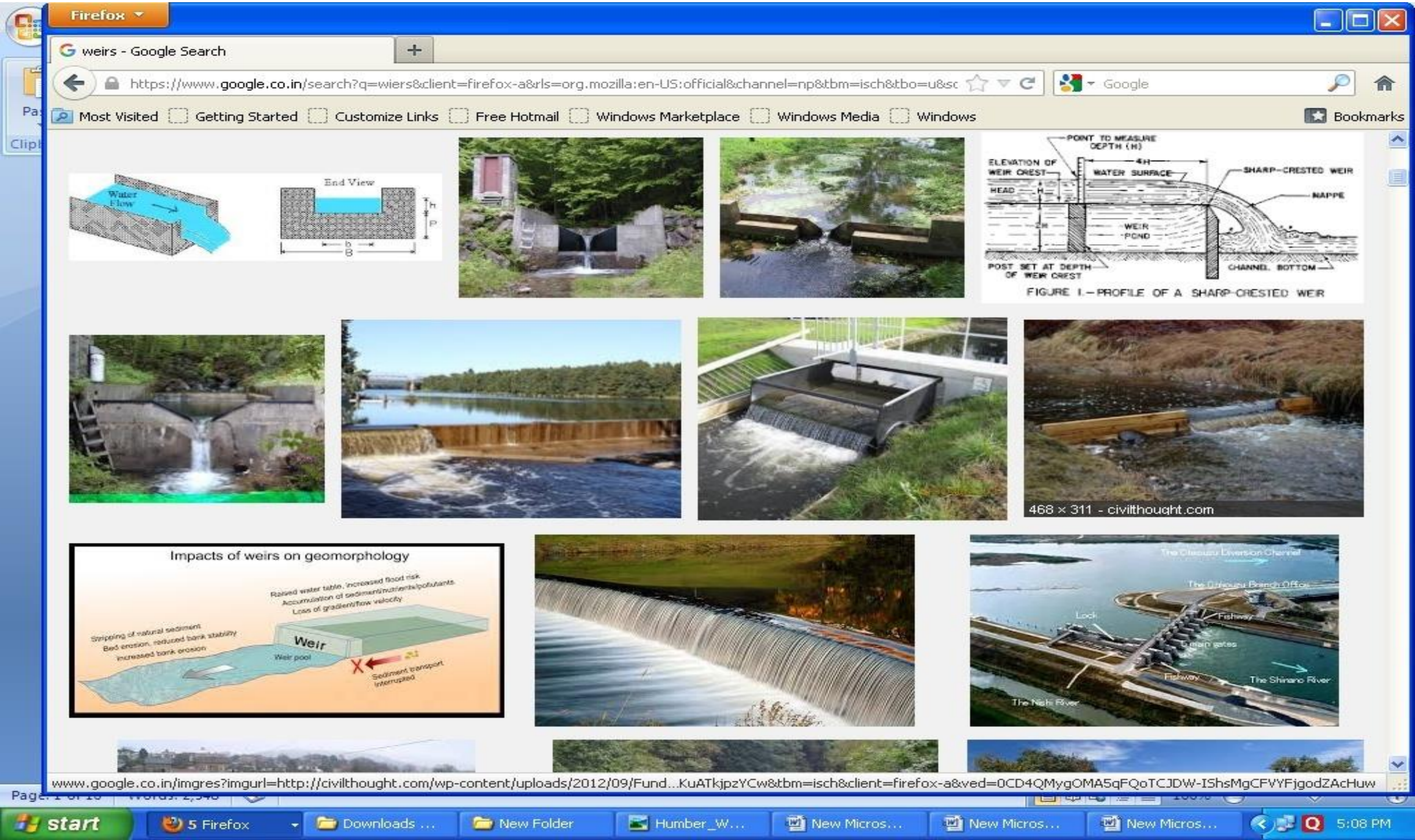
5.DESIGN OF IRRIGATION STRUCTURES – DESIGN OF SUBMERGED WEIRS

INTRODUCTION

OBJECTIVE OF THE PRESENT RESEARCH IS TO DEMONSTRATE THE APPLICATION OF SWAT MODULES IN THE DESIGN OF SUBMERGED WEIRS



DIFFERENT TYPES OF WEIRS




Firefox
weirs - Google Search
https://www.google.co.in/search?q=wiers&client=firefox-a&rls=org.mozilla:en-US:official&channel=np&tbm=isch&tbo=u&sc
Google
Most Visited
Getting Started
Customize Links
Free Hotmail
Windows Marketplace
Windows Media
Windows
Bookmarks
SIDES SLOPE 1 HORIZONTAL TO 4 VERTICAL
RECTANGULAR WEIR
CIPOLLETTI WEIR
90° NOTCH WEIR
BRICK, STONE OR CONCRETE WALL
WATER OVERFLOWS OVER THE WALL
DANGER
WEIRS
surface eddies
bed eddies
Sharp Crest
Fig : Sharp-crested weir
550 × 412 - openchannelflow.com
www.google.co.in/imgres?imgurl=http://www.openchannelflow.com/images/blog/upstream-co...uATkjpzYCw&tbm=isch&client=firefox-a&ved=0CGAQMygoMChqFQoTCJDW-IShsMgCFVYFjgodZAcHuw
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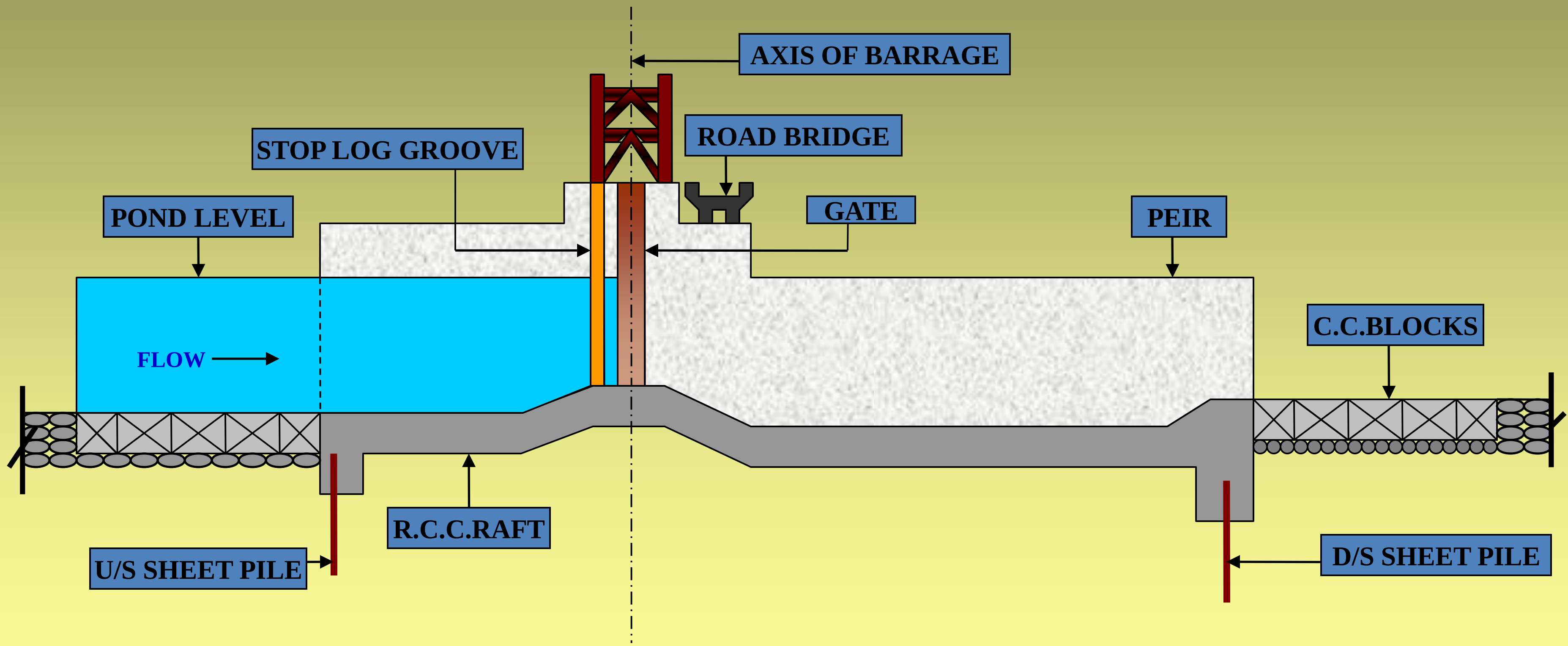
BARRAGE

A GATED STRUCTURE CONSTRUCTED ACROSS A RIVER TO RAISE THE WATER LEVEL FOR DIVERSION



SECTION OF BARRAGE

INTRODUCTION

FUNCTION OF SUBMERGED WEIRS

TO DIVERT THE WATER IN THE MAIN CANAL IT IS NECESSARY TO CONSTRUCT WORKS ACROSS THE RIVER AT THE HEAD OF OFFTAKING CANAL .THEY ARE KNOWN AS CANAL HEAD WORKS. THERE ARE TWO TYPES OF CANAL HEAD WORKS:

- DIVERSION WORKS – WEIR OR BARRAGE
- STORAGE WORKS – DAMS, CHECK DAMS

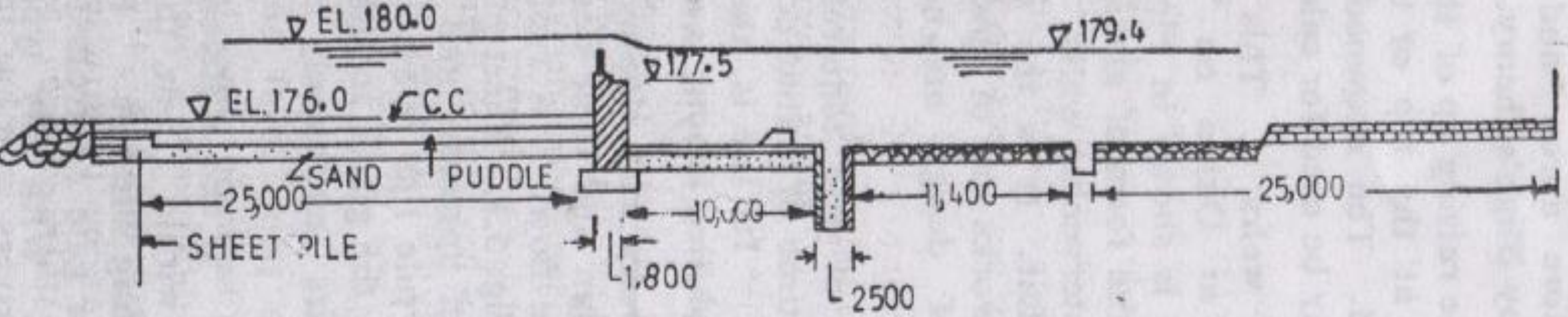


Fig. 5.1 Typical cross section of a vertical drop weir

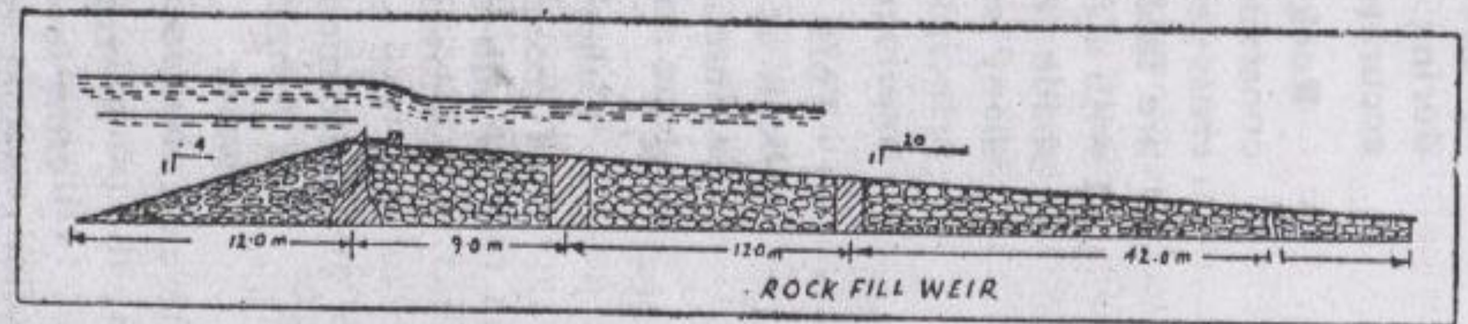
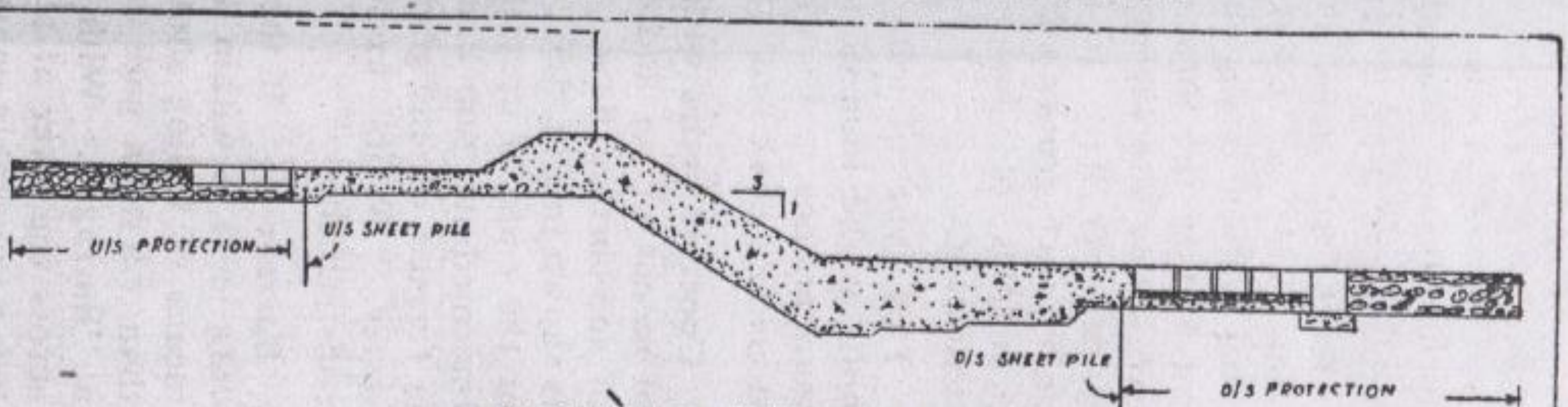
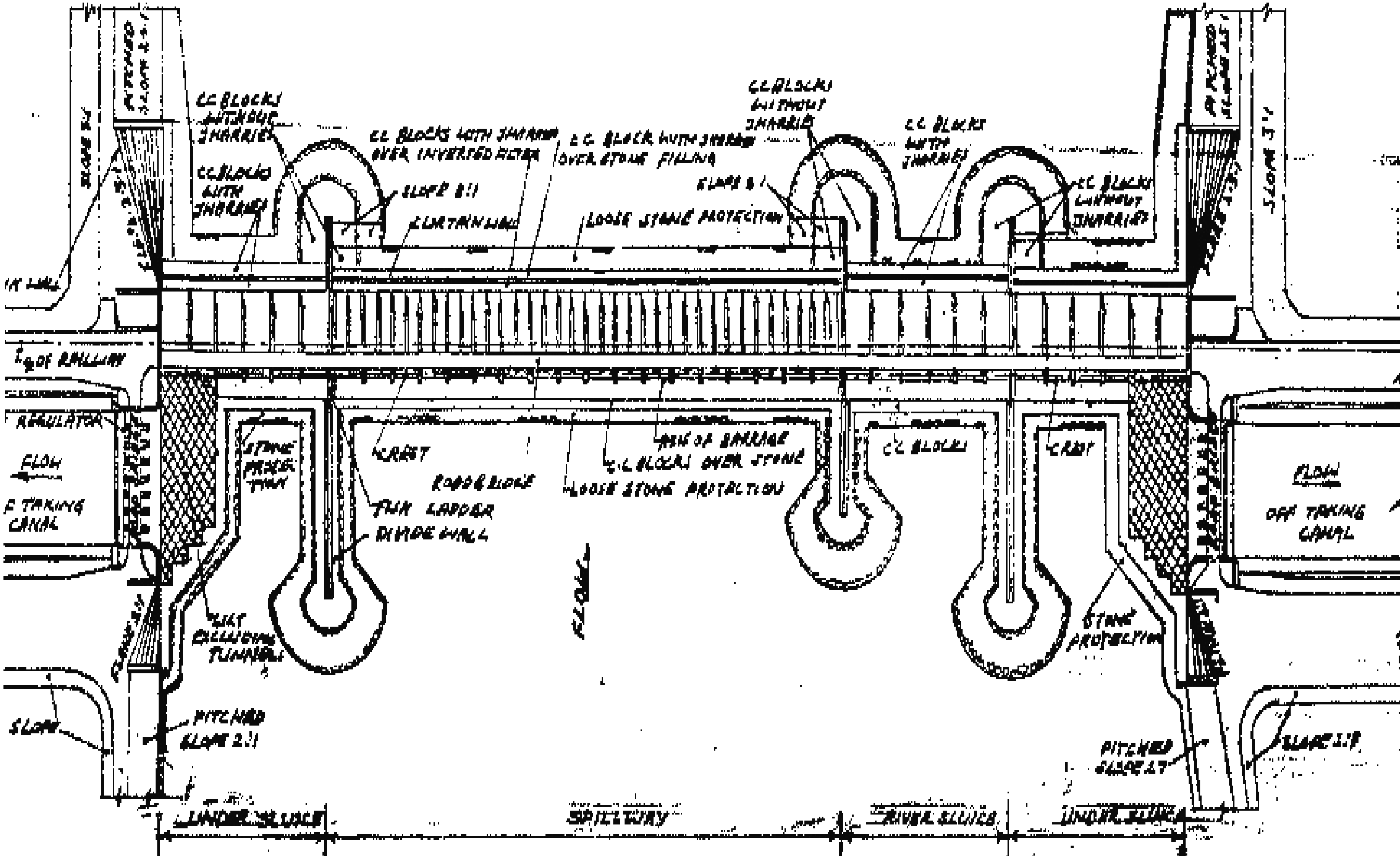


Fig. 5 2 Typical cross-section of a rock fill weir



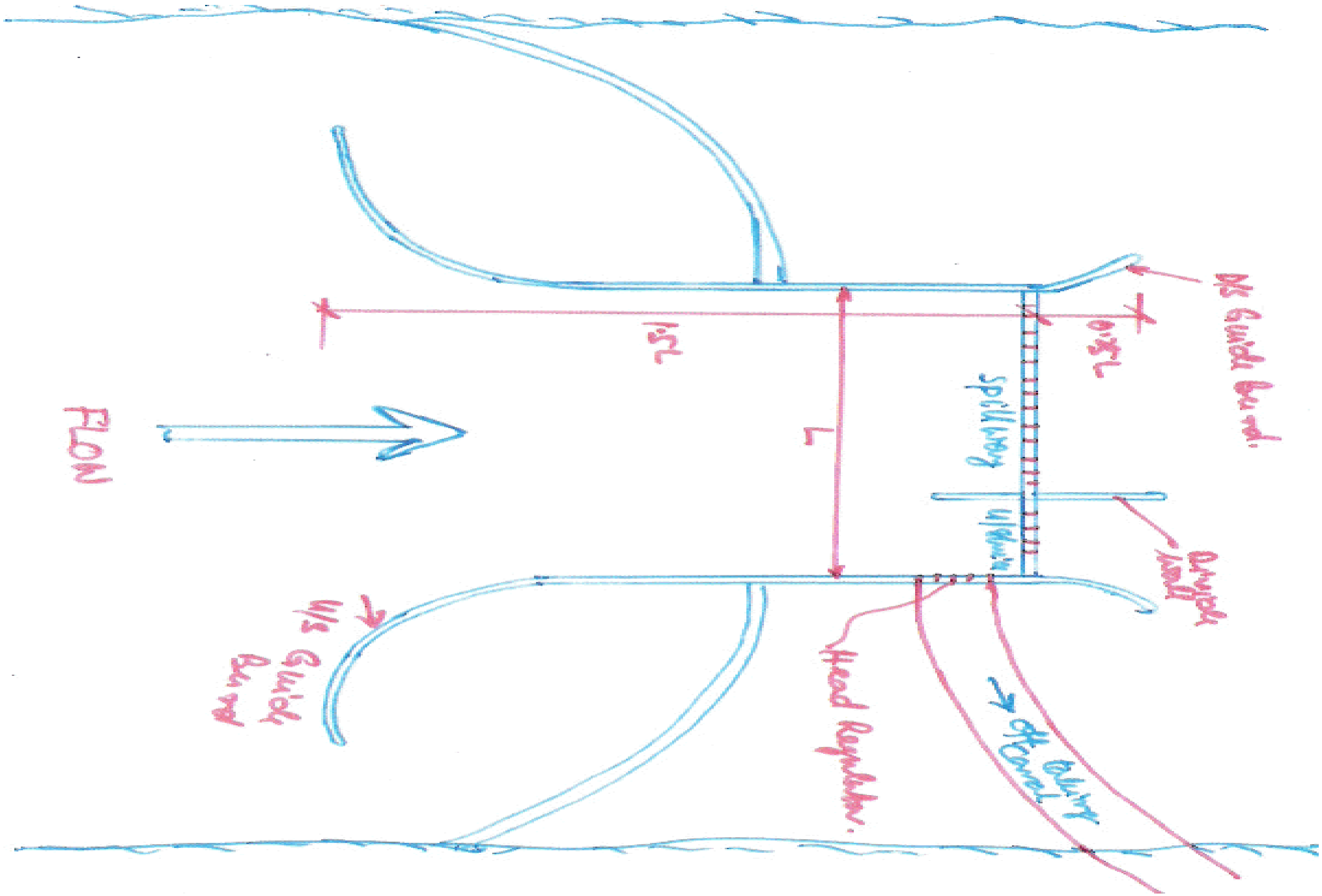
-CONCRETE WEIR WITH SLOPING GLACIS.

A TYPICAL BARRAGE PLAN

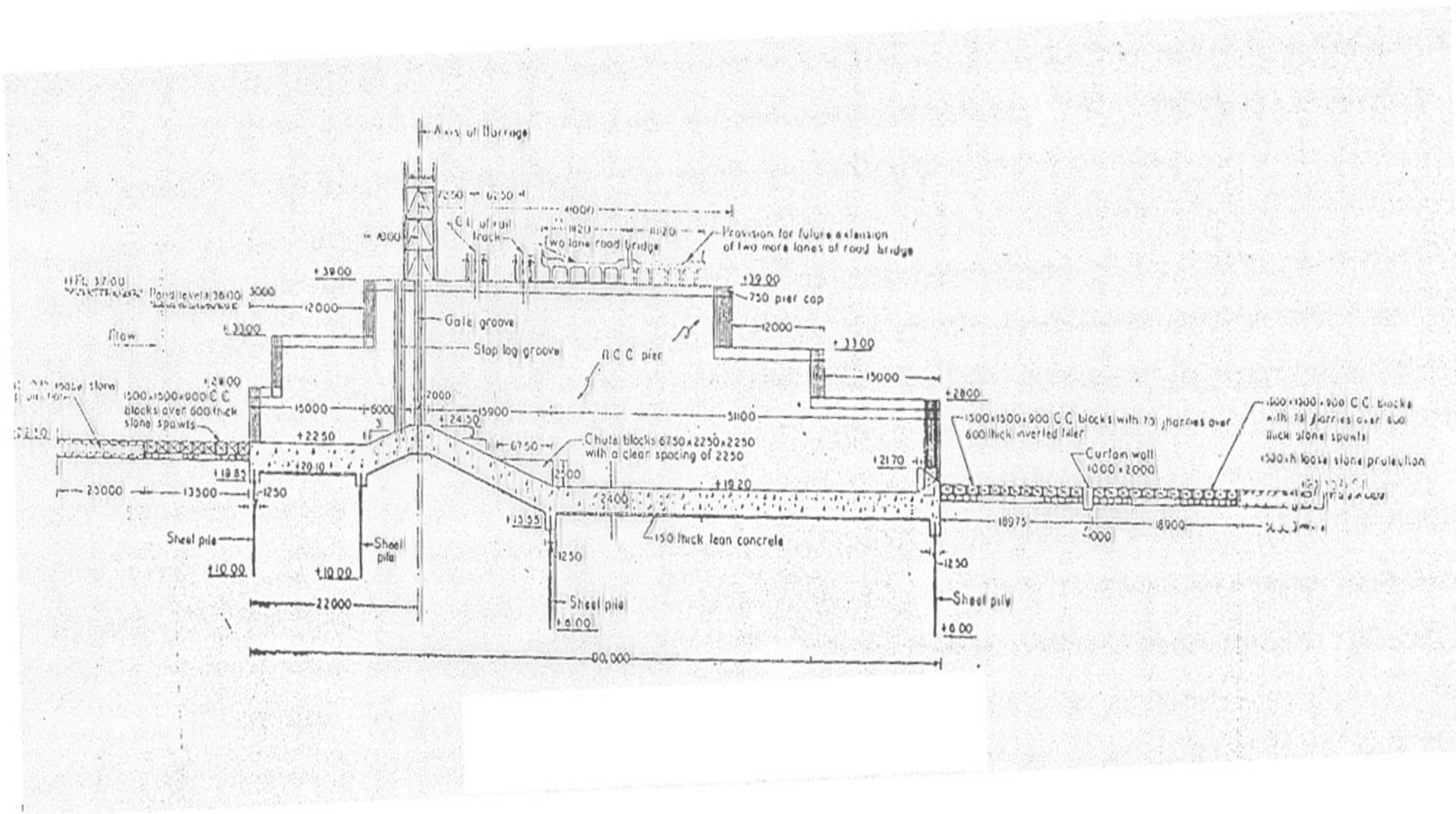


A TYPICAL LAYOUT OF A BARRAGE

A SIMPLE LAYOUT OF BARRAGE/WEIR

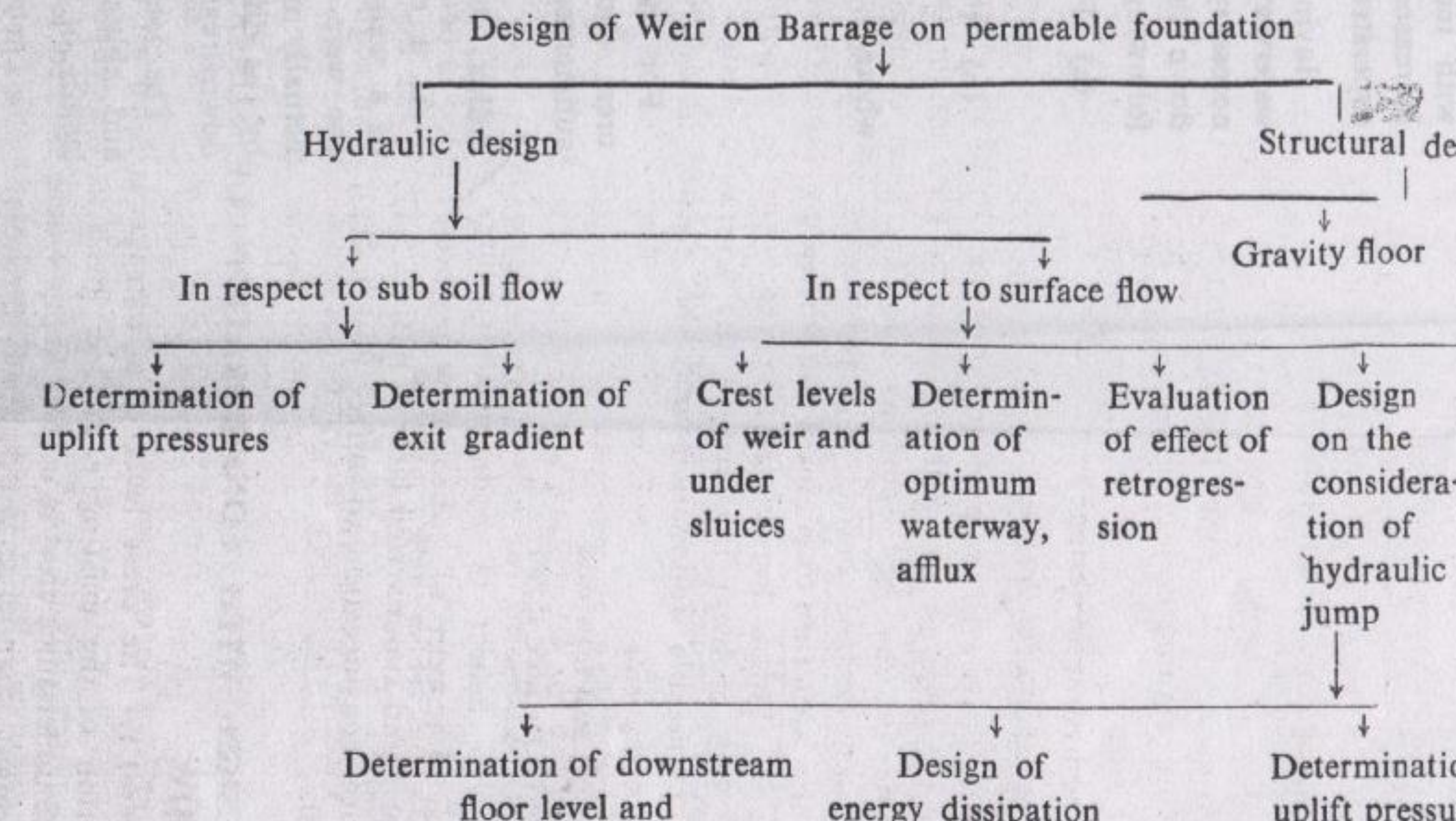


Section Through Spillways



DESIGN OF WEIR OR BARRAGE

Table 5.2



Hydraulic Design of Weir and Barrage

- MOST IMPORTANT PARAMETERS FOR HYDRAULIC DESIGN ARE WATERWAY AND AFFLUX
- AFFLUX MAY BE DEFINED AS DIFFERENCE IN WATER LEVEL AT ANY POINT UPSTREAM OF WEIR BEFORE AND AFTER CONSTRUCTION OF WEIR
- WATERWAY IS THE WIDTH OF WEIR WHICH IS GOVERNED BY VALUE OF AFFLUX

FACTORS GOVERNING WATERWAY

IS 6966 (Part 1) : 1989

8 AFFLUX

8.1 The width of the barrage/weir is governed by the value of afflux (at the design flood) to be permitted and the proposed crest levels. It is also important for the design of downstream cistern, flood protection and river training works, upstream and downstream loose protections and upstream and downstream cut-offs. The maximum permissible value of afflux has to be carefully evaluated depending upon the river conditions upstream and after considering the extent of back-water effect, the area being submerged and its importance.

8.2 In the case of barrages or weirs, an afflux of 1 m is found satisfactory in the upper and middle reaches of the river. In lower reaches

FACTORS GOVERNING WATERWAY

5 DESIGN FLOOD DISCHARGE

For purposes of design of items other than free board, a design flood of 50 year frequency may normally suffice. In such cases where risks and hazards are involved, a review of this criteria based on site conditions may be necessary. For designing the free board, a minimum of 500 year frequency flood or the standard project flood [*see* IS 5477 (Part 4) : 1971] may be desirable.

6 RATING CURVE

6.1 In the absence of detailed data, preliminary rating curve may be prepared by computing the discharges at different water levels using the following formula:

$$Q = \frac{1}{n} . A\ R^{\frac{2}{3}}\ S_f^{\frac{1}{2}}$$

where

Q = rate of flow,

n = rugosity co-efficient (*see* IS 2912 : 1964)

A = area of cross-section of flow,

R = hydraulic mean radius in m, and

FACTORS GOVERNING WATERWAY

9 RETROGRESSION

9.1 Progressive retrogression or degradation of the downstream river and levels as a result of construction of a weir or barrage causes lowering of the downstream river stages which has to be suitably provided for in the design of downstream cisterns. The lowering of river water level due to retrogression on the downstream causes increased exit gradients.

9.2 Retrogression of water levels is more pronounced in alluvial rivers carrying more silt having finer bed material and having steep slope. A value of 1.25 to 2.25 m may be adopted as retrogression for alluvial rivers at lower river stages depending upon the amount of silt in the river, type of bed material and slope. Whenever a proposed barrage/weir is situated downstream of a dam, the possibility of heavier

CODAL PROVISIONS

IS 6966 (Part 1) : 1989

10.2 For meandering alluvial rivers for minimizing shoal formations, the following looseness factor shall be applied to Lacey's waterway for determining the primary value of the waterway.

Silt Factor	*Looseness Factor*
Less than 1	1.2 to 1
1 to 1.5	1 to 0.6

Lacey's waterway is given by the following formula:

$$P = 4.83\ Q^{\frac{1}{2}}$$

where

Q = design flood discharge in cumecs for 50 year frequency flood.

10.2.1 For deciding the final waterway, the following additional considerations may also be taken into account:

a) Cost of protection works and cutoffs,

b) Repairable damages for floods of higher magnitudes, and

c) Afflux constraints as determined by model studies.

CASE STUDY

Lacey's waterway for a submerged weir on a river having bank to bank width 93m and maximum flood discharge 4930 cumecs in alluvial plains as per codal formula is 337m and construction of weir or barrage will cost more than 100 crores rupees for which B.C ratio is not satisfied.

If the maximum flood discharge is passed through the river between the two firm banks of the river, the depth of sheet piles comes to be 18m and cost of sheet piles itself comes to be 6 crores rupees.

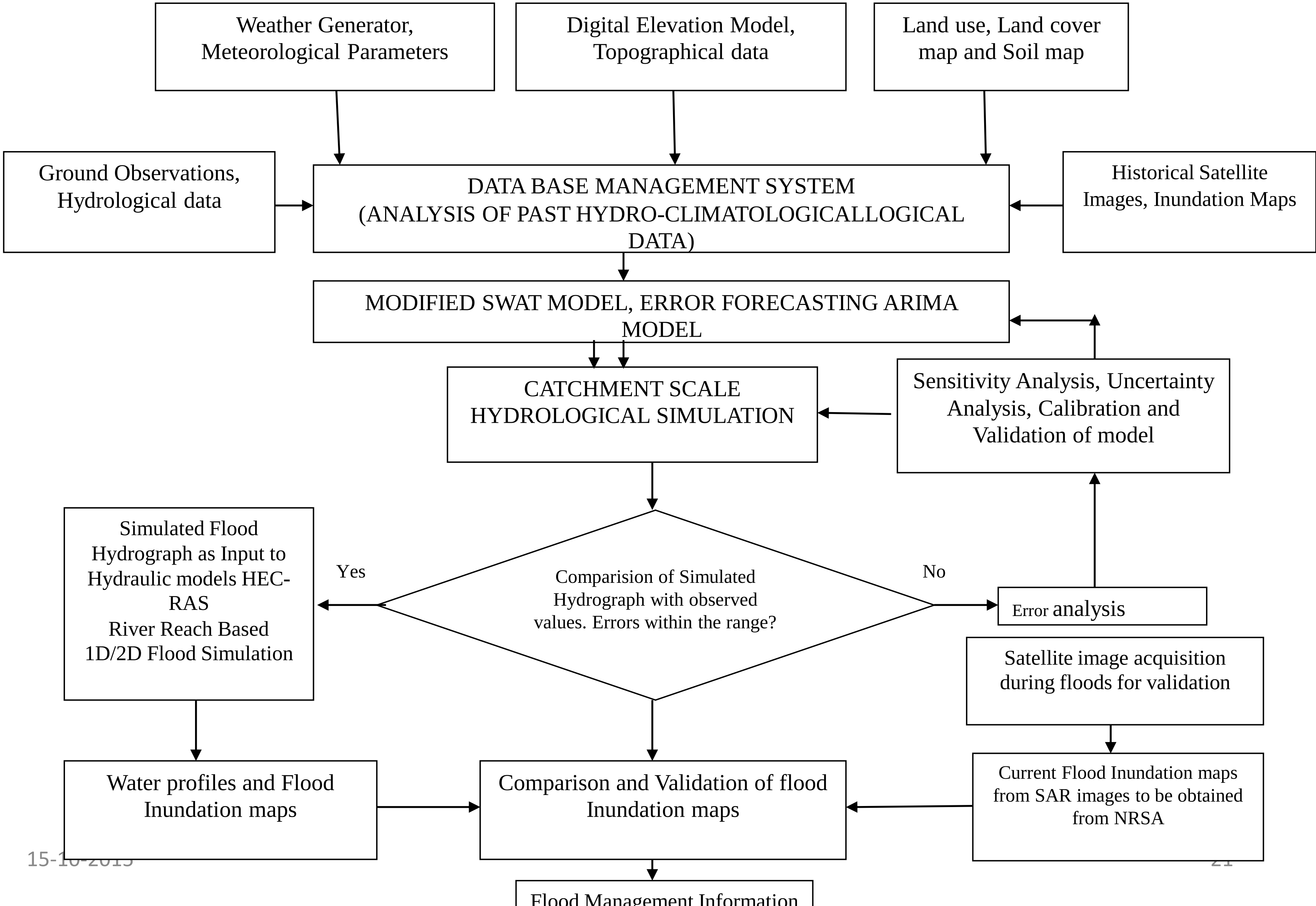
ROLE OF SWAT MODEL
AN INNOVATION

- DERIVING RATING CURVES FOR DATA SCARCE AREA
- DETERMINATION OF DESIGN FLOOD
- DETERMINATION OF SAFE WATERWAY

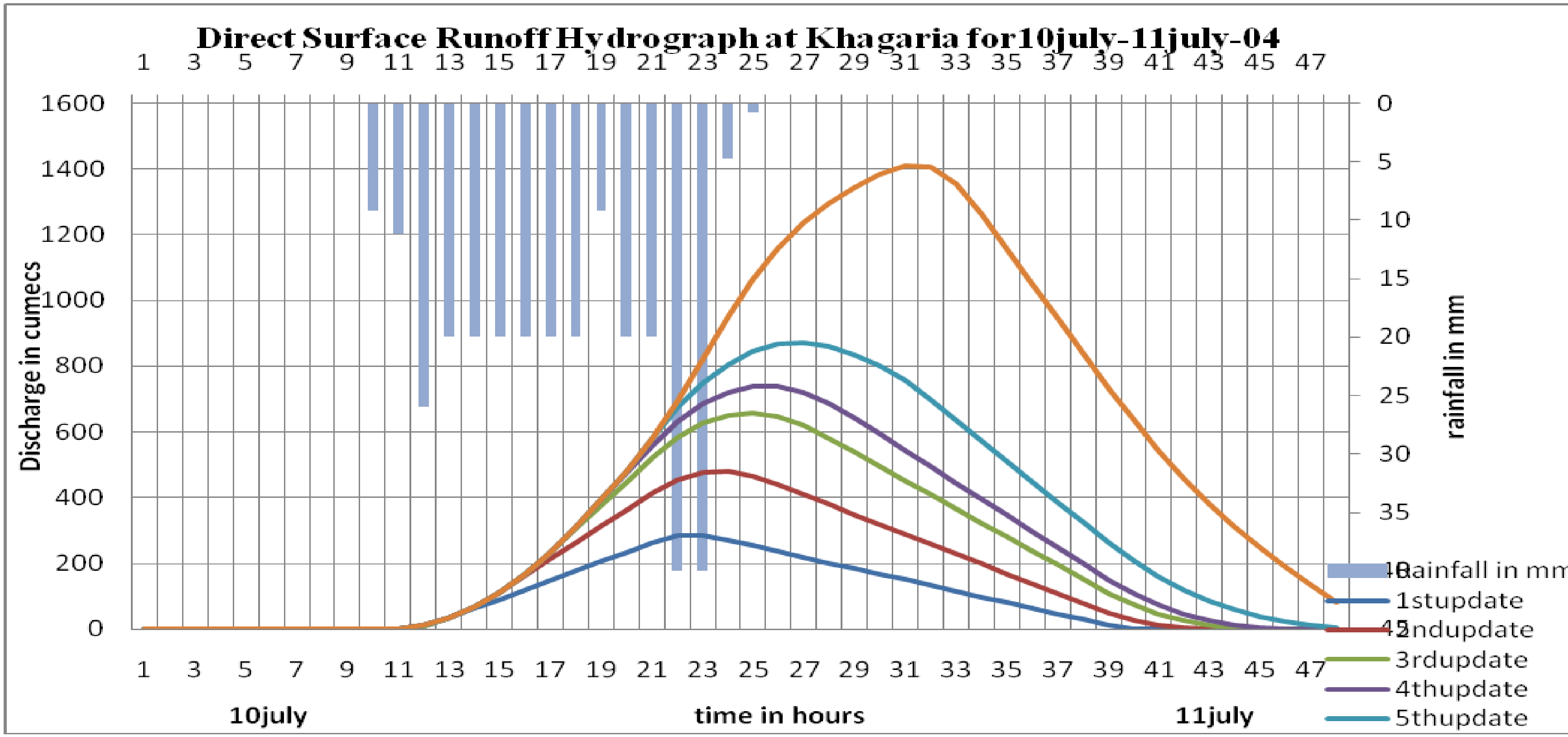
DETERMINATION OF WATERWAY

When the volume of water in the reach exceeds the maximum amount that can be held by the channel, the- excess water spreads across the flood plain.

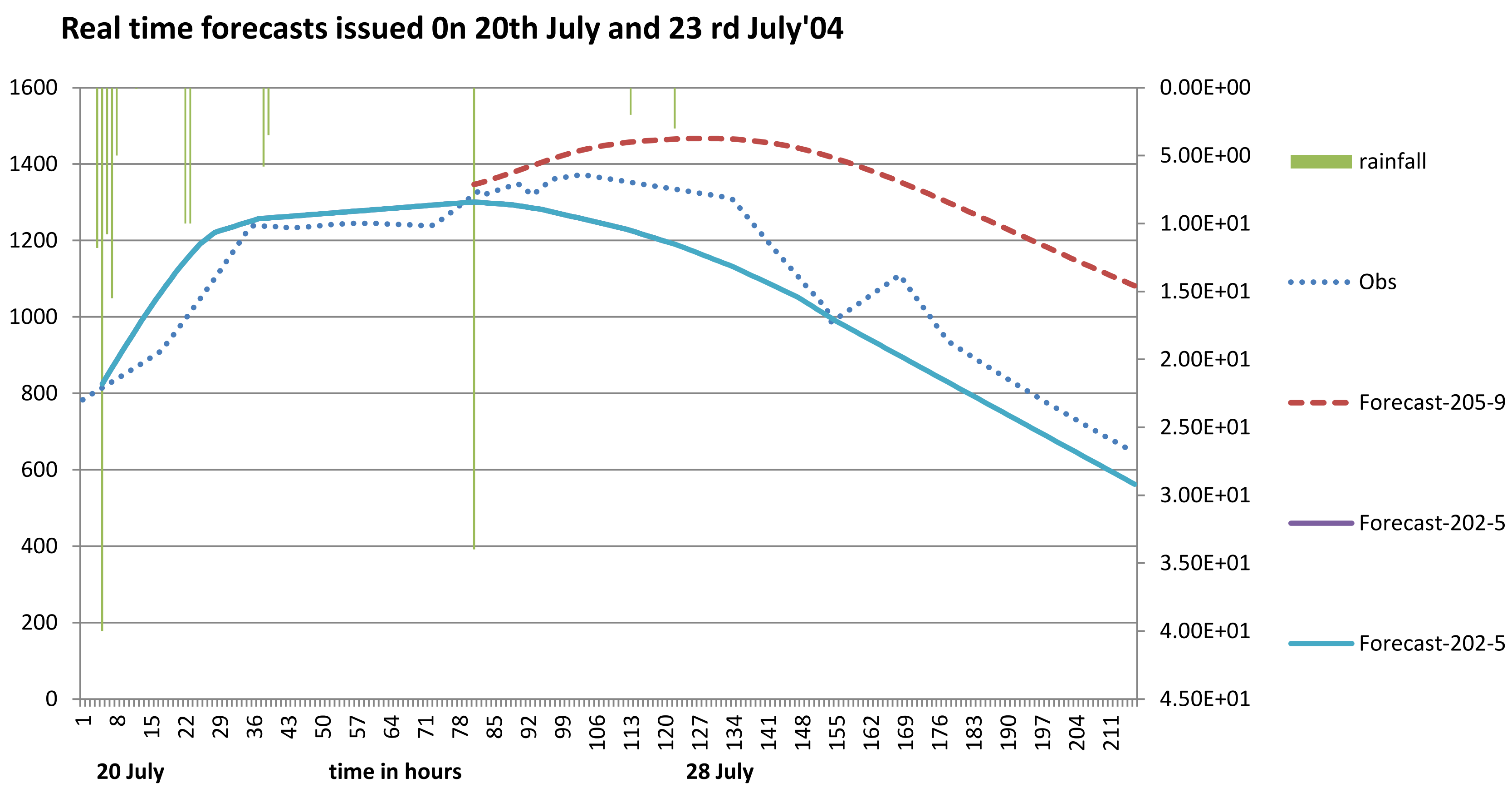
Flood management information network developed by Tiwary (2012)



Real time flood forecasting graph generated by modified SWAT model

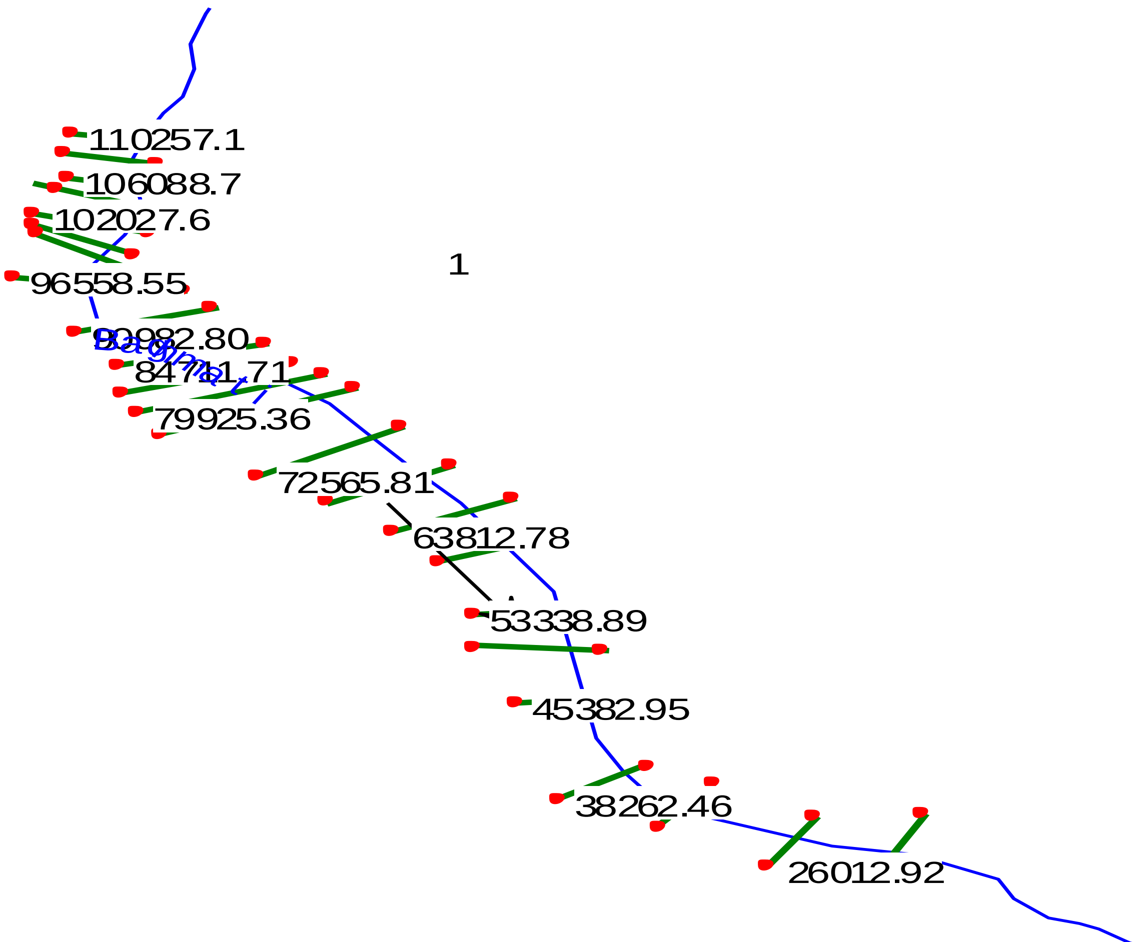


Real time forecasting graphs for 2004 Flood Event

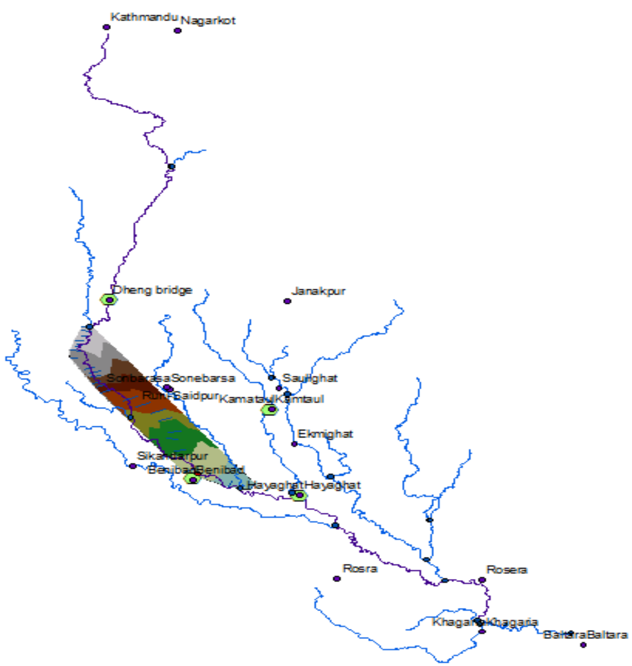


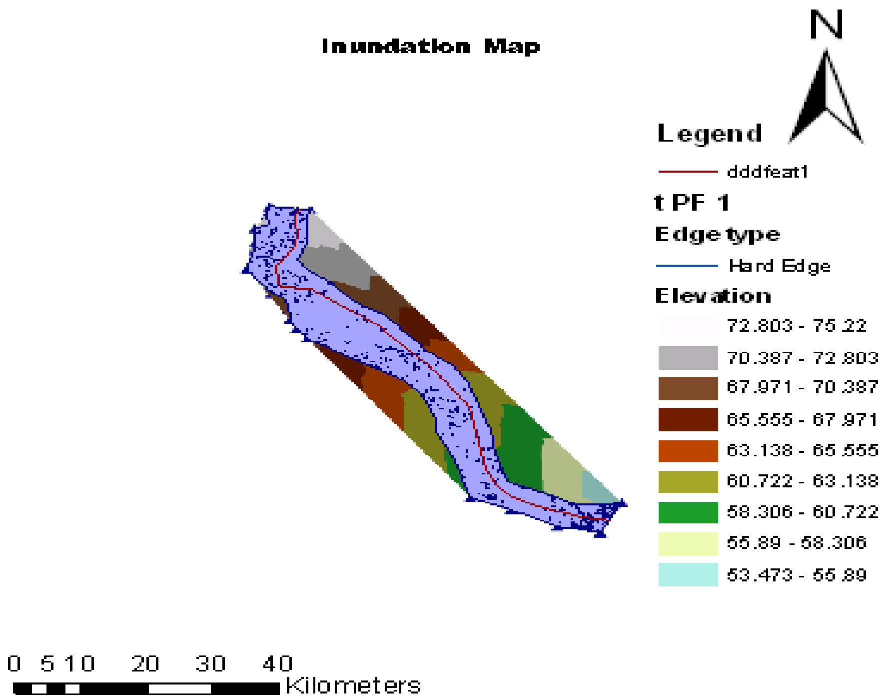
TRANSLATING FORECAST INTO INUNDATION MAP

CROSS-SECTION POSITIONS

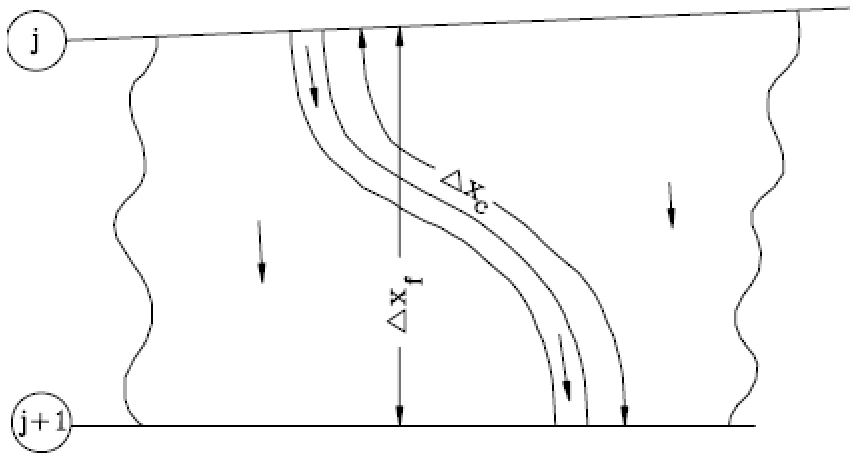


Expected Flood Inundation map of Bagmati river between Dheng Bridge and Hayaghat for July 2004 flood event simulated by SWAT and HEC-RAS





Governing Equations for flood inundation mapping



Two dimensional characteristics of interaction between channel and flood plain flows

Channel and floodplain flows

When the river rises water moves laterally away from the channel, inundating the flood plain and filling the available storage area. As the depth increases, the floodplain begins to convey water downstream generally along a shorter path than that of the main channel. When the river stage is falling, water moves toward the channel from the overbank supplementing the flow in the main channel

Governing equations for unsteady flow and flood inundation mapping

Continuity Equation

The continuity equation describes conservation of mass for the one-dimensional system. From previous text, with the addition of a storage term, S, the continuity equation can be written as:

$$\frac{\partial A}{\partial t} + \frac{\partial S}{\partial t} + \frac{\partial Q}{\partial t} - q_1 = 0$$

Where: x = distance along the channel,

t = time,

Q = flow,

Governing equations for unsteady flow and flood inundation mapping

Momentum Equation

The momentum equation states that the rate of change in momentum is equal to the external forces acting on the system. From Appendix A, for a single channel:

$$\frac{\partial Q}{\partial t} + \frac{\partial (VQ)}{\partial x} + gA\left(\frac{\partial z}{\partial x} + S_f\right) = 0 \quad 0 \qquad (3.2.2.12)$$

Where; g = acceleration of gravity

S_f = friction slope,

V = velocity.

The above equation can be written for the channel and for the floodplain:

$$\frac{\partial Q_c}{\partial t} + \frac{\partial (V_c Q_c)}{\partial x_c} + gA_c\left(\frac{\partial z}{\partial x_c} + S_{fc}\right) = M_f \, 0 \qquad (3.2.2.13)$$

$$\frac{\partial Q_f}{\partial t} + \frac{\partial (V_f Q_f)}{\partial x_f} + gA_f\left(\frac{\partial z}{\partial x_f} + S_{ff}\right) = M_c \quad 0 \qquad (3.2.2.14)$$

Where M_c and M_f are the momentum fluxes per unit distance exchanged between the

SWAT RECOMMENDATION FOR SAFE WATERWAY

The flood plain dimensions recommended by SWAT can be used to find the safe water way needed for design of sheet piles of a submerged weir

SWAT RECOMMENDATION FOR SAFE WATERWAY

Users are required to define the width and depth of the channel when filled to the top of the bank as well as the channel length, slope along the channel length and Manning's "n" value. SWAT assumes the channel sides have a 2:1 run to rise ratio (z_{ch} = 2.1). The slope of the channel sides is then 0.5. The bottom width is calculated from the bankfull width and depth.

SWAT DIMENSION FOR FLOOD PLAIN

Figure 3.8 Illustration of flood plain dimensions

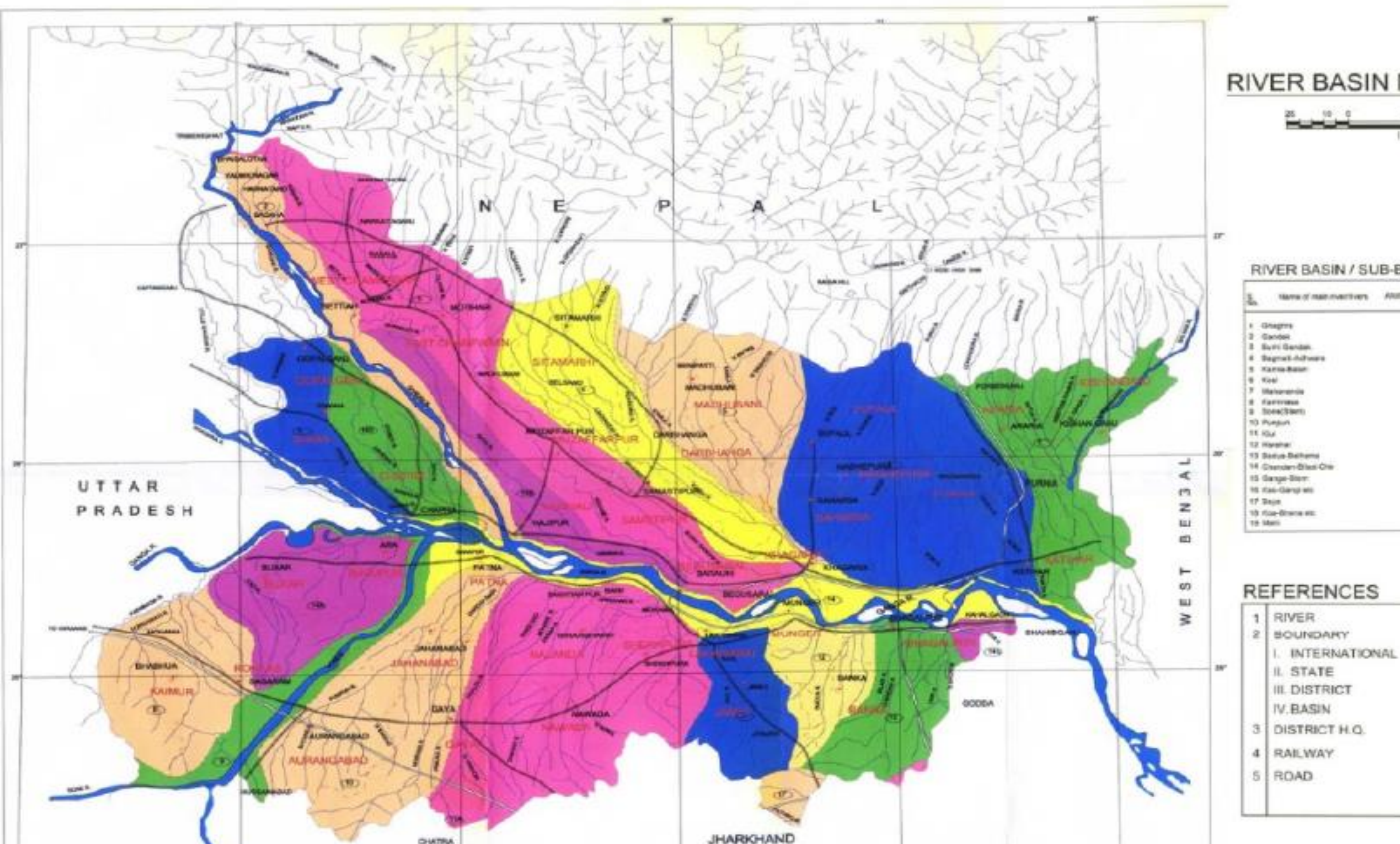
The bottom width of the floodplain, $W_{btm.fld}$, is $W_{btm.fld} = 5 . W_{bankfull}$ SWAT assumes the floor plain side slopes have a 4:1 run to rise ratio ($Z_{fld} = 4$). The slope of the flood plain sides is then 0.25. When flow is present in the flood plain, the calculation of the flow depth, cross-sectional flow area and wetting perimeter is a sum of the channel and floodplain components:

$depth = depth_{bankful} + depth_{fld}$

$A_{ch} = (W_{btm} + Z_{ch} . depth_{bankfull}) . depth_{bankfull} + (W_{btm.fld} + z_{fld} . depth_{fld}) . depth_{fld}$ ......(3.1.4.11)

$P_{ch} = W_{btm} + 2 . depth_{bankfull} . \sqrt{1 + z_{ch}^2} + 4 . W_{bankfull} + 2 . depth_{fld} . \sqrt{1 + z_{fld}^2}$ (3.1.4.12)

STUDY AREA


N E P A L
UTTAR PRADESH
WEST BENGAL
JHARKHAND
RIVER BASIN
RIVER BASIN / SUB-
REFERENCES
1 RIVER
2 BOUNDARY
I. INTERNATIONAL
II. STATE
III. DISTRICT
IV. BASIN
3 DISTRICT H.Q.
4 RAILWAY
5 ROAD

LOCATION OF PUNPUN BARRAGE AND PANTIT WEIR

DESIGN OF PROPOSED PANTIT WEIR ON RIVER PUNPUN

DESIGN DATA

1.High Flood Discharge =4930 Cumecs

2.Lowest (Avg.) Bed Level of the River at Site = 63.84 m

3.High Flood Level before Construction as per design data =66.96 m

4.Permissible afflux = 0.60 m

5.High Flood Level including afflux = 67.56 m

5.Top Level of Protection Works (67.56+1.0 (F.B.)) = 68.56 m

6.Pond Level as per design data = = 66.96 m

7.Lacey's Silt Factor as per design data = 1.0

8.Safe Exit Gradient for the River Bed material = 0.167

9.Concentration = 20%

10.Bed Retrogression = 0.34 m

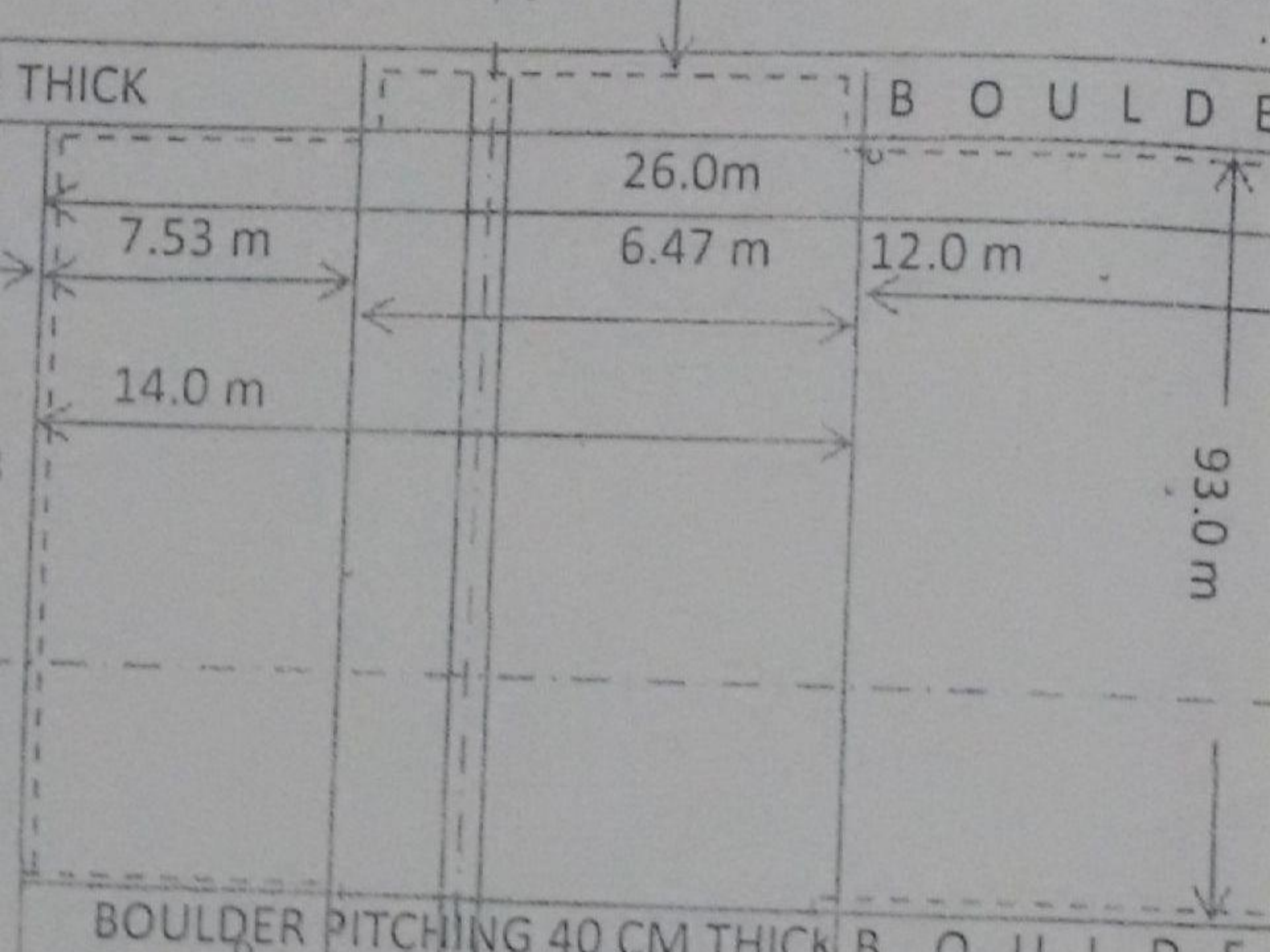
DESIGN OF PROPOSED PANTIT WEIR ON RIVER PUNPUN

DESIGN DATA

- CREST LEVEL AND WATER WAY
- Floor Level and Water Ways
- Keep upstream floor level =63.84 m
- Keep upstream floor level of the weir way =
  63.84+ 1.73 = 65.57 m
- Height of Falling Shutter = 0.96 m

CODAL PROVISION

- As per IS 6966 (Part I) : 1989 Hydraulic Design and Barrages and weirs – Guidelines
- Lacey's waterway = 4.8 * Q^0.5 = 4.83x4930^0.5= 337 m
- Drowning Ratio Barrage bays
- = D/S Water Level – Crest Level /U/S Water Level – Crest Level
- = 0.91
- From graph coeffiecient of discharge for Barrage bays = 1.70
- Discharge through Barrage bay = 1.2x93x3.13^1.5 = 1099.03 Cumec
- Total Discharge = 1099Cumec
- <4930 O.K.
- Lacey's waterway 4.83x4930^0.5 = 337 m
- Looseness Factor 51.7/87.7 = 0.59


THICK
B O U L D E
26.0m
7.53 m
6.47 m
12.0 m
14.0 m
93.0 m
BOULDER PITCHING 40 CM THICK

Determination of Scour Depth

19 SCOUR

19.1 River scour is likely to occur in erodible soils, such as clay, silt, sand and shingle. In non-cohesive soils, the depth of scour may be calculated from the Lacey's formula which is as follows:

$R = 0.473 \left(\frac{Q}{f}\right)^{\frac{1}{3}}$ when looseness factor is more than 1, or

$R = 1.35 \left(\frac{q^2}{f}\right)^{\frac{1}{3}}$ when looseness factor is less than 1

where

R = depth of scour below the highest flood level in m;

Q = high flood discharge in the river in m^3/s;

f = silt factor which may be calculated by knowing the average particle size m_r, in mm, of the soil from the relationship:

comprising of cement concrete blocks
adequate size laid over loose stone shal
provided. The cement concrete blocks shal
of adequate size so as not to get dislodged,
shall generally be of 1 500 × 1 500 × 900
size for barrages in alluvium reaches of rive

20.1.2 The length of upstream block protec
shall be approximately equal to D, the de
depth of scour below the floor level.

20.2 Downstream Block Protection

20.2.1 Pervious block protection shall
provided just beyond the downstream en
impervious floor as well. It shall compris
cement concrete blocks of adequate size
over a suitably designed inverted filter for
grade of material in the river bed. The cen
concrete blocks shall generally be not sma
than 1 500 × 1 500 × 900 mm size to be
with gaps of 75 mm width, packed with gra

20.2.2 The length of downstream b
protection shall be approximately equa
1.5 D. Where this length is substantial, b
protection with inverted filter may be prov
in part of the length and block protection

Using SWAT Module for reducing cost of sheet piles

- Using SWAT flood plain formula Discharge Intensity was found using Manning’s formula
- Flood Intensity was found to be 50cumecs per meter and depth of sheet pile was calculated as as 5m and cost of sheet piles was reduced 6 times (one crore rupees) and total cost of submerged weir was found to be 10 crores which satisfied technoeconomic feasibility condition.

Thank you