Annexure - X

LIST OF QUERIES FROM POTENTIAL CONSULTANTS FOR RFP REFERENCE No: CE/IW/SPMU/RFP/02/22-23 Dated 28/11/2022 ALONG WITH RESPONSES OF IWD, raised during the pre-bid meeting held on 15/12/2022

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
1	1.Clause 21.1 of E. Data Sheet, Page No.33	The number of points to be assigned to positions K-1, K-3, K-4, K-5 shall be determined considering the following three sub-criteria and relevant percentage weights: 1 | Knowledge in Bengali Language | [5%]	We understand the percentage weights for positions K-1, K-3 to K-5 include a component of 5% for "Knowledge in Bengali Language". We kindly request that this also includes experience in geographical regions which has been the norm for many World Bank & ADB projects, i.e. "Knowledge in Bengali Language/experience in geographic region". Please confirm.	No change. Provisions of the RFP document shall prevail.
2	2.Sub-Clause XVII. of Clause 18. Client's Input in Section-7 Terms of Reference, Page No.76	Office space and IT facilities (net connectivity only, desktops & laptops excluded) at RRI office at Haringhata, District Nadia, where the Team Leader along with his staff will be stationed. It is further clarified that usual furniture like, table, chair, almirah etc., would also be provided, as available in the RRI office. However, any refurbishment, additional gadgets /furniture, if required, should be arranged by the Consultant.	We understand that office space is being provided for the consultant at the RRI Office in Haringhata, Nadia. In this regard, we understand that the consultant may choose to use this space if necessary and that this is not compulsory for the consultant to utilize this space for the purpose of this project. Please confirm.	No change. Provisions of the RFP document shall prevail. Consultant shall be stationed at RRI, Haringhata for this project.
3	Clause 19.7. Responsibility of the Consultant in Section-7 Terms of Reference, Page No.76	The Consultant will ensure the use of high-end laptops and desktops to be procured by him for the purpose of the development of inundation model with high resolution DTM, and these laptops and desktops are to be finally handed over to the Client after the completion of the assignment.	Considering that the laptops/desktops utilized for the project need to be handed back to the client, we request that the costs of obtaining the laptops/desktops be made part of a provisional sum which need not be taken into account for the financial evaluation of the proposal. Please confirm.	No change. Provisions of the RFP document shall prevail.

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
4	Clause 22. Training & Capacity Building in Section-7 Terms of Reference, Page No.80	This programme will be done in the following manner: General capacity building in the form of consultation / discussion / knowledge sharing during the development phase of the model as and when necessary Fortnightly technical training with hand holding workshop for handling / upgradation of the model. Monthly management training programme that will cover operation and maintenance of the model	a) Please confirm the mode of the workshop proposed for the fortnightly technical training. I.e., will the consultant have to arrange for a laboratory twice a month or will the workshop need to be scheduled at the client's office itself. Who will bear the expenses of the workshop? b) How many personnel are expected to be trained? c) Please clarify on the monthly management training programme. Whether this program may be part of the same fortnightly training, or will this have to be conducted separately? d) What will be the location for this training programme and how many participants are expected for this ?	Training at RRI Haringhata with attendees' strength around 5-7 in physical mode. Payments to be borne by consultants for refreshments and logistics excluding place and furniture.
5	Table under Clause 41.2, Payments under its contract in Special conditions of contract, Page No.102	The Consultants shall be paid on the basis of their reports submitted, as detailed under section-7 TOR in Timelines, Deliverables & Payment Terms of this document. Such claim for payment, with all documentary support, may be made to PMC. Payment will be made within 60 (Sixty) working days upon receipt of such claim. The Payment mode will be via ECS/NEFT through Govt. Treasury to the declared Bank Account Number of the Consultant.	We request that the client modify the payment terms as below to help improve the cash flow of the project.	No change. Provisions of the RFP document shall prevail.

Sl. No.	Clause Reference & Page No.	Description as per RFP			Bidder's Queries / Issues			Replies of the Department
		Deliverable	**Timeline from the award of contract**	**Percentage payment of the total contract value**	**Deliverable**	**Timeline from the award of contract**	**Percentage payment of the total contract value**	
		Draft Inception Report	1 month from signing of Contract	10%	Draft Inception Report	1 month from signing of Contract	10%	
		Final Inception Report	15 calendar days after receipt of comments, to be communicated with 15 calendar days to the Consultant by IWD from receipt of the Draft Inception Report	Nil	Final Inception Report	15 calendar days after receipt of comments, to be communicated with 15 calendar days to the Consultant by IWD from receipt of the Draft Inception Report	Nil	
		Model Development Report	Within 5.5 months from the date of award.	30%	Model Development Report	Within 5.5 months from the date of award.	40%	
		Draft Final Study Report	Within 6.5 months from the date of award.	30%	Draft Final Study Report	Within 6.5 months from the date of award.	30%	
		Final Study Report	30 calendar days after receipt of comments, to be communicated with 15 calendar days to the Consultant by IWD from receipt of the Draft Final Study Report.	30%	Final Study Report	30 calendar days after receipt of comments, to be communicated with 15 calendar days to the Consultant by IWD from receipt of the Draft Final Study Report.	20%	

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
		Total time for the assignment | 8 months |	Total time for the assignment | 8 months |	
6	Section 2- Instructions to Consultants: ITC 2.4, Page 29 & Page 75-76	Please refer to the section-7 TOR page-76 of this document for client's input to the consultant Office space and IT facilities (net connectivity only, desktops & laptops excluded) at RRI office at Haringhata, District Nadia, where the Team Leader along with his staff will be stationed. It is further clarified that usual furniture like, table, chair, almirah etc., would also be provided, as available in the RRI office. However, any refurbishment, additional gadgets /furniture, if required, should be arranged by the Consultant.	We understand that the project is a lump sum contract for 8 months; therefore, we do not anticipate the team leader and staff being stationed at the RRI office. However, whenever there is a requirement, the team will visit the client and meet with them. Please confirm.	No change. Provisions of the RFP document shall prevail. Team to be stationed at RRI,Haringhata for this project.
7	Terms of Reference: Responsibility of the Consultant Page 76-77, Point no.19.6,19.7,19.10	The Consultant will work in close consultation with RRI, West Bengal, which would be the Nodal Entity on behalf of IWD who may assign counterpart personnel to the study for purposes of transfer of knowledge and capacity building. The Consultant shall provide for the required office space for the IWD counterparts, in case he prefers to partly from his own office preferably at or near Kolkata. The Consultant will conduct regular meetings with RRI & other IWD Officials: ▪ to discuss the progress of the work and preliminary outputs; ▪ give the IWD the opportunity to make comments and suggestions on a timely basis; and ▪ resolve problems and issues that may be encountered. 19.7 The Consultant will	We request that you not make it mandatory for consultants to provide the required office space for the IWD counterparts, as the consultants will interact with the RRI and IWD officials whenever there is a requirement.	No change. Provisions of the RFP document shall prevail.

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
		ensure the use of highend laptops and desktops to be procured by him for the purpose of the development of inundation model with high resolution DTM, and these laptops and desktops are to be finally handed over to the Client after the completion of the assignment. 19.10 The Consultant will impart proper training to the Client's personnel / field staff as and when required to enable independent handling and minor modification / up gradation of the system during the period of Consultancy. He shall also discuss and apprise the Client, step by step activity and relevant technical details being followed in the process of development of the model.		
8	Section 2- Instructions to Consultants: ITC 17.7 & 17.9, Page 32	The Proposals must be submitted no later than: Date: 04/01/2023 Time: 16:00 Hours IST	Looking at the festival season we request you to extend the proposal submission date by 4 weeks after issuing the pre bid clarifications.	No change. Provisions of the RFP document shall prevail.
9	Page 29 Clause 2.3	A pre-proposal conference will be held: Yes Date of pre-proposal conference: 16/12/2022 Time: 14:00 Hours IST Address: Chief Engineer & Project Director, State Project Management Unit (WBMIFMP), Irrigation & Waterways Directorate, Government of West Bengal,9th Floor, Jalasampad Bhavan, Salt Lake, Kolkata, PIN700091, West Bengal, India; Tel: (+91) 3323581315, e-mail: ce.pd.wbmifmp@gmail.com.	It is requested that the preproposal conference be conducted through an online mode as well to allow a wider participation of staff and experts. Please consider.	No change. Provisions of the RFP document shall prevail.

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
10	Page 30 Clause 11.1	Participation of Sub-consultants, Key Experts and Non-Key Experts in more than one Proposal is permissible Yes (More than 2 proposal is not permissible)	Considering the expert has to work with the firm who is awarded the project, kindly clarify why the repetition is limited to 2 proposals only. It is requested that the restriction of two proposals be removed which will benefit the project delivery, whosoever is the preferred firm. This does not necessarily mean that all the bidders will use the same team of experts. Please consider.	Participation of Sub-consultants, Key Experts and Non-Key Experts in more than one Proposal is permissible. Yes (More than 3 proposal is not permissible)
11	Page 31 Clause 16.3	Information on the Consultant's tax obligations in India can be found from the Ministry of Finance, Government of India website [http://finmin.nic.in]. Consultants are responsible for payment of all taxes as applicable in India. Note: The Consultant shall take advice from their tax consultant and shall suitability provide for their indirect tax liability/ Service tax in their quote for this assignment. At source deductions relating to Income Tax (TDS), however, shall be made as applicable as per Statutory laws of India.	We understand that the GST will paid over and above the total fees quoted by the bidders. Please confirm	Fees quoted by the bidder should be inclusive of GST.
12	Page 32-33 Clause 21.1	Knowledge in Bengali Language – 5%	This restricts the bidders to propose experts who may not be native to West Bengal even if the staff are employed with the bidding firms. It is suggested that this weightage be removed and the same added to the training/publications/experience on internationally funded project. Please consider.	No Change. Provisions of the RFP document shall prevail.

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
13	Page 33 iv	Transfer of knowledge program (to be evaluated from the documentation of the bidder, to be provided separately for this topic): [7]	Since the assignment is a short duration one, kindly clarify on the expectations related to the training/transfer of knowledge so that the bidders can address the same in the approach and methodology section.	No Change. Provisions as per Clause 22 of ToR page-80 shall apply.
14	Page 37 Section 3	Tech 7: Code of Conduct (ESHS)	As per Clause 10.1, Page 30 of the Data Sheet, we understand that Tech 7 is not required to be submitted. Please confirm our understanding is correct.	Tech 7 not required.
15	Page 47 Form Tech 6	Signature of Expert Signature of Authorized Representative	Please clarify whether signature of both the expert as well as the authorized representative is required	Yes. Signature of both the expert as well as the authorized representative is required
16	Page 40 B-1	List only previous similar assignments successfully taken up in the last five years, ending Mar 2022.	Considering similar projects are of dynamic nature, which conventionally have a longer project duration, and projects did not progress during the two years of Covid period, it is requested that the experience criteria be allowed to showcase projects undertaken in the last 10 years instead of 5 years. Kindly consider	No Change. Provisions of the RFP document shall prevail.
17	Page 49-50 Form FIN 1	{For a joint venture, either all members shall sign or only the lead member/consultant, in which case the power of attorney to sign on behalf of all members shall be attached}	Since the power of attorney is being submitted as part of the technical proposal, please clarify whether the power of attorney is required to be submitted as part of the financial proposal as well or not.	Power of Attorney for technical proposal is sufficient. He may sign financial proposal.
18	Page 69	The relevant documents and reports, field survey and hydrographic survey data related to rainfall, water level, discharge, cross-section, bathymetry, and sediment as primary input for boundary conditions will be provided by Irrigation &	Since all survey data and information required for undertaking this assignment is being provided by the Client, we understand that no additional survey and investigations are required to be undertaken as part of this assignment. In case the consultant identifies any	The consultant shall bear the cost of additional survey and investigations. The need of additional field survey will generally not arise. But in rare event, it might have to be done and the cost of such survey has to be borne by the consultant.

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
		Waterways Department (IWD) for the purpose of the development of this model.	additional requirement, the same will be brought to the notice of the Client and will be considered as an additional item of work, which will be reimbursed by the Client extra to the fees quoted by the bidder. Please clarify and confirm	
19	Page 70 Clause 15.2.1 Page 64	The Consultant shall process, analyze and the survey and other data to be provided by the Client as the input for model study and also derive any other data to be required for building the model with a comprehensive and holistic approach as per relevant BIS publication (IS: 12094:2000) as required by the DoWR, RD & GR, Ministry of Jal Shakti, Government of India. It is mentioned that survey cross sections in the DwarakeswarRupnarayan River system have been taken @ 500 m c/c (by RTK & ADCP). These apart, closer sections have also been taken at a few vulnerable eroding locations. In case of additional requirements, the Consultant would have to take the same, using the same methodology. The Consultant shall check the accuracy of survey data specially the RLs with respect to high resolution DTM (0.5 m x 0.5 m) available for limited areas of interest (AOI) say around 1100 sq. km out of combined catchment areas of 30762 sq. km and perform the conversion of reference datum from Earth Gravitational Model (EGM) of DTM to Great Trigonometric Survey (GTS) in meter (m)	Please clarify if the accuracy of the survey data is required to be checked on field, since it is mentioned as "if necessary"	No Change. The consultant may have to conduct physical checks on accuracy and survey data on field in case of vulnerable zones, if at all necessary, which will be intimated to the consultant by the IWD. In any and all such cases however, no extra cost shall be borne by the client.

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
		if necessary. These modified / corrected values shall be extrapolated in other areas for the purpose of estimation of the ground contours by using medium resolution DEM like SRTM 30.		
20	Page 73 Clause 16.6	Consultant shall collect other types of data as may be found relevant for the conduct of the study.	In case of the additional data collection warrants the consultant to pay any statutory fees to any department, we understand that the Consultant will facilitate collection of data and the statutory fees will be paid directly by the Client as part of a government-togovernment payment procedure. Please clarify and confirm.	The consultant shall bear the cost.
21	Page 76 Clause 19.5 & 19.6	19.5 The model will be developed and implemented preferably in the designated office of IWD (River Research Institute, at Haringhata, District Nadia) and operationally run during the period of Consultancy along with the counterpart team of Client (RRI Officials). The extent of required space may be indicated by the Consultant. 19.6 The Consultant will work in close consultation with RRI, West Bengal, which would be the Nodal Entity on behalf of IWD who may assign counterpart personnel to the study for purposes of transfer of knowledge and capacity building. The Consultant shall provide for the required office space for the IWD counterparts, in case he prefers to partly from his own office preferably at or near Kolkata	Kindly clarify if it is mandatory that the model development and implementation be undertaken from the IWD office, Haringhata OR the Consultant can undertake the assignment from their office at Kolkata and work in close coordination with the RRI.	It is mandatory that the model development and implementation be undertaken from the RRI office, Haringhata.

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
22	Page 76-77 Clause 19.7	The Consultant will ensure the use of high-end laptops and desktops to be procured by him for the purpose of the development of inundation model with high resolution DTM, and these laptops and desktops are to be finally handed over to the Client after the completion of the assignment	It is requested that the hardware requirements including number and specifications of the laptops/desktops etc be specified by the Client, since these have to be handed over to the Client at the project completion. This will ensure that all bidders are on the same level while making provision for the hardware in the financial proposals, considering this being a QCBS evaluation.	The laptops/desktops used by key personnel of K2-K6 will have to be handed over to the client. For such case, however, the specs of Laptops/Desktops shall not be considered for evaluation.
23	Responsibility of the Consultant 19.9 Page no.77	The Consultant will access the websites of IWD, DVC, CWC, IMD etc for collection of relevant information related to model study. Consultant will ensure a secured data handling environment in case any confidential data is shared by the Client for the model study.	Request to confirm whether the Consultant has to procure or facilitate the procurement of CWC classified data of HO sites in the study area. Since data acquisition is time taking process, any delay will result in an overall deliverables delay, not attributable to the Consultant. Also, we understand that if data has to be procured by the Consultant, the cost of the data will be reimbursed by the Client. Please confirm.	The consultant shall bear the cost. No additional reimbursement shall be provided.
24	Page 78 Clause 21.7	The Final Study Report will include a summary of the work done, achievements and lessons learned as also indicate procedures for carrying out model updates / upgrades because of improvement in data availability. The Consultant will also validate the model during the last 3 months of the assignment, which would be a part of monsoon period of 2023.	Table 3 does not indicate any timelines considered for the model validation for last 3 months. Please clarify. Also, in case the 3 months for model validation are included within the 8 months duration of the assignment, the timelines seem compressed a bit. Please review and clarify.	No Change. Provisions of the RFP document shall prevail.

<table>
<tr><th>Sl. No.</th><th>Clause Reference & Page No.</th><th>Description as per RFP</th><th>Bidder's Queries / Issues</th><th>Replies of the Department</th></tr>
<tr><td>25</td><td>Page 79 Clause 21.8</td><td><table>
<tr><th>Deliverable</th><th>Timeline from the award of contract</th><th>Percentage payment of the total contract value</th></tr>
<tr><td>Draft Inception Report</td><td>1 month from signing of Contract</td><td>10%</td></tr>
<tr><td>Final Inception Report</td><td>15 calendar days after receipt of comments, to be communicated with 15 calendar days to the Consultant by IWD from receipt of the Draft Inception Report</td><td>Nil</td></tr>
<tr><td>Model Development Report</td><td>Within 5.5 months from the date of award.</td><td>30%</td></tr>
<tr><td>Draft Final Study Report</td><td>Within 6.5 months from the date of award.</td><td>30%</td></tr>
<tr><td>Final Study Report</td><td>30 calendar days after receipt of comments, to be communicated with 15 calendar days to the Consultant by IWD from receipt of the Draft Final Study Report.</td><td>30%</td></tr>
</table></td><td>In the delivery and payment milestones, the Consultant is paid only 10% till the submission of the Model Development Report (substantial completion of the assignment), which creates a highly negative cash flow for the project. It is suggested that an intermediate milestone be included prior to the Model Development Report with 30% payment milestone in order to allow a workable cash flow for delivering this assignment. Further, since the scope of the Consultant also covers procurement of the hardware, ensuring a healthy cash flow is considered important for a successful project delivery. Alternatively, it is suggested that an advance payment of at least 10% be paid to the Consultant.</td><td>No Change. Provisions of the RFP document shall prevail.</td></tr>
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Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
		Total time for the assignment | 8 months |		
26	Table 4: List of Key Experts with Man-Months Page No. 81	RS/ GIS Expert B. Tech in Civil Engineering / Geo-informatics or Equivalent with 5 years of experience in RS/GIS applications for resource mapping, preparation and integration of RS/ GIS datasets including processing of DTM. Preference to be given to those with experience in hydrologic applications, 3D analysis and customization and experience in flood inundation mapping	The Client is requested to kindly include Masters / PG in Geo-informatics / Geography or Equivalent. Please confirm.	No Change. Provisions of the RFP document shall prevail.
27	Table 4: List of Key Experts with Man-Months Page No. 81	Data Analyst Graduation in any stream with certificate in Computer Application / Diploma in Information Technology / relevant field with at least 5 years of experience of working with MS Office in Government / Private Organization	The Client is requested to kindly include Graduation in any stream with certificate in Computer Application / Diploma in Information Technology / relevant field or bachelor's degree in any Engineering. Please confirm	No Change. Provisions of the RFP document shall prevail.
28	ITC Section-2 17.7 and 17.9	The Proposals must be submitted no later than: Date: 04/01/2023	We request that the Due date of submitting the proposals may be extended 3 weeks from the date of publication of Prebid query responses and addendums if any	No Change. Provisions of the RFP document shall prevail.
29	ToR clause 18 Pg. 75	WBMIFMP FS Report, including the model report and subsequent model repots simulated after the floods of 2021.	No details have been mentioned in the RFP regarding the hydrological analysis carried out for the two floods in the year 2021. A sequence to WBMIFMP FS report and model reports is given under clients input. (ToR clause 18 Pg. 75) But no details are made available. WAPCOS would like to understand the adequacy of data on hydrology and hydraulics for implementing the initial and boundary conditions in the model. Necessary	This may not be directly relevant for submission of the proposal. However, the original model study report is being shared with all the proposers, by email. Further details would be shared after selection of the consultant.

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
			clarification and details may be provided in this regard. We understand that hydrological analysis is not part of the assignment and client will provide all the relevant data and report	
30	Section 7. Terms of Reference Pg- 58 to 81	Some flood protection works already taken up in lower Damoder, Amta channel, upper Rampur Khal and HurhuraKhal	The RFP mentioned that some flood protection works already taken up in lower Damoder, Amta channel, upper Rampur Khal and HurhuraKhal. It is not clear about the location and relevance of these works in the proposed modeling. This may please be clarified.	Please consult the ToR for clarification.
31	Section 7. Terms of Reference Pg- 58 to 81	Section 7 - ToR, Clause 18 - Client's Input:	MIKE FLOOD is the appropriate model for this assignment under the RFP. In RFP, however, the available software mentioned are MIKE HD, which is not the appropriate module for this assignment. The availability of license for MIKE FLOOD may please be confirmed.	Requisite software is available with the client.
32	Section 7. Terms of Reference Pg- 58 to 81	Section 7 - ToR, Clause 18 - Client's Input:	To undertake various tasks under this scope at the consultancy services, the following software modules under MIKE series will be required. i) Development of flood inundation model – MIKE FLOOD (MIKE 11 & MIKE 21 coupled) ii) Identification of structural and non-structural measures – MIKE FLOOD / MIKE HYDRO (River) iii) Riverbank erosion and protection – MIKE C iv) Mud or Sand transport, morphological modeling in the Rupnarayan River – MIKE 21	Requisite software is available with the client.

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
			HD plus MIKE 21 MT / MIKE 21 ST. The availability of the above software license may be confirmed. The application of different modules for the different task will need range of field data and survey specially bathymetry survey of Rupnarayan River system. The availability of the same may be confirmed.	
33	Section 7. Terms of Reference Pg- 58 to 81	Section 7. Terms of Reference. Clause 16 - Availability of Data:	The RFP mentions that the survey cross-section have been taken at 500 m c/c and also suggested additional data requirement to be collected by the bidder. The detailed extent of data availability has to be marked on a plan so that the bidder can access the suitability and requirement of additional data which will have considerable implication on technical and financial proposal. General information on the location, duration, time of acquisition of data on various parameter including boundary conditions is very important not only for the bidding but also for understanding the adequacy of data for synchronizing the simulation of flows from various rivers, streams and channels. It is requested to provide above details.	It has been clarified in the Prebid meeting that sufficient survey data mentioned in the ToR required for Model Study would be provided. These may be treated as current data, captured in 2022. The consultant might be required to exercise sample check at best in the field. Any other data, if at all required additionally, would have to be collected by the consultant. As such, the information provided are considered sufficient to submit the proposal and that may be factored in.
34	Section 7. Terms of Reference Clause-23 Table 4	International experts having foreign origin would be desirable & given more weightage during evaluation.	Equal weightage may be given at the time of evaluation for Indian and International expert based on qualification, experience in the relevant area of expertise	No Change. Provisions of the RFP document shall prevail.

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
35	Data Sheet: 21.1 (for FTP) Page 33	The number of points to be assigned to positions K-1, K-3, K-4, K-5 shall be determined considering the following three sub-criteria and relevant percentage weights: 1 *General qualifications (general education, training, and experience):* ***[15%]*** 2 *Adequacy for the Assignment (relevant education, training, experience in the sector / similar assignments):* ***[80%]*** 3 *Knowledge in Bengali Language* ***[5%]*** ***Total weight:*** ***100%***	For the positions K-1, K-3, K-4, K-5 5% numbers has been kept as" Knowledge in Bengali language". As it is a complete technology-based project language doesn't matter much. And this criterion will restrict the availability of CVs which may not be desirable for such projects. This Criteria may be set as 1 *General qualifications (general education, training, and experience):* ***[15%]*** 2 *Adequacy for the Assignment (relevant education, training, experience in the sector / similar assignments):* ***[85%]*** ***Total weight:*** ***100%***	No Change.
36	FORM FIN-1 FINANCIAL PROPOSAL SUBMISSION FORM Page 49	Our attached Financial Proposal is for the amount of {Indicate the corresponding to the amount(s) currency(ies)} {Insert amount(s) in words and figures}, including all taxes, duties and levies of all indirect local taxes in accordance with ITC 25.1 in the Data Sheet. The estimated amount of GST local indirect taxes is {Insert currency} {Insert amount in words and figures} which shall be confirmed or adjusted, if needed, during negotiations. {Please note that all amounts shall be the same as in Form FIN-2}	It means, amount of {Indicate the corresponding to the amount(s) currency(ies)} {Insert amount(s)in words and figures}, including all taxes, duties and levies of all indirect local taxes in accordance with ITC 25.1 We understand this above amount is excluding GST and the GST amount will be provided separately in the second item as there is no combined figure in FIN 2 inclusive GST.	No Change. Please follow the guidelines as laid in respect of the Financial Proposal Forms in RFP

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
37	Section 7: TOR page 72	15.4: Identification of structural and non-structural measures	It is understood that some measures are already been identified by the department. The location and extent of such critical zones, already identified by field verification and Google Earth Engine, will be provided by the Irrigation & Waterways Department, Govt. of WB. Consultants will review this and assess the suitability and find additional measures and their locations after discussion with Client. Kindly confirm our understanding.	Study will have to be conducted as per ToR.
38	TOR, Section 7 15.5 Page 73	15.5 Measures finally recommended by the Consultant shall be supplemented by designs, GA & layout drawings	It is understood that a preliminary design will be carried out by the consultants for the proposed intervention and GA & layout drawings will be developed and BOQ and approximate estimate of cost can be done from these drawings. Kindly confirm our understanding	Detail Design, GA and Layout drawings will have to be given by the consultant which will be sufficient to provide estimate for BOQ etc.
39	TOR, Section 7 Client's Input 18 Page 75	River Cross-Sections Data and Chezy resistance coefficient in any.	It is understood that Cross section data for the river system required for this project will be provided by the client. This data will cover the existing embankment information also. Consultants need not do any further topographical survey for the embankments	Data provided will generally be sufficient but in some rare cases , if at all required , that will have to be borne by the consultant at no additional cost.
40	TOR, Section 7 23 List of Key Experts – page80	Team Leader B. Tech in Civil Engineering with master's degree in Water Resource / Hydraulic Engineering or Equivalent having at least 15 years of experience on design & supervision /project management consultancy in	Is 1 crore for a single project means amount of Consultancy Services or Project values? It it for all the projects? "International exposure/experience of not less than 10 years under reputed international firms" does it mean 10 year working experience under reputed	1 Cr Consultancy project value. International experience of 10 years required.

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
		Flood Management /Irrigation sectors, with special emphasis on projects envisaging drainage improvement in river basins having contract amount not less than Rs. 1 (One) Crore for a single project. Preference and more weightage during evaluation will be given for experience in flat alluvial flood plains and also having international exposure/experience of not less than 10 years under reputed international firms	international firms for domestic and overseas project even seating in India or 10 years' experience in overseas project only? Its bit confusing and in TOR of EOI it was not there. It may be written as "International Experience / Exposure is preferable" Kindly clarify.	
41	TOR, Section 7 23 List of Key Experts – page81	Sr Hydraulic Modeller- Postgraduate or Equivalent in Hydrology / Hydraulics / Water Resource Engineering with at least 12 years of international experience in flood modelling with sedimentation and morphological modelling and having extensive knowledge of hydrological and hydrodynamic modelling tools used in sedimentation analysis. International experts having foreign origin would be desirable & given more weightage during evaluation.	Can the Modeller be Indian citizen with at least 12 years of international experience in flood modelling with sedimentation and morphological modelling, and having extensive knowledge of hydrological and hydrodynamic modelling tools used in sedimentation analysis? If he is foreigner, is home input allowed?	No Change. Provisions of the RFP document shall prevail.
42	TOR, Section 7 22Capacity Building page 8	Fortnightly technical training with hand holding workshop for handling / upgradation of the model. Monthly management training programme that	We understand these training will be done after Development of Model only in a form of Workshop (2 nos) not in each fortnight. Training on operation and maintenance of the model will be done in later stage after development and	Training at RRI with attendees' strength around 5-7. Payments to be borne by consultants for refreshments and logistics excluding place and furniture. RFP clause 22 Pg-80 to be followed.

Annexure - X

Sl. No.	Clause Reference & Page No.	Description as per RFP	Bidder's Queries / Issues	Replies of the Department
		will cover operation and maintenance of the model	validation of the mode (1 number) l, not in each month. Training and Workshops will be in the RRI premises.	
43	TOR, Page 77 Clause 15	Office space and IT facilities (net connectivity only, desktops & laptops excluded) at RRI office at Haringhata, District Nadia, where the Team Leader along with his staff will be stationed. It is further clarified that usual furniture like, table, chair, almirah etc., would also be provided, as available in the RRI office. However, any refurbishment, additional gadgets /furniture, if required, should be arranged by the Consultant.	It is understood that the main project office will be set up in RRI Office, Haringhata, District Nadia, and Client will arrange the space and facilities. But some part of the work may be carried out from Consultant's branch office in Kolkata whenever necessary. It is not necessary to sit all the experts in RRI office together	No Change. Provisions of the RFP document shall prevail.
44	Section 2- Instructions to Consultants: ITC 17.7 & 17.9, Page 32	The Proposals must be submitted no later than: Date: 04/01/2023 Time: 16:00 Hours IST	We would request you to kindly extend the proposal submission date by at least two weeks from the date of issue of the Minutes of the Pre-proposal Conference/Replies to Queries on the RFP/ToR for your kind consideration and confirmation.	No Change. Provisions of the RFP document shall prevail.

21/12/22

[D. Sengupta]
Chief Engineer & Project Director
WBMIFMP, I&WD, Govt of WB

Appendix No. – 2
Flood Modelling Study

EXECUTIVE SUMMARY

BACKGROUND

The Damodar River originates from the Chhotonagpur Plateau at Latehar District in Jharkhand and flows through the districts of Latehar, Hazaribagh in Jharkhand and enters Purulia District in West Bengal which is the lowermost riparian State in Damodar Basin. River Damodar bifurcates into two main branches, i.e. Mundeswari and Lower Damodar (Amta Channel) near the border of Burdwan and Hooghly Districts, and both the channels traverse through the districts of Hooghly and Howrah, and ultimately meet River Hooghly, which debouches into Bay of Bengal. The Lower Damodar Sub-basin area is historically flood prone. On average, about 25,600 hectare of cropped area and 366,500 people are affected every year. The major reasons of floods, waterlogging and drainage congestion in the project area are:

- Limited and partly reduced storage capacity of reservoirs, coupled with conflicting needs for water storage against opportunities for effective flood flow retention and storage through the monsoon season.
- Unresolved conflict between constructing and/or abandoning flood embankments, i.e. their use to contain/limit flood spills into the countryside by improving/constructing embankments along both river banks of Lower Damodar River, done on several occasions over the last two centuries, versus abandoning the right bank embankment in most places, where flood damage and failure has occurred over successive years.
- Progressive increase in Mundeswari River bed level due to sediment deposition, leading to a progressive reduction in the river conveyance capacity, thereby transferring conveyance capacity requirement into Amta channel, having a bankful capacity limited to only 1,455 cumec.
- Tidal effects at the outfall of the channels and rivers restricting outflows on a cyclic pattern.
- Restricted conveyance and outflow capacity of aged drainage channels and associated outfall sluice gate structures.

Although flooding cannot be eliminated altogether, there is scope of reduction of duration as well as extent of inundation, by revitalizing critical channels and rivers, remodelling of existing structures and constructing new interventions across the rivers and channels. One dimensional and two dimensional mathematical models are used to study the scope of reduction of flooding. Initially models are calibrated and existing conditions are established. Later calibrated models are used to examine the impact of different preventive measures like dredging, construction of new interventions etc.

APPROACH TO MODELLING

The Damodar River system is in a dynamic state, both in terms of flood flows and the morphology of the river. Any intervention in the natural processes requires in-depth understanding of these processes, and the impact the proposed works would have on the river dynamics. This is only feasible with advanced numerical modelling, that can integrate and resolve all the features at work. The main objectives of flood mitigation, considered during model, are:

- Flood management by various structural measures with optimal utilisation of carrying capacities of the two main rivers branching out of Damodar, i.e. Mundeswari and Amta Channel, and distribution the flood volume of main Damodar river in the above said two branches in such a manner so as to ensure equitable but reduced impacts across the entire flood affected area between right (western) bank of Amta Channel to left (eastern) bank of Mundeswari, for at least a 1 in 10-year return period flood event.
- Protecting the Damodar left bank floodplain against major floods up to a 1 in 25-year return period considering the presence of vital utilities on that side, e.g. Railway Lines, National Highway etc. by improvements of the Amta Channel left embankment.
- Remodelling the dwarf embankment on Amta channel right bank in such a way so that even overbank spilling takes place to any flood beyond its bankful capacity and up to a 1 in 10 yr return period, such spilling can be guided to occur at selected locations/sections, having slightly lower levels and there is no breach to embankment, which potentially impacts the affected persons. The other two vital embankments i.e. Upper Ramur Left and Hurhura Left embankments are also to be protected against floods up to 10 year return period

The different options considered for flood management are given in Table 0-1.

Table 0-1 Different options for flood management

Sl No	Description	Code
1.	a) Desiltation of Mundeswari River for a length of 21.6 km downstream of the Damodar bifurcation point at Beguahana, thereby lowering the Mundeswari bed level, to evenly take the Damodar floodwater on par with the Amta Channel. The Mundeswari bed level is adjusted and graded to ultimately match the existing bed level 20 km downstream of Beguahana. Such desiltation will be in the form of a pilot channel having bed width of **100 m.** (b) Without any ungated regulator across Amta channel (c) Other supplementary interventions including improvement of Amta channel Left, Amta channel Right (dwarf), Upper Rampur Left & Hurhura Left embankments.	For bed width 100 m,BW100 No Weir = W0 No bedbar = BB0 **Code is BW100-W0-BB0**

Sl No	Description	Code
2.	(a) Desiltation of Mundeswari River under the same condition as (a) in Sl.1 above with the exception that the bed width of the pilot channel would be **125 m**. (b) Without any ungated regulator across Amta channel. (C) Other supplementary interventions as stated in (c) under Sl.1 above.	For bed width 125 m,BW125 No Weir = W0 No bedbar = BB0 **Code is BW125-W0-BB0**
3.	(a) Desiltation of Mundeswari River under the same condition as (a) in Sl.1 above with the exception that the bed width of the pilot channel would be **150 m**. (b) Without any ungated regulator across Amta channel. (C) Other supplementary interventions as stated in (c) under Sl.1 above.	For bed width 150 m,BW150 No Weir = W0 No bedbar = BB0 **Code is BW150-W0-BB0**
4.	(a) Desiltation of Mundeswari River under the same condition as (a) in Sl.1 above with the exception that the bed width of the pilot channel would be **175 m**. (b) Without any ungated regulator across Amta channel. (C) Other supplementary interventions as stated in (c) under Sl.1 above.	For bed width 175 m,BW175 No Weir = W0 No bedbar = BB0 **Code is BW175-W0-BB0**
5.	(a) Desiltation of Mundeswari River under the same condition as (a) in Sl.1 above, i.e. bed width **100m**. (b) In addition, there will be an ungated regulator (in the form of a weir) across Amta channel immediate downstream of the bifurcation point to prevent entry of low floods in that channel. (c) Other supplementary interventions as stated in (c) in Sl.1 above.	For bed width 100 m,BW100 Weir = W1 No bedbar = BB0 **Code is BW100-W1-BB0**
6.	(a) Desiltation of Mundeswari River under the same condition same as (a) in Sl.2 above, i.e. bed width **150m.** (b) **7 number of bed bars** to be constructed on left bank of Damodar, immediate upstream of confluence of point at Beguahana to encourage diversion of flow from Damodar to Mundeswari, **but there will be no weir across Amta channel**. (c) Other supplementary interventions as stated in (c) in Sl.1 above.	For bed width 150 m,BW150 No Weir = W0 Bedbar = BB1 **Code is BW150-W0-BB1**

Different mathematical models have been applied in order to address the different time scales (ranging from minutes to years) and length scales (ranging from meters to kilometres) of the study.

- MIKE11 for one dimensional hydrodynamic study for rivers and canals
- MIKE21 for floodplain areas
- MIKEFLOOD for coupling of both MIKE11 and MIKE21 to exchange flow between rivers/canals and floodplain areas.
- MIKE21FM for impact of bed bar

Hydrological analysis and estimation of design floods at Beguahana point have been done. It is prime input to finalize best option and to estimate design parameters like HFL.

Various hydrological data including river discharge (observed as well as derived as stated in Paragraph 2.2.1 above), water level and data related to sediment load, grain size distribution of river bed materials, river/channel cross sections, flood plain bathymetry etc. Hydrological analysis and estimation of design floods at Beguahana are collected from the IWD/Other sources.

Model is setup for existing condition, putting river/channel network, and cross sections, fixing boundary conditions, adding floodplain topographical input data, selecting suitable formula for lateral discharge with assumed parameters (Manning's roughness coefficients for rivers and floodplains) and finally, calibration of the model by simulation and comparison with the available observed values. Model further simulates for for existing condition (**"without project**" condition) and further for different options (**"with project"** condition). After finalising option for flood management, inundation maps are generated to assess the extent and depth of inundation "with interventions" in the post project scenario. Sediment study and analysis are done with the available inputs to further facilitate decision making on selection of particular components, e.g. submerged bed bars, and also to assess sustainability of the desilted section of Mundeswari River required for formulating appropriate maintenance strategy in the post project period

DESIGN FLOOD

The Design Flood is the flood for which the structures planned to design. There is no discharge measured station available just upstream of Beguahana. Discharge data available for longer period is in Durgapur. Hence two way approach is considered.

- Flood frequency analysis is done for discharge data available in Durgapur.
- Synthetic unit hydrograph approach for catchment between Durgapur and Beguahana

The Flood Frequency analysis is based on the observed gauging data for the River Damodar in Durgapur for 43 years (1975-2017). The following statistical distributions for estimating return period floods for a particular location have been applied.

- Normal distribution
- Pearson Type-III
- Extreme value analysis I
- Log normal distribution

The estimated design discharge based on different statistical analysis are given below:

Return Period (T)	Normal Distribution		Log normal Distribution		Extreme value analysis I		Pearson Type III	Average
	MOM	PWM	MOM	PWM	MOM	PWM	MOM	
2	3913	3913	3223	3112	3471	3475	3324	3490
5	6180	6061	5444	5500	5851	5830	5801	5809
10	7366	7185	7161	7409	7427	7389	7486	7346
20	8345	8113	8981	9475	8939	8885	9103	8834
25	8630	8384	9593	10179	9419	9359	9614	9311

The synthetic unit hydrograph approach is based on long term observations in catchments to railway bridges in India. For the derivation of the unit hydrograph, the application of the relationships developed by the Central Water Commission (CWC) of Government of India for the lower Ganga plains sub zone 1 (g) revised Nov. 1994 is considered appropriate.The peak flood of 25 years return period generated from the uncontrolled catchment of the Damodar between Durgapur Barrage and Beguahana works out to be 875.34 m^3/s.

FLOOD MANAGEMENT

Necessary correction by lowering of bed level of Mundeswari is done to establish the design bed level. Figure 0-1 shows existing bed level and design bed level. Existing bed level is drawn based on lowest point of surveyed cross-section and shown in blue colour. The brown line parallel to x-axis is backwater effect from tidal ingress from Rupnarayan River at outfall, extending almost upto 20 km in the upstream. Designed bed level at the offtake of Mundeswari at Beguahana, considered as the Upper terminal point, is fixed at the prevailing bed level of the adjoining Amta channel at the same offtake point (i.e. bifurcation point of the two streams from Damodar River) to maintain natural regime condition. The chainage at Beguahana is 9400m and design bed level is 11.62 m with respect to masl. Desiltation of Mundeswari has been considered upto such a stretch where the level of the tidal ingress touches the existing bed level of Mundeswari. This is considered as the lower terminal point of dredging and the prevailing bed level is fixed as the design bed level at this lower terminal point. Further lowering of bed level would be redundant as upstream flow would be obstructed by the tidal ingress. The chainage at lower terminal point is 40000m and design bed level is 3.855 m. Design bed slope is drawn by joining the design bed levels of the upper and lower terminal points over a straight line and shown in yellow colour. The longitudinal slope of riverbed is 0.25m/km i.e. 1 in 4000.

It reveals from Figure 0-1 that within the overall zone of desiltation for a length of 30.6 km (from 9.4 km to 40 km), further lowering of the existing deepest bed level would be required for a length of 10.6 km (in between 9.4km to 20 km) and further widening of deep channel at design bed level (either at or above the existing deepest level) needs to be done for a length of 9 km (from 20 km to 29 km) by way of partial desiltation. No desiltation needs to be done for a stretch of 9 km length (from 29 km to 38 km). Further full section desiltation for a length of 2 km (from 38 km to 40 km) as per design bed width of the pilot channel would also be required to ensure smooth transition between design bed level of the desilted section and actual bed level of the existing section after termination of desiltation. Therefore, the total effective length, either deepening of bed level along with widening or only widening, becomes 21.6 km (10.6 km + 9 km + 2 km). This length would remain unaltered irrespective of the width of the pilot channel.

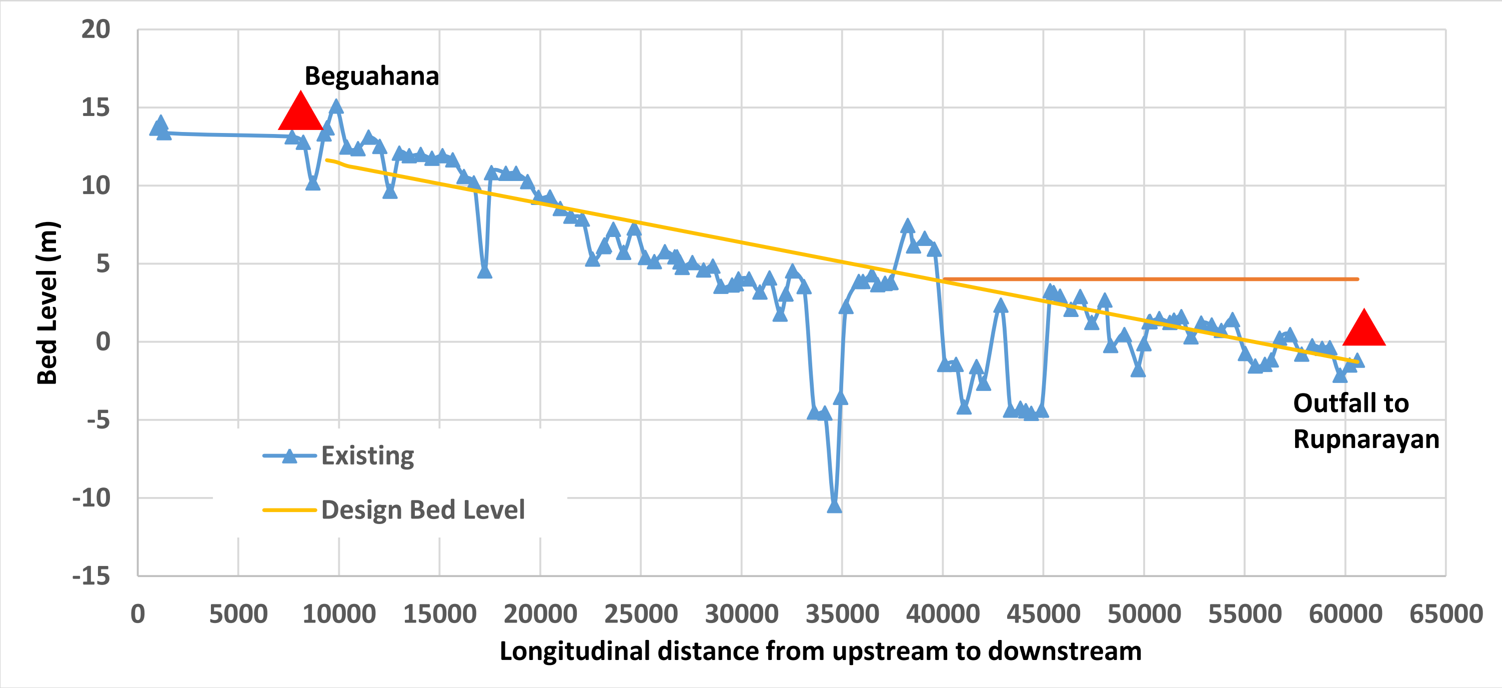


Figure 0-1 Existing Mundeswari longitudinal profile superimposed with design bed level

Without Project

The percentage of how water is shared between the Mundeswari and Amta Channel, in relation to particular flood return periods in the existing (‘without project”) condition are shown in Table 0-2. Following observations are made:

- Spilling in case of Amta channel starts at a flood of return period of 1.3 years. This is too frequent and flood situation will arise almost every year due to such spilling along the right bank.
- At this stage, the corresponding bankful discharge in Amta channel is 1,455 m^3/s downstream of the bifurcation. Similarly, in case of Mundeswari, bank overtopping commences at a discharge of about 2,675 m^3/s, which may be ranked as 2.6-year return period of flood.
- Sharing of flood discharge of Damodar River at Beguahana point by the Mundeswari River is practically insignificant at the initial stage, only 14%, which sharply increases to 51% at 2-year return period of flood. The trend of sharing by Mundeswari, however, gets plateaued as discharge increases further and remains close to 60%.
- The existing degree of protection in the Trans-Damodar Sub-basin (area in between right bank of Amta channel and left bank of Mundeswari River) is extremely limited in the existing condition.

Table 0-2 Flood discharge at Beguahana and pattern of sharing between Mundeswari River and Amta Channel corresponding to different return periods of flood and consequence thereof in Pre-project scenario (as obtained from Numerical Modelling and validated from field observations)

Flood frequency	Flood Discharge (cusec)	Flood Discharge (cumecs)	Sharing by Mundeswari		Sharing by Amta Channel		Total		Remarks	
			%	Quantum	%	Quantum	%	Quantum	Amta Channel	Mundeswari
1	17762	503.03	14.0%	70.0	86.0%	433.00	100%	503.0	No Flooding	No Flooding
1.3	76000	2152.36	33.4%	718.89	67.6%	1455.00	100%	2152.0	Flooding about to start	No Flooding
2	126768	3590.14	49.0%	1759.0	51.0%	1831.00	100%	3590.0	Flooding	No Flooding
2.6	163521	4631.00	57.8%	2675.0	42.2%	1956.00	100%	4631.0	Flooding	Flooding about to start
3	169110	4789.29	59.0%	2826.0	41.0%	1963.00	100%	4789.0	Flooding	Flooding
4	197403	5590.57	59.6%	3332.0	40.4%	2259.00	100%	5591.0	Flooding	Flooding
5	219281	6210.18	59.4%	3689.0	40.6%	2521.00	100%	6210.0	Flooding	Flooding
10	277075	7846.93	59.7%	4685.0	40.3%	3162.00	100%	7847.0	Flooding	Flooding

Flood frequency	Flood Discharge (cusec)	Flood Discharge (cumecs)	Sharing by Mundeswari		Sharing by Amta Channel		Total		Remarks	
15	311418	8819.54	60.0%	5292.0	40.0%	3528.00	100%	8820.0	Flooding	Flooding
20	337737	9564.93	61.5%	5882.0	38.5%	3683.00	100%	9565.0	Flooding	Flooding
25	353000	9997.17	61.7%	6319.0	38.3%	3829.00	100%	9997.0	Flooding	Flooding

With Project

Different options tested in modelling as post project scenario are already discussed in Table 0-1. Mundeswari River is desilted to maintain a pilot channel. The width of pilot channels are varying from 100 m to 175 m in 25 m increment. Typical cross-section is shown in Figure 0-2 and Figure 0-3.

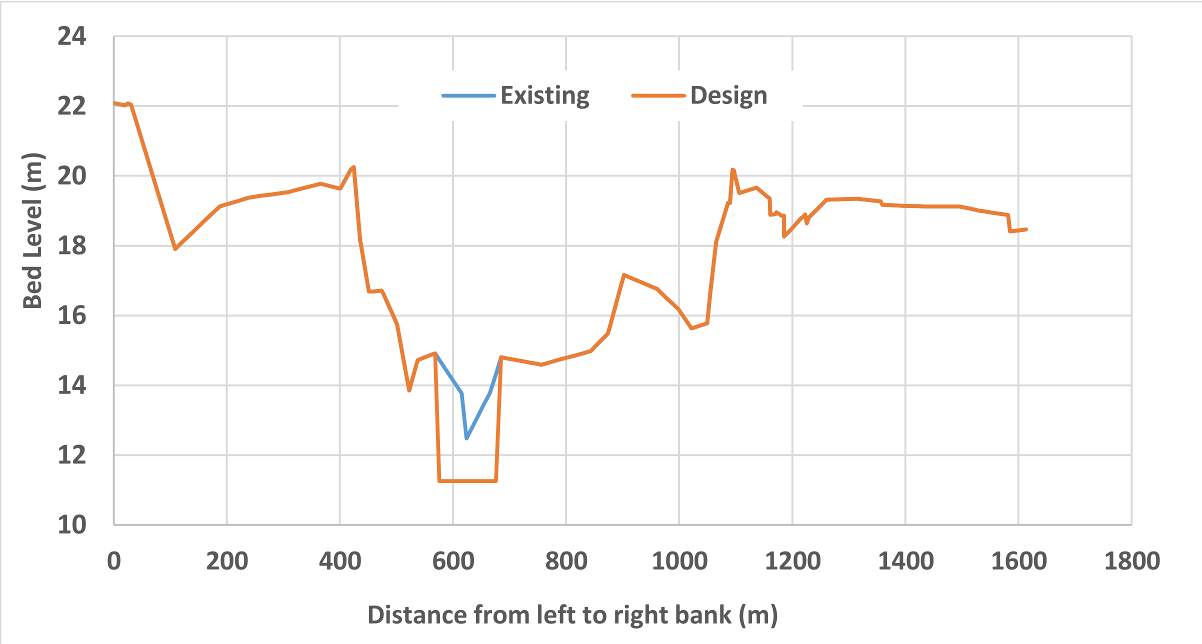


Figure 0-2 Typical cross-section of 100 m pilot channel with existing cross-section (chainage 995 m from Beguahana, river bed need to be dredged fully)

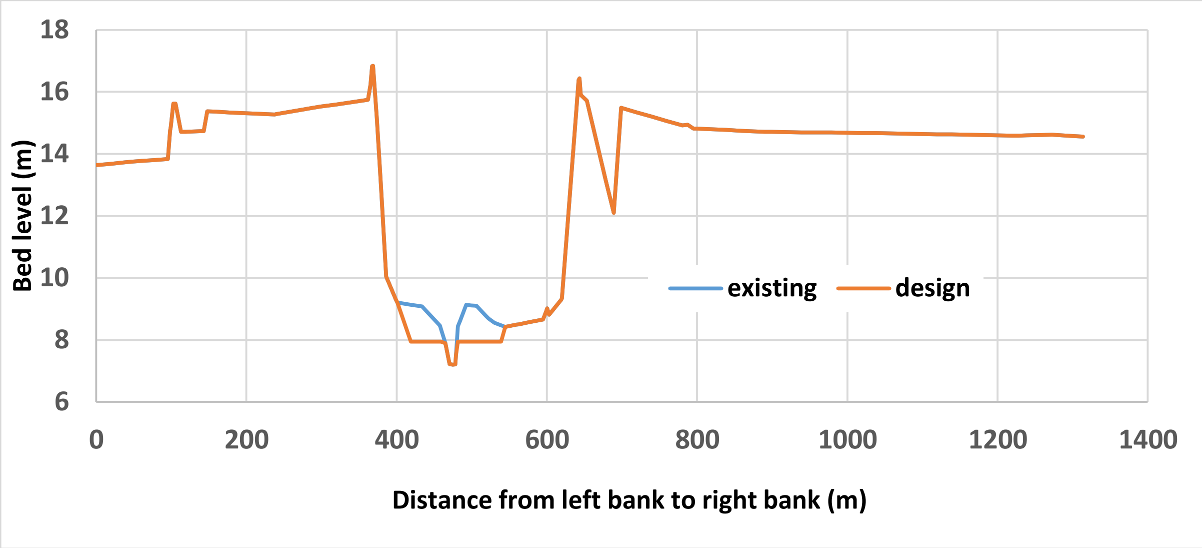


Figure 0-3 Typical cross-section of 100 m pilot channel with existing cross-section (chainage 14239 m from Beguahana, river bed need to be dredged partially)

A comparative analysis of varying bed widths of the pilot channel in Mundeswari River and return periods corresponding to "no flooding" condition is shown in Figure 0-4 and Table 0-3. Clearly, selection of 150 m bed width of the pilot channel appears to be the preferred option, subject to assessment of environmental impacts and conducting economic and financial analysis, due to;

- achieving "no flooding" condition upto 4-year return period floods for both the river sub-basins, which is essentially required for providing equitable degree of relief across the entire project area. Such "no flooding" condition for both the sub-basins can also be achieved with 75 m bed width but the corresponding return period of flood would be only 2.6 year, which is too low. Such "no flooding" condition can also be achieved for somewhat higher return period (upto 4.2-year return period flood in case of Amta channel and 4.6-year return period in case of Mundeswari river) but resultant incremental benefits are likely to outweigh the additional cost.
- Optimal utilisation of capacity of both the channels, resulting in better flood moderation.

However, both the option 3 & 6 as shown in Table 0-18 below, i.e. selecting a bed width of 150 m with or without bed bars to be constructed on the left bank of Damodar river immediately upstream of the bifurcation point at Beguahana offer equal degree of relief. Therefore, the primary consideration for taking the final decision would be after sediment model study with and without bed bar.

Other options are not acceptable, due to, either widely inequitable protection in the concerned river sub-basins due to unfavourable sharing pattern of discharge or extremely limited degree of relief.

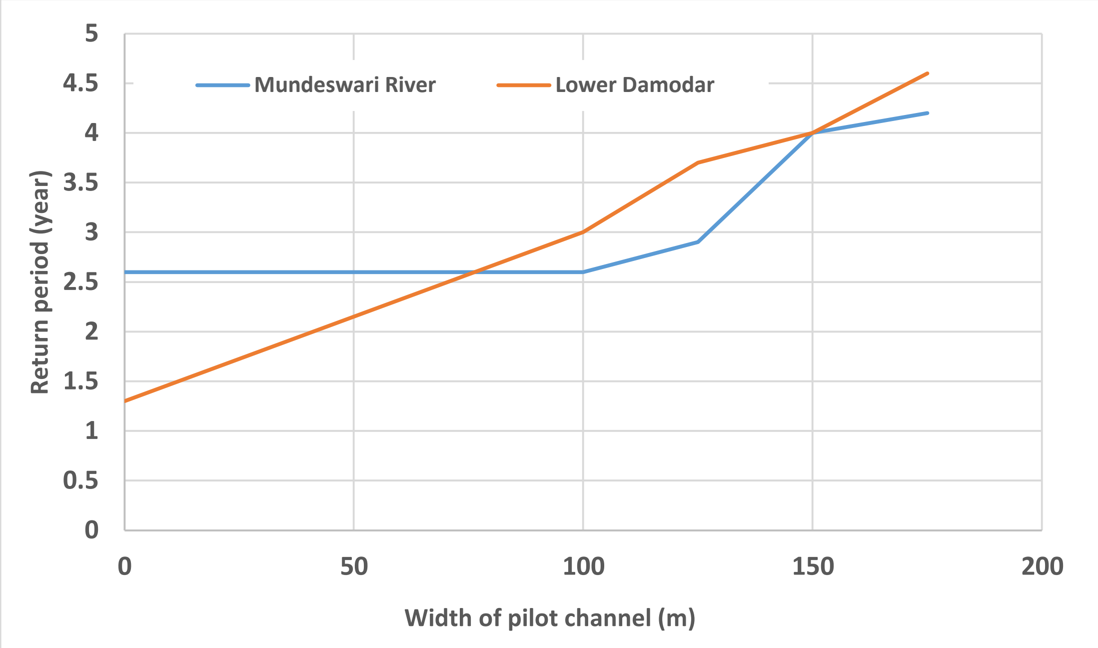


Figure 0-4 Comparison plot between width of pilot channel and return period upto which no flooding

Table 0-3 Summary of return period at no flooding condition with different options

Options	Return Period (Year)	
	Mundeswari	Amta Channel
Existing	2.6	1.3
Option1: BW100-W0-BB0	2.6	3.0
Option2: BW125-W0-BB0	2.9	3.7
Option3: BW150-W0-BB0	4	4
Option4: BW175-W0-BB0	4.6	4.2
Option5: BW100-W1-BB0	2.1	5
Option6: BW150-W0-BB1	4	4

Bankful discharge for Mundeswari with 150m pilot channel is 4137 m^3/s. The percentage of sharing of discharge between Mundeswari and Lower Damodar is consistently maintained at 74% and 26% respectively, other than 1-year return period of flood. The percentage of water sharing for different return period of discharge is shown in Table 0-4.

Table 0-4 Flood discharge at Beguahana and pattern of sharing between Mundeswari River and Amta Channel corresponding to different return periods of flood and consequence thereof in Post-project scenario (**Modelling Code: BW150-W0-BB0**)

Flood frequency	Flood Discharge (cusec)	Flood Discharge (m^3/s)	Sharing by Mundeswari		Sharing by Amta Channel		Total		Remarks	
			%	Quantum	%	Quantum	%	Quantum	Amta Channel	Mundeswari
1	17762.00	503.03	100.0 %	503.00	0.0%	0.00	100%	503	No Flooding	No Flooding
1.3	76000.00	2152.36	75.6%	1627.19	24.4%	525.17	100%	2152	No Flooding	No Flooding
2	126767.94	3590.14	74.6%	2678.25	25.6%	919.08	100%	3590	No Flooding	No Flooding
2.6	163521.00	4631.00	74.0%	3436.20	26.0%	1194.80	100%	4631	No Flooding	No Flooding
3	169109.68	4789.29	74.0%	3544.07	26.0%	1245.21	100%	4789	No Flooding	No Flooding
3.2	171748.00	4864.00	74.0%	3599.36	26.0%	1264.64	100%	4864	No Flooding	No Flooding
4	197403.08	5590.57	74.0%	4137.02	26.0%	1453.55	100%	5591	Flooding about to start	Flooding about to start
5	219281.48	6210.18	73.9%	4589.32	26.1%	1620.86	100%	6210	Flooding	Flooding
10	277074.95	7846.93	73.9%	5798.88	26.1%	2048.05	100%	7847	Flooding	Flooding
15	311418.06	8819.54	73.7%	6500.00	26.3%	2319.54	100%	8820	Flooding	Flooding
20	337737.82	9564.93	73.7%	7049.36	26.3%	2515.58	100%	9565	Flooding	Flooding
25	353000.00	9997.17	73.6%	7357.92	26.4%	2639.25	100%	9997	Flooding	Flooding

Identifying the type and location of interventions

25-year return period of flood has been selected to ascertain the High Flood Level (HFL) for left embankment of Amta channel considering the presence of vital installations on that side. 10-year return period is considered for the dwarf embankment on the right bank of Amta channel to assess the HFL, keeping in view of its lesser strategic importance compared to the left side embankment, which is being considered as the main flood protecting embankment since last 200 years. In addition, procurement of land for raising and strengthening the right side embankment to withstand higher return period floods would be almost impossible and has accordingly been ruled out. Following the same logic, design floods for Upper Rampur left and Hurhura eft embankments are considered to have 10-year return period. Figure 0-5 shows longitudinal profile of HFL for 10-year return period (blue line) along with crest level of existing dwarf embankment on the right bank of Amta channel (orange line). Figure 0-6 shows longitudinal profile of HFL for 25-year return period (blue line), of HFL+1m (in green line) alongwith existing crest level of embankments on the left side (in orange).

Based on these HFL stretches required for armouring of right embankment bank and flood wall at left embankment of Amta channel for Howrah and Hooghly districts have been identified.

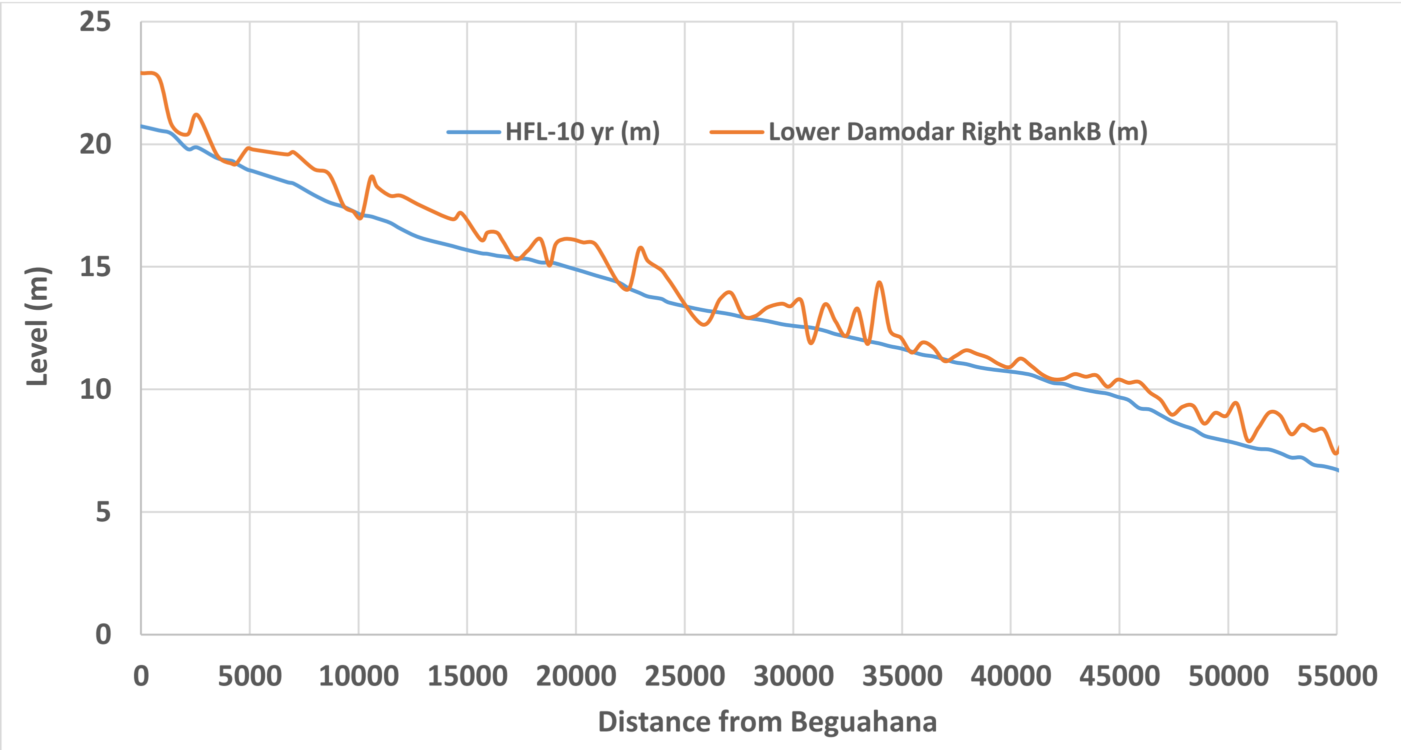


Figure 0-5 Longitudinal profile of Lower Damodar for 10 yr return period

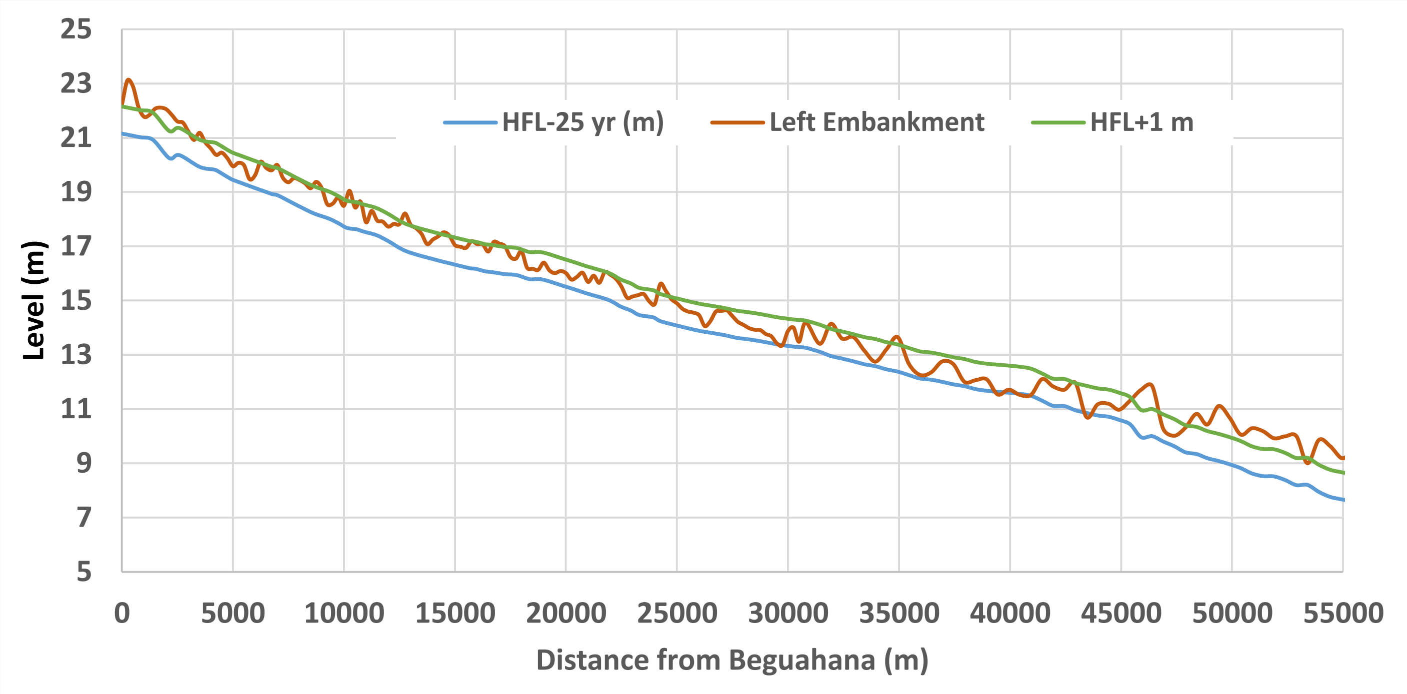


Figure 0-6 Longitudinal profile of Lower Damodar for 25 yr. return period along with left embankment and HFL+1 m

FLOOD INUNDATION CONSIDERING "WITH PROJECT" CONDITION

The objective of generation of inundation maps is to assess the extent and depth of inundation "with interventions" in the post project scenario, corresponding to the past floods which already occurred and had established record of damages. Damage caused in the post project scenario by these floods with the assessed depth and duration of inundation would be converted into economic costs by the Economist to have a direct comparison of such costs with the costs assessed from the recorded damage data in the pre-project scenario. Flood inundation map is generated in "with project" condition considering Option3: BW150-W0-BB0. Out of 14 years of floods (in between 1999 to 2017) having recorded damage data, predicted discharges in 8 years (2004,2005,2008,2010,2011,2013,2015&2016) are having return period of 4 years or less as per model analysis. There would be practically no damage in these 8 years as there would be no inundation in the post project period under "with project" condition. Hence inundation maps are generated for remaining 6years (1999, 2000, 2006, 2007.2009&2017). Two more inundation maps are generated with and without breaching of left embankment of Amta channel. Table 0-9 below represents year, return period, maximum discharge, and total inundated area.

Table 0-5 Summary of flood inundation

Year	Max discharge at Durgapur (m^3/s)	Return period	Inundated area (km^2)
1999	6122.1	5.7	183.5
2000	6322.9	6.3	215.5
2004	1971.1	1.34	
2005	1058.3	1.13	
2006	7693	11.6	347
2007	8373.3	16	609
2008	2664.6	1.58	
2009	8823.5	20	742
2010	243.5	<1	
2011	4050.1	2.48	
2013	4622.7	3.1	
2015	3631.6	2.14	
2016	3412.2	1.98	
2017	7063.6	9.1	262.97
25yr without breaching of left bank	9311	25	762.51
25yr with breaching of left bank	9311	25	1061

SEDIMENT STUDY

Sediment study and analysis are done to facilitate decision making on selection of submerged bed bars, and also to assess sustainability of the desilted section of Mundeswari River required for formulating appropriate maintenance strategy.

Sediment Load

Average suspended sediment load of 21 years of measurement is 1 MCM/year. Maximum and minimum suspended sediment load is 2.3 MCM and 0.015 MCM respectively. Suspended sediment comprises of coarse particle (i.e. grain sizes more than 0.2mm), medium particle (between 0.075mm and 0.2mm) and fine particle (i.e. grain sizes less than 0.075mm). Average of 21 year of measurement shows that fine particle is 86.6% which is mostly wash load and has negligible impact on morphological change. Corresponding average values of medium and coarse particles are 5.5% and 7.8% respectively.

Direct measurements of bed load are rather difficult and therefore rare. According to IS 5477-II: 1994. “Fixing the capacities of reservoirs-methods” published Bureau of Indian Standard (BIS) bed load would be 10-20% of suspended load. In this study average bed load is considered as 15% of suspended sediment load which becomes 0.15 MCM (0.15x1 MCM).

Bed bar

For morphological development of alluvial rivers with interaction between bed bathymetry and hydrodynamics, only bed material transport is of interest. Thus, only bed load and the part of the suspended load originating from the bed material is considered. The behaviour of suspended load is fundamentally different from that of bed load, which has to be taken into consideration in the sediment transport modelling. A variety of sediment transport formulae for bed load and non-cohesive suspended load exist and each representative for certain type of river flow regimes. Sediment transport have been estimated in this study by the 2-D model by using VanRijn sediment transport formula. Grain size i.e. d_{50} is considered as 0.31 mm. Simulation is done for 4yr (Bankful discharge at post project scenario),10 year and 25 year return period of discharge. Very negligible changes in bed level between with and without bed bar are observed. Therefore without submerged bed bars i.e. Option3: BW150-W0-BB0 are considered as final option.

Long term simulation

Model is simulated for 40 years with Option3: BW150-W0-BB0. It is observed that deposition occurs downstream of Beguahana and continues upto 25 km excluding 4 km in piecemeal. After that erosion is observed. The average annual rate of deposition varies from 0.0006 m/year to 0.087m/year. The same for erosion is varying between 0.0005 m/year and 0.075 m/year. Within the overall length of 30.6 km (from 9.4 km to 40 km in Figure 0 21), 21 km experience deposition whereas erosion occurs in 9.6 km. It would be concluded that average annual deposition rate is less and have not observed significant bed level changes. Hence maintenance strategy is not required. However it is recommended to survey cross-section once in two years to quantify deposition and take care the pilot channel.

CONTENTS

FIGURES

TABLES

2.1. INTRODUCTION

The Damodar River originates from the Chhotonagpur Plateau at Latehar District in Jharkhand and flows through the districts of Latehar, Hazaribagh in Jharkhand and enters Purulia District in West Bengal which is the lowermost riparian State in Damodar Basin. There are five reservoirs (Maithon, Panchet, Tilaiya, Konar and Tenughat) in Damodar-Barakar basin. The five dams at Tilaiya, Konar, Maithon, Panchet and Tenughat with storage volume of 380.71 MCM, 247.96 MCM, 896.79 MCM, 939.19 MCM, 618.18 MCM have been completed during the years 1953, 1955, 1957, 1959, 1981 respectively. A barrage at Durgapur in Burdwan district of West Bengal was constructed in year 1955. These reservoirs are primarily operated for power generation, irrigation, municipal and industrial water supply and flood management. River Damodar bifurcates into two main branches, i.e. Mundeswari and Lower Damodar (Amta Channel) near the border of Burdwan and Hooghly Districts, and both the channels traverse through the districts of Hooghly and Howrah, and ultimately meet River Hooghly, which debouches into Bay of Bengal. The river carries a huge amount of silt from its upper catchment area as it traverses the alluvial plains.

2.1.1. BACKGROUND

The Lower Damodar Sub-basin area is historically flood prone. On average, about 25,600 hectare of cropped area and 366,500 people are affected every year. The major reasons of floods, waterlogging and drainage congestion in the project area are:

- Limited and partly reduced storage capacity of reservoirs, coupled with conflicting needs for water storage against opportunities for effective flood flow retention and storage through the monsoon season.
- Unresolved conflict between constructing and/or abandoning flood embankments, i.e. their use to contain/limit flood spills into the countryside by improving/constructing embankments along both river banks of Lower Damodar River, done on several occasions over the last two centuries, versus abandoning the right bank embankment in most places, where flood damage and failure has occurred over successive years.
- Progressive increase in Mundeswari River bed level due to sediment deposition, leading to a progressive reduction in the river conveyance capacity, thereby transferring conveyance capacity requirement into Amta channel, having a bankful capacity limited to only 1,455 cumec.
- Tidal effects at the outfall of the channels and rivers restricting outflows on a cyclic pattern.
- Restricted conveyance and outflow capacity of aged drainage channels and associated outfall sluice gate structures.

Although flooding cannot be eliminated altogether, there is scope of reduction of duration as well as extent of inundation, by revitalizing critical channels and rivers, remodelling of existing structures and constructing new interventions across the rivers and channels. One dimensional and two dimensional mathematical models are used to study the scope of reduction of flooding. Initially models are calibrated and existing conditions are established. Later calibrated models are used to examine the impact of different preventive measures like dredging, construction of new interventions etc.

2.1.2. STRUCTURE OF REPORT

- Approach to modelling:

The approach taken for modelling the Lower Damodar flood situation, together with an overview of the mathematical modelling tools used (i.e. MIKE 11, MIKE 21, MIKE 21FM and MIKE FLOOD), is described in Section 2.1.3.

- Assessment of design peak floods and flood frequency analysis:

Computation of design peak floods corresponding to different return periods from the data provided in Section 2.2 and also ascertaining the return periods of floods occurred in different years (from 1999 to 2017) taking the help of flood frequency analysis, have been shown in Section 2.3. It is to be mentioned here that in absence of any gauge-discharge station at the point where the main Damodar River bifurcates into Mundeswari River and Amta Channel (Beguahana), discharge data available at the nearest control structure, i.e. Durgapur Barrage, which is at 117 km upstream of the bifurcation point at Beguahana, have been considered. These discharge values have been added with the runoff discharge generated in between Durgapur Barrage and Beguahana, calculated by Synthetic Unit Hydrograph, to arrive at the total discharge at Beguahana point. Details may be seen at Section 2.4 including Sub-sections thereunder.

- Input data collection and processing:

Apart from considering the discharge at Beguahana point, following inputs to the model as detailed in Section 2.3, have further been considered:

(a) Observed discharge and water level data at various gauge locations maintained by the IWD on Mundeswari River and Amta Channel for calibration of the model.

(b) Observed suspended sediment load on Damodar River at Jamalpur (22 km upstream of the Beguahana point), maintained by Central Water Commission, Ministry of Water Resources, Government of India.

(c) Analysis of grain-size distribution collected in April 2018 by the IWD at 4 (four) different locations on Mundeswari river and Amta Channel.

(d) Channel cross sections.

(e) Bathymetry delineating floodplain topography and results of contour survey done in 2013 by another Consultant engaged by the IWD, to generate 30m Digital Elevation Modelling (DEM).

- Setting up and calibration of the model:

Setting up of the model and its calibration has been discussed in Section 2.4.

- Simulating model under different conditions:

Simulating the model for different options of flood management including combinations thereof to arrive at the appropriate solution envisaging maximisation of benefits (reduced depth, duration and areal extent for particular scale events) have been presented in Section 2.5

- Presentation of outputs and discussions on results:

These have also been dealt in Section 2.5

- Flood inundation maps

Flood inundation maps are developed to assess the extent and depth of inundation "with interventions" in the post project scenario, corresponding to the past floods which already occurred and had established record of damages.

- Sediment Study:

Study on sediment analysis of the proposed re-excavation of Mundeswari River in the form of a pilot channel has been made and its implication/impact on selection of interventions under any particular option and also sustainability of the desilted stretch of Mundeswari River has been discussed in Section 2.7.

2.1.3. APPROACH TO MODELLING

A stage by stage approach is taken to in this modelling study exercise as described below.

2.1.3.1. IDENTIFYING THE BROAD OBJECTIVES

Following are the main objectives of flood mitigation, considered during model analysis

- Flood management by various structural measures with optimal utilisation of carrying capacities of the two main rivers branching out of Damodar, i.e. Mundeswari and Amta Channel, and distribution the flood volume of main Damodar river in the abovesaid two branches in such a manner so as to ensure equitable but reduced impacts across the entire flood affected area between right (western) bank of Amta Channel to left (eastern) bank of Mundeswari, for at least a 1 in 10-year return period flood event.

- Protecting the Damodar left bank floodplain against major floods up to a 1 in 25-year return period considering the presence of vital utilities on that side, e.g. Railway Lines, National Highway etc. by improvements of the Amta Channel left embankment.
- Remodelling the dwarf embankment on Amta channel right bank in such a way so that even overbank spilling takes place to any flood beyond its bankful capacity and up to a 1 in 10 yr return period, such spilling can be guided to occur at selected locations/sections, having slightly lower levels and there is no breach to embankment, which potentially impacts the affected persons. The other two vital embankments i.e. Upper Ramur Left and Hurhura Left embankments are also to be protected against floods up to 10 year return period

2.1.3.2. DETERMINING VARIOUS OPTIONS

Possible options for running the model are tabulated below:

Sl No	Description of options
1.	(a)Desiltation of Mundeswari River for a length of 21.6 km downstream of the Damodar bifurcation point at Beguahana, thereby lowering the Mundeswari bed level, to evenly take the Damodar floodwater on par with the Amta Channel. The Mundeswari bed level is adjusted and graded to ultimately match the existing bed level 20 km downstream of Beguahana. Such desiltation will be in the form of a pilot channel having bed width of 100 m (b) Without any ungated regulator across Amta channel (c) Other supplementary interventions including improvement of Amta channel Left, Amta channel Right (dwarf), Upper Ramur Left & Hurhura Left embankments.
2.	(a) Same as (a) in Sl.1 above with the exception that the bed width of the pilot channel would be 125 m (b) Without any ungated regulator across Amta channel. (c) Same as (c) in Sl.1 above.
3.	(a) Same as (a) in Sl.1 above with the exception that the bed width of the pilot channel would be 150 m (b) Without any ungated regulator across Amta channel. (c) Same as (c) in Sl.1 above.
4.	(a) Same as (a) in Sl.1 above with the exception that the bed width of the pilot channel would be 175 m (b) Without any ungated regulator across Amta channel.

Sl No	Description of options
	(c) Same as (c) in Sl.1 above.
5.	(a) Same as (a) in Sl.1 above. (b) In addition, there will be an ungated regulator (in the form of a weir) across Amta channel immediate downstream of the bifurcation point to prevent entry of low floods in the channel. (c) Same as (c) in Sl.1 above.
6.	(a) Same as (a) in Sl.1 above with the exception that the bed width of the pilot channel would be 150 m (b) 7 number of bed bars to be constructed on left bank of Damodar, immediate upstream of confluence of point at Beguahana to encourage diversion of flow from Damodar to Mundeswari, but there will be no weir across Amta channel. (c) Same as (c) in Sl.1 above.

2.1.3.3. SELECTING VARIOUS MATHEMATICAL MODELS

Different mathematical models have been applied in order to address the different time scales (ranging from minutes to years) and length scales (ranging from meters to kilometres) of the study.

- MIKE11 for one dimensional hydrodynamic study for rivers and canals
- MIKE21 for floodplain areas
- MIKEFLOOD for coupling of both MIKE11 and MIKE21 to exchange flow between rivers/canals and floodplain areas.
- MIKE21FM for impact of bed bar

One dimensional modelling

MIKE 11 is a one-dimensional (1D) modelling system for river networks and estuaries. The modelling of unsteady flow is based on an implicit, finite difference numerical solution of the one-dimensional shallow water equations (Saint Venant equations). The numerical algorithms provide efficient and accurate solutions in branched and looped pipe and river networks.

The computational scheme is applicable to vertically homogeneous flow conditions. These conditions are found in open rivers, channels and flood plains extending from steep rivers to tidal-influenced estuaries. The hydrodynamic (HD) module offers a variety of flow formulations including steady, quasi steady and fully dynamic flow. A number of structures can be modelled with the system such as broad crested weirs, culverts, bridges, control structures, sluice gates, radial gates etc. It also enables description of complex reservoir operation policies.

Input for the one-dimensional model is geometry of defined cross-sections along the river, discharge time series at the upstream end, and water level time series and/or discharge rating curves at the downstream end. Other input parameters are lateral flow time series, extraction of flow.

Outputs from the model are discharge and water level at all defined cross-sections (computational points) in the model. Derived data such as flow velocities, depths, hydraulic radii, bed shear stresses are also results from the model.

Two dimensional modelling (MIKE21)

MIKE 21 Flow Model is a generalised modelling system for two-dimensional (2D) free-surface flows. MIKE 21 Flow Model is applicable to the simulation of hydraulic and environmental phenomena in lakes, reservoirs, estuaries, bays, coastal areas and seas.

The hydrodynamic (HD) module is the basic module in the MIKE 21 Flow Model. It provides the hydrodynamic basis for the computations of all other modules like sediment transport and dispersion. The fully dynamic coupled St. Venant equations of continuity of momentum as well as mass are solved on a finite difference grid (rectilinear).

Input for the MIKE 21 model is the river bed levels at all grid points (interpolation between cross-sections is facilitated), and time series of either flux (discharge per meter width) or water levels along all grid points at the open boundaries.

Output from MIKE 21 is the flux in two horizontal directions (perpendicular to each other), as well as the depth at each grid point. This may further be transformed into output of flow velocity and direction as well as water level.

MIKE21FM

MIKE21FM has same capability and application as described in two dimensional modelling (MIKE21). The only difference is MIKE21 uses rectangular grid whereas MIKE21FM is flexible mesh, which allows maximum flexibility for adapting grid resolution of the model domain.

MIKE Flood

MIKE FLOOD is a complete toolbox for flood modelling available. It includes a wide selection of 1D and 2D flood simulation engines, enabling one to model virtually any flood problem whether it involves rivers, floodplains, and floods in streets, drainage networks, coastal areas, dam and dike breaches or any combination of the above. When simulating river flooding, the combination of a 1D open channel model, using MIKE 11, and a 2D overland flow, using MIKE 21, is typically preferred. MIKE 11 and MIKE 21 can be coupled either at specific points or distributed along entire river stretches on either side of the main river channel. Coupling of MIKE11 and MIKE21 are made through different linkage options. Five different types of links are presently available in MIKE Flood:

- Standard Link
- Lateral Link
- Structure Link
- Side Structures Link
- Zero Flow links (XFlow=0 and YFlow=0)

In this study lateral link is used. A lateral link allows a string of MIKE 21 cells/elements to be laterally linked to a given reach in MIKE 11, either a section of a branch or an entire branch. Flow through the lateral link is calculated using a structure equation. This type of link is particularly useful for simulating overflow from a river channel onto a flood plain. This structure is typically a weir that represents over topping of a river bank or levee. The geometry of the structure is determined from cross section bank markers, MIKE 21 topographical levels, and a combination of the highest of each.

An example is shown:

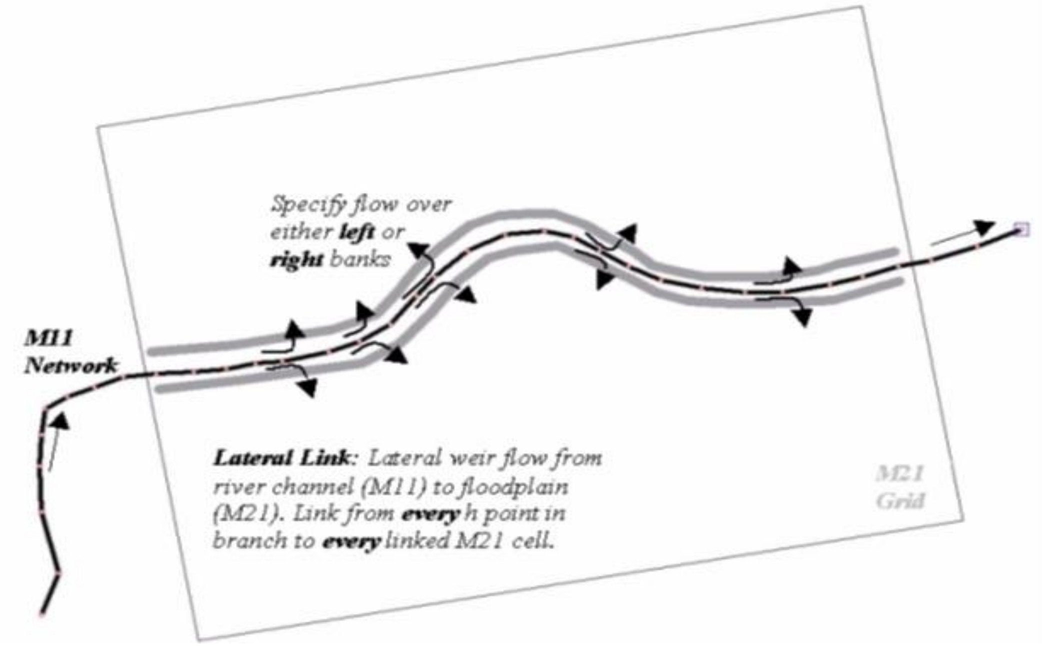


Figure 0-7 Schematic of lateral link

2.1.3.4. ASSESSING DESIGN FLOOD BY FLOOD FREQUENCY ANALYSIS

Hydrological analysis and estimation of design floods at Beguahana point have been done as detailed in Section 2.2. Also, past floods during 1999 to 2017 (against which reported damage data are available) have been ranked according to the corresponding return periods.

2.1.3.5. INPUT DATA COLLECTION AND PROCESSING

Various hydrological data including river discharge (observed as well as derived as stated in Paragraph 2.2.4 above), water level and data related to sediment load, grain size distribution of river bed materials, river/channel cross sections, flood plain bathymetry etc. Hydrological analysis and estimation of design floods at Beguahana are collected from the IWD/Other sources and processed to serve as inputs along with reasonable assumptions, wherever required. These are further discussed in Section 2.3.

2.1.3.6. SUBSEQUENT STAGES

Subsequent stages, are stated below:

- Setting up the model for existing condition, putting river/channel network, and cross sections, fixing boundary conditions, adding floodplain topographical input data, selecting suitable formula for lateral discharge with assumed parameters (Manning's roughness coefficients for rivers and floodplains and finally, calibration of the model by simulation and comparison with the available observed values. (Refer to Section 2.4)
- Simulating the model for existing condition ("without project" condition) and further for different options stated in paragraph 2.1.3.2 hereinbefore ("with project" condition).(Refer to Section 2.5)
- Presentation of outputs i.e. High Flood Levels (HFL) inundation in post project cases in tabular, graphical and map forms to facilitate selection of the preferred option, discussion of results to assess resultant minimisation of damage due to the structural interventions required for economic and financial analysis of various combination of options (Refer to Section 2.6).
- Running the model for sediment study and analysis, with the available inputs to further facilitate decision making on selection of particular components, e.g. submerged bed bars, and also to assess sustainability of the desilted section of Mundeswari River required for formulating appropriate maintenance strategy in the post project period (Refer to Section 2.7).

2.2. DESIGN FLOOD

The Design Flood is the flood for which the structures planned to design. There is no discharge measured station available just upstream of Beguahana. Discharge data available for longer period is in Durgapur. Hence two way approach is considered.

- Flood frequency analysis is done for discharge data available in Durgapur.
- Synthetic unit hydrograph approach for catchment between Durgapur and Beguahana

2.2.1. FLOOD FREQUENCY ANALYSIS

The Flood Frequency analysis is based on the observed gauging data for the River Damodar in Durgapur (117 km from Beguahana). Annual maximum discharge is collected from1975 to 2017. For food frequency analysis minimum 30 years of data is required. So 43 years of discharge data is sufficient to do the analysis. Since the analysis assumes that the flood events are independent of each other, it is appropriate to take the annual flood peaks and not to base the analysis on the partial duration series, which enhances the risk of flood events not being independent of each other. The annual series is most commonly used and the design flood values derived from it are more appropriate for extrapolation.

The annual peak discharges at Durgapur Barrage have been collected from IWD and presented below in a tabular form:

Table 0-6 Annual peak discharge passing down Durgapur Barrage

Sl.No.	Year	Discharge (m^3/s)	Sl.No.	Year	Discharge ($m^{3/}s$)	Sl.No.	Year	Discharge ($m^{3/}s$)
1	1975	4362.60	16	1990	3341	31	2005	1058
2	1976	5649.10	17	1991	2451	32	2006	7693
3	1977	3996.10	18	1992	1035	33	2007	8373
4	1978	10741.30	19	1993	3864	34	2008	2665
5	1979	1025.80	20	1994	3326	35	2009	8824
6	1980	4598.50	21	1995	8631	36	2010	244
7	1981	1560.20	22	1996	3506	37	2011	4050
8	1982	621.60	23	1997	2329	38	2012	2427

9	1983	2215.80	24	1998	4104	39	2013	4623
10	1984	5173.90	25	1999	6122	40	2014	2095
11	1985	3458.10	26	2000	6323	41	2015	3632
12	1986	3560.30	27	2001	1852	42	2016	3412
13	1987	5338	28	2002	1674	43	2017	7064
14	1988	1432	29	2003	2294			
15	1989	2185	30	2004	1971			

The following statistical distributions for estimating return period floods for a particular location have been applied.

- Normal distribution
- Pearson Type-III
- Extreme value analysis I
- Log normal distribution

The parameters of the distribution used in this analysis is method of moments (MOM) and probability of weighted moments (PWM). Detailed stages of calculation have been shown in the Annex to Appendix-2.

The analytical results of the Flood Discharge at Durgapur against Flood Frequency are presented in Table 0-7.

Table 0-7 Design flood passing down Durgapur Barrage

Return Period (T)	Normal Distribution		Log normal Distribution		Extreme value analysis I		Pearson Type III	Average
	MOM	PWM	MOM	PWM	MOM	PWM	MOM	
2	3913	3913	3223	3112	3471	3475	3324	3490
5	6180	6061	5444	5500	5851	5830	5801	5809
10	7366	7185	7161	7409	7427	7389	7486	7346
20	8345	8113	8981	9475	8939	8885	9103	8834
25	8630	8384	9593	10179	9419	9359	9614	9311

In a like manner, return periods various past floods that already occurred during 1999 to 2017 having corresponding reported damage values, have been calculated and shown in the said Annex to Appendix-2.

2.2.2. SYNTHETIC UNIT HYDROGRAPH

For the derivation of the unit hydrograph, the application of the relationships developed by the Central Water Commission (CWC) of Government of India for the lower Ganga plains sub zone 1 (g) revised Nov. 1994 is considered appropriate. The synthetic hydrograph approach is recommended for adoption by CWC for catchments up to 5,000 km^2. The catchment area between Durgapur to Beguahana is 1,179 km^2.

From the report, the synthetic unit graph relationships are based upon the hourly stage and discharge data observed for five to ten years at 21 railway bridge catchments, and hourly automatic recording raingauge data within and around these catchments in the same hydro meteorologically homogeneous sub-zone or region. The rainfall data have been used by the Indian Meteorological Department to analyse the rainfall isopleths of 25 year, 50 year and 100 year return periods. The design flood is estimated based upon the assumption that a T year rainfall produces a T year flood, after accounting rainfall abstractions and baseflow.

The peak flood of 25 years return period generated from the uncontrolled catchment of the Damodar between Durgapur Barrage and Beguahana works out to be 875.34 m^3/s. Further details may be seen in the Annex to Appendix-2. The annual peak discharge at Beguahana point is arrived at by adding the design flood corresponding to any particular return period passing down Durgapur Barrage with the discharge figure computed above using synthetic hydrograph, as contribution of uncontrolled catchment in between Durgapur Barrage point and Beguahana. No flood attenuation is considered in the process, in between Durgapur Barrage and Beguahana point to be on the conservative side.

Design discharge with different return period at Beguahana is used as input parameter. Figure 0-8 shows time series of design discharge with 25-year return period.

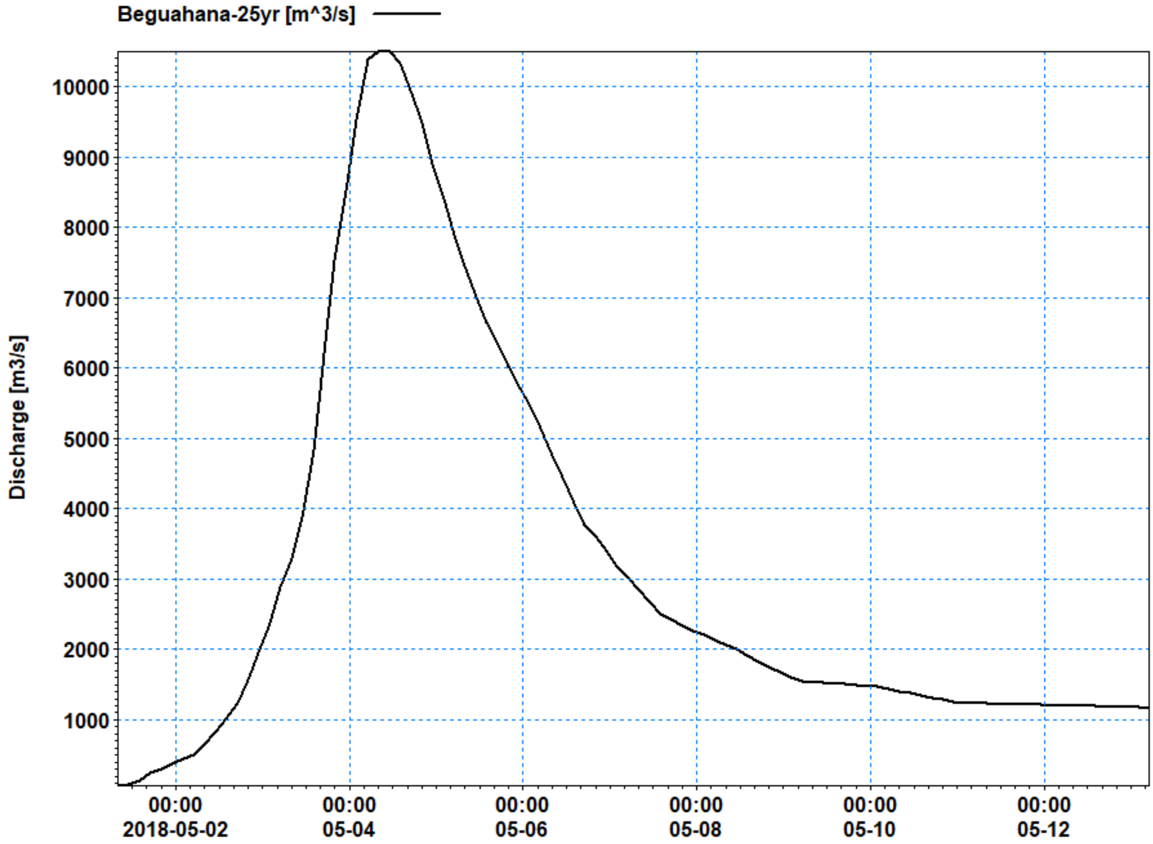


Figure 0-8 Hydrograph for Design Flood of 25-year Return Period for Damodar at Beguahana

2.3. HYDROLOGICAL AND SEDIMENT DATA

2.3.1. HYDROLOGY DATA

Discharge data at Beguahana point:

Design discharge computed in Paragraph 2.2 above have been considered.

Discharge and water level data of Mundeswari River and Amta channel and tidal levels at outfall:

The discharge and water level data of Mundeswari River and Amta channel at different locations have also been collected from IWD/Central Water Commission, (CWC) Government of India for using as boundary condition and calibration of model. Discharges of Mundeswari River and Amta channel are measured at Harinkhola and Champadanga respectively. Water level data for Mundeswari river are available at Harinkhola ant these for Amta Channel are maintained at Champadanga, Amta and upstream of Ulughata Sluice at its outfall. Water levels for Hurhura channel (lower part of Mundeswari river) are available at Muchighata. Tidal data are available at downstream of Ulughata sluice, at the confluence of river Hooghly and also at Buxi on Rupnarayan River. All the available dataset used as input in the modelling have been shown below in Table 0-8.

Table 0-8 Details of available observed discharge and water level data

Name	Type	River	Frequency	Availability	Remarks
Harinkhola	Discharge	Mundeswari	4 times a day	2017	Irrigation Department
Champadanga	Discharge	Lower damodar	4 times a day	2017	Irrigation Department
Harinkhola	Water Level	Mundeswari	Hourly	2015-17	CWC
Champadanga	Water Level	Lower damodar	Hourly	2015-17	CWC
Amta	Water Level	Lower damodar	3 hourly	2015-17	Irrigation Department
Muchighata	Water Level	Hurhura Khal	Daily	2017	Irrigation Department
Ulughata sluice us	Water Level	Lower damodar	7 times a day	2017	PWD department
Ulughata sluice Ds	Water Level	Lower damodar	7 times a day	2017	PWD department

Name	Type	River	Frequency	Availability	Remarks
Buxi	Water Level	Rupnarayan	6 times a day	2015-17	Irrigation Department
Durgapur Barrage	Discharge	Damodar	Annual Maximum	1975-2017	Irrigation Department
Durgapur Barrage	Outflow	Damodar	Daily	1991-2001, 2005-17	Irrigation Department

Although the data series shown in the above Table 0-8 are for quite short periods those had to be considered in absence other alternative sources. Furthermore, results of model studies have been compared with the field conditions prevailing in recent past, by the concerned IWD officials, and declared as compatible.

2.3.2. SEDIMENT LOAD CHARACTERISTICS

Sediment transport in the river is divided into bed load, suspended load and wash load. The definition of the latter is that it does not interact with the river bed, i.e. wash load with the finest particles remains in suspension. Suspended load moves most of the time in suspension but is in contact with the river bed with exchange of material (erosion and deposition). Suspended load and wash load is influenced by the effect of dispersion (due to flow circulation, wave actions, wind driven currents, layered flow etc.).

2.3.3. SUSPENDED SEDIMENT LOAD

Daily suspended sediment load is available at Jamalpur which is around 22 km upstream of the Beguahana bifurcation. This station was being maintained by Central Water Commission (CWC), GoI. Data for monsoon period (Mid-June to Mid-October) during 1990-2011 have been made available by the IWD. The suspended sediment data have been characterised as coarse particle (i.e. grain sizes more than 0.2mm), medium particle (between 0.075mm and 0.2mm) and fine particle (i.e. grain sizes less than 0.075mm). Discharge data for the same period are, however, not available. Figure 0-9 shows time series of suspended sediment load. The observed daily maximum suspended sediment load is 0.43 million tonne/day.

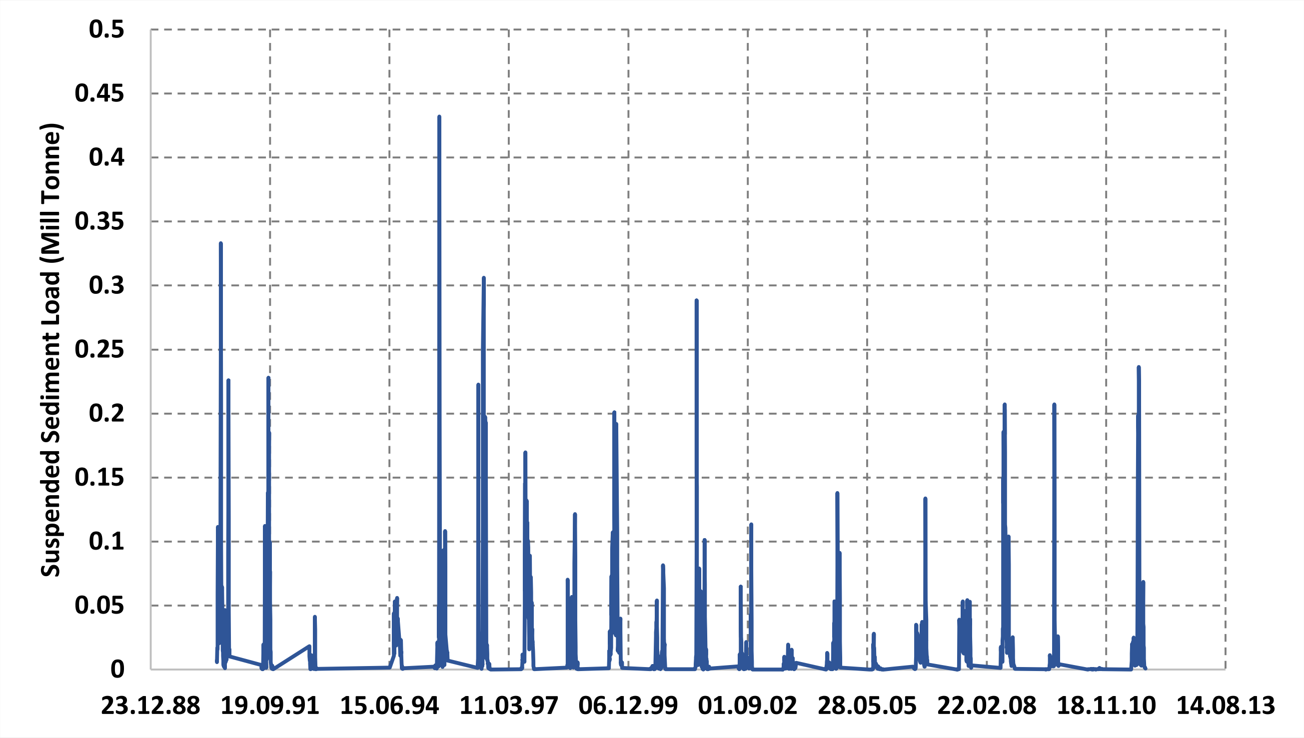


Figure 0-9 Observed suspended sediment load time series at Jamalpur

For better understanding graphical representation of suspended sediment load for yearly is shown in Figure 0-10. The 21 years of measurements are summarised in Table 0-9. It is noted that the measured annual sediment load is around 0.026 -4.123 million tonnes. With a relative density of sand of 2.65, and a porosity of 0.35, the deposited sediment density becomes 1,720 kg/m^3, and the measured suspended sediment volumes are 0.015-2.3 MCM per year. Average suspended sediment load of 21 year of measurement is 1 MCM per year.

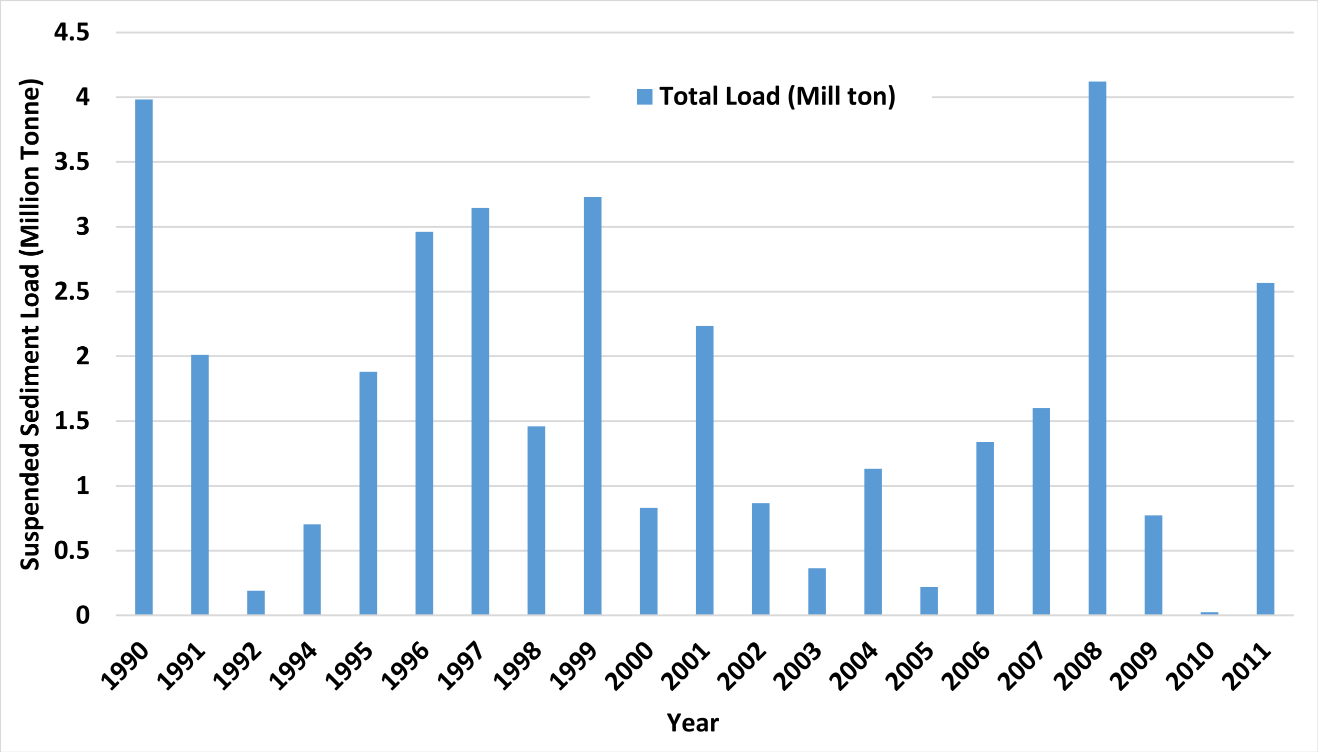


Figure 0-10 Annual suspended Sediment Load during 1990-2011

Table 0-9 Measurements of accumulated suspended sediment at different years

year	Total load (Mil ton)	Total load (MCM)	year	Total load (Mil ton)	Total load (MCM)
1990	3.983	2.309	2002	0.867	0.503
1991	2.013	1.167	2003	0.365	0.212
1992	0.192	0.111	2004	1.133	0.657
1994	0.704	0.408	2005	0.220	0.128
1995	1.881	1.090	2006	1.342	0.778
1996	2.962	1.717	2007	1.601	0.928
1997	3.146	1.824	2008	4.123	2.390
1998	1.458	0.845	2009	0.771	0.447
1999	3.229	1.872	2010	0.026	0.015
2000	0.832	0.482	2011	2.567	1.488
2001	2.234	1.295	**Average**	**1.697**	**0.984 approx 1**

The distribution between the three categories of sediment is listed in Table 0-10. It is noticed that percentage of coarse particle is varying between 0.06-14.7. Average of 21 year of measurement shows that fine particle is 86.6% which is mostly wash load and has negligible impact on morphological change. Corresponding average values of medium and coarse particles are 5.5% and 7.8% respectively.

Table 0-10 Percentage of three particles (Coarse, medium and fine)

year	Coarse (< 0.075 mm) (%)	Medium (0.075 - 0.2 mm (%)	Fine (>0.2 mm) (%)	year	Coarse (< 0.075 mm) (%)	Medium (0.075 - 0.2 mm (%)	Fine (>0.2 mm) (%)
1990	14.7%	8.6%	76.7%	2002	7.7%	5.0%	87.3%
1991	10.9%	5.7%	83.4%	2003	5.7%	6.8%	87.5%
1992	5.2%	2.8%	92.0%	2004	8.9%	9.2%	81.9%
1994	12.2%	9.4%	78.5%	2005	3.9%	3.0%	93.0%
1995	9.6%	7.6%	82.8%	2006	8.5%	6.9%	84.6%
1996	7.0%	4.8%	88.2%	2007	8.1%	6.8%	85.1%
1997	7.0%	3.7%	89.3%	2008	8.2%	6.6%	85.2%
1998	9.8%	5.7%	84.5%	2009	3.9%	2.7%	93.4%
1999	12.8%	6.4%	80.8%	2010	0.6%	0.3%	99.1%
2000	5.1%	3.7%	91.1%	2011	6.4%	5.2%	88.4%
2001	8.1%	5.3%	86.7%	**Average**	**7.8%**	**5.5%**	**86.6%**

2.3.4. BED LOAD

Direct measurements of bed load are rather difficult and therefore rare. Also in the Damodar River such data are unavailable. Indicative values of bed load compared to the total load are mentioned in literature. Published estimates of sediment yield usually refer exclusively to suspended sediment only and assume a constant bed-load component. According to IS 5477-II: 1994. “Fixing the capacities of reservoirs-methods” published Bureau of Indian Standard (BIS) bed load would be 10-20% of suspended load. In this study average bed load is considered as 15% of suspended sediment load which becomes 0.15 MCM (0.15x1 MCM).

2.3.5. GRAIN SIZE

Bed samples collected in 4 locations of Mundeswari River and Amta channel by IWD have been analysed. The results are presented in Table 0-11. The average D50 of 4 samples is 0.31 mm. This signifies medium sand.

Table 0-11 Analysis of bed samples collected from river bed of Mundeswari and Amta Channel

Sample No	Date of Collection	Median grain size (D50), mm	Silt factor denoting silt grading=1.76X√Dmean
74/18	25-04-2018	0.32	1.06
75/18	25-04-2018	0.25	0.91
76/18	25-04-2018	0.345	1.13
77/18	25-04-2018	0.33	1.08
Average		**0.31**	**1.04**

2.3.6. SUMMARY ON SEDIMENT LOAD ASSUMPTIONS

Direct measurements as well as estimates have been provided in the preceding sections on suspended load and bed load. The assumed sediment load for this study is therefore as listed in Table 0-12.

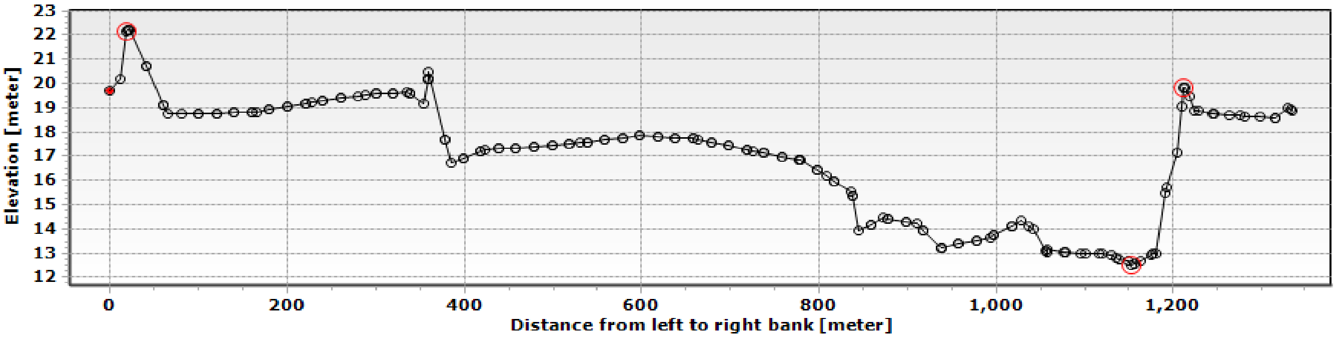
Table 0-12 Summary of assumed sediment load for the study

Components of total load	Suspended load	Bed load	Total load
Sediment Load (MCM/yr)	**1.00**	**0.15**	**1.15**
Fine suspended (<0.075mm) (MCM/yr)	0.866		
	86.6% of suspended		
Medium suspended(Between 0.075 mm and 0.2mm) (MCM/yr)	0.055		
	5.5% of suspended		
Coarse suspended	0.078		

Components of total load	Suspended load	Bed load	Total load
(>0.2mm) (MCM/yr)	7.8% of suspended		
Percentage distribution	**86.96% of Total**	**13.04% of Total**	**100%**

2.3.7. CROSS-SECTION

Cross-section surveys were carried out by JACOBS in 2013, and these have been used for formulating the model. The spacing between cross-sections varies from less than 100 m to 1 km. Cross-section data (2018) for the Mundeswari River from the bifurcation point to 20 km downstream have been provided by the Irrigation and Waterways Department (IWD). Eptisa has also surveyed cross-sections on the Lower Damodar (Amta Channel) from Ch. 30.8 km to 55.25 km (April, 2018). IWD surveyed to include the left and right bank levels for the Lower Damodar, Hurhura, and Upper Rampur at 250 m spacing. They have also similarly surveyed cross-sections for the Upper Rampur, Lower Rampur, Maja Damodar, Short-cut Khal, Madaria Khal, Gaighata Khal. Initial observation on cross-section of canals show negative longitudinal slope at many locations which suggests there is significant sedimentation in these waterways. Another observation is that cross-sections near the bifurcation show that the bed level has risen about 2 m, which is the main reason why flow is primarily diverted into the Lower Damodar, thereby generating floods at low discharge (about 2,150 m^3/s). Two typical cross-sections are shown in Figure 0-11.



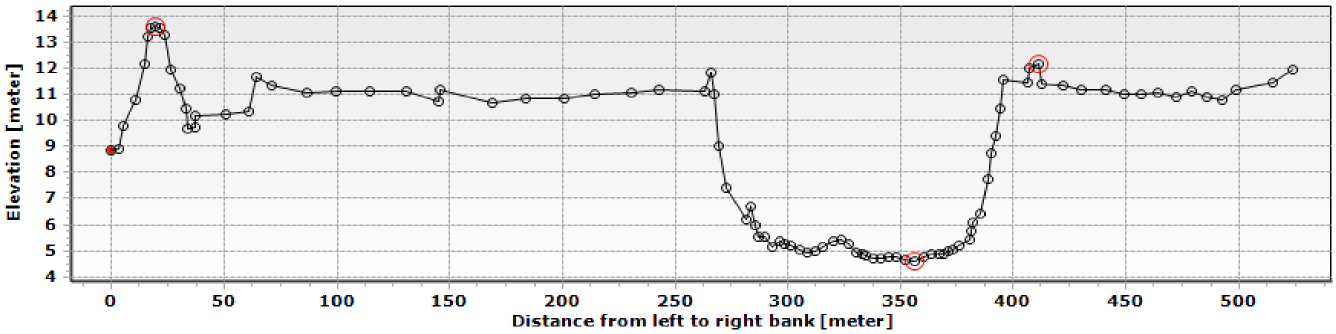


Figure 0-11 Typical cross-section (Top: Mundeawari River at 12025 m, Bottom: Lower Damodar at 32436 m)

2.3.8. BATHYMETRY

Bathymetry describes the floodplain topography of the study area. A contour survey at 0.5m interval was done in 2013 by JACOBS. These contours are used to generate 30 m resolution DEM. Figure 0-12 shows the generated DEM that has been used as the base for the 2D model.

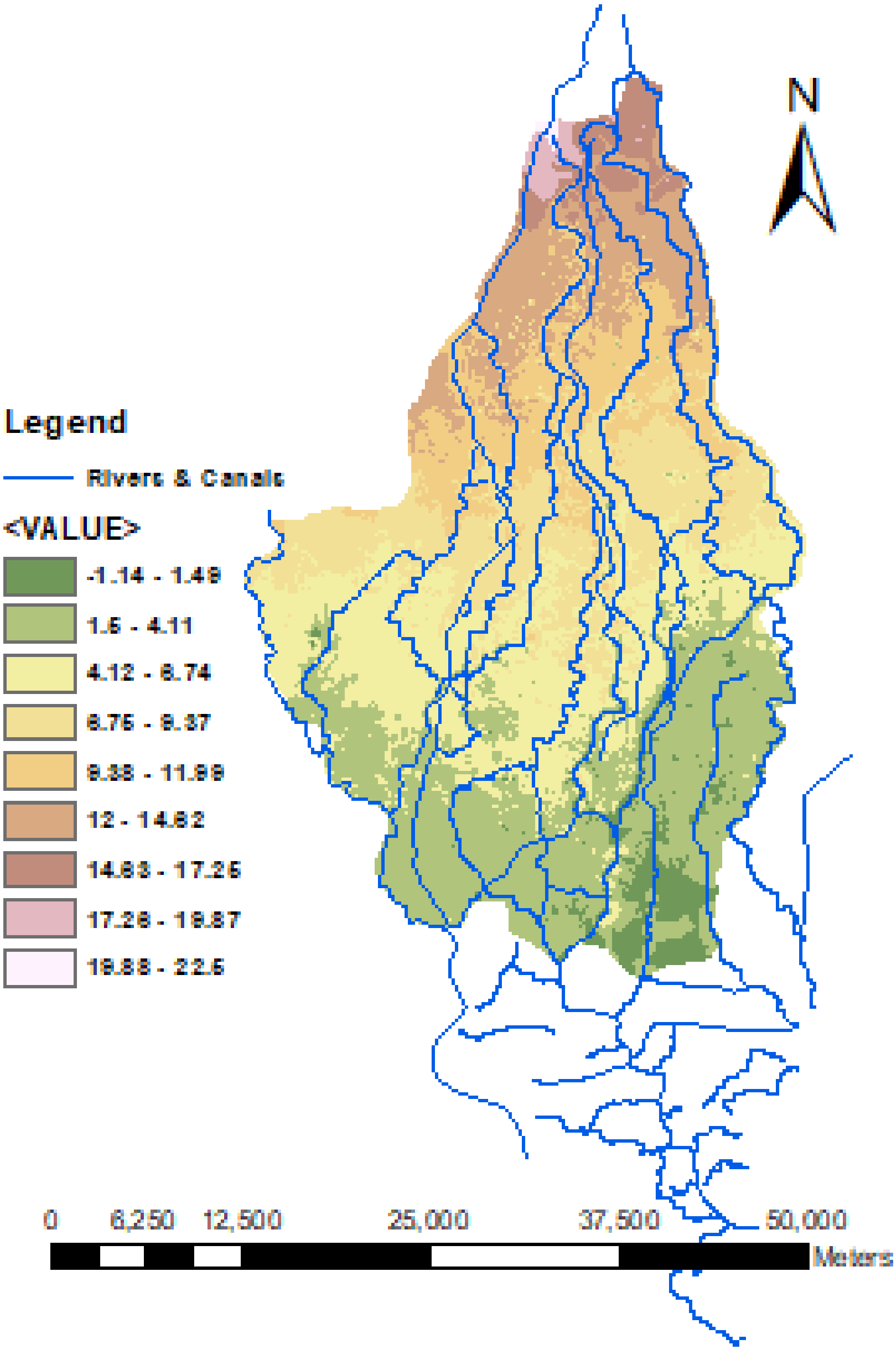


Figure 0-12 DEM of study area prepared from surveyed contour

2.4. MODEL SET UP (EXISTING CONDITION)

This section deals with detailed model set up and calibration of model for existing condition.

2.4.1. MIKE11 MODEL SET UP

2.4.1.1. RIVER NETWORK

The one dimensional hydrodynamic model has been set up for the area from upstream of bifurcation point of Mundeswari River and Lower Damodar at Beguahana to outfall of Lower Damodar River in Hooghly River. Number of Rivers and canals included in the model are 45. At upstream model is extended upto 8.5 km. The reason is to make sure boundary condition doesn't have any impact on model result at bifurcation point. Model network is shown in Figure 0-13.

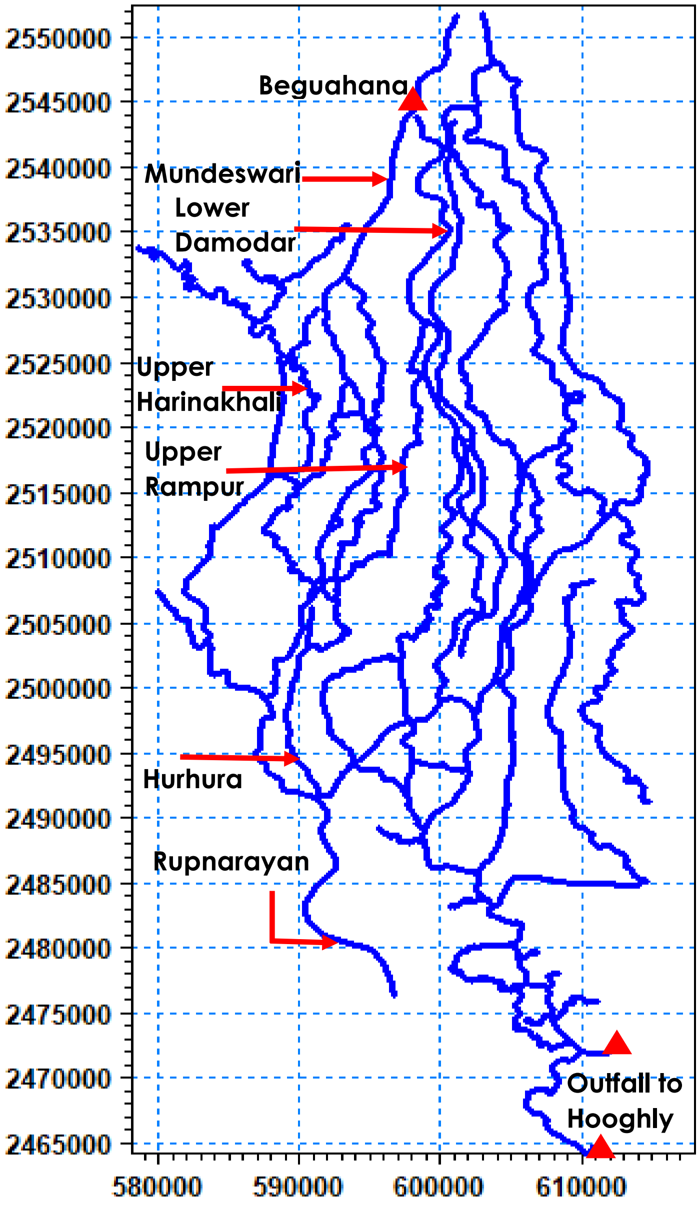


Figure 0-13 One dimensional model network set up for study area (X and Y coordinates are in meters)

2.4.1.2. CROSS-SECTION

Incorporation of cross sections of rivers/channels has already been stated in Paragraph 2.3.7 hereinbefore.

2.4.1.3. BOUNDARY CONDITION

Figure 0-14 shows location of boundary (red triangle) used in model. Discharge is applied at the upstream boundary whilst tide levels are used as downstream. There are discharge stations at Harinkhola and Champadanga where observed data series are available. Discharge is also diverted from Mundeswari river to Upper Harinakhali channel at upstream of Harinkhola Gauge discharge station. Hence discharge just upstream of the bifurcation is taken to be the sum of the observed discharges at Harinkhola (for Mundeswari), Champadanga (for Amta channel), and also the discharge diverted from Mundeswari river to Upper Harinakhali channel.

In the model, the initial step uses the sum of the discharges at Harinkhola and Champadanga as the first discharge input at Beguahana. In the next step, the diverted flow through Upper Harinakhali channel, calculated by the model is further added to the observed discharge values and the model is run again. This trial and error goes on until a water balance among discharge at Beguahana (just upstream of the bifurcation), Harinkhola, Champadanga and diverted through Upper Harinakhali are established. The final upstream discharge is shown in Figure 0-15, all corresponding to the critical flood period of 2017, from 23.07.18 to 31.08.18.

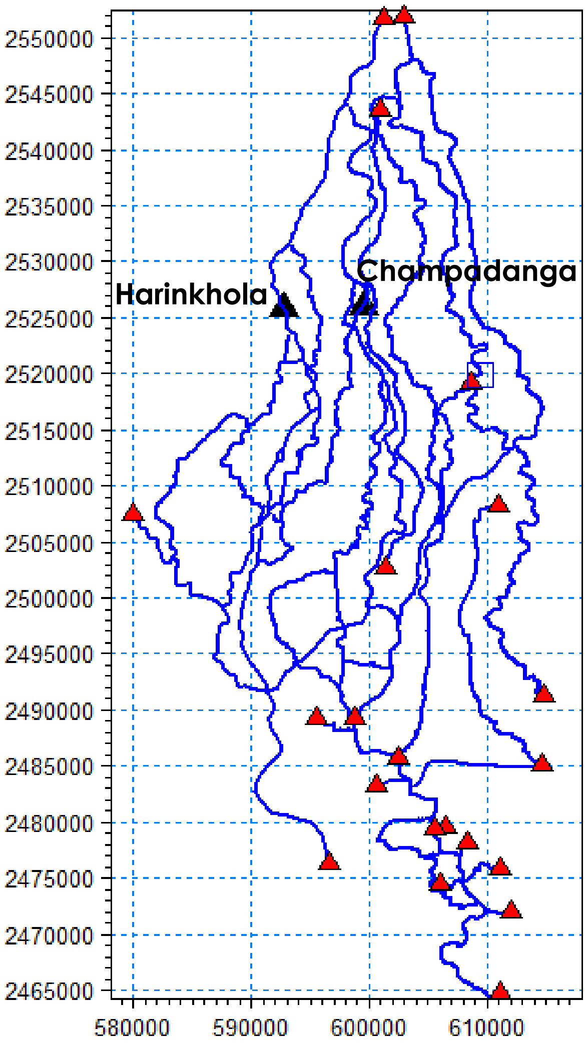


Figure 0-14 Location of boundary used in models (Red triangles) (X and Y coordinates are in meters)

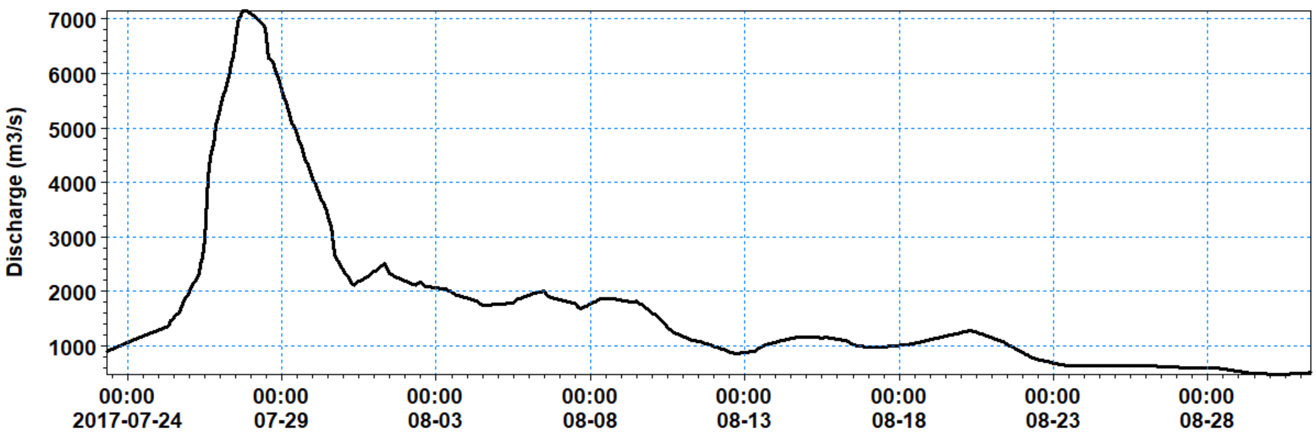


Figure 0-15 Upstream discharge used at Beguahana before bifurcation.

2.4.2. MIKE21 MODEL SET UP

2.4.2.1. BATHYMETRY

Relevant information of bathymetry to describe floodplain topography of the study area has already been discussed in Paragraph 2.3.8 hereinbefore.

2.4.2.2. BED RESISTANCE

In case of extreme flood, water spreads in the floodplain area where bed resistance will be reduced by vegetation cover, bushes etc. Considering the above, the Manning's roughness coefficient for the floodplain area is therefore taken as 0.04.

2.4.3. MIKE FLOOD MODEL SET UP

The MIKE Flood model is set up as a link between MIKE11 and MIKE21. In case of a high flood wave, the water will spread through lateral links shown in the Figure 0-7. The lateral flow from river to floodplain is calculated based upon standard weir formula. The weir formula is:

$$Q = wCh_1^k\left[1 - \left(\frac{h_2}{h_1}\right)^k\right]^{0.385}$$

Where *w* = width, *C* = weir coefficient (1.838 $m1^{/2}$/s), *k* = exponential coefficient (1.5),

*h*1 = depth of w ater above weir level upstream (*Hus* - *Hw*) and

*h*2 = depth of water above weir level downstream (*Hds* - *Hw*).

This equation is actually a free overflow term (*wChk*) combined with a scaling term for submergence ($[...]^{0.385}$) that approaches 0 as *h*1 approaches *h*2.

2.4.4. RESULTS

2.4.4.1. CALIBRATION

Model is simulated for 2017 (23rd July to 31st August). To support the routing calibration, two discharge stations and two water level stations have been identified. The details are given in Table 0-8.

Calibration involves adjusting the Manning's resistance values (friction) to flow of water over in the river channels and/or overland. Manning's n values, after calibration, finally adopted as 0.0357 for Mundeswari, 0.031 for Lower Damodar, 0.033 for other canals and rivers and 0.04 for overland. The model calibration results are compared with the discharge observations at Harinkhola and Champadanga as shown in in Figure 0-16 and Figure 0-17 respectively. It shows the formulated model provides a discharge pattern that matches quite closely the recorded values at both stations. The discharge distribution between the Mundeswari and Lower Damodar at the bifurcation is also well represented which confirms the model calibration is good. However, for low flow discharge at Champadanga, the calibration matching is not upto the mark. Investigation revealed that there was breaching of the embankments during the flood period of 2017 at a number of locations immediately after passing of peak floods which have caused movement of considerable extent of river discharge into the countryside by lateral flow through the breached sections. As a result, the observed discharges are lower compared to the discharges predicted by the model. This explain the mismatch between observed and simulated discharge for smaller discharge values during receding flood. Due to the same reason, Figure 0-19 show that the calibrated model water levels are higher than the water level observations at Champadanga. Again, the results in Figure 0-18 and Figure 0-19 confirm almost perfect matching at peak levels. Thus, the model stands validated.

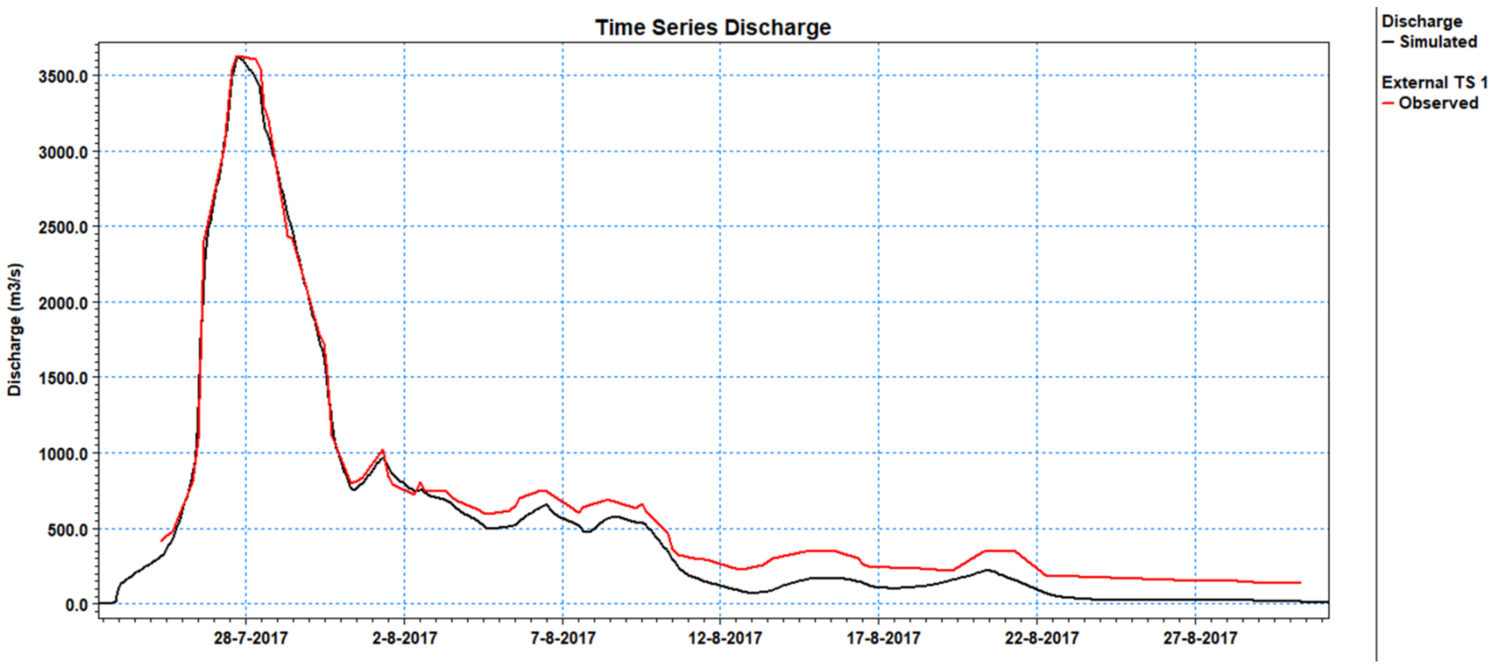


Figure 0-16 Comparison of discharge at Harinkhola (Observations (red) and Model Results (black))

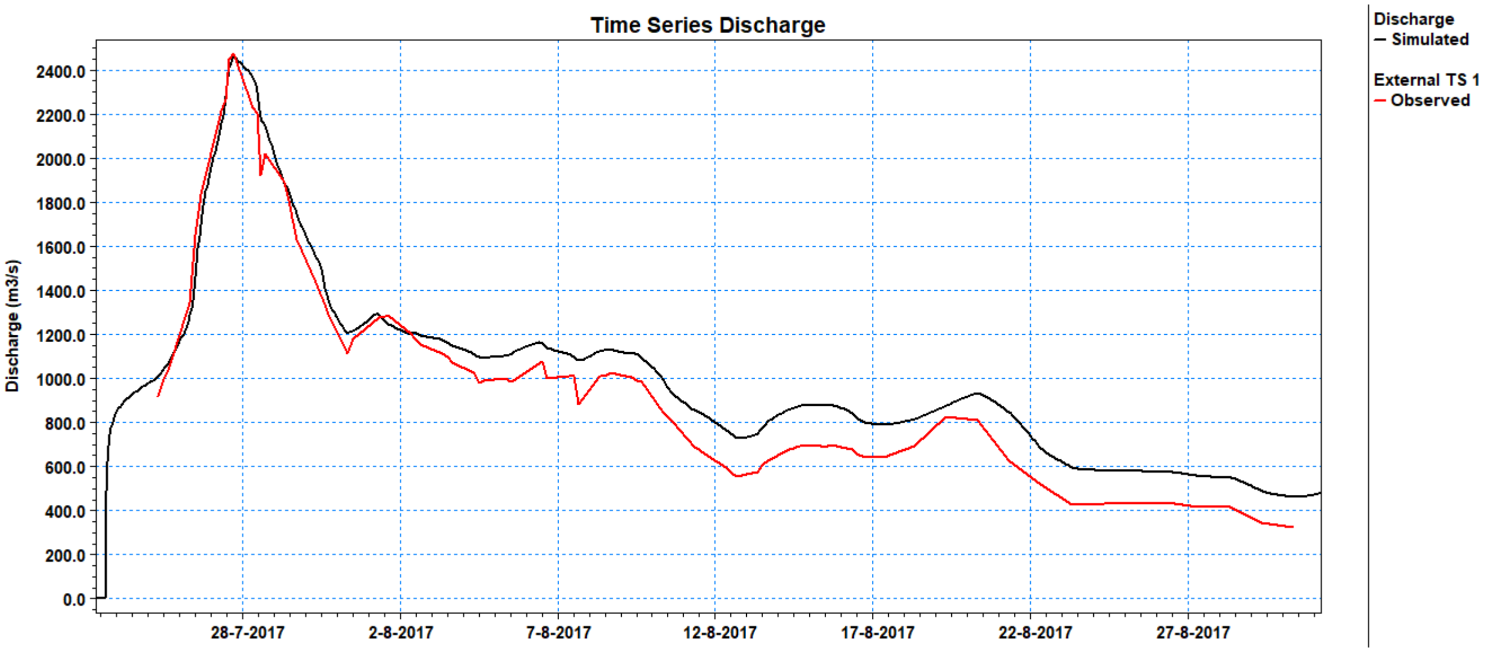


Figure 0-17 Comparison of discharge at Champadanga (Observations (red) and Model Results (black))

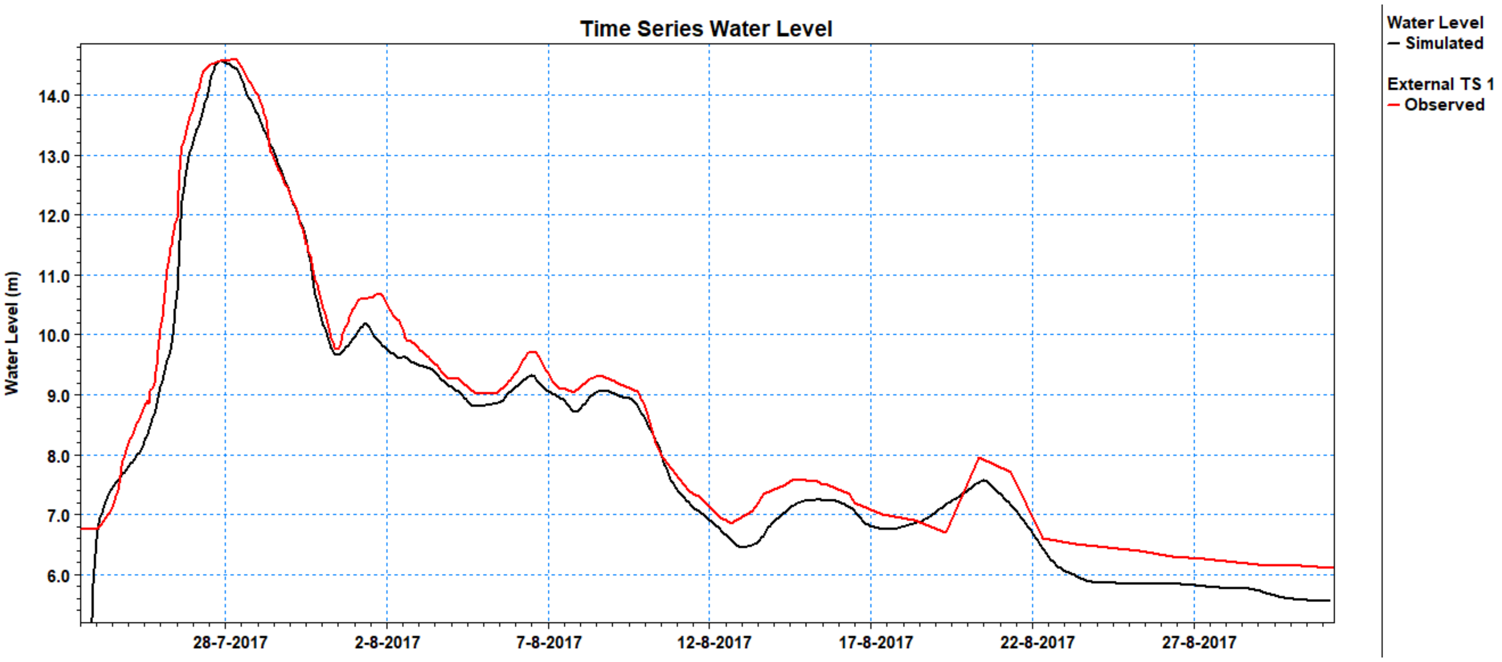


Figure 0-18 Comparison of water level at Harinkhola (Observations (red) and Model Results (black))

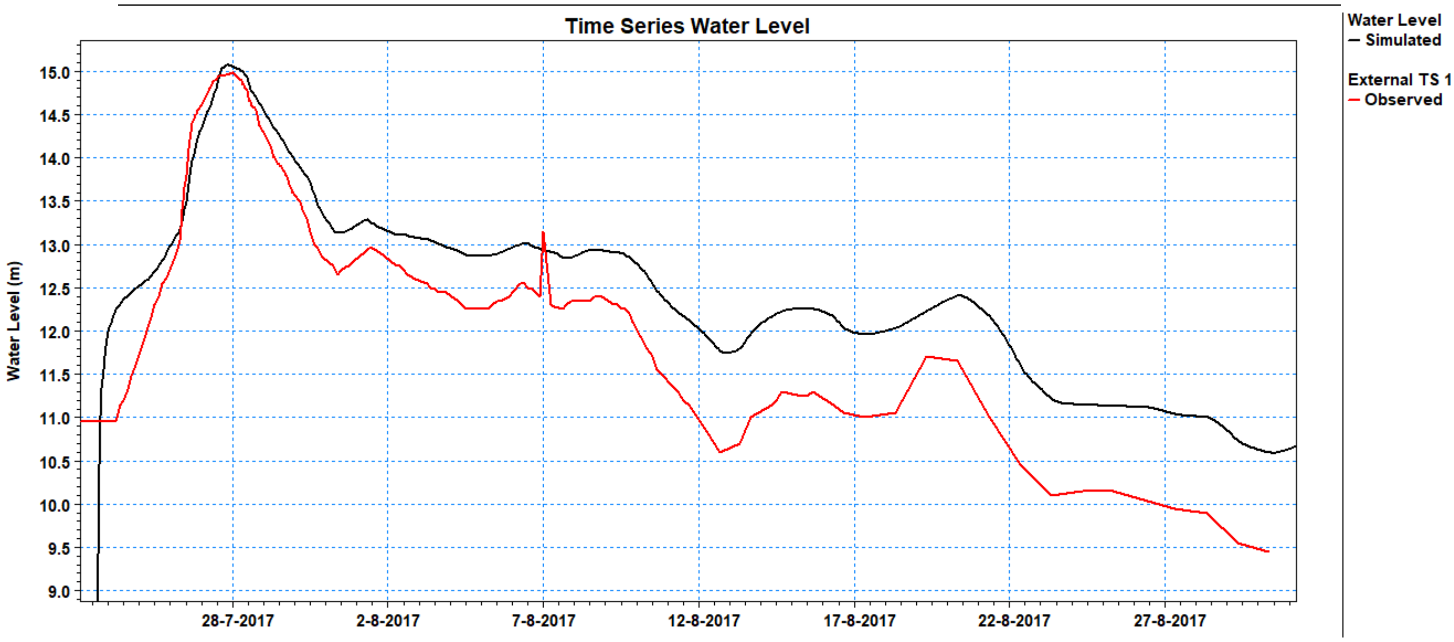


Figure 0-19 Comparison of water level at Champadanga (Observations (red) and Model Results (black))

It has already been stated that MIKE FLOOD model has been used to simulate the 2017 flood (23rd July to 31st August). It illustrates the extent of flooding across the floodplain area. Figure 0-20 is a flood map for the 28th July, 2017 flood. The inundated area in Howrah and Hooghly districts was provided by IWD and is indicated by the red polygons. The simulated model results show the inundated area matches well except for the area between the left bank of Maja Damodar and right bank of Lower Damodar. The reason may be attributed to possible clogging of the confluence of Maja Damodar and Lower Damodar due to sedimentation which pushed the water to overtop the right bank of Lower Damodar downstream of the confluence.

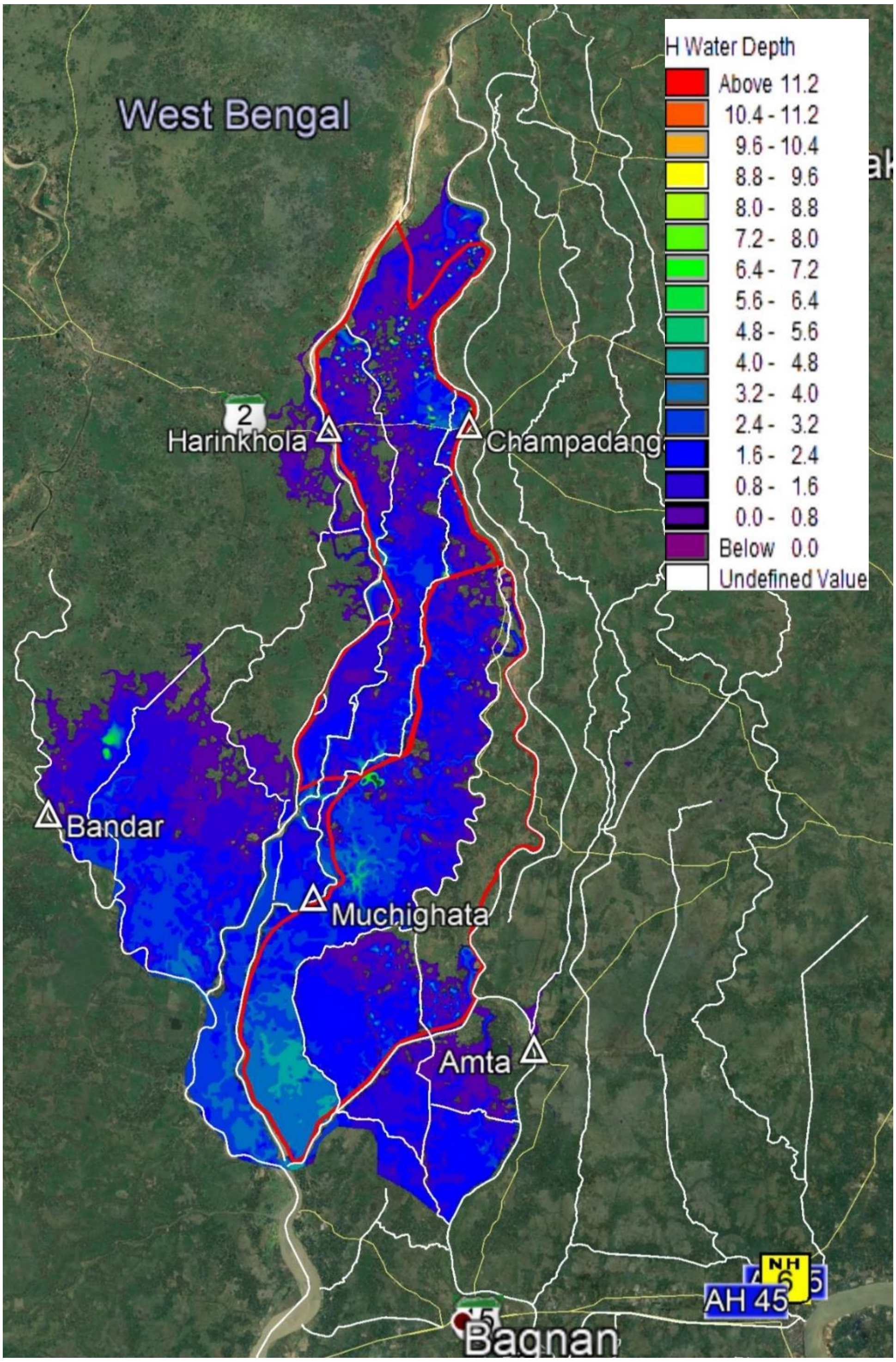


Figure 0-20 Floodmap generated for flood in 2017 (Red polygon is the observed inundated at Howrah and Hooghly region)

2.5. FLOOD MANAGEMENT: DIFFERENT OPTIONS (DESIGN CONDITION)

The main objectives of flood management, considered during model analysis are already discussed in section 2.1.3.1. The model is simulated for the existing (“without project”) condition as well as for the various possible combination of options/interventions representing “with project” conditions. In both cases (“without project” and “with project”) design discharge (section 2.2) are used as major input.

Necessary correction by lowering of bed level of Mundeswari is done to establish the design bed level. Figure 0-21 shows existing bed level and design bed level. Existing bed level is drawn based on lowest point of surveyed cross-section and shown in blue colour. It may be seen that at some locations, the existing bed levels are extremely low. The reason of having such low levels is attributable to the presence of relatively narrow sections at these locations, resulting in bed scour to accommodate the flood volume. It may be mentioned here that the width of the strip having such low levels is generally narrow, representing somewhat “V” shaped gorge. The brown line parallel to x-axis is backwater effect from tidal ingress from Rupnarayan River at outfall, extending almost upto 20 km in the upstream. Designed bed level at the offtake of Mundeswari at Beguahana, considered as the Upper terminal point, is fixed at the prevailing bed level of the adjoining Amta channel at the same offtake point (i.e. bifurcation point of the two streams from Damodar River) to maintain natural regime condition. The chainage at Beguahana is 9400m and design bed level is 11.62 m with respect to masl. Desiltation of Mundeswari has been considered upto such a stretch where the level of the tidal ingress touches the existing bed level of Mundeswari. This is considered as the lower terminal point of dredging and the prevailing bed level is fixed as the design bed level at this lower terminal point. Further lowering of bed level would be redundant as upstream flow would be obstructed by the tidal ingress. The chainage at lower terminal point is 40000m and design bed level is 3.855 m. Design bed slope is drawn by joining the design bed levels of the upper and lower terminal points over a straight line and shown in yellow colour. It may be seen that the existing lowest bed slopes more or less match with the profile of the design bed slope. The longitudinal slope of riverbed is 0.25m/km i.e. 1 in 4000, which is quite favourable to drain out the discharge and more or less compatible with such longitudinal slope of riverbed of similar rivers/channels.

It reveals from Figure 0-21 that within the overall zone of desiltation for a length of 30.6 km (from 9.4 km to 40 km), further lowering of the existing deepest bed level would be required for a length of 10.6 km (in between 9.4km to 20 km) and further widening of deep channel at design bed level (either at or above the existing deepest level) needs to be done for a length of 9 km (from 20 km to 29 km) by way of partial desiltation. No desiltation needs to be done for a stretch of 9 km length (from 29 km to 38 km). Further full section desiltation for a length of 2 km (from 38 km to 40 km) as per design bed width of the pilot channel would also be required to ensure smooth transition between design bed level of the desilted section and actual bed level of the existing section after termination of desiltation. Therefore, the total effective length, either deepening of bed level along with widening or only widening, becomes 21.6 km (10.6 km + 9 km + 2 km). This length would remain unaltered irrespective of the width of the pilot channel, varying from 100m to 175 m.

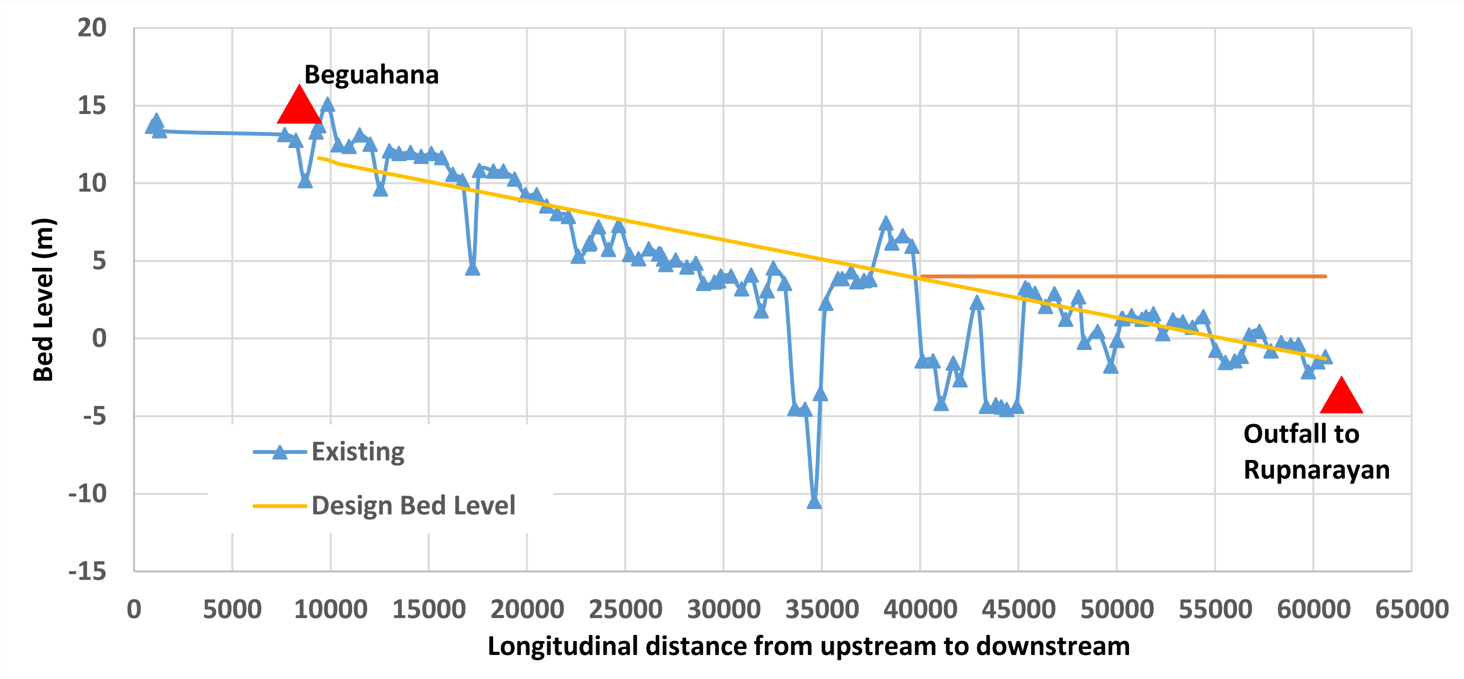


Figure 0-21 Existing Mundeswari longitudinal profile superimposed with design bed level

Various combination of options has already stated in Paragraph 2.1.3.2 hereinbefore, however these are reiterated below in Table 0-13 for ready reference as model simulation has been done for these options.

Table 0-13 Different options for flood management

Sl. No	Description	Code
1.	a) Desiltation of Mundeswari River for a length of 21.6 km downstream of the Damodar bifurcation point at Beguahana, thereby lowering the Mundeswari bed level, to evenly take the Damodar floodwater on par with the Amta Channel. The Mundeswari bed level is adjusted and graded to ultimately match the existing bed level 20 km downstream of Beguahana. Such desiltation will be in the form of a pilot channel having bed width of **100 m.** (b) Without any ungated regulator across Amta channel (c) Other supplementary interventions including improvement of Amta channel Left, Amta channel Right (dwarf), Upper Rampur Left & Hurhura Left embankments.	For bed width 100 m,BW100 No Weir = W0 No bedbar = BB0 **Code is BW100-W0-BB0**
2.	(a) Desiltation of Mundeswari River under the same condition as (a) in Sl.1 above with the exception that the bed width of the pilot channel would be **125 m**. (b) Without any ungated regulator across Amta channel. (C) Other supplementary interventions as stated in (c) under Sl.1	For bed width 125 m,BW125 No Weir = W0 No bedbar = BB0 **Code is BW125-W0-BB0**

Sl. No	Description	Code
	above.	
3.	(a) Desiltation of Mundeswari River under the same condition as (a) in Sl.1 above with the exception that the bed width of the pilot channel would be **150 m**. (b) Without any ungated regulator across Amta channel. (C) Other supplementary interventions as stated in (c) under Sl.1 above.	For bed width 150 m,BW150 No Weir = W0 No bedbar = BB0 **Code is BW150-W0-BB0**
4.	(a) Desiltation of Mundeswari River under the same condition as (a) in Sl.1 above with the exception that the bed width of the pilot channel would be **175 m**. (b) Without any ungated regulator across Amta channel. (C) Other supplementary interventions as stated in (c) under Sl.1 above.	For bed width 175 m,BW175 No Weir = W0 No bedbar = BB0 **Code is BW175-W0-BB0**
5.	(a) Desiltation of Mundeswari River under the same condition as (a) in Sl.1 above, i.e. bed width **100m**. (b) In addition, there will be an ungated regulator (in the form of a weir) across Amta channel immediate downstream of the bifurcation point to prevent entry of low floods in that channel. (c) Other supplementary interventions as stated in (c) in Sl.1 above.	For bed width 100 m,BW100 Weir = W1 No bedbar = BB0 **Code is BW100-W1-BB0**
6.	(a) Desiltation of Mundeswari River under the same condition same as (a) in Sl.2 above, i.e. bed width **150m.** (b) **7 number of bed bars** to be constructed on left bank of Damodar, immediate upstream of confluence of point at Beguahana to encourage diversion of flow from Damodar to Mundeswari, **but there will be no weir across Amta channel**. (c) Other supplementary interventions as stated in (c) in Sl.1 above.	For bed width 150 m,BW150 No Weir = W0 Bedbar = BB1 **Code is BW150-W0-BB1**

2.5.1. RESULT AND DISCUSSIONS

2.5.1.1. WITHOUT PROJECT

The Model results are analysed to understand the percentage of how water is shared between the Mundeswari and Amta Channel, in relation to particular flood return periods in the existing (‘without project”) condition. The results are shown in Table 0-14, Following observations are made:

- Spilling in case of Amta channel starts at a flood of return period of 1.3 years. This is too frequent and flood situation will arise almost every year due to such spilling along the right bank.
- At this stage, the corresponding bankful discharge in Amta channel is 1,455 m^3/s downstream of the bifurcation. Figure 0-22 shows the longitudinal profile of the Amta channel at this discharge. Similarly, in case of Mundeswari, bank overtopping commences at a discharge of about 2,675 m^3/s, which may be ranked as 2.6-year return period of flood.
- Sharing of flood discharge of Damodar River at Beguahana point by the Mundeswari River is practically insignificant at the initial stage, only 14%, which sharply increases to 51% at 2-year return period of flood. The trend of sharing by Mundeswari, however, gets plateaued as discharge increases further and remains close to 60%. It may be stated that the river remains comparatively under-utilised at very low frequency floods, having return period upto 2 years, although its bankful capacity is 1.84 times of that of Amta channel.
- Discharge sharing pattern for Amta channel is more or less reverse of that for Mundeswari.
- The existing degree of protection in the Trans-Damodar Sub-basin (area in between right bank of Amta channel and left bank of Mundeswari River) is extremely limited in the existing condition. As a matter of fact, inundation is bound to take place whenever the discharge of Damodar at Beguahana exceeds 2,152 m^3/s (having return period of 1.3 years). This inference from modelling also stands validated in terms of field experience, as stated by IWD.

Table 0-14 Flood discharge at Beguahana and pattern of sharing between Mundeswari River and Amta Channel corresponding to different return periods of flood and consequence thereof in Pre-project scenario (as obtained from Numerical Modelling and validated from field observations)

Flood frequency	Flood Discharge (cusec)	Flood Discharge (cumecs)	Sharing by Mundeswari		Sharing by Amta Channel		Total		Remarks	
			%	Quantum	%	Quantum	%	Quantum	Amta Channel	Mundeswari
1	17762.00	503.03	14.0%	70.0	86.0%	433.00	100%	503.0	No Flooding	No Flooding
1.3	76000.00	2152.36	33.4%	718.89	67.6%	1455.00	100%	2152.0	Flooding about to start	No Flooding
2	126767.94	3590.14	49.0%	1759.0	51.0%	1831.00	100%	3590.0	Flooding	No Flooding

Flood frequency	Flood Discharge (cusec)	Flood Discharge (cumecs)	Sharing by Mundeswari		Sharing by Amta Channel		Total		Remarks	
2.6	163521.00	4631.00	57.8%	2675.0	42.2%	1956.00	100%	4631.0	Flooding	Flooding about to start
3	169109.68	4789.29	59.0%	2826.0	41.0%	1963.00	100%	4789.0	Flooding	Flooding
4	197403.08	5590.57	59.6%	3332.0	40.4%	2259.00	100%	5591.0	Flooding	Flooding
5	219281.48	6210.18	59.4%	3689.0	40.6%	2521.00	100%	6210.0	Flooding	Flooding
10	277074.95	7846.93	59.7%	4685.0	40.3%	3162.00	100%	7847.0	Flooding	Flooding
15	311418.06	8819.54	60.0%	5292.0	40.0%	3528.00	100%	8820.0	Flooding	Flooding
20	337737.82	9564.93	61.5%	5882.0	38.5%	3683.00	100%	9565.0	Flooding	Flooding
25	353000.00	9997.17	61.7%	6319.0	38.3%	3829.00	100%	9997.0	Flooding	Flooding

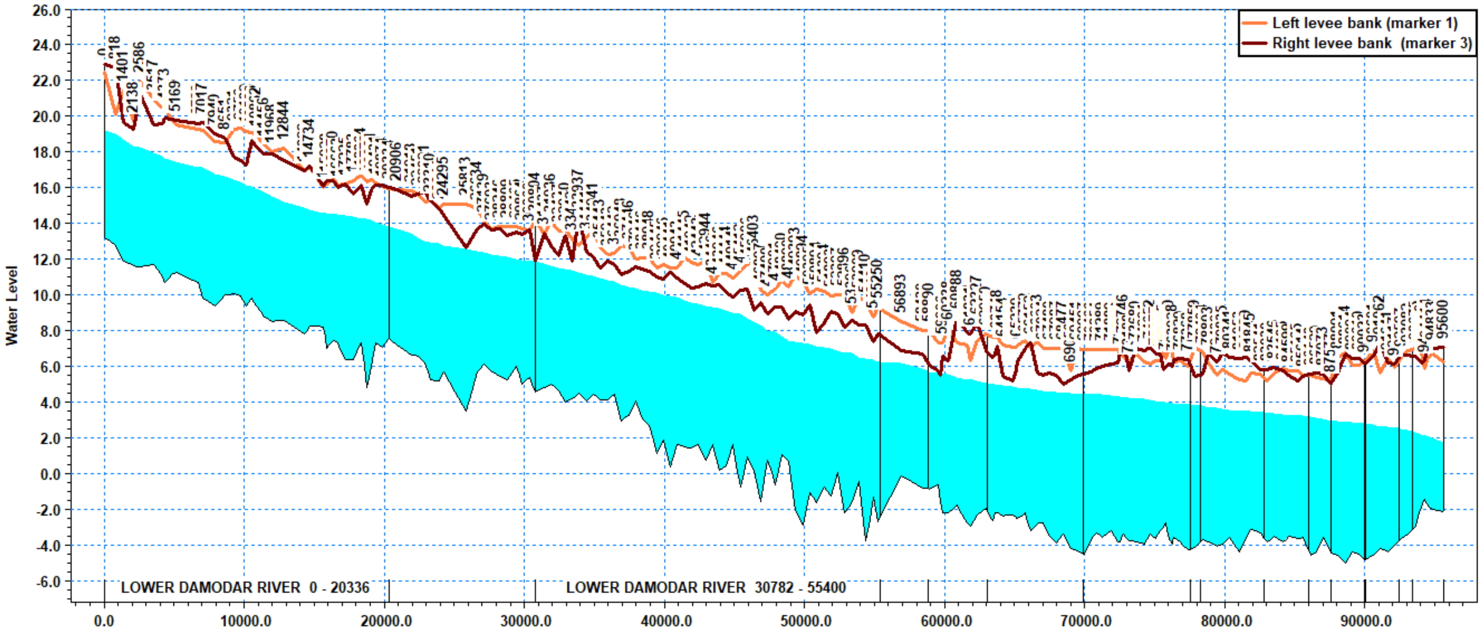


Figure 0-22 Longitudinal profile of Lower Damodar River with discharge of 1455 m^3/s

2.5.1.2. WITH PROJECT

OPTION 1: BW100-W0-BB0 (REFER TO TABLE 0-9 UNDER SECTION 2.5)

In this option Mundeswari River is desilted to maintain a 100 m pilot channel. Typical cross-section is shown in Figure 0-23 and Figure 0-24. Design discharge with 25 year return period discussed in section 2.2 is used as input parameter and maximum tide level as downstream control.

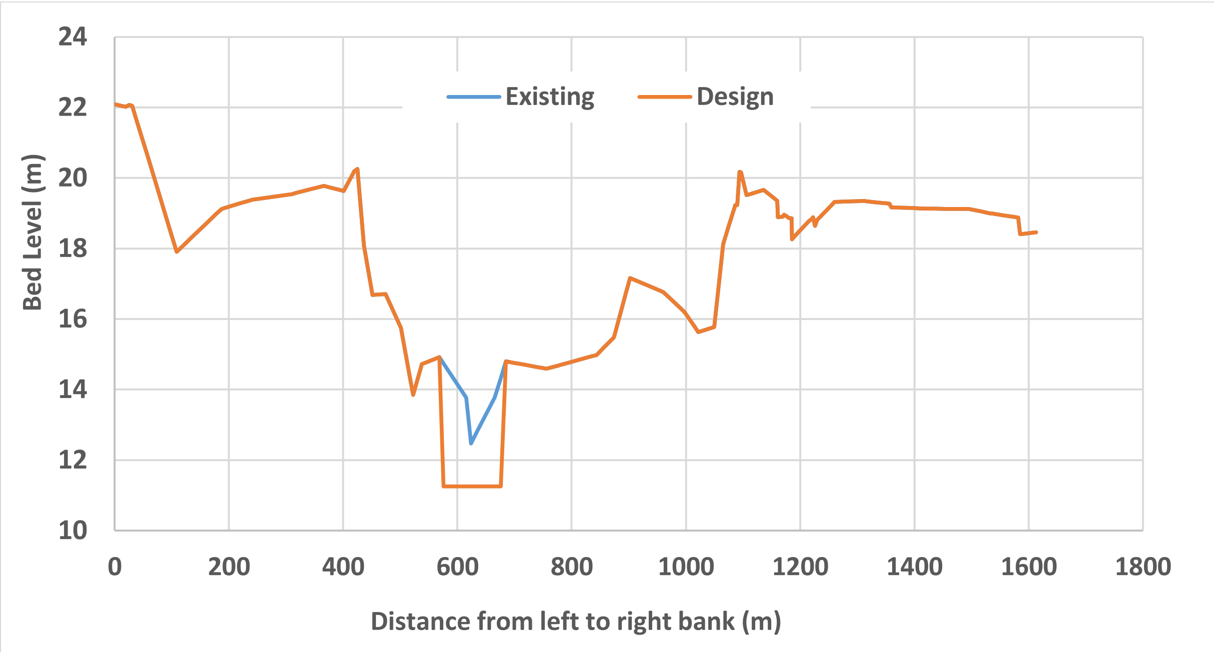


Figure 0-23 Typical cross-section of 100 m pilot channel with existing cross-section (chainage 995 m from Beguahana, river bed need to be dredged fully)

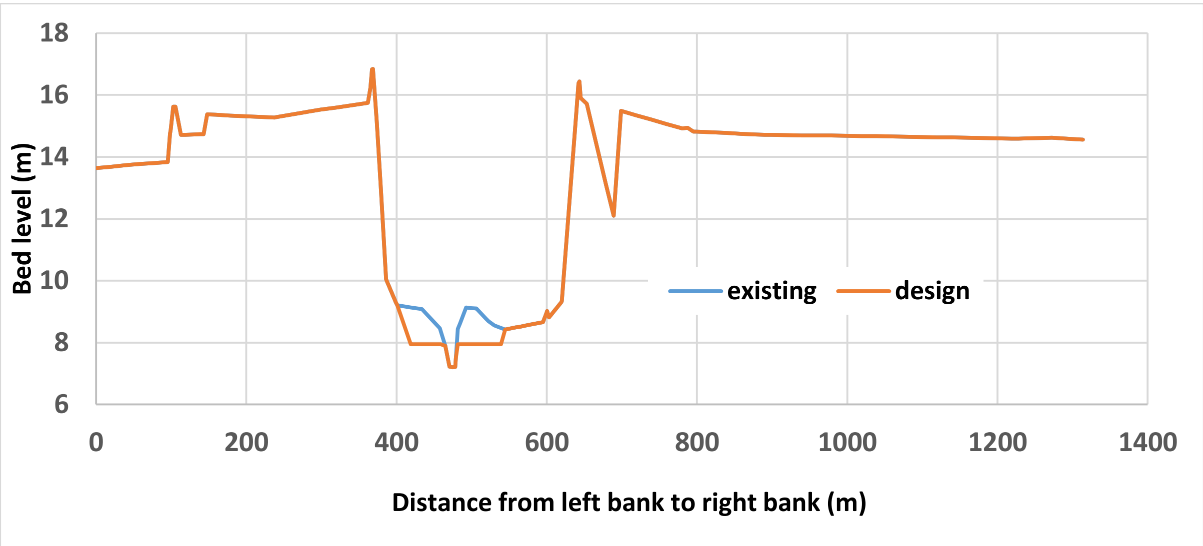


Figure 0-24 Typical cross-section of 100 m pilot channel with existing cross-section (chainage 14239 m from Beguahana, river bed need to be dredged partially)

Discharge sharing between Mundeswari and Lower Damodar is shown in Table 0-15. It shows upto 3 year return period of discharge there is no flooding in Lower Damodar. In existing condition it was 1.3 year return period of discharge. In Mundeswari flooding starts at discharge with 2.6 year of return period which is same as existing condition. It is also observed that flooding is about to start with discharge of 1455 m^3/s just after bifurcation at Lower Damodar. Similarly for Mundeswari overtopping of bank will start around 3204.65 m^3/s.

Table 0-15 Flood discharge at Beguahana and pattern of sharing between Mundeswari River and Amta Channel corresponding to different return periods of flood and consequence thereof in Post-project scenario (**Modelling Code: BW100-W0-BB0**)

Flood frequency	Flood Discharge (cusec)	Flood Discharge (m^3/s)	Sharing by Mundeswari		Sharing by Amta Channel		Total		Remarks	
			%	Quantum	%	Quantum	%	Quantum	Amta Channel	Mundeswari
1	17762.00	503.03	75.4%	379.00	24.6%	124.00	100%	503	No Flooding	No Flooding
1.3	76000.00	2152.36	68.2%	1468.00	31.8%	684.00	100%	2152	No Flooding	No Flooding
2	126767.94	3590.14	69.6%	2499.00	30.4%	1091.00	100%	3590	No Flooding	No Flooding
2.6	163521.00	4631.00	69.2%	3204.65	30.8%	1426.35	100%	4631	No Flooding	Flooding about to start
3	169109.68	4789.29	69.6%	3333.34	30.4%	1455.94	100%	4789	Flooding about to start	Flooding
4	197403.08	5590.57	69.6%	3891.04	30.4%	1699.53	100%	5591	Flooding	Flooding
5	219281.48	6210.18	69.2%	4297.45	30.2%	1875.47	100%	6210	Flooding	Flooding
10	277074.95	7846.93	69.1%	5422.23	30.9%	2424.70	100%	7847	Flooding	Flooding
15	311418.06	8819.54	69.1%	6094.30	30.9%	2725.24	100%	8820	Flooding	Flooding
20	337737.82	9564.93	69.0%	6599.80	30.0%	2869.48	100%	9565	Flooding	Flooding
25	353000.00	9997.17	69.0%	6898.05	31.0%	3099.12	100%	9997	Flooding	Flooding

OPTION 2: BW125-W0-BB0 (REFER TO TABLE 0-9 UNDER SECTION 2.5)

Here a 125 m wide pilot channel in Mundswari River is introduced and impact on water sharing between Mundeswari and Lower Damodar are examined keeping upstream discharge same i.e. discharge with 25 year return period. There is no flooding upto 3.7 year return period for Lower Damodar which is higher than option 1. In Mundeswari upto 2.9 year return period flooding doesn't occur.

OPTION 3: BW150-W0-BB0 (REFER TO TABLE 0-9 UNDER SECTION 2.5)

Mundeswari is desilted to maintain a 150 m pilot channel. Again it is simulated for 25 yr return period of discharge. Model result is further analysed to understand percentage of water sharing between Mundeswari and Lower Damodar (Amta Channel) corresponding to different return period of discharge and consequence which both river experience. The result is shown in Table 0-16. It shows for both river upto 4 year return period there is no flooding. Both river experience equal degree of relief from flooding which is the prime objective of flood management. Bankful discharge for Mundeswari is increased and become 4137 m^3/s. The percentage of sharing of discharge between Mundeswari and Lower Damodar is consistently maintained at 74% and 26% respectively, other than 1-year return period of flood.

Table 0-16 Flood discharge at Beguahana and pattern of sharing between Mundeswari River and Amta Channel corresponding to different return periods of flood and consequence thereof in Post-project scenario (**Modelling Code: BW150-W0-BB0**)

Flood frequency	Flood Discharge (cusec)	Flood Discharge (m^3/s)	Sharing by Mundeswari		Sharing by Amta Channel		Total		Remarks	
			%	Quantum	%	Quantum	%	Quantum	Amta Channel	Mundeswari
1	17762.00	503.03	100.0 %	503.00	0.0%	0.00	100%	503	No Flooding	No Flooding
1.3	76000.00	2152.36	75.6%	1627.19	24.4%	525.17	100%	2152	No Flooding	No Flooding
2	126767.94	3590.14	74.6%	2678.25	25.6%	919.08	100%	3590	No Flooding	No Flooding
2.6	163521.00	4631.00	74.0%	3436.20	26.0%	1194.80	100%	4631	No Flooding	No Flooding
3	169109.68	4789.29	74.0%	3544.07	26.0%	1245.21	100%	4789	No Flooding	No Flooding
3.2	171748.00	4864.00	74.0%	3599.36	26.0%	1264.64	100%	4864	No Flooding	No Flooding

Flood frequency	Flood Discharge (cusec)	Flood Discharge (m^3/s)	Sharing by Mundeswari		Sharing by Amta Channel		Total		Remarks	
			%	Quantum	%	Quantum	%	Quantum	Amta Channel	Mundeswari
4	197403.08	5590.57	74.0%	4137.02	26.0%	1453.55	100%	5591	Flooding about to start	Flooding about to start
5	219281.48	6210.18	73.9%	4589.32	26.1%	1620.86	100%	6210	Flooding	Flooding
10	277074.95	7846.93	73.9%	5798.88	26.1%	2048.05	100%	7847	Flooding	Flooding
15	311418.06	8819.54	73.7%	6500.00	26.3%	2319.54	100%	8820	Flooding	Flooding
20	337737.82	9564.93	73.7%	7049.36	26.3%	2515.58	100%	9565	Flooding	Flooding
25	353000.00	9997.17	73.6%	7357.92	26.4%	2639.25	100%	9997	Flooding	Flooding

OPTION 4: BW175-W0-BB0 (REFER TO TABLE 0-9 UNDER SECTION 2.5)

Here a 175 m wide pilot channel in Mundswari River is introduced and impact on water sharing between Mundeswari and Lower Damodar are examined keeping upstream discharge same i.e. discharge with 25 year return period. There is no flooding upto 4.6 year return period for Lower Damodar which is higher than option 3. In Mundeswari upto 4.2 year return period flooding does not occur. Though return period for no flooding condition is increased but the additional degree of equal relief to both the Mundeswari and Amta sub-basin cannot practically be provided.

OPTION 5: BW100-W1-BB0 (REFER TO TABLE 0-9 UNDER SECTION 2.5)

In this option an ungated weir at the immediate downstream of bifurcation point of river Damodar, at Beguahana across Amta Channel is constructed. Weir crest level is kept at 5 m from lowest river bed level to ensure upto 2265.65 m^3/s (80000 cusecs) at Damodar, no discharge (except environmental flow, water required for drinking and irrigation) will pass through Amta Channel. Mundeswari River is desilted to maintain 100 m pilot channel. Upstream boundary condition remains same. The result is shown in Table 0-17. The result shoes there is no flooding upto 5 year return period for Lower Damodar which is higher among all options. In Mundeswari River return period with no flooding condition is reduced to 2.1 year which is lower than existing situation. The benefit is, therefore, lop-sided and may not be acceptable as Mundeswari sub-basin would be inundated at the altar of Amta channel sub-basin.

Table 0-17 Flood discharge at Beguahana and pattern of sharing between Mundeswari River and Amta Channel corresponding to different return periods of flood and consequence thereof in Post-project scenario (**Modelling Code : BW100-W1-BB0**)

Flood frequency	Flood Discharge (cusec)	Flood Discharge (m^3/s)	Sharing by Mundeswari		Sharing by Amta Channel		Total		Remarks	
			%	Quantum	%	Quantum	%	Quantum	Amta Channel	Mundeswari
1	17762.00	503.03	100.0%	503.00	0.0%	0.00	100%	503	No Flooding	No Flooding
1.3	76000.00	2152.36	100.0%	2152.36	0.0%	0.00	100%	2152	No Flooding	No Flooding
2.1	126767.94	3722.00	86.1%	3204.64	13.9%	517.36	100%	3590	No Flooding	Flooding about to start
3	169109.68	4789.29	81.0%	3879.32	19.0%	910.00	100%	4789	No Flooding	Flooding
4	197403.08	5590.57	79.0%	4416.55	21.0%	1174.02	100%	5591	No Flooding	Flooding
5	219281.48	6210.18	76.6%	4757.00	23.4%	1453.20	100%	6210	Flooding about to start	Flooding
10	277074.95	7846.93	75.7%	5940.12	24.3%	1906.80	100%	7847	Flooding	Flooding
15	311418.06	8819.54	73.1%	6447.09	26.9%	2372.46	100%	8820	Flooding	Flooding
20	337737.82	9564.93	71.4%	6829.36	28.6%	2735.57	100%	9565	Flooding	Flooding
25	353000.00	9997.17	71.0%	7097.99	29.0%	2899.18	100%	9997	Flooding	Flooding

OPTION 6: BW150-W0-BB1 (REFER TO TABLE 0-9 UNDER SECTION 2.5)

Figure 0-25 shows image near bifurcation point. It shows presently flow direction is towards Amta Channel. The reason could be either deposition of excessive sediment at the offtake of Mundeswari River or due to natural meandering properties. Hence sustainability of desiltation of the pilot channel in Mundeswari needs to be verified. Accordingly, a two-dimensional hydrodynamic model is set up using MIKE21 FM to examine the behaviour of the river system by putting 7 numbers bed bar at upstream of bifurcation along with desiltation of pilot channel of 150 m width, in Mundeswari. Same model is used for 150 m pilot channel without bed bar. Triangular mesh is generated for model area. Different sizes of mesh is created according to flow condition and channel sizes. Finer mesh is generated for pilot channel and bedbar whereas coarser size of triangular mesh is created for floodplain area.

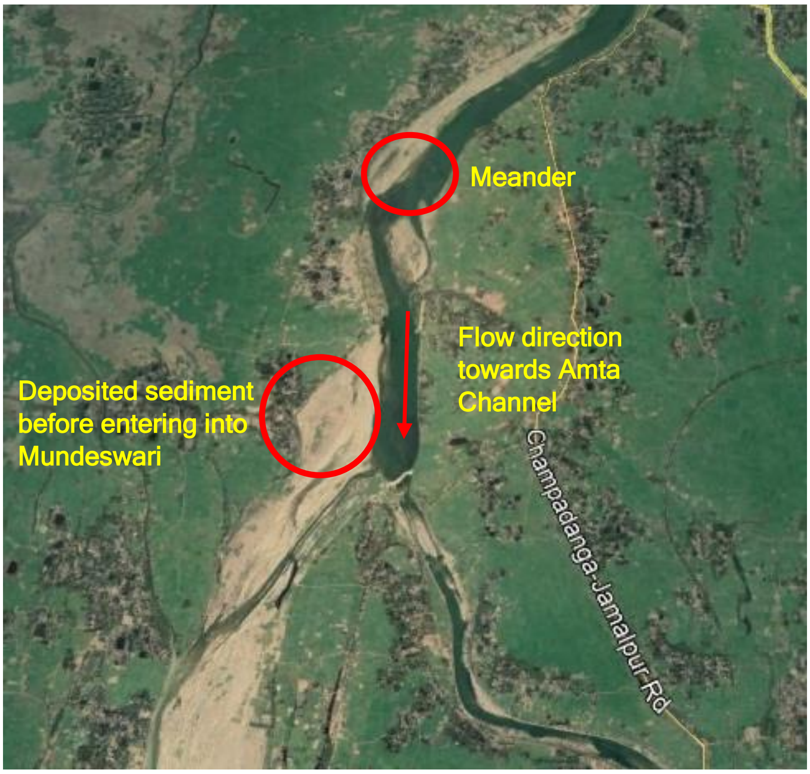


Figure 0-25 Existing flow direction and deposited sediment

Figure 0-26 and Figure 0-27 shows model area along with bathymetry and pilot channel. Figure 0-28 and Figure 0-29 shows bathymetry near bedbar. Bathymetry is generated based on xyz points surveyed by Jacobs and IWD department (mentioned in section 2.4.1.2). These bedbar are designed as submerged groynes. Length and section of bedbar are provided by IWD. Model is simulated for 25 year return period. At downstream water level extracted from one dimensional is used as boundary.

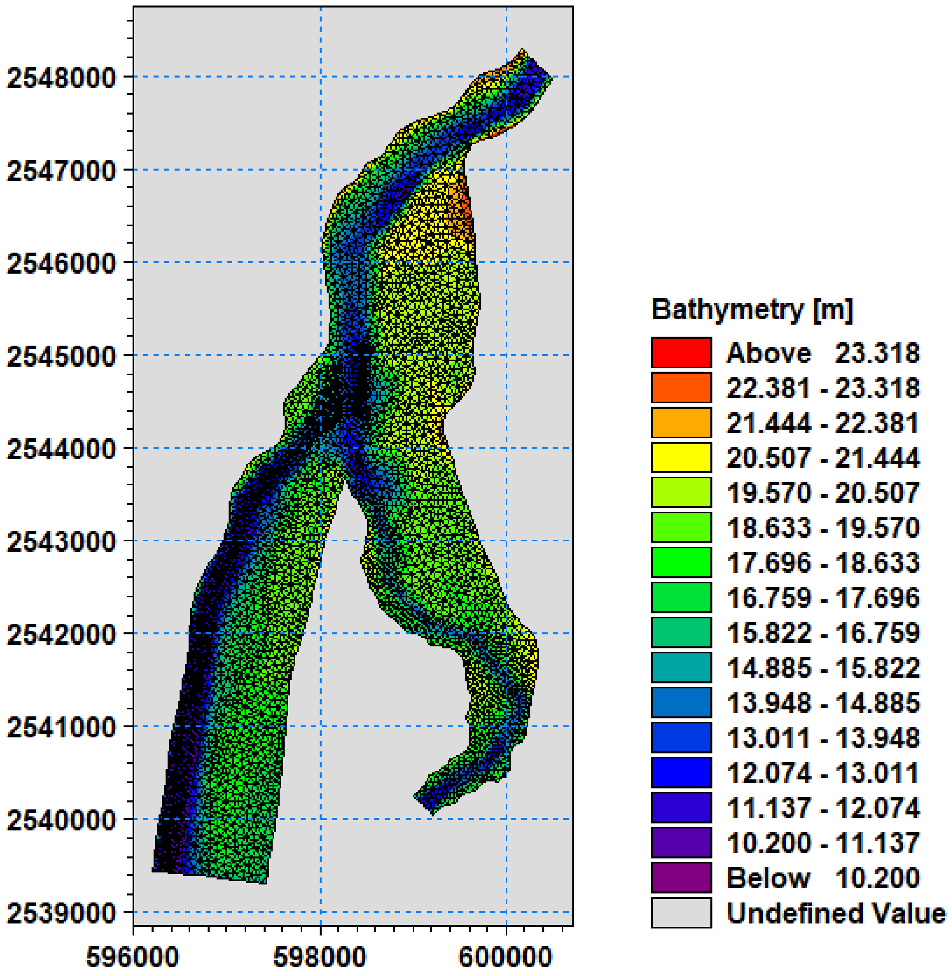


Figure 0-26 Model area along with bathymetry

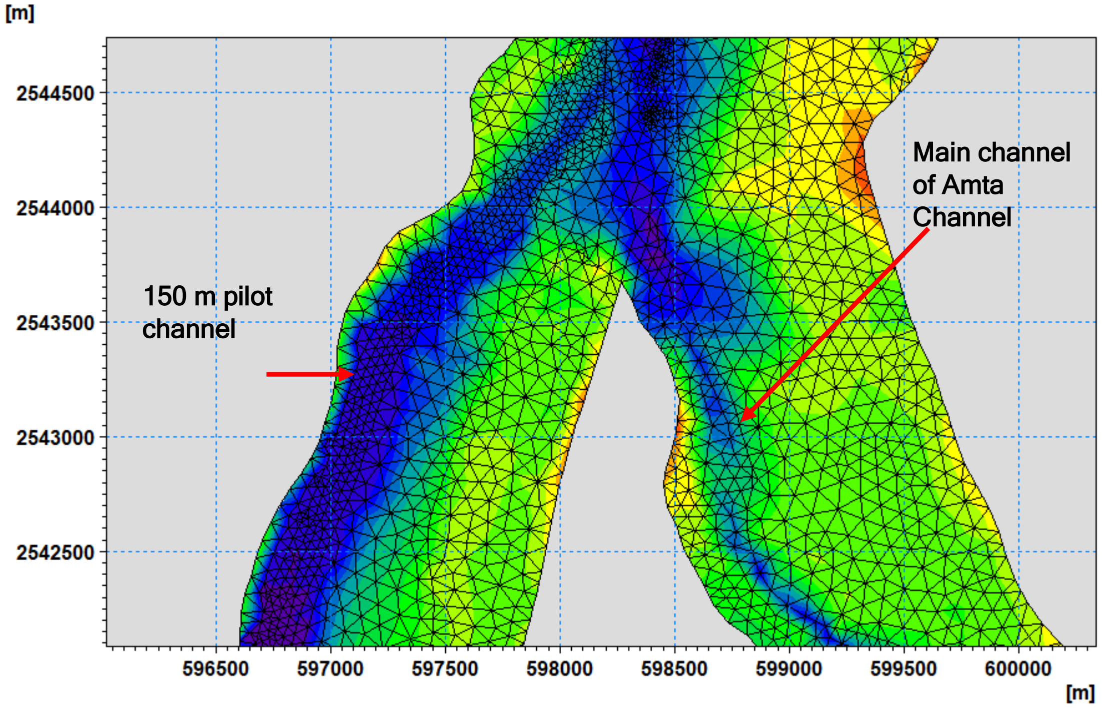


Figure 0-27 Bathymetry showing main channel of Amta channel and 150 m pilot channel in Mundeswari

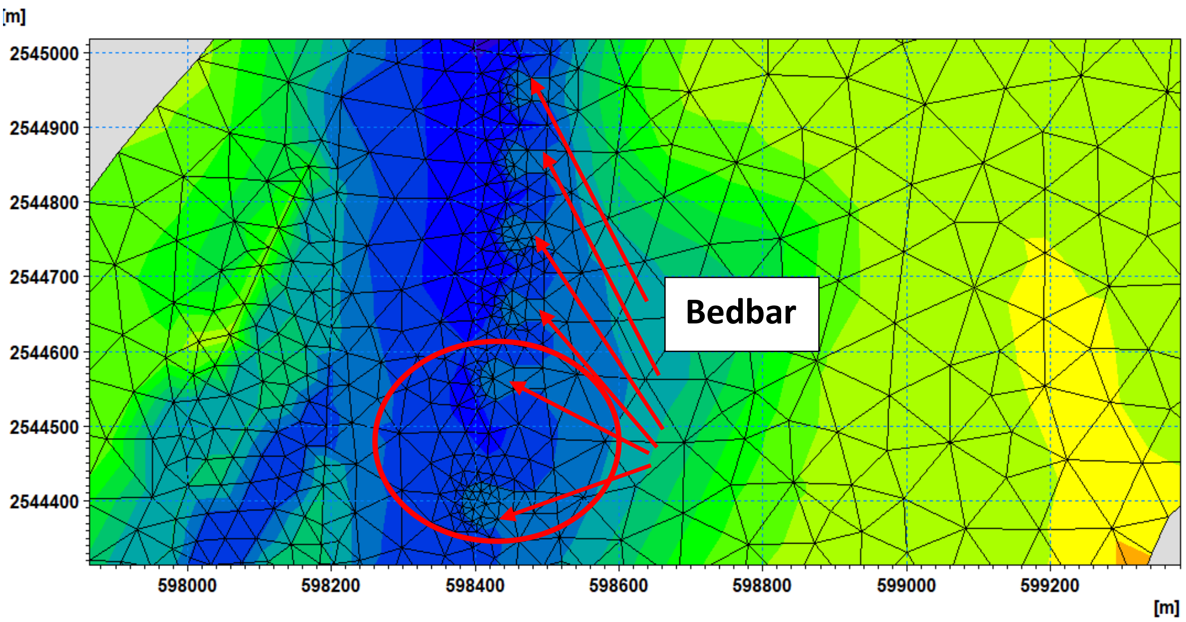


Figure 0-28 Bathymetry along with bedbars

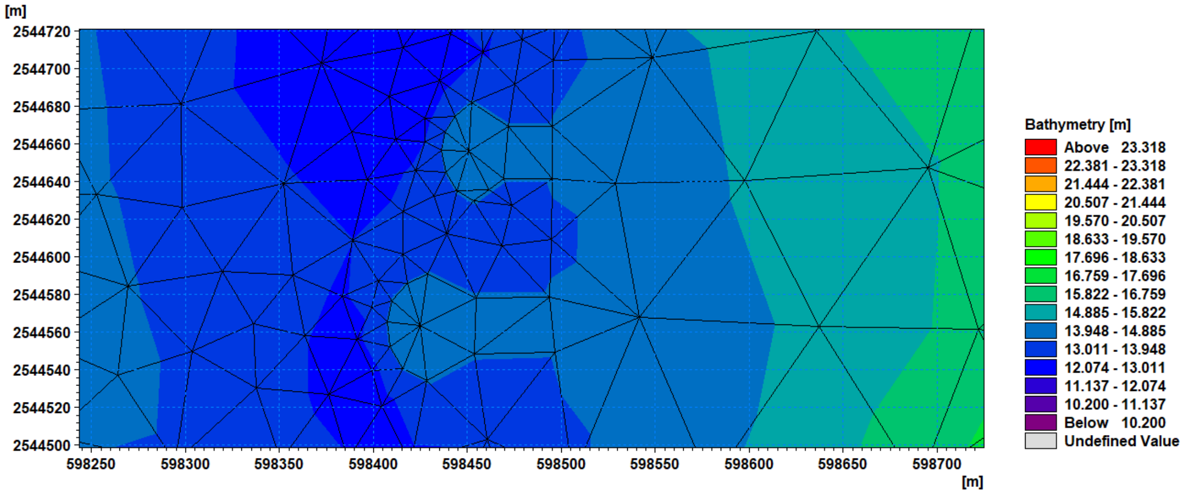


Figure 0-29 Bathymetry near bedbar (Red circle in Figure 0-29)

Figure 0-30 shows discharge time series at Mundeswari with and without bedbar. There is negligible change in discharge. Further studies are done on sustainability by setting up sediment model. The result is discussed in section 2.7.

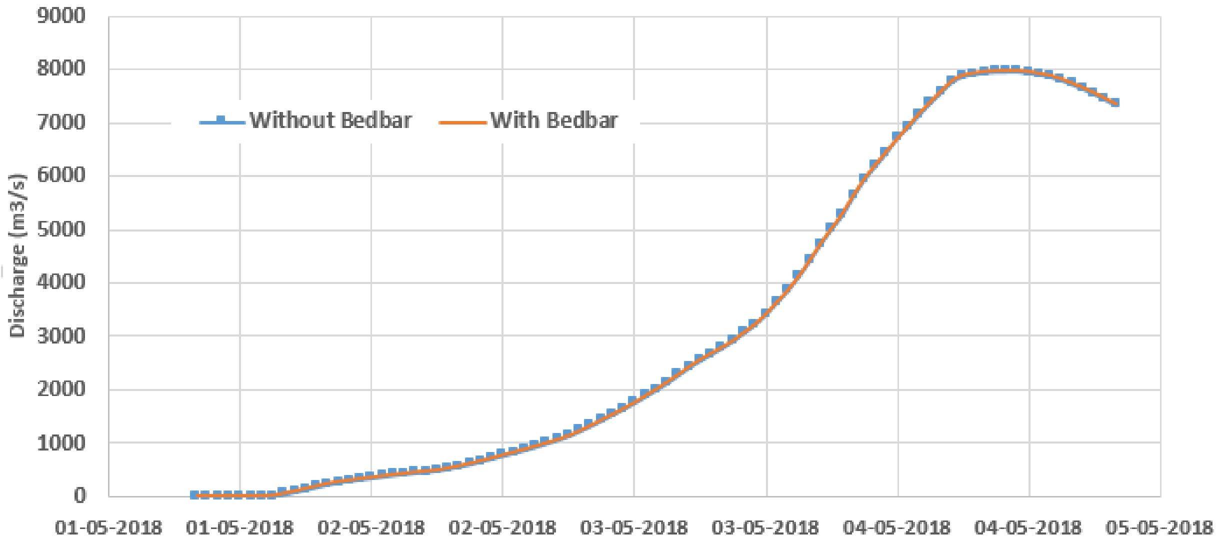


Figure 0-30 Discharge time series with and without Bedbar (150 m dredging in Mundeswari for both case)

2.5.2. DISCUSSIONS ON OPTION ANALYSIS

A comparative analysis of varying bed widths of the pilot channel in Mundeswari River and return periods corresponding to "no flooding" condition is shown in Figure 0-31 and Table 0-18. Clearly, selection of 150 m bed width of the pilot channel appears to be the preferred option, subject to assessment of environmental impacts and conducting economic and financial analysis, due to;

- achieving “no flooding” condition upto 4-year return period floods for both the river sub-basins, which is essentially required for providing equitable degree of relief across the entire project area. Such “no flooding” condition for both the sub-basins can also be achieved with 75 m bed width but the corresponding return period of flood would be only 2.6 year, which is too low. Such “no flooding” condition can also be achieved for somewhat higher return period (upto 4.2-year return period flood in case of Amta channel and 4.6-year return period in case of Mundeswari river) but resultant incremental benefits are likely to outweigh the additional cost.
- Optimal utilisation of capacity of both the channels, resulting in better flood moderation.

However, both the option 3 & 6 as shown in Table 0-18 below, i.e. selecting a bed width of 150 m with or without bed bars to be constructed on the left bank of Damodar river immediately upstream of the bifurcation point at Beguahana offer equal degree of relief. Therefore, the primary consideration for taking the final decision would be after sediment model study with and without bed bar.

Other options are not acceptable, due to, either widely inequitable protection in the concerned river sub-basins due to unfavourable sharing pattern of discharge or extremely limited degree of relief.

Figure 0-31 Comparison plot between width of pilot channel and return period upto which no flooding

Table 0-18 Summary of return period at no flooding condition with different options

Options	Return Period (Year)	
	Mundeswari	Amta Channel
Existing	2.6	1.3
Option1: BW100-W0-BB0	2.6	3.0
Option2: BW125-W0-BB0	2.9	3.7
Option3: BW150-W0-BB0	4	4
Option4: BW175-W0-BB0	4.6	4.2
Option5: BW100-W1-BB0	2.1	5
Option6: BW150-W0-BB1	4	4

2.5.3. APPROACH METHODOLOGY FOR IDENTIFYING THE TYPE AND LOCATION OF INTERVENTIONS

2.5.3.1. SELECTION OF RETURN PERIODS OF FLOOD FOR ASSESSING THE HIGH FLOOD

Levels (HFL) Option-3 pertaining to Model Code: BW150-W0-BB0 is selected for model simulation. The results would be the same for Option-4, pertaining to BW150-W0-BB1

25-year return period of flood has been selected to ascertain the High Flood Level (HFL) for left embankment of Amta channel considering the presence of vital installations on that side as already explained in Paragraph 2.2.

10-year return period is considered for the dwarf embankment on the right bank of Amta channel to assess the HFL, keeping in view of its lesser strategic importance compared to the left side embankment, which is being considered as the main flood protecting embankment since last 200 years. In addition, procurement of land for raising and strengthening the right side embankment to withstand higher return period floods would be almost impossible and has accordingly been ruled out. Following the same logic, design floods for Upper Rampur left and Hurhura eft embankments are considered to have 10-year return period.

Figure 0-32 shows longitudinal profile of HFL for 10-year return period (blue line) along with crest level of existing dwarf embankment on the right bank of Amta channel (orange line). Figure 0-33 shows longitudinal profile of HFL for 25-year return period (blue line), of HFL+1m (in green line) alongwith existing crest level of embankments on the left side (in orange). There is generally no need of considering any free board above HFL or the Amta channel right embankment as this embankment would spill in case of floods having return period more than 4 years. The embankment section would be adequately protected against breaching, even during overbank spilling. However, such spilling can not be allowed for left embankment along Amta channel and requirement of free board is well established. The minimum free board prescribed in IS:12094-2000 (Guidelines for Planning and Design of River Embankments) as a guidance in absence of detailed analysis is 1.5 upto a design discharge of 3000 cumec, which should be applicable for Amta channel from discharge point of view. Reason of maintaining the free board as per IS code is to avoid overtopping in cases of intense wave action, unexpected rise of river level due to change in the river course or aggradation of river bed or settlement of embankment. None of the conditions are truly applicable for Amta channel left embankments which are century old, generally quite stable and not subjected to intense wave action. Amta channel bed is also in regime condition for many years without any sign of aggradation. Moreover, the discharge figures corresponding to different return periods are also on the conservative side as attenuation in channel valley has been disregarded. It would also not be possible to acquire additional land for bigger section of embankment, if the free board is considered as 1.5m. In view of all these aspects, free board in case of Amta channel left embankment is fixed as 1.0m.

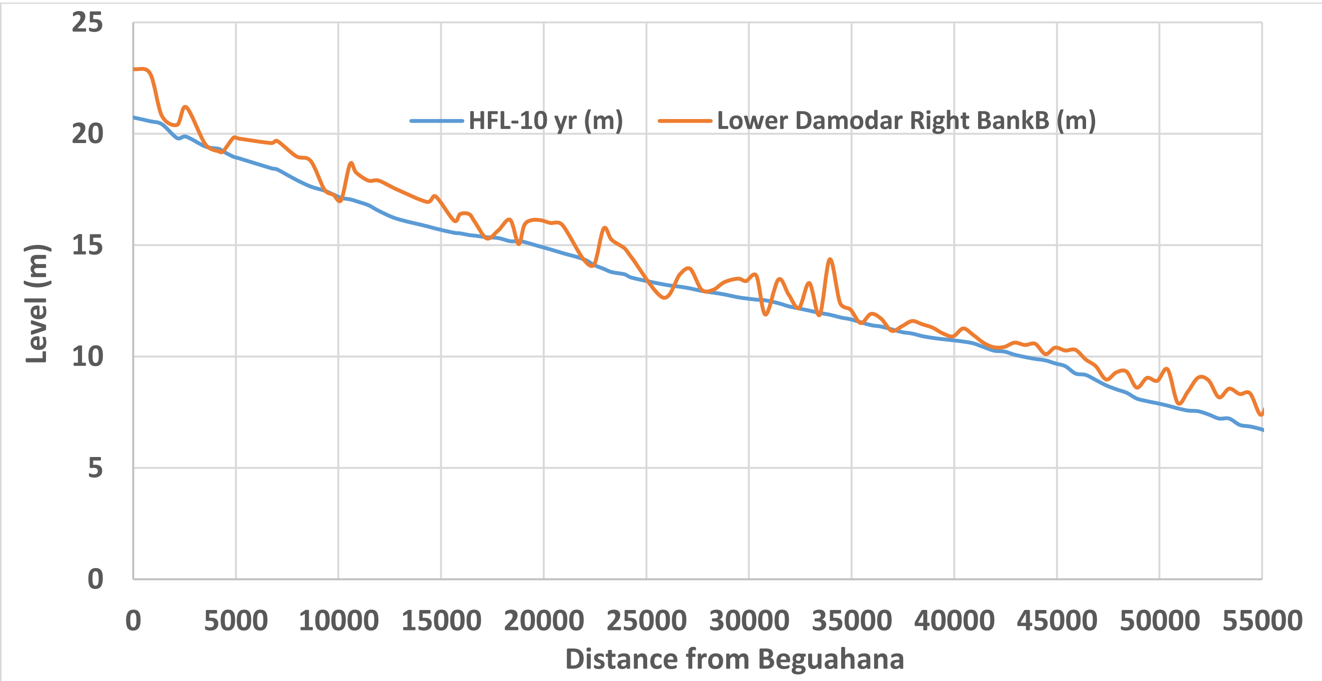


Figure 0-32 Longitudinal profile of Lower Damodar for 10 yr return period

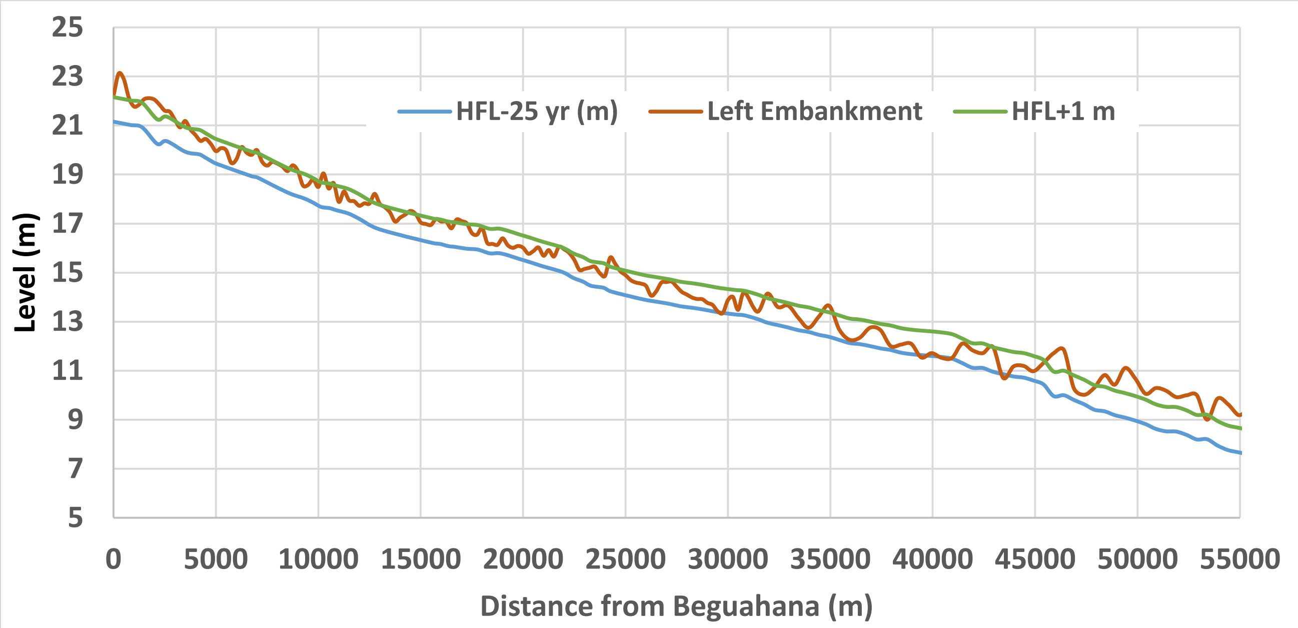


Figure 0-33 Longitudinal profile of Lower Damodar for 25 yr return period along with left embankment and HFL+1 m

2.5.3.2. IDENTIFICATION OF EMBANKMENT STRETCHES FOR IMPROVEMENT BASED ON HFLS

Based on these HFL stretches required for armouring of right embankment bank and flood wall at left embankment of Amta channel for Howrah and Hooghly districts have been identified and corresponding stretch lengths has been assessed by simulating the model. Results for Amta channel are given in Table 0-19, Table 0-20, Table 0-21 and Table 0-22.

Table 0-19 Location of armouring of country side slope including the crest of embankment by cement concrete with suitable energy dissipating arrangement for allowing spill (Based on 10yr design discharge) for Howrah

Chainage			From		To		From		To	
From	To	Length	Longitude	Lattitude	Longitude	Lattitude	X	Y	X	Y
50825	50975	150	87.978	22.631	87.977	22.630	600501.9	2502989	600411.6	2502895
45870	47430	1560	88.000	22.661	87.991	22.657	602706.1	2506329	601809	2505903
44314	45034	720	87.995	22.672	87.998	22.665	602228.5	2507526	602526.6	2506735
40770	42730	1960	87.995	22.700	87.999	22.685	602196.3	2510606	602571.3	2508984
39170	40230	1060	87.992	22.712	87.991	22.703	601907.1	2511932	601766.6	2511028
36270	37730	1460	87.987	22.736	87.990	22.723	601360.6	2514627	601645.8	2513185

Chainage		Length	From		To		From		To	
From	To		Longitude	Lattitude	Longitude	Lattitude	X	Y	X	Y
34870	35930	1060	87.995	22.744	87.989	22.738	602151	2515531	601584.2	2514871
33200	33730	530	87.992	22.758	87.992	22.754	601875.1	2517111	601895.5	2516619
32000	32700	700	87.990	22.769	87.990	22.763	601603.1	2518310	601662.9	2517572
30450	31250	800	87.983	22.781	87.988	22.775	600913.9	2519563	601449.2	2518990

Table 0-20 Location of armouring of country side slope including the crest of embankment by cement concrete with suitable energy dissipating arrangement for allowing spill (Based on 10yr design discharge) for Hooghly

Chainage		Length	From		To		From		To	
From	To		Longitude	Lattitude	Longitude	Lattitude	X	Y	X	Y
27350	28700	1350	87.968	22.804	87.974	22.791	599337	2522141	599995	2520747
24800	26600	1800	87.961	22.827	87.966	22.810	598661	2524639	599104	2522855
21500	22700	1200	87.969	22.852	87.969	22.845	599420	2527489	599452	2526648
18400	19100	700	87.952	22.872	87.953	22.866	597690	2529702	597761	2529039
16700	17950	1250	87.952	22.888	87.951	22.877	597627	2531422	597602	2530204
8950	10450	1500	87.971	22.938	87.972	22.933	599567	2536998	599682	2536456
3250	4800	1550	87.972	22.978	87.969	22.970	599603	2541376	599325	2540560
1200	2350	1150	87.961	22.990	87.970	22.982	598453	2542788	599376	2541841

Table 0-21 Location of Construction of flood wall in left bank of Damodar (embankment top ≤ HFL+1.00m and based on 25yr design discharge) for Howrah

Chainage		Length	From		To		From		To	
From	To		Longitude	Lattitude	Longitude	Lattitude	X	Y	X	Y
34970	45591	10621	87.999	22.743	88.004	22.663	602563.8	2515454	603145.7	2506573
46531	48023	1492	87.999	22.656	87.989	22.651	602671.5	2505730	601639.6	2505245
53165	53585	420	87.975	22.615	87.978	22.611	600251.7	2501253	600558.4	2500736

Table 0-22 Location of Construction of flood wall in left bank of Damodar (embankment top ≤ HFL+1.00m and based on 25yr design discharge) for Hooghly

Chainage		Length	From		To		From		To	
From	To		Longitude	Lattitude	Longitude	Lattitude	X	Y	X	Y
3700	6900	3200	87.97793	22.97508	87.96163	22.95287	600242	2541095	598587	2538625
8600	12700	4100	87.97164	22.94664	87.97882	22.91528	599618	2537942	600377	2534475
14500	24200	9700	87.96942	22.90238	87.96743	22.83025	599422	2533041	599271	2525054
24900	34970	10070	87.96602	22.82517	87.99889	22.74334	599129	2524491	602563.8	2515454

2.6. GENERATION OF FLOOD INUNDATION CONSIDERING "WITH PROJECT" CONDITION

2.6.1. OBJECTIVE

The objective of generation of inundation maps is to assess the extent and depth of inundation "with interventions" in the post project scenario, corresponding to the past floods which already occurred and had established record of damages. Damage caused in the post project scenario by these floods with the assessed depth and duration of inundation would be converted into economic costs by the Economist to have a direct comparison of such costs with the costs assessed from the recorded damage data in the pre-project scenario.

2.6.2. CONSIDERATIONS

In this section, flood inundation map is generated in "with project" condition considering Option3: BW150-W0-BB0 (Refer to Table 0-18), and discharges with relevant HFLs for different return periods of flood.

2.6.3. METHODOLOGY

Out of 14 years of floods (in between 1999 to 2017) having recorded damage data, predicted discharges in 8 years (2004,2005,2008,2010,2011,2013,2015&2016) are having return period of 4 years or less as per model analysis. There would be practically no damage in these 8 years as there would be no inundation in the post project period under "with project" condition. Hence inundation maps are generated for remaining 6years (1999, 2000, 2006, 2007.2009&2017). Two more inundation maps are generated with and without breaching of left embankment of Amta channel. Table 0-23 below represents year, return period, maximum discharge, and total inundated area. Block wise inundated area and depth have been shown in Table 0-24 to Table 0-29. Two more tables, i.e. Table 0-30 & Table 0-31 are added in the list to represent the Blockwise inundation data corresponding to 25-year return period of flood in "without breach to left embankment of Amta channel " and "with breach to left embankment" condition respectively.

Table 0-23 Summary of flood inundation

Year	Max discharge at Durgapur (m^3/s)	Return period	Inundated area (km^2)	Remarks
1999	6122.1	5.7	183.5	See table 6-2

Year	Max discharge at Durgapur (m^3/s)	Return period	Inundated area (km^2)	Remarks
2000	6322.9	6.3	215.5	See table 6-3
2004	1971.1	1.34		No damage
2005	1058.3	1.13		No damage
2006	7693	11.6	347	See table 6-6
2007	8373.3	16	609	See table 6-5
2008	2664.6	1.58		No damage
2009	8823.5	20	742	See table 6-7
2010	243.5	<1		No damage
2011	4050.1	2.48		No damage
2013	4622.7	3.1		No damage
2015	3631.6	2.14		No damage
2016	3412.2	1.98		No damage
2017	7063.6	9.1	262.97	See table 6-4
25yr without breaching of left bank	9311	25	762.51	See table 6-8
25yr with breaching of left bank	9311	25	1061	See table 6-9

Table 0-24 Detailed block wise inundation for Year 1999

Block Name	Area Inundated (km2)	Average Depth (m)	Remarks
Pursurah	0.2	0.35	between Upper Rampur and Lowerdamodar
Pursurah	10	0.9	
Udaynaraynpur	0.2	0.3	
Khanakul I	40	0.6	

Block Name	Area Inundated (km2)	Average Depth (m)	Remarks
Khanakul II	68.1	1.08	Between lower damodar right and left Hurhura
Amta II	49	0.65	
Amta II	16	1.85	Between Hurhura right Rupnarayan river

Table 0-25 Detailed block wise inundation for Year 1999

Block Name	Area Inundated (km2)	Average Depth (m)	Remarks
Pursurah	3	0.65	between Upper Rampur and Lowerdamodar
Pursurah	15.7	1	
Udaynaraynpur	2.5	0.4	
Khanakul I	60	0.67	
Khanakul II	68.1	1.12	Between lower damodar right and left Hurhura
Amta II	50.2	0.7	
Amta II	16	1.9	Between Hurhura right Rupnarayan river

Table 0-26 Detailed block wise inundation for Year 2017

Block Name	Area Inundated (km2)	Average Depth (m)	Remarks
Pursurah	6	0.88	between Upper Rampur and Lowerdamodar
Pursurah	20.2	1.14	
Udaynaraynpur	4.5	0.52	
Khanakul I	65	0.82	
Khanakul II	91	1.3	Between lower damodar right and left Hurhura
Amta II	60.27	0.8	
Amta II	16	2	Between Hurhura right Rupnarayan river

Table 0-27 Detailed block wise inundation for Year 2007

Block Name	Area Inundated (km2)	Average Depth (m)	Remarks
Pursurah	9	1.48	between Upper Rampur and Lowerdamodar
Pursurah	70	1.24	
Udaynaraynpur	52	0.8	
Khanakul I	121	1.18	
Khanakul II	120	1.97	Between lower damodar right and left Hurhura
Amta II	80	1.5	
Amta II	16	3.05	Between Hurhura right Rupnarayan river
Raina II	24	0.25	
Arambagh	117	0.58	

Table 0-28 Detailed block wise inundation for Year 2006

Block Name	Area Inundated (km2)	Average Depth (m)	Remarks
Pursurah	7	0.92	between Upper Rampur and Lowerdamodar
Pursurah	30	1.25	
Udaynaraynpur	26	0.78	
Khanakul I	80	0.89	
Khanakul II	101	1.57	Between lower damodar right and left Hurhura
Amta II	63.4	0.97	
Amta II	16	2.3	Between Hurhura right Rupnarayan river
Raina II	9.6	0.21	
Arambagh	14	0.47	

Table 0-29 Detailed block wise inundation for Year 2009

Block Name	Area Inundated (km2)	Average Depth (m)	Remarks
Pursurah	10	1.48	between Upper Rampur and Lowerdamodar
Pursurah	81	1.28	
Udaynaraynpur	84	1.19	
Khanakul I	150	1.38	
Khanakul II	125	3.2	Between lower damodar right and left Hurhura
Amta II	108	3.93	
Amta II	16	3.8	Between Hurhura right Rupnarayan river
Raina II	28	0.28	
Arambagh	140	0.51	

Table 0-30 Detailed block wise inundation for 25 year without left bank breach

Block Name	Area Inundated (km2)	Average Depth (m)	Remarks
Pursurah	10.51	1.59	between Upper Rampur and Lowerdamodar
Pursurah	85	1.37	
Udaynaraynpur	88	1.29	
Khanakul I	150	1.45	
Khanakul II	125	3.3	Between lower damodar right and left Hurhura
Amta II	108	4.14	
Amta II	16	4.05	Between Hurhura right Rupnarayan river
Raina II	28	0.37	
Arambagh	152	0.65	

Table 0-31 Detailed block wise inundation for 25 year with left bank breach

Block Name	Area Inundated (km2)	Average Depth (m)	Remarks
Pursurah	10.51	1.59	between Upper Rampur and Lowerdamodar
Pursurah	85	1.37	
Udaynaraynpur	54	0.96	
Khanakul I	150	1.45	
Khanakul II	125	3.3	Between lower damodar right and left Hurhura
Amta II	108	3.3	
Amta II	16	4.02	Between Hurhura right Rupnarayan river
Raina II	28	0.37	
Arambagh	152	0.65	
Amta I	115.5	1.45	due to breach on left bank
Uluberia II	12	1.56	due to breach on left bank
Bagnan I	4.5	1.77	due to breach on left bank
Jagatballavpur	43.8	1.1	due to breach on left bank
Jangipara	78	0.95	due to breach on left bank
Tarakeswar	61	0.9	due to breach on left bank
Haripal	9	1	due to breach on left bank
Udaynaraynpur	9.5	0.75	Left of Left bank due to breach
Raillway	18 km		due to breach on left bank
Road	30 km		due to breach on left bank

2.6.4. PRESENTATION ON SAMPLE BASIS

Flood inundation maps for year 1999, 2006 and also breach to left embankment of Amta channel (Lower Damodar) in 25-year return period of flood have been generated by model simulation in the post project period (with project" condition) are appended as representative samples in Figure 0-34, Figure 0-35 and Figure

0-36. All floodmaps are given drawing folder (Refer: EIPL/MAPS/DFSR/15 to EIPL/MAPS/DFSR/22)

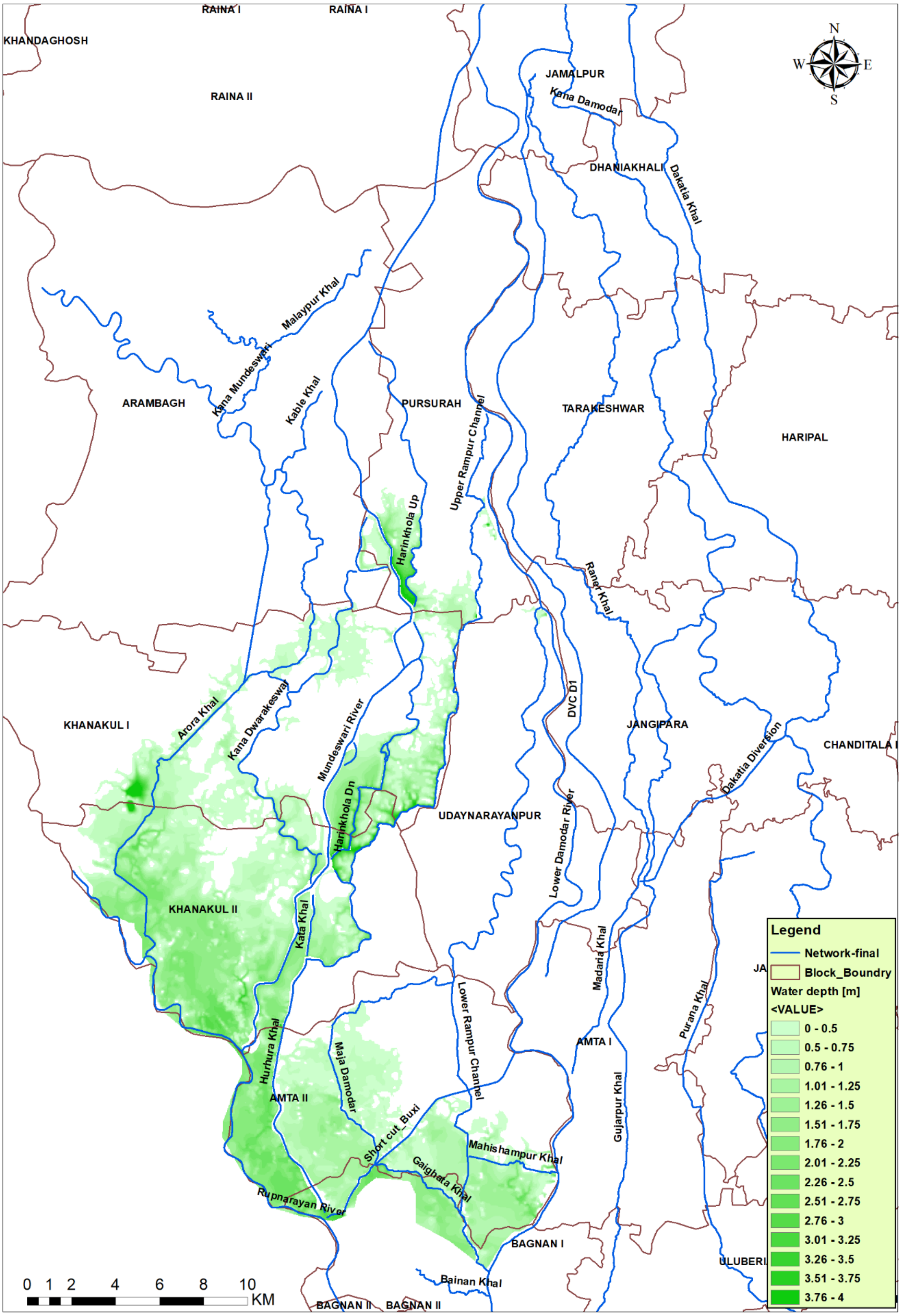


Figure 0-34 Flood inundation map for 1999 (Return period 5.7 year)

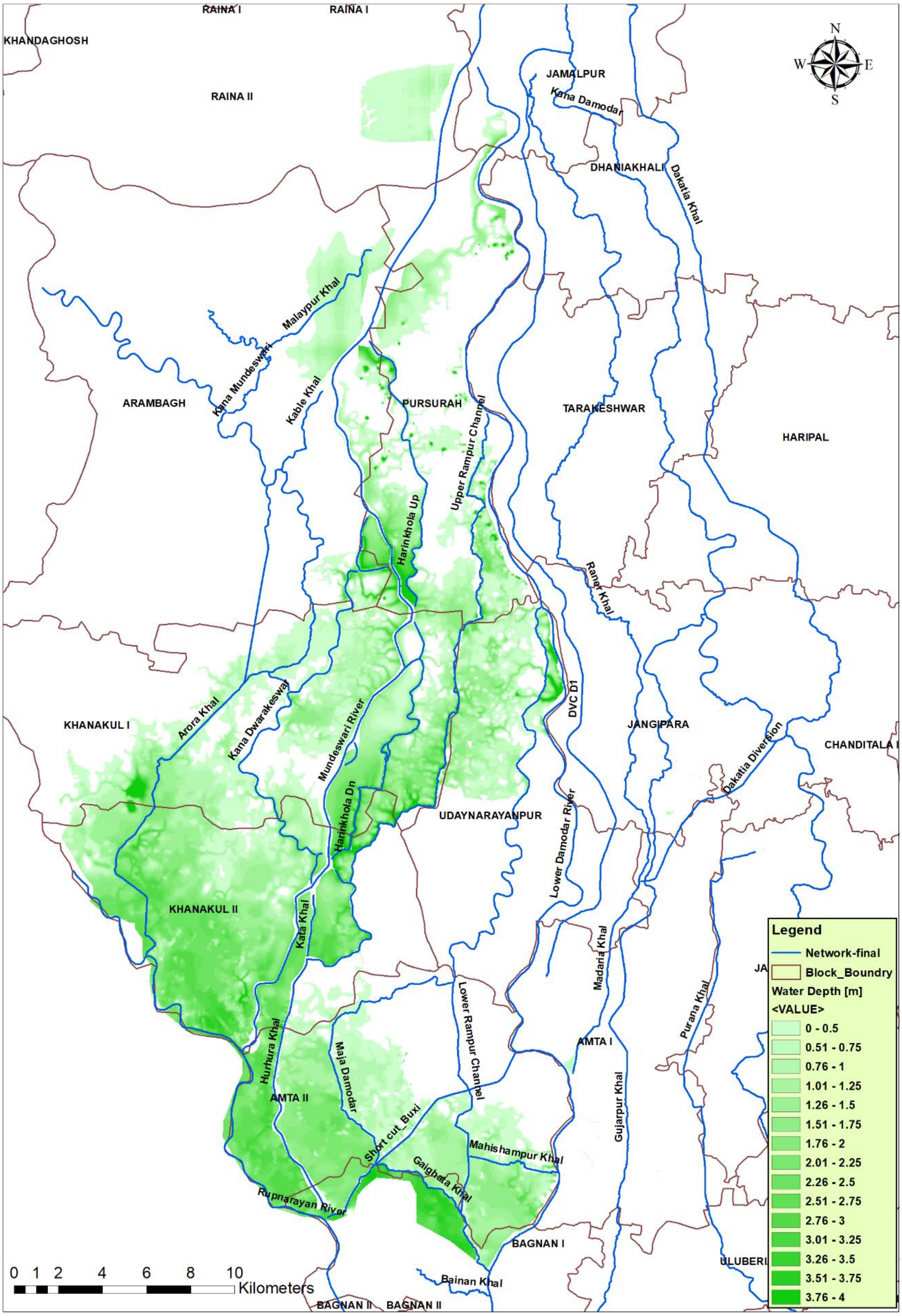


Figure 0-35 Flood inundation map for 2006 (Return period 11.6 year)

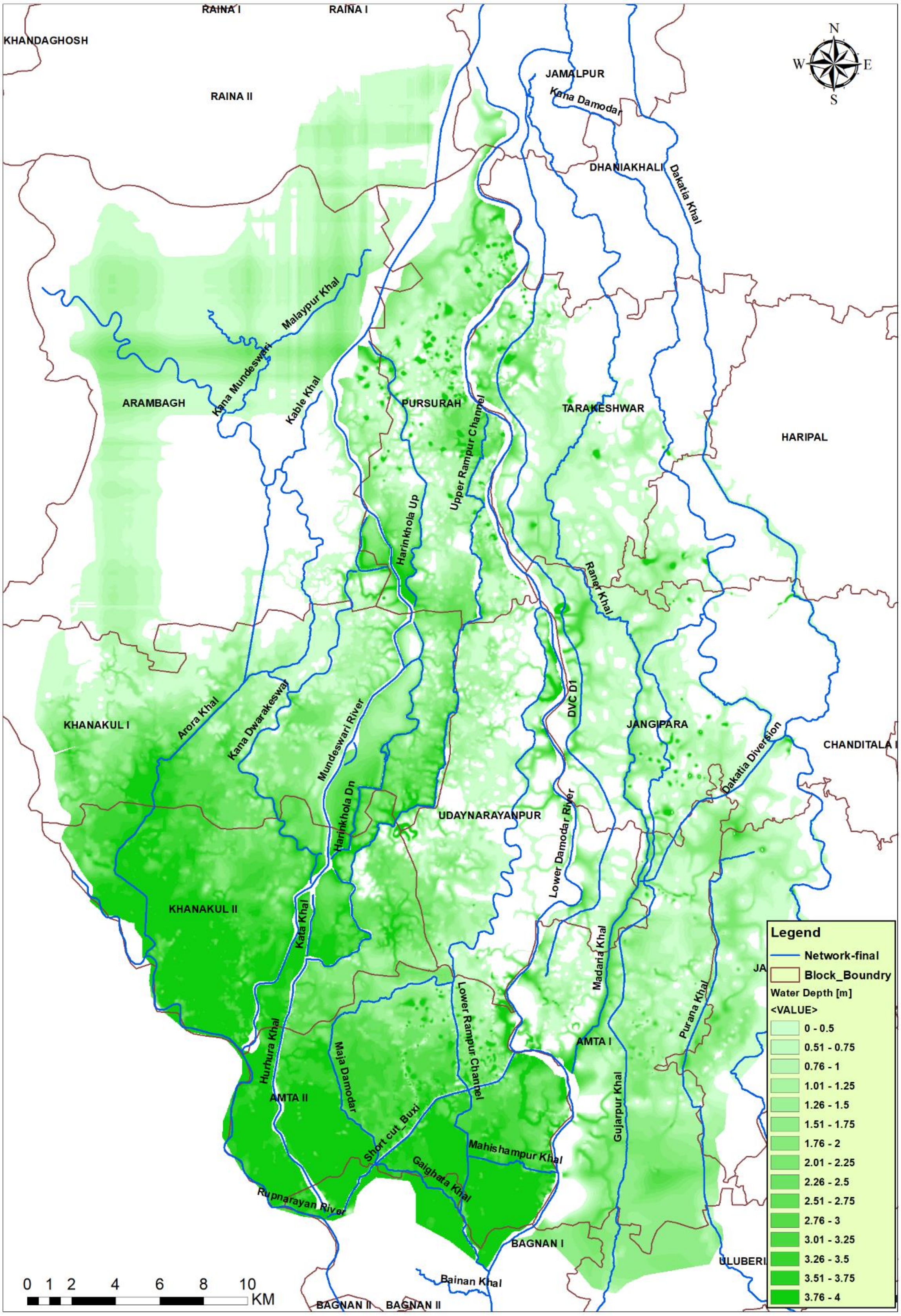


Figure 0-36 Flood inundation map for left bank breach (Return period 25 year)

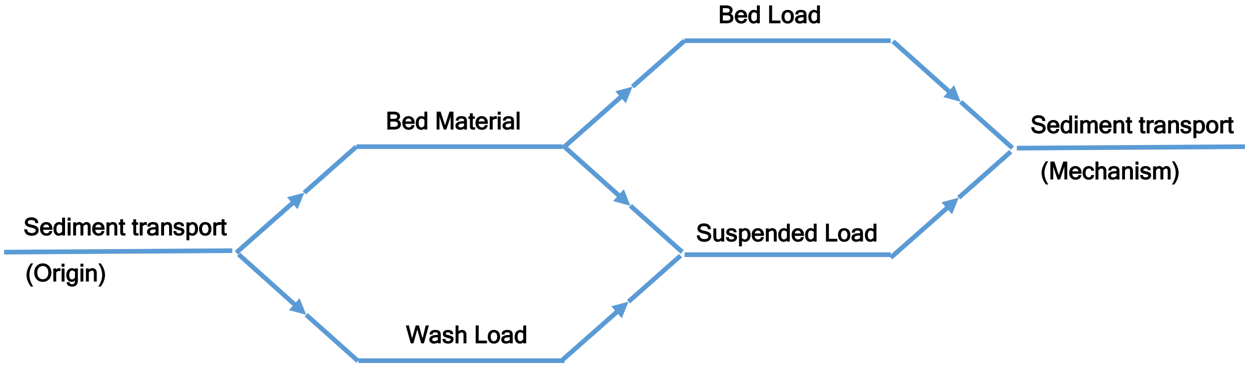
2.7. SEDIMENT STUDY

This section deals with sediment study and analysis, with the available inputs to further facilitate decision making on selection of particular components, e.g. submerged bed bars, and also to assess sustainability of the desilted section of Mundeswari River required for formulating appropriate maintenance strategy in the post project period.

2.7.1. MODE OF TRANSPORT: WASH LOAD, SUSPENDED LOAD OR BED LOAD

Traditionally, three types of sediment transport are defined: Bed load, suspended load and wash load. Among others, a comprehensive description is given by Engelund and Hansen (1967) and Jansen et al. (1979).

The latter defines bed load transport as the transport of bed material that is rolling and sliding along the bed. Suspended load transport is defined as the transport of sediment, which is suspended in the fluid for some time. According to the mechanism of suspension, suspended sediment may belong to the bed material and the wash load. Wash load is defined as the transport of material finer than the bed material. It has no relation to the transport capacity of the stream. Usually, a grain diameter of around 0.06 mm (silt and clay) divides the region of wash load and bed material load.



2.7.2. SEDIMENT TRANSPORT MODELS

For morphological development of alluvial rivers with interaction between bed bathymetry and hydrodynamics, only bed material transport is of interest. Thus, only bed load and the part of the suspended load originating from the bed material is considered. The behaviour of suspended load is fundamentally different from that of bed load, which has to be taken into consideration in the sediment transport modelling.

A variety of sediment transport formulae for bed load and non-cohesive suspended load exist and each representative for certain type of river flow regimes. The differences between transport rate predictions from individual formulas and assuming the same basic sediment properties can easily exceed a factor of say 5. Thus, there is inherently a large uncertainty in sediment transport predictions. Accurate calibration based on extensive sediment data (bed load transport, suspended load transport, grain sizes of bed load and suspended load etc.) is required for selecting the most appropriate model.

2.7.3. SUBMERGED BED BAR

Two dimensional model set up for hydrodynamic study described in section 0 is used for sediment study. Grain size i.e. d_{50} is considered as 0.31 mm (see section 2.3.5). Sediment transport have been estimated by the 2-D model by using VanRijn sediment transport formula. Simulation is done for Bankful discharge (4 yr return period), 10 year return period and 25 year return period of discharge. Model result for bed level change with and without bedbar for 10 year return period is shown in Figure 0-37. Initial bed level, bed level with and without bedbar is shown in Figure 0-38. It shows very negligible changes in bed level between with and without bedbar. Cross-section of Mundeswari River at existing condition, without and with bed bar are shown to illustrate the effect of bed bar. Cross-sections are extracted at 1900 m and 2700 m from Beguahana (Figure 0-39). It shows slight erosion for without and with bed bar respective to existing condition. It is also noticed that minor difference in bed level without and with bed bar.

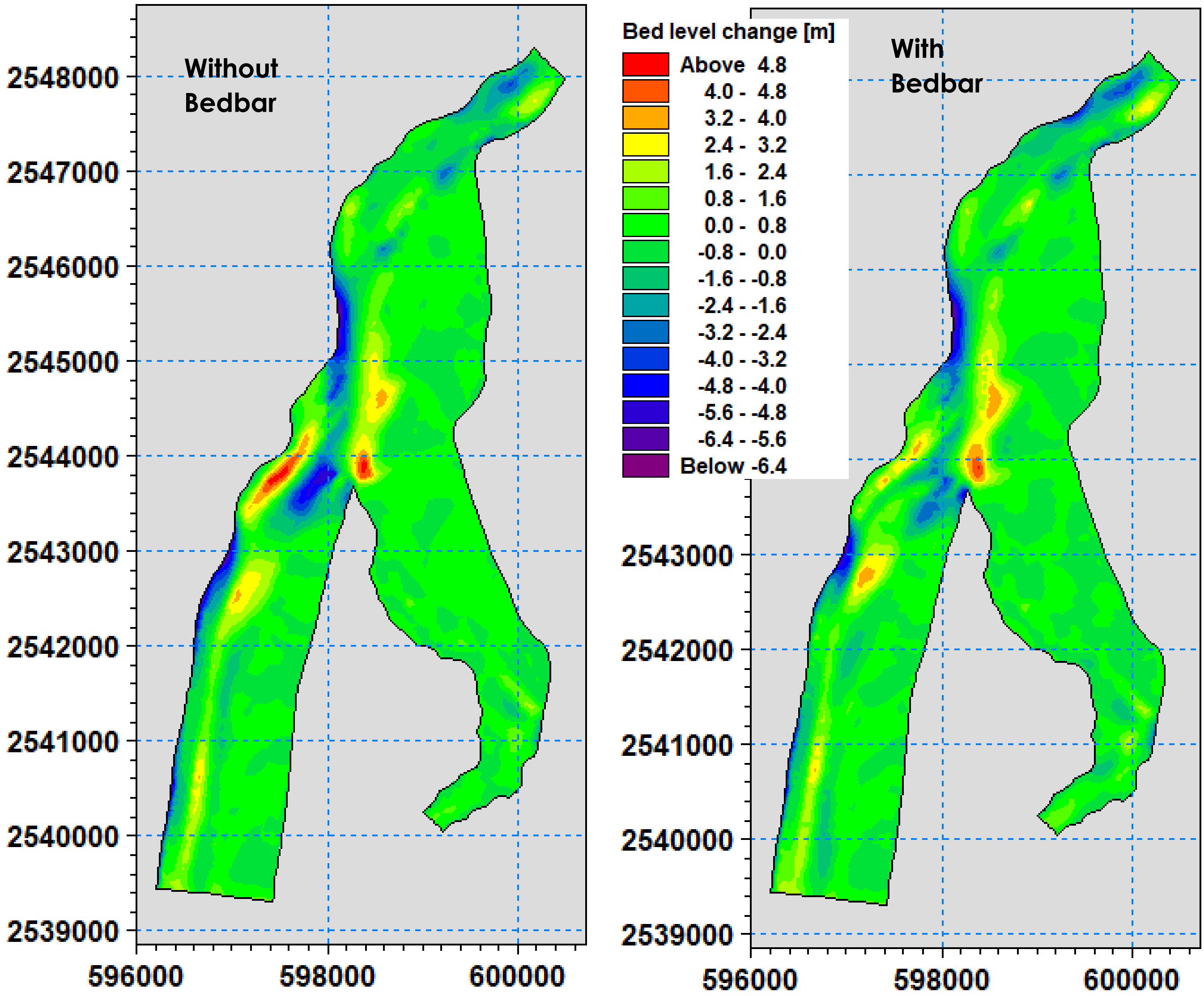


Figure 0-37 Bed level change with and without bedbar (10 year design discharge)

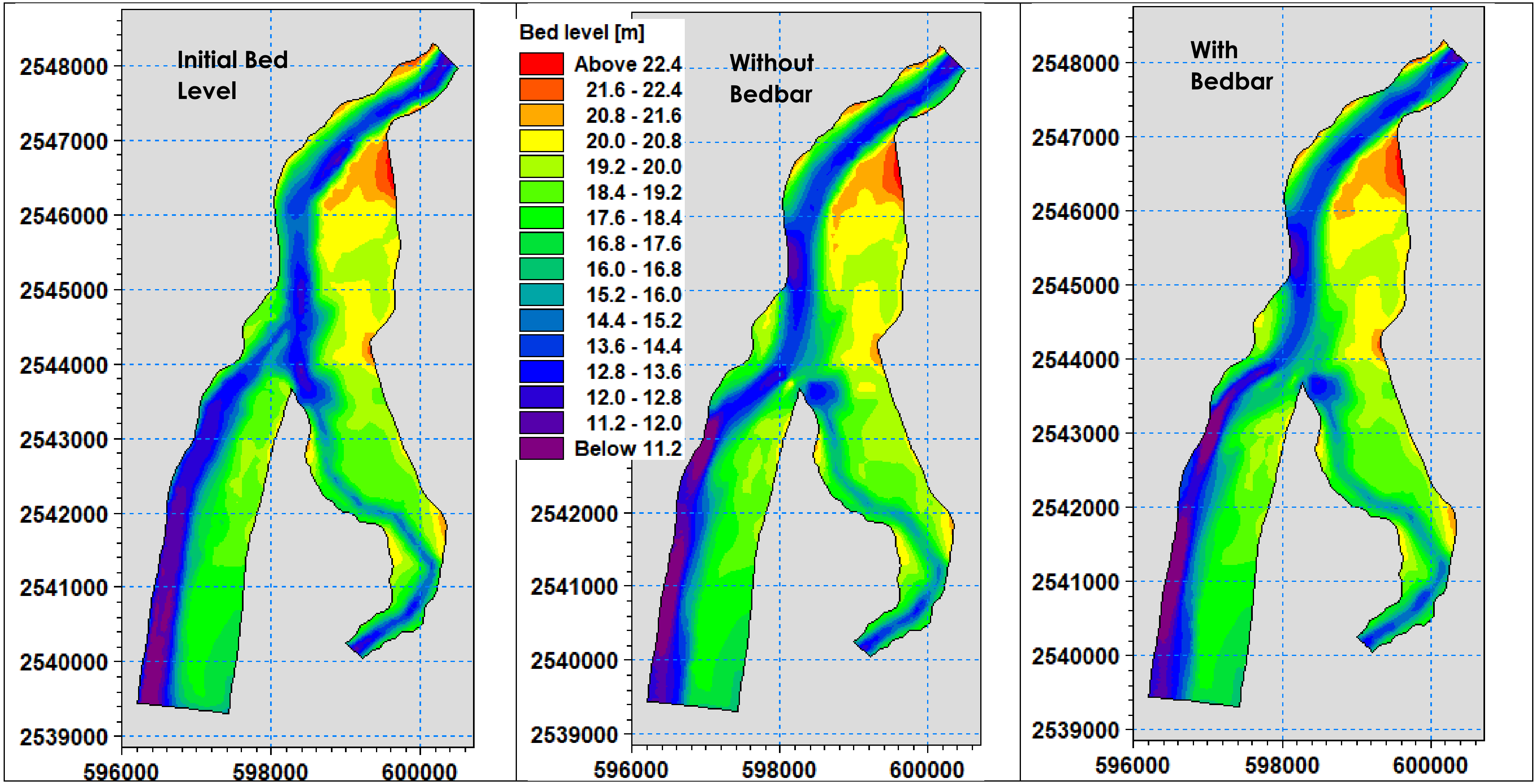
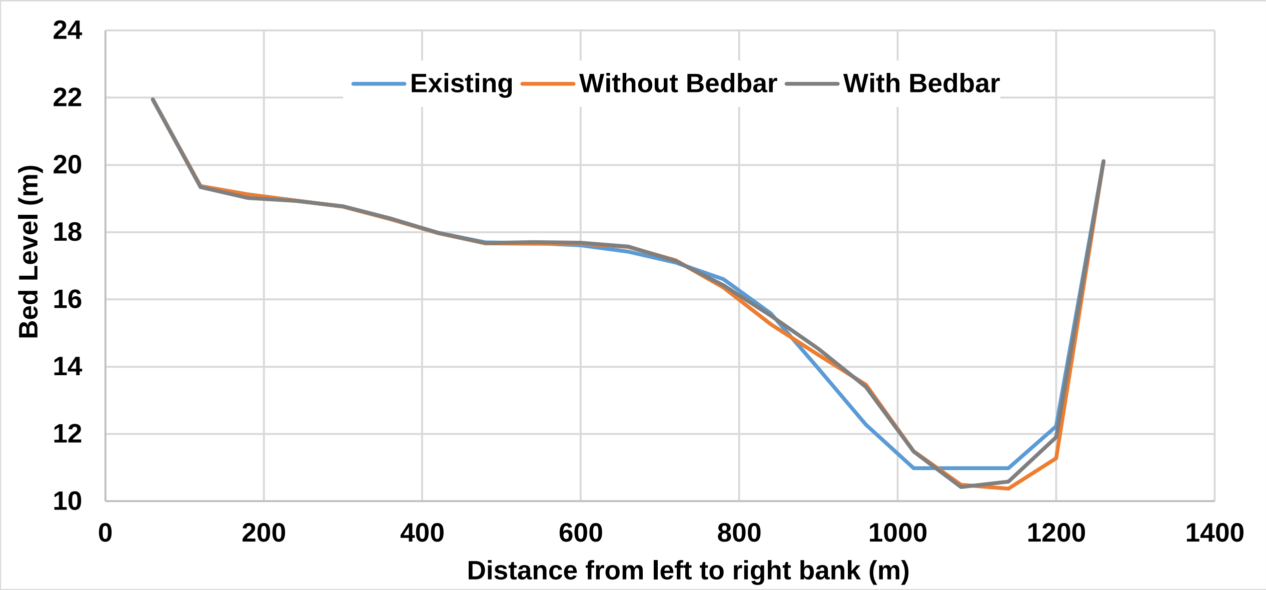


Figure 0-38 Simulated Bed level (from left to right: Initial bed level, without bedbar, with bedbar)



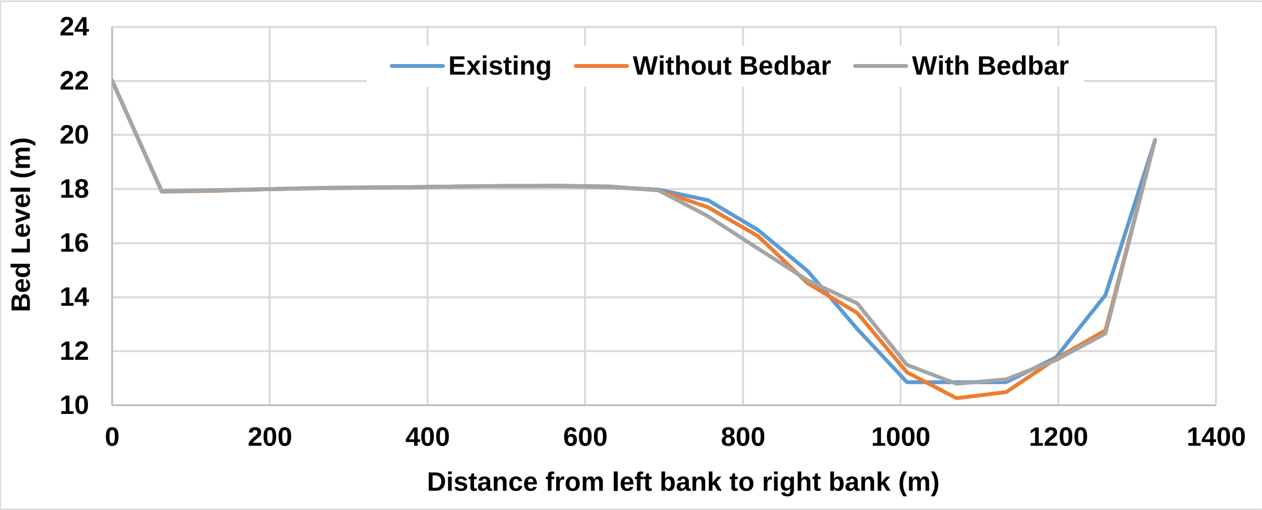


Figure 0-39 Cross-section at chainage 1900 m (Top) and 2700 m (Bottom) [existing, without bed bar and with bed bar]. Discharge is of 10 year return period

2.7.4. SUSTAINABILITY OF DESILTED CHANNEL

The sustainability of desilted channel are also studied to strategize maintenance of the channel. Model is simulated to determine the long term morphological trends in the Mundeswari River bed. This is important particularly as long term aggradation (rise) of the river bed would have significant consequences for the sustainability of the desilted channel. In this study 40 years are considered as project period. Therefore model is simulated for 40 years to estimate average annual deposition and erosion rate of desilted channel.

Grain size i.e. d_{50} is considered as 0.31 mm (see section 2.3.5). Sediment transport have been estimated by using VanRijn sediment transport formula. Daily outflow data at Durgapur Barrage is available for 1991-2001 and 2005-2017. Daily suspended sediment load is available for 1990-2011. Common time period is 1991-2001 and 2005-2011 i.e. 18 years. These 18 years of discharge are repeated to generate 40 years of discharge and used as major input in the model. There is no observed bed load available. Hence time series of bed load is generated using the model. Upstream boundary condition used as sediment supply. This boundary condition is applied when neither the bottom level nor the sediment transport is known. Instead the inflow of sediment is computed by the sediment transport engine and set equal to the sediment transport capacity based on velocity, cross-section area, longitudinal slope and grain size. Average annual observed bed load is 15% of suspended load which gives 0.15x1 = 0.15 MCM (section 2.3.4). The model is simulated initially for 18 years and bed load is estimated. The table shows bed load for different year. Average annual bed load is 0.156 MCM which matches with observed bed load. These 18 years of bed load are repeated to generate 40 years of bed load and used as an input.

Table 0-32 Simulated Bed Load for 1991-2011

Year	Simulated Bed Load (MCM)	Year	Simulated Bed Load (MCM)
1991	0.104	2001	0.052
1992	0.012	2005	0.02
1993	0.127	2006	0.23
1994	0.271	2007	0.358
1995	0.249	2008	0.164
1996	0.15	2009	0.133
1997	0.187	2010	0.001
1998	0.123	2011	0.207
1999	0.272	**Average Annual Bed Load**	**0.156**
2000	0.147		

Figure 0-40 shows longitudinal profile of design bed level (black line) and bed level after 40 year (brown line). It is observed that deposition occurs downstream of Beguahana and continues upto 25 km excluding 4 km in piecemeal. After that erosion is observed. The average annual rate of deposition varies from 0.0006 m/year to 0.087m/year. The same for erosion is varying between 0.0005 m/year and 0.075 m/year. Within the overall length of 30.6 km (from 9.4 km to 40 km in Figure 0-21), 21 km experience deposition whereas erosion occurs in 9.6 km.

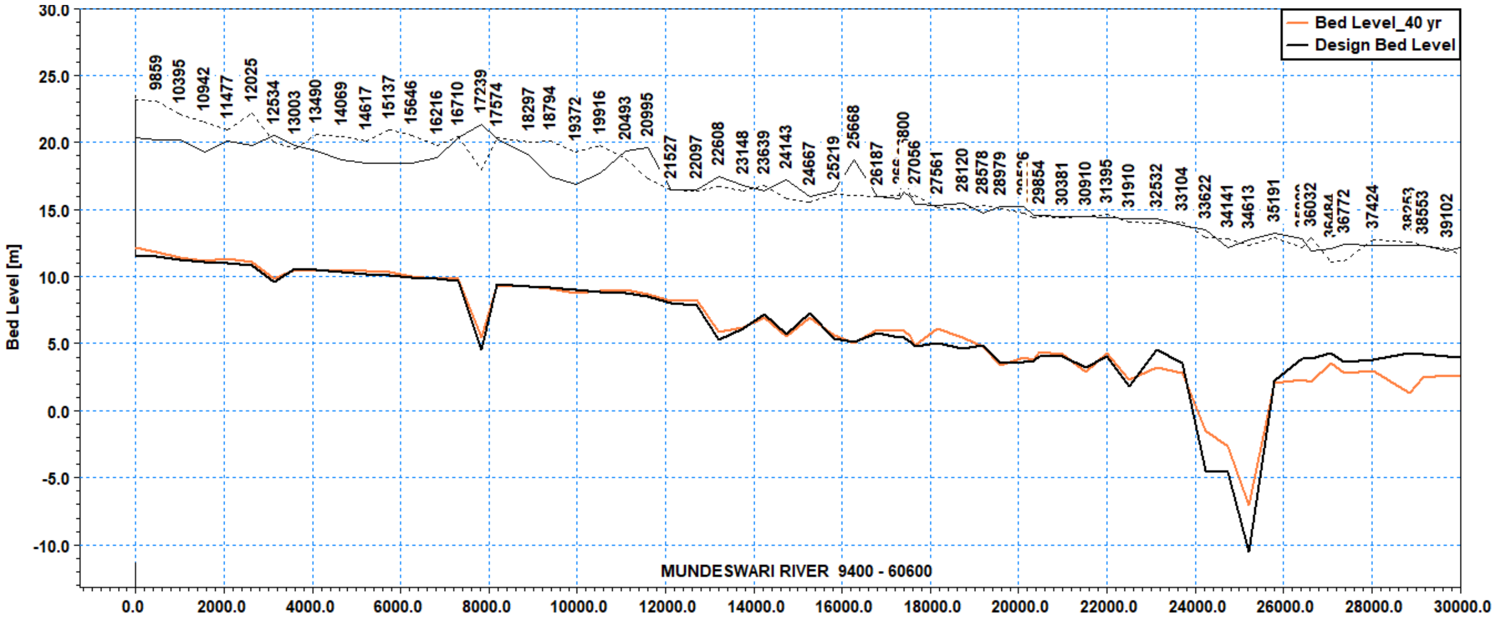


Figure 0-40 Longitudinal profile of bed level of Mundeswari River (Design bed level and Bed level after 40 year)

Average annual bed level change at different locations are given in table based on 40 year of simulation.

Table 0-33 Average annual bed level change at different location (Negative is erosion and positive is deposition) (Chainage at Beguahana is 9400 m, Figure 0-21)

Chainage (m)	Bed Level Change (m)	Chainage (m)	Bed Level Change (m)	Chainage (m)	Bed Level Change (m)
9400	0.014	20492.9	0.008	29736.1	0.001
9858.58	0.007	20994.7	0.005	29854	0.009
10395.2	0.006	21527.3	0.004	30380.7	0.005

Chainage (m)	Bed Level Change (m)	Chainage (m)	Bed Level Change (m)	Chainage (m)	Bed Level Change (m)
10941.8	0.001	22097.2	0.011	30910.3	-0.008
11476.7	0.008	22608.5	0.014	31394.7	0.006
12025.3	0.005	23148.5	0.004	31909.6	0.014
12534.4	0.006	23639.5	-0.008	32532.4	-0.033
13003.4	-0.003	24143.1	-0.006	33103.7	-0.019
13489.9	-0.002	24666.7	-0.008	33621.5	0.076
14068.7	0.005	25218.7	0.007	34140.6	0.049
14616.6	0.005	25668.3	-0.003	34612.9	0.087
15137	0.008	26187.4	0.007	35190.6	-0.006
15646.1	0.001	26693	0.012	35819.9	-0.041
16215.8	0.001	26800.4	0.012	36031.5	-0.043
16709.8	0.004	26945.8	0.01	36483.6	-0.018
17238.5	0.024	27055.7	0.002	36772.5	-0.025
17573.6	-0.004	27560.6	0.029	37423.7	-0.02
18296.8	-0.002	28120.1	0.021	38253.2	-0.075
18793.9	-0.002	28578	-0.004	38552.6	-0.041
19371.5	-0.006	28979.3	-0.001	39102.2	-0.036
19915.7	0.002	29526	0.01	39582.5	-0.038

It would be concluded that average annual deposition rate is less and have not observed significant bed level changes. Hence maintenance strategy is not required. However it is recommended to survey cross-section once in two years to quantify deposition and take care the pilot channel.

While the best available technology has been applied to model study, the available data are minimally adequate to conduct the study. River morphology is essentially a chaotic process. It is essential that river flows and morphology are closely monitored in the long term. In absence of bed load measurements assumptions are made based on Indian standards. It is advisable to carry out bed load measurement at few locations to establish relation between suspended load and bed load.