Government of West Bengal
Irrigation & Waterways Department
Jalasampad Bhaban, 3rd Floor, Western Block
Bidhannagar, Salt Lake City, Kolkata 700091

Memo No. 93 – IFC
IW/O/IFC/4M-30/2014

Dated, 26th March 2018

MEMORANDUM

With a view to taking a holistic approach to evolve appropriate technical solution to the problem of erosion in river and sea-coast in various districts of the State in consideration of hydro-morphological condition of the rivers, characteristics of riverbank and sea-beach materials, availability of construction materials for protection of riverbanks or sea-coast, a Technical Experts' Committee (TEC), headed by Dr. D Sen, Head, School of Water Resources, IIT Kharagpur, Dr. S. Mukherjee, Professor, Department of Civil Engineering, Jadavpur University and various other Engineers Officers of this Department was constituted vide Memo No.200-IFC/IW/O/4M-30/2014 dated 10th September 2014.

2. The TEC, after holding detailed deliberation on various pertinent issues including review of existing provision of BIS Codes and other guidelines of CWC, IRC, etc. and also the standard practices of this Department in six meetings, has brought out detailed guidelines on standardization of riverbank protection and coastal protection works for different districts of the State, clustered in five zones. The report of the TEC has since been accepted by the Government in this Department.

3. A copy of the said Report comprising two parts, i.e. general discussion on the mechanism of erosion and governing principles as well as approach methodology to take up anti-erosion works in the first part, and zonewise recommendation on standardized measures for such anti-erosion works in the second part, is enclosed herewith as Annex.

4. All schemes relating to riverbank and coastal protection works should henceforth be prepared in accordance with the recommendations made by the Committee for different zones.

Any departure from the standardized measures suggested in the Report will require adequate technical justification, supported by facts and figures.

5. Although the Committee did not offer detailed recommendations on relatively new technological developments such as use of Polypropylene (PP) Geobags, Geo-reinforced Wall, High Density Polyethylene (HDPE) sand bags, concrete Tetrapods, etc., field level officers of this Department are encouraged to embrace the new technologies, subject to proven track record of economy, durability and suitability of application under different conditions of exposure.

6. These guidelines will have immediate effect on all the schemes, other than those schemes, which have already been cleared by the Departmental Screening Committee.

7. All concerned may accordingly be informed.

Sd/-
G Chattopadhyay
Secretary to the
Government of West Bengal

Encl. Annex

No.93/1(11) – IFC **Dated, 26th March 2018**

Copy with copy of Annex forwarded for information to:

1 Dr. Dhrubajyoti Sen
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3 The Chairman
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4 The Chairman
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MoWR, RD & GR, Government of India
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5 The Chief Engineer (B & BBO)
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"Maranatha" Pokhesh, P.O. Rynjah (Upling)
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6 The Chief Engineer (TBO)
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9 The Principal Secretary
Public Works & Public Works (Roads) Department
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10 Finance (Audit) Department, Group –F
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11 The General Manager
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D SenGupta
Joint Secretary to the
Government of West Bengal

Encl. as stated

No.93/2(7) – IFC **Dated, 26th March 2018**

Copy with copy of Annex forwarded for information to:

1 Chief Engineer
Teesta Barrage Project
Irrigation & Waterways Directorate

2 Chief Engineer (North East)
Irrigation & Waterways Directorate

3 Chief Engineer (North)
Irrigation & Waterways Directorate

4 Chief Engineer (West)
Irrigation & Waterways Directorate

5 Chief Engineer (South West)
Irrigation & Waterways Directorate

6 Chief Engineer (South)
Irrigation & Waterways Directorate

7 Chief Engineer (D & R)
Irrigation & Waterways Directorate

All officers under his control may please be informed.

D SenGupta
Joint Secretary to the
Government of West Bengal

Encl. as stated

No.93/3 – IFC **Dated, 26th March 2018**

Copy with copy of Annex forwarded for information to:

Sujay Saha
Deputy Director
Advance Planning, Project Evaluation & Monitoring Cell
Irrigation & Waterways Directorate

– with a request to upload this Order and also separately the guidelines on the departmental website in the Home Page.

D SenGupta
Joint Secretary to the
Government of West Bengal

Encl. as stated

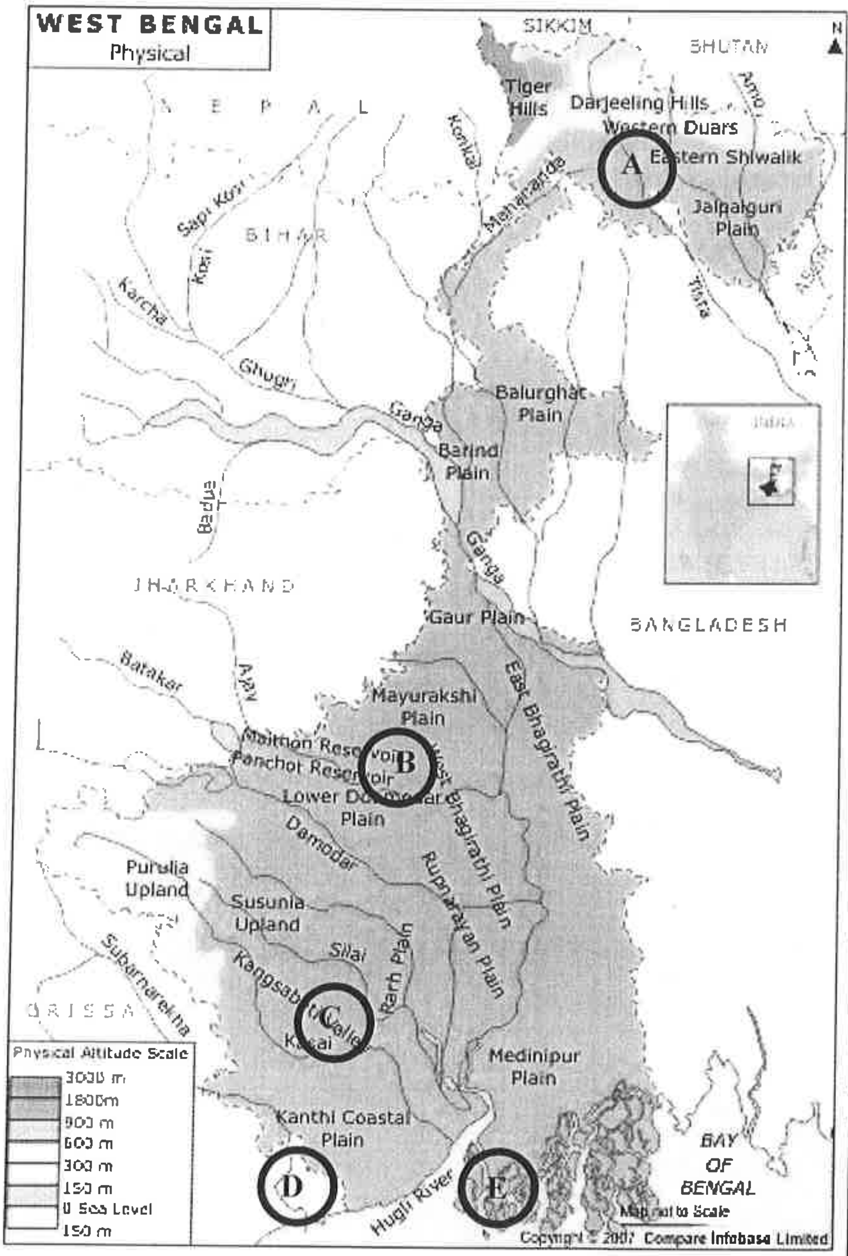
Guidelines on riverbank protection and anti-sea erosion works in West Bengal

1.0 Introduction

This manual provides guidelines for planning and design of bank protection measures for the rivers and sea-coasts of West Bengal. Since the nature and characteristics of these rivers vary considerably (Figure 1), the manual discusses the following:

(a) The general considerations that have to be borne in mind while planning/selecting the protection works

(b) The specific measures that are appropriate for protecting the banks of rivers and sea-faces



Zone A: North Bengal districts i.e. Darjeeling, Jalpaiguri, Alipurduar & Coochbehar.
Soil: Boulder mixed with shingles/Alluvial
District mostly covered: Darjeeling, Jalpaiguri, Coochbehar, Alipurduar.

Zone B : North Central (Uttar & Dakshin Dinajpur), Central (Malda & Murshidabad, Western (Birbhum, Bankura, Burdwan) , Non - tidal zones in Paschim & Purba Medinipur, Hooghly & Howrah and Eastern (Nadia & non-tidal zones of North 24-Parganas district.
Soil: Silty loam/Clay/Sand stratified

Zone C: Tidal zones in South Bengal in Paschim/Purba Medinipur, (except sea coast), Hooghly, Howrah, Kolkata, North & South 24-Parganas (except Sundarban area).
Soil: Silty clay/Clayey silt loam.

Zone D : Coast line in Purba Medinipur District at Digha-Shankarpur, Tajpur area.
Soil: Mostly stratified

Zone E: Sundarban areas in North & South 24-Parganas and sea dykes in Purba Medinipur away from coast line.
Soil: Clayey silty loam.

Figure 1: Characterization of the rivers of West Bengal
Map courtesy: Maps of India (*www.mapsofindia.com/*)

2.0 References

The following national and international standards/manuals/guidelines have been referred to while framing this manual. These and any other text appropriate to the subject may be referred to, while framing a proposal on bank protection measure at a site.

(a) BIS(1995) IS: 14262 "Planning and design of revetment – Guideline"
(b) BIS(2013) IS: 14262 "Planning and design of revetment – Guideline" (draft revision)
(c) CWC (2012) "Handbook for Flood Protection, Anti-erosion and River-training Works", Central Water Commission, New Delhi
(d) WES (1997) "The WES Stream Investigation and Stream Stabilization Handbook", U. S. Army Waterways Experimentation Station, Vicksburg, Mississippi, USA.
Available in public domain at the following website:http://chl.erdc.usace.army.mil/ Media/2/8/7/StreambankManual.pdf
(e) USACE (1991) "Hydraulic Design of Flood Control Channels, EM-1110-2-1601", U.S. Army Corps of Engineers (1991), USA.
Available in public domain at the following website: http://www.publications.usace.army.mil/ Portals/76/Publications/EngineerManuals/EM_1110-2-1601.pdf
(f) BC (2000) "Riprap design and construction guide", Public Safety Section, Water Management Branch, Province of British Columbia, Canada
Available in public domain at the following website:http://www.env.gov.bc.ca/ wsd/public_safety/flood/pdfs_word/riprap_guide.pdf

3.0 General Considerations

River / Estuary / Sea-case erosion is a result of interaction between the forces generated by river / tide / sea hydrodynamics and the soil or earth forming the bank line. These are elaborated in the following paragraphs which may have to e kept in mind by the engineer while conceptualizing a scheme for bank protection.

3.1 Flow characteristics

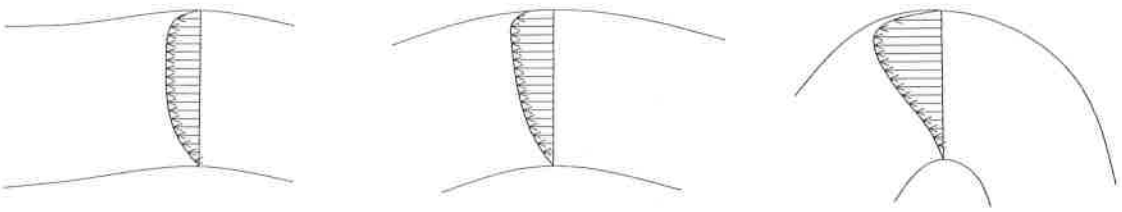
The hydrodynamic loadings vary depending broadly upon the condition on whether the flow is:

(a) Through a river unaffected by tide
(b) Through a river that is tidal

Some other considerations are listed in the following paragraphs.

3.1.1 Bank curvature

For flow in rivers, the depth averaged velocity in the flow direction varies across the river width (in plan view) depending upon the curvature of the bank, as in meanders (Figure 2).



(a) (b) (c)

Figure 2: Plan view of depth-averaged velocity profiles in streams/rivers with (a) Low curvature; (b) Medium curvature, and (c) High curvature

Considerations on the velocity variation is important as, in the absence of field measurement of velocity, a suitable increased velocity needs to be adopted in the design of bank protection.

3.1.2 Impinging flow

Flow in river bends produces impinging flows in the upper layers of the flowing water (Figure 3).

Figure 3: Impinging flow in channel bends

3.1.3 Secondary flow

Flow in river bends produces secondary flows (Figure 4) which enhances the hydrodynamic loadings on the river bank.

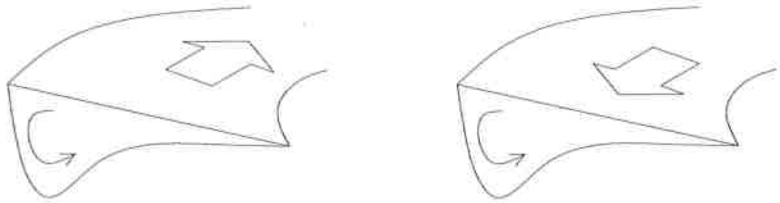


Figure 4: Secondary flow in channel bends (the main flow direction may be in any direction)

3.1.4 Rapid depletion of water stage

In some rivers, the flow situation may be such that the water level may deplete rapidly from a high to a low stage within a relatively short period of time which may not permit release of the pore water pressure within the riverbank material. This may lead to failure of the bank.

3.1.5 Overbank flow

For some rivers, the high flood level may exceed the bank level (Figure 5). In this case, the bank protection measure has to be carefully planned for flood discharges.

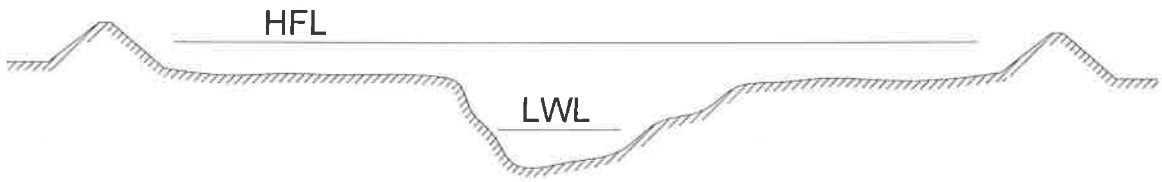


Figure 5: High flood level (HFL) above riverbank that requires protection

3.1.6 Waves due to wind

For some rivers, the closeness to the sea sets up waves that impinge on the bank, causing further erosion.

3.1.7 Waves due to navigation

In some rivers, the passage of vessels generates additional waves that tend to erode the bank further, in addition to the hydrodynamic loadings.

3.1.8 Sea waves

These are the waves generated in the sea which impinge on the shorelines of estuaries and sea-faces.

3.1.9 Other factors

Human activities and animal grazing on the banks may aid in bank erosion.

3.2 Geotechnical characteristics

Variations in earth/soil characteristics of the riverbank also influence the decision on the erosion protection measures. These geotechnical characteristics of the rivers of West Bengal, as indicated in Figure 1, are not always alluvial. On the other hand guidelines such as those given in IS: 14262 (Indian Standard on Planning and Design of Revetment) are developed for alluvial rivers (Reference: Section 1, IS: 14262). Of course, most of the protection works primarily meant for alluvial rivers may also be applied to other types of riverbank materials. Nevertheless, the following geotechnical considerations may be kept in mind while designing bank-protection works.

3.2.1 Soil homogeneity

While implementing bank protection measures, it is important to remember that the type of soil of the bank may be differ according to location. Bank soils may be classified as:
Homogenous:

* Alluvial material
* Estuarine silt

Non-homogenous:

* Cay/silt soils
* Layered soils clay/silt/sand

3.2.2 Bank failure mechanisms

Failure of unprotected banks has been widely studied and details are available in references like reference (d) mentioned in Section 2.0. Examples of different modes of geotechnical stream bank failure include the following:

* Soil fall
* Rotational slip
* Slab failure
* Cantilever failure
* Pop-out failure
* Piping
* Dry granular flow
* Wet earth flow, etc.

3.3 Scouring of riverbeds during floods

Scour of the riverbeds takes place during floods. Bend scour occurring towards the outer bank of a meandering river is of great concern to the designers of bank protection.

3.3.1 Scour formation in river bends

Bend scour, that is, the scour forming at a meander bend (Figure 6a) is due to the impinging and secondary flow currents, as discussed in Section 3.2, apart from the shear stress generated by the longitudinal (stream-wise) flow velocity. Bend scour is greater than that occurs in a straight channel (Figure 6b). Further, it is observed that the maximum depth of scour is greater during the passage of flood.

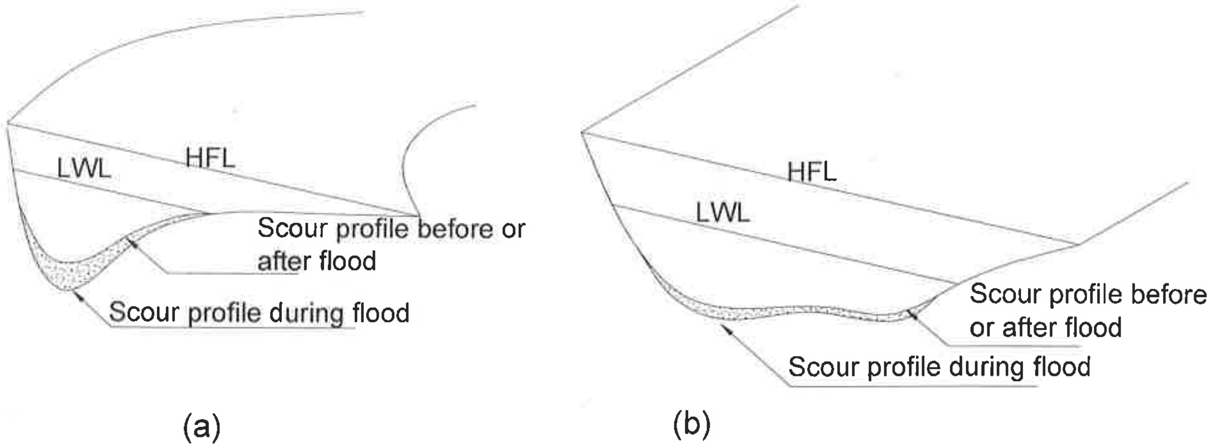


Figure 6: Scour formation (a) At bend; and (b) In straight reach

3.3.2 Depth of scour

IS: 14262 "Planning and design of revetment – Guideline" recommends the following for estimation of the maximum depth of scour (R, as per reference BIS 2013) at the bend:

$R = 0.473\ [Q/f]^{1/3}$ for waterway equal to or more than Lacey's waterway

In case where the waterway is less than that recommended by Lacey's and also the flow is non uniform, R is recommended to be calculated as:

$R = 1.35\ [q^2/f]^{1/3}$, and

$f = 1.76\ \sqrt{d_{50}}$

Where

R = Regime depth in m,
Q = design discharge in m^3/s,
q = discharge per unit width in $m^3/s/m$,
f = silt factor, and
d_{50} = mean particle diameter of river bed material in mm.

Maximum anticipated scour for launching apron has been recommended as = 1.5 R

Although the Lacey's regime equations are frequently used in India for finding the maximum scour depth and recommended in BIS codes, the following points may be considered while applying the same:

1. Lacey's regime equations are truly applicable for uniform flow
2. Scour depth in the bend may be higher than that predicted by Lacey's regime equations because of (a) Higher velocity, and consequently greater unit discharge, on the concave side of the bend, (b) Impinging flow in the bend, and (c) Secondary currents.

Hence, if the Lacey's regime equation is used for predicting maximum scour depth at bends, the increased velocity and unit discharges is required to be used. Or else, if Lacey's regime equation is used for predicting general scour for straight reach, a suitable multiplication factor has to be used. The data of the United States Army Corps of

Engineers (USACE 1991) gives a graphical relation between bend scour and mean water depth in main channel (Figure 7). The graph is for sand-bed rivers, from which it may be observed that for rivers with large bend, the maximum depth of scour varies between 1.5 and 2.0 times mean water depth in approach channel. This may be seen to be slightly higher than that recommended in IS 14262 (recommended factor of multiplication with R being 1.5). The British Columbia manual on riprap design (Reference: BC 2000) also suggests a factor that may be computed as lying between 1.5 and 2.0 for rivers in bend.

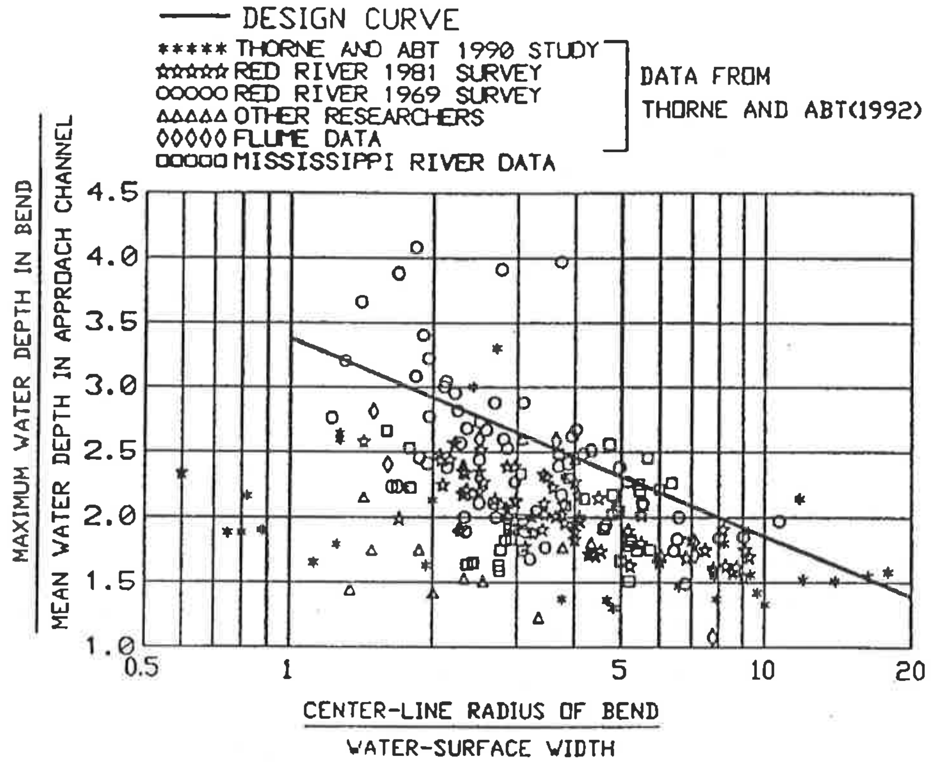


Figure 7: Relation between maximum water depth in channel bend to the mean water depth in channel for sand bed rivers.

Design curves for sour in bends (Figure 7) are designated as safe design curves which represents upper limit for channels with irregular alignment.

4.0 Bank protection measures

Bank protection measures are of different types. These may broadly be classified under :

I. Hard measures :

(a) Direct, as revetments/pitching/riprap, etc. which attempt to protect the bank directly from the erosive action of hydrodynamic loadings

(b) Indirect, as spurs/groynes/vanes, etc. which attempt to divert the flow away from the affected reach of the river. it is advised that planning for such indirect measures should always be based upon experimental studies, either through physical models, or through mathematical (numerical) simulation models. Once done, the actual design may be adopted based upon the model observations.

II. Soft measures

These include protection of eroding bank by vegetative cover, mostly vetevar plantation.

In this manual, only hard measures involving direct methods of bank protection have been discussed which are used or are being considered for application for the rivers of West Bengal.

4.1 Revetment or pitching

Revetment, a term in general use for bank and slope protection with stone pitching, is discussed in this section. Relevant guidelines and manuals are given under Section 2.0 References. These documents need to be referred to for detailed design of revetment protection of riverbanks against erosion. In the following sections, some of these and additional considerations are emphasized that need to be kept in mind for successful performance of revetment structures in the field.

4.1.1 Stable slope for revetments

It is generally recommended that a stable slope, not steeper than 2H:1V, is desirable for constructing revetment protection for an affected slope. Although a slope steeper than 2H:1V may perhaps be stable for a dry slope, additional shearing stresses created by the underwater currents in a river is likely to destabilise revetment materials (Figure 8).

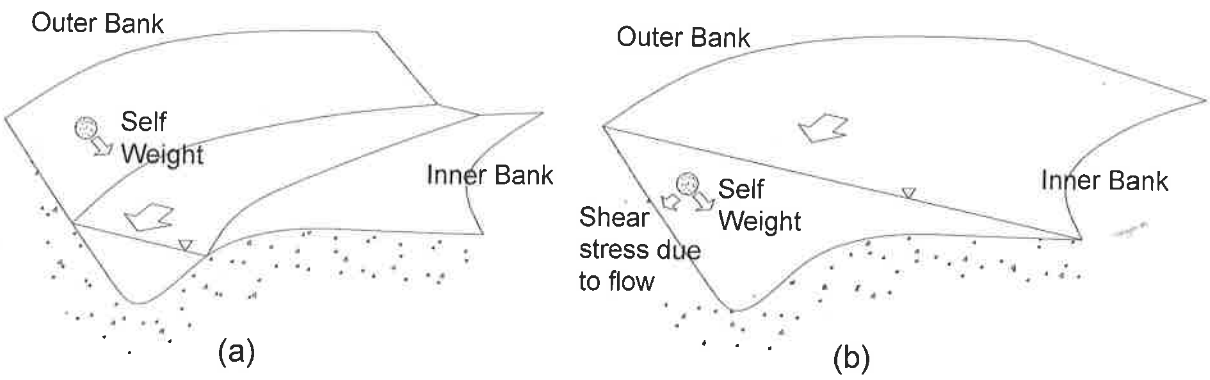


Figure 8: An object that may be stable on dry slope as during low flows (a) may not be so under the additional shear stresses under submerged condition during floods (b).

Hence, the following guidelines may be observed for attaining a stable slope before placing the revetment material:

1. When sufficient land is available for setback
   In this case, the land may be graded at least up to the low water level (LWL). Below LWL, the slope has to be made up by dumping suitable materials, like sand or earth filled gunny bags (Figure 9).

2. When sufficient land is not available for setback
   This case may arise when a building or some imp structure is present very close to the affected riverbank. In this case, both above and below LWL, the slope has to be made up by dumping suitable materials, like sand or earth filled gunny bags (Figure 10).

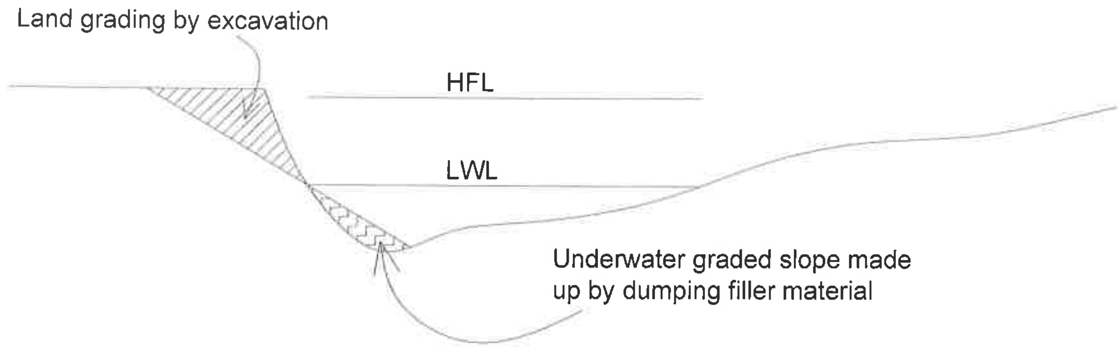


Figure 9: Land grading when sufficient setback space is available

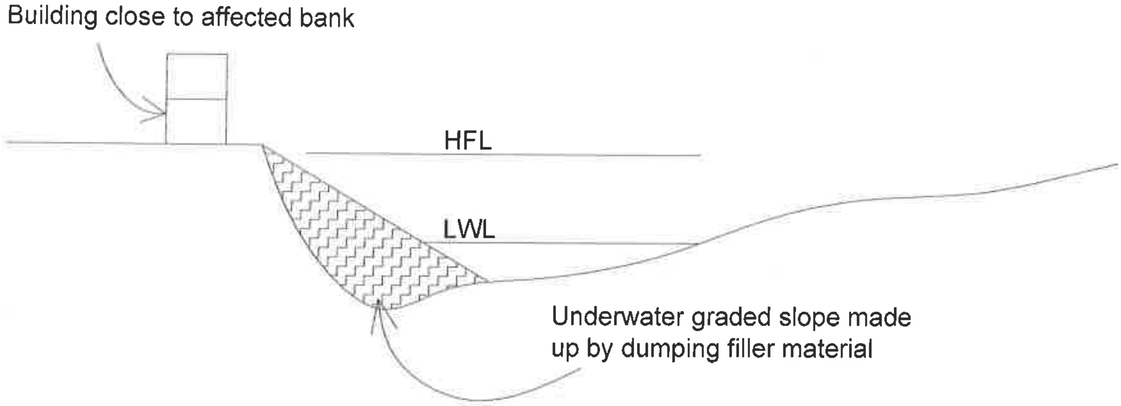


Figure 10: Slope makeup by filling when sufficient setback space is not available

4.1.2 *Provision of filter below revetments*

The requirement of filters below revetments may arise under two situations, explained below.

1. One of the failure modes of revetment is because of piping caused by seepage pressure generated within the riverbank under rapid depletion condition of the water level in the river (Figure 11a). In order to prevent this situation, which is likely to occur above the low water level (LWL), it is helpful to provide a layer of filter below the riprap (Figure 11b).

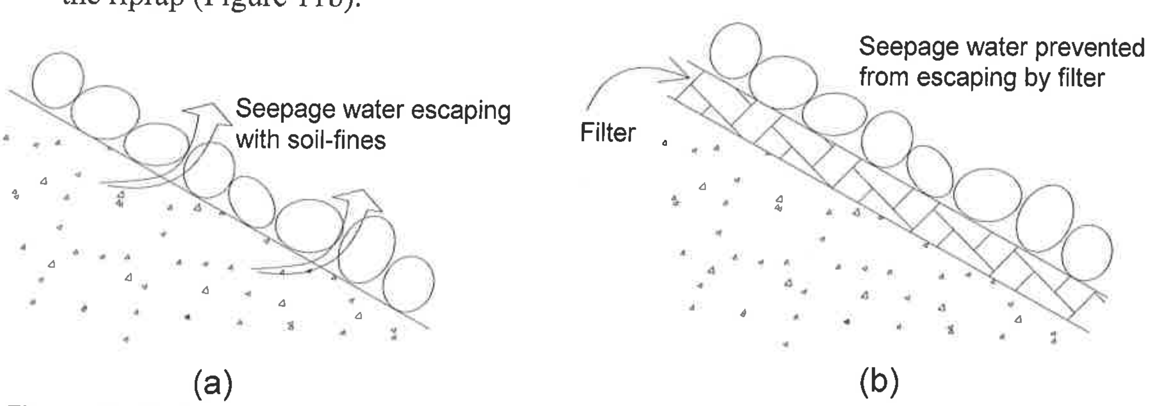


Figure 11: Under rapid depletion of river water level, escaping seepage water may wash out soil fines, leading to piping failure (a), which may be prevented by a layer of filter (b)

2. Another reason for the failure of revetment is by the removal of fine riverbed particles from within the gaps of revetment boulders or blocks by suction action (Figure 12a). This situation is more common during high flows, when the high underwater currents generated by impinging and secondary flows, generate turbulent vortices within the gaps. As a result, the revetment boulders or blocks tend to sink within the underlying riverbed. The revetment material can be made safe from this condition by providing and underlying filter (Figure 12b).

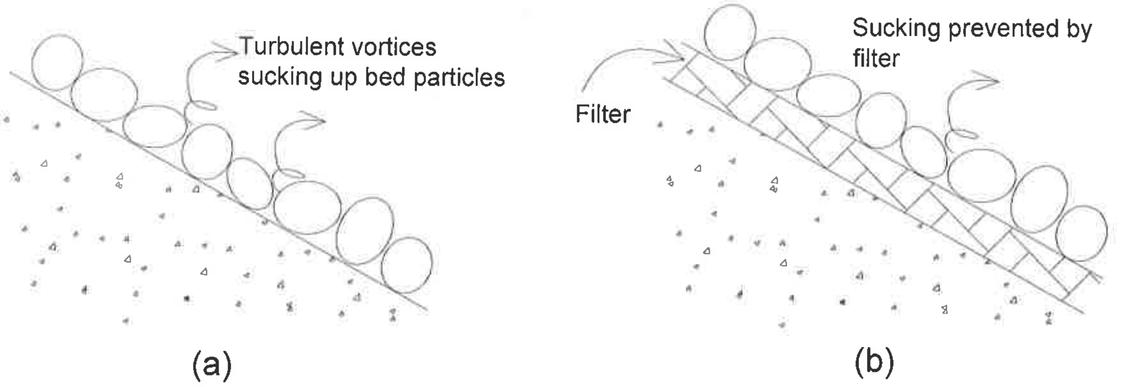


Figure 12: Under flood flows, underwater currents may generate turbulent eddies within the gaps of revetment material, sucking out riverbed particles (a), which may be prevented by filter (b)

It is, therefore, recommended that a suitable filter be placed underlying the revetment, both above and below the low water level. However, since underwater placement of granular filters or geo-filters has been reported to be difficult in practice, it is recommended to place "Tarja-mats" or "Darma-mats" made up of good-quality bamboo-splicing for underwater filters. Typical placement of filters is shown in Figure 13.

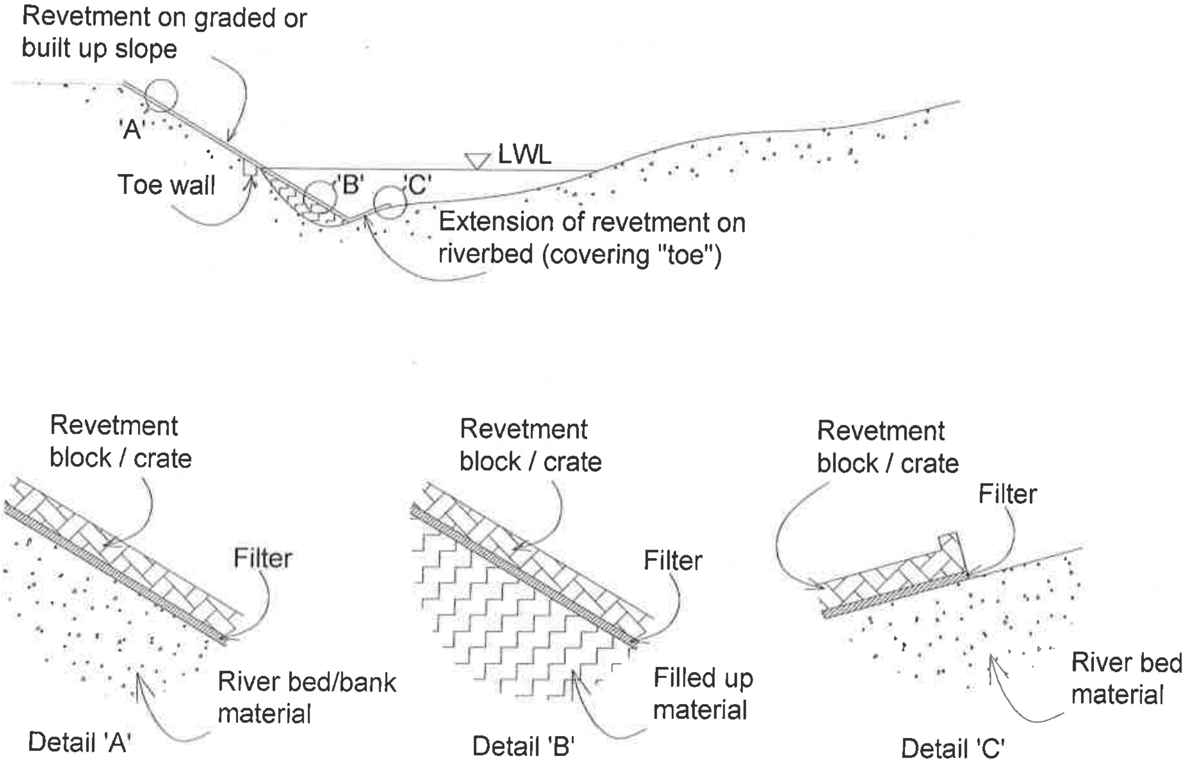


Figure 13: Placement of filter on graded/built-up slope of riverbank and in the toe region

4.1.3 Extent of revetment below low water line

The requirement of providing revetment beyond the point where the graded slope meets the riverbed arises from the fact that high shear stresses occur at this location (Figure 14a). The revetment extending beyond the "toe" launches with increasing scour during floods and helps to protect the rest of the revetment lying on the slope (Figure 14b).

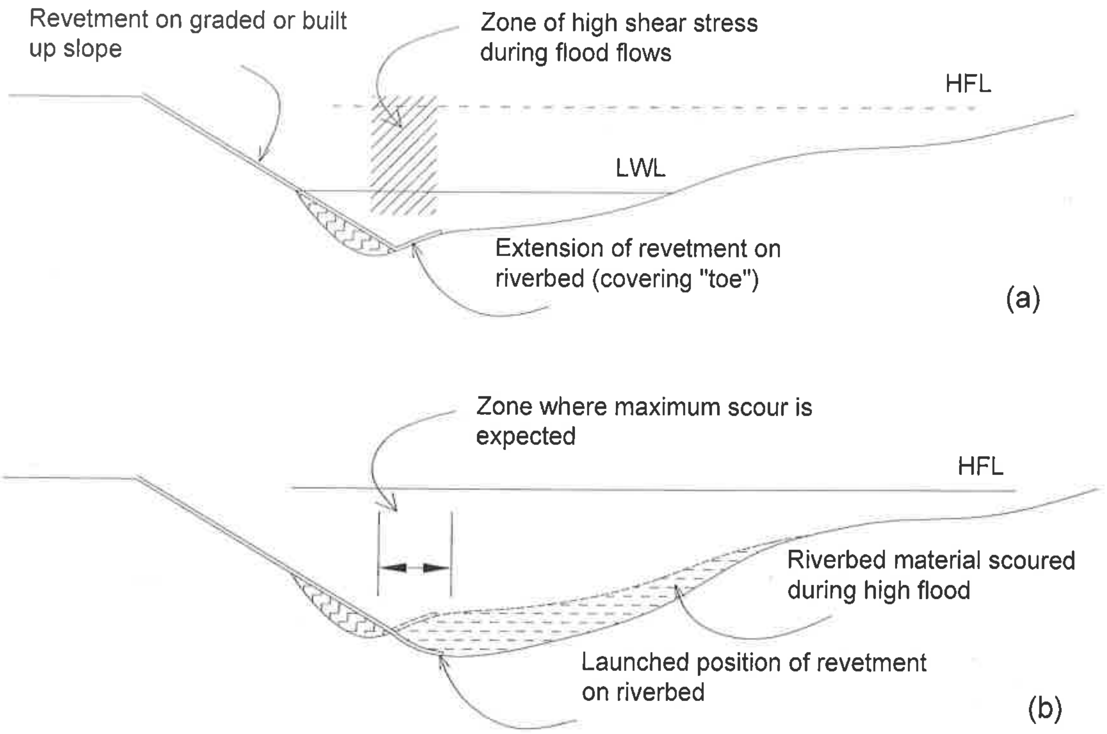


Figure 14: (a) Revetment toe protection for countering zone of high shear stress; (b) Typical scour pattern during flood flows and protection of toe by the "launched" toe revetment

The length of a "launching apron" up to which the toe protection is recommended by the reference CWC (2012) as 1.5 D_s, where D_s is the depth of scour measured below the low water level (Figure 15). It is further recommended that the toe protection should extend at least some distance beyond the filled up riverbank below low water level.

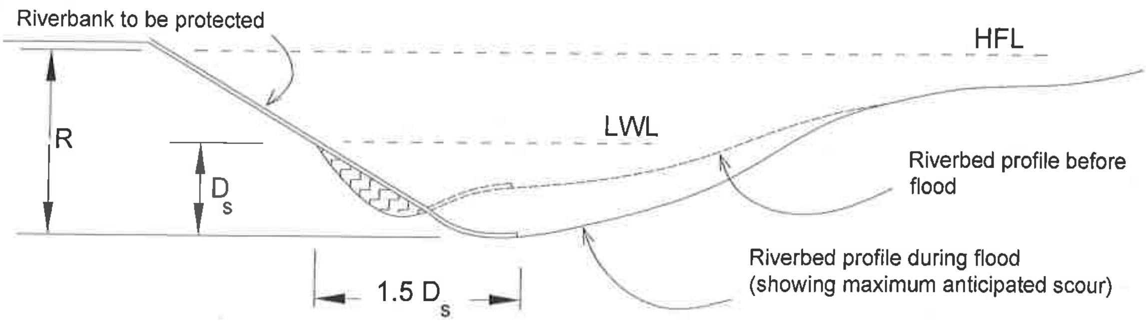


Figure 15: Recommended extent of revetment below low water line

The thickness of the revetment, T (in m) according to reference BIS (1995) is given as:

$$T = \frac{V^2}{2g(S_s - 1)}$$

In the above equation, V is the velocity (m/s), g is the acceleration due to gravity (m/s^2), and S_s is the specific gravity (relative density) of the stones used for the revetment.

It may be emphasized that the velocity near the toe of the revetment is rather high, as noted in Section 3.0 and also shown as high shear zone in Figure14a. In the absence of observed velocity at the bend, a suitable incremented velocity may be used for determining the thickness of the revetment.

As for the launching apron, reference CWC (2012) has adopted a thickness of 1.5 T, where T is the thickness of the revetment as found out above.

4.1.4 Application of crated stones/crated sand bags

For greater stability of the revetment near the toe (against the high shear stresses expected in this zone, Figure 14a), it is recommended that instead of placing individual revetment material, like sand- filled gunny bags (or stones, or any other material being used), which are likely to get washed away by the underwater currents at this location, it would be safer to place crated bags, etc. (Figure 16).

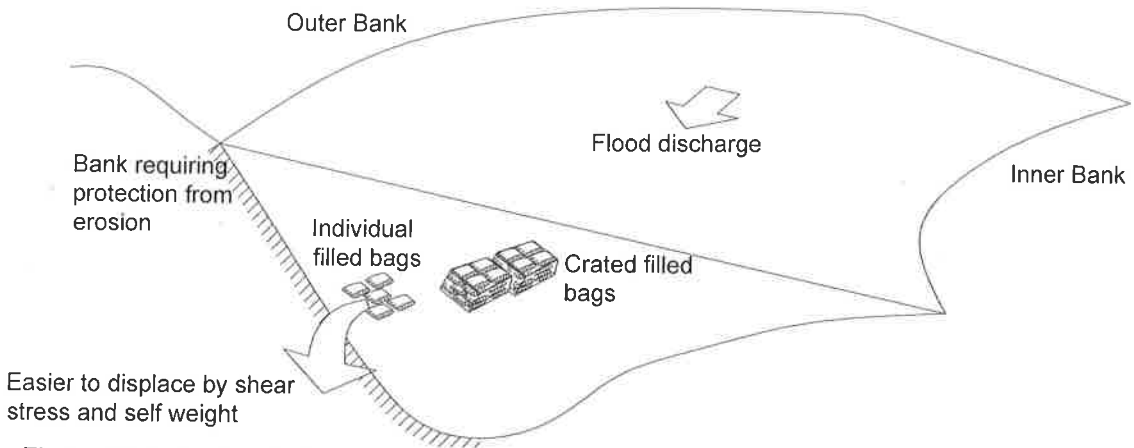


Figure 16: Use of crated bags/boulders versus individual placement for greater stability

4.1.5 Requirement of shallow bed bars for revetment protection

In order to counter the secondary flows near the toe of the inner bend, it is recommended that low-height bed-bars may be placed at certain interval along the bank (Figure 17). This would also help in inducing sedimentation along the toe thus preventing toe scour.

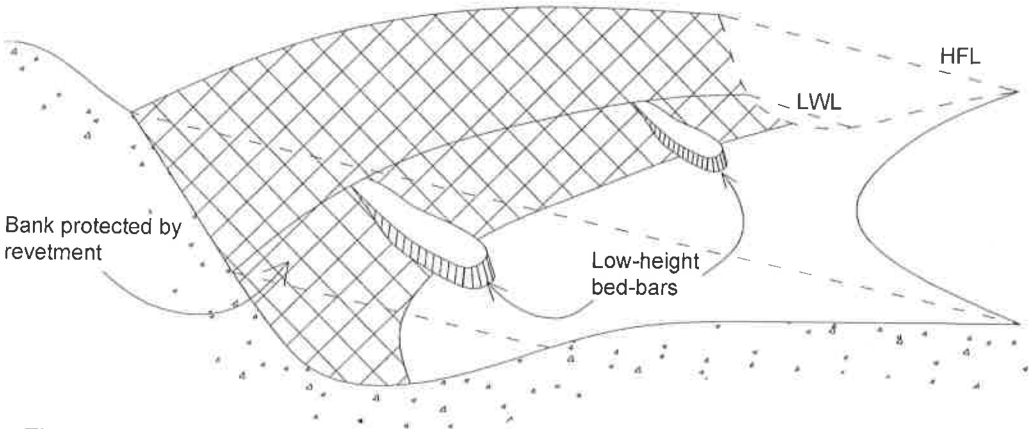


Figure 17: Construction of low-height bed-bars along the toe of the protected zone

4.1.6 Longitudinal (upstream and downstream) extent of revetment

IS 14262 indicates (Figure 7, BIS 1995 / BIS 2013) that there should be sufficient extension of the revetment protection both on the upstream and downstream directions along the riverbank. However, since there is no definite guideline provided in the aforesaid code or in CWC 2012, it is left to the judgment and discretion of the engineer in charge. It is presumed that the engineer will give due consideration to the upstream and downstream site conditions along the bank and decide upon the extension lengths.

Wherever the revetments are ended, it is recommended to have the revetment "keyed-in" into the banks for strengthening at the terminal edges of the revetments. WES (1997) suggests that the downstream keying should be given more attention as the trailing vortices here may cause bank failure just downstream of the riprap.

4.1.7 Arrangement of revetment at "toe"

The toe end of the revetment apron, as discussed in this manual, is of the launching apron type assuming that there is no hard stratum at or near the bed which may permit the construction of a key/sheet pile/toe-wall. The far end of the launching apron (recommended to be composed of crated filled-bags/boulders) towards the river centre-line may be strengthened with an additional layer of crated bags/boulders. Since the filter recommended is of the fascine mattress type, made up of bamboo-splicing mats (tarja/darma mats), it may not be possible to wrap these to the toe end revetment.

4.1.8 Arrangement of revetment at top end (bank line)

The revetment should extend in the vertical direction up to the design high water elevation plus some allowance for freeboard. The design high water may be fixed considering factors like wave action, which may be due to wind or boat traffic.

On many occasions, it is observed that the high flood level crosses the riverbank as the flow takes place over the flood plains. In such cases, the rising and receding flood flows may endanger the top end of the revetment. USACE (1991) recommends a "horizontal collar" at the top end where the revetment meets the bank edge (Figure 18).

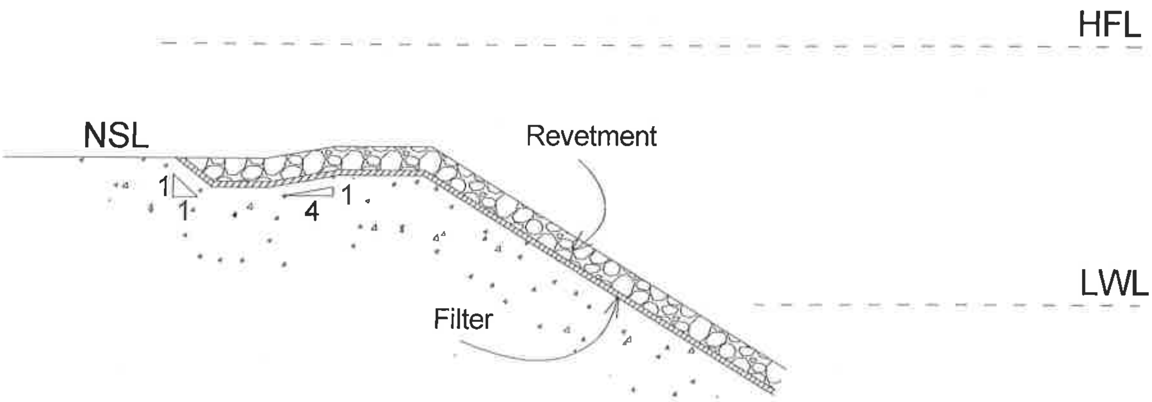


Figure 18: Top end key-in for revetment in case of HFL far exceeding flood plain NSL

4.2 Vegetal method of bank protection

CWC (2012) recommends that for the cases of bank erosion, when the current is not too strong, the engineer in charge may consider using the application of protecting the bank with a vegetation cover. The "Vetiver" grass is being applied nowadays in several cases of bank erosion prevention, especially in South-East Asia. Also, there are instances of its successful implementation in Assam and Bangladesh.

Though a cost effective method, and one which is environment friendly, care must be taken for choosing the right kind of Vetiver that would survive the particular condition of the proposed site.

5.0 Recommendations

Selection of an appropriate river bank protection works depends on various factors, viz. hydro-morphological conditions of river, type of bank material, velocity of flow and discharge , availability of materials etc. It has been noticed that available BIS Code , CWC Guidelines, IRC Publications etc do not always provide general guidelines and do not always address the case specific requirements. Moreover, effect of tide and consequent wave run up has not been considered by any standard. Irrigation & waterways Department has developed a data base on different types of bank protective works adopted in various rivers in different districts, based on the experience of last nine decades. Accordingly, recommendations on proposed bank protective works have been made zonewise in the entire State, following a judicious consultation of prevailing Codes/Standards and on the basis of good engineering practices relying upon practical experience of both sustainability and failure. Theses recommendations, herein after called guidelines, have been detailed in the following chapters.

It is, therefore, recommended that all future bank erosion measures may comply with the provisions given in the guidelines. However guidelines, although region and river specific, may not always provide readymade solution to problems of unique nature, which may be worked out separately. It may further be stated here that use of conventional materials for bank protection i.e. boulder, Cement concrete block, empty cement poly bags etc have mostly been considered in the guide lines. Officers of the Irrigation & Waterways Department are also encouraged to embrace new technological development and to explore the options of using other materials mostly, polypropylene (PP) , Geobags or High Density Poly Ethelene (HDPE), sand bags conforming to BIS or other International Standard, subject to proven track record of economy, durability and suitability of application under different condition of exposure.

6.0 Guidelines, proposed by Technical Expert Committee, for bank/bed protection of river /sea face , shall be followed by Irrigation & Waterways Deptt , Govt of West Bengal

6.1 Zone A : North Bengal Districts

District covered : Darjeeling, Jalpaiguri, Alipurduar & Coochbehar

Sub Zone A1 : Boulder or boulder mixed with shingles zone near foothills with silt factor more than 3.50 .

Bank Protection : Type I (where height of bank top from river bed is less than 5.0 metre)

Description : Boulder sausage matressing as pitching and boulder in sausage as apron with boulder sausage deflectors as per Fig 1 with dimension as per Table I.

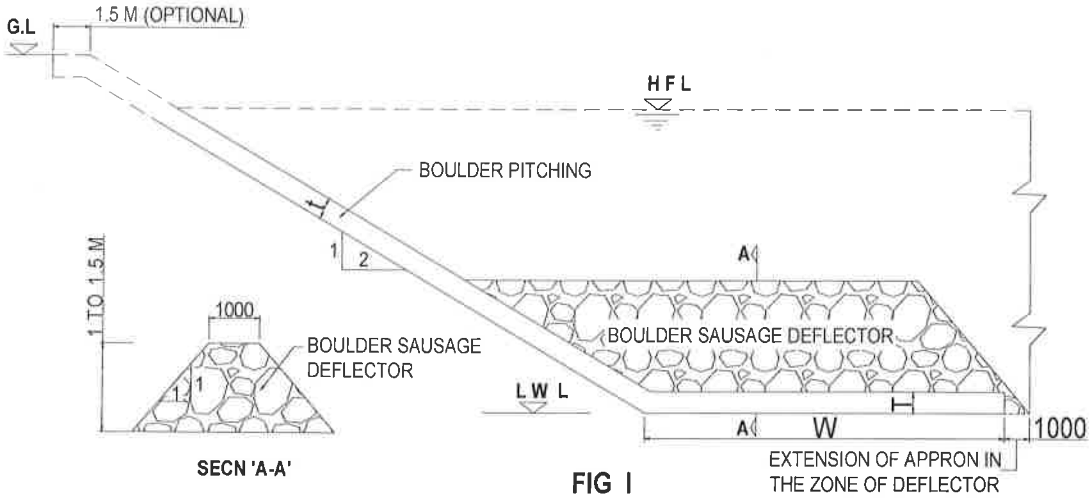


FIG I

(SUBZONE AI, PROTECTION TYPE 1

Table 1.0

Discharge	Type of pitching	Thk of pitching, t (m)	Type of apron	Thk of apron , T(m)	Length of apron, W(m)	Remarks
<2500 cumec	Boulder (N.B variety), sausage, matressing	0.45	Boulder sausage apron	0.60	1.5x [1.5D* - (HFL-LWL)]	see Note below
>2500 cumec	do	0.60	do	0.90	do	do

* D = nominal scour depth

Details of boulder sausage deflector (for all discharge) :

Trapizoidal boulder sausage deflector , maxm height of 1.50 metre, top width generally 1.0 metre with side slope 1:1 , to be laid at a spacing of 2.5 x W (W being the length of apron, apron length being extended by 1.0 metre at the location of deflector to accomodate tapering transition).

Note. Pitching should be extended on bank top and continued for at least 1.50 metre in case HFL is above bank top and consequent spilling of bank takes place. Minimum thickness & weight of boulder to be decided on the basis at site condition as well as availibility .

I. Rationale of selection of bank protection in Sub Zone AI (Type 1)

Ref: Fig 1 , Table 1

1. Weight of stone/boulder/crated boulder :

IS: 14262 - 1995 recommends , ref cl. 3.3 , P-1 of this Standard ,

$$W = \frac{0.02323}{K} \times \frac{S_g}{(S_g - 1)^3} V^6 \quad \text{and} \quad K = \sqrt{1 - \frac{Sin^2\theta}{Sin^2\phi}}$$

where, W = weight of individual stone/boulder in kg

S_g = Specific gravity of boulder, for this case , 2.65

V = velocity flow, in this zone , is generally above 3.50 metre/sec

θ = angle of bank slope with horizontal = 26.57 degree (2(H):1(V))

ϕ = angle of repose of material of protection work = 27.0 degree

Substituting these values, K= 0.171 W = 147.32 kg

Boulders are provided in crates, so minimum weight is guranted.

2. Size of boulder :

Diameter (Ds) of boulder (or average size of crated boulder) , as given in cl. 3.3 and 3.4 , P-1 of IS : 14262 -1995 is as below ;

$$D_s = 0.124 \sqrt[3]{\frac{W}{S_g}}$$

D_S = 0.47 metre

3. Thickness of apron

IS : 14262 - 1995 (cl. 3.5 , P-2) recommends two layers of boulders of dia D_s in sausage mattress for pitching . Thus the thickness (t) of pitching may be estimated as ;

t = 2 * D_s .... (i)

The following formula is given in Cl. 3.5 of IS : 14262 - 1995 for the boulders of the pitching to withstand negative pressure created by velocity ;

$$t = \frac{V^2}{2g(S_g - 1)} \quad \text{.... (ii)}$$

Here , t is thickness of pitching in metre, V, S_g defined earlier

Pitching thickness , t, may be evaluated from Eqn (i) or (ii) but from practical considerations, the minimum value of 't' is proposed as 0.45 metre for rivers with design discharge <2500 cumec and 0.60 metre for discharge > 2500 cumec.

Thickness of apron pitching , T , in the bed as recommended in Central Water Commission guidelines is given as T = 1.5 t .

4. Length of apron

Central Water Commission guidelines recommend that the length of the apron in the bed should be 1.5*[1.5*R - (HFL - Bed Level at LWL)].

6.1.1 Subzone A-I

Bank Protection : Type 2 (height of bank top from river bed is more than 5.0 metre and bank is steep)

In Subzone A - I , the river bed is composed of boulders (medium or small) mixed with shingles , near the foothills , with silt factor more than 3.50 .

In such beds, Lacey's scour depth formula is not applicable, which is only valid for alluvial river beds.

To obtain scour depth in (small) boulder river beds , the formula given by P.Sen ("Depth of scour in gravelly and boulder beds" , Journal of the Institute of Engineers (India), Volm 77 , 1997 , P-209 to P-214) may be used. According to this formula the depth of scour from HFL (R) may be computed as ;

$$R = \frac{0.2q^{0.855}}{d_{50}^{0.3}}$$

The above formula is applicable for discharges>500 cumec . For smaller discharges, the following formula shall be used ;

$$R= 0.22\ Q^{0.37}\ d_{50}^{\ -0.11}$$

[Limits : Q between $5 m^3/sec$ and $500\ m^3/sec$, Bed slope between 0.02 and 0.0015]
[Ref formula developed by R.D. Hey , Jnl. of Hyd. Div. ASCE Proceedings Vol. 112, 1986 page 682]:

The apron length can the be computed as ,

$$W_A = 1.5D - 1.5*[1.5*R - (HFL - Bed\ Level\ at\ LWL)]$$

The details of the protection work with deflectors as per Fig 2 on the river side may be provided as detailed in secn A-A , for all cases other than stable parallel flow .

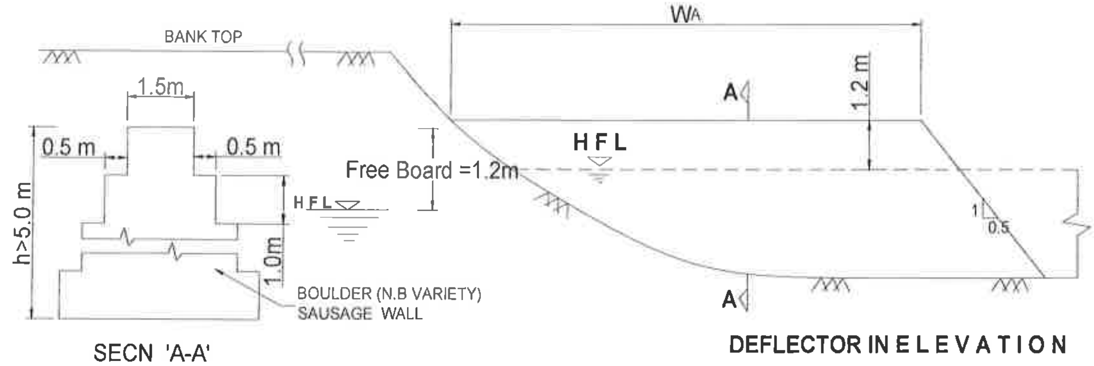


FIG 2 (SUBZONE AI, PROTECTION TYPE 2)

Deflectors are to be trapizoidal (as shown in Fig 2) with boulder sausage. Maxm height of such deflectors shall be such that the top level of deflectors are 1.20 metre above the HFL. Top width of deflector is 1.50 metre with side slope of 1:1. Spacing of deflectors shall be $2.5W_A$.

<u>**6.1.2 Sub Zone A - II :**</u> Mature zone of rivers , far away from the foothills, nearing plain land/plateau , silt factor less than 3.5.

Bank protection : Type 3

Description : Loose boulder single layer with bitumen grouting/multiple layers without bitumen grouting above shingle filter and loose boulder apron with or without boulder sausage deflectors, as per Fig. 3 with dimension as per Table 2.0.

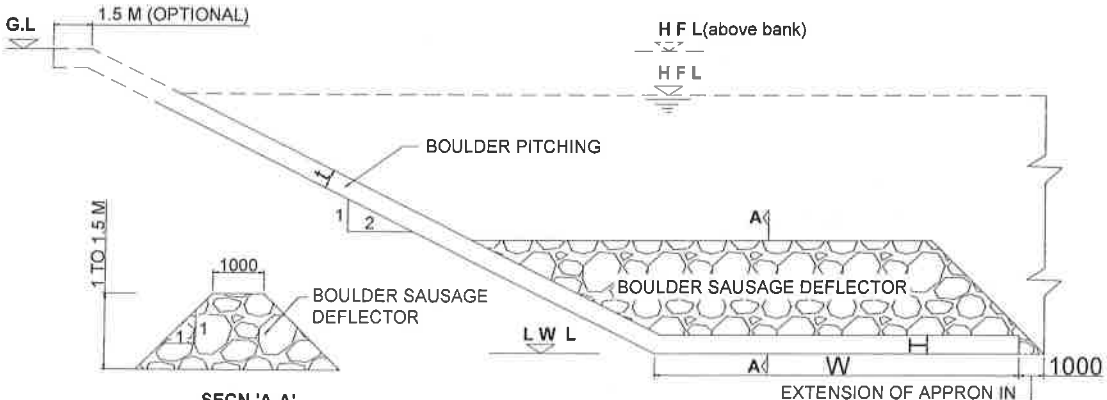


FIG III

(SUBZONE AII, PROTECTION TYPE 3

Table 2.0

Discharge	Type of pitching	Thk of pitching, t (m)	Type of apron	Thk of apron, T(m)	Length of apron, W(m)	Remarks
<2500 cumec	Single layer boulder (N.B variety), with bitumen grou-ting to fill up voids	0.23	Loose boulder (N.B variety) apron	0.46	1.5x [1.5D** - (HFL-LWL)]	see Notes below
>2500 cumec but less than 4500 cumec	Boulder (N.B variety) pit- ching over 0.10 m thick shingles filter, inter- stices & voids to be filled and packed by small boulder or shingles.	0.38	do	0.60	do	do
> 4500 cumec	Boulder (NB variety) pitching over 0.15 m thick shingle filter, interstices/void between boul-ders to be filled & packed by small boulder/ shingles.	0.45	do	0.90	do	do

** D = nominal scour depth

Details of boulder sausage deflector :

To be used only in eroding zone in meandering rivers as per details provided in Table 1.0 and also in conformity to the section shown Secn A-II above.

Note 1. Pitching should be extended on bank top and continued for at least 1.50 metre in case H.F.L is above bank/embankment crest level.

2. Minimum weight of boulder is to be decided on the basis of site condition as well as availability .
3. Bank protection works may as well be used for embankment protection .
4. To consider silt factor 'f' as recommended by R.R.I, West Bengal , while computing the scour depth / length of apron.

II. Rationale of selection of bank protection in Sub Zone AII

To find out the minm weight of stone/boulder to be used in bank protection, ref cl. 3.3 , P-1 of IS : 14262 -1995 , following expression shall be used like earlier ;

$$W = \frac{0.02323}{K} \times \frac{S_g}{(S_g - 1)^3} V^6 \qquad \text{and} \qquad K = \sqrt{1 - \frac{Sin^2\theta}{Sin^2\phi}}$$

where, W = weight of stone/boulder in kg

S_g = Specific gravity of boulder, for this case , 2.65

V = velocity flow, in this zone , is generally above 2.50 metre/sec
θ = angle of bank slope with horizontal = 26.57 degree (2(H):1(V))
ϕ = angle of repose of material of protection work = 27.0 degree

Substituting these values, K= 0.171 W = 19.57 kg
Minimum weight of boulder for protection is generally 30.0 kg or more.
After having the weight of individual stone , size (D_s) of same shall be given vide cl. 3.4 , P-1 of IS : 14262 -1995, from sliding consideration ,

$$D_s = 0.124 \sqrt[3]{\frac{W}{S_g}}$$

D_S = 0.28 metre

Thickness (t) of protective layer, pitching or launching appron , vide cl. 3.5 , P-2 of IS : 14262 - 1995 , may be defined as follows ;

$$t = \frac{V^2}{2g\left(S_g - 1\right)}$$

Here , t is thickness of pitching in metre, V, S_g defined earlier t = 0.19 metre

For safety two layers of stone as per 'D_S' ,i,e, t = 2 x 0.28 m, or 0.56 metre are to be provided as per IS:14262 - 1995

As per IRC:89-1997, thickness is governed by total discharge (Q) , that is ,

$$t = 0.06Q^{\frac{1}{3}}$$

where , t is the thickness of pitching & Q is the design discharge through channel/river
For discharge = 2500 cumec , t = 0.81 metre
So , there is a wide variation in above calculated thicknesses (two layers of 0.28 m to 0.81 metre). Based on practical experience and rationalization , thickness of pitching has been linked with sliding consideration , as shown in Table 3.0.

Thickness of boulder apron is generally kept at 1.50 times thickness of pitching , after suitable rounding off and rationalisation subject to a minimum not less than 0.46 metre.

Length of apron W_A is recommended in CWC guideline as 1.5D, where 'D' is the depth of scour brlow LWL = 1.5R-(HFL - LWL)

If the river bed is alluvial , Lacy's scour depth equation may be used for calculating 'R'.

To obtain scour depth in (small) boulder river beds , the formula given by P.Sen ("Depth of scour in gravelly and boulder beds" , Journal of the Institute of Engineers (India), Volm 77 , 1997 , P-209 to P-214) may be used. According to this formula the depth of scour from HFL (R) may be computed as ;

$$R = \frac{0.2q^{0.855}}{d_{50}^{0.3}}$$

d_{50} between 0.2m and 0.04 m, Bed slope between 0.005 and 0.0008

The above formula is applicable for discharges>500 cumec upto 10000 cumec . For smaller discharges, the following formula shall be used ;

$$R= 0.22\ Q^{0.37}\ d_{50}^{\ -0.11}$$

[Limits : Q between 5m^3/sec and 500 m^3/sec, Bed slope between 0.02 and 0.0015]
[Ref formula developed by R.D. Hey , Jnl. of Hyd. Div. ASCE Proceedings Vol. 112, 1986 page 682]:

The apron lemgth can the be computed as ,

W_A = 1.5D - 1.5*[1.5*R - (HFL - Bed Level at LWL)]

6.2 Zone B : North Central, Central, Western and Eastern districts in non tidal zone.

District covered: Uttar and Dakshin Dinajpur, Malda, Murshidabad, Nadia, Birbhum, Bankura , Burdwan and non tidal area of Hooghly , Howrah & Paschim Medinipur .

Sub Zone B I : Ganga-Padma, Bhagirathi, Fulahar river in Malda, Murshidabad & Nadia.

Bank Protection : Type 4A (Considerable erosion between LWL & HFL but bank slope is flatter than 1(V):2(H) and calculated scour depth is more than the scour depth observed after passage of flood multiplied by 1.25 .

Sub Category 4A/I, where there is sufficient space on bank top to set back as per Fig 4A/I with dimension as per Table 3.0

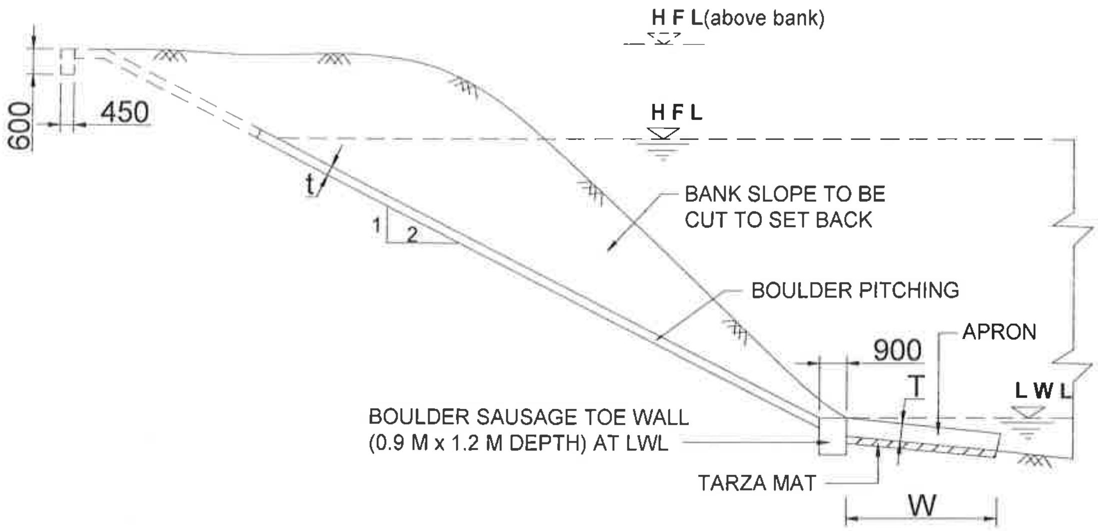


Fig 4A/I (Sub Zone BI, Protection Type 4AII)

Table 3.0

River	Type of pitching	Thk of pitching, t (m)	Type of apron	Thk of apron , T(m)	Length of apron, W(m)	Remarks
Ganga Padma	Double layer stone boulder pitching over geojute/geosynthetic filter (woven type) conforming to specification laid down.	0.46	Boulder sausage apron of 1m x 1m over layer of Torza Mat.	0.60	1.5x [1.5D -(HFL-LWL)] D = nominal scour depth	see Notes below
Bhagirathi & Fulhar	Single layer stone boulder pitching over bitumen treated geojute/geosynthetic filter (woven type) conforming to specification laid down.	0.23	Loose boulder apron over a layer of Tarja Mat.	0.46	do	do

Note : 1. Pitching should be extended on bank top and continued for at least 1.50 m with a key at the end if HFL is above bank top.

2. Minimum weight of boulder to be considered on the basis of site condition as well as availaibility.

3. Consider silt factor , 'f' , as recommended by R.R.I.

6.2.1 <u>Sub Zone B I</u> :

Bank protection : Type 4A

Description : Sub category 4AII when there is practically no scope to set back, protection should be as per Fig 4A/ II with dimensions in Table 4.0 .

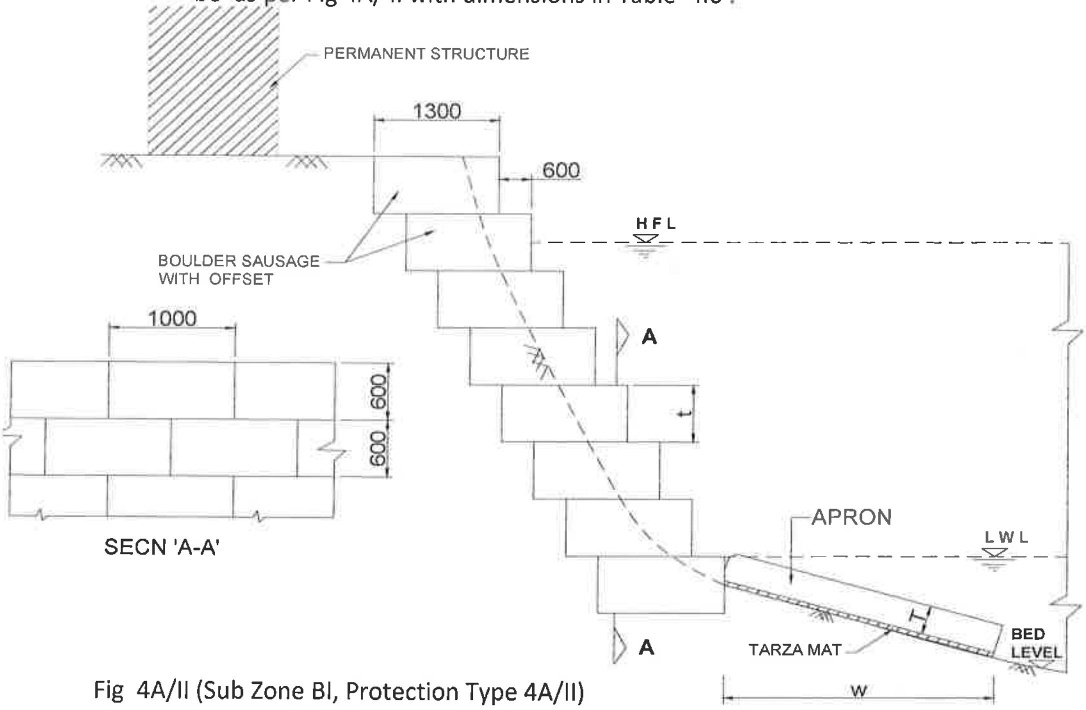


Fig 4A/II (Sub Zone BI, Protection Type 4A/II)

Table 4.0

River	Type of pitching	Thk of pitching, t (m)	Type of apron	Thk of apron , T(m)	Length of apron, W(m)	Remarks
Ganga Padma	Boulder sausage of 1.3 m wide x 0.6 m height x 1.0 m long , to be put one after another with offset of 0.60 m across the flow and in a staggered fashion along the flow.	0.6	Boulder sausage apron of 1m x 1m over layer of Torza Mat.	0.60	1.5x [1.5D -(HFL-LWL)] D = nominal scour depth	see Notes below
Bhagirathi & Fulhar	Single layer stone boulder pitching over bitumen free geojute/geosynthetic filter (woven type) conforming to specification laid down.	0.60	Loose boulder apron over a layer of Tarja Mat.	0.46	do	do

Note : 1. Length of the protection in this manner should not be continued for more than 100 metre at a stretch.

2. Minimum weight of boulder to be considered on the basis of site condition as well as availaibility.

3. Consider silt factor , 'f' , as recommended by R.R.I.

Sub Zone B I :

Bank protection : Type 4B I

Considerable erosion between LWL and HFL together with bed scour, resulting in steeper bank slope than 1(V):2(H) and calculated scour depth is less than scour depth observed after passage of flood multiplied by 1.25 .

Description : Sub category 4B/I , when there is sufficient slope on bank top to set back , as per Fig 4B II with dimensions as per Table 4.0 .

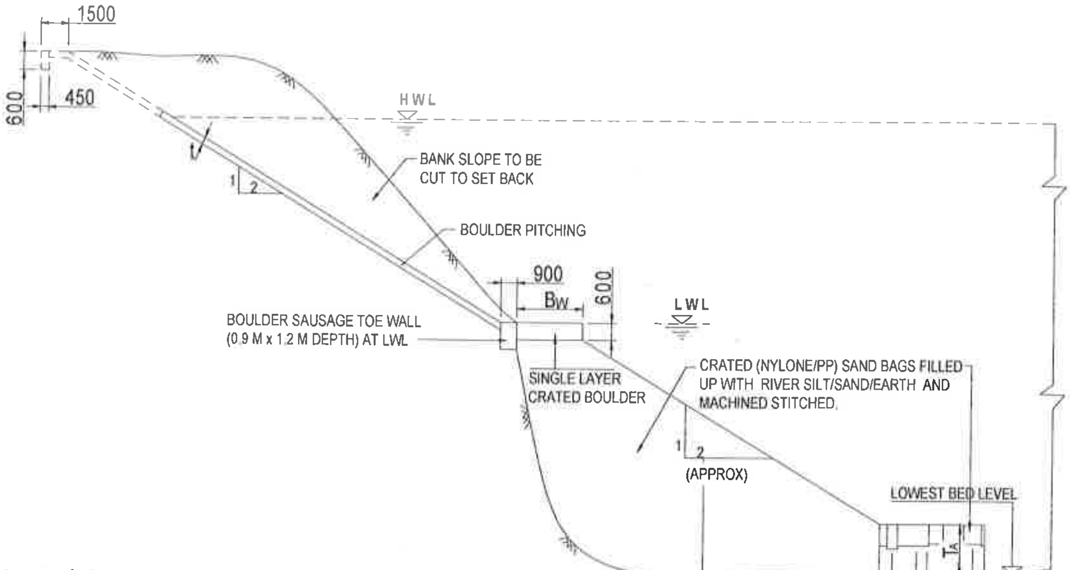


Fig 4B/I (Sub Zone B I, Protection Type 4B II)

Table 5.0

River	Type of pitching	Thk of pitching, t (m)	Type of filler material for scour hole	Width at berm /LWL, Bw (m) , T(m)	Width of extn of end protection B_B (m)	Thk of filler materials at end , T_A (m)	Remarks
Ganga Padma	Double layer stone boulder pitching over bitumen treated geojute/geosynthetic filter (woven type) conforming to specification laid down.	0.46	crated (Nylone /PP) sand bags/ similar poly- bags filled up with river silt/ sand/earth & m/c stitched. (crate size 1mx1mx1m)	6.00	10.0 m or 0.5 x D whichever is lesser . D = nominal scour depth below LWL	3.0	see note below
Bhagirathi & Fulhar	Single layer stone boulder pitching over bitumen treated geojute/geosynthetic filter (woven type) conforming to specification laid down.	0.23	do	3.00	3.0 m or 0.5 x D whichever is lesser . D = nominal scour depth below LWL	2.0	do

Noets :

1. Pitching should be extended on bank top & continued for a length of 1.50 metre with a key at the end if H F L is above bank top level.
2. Minm weight of boulder to be considered on the basis of site condition as well as availaibility.
3. Considered silt factor , 'f' as recommended by R.R.I.
4. Length of Tarza Mat should be 5.0 metre + B_B at the lowest bed level , where bed level is more or less flat.

Rationale of selection :

Since scour has already been taken up , there is no need of providing launching apron. The imminent need is to fill up the scour hole by a solid mass which could be done by crated (Nylon/PP) polybags (i,e 2nd hand cement bags, machine stitched after filling with river sand/silt). Since polybags exposed to wetting & drying may fast disintegrate , those would be covered at the berm level by boulder sausage . Use of Tarza mat at end location of the filling , when bed slope is more or less flat is strongly recommended to avoid the tendency of local scour of bed material.

Zone B I :

Bank Protection : Type 4B II

Sub category 4B II, where there is practically no space to set back , protection should be as per Fig 4B/II, with dimensions as per Table 6.0

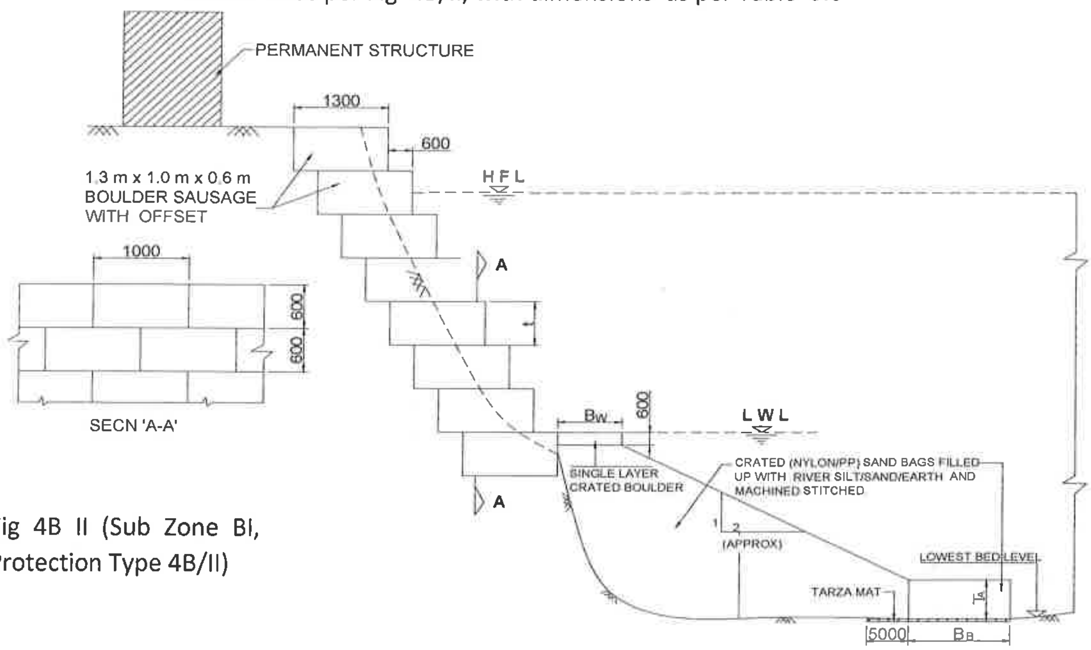


Fig 4B II (Sub Zone BI, Protection Type 4B/II)

Table 6.0

River	Type of pitching	Thk of pitching, t (m)	Type of filler material for scour hole	Width at berm /LWL, Bw (m) , T(m)	Width of extn of end protection B_B (m)	Thk of filler materials at end , T_A (m)	Remarks
Ganga/ Padma	Same as mentioned Table 4.0		As mentioned in Table 5.0	6.0	As mentioned in Table 5.0	3.0	see note below
Bhagirathi/ Fulhar	Same as mentioned Table 4.0		As mentioned in Table 5.0	3.0	As mentioned in Table 5.0	2.0	do

Noets :

1. Length of protection in this manner should not be continued for length more than 100 metre at a stretch..
2. Minm weight of boulder to be considered on the basis of site condition as well as availaibility.
3. Considered silt factor , 'f' as recommended by R.R.I.
4. Length of Tarza Mat should be 5.0 metre + B_B at the lowest bed level , where bed level is more or less flat.

6.2.2 Sub Zone B II : All river other than Ganga-Padma , Bhagirathi & Fulhar in the district mentioned under Zone B.

Bank protection : Type 5

Description : Single layer loose boulder over a layer of filter with sausage toe wall and nominal boulder sausage apron as per Fig 5 and dimensions as per Table 7.0

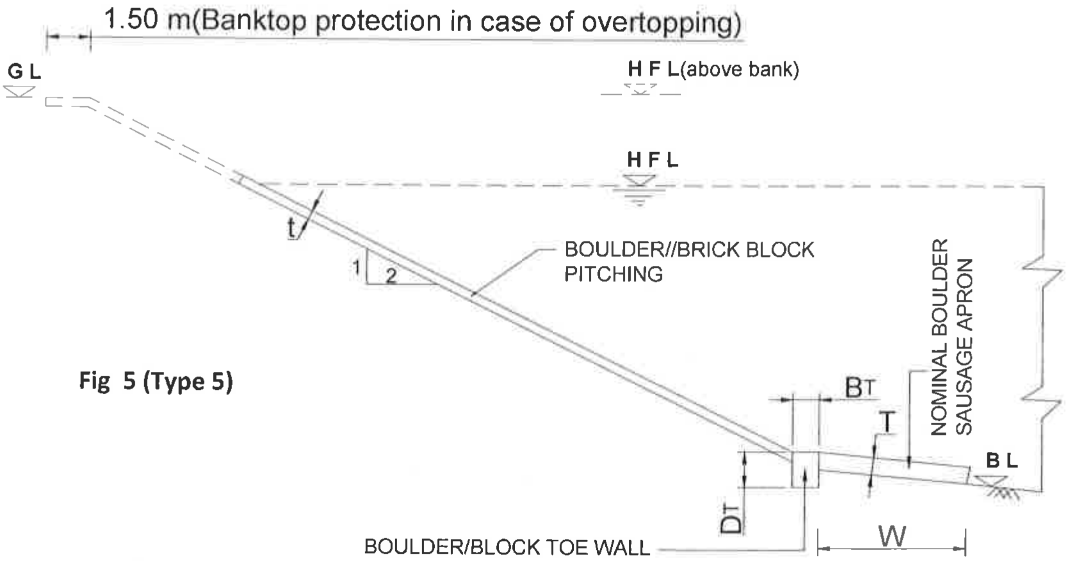


Fig 5 (Type 5)

Table 7.0

River	Type of pitching	Thk of pitching, t (m)	Toe wall		Type of apron	Thk of apron, 'T' (m)	Length of apron, 'W' (m)	Remarks
			width B_T (m)	Depth D_T(m)				
Mayurakshi, Ajoy, Damodar, Kansabati, Subarnarekha	Single layer stone/ laterite boulder/brick block (0.53x0.53) pitching over bitumen treated geojute/ geosynthetic filter (woven type) conforming to specification laid.	0.23 to 0.30	0.60	1.20	Loose boulder sausage apr-on of nominal length	0.60	3.00	see notes below
All other rivers	do	0.23 to 0.30	0.60	0.90	Crated boul-der 3m x 3m x 0.46 ht placed alter- nately ie 6.0 m c/c.	0.46	3.0	do

Note : 1. Pitching should be extended on bank top and continued for at least 1.50 m with a key at the end if HFL is above bank top.

2. Variety and minimum weight of boulder to be considered on the basis of site condition as well as availaibility.

Zone B (contd): (All river in North Central, Central, Western and Eastern district in non tidal zone.

Berm protection : Type 6

Suggested when protection is required to arrest erosion of berm land, which, if continued unabated, may e\affect the embankment or river bank line.

Description : Trapizoidal bed bars mostly submerged, with core of loose boulder covering all around by crated boulder as per Fig 6.

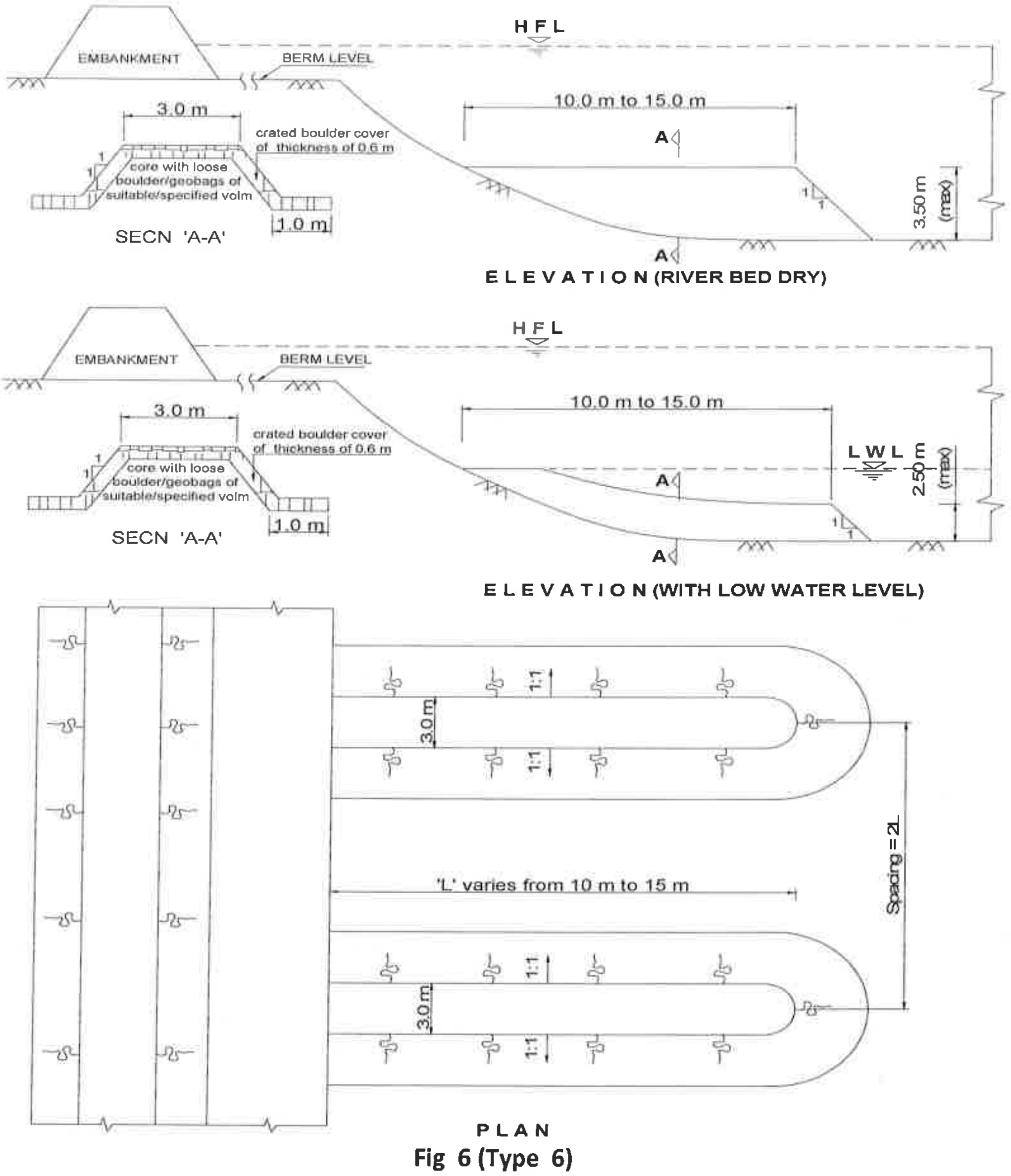


Fig 6 (Type 6)

6.3 Zone C : Tidal zone in South Bengal (Other than Sundarban and coast line of Purba Medinipur)

Dist. covered : Tidal zone of Purba Medinipur, Paschim Medinipur, Howrah, Kolkata, Hooghly, North & South 24 Parganas (Other than Sundarban & coastal area of Purba Medinipur).

6.3.1 Sub Zone C I : Bank slope of river is flatter than 1(V):2(H) and calculated scour depth is more than the observed scour .

Bank/Embankment protection : Type 7/I

Description : 0.225 m thick boulder/0.25 m thick brick block /0.3 m thick cement concrete block pitching over a layer of filter supported by toe wall and with occasional use of cylidrical sausage where bed erosion is dominant, as per Fig 7/I and dimensions as per Table 8.0.

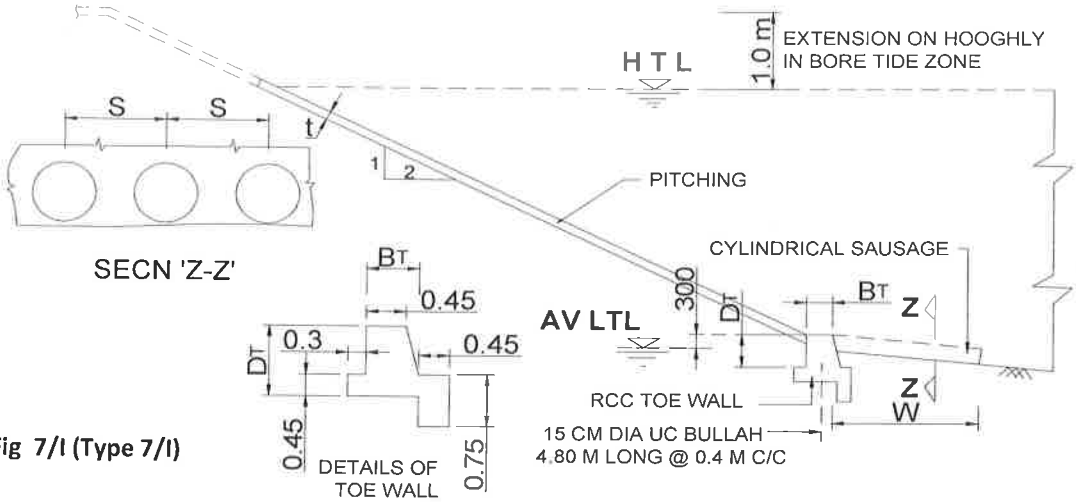


Fig 7/I (Type 7/I)

Table 8.0

River	Type of pitching	Thk of pitching, t (m)	Toe wall			Cylindrical sausage			
			Descrip trion	width B_T (m)	Depth D_T(m)	Descrip trion	Length, L (m)	Dia , D(m)	Spaci-ng , S(m)
Hooghly (in the zone of bore tide, secn narrow)	Cement conc block pitching over bitumen treated geojute/geo-synthetic filter conforming to specification.	0.3	RCC toe wall over EUC bullah piles	0.60	1.10	-	-	-	-
Hooghly (Other than of bore tide zone)	Boulder/brick block pitching over bitumen treated geojute/geo-synthetic filter (woven type) conforming to specification.	0.25 to 0.30 thk	RCC toe wall only	0.50	1.0	Boulder/brick in wire net cage	6.0	1.0	1.5
River other than Hooghly *	do	do	Boulder/ brick with in iron wire carte **	0.60	0.90	do	5.0	0.75	1.15

* where Bed slope of river is flatter than 1(V):2(H) and calculated scour depth is more than the observed scour .

** Toe wall would be rectangular

Note : Boulder , minimum weight of which is to be considered on the basis of site condition as well as availibility , is preferred over bricks.

6.3.2 Sub Zone C II : Bank slope of the river is steeper than 1(V):2(H) and calculated scour depth is less than the obseved scour depth .

Bank/Embankment protection : Type 7/II

Description : Filling up of scour hole , already fromed, with crated (Nylon/PP) bags filled up with sand/silt, formation of a berm at L.W.L , boulder/brick block pitching over a layer of filter from L W L to H W L, after regrading bank slope preferably to 1(V):2.5(H) but not steeper than 1(V):2(H), as per Fig 7/II.

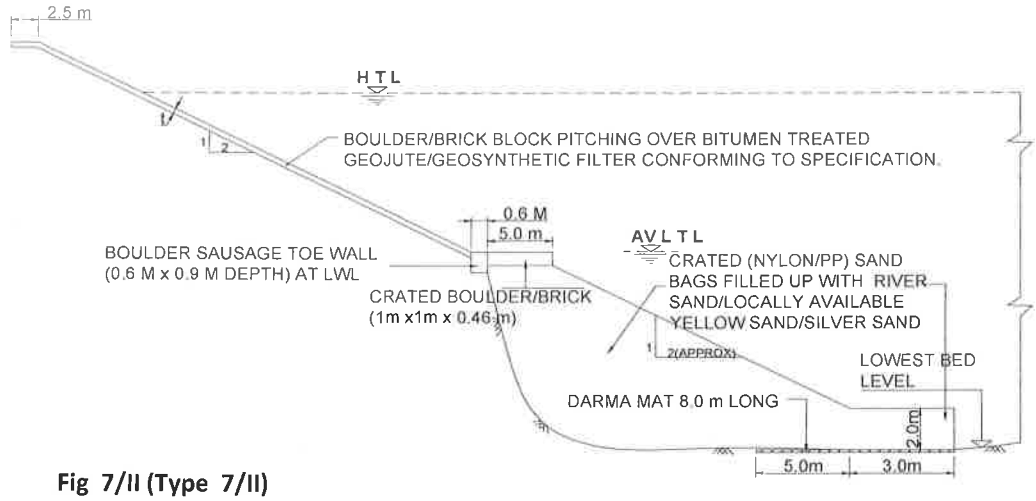


Fig 7/II (Type 7/II)

Note : Boulder , minimum weight of which is to be considered on the basis of site condition as well as availability , is preferred over bricks.

6.4 Zone D : Coastal protection work in Digha -Sankarpur and adjoining areas.

District covered : Purba Medinipur

Embankment/Shore protection : Type 8

Description : Sea wall by laterite stone boulder, brick masonry guardwall at country side , walk way in the form of interlocking paver block, block over cement concrete bank protection on the sea side of sea wall by cast-in-situ cement concrete block over black stone boulder pitching , sheet piling at the toe of protection as per Fig 8 below .

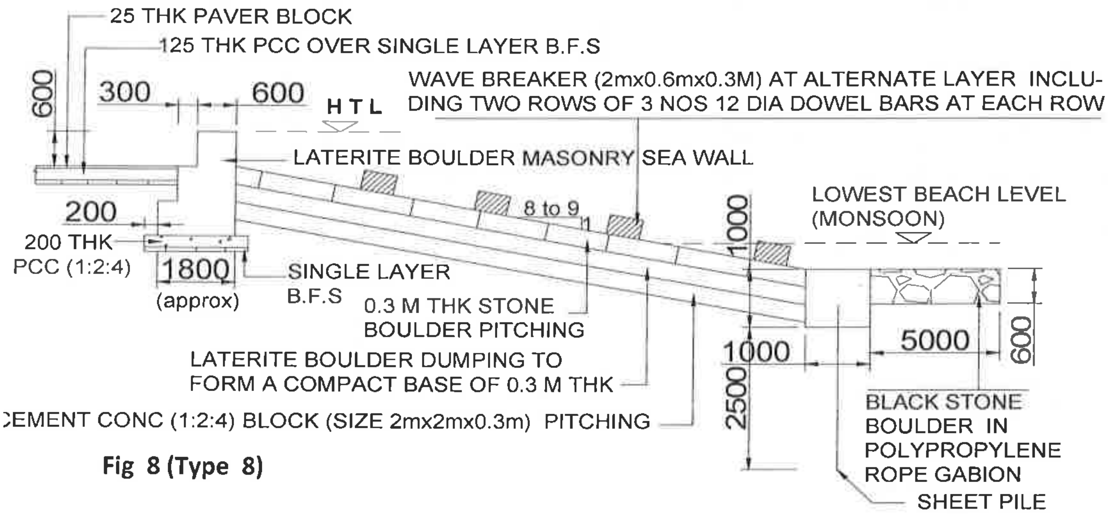


Fig 8 (Type 8)

6.5 Zone E : Sunderban areas in North & South 24 Parganas and Sea dykes in Purba Medinipur, away from coast line

District covered : Parts of North , South 24 Parganas & Purba Medinipur

Embankment protection : Type 9

Description : Brick block pitching (single unit or in polypropylene rope gabion)/dry brick pitching on river or sea side slope over woven geosynthetic filter with toe walls as per fig given below with dimensions as per Table 9.0

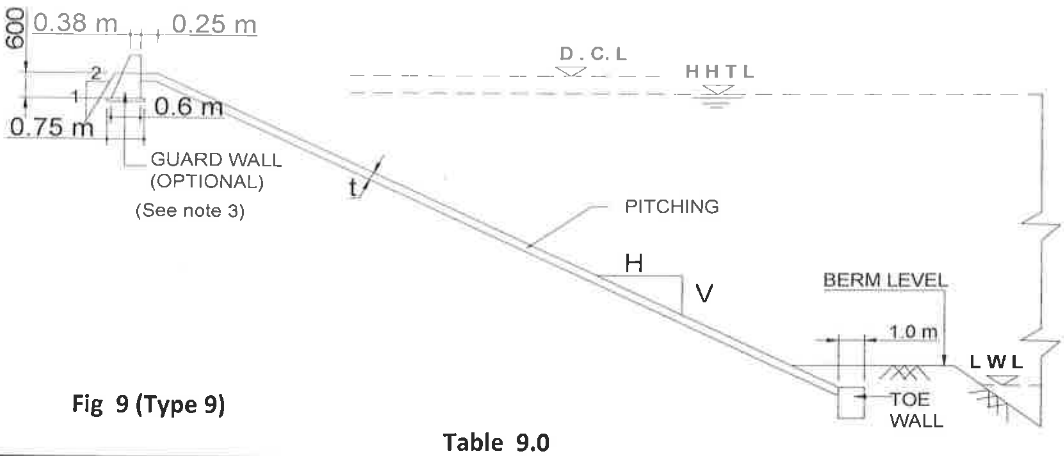


Fig 9 (Type 9)

Table 9.0

River/Sea	Type of pitching	Thk of pitching, t (m)	Slope of pitching H	Slope of pitching V	Design crest level of embankment (DCL): HHWL, Z_o (m)	Wave run up γ (m)	Settle ment, 'S' (m)	Free board, 'f' (m)	Total 'Z' (m)	Toe wall descrip tion
Sea facing dykes	0.53m x 0.53 m brick block/ 0.45 thk boulder pitching, 8 nos of such being put in polypropylene rope gabion of size not exceeding 2.4m x 2.4m over geo- synthetic filter (see note 4)	0.25	5	1	Note 1	2.47	0.30	1.50	4.27	Loose brick in polypropylene rope gabion
River embankment facing or near sea within 3 km u/s of confluence of river with sea	do	0.25	5	1	Note 1	2.39	0.30	1.50	4.19	do
River emabnkment aligned more or less in north-south dirn	0.53m x 0.53 m brick block pitching over geosynthetic filter	0.25	3	1	Note 1	0.75	0.30	1.50	2.55	Loose brick in iron wire net
River emabnkment aligned more or less along east- west & minor creeks / channels	Dry brick pitching over geosynthetic filter	0.2	3	1	Note 1	0.75	0.30	1.50	2.55	do

Note 1 HHTL value to be considered at a particular location as per available data.

2. The value of wave run up , 'γ', calculated from the following formula may be considere , taking reference from the Project of 'Reconstruction of Aila affected Sundarban Embankment' approved by by the MOWR, RDPGR. Settlement has been considered as 0.30 m and free board 1.50 metre as per approved design note of the same project.

$$\gamma = 8H \tan \alpha Cos\beta$$

γ = Height of wave run up (m)
H = Height of wave (m)
α = Angle of slope of embankment/dyke
Value of α may be taken as 11.3° for sea dyke and river embankment similar to sea dyke with in 3.0 km u/s of confluence of river with sea, 18.4° for other rivers.

β = Angle of approach between the embankment/dyke & the wave crest
Value of b shall be 0° for sea dyke , 15° for river embankment with in 3.0 km u/s of confluence of river with sea and 75° for other river.

$$H = \frac{\left(0.17\sqrt{VF} + 2.5 - \sqrt[4]{F}\right)}{3.2808}$$

V = Wind speed in miles per hour , considered as 62 miles/hour for river embankment and 78 miles/hour for sea dyke.
F = Fetch in mile, 8.0 mile for sea dyke and 4.0 mile for river embankment.

3. If designed Crest Level (DCL) can not be attained due to space constraint , a masonry guard wall of suitable exposed height may be constructed to avoid spilling of tidal water over the embankment.
4. Brick blocks in gabion may be replaced by cast-in-situ M20 cement concrete block of size 2.15 m x 2.15 m x 0.30 m if site condition permits.

6.5.1 Zone E : Sunderban areas in North & South 24 Parganas

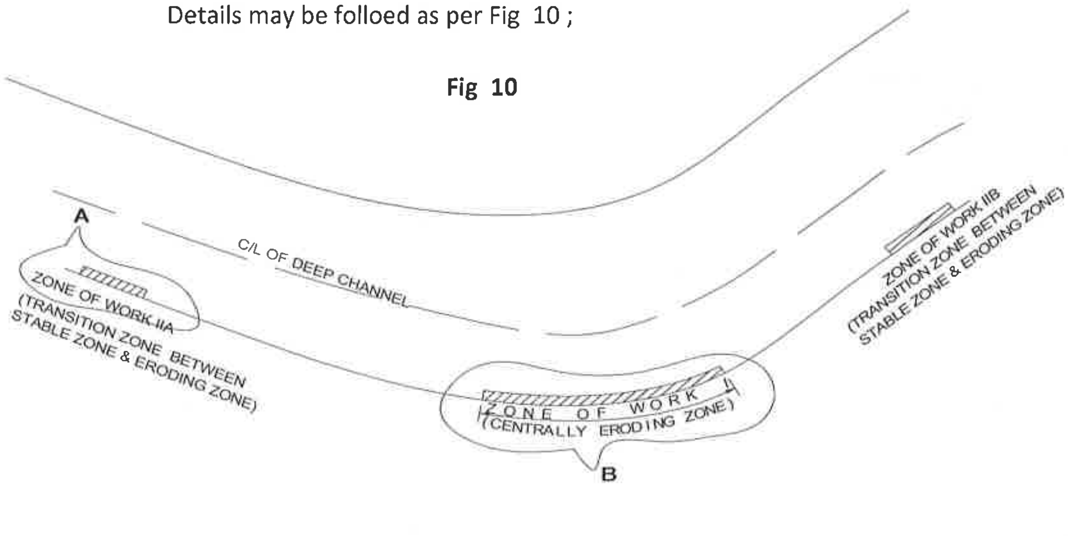
District covered : Parts of North & south 24 Parganas

Embankment protection : Type 10

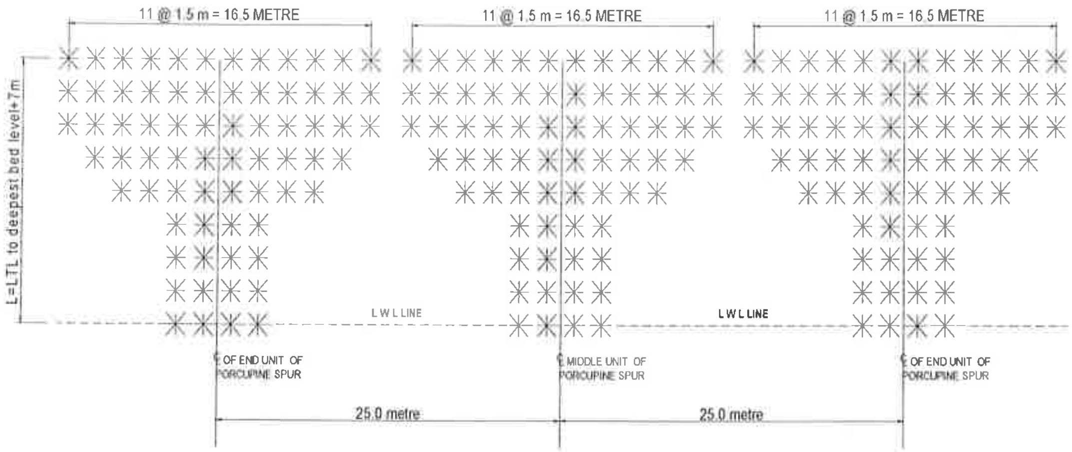
Description : At concave and eroding bank , opposite to silted bank , cluster of bamboo porcupine cage to function as semi permeable spurs at the transition zone where deep channel tends to be more deeper and shift towards eroding bank (at both u/s & d/s locations of the critically affected eroding zone for deflecting deep channel , where as such cages are to be placed in the critically eroding zone to invite siltation.

Details may be folloed as per Fig 10 ;

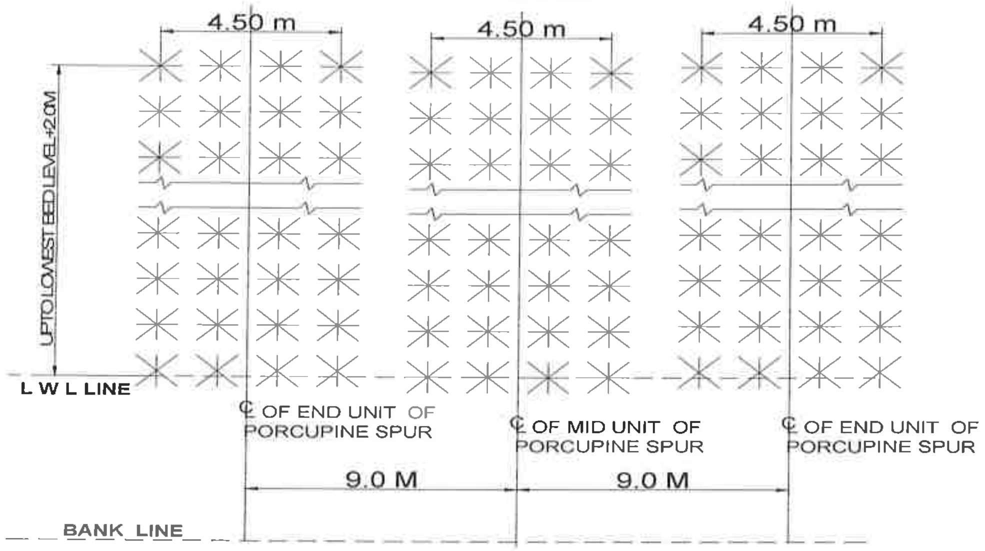
Fig 10



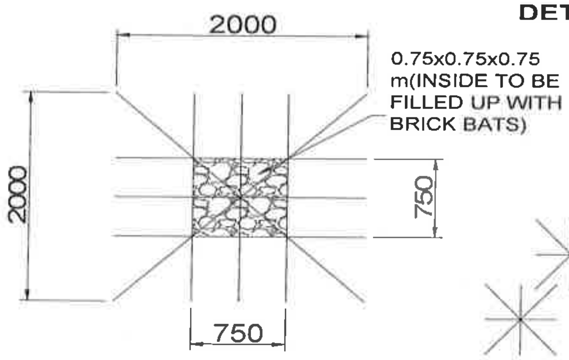
Note: Precise location of transition zone to be ascertained by survey of deep channel profile.

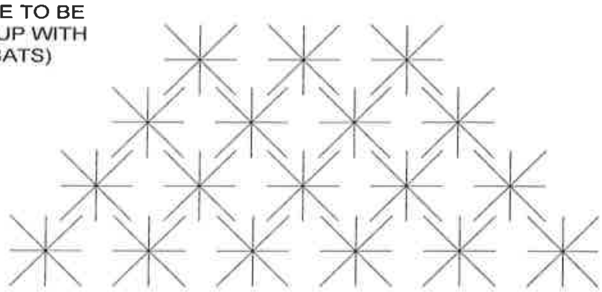


DETAILS 'A'



DETAIL 'B'





DETAILS OF INDIVIDUAL BAMBOO PORCUPINES

Porcupines being dumped in elevation

General Note : No permanent work on improvement of embankment should be done in the zone of anti-erosion works using porcupines as shown above , for a period of one year , in order to observe the performance of the anti-erosion works executed. Embankment work in the zone should be restricted to strengthening of country side with raising if necessary. In case of strong wave action, river side slope may be protected by earth filled poly bags/darma mat as a temporary measure.