Terms of Reference for Mathematical Model Study on the Darakeswar-Rupnarayan River System in the Districts of Howrah, Hooghly, East and West Midnapore, West Bengal, India

Background

The Government of West Bengal (GOWB) has taken up a project titled 'West Bengal Major Irrigation and Flood Management Project" (WBMIFMP) under financing from the International Bank for Reconstruction and Development (IBRD) and from the Asian Infrastructure Investment Bank (AIIB). The total approved cost of WBMIFMP is US$ 490 Million, out of which contribution by each of the Bank is US$ 145 Million. The balance amount of US$ 123 Million is being provided by the GOWB. The project is being implemented by the Irrigation & Waterways Department (IWD) of the GOWB.

2. The Project Development Objectives (PDO) are to improve irrigation service delivery, strengthen flood risk management and improve climate change resilience adaptation in the Project area, in Purba & Paschim Bardhaman, Hooghly and Howrah Districts of the State. A few of the construction activities of the project like improvement of flood embankments on River Lower Damodar River, Amta Channel, Upper Rampur & Hurhurah Khal (Channel) by construction of flood wall, countryside and river side protection etc., have already been grounded.

3. Meanwhile, the project area and the adjoining areas under the sub-basin of other rivers, mainly Darakeswar-Rupnarayan, Silabati & Kangsabati suffered from consecutive floods, firstly during end of July to middle of August 2021and next during end of September to 2nd week of October, due to heavy to very heavy rainfall across a vast area in the project districts of Purba & Paschim Bardhaman, Bankura, Hooghly & Howrah and the adjoining districts of Purba & Paschim Medinipur, extending up to the Upper Damodar-Barakar catchment in Jharkhand, caused by Depression & Low pressure Area in the Bay of Bengal. Heavy releases from the DVC dams in the upstream worsened the flood situation, because of synchronization of such releases with the runoff discharge of the lower catchment. This resulted in breaches & overtopping of embankments and widespread inundation in around 750 sq. km of areas in West Bengal, on each of the occasions, out of which the affected project area on each occasion was around 300 sq.km.

4. Although flooding within the project area was only a fraction of the total inundated area in terms of magnitude and extent of damages, the Darakeswar-Rupnarayan subbasin in Khanakul I & II Blocks in Hooghly district and Amta II Block in Howrah district, contiguous with the Lower Damodar subbasin under the project, suffered from much heavier damages compared to the project area due to more

inundation and loss of public and private properties, for nearly a month. In absence of a defined geophysical boundary between the two sub-basins, it is becoming difficult to showcase and justify the impact of the project, particularly when areas of both the sub-basins lie within the same administrative block boundary. Inter subbasin transfer of water has taken place, as observed during the recent floods and it has been experienced that these two sub-basins, i.e., Darakeswar-Rupnarayan subbasin and the Lower Damodar subbasin are interdependent and inseparable. Severe congestion in the Darakeswar-Rupnarayan River system has been noticed this time, which is the main outfall channel for the project area. Due to apparent shifting of problem of drainage congestion from Lower Damodar River system to this main outfall river, i.e., Darakeswar-Rupnarayan, it has now been felt that the project development objective in flood management sector cannot fully be achieved without addressing the issue of drainage congestion in Darakeswar-Rupnarayan River system, which has not properly been looked into during the hydrodynamic model study conducted for the WBMIFM Project.

5. In this backdrop, the it has been decided to undertake a holistic study on Dwarakeswar-Rupnarayan River system and the Terms of Reference for the consultancy assignment has been prepared accordingly.

Introduction:

6. Upper part of the Rupnarayan River system comprises Darakeswar & its tributary Gandheswari. Darkeaswar has its origin near Lat 23.4286 N & Long 86.5158 E, Block Para, District Purulia. After traversing through Purulia it enters Bankura and meets its first major tributary, Gandheswari, near Lat 23.2277 N & Long 87.1212 E, Block Bankura-I. It then flows to Hooghly District and meets another major tributary, Silabati, near Lat 22.6646 N & Long 87.8117 E, at Bandar, Block Khanakul II. The river system after confluence with Silabati is known as Rupnarayan, flows as along the border of the Hooghly & Howrah Districts along the left bank and Paschim & Purba Medinipur Districts along the right bank. The river ultimately debouches to the Hooghly River near Lat 22.2124 N & Long 88.0478 E (Gadiara, Howrah District on left (eastern) bank & Geonkhali, Hooghly District on right (western bank). From Bandar to Gadiara, the river meets Arora Khal, Mundeswari River Hurhurah Khal and Buxi Khal on the left bank and Chandreaswar Khal, Palaspai & Durbachati Rivers along the right bank, apart from a number of local drainage channels. The Rupnarayan in the State, is one of the most important flood outlets for the four main river subbasin areas (Kangsabati, Shilabati, Darakeswar & Damodar) of the District of Purulia, Paschim Burdwan, Purba Burdwan, Purba Midnapur, Paschim Midnapur, Hooghly & Howrah of West Bengal and also a few districts of Jharkhand (Plate-1). Effect

of tides in River Hooghly also impacts Rupnarayan almost up to Bandar Point, either directly or due to the backwater. Over the years, the river system as a whole has been deteriorating. This has particularly been manifested during formation of successive Low-Pressure Areas in the Bay of Bengal, causing near synchronization of heavy to very heavy widespread rainfall activities in various subbasins stated above and resulting in high discharge in the Rupnarayan River system. Due to acute drainage congestion in Rupnarayan, all the tributaries were flowing very high, overtopping and breaching embankments, causing widespread inundation. (Plate-2).

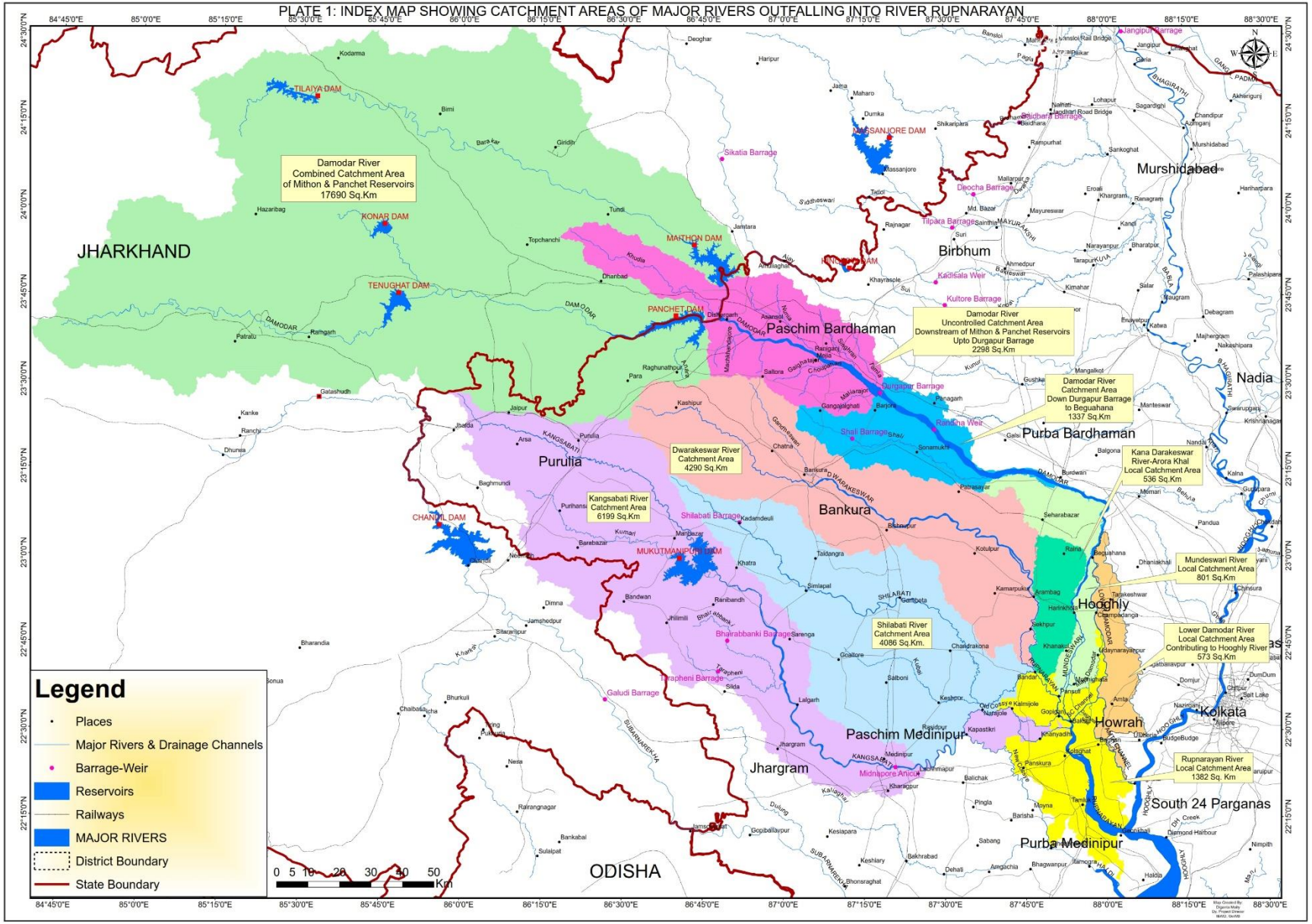

Plate 1: Index Map of Catchment Areas of Rupnarayan River System

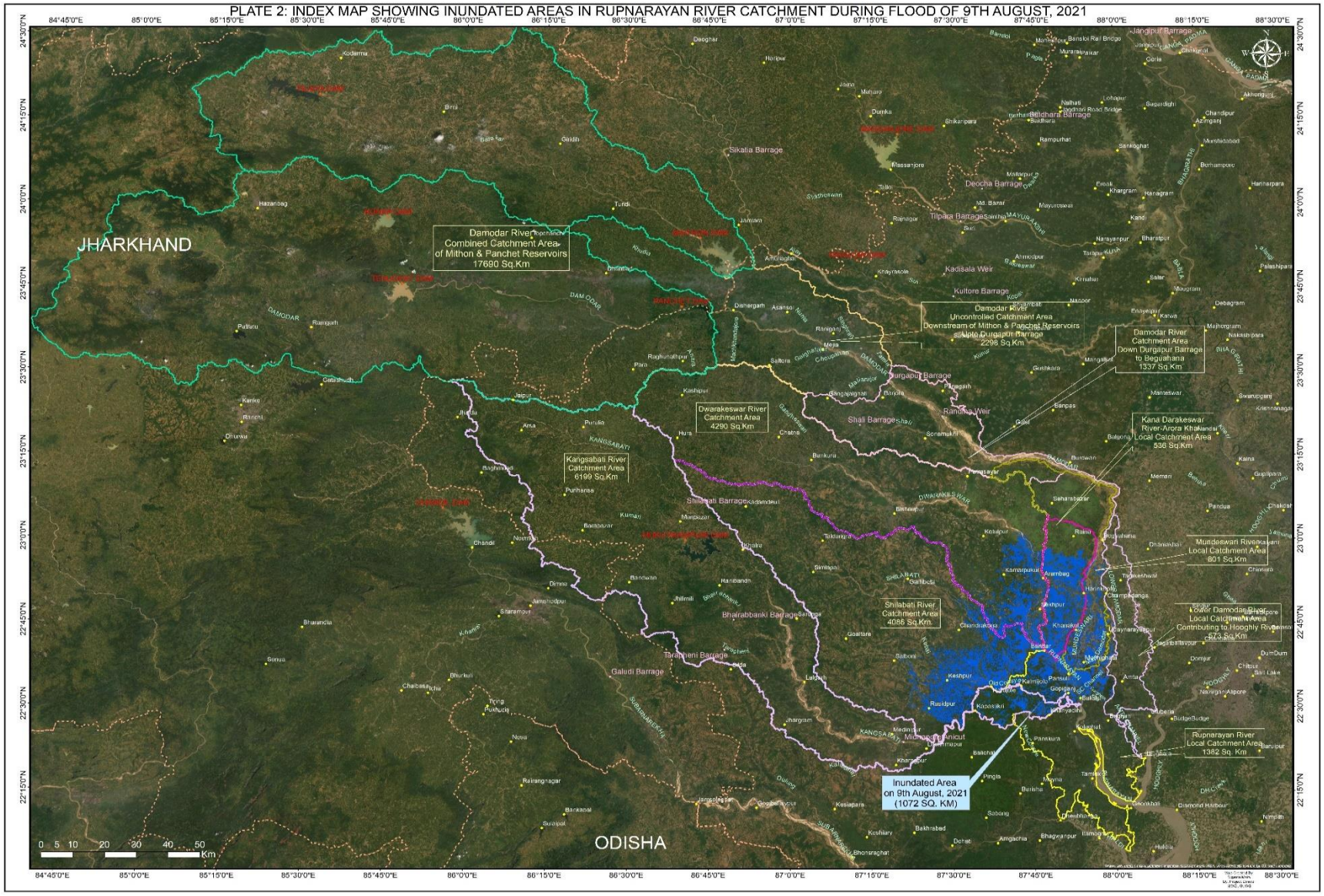

Plate 2: Inundation Map of Critical Flood Prone Areas within Rupnarayan River Catchment

Need of New Model Study:

7. The two mathematical models, one for Kangsabati-Shilabati system under Ghatal & adjoining area, covering Kangsabati & Silabati River System and the other for Lower Damodar-Mundeswari system under West Bengal Major Irrigation and Flood Management Project (WBMIFMP) have been developed. The structural interventions proposed in WBMIFMP on the basis of mathematical model, are now being implemented with the loan assistance from World Bank (WB) & Asian Infrastructure Investment Bank (AIIB) whereas the interventions proposed for Ghatal & adjoining areas under the project titled "Ghatal Master Plan" (GMP) are under consideration of Ministry of Jal Shakti, Govt. of India (GOI) for its final clearance.

8. These two models have been developed independently with different sets of boundary conditions for the purpose of flood management for two different sub-basins of river Rupnarayan. The Lower Damodar-Mundeswari-Hurhura sub-basin (catchment area of 17368 sq. km) is situated on its eastern side (right bank) whereas the Kangsabati (Old Cossye) & Shilabati-Durbachaty sub-basin (catchment area of 7186 sq. km) contributes flood water from its western side (left bank). These two sub-basins are separated by the Dwarakeswar River, Shankari River and Arora khal system (catchment area 4826 sq. km) which contributes flood water from the northern side of river Rupnarayan. In addition to above, there is a local catchment area of 1382 sq. km which caters run-off discharge through minor drainage channels, which directly outfall into this river. Ruling levels as well as duration of high flood levels (above EDL) as observed in various gauge stations of the Lower Damodar River system and other rivers falling in Rupnarayan during end July to early August 2021 /end September to early October, 2021, are presented in Table-1 below.

Table-1: River Gauge Details

River System	Location of gauge	Location District	EDL (m)	Duration of flowing above EDL (hrs)	Max level attained in the two spells (m)
Dwarakeswar (Upper Rupnarayan)	Shakepore (R/B of Dwarakeswar, about 18 km U/S of Bandar, the confluence point Shilabati & Rupnarayan	Hooghly	12.35	18/18	12.99/13.14
Rupnarayan	Bandar (L/B of Rupnarayan, near confluence point Shilabati & Rupnarayan)	Paschim Medinipur	7.46	108/90	8.56/7.92

Rupnarayan	Ranichak (L/B of Rupnarayan, around 5.5 km upstream of the confluence of Mundeswari & Rupanarayan at Pansuili on the R/B).	Paschim Medinipur	5.94	204/156	7.80/7.37
	Gopiganj (L/B of Rupnarayan, around 6.8 km upstream of the confluence of Hurhurah & also Buxi Khal with Rupanarayan at Buxi on the R/B)		5.65	56/90	5.99/6.14
Old Cossye (on the right bank /western side of Rupnarayan)	Kalmijore	Paschim Medinipur	9.90	48/48	10.50/10.55
Mundeswari (Branch of Damodar River located on the left bank /eastern side of Rupnarayan)	Harinkhola (about 30 km upstream of the confluence of Mundeswari & Rupanarayan at Pansuili	Hooghly	13.41	-/42	13.10/14.30
Hurhurah (Branch of Mundeswari)	Muchighata (about 15 km upstream of the confluence of Hurhurah & Rupanarayan at Buxi)	Howrah	6.77	132/102	8.54/8.73
Amta channel (Branch of Damodar River)	Amta (about 36 km upstream of the confluence of Amta channel & Hooghly River at Buxi)	Howrah	6.24	144/114	6.74/7.85

9. In most of such cases, failure of vulnerable river embankments like overtopping and breaches becomes inevitable. Apart from these, other damages like slips, subsidence, formation of piping / seepage path within the body of the embankments due to formation of rat holes / dead roots, exit gradient failure, bank erosion are common phenomena. Local sluices, inlets, wooden bridges etc., are also damaged to varied extent. The terrain being flat, inter basin transfer of water takes place due to absence of definite ridge line between these adjoining sub-basins and the flood situation in most of the areas within Ghatal, Khanakul-II and Amta-II blocks become very severe. The index map (Plate-2), focussing the actual extent of inundation areas has been prepared by using ERDAS

IMAGINE and SENTINEL-1 SLC Imagery captured on dated 9th August, 2021 covering the affected districts of Paschim Medinipur, Hooghly and Howrah. The details of inundation in some are presented below.

Table-2: Sub basin wise area of inundation on 9th August, 2021

Sl. No.	River / Khal	Area of Sub-Basin (Sq. Km)	Area of Inundation (Sq. Km)	Extent of Inundation
1	Arora	536	204	38%
2	Dwarakeswar	4290	171	4%
3	Kangsabati	6199	49	1%
4	Lower Damodar-Mundeswari	801	94	12%
5	Rupnarayan Local	1382	145	10%
6	Shilabati	4086	371	9%
	Total		**734**	

10. For the purpose of development of existing mathematical models under GMP and WBMIFMP, the effect of synchronization of floods as well as inter-basin transfer of flood flow have not been considered. As in the GMP model, the effect of flood discharge from Lower Damodar-Mundeswari sub-basin area through Mundeswari, Hurhura and Short Cut Channel system was ignored with a concept that, river Rupnarayan, being the main receptacle, would be capable of absorbing critical flood discharge from Kangsabati (Old Cossye) and Shilabati system. But actually, during synchronization of flow, the flood discharge from Lower Damodar-Mundeswari sub-basin becomes so dominant that it hardly allows the passing of outflows from other tributaries. Also, the inadequate cross-sections of river Rupnarayan at some critical stretches along with the tidal influence of river Hooghly accentuate the drainage congestion in Rupnarayan. On the other hand, the 2D model of WBMIFMP did not consider the effect of synchronization of discharge in all the tributaries of Rupnarayan impacting its carrying capacity during critical flood period and effect of inter basin transfer from Dwarkaswar-Rupnarayan local catchment to Lower Damodar-Mundeswari sub-basin. It focussed on Lower Damodar-Mundeswari subbasin only and assessed the impact of discharge of Mundeswari flowing out through the local channels (Kana Darakeswar

and Arora Khal system), which outfall at river Rupnarayan.

11. Similar inter basin transfer of flood discharge also takes place between catchment areas of Dwarakeswar & Shankari and Kangsabati (Old Cossye) & Shilabati system through local drainage channels like Ketia, Katan and Kanki khals depending upon which sub-basin is ruling high during critical flood period.

12. Therefore, in order to assess and address the flood issues in the severely flood and waterlogged distressed zones in adjacent districts of Howrah, Hooghly and Paschim Medinipur, where river Rupnarayan is the one and only receptacles of combined flood discharges from three adjoining sub-basins of Lower Damodar-Mundeswari, Dwarakeswar-Arora, Kangsabati (Old Cossye)-Shilabati systems and local catchment of Chandreswar Khal, development of a comprehensive hydro-dynamic model for the entire stretch of river Rupnarayan from its origin to its outfall is the need of the hour. Similarly, the effect of siltation and sedimentation of river Rupnarayan resulting in the formation of shoals at some critical locations is inducing severe bank erosion issues on both the banks and as such these problems also need to be addressed properly through this model study. A thorough investigation needs to be carried out immediately focussing this river system for assessing the carrying capacity and exploring drainage improvement and controlling measures.

13. The locations of boundary conditions as considered in the previous models and in the proposed model are listed below in Paragraph 16.1. An index map showing the locations of all the boundary conditions along with locations of vulnerable spots are presented in Plate-3.

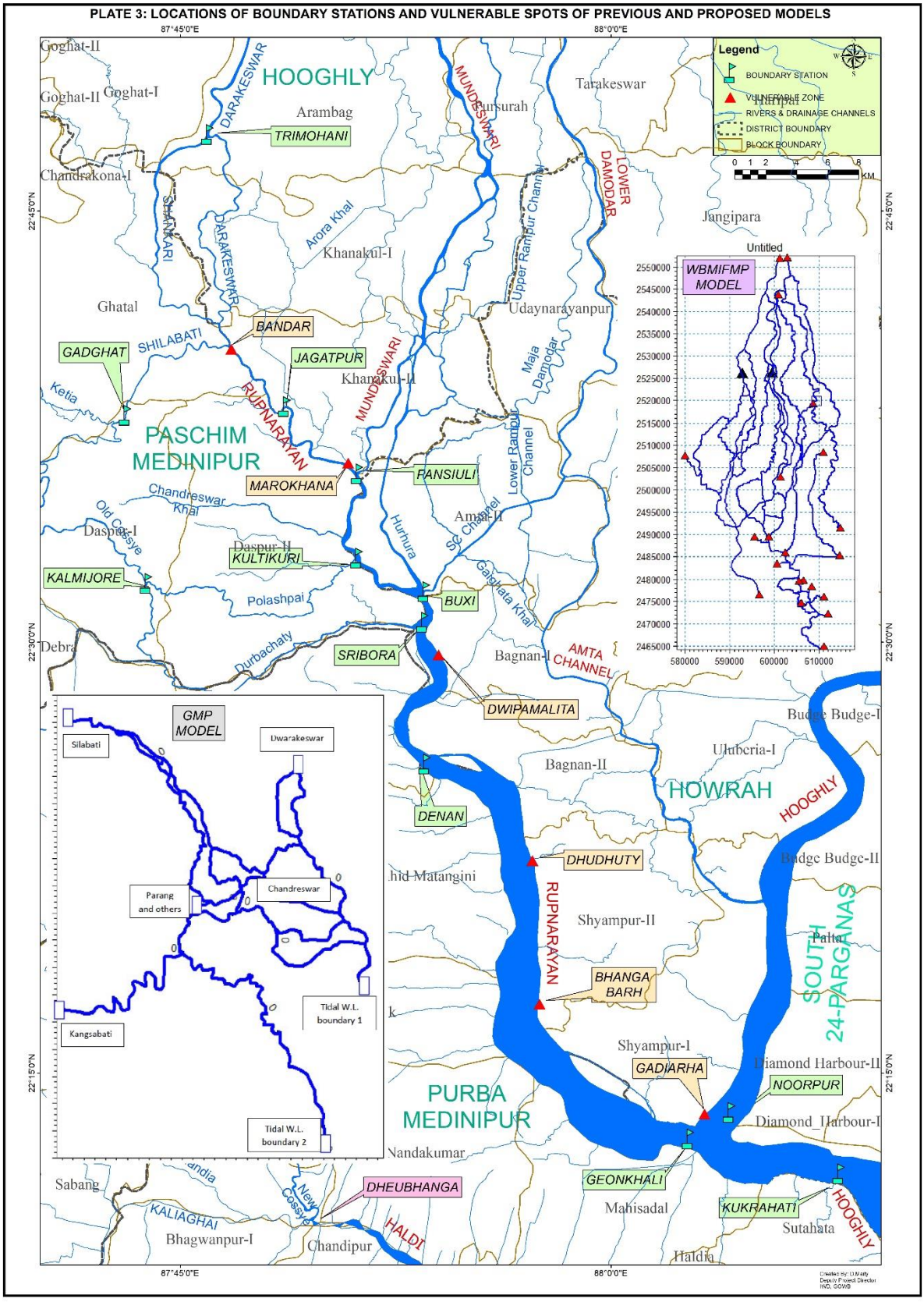
PLATE 3: LOCATIONS OF BOUNDARY STATIONS AND VULNERABLE SPOTS OF PREVIOUS AND PROPOSED MODELS
87°45'0"E
88°0'0"E
22°45'0"N
22°30'0"N
22°15'0"N
Legend
BOUNDARY STATION
VULNERABLE ZONE
RIVERS & DRAINAGE CHANNELS
DISTRICT BOUNDARY
BLOCK BOUNDARY
KM
HOOGHLY
PASCHIM MEDINIPUR
PURBA MEDINIPUR
HOWRAH
SOUTH 24-PARGANAS
TRIMOHANI
BANDAR
JAGATPUR
GADGHAT
MAROKHANA
FANSIULI
KULTIKURI
KALMIJORE
BUXI
SRIBORA
DWIPAMALITA
DENAN
DHUDHUTY
BHANGA BARH
GADIARHA
NOORPUR
GEONKHALI
KUKRAHATI
DHEUBHANGA
DARAKESWAR
SHILABATI
RUPNARAYAN
MUNDESWARI
Upper Rampur Channel
LOWER DAMODAR
Maja Damodar
Lower Rampur Channel
Arora Khal
Chandreswar Khal
Old Cossye
Hurhura
Polashpai
Durbachaty
Gaighata Khal
AMTA CHANNEL
New Cossye
KALIAGHAI
HALDI
HOOGHLY
Untitled
WBMIFMP MODEL
GMP MODEL
Silabati
Dwarakeswar
Parang and others
Chandreswar
Kangsabati
Tidal W.L. boundary 1
Tidal W.L. boundary 2
Goghat-II
Goghat-I
Chandrakona-I
Ghatal
Khanakul-I
Khanakul-II
Arambag
Tarakeswar
Jangipara
Udaynarayanpur
Amal-II
Daspur-I
Daspur-II
Debra
Bagnan-I
Bagnan-II
Uluberia-I
Budge Budge-I
Budge Budge-II
Shyampur-I
Shyampur-II
Diamond Harbour-II
Diamond Harbour-I
Mahisadal
Haldia
Sutahata
Sabang
Bhagwanpur-I
Chandipur
Nandakumar
Created by: D.Maity
Deputy Project Director
IWD, GOWB

Objectives of the Consultancy:

14. Development of a comprehensive hydro-dynamic (mathematical) model in 2D or coupled 1D-2D for flood and 2D sediment, river morphology modelling (for riverbank erosion, sustainability of flood management like dredging) for Darakeswar-Rupnarayan River system by taking into consideration its entire catchment areas as presented in Plate 1.

This new model is to be developed after reviewing/ integrating the existing mathematical models already developed under the West Bengal Major Irrigation & Flood Management Project (WBMIFMP) for Lower Damodar-Mundeswari Sub Basin as well as under the Ghatal Master Plan (GMP) for Kangsabati-Shilabati Sub Basin. The model will also incorporate the effect of tidal lockage of river Rupnarayan from its origin at Bandar up to its outfall into river Hooghly at Geonkhali along with the effect of siltation. 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 & Waterways Department (IWD) for the purpose of the development of this model.

Apart from development, calibration and validation of the model, the objectives include, *inter alia*, suggesting suitable drainage improvement and other flood mitigation measures in the said river system.

Scope of the Consultancy Service:

15. broad scope of the Consultancy Services are summarized below:

a. ***Understanding the river system by site visits and desk studies on various records and documents, reports etc. to be provided by the Client.***

b. ***Analyzing survey data to be provided by the Client and deriving /processing any other secondary data required for the model study.***

c. ***Development of the flood inundation model, its calibration and validation.***

d. ***Identification of structural and non-structural measures that are consistent with the overall approach to reduce the depth-area-duration of flooding in the critically flood prone areas and to prevent bank erosion in vulnerable river reaches***.

The scope has further been detailed below: -

15.1 ***Understanding the river system and desk studies***

15.1.1 The Consultant shall conduct site visits of critical flood prone zones, locations of vulnerable stretches due to erosion, outfall points of river Rupnarayan with Hooghly and outfall points of

other important rivers and drainage channels such as Dwarakeswar, Shilabati, Mundeswari, Hurhura, Chandreswar Arora, Buxi Khal, Palashpai, Durbachaty etc. The Consultant will also visit other important locations as considered by him for this comprehensive study.

15.1.2 The Consultant shall perform desktop studies on available reports and documents pertaining to historical flood events, GIS based maps on river systems and their catchment areas; administrative boundaries up to mouza level; locations of important structures and gauging points, model parameters, satellite imageries etc.

15.2 ***Analyzing survey data***

15.2.1 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 Dwarakeswar-Rupnarayan 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) 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.

15.3 ***Development of the flood inundation model, its calibration and validation***

15.3.1 A 2D or coupled 1D-2D mathematical model is to be developed for river Darakeswar-Rupnarayan River system from Trimohini (bifurcation point of Darakeswar & Shankari, in Block Khanakul I, District Hooghly, near Lat 22.7944 N & Long 87.7659 E) to confluence of Rupnarayan & Hooghly, near Lat 22.2124 N & Long 88.0478 E at Geonkhali on the right (western) bank in district Purba Medinipur /Gadiara, on the left (eastern) bank in District Howrah, after taking into consideration all the boundary conditions as proposed by the Client for critically flood affected zones by using MIKE+ software (Mike 21 FM /Mike 21 C) having sedimentation module), already procured by the Client.

15.3.2 The Consultant should calibrate and validate the model using high-resolution Digital Terrain Model (DTM) to be provided by the Client, along with tide data of 7 days for 12 hours a day @ 1 hour interval for one monsoon season (2022). at all boundary condition, bathymetry and topo sheet data (bank to bank or high to high points) in X, Y and Z (RL in GTS) format, discharge and suspended load data considering different tide phases. The Consultant should run the model for mud or sand transport sediment in the Rupnarayan to assess the rate of silt deposition or mechanism of chars/bars formation.

15.3.3 The consultant should generate the hydrograph and tide curve (wherever applicable) for each boundary point for future prediction of the Rupnarayan river system.

15.3.4 The Consultant shall study the approach and methodology being adopted to develop a comprehensive flood forecasting model by Damodar Valley Corporation (DVC) for entire Damodar River system from its origin in Jharkhand to its outfall into river Hooghly under National Hydrology Project (NHP).

15.3.5 The Consultant will finally develop a 2D or coupled 1D-2D mathematical model for river Darkeswar- Rupnarayan for the stretch mentioned in Paragraph 15.3.1 above. While developing the model, the following requirements are to be fulfilled, i.e.,

a) The existing models of the Lower Damodar Sub-basin under WBMIFMP and that of Silabati-Kangsabati River system under GMP would have to be integrated with the new model of Dwarakeswar-Rupnarayan.
b) Four Rivers (Banka, Behula, Kana Nadi & Kana Damodar), which were offshoots /branches of Damodar River in the past but now delinked from the river, would have to be considered to have been carrying the share of discharge of Damodar (depending on their bankful capacities), on condition of bridging the missing links (from left bank of Damodar to their present offtakes). It would be desirable to understand the effect of the reduction of discharges of Damodar due to diversion of a part in to these rivers, in the entire Lower Damodar & the adjoining Dwarakeswar-Rupnarayan sub-basins, due to diversion of flow.

15.3.6. Through repeated simulation runs including those representing the historical floods, the inundation model should be able to generate the flood inundation maps corresponding to the discharges having various return periods, i.e., 5-year, 10-year, 15-year, 20-year & 25-year and also the limiting discharge that cause overtopping of the banks and embankments, in the pre-project and post project condition. The modelling results are to be verified using satellite images of

inundation captured on the day of flood or as near a date after the flood as possible / recorded field observations /other existing information.

15.3.7 It is important to mention here that apart from developing the inundation model, the other main focal point of the study is suggesting measures for increasing the conveyance capacity of the Darakeswar-Rupnarayan River System. **In order to do this, the Consultant should provide HFL data at various control points against various return periods of floods, i.e., 5-year, 10-year, 15-year and 20-year & 25-year. Normally, return periods are denoted in terms of peak value of discharge. However, in the instant case, it would be necessary to relate the return period in terms of total flood volume flowing through the river system flowing during a specified period of time**. While the peak discharge in the Darakeswar-Rupnarayan river system needs to be calculated based on suitable percentage of combination of peak discharges of all the tributaries, the flood volume may be calculated using hydrograph, with the condition that peak discharge flowing for 24 hours and dominant discharge (may be 75% to 80% of the peak) flowing for another 96 hours, thus covering a longer period (120 hours, more or less). This is due to the fact that, peak discharge of various rivers has lag times. It is to be noted that HFL lines for all these discharges, should be drawn both in the pre (without interventions) as well as post (with interventions) project conditions.

15.3.8 The calibration and validation exercises for these models may be carried out on the basis of observed records of historical floods, ensuring that over-fitting is not attempted to. The inundation model shall take into consideration, the effect of various combination of synchronization of critical flood discharges from all the subbasins of river Rupnarayan along with the effect of tidal lockage at the outfall points of all its important tributaries as well as the outfall point of it in river Hooghly. The model should be able to predict extent and depth of inundation, velocity of flood water and duration of inundation at any location in the critical flood zones as well as at critical stretches of river Rupnarayan. The model should also be capable of identifying the potential siltation zones in Rupnarayan through the development of a suitable model for sedimentation. The other key factors such as local precipitation, LULC, location of structures etc. should also be taken care of by the model during its development.

15.4 ***Identification of structural and non-structural measures***

15.4.1 The Consultant will identify a comprehensive set of structural and non-structural measures in Dearakeswar-Rupnarayan river system for lowering the HFL or containing the HFL within the

river valley to avoid bank spilling, from Trimohini to confluence of Rupnarayan & Hooghly, River, that are consistent with the overall approach to reduce the depth-area-duration of flooding in the critically flood prone areas, after due consideration of synchronization of discharges from all the tributary rivers /channels.

15.4.1.1 These may include would include but may not be limited to, dredging /desiltation of river and drainage channels with proposed section of such desiltation works. Proposal of any desiltation /dredging work including removal of local sandbars in the Darakeswar-Rupnarayan System, from Trimohini to Geonkahli point, shall be accompanied with work methodology and disposal plan. Long-term sustainability of such desiltation /dredging proposals must be checked against the sediment load, which would be dominant from upland discharge during monsoon periods and from downstream tidal effect during non-monsoon periods.

15.4.1.2 Another option could be raising and strengthening the existing embankments or constructing new lines of embankments, capable of sustaining floods varying magnitude, i.e., having return periods of 10-year & 25-year. As already stated in Paragraph 15.3.7 above, the return periods should be related to not only to the peak floods but also with the flood volume

15.4.2 The Consultant will also suggest measures for prevention of bank erosion in the vulnerable stretches of river Darakeswar-Rupnarayan within the above said reach on the basis of results / outcomes of the final model. 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.

15.4.3 The Consultant will further suggest the suitability and details of interventions like new control structures, e.g., construction of outfall regulators at the confluence of various local drainage channels with River Rupnarayan, to avoid backflow in these channels from the main river, during critical flood periods.

15.5 **While recommending various structural measures, techno-economic analysis of various options should be carried out to choose the most cost-effective and viable /feasible option. This would require preparation of rough cost estimates based on the Scheduled /Analyzed rates. The Consultant should also consider the land availability, transport facilities and access issues, while suggesting any interventions. Measures finally recommended by the Consultant shall be supplemented by designs, GA & layout drawings**,

Availability of Data:

16.1 Extensive ground and hydrographic surveys have been conducted by IWD in some priority areas. Softcopies of all these raw data of cross-section, water level, discharge, sediment, tide etc. will be shared with the Consultant for performing the mathematical model study.

16.2 The high resolution DTM procured from NRSC and other types of satellite imageries downloaded from USGS and ESA like SRTM 30, LANDSAT 8, SENTINEL-1 SAR and SENTINEL-2A will also be provided for the purpose of inundation area mapping and its validation.

16.3 The videos and photographs of important events, structures, geo-tagged gauging sites etc. will also be provided to the Consultant depending upon their availability.

16.4 The relevant documents, including historical records and reports will also be made available to the Consultant as and when necessary.

16.5 A detailed list of data, which will be provided to the Consultant is given under the Paragraph 18, Client's Input.

16.6 Consultant shall collect other types of data as may be found relevant for the conduct of the study.

Boundary and validation points for the Rupnarayan Mathematical Model:

17.1 **Rupnarayan River System**

I. Boundary points

i. River Dwarakeswar at Trimohani (near Lat 22.6682 N & Long 87.7729 E)
ii. River Shilabati at Gadghat (near Lat 22.6316 N & Long 87.7183).
iii. Outfall of Chandreswar Khal at Gopiganj on the sluice structure (near Lat 22.5621 N & Long 87.8413 E).
iv. Outfall of river Palashpai at Kultikri, on right (eastern) bank of Rupnarayan (near Lat 22.5483 N & Long 87.8512 E).
v. Outfall of river Durbachati at Sribora on right (eastern) bank of Rupnarayan (near Lat 22.5088 N & Long 87.8844 E).
vi. River Old Cossye at Kalmijore (near Lat 22.5687 N & Long. 87.7065 E).
vii. Outfall of Arora Khal at Jagatpur, on the wooden bridge left (eastern) bank of Rupnarayan (near Lat 22.6375 N & Long 87.8106 E).

viii. Outfall of river Mundeswari at Pansiuli on left (eastern) bank of Rupnarayan (near Lat 22.5982 N & Long 87.8523 E).

ix. Outfall of Huhurah khal (near Lat 22.5307 N & Long 87.8310 E) and Short Cut Channel at Buxi Bridge on left (eastern) bank of river Rupnarayan (near Lat 22.5313 N & Long 87.8973 E).

x. River Hooghly at Kukrahati (near Lat 22.1823 N & Long 88.1029E) and Noorpur (near Lat 22.2316 N & Long 88.0711 E).

II. Validation points

i. River Silabati confluence with Rupnarayan at Bandar, near Lat 22.6646 N & Long 87.8117 E.

ii. Denan /Kolaghat on right (western) bank of river Rupnarayan (near Lat 22.4268 N & Long 87.8921 E).

17.2 Boundary Conditions considered in GMP Model

Tidal W.L. boundary i.: Gopiganj on River Rupnarayan. ii. Tidal W.L. boundary 2: Dhewbhanga near the confluence of Rivers New Cossye and Kaliaghai. iii. Shilabati; iv. Kangsabati; v. Parang and others; vi. Chandreswar Khal and vii. Dwarakeswar

17.3 Boundary Conditions considered in WBMIFMP Model

Boundary Description	Boundary Type	Name of River / Khal	Chainage (m)
Closed		Amargachi Khal	0
Closed		Dhopa Khal	0
Open	Q-h	DVC D1	49209
Closed		Gadaipur Khal	0
Closed		Gadaipur Khal	2114.5
Closed		Gujarpur Khal	0
Closed		Gujarpur Khal	40368
Closed		Kalatala Khal	0
Closed		Kana Damodar	0
Open	Water Level	Lower Damodar River	95600
Open	Water Level	Lower Damodar	15205
Closed		Purana Khal	0
Closed		Purana Khal	29800
Closed		Raner Khal	0
Open	Inflow	Mundeswari River	941
Closed		Boalia Khal	3218
Open	Inflow	Rupnarayan River	16385
Open	Water Level	Rupnarayan River	62008.5
Open	Water Level	Kana Damodar	34622

Boundary Description	Boundary Type	Name of River / Khal	Chainage (m)
Closed		Bainan Khal	0
Closed		Maja Damodar	0
Closed		Upper Rampur Channel	0
Closed	Discharge (Q)	Banka	23°20'36"N, 87°35'55"E
Closed	Discharge (Q)	Behula	23.167359°N 87.999446°E
Closed	Discharge (Q)	Kana Nadi	23.076430 N 87.9942990 E
Closed	Discharge (Q)	Kana Damodar	23.073770N 87.993430E

Client's Input:

18. The following amenities/data will be provided by the Client:

I. River Cross-Sections Data and Chezy resistance coefficient in any.
II. Water Levels & Discharge Data.
III. Bathymetric Data.
IV. Tide Data.
V. Sediment Data with particle size distribution of suspended and bed load, settling velocity of a single particle, turbulent diffusion coefficient and bed shear stress if any.
VI. Point Rainfall Data.
VII. High resolution DTM procured from NRSC and other types of satellite imageries downloaded from USGS and ESA like SRTM 30, LANDSAT 8, SENTINEL-1 SAR and SENTINEL-2A will also be provided for the purpose of inundation area mapping and its validation.
VIII. Hardware dongle of MIKE+ software (Mike 21 FM /Mike 21 C having sedimentation module).
IX. The facility to use high end Workstation installed in Client's office supported with RS/GIS software like ERDAS IMAGINE-2021 & ARCGIS-10.8.
X. WBMIFMP FS Report, including the model report and also subsequent model repots simulated after the floods of 2021.
XI. GMP mathematical model study Report.
XII. Accesses to existing mathematical models of GMP & WBMIFMP (developed so far).
XIII. Available historic and current data on hydrometeorology, hydrology and hydraulics;

available thematic maps; rainfall data; topographic data; embankment and breach details.

XIV. Authorization letter will be given for providing access to other State and Central agencies for the purpose of collection of data, including the approach methodology being adopted to develop a comprehensive flood forecasting model by Damodar Valley Corporation (DVC) for entire Damodar River system from its origin in Jharkhand to its outfall into river Hooghly under National Hydrology Project (NHP).

XV. Access to MIS & Web-GIS under WBMIFMP.

XVI. Counterpart staff and facilitate implementing and operation of inundation model.

XVII. 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.

Responsibility of the Consultant:

198. The responsibilities of the Consultant would include but not be limited to the following:

19.1Conduct and complete the Consultancy as per the agreed ToR and scope of the Consultancy.

19.2Collect data as needed for modelling from concerned agencies as agreed upon by the Client.

19.4 Conduct field visits as required for data collection or to verify model results.

19.5 Undertake data conversion of source data as needed for modelling and generate GIS maps as required for the modelling system.

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. 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 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.

19.9 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.

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.

19.10 The Consultant should not engage any Sub-Consultant to execute the assignment.

Handling of Restricted Data:

20. The Consultant and his personnel engaged for this work, either during the term or even after the expiry of this Contract, disclose any proprietary or confidential information relating to the assignment, the Contract or the Client's business or operations without the prior written consent of the Client. Certain data (such as discharge data, bathymetric & sediment data, high resolution DTM or contour information generated therefrom) which may be procured / prepared and used in development and operation of flood model may be considered 'restricted' as per GoI's Ministry of Defense and Ministry of Jal Shakti guidelines. Keeping in view security guidelines for data secrecy and to provide optimum functionality and to enable sharing data, a secure data handling environment should be used. The unit will be equipped with necessary hardware and software and peripheral units, but will not be connected with outside LAN networks. Entry to the confidential unit shall be appropriately screened for authorized consultant staff. Confidentiality and non-disclosure Agreements are to be signed by the Consultancy firm, as well as the individual Expert deputed for working in this area. A detailed record of all the confidential data will be maintained in the register and data will be transferred only after approval. No original data kept on storage hardware will be modified or changed. Change / modification required if any will be done only after copying the data.

Timelines, Deliverables & Payment Terms:

21. Following timelines are specified**:**

21.1The period of Consultancy assignment will be of 8 (Eight) months from the date of signing of Contract and shall comprise the following stages, with associated outputs and deliverables. All reports, compiled & generated data, maps and model output along with metadata will be submitted electronically. Consultant will prepare the reports in a format to be agreed upon by the Client and 4 nos. hard copies of each report shall also be submitted.

21.2 During the initial phase of the assignment, the Consultant will review existing studies and models, visit sites and outline the detailed work programme for development, testing and validation of the model. The Consultant shall submit the Inception Report, which will define a time-bound strategy for collection of additional data, if any, and confirm details of the modelling strategy.

21.3 In the next phase, the Consultant will review all historical hydrologic and hydraulic data and carry out quality control procedures. Corrections and data gap filling will be done as and when necessary. Requests for all the required data shall be provided well in advance by the Consultant to the client so that required information is made available in a timely manner. All data from the defined sources will be compiled in the GIS database. This comprehensive data base shall include hydrologic & hydraulic data, maps, DTM and any RS datasets that would be useful for this assignment. The thematic GIS data may include but not limited to: administrative data, hydro-meteorological network stations, topography, LULC, soils, water storage / diversion structures, embankment alignment and profile (including locations of vulnerable sections and previous breaches), and historical flood events. The RL conversion from EGM to GTS in m shall be done by the Consultant during development of the inundation model.

21.4 After that, the Consultant will build, test, calibrate and validate the model based on observed data as per Consultation with the Client. The model and all compiled data will be transferred to the Client. The principal outputs of modelling will be:

- Comparison of the suitability of the different types of input data.
- Simulate the existing floods with reasonable accuracy (avoiding over-fitting).
- Predictions of water levels and discharges at the identified locations for historical floods.
- Predictions of deposition of sediments at identified river stretches and erosion of river banks.
- Suggestion of suitable structural and non-structural interventions at strategic locations for efficient flood management in critical areas.

21.5 The Consultant shall submit a Model Development Report on development and

operationalization of the model along with the detailed narratives on suggestive interventions for flood and erosion management in river Rupnarayan and its all tributaries.

21.6 In the final phase, the designated officers of I&WD should be trained by the Consultant in order to handle the model independently. The approach and methodology adopted for the execution of the assignment would be the property of IWD not to be shared / replicated by the Consultant anywhere else without the written consent of the Client. The Consultant will devise a User Manual / Technical Guide for the operation and maintenance of the model.

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.

21.8 The deliverables with the timelines and the payment terms are presented in the Table-3.

Table-3: Deliverables with Timelines

Deliverable	Timeline from the award of contract	Percentage payment of the total contract value
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
Model Development Report	Within 5.5 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%
Total time for the assignment	**8 months**	

The deliverable as listed above shall be submitted by the Consultant in electronic / soft copy and 4

(four) hard copies.

21.9 Contents of various deliverables are briefly summarized below:

21.9.1 **Inception Report**:

The Consultant shall provide an "Inception Report" clearly indicating how consultant has planned to achieve the assigned objectives of this consultancy. The report shall include objective of the study, detailed work plan along with time schedule, methodology for modelling and suggestive interventions for flood and erosion management, data requirement, review of available data and data gaps, if any. The inception report shall indicate the time schedule showing major milestones, task deliverables, completion dates and any interdependencies.

21.9.2 **Model Development Report**:

This report should cover hydrodynamic model for flood management, sediment and morphology model for bank erosion and long-term sustainability of flood management measures. Model set up, initial calibration and validation, parameters used, model output will have to be included. The principal outputs of the model have already been detailed at Paragraph 21.4 & 21.5.

21.9.3 **Draft Final Report**:

This will contain the complete data set, model development and output, drawings showing HFL lines at various locations for the specified sets of return periods of floods, inundation maps with and well as without interventions. The report will also cover output of different interventions (structural, non-structural) which would include but may not be limited to, dredging /desiltation of river and drainage channels with proposed section of such desiltation works, construction of hydraulic structures at outfall /other control points, and river training /bank protection works at eroding areas. Long-term sustainability of desiltation /dredging proposals tested through morphological modelling need to be covered in this report. A disposal plan for dredging will also be mentioned in the report. Various options of structural interventions on Rupnarayan for improvement of carrying capacity and minimization of flooding in the surrounding areas shall specifically be mentioned river shall specifically be mentioned, along with rough cost estimates and techno-economical viabilities.

21.9.4 **Final Report**

Consultant shall submit the final report to the client after compiling all the comments. The Consultant will devise a User Manual / Technical Guide for handling/upgradation of the model.

Training & Capacity Building:

22. 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

List of Key Experts:

23. A tentative list of personnel required to be engaged for this assignment by the Consultant is furnished in Table-4 below:

Table 4: List of Key Experts with Man-Months

Sl. No.	Position/head	Required Qualification & Experience	Duration (Man Months)
1	Team Leader /One	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 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.	08
2	Sr. Hydraulic Modeler /One	Post Graduate 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.	05

Sl. No.	Position/head	Required Qualification & Experience	Duration (Man Months)
3	Deputy Hydraulic Modeler /One	Post Graduate or Equivalent in Hydrology / Hydraulics / Water Resource Engineering with at least 12 years of experience in flood modelling.	08
4	Structural Engineer /One	Post Graduate in Civil Engineering /Water Resource Engineering with at least 12 years of experience in planning, estimation, design & execution of flood management interventions, including hydraulic structures and river training works.	05
5	RS/ GIS Expert /One	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.	04
6	Data Analyst /One	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.	08
Total 6 Nos.			38

Note: Requirement of Non-Key Experts / other support staff would have to be separately assessed by the Consultant.