Final Research Report

THE PILOT PROJECT IN DIFFERENT AREAS OF BANGLADESH USING BAMBOO BANDALING STRUCTURES TO REDUCE RIVER BANK EROSION, LAND RECLAMATION AND INCREASE NAVIGATION

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Preface

This report presents the outcome of the research related to the project “The pilot project in different areas of Bangaldesh using bamboo bandaling structures to reduce river bank erosion, land reclamation and increase navigation”, carried out by River Research Institute (RRI) and funded by Government of Bangladesh (G.B) during the financial year 2017-18, 2018-19, 2019-20 and 2020-21.

River bank erosion is one of the most important processes in lateral migration of the river channel. Bank erosion claims every year fertile agricultural lands in the margin of the rivers all around the world and contributes to the suspended sediment load in the rivers. Erosion and channel-shifting during the monsoon more specifically, during the rising and recession stage result in serious damage to properties and livelihoods in Bangladesh. So far, different structural measures have been undertaken using different types of structures to address the erosion problem mainly in piecemeal manner. Adoption of hard material protection is costly for a country like Bangladesh and not always environment friendly. However, the problems can also be reduced by constructing low-cost bandal type structures; with the added advantages of agricultural land reclamation as well as navigational channel development. This research will be milestone for low cost measure against bank erosion in our riverine country and will also provide us with tools for guidance of river morphology as well as land reclamation.

In this research we have collected data from alluvial, tidal & flashy river before and after Bamboo Bandaling Structures. We have collected water quality data, sediment concentration data and Hydro-morphological data. Also soil boring in some areas are done. It is found that alluvial river is very suitable for low cost bamboo bandaling measure against bank erosion. Huge land reclamation is also observed.

I am grateful to Md.Alim uddin, Director General, River Research Institute and Professor Dr. Mohammed Almujaddade Alfasane, Department of Botany, University of Dhaka for their valuable advices, suggestions and co-operation during the study period.

I like to be particular in my appreciation for the research team members who have worked hard for completion of the research within the stipulated time. Sincere thanks are extended to all who have helped us directly or indirectly in connection with this study.

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Executive Summary

Introduction

River bank erosion is one of the silent disasters that takes place in Bangladesh each year and constantly creating immense multi-dimensional socio-economic problems. This disaster frequently grabs river bank area which is often unpredictable. As river bank erosion is one of Bangladesh's major natural disasters, displaces thousands of families each year, state-sponsored bamboo and bio-engineering intervention, to mitigate riverbank erosion, provides significant prospects to reduce the damaging effects of bank erosion. Usually, protective measures are applied against bank erosion for short-term basis. The local and temporal problems related to bank erosion and channel shifting is considered. As typical riverbank protection methods with geo-bags or concrete blocks are expensive, the cost-effective, local technology using locally-available material and manpower provides a sustainable way to arrest river bank erosion. Massive structures like groynes, revetment and hard points are expensive and often unfavorable to environment. In that case, for the longer reaches of the large-scale alluvial rivers of Bangladesh, Bamboo Bandal Structures are more cost effective to mitigate river bank erosion related problems. The Bandal Structures have their ability to shift sediment loads towards the bank line and also utilized to divert water flow towards the mid river, to facilitate natural dredging, smooth navigation and erosion mitigation. Under these circumstances this research has been taken during 2017 for the period October'2017 to June' 2021.

Aims of the study

The main aims of the research are- i) to examine the impact of bamboo bandal structures in flashy rivers for bank protection, land reclamation and increase navigation, ii) to examine the impact of bamboo bandal structures in alluvial rivers for bank protection, land reclamation and increase navigation, iii) to examine the impact of bamboo bandal structures in tidal rivers for bank protection, land reclamation and increase navigation, iv) to examine the effectiveness of proposed bamboo bandal design from laboratory investigation, v) to develop guide lines for effective implementation of bamboo bandal structures to achieve desire goals.

Approaches and Methodology

A detailed research work accomplished to understand and resolve the key problems related to bank erosion of the different rivers of Bangladesh. It is carried out based on the field visit, sample collection of the river, In-situ test and laboratory investigation of the samples, constructing bandal structures on the river bank etc. In this research work, thirteen rivers including meandering, braided, flashy and tidal in Dhaka, Rajshahi, Mymensingh, Barishal and Khulna divisions are selected on the basis of their discharge, flow depth and sediment load. Among them Madhumati at Faridpur, Gorai at Rajbari, Arial khan at Faridpur and Dhaleswari at Sirajganj are considered as meandering rivers. Padma at Faridpur and Jamuna at Sirajganj are considered as braided rivers. Kangso, Sumeshswary and Nitai at Netrokona are considered as flashy rivers. Besides, tidal river including Sugandha at Barishal, Bhadra, Rupsha and Atai at Khulna are also considered for selecting potential sites for constructing bamboo bandaling structures.

A typical bandal has an opening below (permeable part) to allow the passage of flow through the structure and a blocked upper portion (impermeable part) towards the near surface flow at u/s to the main channel direction. But here we have implemented bandal like structures without upper blocking and the design was developed by RRI and verified by BWDB. The morphological changes around the bandal are characterized by a small scour hole followed by a sediment deposition at the d/s. Due to placement of bandals in the above study areas, sedimentation occurred partly near bank sides and erosion occurred in the main channel. This phenomenon made more sediment particles pass along with low flow partly towards banks, whereas it allowed more flow along with less sediment particles to move towards main channel. When proceeding to downstream direction, an interchange of water and sediment particles took place and gradually the effect of the bandalling diminished. However, the next bandals brought about a similar change in flow and sediment distribution in transverse direction and consequently second bandal towards downstream repeated the same process in rotation. Bandal type structures have been constructed in the selected erosion prone areas of the pre-considered rivers between January 2018 and June 2021. At every site series of bandal type structures were constructed covering the erosion prone stretch of the river fully or partially.

Key Finding and recommendations

The effects of bamboo bandaling structures in different rivers at different depths and at different geographical and morphological conditions on river flow and sedimentation are investigated through 'the pilot project in different areas of Bangladesh using bamboo bandaling structures to reduce river bank erosion, land reclamation and increase navigation' project. Under this project, the overall impact of bamboo bandaling on river environment especially physicochemical and biological parameters in the river ecosystem before and after bandaling are also considered. Fourteen rivers including meandering, braided, flashy and tidal in 6 district in whole Bangladesh are investigated. The following outcomes can be drawn from this project:

- The bandals are working as a river bank protection structures. Most of the cases, the use of bamboo bandaling structures are very much effective as a bank protection tool with land reclamation.
- It is observed that bandals, especially series of bandals can easily reduce flow velocity near the bank and causes sedimentation at the bank and consequently deepening river bed after a few meter distance from bandaling end towards mid of the river.
- Generally, it is better to guide flow pattern of river from suitable up stream through bamboo bandals. There are always key location.
- Long bandals with two or three part will give good result.
- Angle between bandals and river bank should be from 30^0 to 45^0
- Impact of Bandals in Rivers of Khulna where water level difference is high due to tidal effect is very appreciable for bamboo bandaling . But impact of bandals in river of Barishal where little water level difference due to tidal effects seems not feasible for bamboo drive.
- Sandy bank or bank with sand layer below clay layer is not suitable for bamboo bandals. But in this situation bandals will also work if river sufficiently dried during dry season and long banndals with dense combination placed. Good result can also be attained if flow diversion from u/s is possible by bamboo bandal structures.
- Vortex formation, direct water fall upon bandals and severe velocity from storm surges may damage bandals. Two bandals at chandgaon destroyed during the Amphan by direct storm surges. But road and locality saved because of the bandals. Later bandals were repaired and working good.
- First bandal should be doubled to protect huge water thrust.
- As typical riverbank protection methods with geo-bags or concrete blocks are expensive, the cost-effective, local technology using locally-available material and manpower provides a sustainable way to stem river erosion.
- In some cased combination of measures like geo-bag, bamboo bandal structre and dredging can be implemented for proper output.

- Key locations have to be identified for bandal structure to successfully attain erosion protection and land reclamation.
- Earth work has to included with proposed design to make steep bank slope mild.
- Sufficient bandals have to be constructed for desired output.
- Bamboo bandal can safe guard existing costly structure
- RRI can be mandated upto certain limit to implement field level low cost and innovative projects
- Despite being low-cost, eco-friendly, and effective for land reclamation and navigation, the most crucial limitation of bamboo bandalling structures is their lack of sustainability. Bamboo bandalling structures are comparatively weak and cannot exist in major rivers with high water flow or velocity. However, they can work in minor rivers where water flow, or velocity, is low or medium. So, RRI has to take research for the bandalling structures to be constructed by R.C.C. pillar instead of bamboo for more sustainability.

Implication of this research:

This research will provide a clear idea about impact of Bamboo Bandaling Structures upon alluvial, flashy and tidal river in Bangladesh. The successful implementation and charming output of Bamboo Bandal Structures will attract policy making and management authority to extensive use of low cost Bamboo Bandaling Structures even at remote area of Bangladesh for mitigation of suffering of poor people and increased agricultural product through erosion protection and land reclamation. This research will also be a basis for future research.

CHAPTER 1

INTRODUCTION

1.1 General

When riverbank erosion, one of Bangladesh's major natural disasters, displaces thousands of families each year, state-sponsored bamboo and bio-engineering intervention, to mitigate riverbank erosion, provides significant prospects to reduce the damaging effects of bank erosion. As typical riverbank protection methods with geo-bags or concrete blocks are expensive, the cost-effective, local technology using locally-available material and manpower provides a sustainable way to arrest river bank erosion. Conventionally, spurs, groynes, revetments or a combination of them are used to manage and mitigate river erosion and related problems. However, these structures are too expensive to adapt to the longer reaches of the large-scale alluvial rivers of Bangladesh. The key mechanism of bandal structures is their ability to shift sediment loads towards the bank line, where water flows at a reduced velocity. It is also utilized to divert water flow towards the mid river, to facilitate natural dredging, smooth navigation and erosion mitigation. On the basis of empirically-understood working principles of bandal structures, it is used as a low cost and environment friendly measure to stabilize the river banks of Bangladesh.

1.2 Background of the Study

Bank erosion and channel shifting of the untrained alluvial rivers of Bangladesh are big problems to the socio-economic and environmental sector of the country (Klaassen, 2002). On average more than 8,000 ha of land is losing annually due to bank erosion. Although different study reports confirm that there is a tendency of decreasing rate of erosion due to implementation of large number of riverbank protective works during the last few decades by Bangladesh Water Development Board (BWDB). Failure of implemented bank protective works is also remarkable. During pre and post monsoon of each year, the erosion process becomes more vigorous. Flood and heavy rainfall also accelerates the erosion process (Hossain et al., 2010).

Now a days, the increasing demand of low cost river training structures which can be friendly to the environment reminds the necessity of different types of structures. Traditional structures such as groynes, weirs, revetments, etc., are used to maintain a suitable channel for the purpose of flood control, erosion protection, enhancing navigation conditions and also restoration of the natural habitat of river environment. However, the construction and maintenance of these structures represent an undesirable cost and time consuming in actual days. So, applying these conventional methods of countermeasure, the river bank erosion at the short term basis can be obtained, whereas, the long term stable channel or regime channel can never be developed. The possibility of using bandals for long-term channel stabilization is examined using field data and laboratory investigation (Rahman *et al.*, 2003).

Bangladesh is a riverine country with an area of about 1,47,570 sq km. There are rivers, beels, lakes and haors and open water bodies covering a total area of about 9,634 sq km. About 70% of the total land area of the country is prone to flooding in monsoon. As to climate, the climate of Bangladesh is characterized by humidity, temperate climate and reverse wind flow in winter and summer, which are obvious with seasonal variations. Due to this diverse nature, floods occur almost every year in the monsoons and most of the land in the country is inundated and the banks of the river are in risk of erosion. As a result, huge amount of resources are under threat. The use of bandaling, as an indigenous technology, to prevent river bank erosion, land reclamation and enhance river navigability by attracting silt and sand towards the river banks is a timely step for our Bangladesh. As a developing country, optimum use of money is required. At present, the average cost of bank protection in small rivers is around Tk 4-5 lakh and in big rivers it is around Tk 8-10 lakh per meter. On the other hand, the cost is only 5 thousand taka per meter for the use of bandaling structures. The present study has been done in different parts of the country by constructing bamboo bandaling structures on different rivers. After constructing bamboo bandaling structure huge agricultural land and houses, mosques, madrasas, schools and colleges are protected from river bank erosion. Moreover, through the study, as the characteristics of different rivers in Bangladesh are different, proper knowledge has been obtained about the exact depth to which bamboo bandaling is effective in the case of any river.

1.3 Objective of the Study:

The main objective of the study is to examine degree of effectiveness of Bamboo Bandal Structures at field level for different circumstances in different type of rivers like flashy, alluvial and tidal river.

1.4 Specific Objectives:

- To examine the impact of bamboo bandal structures in flashy rivers for bank protection, land reclamation and increase navigation.
- To examine the impact of bamboo bandal structures in alluvial rivers for bank protection, land reclamation and increase navigation.
- To examine the impact of bamboo bandal structures in tidal rivers for bank protection, land reclamation and increase navigation.
- To examine the effectiveness of proposed bamboo bandal design from laboratory investigation.
- To develop guide lines for effective implementation of bamboo bandal structures to achieve desire goals.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Bangladesh has a subtropical monsoon climate and during the monsoon, extensive riverbank spills and riverbank erosion are typical. Riverbank erosion mainly occurs due to heavy rainfall, particularly in the upstream region, and resulting increased water flow and sediment supply to the rivers. The easily erodible nature of the river bank also contributes to the bank erosion. Most recently, due to climate change, the rate of riverbank erosion has drastically increased, resulting in loss of valuable land at a faster pace and as a consequence millions of people suffer every year. In order to reduce the suffering of the people and minimize national losses a number of studies and researches related to the erosion/deposition, sediment transport, velocity distribution, channel stabilization, scour around the structures and different bank protection works have been carried out by different researchers. Literature Review provides a scope for reviewing the reserved knowledge and information to the proposed studies/researches of related field. The summary of different studies and researches relevant to this study as well as some related terminologies has been discussed in the following sections.

2.2 Previous Studies and Researches on Traditional Erosion Protection Methods.

Barman, S. et al. (2020) studied a case about erosion and scour protection of guide bund for a major river bridge on national highway in India and other applications using TechRevetment® technology. In This study, permanent erosion and scour protection works for a guide bund where TechRevetment® technology has been adopted. The river guide bund protection works were undertaken using Articulating Block (AB) concrete mattress for guide bund and embankment structures upstream and downstream of the location of a new bridge structure over Jia Bharali River in the state of Assam, India. At the bridge location, the river is characterized by a braided pattern with its width varying from 1 km to 7 km. The bed level elevations at the deepest point in the channel range from 72.5 m approximately 11.8 km upstream of the bridge, to 61.4m approximately 7.2km downstream. The average longitudinal slope of the river was estimated as 1m in 1709m. Hydrologic studies of the site and contributing catchment areas, along with records of historic monsoon seasons were used to develop a design discharge of 10,000 cubic meters per second to represent a 100-year return period. The High Flood Level (HFL) induced water depth to vary from 2.5m to 7.5m across the channel width. Model studies were used to estimate that the mean and maximum velocity of flow along the guide bund varied between 1.766 m/s and 2.7 m/s respectively based on which the scour depth was estimated to vary between 17m to 25 m below HFL.

Mamun Hossain et al. (2017) studied a case about Utility of River Training Structures and Present Status in Patuakhali District Bangladesh. In this study, three categories of river training structure were found at different locations of the study area. Revetment with cement concrete (CC) block including 1.75 km bank protection measure from erosion due to high velocity tidal current at Lebukhali point (0.715 km), Patuakhali town protection point 2 (0.62 km) and Khepupara Bandar & town protection (0.42 km). Among them Lebukhali point was found more offensive comparing with other points. The level of risk of all structures were averaged under low to medium except Lebukhali point. The training structures were found moderately stable due to maintenance and effectively acting as qualitative benefit for inhabitants in socio-economic aspect.

Md. Shofiul Islam (2008) studied a case about river bank erosion and sustainable protection strategies. In this study, a scale model study was conducted at River Research Institute (RRI) to find out the effectiveness of this hard measure (T-head groyne) and also find out an appropriate hydraulic structure and its location to stop the bank erosion at Kazipur, Sirajgonj. But after a series of test runs in the scale model, three groynes were recommended instead of single groyne along with the optimum design parameters of the groynes, size of the riprap and length of the falling apron (Details may be found in RRI, 1996). But considering huge cost, series of spurs were proposed by the client and then tested in the scale model. Based on the test results, seven spurs were recommended to protect 5 km area.

Md. Anisur Rahman (2010) studied a case about comparative analysis of design and performance of bank protection works of jamuna river at titporol and debdanga. This study has been conducted to determine the probable cause of the damage of riverbank protective works constructed on the right bank of Jamuna River at some selected locations of Sariakandi. BWDB implemented the protective works at Titporol and Debdanga along the Right Bank of the Jamuna River during November 2004 to April 2005. From field investigation on 28 June 2005 it was found that the revetment work at Debdanga performed well during early flood after construction. But some portion of upstream revetment at Titporol, however, damaged in June 2005 and mitigation measures by dumping of sand filled synthetic bags were carried out to stop further collapsing of river bank. In order to find the probable causes of failure of protective works at Titporol, investigation has been carried out through checking the adequacy of the design of the revetment, slope stability analysis and field investigation. Design of the revetment has been reviewed using the standard procedure mentioned in the Design Manual of BWDB and have been found satisfactory. From the analysis of field condition it is revealed that the damage of revetment works occurred due to low shear strength of soil and the presence of pore water pressure developed behind the geo-textile filter. It is apprehended that for the lack of free drainage, pore water pressure developed behind the geo-textile filter and this resulted failure of bank slope. At the damaged portion, subsoil water might have been drained from underground source or from the existing ponds behind the revetment works as was found at the protective site of Titporol. On the other hand, no such kind of underground source of water or existing ponds near the revetment- works site at Debdanga was found. Therefore, the protective-works at Debdanga performed well.

Mohammad Nazim Uddin et al. (2017) studied a case about response of river training structure against the changing flow and morphology in a sand bed braided river. The response of the Sirajganj Hard Point (SHP) against the changing flow and morphology has been investigated in the study. The Jamuna is a braided river. The channel boundaries are consisted with fine sand and susceptible to erosion easily. The morphology of the Jamuna is strongly affected by the variable discharge and is changed over time. Even after a single flood, the river does not return to its previous morphology and it has to adjust with the changed morphology. During adjustment to its new morphology, erosion at some places and deposition at other places makes the river very dynamic. To protect its bank from erosion different types of structure have been constructed at several locations along the both banks of the Jamuna River. Among them Sirajganj Hard Point (SHP) is one of the robust and most expensive river training structure in Bangladesh. But since its construction the Hard Point has been damaged partially several times. To investigate the causes of failure of the Hard Point 3-D hydraulic data was measured using ADCP in the dry and flood season. The dry season satellite images have also been used to clarify the failure event. It has been investigated from this study that the flow pattern around the Hard Point is changed with the morphological change of the river. Oblique flow is generated due to formation and movement of sandbar. It attacked the eastern straight part of the Hard Point. The situations become worsen due to harmonization of several factors with the oblique flow. The factors are shifting of thalweg towards Hard Point, dune movement, riprap failure, development of scour hole and flow slides.

Md. Amirul Hossain et al. (2017) studied a case about a low cost river bank protection innovative technique for the tidal rivers of the south west region of Bangladesh. The Polder 29 situated in the south west zone has been adversely affected by river bank erosion causing embankment washing away that leads to flooding and salinity intrusion inside the Polder. A study was conducted at erosion vulnerable site of Polder 29 to identify causes of erosion and developed an innovative low cost adaptive approach for river bank protection. Prevailing problem analysis, data collection, model development, morphological behavior of the area, design for low cost innovative type river bank erosion protection measure were the approaches for this research. The hydrodynamic model was calibrated and validated for both water level and discharge. Simulations were carried out for both dry and monsoon seasons to establish a baseline condition, existing flow distribution, current field, erosion vulnerable area, suitable design parameters for low cost innovative type bank protective measures. Cost of recommended measures of bank protection by constructing series of permeable concrete spars with flow reducing measures at upper portion for Polder 29 is about BDT 60million (US$ 0.75 million). The conventional method of bank protection with Cement Concrete (CC) blocks supported by geo-textiles needs cost of BDT 570million (US$ 7.13 million), which is 9.5 times higher than the low cost innovative type bank protective measures recommended by the study.

Tanveer Ahmad (2014) studied a case about river bank protection works for the Baleshwar river in Pirojpur district. A river embankment section along the left bank of the Baleshwar River, just upstream of the Pirojpur town was chosen for design study. Statistical analyses were performed on the Annual High Tidal Water Level to estimate 1-in-50 year tidal height with storm surges as design water level. The Design Water Level and soil data obtained from the project were used to design structural parameters for the river embankment. Finally a comparison was made between the existing and performed designs. The river has meandering with braided condition and possesses silt carrying capacity. The bank movement occurs frequently. The flood has an impact on that region and during monsoon period, salinity become harmless on cultivation. The Seismic effect on the constructed embankment was found to be negligible. This river also has a tremendous tidal effect twice a day that also contributes to the rise in the water surface level. Storm surge has another contribution on the rising of water level that also was estimated from previous surge data and was added to the design of embankment crest level.

Maminul Haque Sarker et al (2011) studied a case about river bank protection measures in the Brahmaputra-Jamuna River. In this study, revetment type structures are found to be more stable in the Jamuna River than groyne type structures. Revetment structures also differ from each other by their construction methods, construction materials and cost. The structures that are extended deeper and materials consisting of boulders are costly, but they are more stable and their performance is better. On the other hand structures made of sand filled geobags, which are the cheapest among the revetment type, are also stable but definitely not to the same extent as the guide bund. Costly solutions such as guide bunds can be recommended only for structures that are used to protect very sensitive and costly establishments. On the other hand the less costly revetment constructed with sand filled geo-bags may be used for protecting agricultural land, towns and commercial centers. A detailed study needs to be carried out to assess the impact of the structures in reducing the erosion rate and influencing the overall morphology of the Jamuna River. The performance or stability of the different types of structures constructed with different materials should be evaluated along with vigorous investigation in connection with the local morphology of the river.

Maarten van der Wal (2020) studied about Bank Protection Structures along the Brahmaputra-Jamuna River. The main part of the investigation was focused on reducing local scour holes near river training works. The most promising results are river training works with gentle bank slopes, permeable groynes, bed protections in dredged trenches with gentle side slopes, and methods to increase locally the bearing capacity of the subsoil. It is recommended to increase the knowledge of the failure mechanisms in the Brahmaputra-Jamuna River by improved monitoring in the field, the setup of a database with descriptions of all observed flow slides and the circumstances in which they occur. In addition to these recommendations, a field test facility is proposed to verify the knowledge of the failure mechanisms in that river. These activities will optimise the design of new river training structures with a very low risk of damages by flow slides and geotechnical instabilities and they will contribute to an improvement of the current design guidelines for river training structures.

Khan, S.K. et al. (2015) studied about different riverbank protection works in Bangladesh. From this study, it was investigated that the bank developed by sand filled geo-textile bags through areal coverage method is cheaper than any other bank protection work. Revetment serves better as bank protection measures while groynes/spurs are problematic as bank protection measures in large rivers as experienced in Bangladesh. Cost effective riverbank protection commonly relies on the falling or launching principle. Considering the cost and sustainability of revetment and the falling apron, spurs and groynes are not suitable for our country because the morphology of our rivers is changed rapidly. Considering other types of protective works, revetment work is more cost effective solution in context of Bangladesh as it doesn't hamper the direction of flow on the channel & regular maintenance works need to be ensured.

2.3 Previous Studies and Researches on Bandal Type Structures

Rahman, M. M. et al. (2006) studied about prediction of local scour depth around bandal-like structures. An analytical model for the prediction of local scour depth around bandal-like structures is developed using the basic features of laboratory experiments under clear-water scour. The developed model is applied to available laboratory data as well as field data along the Jamuna River in Bangladesh. It was found that the model fits the experimental data having relatively shorter length but failed to predict the field data where length of the structure was relatively longer. The underlying reasons of such success and failures of the model for the prediction of local scour depth around BLS is discussed with the future target to develop more generalized prediction model.

Teraguchi, H. et al. (2011) studied about alternative method for river training works: bandal-like structures. In this study, the applicability of bandal-like structures as an alternative method for traditional river training structures like groynes is investigated. This structure is usually used in Indian Sub-Continents for riverbank protection and improvement of navigation conditions in alluvial rivers. The mechanism behind the utilization of this type of structure which affects the flow patterns and sediment transport process was studied through experimental measurements and numerical simulations. During the calculations, the water flow was computed by solving the

Reynolds-averaged Navier-Stokes equations in 3D domain. The k−ε model was used for the turbulence closure and the numerical simulation was conducted on the unstructured meshes with the finite volume method. The main characteristics of the sediment erosion/deposition process around the bandal-like structures were clarified. The promising use of bandal-like structures was demonstrated through the comparisons with conventional structures as impermeable groynes.

Rahman, M.L. and Osman, M.S. (2015) studied a case about river bank erosion protection using bamboo bandalling structure. Under the framework of this study, bamboo bandals have been placed on the erosion prone bank of the river Jamuna near the Shaheed Salahuddin Cantonment in the u/s of the Bangabandhu Bridge East Guide Bund, Bhuapur, Tangail. Due to the effect of the constructed bamboo bandals in the meander bend, huge sedimentation behind the bandals occurred and at the same time river course matches with upstream and downstream reach. This matching gives an indication of channel stabilization by stopping the river bank erosion in the bend as well as reducing the intensity of secondary flow which is responsible for accelerating the river bank erosion. It is observed that water flow is diverted towards the main channel and low flow velocity near the river bank. Due to low flow velocity, sedimentation occurred near the river bank between the constructed bandals indicating that bandaling can be used successfully as river bank erosion protection structures as like as the conventional groyne/spur like structures.

Rahman, M.M. et al. (2003) studied about channel stabilization using bandaling. In this study, performance of bandals to increase flow depth in the navigational channels was investigated. On the basis of empirically understood working principles of bandals, it is revealed that bandals can be used as a method of bank protection/channel stabilization, which is highlighted in this study. Outlines of the experimental methods on bandals are also highlighted briefly.

Rahman, M.L. and Osman, M.S. (2018) studied about sedimentation by bamboo bandaling structures near the river bank. In this study, an experimental investigation was done in the laboratory of River Research Institute, Faridpur. In the laboratory flume, a series of bamboo bandals were placed to see their effects on flow and sediment transport. This is a low cost approach for river bank erosion protection. For this low cost approach, a detailed investigation in the laboratory was needed before implementation in the field. It was observed from the laboratory investigation that water flow diverted towards the mid channel due to placement of bandals near the river bank resulting in comparatively less flow velocity near then river bank &

cosequent sediment deposition due to reduced sediment transport capacity. This type of sedimentation near the river bank gives an indication that the bandal like structures can be used successfully for the river bank erosion protection.

Rahman, M.M. et al. (2004) studied about on the formation of stable river course. In this study, as an alternative low cost method that can be adaptive within local socio-economic and environmental condition, the possibility of use of bandals for the formation of stable river course is explored. The basic features of bandals in terms of flow and sediment control are clarified using simplified mobile bed experiments. Based on experimental results, simplified analytical models for the prediction of main channel degradation and local scouring around the structures are developed and verified using experimental data. The model predicts the experimental results reasonably well. Finally, the concept of gradual method for river course stabilization is discussed on long-terms basis.

Teraguchi, H. et al. (2011) studied about analysis of bed variation around bandal-like structures. In this study, the present investigation is focused on river bed variation caused by flow patterns around bandal-like structure in channels. This type of structure have been used from the past in the Indian Sub-Continent to protect the river bank from erosion and to maintain the navigational conditions in alluvial rivers as the Jamuna river in Bangladesh. Few laboratory studies and field observations using bandal-like structures was realized to verify the real applicability of them as an alternative structure over conventional river training structures as groynes (impermeable and permeable ones). To clarify the effectiveness of bandals in river morphology, detailed investigation about the complex flow structures and sediment transport mechanism influenced by bandal-like structures was realized. Laboratory experiments were conducted in a straight flume with two structures positioned on one side of channel to the measurements of the velocity field and bed level near the structures under live-bed scour condition. A morphological model based on unstructured meshes was developed to simulate the flow patterns and bed variation around these structures. The experimental and numerical results of flow distributions and bed level variation around each type of structure were analyzed. The bandal-like structure shows promising results as the reduction of local scour around them and deposition of sediment at downstream of Bandals in comparison with the conventional structures as groynes.

Rahman, M.M. et al. (2005) studied about formation of navigational channel using bandal-like structures. In this study, the effectiveness of bandal-like structures (BLS) for the formation or restoration of navigational channel is tested. The basic feature of BLS in terms of flow and sediment control are clarified using simplified mobile bed experiments where a series of such structures were installed on both side banks. Based on the experimental results and flow visualization, simplified analytical model for the prediction of main channel degradation (as a measure of navigational channel formation or restoration) was developed and verified using experimental data. The model predicts the experimental results reasonably well.

Nakagawa, H. et al. (2016) studied about investigation of suspended sediment transport and bed deposition around bandal-like structures. In this study, they investigated the flow structure, suspended load concentration and bed deposition characteristics around a group of bandal-like structures with experimental methods. The experiments demonstrate that the local flow around Bandal-like structures are complex due to the flow separation, the upward flow, the flow circulation and the interaction between the mainstream and the bay area. In particular, the upward flow passing through the lower part of the bandal-like structures plays an important role in supplying sediment to as well as promoting sediment deposition in the bay area.

Rumana Sharmin (2009) studied about effectiveness of bandaling and dredging for the maintenance of navigational channel in the Jamuna River. The study areas were selected where bandaling and dredging - both means were used to maintain navigability. In Manikdah, BIWTA applied only bandaling, whereas in Aricha only dredging was adopted to serve the purpose. In Char Pechakhola both bandalling and dredging were applied simultaneously to maintain the navigational channel. In the year of 2006, it was observed that during dry season, dredging failed to bring desired outcome in Char Pechakhola-Nakalia channel because of high velocity. Besides, dredged volume was dumped in the channel, which ultimately caused huge sediment deposition in the main channel. Consequently, the authority chose bandalling as an alternative option to keep the channel navigable.

2.4 Summary of Findings from Literature Review

Several studies have been carried out till date to manage and mitigate river erosion and related problems of the different types of rivers in Bangladesh as well as all over the world. Bangladesh has a long history of combating the damaging effects of river bank erosion. In order to cope with the bank erosion disaster, several types of protection measures were undertaken in the past. Some of them came up with intended outcomes while others failed to serve the purpose under different circumstances and field conditions.

Traditionally spurs, groynes, revetments or a combination of them are used to manage and mitigate river erosion and related problems in Bangladesh. Now-a-days sand field geo-bags are also being used for bank erosion mitigation. Although geo-bag protection is considered as a temporary measure it has been going acceptance because it involves comparatively less cost. However all these structures as a whole are too expensive to adapt to the longer reaches of the large-scale alluvial rivers of Bangladesh. As typical riverbank protection methods with geo-bags or concrete blocks are expensive, the cost-effective, local technology using locally-available material and manpower provides a sustainable way to arrest river bank erosion. Channel-shifting problems can also be reduced by constructing low-cost bandal type structures; with the added advantages of agricultural land reclamation as well as navigational channel development. In large multichannel rivers, generally a subsidiary channel takes off from the parent one and attacks the bank. The method is useful in improving the navigable depth by diverting the flow through the active channel and closing the subsidiary channel.

Given the recurrent nature of bank erosion of all types (small to major) of rivers in Bangladesh a low cost alternative can be used to maintain the navigation conditions in the alluvial rivers. It can be made by bamboo or wood pieces and the technique used to its construction is easy. Since 2005 RRI has been conducting experiments both in laboratory and field to investigate the efficacy of the bandaling as low cost alternative to conventional bank protection works. Bamboo bandal has been envisaged as a low cost solution for river training in order to mitigate damaging impacts of river bank erosion as well as to improve navigability of the rivers. So far, bamboo bandals have been implemented both in large and small rivers. The rivers concerned are both tidal and non-tidal. The outcomes of such implementation indicate that bamboo bandals can be used as an alternative to the traditional methods on selective basis.

CHAPTER 3

THEORETICAL BACKGROUND

3.1 General

Bandal structures consist of a framework of bamboo driven into the riverbed during low water stage and supported by struts. Bamboo mats are fixed to the framework near the water level. Bandal structures are commonly applied to improve or maintain the depth of river channels for navigation during low water periods or to close secondary channels by redistribution of discharge and sediment load at bifurcations. The individual bandals are oriented at an angle of 30 to 40 degrees (inclined downstream) to reduce the flow velocity near the bank line and to increase the flow velocity along the thalweg (Figure 3.1). As a rule of thumb the blockage of the flow section should be about 50% (i.e., panel height and clearance from lower panel edge to river bed level at time of installation should be about equal). Due to the fact that blockage ratio of bandals change with water depth, their efficiency depends strongly on the actual water depth. Since the stage and depth of flow vary with time, a good performance is achieved only during particular time period when an optimal blockage ratio of the individual bandals is achieved. These structures may be used for water depth up to 4m to 5m. But in our project and research we have used bandal like structure of new proposed design (Fig-4.2) for effective output.

3.2 Bandal Structures and its History

Bandals are one of the local structures developed in the Indian Sub-continent to improve or maintain the flows depth for navigation during low flow season. The main characteristics of bandal-like structures are that they obstruct the high velocity flow near the water surface through the upper blocked portion conducting it to the main channel and allow the reduced velocity flow to pass near the riverbed. They usually are oriented at an angle with the main flow direction (30^o ~40^o) and provide indirect protection by diverting potentially erosive currents away from the riverbank and by guiding the flow in a desired channel course. These are made of naturally available materials such as bamboo and wood pieces (Figure 3.2) that are regarded as inexpensive method over conventional structures as impermeable groynes.

The undocumented history towards the use of bandalling in Bangladesh may be traced back to the British colonial period, sometimes 200-300 years back according the professionals of BIWTA. During the dry season, several islands are emerged within waterways that hamper normal ship movement. Sometimes, bars/islands are smaller in height and submerged in nature. As a result, these are not visible during navigation. A story from BlWTA is stated as, during the British colonial period, a heavily loaded ship was stopped on such a submerged island/bar. All attempts to make the ship in operation were in vain. Finally, it was decided to abandon the ship until the next monsoon. In such a situation, one Bangladeshi Captain wanted to try to rescue the ship by using some technique he thought about. The generated idea was bandaling and could successfully rescue the ship and since then bandaling was being practiced by BIWTA. More and more experiences have been gathered with time.

A bandal structure physically appears as a vertical screen mounted on a frame. In general, the screen is made of bamboo mats and the frame consists of a series of bamboo sticks (Figure 3.2). As bamboos are locally available and low-priced labors are easily employable on site, bandal structures have achieved a wide use in some large braided and meandering rivers. According to the physical appearance, a bandal structure can be described as a combined structure of an impermeable groyne in the upper part and a permeable groyne in the lower part (Zhang et al., 2010). When the sediment-laden flow approaches a bandal structure, the low sediment-concentrated flow of the upper layer is diverted to the mainstream and is accelerated, resulting in mainstream bed degradation and increase of water depth. It is the mechanism for the navigability enhancement. On the other hand, the high sediment-concentrated flow of the lower layer passes through the bandal structure and sediment deposition occurs behind it due to the velocity reduction there (Rahman et al., 2004). As sediment deposits along the river bank, the risk of bank erosion is reduced and a new agricultural land is created. In other words, bandal is not only effective for the improvement of domestic navigation but also promising in farmland protection and disaster mitigation. Unfortunately, the performance of bandal is not always as efficient as desired according to analyses of field data obtained in major Bangladeshi Rivers (Rahman et al., 2003). In order to make full use of this indigenous method, there is a crucial need to combine updated insight of river dynamics with local indigenous knowledge and experiences. The structure having the similar functions as bandal structures is defined as bandal-like structure herein despite its construction materials; shape and layout are similar almost. In the past decade, several groups have conducted research on the flow and the bed morphology around bandal-like structures, e.g. Rahman et al. (2004), Zhang et al. (2010), Uddin (2010), Nakagawa et al. (2013) and Rahman and Osman (2015). These researches revealed the complex flow structure around bandal-like structures and some of the advantages of bandal-like structures over other traditional river training works.

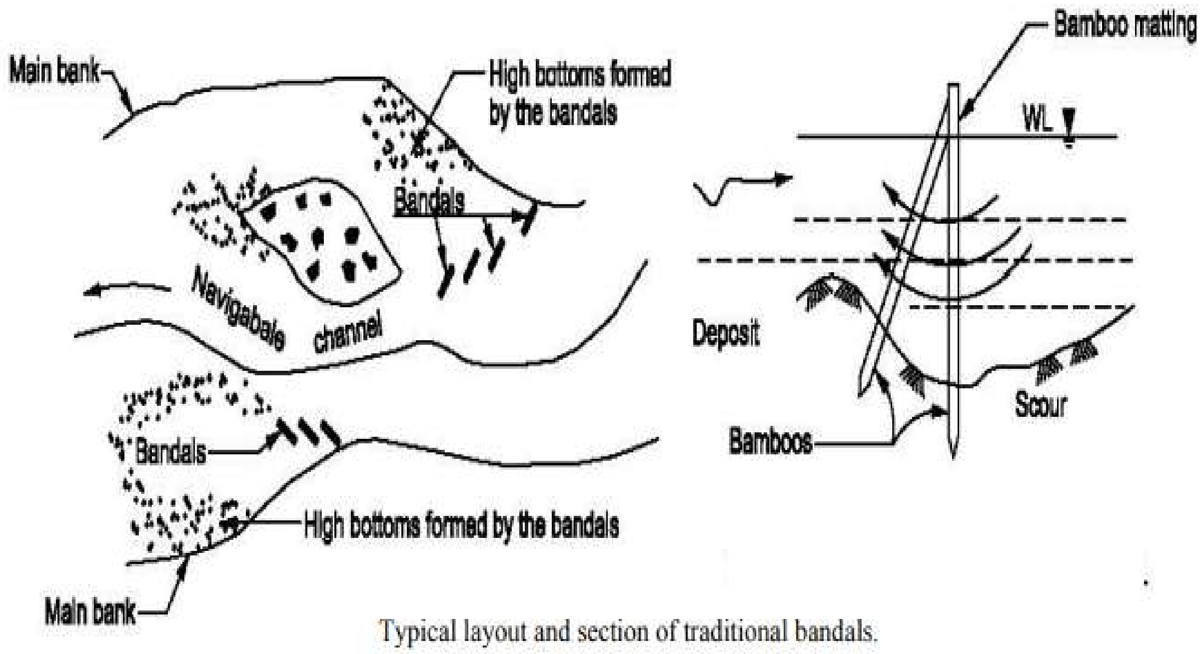


Figure 3.1 Typical layout and section of bandals

Figure 3.2 Typical bandal constructed alongside the river

3.3 Function of Bandalling

A typical bandal has an opening below (permeable part) to allow the passage of flow through the structure and a blocked upper portion (impermeable part) towards the near surface flow at u/s to the main channel direction. The morphological changes around the bandal are characterized by a small scour hole followed by a sediment deposition at the d/s which is shown in the Figure 3.3.

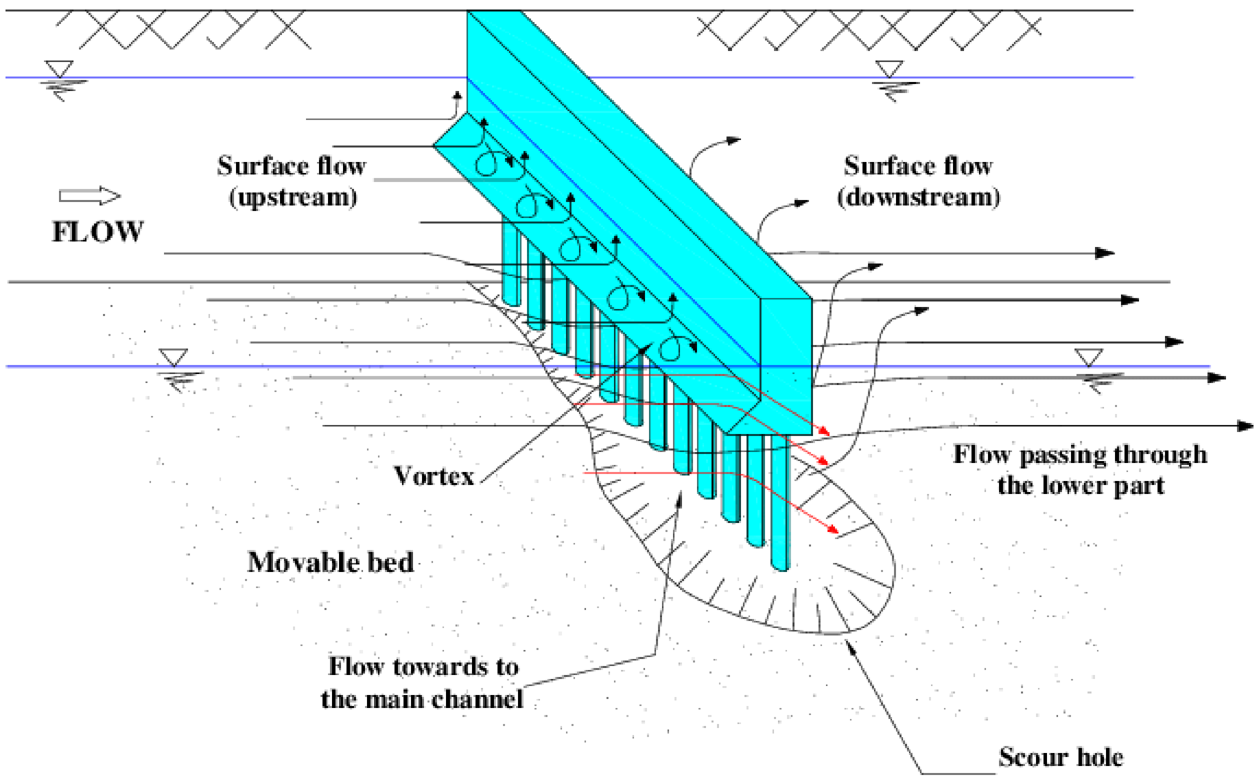


Figure 3.3 Function of bandal structure

3.4 Working Principle

The working principles of bandals for the control of water and sediment flow are shown schematically in Figure 3.4 (Rahman et al., 2003a; 2003b). Within the lower half of the flow depth, major portion of the sediment flow is concentrated, while, the reverse is true for the water flow discharges. The essential characteristics of bandals are that they are positioned at an angle and orientation with main flow in order to maintain the flow acceleration. The surface flow is being forced to the upstream face creating significant pressure difference between the upstream and downstream side of bandal. The bottom flow is directed perpendicular to bandal resulting near bed sediment transport along the same direction. Therefore, much sediment is supplied towards the one side of channel and relatively much water is transported to the other side. The reduced flow passing through the opening of bandals is not sufficient to transport all the sediment coming towards this direction.

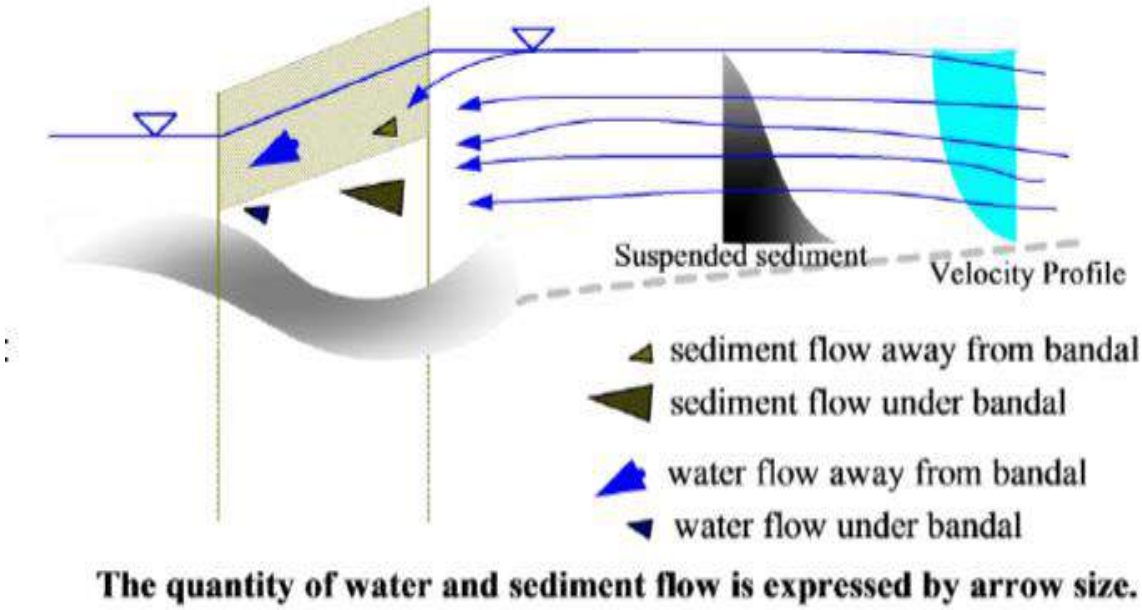


Figure 3.4 Basic working principles of bandals

CHAPTER 4

APPROACH AND METHODOLOGY

4.1 Project/Study area

Bangladesh is predominantly a low-lying riverine country situated in the South Asian Subcontinent. There are almost 700 rivers including convergence of Ganges (Padma), Brahmaputra (Jamuna), and Meghna and their tributaries run through the country . The physical characteristics, geographical position, climatic condition, and auto-cyclic fluvial courses have produced numbers of big multichannel river flowing through the country with separate channel width of up to 5 km in which scour generated around 50 m depth . The channel width becoming large and depth is reducing over the year due to unfavorable geographical location and river flow control by the countries upstream reaches, that's leading to unexpected erosion-deposition processes along the river. Thus, bank erosion and channel shifting of alluvial rivers are under serious problem in social, economic, and environmental aspect . The alluvial floodplain rivers are always flowing on common geomorphological process which causes of bank erosion.

The coastal region of Bangladesh has been marked as a critical disaster hotspot. This region mainly includes—Khulna, Satkhira, Bagerhat and Jessore, Patuakhali, Barishal, Noakhali, Feni, Chittagong and Coxesbazar, which have high concentrations of rivers and canals, forming a dynamic coastal ecosystem. The coastal ecological system is changing more rapidly than before due to different cross-cutting social, political and natural factors. Prolonged and recurring water-logging due to inappropriate and poorly-managed engineering interventions, semi-intensive aquaculture, and diversion of river flow in the upstream have all dramatically altered human livelihoods. On top of that, climate change effects have exacerbated the crisis in recent years.

. The ecosystem relies on a delicate balance between water flows from two directions: downward flow from the Source River and drainage tributaries, and upward flows of sediment-laden estuarine rivers from the Bay of Bengal (that causes riverbed siltation). Riverbed siltation and brackish water effect due to sea-level rise and high tide have led to prolonged and recurring water-logging in southwest Bangladesh in the last two to three decades.

Hill catchment draining into the northeast and southeast regions is characterised by flash floods that are mostly of short duration but unpredictable in frequency and intensity. Several floods may occur in the flashy rivers in any water year. The Northeast Region (NE) of Bangladesh comprises 17.5% of the total area of Bangladesh. There are altogether 373 Haors distributed in the districts of Sylhet, Sunamganj, Moulvibazar, Habiganj, Netrokona, Kishoreganj and Brahmanbaria in this region. The Northeast region experiences flash flood during pre-monsoon and monsoon seasons. Early flash floods during the months of April-May damage the main crop Boro rice nearly or just before the harvesting. About 60% of the total runoff in the region is produced, mostly in the form of flash flood occurring outside Bangladesh, by the three Indian catchments- the Meghalaya River catchments, the Barak River catchment, and the Tripura River catchments.

So, to cover these three different characterized river system river of six districts, Faridpur, Rajbari, Barisal, Khulna, Sirajgong and Netrokona are selected for the pilot project.

Project locations are selected in the erosion prone area of different rivers at different geographical and geological conditions in whole Bangladesh to investigate the effects of bamboo bandaling structures on water flow and sediment transport. Thirteen rivers including meandering, braided, flashy and tidal in Dhaka, Rajshahi, Mymensingh, Barishal and Khulna divisions are selected on the basis of their discharge, flow depth and sediment load. Among them Madhumati at Faridpur, Gorai at Rajbari, Arial khan at Faridpur and Dhaleswari at Sirajganj are considered as meandering rivers. Padma at Faridpur and Jamuna at Sirajganj are considered as braided rivers. Kangso, Sumeshswary and Nitai at Netrokona are considered as flashy rivers. Besides, tidal river including Sugandha at Barishal, Bhadra, Vairab, Rupsha and Atai at Khulna are also considered for selecting potential sites for constructing bamboo bandaling structures.

Due to placement of bandals in the above study areas, sedimentation occurred partly near bank sides and erosion occurred in the main channel. This phenomenon made more sediment particles pass along with low flow partly towards banks, whereas it allowed more flow along with less sediment particles to move towards main channel. When proceeding to downstream direction, an interchange of water and sediment particles took place and gradually the effect of the bandaling diminished. However, the next bandals brought about a similar change in flow and sediment distribution in transverse direction and consequently second bandal towards downstream repeated the same process in rotation. Details of selected project sites are shown in **Table 4.1** and **Figure. 4.1**. The site selection has been made based on the information of susceptibility to the erosive action of the river.

Table 4.1: Study area the pilot project in different areas of Bangladesh using bamboo bandaling structures

Serial No.	Project Site Name	River	Upazila	District	Division
1	Konagram, Jamshapur & Narua Kheyaghat	Gorai	Baliakandi	Rajbari	**Dhaka**
2	Kamarkhali Bazar	Madhumati	Modhukhali	Faridpur	**Dhaka**
3	Char Balashia & Shimultoli	Arial Khan	Sadarpur	Faridpur	**Dhaka**
4	Goldangirchar & Digrirchar	Padma	Faridpur Sadar	Faridpur	**Dhaka**
5	Charjoikuri	Padma	Rajbari Sadar	Rajbari	**Dhaka**
6	u/s of cross bar-1	Jumuna	Sirajganj Sadar	Sirajganj	**Rajshahi**
7	Neorgacha	Dhaleshwari	Chauhali	Sirajganj	**Rajshahi**
8	Brahmangram & Enayetpur	Jumuna	Belkuchuci	Sirajganj	**Rajshahi**
9	Rehaipukuria & Dewangonj Bazar	Jumuna	Chauhali	Sirajganj	**Rajshahi**
10	u/s & d/s of Jaria Bridge	Kangsa	Purbadhala	Netrokona	**Mymensingh**
11	u/s of Jaria Bridge	Somesshwari	Purbadhala	Netrokona	**Mymensingh**
12	Shankarpur Bazar	Nitai	Purbadhala	Netrokona	**Mymensingh**
13	u/s & d/s of Doarika Bridge	Sugandha	Babuganj	Barishal	**Barishal**
14	Ambaria	Atai	Dighalia	Khulna	**Khulna**
15	Kharnia bazar & Chandgoar	Bhadra	Dumuria	Khulna	**Khulna**
16	Shoilpur Ghat	Rupsa	Rupsa	Khulna	**Khulna**
17	Lashkarpur & Modhupur	Atai	Terokhada	Khulna	**Khulna**
		13	**14**	**6**	**5**

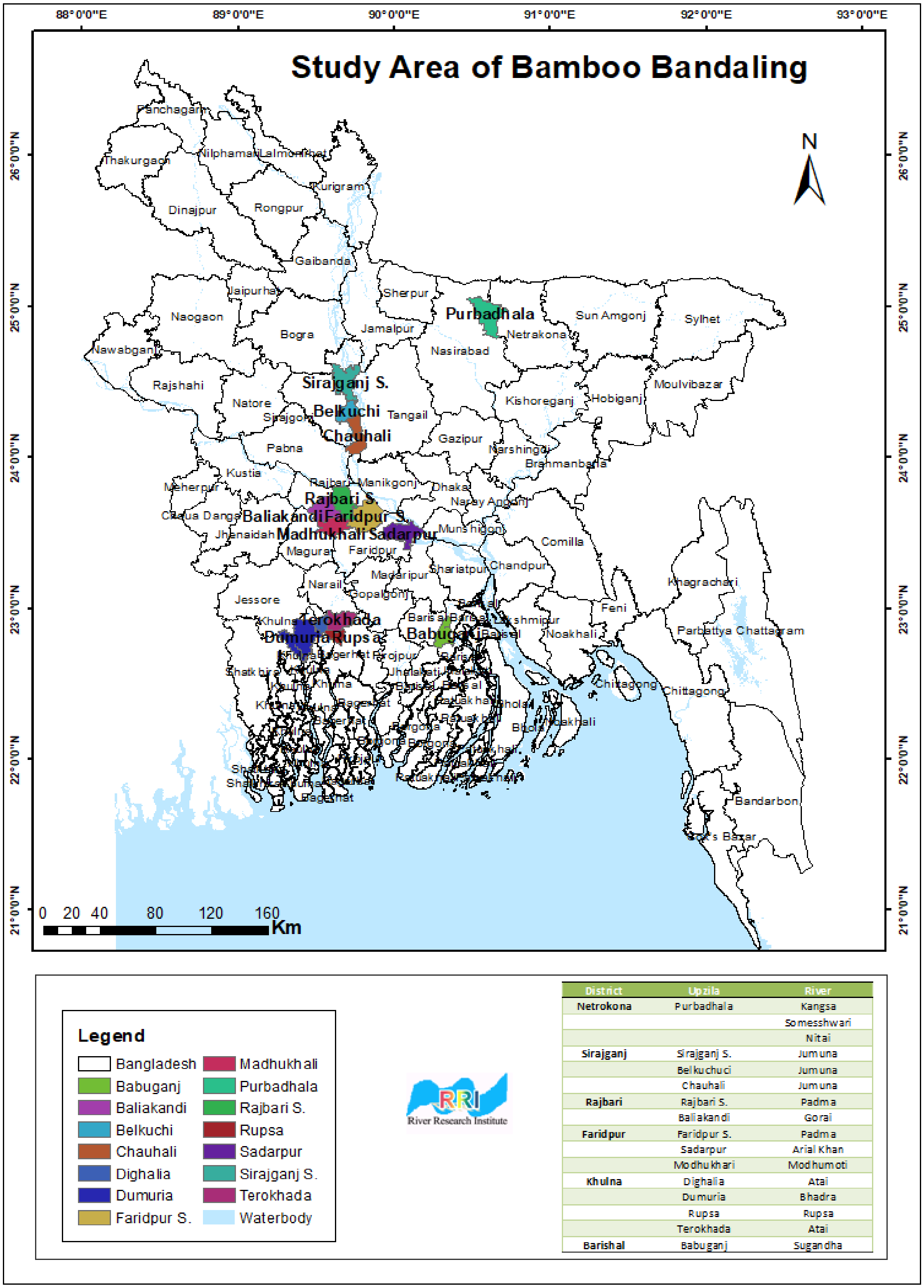


Figure 4.1 Project/Study areas of the bandal structures in different Upazilas of Bangladesh

4.2 Construction of Bandal type Structures

Bandal type structures have been constructed in the selected erosion prone areas of the pre-considered rivers between January 2018 and June 2021. At every site a series of bandal type structures are constructed covering the erosion prone stretch of the river fully or partially. The design features of bandal type structure are shown in **Figure 4.2, 4.3** and **Table 4.2**.

Table 4.2 The design features of bandal type structure

Type of bamboo	: Barrack
Length of the Vertical main Bamboo pole	: =>7.5 m
Length of Inclined bamboo	: =>7.5 m
Length of Vertical bamboo with Inclined (Tie)	: =>6 m
Length of the Horizontal Bamboo (Runner)	: =>6 m
Inserted bamboo pole below the ground level	: 4.0 m
Bamboo pole above the ground level	: 3.5 m
Diameter of the bamboo	: 6 to 8 cm
Distance between vertical main bamboo	: 30 cm C/C
Distance between horizontal bamboo (runner)	: 50cm C/C
1st Horizontal bamboo above the ground	: 75 cm
Angle towards downstream (depending on situation especially flow condition, depth and width of the river)	: 30^0 to 45^0
Distance between main bamboo pole and tie bamboo	: 0.75 m
Distance between main bamboo pole and inclined bamboo	: 3 m at G.L.
Length of the Bullah	: 7.5 m
Spacing of the Bullah	: 10 m C/C
Diameter of the Bullah	: 10 to 13 cm

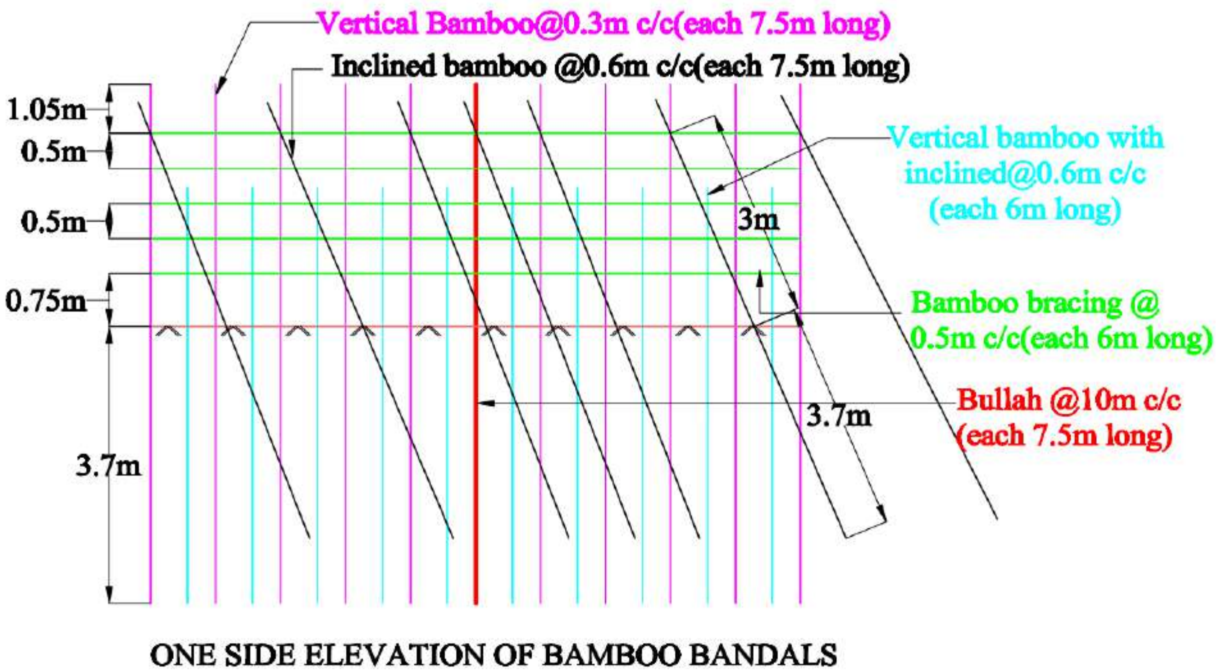


Figure 4.2 Design Features of Bandal type Structure

Figure 4.3 Constructed bandal structures at Enayetpur, Sirajgonj as per Design

4.2.1 Construction of Bandal Structures at Gorai River

Bandal type structures have been constructed in the erosion prone area of the left bank of the Gorai river at Narua and Jamshapur kheya ghat, Baliakandi upazila under Rajbari district in January 2019. In the first year, 1200 meter bandal structures have been constructed at u/s & d/s of Jamshapur kheyaghat and 250 meter at u/s of Narua kheyaghat. In the 2nd Year (March 2020), additional 500 meter at u/s & d/s of Jamshapur kheyaghat and 250 meter at the u/s of Narua kheyaghat have been constructed for maintenance of bamboo bandals as some bamboo were broken due to heavy flow in monsoon, and for more area coverage to protect bank and for preserving sedimentation. In the 3rd Year (April 2021), 800 meter bandal structures between Jamshapur and Narua kheya ghat and 1200 meter bandal structures at the d/s of the Narua kheya ghat have been constructed. In total 4200 meter bandal structures have been constructed at and around Jamshapur kheyaghat and Narua kheyaghat. The individual bandals are oriented at an angle of 30^0-35^0 towards downstream (Figures 4.4 and 4.5).

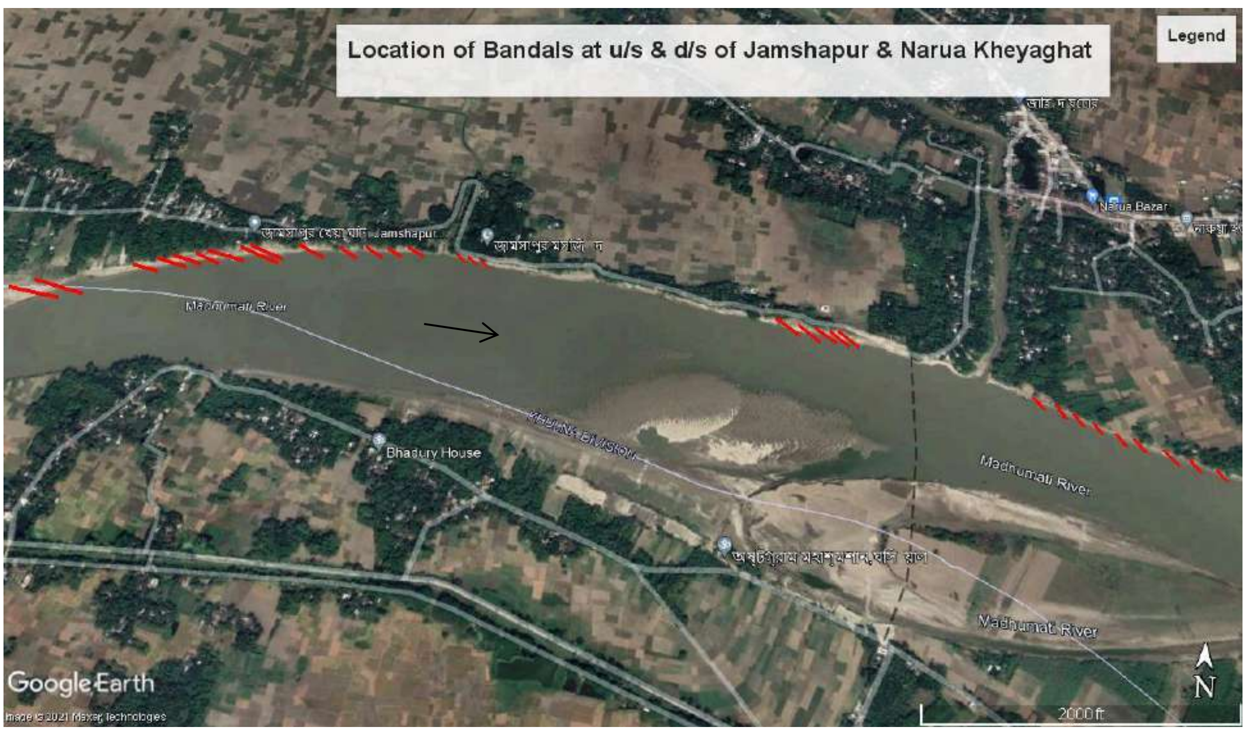


Figure 4.4 Location of the bandal structures at u/s & d/s of Jhamshapur & Narua kheyaghat

Figure 4.5 Bandal structures at u/s and d/s of Jhamshapur and Narua kheyaghat

4.2.2 Construction of Bandal Structures at Madhumati River

Bandal type structures have been constructed in the erosion prone area of the left and right bank of the Madhumati River at u/s & d/s of Kamarkhali bridge, Madhukhali upazila under Faridpur district in January 2019. 2000 meter bandal structures have been constructed at d/s of Kamarkhali bridge in the left bank near Kamarkhali Bazar and 650 meter bandal structures have been constructed at u/s of Kamarkhali bridge in the right bank of the Madhumati River. In total 2650 meter bandal structures have been constructed at u/s & d/s of Kamarkhali Bridge. The individual bandals are oriented at an angle of 30^0-35^0 towards downstream (Figures 4.6 and 4.7).

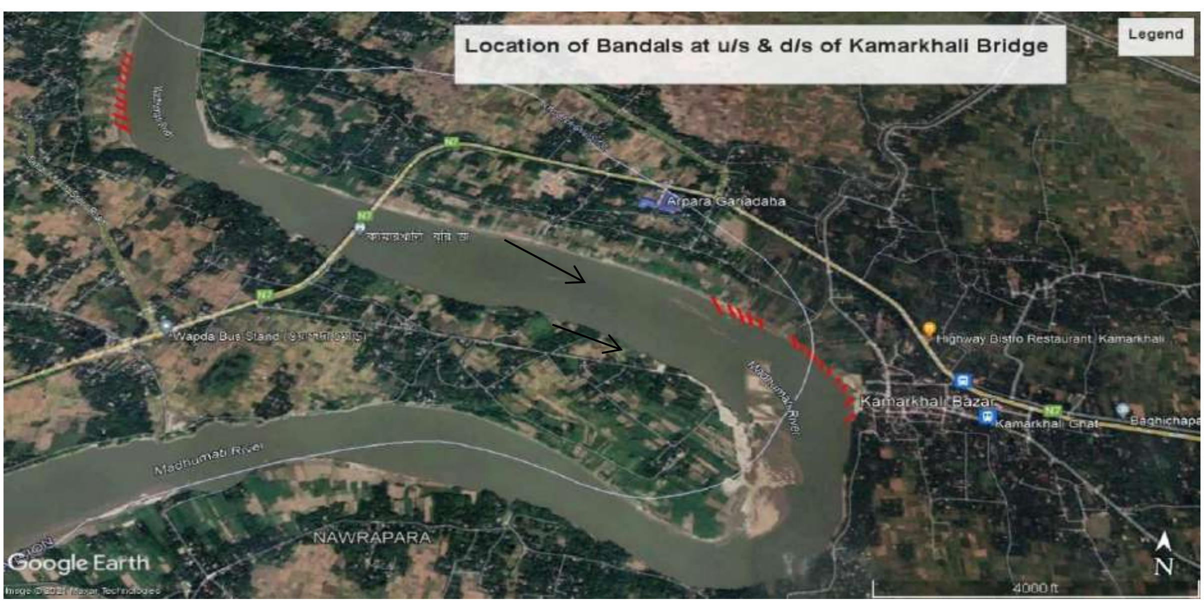


Figure 4.6 Location of the bandal structures at u/s & d/s of Kamarkhali Bridge

Figure 4.7 Bandal structures at u/s and d/s of Kamarkhali Bridge

4.2.3 Construction of Bandal Structures at Arial Khan River

Bandal type structures have been constructed in the erosion prone area of the right and left bank of the Arial Khan river at u/s & d/s of Chandrapara Ghat, Sadarpur upazila under Faridpur district in April 2019. In the first year, 650 meter bandal structures have been constructed at u/s of Chandrapara Ghat (Char Balashia) in the right bank. In the 2nd Year (March 2020), 850 meter bandal structures have been constructed at u/s of Chandrapara Ghat (Char Balashia) in the right bank. In the 3rd Year (February 2021), 450 meter bandal structures have been constructed at u/s of Chandrapara Ghat (Char Balashia) in the right bank and 750 meter bandal structures have been constructed at d/s of Chandrapara Ghat (Shimultoli) in the left bank. In total 2700 meter bandal structures have been constructed at u/s & d/s of Chandrapara Ghat. The individual bandals are oriented at an angle of 30^0-35^0 towards downstream (Figures 4.8, 4.9 and 4.10).

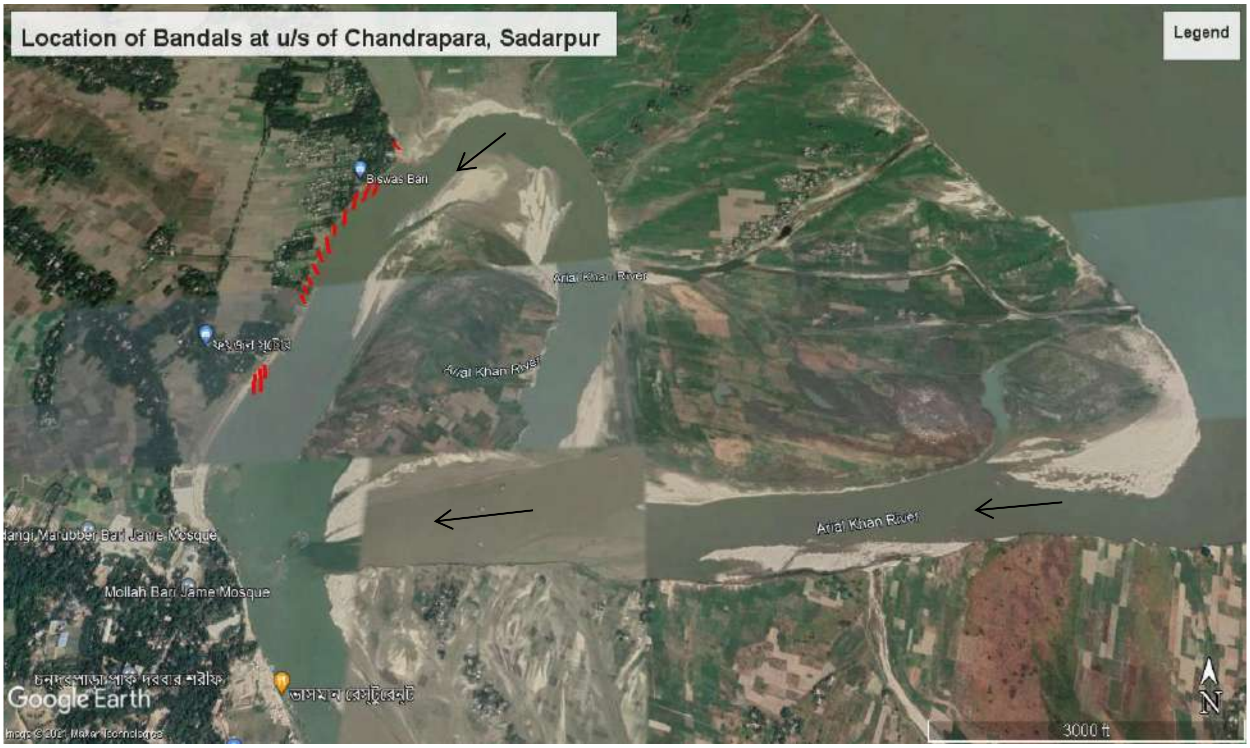


Figure 4.8 Location of the bandal structures at u/s of Chandrapara Ghat, Sadarpur

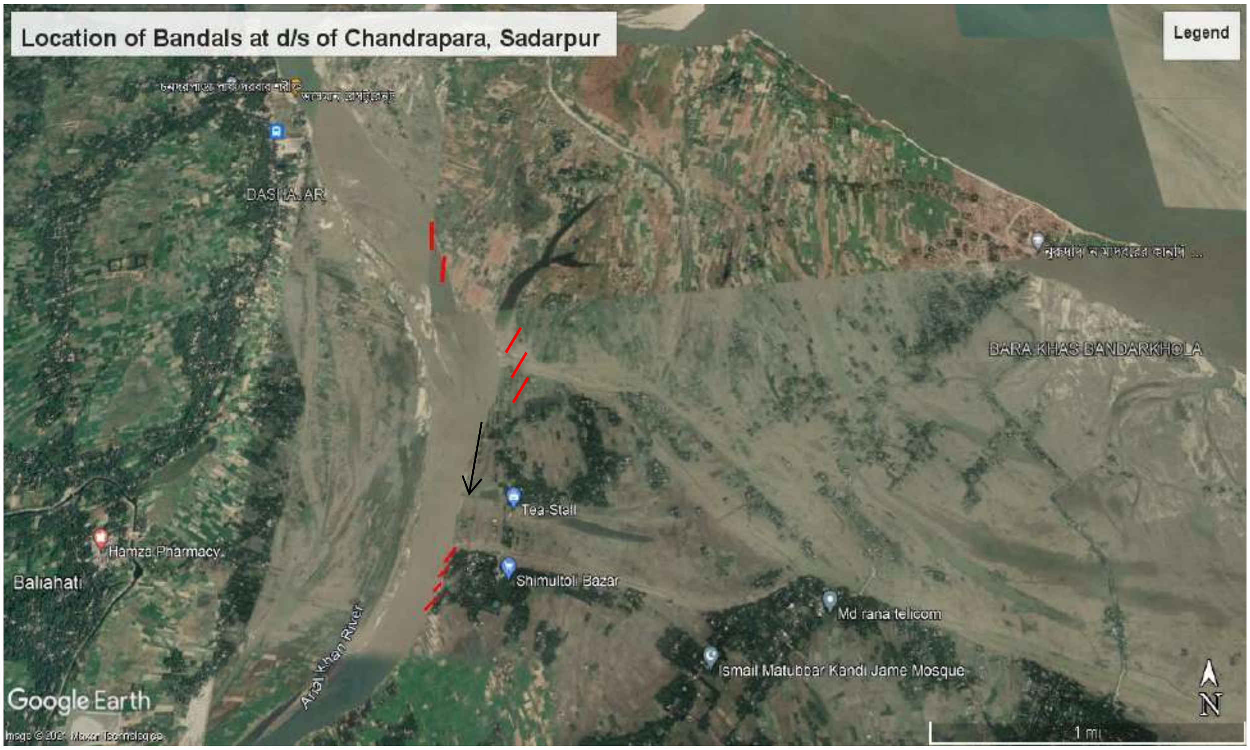


Figure 4.9 Location of the bandal structures at d/s of Chandrapara Ghat, Sadarpur


Figure 4.10 Bandal structures at u/s and d/s of Chandrapara Ghat, Sadarpur

4.2.4 Construction of Bandal Structures at Branch Channel of Padma River

Bandal type structures have been constructed in the erosion prone area of the right bank of the branch channel of Padma river at Goldangirchar and Digrirchar, Faridpur sadar upazila under

Faridpur district in January 2021. Around 2800 meter bandal structures have been constructed at Goldangirchar and 1875 meter bandal structures have been constructed at Digrirchar under Faridpur sadar upazila. In total about 4375 meter bandal structures have been constructed at Goldangirchar and Digrirchar. Some bandals have been constructed as V-shape due to back flow effect at an angle 45^0 with the flow direction. The individual bandals are oriented at an angle of 30^0-40^0 towards downstream (Figures 4.11 and 4.12).

Figure 4.11 Location of the bandal structures at Goldangirchar & Digrirchar, Faridpur

Figure 4.12 Bandal structures at Goldangirchar & Digrirchar, Faridpur

4.2.5 Construction of Bandal Structures at Padma River

Bandal type structures have been constructed in the erosion prone area of the right bank of the Padma river at Charjoikuri, Rajbari sadar upazila under Rajbari district in January 2021. Around 1600 meter bandal structures have been constructed at Charjoikuri under Rajbari sadar upazila. The individual bandals are oriented at an angle of 30^0-40^0 towards downstream. Bandal type structures have been constructed from upstream to downstream (Figures 4.13 and 4.14).

Figure 4.13 Location of the bandal structures at Charjoikuri, Rajbari

Figure 4.14 Bandal structures at Charjoikuri, Rajbari

4.2.6 Construction of Bandal Structures at Jamuna River

Bandal type structures have been constructed in the erosion prone area of the right bank of the Jamuna river at u/s of cross bar-01, Sirajgonj sadar upazila under Sirajgonj district in April 2021. Around 2600 meter bandal structures have been constructed at u/s of cross bar-01, Sirajgonj sadar upazila. The individual bandals are oriented at an angle of 30^0-40^0 towards downstream. Bandal type structures have been constructed from upstream to downstream (Figures 4.15 and 4.16).

Figure 4.15 Location of the bandal structures at u/s of Cross Bar-01, Sirajganj

Figure 4.16 Bandal structures at u/s of Cross Bar-01, Sirajganj

4.2.7 Construction of Bandal Structures at Jamuna River

Bandal type structures have been constructed in the erosion prone area of the right bank of the Jamuna river at d/s of Enayetpur spur near Khaza Yunus Medical College, Belkuchi upazila under Sirajgonj district in March 2020. In the first year, 1700 meter bandal structures have been constructed at d/s of Enayetpur spur in the right bank of the Jamuna river. In the 2nd Year (January 2021), 1600 meter bandal structures have been constructed at d/s of Enayetpur spur near Khaza Yunus Medical College, Belkuchi upazila under Sirajgonj district. In total 3300 meter bandal structures have been constructed at d/s of Enayetpur spur near Khaza Yunus Medical College, Belkuchi upazila under Sirajgonj district. The individual bandals are oriented at an angle of 30^0-45^0 towards downstream (Figures 4.17 and 4.18).

Figure 4.17 Location of the bandal structures at d/s of Enayetpur spur, Belkuchi

Figure 4.18 Bandal structures at d/s of Enayetpur spur, Belkuchi

4.2.8 Construction of Bandal Structures at Branch Channel of Jamuna River

Bandal type structures have been constructed in the erosion prone area of the left bank of the branch channel of Jamuna river at Rehaipukhuria, Chouhali upazila under Sirajgonj district in March 2021. Around 2250 meter bandal structures have been constructed at Rehaipukhuria, Chouhali upazila. The individual bandals are oriented at an angle of 30^0-45^0 towards downstream (Figures 4.19 and 4.20).

Figure 4.19 Location of the bandal structures at Rehaipukhuria, Chouhali

Figure 4.20 Bandal structures at Rehaipukhuria, Chouhali

4.2.9 Construction of Bandal Structures at Dhaleshwari River

Bandal type structures have been constructed in the erosion prone area of the left and right bank of the Dhaleshwari river at Neorgacha, Chouhali upazila under Sirajgonj district in January 2021. Around 2250 meter bandal structures have been constructed at Neorgacha, Chouhali upazila. Some bandals have been constructed as V-shape due to back flow effect at an angle 45^0 with the flow direction. The individual bandals are oriented at an angle of 30^0-45^0 towards downstream (Figures 4.21 and 4.22).

Figure 4.21 Location of the bandal structures at Neorgacha, Chouhali

Figure 4.22 Bandal structures at Neorgacha, Chouhali

4.2.10 Construction of Bandal Structures at Kangsa and Sumeshari River

Bandal type structures have been constructed in the erosion prone area of the left and right bank of the Kangsa river and right bank of the Sumeshari river at u/s of Jaria Bridge and left and right bank of the Kangsa river at d/s of Jaria Bridge, Purbadhala upazila under Netrokona district in March 2019. In the first year, 2000 meter bandal structures have been constructed at u/s of Kangsa and Sumeshari confluence (u/s of Jaria Bridge) and 1500 meter bandal structures have been constructed at d/s of Jaria Bridge, Purbadhala upazila under Netrokona district. In the 2nd Year (February 2020), 3500 meter bandal structures have been constructed at u/s of Kangsa river, Purbadhala upazila under Netrokona district. In total 7000 meter bandal structures have been constructed at u/s of Kangsa and Sumeshari Confluence (u/s of Jaria Bridge) and d/s of Jaria Bridge, Purbadhala upazila under Netrokona district. The individual bandals are oriented at an angle of 30^0-45^0 towards downstream (Figures 4.23 and 4.24).

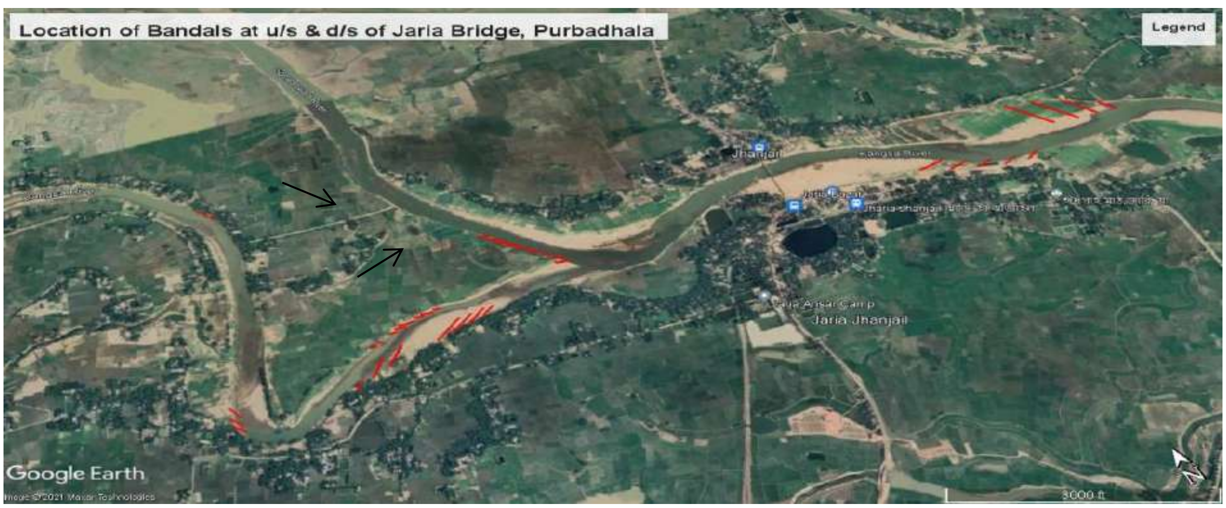


Figure 4.23 Location of the bandal structures at u/s & d/s of Jaria Bridge, Purbadhala

Figure 4.24 Bandal structures at Kangsa and Sumeshwari River, Purbadhala

4.2.11 Construction of Bandal Structures at Nitai River

Bandal type structures have been constructed in the erosion prone area of the left and right bank of the Nitai river at u/s of Shankarpur Bazar, Purbadhala upazila under Netrokona district in March 2019. In the first year, 1500 meter bandal structures have been constructed at u/s of Shankarpur Bazar, Purbadhala upazila in the left bank of the Nitai river. In the 2nd Year (December 2020), 500 meter bandal structures have been constructed at u/s of Shankarpur Bazar, Purbadhala upazila in the left bank. In total 2000 meter bandal structures have been constructed at u/s of Shankarpur Bazar, Purbadhala upazila under Netrokona district. The individual bandals are oriented at an angle of 30^0-40^0 towards downstream (Figures 4.25 and 4.26).

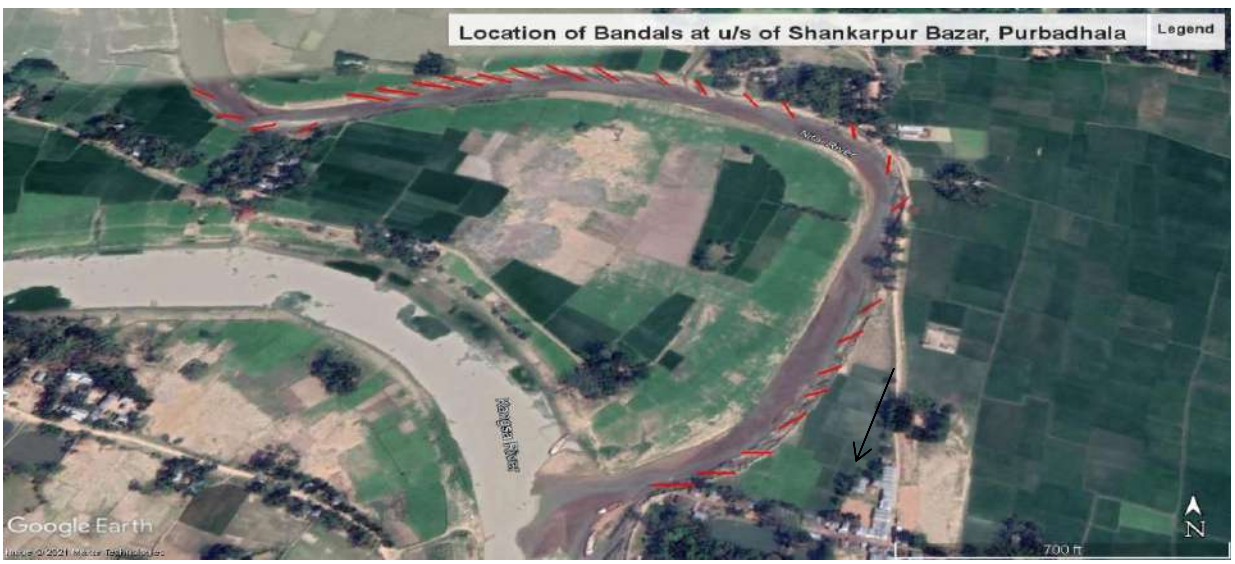


Figure 4.25 Location of the bandal structures at u/s of Shankarpur Bazar, Purbadhala

Figure 4.26 Bandal structures at u/s of Shankarpur Bazar, Purbadhala

4.2.12 Construction of Bandal Structures at Shugandha River

Bandal type structures have been constructed in the erosion prone area of the right bank of the Shugandha river at u/s and d/s of Doarika Bridge, Babugonj upazila under Barishal district in March 2020. In the first year, 2000 meter bandal structures have been constructed at d/s of Doarika Bridge, Babugonj upazila under Barishal district. In the 2nd Year (February 2021), 2800 meter bandal structures have been constructed at u/s of Doarika Bridge, Babugonj upazila under Barishal district. In total 4800 meter bandal structures have been constructed at u/s and d/s Doarika Bridge, Babugonj upazila under Barishal district. The Shugandha river is tidally affected. So, some V-shape bandal structures have been constructed with 45^0 angles with the flow direction (Figures 4.27 and 4.28).

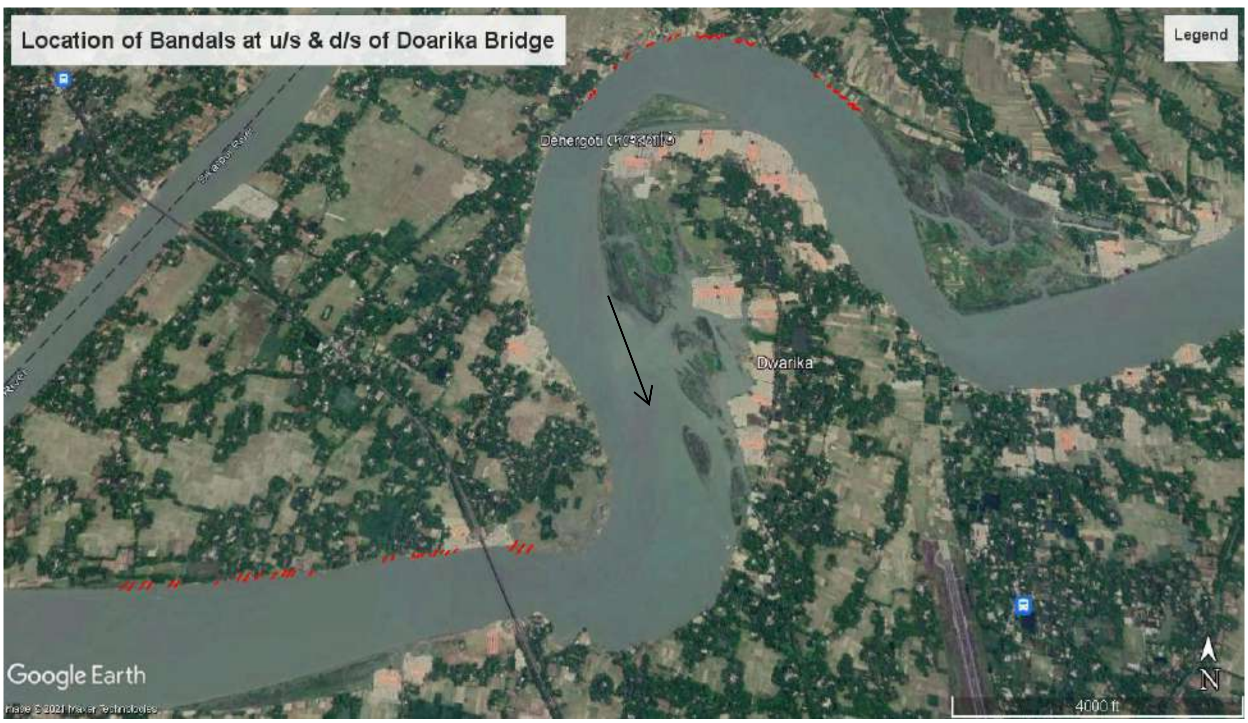


Figure 4.27 Location of the bandal structures at u/s & d/s of Doarika Bridge, Babuganj

Figure 4.28 Bandal structures at u/s & d/s of Doarika Bridge, Babuganj

4.2.13 Construction of Bandal Structures at Atai and Rupsha River

Bandal type structures have been constructed in the erosion prone area of the left bank of the Atai and Rupsha river at Shoilpur, Rupsha upazila; Laskarpur-Madhupur, Terokhada upazila and Ambaria, Digholia upazila under Khulna district in February 2020. Total 3800 meter bandal structures have been constructed at Shoilpur, Rupsha upazila; Laskarpur-Madhupur, Terokhada upazila and Ambaria, Digholia upazila under Khulna district. The Atai and Rupsha rivers are tidally affected. In this case, V-shape bamboo bandalling structures have been constructed with 45^0 angles with the flow direction. The new arrangement is facilitated with both the flood and ebb tide from u/s to d/s and vice versa. There is an arrangement at the u/s for flow entry and flow out and also the same arrangement in the d/s to ensure the flood and ebb tide (Figures 4.29, 4.30, 4.31, 4.32, 4.33 and 4.34).

Figure 4.29 Location of the bandal structures at Shoilpur, Rupsha, Khulna

Figure 4.30 Bandal structures at Shoilpur, Rupsha, Khulna

Figure 4.31 Location of the bandal structures at Laskarpur-Madhupur, Terokhada,Khulna

Figure 4.32   Bandal structures at Laskarpur-Madhupur, Terokhada,Khulna

Figure 4.33 Location of the bandal structures at Ambaria, Digholia, Khulna

Figure 4.34 Bandal structures at Ambaria, Digholia, Khulna

4.2.14 Construction of Bandal Structures at Bhadra River

Bandal type structures have been constructed in the erosion prone area of the right bank of the Bhadra river at Chandgoar and left and right bank of the Bhadra river at Kharnia Bazar, Dumuria upazila under Khulna district in January 2020. 1750 meter bandal structures have been constructed at at Chandgoar and 1750 meter bandal structures have been constructed at Kharnia Bazar, Dumuria upazila under Khulna district. Total 3500 meter bandal structures have been constructed at Chandgoar and Kharnia Bazar, Dumuria upazila under Khulna district. The Bhadra river is tidally affected. In this case, V-shape bamboo bandalling structures have been constructed with 45^0 angles with the flow direction. The new arrangement is facilitated with both the flood and ebb tide from u/s to d/s and vice versa. There is an arrangement at the u/s for flow entry and flow out and also the same arrangement in the d/s to ensure the flood and ebb tide (Figures 4.35, 4.36, 4.37 and 4.38).

Figure 4.35 Location of the bandal structures at Chandgoar, Dumuria, Khulna

Figure 4.36   Bandal structures at Chandgoar, Dumuria, Khulna

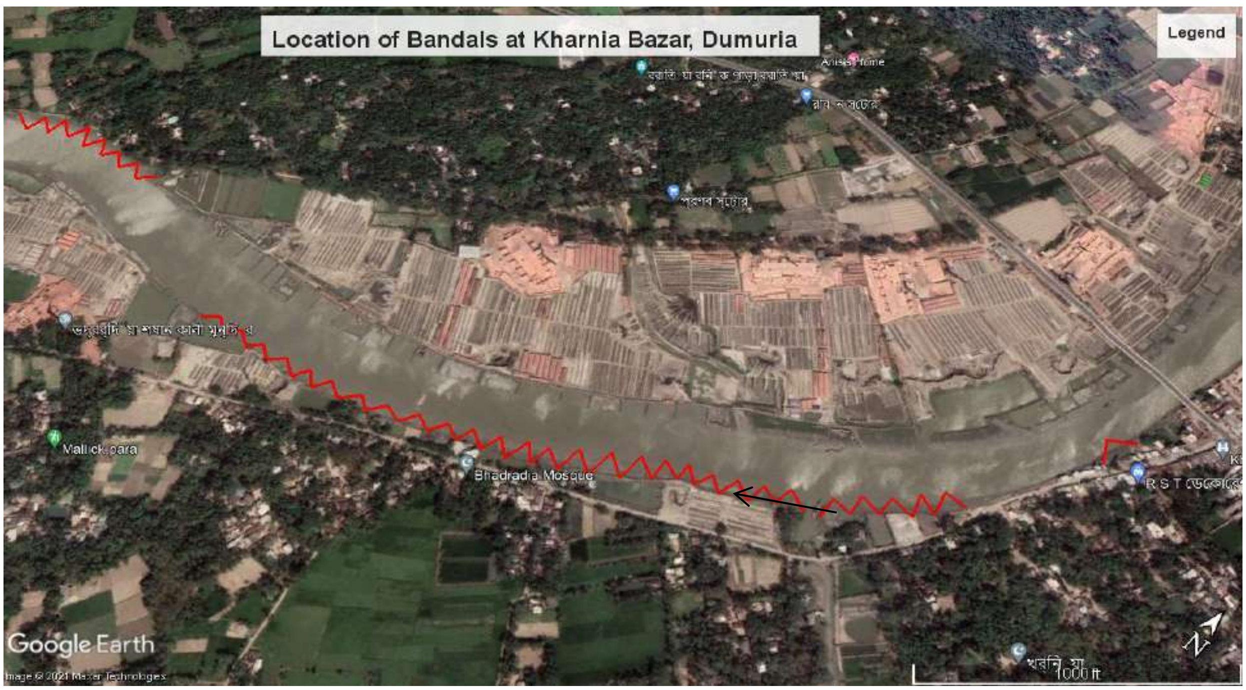


Figure 4.37 Location of the bandal structures at Kharnia Bazar, Dumuria, Khulna

Figure 4.38   Bandal structures at Kharnia Bazar, Dumuria, Khulna

4.3 Data collection/ Survey

Bathymetry data, bank line data, discharge, velocity and water level data were collected from the study areas before and after construction of bandal structures at different sites. WinProfile bathymetric Survey Software has been used for data collection. The position (x, y) received from the GPS is in WGS-84 ellipsoid were later converted to Universal Transverse Mercator (UTM) by the data acquisition software. Electronic Total Station (TS) has been used to Survey the bank part of the river shallow depths, bank slope & bank part. Universal Cup type current metre has been used to take velocity measurement. Velocity has been measured using three point measurement method at 0.2d, 0.6d and 0.80d point. However, where the depth is below 1.50m that vertical velocity have taken only 0.6d point. One fiber Gauge has been installed at Survey site near discharge location and observation Water Level (WL) at one hour interval during the Survey time. X-Section survey done by bathymetric & topographic Survey work and combined both data by AutoCAD software. Then generate X-Section graph by excel software. Sediment Concentration data are collected and also Soil boring is done for some sites to investigate soil strata condition. Water quality data for different sites has been collected and are tested to examine adverse impact if any for river water. The data and satellite images were used to detail analysis for effectiveness and impact of bamboo bandal type structures. Detailed data collection from Padma at C & B Ghat Faridpur and at Rajbari, from Jamuna at Eunus Ali Medical College, Sirajgonj, from Sughandha river at Barisal, from Kagshu river at Purbadhala, Netrokona. Also data are collected from Gorai at Narua, Baliakandi, from Modhumati at Kamarkhali, Modhukahli,Faridpur, from Arial Khan at Chandrapara, Sadarpur, Faridpur, from Vodra river at Kharnia Bazar, Dumuria, Khulna, from Rupsha at Shoilpur, Khulna, from Jamuna branch channels at Rehipukuria, Dewangonj, Chowhali, Sirajgonj.

Figure 4.39 Survey in rivers

Figure 4.40 Survey in rivers

CHAPTER 5

PERFORMANCE ANALYSIS AND DISCUSSION

5.1 General

Survey data of each site at different times are selected to show bed contour of the channel. Golden Software (surfer) is used to represent the bed contour of the study sites. A color scale is defined in the bed contour map to demonstrate the bed levels in the channel. From the bed contour map and post bandal photographs it is clearly seen that, the change of bed level due to construction of bandal type structures at each site.

5.2 Performance of Bandal Structures at Gorai River

From figures 5.1 and 5.2, it is revealed that the left bank of the Gorai River is shifted towards the right (river side) during the last three years. The constructed bandal structures near the Jamshapur kheyaghat functioned well to river bank erosion protection through near bank sedimentation. It is evident from the figure 5.3 so that there is about more than 40 meters sedimentation towards the horizontal direction and about more than 3 meters sedimentation in the vertical direction near the left bank. Some Bamboo Bandal Structures since 2019 but no pre data taken. From actual field condition and photograph huge sedimentation recorded since 2019. It is seen from photographs smaller local scour occurred around the tip of the structures due to the higher velocity and the vertical vortex formed at the upstream area of structure caused by the downward flow. At the upstream of the river reach, there is less sedimentation due to beginning thrust of flowing water pressure, but there is river bank erosion protection. This position will be improved if bamboo bandaling structures are constructed in further upstream of this reach. At the remaining downstream of the river reach (Narua kheyaghat); there is also less sedimentation due to steep slope of the river reach, but river bank erosion protection. It is also mentioned that even in opposite side of the bandal structures, there is little bit bank erosion due to constrict of the flow area and higher velocity at the right bank. At Kheyaghat huge geo bag were failing to protect nearby roads bazar and mosque, but bamboo bandal has protected the geo bag to function properly and steep bank becomes mild one.

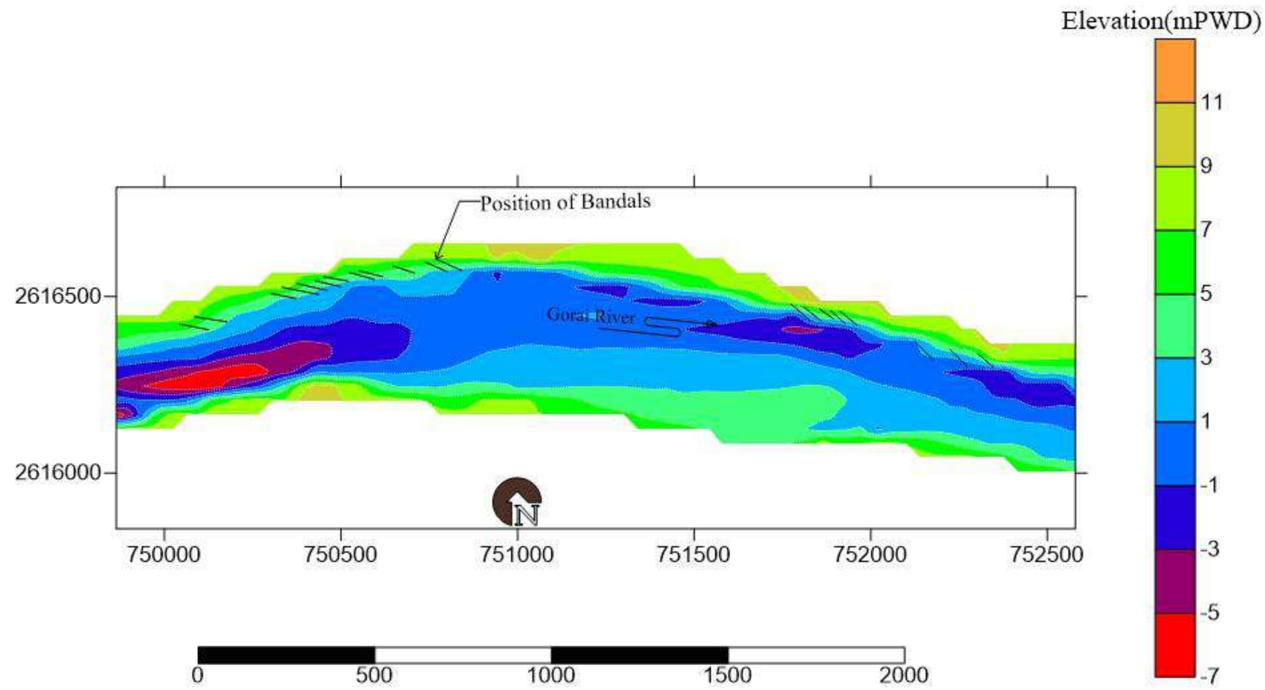


Figure 5.1 Bed elevations of the Gorai River in November 2020

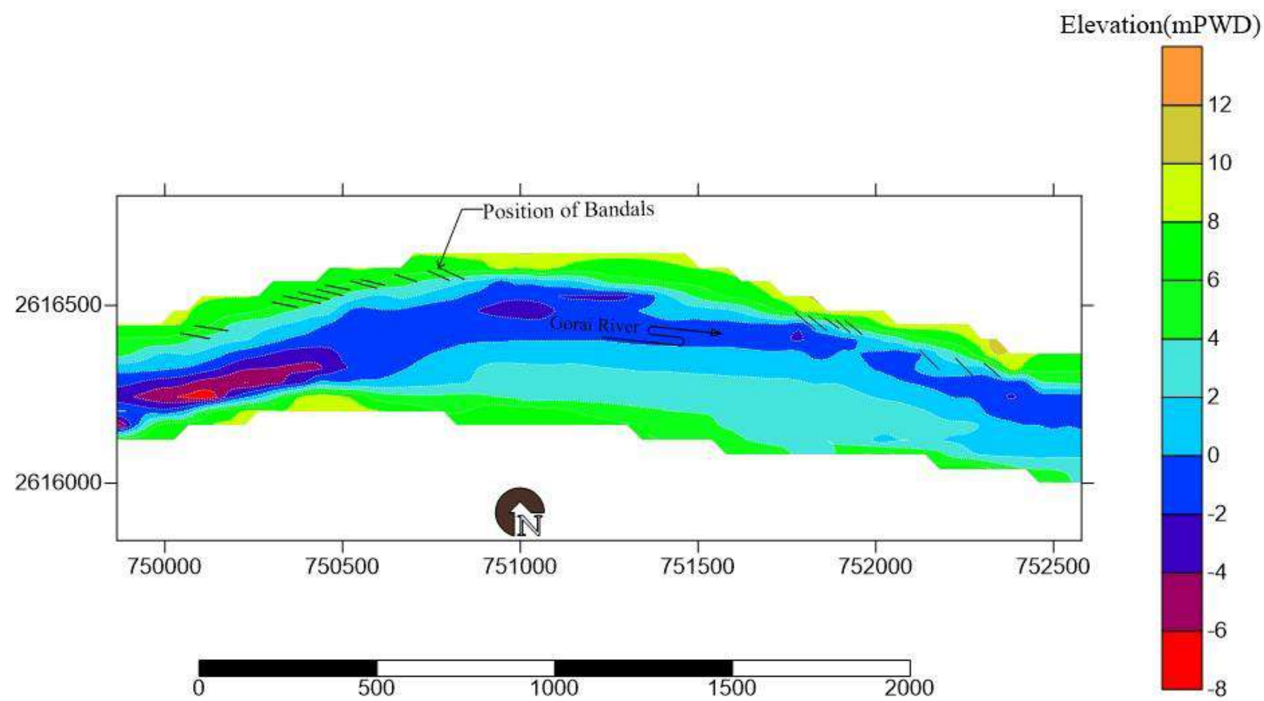
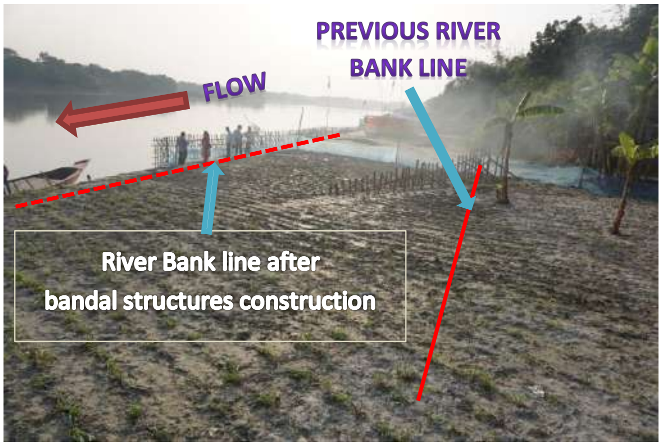


Figure 5.2 Bed elevations of the Gorai river in November 2021



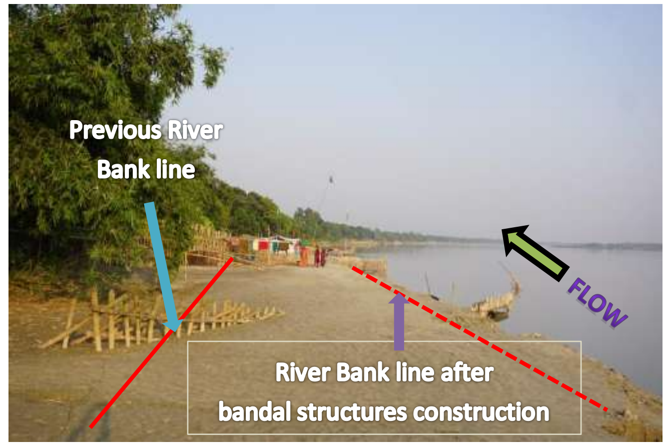


Figure 5.3 Sediment depositions on river bank induced by bandal-like structures at the left bank of Gorai River

5.3 Perfomance of Bandal Structures at Madhumati River

From figures 5.4 and 5.5, it is revealed that the right bank of the Madhumati River is shifted towards the left (river side) at u/s of Kamarkhali Bridge and left bank of the Madhumati River is shifted towards the right (river side) at d/s of Kamarkhali Bridge during the last three years. The constructed bandal structures at the u/s of Kamarkhali Bridge as well as at the d/s of Kamarkhali Bridge functioned well to river bank erosion protection through near bank sedimentation. It is evident from the figures 5.6 and 5.7 so that there is about more than 50 meters sedimentation towards the horizontal direction and about more than 3 meters sedimentation in the vertical direction near the right and left bank respectively. Bamboo Bandal Constructed during 2019 and no pre data was taken. Actually sedimentation is huge as in field visible in photograph. It is seen from photographs smaller local scour occurred around the tip of the structures due to the higher velocity and the vertical vortex formed at the upstream area of structure caused by the downward flow. At the upstream of the river reach, there is less sedimentation due to beginning thrust of flowing water pressure, but there is river bank erosion protection. This position will be improved if bamboo bandalling structures are constructed in further upstream of this reach. At the remaining downstream of the river reach (d/s of Kamarkhali Bazar); there is also less sedimentation due to steep slope of the river reach, but river bank erosion protection. It is also mentioned that even in opposite side of the bandal structures, there is little bit bank erosion due to constrict of the flow area and higher velocity at the left and right bank respectively.

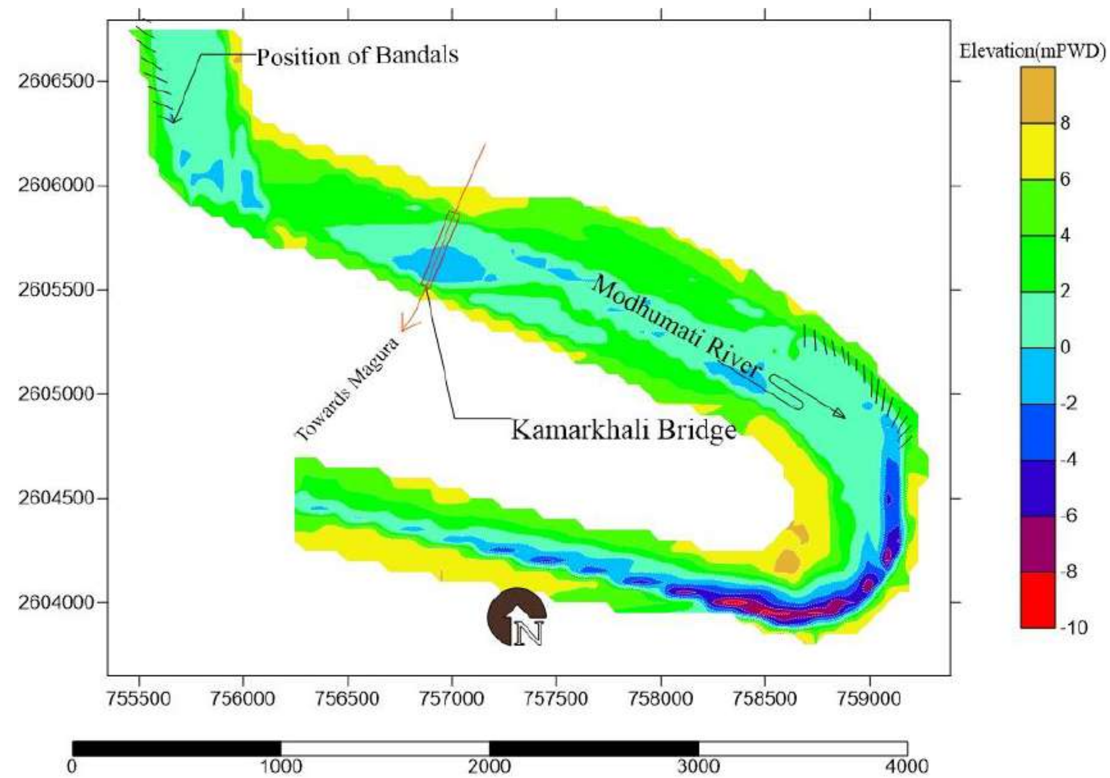


Figure 5.4 Bed elevations of the Madhumati River in November 2020

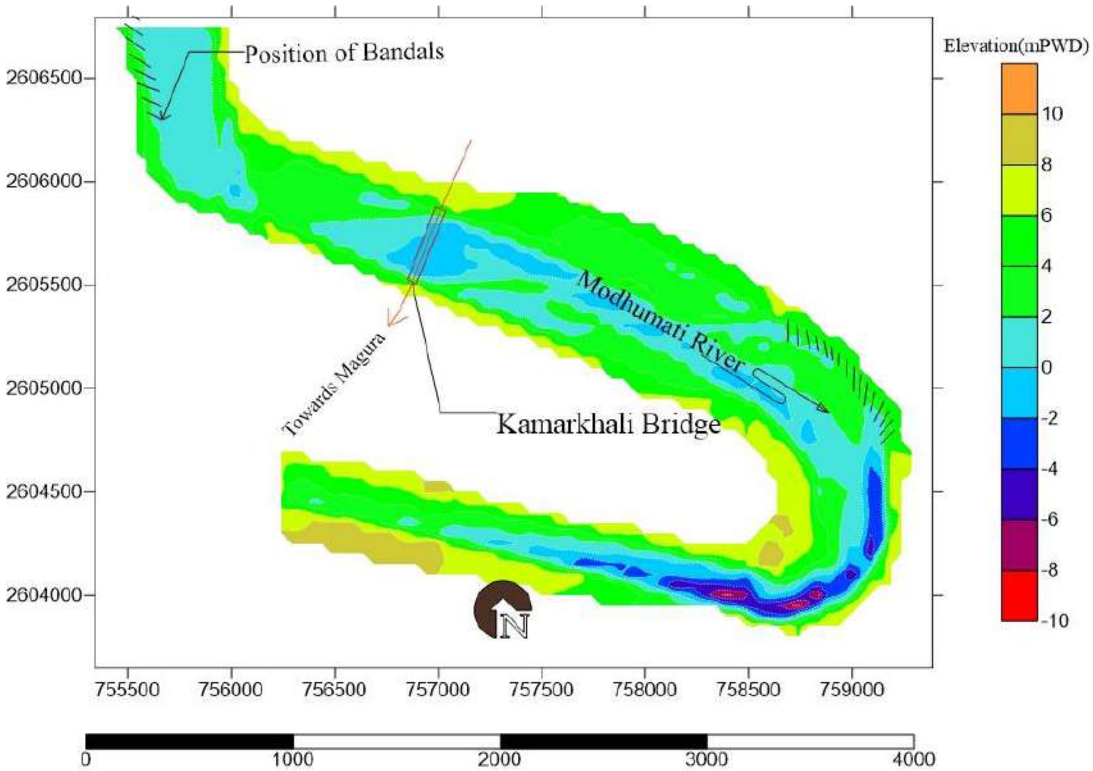


Figure 5.5 Bed elevations of the Madhumati River in November 2021

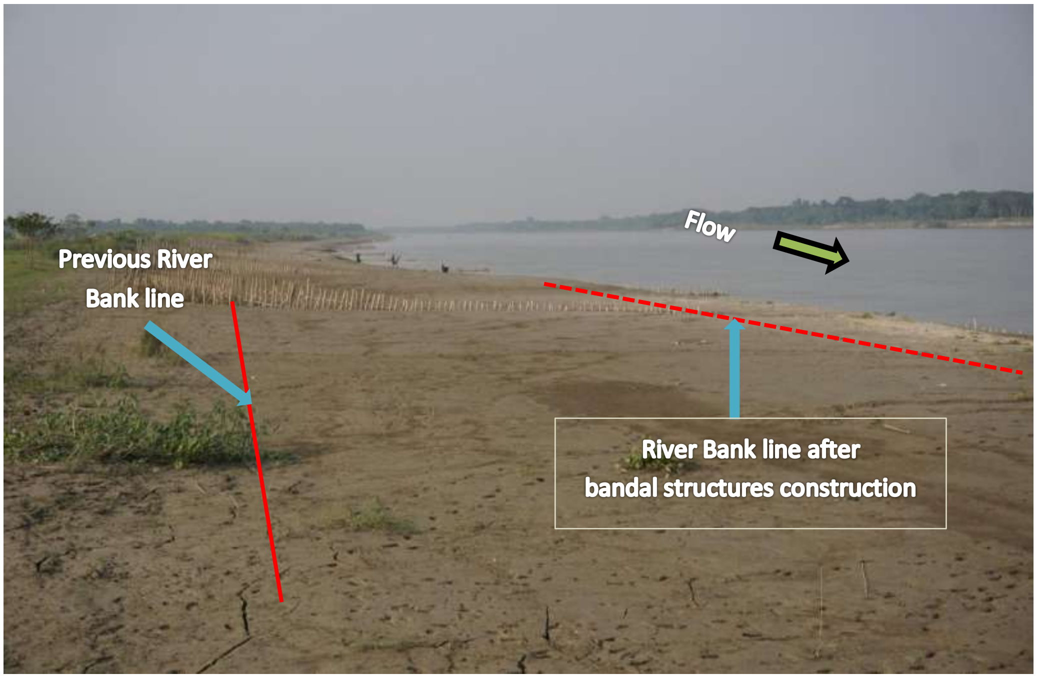


Figure 5.6 Sediment depositions on river bank induced by bandal-like structures at the right bank of Madhumati River (u/s of Kamarkhali Bridge)

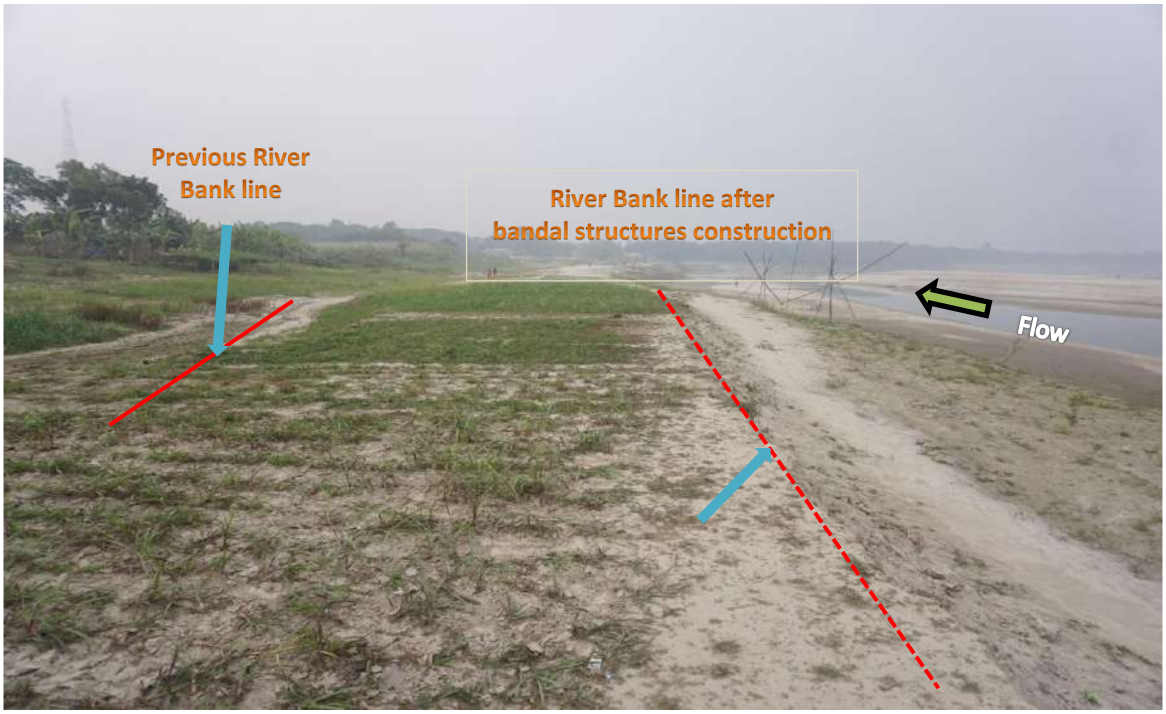


Figure 5.7 Sediment depositions on river bank induced by bandal-like structures at the left bank of Madhumati River (d/s of Kamarkhali Bridge)

5.4 Perfomance of Bandal Structures at Arial Khan River

From figures 5.8 and 5.9, it is revealed that the right bank of the Arial Khan River is shifted towards the left (river side) at u/s of Chandrapara ghat during the last three years. From figure 5.11, it is revealed that the left bank of the Arial Khan River is shifted towards the right (river side) at d/s of Chandrapara ghat in some area but erosion occurred in the left bank in some area due to damaging of the bandal structures during the last one year due to insufficient bandals . The constructed bandal structures at the u/s of Chandrapara ghat functioned well to river bank erosion protection through near bank sedimentation. It is evident from the figures 5.10 and 5.12 so that there is about more than 50 meters and 30 meters sedimentation towards the horizontal direction and about more than 3 meters sedimentation in the vertical direction near the right and left bank respectively. At Balshar ghat, u/s of Chandrapara bandal constructed during 2019 but no pre data was taken. Actual field condition and photograph taken reveal huge sedimentation. Later during 2020 loop cut opened with consequence of bandal impact. Afterwards some dredging for lake formation at u/s of Chandrapara during 2021. It is seen from photographs smaller local scour occurred around the tip of the structures due to the higher velocity and the vertical vortex formed at the upstream area of structure caused by the downward flow. At the upstream of the river reach, there is less sedimentation due to beginning thrust of flowing water pressure, but there is river bank erosion protection. This position will be improved if bamboo bandalling structures are constructed in further upstream of this reach. At the remaining downstream of the river reach (d/s of Chandrapara ghat); there is some erosion occurred due damaging of bandal structures in some portion.

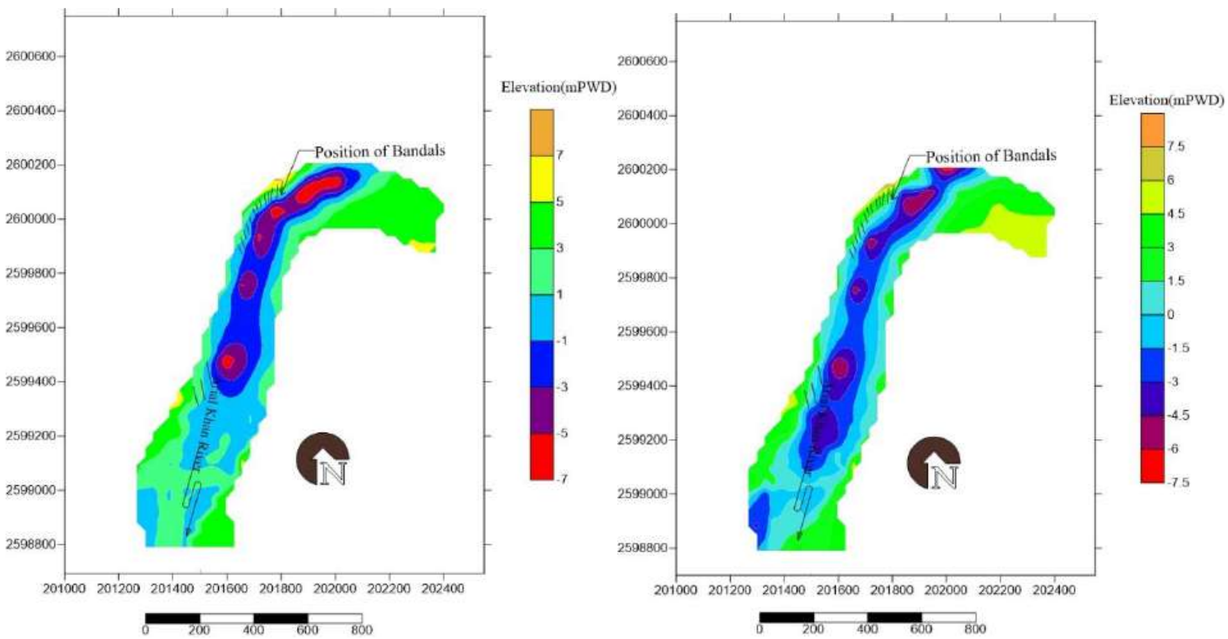


Figure 5.8 Bed elevations of the Arial Khan River in October 2019 and in June 2020 respectively (u/s of Chandrapara ghat)

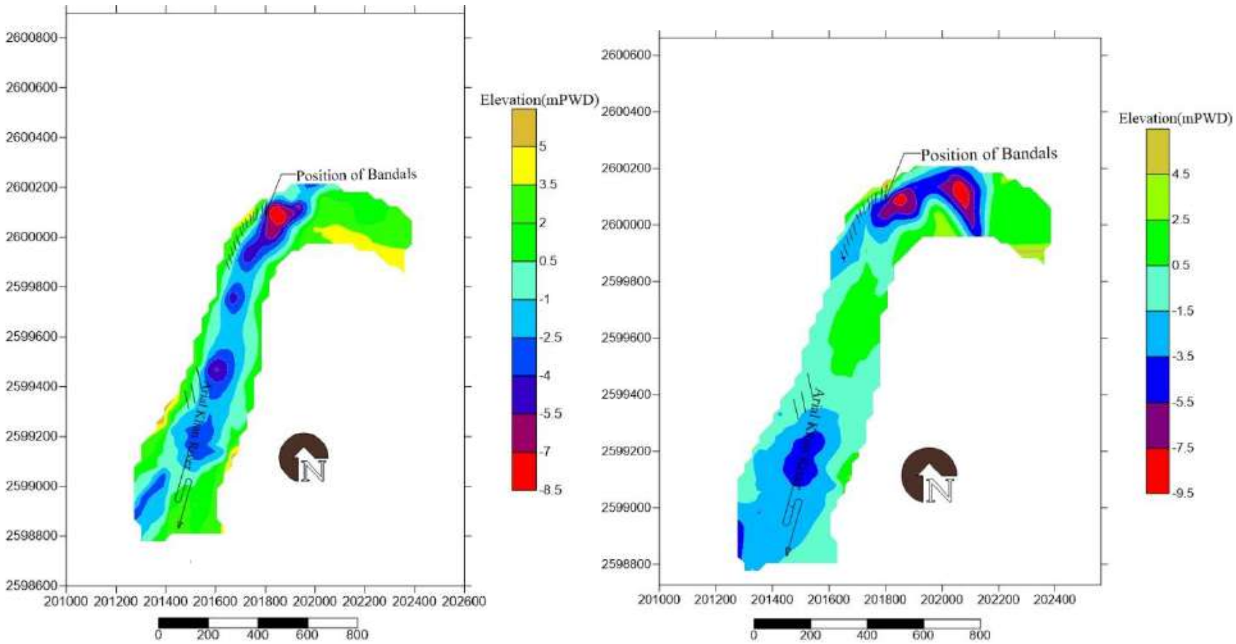


Figure 5.9 Bed elevations of the Arial Khan River in July 2020 and in October 2020 respectively (u/s of Chandrapara ghat)

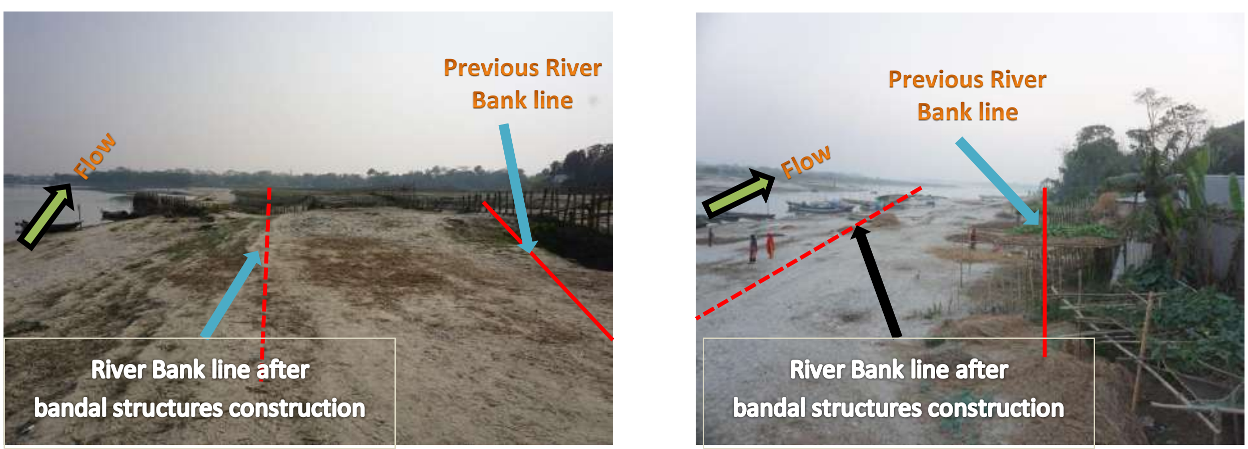


Figure 5.10 Sediment depositions on river bank induced by bandal-like structures at the right bank of Arial Khan River (u/s of Chandrapara ghat)

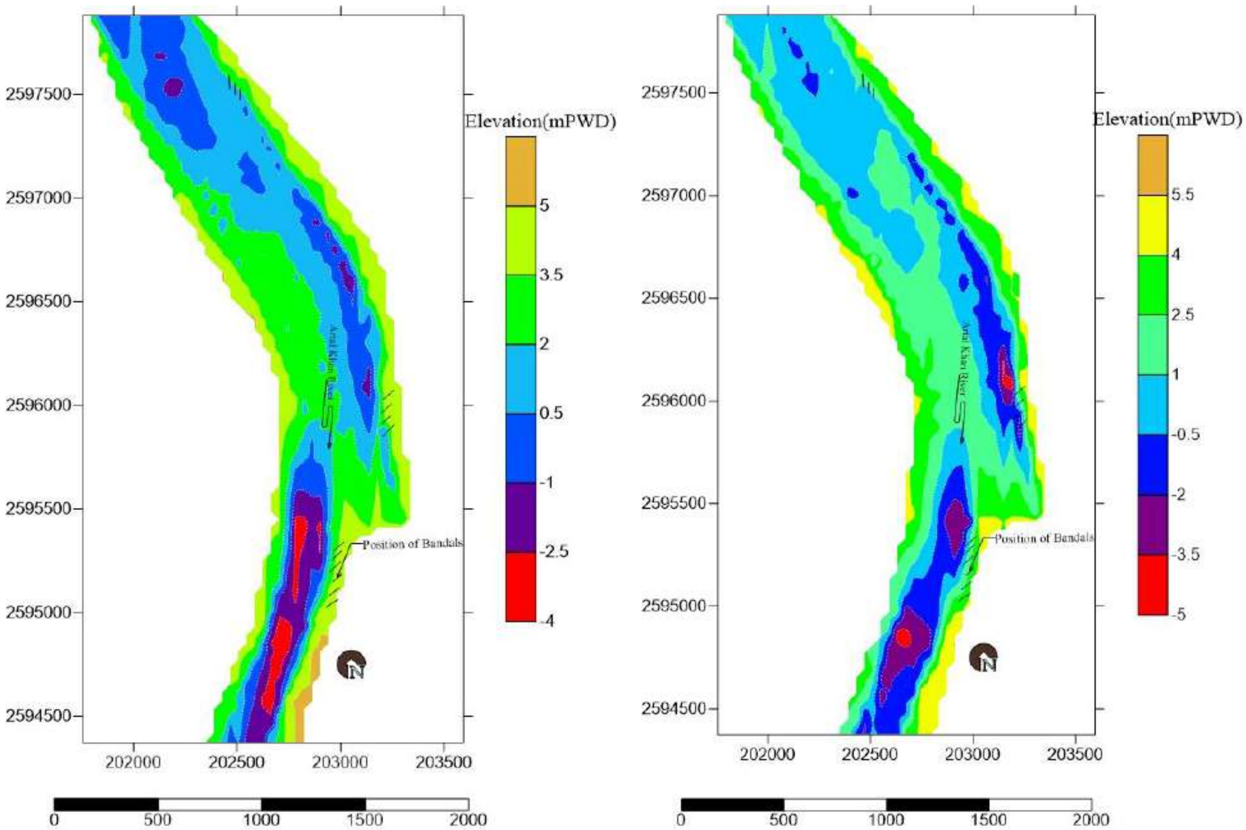
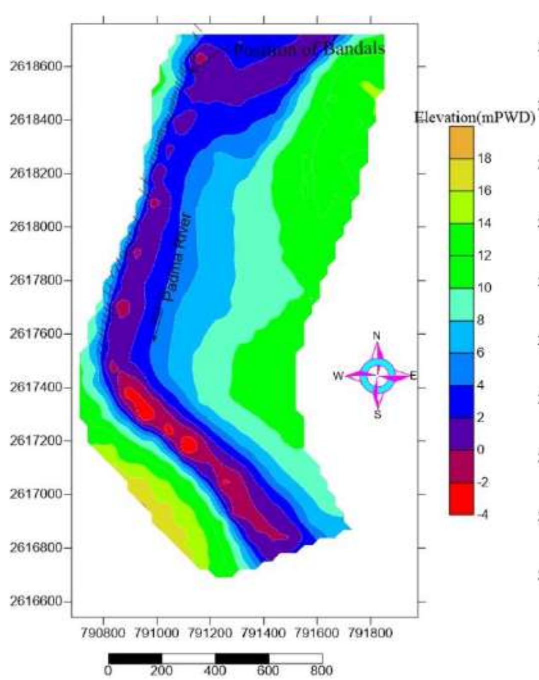


Figure 5.11 Bed elevations of the Arial Khan River in August 2021 and in November 2021 respectively (d/s of Chandrapara ghat)

Figure 5.12 Sediment depositions on river bank induced by bandal-like structures at the right bank of Arial Khan River (d/s of Chandrapara ghat)

5.5 Perfomance of Bandal Structures at Brach Channel of Padma River

From figures 5.13 and 5.15, it is revealed that the left bank of the Padma River is shifted towards the left (river side) during the last one year. The constructed bandal structures near the Goldangirchar and Digrirchar functioned well to river bank erosion protection through near bank sedimentation. It is evident from the figures 5.14 and 5.16 so that there is about more than 200 meters and more than 300 meters sedimentation towards the horizontal direction and about more than 3 meters sedimentation in the vertical direction near the right bank of Padma River in Goldangirchar and Digrirchar respectively. It is seen from photographs smaller local scour occurred around the tip of the structures due to the higher velocity and the vertical vortex formed at the upstream area of structure caused by the downward flow. At the upstream of the river reach, there is less sedimentation due to beginning thrust of flowing water pressure, but there is river bank erosion protection. This position will be improved if bamboo bandaling structures are constructed in further upstream of this reach. At the remaining downstream of the river reach; there is also less sedimentation due to absence of protective measures, but river bank erosion protection. It is also mentioned that even in opposite side of the bandal structures, there is little bit bank erosion due to constrict of the flow area and higher velocity at the left bank.



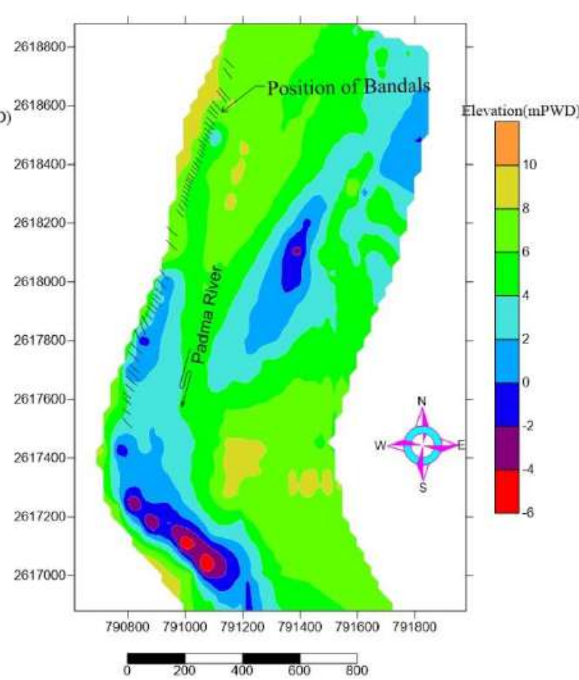


Figure 5.13 Bed elevations at the right bank of Padma River in February 2021 and in August 2021 respectively (u/s of C & B ghat, Goldangirchar)

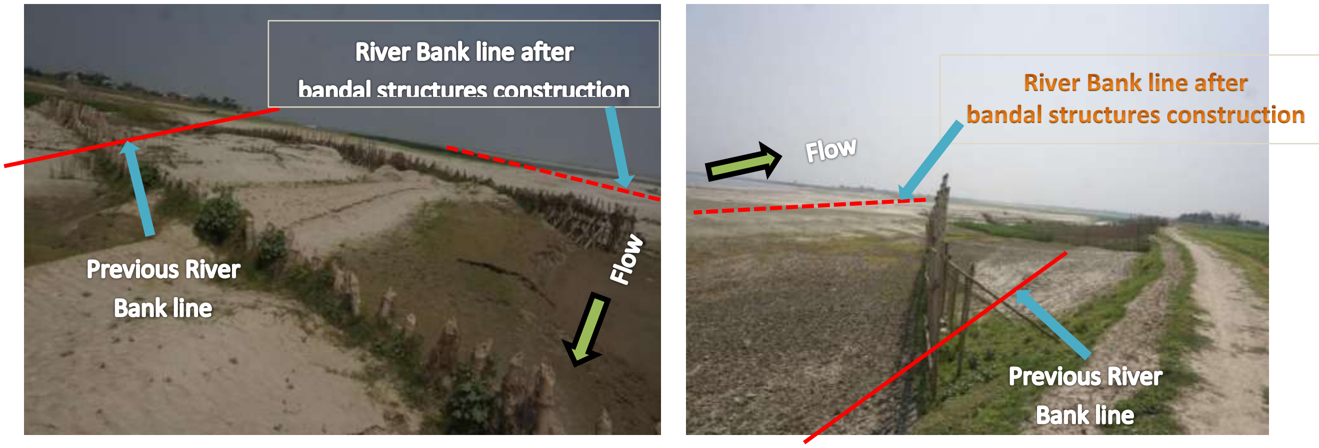


Figure 5.14 Sediment depositions on river bank induced by bandal-like structures at the right bank of Padma River (u/s of C & B ghat, Goldangirchar)

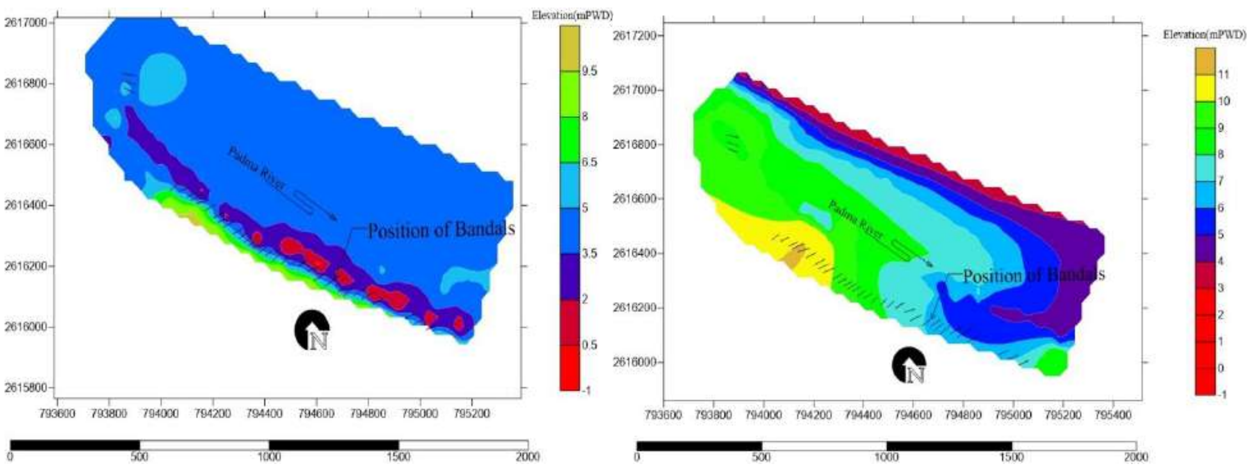


Figure 5.15 Bed elevations at the right bank of Padma River in June 2021 and in December 2021 respectively (Digirirchar)

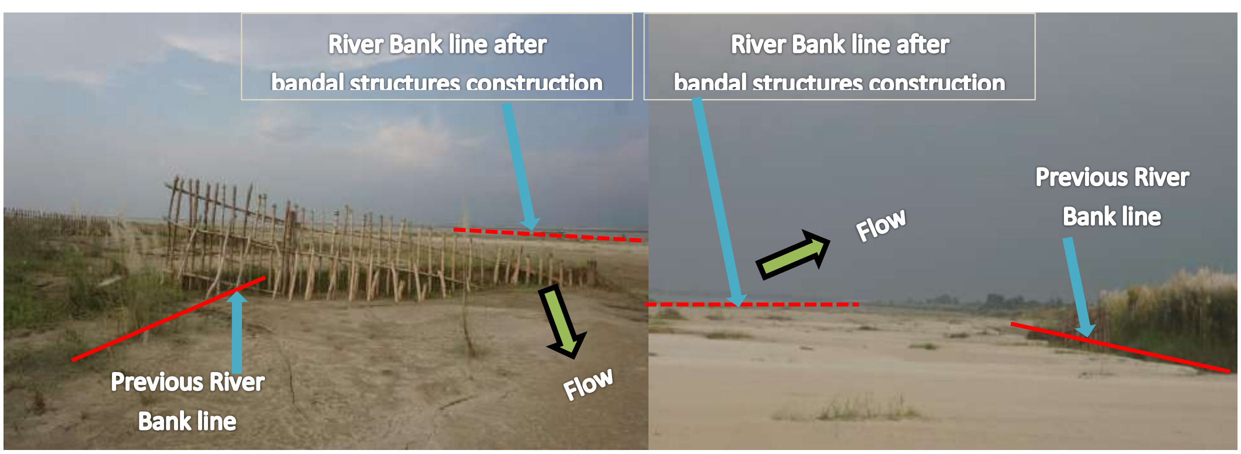


Figure 5.16 Sediment depositions on river bank induced by bandal-like structures at the right bank of Padma River (Digirirchar)

5.6 Perfomance of Bandal Structures at Padma River

From figure 5.17, it is revealed that the left bank of the Padma River is shifted towards the left (river side) during the last one year. The constructed bandal structures near the Charjoikuri functioned well to river bank erosion protection through near bank sedimentation. It is evident from the figure 5.18 so that there is about 1 meter sedimentation in the vertical direction near the right bank of Padma River in Charjoikuri. It is seen from photographs the bamboo bandals are cutup by local people for their vessel movement. If the bandal structures were there, it would be a desirable level of sedimentation and bank protection.

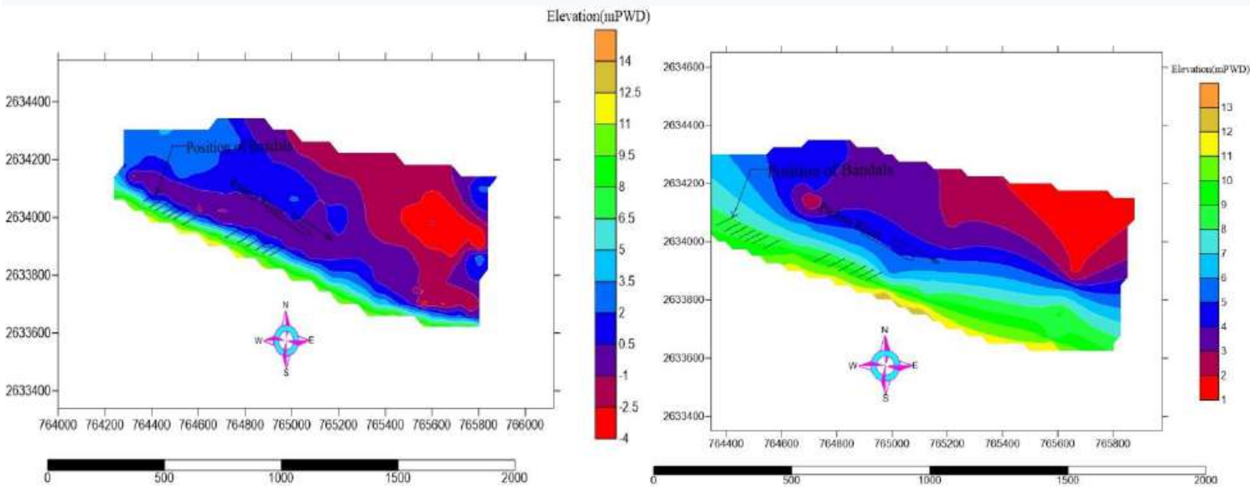
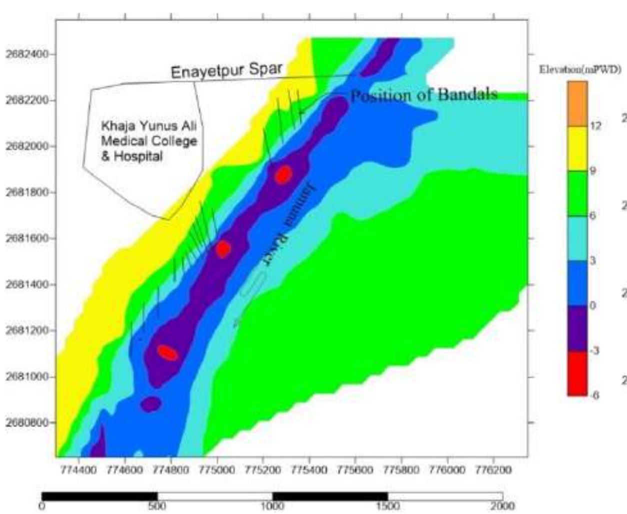


Figure 5.17 Bed elevations at the right bank of Padma River in August 2021 and in December 2021 respectively (Charjoikuri)

Figure 5.18 Sediment depositions on river bank induced by bandal-like structures at the right bank of Padma River (Charjoikuri)

5.7 Perfomance of Bandal Structures at Jamuna River

From figures 5.19 and 5.20, it is revealed that the right bank of the Jamuna River is shifted towards the right (river side) during the last one year. The constructed bandal structures near the Khaja Eunus Ali Medical College, Enayetpur functioned well to river bank erosion protection through near bank sedimentation. It is evident from these figures so that there is about more than 50 meters sedimentation towards the horizontal direction and about more than 1 meter sedimentation in the vertical direction near the right bank of Jamuna River. Here land up liftation is remarkable but some reclaimed land is eroded later due to some improper measure taken by Khaja Eunus Ali Medical College. From figures 5.21 and 5.22, it is revealed that there is about more than 20 meters sedimentation towards the horizontal direction and about more than 1 meter sedimentation in the vertical direction near the left bank of Jamuna River in u/s of these bandals at Rehaipukhuria, Chouhali. But d/s of these bandals, there is some erosion occurred and damaged the bandals due to oblique flow. From figure 5.23, it is revealed that there is about more than 40 meters sedimentation towards the horizontal direction and about more than 1 meter sedimentation in the vertical direction near the right bank of Jamuna River in u/s of Cross bar-01, Sirajganj. It is seen from photographs smaller local scour occurred around the tip of the structures due to the higher velocity and the vertical vortex formed at the upstream area of structure caused by the downward flow. At the upstream of the river reach, there is less sedimentation due to beginning thrust of flowing water pressure, but there is river bank erosion protection. This position will be improved if bamboo bandalling structures are constructed in further upstream of this reach.



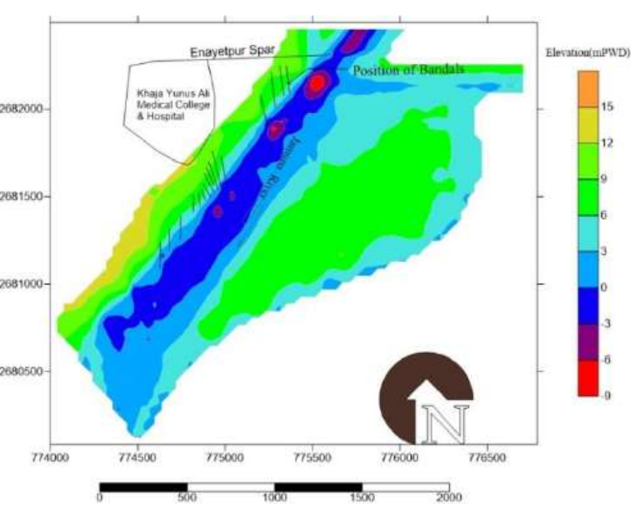


Figure 5.19 Bed elevations at the right bank of Jamuna River in November 2020 and in November 2021 respectively (d/s of Enayetpur Spur)

Figure 5.20 Sediment depositions on river bank induced by bandal-like structures at the right bank of Jamuna River (d/s of Enayetpur Spur)

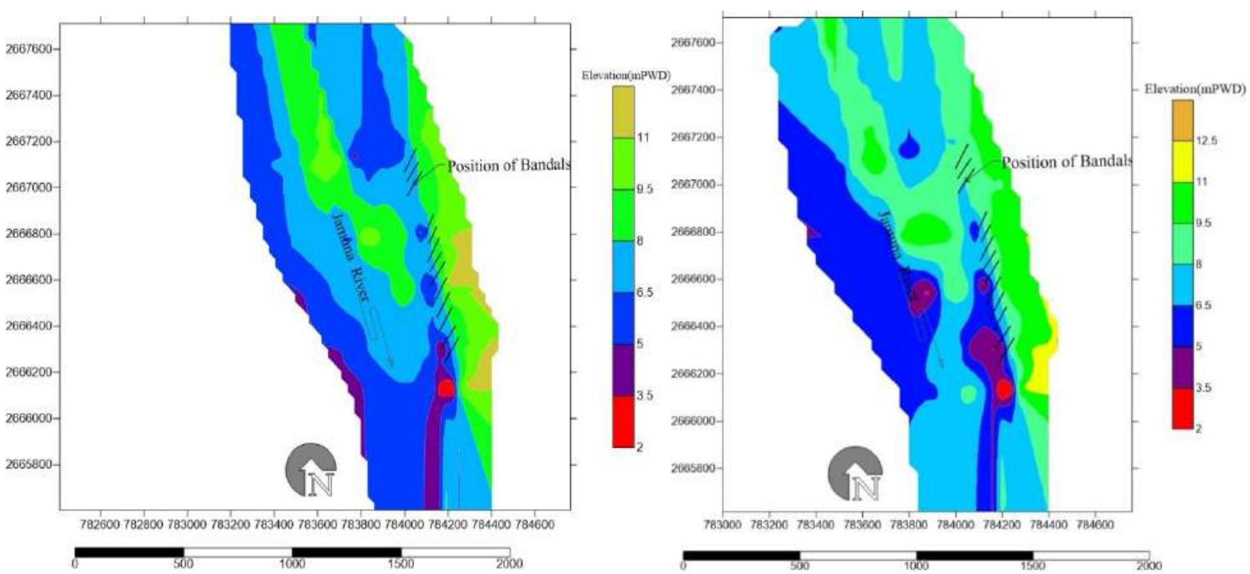


Figure 5.21 Bed elevations at the left bank of Jamuna River in May 2021 and in November 2021 respectively (Rehaipukhuria, Chouhali)

Figure 5.22 Sediment depositions on river bank induced by bandal-like structures at the left bank of Jamuna River (Rehaipukhuria, Chouhali)

Figure 5.23 Sediment depositions on river bank induced by bandal-like structures at the right bank of Jamuna River (u/s of Cross bar-01, Sirajganj)

5.8 Perfomance of Bandal Structures at Dhaleshwari River

From figures 5.24 and 5.25, it is revealed that the left and right bank of the Dhaleshwari River is shifted towards the river side during the last one year. The constructed bandal structures near the Neorgacha and Khan Bazar functioned well to river bank erosion protection through near bank sedimentation. It is evident from the figure 5.25 so that there is about more than 40 meters sedimentation towards the horizontal direction and about more than 2 meters sedimentation in the vertical direction near the left and right bank. Here river is too meandering and four bend were covered. At Important Neorgacha market and upstream of the market there is huge sedimentation and land reclamation and consequently important land are protected and river shifted towards char area. Here people dumped some geo- bag during highest discharge which help the bandal to protected the bank as water was flowing above the bandal and bank. Between Neorgacha bazar and khan bazar some erosion at country side due to insufficient bandal though at early stage the situation was different and erosion was at high flood when the whole land was inundated and flow pattern totally change. Huge bandal were successfully constructed to protect important bazar and land and huge land reclamation here. But immediate after khan bazar erosion occurred at a bend at country side due to insufficient bandal and high channel depth. It is seen from photographs smaller local scour occurred around the tip of the structures due to the higher velocity and the vertical vortex formed at the upstream area of structure caused by the downward flow. At the upstream of the river reach, there is less sedimentation due to beginning thrust of flowing water pressure, but there is river bank erosion protection. This position will be improved if bamboo bandaling structures are constructed in further upstream of this reach. At the remaining downstream of the river reach; there is also less sedimentation due to absence of protective measures, but river bank erosion protection. It is also mentioned that even in opposite side of the bandal structures, there is little bit bank erosion due to constrict of the flow area and higher velocity at the left and right bank respectively.

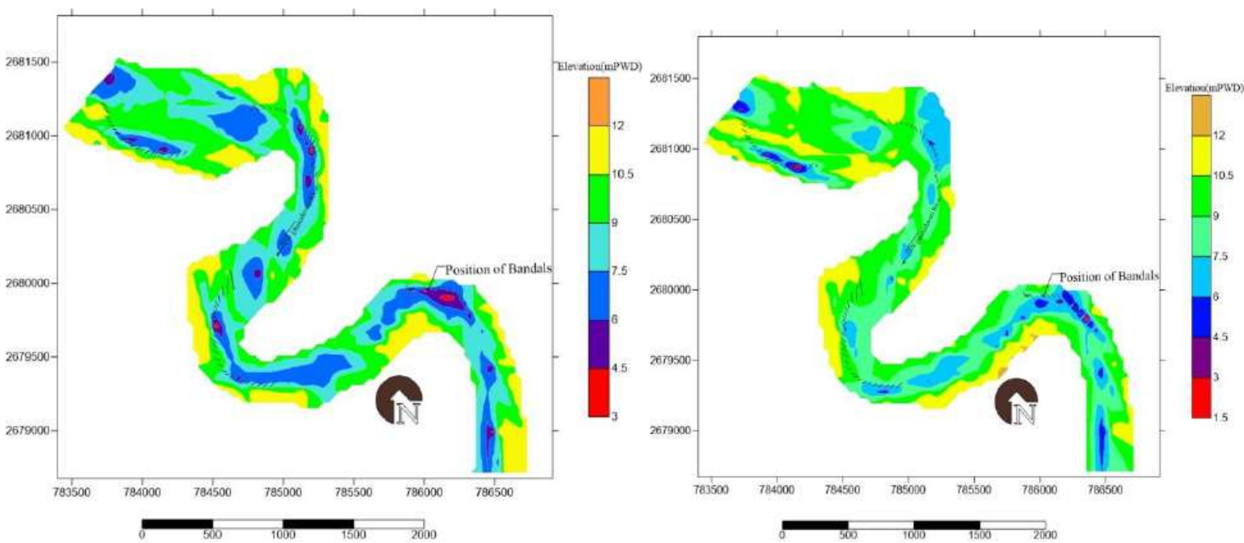


Figure 5.24 Bed elevations at the Dhaleshwari River in June 2021 and in November 2021 respectively (Neorgacha, Chouhali)

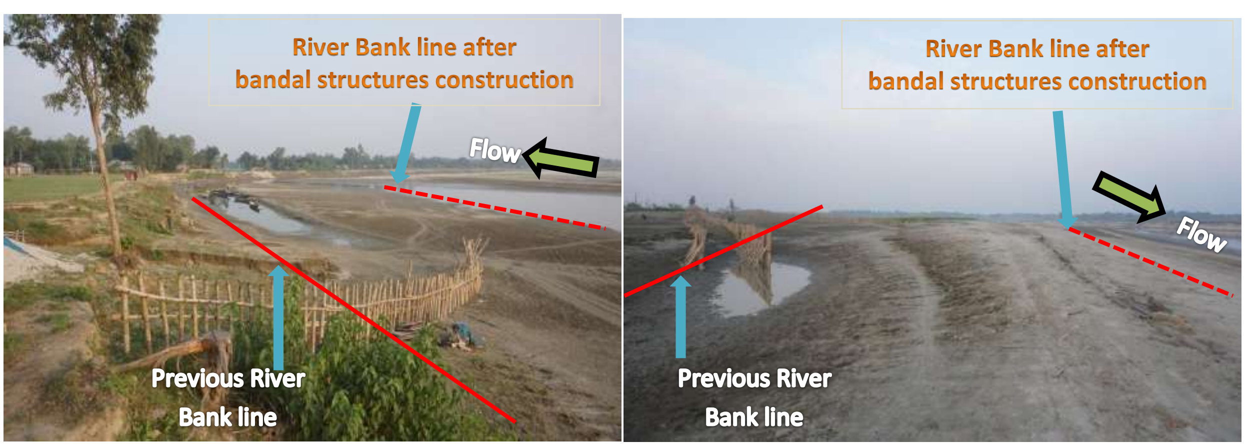


Figure 5.25 Sediment depositions on river bank induced by bandal-like structures at the left and right bank of Dhaleshwari River (Neorgacha, Chouhali)

5.9 Perfomance of Bandal Structures at Kangsa-Sumeshwari Rivers

From figures 5.26, and 5.27, it is revealed that the right bank of the Kangsa-Sumeshwari Rivers is shifted towards the river side during the last one year. The constructed bandal structures near the Jaria Bridge functioned well to river bank erosion protection through near bank sedimentation. It is evident from the figure 5.28 so that there is about more than 10 meters sedimentation towards the horizontal direction and about more than 1 meter sedimentation in the vertical direction near the bank. Not only valuable village house and roads are protected but also cultivable land reclaimed at confluence of kangsa and Sumeshwari. It is seen from photographs smaller local scour occurred around the tip of the structures due to the higher velocity and the vertical vortex formed at the upstream area of structure caused by the downward flow. At the upstream of the river reach, there is less sedimentation due to beginning thrust of flowing water pressure, but there is river bank erosion protection. This position will be improved if bamboo bandalling structures are constructed in further upstream of this reach. At the remaining downstream of the river reach; there is also less sedimentation due to absence of protective measures, but river bank erosion protection. It is also mentioned that even in opposite side of the bandal structures, there is little bit bank erosion due to constrict of the flow area and higher velocity.

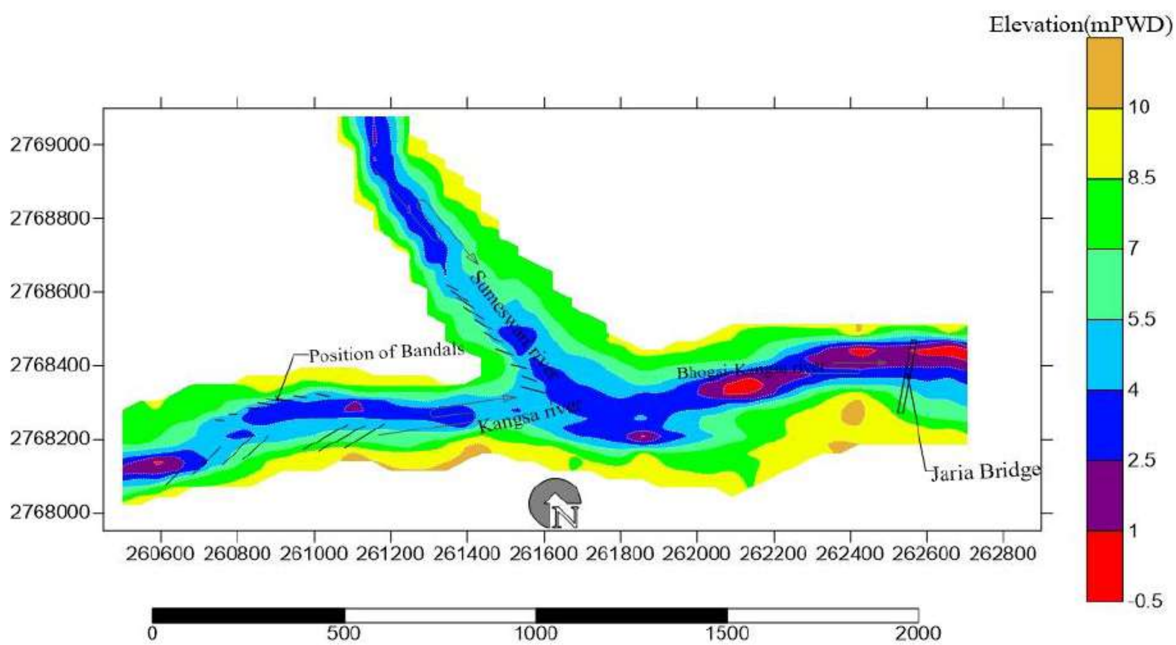


Figure 5.26 Bed elevations at the Kangsa-Sumeshwari Rivers in June 2021 (u/s & d/s of Jaria Bridge, Purbadhala)

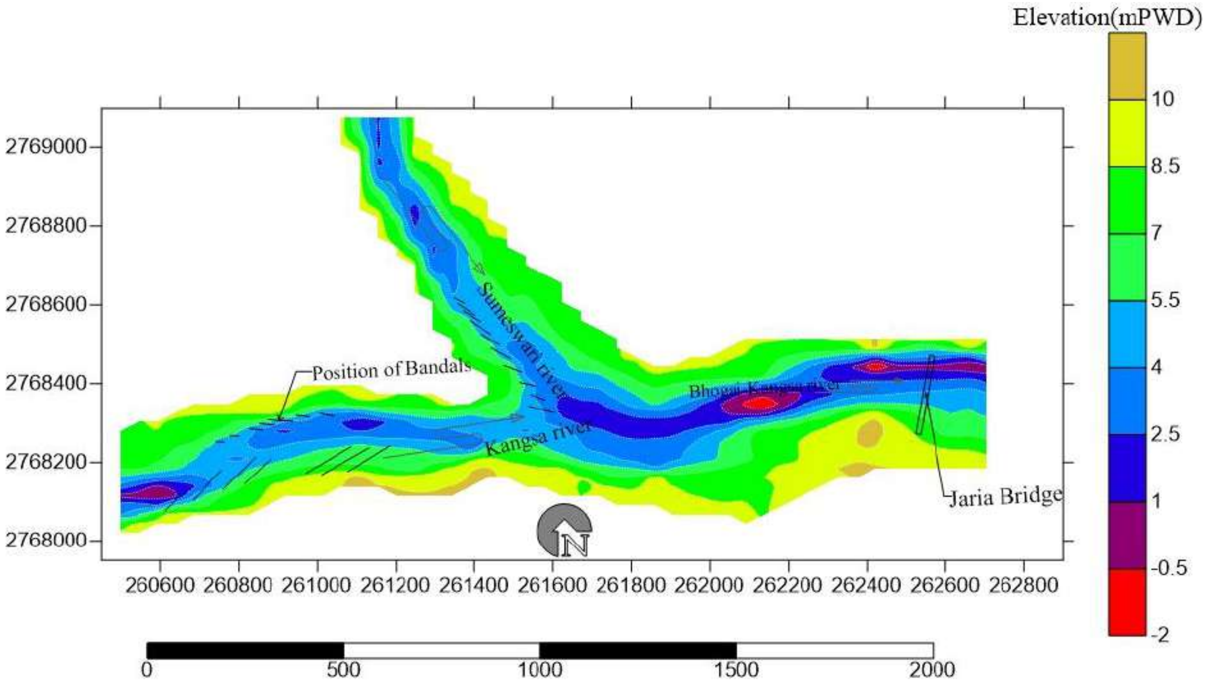


Figure 5.27 Bed elevations at the Kangsa-Sumeshwari Rivers in November 2021 (u/s & d/s of Jaria Bridge, Purbadhala)

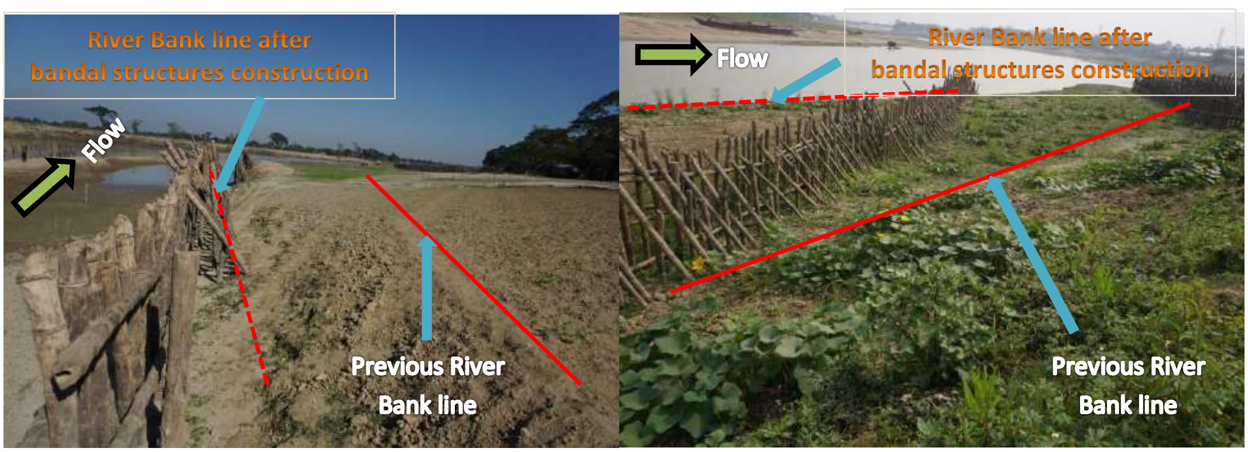


Figure 5.28 Sediment depositions on river bank induced by bandal-like structures at the Kangsa-Sumeshwari Rivers (u/s & d/s of Jaria Bridge, Purbadhala)

5.10 Perfomance of Bandal Structures at Nitai River

From figures 5.29, and 5.30, it is revealed that the right bank of the Nitai River is shifted towards the river side during the last one year. The constructed bandal structures near the Shankarpur Bazar functioned well to river bank erosion protection through near bank sedimentation. It is evident from the figure 5.31 so that there is about more than 10 meters sedimentation towards the horizontal direction and about more than 2 meters sedimentation in the vertical direction near the bank. and important bazar, village roads and two important village residential area are protected from river erosion. Also tendency for Nitai to meet with Kangsa at upstream of Shankarpur Bazar was protected to save huge area from disaster. It is seen from photographs smaller local scour occurred around the tip of the structures due to the higher velocity and the vertical vortex formed at the upstream area of structure caused by the downward flow. At the upstream of the river reach, there is less sedimentation due to beginning thrust of flowing water pressure, but there is river bank erosion protection. This position will be improved if bamboo bandalling structures are constructed in further upstream of this reach. At the remaining downstream of the river reach; there is also less sedimentation due to absence of protective measures, but river bank erosion protection. It is also mentioned that even in opposite side of the bandal structures, there is little bit bank erosion due to constrict of the flow area and higher velocity.

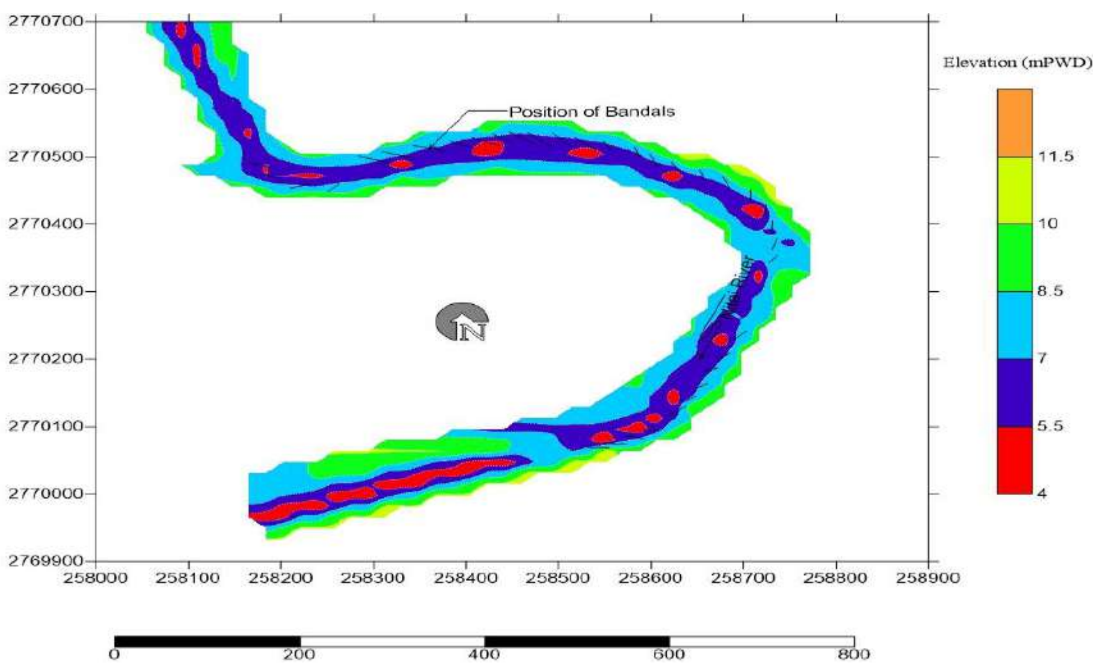


Figure 5.29 Bed elevations at the Nitai River in June 2021 (u/s of Shankarpur Bazar, Purbadhala)

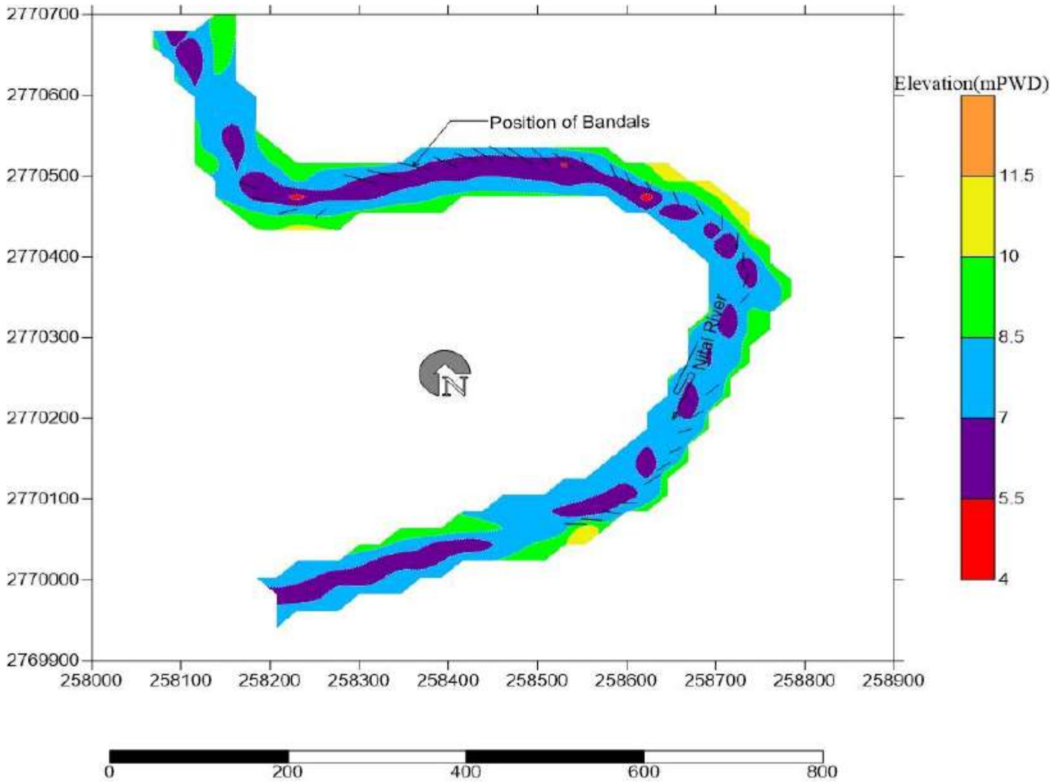


Figure 5.30 Bed elevations at the Nitai River in November 2021 (u/s of Shankarpur Bazar, Purbadhala)

Figure 5.31 Sediment depositions on river bank induced by bandal-like structures at the Nitai River (u/s of Shankarpur Bazar, Purbadhala)

5.11 Perfomance of Bandal Structures at Sugandha River

From figure 5.32, it is revealed that the constructed bandal structures at Sugandha River near the Doarika Bridge, Babuganj not functioned well to river bank erosion protection due to less sediment in the water. Also even in dry season water level too high in this tidal river. On the other hand in some areas bed soil are too loose and also bank soil. So river bank eroded at bottom and consequently bank soil collapse. Due to high water level bandal was not sufficiently long in to the river to divert the flow. From figure 5.33, it is seen that the soil condition of the Sugandha River is very instable and the bank is very steep. This is the reason for failing the bandal structures in Sugandha River.

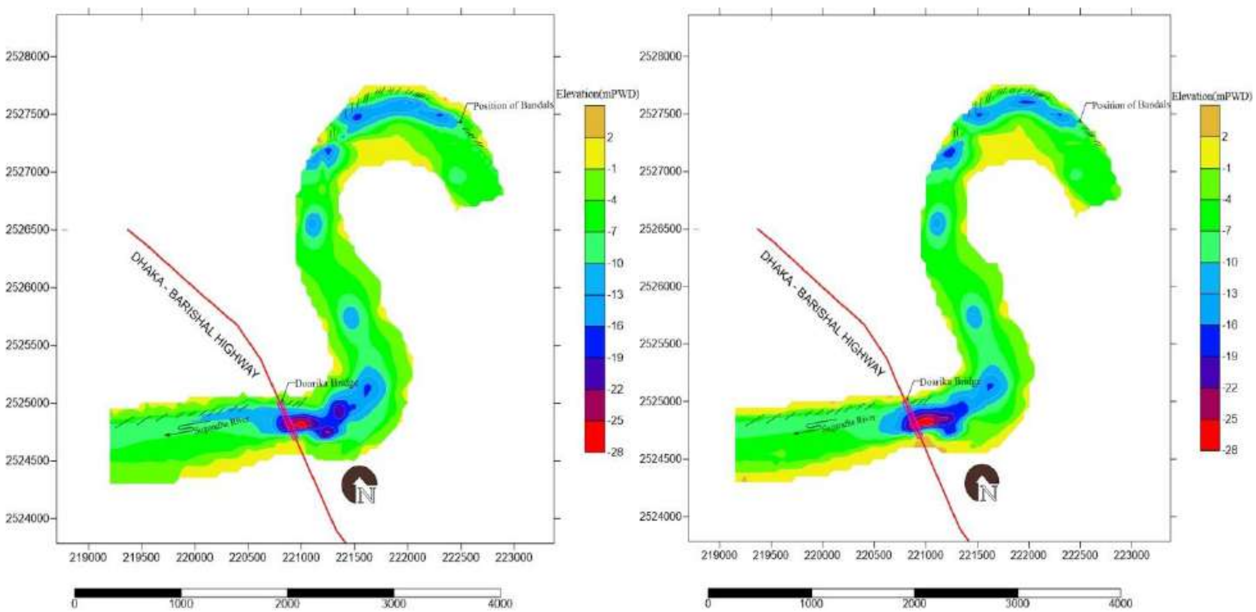


Figure 5.32 Bed elevations at the Sugandha River in November 2020 and in November 2021 respectively (u/s & d/s Doarika Bridge, Babuganj)

Figure 5.33 Bank erosion induced by instability of the of soil condition in Sugandha River (u/s & d/s Doarika Bridge, Babuganj)

5.12 Perfomance of Bandal Structures at Rupsha-Atai Rivers

From figures 5.34 and 5.35, it is revealed that the right banks of the Rupsha-Atai River are shifted slightly towards the river side during the last two years. The constructed bandal structures near the Shoilpur ghat, and Ambaria School functioned well to river bank erosion protection through near bank sedimentation. It is evident from these figures so that there is about more than 5 meters sedimentation towards the horizontal direction and about more than 0.5 meter sedimentation in the vertical direction near the right bank. It is seen from photographs the deposited sediment is very fine particles. Due to finer particles it is washed out during wave action. Sediment deposition is little bit because the velocity of these rivers is comparatively low.

At Madhupur-Laskarpur there is soil layer below 25-30 feet depth which is organic and SPT value is 1-3. So bank is eroded from bottom to collapse the bank area. Besides in some area soil is so organic to produce bubble from bottom of the river.

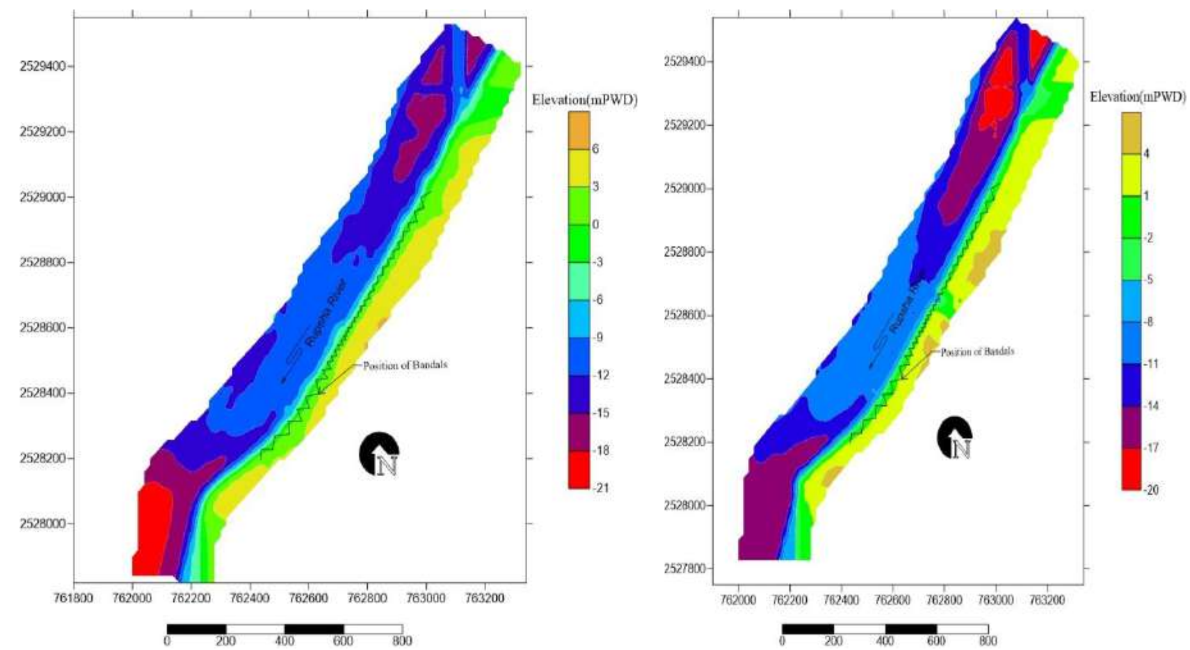


Figure 5.34 Bed elevations at the Rupsha River in July 2020 and in August 2021 respectively (near Shoilpur ghat, Rupsha)

Figure 5.35 Sediment depositions on river bank induced by bandal-like structures at the Rupsha-Atai Rivers

5.13 Perfomance of Bandal Structures at Vadra River

From figures 5.36 and 5.37, it is revealed that the right bank of the Vadra River near Chandgoar is shifted slightly towards the river side during the last two years. The constructed bandal structures functioned well to river bank erosion protection through near bank sedimentation. It is evident from these figures so that there is about more than 10 meters sedimentation towards the horizontal direction and about more than 1 meter sedimentation in the vertical direction near the right bank. It is seen from photographs the deposited sediment is very fine particles. Due to finer particles it is washed out during wave action. From figures 5.39 and 5.40, it is revealed that the left bank of the Vadra River near Kharnia Bazar is shifted towards the right side during the last three years. The constructed bandal structures functioned well to river bank erosion protection through near bank sedimentation. It is evident from these figures so that there is about more than 10 meters sedimentation towards the horizontal direction and about more than 2 meters sedimentation in the vertical direction near the right bank. It is seen from photographs smaller local scour occurred around the tip of the structures due to the higher velocity and the vertical vortex formed at the upstream area of structure caused by the downward flow. At the upstream of the river reach, there is less sedimentation due to beginning thrust of flowing water pressure due to ebb tide, but there is river bank erosion protection. This position will be improved if bamboo bandalling structures are constructed in further upstream of this reach. At the remaining downstream of the river reach, there is also less sedimentation due to direct impact of the flowing water thrust due to flood tide, but river bank erosion protection. It is also mentioned that even in opposite side of the bandal structures, there is little bit bank erosion due to constrict of the flow area and higher velocity at the right bank.

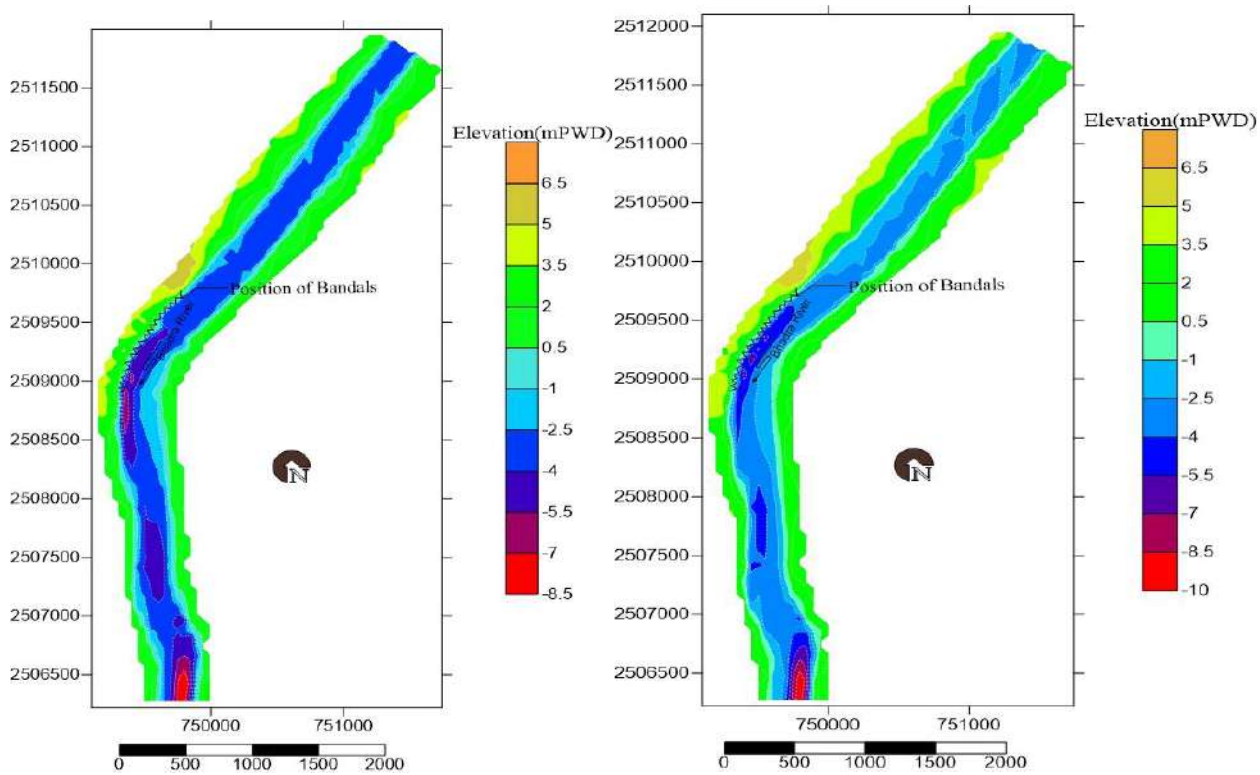


Figure 5.36 Bed elevations at the Bhadra River in October 2020 and in November 2021 respectively (near Chandgoar, Dumuria)

Figure 5.37 Sediment depositions on river bank induced by bandal-like structures at the Bhadra River (near Chandgoar, Dumuria)

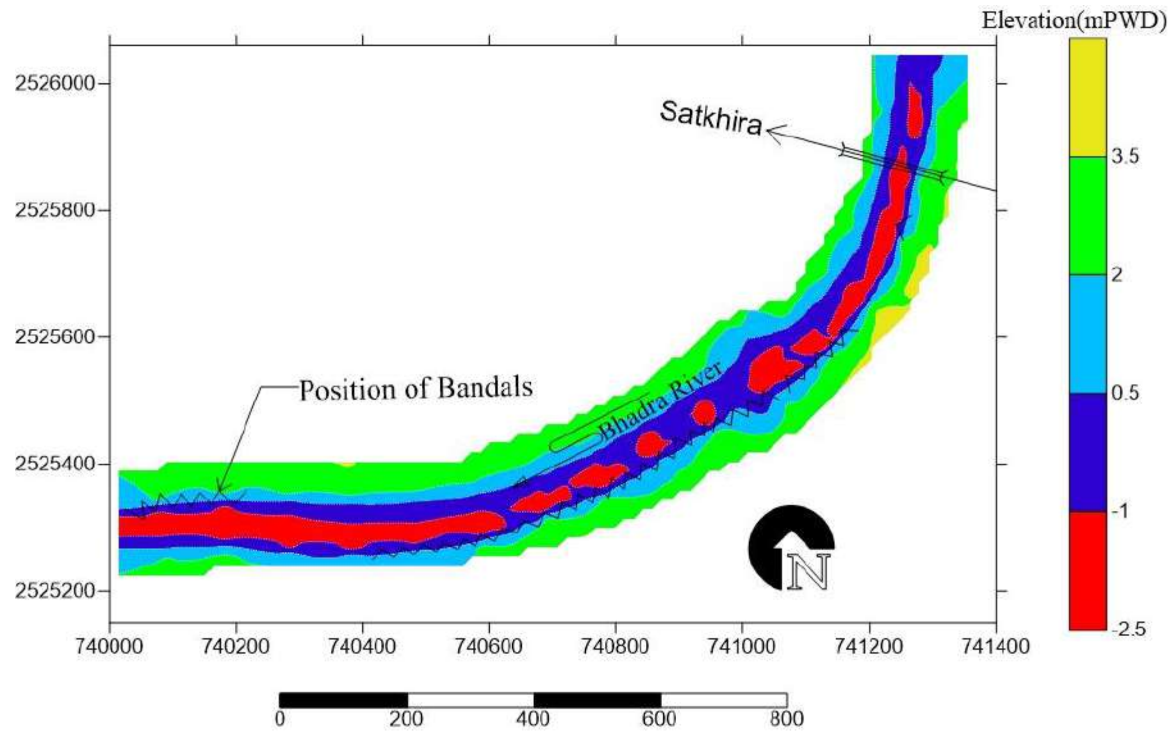


Figure 5.38 Bed elevations at the Bhadra River in December 2019 (Kharnia Bazar, Dumuria)

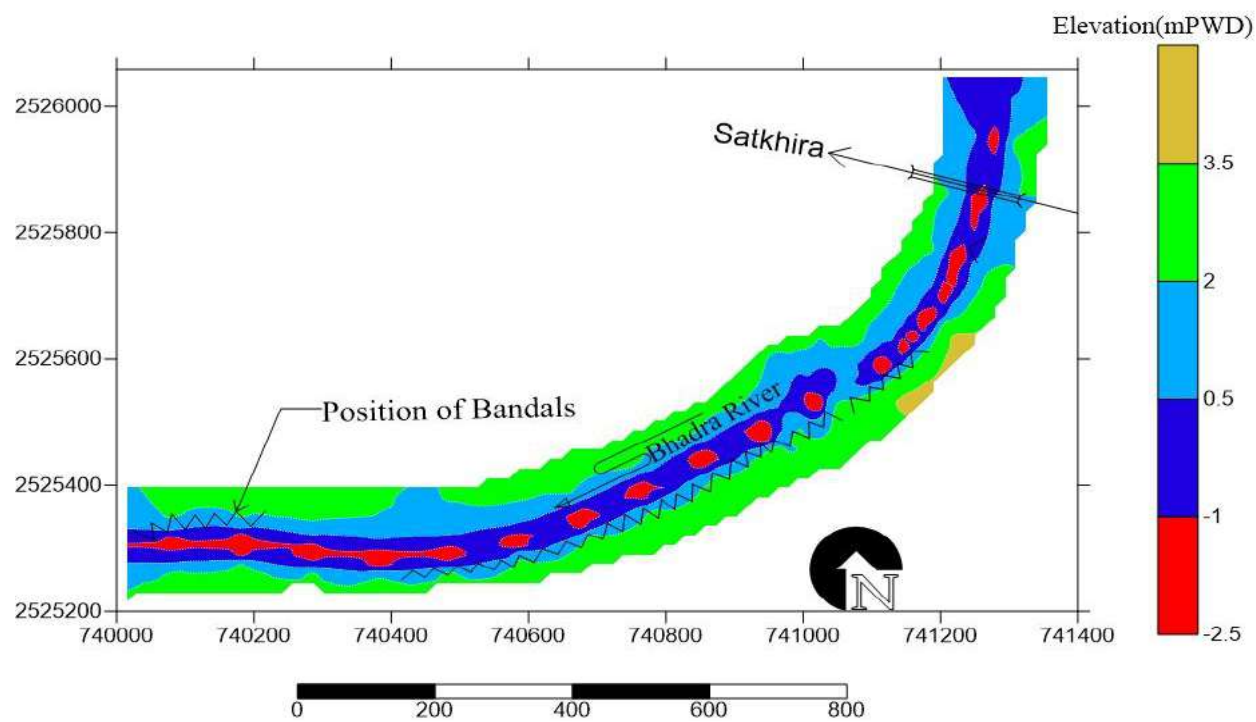


Figure 5.39 Bed elevations at the Bhadra River in October 2021 (Kharnia Bazar, Dumuria)

Figure 5.40 Sediment depositions on river bank induced by bandal-like structures at the Bhadra River (Kharnia Bazar, Dumuria)

5.14 DISCUSSION

In the case of bandal type structures, it is seen that the higher flow velocity deviated from the structures to the main channel which is more effective than the impermeable groynes case (Figures 5.41 and 5.42). Due to the influence of the bandal type structures diverting the flow from bank to the main channel, the effect of flow on bed near the structure is minimized. This point is an important characteristic of the bandal type structures utilization in which the energy of the flow at the lower part is also reduced by the presence of piles which causes disturbances in flow patterns which affects the erosion/deposition process over there. There was a considerable pressure different between the upstream and downstream side of the bandal type structures (Figures 5.43). Bank line shifting and sediment deposition induced by bandal type structures are shown in the following figure. (Figure 5.44 and 5.45)

The present study has focused on the assessment of performance of bandal type structures in different riverine environment with particular emphasis on erosion protection and land reclamation. The results of bandal type structures show that, smaller local scour around tip of the structures and a significant sediment deposition near the river bank. The main channel degradation occurs due to bandal type structures. Therefore, the bandal type structures can also be used to stabilize the navigational river channels. Due to placement of bandals in the above study areas, sedimentation occurred partly near bank sides and erosion occurred in the main channel. This phenomenon made more sediment particles pass along with low flow partly towards banks, whereas it allowed more flow along with less sediment particles to move towards main channel. Physical/numerical model study using bandal type structures are expected considering submerged condition during a flood event and the effect of suspended sediment on erosion /deposition process for accurate estimation of bed deformation around the bandal type structures. Also, more field investigations are expected to verify the applicability of bandal type structures in future planning of adaptive works.

Due to the influence of the bandal type structures placed properly on the migrating river bends, huge sedimentation occurred between the bandal type structures, which give an indication of channel stabilization by stopping the outer bank erosion at bend location as well as reducing the effects of secondary flow which is responsible for accelerating the bank erosion.

From the field investigations it is seen that, bandal type structures are suitable for all kinds of rivers such as flashy, tidal, non-tidal, braided and meandering except the tidal rivers such as Sandha, Sugandha, etc where water contains minimum sediment with finer particles, bed and bank material is very unstable and the bank slope is very steep and there is deep channel near bank even during dry season i.e. high water level near bank even in dry season for which bandal structures can't be entered sufficiently into the river. Moreover, some bandal structures have failed due to oblique flow that has come from the main channel and damaged the bandal structures. At C & B Ghat in Faridpur sadar upozilla, river bank is consist of loose sand with low SPT value and there were deep channel immediate after the bank. Even with these unfavorable conditions, bandal performance was satisfactory as flow was diverted with big bandals from upstream and there was no more oblique flow. Also BIWTA did some dredging work at opposite bank. Again in Atai river at Ambaria, bandal performance is very good. Where as, in the same river at Madhupur-Laskarpur bandal failed as there is a organic soil layer at 25-30 feet depth for which river bank is automatically eroded. On the other hand bed soil at Ambaria, Khulna and at Nitai, Netrokona is too hard to drive bamboo but output is fantastic. For rivers in Khulna, water level decrease sufficiently during ebb-tide to favor bamboo drive but for river in Barishal little water decrease during ebb-tide for which unfavorable situation for bamboo drive. So in Sugandha river at Barishal bamboo failed due to high water level for which bandal was not long enough into the river and loose bank and bed soil accelerated bank failure. For alluvial river, there are always key locations for bamboo bandaling but for tidal river due to two directional flow, selection of key location is difficult. So not only flow condition but also bank and bed soil condition have to be considered for proper functioning of bandal structures. As we experienced sudden bank failure during bamboo drive and also we observed bamboo sink even with self weight in Sugandha at Barishal. Similarly in Atai at Madhupur-Laskarpur, Khulna during bamboo driving organic layer of bed soil eject chemical to harm skin of the labour. Again steep bank should converted to mild one through earth work. So before bamboo bandal structures flow pattern of rivers, bank and bed soil condition, bank slope condition have to be studied properly to select location and layout angel of bandals. There should be sufficient bandals for proper output. Some vegetation in some cases specially for tidal rivers well helpful to grab the sediment. Some times geo bag beside the bandal in the river can give good result. Actually combination of measures like bandal, geo bag, dredging will give good result.

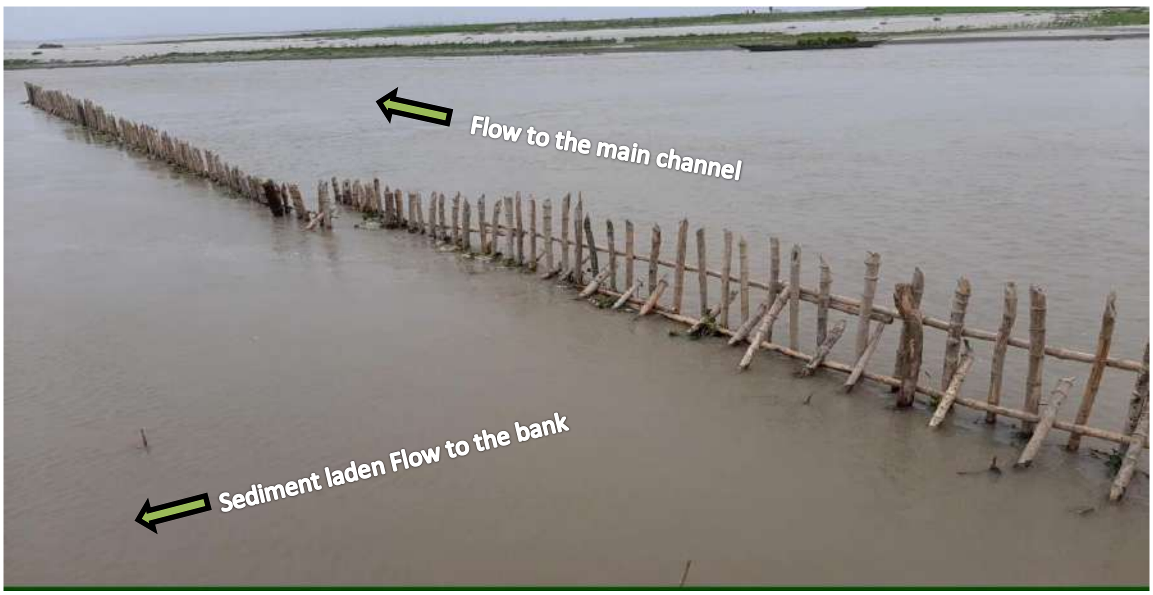
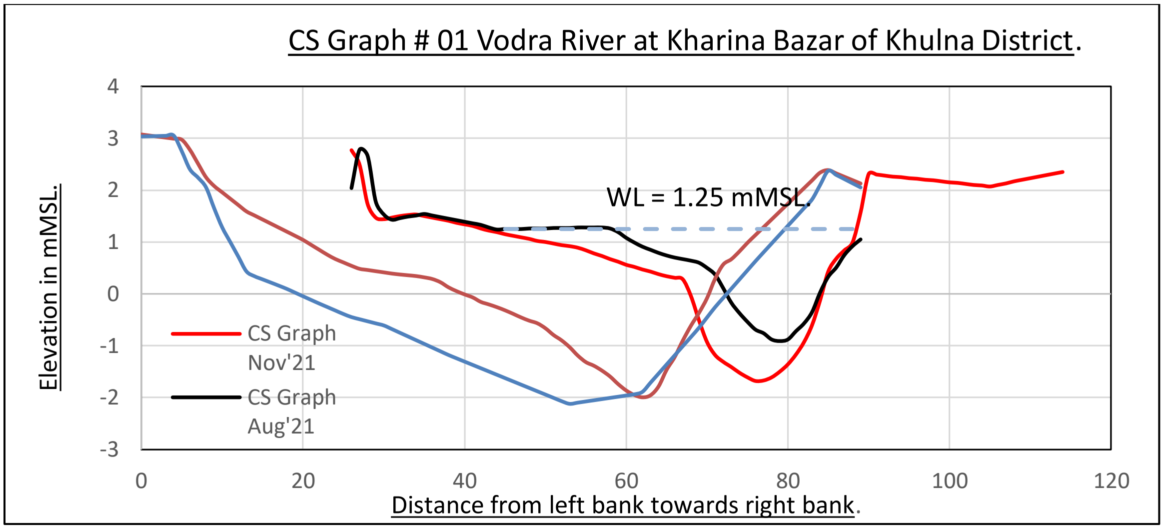
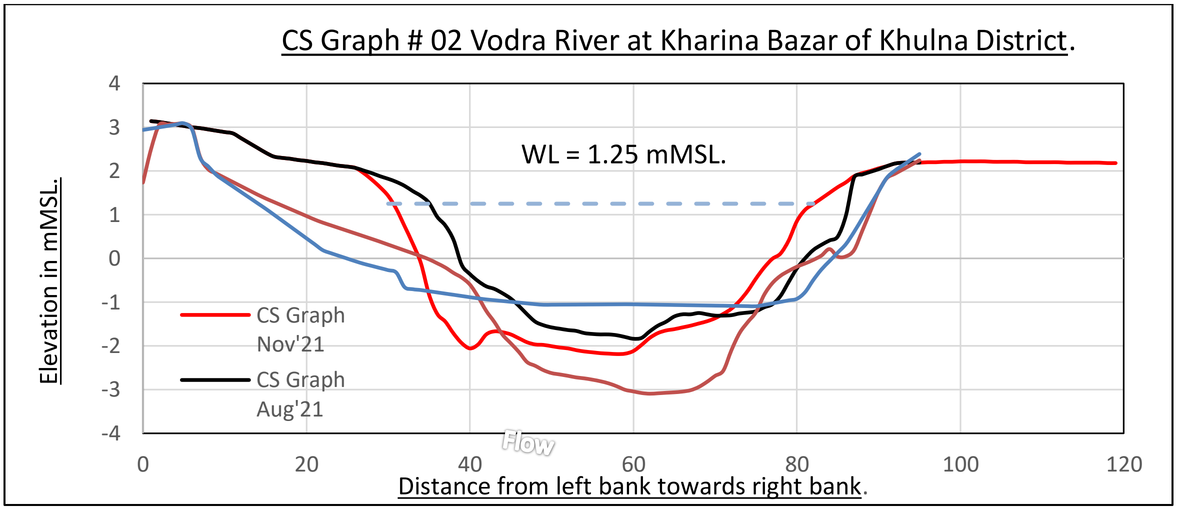


Figure 5.41 Higher flow velocity deviated to the main channel by bandal-like structures

Figure 5.42 Higher flow velocity deviated to the main channel by bandal-like structures

Figure 5.43 Pressure difference between the upstream and downstream side of the bandal-like structures





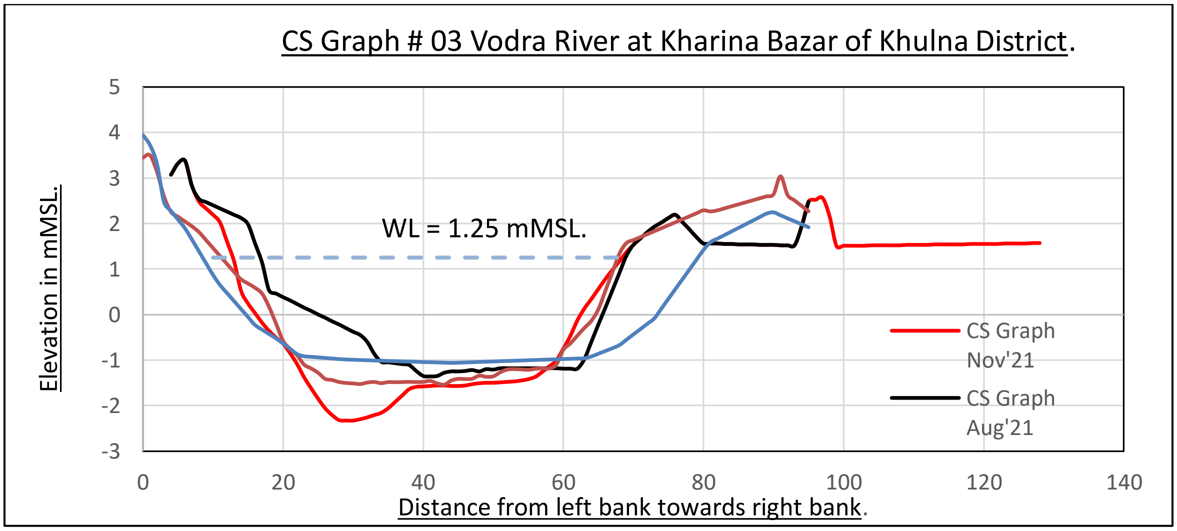


Figure 5.44 Bank line shifting and sedimentation induced by bandal-like structures

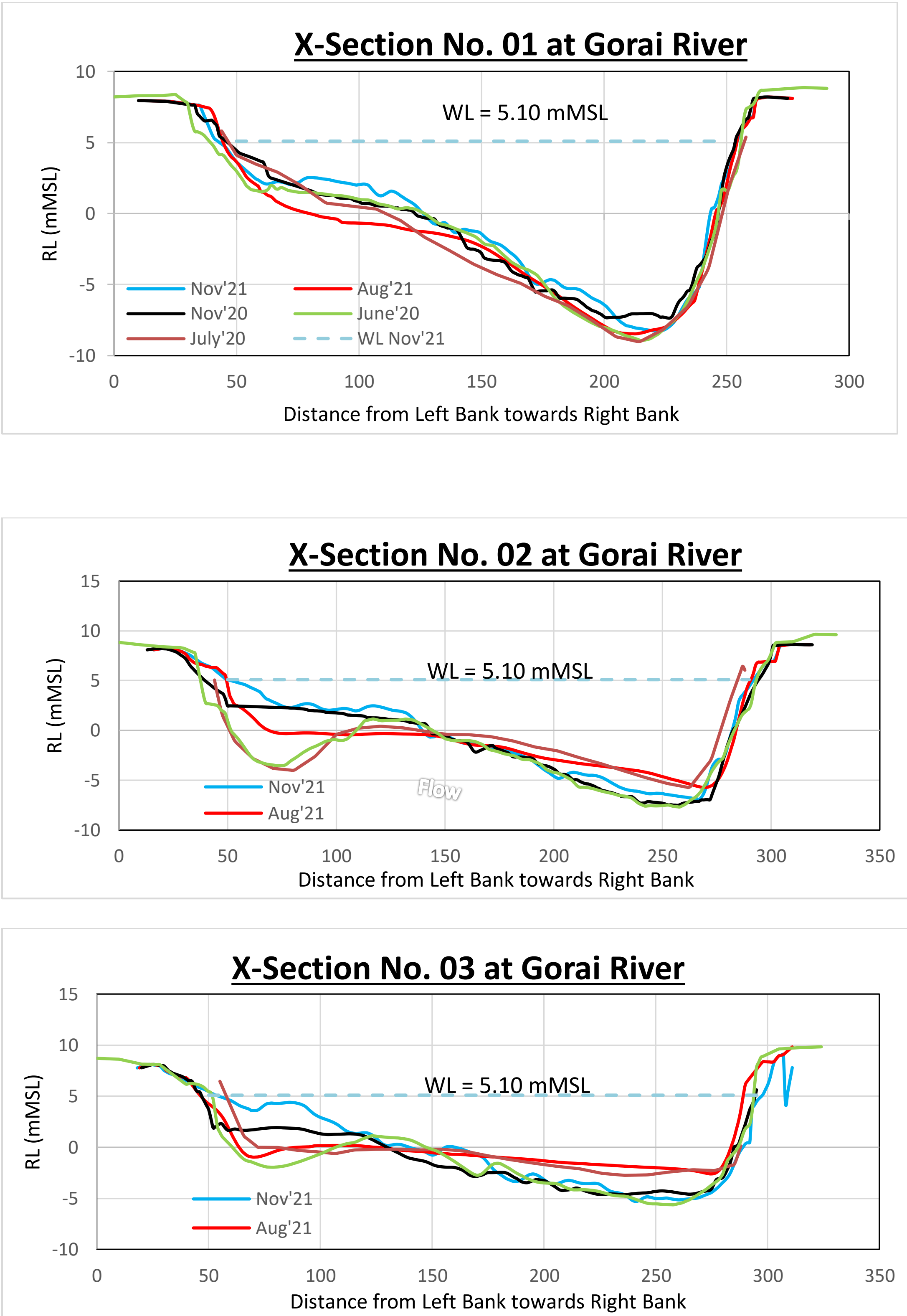


Figure 5.45 Bank line shifting and sedimentation induced by bandal-like structures

Figure 5.46 Oblique flow from main channel hit to the bandal-like structures in Jamuna River

5.15 CONCLUSIONS

The effects of bamboo bandaling structures in different rivers at different depths and at different geographical and morphological conditions on river flow and sedimentation are investigated through 'the pilot project in different areas of Bangladesh using bamboo bandaling structures to reduce river bank erosion, land reclamation and increase navigation' project. Under this project, the overall impact of bamboo bandaling on river environment especially physicochemical and biological parameters in the river ecosystem before and after bandaling are also considered. Fourteen rivers including meandering, braided, flashy and tidal in 6 district in whole Bangladesh are investigated. The following outcomes can be drawn from this project:

- The bandals are working as a river bank protection structures. Most of the cases, the use of bamboo bandaling structures are very much effective as a bank protection tool with land reclamation.
- It is observed that bandals, especially series of bandals can easily reduce flow velocity near the bank and causes sedimentation at the bank and consequently deepening river bed after a few meter distance from bandaling end towards mid of the river.
- The important focusing point is bandal stability. Specially oblique flow causes damaged to the bank and bandal. In case of sandy bed, loose soil washed out from bed due to oblique flow and failure of bandals.
- Generally, it is better to guide flow pattern of river from suitable up stream through bamboo bandals. There are always key location.
- Long bandals with two or three part will give good result.
- Angle between bandals and river bank should be from 30^0 to 45^0
- Impact of Bandals in Rivers of Khulna where water level difference is high due to tidal effect is very appreciable for bamboo bandaling . But impact of bandals in river of Barishal where little water level difference due to tidal effects seems not feasible for bamboo drive.
- Sandy bank or bank with sand layer below clay layer is not suitable for bamboo bandals. But in this situation bandals will also work if river sufficiently dried during dry season and long banndals with dense combination placed. Good result can also be attained if flow diversion from u/s is possible by bamboo bandal structures.
- Vortex formation, direct water fall upon bandals and severe velocity from storm surges may damage bandals. Two bandals at chandgaon destroyed during the Amphan by direct storm surges. But road and locality saved because of the bandals. Later bandals were repaired and working good.
- First bandal should be doubled to protect huge water thrust.

- As typical riverbank protection methods with geo-bags or concrete blocks are expensive, the cost-effective, local technology using locally-available material and manpower provides a sustainable way to stem river erosion.
- In some cased combination of measures like geo-bag, bamboo bandal structre and dredging can be implemented for proper output.
- Key locations have to be identified for bandal structure to successfully attain erosion protection and land reclamation.
- Earth work has to included with proposed design to make steep bank slope mild.
- Sufficient bandals have to be constructed for desired output.
- Bamboo bandal can safe guard existing costly structure
- RRI can be mandated upto certain limit to implement field level low cost and innovative projects

5.16 Recommendation

- Despite being low-cost, eco-friendly, and effective for land reclamation and navigation, the most crucial limitation of bamboo bandalling structures is their lack of sustainability. Bamboo bandalling structures are comparatively weak and cannot exist in major rivers with high water flow or velocity. However, they can work in minor rivers where water flow, or velocity, is low or medium. So, RRI has to take research for the bandalling structures to be constructed by R.C.C. pillar instead of bamboo for more sustainability.
- BWDB can take some projects for bank protection and land reclamation along with traditional measures
- To protect cultivable land and villege dwelers RRI can have mandate to work with bamboo bandal with its revenue budget initially. Finally RRI can take more big projects in this respect.
- RRI should strengthen for survey work and implementation of low cost measures like bamboo bandaling.

5.17 Implication of this research

This research will provide a clear idea about impact of Bamboo Bandaling Structures upon alluvial, flashy and tidal river in Bangladesh. The successful implementation and charming output of Bamboo Bandal Structures will attract policy making and management authority to extensive use of low cost Bamboo Bandaling Structures even at remote area of Bangladesh for mitigation of suffering of poor people and increased agricultural product through erosion protection and land reclamation. This research will also be a basis for future research.

5.18 REFERENCES

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Sediment depositions on river bank induced by bandal-like structures at the left bank of Gorai River

Sediment depositions on river bank induced by bandal-like structures at the right bank of Madhumati River (u/s of Kamarkhali Bridge)




Sediment depositions on river bank induced by bandal-like structures at the left bank of Madhumati River (d/s of Kamarkhali Bridge)




Sedimen t depositions on river bank induced by bandal-like structures at the right bank of Arial Khan River (u/s of Chandrapara ghat)

Sediment depositions on river bank induced by bandal-like structures at the right bank of Arial Khan River (d/s of Chandrapara ghat)

Sediment depositions on river bank induced by bandal-like structures at the right bank of Padma River (u/s of C & B ghat, Goldangirchar)

Sediment depositions on river bank induced by bandal-like structures at the left and right bank of Dhaleshwari River (Neorgacha, Chouhali)

Sediment depositions on river bank induced by bandal-like structures at the left bank of Jamuna River (Rehaipukhuria, Chouhali)

Sediment depositions on river bank induced by bandal-like structures at the right bank of Jamuna River (d/s of Enayetpur Spur)

Sediment depositions on river bank induced by bandal-like structures at the right bank of Jamuna River (u/s of Cross bar-01, Sirajganj)

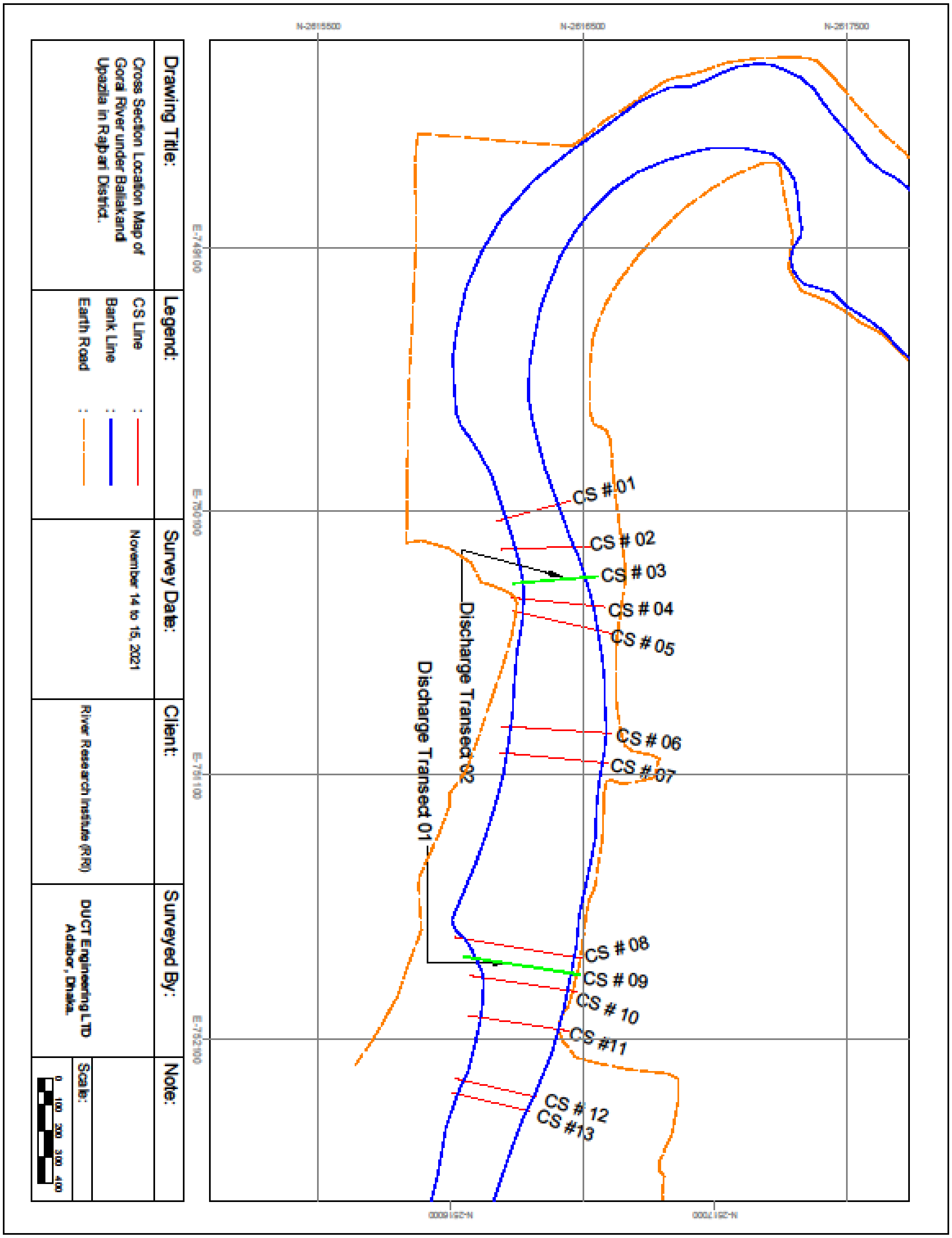
Bed elevations at the Kangsa-Sumeshwari Rivers in June 2021 (u/s of Jaria Bridge, Purbadhala)


Sediment depositions on river bank induced by bandal-like structures at the Nitai River (u/s of Shankarpur Bazar, Purbadhala)


Sediment depositions on river bank induced by bandal-like structures at the Bhadra River (Kharnia Bazar, Dumuria)


Sediment depositions on river bank induced by bandal-like structures at the Bhadra River (near Chandgoar, Dumuria)

APPENDIX-B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Cross Section Location Map of Gorai River under Baliakandi Upazila in Rajbari District.
Legend:
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Bank Line :
Earth Road :
Survey Date:
November 14 to 15, 2021
Client:
River Research Institute (RRI)
Surveyed By:
DUCT Engineering LTD Adabor, Dhaka.
Note:
Scale:
0 100 200 300 400
CS # 01
CS # 02
CS # 03
CS # 04
CS # 05
CS # 06
CS # 07
CS # 08
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CS # 10
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CS # 12
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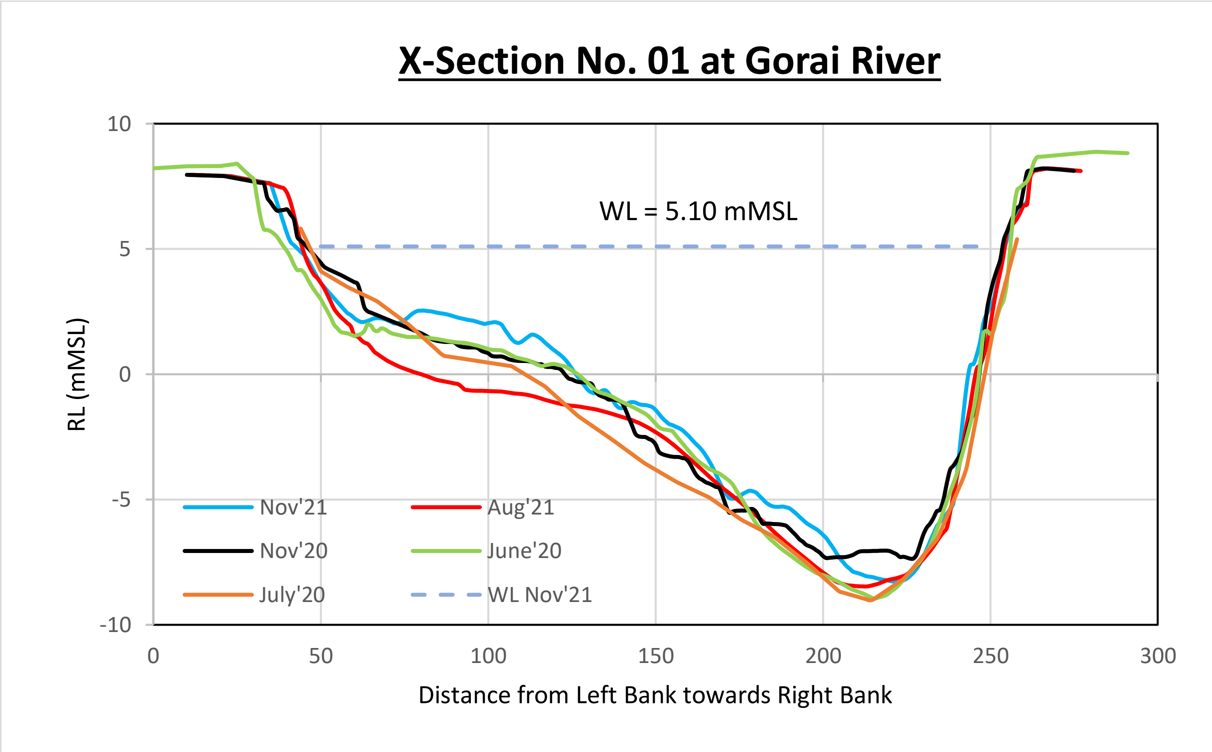
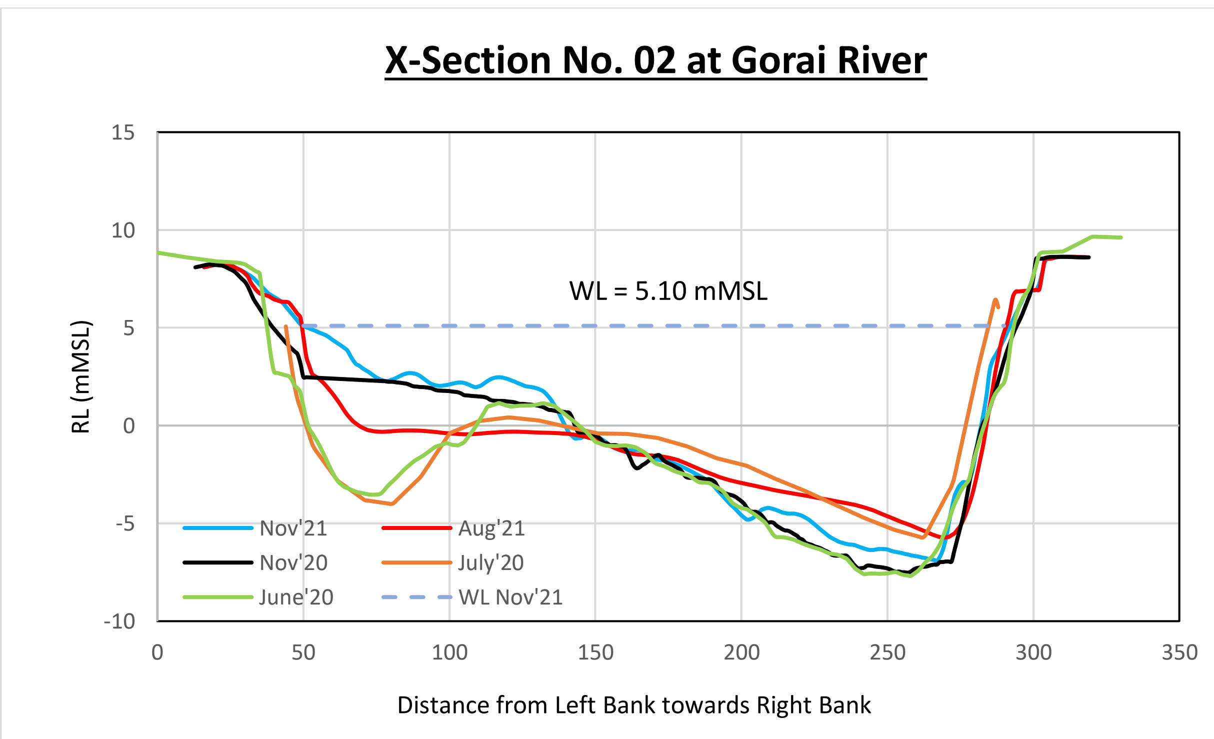
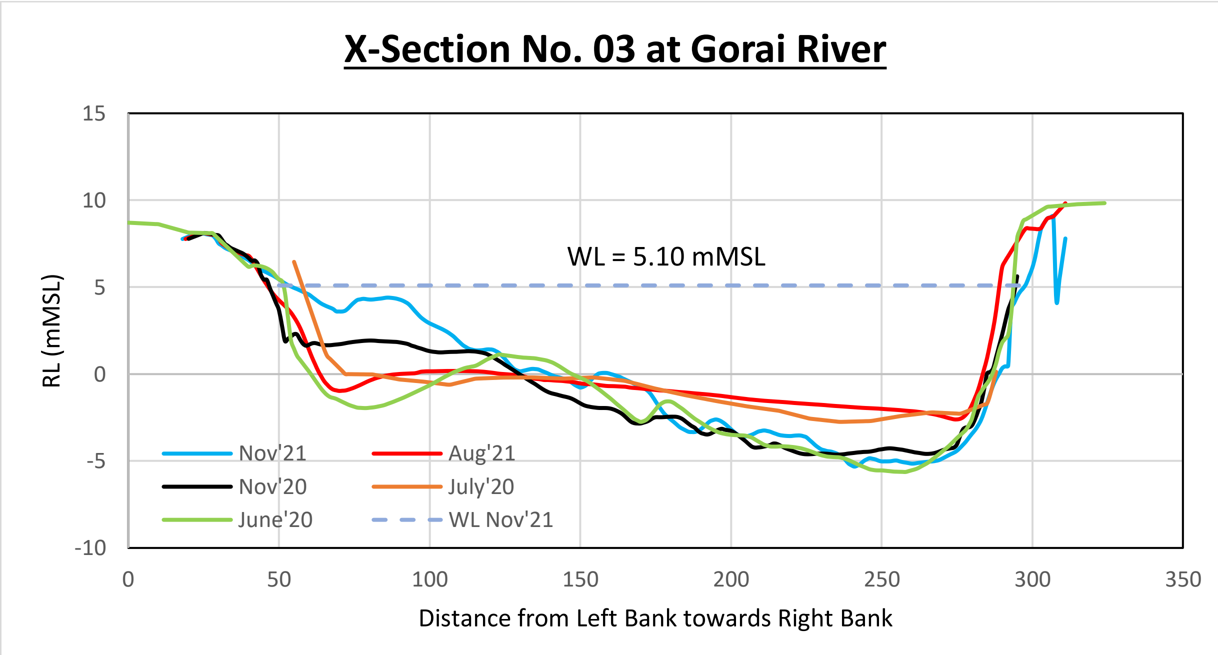
Discharge Transect 02
Discharge Transect 01


X-Section No. 01 at Gorai River
WL = 5.10 mMSL
RL (mMSL)
10
5
0
-5
-10
0
50
100
150
200
250
300
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
June'20
July'20
WL Nov'21


X-Section No. 02 at Gorai River
WL = 5.10 mMSL
RL (mMSL)
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
July'20
June'20
WL Nov'21


X-Section No. 03 at Gorai River
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RL (mMSL)
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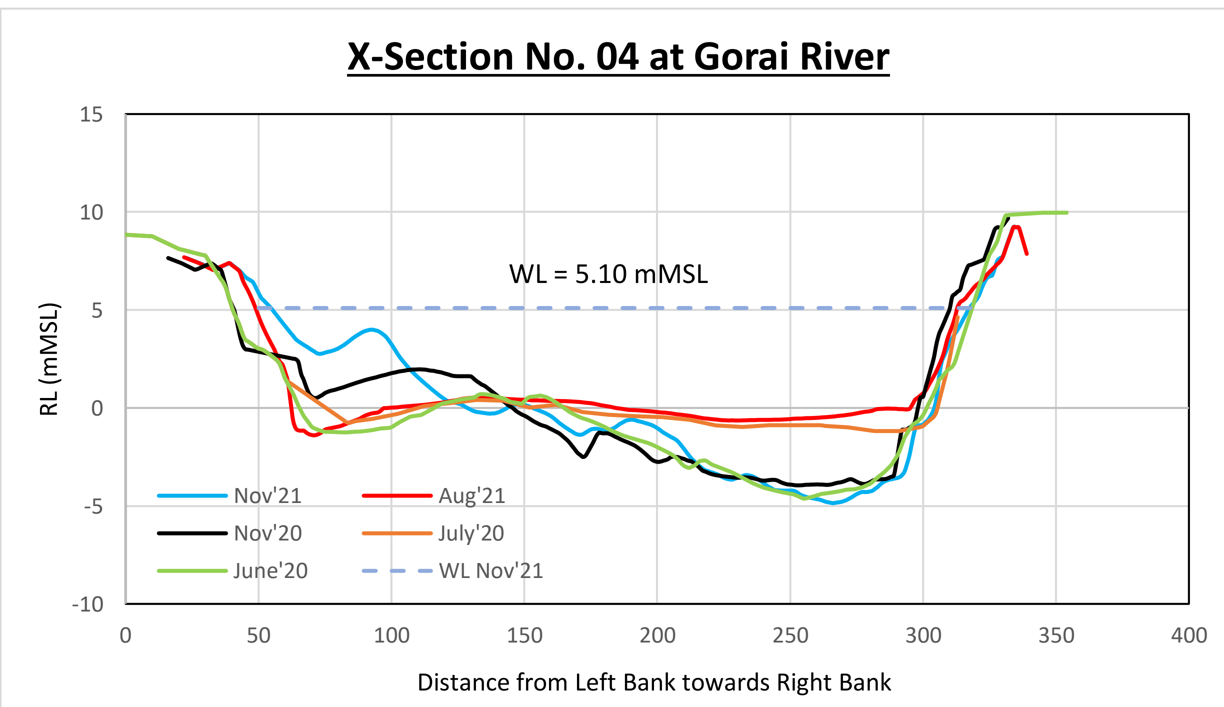
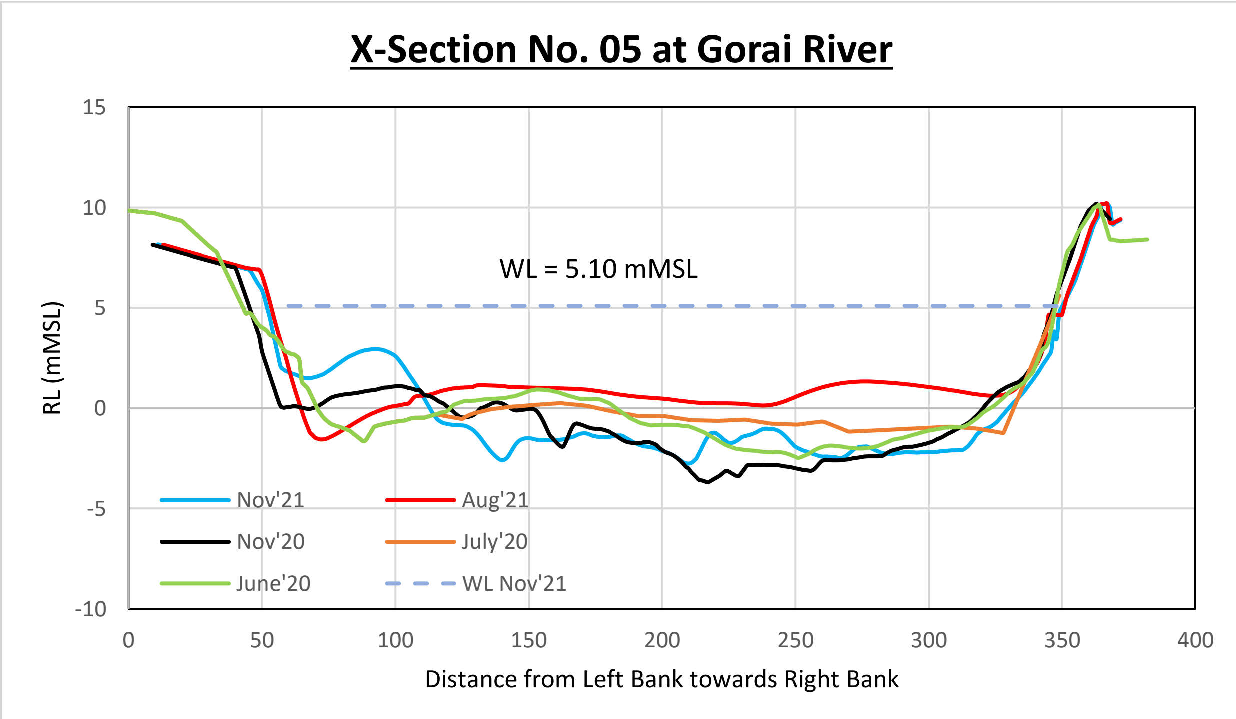
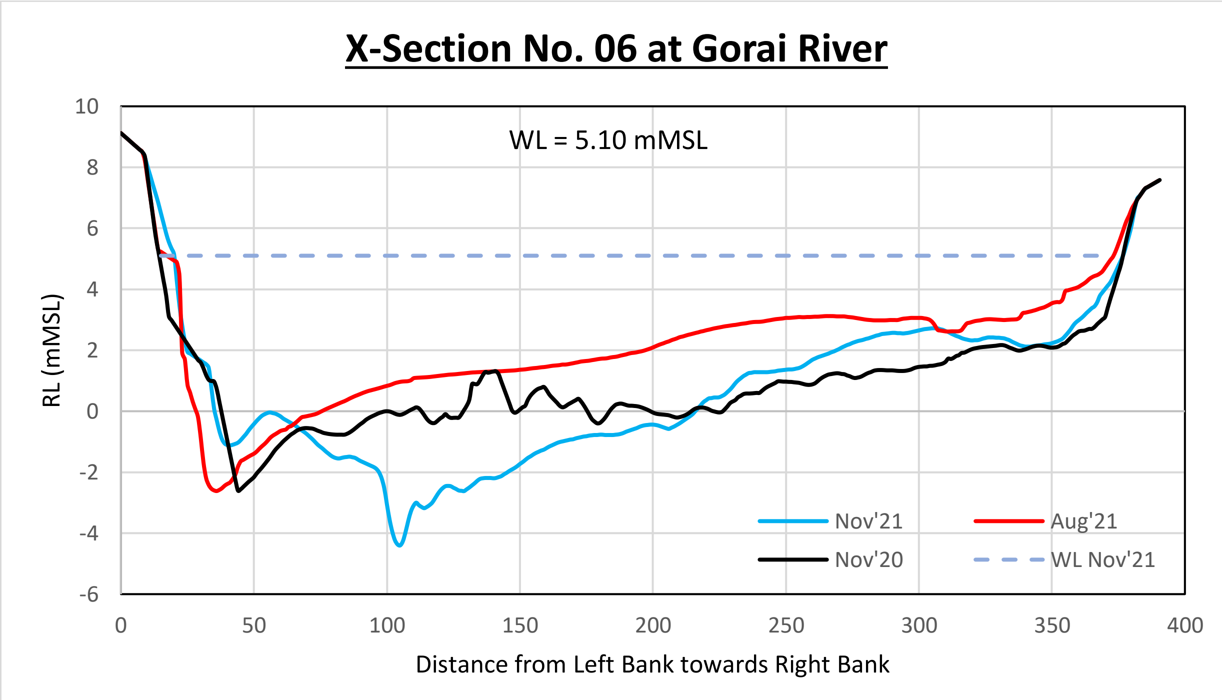
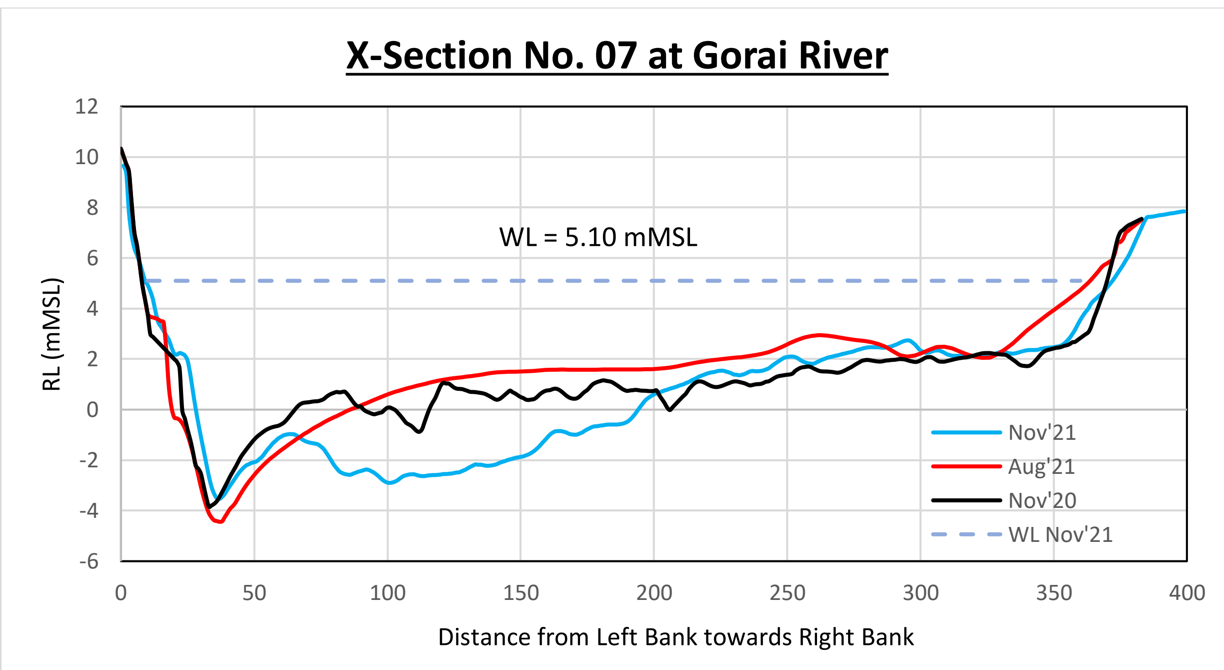
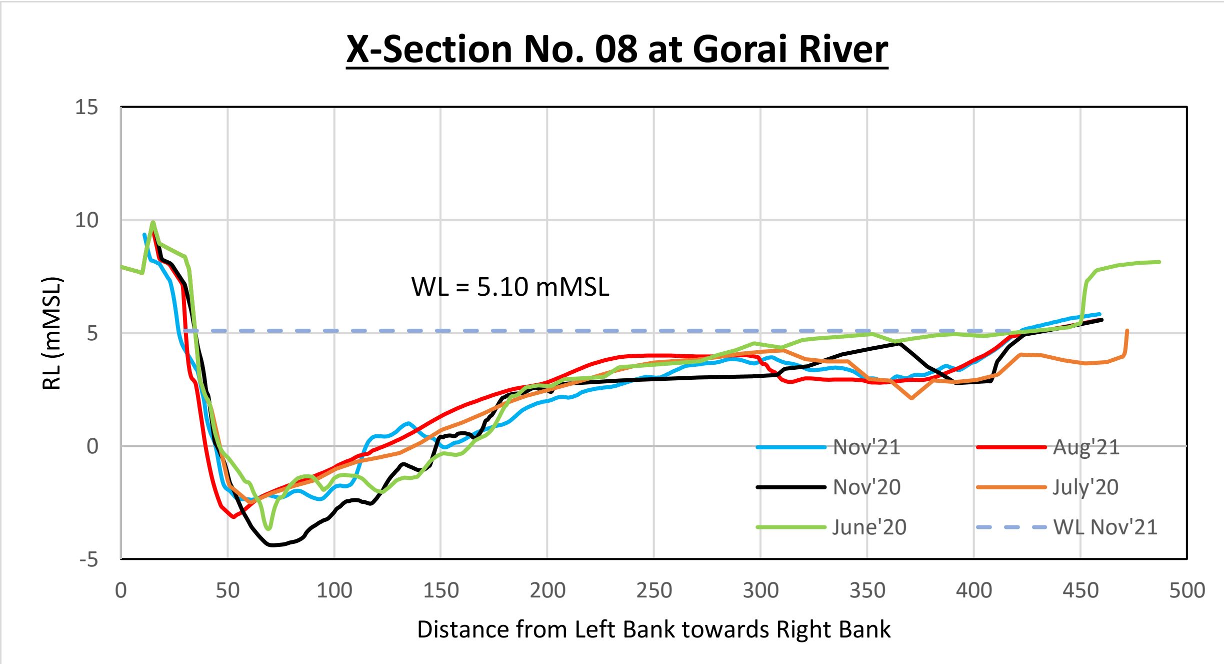
10
5
0
-5
-10
0
50
100
150
200
250
300
350
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
July'20
June'20
WL Nov'21


X-Section No. 04 at Gorai River
WL = 5.10 mMSL
RL (mMSL)
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
July'20
June'20
WL Nov'21

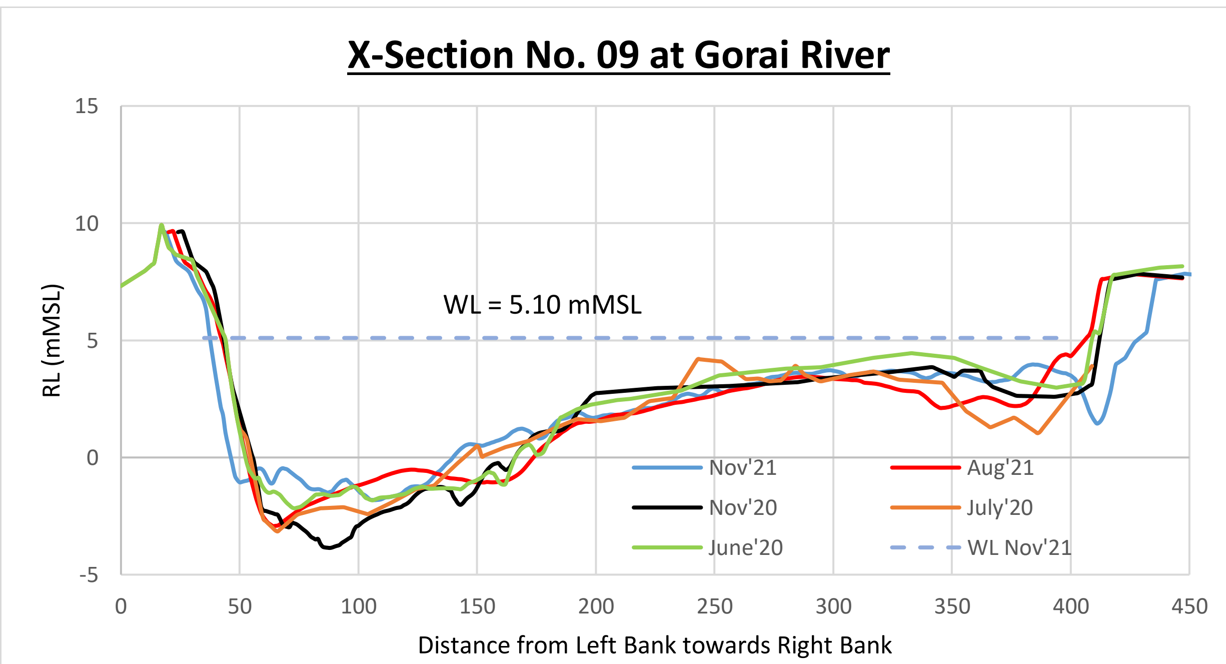

X-Section No. 05 at Gorai River
WL = 5.10 mMSL
RL (mMSL)
15
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
July'20
June'20
WL Nov'21


X-Section No. 06 at Gorai River
WL = 5.10 mMSL
RL (mMSL)
10
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
WL Nov'21

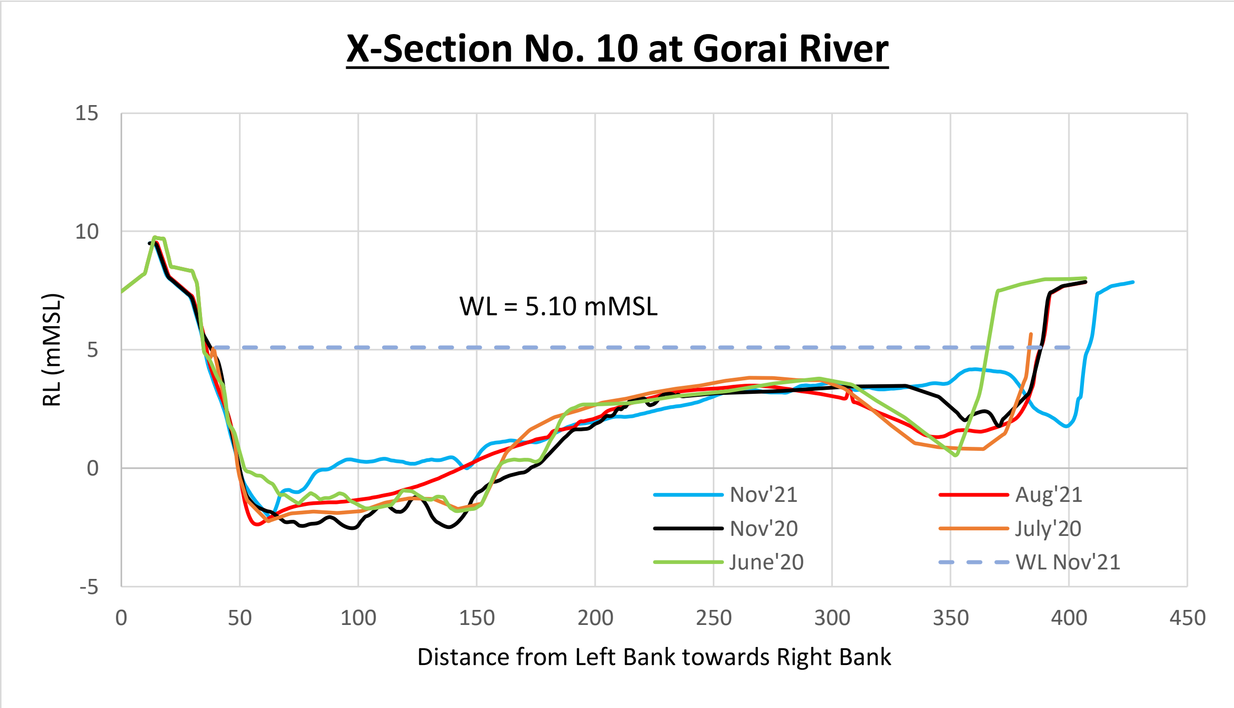

X-Section No. 07 at Gorai River
WL = 5.10 mMSL
RL (mMSL)
12
10
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
WL Nov'21



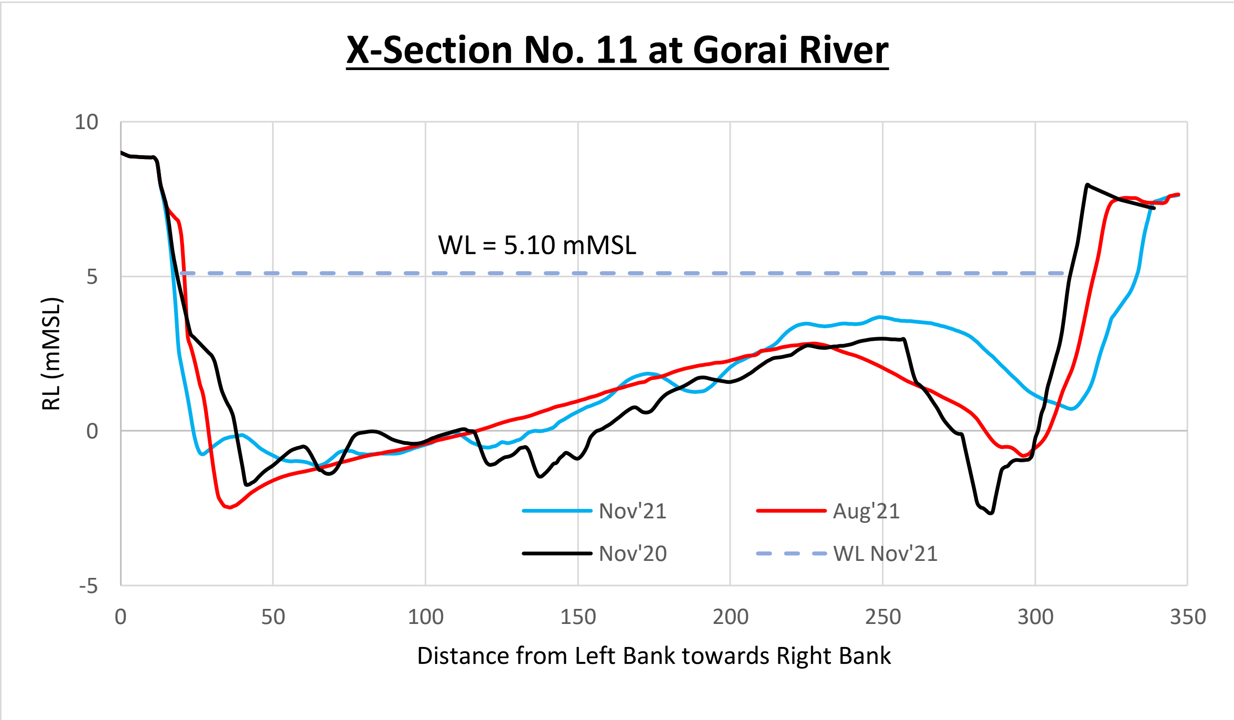
X-Section No. 08 at Gorai River
WL = 5.10 mMSL
RL (mMSL)
15
10
5
0
-5
0
50
100
150
200
250
300
350
400
450
500
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
July'20
June'20
WL Nov'21



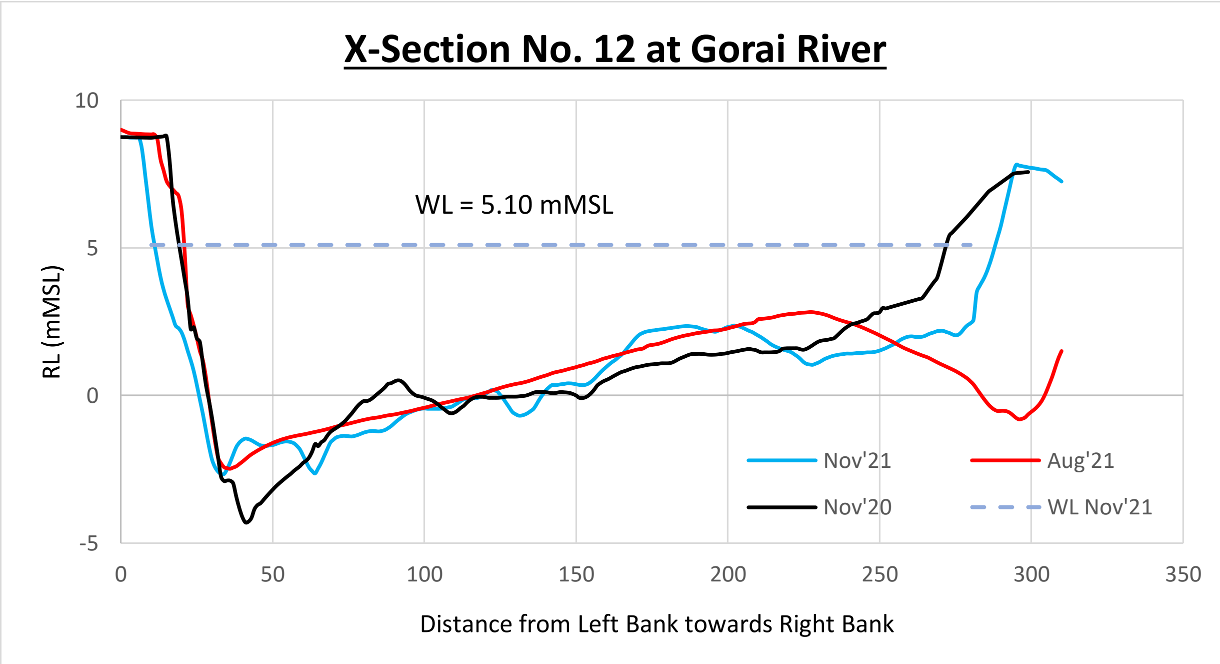
X-Section No. 09 at Gorai River
WL = 5.10 mMSL
RL (mMSL)
15
10
5
0
-5
0
50
100
150
200
250
300
350
400
450
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
July'20
June'20
WL Nov'21



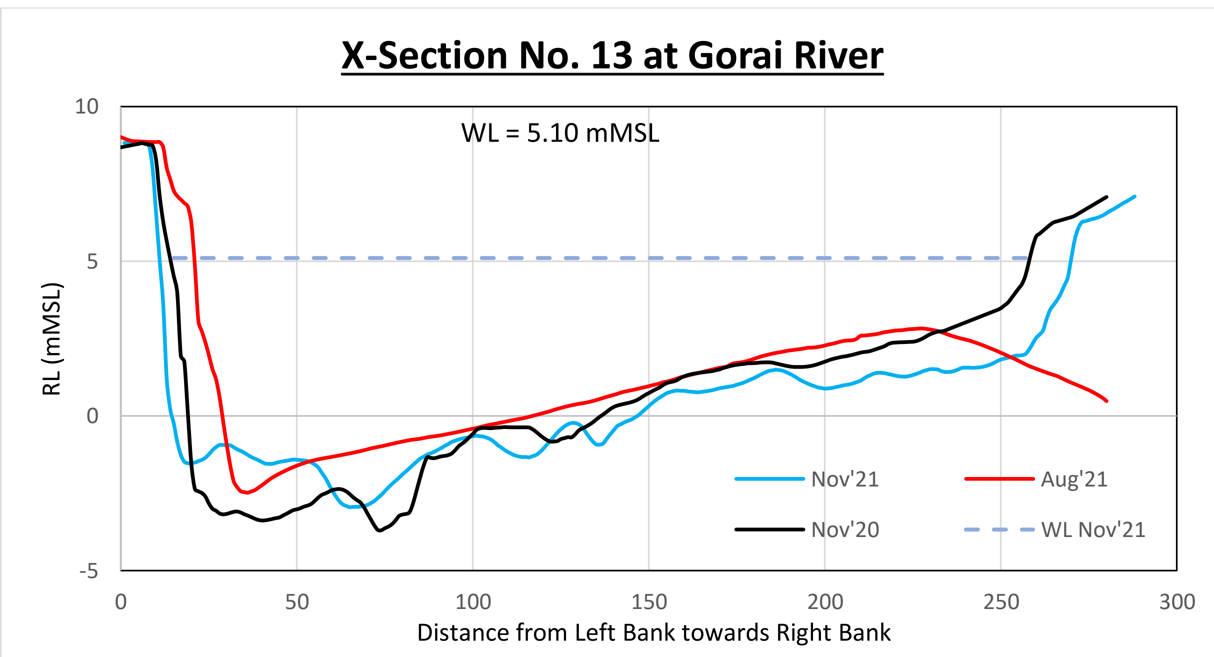
X-Section No. 10 at Gorai River
WL = 5.10 mMSL
RL (mMSL)
15
10
5
0
-5
0
50
100
150
200
250
300
350
400
450
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
July'20
June'20
WL Nov'21



X-Section No. 11 at Gorai River
WL = 5.10 mMSL
RL (mMSL)
10
5
0
-5
0
50
100
150
200
250
300
350
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
WL Nov'21

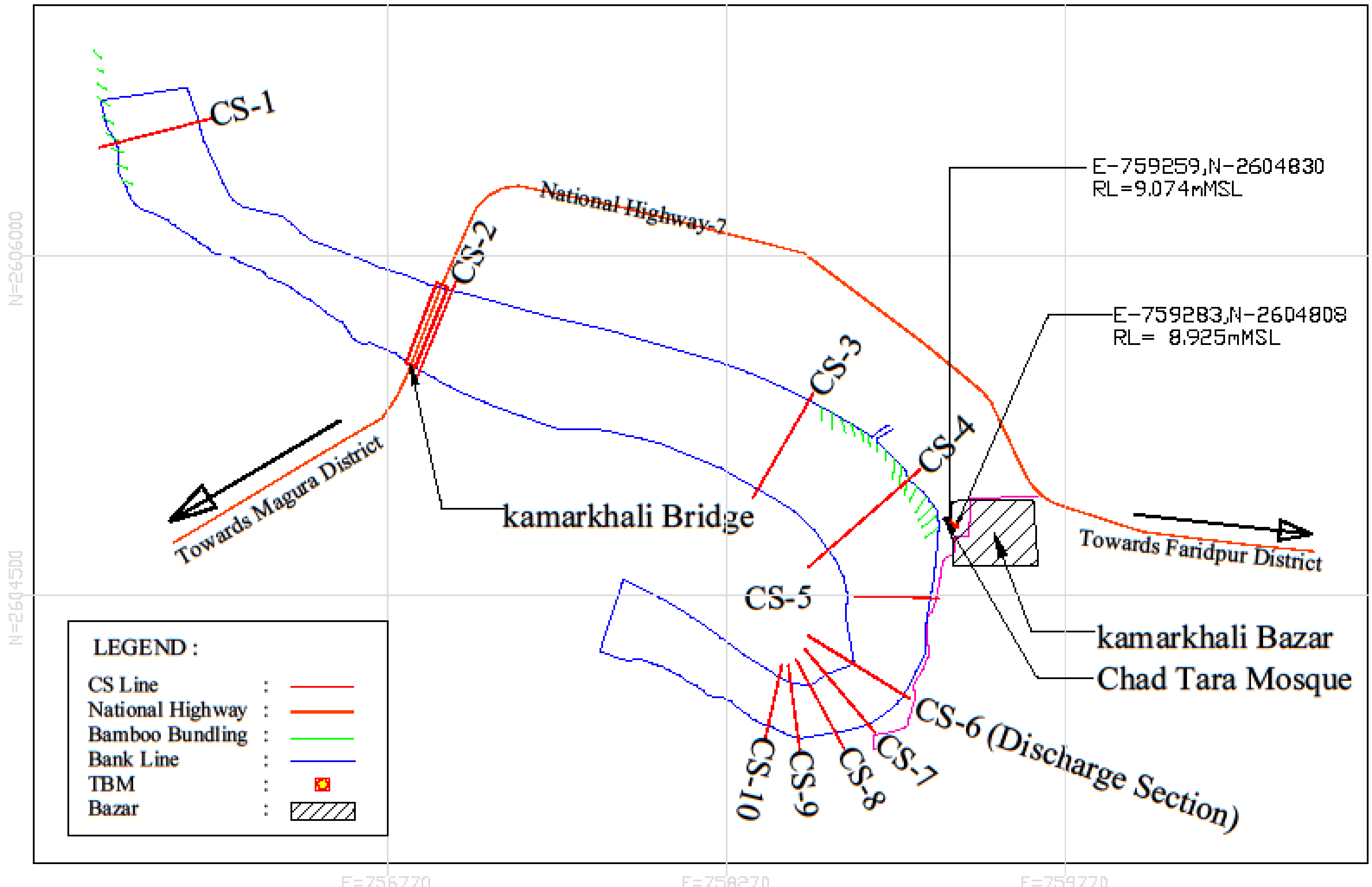


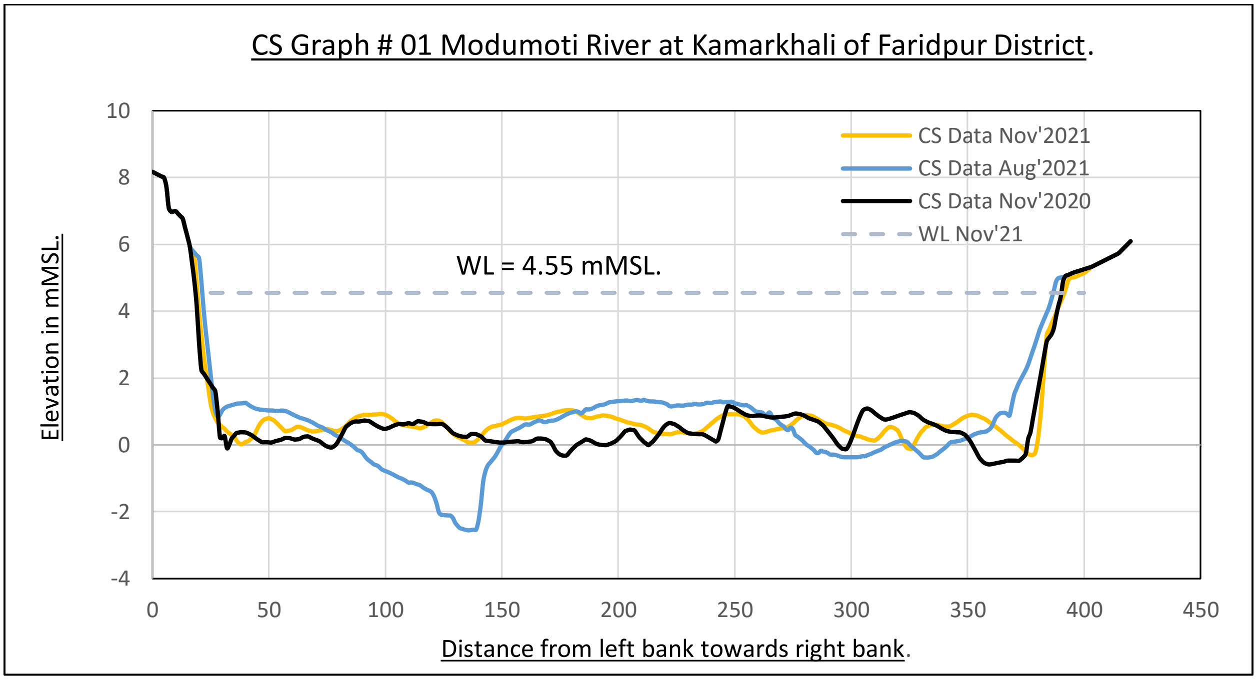
X-Section No. 12 at Gorai River
WL = 5.10 mMSL
RL (mMSL)
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
WL Nov'21



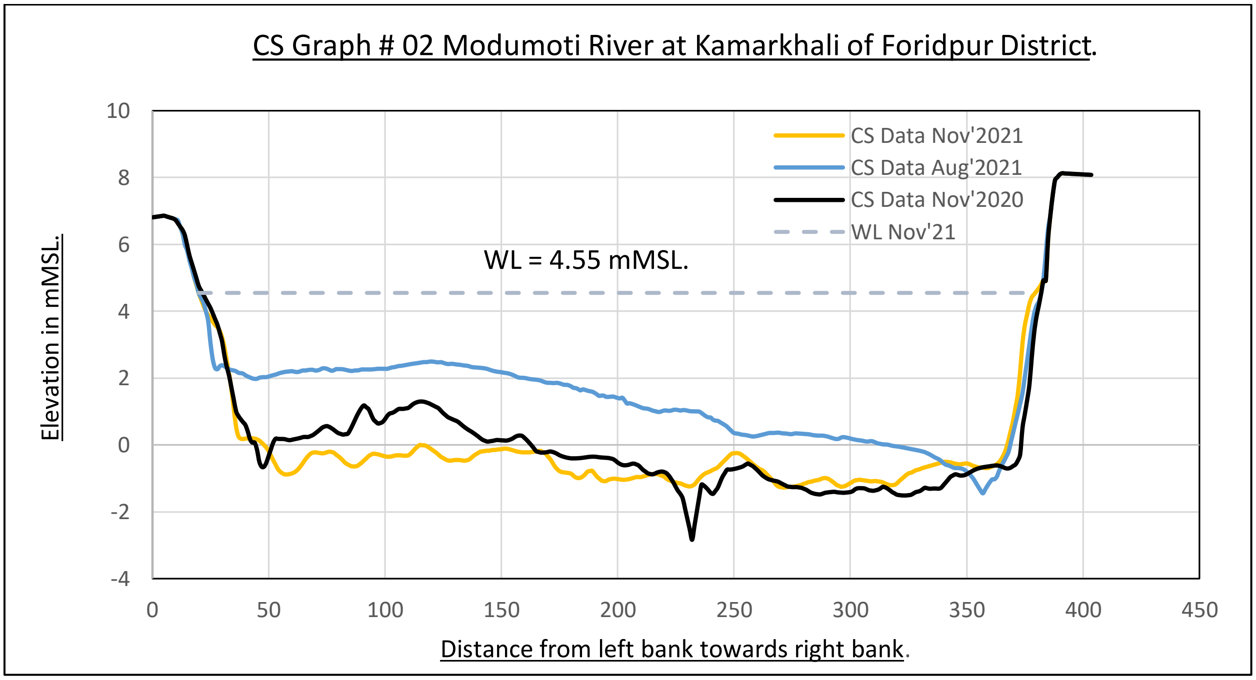
X-Section No. 13 at Gorai River
WL = 5.10 mMSL
RL (mMSL)
Distance from Left Bank towards Right Bank
Nov'21
Aug'21
Nov'20
WL Nov'21

Base Map of Modumoti River at Kamarkhali

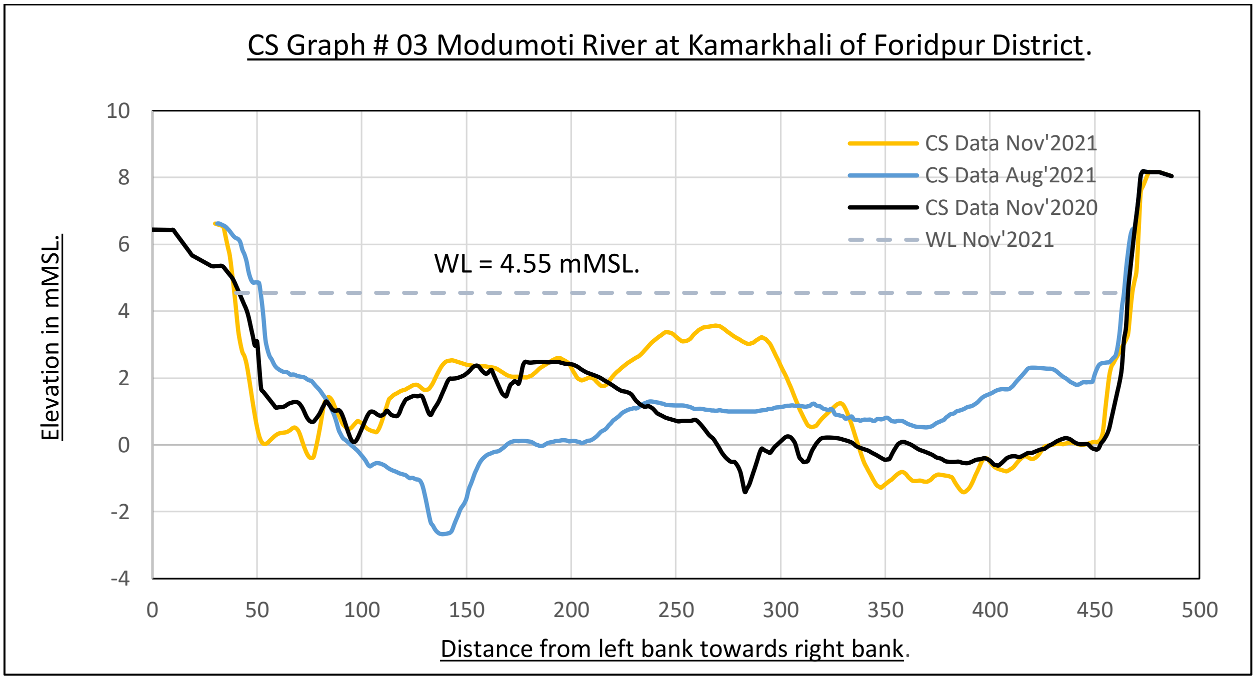


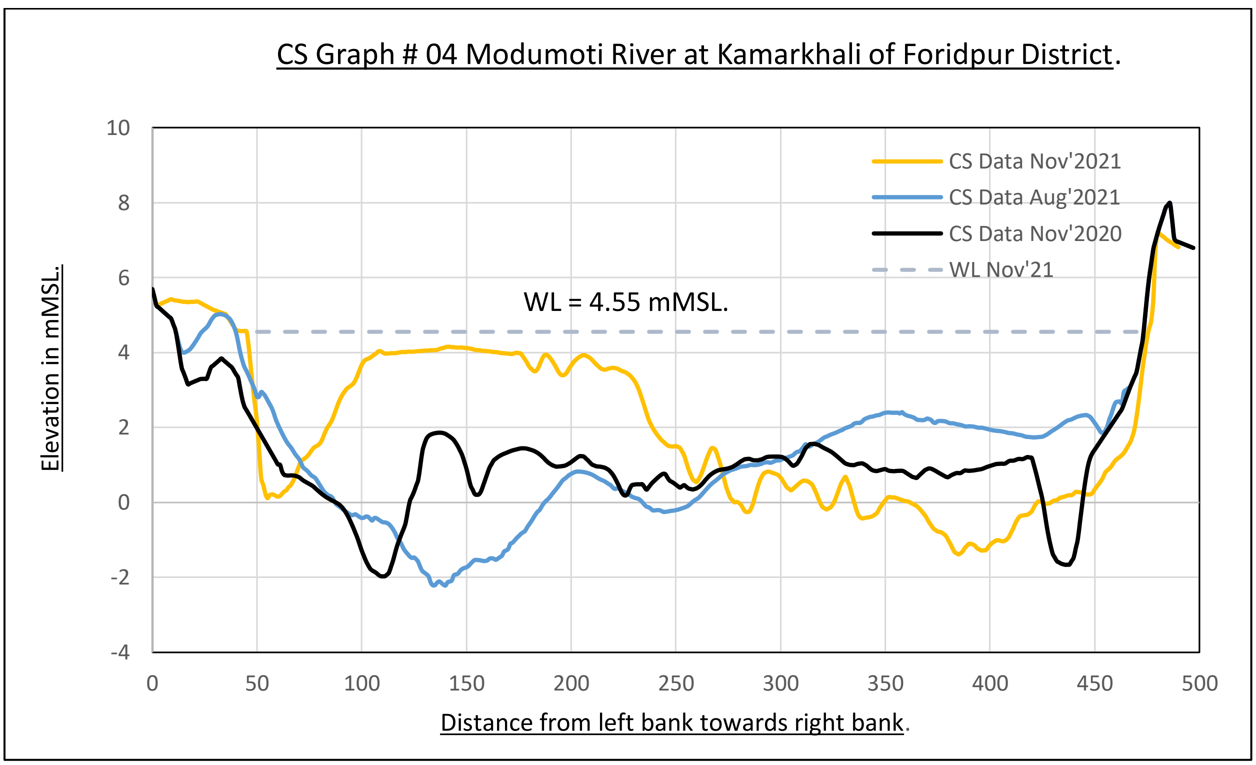


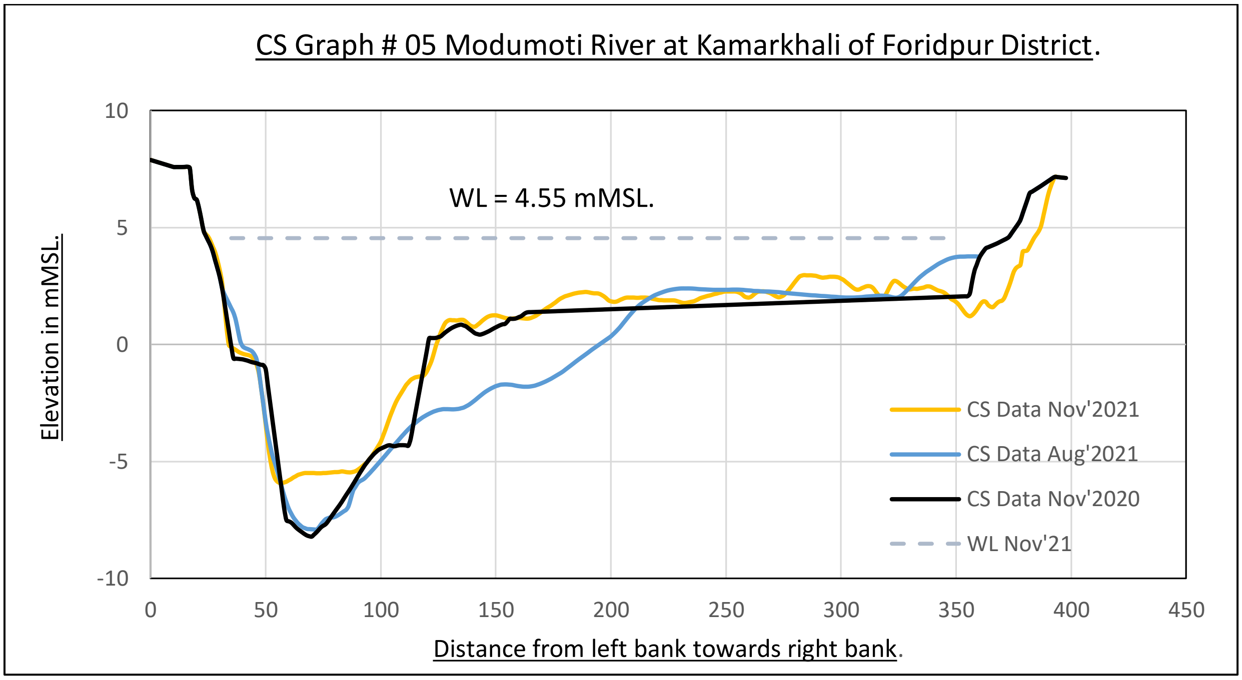
CS Graph # 01 Modumoti River at Kamarkhali of Faridpur District.
CS Data Nov'2021
CS Data Aug'2021
CS Data Nov'2020
WL Nov'21
WL = 4.55 mMSL.
Elevation in mMSL.
10
8
6
4
2
0
-2
-4
0
50
100
150
200
250
300
350
400
450
Distance from left bank towards right bank.

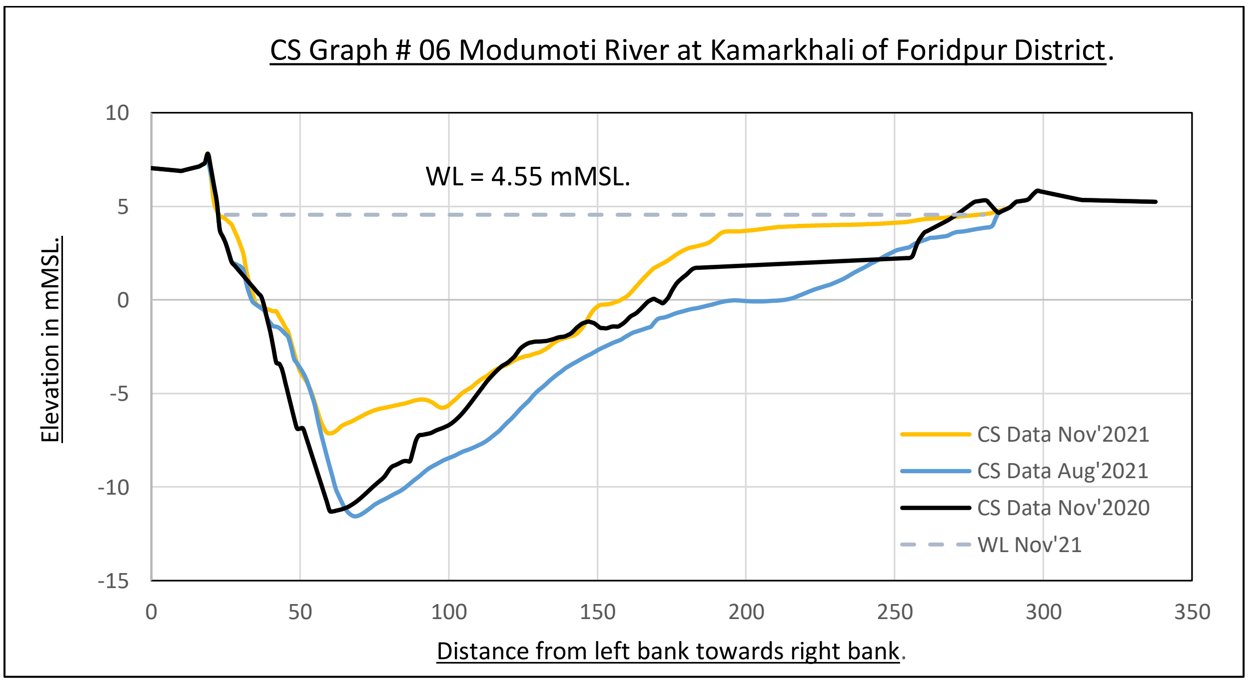


CS Graph # 02 Modumoti River at Kamarkhali of Foridpur District.
CS Data Nov'2021
CS Data Aug'2021
CS Data Nov'2020
WL Nov'21
WL = 4.55 mMSL.
Elevation in mMSL.
10
8
6
4
2
0
-2
-4
0
50
100
150
200
250
300
350
400
450
Distance from left bank towards right bank.

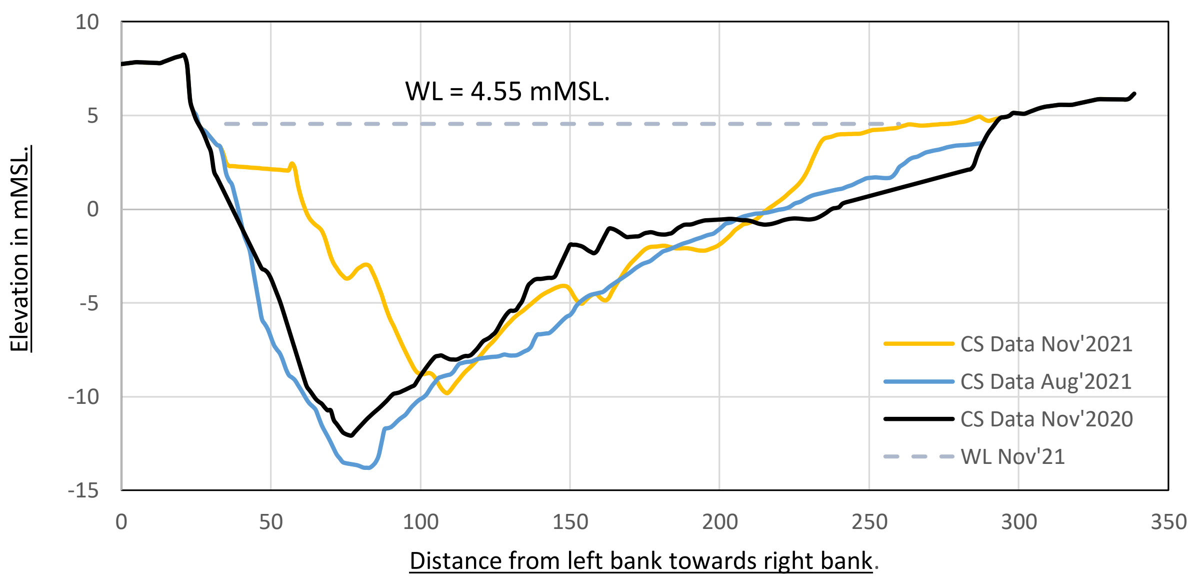

CS Graph # 03 Modumoti River at Kamarkhali of Foridpur District.
CS Data Nov'2021
CS Data Aug'2021
CS Data Nov'2020
WL Nov'2021
WL = 4.55 mMSL.
Elevation in mMSL.
10
8
6
4
2
0
-2
-4
0
50
100
150
200
250
300
350
400
450
500
Distance from left bank towards right bank.


CS Graph # 04 Modumoti River at Kamarkhali of Foridpur District.
CS Data Nov'2021
CS Data Aug'2021
CS Data Nov'2020
WL Nov'21
WL = 4.55 mMSL.
Elevation in mMSL.
10
8
6
4
2
0
-2
-4
0
50
100
150
200
250
300
350
400
450
500
Distance from left bank towards right bank.

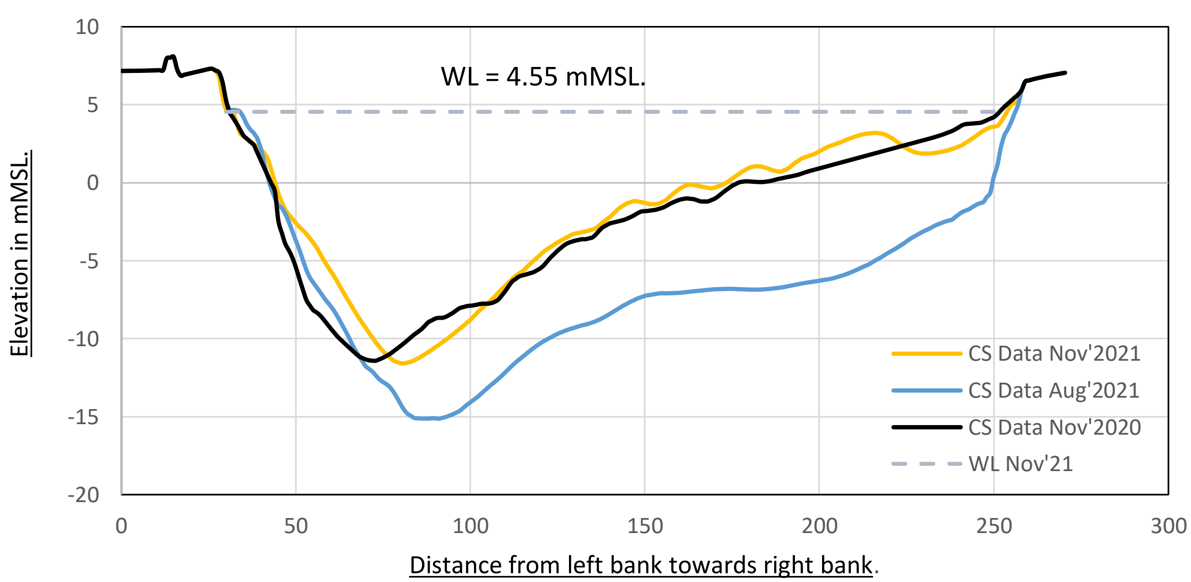

CS Graph # 05 Modumoti River at Kamarkhali of Foridpur District.
WL = 4.55 mMSL.
Elevation in mMSL.
10
5
0
-5
-10
0
50
100
150
200
250
300
350
400
450
Distance from left bank towards right bank.
CS Data Nov'2021
CS Data Aug'2021
CS Data Nov'2020
WL Nov'21

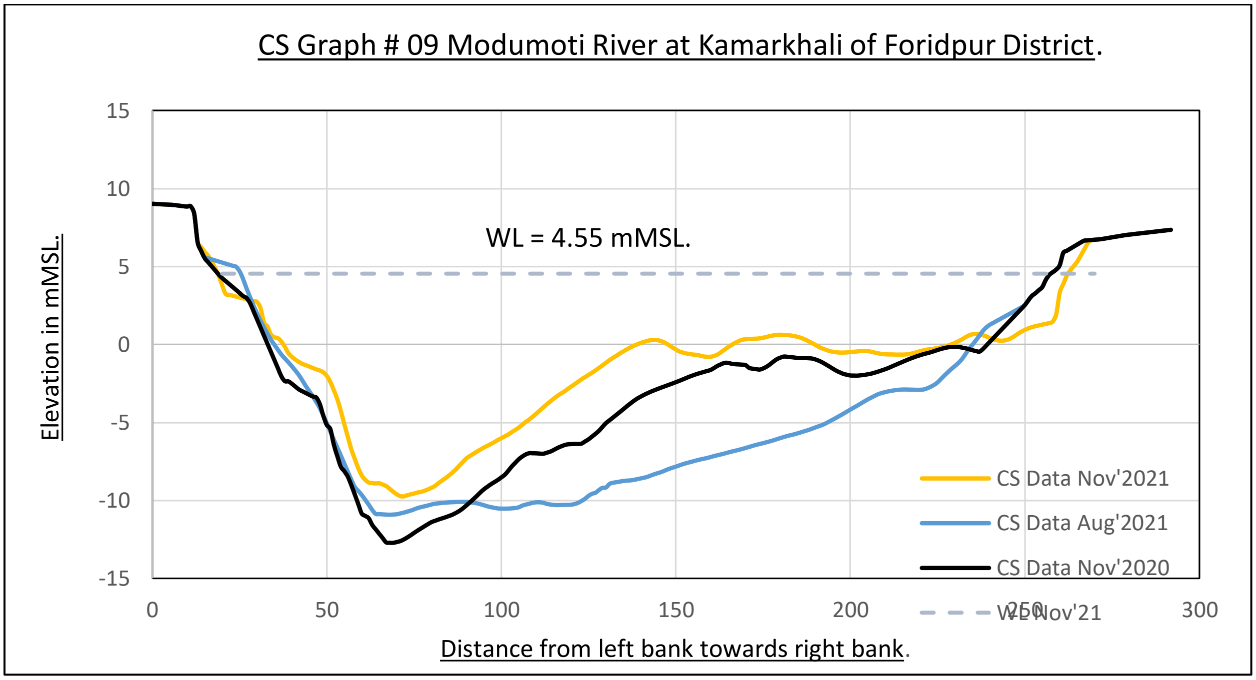

CS Graph # 06 Modumoti River at Kamarkhali of Foridpur District.
WL = 4.55 mMSL.
Elevation in mMSL.
10
5
0
-5
-10
-15
0
50
100
150
200
250
300
350
Distance from left bank towards right bank.
CS Data Nov'2021
CS Data Aug'2021
CS Data Nov'2020
WL Nov'21

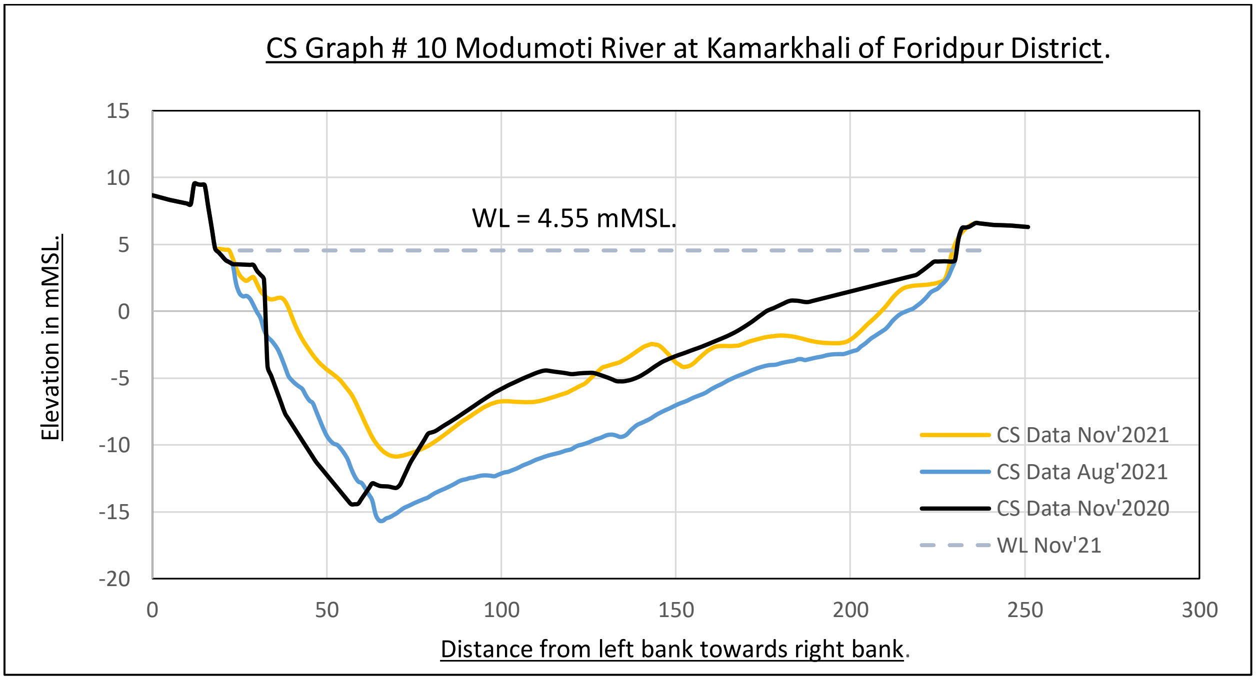
CS Graph # 07 Modumoti River at Kamarkhali of Foridpur District.

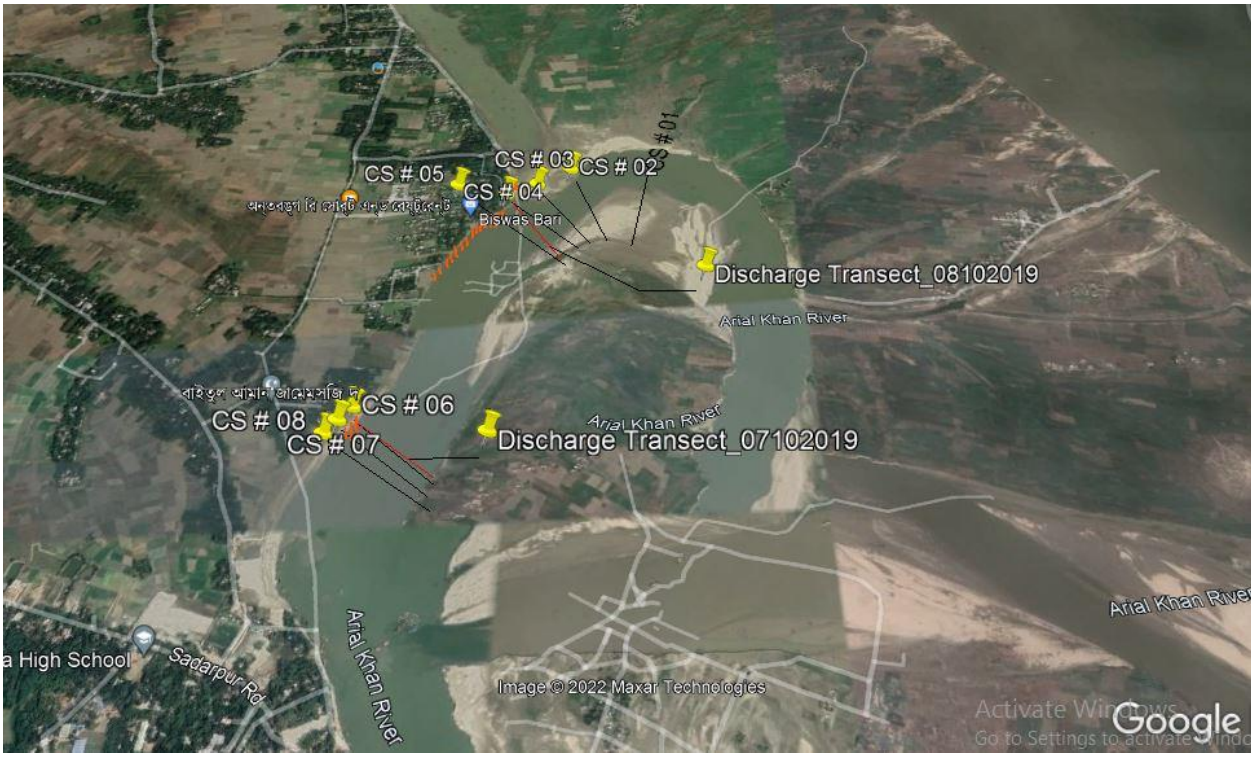


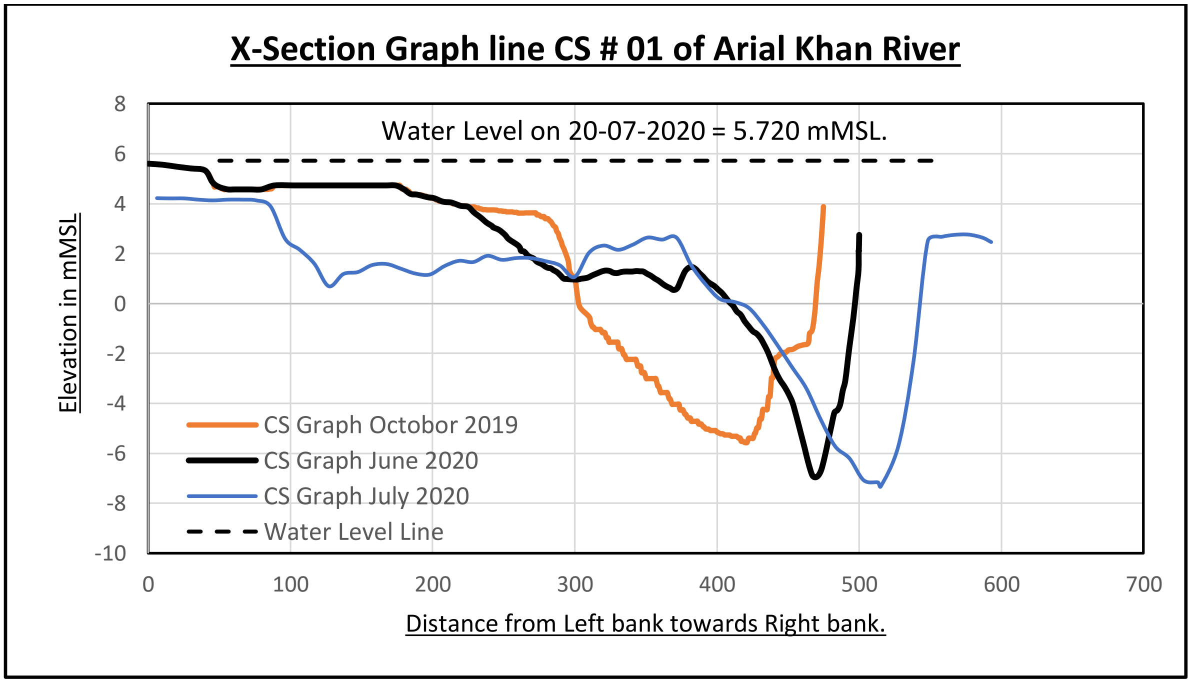
CS Graph # 08 Modumoti River at Kamarkhali of Foridpur District.

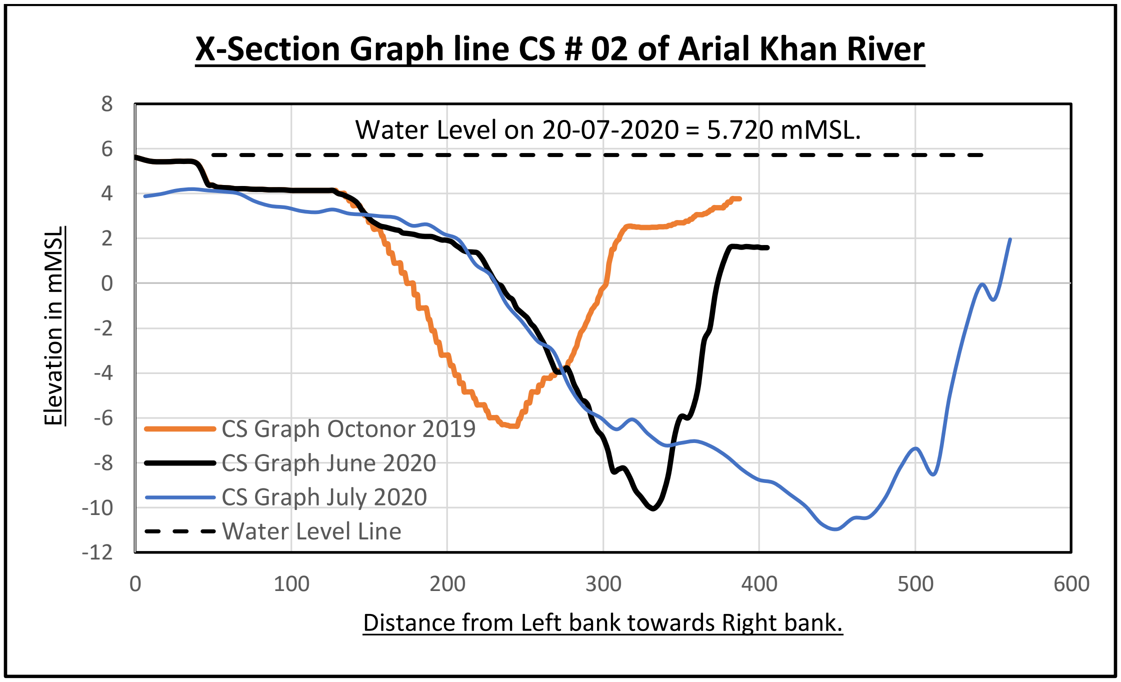



CS Graph # 09 Modumoti River at Kamarkhali of Foridpur District.
WL = 4.55 mMSL.
Elevation in mMSL.
15
10
5
0
-5
-10
-15
0
50
100
150
200
250
300
CS Data Nov'2021
CS Data Aug'2021
CS Data Nov'2020
WL Nov'21
Distance from left bank towards right bank.

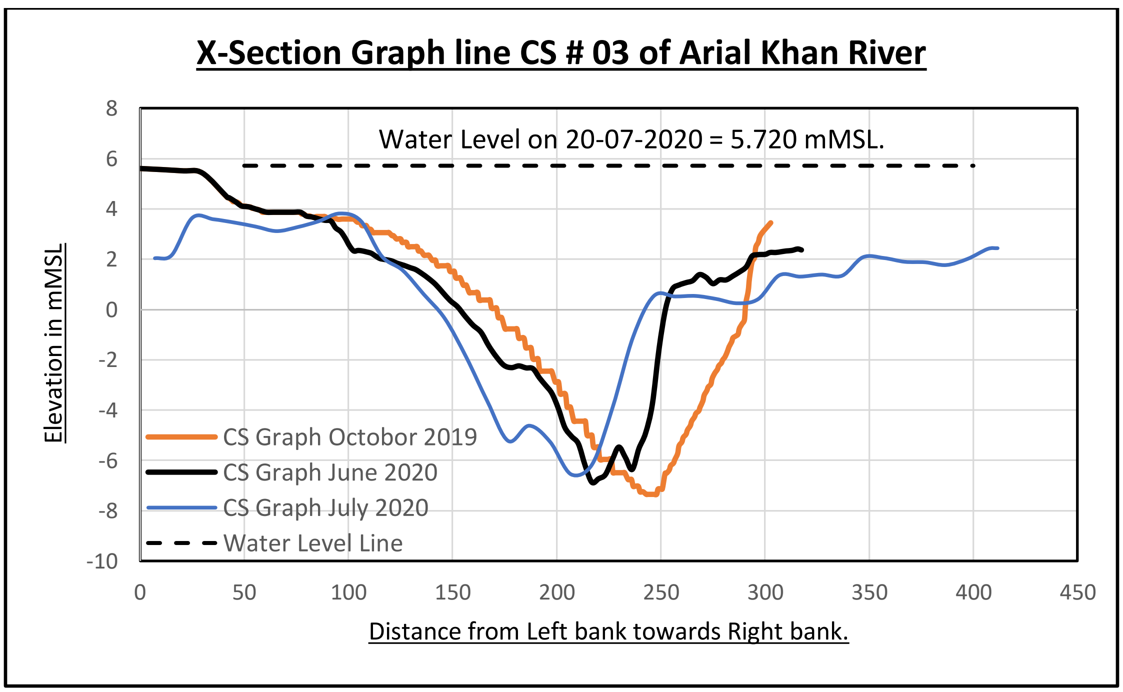

CS Graph # 10 Modumoti River at Kamarkhali of Foridpur District.
WL = 4.55 mMSL.
Elevation in mMSL.
15
10
5
0
-5
-10
-15
-20
0
50
100
150
200
250
300
CS Data Nov'2021
CS Data Aug'2021
CS Data Nov'2020
WL Nov'21
Distance from left bank towards right bank.


CS # 05
CS # 03
CS # 02
CS # 04
Biswas Bari
Discharge Transect_08102019
Arial Khan River
CS # 06
CS # 08
CS # 07
Arial Khan River
Discharge Transect_07102019
Arial Khan River
Arial Khan River
a High School
Sadarpur Rd
Image © 2022 Maxar Technologies
Google

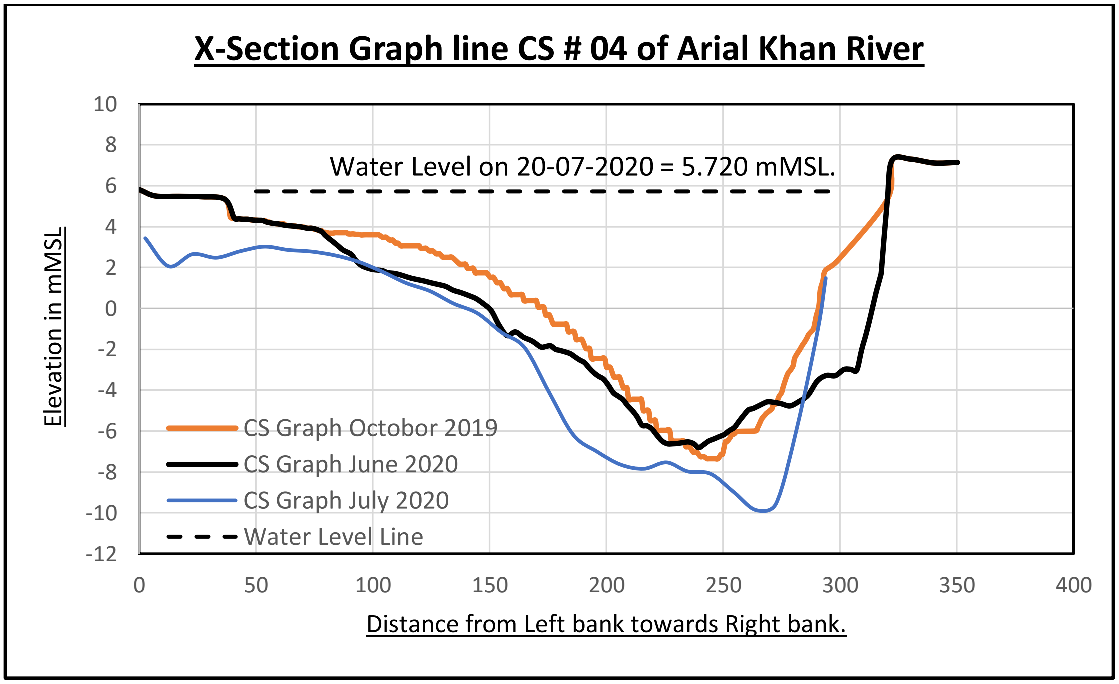

X-Section Graph line CS # 01 of Arial Khan River
Water Level on 20-07-2020 = 5.720 mMSL.
Elevation in mMSL
8
6
4
2
0
-2
-4
-6
-8
-10
0
100
200
300
400
500
600
700
CS Graph Octobor 2019
CS Graph June 2020
CS Graph July 2020
Water Level Line
Distance from Left bank towards Right bank.

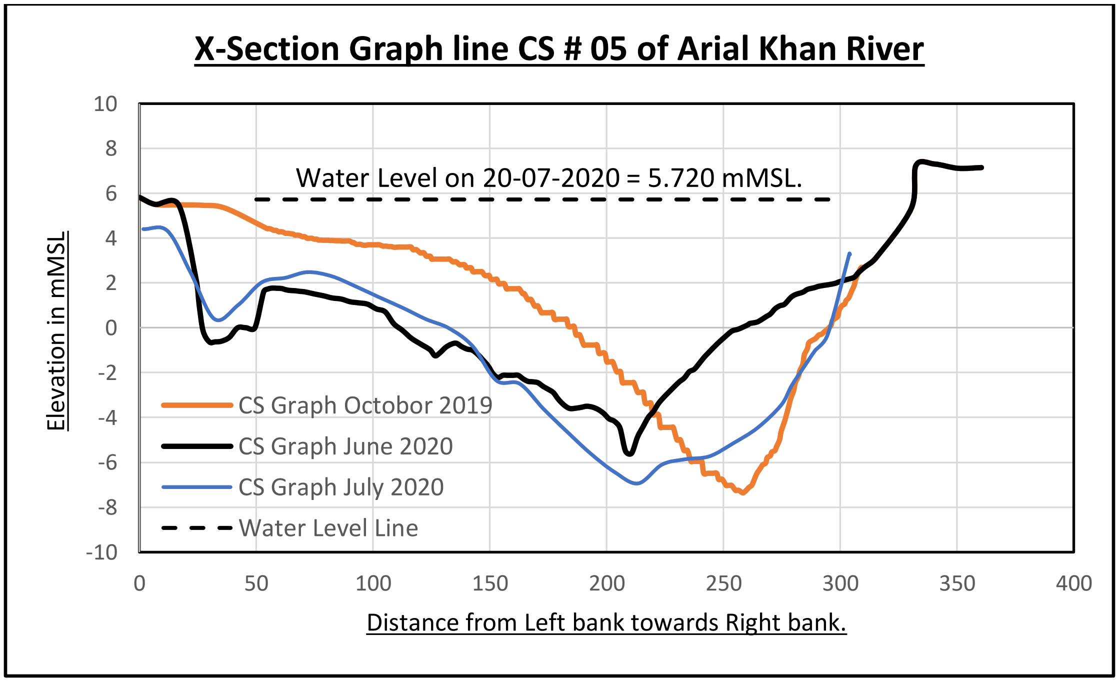


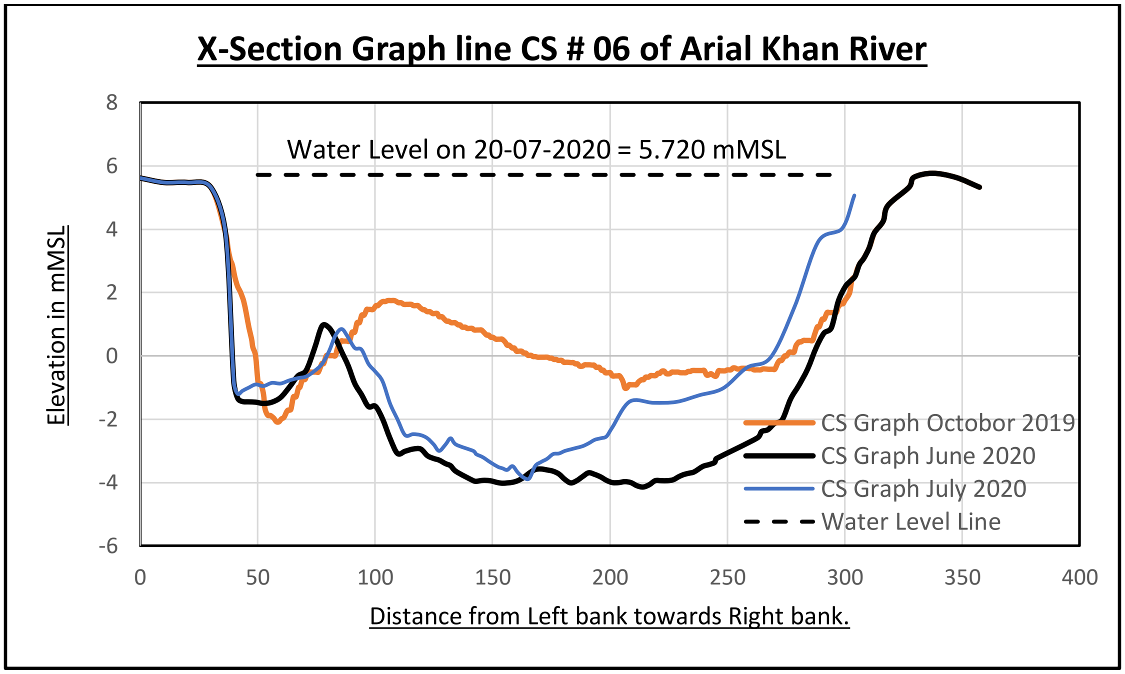
X-Section Graph line CS # 02 of Arial Khan River
Water Level on 20-07-2020 = 5.720 mMSL.
Elevation in mMSL
8
6
4
2
0
-2
-4
-6
-8
-10
-12
0
100
200
300
400
500
600
Distance from Left bank towards Right bank.
CS Graph Octonor 2019
CS Graph June 2020
CS Graph July 2020
Water Level Line

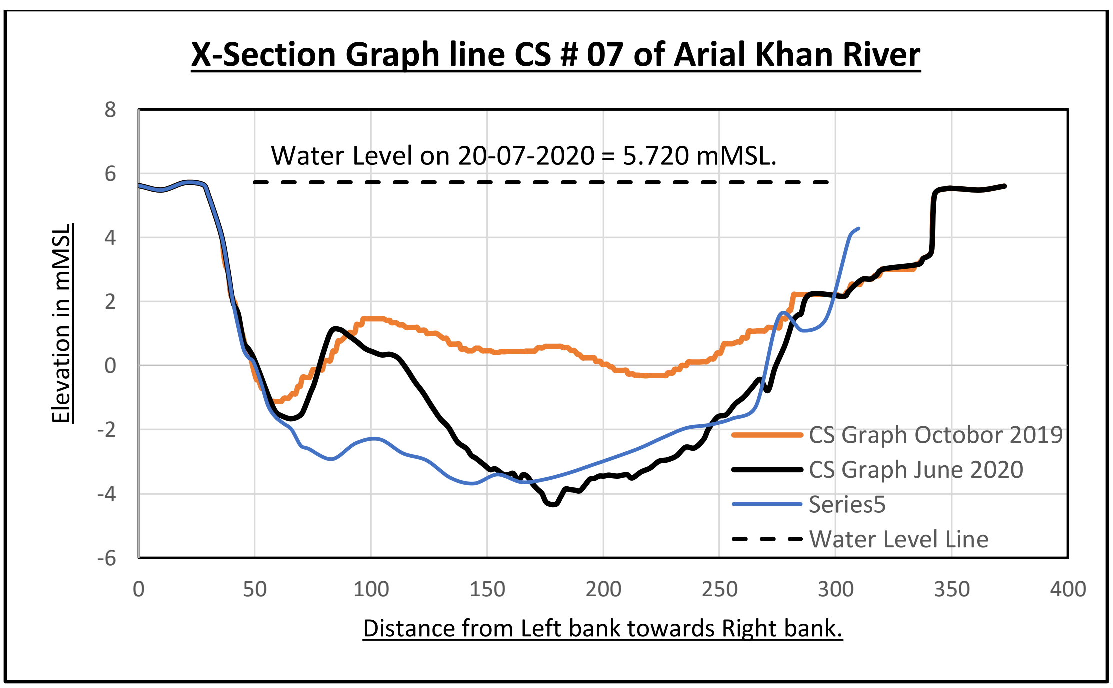


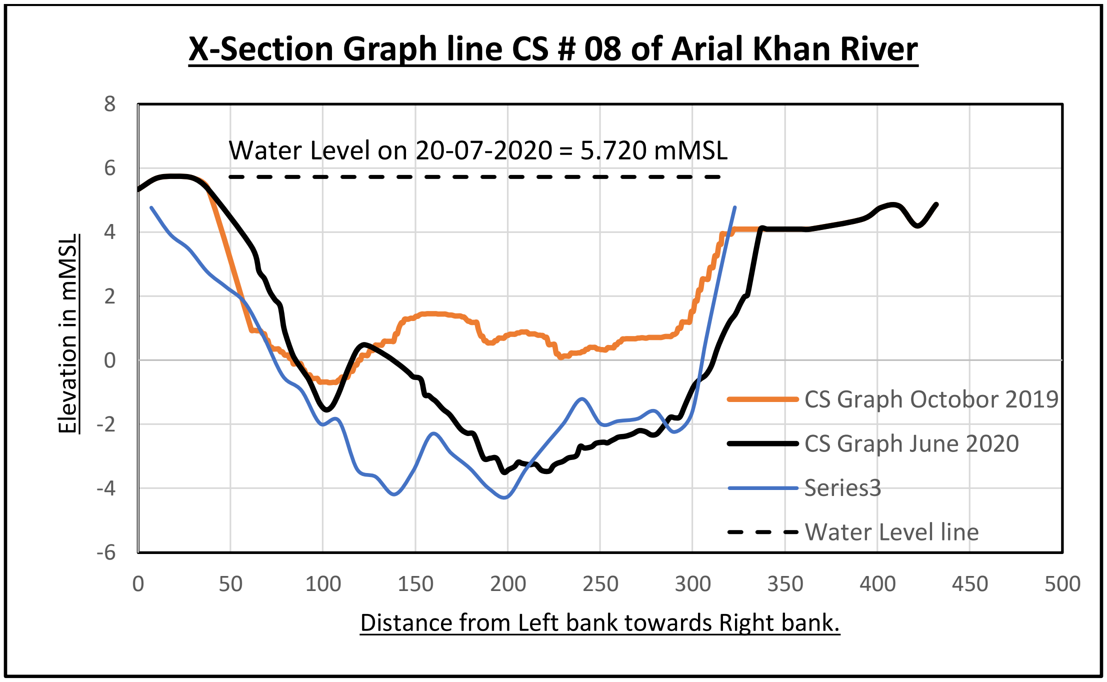
X-Section Graph line CS # 03 of Arial Khan River
Water Level on 20-07-2020 = 5.720 mMSL.
Elevation in mMSL
8
6
4
2
0
-2
-4
-6
-8
-10
0
50
100
150
200
250
300
350
400
450
Distance from Left bank towards Right bank.
CS Graph Octobor 2019
CS Graph June 2020
CS Graph July 2020
Water Level Line

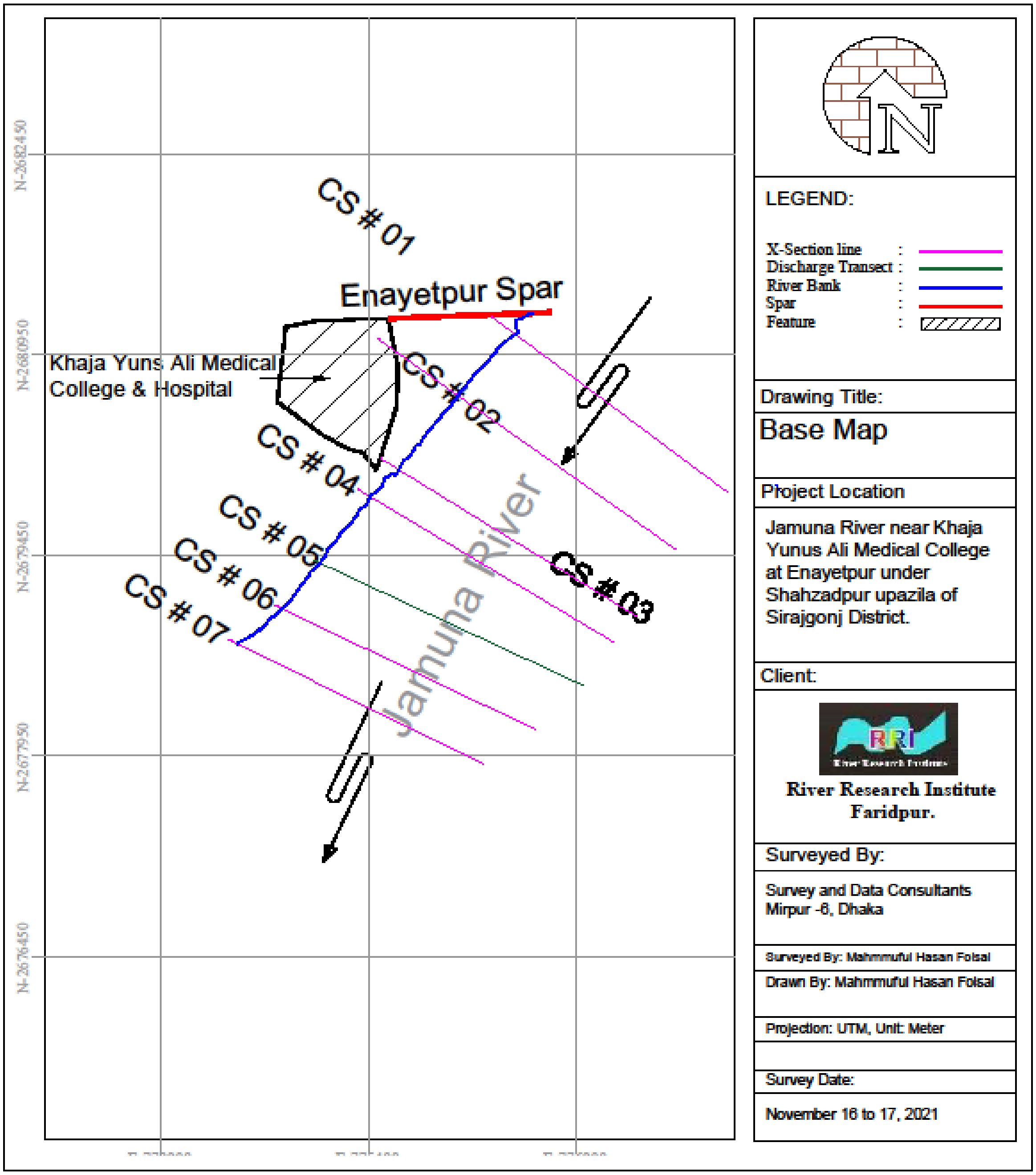

X-Section Graph line CS # 04 of Arial Khan River
Water Level on 20-07-2020 = 5.720 mMSL.
Elevation in mMSL
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
0
50
100
150
200
250
300
350
400
CS Graph Octobor 2019
CS Graph June 2020
CS Graph July 2020
Water Level Line
Distance from Left bank towards Right bank.

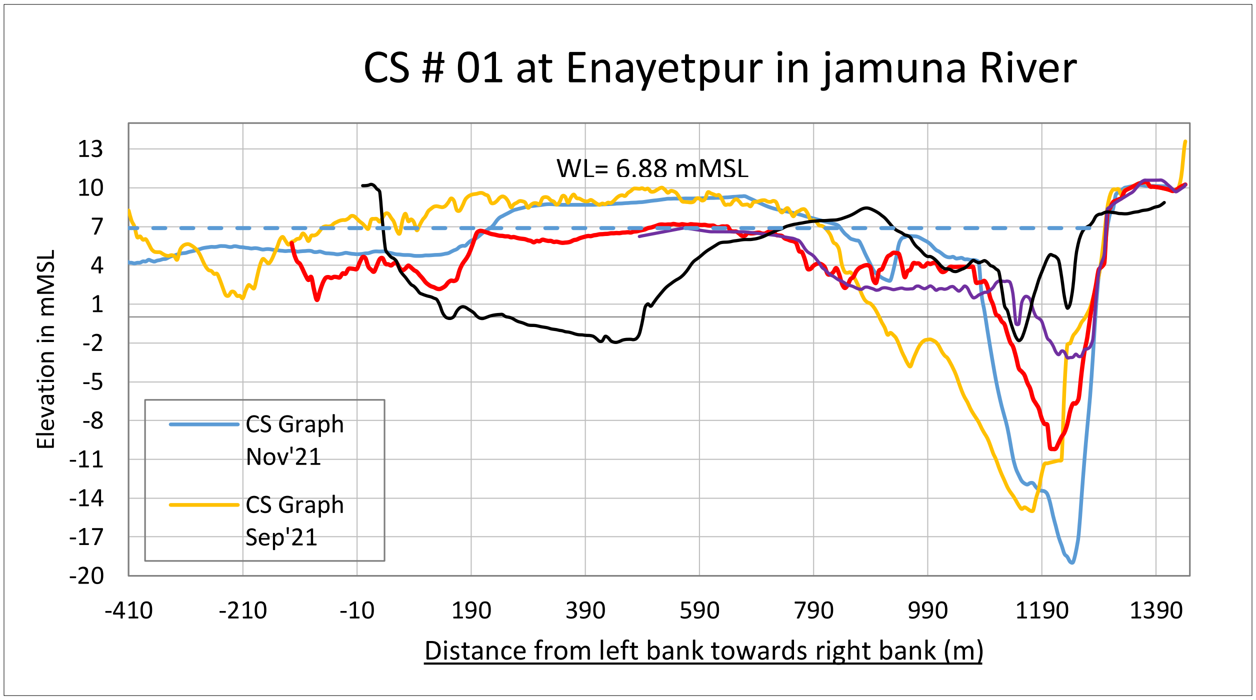

X-Section Graph line CS # 05 of Arial Khan River
Water Level on 20-07-2020 = 5.720 mMSL.
Elevation in mMSL
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
50
100
150
200
250
300
350
400
CS Graph Octobor 2019
CS Graph June 2020
CS Graph July 2020
Water Level Line
Distance from Left bank towards Right bank.

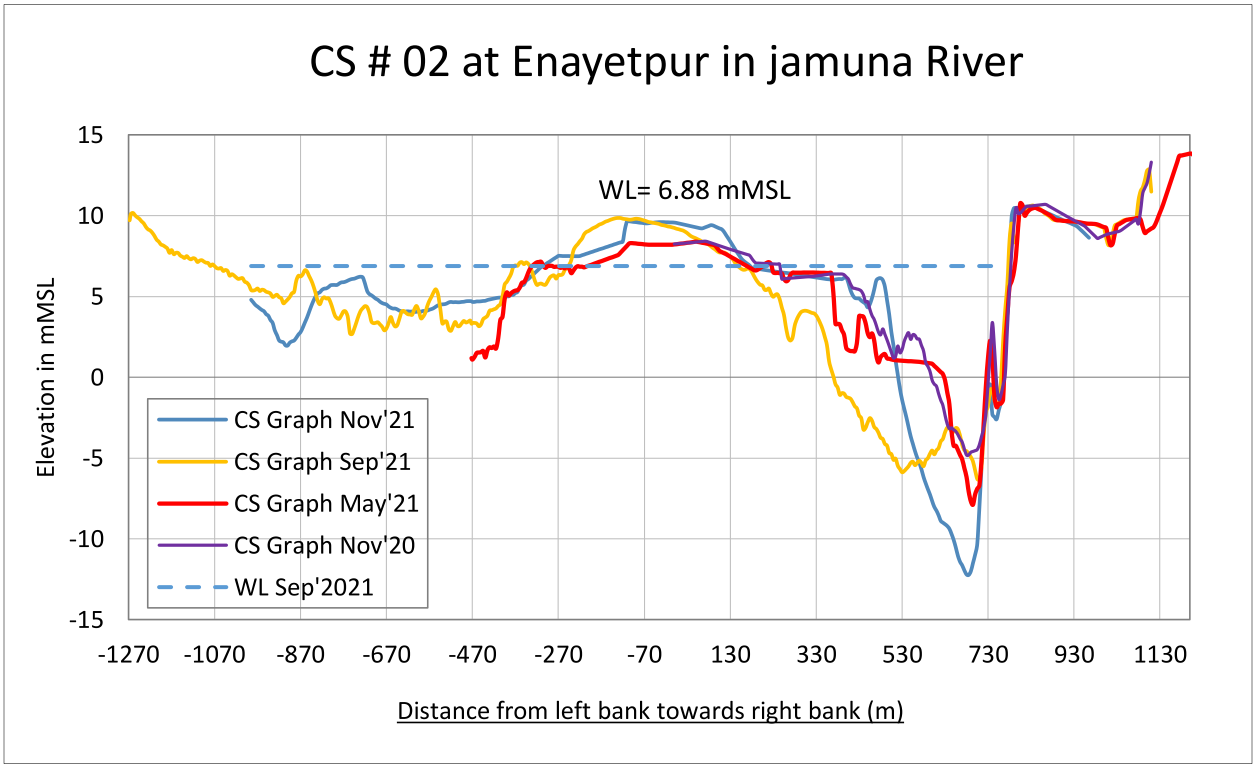

X-Section Graph line CS # 06 of Arial Khan River
Water Level on 20-07-2020 = 5.720 mMSL
Elevation in mMSL
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
Distance from Left bank towards Right bank.
CS Graph Octobor 2019
CS Graph June 2020
CS Graph July 2020
Water Level Line

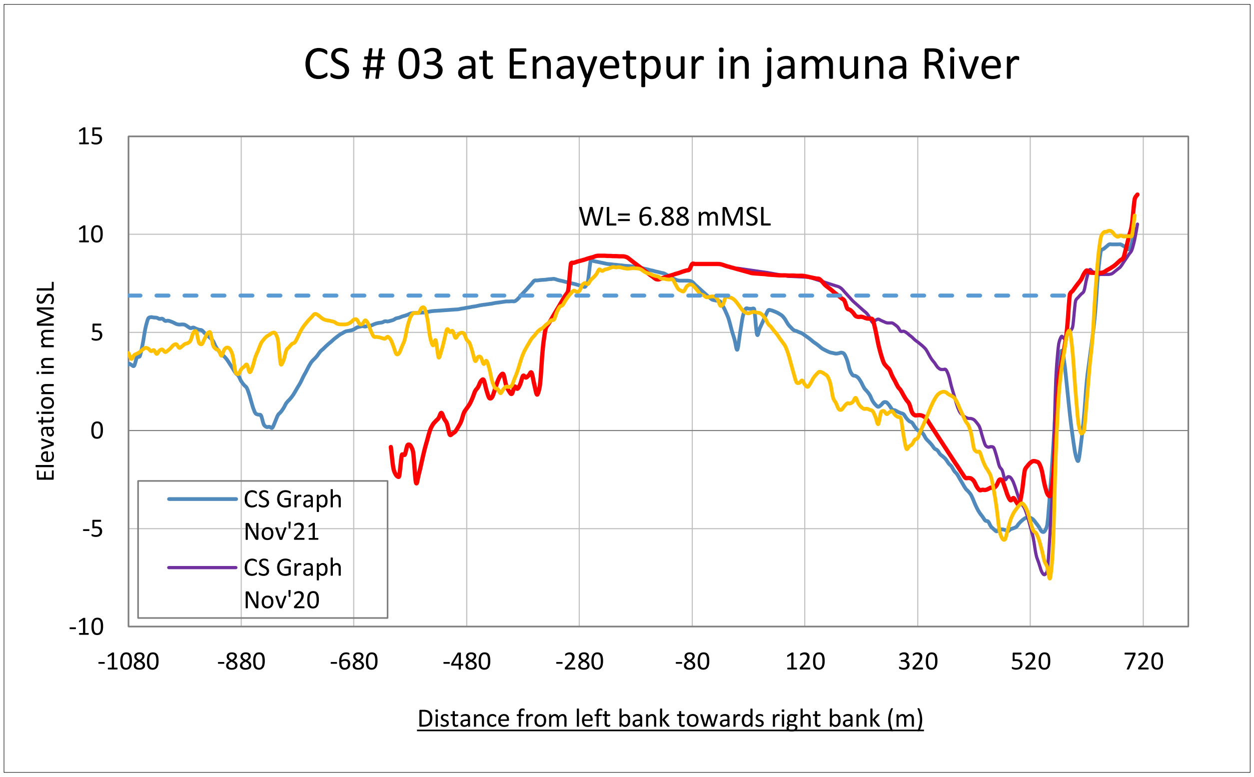

X-Section Graph line CS # 07 of Arial Khan River
Water Level on 20-07-2020 = 5.720 mMSL.
Elevation in mMSL
8
6
4
2
0
-2
-4
-6
0
50
100
150
200
250
300
350
400
Distance from Left bank towards Right bank.
CS Graph Octobor 2019
CS Graph June 2020
Series5
Water Level Line


X-Section Graph line CS # 08 of Arial Khan River
Water Level on 20-07-2020 = 5.720 mMSL
8
6
4
2
0
-2
-4
-6
Elevation in mMSL
0
50
100
150
200
250
300
350
400
450
500
Distance from Left bank towards Right bank.
CS Graph Octobor 2019
CS Graph June 2020
Series3
Water Level line

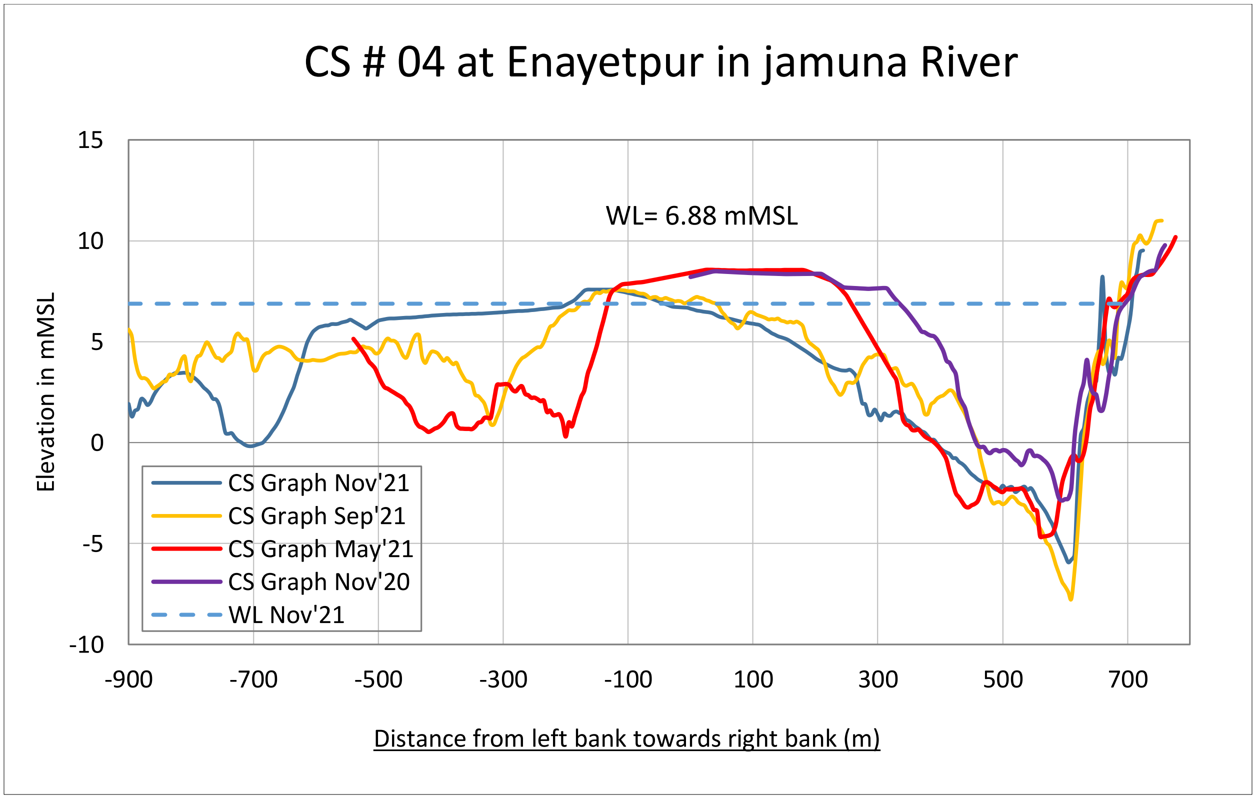

N-2682450
N-2680950
N-2679450
N-2677950
N-2676450
CS # 01
Enayetpur Spar
Khaja Yuns Ali Medical
College & Hospital
CS # 02
CS # 04
CS # 05
CS # 06
CS # 07
CS # 03
Jamuna River
LEGEND:
X-Section line :
Discharge Transect :
River Bank :
Spar :
Feature :
Drawing Title:
Base Map
Project Location
Jamuna River near Khaja Yunus Ali Medical College at Enayetpur under Shahzadpur upazila of Sirajgonj District.
Client:
River Research Institute Faridpur.
Surveyed By:
Survey and Data Consultants
Mirpur -6, Dhaka
Surveyed By: Mahmmuful Hasan Foisal
Drawn By: Mahmmuful Hasan Foisal
Projection: UTM, Unit: Meter
Survey Date:
November 16 to 17, 2021


CS # 01 at Enayetpur in jamuna River
WL= 6.88 mMSL
Elevation in mMSL
13
10
7
4
1
-2
-5
-8
-11
-14
-17
-20
CS Graph Nov'21
CS Graph Sep'21
-410
-210
-10
190
390
590
790
990
1190
1390
Distance from left bank towards right bank (m)

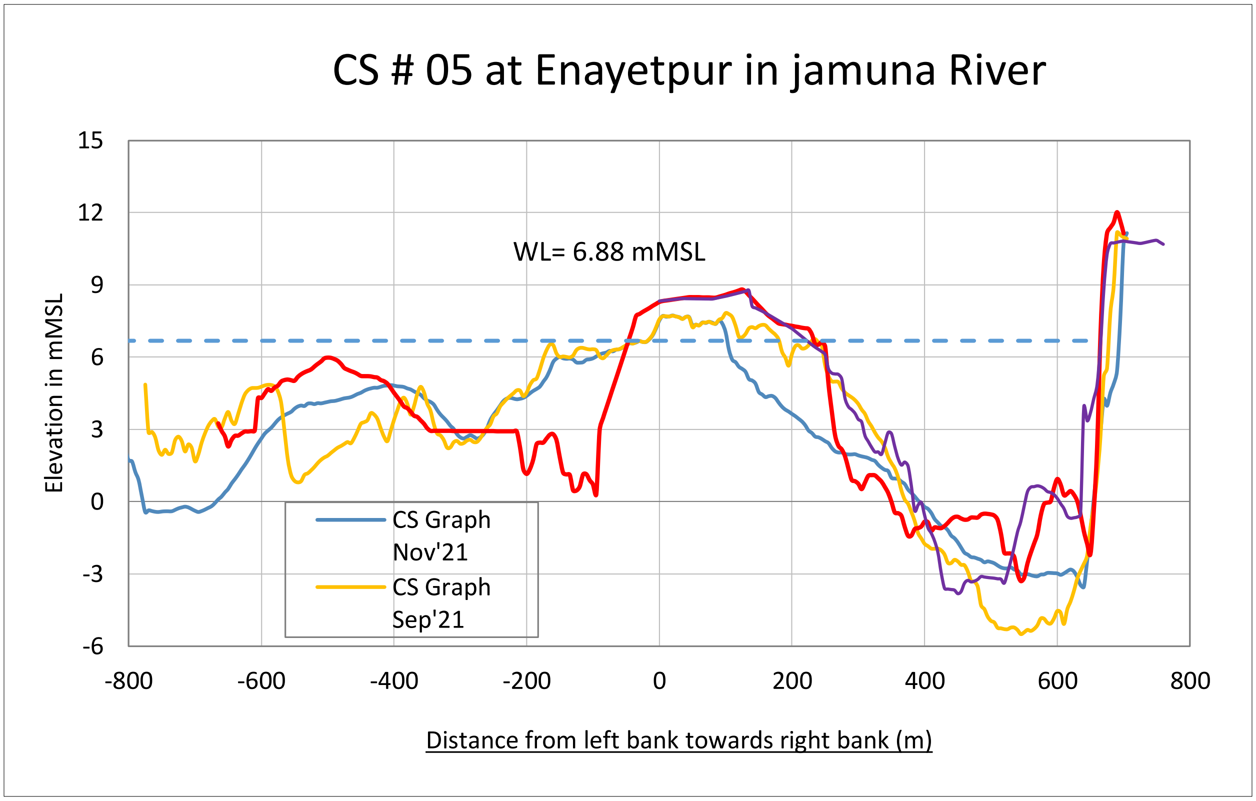

CS # 02 at Enayetpur in jamuna River
WL= 6.88 mMSL
Elevation in mMSL
15
10
5
0
-5
-10
-15
CS Graph Nov'21
CS Graph Sep'21
CS Graph May'21
CS Graph Nov'20
WL Sep'2021
-1270
-1070
-870
-670
-470
-270
-70
130
330
530
730
930
1130
Distance from left bank towards right bank (m)

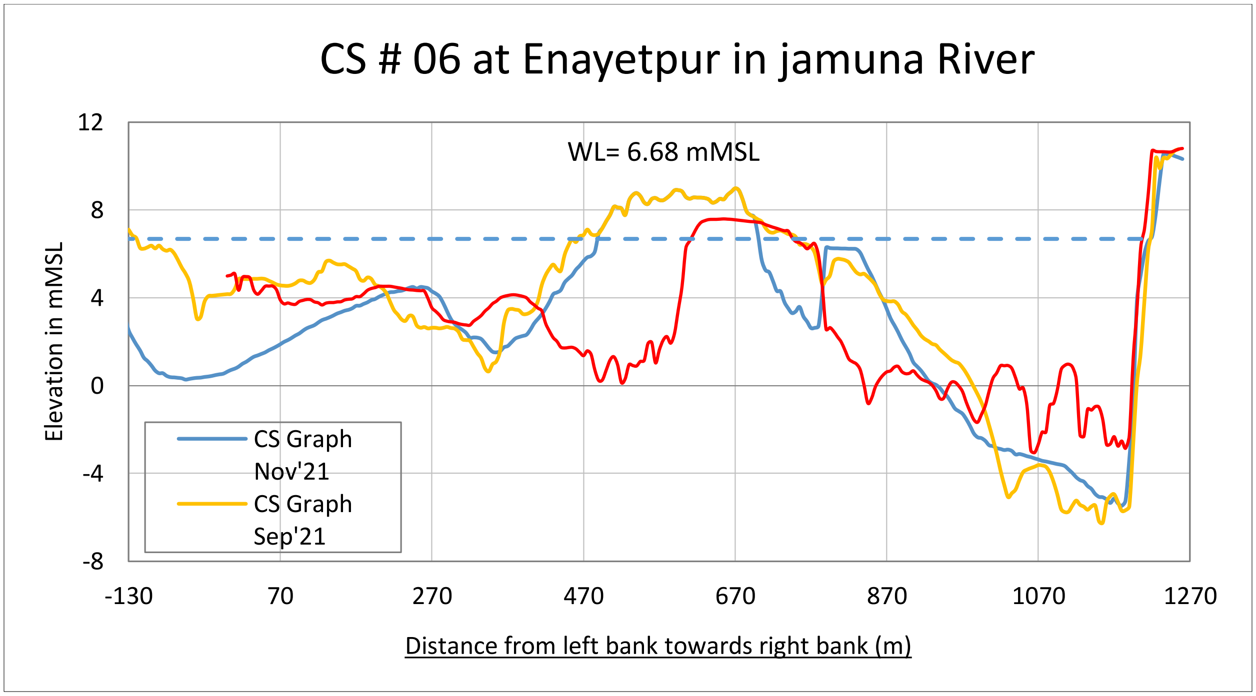


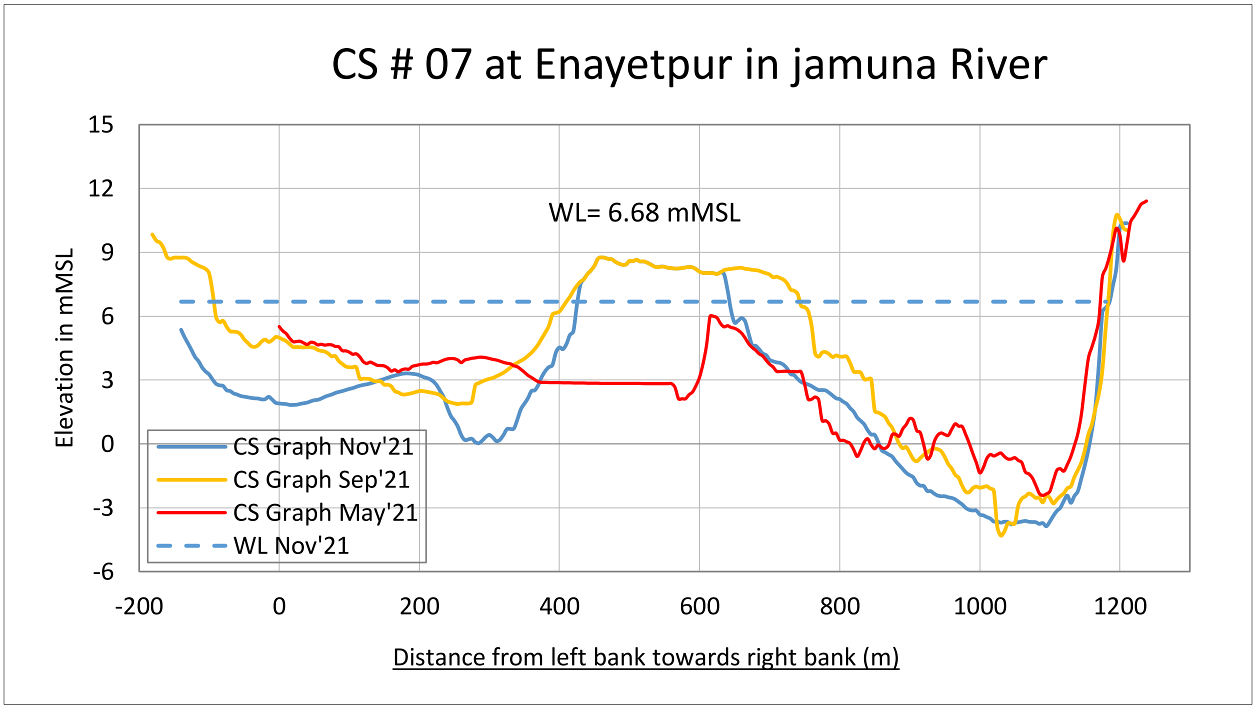
CS # 03 at Enayetpur in jamuna River
WL= 6.88 mMSL
Elevation in mMSL
15
10
5
0
-5
-10
-1080
-880
-680
-480
-280
-80
120
320
520
720
CS Graph Nov'21
CS Graph Nov'20
Distance from left bank towards right bank (m)



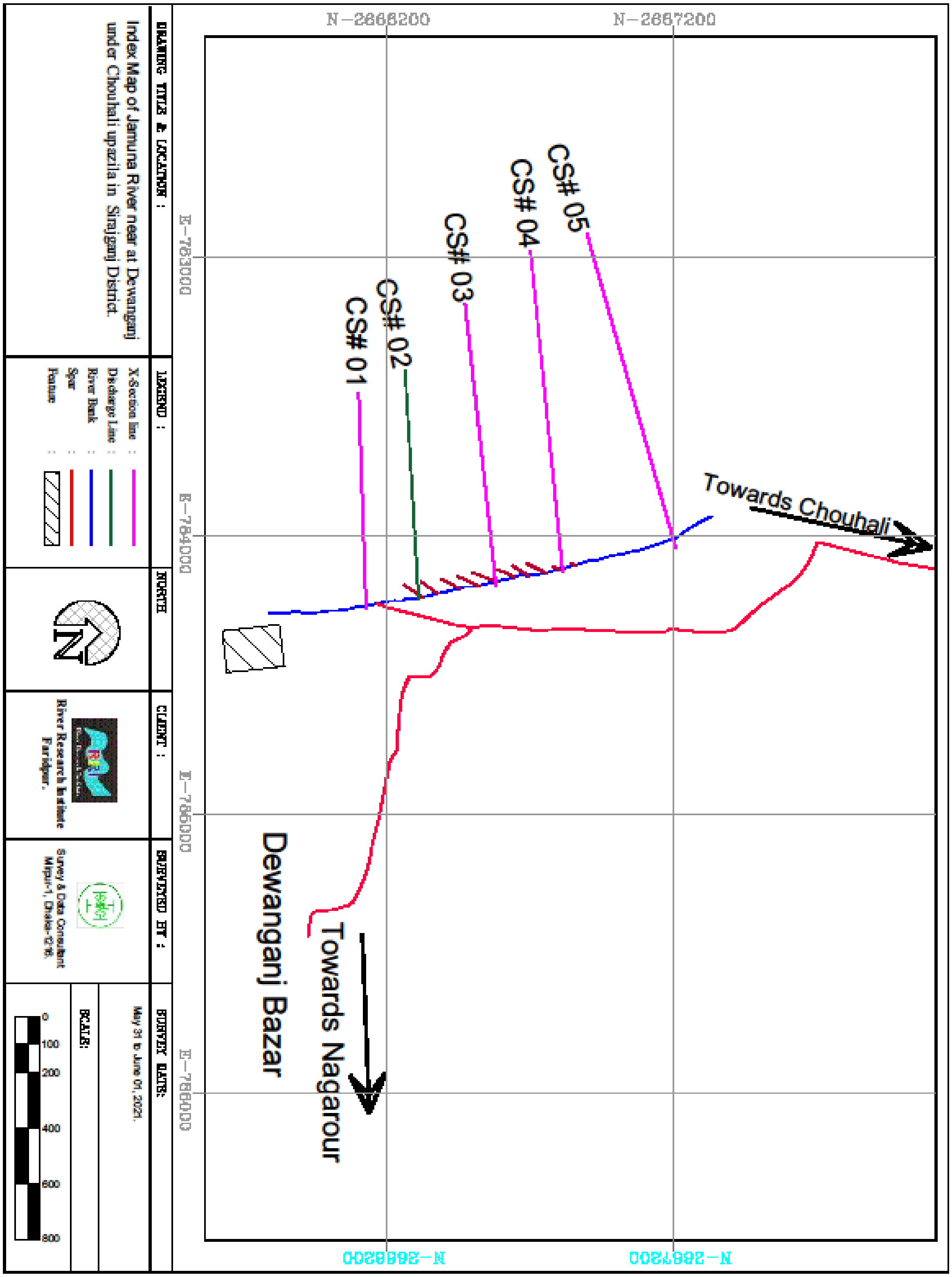
CS # 04 at Enayetpur in jamuna River
WL= 6.88 mMSL
Elevation in mMSL
15
10
5
0
-5
-10
-900
-700
-500
-300
-100
100
300
500
700
CS Graph Nov'21
CS Graph Sep'21
CS Graph May'21
CS Graph Nov'20
WL Nov'21
Distance from left bank towards right bank (m)


CS # 05 at Enayetpur in jamuna River
WL= 6.88 mMSL
Elevation in mMSL
15
12
9
6
3
0
-3
-6
-800
-600
-400
-200
0
200
400
600
800
CS Graph Nov'21
CS Graph Sep'21
Distance from left bank towards right bank (m)

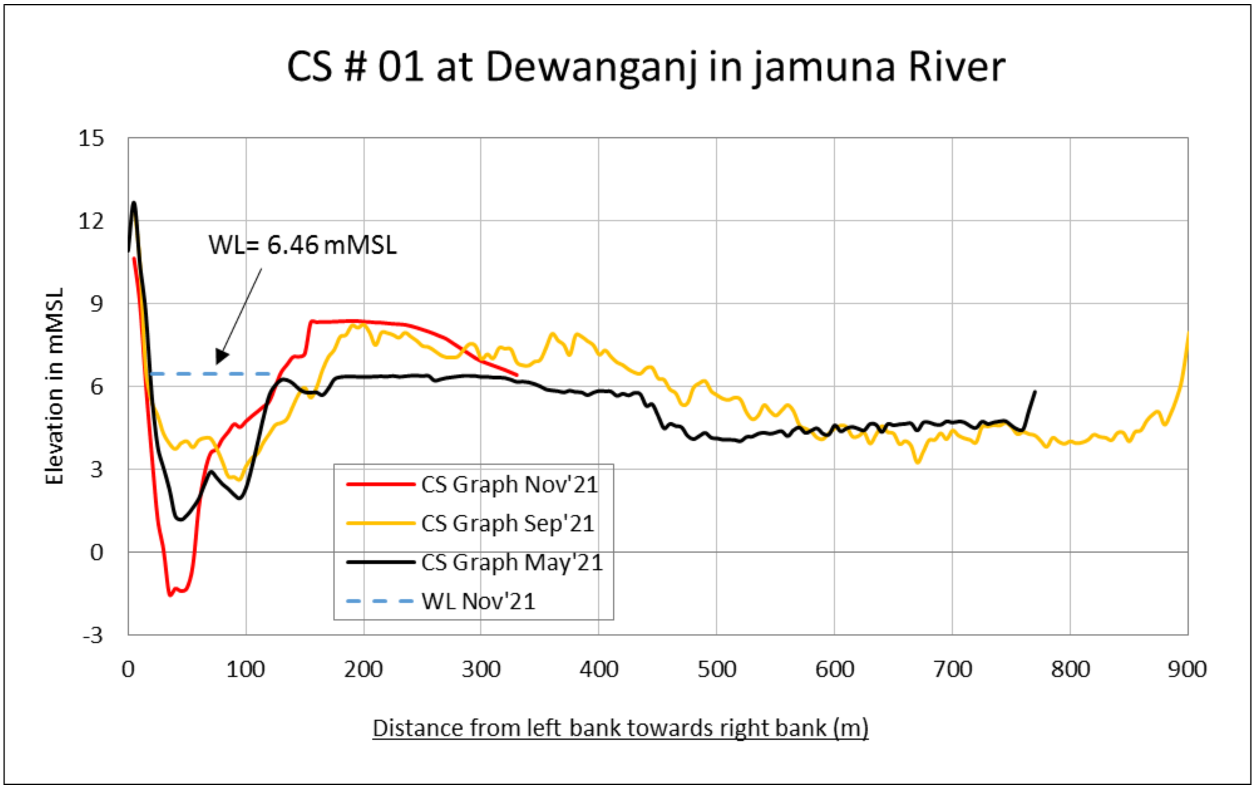

CS # 06 at Enayetpur in jamuna River
WL= 6.68 mMSL
Elevation in mMSL
12
8
4
0
-4
-8
-130
70
270
470
670
870
1070
1270
CS Graph Nov'21
CS Graph Sep'21
Distance from left bank towards right bank (m)



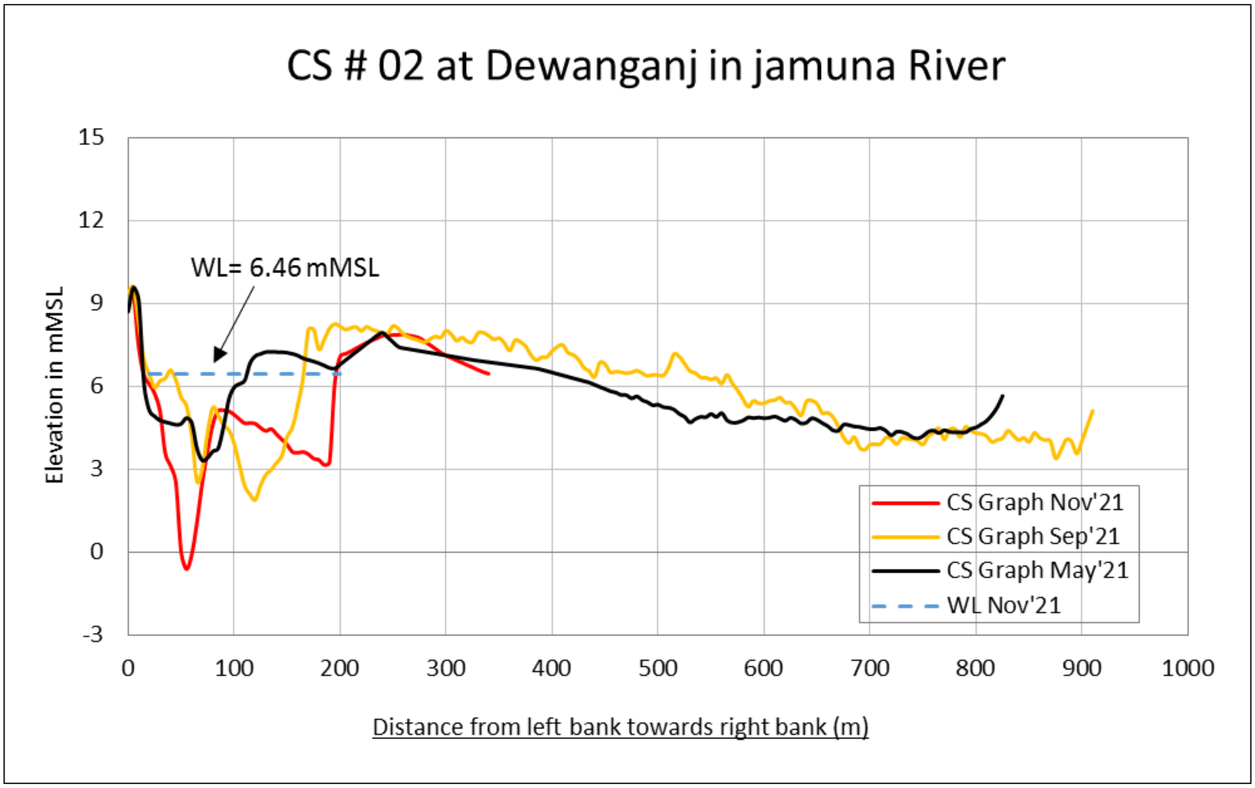
CS # 07 at Enayetpur in jamuna River
WL= 6.68 mMSL
Elevation in mMSL
15
12
9
6
3
0
-3
-6
-200
0
200
400
600
800
1000
1200
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'21
CS Graph May'21
WL Nov'21



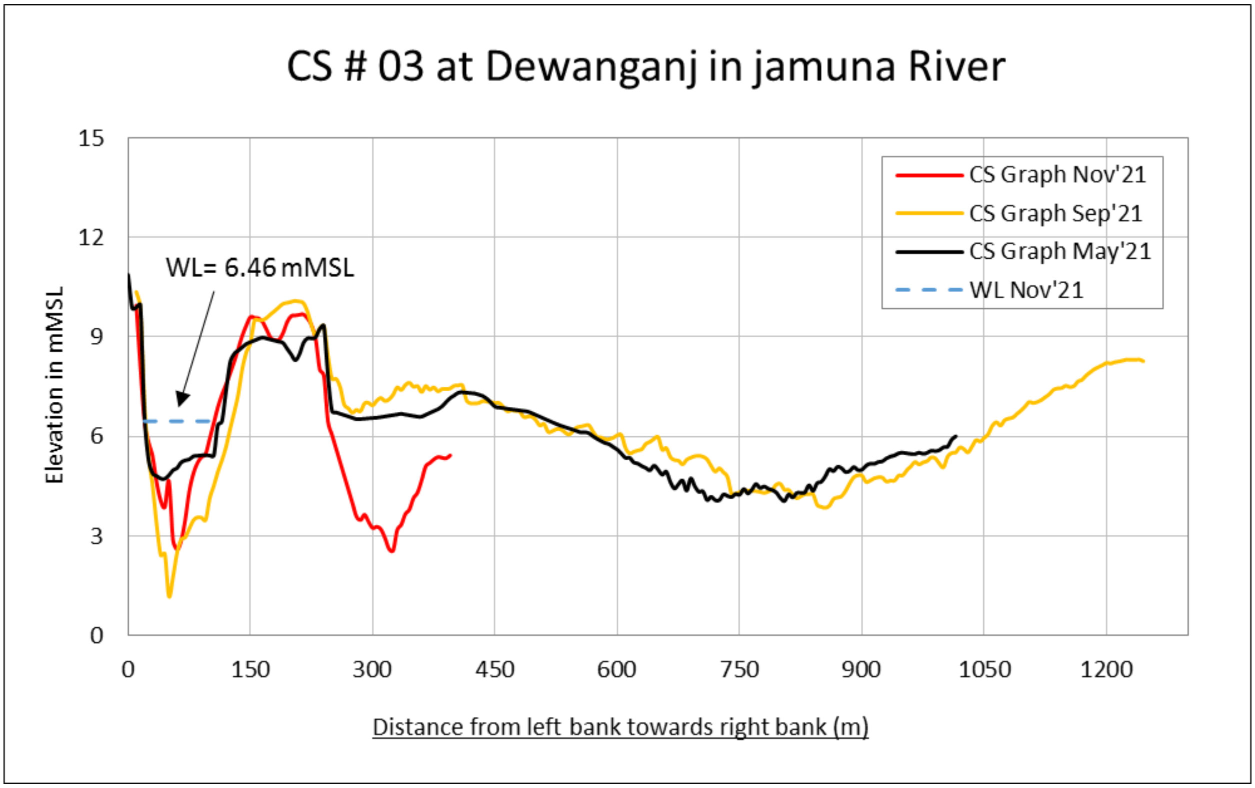
N-2668200
N-2667200
E-763000
E-764000
E-765000
E-766000
CS# 01
CS# 02
CS# 03
CS# 04
CS# 05
Towards Chouhali
Towards Nagarour
Dewanganj Bazar
DRAWING TITLE & LOCATION :
Index Map of Jamuna River near at Dewanganj under Chouhali upazila in Sirajganj District.
LEGEND :
X-Section line :
Discharge Line :
River Bank :
Spur :
Feature :
NORTH
CLIENT :
River Research Institute Faridpur.
SURVEYED BY :
Survey & Data Consultant Mirpur-1, Dhaka-1216.
SURVEY DATE:
May 31 to June 01, 2021.
SCALE:
0
100
200
400
600
800

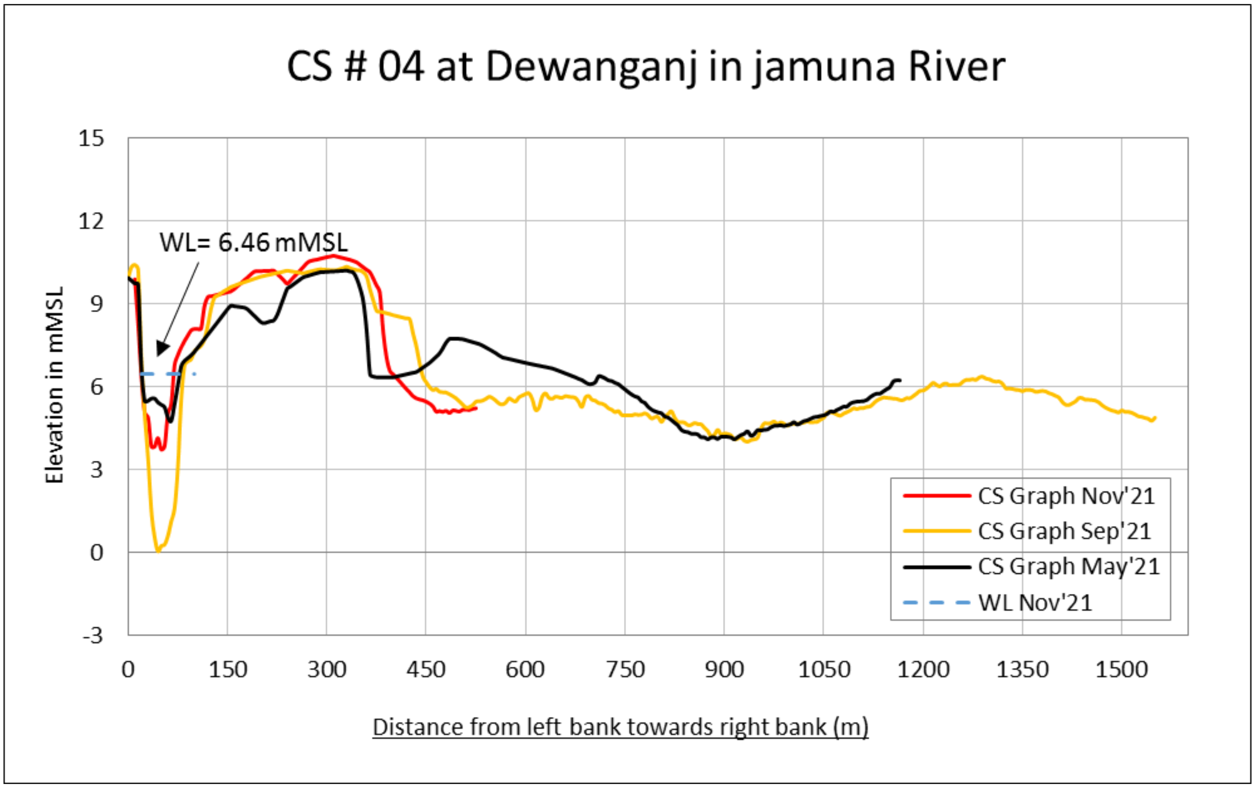


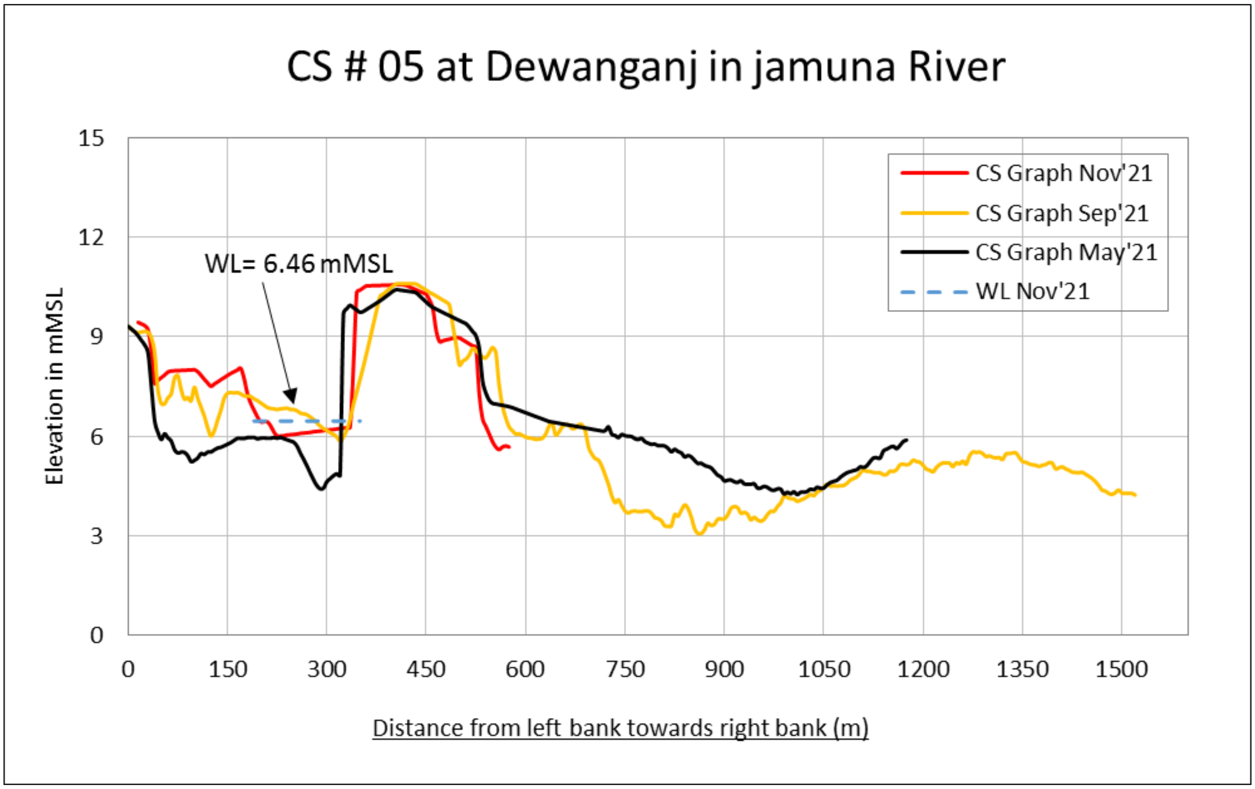
CS # 01 at Dewanganj in jamuna River
WL= 6.46 mMSL
Elevation in mMSL
15
12
9
6
3
0
-3
0
100
200
300
400
500
600
700
800
900
CS Graph Nov'21
CS Graph Sep'21
CS Graph May'21
WL Nov'21
Distance from left bank towards right bank (m)



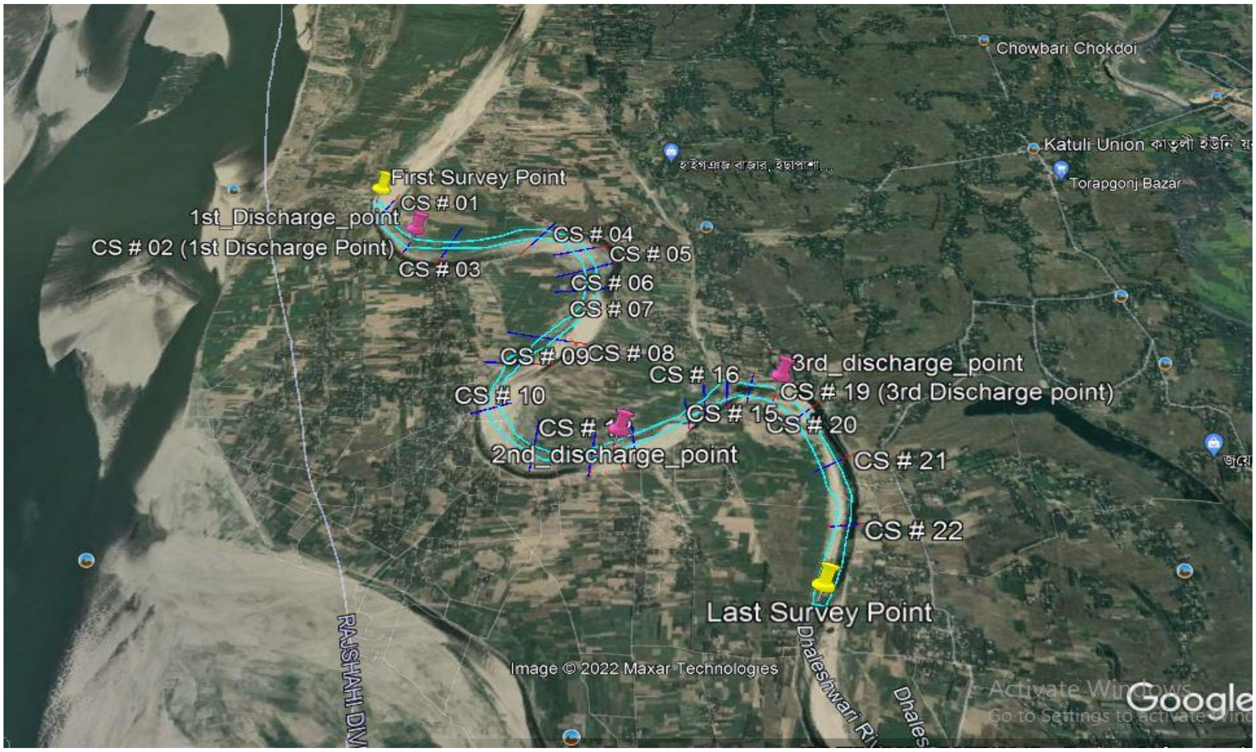
CS # 02 at Dewanganj in jamuna River
WL= 6.46 mMSL
Elevation in mMSL
15
12
9
6
3
0
-3
0
100
200
300
400
500
600
700
800
900
1000
CS Graph Nov'21
CS Graph Sep'21
CS Graph May'21
WL Nov'21
Distance from left bank towards right bank (m)

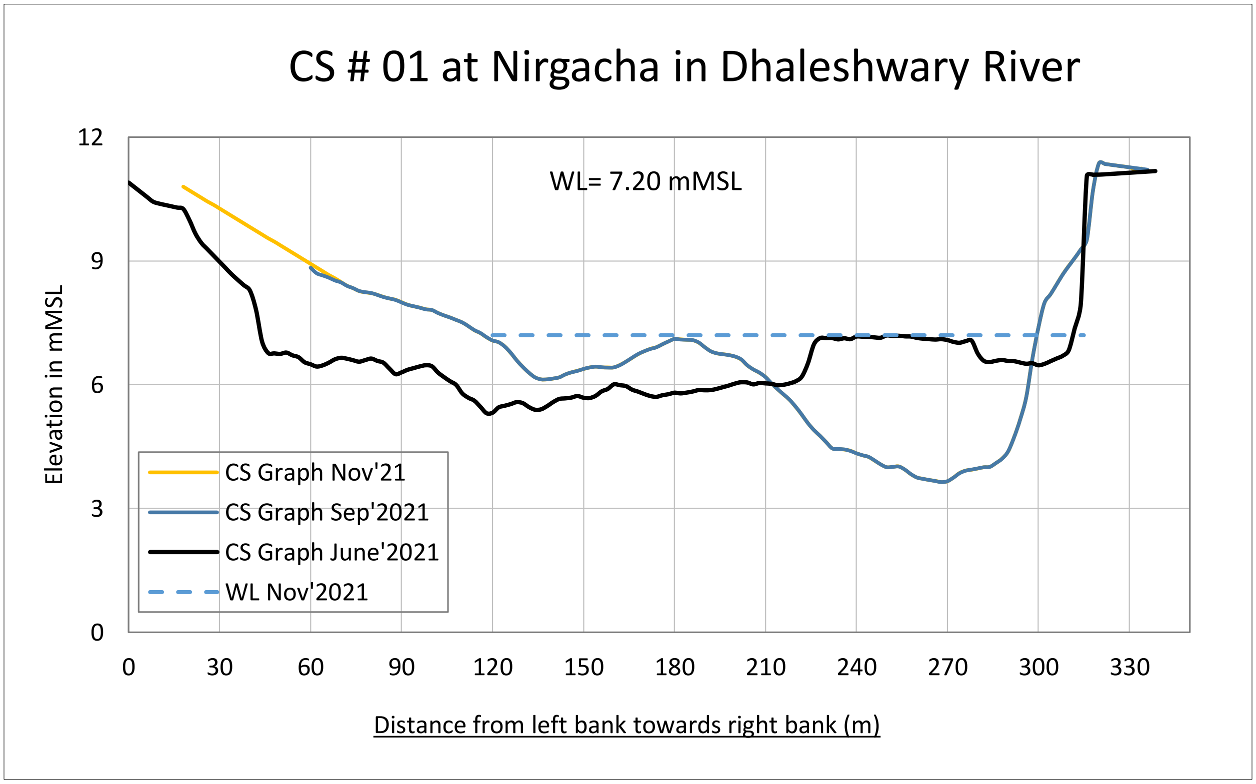

CS # 03 at Dewanganj in jamuna River
WL= 6.46 mMSL
CS Graph Nov'21
CS Graph Sep'21
CS Graph May'21
WL Nov'21
Elevation in mMSL
0
3
6
9
12
15
0
150
300
450
600
750
900
1050
1200
Distance from left bank towards right bank (m)

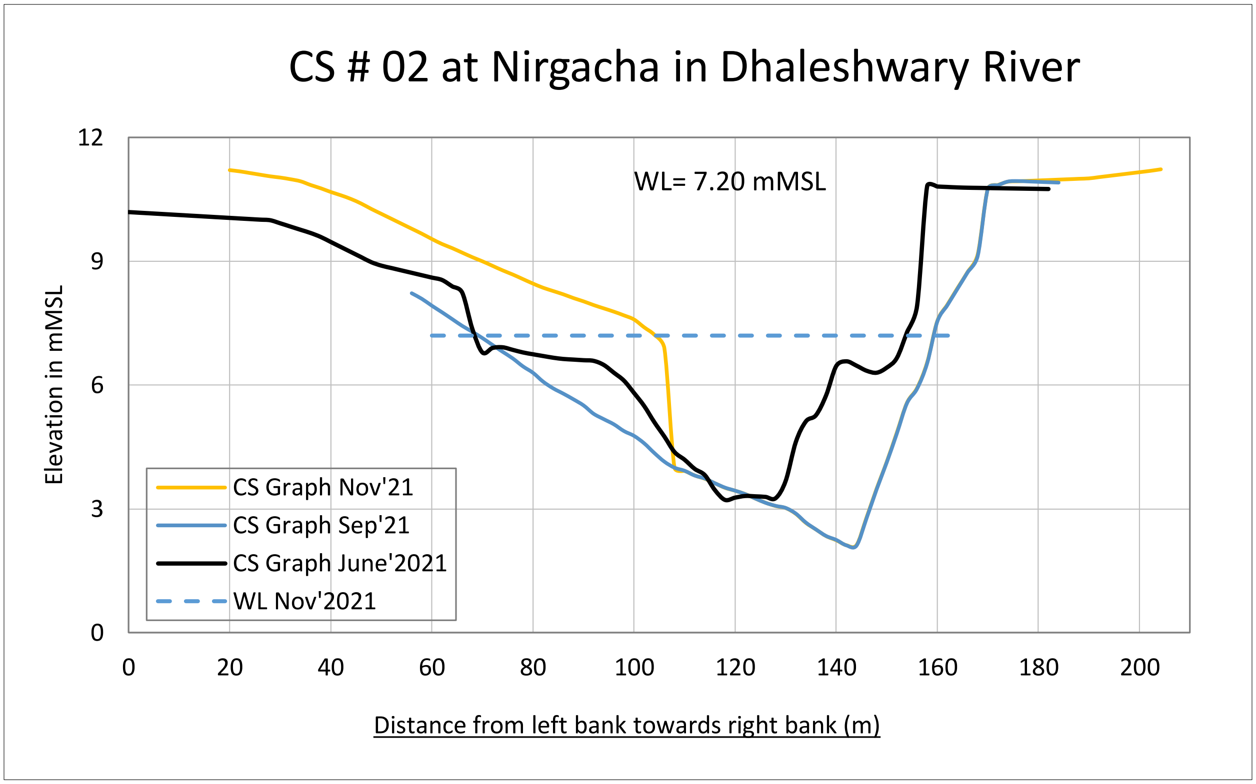

CS # 04 at Dewanganj in jamuna River
WL= 6.46 mMSL
CS Graph Nov'21
CS Graph Sep'21
CS Graph May'21
WL Nov'21
Elevation in mMSL
-3
0
3
6
9
12
15
0
150
300
450
600
750
900
1050
1200
1350
1500
Distance from left bank towards right bank (m)



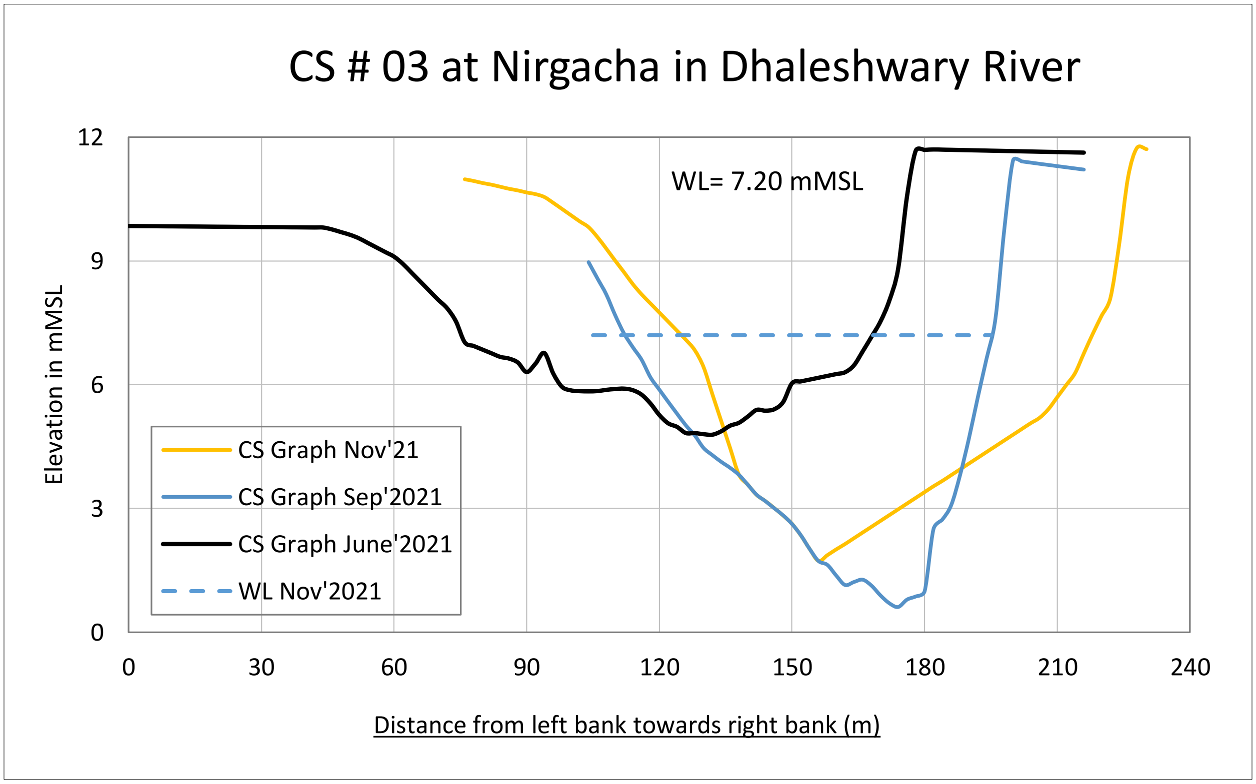
CS # 05 at Dewanganj in jamuna River
WL= 6.46 mMSL
CS Graph Nov'21
CS Graph Sep'21
CS Graph May'21
WL Nov'21
Elevation in mMSL
15
12
9
6
3
0
0
150
300
450
600
750
900
1050
1200
1350
1500
Distance from left bank towards right bank (m)


Chowbari Chokdoi
Katuli Union
Torapgonj Bazar
First Survey Point
CS # 01
1st_Discharge_point
CS # 02 (1st Discharge Point)
CS # 03
CS # 04
CS # 05
CS # 06
CS # 07
CS # 09
CS # 08
CS # 10
CS # 16
3rd_discharge_point
CS # 19 (3rd Discharge point)
CS # 15
CS # 20
2nd_discharge_point
CS # 21
CS # 22
Last Survey Point
Image © 2022 Maxar Technologies
RAJSHAHI DIV
Dhaleshwari Ri
Google

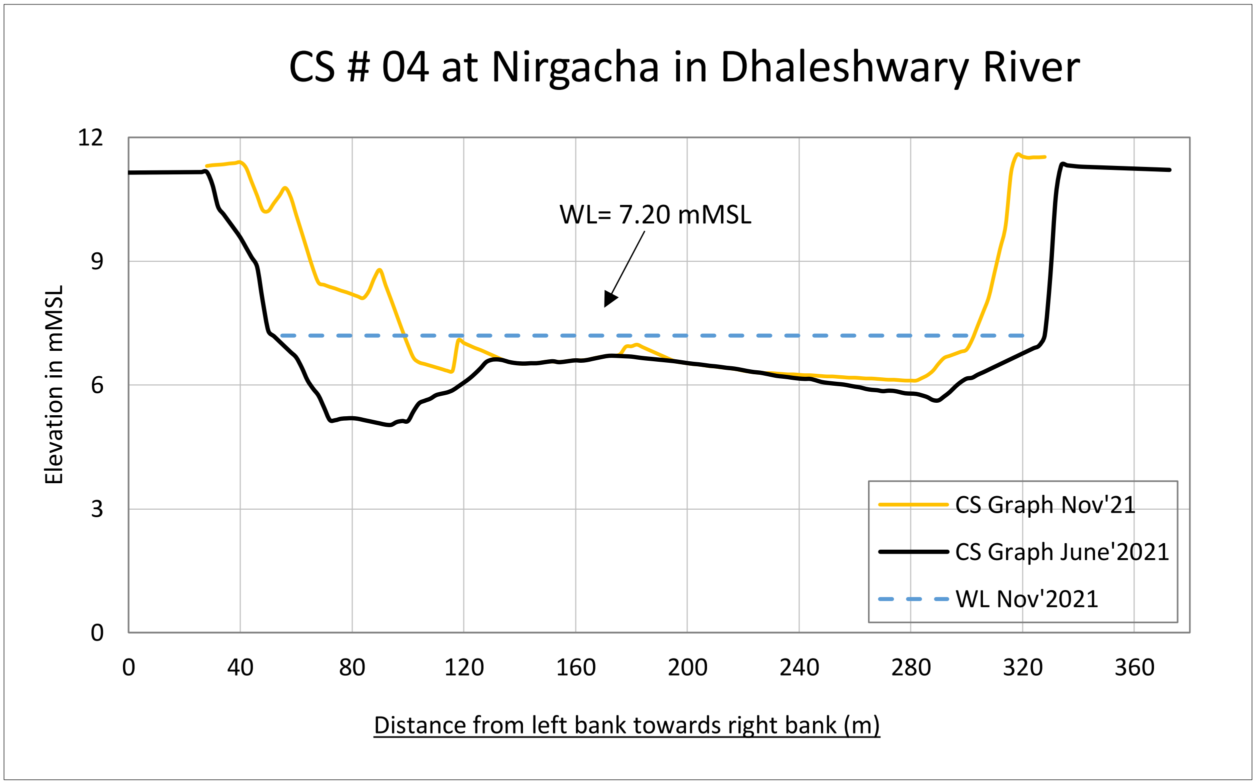

CS # 01 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
Distance from left bank towards right bank (m)
0
3
6
9
12
0
30
60
90
120
150
180
210
240
270
300
330
CS Graph Nov'21
CS Graph Sep'2021
CS Graph June'2021
WL Nov'2021

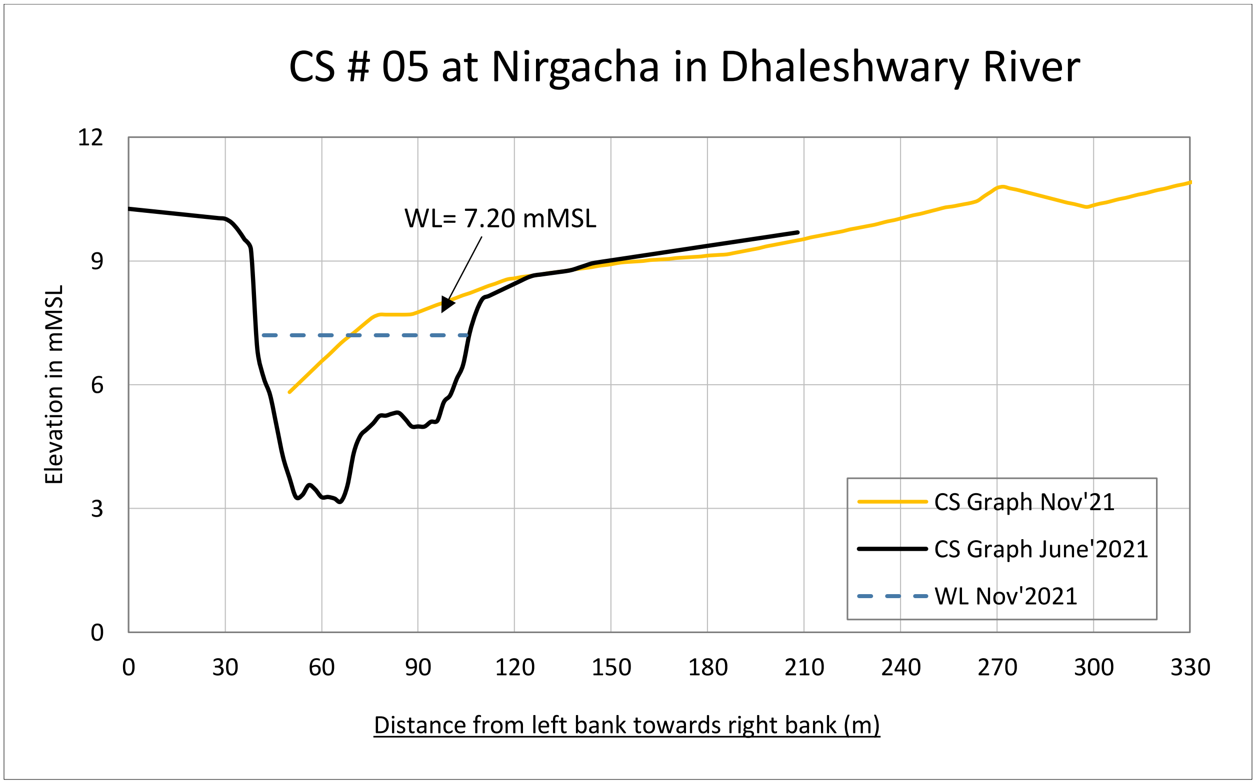


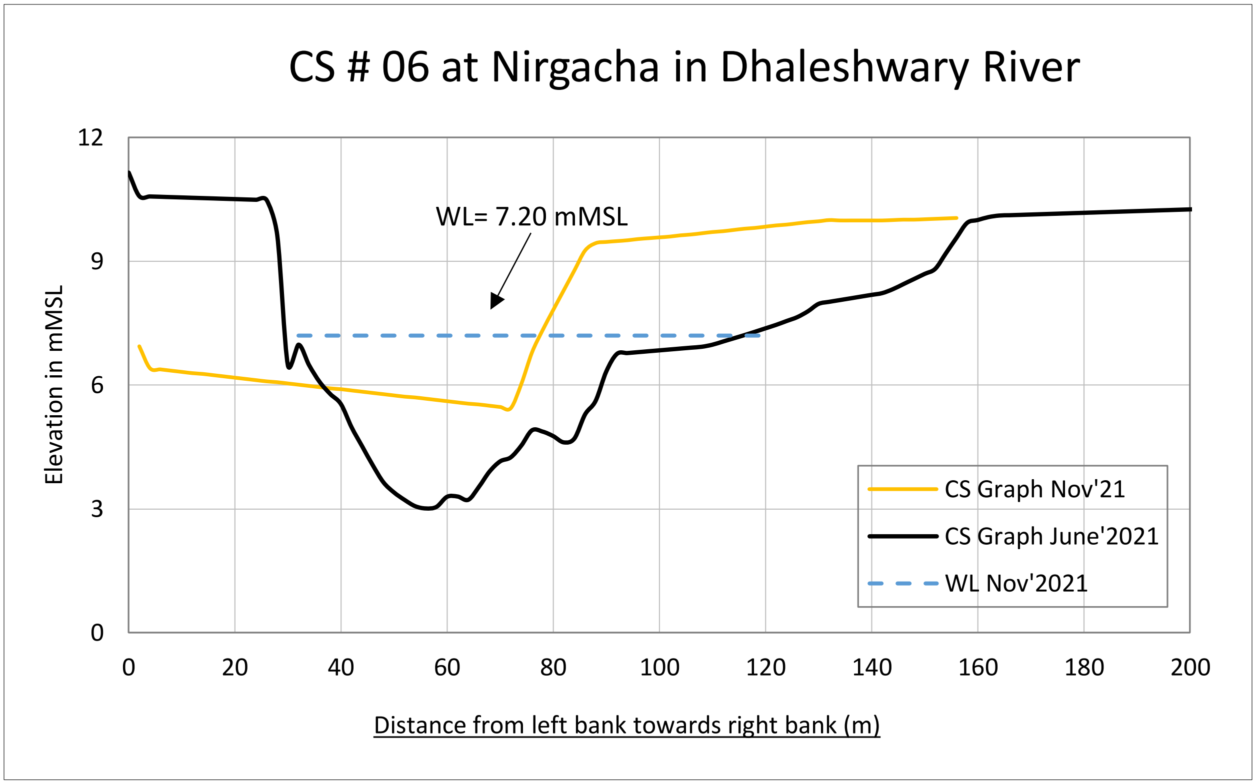
CS # 02 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
0
3
6
9
12
0
20
40
60
80
100
120
140
160
180
200
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'2021
WL Nov'2021

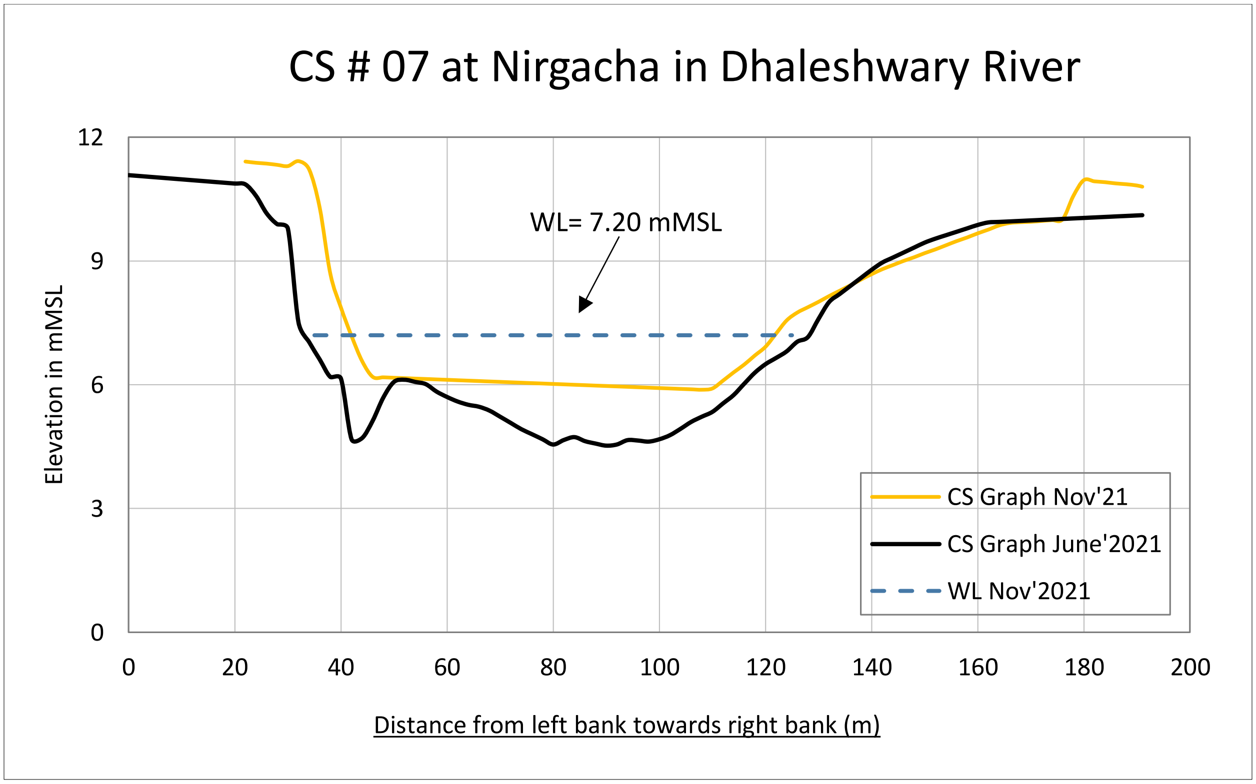


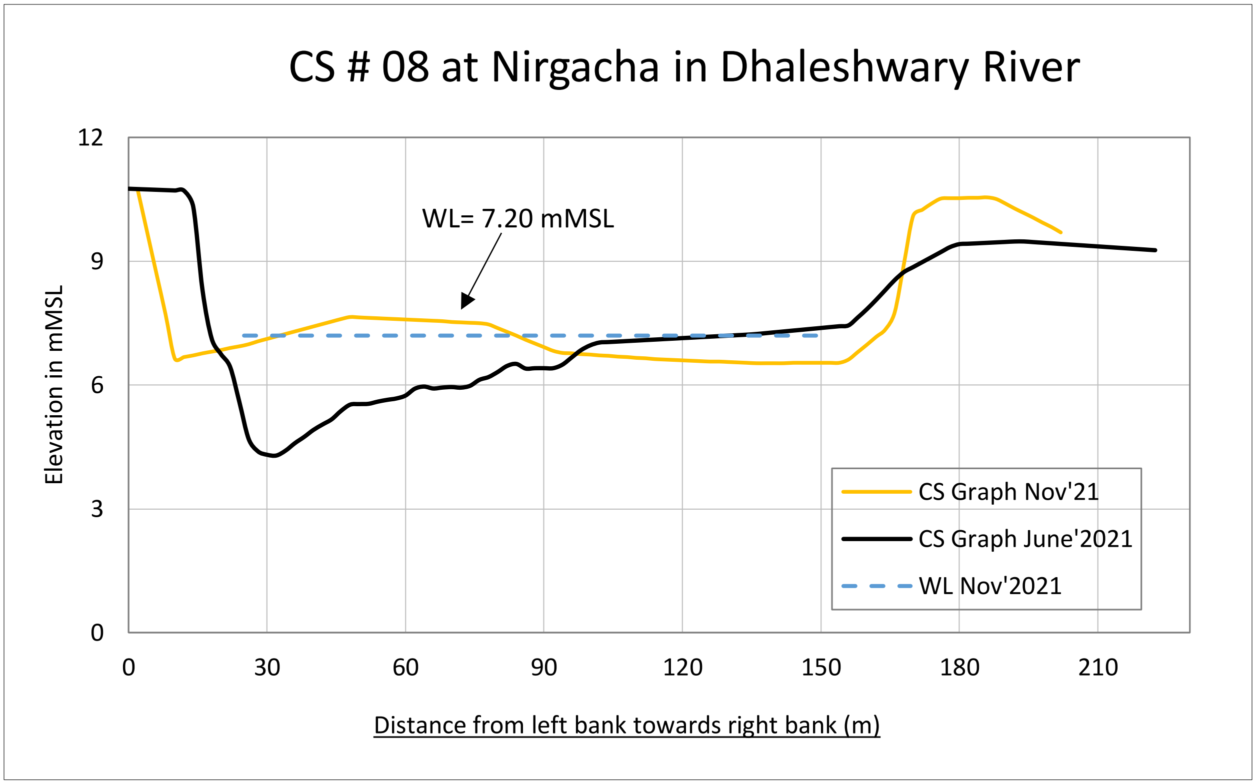
CS # 03 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
0
3
6
9
12
0
30
60
90
120
150
180
210
240
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'2021
CS Graph June'2021
WL Nov'2021

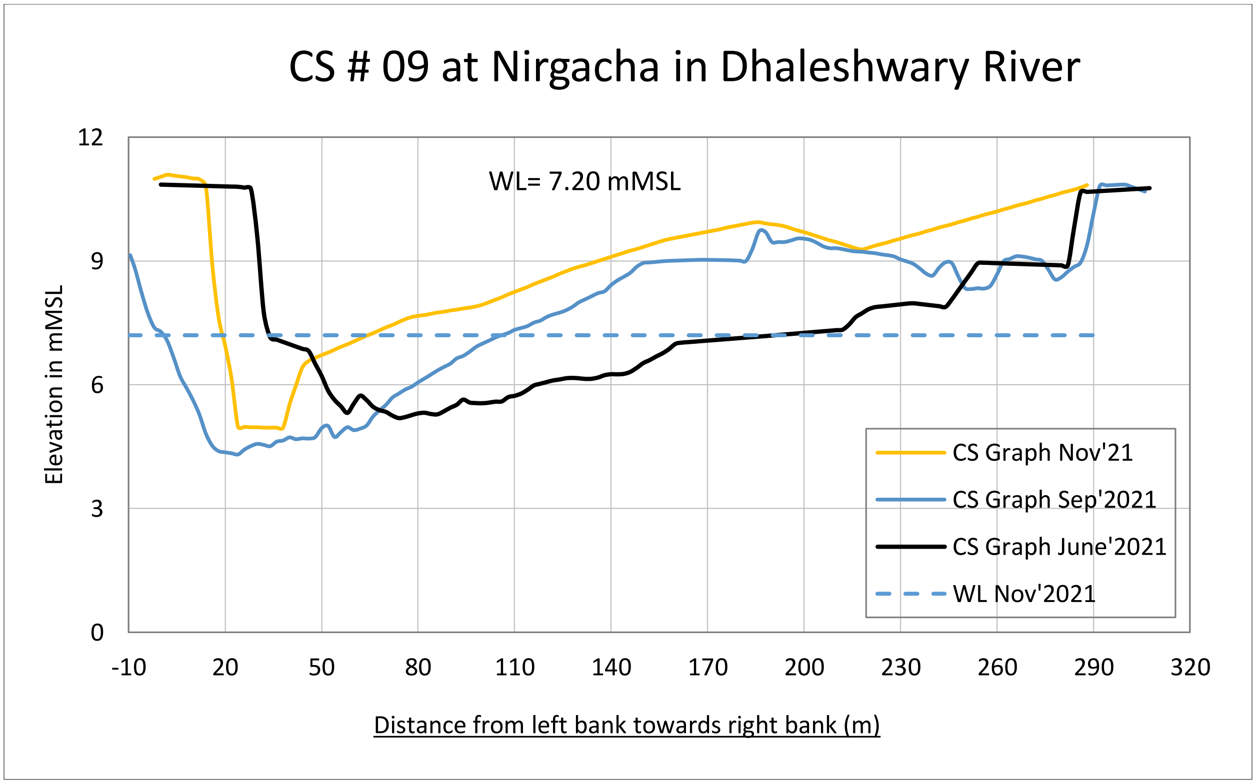

CS # 04 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
0
3
6
9
12
0
40
80
120
160
200
240
280
320
360
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph June'2021
WL Nov'2021

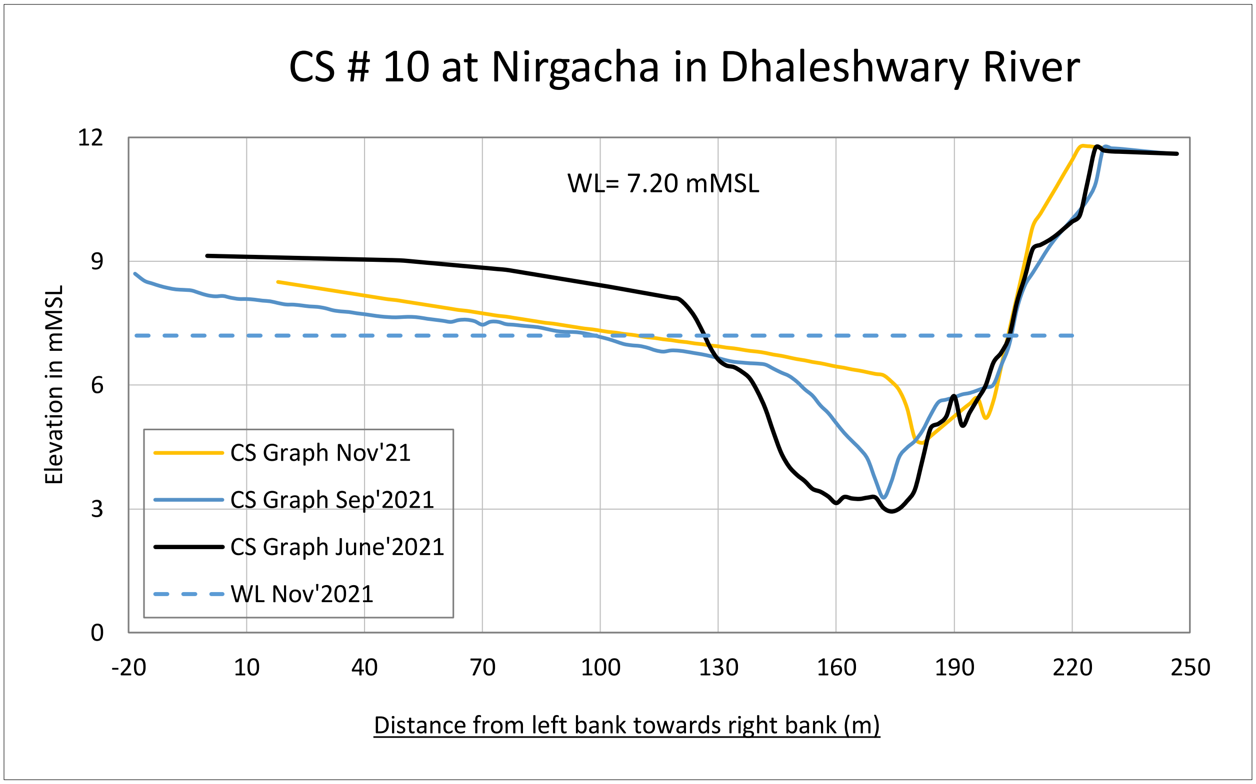

CS # 05 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
0
3
6
9
12
0
30
60
90
120
150
180
210
240
270
300
330
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph June'2021
WL Nov'2021

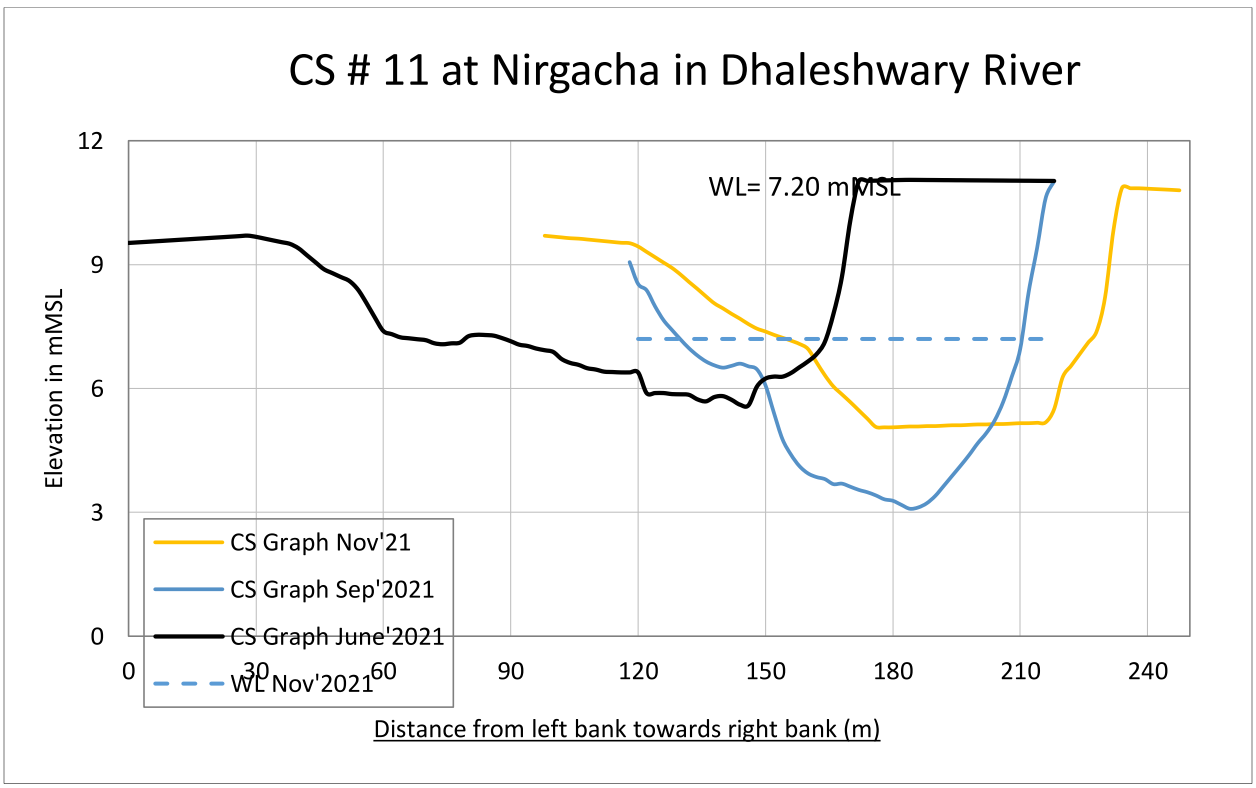

CS # 06 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
0
20
40
60
80
100
120
140
160
180
200
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph June'2021
WL Nov'2021

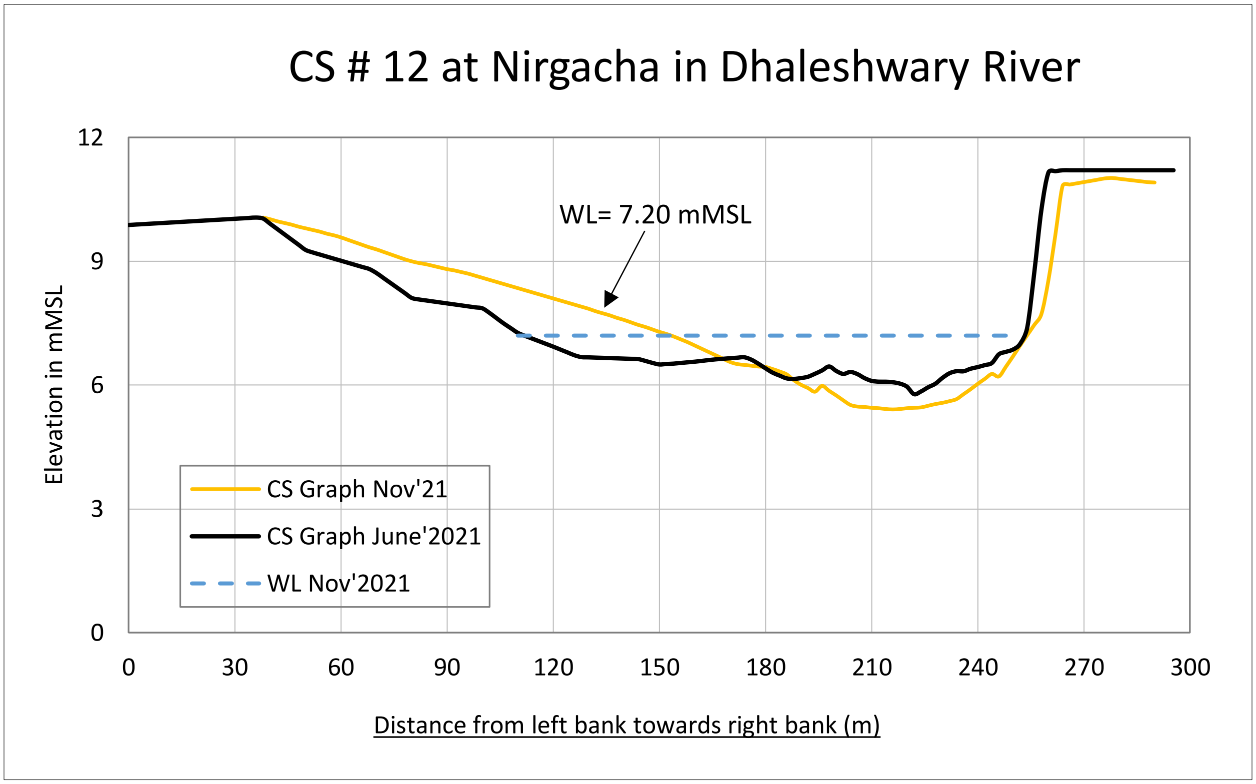

CS # 07 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
0
20
40
60
80
100
120
140
160
180
200
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph June'2021
WL Nov'2021

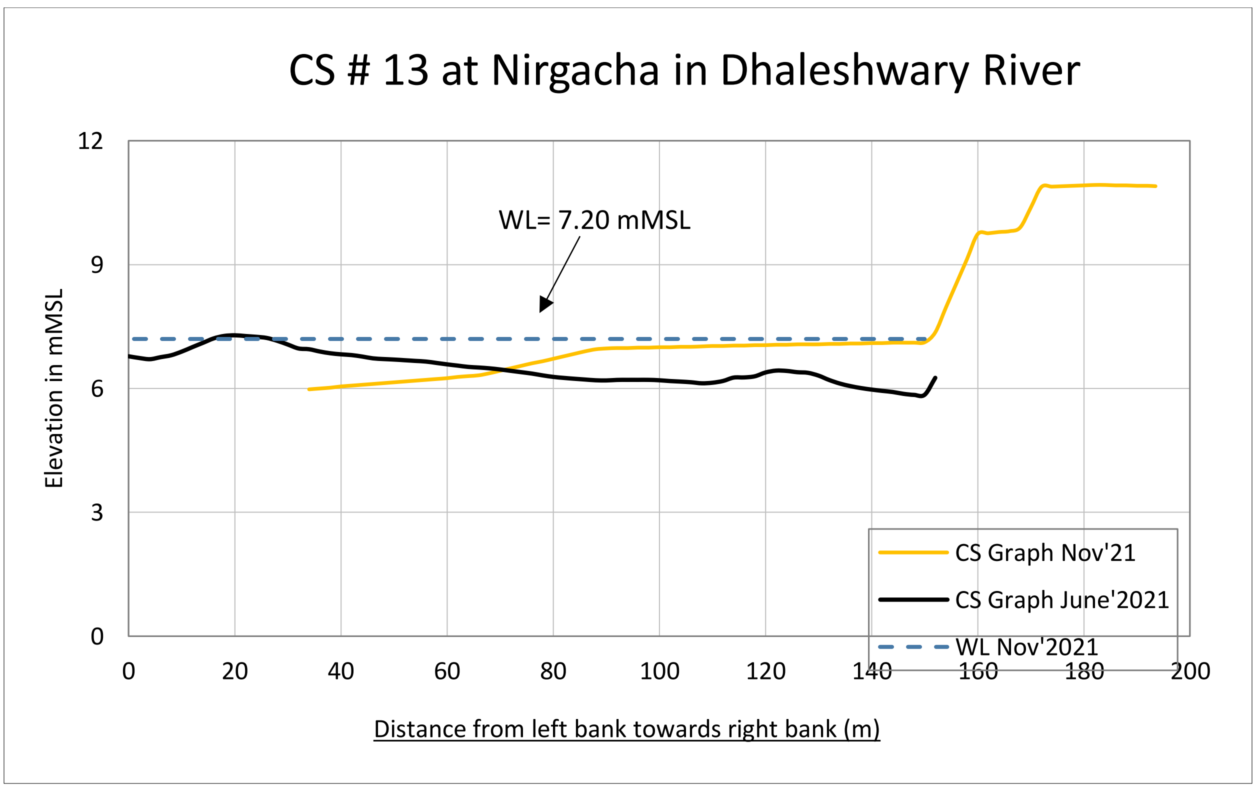

CS # 08 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
0
30
60
90
120
150
180
210
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph June'2021
WL Nov'2021

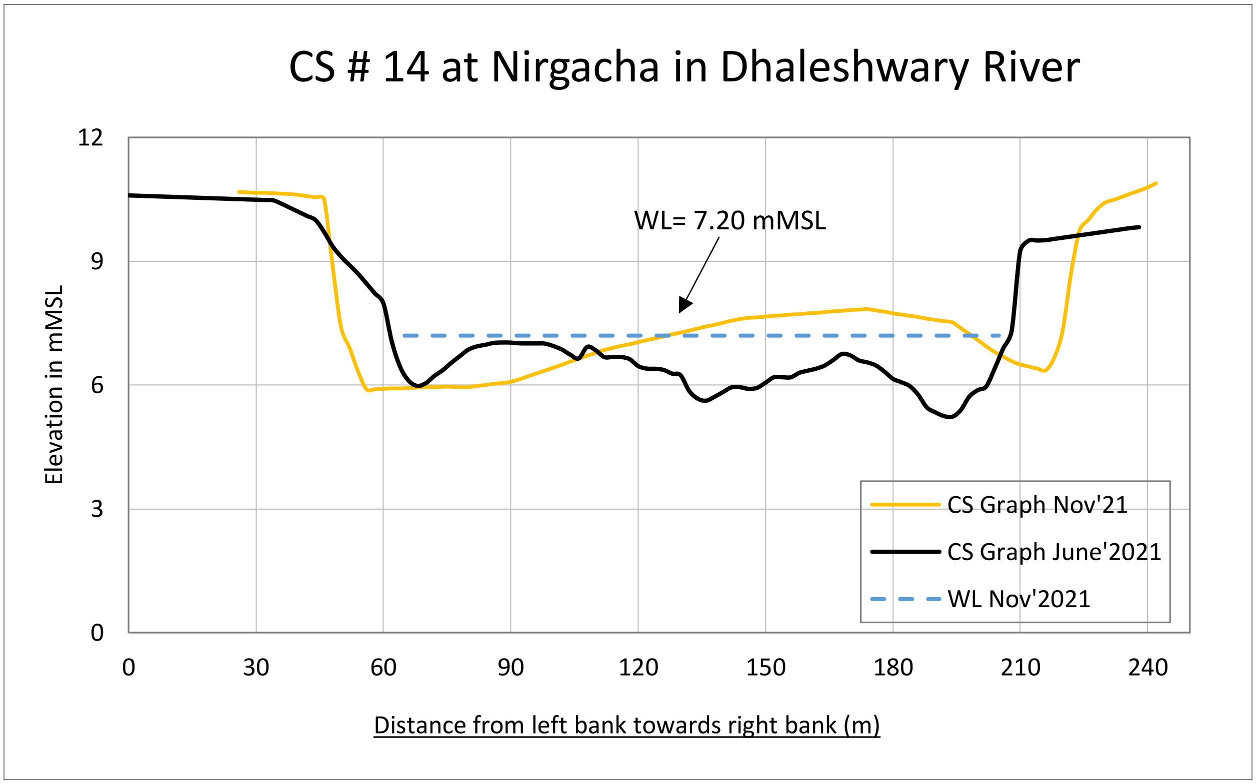

CS # 09 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
-10
20
50
80
110
140
170
200
230
260
290
320
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'2021
CS Graph June'2021
WL Nov'2021

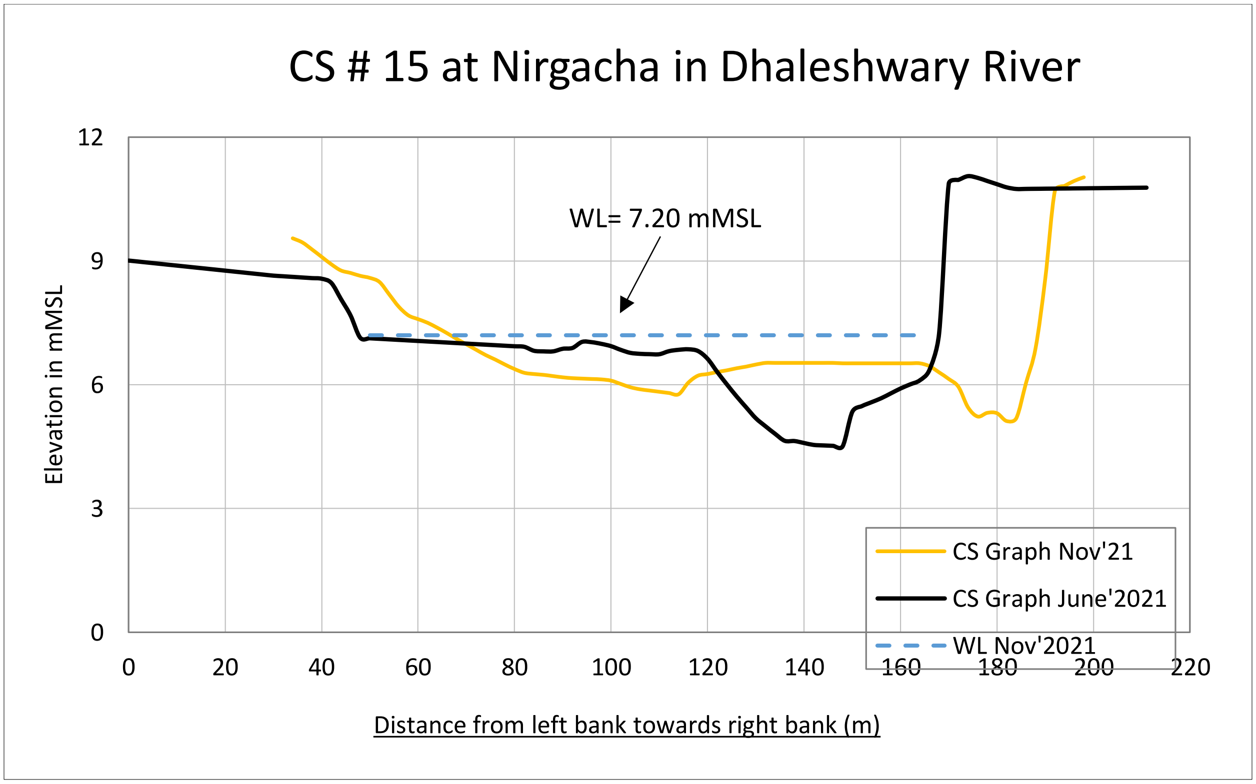

CS # 10 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
-20
10
40
70
100
130
160
190
220
250
CS Graph Nov'21
CS Graph Sep'2021
CS Graph June'2021
WL Nov'2021
Distance from left bank towards right bank (m)

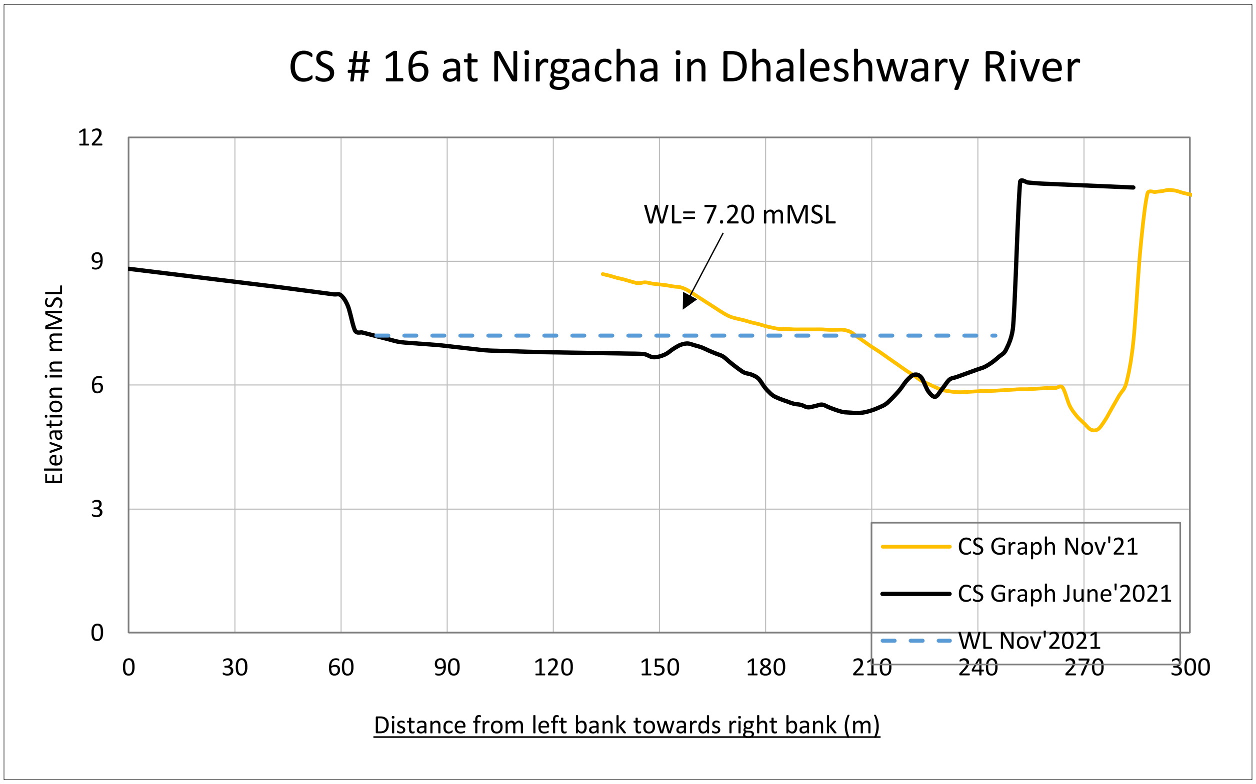

CS # 11 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
0
30
60
90
120
150
180
210
240
CS Graph Nov'21
CS Graph Sep'2021
CS Graph June'2021
WL Nov'2021
Distance from left bank towards right bank (m)

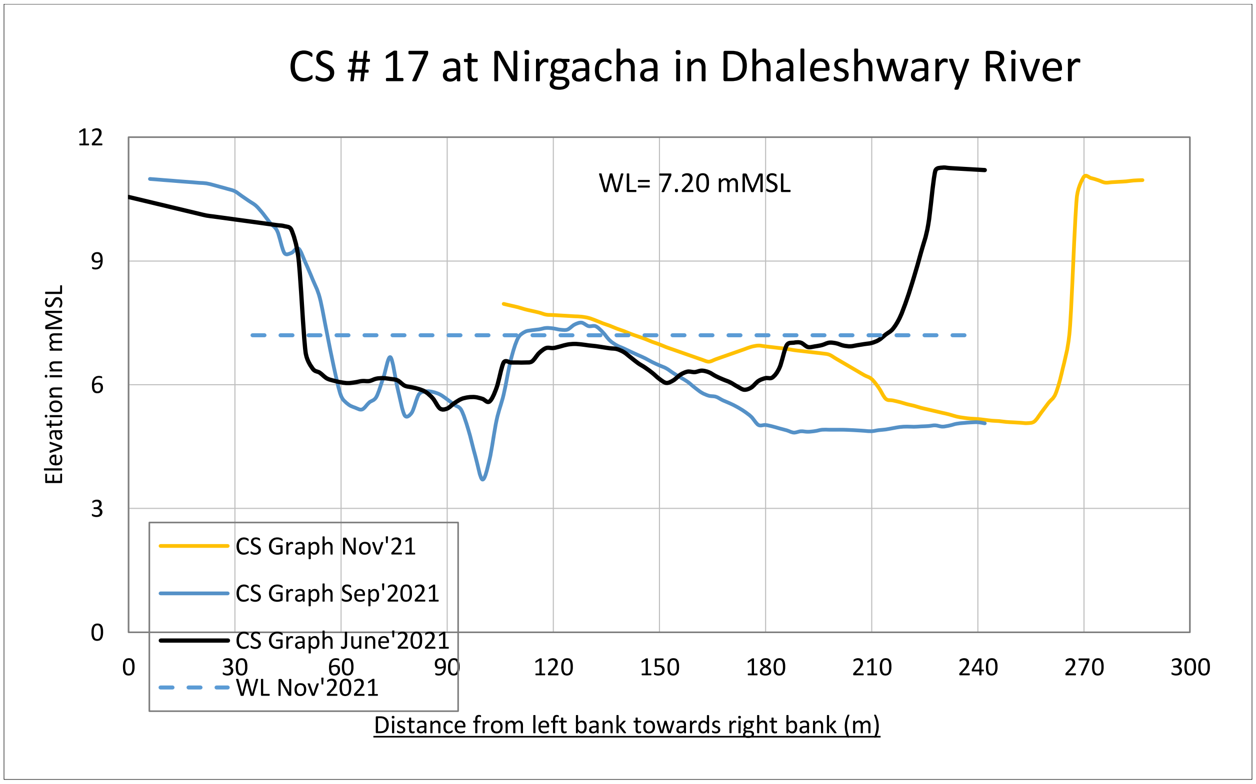

CS # 12 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
0
3
6
9
12
0
30
60
90
120
150
180
210
240
270
300
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph June'2021
WL Nov'2021

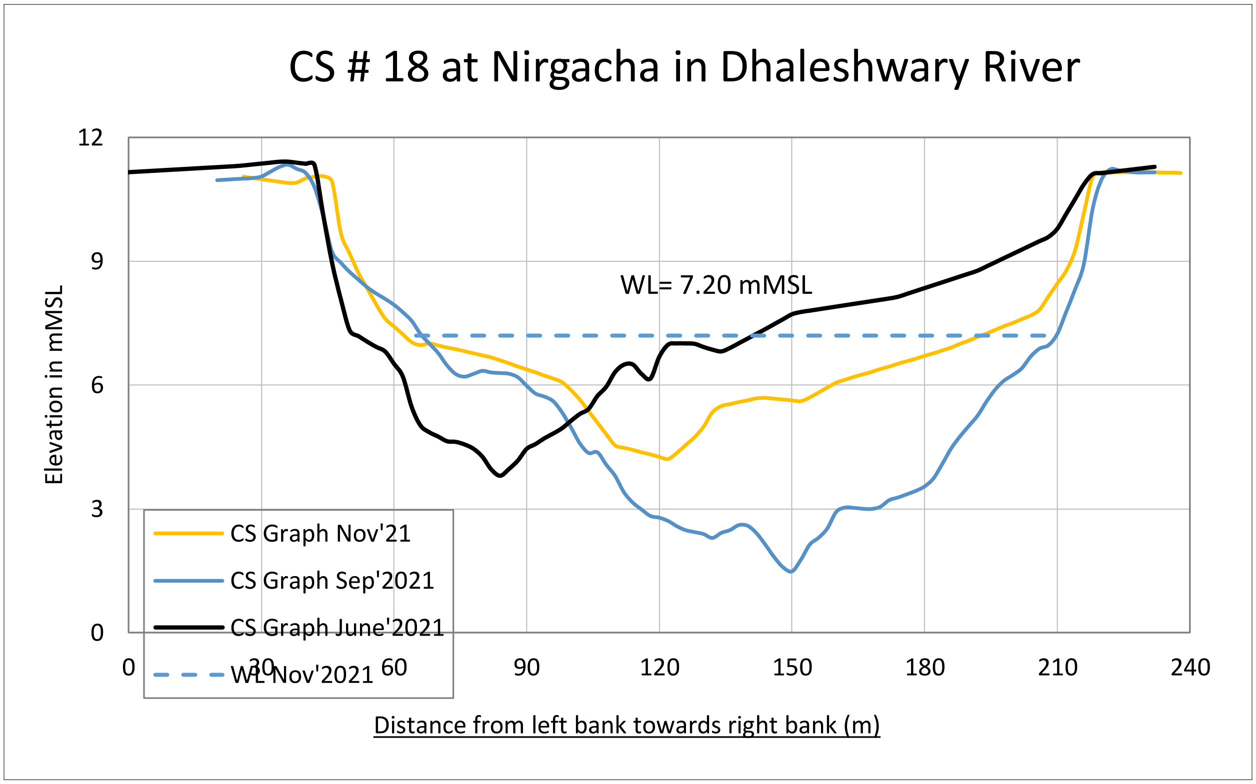

CS # 13 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
0
3
6
9
12
0
20
40
60
80
100
120
140
160
180
200
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph June'2021
WL Nov'2021

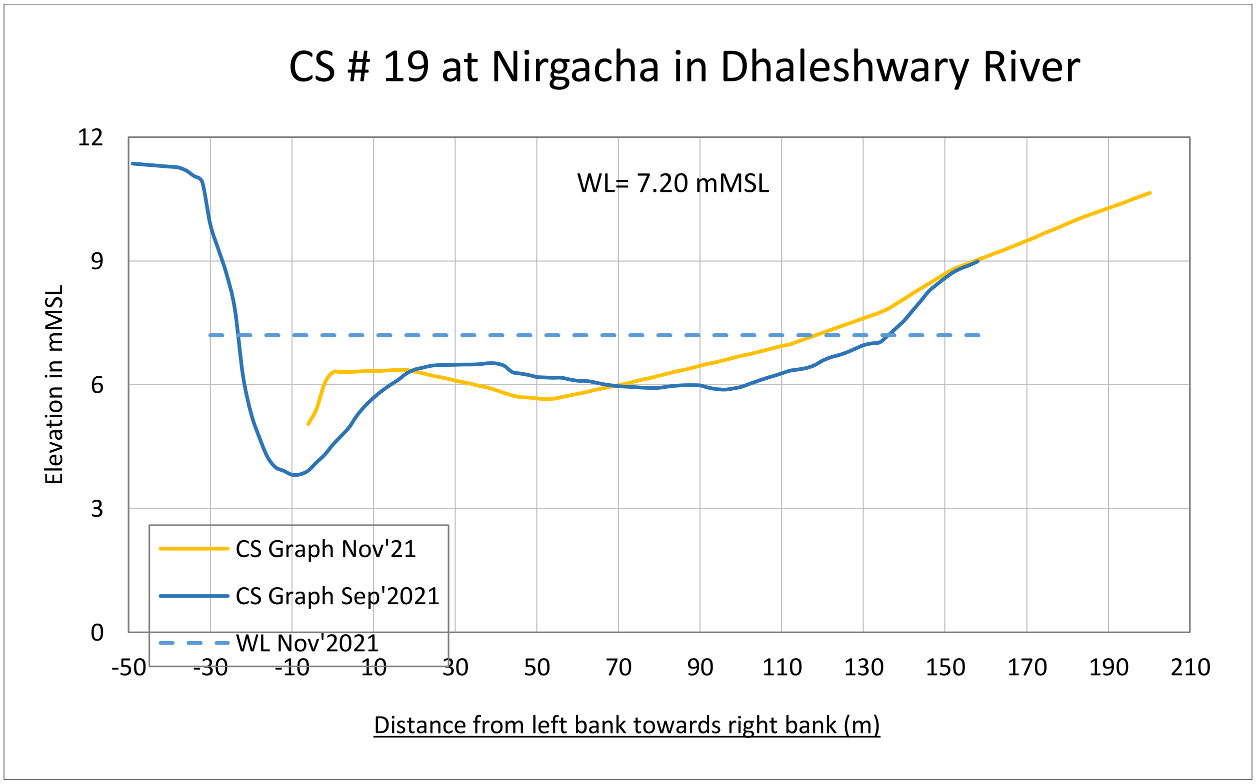

CS # 14 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
0
30
60
90
120
150
180
210
240
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph June'2021
WL Nov'2021

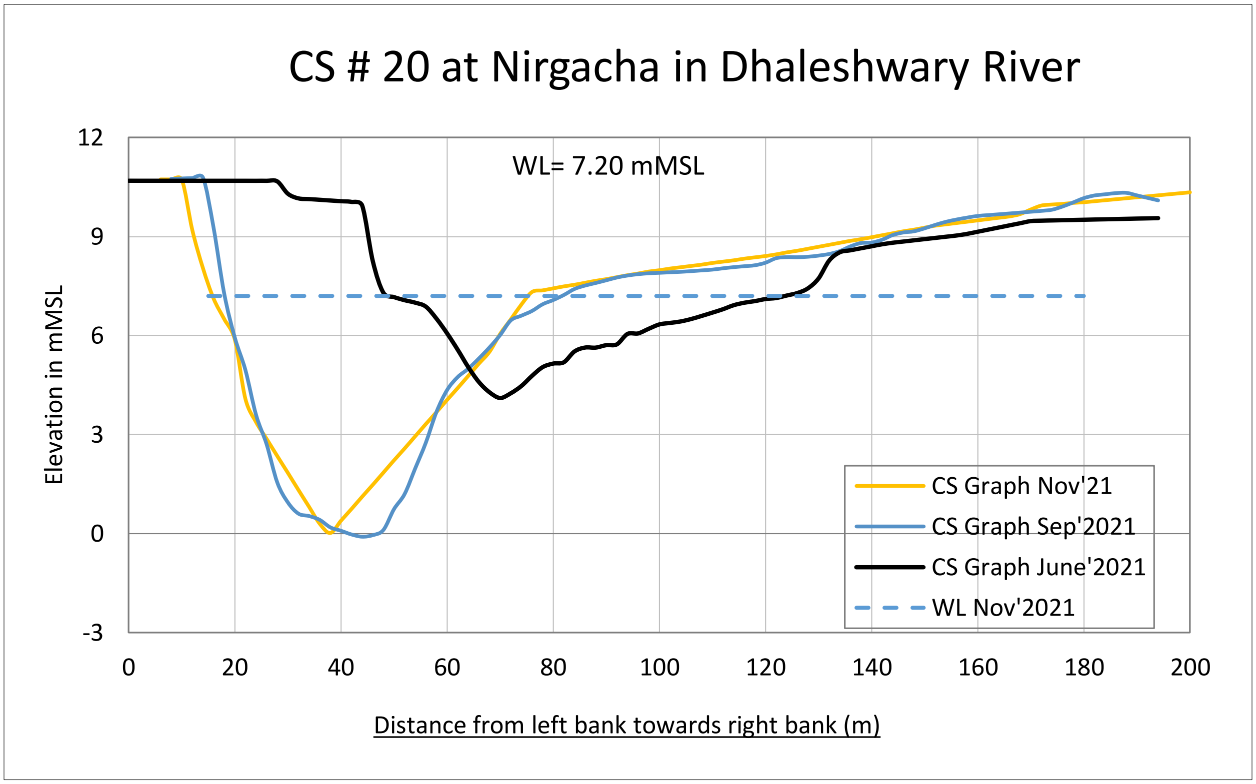

CS # 15 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
0
20
40
60
80
100
120
140
160
180
200
220
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph June'2021
WL Nov'2021

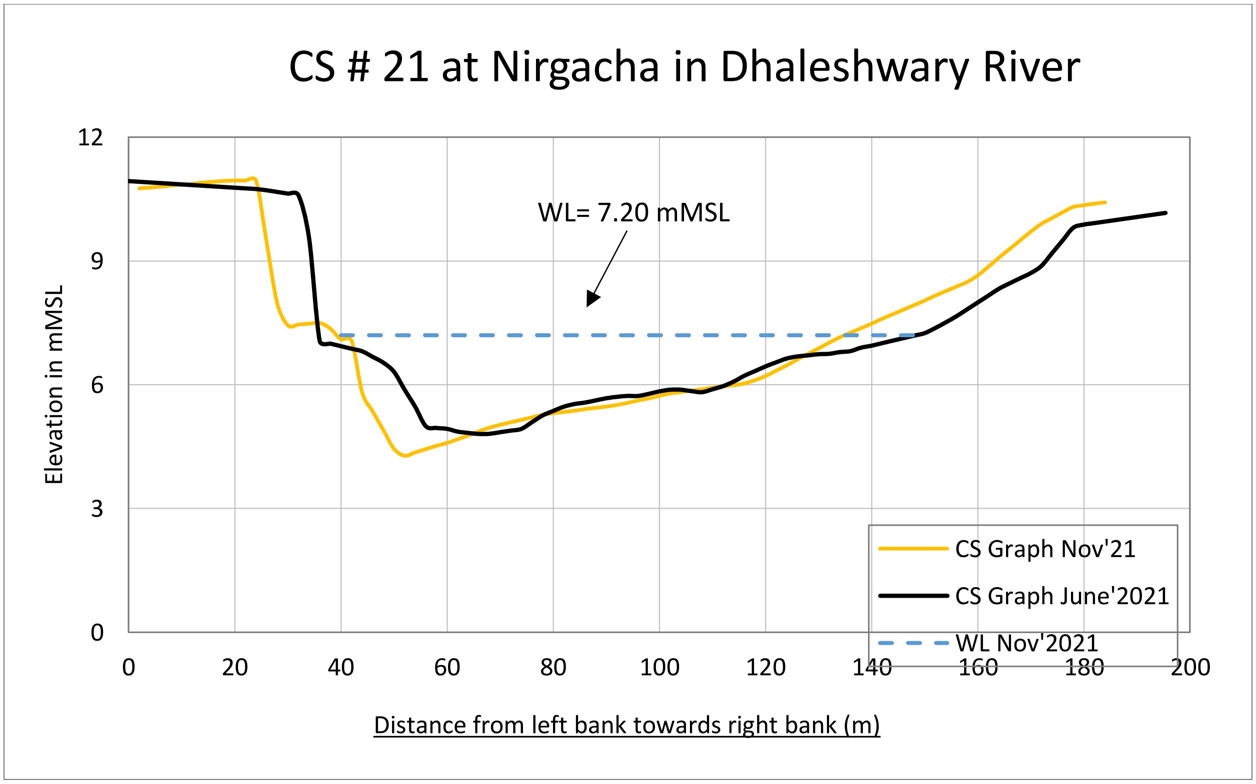

CS # 16 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
0
30
60
90
120
150
180
210
240
270
300
CS Graph Nov'21
CS Graph June'2021
WL Nov'2021
Distance from left bank towards right bank (m)

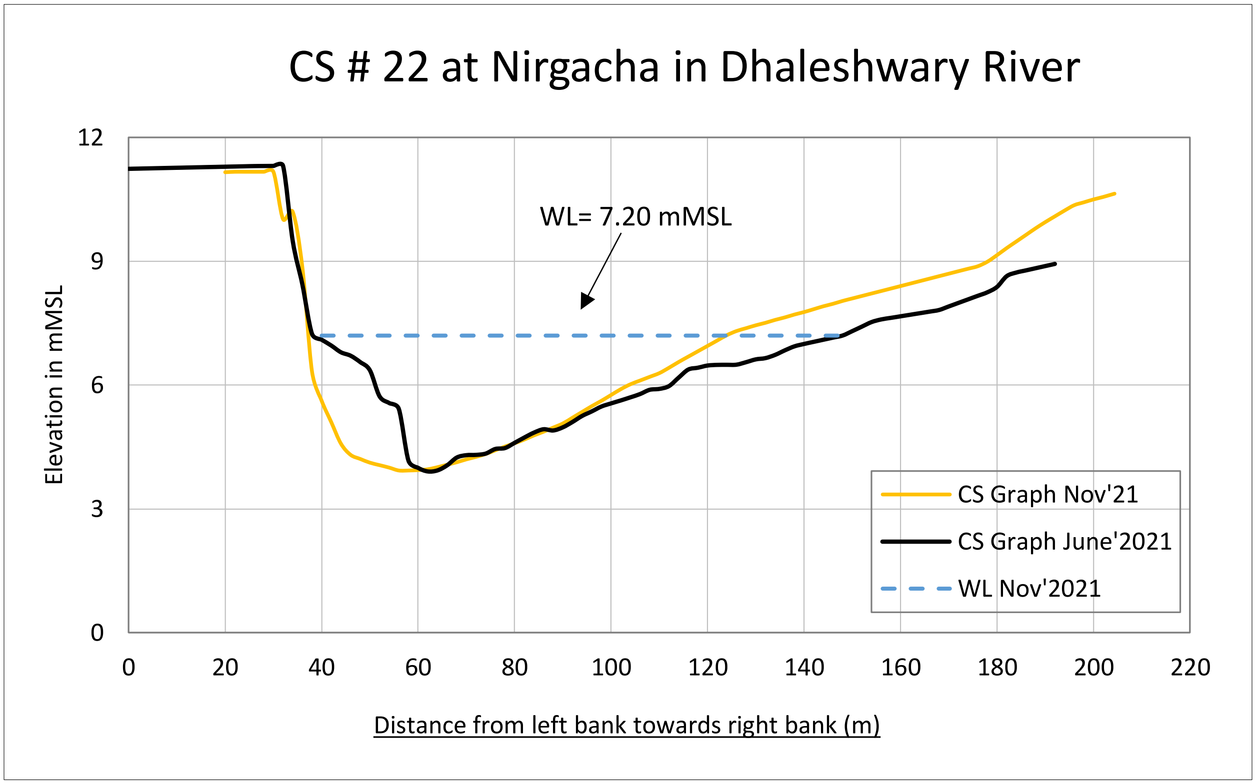

CS # 17 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
0
30
60
90
120
150
180
210
240
270
300
CS Graph Nov'21
CS Graph Sep'2021
CS Graph June'2021
WL Nov'2021
Distance from left bank towards right bank (m)

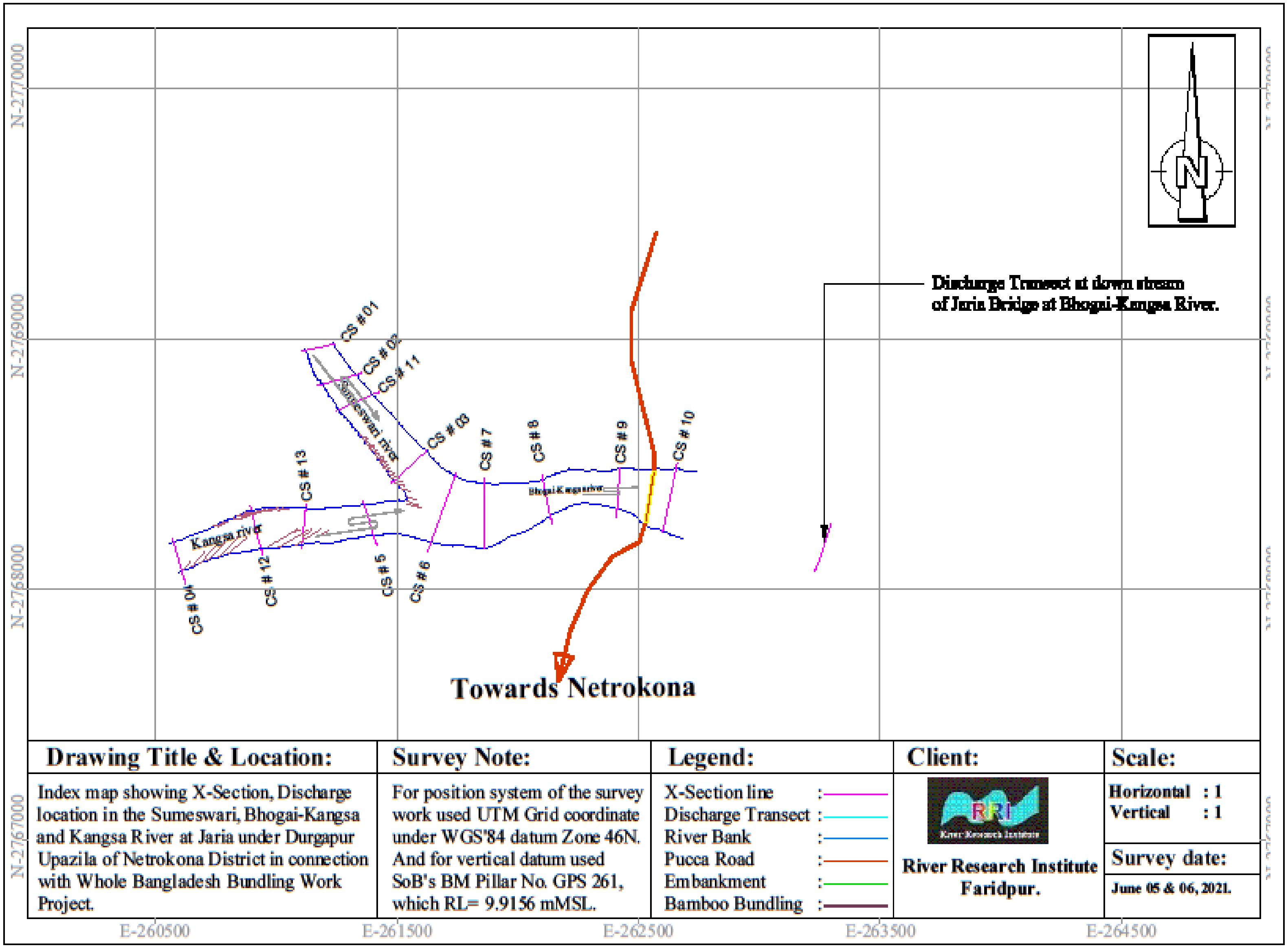

CS # 18 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
0
30
60
90
120
150
180
210
240
CS Graph Nov'21
CS Graph Sep'2021
CS Graph June'2021
WL Nov'2021
Distance from left bank towards right bank (m)

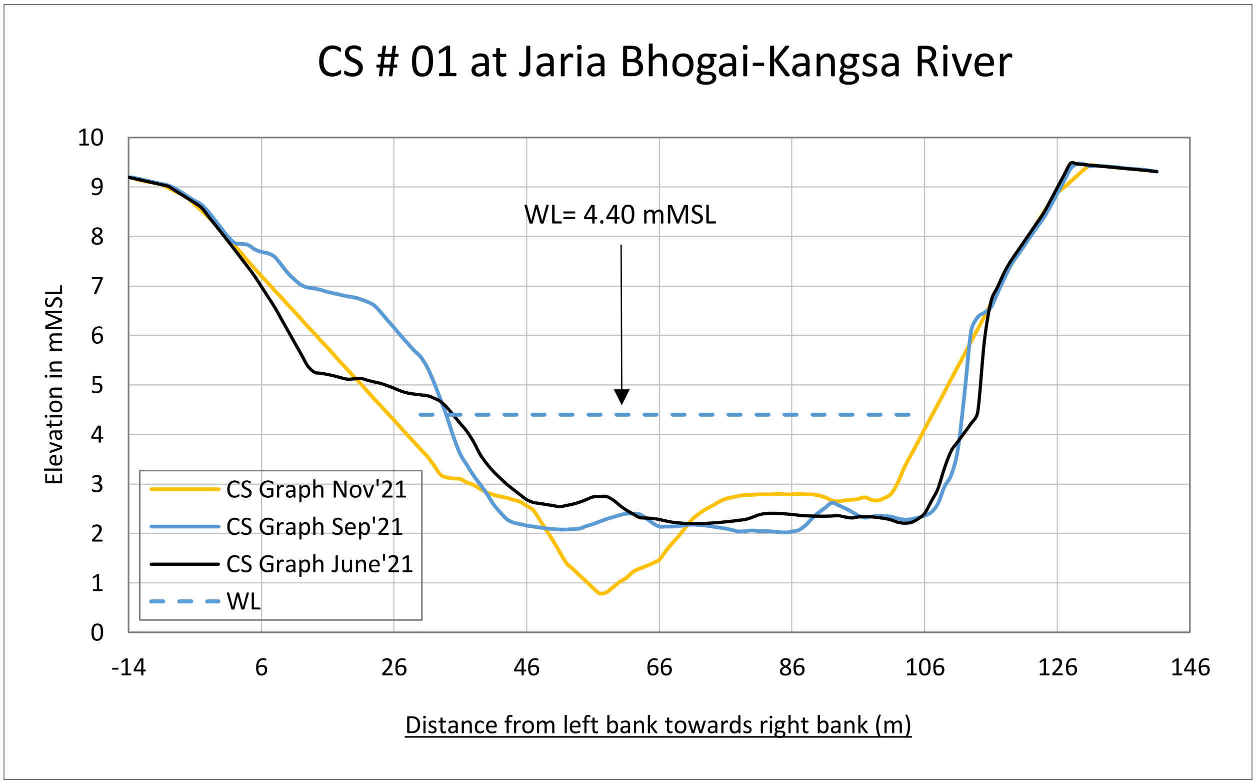

CS # 19 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
-50
-30
-10
10
30
50
70
90
110
130
150
170
190
210
CS Graph Nov'21
CS Graph Sep'2021
WL Nov'2021
Distance from left bank towards right bank (m)


CS # 20 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
12
9
6
3
0
-3
Elevation in mMSL
0
20
40
60
80
100
120
140
160
180
200
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'2021
CS Graph June'2021
WL Nov'2021

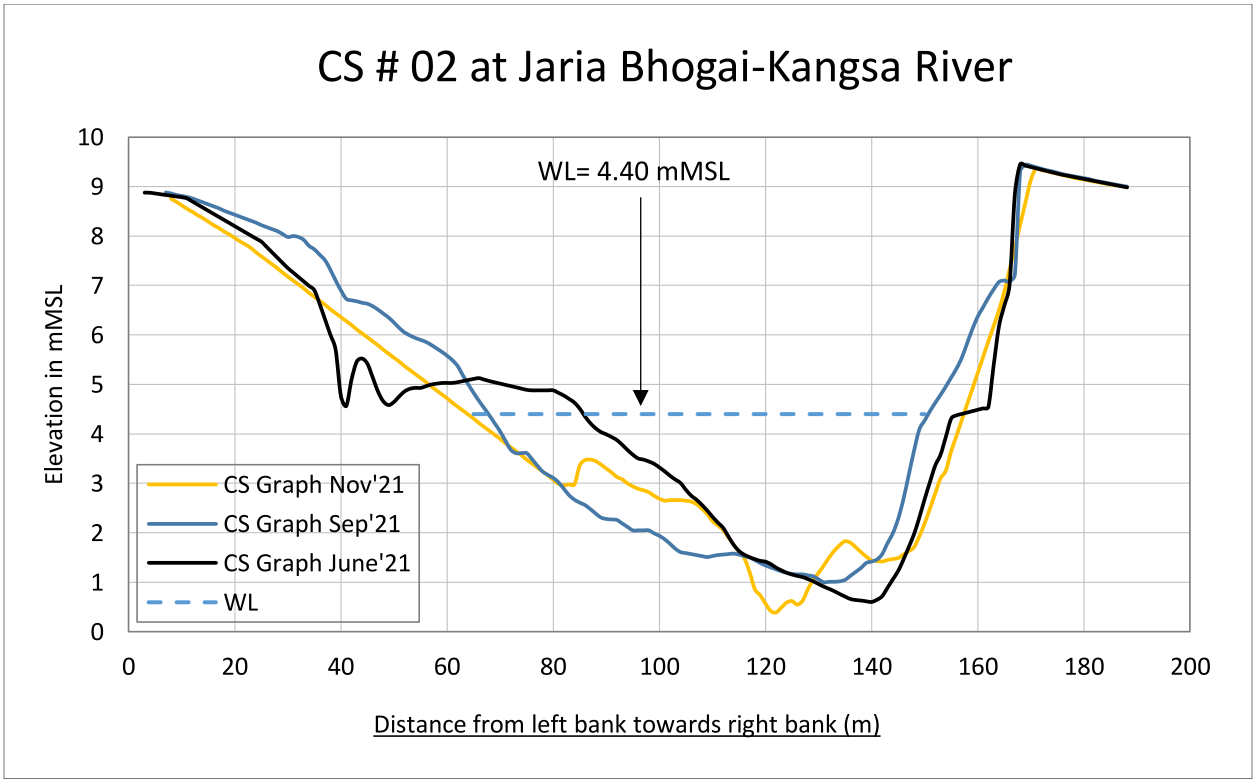

CS # 21 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
12
9
6
3
0
Elevation in mMSL
0
20
40
60
80
100
120
140
160
180
200
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph June'2021
WL Nov'2021


CS # 22 at Nirgacha in Dhaleshwary River
WL= 7.20 mMSL
Elevation in mMSL
12
9
6
3
0
0
20
40
60
80
100
120
140
160
180
200
220
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph June'2021
WL Nov'2021

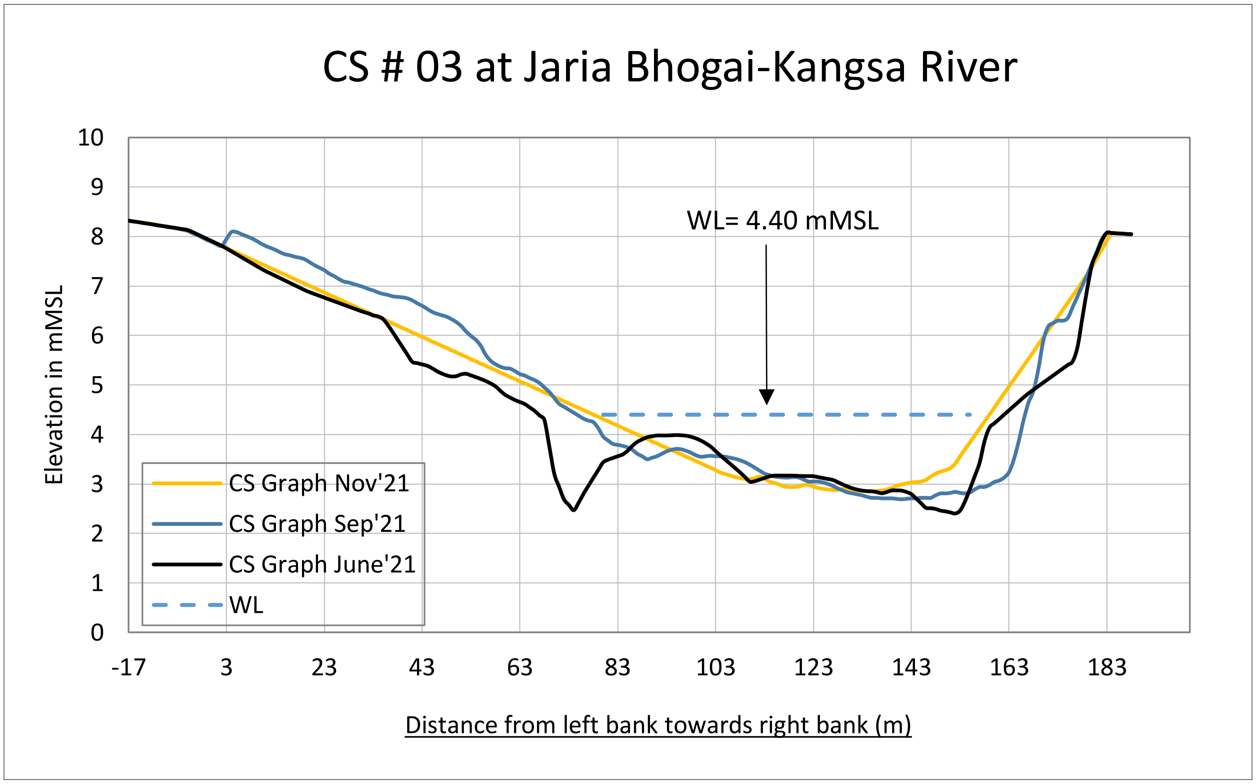

N-2770000
N-2769000
N-2768000
N-2767000
E-260500
E-261500
E-262500
E-263500
E-264500
N
Discharge Transect at down stream
of Jaria Bridge at Bhogai-Kangsa River.
CS # 01
CS # 02
CS # 11
CS # 03
CS # 7
CS # 8
CS # 9
CS # 10
CS # 13
CS # 04
CS # 12
CS # 5
CS # 6
Kangsa river
Sumeswari river
Towards Netrokona
Drawing Title & Location:
Index map showing X-Section, Discharge location in the Sumeswari, Bhogai-Kangsa and Kangsa River at Jaria under Durgapur Upazila of Netrokona District in connection with Whole Bangladesh Bundling Work Project.
Survey Note:
For position system of the survey work used UTM Grid coordinate under WGS'84 datum Zone 46N. And for vertical datum used SoB's BM Pillar No. GPS 261, which RL= 9.9156 mMSL.
Legend:
X-Section line :
Discharge Transect :
River Bank :
Pucca Road :
Embankment :
Bamboo Bundling :
Client:
River Research Institute
Faridpur.
Scale:
Horizontal : 1
Vertical : 1
Survey date:
June 05 & 06, 2021.



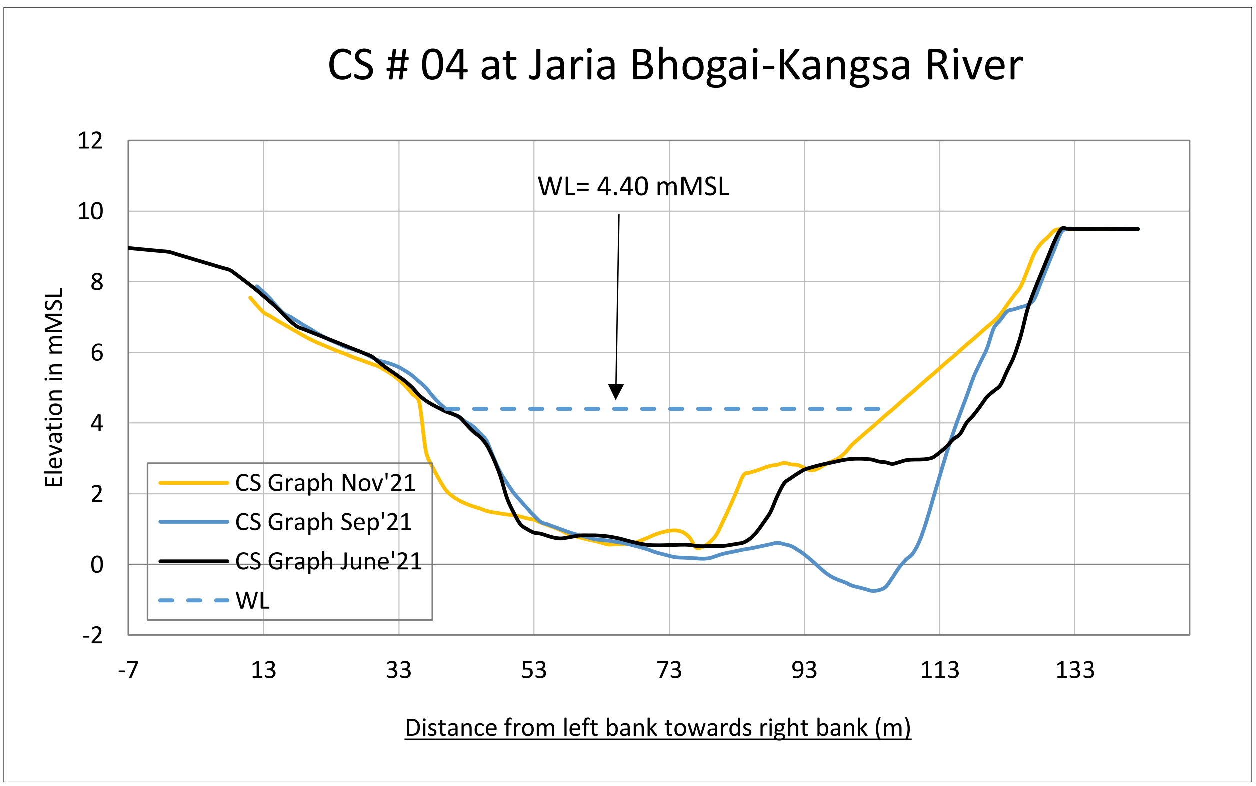
CS # 01 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
10
9
8
7
6
5
4
3
2
1
0
-14
6
26
46
66
86
106
126
146
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'21
WL



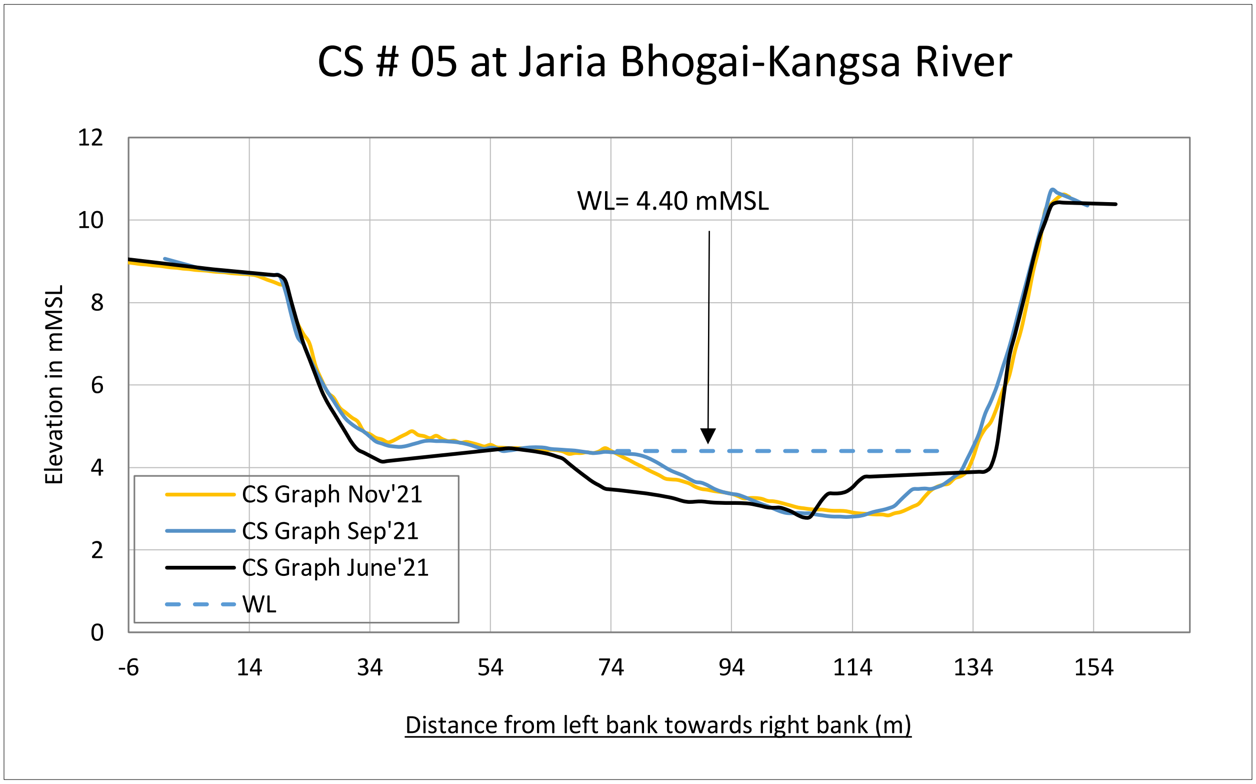
CS # 02 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
10
9
8
7
6
5
4
3
2
1
0
0
20
40
60
80
100
120
140
160
180
200
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'21
WL

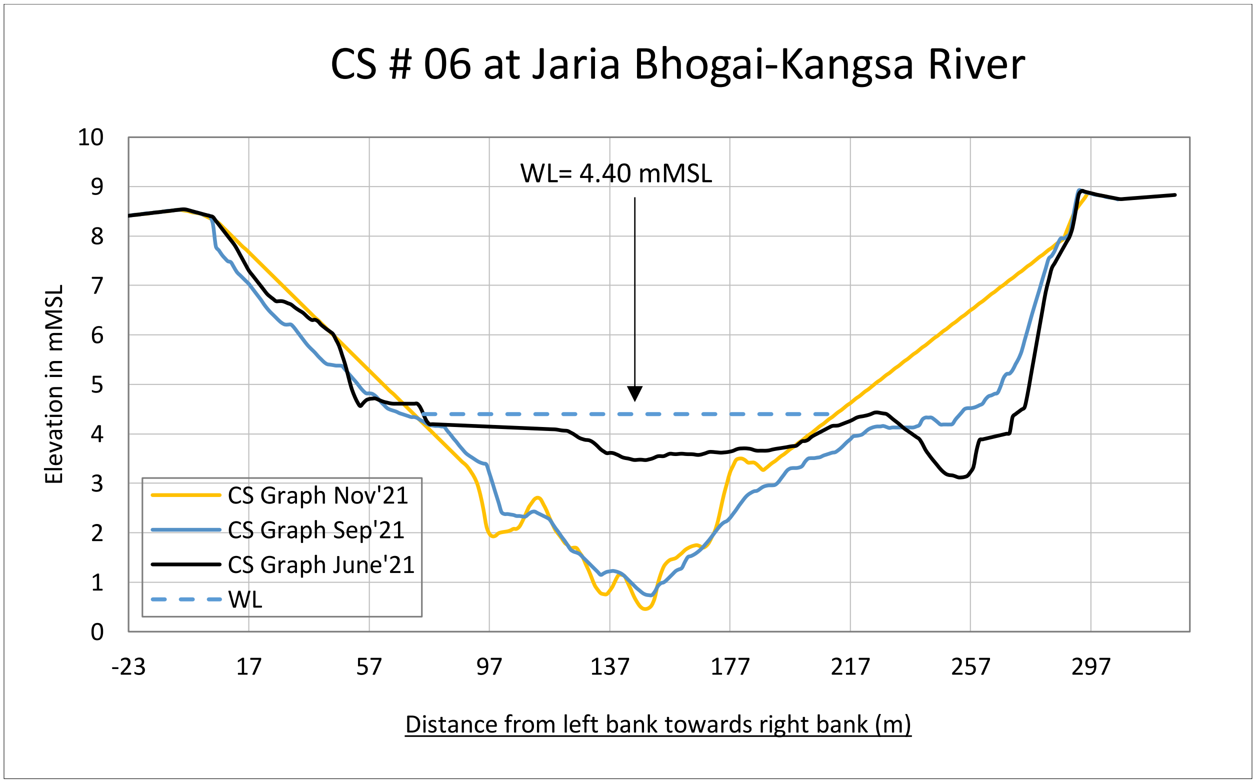


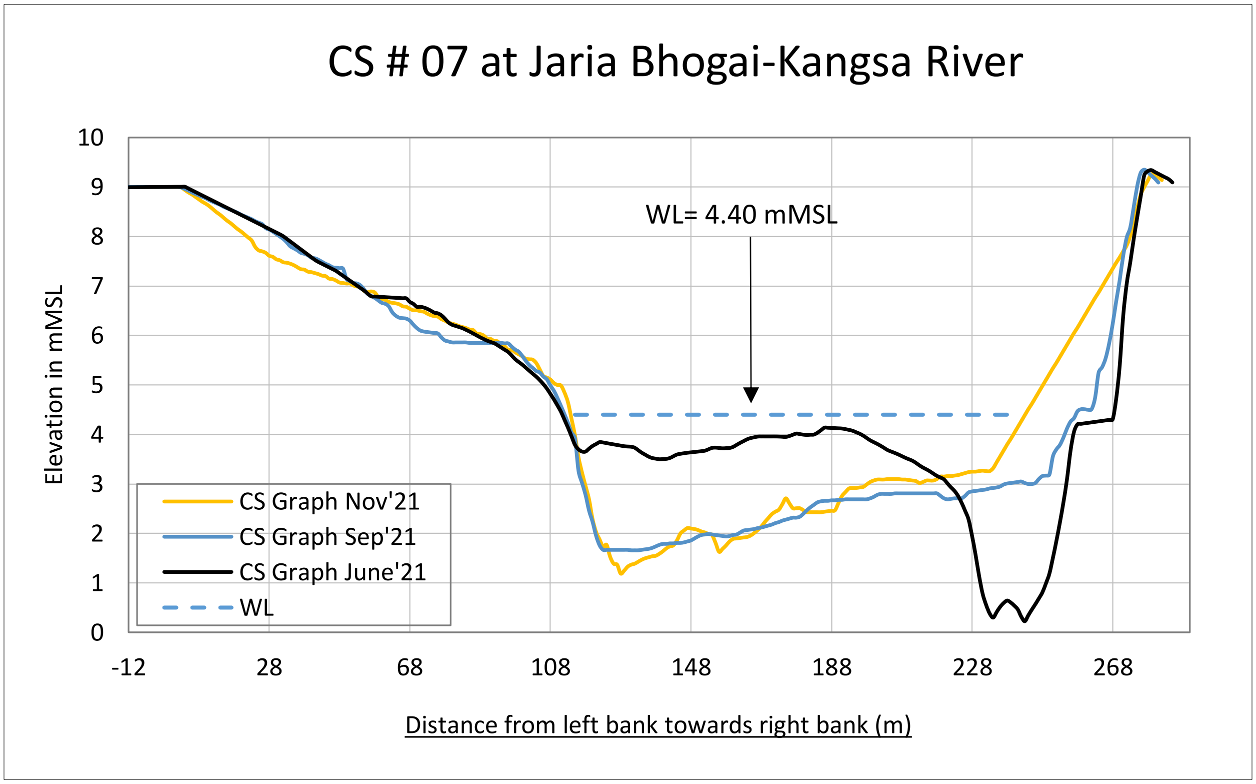
CS # 03 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'21
WL
10
9
8
7
6
5
4
3
2
1
0
-17
3
23
43
63
83
103
123
143
163
183

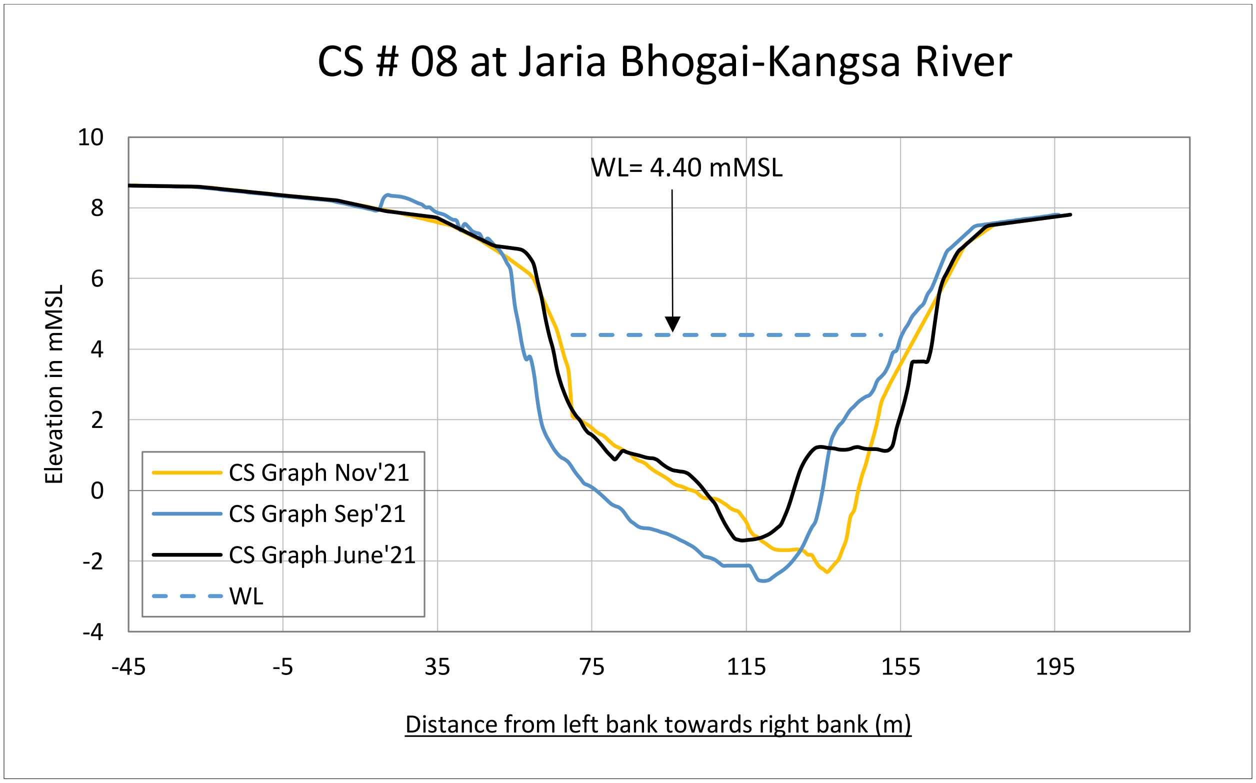


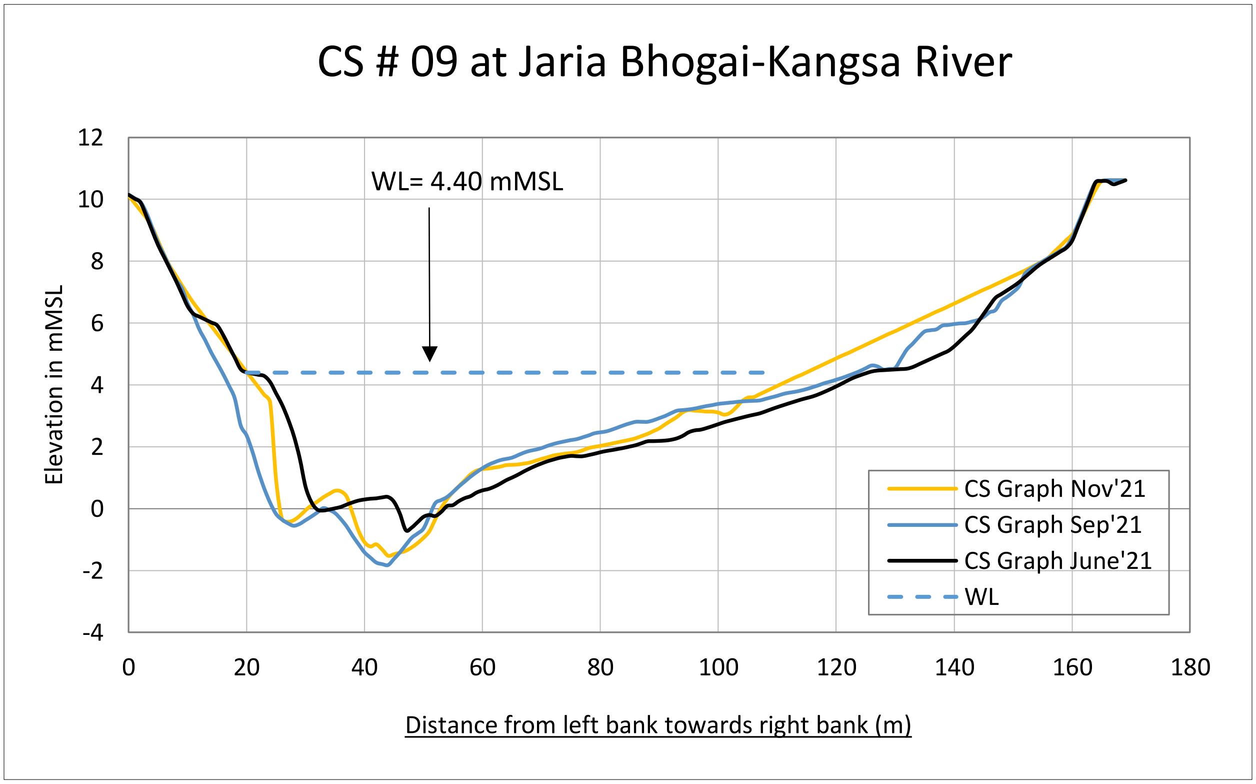
CS # 04 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'21
WL
12
10
8
6
4
2
0
-2
-7
13
33
53
73
93
113
133

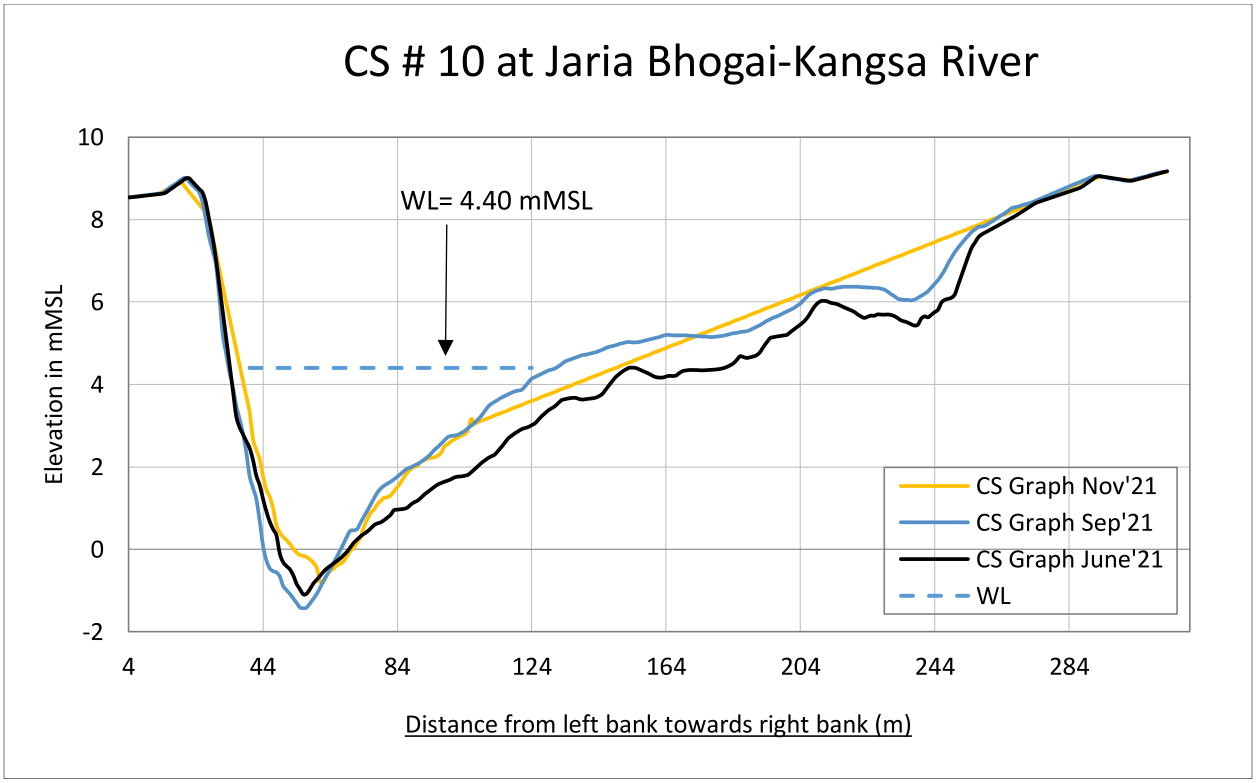

CS # 05 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
12
10
8
6
4
2
0
-6
14
34
54
74
94
114
134
154
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'21
WL

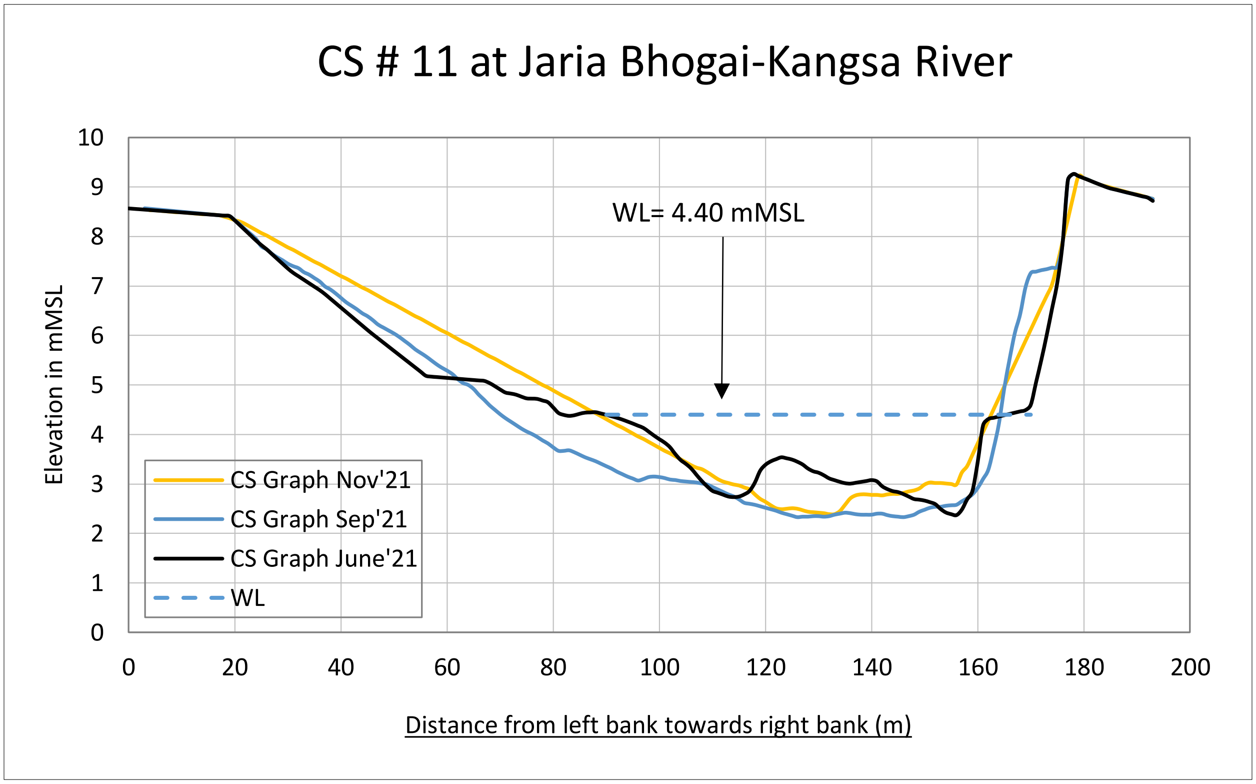

CS # 06 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
10
9
8
7
6
5
4
3
2
1
0
-23
17
57
97
137
177
217
257
297
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'21
WL

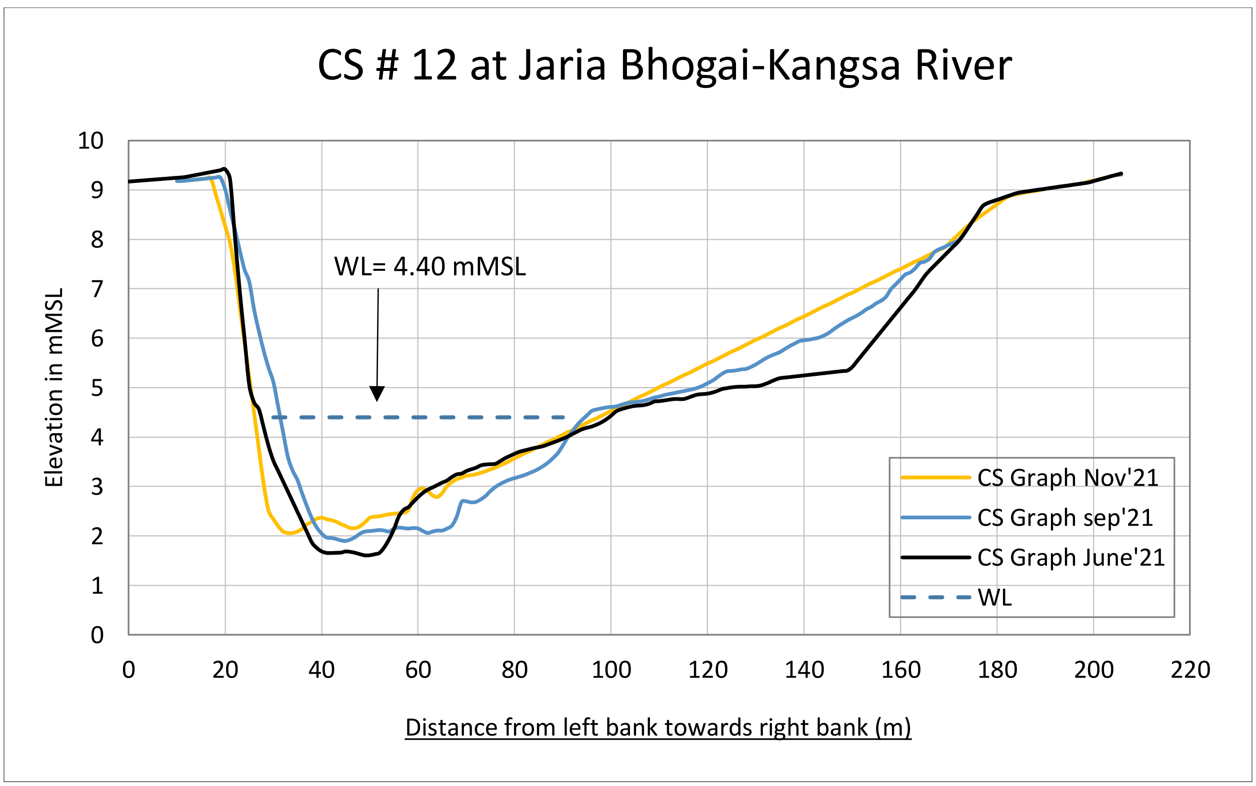

CS # 07 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
10
9
8
7
6
5
4
3
2
1
0
-12
28
68
108
148
188
228
268
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'21
WL

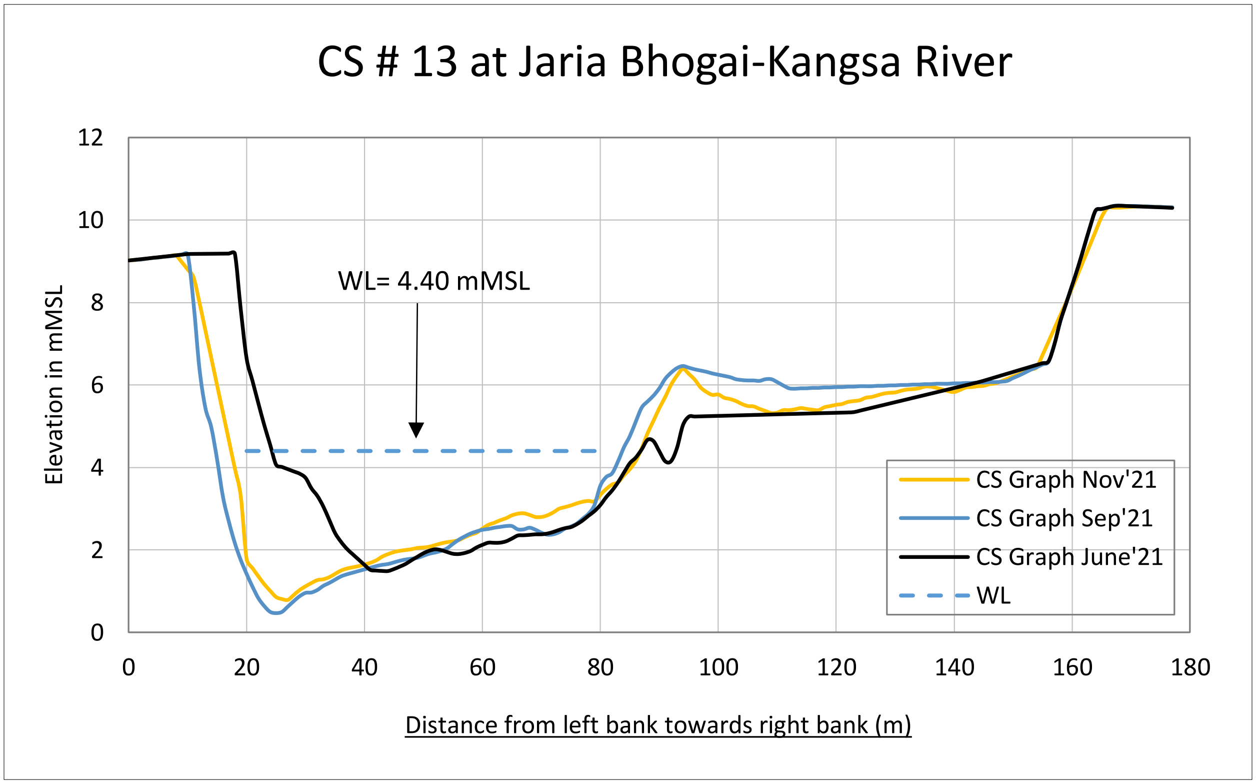

CS # 08 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
10
8
6
4
2
0
-2
-4
-45
-5
35
75
115
155
195
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'21
WL


CS # 09 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
12
10
8
6
4
2
0
-2
-4
0
20
40
60
80
100
120
140
160
180
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'21
WL
Distance from left bank towards right bank (m)

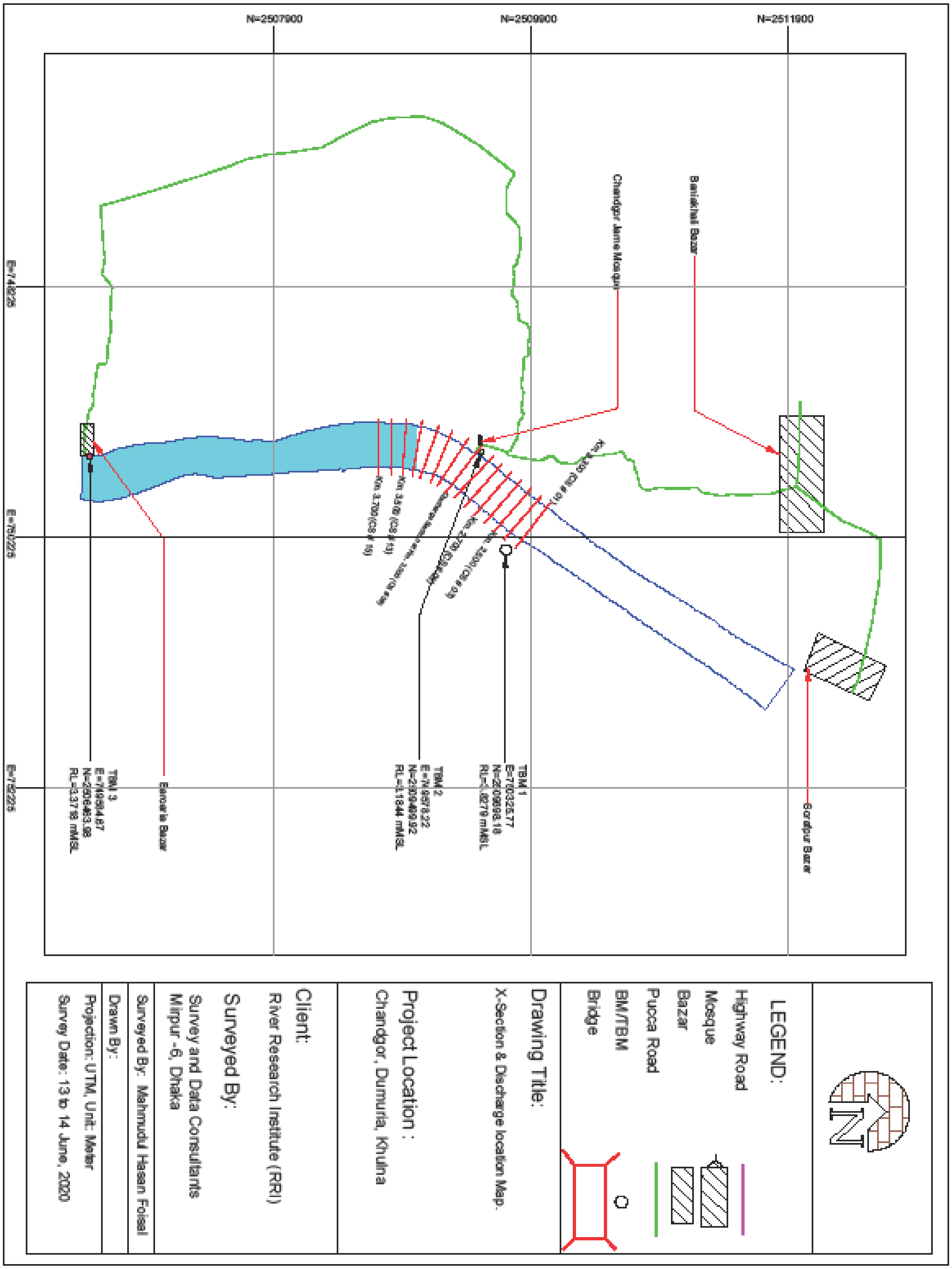

CS # 10 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
10
8
6
4
2
0
-2
4
44
84
124
164
204
244
284
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'21
WL
Distance from left bank towards right bank (m)

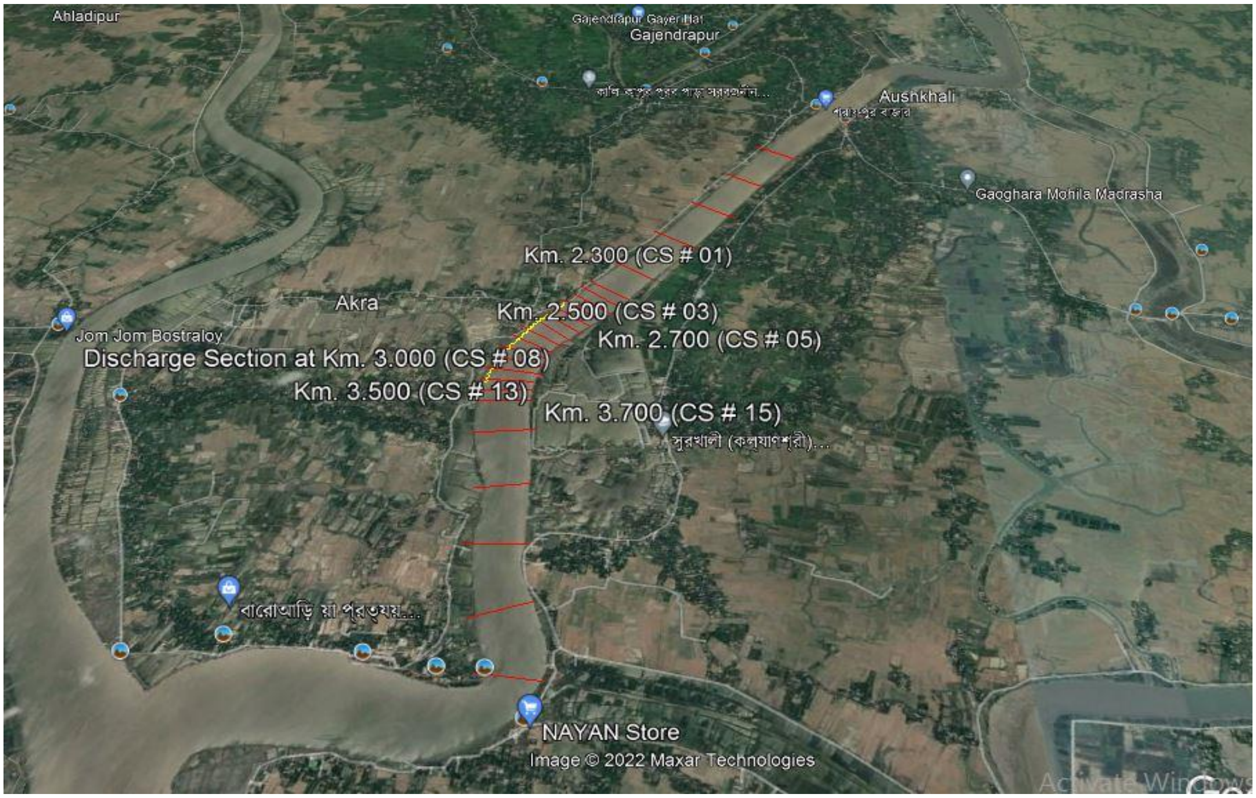

CS # 11 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'21
WL
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100
120
140
160
180
200

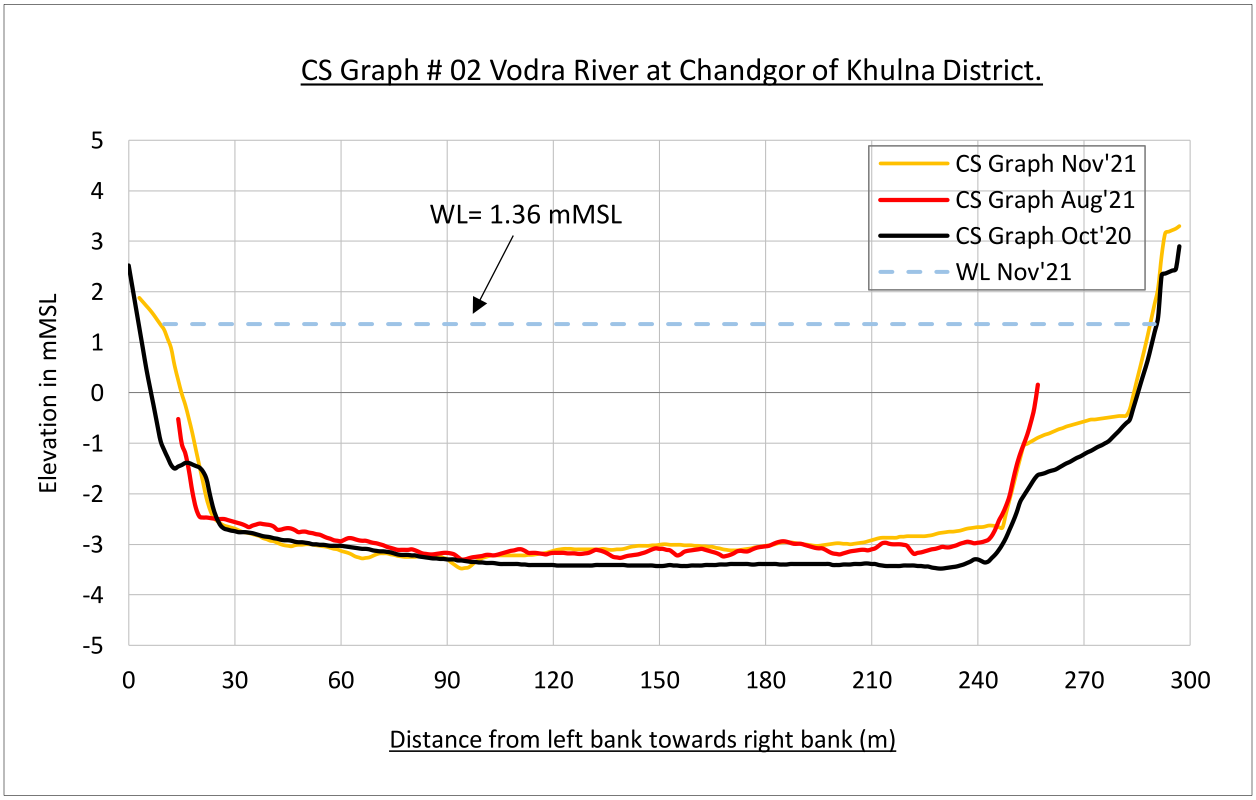

CS # 12 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph sep'21
CS Graph June'21
WL
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100
120
140
160
180
200
220

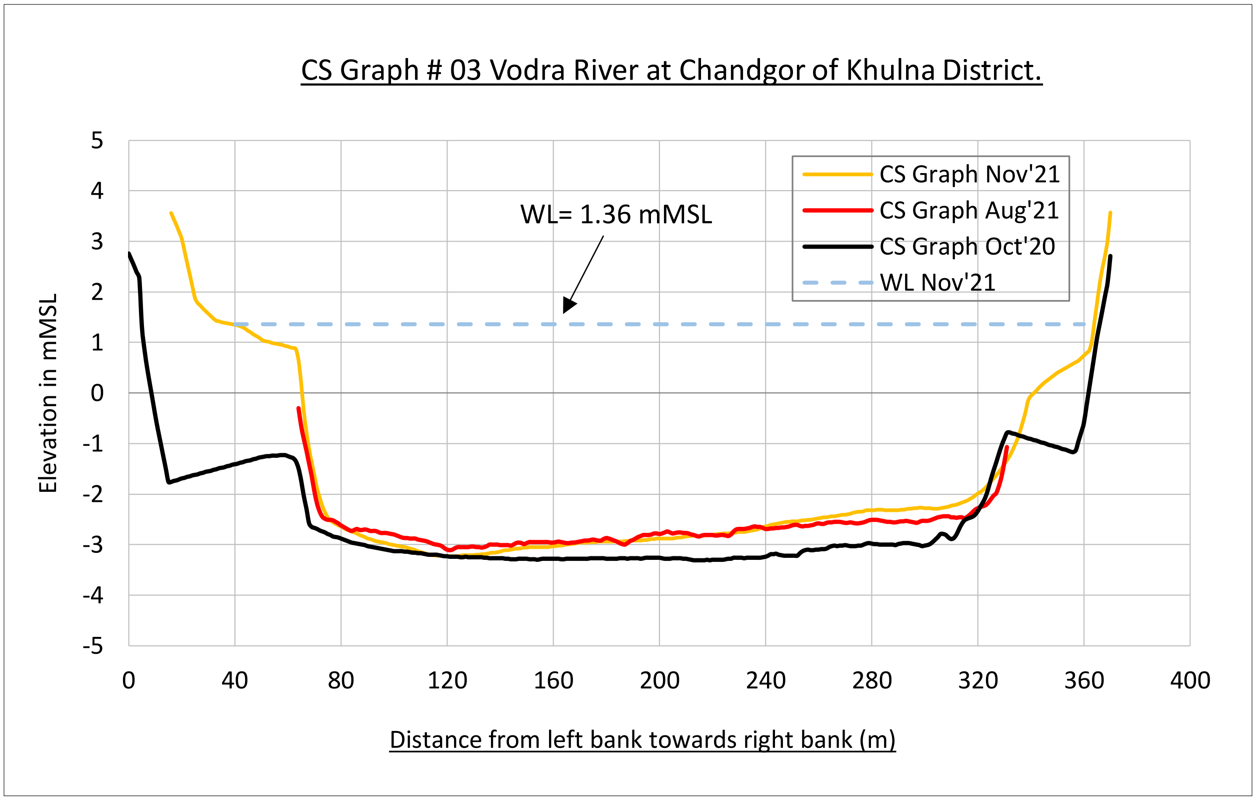


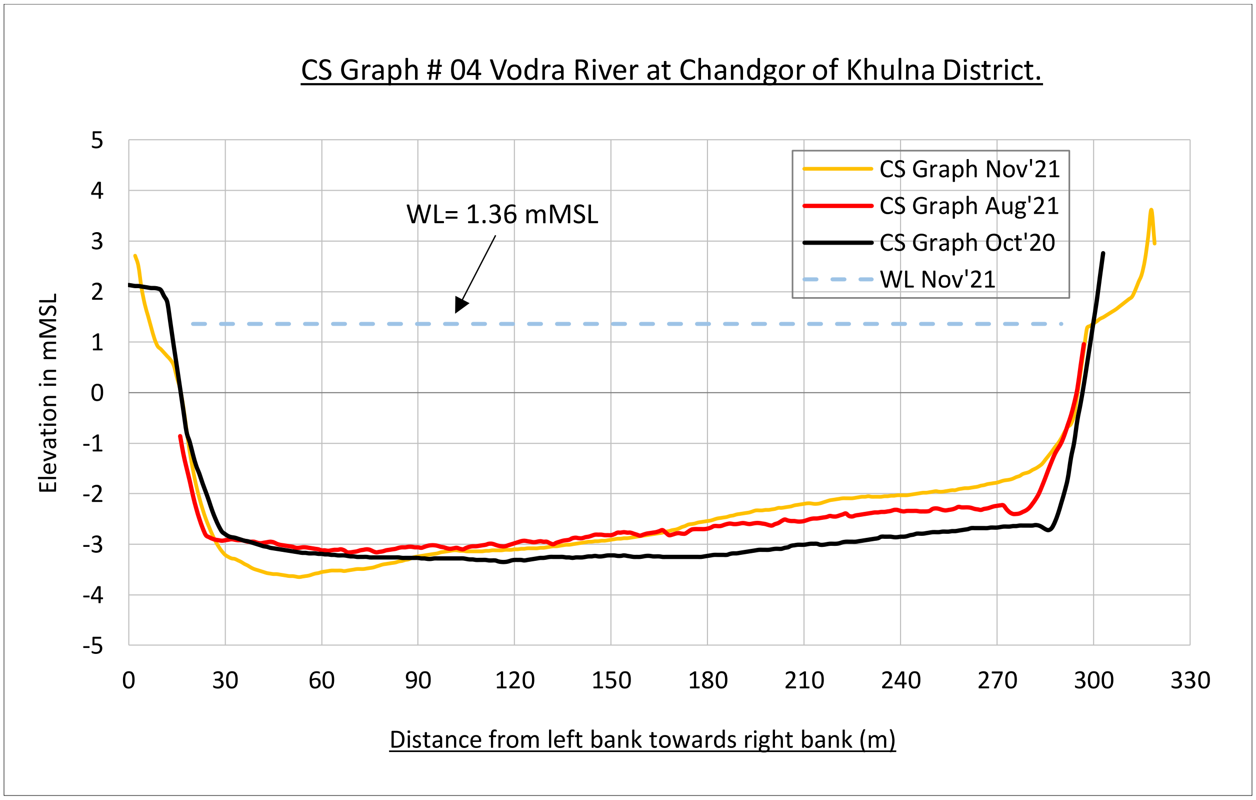
CS # 13 at Jaria Bhogai-Kangsa River
WL= 4.40 mMSL
Elevation in mMSL
Distance from left bank towards right bank (m)
CS Graph Nov'21
CS Graph Sep'21
CS Graph June'21
WL
0
2
4
6
8
10
12
0
20
40
60
80
100
120
140
160
180

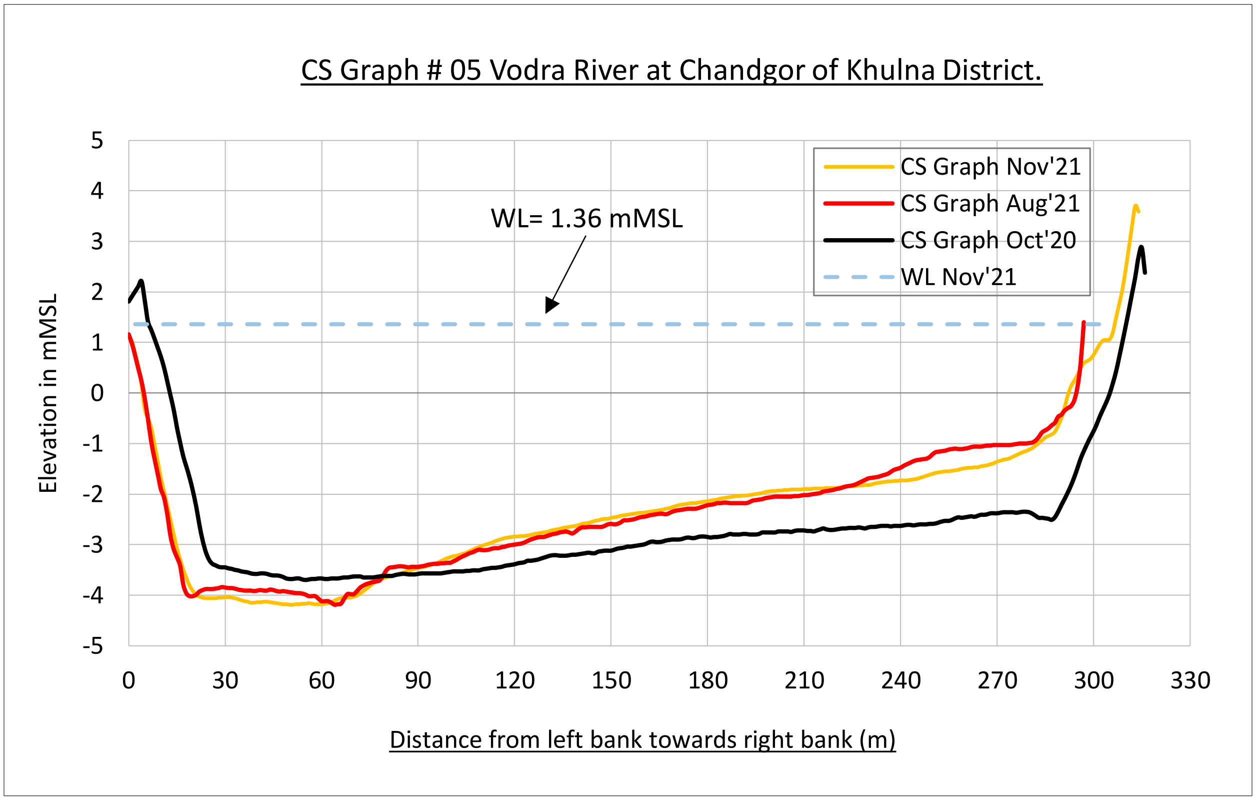

N=2507900
N=2509900
N=2511900
Chandgor Jame Mosque
LEGEND:
Highway Road
Mosque
Bazar
Pucca Road
BM/TBM
Bridge
Drawing Title:
X-Section & Discharge location Map.
Project Location :
Chandgor, Dumuria, Khulna
Client:
River Research Institute (RRI)
Surveyed By:
Survey and Data Consultants
Mirpur -6, Dhaka
Surveyed By: Mahmudul Hasan Foisal
Drawn By:
Projection: UTM, Unit: Meter
Survey Date: 13 to 14 June, 2020

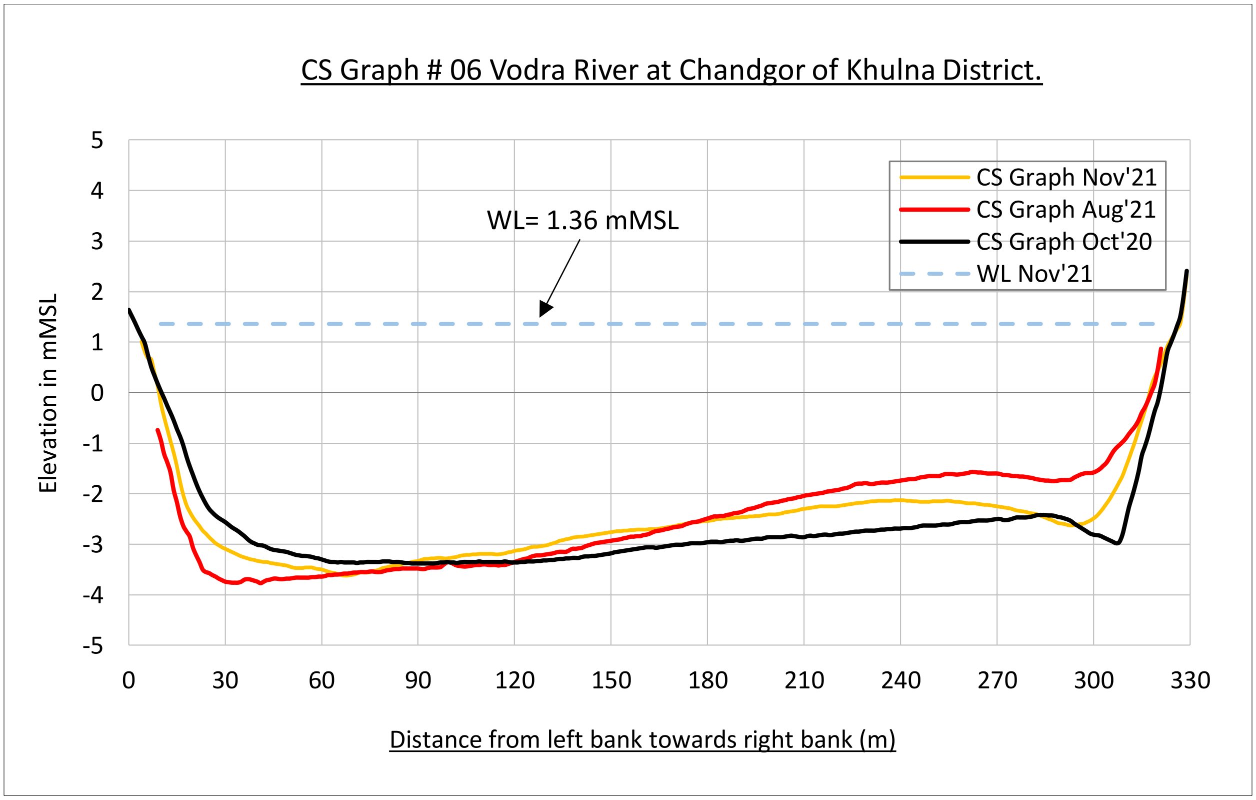

Ahladipur
Gajendrapur
Aushkhali
Gaoghara Mohila Madrasha
Km. 2.300 (CS # 01)
Akra
Km. 2.500 (CS # 03)
Km. 2.700 (CS # 05)
Jom Jom Bostraloy
Discharge Section at Km. 3.000 (CS # 08)
Km. 3.500 (CS # 13)
Km. 3.700 (CS # 15)
NAYAN Store
Image © 2022 Maxar Technologies

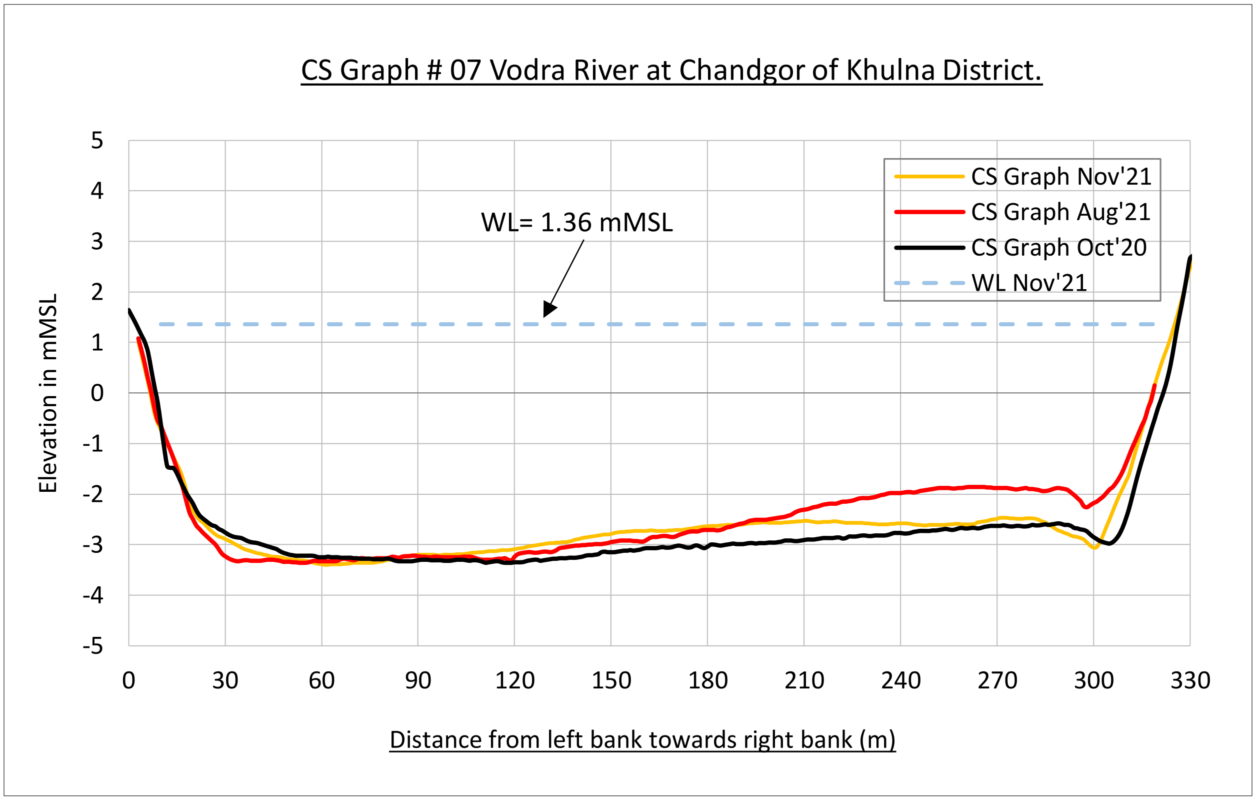

CS Graph # 02 Vodra River at Chandgor of Khulna District.
Elevation in mMSL
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
30
60
90
120
150
180
210
240
270
300
Distance from left bank towards right bank (m)
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21

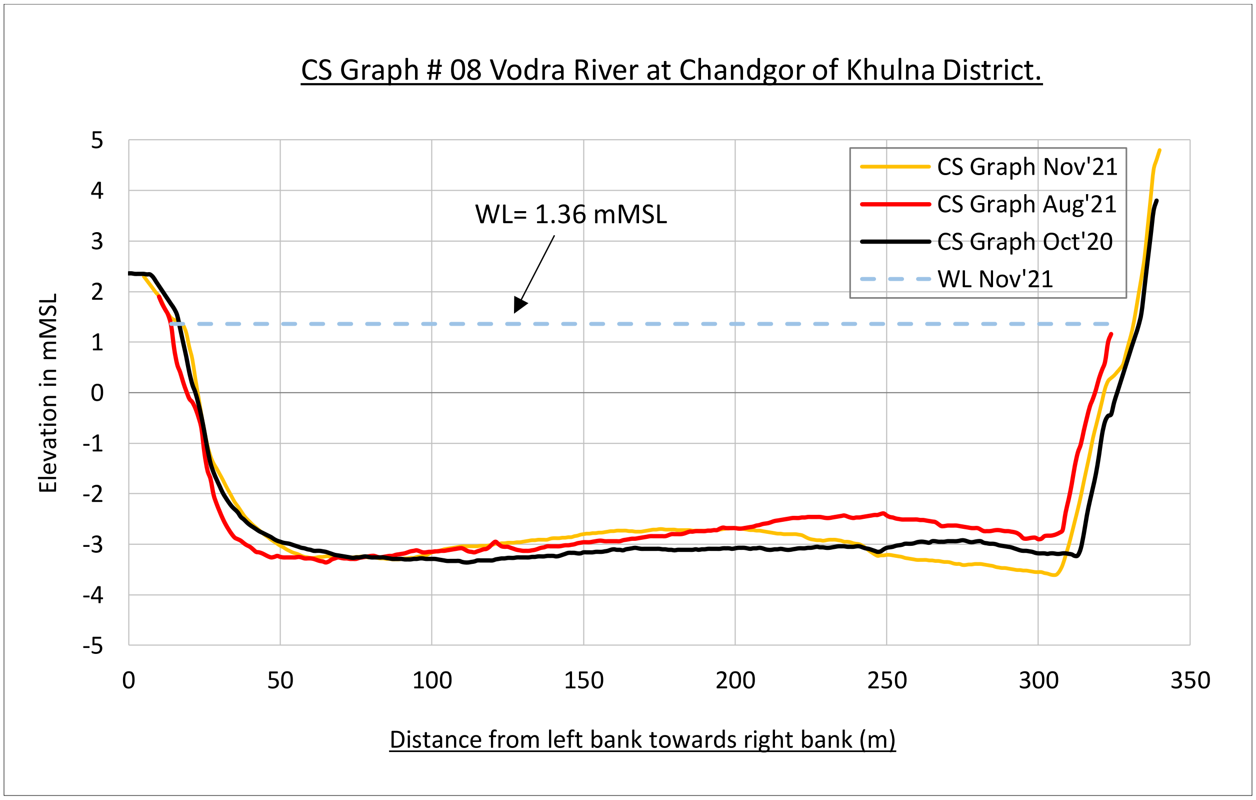

CS Graph # 03 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
Distance from left bank towards right bank (m)
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
40
80
120
160
200
240
280
320
360
400

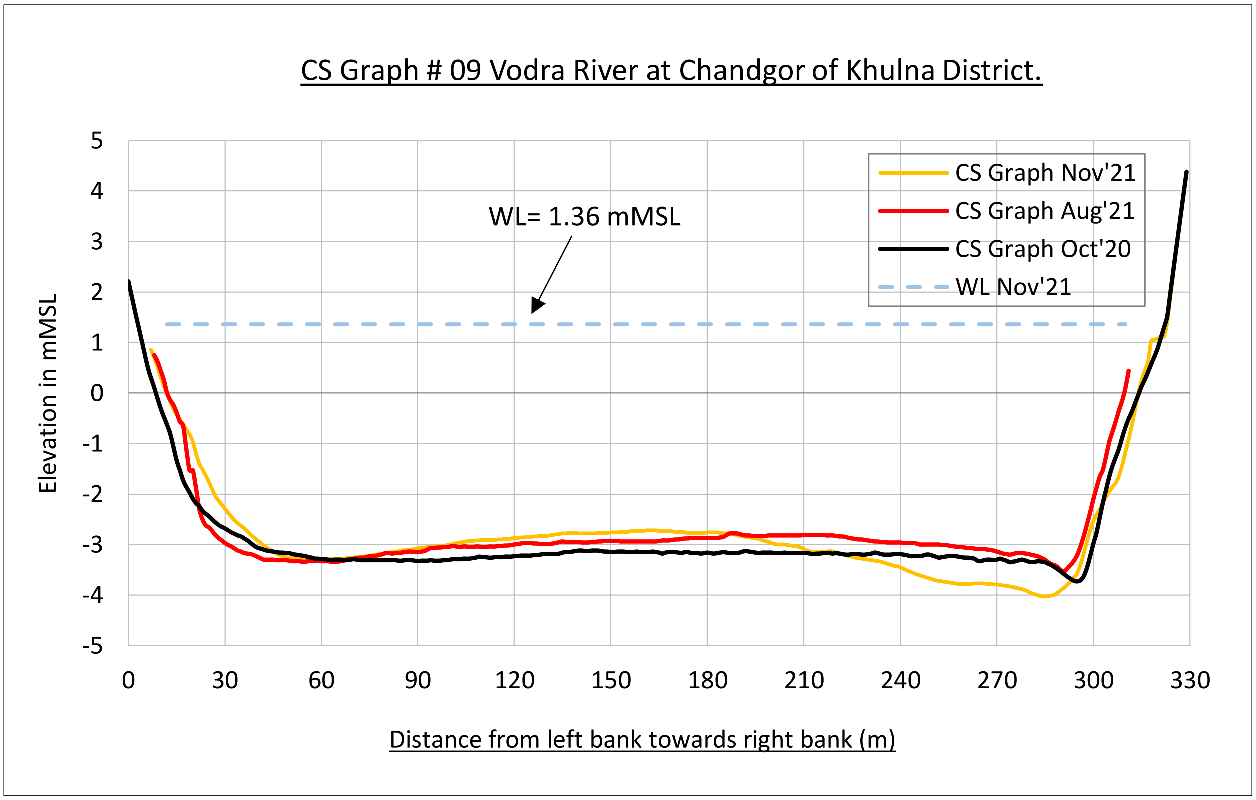

CS Graph # 04 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
Distance from left bank towards right bank (m)
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
30
60
90
120
150
180
210
240
270
300
330

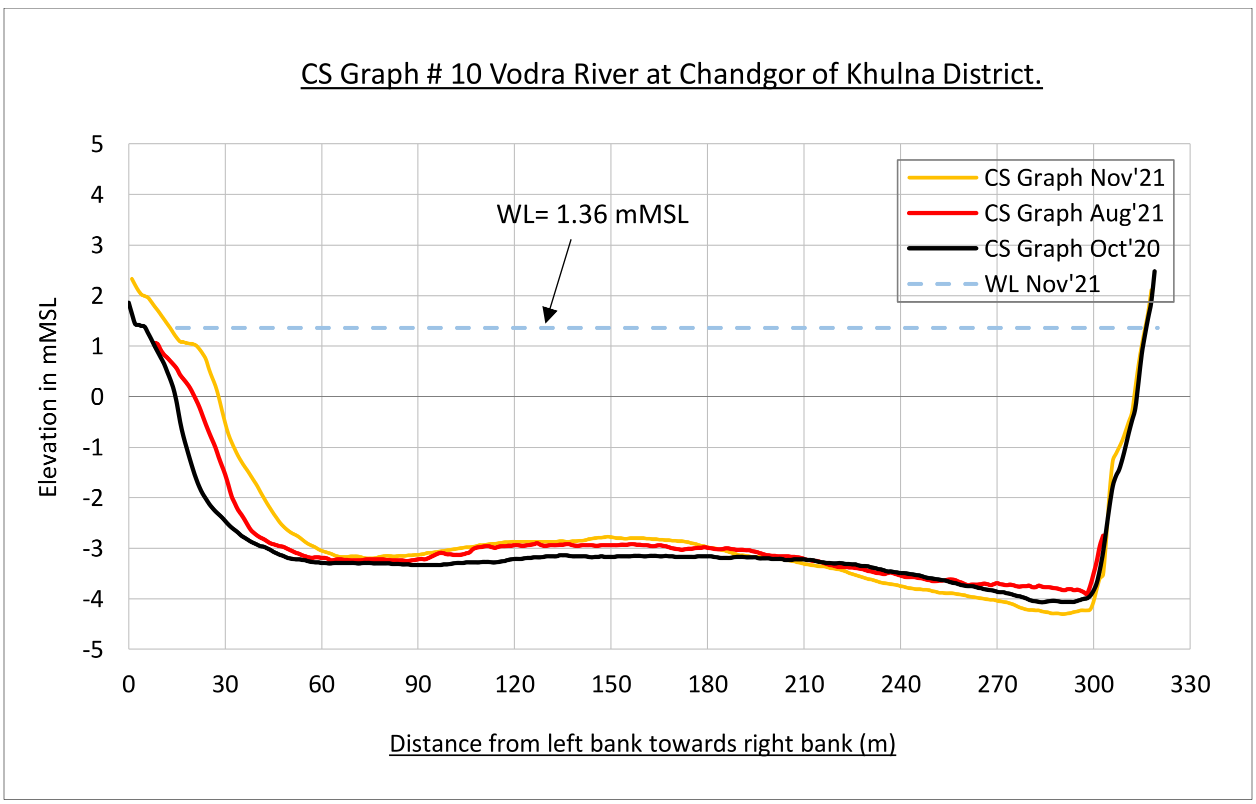

CS Graph # 05 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
30
60
90
120
150
180
210
240
270
300
330
Distance from left bank towards right bank (m)

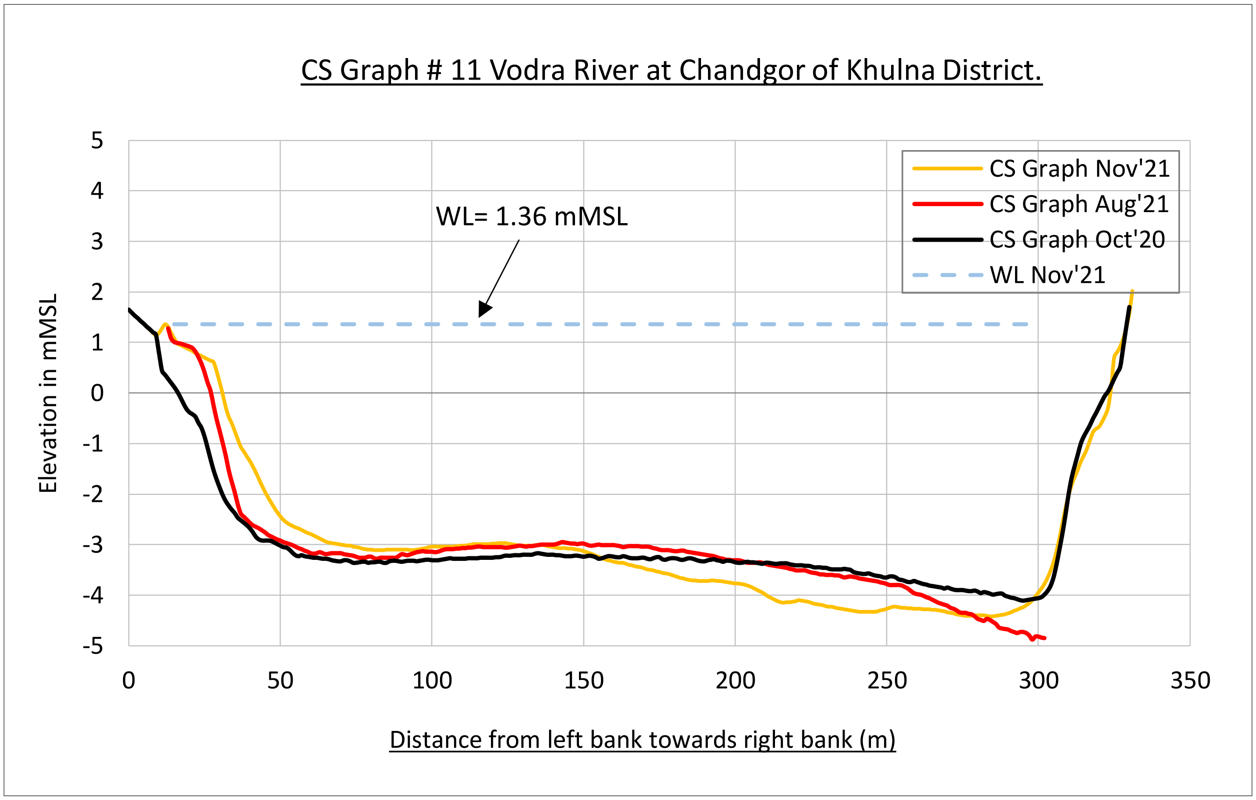

CS Graph # 06 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
30
60
90
120
150
180
210
240
270
300
330
Distance from left bank towards right bank (m)

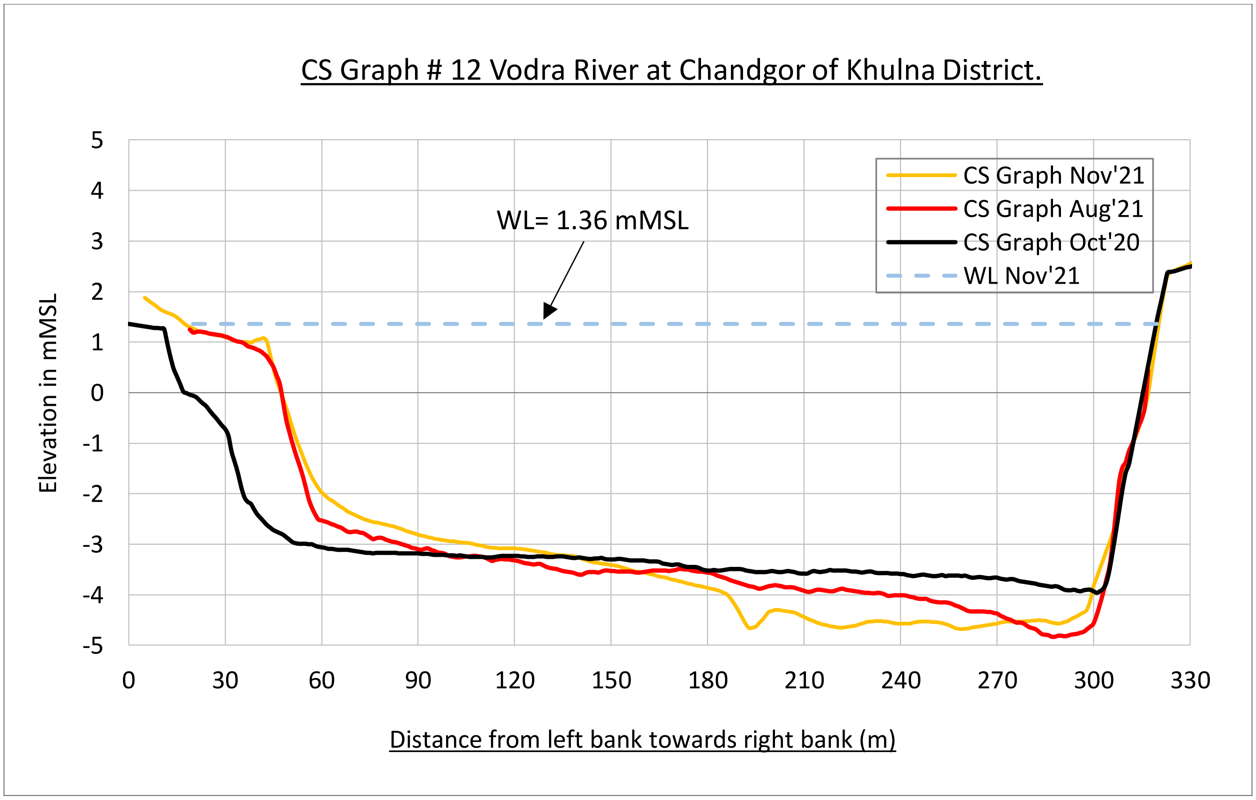

CS Graph # 07 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
30
60
90
120
150
180
210
240
270
300
330
Distance from left bank towards right bank (m)

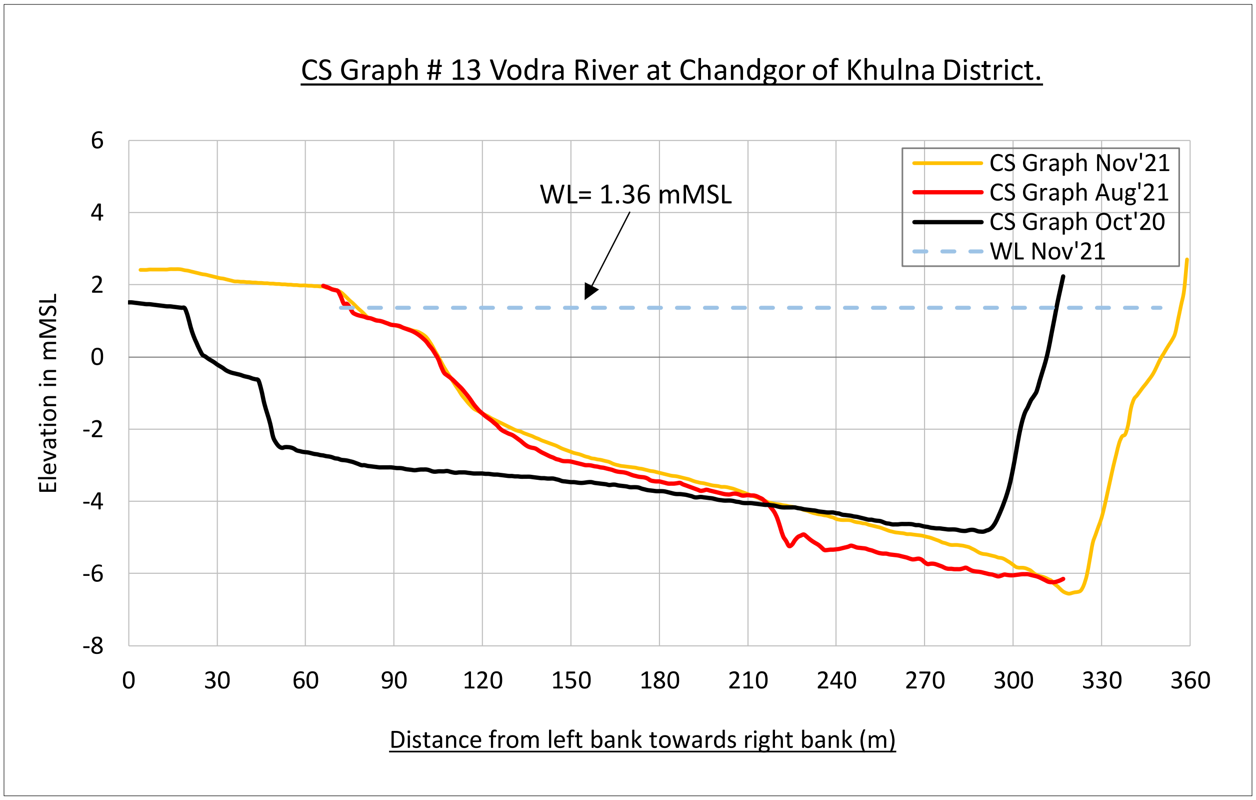

CS Graph # 08 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
50
100
150
200
250
300
350
Distance from left bank towards right bank (m)

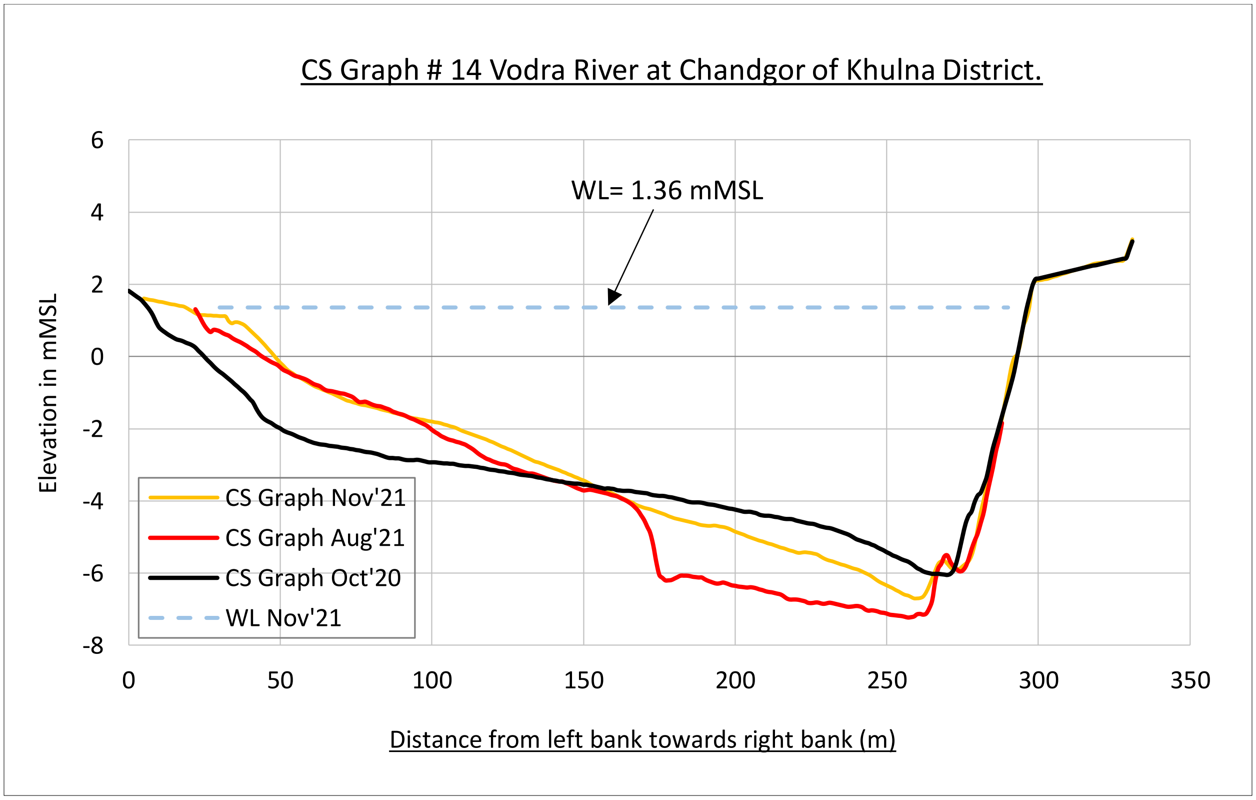

CS Graph # 09 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
30
60
90
120
150
180
210
240
270
300
330
Distance from left bank towards right bank (m)

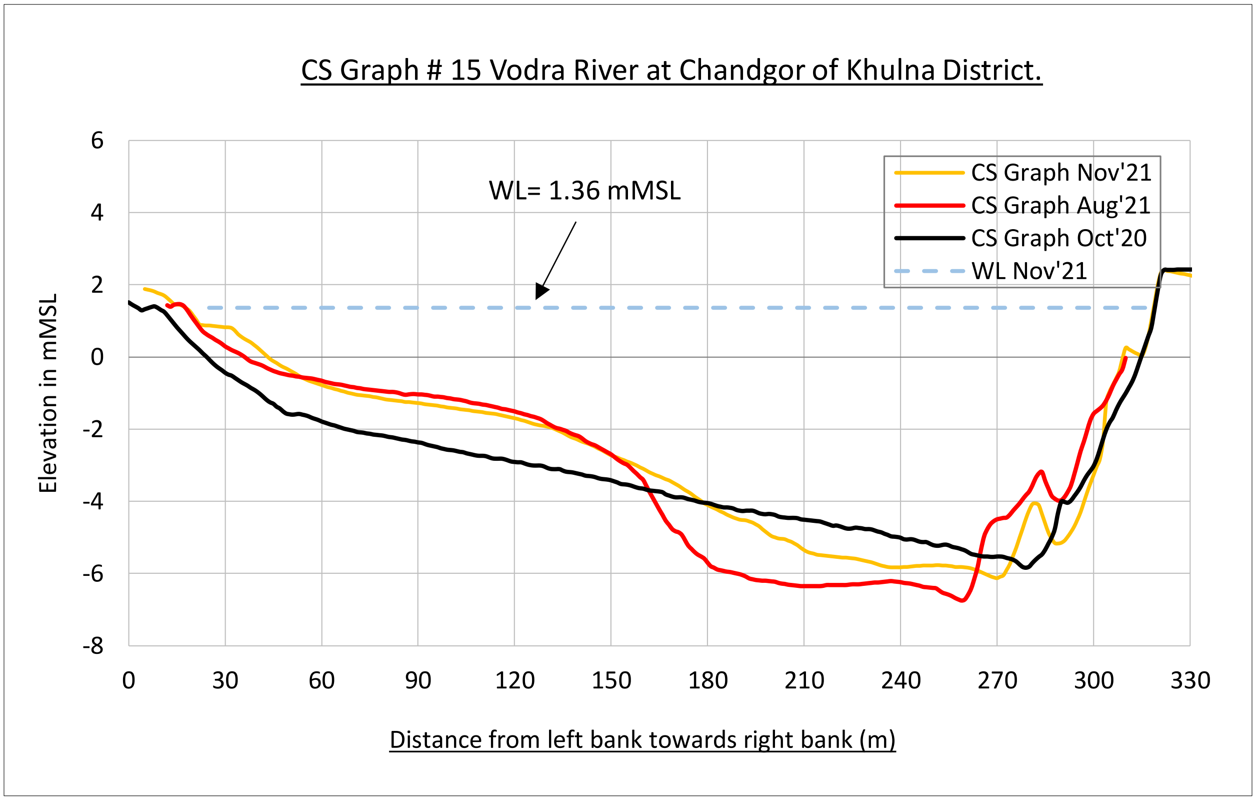

CS Graph # 10 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
30
60
90
120
150
180
210
240
270
300
330
Distance from left bank towards right bank (m)

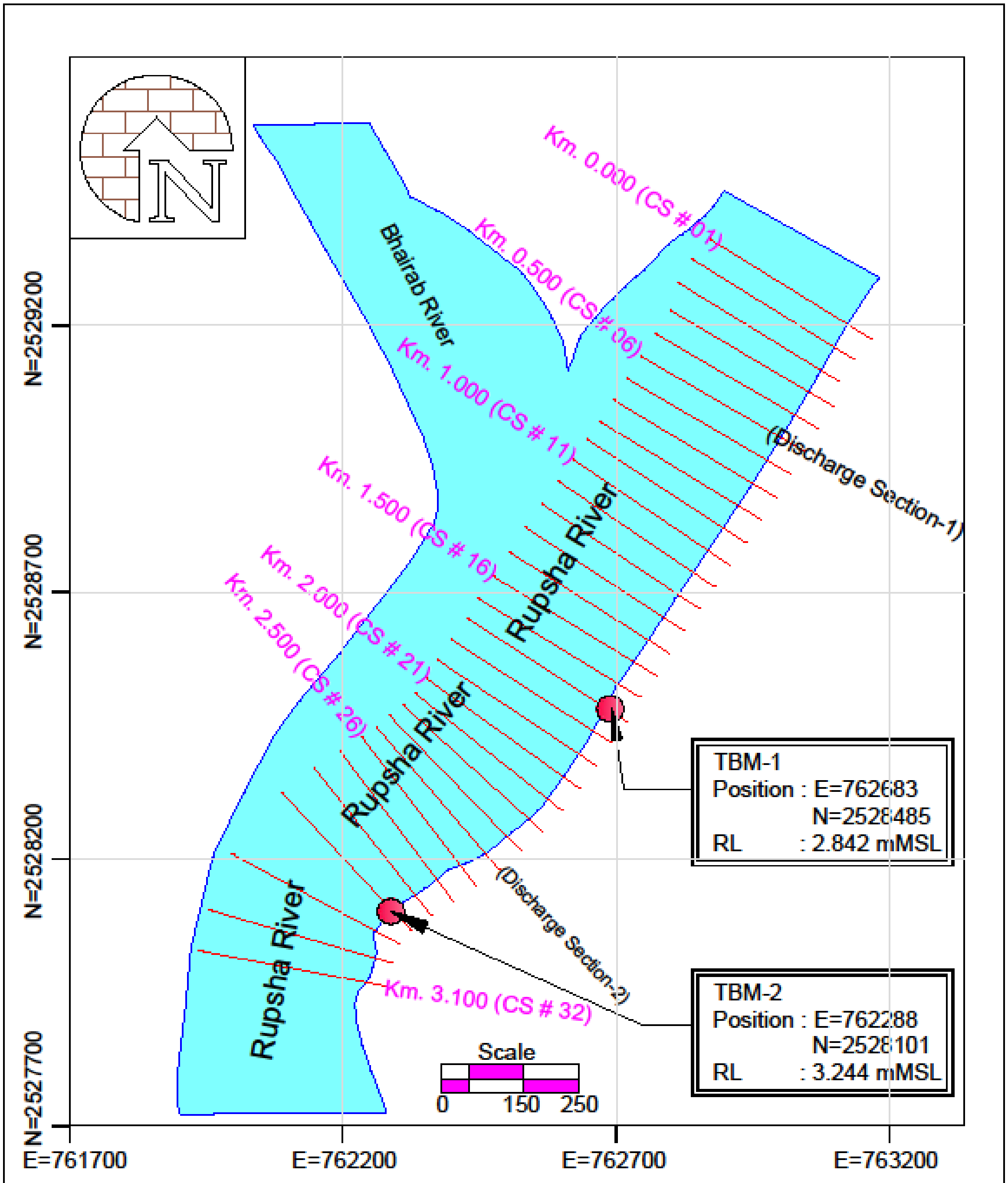

CS Graph # 11 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
50
100
150
200
250
300
350
Distance from left bank towards right bank (m)


CS Graph # 12 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
30
60
90
120
150
180
210
240
270
300
330
Distance from left bank towards right bank (m)

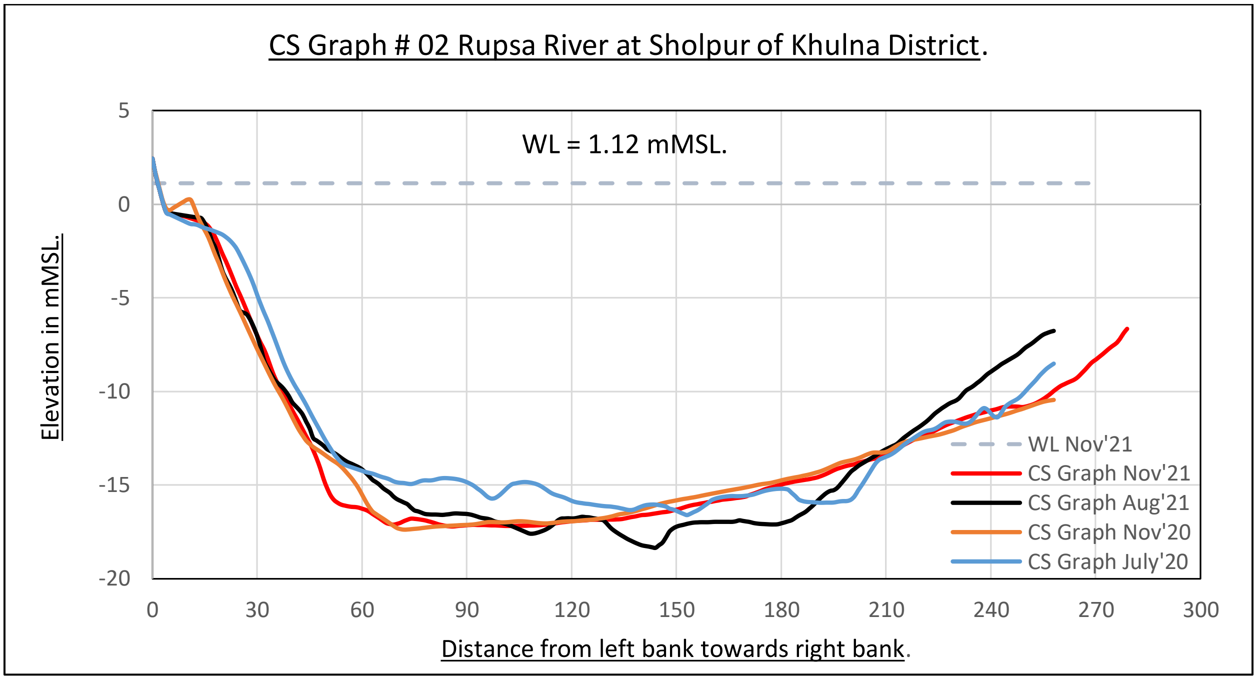

CS Graph # 13 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
6
4
2
0
-2
-4
-6
-8
0
30
60
90
120
150
180
210
240
270
300
330
360
Distance from left bank towards right bank (m)


CS Graph # 14 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
6
4
2
0
-2
-4
-6
-8
0
50
100
150
200
250
300
350
Distance from left bank towards right bank (m)

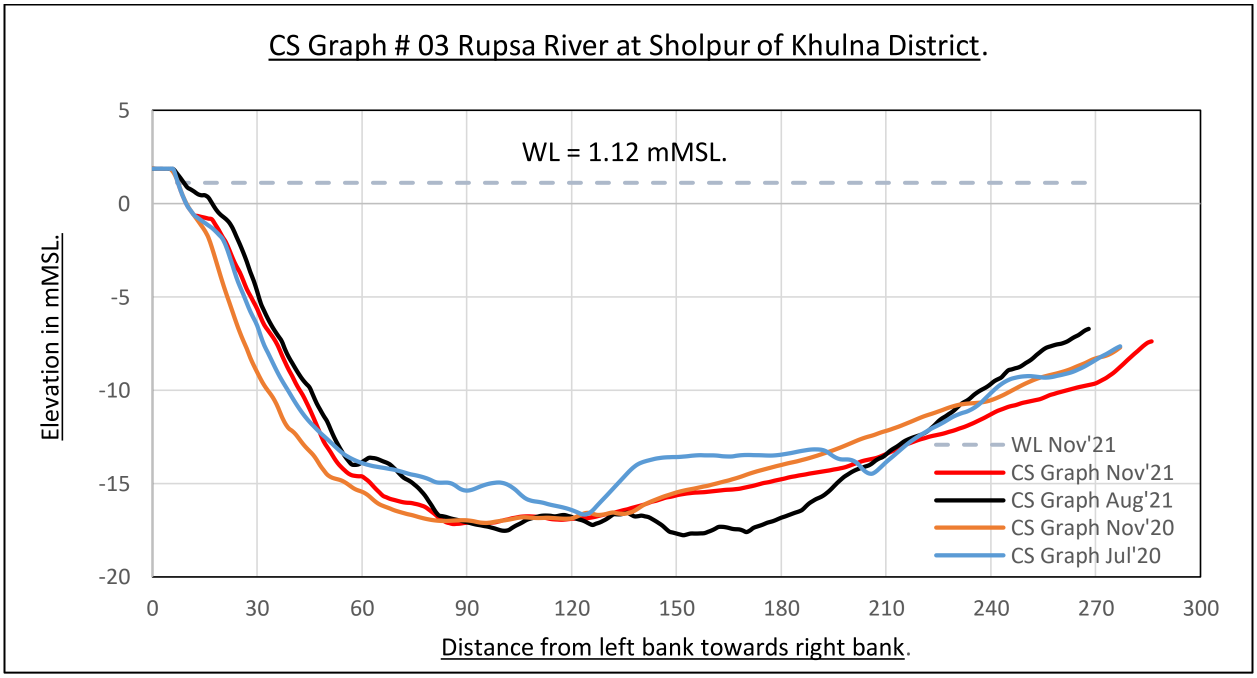

CS Graph # 15 Vodra River at Chandgor of Khulna District.
WL= 1.36 mMSL
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
WL Nov'21
Elevation in mMSL
6
4
2
0
-2
-4
-6
-8
0
30
60
90
120
150
180
210
240
270
300
330
Distance from left bank towards right bank (m)



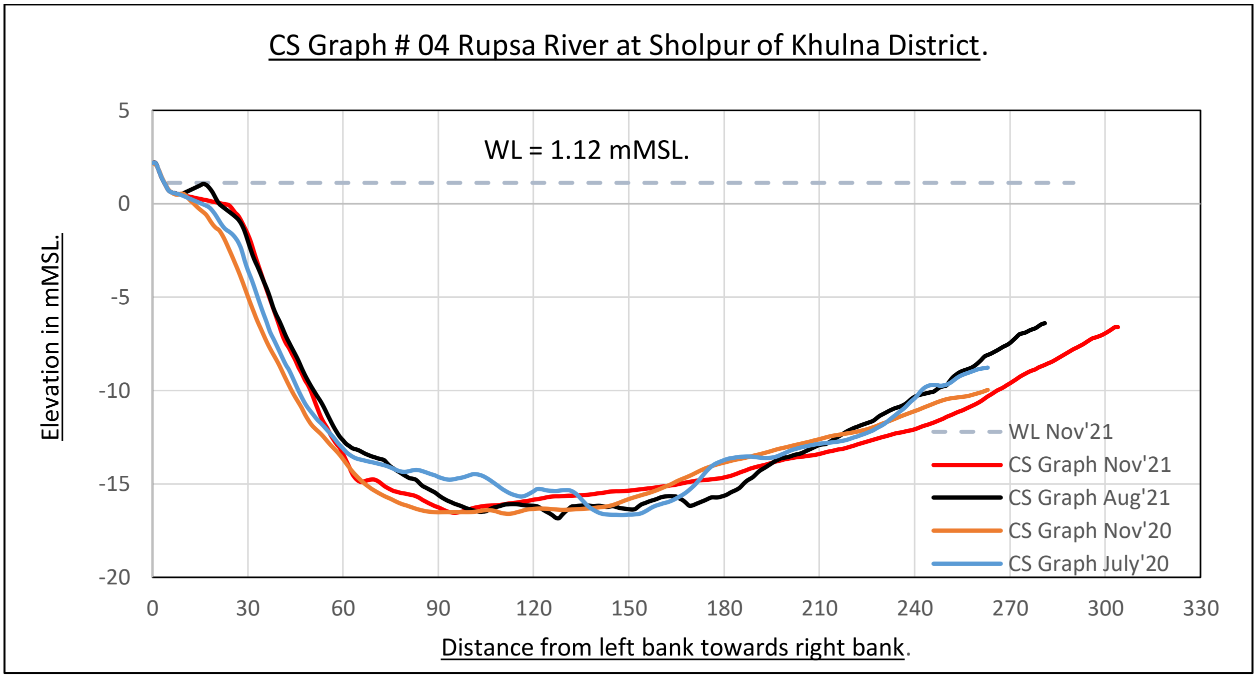
Drawing Title:	Client:	LEGEND:
X-Section & Discharge Location Map	River Research Institute (RRI)	X-Section
Project Location :	Surveyed By:	TBM
Sholpur, Rupsha, Khulna	Survey and Data Consultants Mirpur -6, Dhaka	River Bank



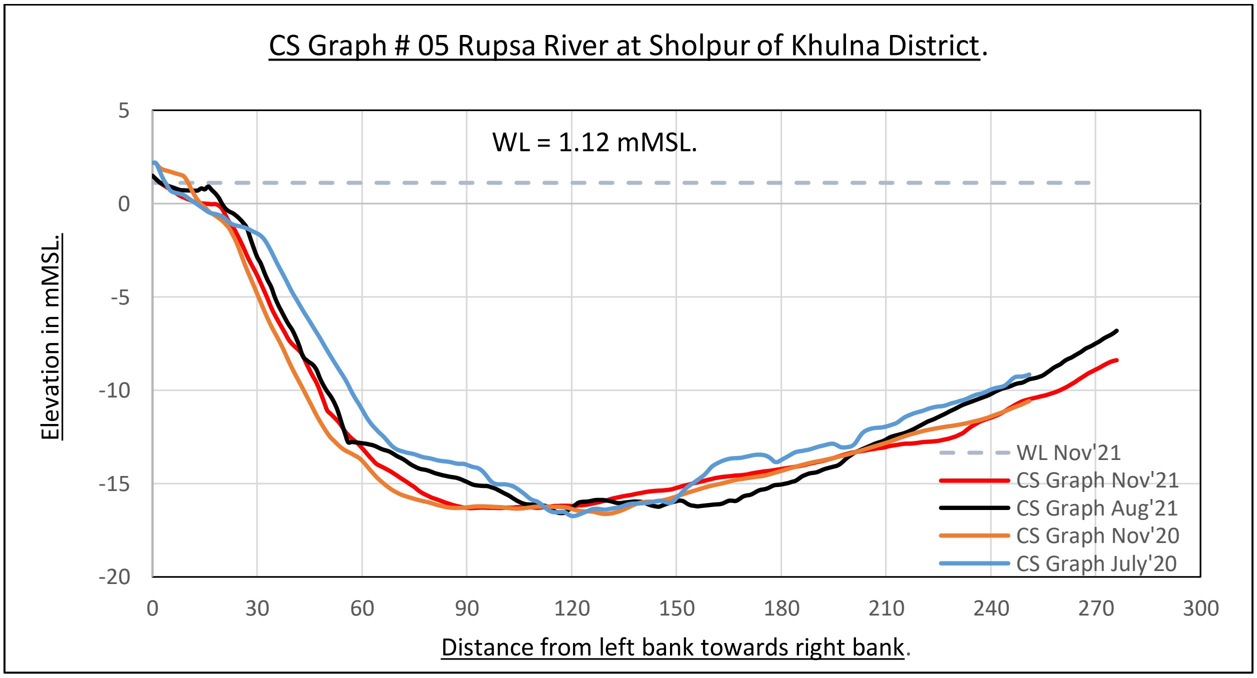
CS Graph # 02 Rupsa River at Sholpur of Khulna District.
WL = 1.12 mMSL.
Elevation in mMSL.
5
0
-5
-10
-15
-20
0
30
60
90
120
150
180
210
240
270
300
Distance from left bank towards right bank.
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph July'20



CS Graph # 03 Rupsa River at Sholpur of Khulna District.
WL = 1.12 mMSL.
Elevation in mMSL.
5
0
-5
-10
-15
-20
0
30
60
90
120
150
180
210
240
270
300
Distance from left bank towards right bank.
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph Jul'20

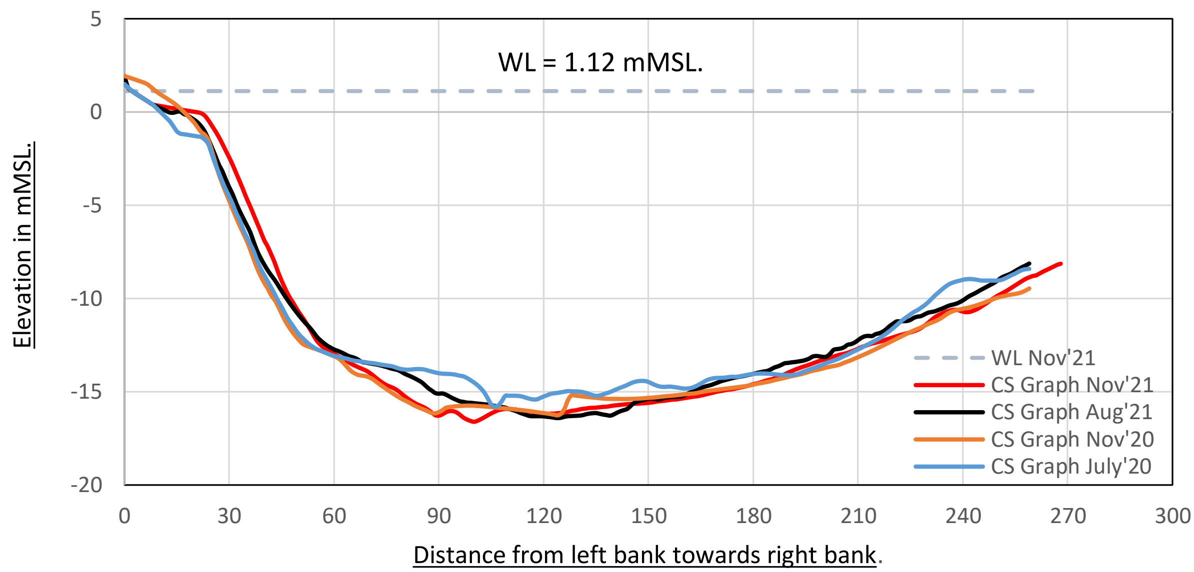


CS Graph # 04 Rupsa River at Sholpur of Khulna District.
WL = 1.12 mMSL.
5
0
-5
-10
-15
-20
0
30
60
90
120
150
180
210
240
270
300
330
Elevation in mMSL.
Distance from left bank towards right bank.
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph July'20

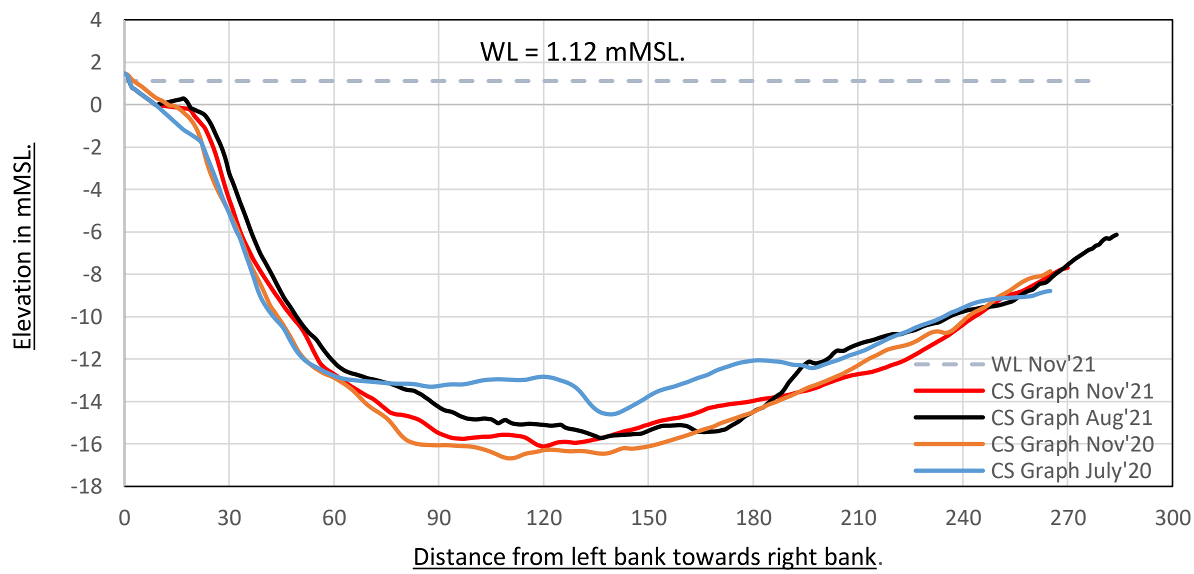


CS Graph # 05 Rupsa River at Sholpur of Khulna District.
WL = 1.12 mMSL.
5
0
-5
-10
-15
-20
0
30
60
90
120
150
180
210
240
270
300
Elevation in mMSL.
Distance from left bank towards right bank.
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph July'20

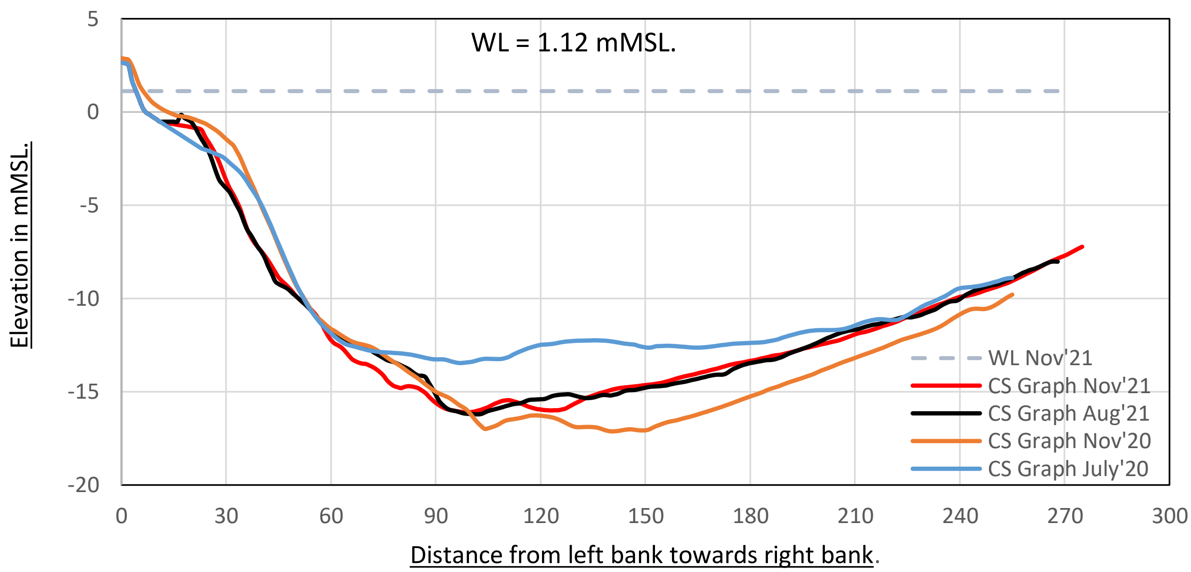
CS Graph # 06 Rupsa River at Sholpur of Khulna District.



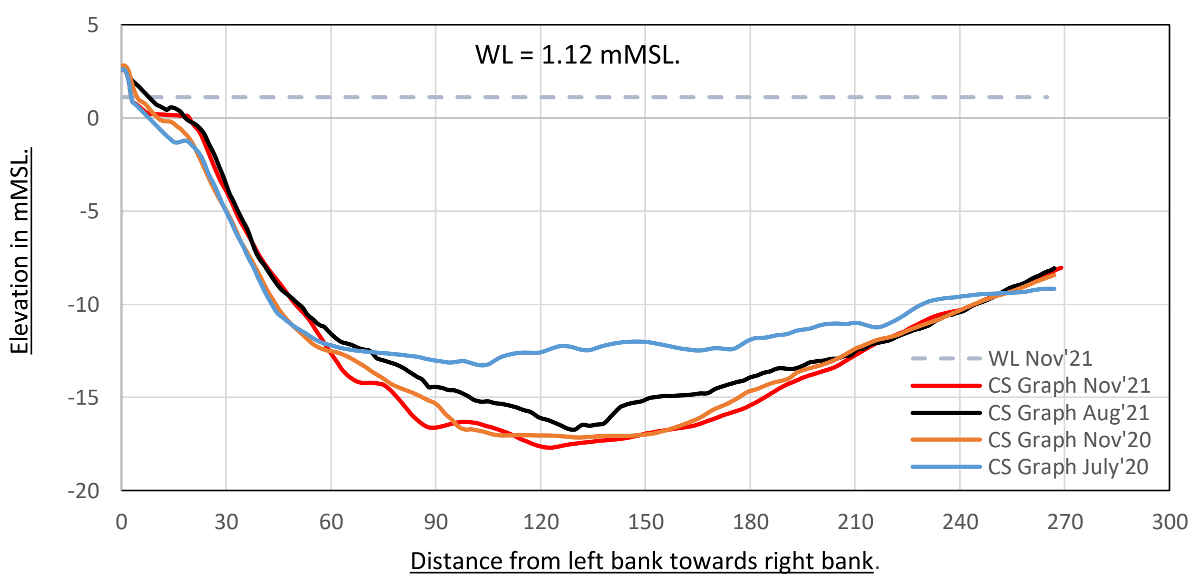
CS Graph # 07 Rupsa River at Sholpur of Khulna District.

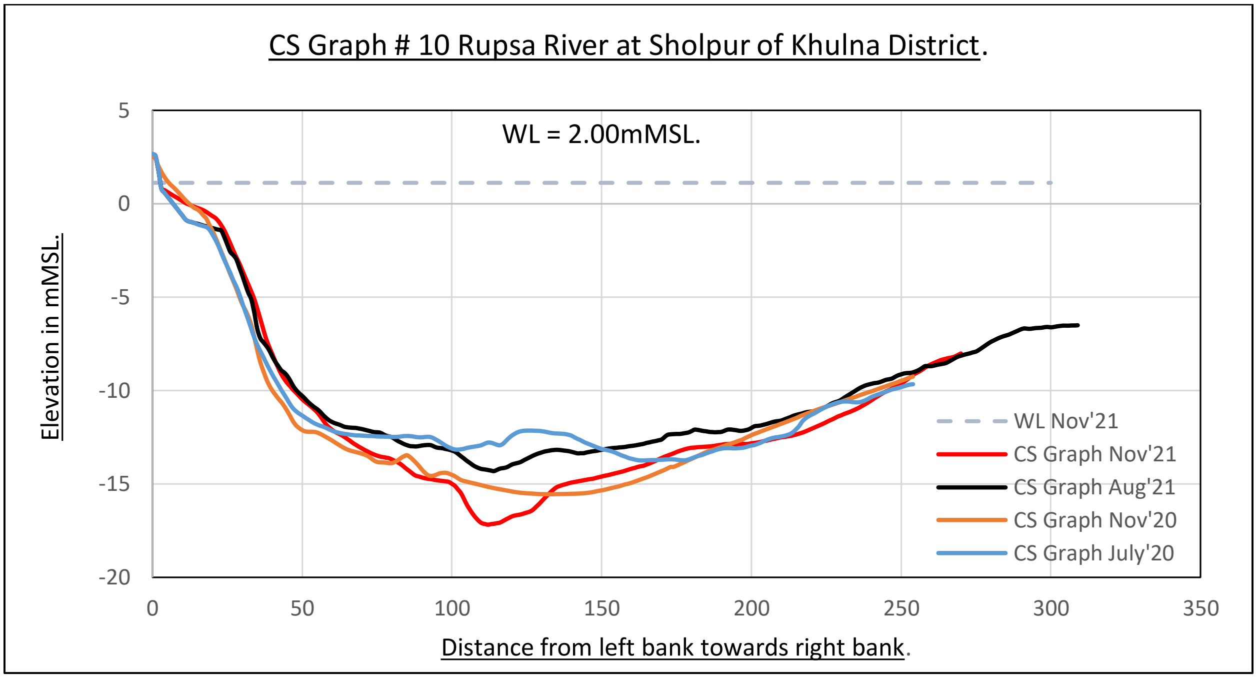


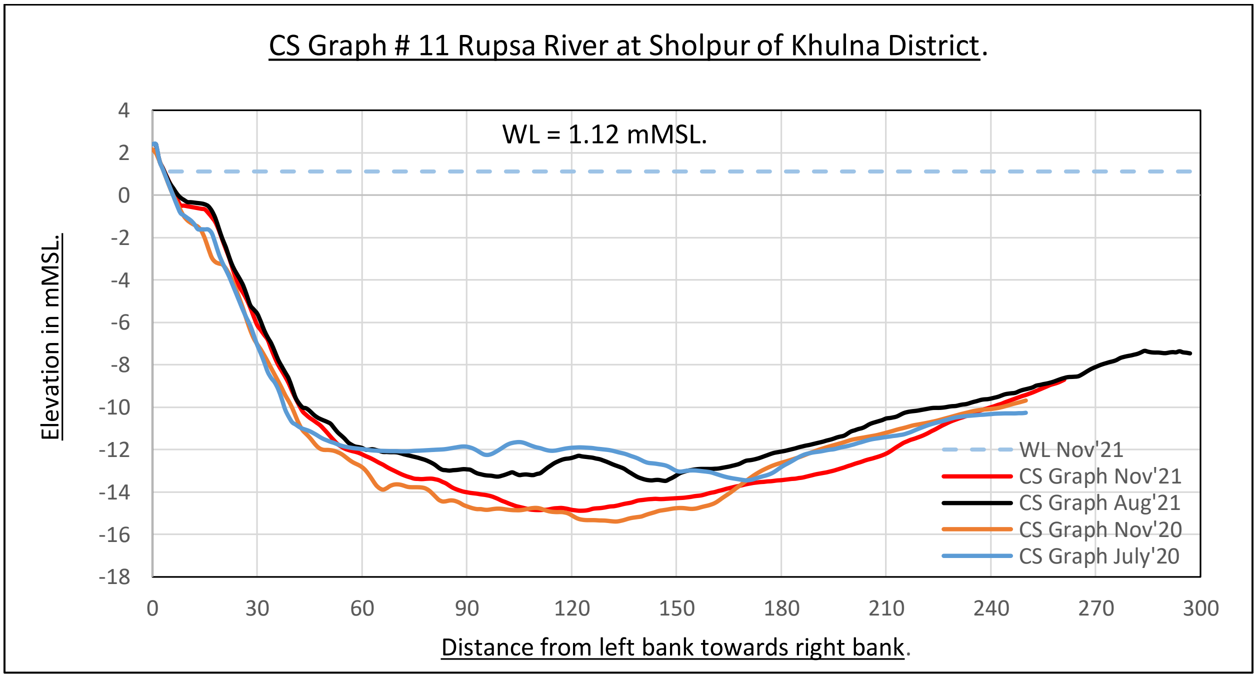
CS Graph # 08 Rupsa River at Sholpur of Khulna District.

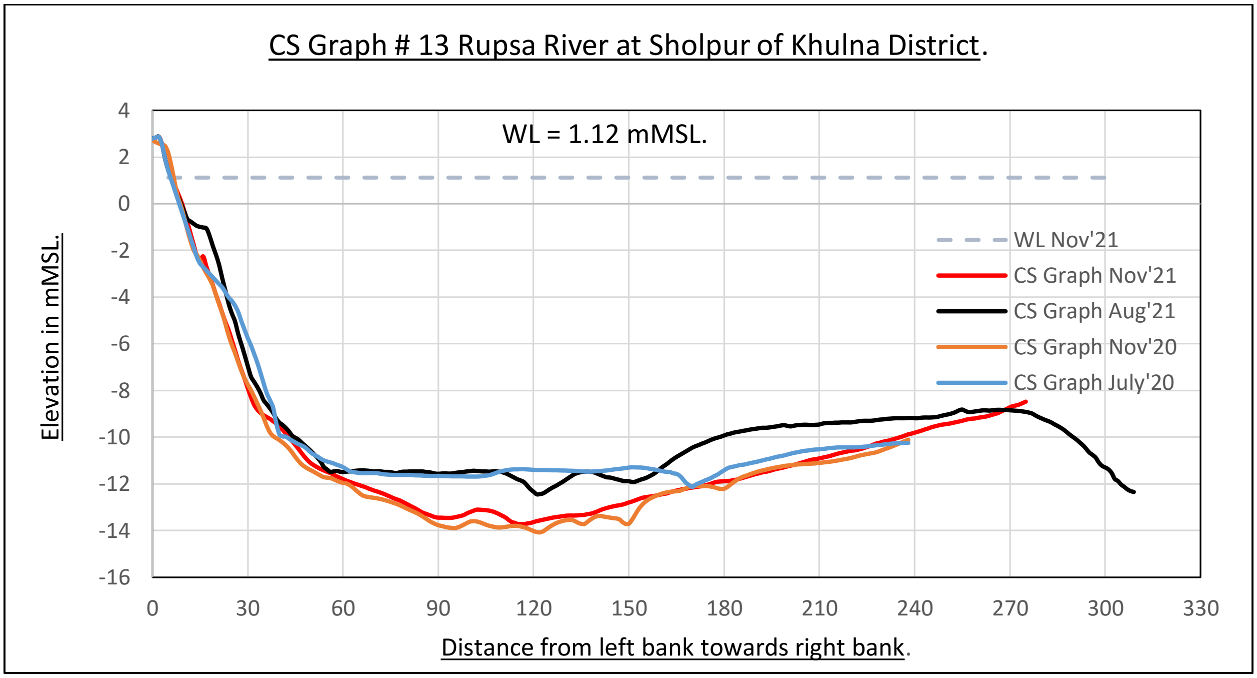


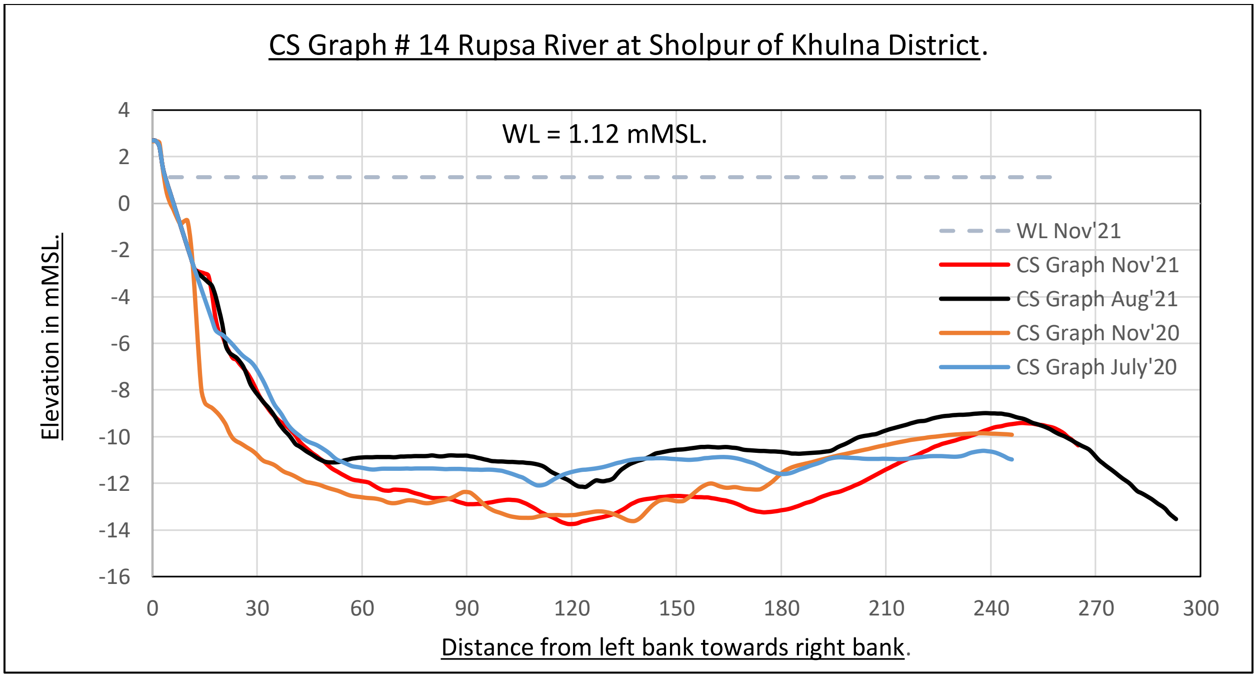
CS Graph # 09 Rupsa River at Sholpur of Khulna District.

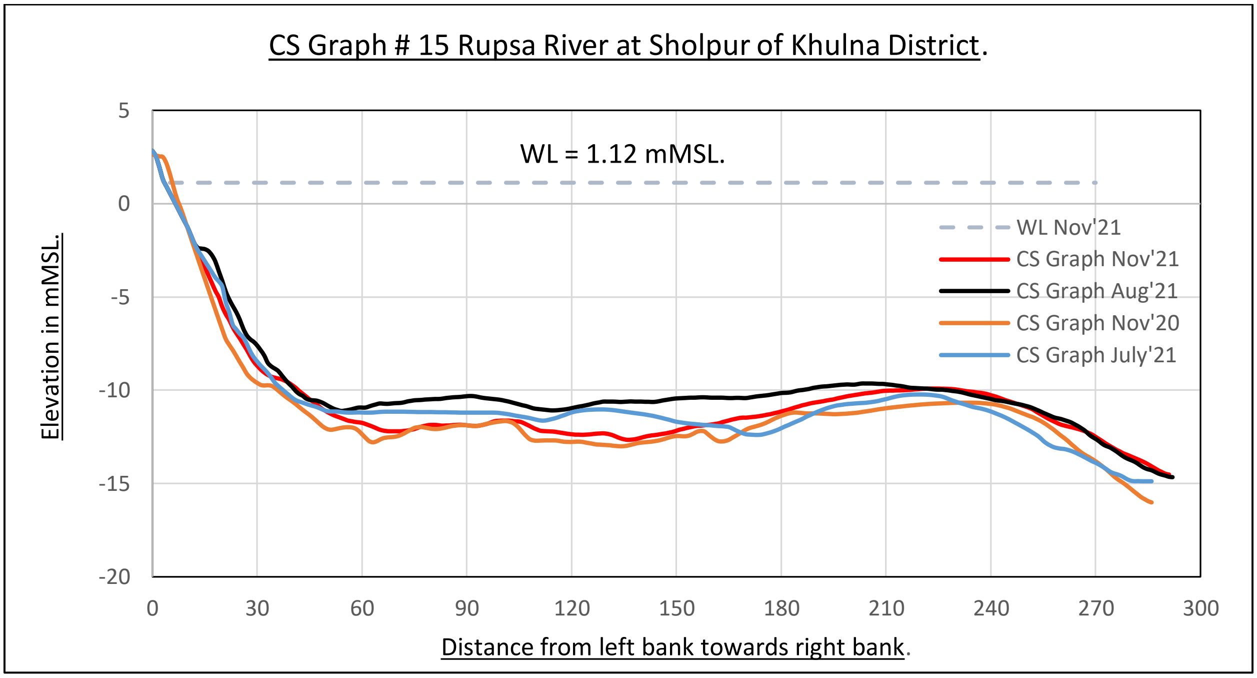



CS Graph # 10 Rupsa River at Sholpur of Khulna District.
WL = 2.00mMSL.
Elevation in mMSL.
5
0
-5
-10
-15
-20
0
50
100
150
200
250
300
350
Distance from left bank towards right bank.
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph July'20

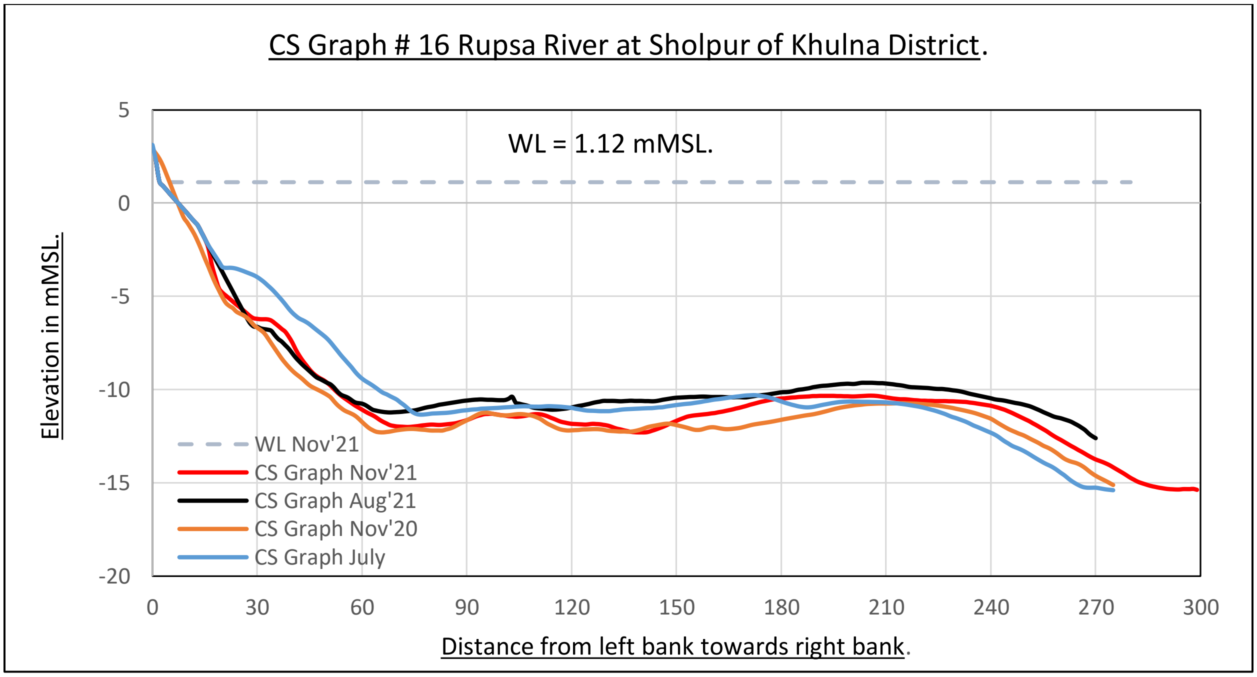

CS Graph # 11 Rupsa River at Sholpur of Khulna District.
WL = 1.12 mMSL.
Elevation in mMSL.
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
30
60
90
120
150
180
210
240
270
300
Distance from left bank towards right bank.
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph July'20


CS Graph # 13 Rupsa River at Sholpur of Khulna District.
WL = 1.12 mMSL.
Elevation in mMSL.
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
0
30
60
90
120
150
180
210
240
270
300
330
Distance from left bank towards right bank.
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph July'20

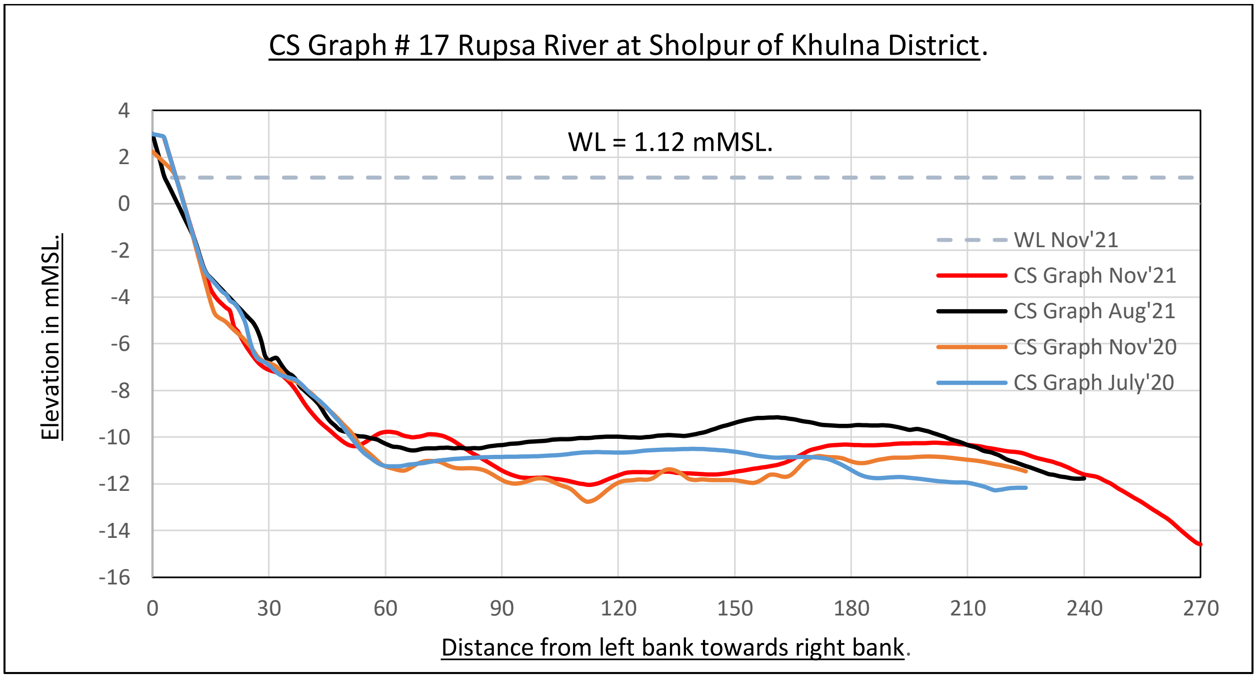

CS Graph # 14 Rupsa River at Sholpur of Khulna District.
WL = 1.12 mMSL.
Elevation in mMSL.
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
0
30
60
90
120
150
180
210
240
270
300
Distance from left bank towards right bank.
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph July'20



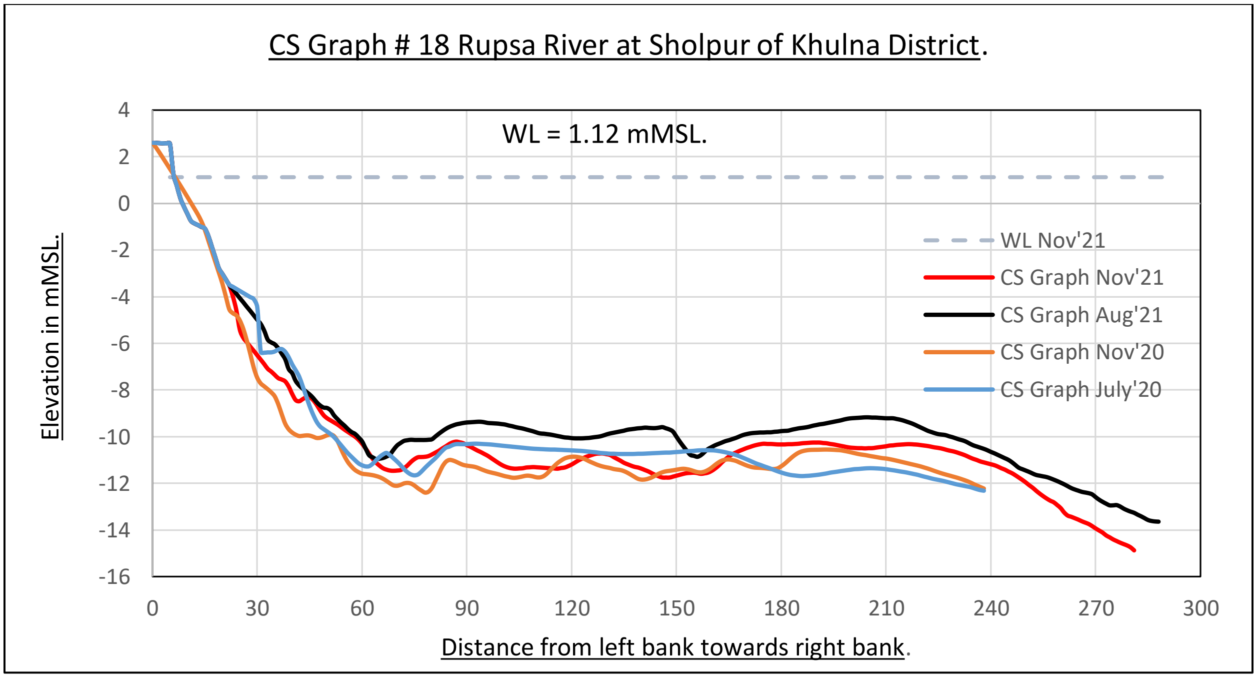
CS Graph # 15 Rupsa River at Sholpur of Khulna District.
WL = 1.12 mMSL.
Elevation in mMSL.
5
0
-5
-10
-15
-20
0
30
60
90
120
150
180
210
240
270
300
Distance from left bank towards right bank.
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph July'21



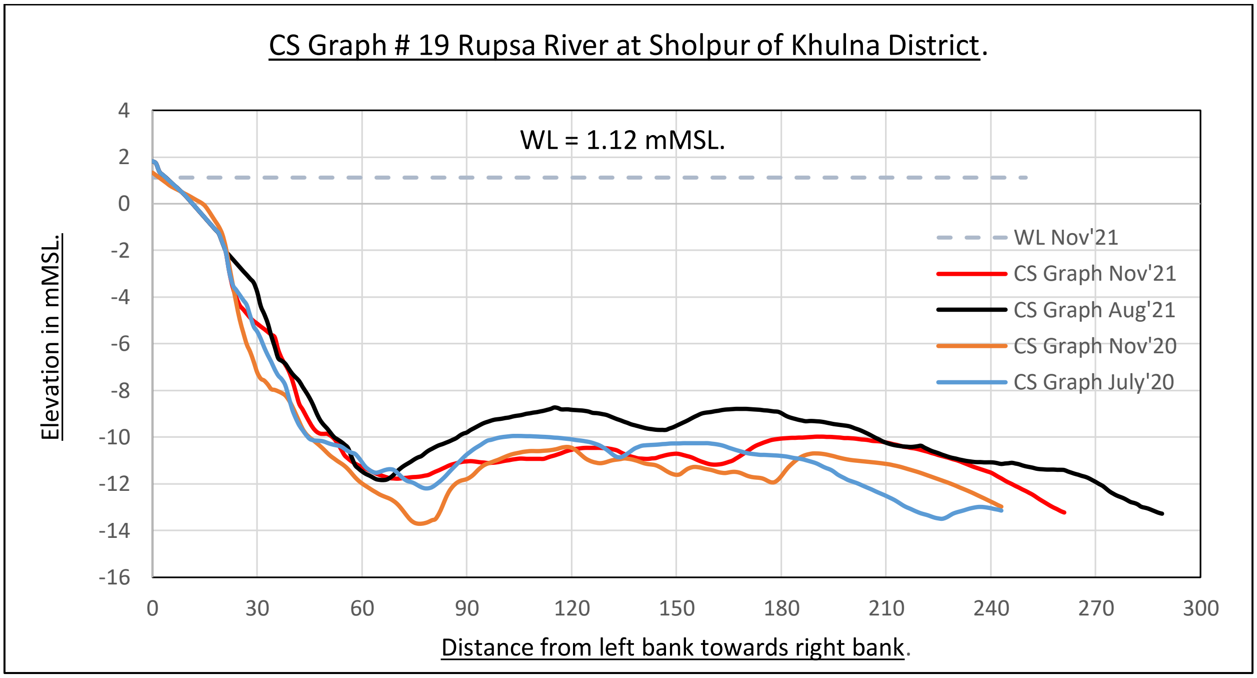
CS Graph # 16 Rupsa River at Sholpur of Khulna District.
WL = 1.12 mMSL.
Elevation in mMSL.
5
0
-5
-10
-15
-20
0
30
60
90
120
150
180
210
240
270
300
Distance from left bank towards right bank.
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph July

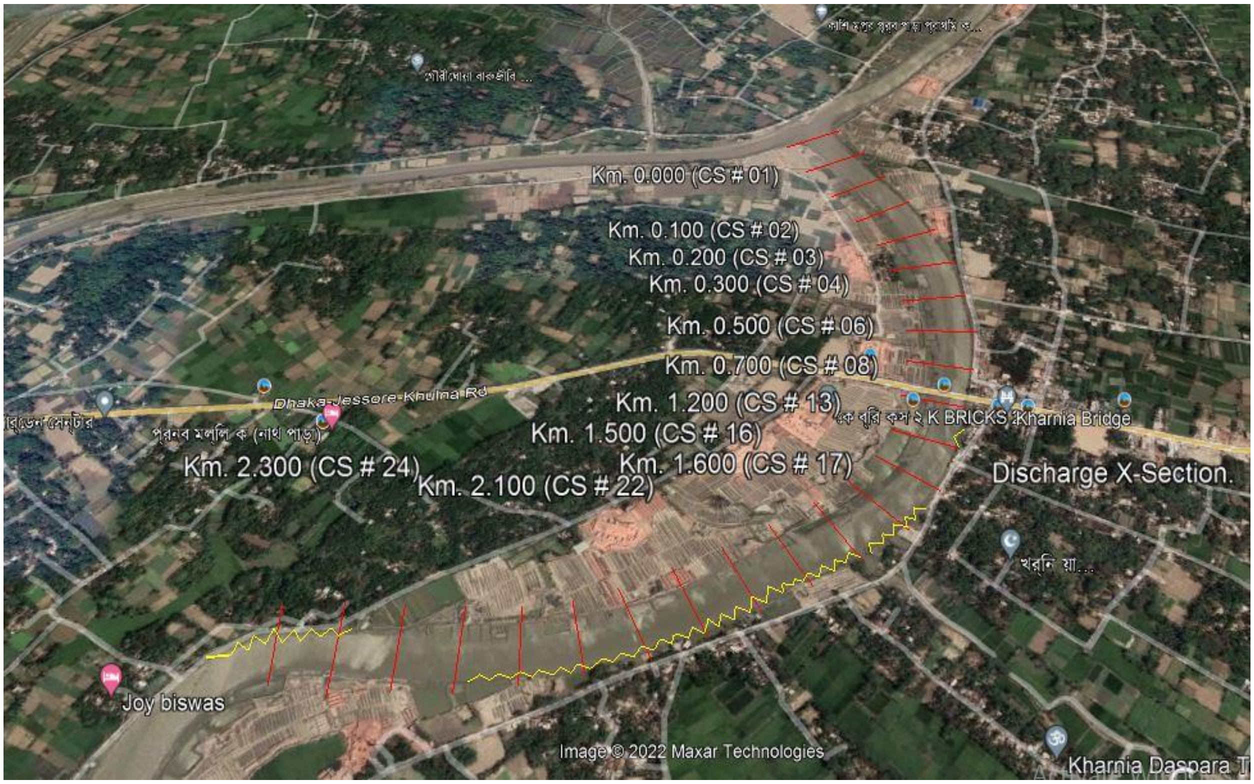


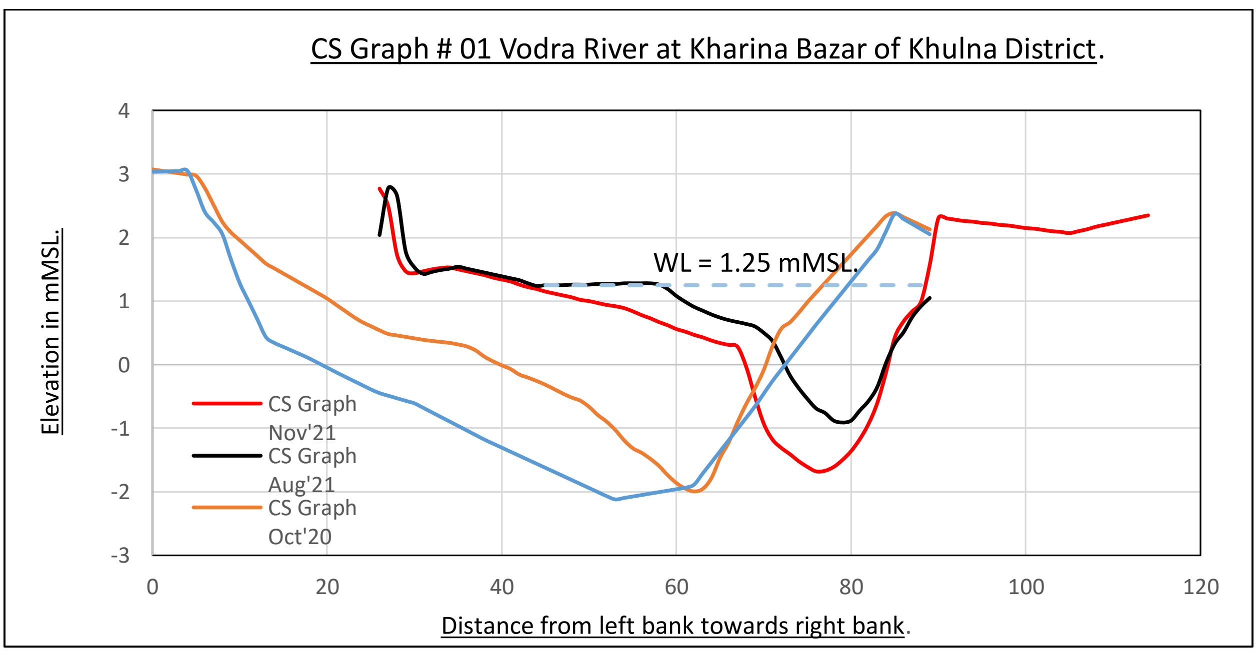
CS Graph # 17 Rupsa River at Sholpur of Khulna District.
WL = 1.12 mMSL.
Elevation in mMSL.
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
0
30
60
90
120
150
180
210
240
270
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph July'20
Distance from left bank towards right bank.

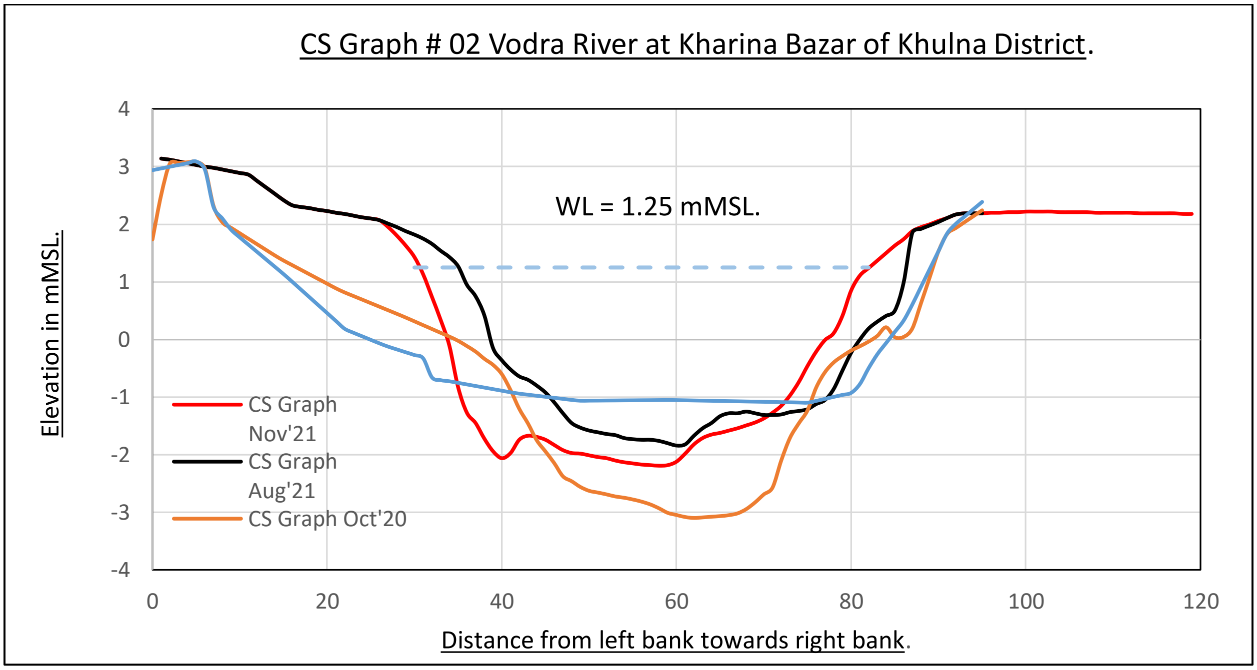


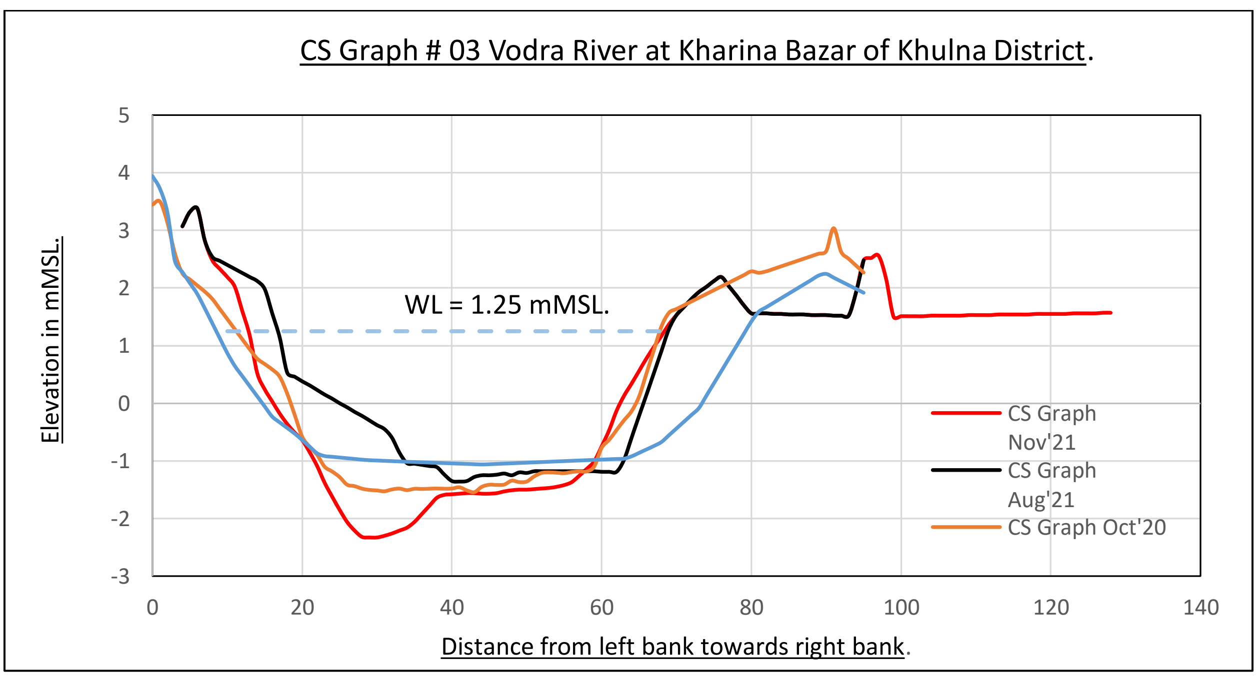
CS Graph # 18 Rupsa River at Sholpur of Khulna District.
WL = 1.12 mMSL.
Elevation in mMSL.
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
0
30
60
90
120
150
180
210
240
270
300
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph July'20
Distance from left bank towards right bank.

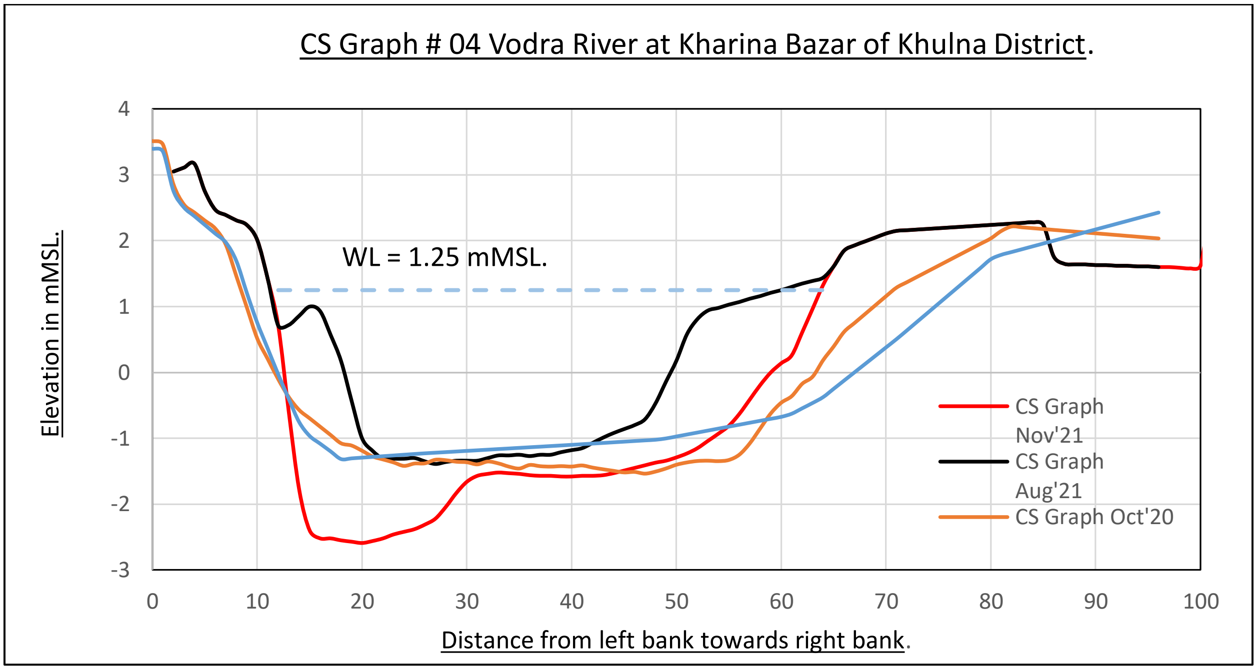

CS Graph # 19 Rupsa River at Sholpur of Khulna District.
WL = 1.12 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
0
30
60
90
120
150
180
210
240
270
300
WL Nov'21
CS Graph Nov'21
CS Graph Aug'21
CS Graph Nov'20
CS Graph July'20

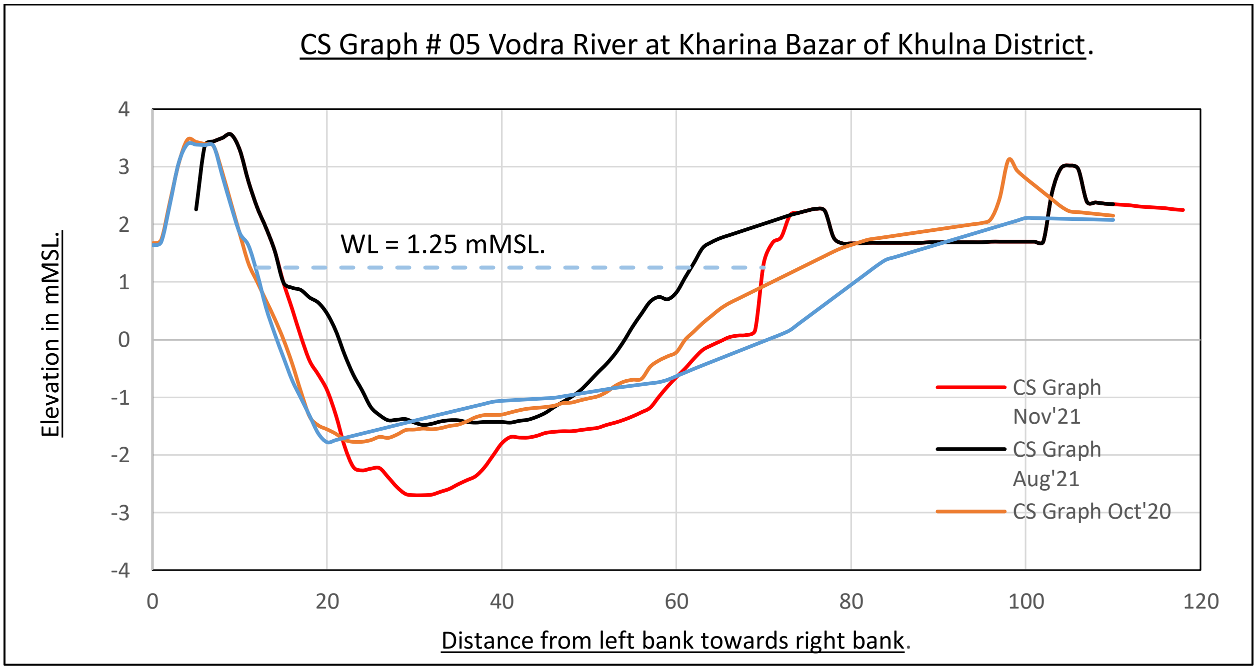

Km. 0.000 (CS # 01)
Km. 0.100 (CS # 02)
Km. 0.200 (CS # 03)
Km. 0.300 (CS # 04)
Km. 0.500 (CS # 06)
Km. 0.700 (CS # 08)
Km. 1.200 (CS # 13)
Km. 1.500 (CS # 16)
Km. 1.600 (CS # 17)
Km. 2.100 (CS # 22)
Km. 2.300 (CS # 24)
Dhaka-Jessore-Khulna Rd
K BRICKS
Kharnia Bridge
Discharge X-Section.
Joy biswas
Image © 2022 Maxar Technologies
Kharnia Daspara

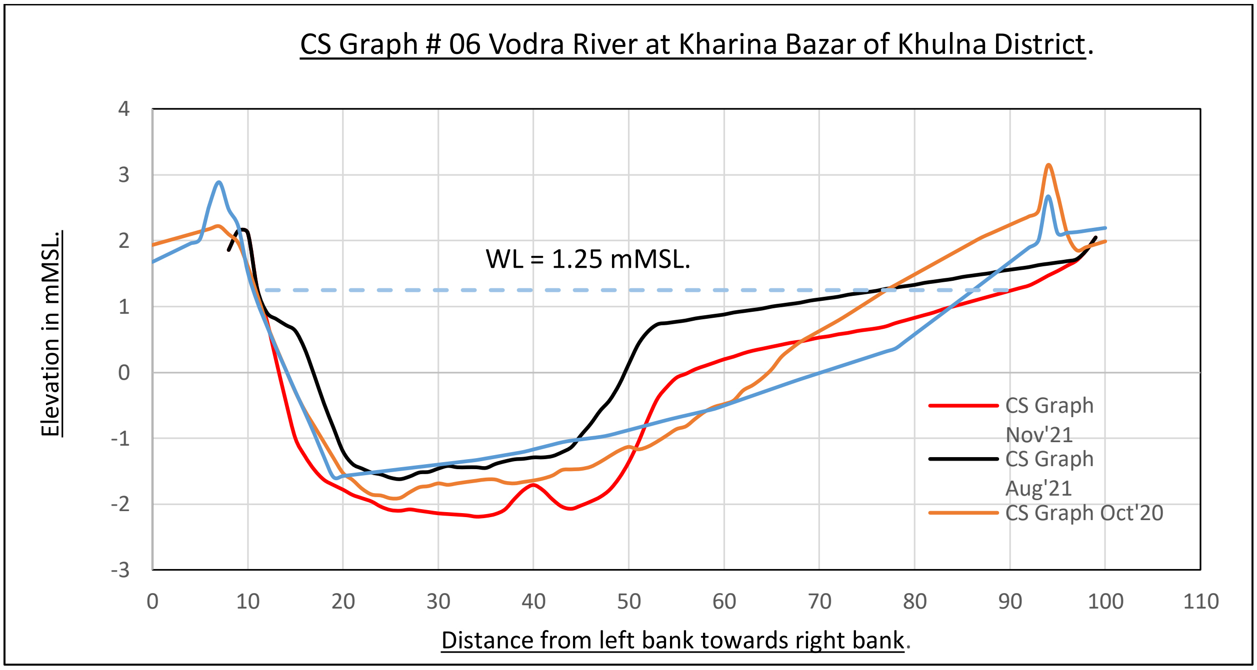

CS Graph # 01 Vodra River at Kharina Bazar of Khulna District.
Elevation in mMSL.
4
3
2
1
0
-1
-2
-3
0
20
40
60
80
100
120
WL = 1.25 mMSL.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
Distance from left bank towards right bank.

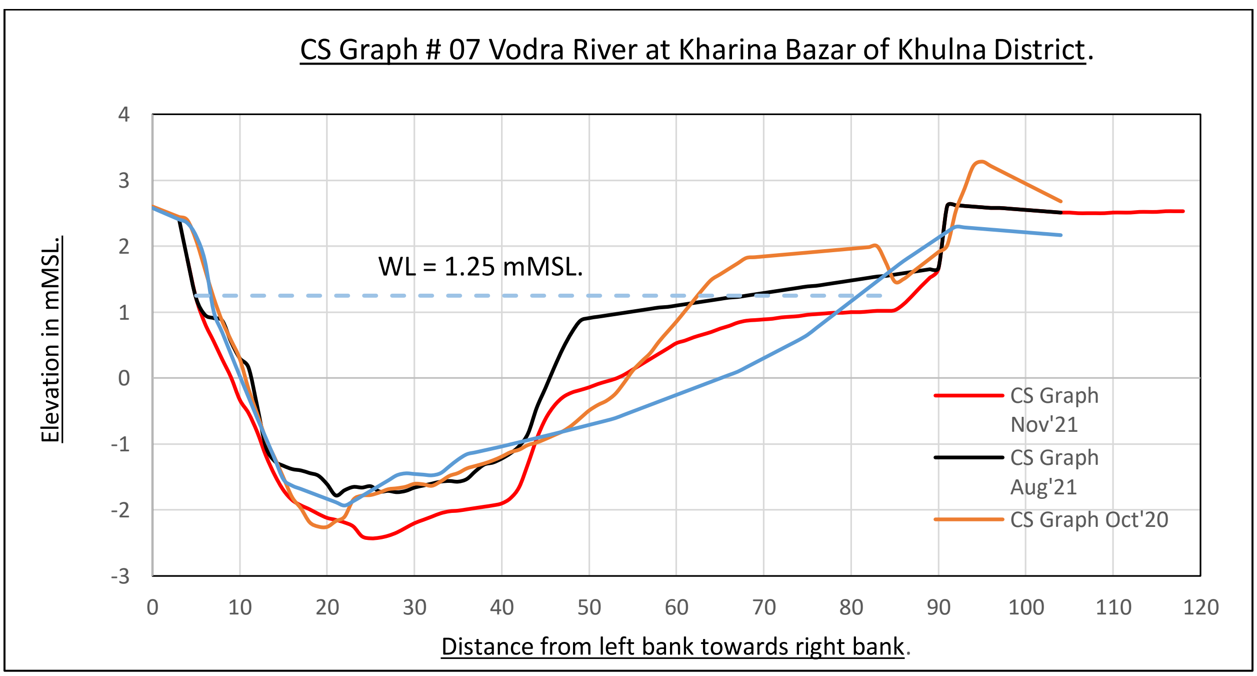

CS Graph # 02 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
4
3
2
1
0
-1
-2
-3
-4
0
20
40
60
80
100
120
Distance from left bank towards right bank.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20

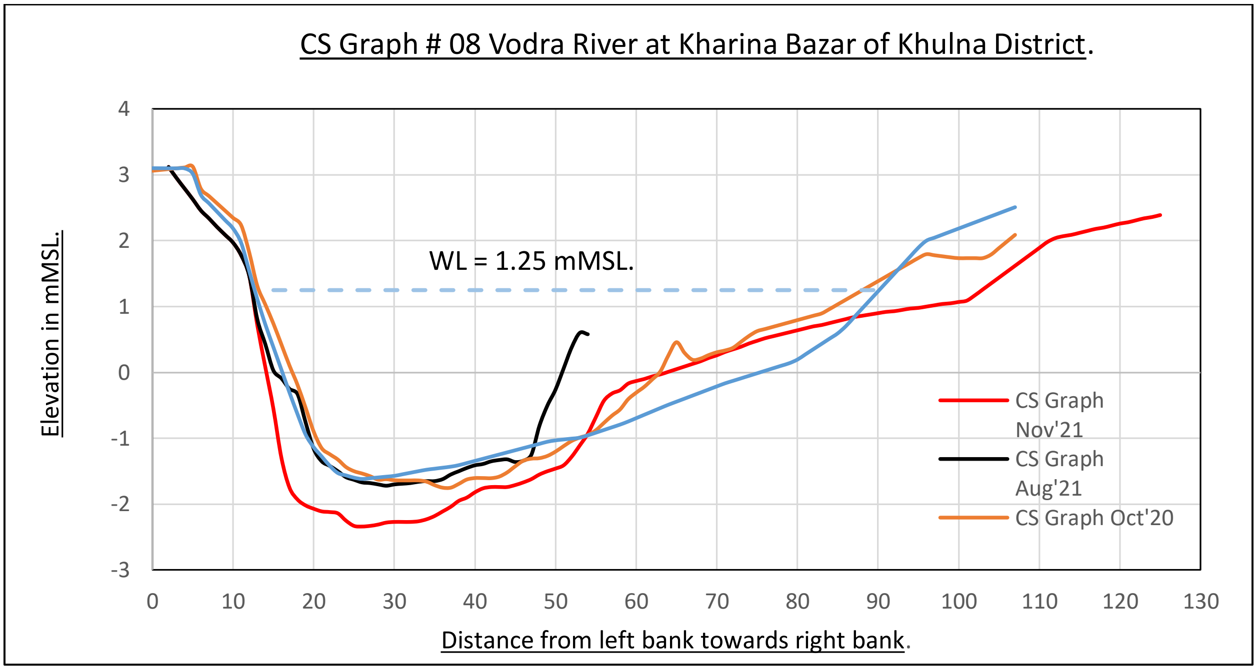

CS Graph # 03 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
5
4
3
2
1
0
-1
-2
-3
0
20
40
60
80
100
120
140
Distance from left bank towards right bank.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20

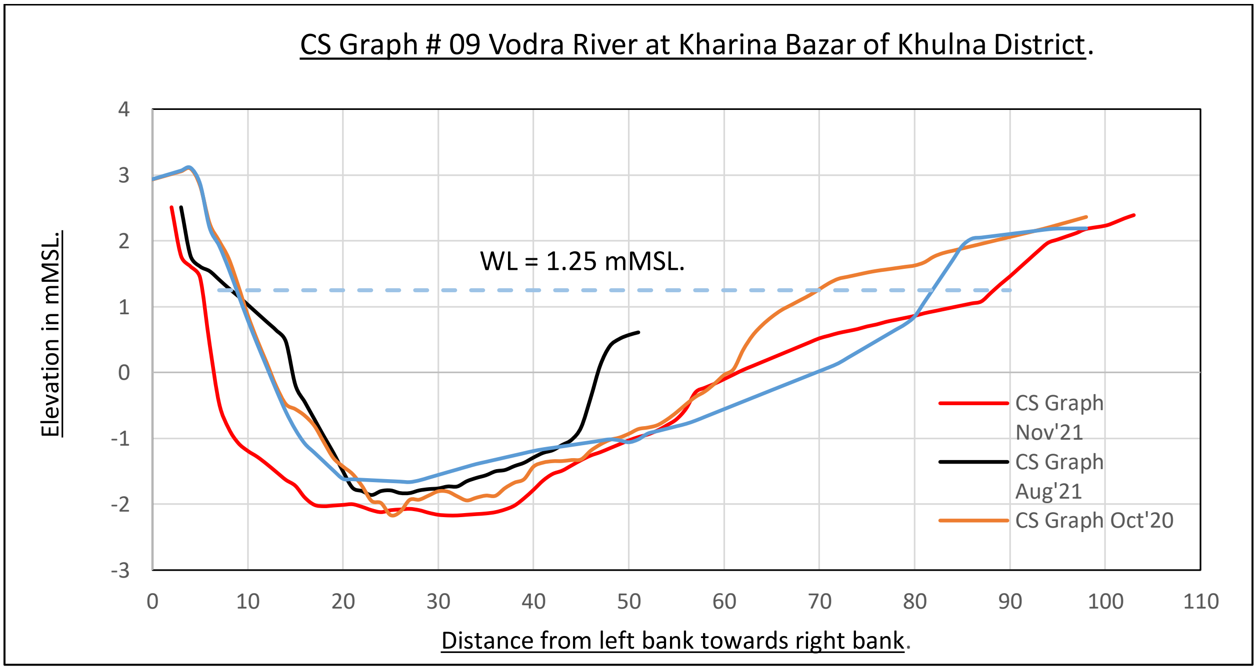

CS Graph # 04 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100

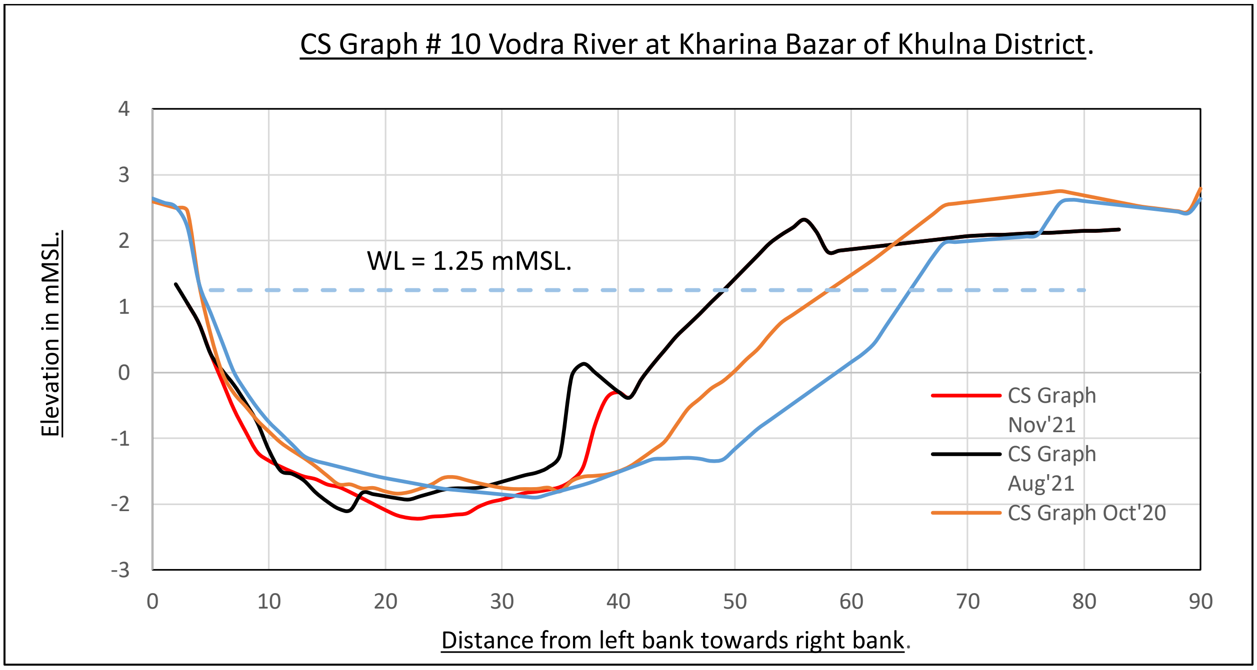

CS Graph # 05 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
4
3
2
1
0
-1
-2
-3
-4
0
20
40
60
80
100
120

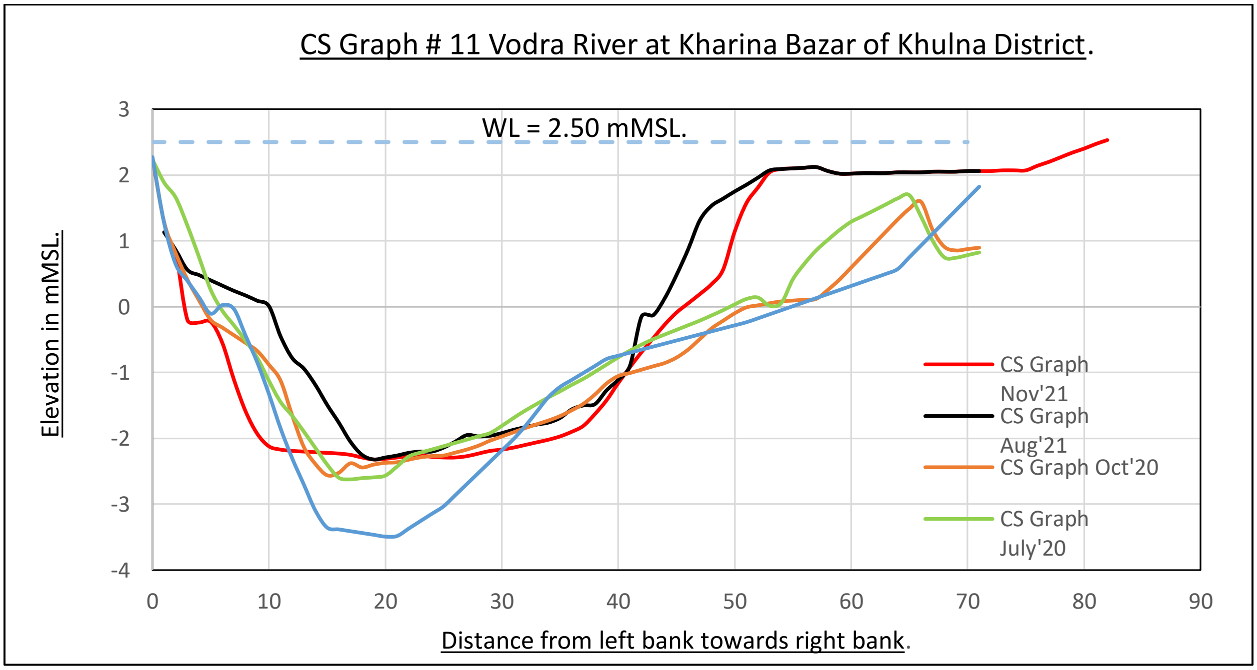

CS Graph # 06 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110

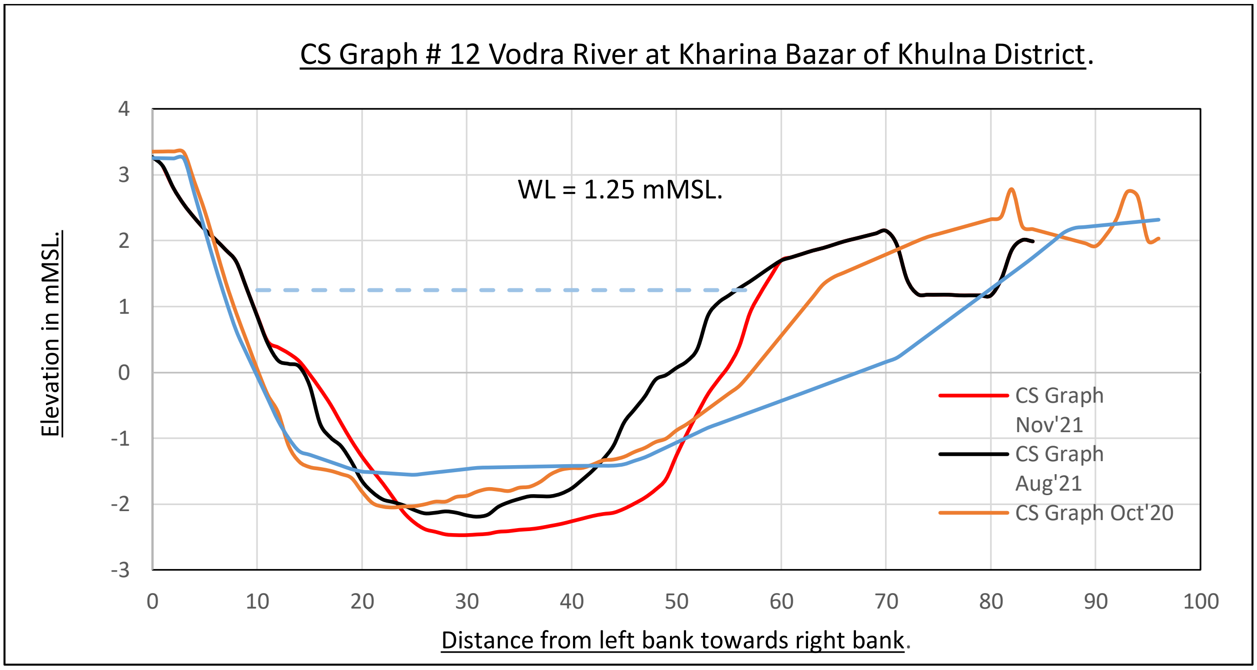

CS Graph # 07 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120

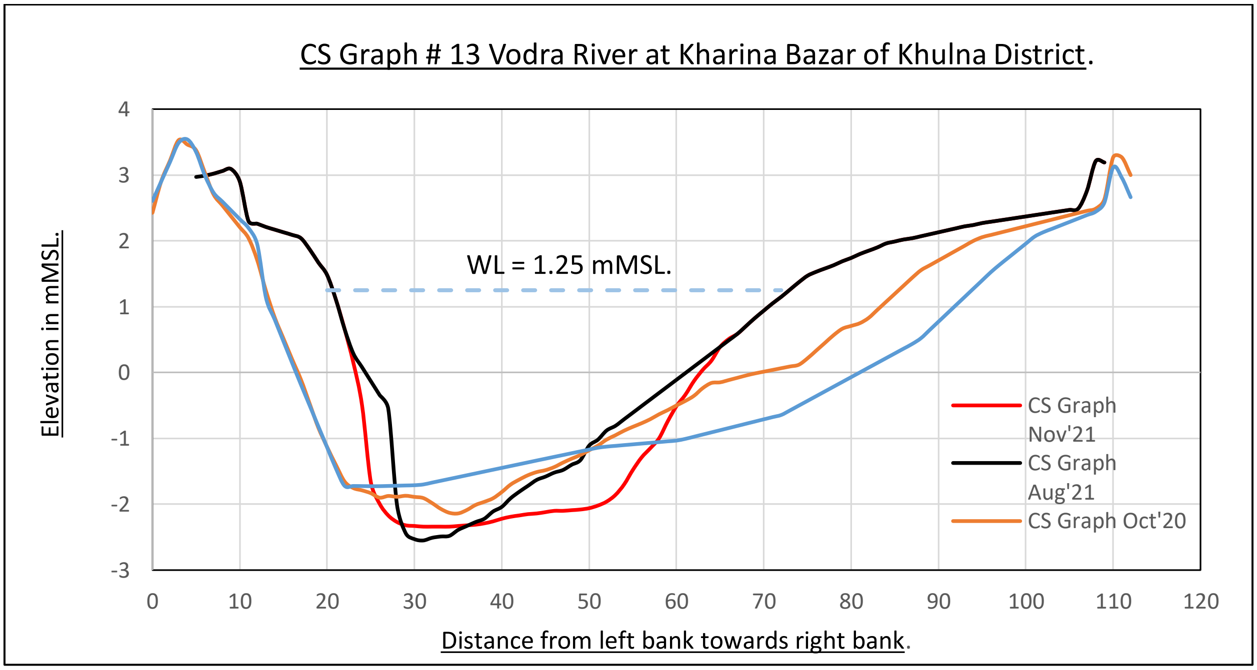

CS Graph # 08 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20

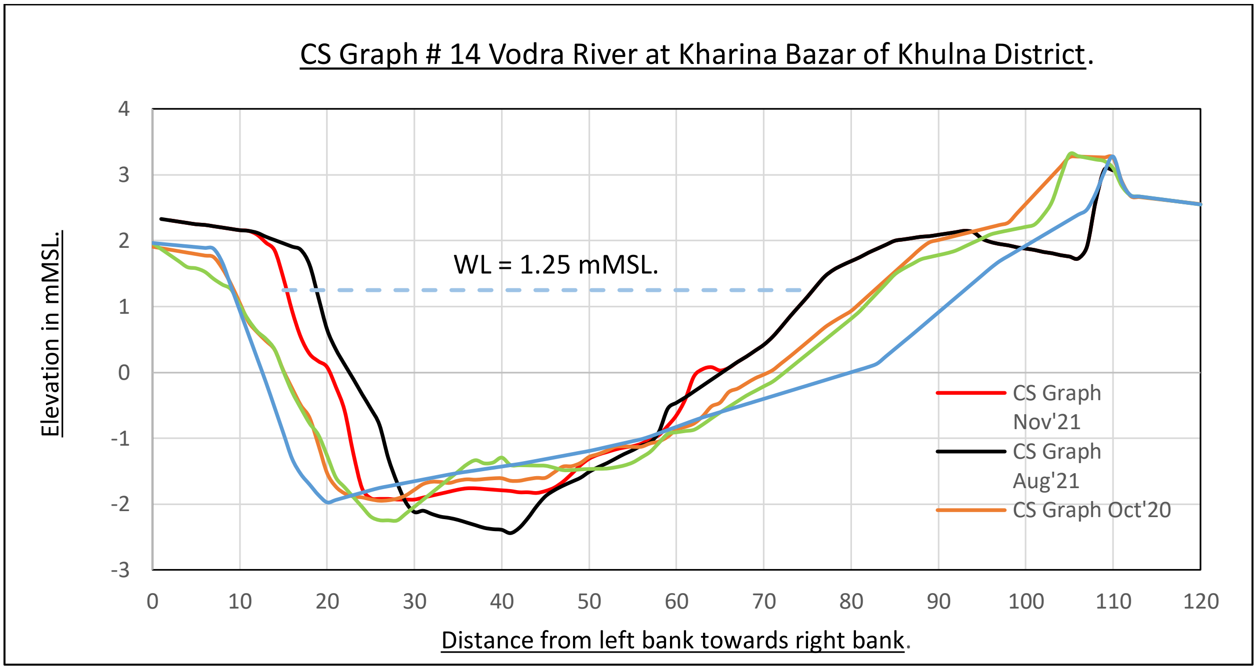

CS Graph # 09 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20


CS Graph # 10 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90

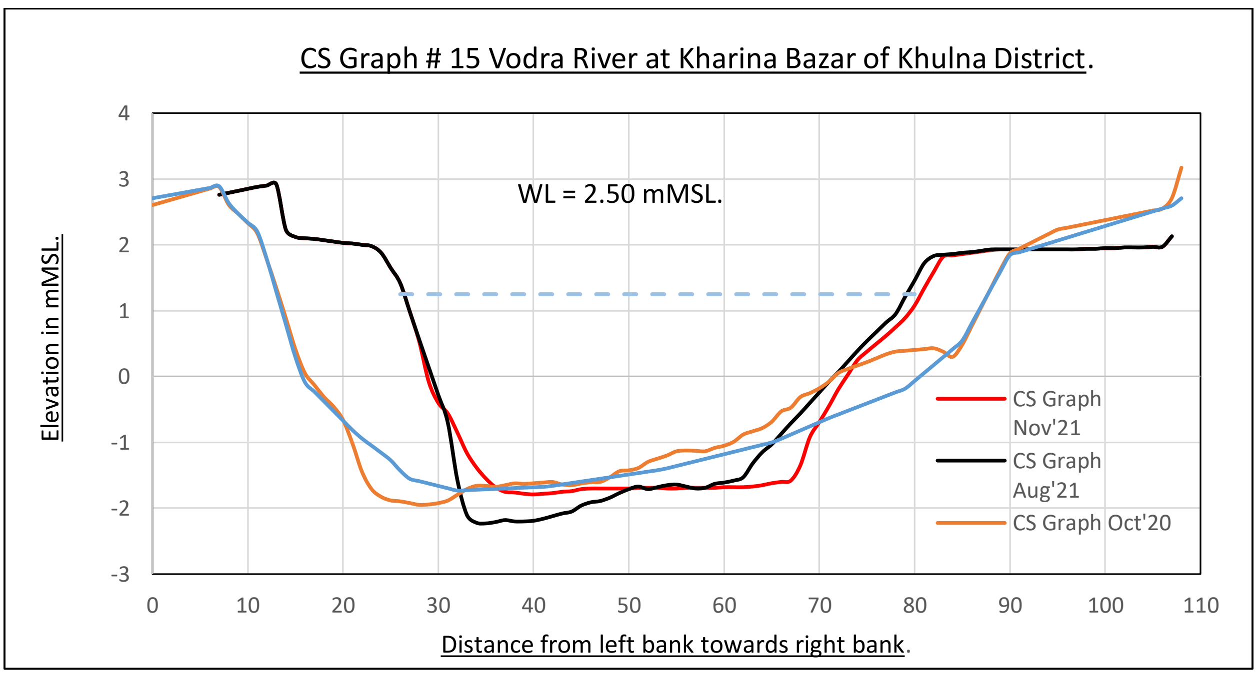

CS Graph # 11 Vodra River at Kharina Bazar of Khulna District.
WL = 2.50 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
CS Graph July'20
3
2
1
0
-1
-2
-3
-4
0
10
20
30
40
50
60
70
80
90


CS Graph # 12 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20

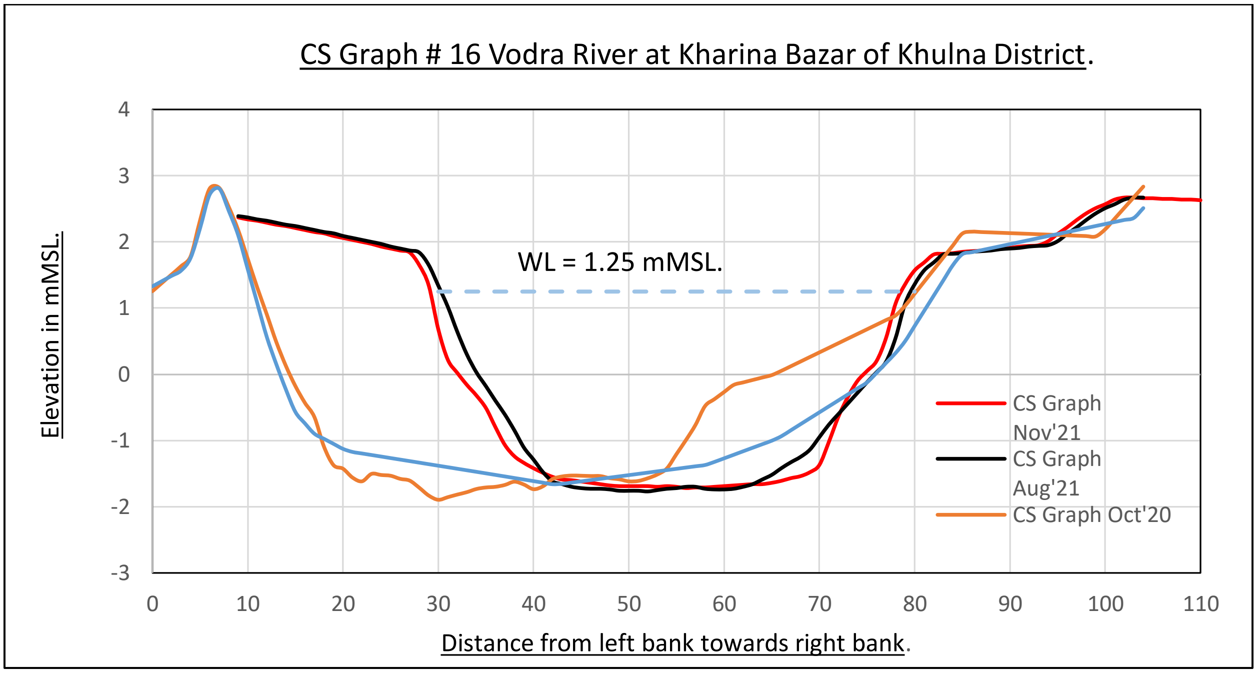

CS Graph # 13 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20



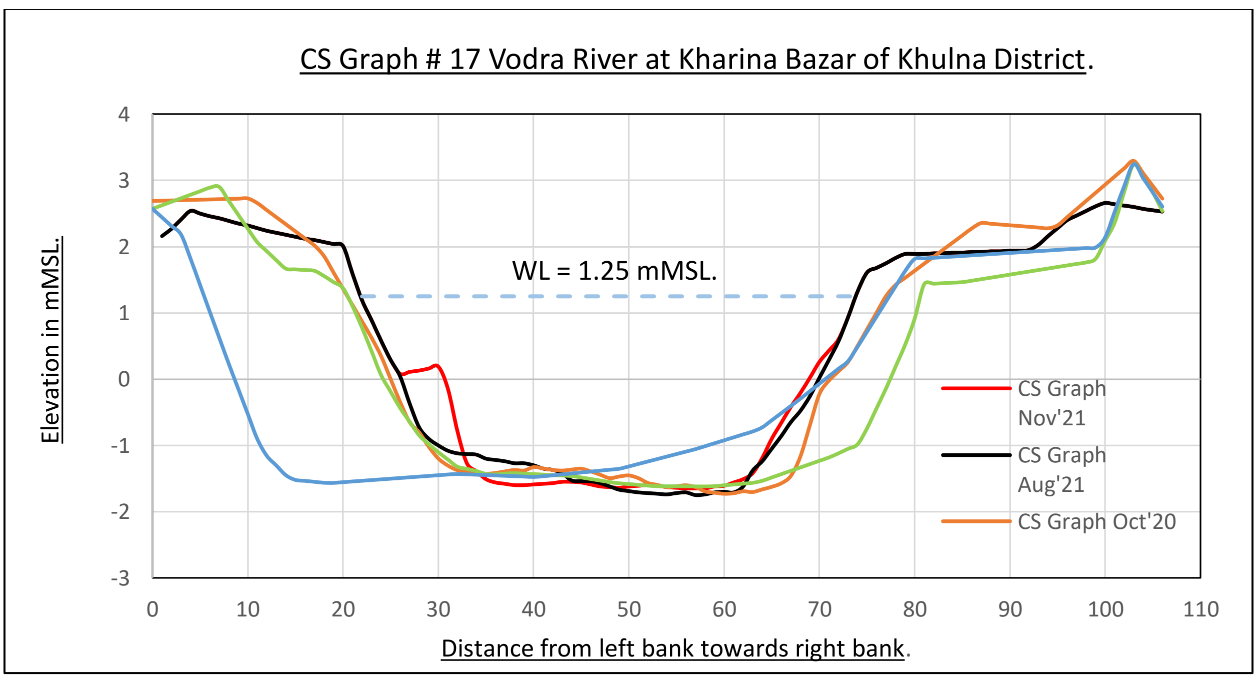
CS Graph # 14 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120



CS Graph # 15 Vodra River at Kharina Bazar of Khulna District.
WL = 2.50 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110

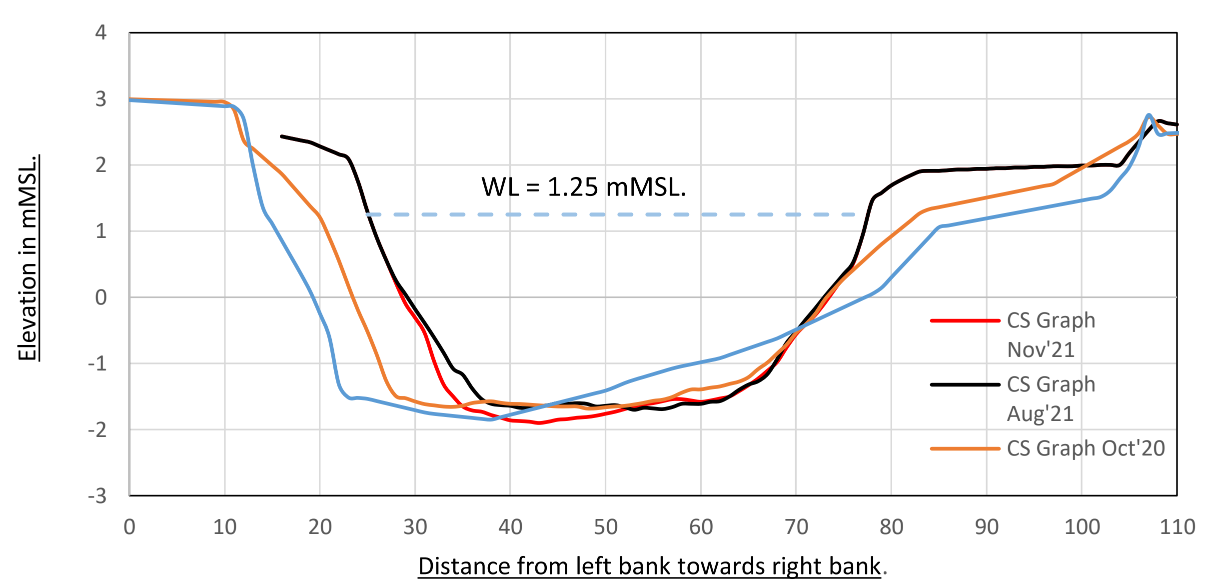


CS Graph # 16 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110

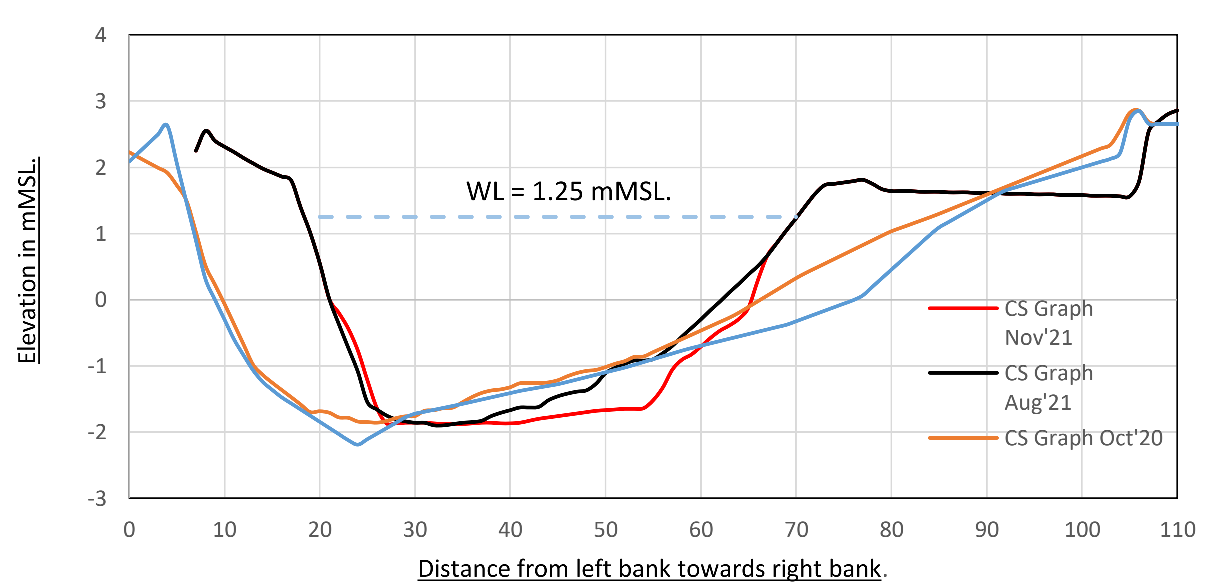


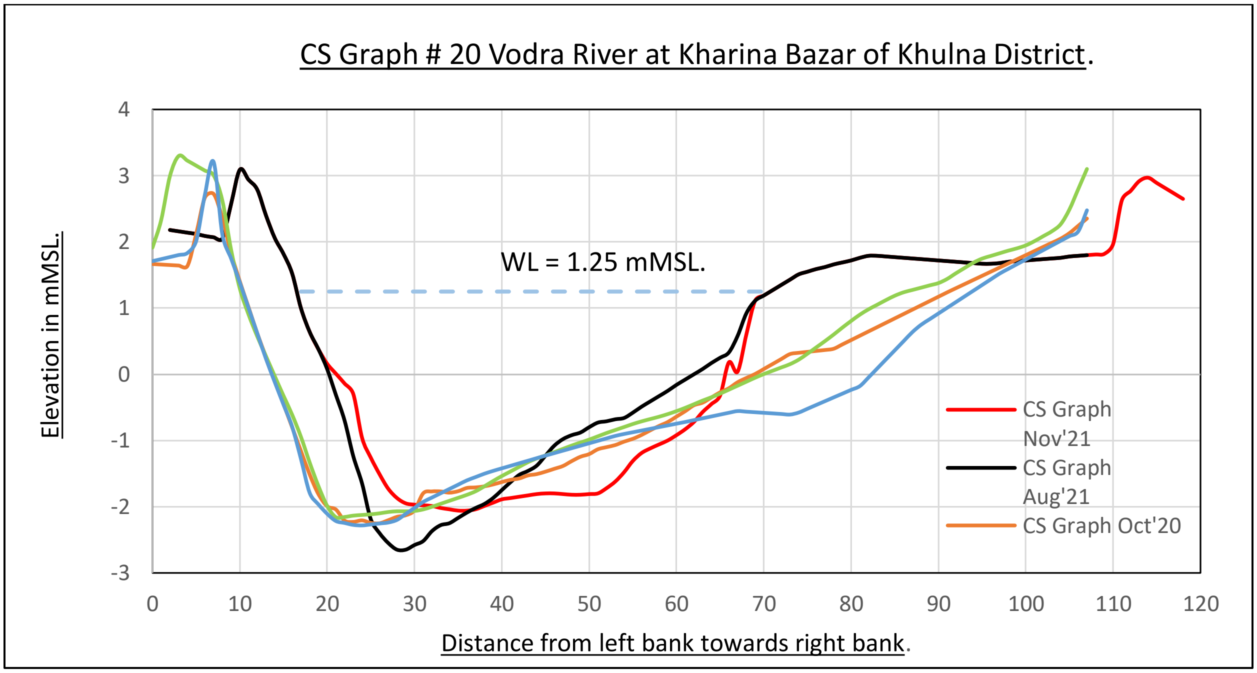
CS Graph # 17 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110

CS Graph # 18 Vodra River at Kharina Bazar of Khulna District.

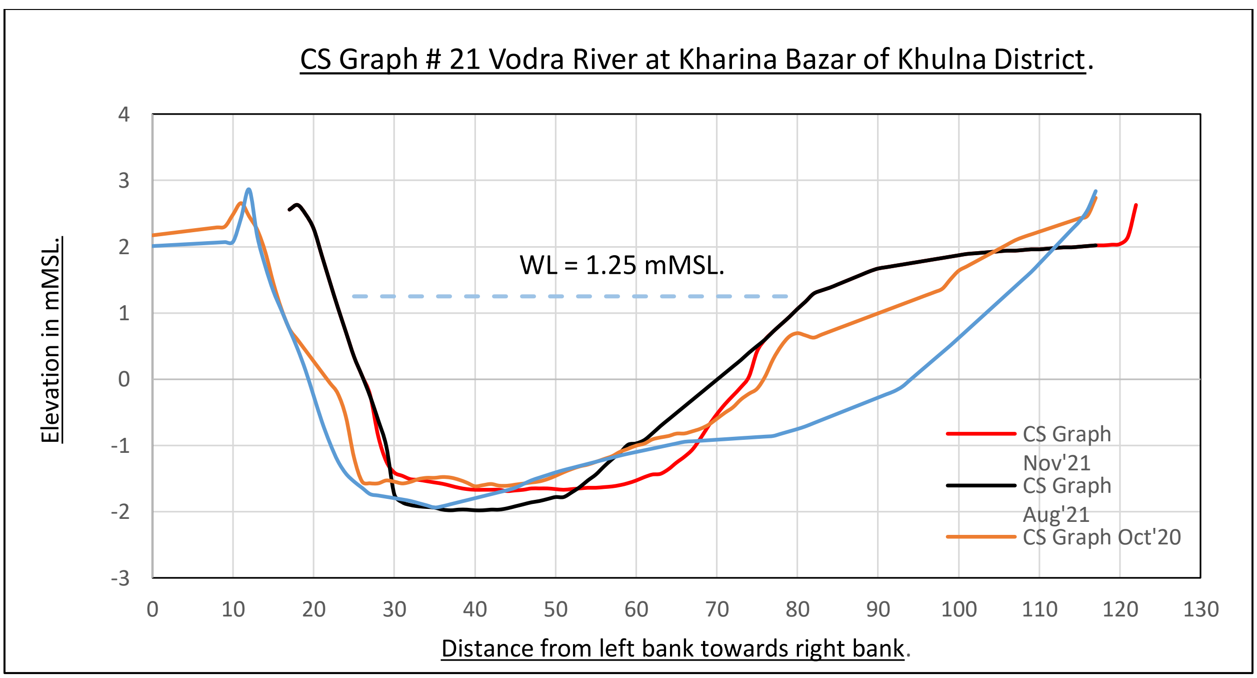


CS Graph # 19 Vodra River at Kharina Bazar of Khulna District.

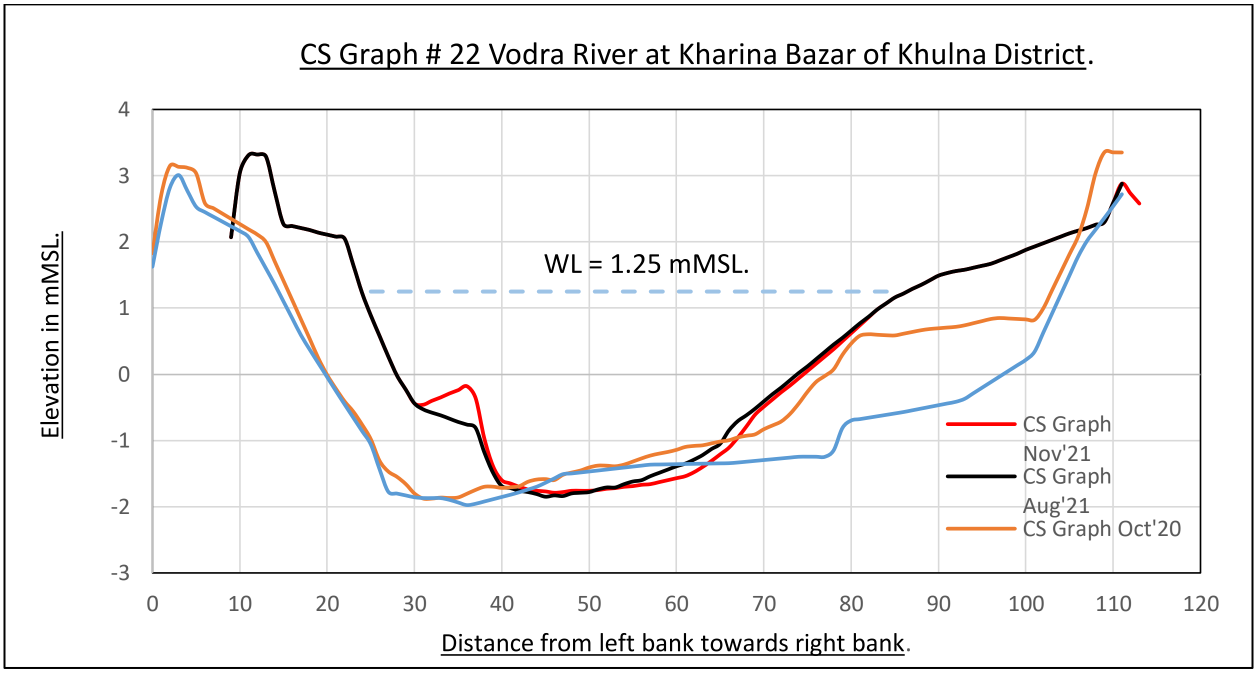


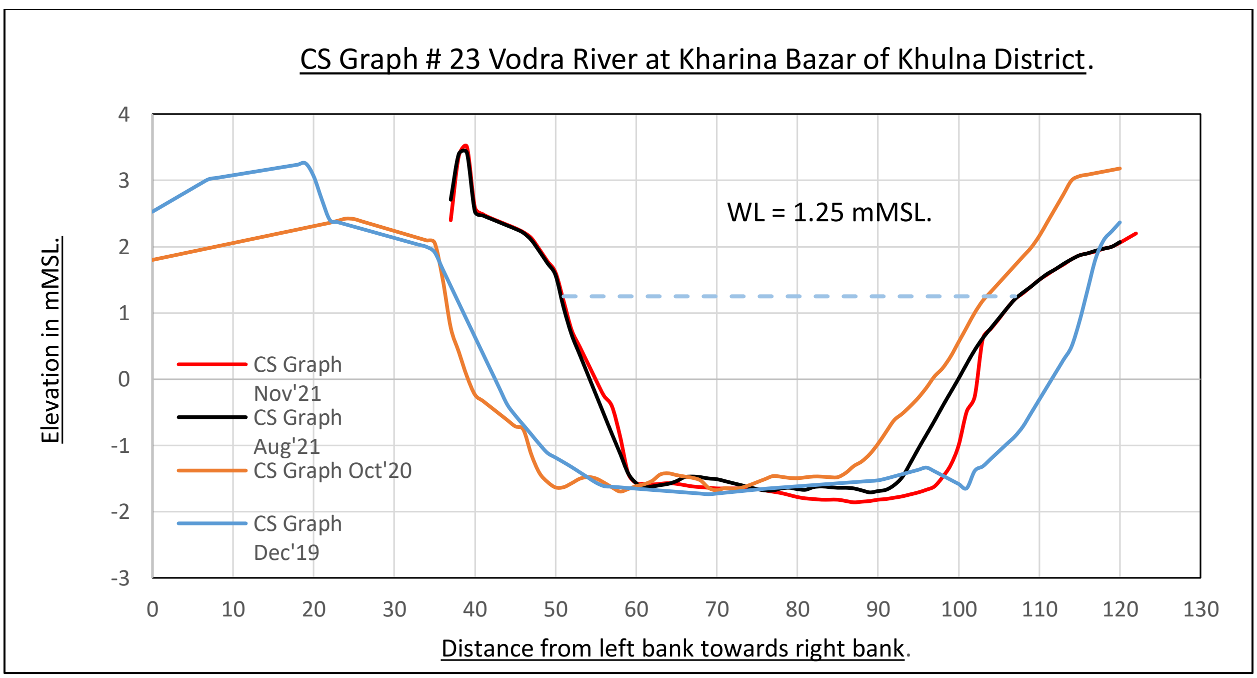


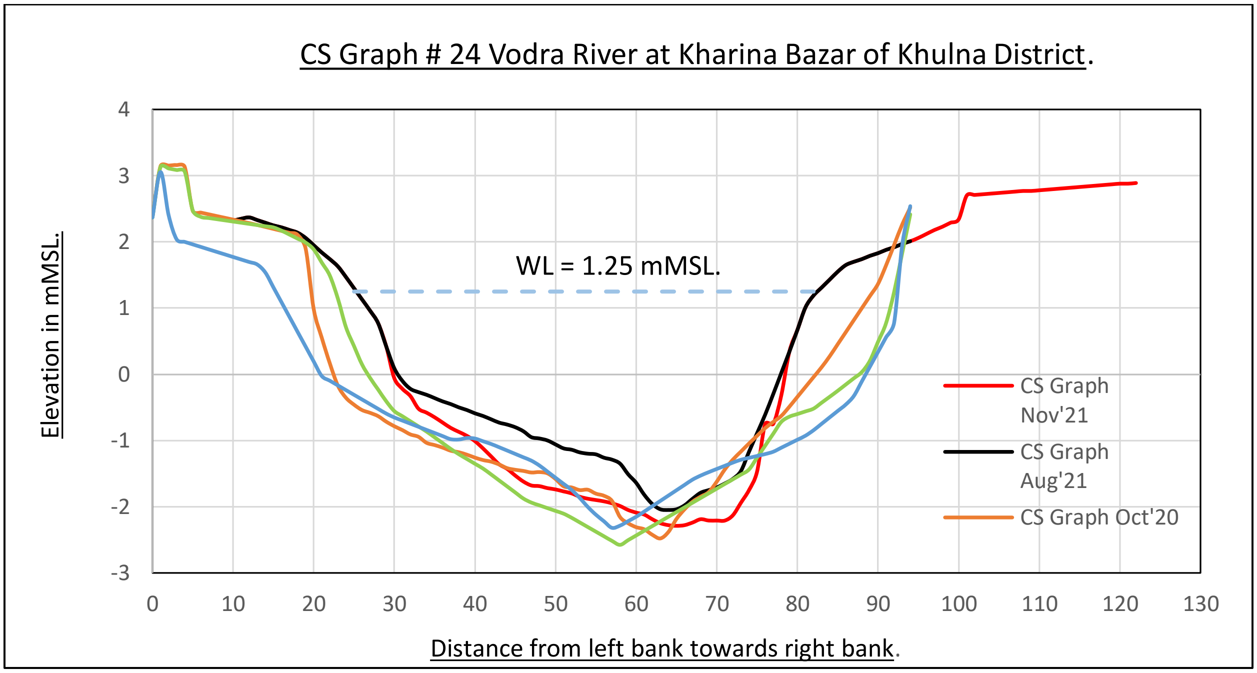
CS Graph # 20 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20



CS Graph # 21 Vodra River at Kharina Bazar of Khulna District.
WL = 1.25 mMSL.
Elevation in mMSL.
Distance from left bank towards right bank.
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20


CS Graph # 22 Vodra River at Kharina Bazar of Khulna District.
Elevation in mMSL.
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120
WL = 1.25 mMSL.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
Distance from left bank towards right bank.


CS Graph # 23 Vodra River at Kharina Bazar of Khulna District.
Elevation in mMSL.
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
WL = 1.25 mMSL.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
CS Graph Dec'19
Distance from left bank towards right bank.


CS Graph # 24 Vodra River at Kharina Bazar of Khulna District.
Elevation in mMSL.
4
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
WL = 1.25 mMSL.
CS Graph Nov'21
CS Graph Aug'21
CS Graph Oct'20
Distance from left bank towards right bank.

FIELD BORE LOG

DELTA SOIL ENGINEERS

871, Rokeya Sarani, Mirpur, Dhaka

PROJECT :

LOCATION : আবাড়ীয়া , খুলনা

BORE HOLE NO. A (1)

GROUND LEVEL R.L. : 0.04

GROUND WATER LEVEL : 2½m

DATE :

TIME : 09:00 am

DATE	NUMBER OF SAMPLE	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 6" PENETRATION 6"	6"	6"	SPT	STANDARD PENETRA-TION RESISTANCE (S P T) BLOWS PER 0.30m / 1ft (10 20 30 40 50)	INDEX: DISTURBED / UNDISTURBED REMARKS
	D-1							1	0	1	1		1.5m
	D-2							1	1	2	3		2m 3.0m
	D-3							1	1	1	2		4.5m
	D-4							1	1	2	3		5½m 6.0m
	D-5							1	2	2	4		7.5m
	D-6							2	2	3	5		9.0m
	D-7							2	2	4	6		10.5m
	D-8							3	3	5	8		12.0m
	D-9							3	4	6	10		13.5m
	D-10						100 mm (4") ϕ	5	6	10	16		14.0m 15.0m
	D-11							5	7	12	19		16.5m
	D-12							6	8	15	23		18.0m
	D-13							6	8	17	25		19.5m
	D-14												21.0m
	D-15												22.5m
	D-16												24.0m
	D-17												25.5m
	D-18												27.0m
	D-19												28.5m
	D-20												30.0m

Client/Consultant

Field Supervisor

Driller

FIELD BORE LOG
DELTA SOIL ENGINEERS
871, Rokeya Sarani, Mirpur, Dhaka

PROJECT :	**GROUND LEVEL R.L. :**
LOCATION : লস্করপুর , খুলনা	**GROUND WATER LEVEL :**
BORE HOLE NO. A (2)	**DATE :** **TIME : 09:00 am**

DATE	NUMBER OF SAMPLE	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 6" PENETRATION 6"	6"	6"	SPT	STANDARD PENETRATION RESISTANCE (S P T) BLOWS PER 0.30m / 1ft (10 20 30 40 50)	INDEX / UNDISTURBED REMARKS
	D-1							1	0	1	1		1.5m
	D-2							2	2	3	5		3.0m
	D-3							2	2	4	6		4.5m
	D-4							1	1	2	3		6.0m
	D-5							1	2	2	4		7.5m
	D-6							1	1	2	3		9.0m
	D-7							1	2	3	5		10.5m
	D-8							1	2	3	5		12.0m
	D-9						100 mm (4") ϕ	2	3	3	6		13.5m
	D-10							2	3	4	7		15.0m
	D-11							3	4	5	9		16.5m
	D-12							2	4	4	8		18.0m
	D-13							2	4	5	9		19.5m
	D-14												21.0m
	D-15												22.5m
	D-16												24.0m
	D-17												25.5m
	D-18												27.0m
	D-19												28.5m
	D-20												30.0m

Client/Consultant   Field Supervisor   Driller

FIELD BORE LOG

DELTA SOIL ENGINEERS

871, Rokeya Sarani, Mirpur, Dhaka

PROJECT :

LOCATION : ঝংকরপুর বাজার , নেত্রকোনা

BORE HOLE NO. 01

GROUND LEVEL R.L. :

GROUND WATER LEVEL :

DATE : TIME : 09:00 am

DATE	NUMBER OF SAMPLE	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 6" PENETRATION 6"	6"	6"	SPT	STANDARD PENETRA-TION RESISTANCE (S P T) BLOWS PER 0.30m / 1ft (10 20 30 40 50)	INDEX (▨ / ■ UNDISTURBED) REMARKS
	D-1	▨					100 mm (4") φ	1	2	3	5		1.5m
	D-2	▨						2	3	5	8		3.0m
	D-3	▨						2	2	4	6		4.5m
	D-4	▨						2	3	4	7		6.0m
	D-5	▨						2	3	6	9		7.5m
	D-6	▨						3	4	7	11		9.0m
	D-7	▨						4	5	8	13		10.5m
	D-8	▨						4	6	9	15		12.0m
	D-9	▨						5	7	10	17		13.5m
	D-10	▨						6	8	13	21		15.0m
	D-11	▨						6	8	13	21		16.5m
	D-12	▨						7	9	14	23		18.0m
	D-13	▨						8	10	16	26		19.5m
	D-14	▨											21.0m
	D-15	▨											22.5m
	D-16	▨											24.0m
	D-17	▨											25.5m
	D-18	▨											27.0m
	D-19	▨											28.5m
	D-20	▨											30.0m

Client/Consultant

Field Supervisor

Driller

Easting - 750323
Northing - 2616521

FIELD BORE LOG

DELTA SOIL ENGINEERS

871, Rokeya Sarani, Mirpur, Dhaka

PROJECT : বা: পা: উ: বো:	GROUND LEVEL R.L. : (–) 4'-6"
LOCATION : নারুয়া খেয়া ঘাট, রাজবাড়ী	GROUND WATER LEVEL : (–) 7'-6"
BORE HOLE NO. 03	DATE : 28-6-21 TIME : 09:00 am

DATE	NUMBER OF SAMPLE	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION: 15cm	15cm	15cm	SPT	STANDARD PENETRA-TION RESISTANCE (S P T) BLOWS PER 0.30m / 1ft (10, 20, 30, 40, 50)	INDEX (DISTURBED / UNDISTURBED) REMARKS
	D-1	Disturbed					100 mm (4") ϕ	1	1	2	3		1.5m
	D-2	Disturbed						1	2	2	4		U-D-1 3.0m 7'-8'-6"
	D-3	Disturbed						2	3	4	7		4.5m
	D-4	Disturbed						2	3	3	6		6.0m
	D-5	Disturbed						3	4	5	9		7.5m
	D-6	Disturbed						4	5	6	11		9.0m
	D-7	Disturbed						5	8	10	18		10.5m
	D-8	Disturbed						6	8	11	19		12.0m
	D-9	Disturbed						7	7	10	17		13.5m
	D-10	Disturbed						8	8	12	20		15.0m
	D-11	Disturbed						9	10	13	23		16.5m
	D-12	Disturbed						10	12	14	26		18.0m
	D-13	Disturbed						18	15	16	31		20.0m

Client/Consultant

Field Supervisor

Driller
Lokn
28-6-21

Final Report on The pilot project in different areas of Bangladesh using Bamboo Bandaling Structures to reduce river erosion, River Research Institute, Faridpur

Prepared by:

Prof. Dr. Mohammed Almujaddade Alfasane

Consultant (Hydrobiologist and Ecosystem service)

The Final Report is prepared after the completion of the work on the project. The presented details report and recommendations are given below:

Introduction:

Bank erosion is the most common problem faced in river engineering practices in many countries, especially in Bangladesh and this has been recognized as an awful threat to the society. So control of erosion is very much important to save agricultural land, property and infrastructures like bridges, culverts, buildings etc. located alongside the rivers.

A 'Bamboo Bandaling Structures' is a complex, multilayered bamboo palisade that can protect the riverbank from flash floods, in the process increasing navigability of the river. Depending on the width and strength of the river, several bamboo posts, are installed vertically into the riverbed where its bank is vulnerable to erosion. The vertical bamboo posts are supported by horizontal ones of the same length. Depending on the strength of the river, several layers of bamboo palisades are installed at vulnerable points of the riverbank.This method is not unknown to Bangladesh's river researchers and engineers. According to Kazi Rezaul Karim, chief scientific officer at the Bangladesh River Research Institute (BRRI), "The network of bamboo palisades acts as a natural dredging machine. The bamboo palisades, installed at an angle of 45-50 degrees towards the direction of the river current, obstruct the river current and trap alluvial silt. In this way, the palisades naturally rebuild the banks and increase the amount of fertile croplands. On the other hand, the palisades divert the current to the centre of the river. As a result, the river naturally scours the riverbed instead of the banks which increases its navigability." To assess its effectiveness, BRRI has set up a series of bamboo palisades along different channels of the

Jamuna and Padma rivers. “We have already got satisfactory results to some extent. We set up palisades along the course of the Gorai river. We have experienced effectiveness of the palisades this monsoon. Most parts of the banks are still intact and we are expecting that the river’s navigability will also increase in the next dry season. Since it’s a natural process, we shall have to wait a couple of years more to fully understand its efficacy.”

Every year, Bangladesh’s economy gets badly affected due to river erosion. According to the Bangladesh Water Development Board, more than two and half crore people of 43 districts have lost their homes due to river erosion in the last 10 years. In the last four decades, Bangladesh has lost more than 100,000 hectares of land due to river erosion, an area larger than many of the districts of Bangladesh. The government also spends a large amount of resources to protect the riverbanks. For instance, the government took up 76 development projects in the water development sector for the fiscal year of 2018-2019. 30 of these development projects are to protect the riverbanks and to dredge the riverbeds. These projects have consumed no less than Tk 21,000 crore.

However, mounting loss of land and resources prove that these conventional, fuel intensive methods are failing and it is high time for the government to think about alternative methods to reduce river erosion. And bundaling, a natural and ‘green’ way to protect the riverbank and dredge rivers, deserves serious consideration.

The project in different areas of Bangladesh using Bamboo Bandaling Structures to reduce river erosion, keeping all these forces and functions of Bamboo Bandaling Structures in a river ecosystems in mind the present piece of project work was undertaken to fulfill a number of objectives particularly on the diversity of its phytoplankton and macrophyte community and the factors regulating them and effects on the river ecosystem. The findings of the results concluded that the effects of physicochemical and biological parameters in the river water ecosystem before and after bamboo bandaling.

Aims and objectives

Following are the aims and objectives of the project:

1. What are the composition of phytoplankton and aquatic macrophytes?

2. What are the species richness and diversity of phytoplankton and aquatic macrophytes?
3. What is the trend between diversity of phytoplankton and aquatic macrophytes and water quality measuring index?
4. What are the composition of Chlorophyll *a* (chl *a*) and phaeopigment as biomass?
5. What are the qualitative estimation with generic and species identification of phytoplankton and aquatic macrophytes?
6. How much the numerical counts of phytoplankton?
7. How the quantitative aspects of different species of phytoplankton do vary?
8. How the biomass of phytoplankton fluctuates before and after bamboo bandaling?
9. What are the trends of densities of phytoplankton before and after bamboo bandaling?
10. How the chemical water quality parameters influences before and after bamboo bandaling?
11. Synergistic effect of all factors on the water quality of the river before and after bamboo bandaling.
12. Temporal and spatial variation of the factors related to the water quality.
13. To make a commendation on the water quality of the rives before and after bamboo bandaling.

Study area

The project work was started in the following rivers of the selected areas. For the purpose of the effects of bamboo bandaling structures on the aquatic biodiversity as well as water quality.

(a) Faridpur : Paddma River
(b) Barisal: Kirtonkhula and Sondha River
(c) Netrokona: Kongso and Someswari
(d) Khulna: Bhadra River

Sampling programs

Samples from the above mentioned selected areas of the rivers were collected. Sample collections were carried out mostly between 09:00 and 12:00 am. The field trip was arranged via road and waterways.

Collection of samples and field measurements

Water sample for chemical analysis

Integrated water samples were collected from each station from one meter depth by a PVC pipe fitted with a check valve at the end (Plate-14). The sampler had a capacity of 2.5 L. At each time the sampler was dipped slowly under water to 1 meter depth. After a few seconds the sampler was taken out of the water and trapped sample water was directly transferred to a 5 L capacity plastic carboy. The sampler was dipped two times to get 5 L capacity. The carboy was transported to the laboratory for further analysis. Care was taken to avoid jerking during transport of the samples.

Water sample for phytoplankton study

Pyrex flat glass bottles each having 1 L capacity were kept ready to collect phytoplankton samples for each station. One mL Lugol's solution was poured into each empty bottle just before sample water was added from the integrated water sampler via a plastic funnel. After filling the bottle was sealed off by putting rubber cork on the mouth. After taking the sample to the laboratory the bottle was kept in the dark for the sedimentation of phytoplankton for counting.

Laboratory procedure

Filtration and preservation

After reaching the laboratory, filtration of water samples for chemical analysis was carried out. A vacuum pump fitted to a Sartorius-Membrane Filter Holder (Gmbh, Göttingen, FRG) was used for the purpose. The water sample was shaken gently and then 100-250 mL of water was measured with the help of a graduated measuring cylinder and poured into the cup of the Sartorius device. Whatman GF/C 2.7 cm circles were used with the device to filter the water. After filtration the filter paper was rolled up with the help of a Millipore pincet and put into a screw capped Pyrex glass tube of 10 mL capacity. This sample was used for the determination of phytoplankton biomass as chl-a. The filtrate of each sample was transferred to a acid washed, clean screw capped polystyrene bottles (500 mL capacity) for nutrient analysis.

Chemical parameter measurements

All the chemical analyses made in the present investigation were followed by standard procedures. A brief description of the procedure for each determination together with the citation of the methodology followed has been summarized below:

Biochemical oxygen demand (BOD):

The BOD is commonly determined by measuring the concentration of dissolve oxygen (DO) in the sample before and after incubation at 20ºC under dark condition for 5 days. DO of sample water (D_1) before incubation was measured by DO Meter (DO-5509) and after 5 days of incubation the DO of sample water (D_2) was measured by the same instrument (APHA 1998).

Calculation

The following formula is used for calculating Biological Oxygen Demand of water,

Then, BOD (mg/L) = D_1-D_2 Where,

D_1 = dissolved oxygen of diluted sample (mg/L), before incubation

D_2 = dissolved oxygen of diluted sample (mg/L), at the end of 5 days incubation.

Heavy metal (Ni, Cr, As, Cd, Pb and Hg):

Lead, Cadmium, Chromium, Nickel, Copper, Zinc, Arsenic, Calcium (Ca), and Magnesium (Mg) in water samples were determined with an atomic absorption spectrophotometer (AAS) (Model: AA-7000, Shimadzu) followed by APHA 3111, which was calibrated using certified reference material (CRMs) (APHA, 1998).

Atomic absorption spectrophotometer

Soluble reactive phosphorus (SRP):

SRP determination has been followed after Murphy and Riley (1962). The dilution factor ranged from 2 to 10. Considering the dilution factor accurately measured sample was poured in acid washed 100 mL capacity Pyrex conical flasks. Then required amount of distilled water was added to each sample to make the volume 50 mL. 5 mL mixed reagent (a mixture of 30 mL ammonium molybdate, 75 mL H_2SO_4, 30 mL freshly prepared ascorbic acid and 15 mL potassium antimonyl tartarate) was dispensed in each flask. The solution of the flask was mixed properly and after 5 to 10 minutes blue color developed, then the extinctions were measured using 885 nm wavelength with the help of 4 cm path length quartz cuvettes.

Soluble reactive silicate (SRS):

The determination of soluble reactive silicate was followed after Wetzel and Likens (1979). The dilution factor ranged from 2 to 5. Considering the dilution factor accurately measured sample was poured in acid washed pyrex conical flasks of 100 mL capacity each used to determine SRS. Sequentially 5 mL 0.25N HCl, 5 mL of 5% ammonium molybdate and 5 mL 1% disodium EDTA was added to it. The sample was mixed properly and kept undisturbed for next five minutes. Then 10 mL of 17% sodium sulfite was added to each flask. Blue color developed according to the concentration of SRS in the sample. A reagent blank and standard series of silica was also treated in the same manner. Sub-samples from each of these were measured in a Schimadzu spectrophotometer (UV-120-02) at a wave length of 700 nm using 1cm path length quartz glass cuvette. Finally the values were calculated by regression analysis with the help of standard series.

References:

APHA 1998. Standard Methods for the Examination of Water and Wastewater, 20th edition. American Public Health Association, Washington.

Murphy, J. and Riley, J.P. 1962. A modified single solution method for the determination of phosphate in natural water. Analyt. Chem. Acta. **27**: 31-36.

Wetzel, R.G. and Likens. 1979. Limnological analysis. W. B. Saunders Co., Philadelphia, pp. 357.

Hydrobiological parameter measurements

All the hydrobiological and biological analysis made in the present investigation were followed by standard procedures.

Biological parameters

Chlorophyll-a (chl-a)and phaeopigment

Pigment extraction was done from the fresh cells of phytoplankton trapped onto the filter paper during filtration of water collected from the pelagic zone of the river. The method of extraction was as follows: test tube containing rolled filter paper was treated with 5 mL hot 90% ethanol (kept boiling at 75°C in a water bath, model Eyela, Thermopet NTT-211, Japan). Then the test tube containing filter paper dipped in to ethanol was given a hot and cold treatment by putting it firstly in the hot water bath for three minutes and then cooling in tap water carefully. After cooling, the pigment was extracted (1st) and was transferred to another glass tube while the filter paper was given second extraction treatment in the same manner as mentioned above. The extracted pigment solutions (1^{st} and 2^{nd}) were poured in a measuring cylinder to make it 10 mL by adding extra 90% alcohol if necessary. Then the pigment samples were taken in 1 cm path length quartz glass cuvette and optical density (OD) was measured in a spectrophotometer at wave length 665 nm and 750 nm against 90% ethanol as blank. The acidification was done by adding in 3.7 µL HCl in each cuvette (for a volume c 3.7 mL). Finally the concentration of chl-a and phaeopigment were calculated after Marker *et al*. (1980).

Preparation of samples for the quantification and diversity analyses of phytoplankton

The Pyrex glass bottle containing one liter river water fixed with Lugol's solution was kept undisturbed in the dark for 48 h in order to facilitate sedimentation of phytoplankton individuals. After sedimentation, the overlying water from the bottle was withdrawn by using a vacuum pump in such a way that the accumulated layer of plankton sediment is not disturbed. After removing the water of the bottle successfully the sediment layer of phytoplankton was stirred up and the solution was transferred to a 50 mL screw capped glass vials for further handling. Here in after this solution is termed as 'plankton concentrates'.

Phytoplankton quantification

Counting of phytoplankton was also done with the help of a HBCC under a compound microscope (Nikon SE, Japan) at a magnification of 10 × 40. Each sample was counted three times. A minimum total of 100 cells (for three counts) were used for the identification of dominant phytoplankton taxa. Some taxa whose count fell below 100 were treated as present (p) only. Finally the cell density of phytoplankton was calculated as follows:

Density as ind/L = (v/3.015 µL × total count)

where,

v = volume of plankton concentrate in µL.

3.015 = volume of the counting chamber for three replicate counting (chamber volume = 1.05 µL).

total count = total number of individuals present in three replicate counting.

Qualitative analysis of phytoplankton

Before counting of the phytoplankton individual a random checking of the sedimented planktonic material was carried out under high magnification for identification up to species level. For identification, algal literatures as well as publications available for Bangladesh, other world monographs and books will be consulted .

All measurements carried out *ex situ* and *in situ* for the selected areas were recorded properly. The values for different parameters were digitized in a PC and a data base was created in Excel programme. The values were then manipulated to calculate monthly, seasonal or annual means with standard error as applicable. Finally, synergistic effect of all factors on the water quality of the river were made.

Results and Discussion:

Protecting bank erosion with bamboo structures is a good initiative. These are low-cost, eco-friendly, and effective for land reclamation.

The river is characterized by shallow water regions with rapid current especially in monsoon. There is no record for ecohydrological studies on the above mentioned rivers, which eventually demands a scientific investigation. So, the present study is designed to carry out ecological as well as hydrological perspectives with drawing attention of genetic diversity of dominant aquatic flora in the river corridor.

Samples were collected from the Rivers and were made from surface to bottom of the river at different depths. With the help of Schindler's depth sampler water from different depths was collected. Air temperature, water temperature, secchi depth, pH, total dissolved solids (TDS), dissolved oxygen (DO) and conductivity were measured in *situ* using portable devices. Biochemical oxygen demand (BOD), Soluble reactive phosphorus (SRP), Soluble reactive silicate (SRS), Heavy metal (Ni, Cr, As, Cd, Pb and Hg), Identification of Chlorophyll *a* (chl *a*) and phaeopigment as biomass, Qualitative estimation with Generic and Species identification of phytoplankton and aquatic macrophytes, Numerical counts of phytoplankton and aquatic macrophytes of river water were measured. Rare/threatened macrophytes and periphytic algae of river sediments were collected from the littoral zone of the river. Samples of Phytoplankton were collected by sedimentation technique with Lugol's solution and quantification of plankton were made with the help of a HBCC (Helber bacterial counting chamber, having a fixed volume 1.005 µl) under compound microscope and photography were also taken.

According River Continuum Concept (RCC) biological communities in the stream may vary greatly in different retention zones with high alluvial sedimentation. This fact will support the RCC evidently. In addition sources of organic matter and energy mainly allochtonous and autochtonous vary greatly in the continuum. These nutrient loads affect the benthic biological communities as well as phytoplankton population. Riverine phytoplankton production is clearly highest in retention zones. Inputs of organic and mineral matter, hydromorphological modifications on watercourses reduction the predictability of the RCC and altered the eco-hydrological process of retention zones.

Degree or magnitude of eco-hydrology induced variables on different retention zones of river ecosystem will be known specific time period. A comparable study of eco-hydrological status of the river will be achieved through the study of hydrological and biological parameters. Anthropogenic pressures in different sites of the river will be known by IMPRESS analysis. Thus it will be possible to link the water quality and climatic variables with human impact.

This study will certainly strengthen our knowledge of ecological water quality study. Environmental impact assessment at the river basin area will enhance the understanding the degree of pressure on aquatic organisms due to anthropogenic activities. Thus it will establish useful tool for aquatic resource management and monitoring in our country.The research area itself is a new approach in aquatic ecosystems of Bangladesh. The methodologies and technologies we proposed are ultramodern and have not yet been carried out in these rivers of Bangladesh. This research will be quite informative, innovative, and useful for river ecosystems and management of Bangladesh.

Analysis of ecological water quality relating with ecology in the river ecosystems of Bangladesh observed rarely. Different research activities were carried out but it was not enough to provide a view of eco-hydrology. In case of the Rivers the data of biology, ecology and hydrology were lacking to establish the status of the river. The river counters intensive attractive value for the tourists surrounded by highly scenic geography and natural resources. A combined approach will be needed for better management of the morphometry and aquatic flora and fauna of the river. The project will support future analysis and pave a new way of eco-hydrological research for the future researcher in aquatic ecosystems of Bangladesh.

Results (2019-2020):

BOD:

Padma River:

The concentration of BOD is the highest in the middle (0.59 mg/l) during and the lowest (0.34 mg/l) was found during before bandalingbut the maximum concentration (0.87) was found at the dawn stream during the first phase of the sampling. The highest concentration (1.30 mg/l) was found at the sixth session of before bandaling in the downstream in this river and the lowest concentration (0.33 mg/l) was detected at during the fourth session in the downstream. The highest average concentration of BOD was found in the upstream and the lowest was detected in the downstream for this river (fig. 1).

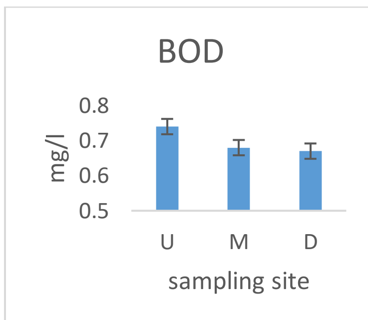


Fig.1. Showing the average concentration of BOD of the river Padma (2019-2020).

Arialkha river:

Sampling was carried out only for two sessions in this river. The highest concentration of BOD (1.30 mg/l) was found in the downstream in the second phase of the experiment and the lowest concentration (0.43 mg/l) was detected in the upstream at after bandaling at the first session of experiment. The highest average concentration was found in the downstream and the lowest was in the upstream for this river (Fig. 2).

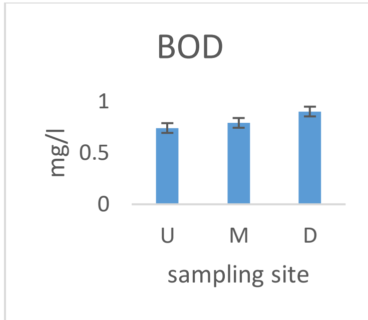


Fig.2. Showing the average concentration of BOD of the river Arialkha (2019-2020).

Baliakandi river:

In this river sampling was also carried out for two sessions. The highest concentration of BOD (1.30 mg/l) was found in the upstream in the second phase of the experiment and the lowest concentration (0.43 mg/l) was detected in the downstream during after bandaling at the second session of experiment. The highest average concentration was found in the upstream and the lowest was in the downstream for this river (Fig. 3).

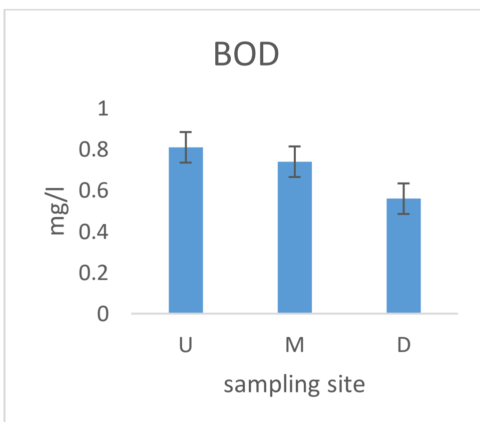


Fig.3. Showing the average concentration of BOD of the river Baliakandi (2019-2020).

Sugondha river:

A total of eight phases of experiments were done in this river. The highest concentration (1.2 mg/l) of BOD was detected at downstream during before bandaling of seventh phase of the experiment and the lowest concentration (0.31 mg/l) was also found at downstream during after bandaling period of second phase. The highest average concentration was found in the upstream and the lowest was in the downstream for this river (Fig. 4).

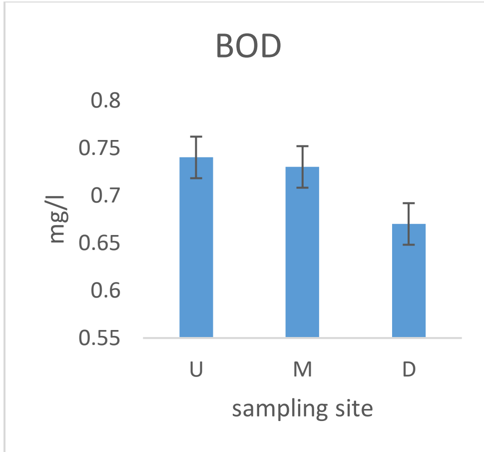


Fig. 4. Showing the average concentration of BOD of the river Sugondha (2019-2020).

Kongsho river:

A total of eight phases of experiments were done in this river. The highest concentration (1.2 mg/l) of BOD was detected at upstream during after bandaling of first phase of the experiment and the lowest concentration (0.41 mg/l) was also found at the middle during after bandaling period of second phase. The highest average concentration was found in the upstream and the lowest was in the middle for this river (Fig. 5).

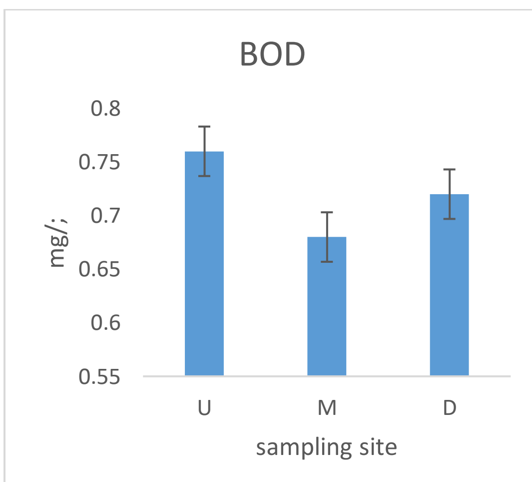


Fig. 5. Showing the average concentration of BOD of the river Kongsho (2019-2020).

Bhadra river:

A total of eight phases of experiments were done in this river. The highest concentration (1.3 mg/l) of BOD was detected at upstream during after bandaling of seventh phase of the experiment and the lowest concentration (0.41 mg/l) was also found at the downstream during after bandaling period of third phase. The highest average concentration was found in the upstream and the lowest was in the downstream for this river (Fig. 6).

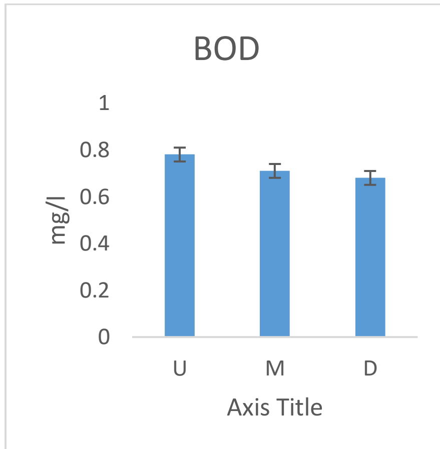


Fig. 6. Showing the average concentration of BOD of the river Bhadra (2019-2020).

Heavy metal:

Nickle (Ni):

Padma river:

No Ni was found at any phase of the experiment in this river. The concentration was always below the detection level.

Arialkha river:

No Ni was found at any phase of the experiment in this river. The concentration was always below the detection level.

Baliakandi river:

No Ni was found at any phase of the experiment in this river. The concentration was always below the detection level.

Sugondha river:

No Ni was detected at any phase of the experiment in this river. The concentration was always below the detection level.

Kongsho river:

No Ni was available at any phase of the experiment in this river. The concentration was always below the detection level.

Bhadra river:

No Ni was detected at any phase of the experiment in this river. The concentration was always below the detection level.

Chromium (Cr):

Padma river:

No Cr was found at any phase of the experiment in this river. The concentration was always below the detection level.

Arialkha river:

No Cr was found at any phase of the experiment in this river. The concentration was always below the detection level.

Baliakandi river:

No Cr was found at any phase of the experiment in this river. The concentration was always below the detection level.

Sugondha river:

No Cr was detected at any phase of the experiment in this river. The concentration was always below the detection level.

Kongsho river:

No Cr was available at any phase of the experiment in this river. The concentration was always below the detection level.

Bhadra river:

No Cr was detected at any phase of the experiment in this river. The concentration was always below the detection level.

Arsenic (As):

Padma river:

Most of the phases of the experiment the concentration of As was below the detection level. Only twice As was found in the middle in very low concentration (0.002 mg/l). Firstly it was detected at the fifth phase of the experiment during after bandalingand secondly it was detected also during after bandaling at the seventh phase of the experiment.

Arialkha river:

Only once in two phases of experiment As was detected in a very low concentration (0.002 mg/l) which was detected in the before bandaling of the first phase of the experiment in the middle. Most of the time the concentration was below the detection level.

Baliakandi river:

Only once in two phases of experiment As was detected in a very low concentration (0.003 mg/l) which was detected in the middle during before bandaling of the first phase of the experiment. Most of the time the concentration was below the detection level.

Sugondha river:

Five phases of the experiment As was detected in the three sites of this river where twice in the middle and downstream and only once in the upstream. The highest concentration (0.003 mg/l) was detected for two times, once in the middle during before bandaling of the eighth phase of the experiment and once in the downstream during after bandaling of the second phase of the experiments. On the other times the concentration was 0.002 mg/l and the concentration was below the detection level most of the time.

Kongsho river:

Only four phases of the experiment among ten phases As was detected in the three sites of this river for twice in each site of the river. The highest concentration (0.003 mg/l) was detected in the middle during before bandaling of the eighth phase of the experiments. On the other times the concentration was 0.002 mg/l and most of the time As concentration was below the detection level in this river.

Bhadra river:

Only three phases of the experiment among eight phases As was detected in the three sites of this river for twice in upstream and once in the middle site but no As was detected at the downstream of the river. The concentration was 0.002 mg/l for all the available times and most of the time As concentration was below the detection level in this river.

Cadmium (Cd):

Padma river:

Most of the phases of the experiment the concentration of Cd was below the detection level. Only four times Cd was found in this river once in each of the upstream and in the middle and twice in the downstream. The highest concentration was (0.003 mg/l) detected in the upstream. On the three other time the concentration was 0.002 mg/l.

Arialkha river:

Only once in two phases of experiment Cd was detected in a very low concentration (0.002 mg/l) which was detected in the after bandaling of the first phase of the experiment in the middle site. Rest of the time on the different site the concentration was below the detection level.

Baliakandi river:

Only once in two phases of experiment Cd was detected in a very low concentration (0.002 mg/l) which was detected in the downstream during before bandaling of the second phase of the experiment. Rest of the time the concentration was below the detection level.

Sugondha river:

Only thrice in three different sites of the experiment Cd was detected, once in every site. The highest concentration (0.003 mg/l) was detected in the downstream during before bandaling of the first phase of experiment. On the other times the concentration was 0.002 mg/l and the concentration was below the detection level rest of the time.

Kongsho river:

Only four times of the experiment among ten phases Cd was detected in the three sites of this river for twice in the downstream and once for upstream and middle of the river. All the time the concentration was 0.002 mg/l and rest of the time Cd concentration was below the detection level in this river.

Bhadra river:

Only three phases of the experiment among eight phases Cd was detected in the three sites of this river for once in every site of the river. The highest concentration was 0.003 mg/l for the middle and downstream but the concentration was 0.002 in the upstream during after bandaling of the fourth phase and rest of the time Cd concentration was below the detection level in this river.

Lead (Pb):

Padma river:

Most of the phases of the experiment the concentration of Pb was below the detection level but the concentration was a little higher than the other heavy metal in this site. Only six times Pb was found in this river twice in each of the upstream, middle and in the downstream. The highest concentration was (0.03 mg/l) detected in the downstream during after bandaling of the second phase of the experiment. Rest of time the concentration was 0.02 mg/l.

Arialkha river:

Two phases of experiment had been carried out here in this river and Pb was comparatively higher concentration (0.02 mg/l) than the other heavy metal which was detected in the after bandaling of the first phase of the experiment in the middle site and during before bandaling of the second phase of the experiment in the downstream. Upstream was totally free from Pb accumulation. Rest of the time on the different site the concentration was below the detection level.

Baliakandi river:

Only once in two phases of experiment Pb was detected comparatively in higher concentration (0.03 and 0.02 mg/l) which was detected in the upstream during before bandaling of the first phase and in the middle during the after bandaling in the middle of the experiment. Downstream was found free from Pb accumulation. Rest of the time the concentration was below the detection level.

Sugondha river:

Only four times in three different sites of the experiment Pb was detected, once in upstream and in middle and twice in the downstream. The highest concentration (0.03 mg/l) was detected in the downstream during after bandaling of the sixth phase of the experiment. On the other times the concentration was 0.02 mg/l and the concentration was below the detection level rest of the time.

Kongsho river:

Six phases of the experiment among ten Pb was detected in the three sites of this river for twice in the upstream and middle and thrice for downstream of the river. The concentration of this heavy metal was comparatively higher than the previous heavy metal. The highest concentration was (0.03 mg/l) detected once in the middle and once in the downstream. Rest of the time Pb concentration was 0.02 mg/l or below the detection level in this river.

Bhadra river:

Only four phases of the experiment among ten Pb was detected in the three sites of this river for once in the upstream and the middle and twice in the downstream of the river. The highest concentration was 0.03 mg/l which was detected at the middle and the other cases the concentration was 0.02 in the upstream and downstream and rest of the time Pb concentration was below the detection level in this river.

Mercury (Hg):

Padma river:

No Hg was detected in any site of the river during the experiment. The concentration was always below the detection level.

Arialkha river:

No Hg was detected in any site of the river during the experiment. The concentration was always below the detection level.

Baliakandi river:

No Hg was detected in any site of the river during the experiment. The concentration was always below the detection level.

Sugondha river:

No Hg was detected in any site of the river during the experiment. The concentration was always below the detection level.

Kongsho river:

No Hg was detected in any site of the river during the experiment. The concentration was always below the detection level.

Bhadra river:

No Hg was detected in any site of the river during the experiment. The concentration was always below the detection level.

Soluble reactive phosphorus (SRP):

Padma River:

The concentration of SRP was the highest in the middle (16.66 µg/l) during before bandaling in the upstream at the tenth phase of the experiment and the lowest (3.20 µg/l) was found during before bandaling at the middle during the third phase of the sampling. The highest average concentration of SRP (8.46 µg/l) was found in the upstream and the lowest (7.74 µg/l) was detected in the middle for this river (fig. 7).

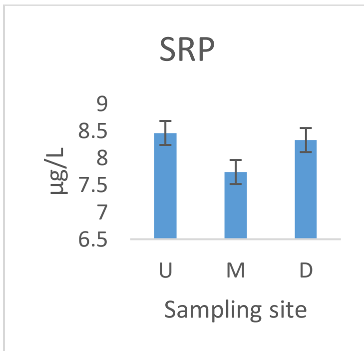


Fig. 7. Showing the average concentration of SRP of the river Padma (2019-2020).

Arialkha river:

Sampling was carried out only for two sessions in this river. The highest concentration of SRP (10.93 µg/l) was found in the downstream in the second phase during before bandaling of the experiment and the lowest concentration (1.30 µg/l) was also detected in the downstream during after bandaling at the first session of experiment. The highest average concentration of SRP (5.87 µg/l) was found in the middle and the lowest (4.36 µg/l) was found in the upstream for this river (Fig. 8).

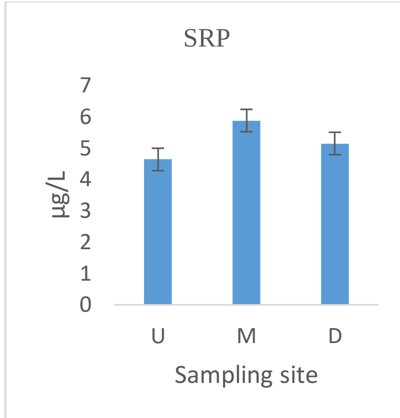


Fig. 8. Showing the average concentration of SRP of the river Arialkha (2019-2020).

Baliakandi river:

In this river sampling was also carried out for two sessions. The highest concentration of SRP (5.10 µg/l)) was found in the middle during after bandaling in the first phase of the experiment and the lowest concentration (2.55 µg/l) was detected in the downstream during after bandaling at the first phase of the experiment. The highest average concentration of SRP (4.56 µg/l) was found in the middle during after bandalingand the lowest (3.70 µg/l) was also found during after bandaling in the downstream for this river (Fig.9).

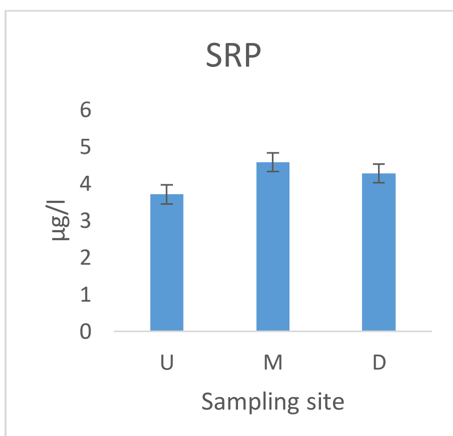


Fig. 9. Showing the average concentration of SRP of the river Baliakandi (2019-2020).

Sugondha river:

A total of eight phases of experiments were done in this river. The highest concentration (14.87 µg/l) of SRP was detected at upstream during after bandaling of fifth phase of the experiment and the lowest concentration (2.37 µg/l) was also found at upstream during before bandaling period of sixth phase. The highest average concentration of SRP (6.89 µg/l) was found in the upstream and the lowest (6.46 µg/l) was in the downstream for this river (Fig. 10).

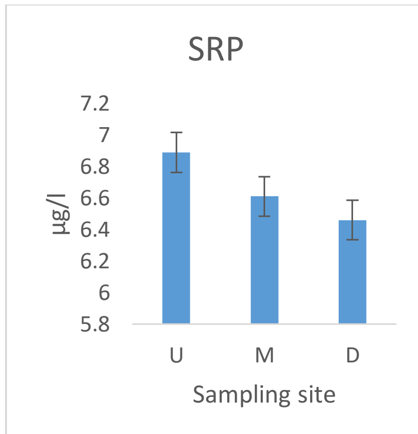


Fig. 10. Showing the average concentration of SRP of the river Sugondha (2019-2020).

Kongsho river:

A total of eight phases of experiments were done in this river. The highest concentration (14.59 µg/l)) of SRP was found at the middle during before bandaling of fourth phase of the experiment and the lowest concentration (1.20 µg/l) was also found at the upstream during before bandaling period of the third phase of the experiment. The highest average concentration of SRP (5.93 µg/l) was found in the downstream and the lowest concentration (5.36 µg/l) was in the upstream for this river (Fig. 11).

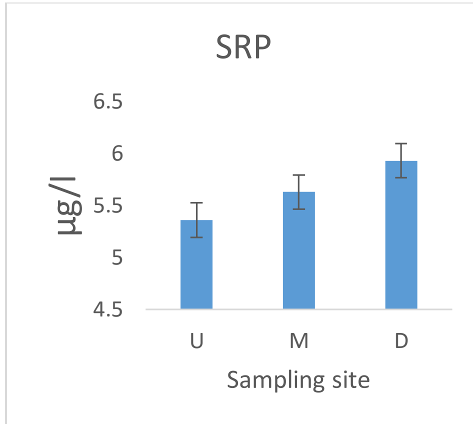


Fig. 11. Showing the average concentration of SRP of the river Kongsho (2019-2020).

Bhadra river:

A total of eight phases of experiments were done in this river. The highest concentration (11.56 µg/l) of SRP was detected in the middle during before bandaling of fourth phase of the experiment and the lowest concentration (1.09 µg/l) was found at the downstream during after bandaling period of sixth phase. The highest average concentration of SRP (5.58 µg/l) was found in the upstream and the lowest concentration (4.85 µg/l) was detected in the downstream for this river (Fig. 12).

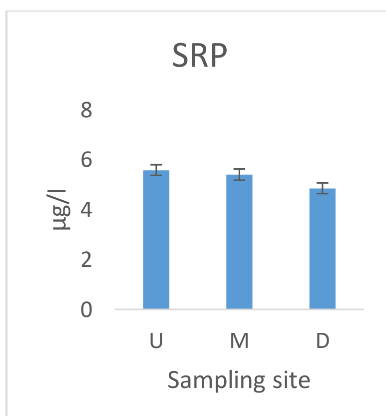


Fig. 12. Showing the average concentration of SRP of the river Bhadra (2019-2020).

Soluble reactive silicate (SRS):

Padma River:

The concentration of SRP was the highest in the downstream (12.23 mg/l) during after bandaling at the eighth phase of the experiment and the lowest concentration (0.23 mg/l) was also found during before bandaling at the downstream during the fourth phase of the sampling. The highest average concentration of SRP (3.55 mg/l) was found in the upstream and the lowest (3.09 mg/l) was detected in the downstream for this river (fig. 13).

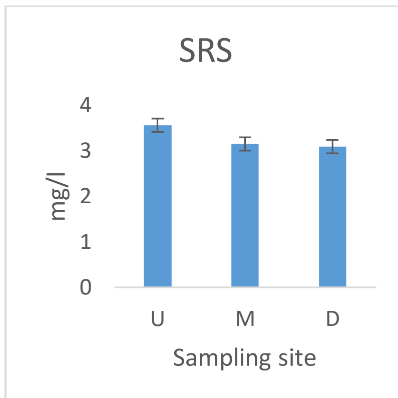


Fig. 13. Showing the average concentration of SRS of the river Padma (2019-2020).

Arialkha river:

Sampling was carried out only for two phases in this river. The highest concentration of SRP (6.88 mg/l) was found in the upstream in the second phase during before bandaling of the experiment and the lowest concentration (1.48 mg/l) was also detected in the upstream during after bandaling at the first session of experiment. The highest average concentration of SRP (4.15 mg/l) was found in the upstream and the lowest concentration (3.57 mg/l) was found in the downstream for this river (Fig. 14).

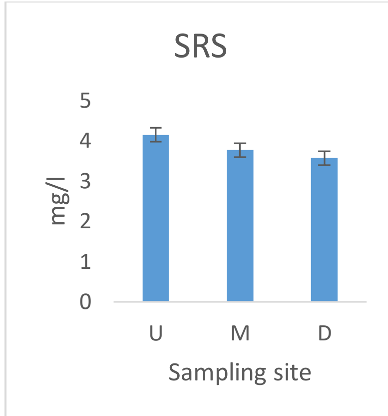


Fig. 14. Showing the average concentration of SRS of the river Arialkha (2019-2020).

Baliakandi river:

In this river sampling was also carried out only for two phases. The highest concentration of SRP (7.50 mg/l)) was found in the upstream during before bandaling in the first phase of the experiment and the lowest concentration (0.46 mg/l) was detected in the middle during before bandaling at the second phase of the experiment. The highest average concentration of SRP (3.40 mg/l) was found in the upstream and the lowest average concentration (1.92 mg/l) was in the downstream for this river (Fig. 15).

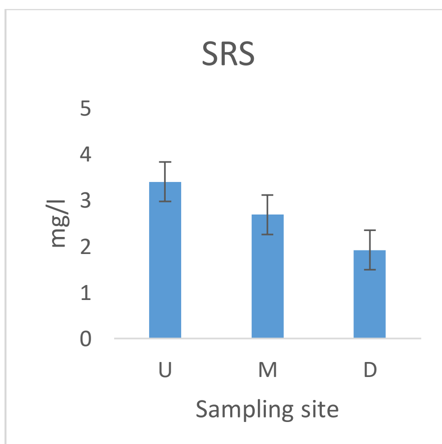


Fig. 15. Showing the average concentration of SRS of the river Baliakandi (2019-2020).

Sugondha river:

A total of eight phases of experiments were done in this river. The highest concentration (4.51 mg/l) of SRP was detected at downstream during before bandaling of first phase of the experiment and the lowest concentration (0.26 mg/l) was also found at the middle during after bandaling period of fifth phase. The highest average concentration of SRP (1.24 mg/l) was found in the downstream and the lowest (0.96 mg/l) was in the middle for this river (Fig. 16).

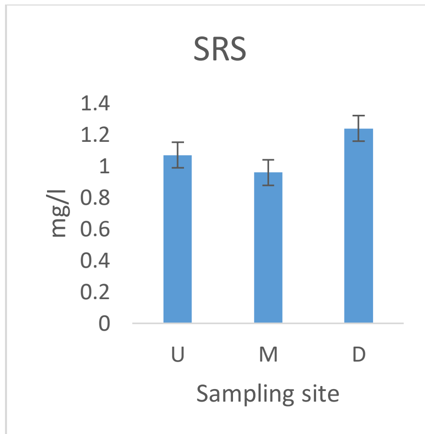


Fig. 16. Showing the average concentration of SRS of the river Sugondha (2019-2020).

Kongsho river:

A total of ten phases of experiments were done in this river. The highest concentration of SRP (3.31 mg/l) was found at the downstream during after bandaling of eighth phase of the experiment and the lowest concentration (0.28 mg/l) was also found at the middle during before bandaling period of the tenth phase of the experiment. The highest average concentration of SRP (1.25 mg/l) was found in the up and downstream and the lowest concentration (1.07 mg/l) was in the middle for this river (Fig. 17).

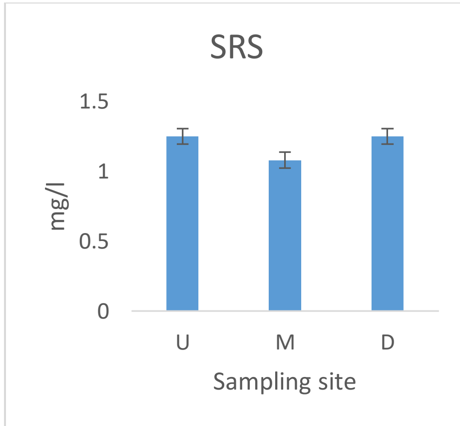


Fig. 17. Showing the average concentration of SRS of the river Kongsho (2019-2020).

Bhadra river:

A total of eight phases of experiments were done in this river. The highest concentration of SRP (7.05 mg/l) was detected in the downstream during after bandaling of fourth phase of the experiment and the lowest concentration (0.22 mg/l) was found at the middle during before bandaling period of eighth phase. The highest average concentration of SRP (1.94 mg/l) was found in the downstream and the lowest concentration (1.41 mg/l) was detected in the upstream for this river (Fig. 18).

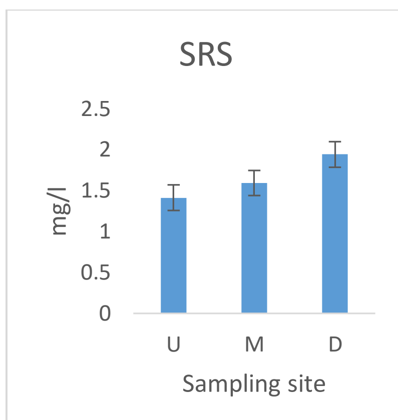


Fig. 18. Showing the average concentration of SRS of the river Bhadra (2019-2020).

Chlorophyll a (Chl a):

Padma River:

Experiment was carried out only for five phases for biological parameter in this river. The concentration of Chl a was the highest in the middle (13.67 µg/l) during before bandaling at the third phase of the experiment and the lowest concentration (1.10 µg/l) was also found during after bandaling at the downstream during the fourth phase of the experiment. The highest average concentration of Chl a (5.99 µg/l) was found in the middle and the lowest (4.88 µg/l) was detected in the upstream for this river (fig. 19).

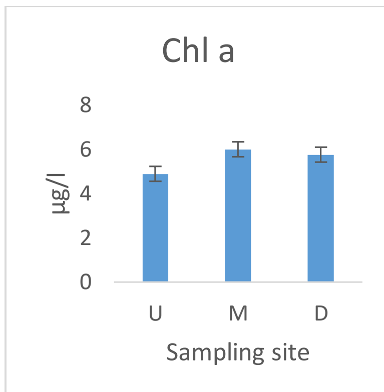


Fig. 19. Showing the average concentration of Chl a of the river Padma (2019-2020).

Arialkha river:

Sampling was carried out only for three times in this river for biological parameters, once in the before bandalingand twice in the after monsoon. The highest concentration of Chl a (9.27 µg/l) was found in the middle during third time of the experiment during after bandalingand the lowest (1.56 µg/l) was also found in the middle during after bandaling at the second time of experiment. The highest average concentration of SRP (5.76 µg/l) was found in the middle and the lowest concentration (3.48 µg/l) was found in the downstream for this river (Fig. 20).

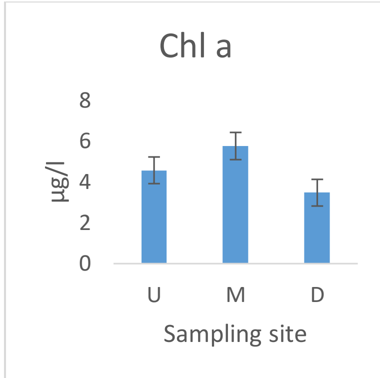


Fig. 20. Showing the average concentration of Chl a of the river Arialkha (2019-2020).

Baliakandi river:

Sampling was also carried out here only for two phases. The highest concentration of Chl a (8.88 µg/l)) was found in the middle during after bandaling in the second phase of the experiment and the lowest concentration (1.22 µg/l) was detected in the middle during before bandaling of the second phase of the experiment. The highest average concentration of SRP (4.78 µg/l) was found in the middle and the lowest average concentration (2.52 µg/l) was in the upstream for this river (Fig. 21).

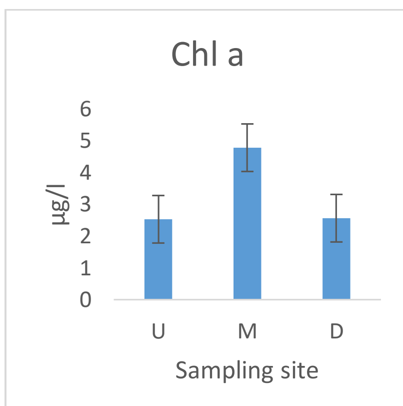


Fig. 21. Showing the average concentration of Chl a of the river Baliakandi (2019-2020).

Sugondha river:

A total of five phases of experiments were done in this river for biological parameters. The highest concentration of Chl a (9.46 µg/l) was detected at the middle during before bandaling of second phase of the experiment and the lowest concentration (1.09 µg/l) was also found at the upstream during after bandaling period of third phase. The highest average concentration of Chl a (3.86 µg/l) was found in the middle and the lowest (3.14 µg/l) was in the upstream for this river (Fig. 22).

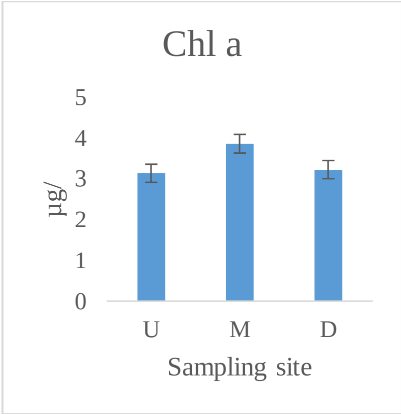


Fig. 22. Showing the average concentration of Chl a of the river Sugondha (2019-2020).

Kongsho river :

A total of five phases of experiments were done in this river for biological parameters. The highest concentration of Chl a (4.98 µg/l) was found at the downstream during after bandaling of first phase of the experiment and the lowest concentration (1.17 µg/l) was also found at the middle during after bandaling period of the fifth phase of the experiment. The highest average concentration of Chl a (2.81 µg/l) was found in the up and upstream and the lowest concentration (2.45 µg/l) was in the middle for this river (Fig. 23).

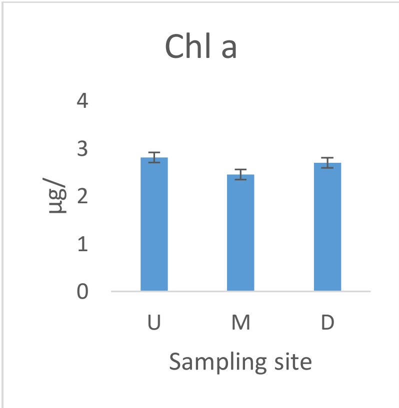


Fig. 23. Showing the average concentration of Chl a of the river Kongsho (2019-2020).

Bhadra river:

A total of five phases of experiments were done in this river. The highest concentration of Chl a (6.98 µg/l) was detected in the downstream during before bandaling of fifth phase of the experiment and the lowest concentration (0.36 µg/l) was found at the downstream during before bandaling period of third phase of experiment. The highest average concentration of Chl a (3.46 µg/l) was found in the downstream and the lowest concentration (3.40 µg/l) was detected in the middle for this river (Fig. 24).

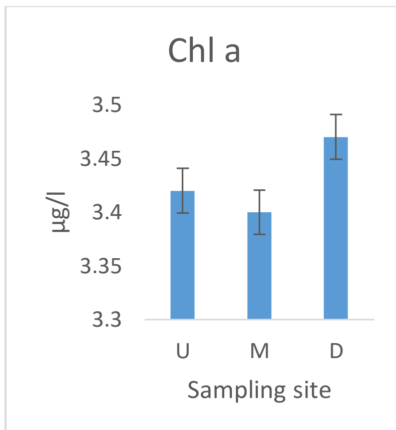


Fig. 24. Showing the average concentration of Chl a of the river Bhadra (2019-2020).

Phaeopigment:

Padma River:

Experiment was carried out only for five phases for biological parameter in this river. The concentration of phaeopigment was the highest in the middle (1.04 µg/l) during before bandaling at the fifth phase of the experiment and the lowest concentration (0.09 µg/l) was also found during before bandaling at the upstream during before bandaling of the fifth phase of the experiment. The highest average concentration of phaeopigment (0.80 µg/l) was found in the middle and the lowest (0.54 µg/l) was detected in the downstream for this river (fig. 25).

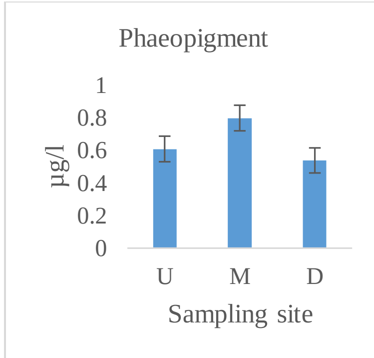


Fig. 25. Showing the average concentration of phaeopigment of the river Padma (2019-2020).

Arialkha river:

Sampling was carried out only for three times in this river, once in the before bandalingand twice in the after monsoon. The highest concentration of phaeopigment (0.98 µg/l) was found in the middle at third time of the experiment during after bandalingand the lowest (0.09 µg/l) was also found in the upstream during after bandaling at the second time of experiment. The highest average concentration of phaeopigment (0.72 µg/l) was found in the middle and the lowest concentration (0.41 µg/l) was found in the upstream for this river (Fig. 26).

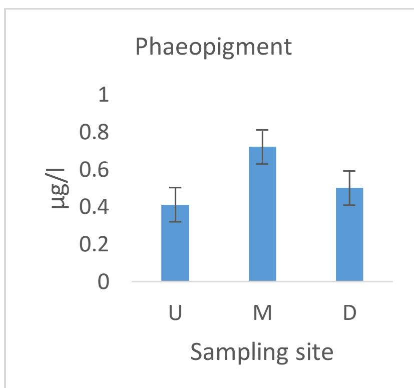


Fig. 26. Showing the average concentration of phaeopigment of the river Arialkha (2019-2020).

Baliakandi river:

In this river sampling was also carried out only for two phases. The highest concentration of phaeopigment (0.89 µg/l)) was found in the middle during before bandaling in the first phase of the experiment and the lowest concentration (0.46 µg/l) was detected in the upstream during before and after bandaling of the first and second phase of the experiment. The highest average concentration of phaeopigment (0.62 µg/l) was found in the middle and the lowest average concentration (0.22 µg/l) was in the upstream for this river (Fig. 27).

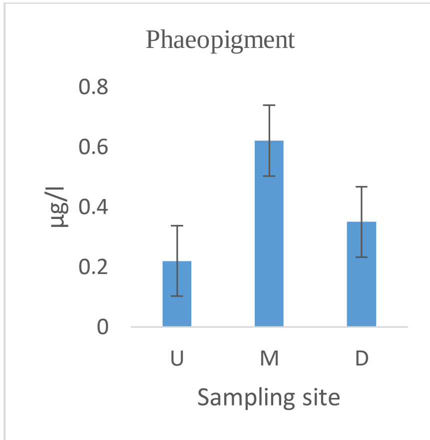


Fig. 27. Showing the average concentration of phaeopigment of the river Baliakandi (2019-2020).

Sugondha river:

A total of five phases of experiments were done in this river. The highest concentration of phaeopigment (0.50 µg/l) was detected at upstream during before bandaling of first phase of the experiment and the lowest concentration (0.01 µg/l) was also found at the downstream during before bandaling of the third phase. The highest average concentration of phaeopigment (0.17 µg/l) was found in the downstream and the lowest (0.13 µg/l) was in the upstream and in the middle for this river (Fig. 28).

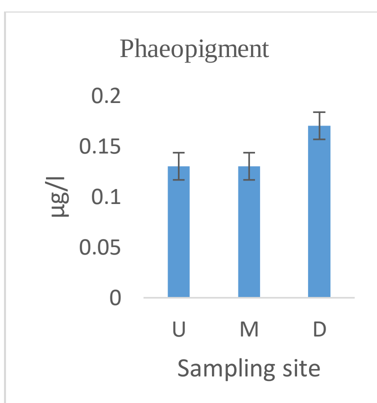


Fig. 28. Showing the average concentration of phaeopigment of the river Sugondha (2019-2020).

Kongsho river:

A total of five phases of experiments were done in this river for biological parameters. The highest concentration of phaeopigment (0.30 µg/l) was found at the upstream during before bandaling of the first phase of the experiment and the lowest concentration (0.03 µg/l) was also found at the upstream during after bandaling of the first phase and before bandaling of the third phase of the experiment. The average concentration of phaeopigment (0.12 µg/l) was found the same for the all three sites (Fig. 29).

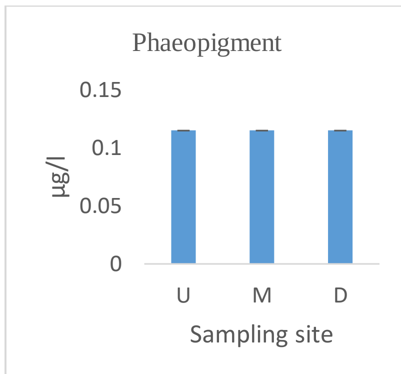


Fig. 29. Showing the average concentration of phaeopigment of the river Kongsho (2019-2020).

Bhadra river:

A total of five phases of experiments were done in this river for biological parameters. The highest concentration of phaeopigment (0.40 µg/l) was detected in the upstream during before bandaling of the first phase of the experiment and the lowest concentration (0.02 µg/l) was found at the downstream and in the middle during before and after bandaling of the third phase. The highest average concentration of phaeopigment (0.12 µg/l) was found in the up and downstream and the lowest concentration (0.11 µg/l) was detected in the middle for this river (Fig. 30).

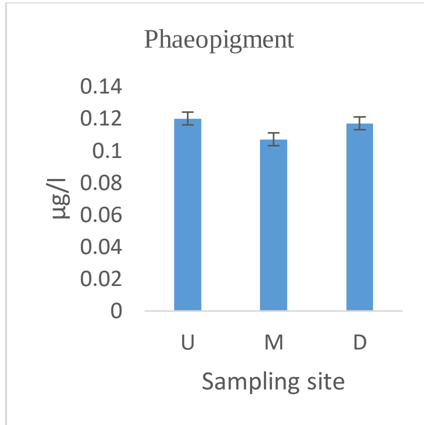


Fig. 30. Showing the average concentration of phaeopigment of the river Bhadra(2019-2020).

Numerical count of Phytoplankton (No. of ind.×10^4):

Padma River:

The numerical count of phytoplankton was the highest in the middle (15.27 µg/l) during before bandaling at the third phase of the experiment and the lowest concentration (0.98 µg/l) was also found during after bandaling at the middle during the third phase of the sampling. The highest average numerical count of phytoplankton (7.83 µg/l) was found in the middle and the lowest (5.27 µg/l) was detected in the upstream for this river (fig. 31).

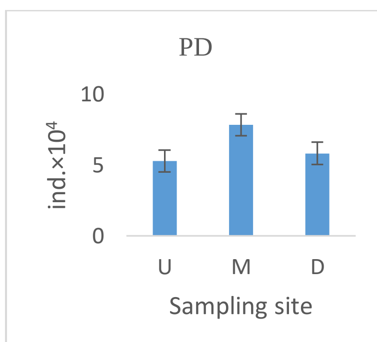


Fig. 31. Showing the average concentration of numerical count of phytoplankton of the river Padma (2019-2020).

Arialkha river:

Sampling was carried out only for three times, once in the before bandalingand twice in the after bandaling(second and third). The highest numerical count of phytoplankton (11.20 µg/l) was found in the middle in the third time of the experiment and the lowest concentration (1.53 µg/l) was also detected in the middle during after bandaling in the second time of experiment. The highest average numerical count of phytoplankton (7.43 µg/l) was found in the middle and the lowest concentration (3.28 µg/l) was found in the upstream for this river (Fig. 32).

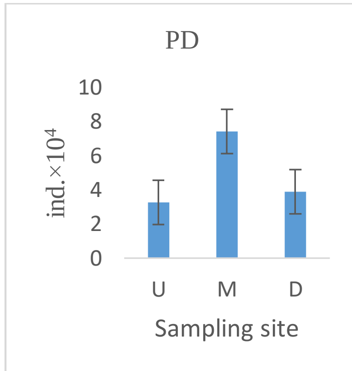


Fig. 32. Showing the average concentration of numerical count of phytoplankton of the river Arialkha(2019-2020).

Baliakandi river:

In this river sampling was also carried out only for two phases. The highest numerical count of phytoplankton (9.67 µg/l)) was found in the middle during before bandaling in the second phase of the experiment and the lowest concentration (1.98 µg/l) was detected in the downstream during before bandaling at the first phase of the experiment. The highest average numerical count of phytoplankton (5.39 µg/l) was found in the middle and the lowest average (2.67 µg/l) was in the downstream for this river (Fig. 33).

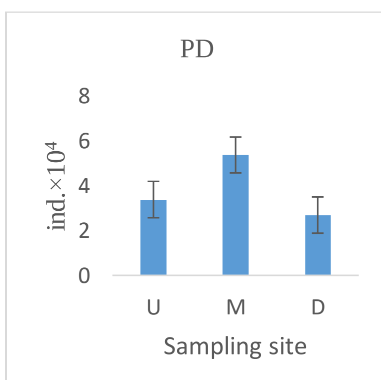


Fig. 33. Showing the average concentration of numerical count of phytoplankton of the river Baliakandi (2019-2020).

Sugondha river:

A total of five phases of experiments were done in this river for biological parameters. The highest numerical count of phytoplankton (11.97 µg/l) was detected in the middle during after bandaling of first phase of the experiment and the lowest concentration (1.58 µg/l) was also found at the upstream during after bandaling period of third phase. The highest average numerical count of phytoplankton (7.57 µg/l) was found in the middle and the lowest (3.65 µg/l) was in the downstream for this river (Fig. 34).

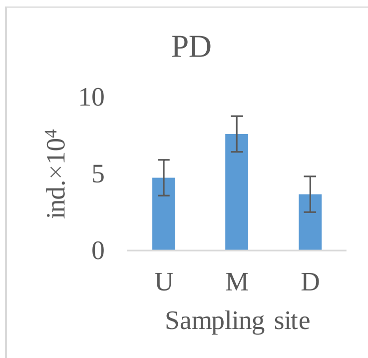


Fig. 34. Showing the average concentration of numerical count of phytoplankton of the river Sugondha (2019-2020).

Kongsho river:

A total of five phases of experiments were done in this river for biological parameters. The highest numerical count of phytoplankton (11.98 µg/l) was found at the middle during after bandaling of first phase of the experiment and the lowest concentration (1.57 µg/l) was also found at the upstream during after bandaling of the third phase of the experiment. The highest average numerical count of phytoplankton (6.19 µg/l) was found in the middle and the lowest (3.54 µg/l) was in the upstream for this river (Fig. 35).

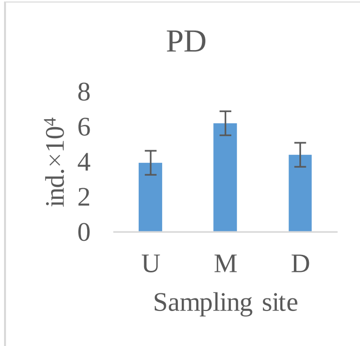


Fig. 35. Showing the average concentration of numerical count of phytoplankton of the river Kongsho (2019-2020).

Bhadra river:

A total of five phases of experiments were done in this river for biological parameters. The highest numerical count of phytoplankton (10.35 µg/l) was detected in the middle during after bandaling of the fifth phase of the experiment and the lowest concentration (0.50 µg/l) was found at the downstream during before bandaling period of the third phase. The highest average numerical count of phytoplankton (6.04 µg/l) was found in the middle and the lowest concentration (3.24 µg/l) was detected in the upstream for this river (Fig. 30).

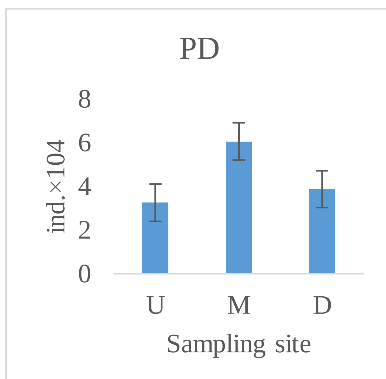


Fig. 36. Showing the average concentration of numerical count of phytoplankton of the river Bhadra (2019-2020).

Phytoplankton and macrophytes counting

Phytoplankton counting:

Phytoplankton belonging to different classes has been counted and identified during this time of 2019-20. A total of 39 species of Chlorophyceae, 35 species of Bacillariophyceae, 30 species of Euglenophyceae, 15 species of Cryptophyceae, 6 species of Cyanophyceae, 3 species of Dinophyceae and 1 species of Chrysophyceae were indentified.

Macrophyte counting:

Macrophytes belonging to monocotyledons and dicotyledons were enumerated form all six sampling rivers. A total of 48 species of macrophytes were found during the first session of the experiment.

Results on (2020-21)

BOD:

Padma River:

Sampling was done for eight phases in this river for chemical parameters. The highest concentration of BOD (1.43 mg/l) was the in the downstream during after bandaling of the seventh phase and the lowest (0.38 mg/l) was found in the upstream during before bandaling of first phase. The highest average concentration of BOD (0.82 mg/l) was found in the middle and the lowest (0.77 mg/l) was detected in the upstream for this river (fig. 1).

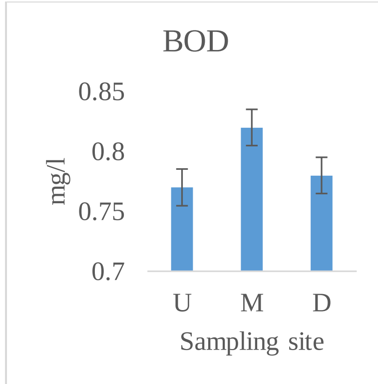


Fig. 1. Showing the average concentration of BOD of the river Padma (2020-2021).

Arialkha river:

Sampling was carried out only for two sessions in this river for chemical parameters. The highest concentration of BOD (1.39 mg/l) was found during before bandaling in the upstream in the first phase of the experiment and the lowest concentration (0.49 mg/l) was detected both in the upstream and middle at before and after bandaling of the second session of experiment. The highest average concentration of BOD (1.04 mg/l) was found in the downstream and the lowest (0.64 mg/l) was in the middle for this river (Fig. 2).

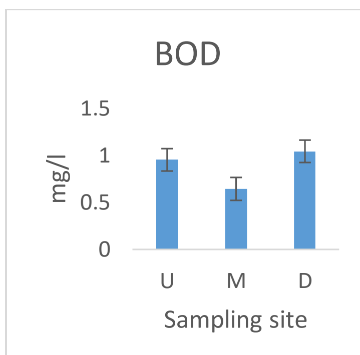


Fig. 2. Showing the average concentration of BOD of the river Arialkha (2020-2021).

Baliakandi river:

In this river sampling was also carried out for two sessions for chemical parameters. The highest concentration of BOD (1.27 mg/l) was found in the downstream during before bandaling in the first phase of the experiment and the lowest concentration (0.48 mg/l) was detected in the upstream during before bandaling of the second phase of experiment. The highest average concentration (1.02 mg/l) was found in the downstream and the lowest (0.80 mg/l) was in the middle for this river (Fig. 3).

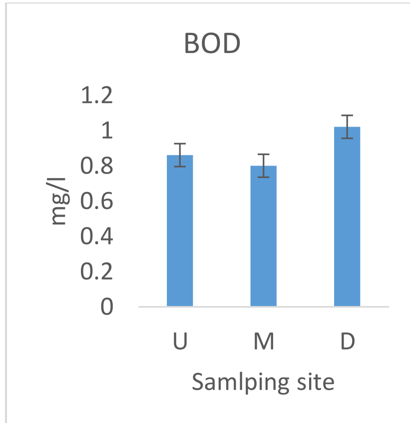


Fig.3. Showing the average concentration of BOD of the river Baliakandi (2020-2021).

Sugondha river:

A total of eight phases of experiments were done in this river for chemical parameters. The highest concentration of BOD (1.35 mg/l) was detected at downstream during after bandaling of the third phase of the experiment and the lowest concentration (0.22 mg/l) was also found at downstream during before bandaling period of the seventh phase. The highest average concentration (0.76 mg/l) was found in the upstream and the lowest (0.66 mg/l) was in the middle for this river (Fig. 4).

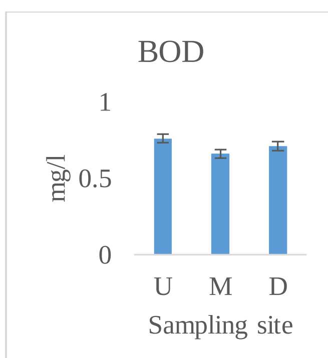


Fig. 4. Showing the average concentration of BOD of the river Sugondha (2020-2021).

Kongsho river:

A total of ten phases of experiments were done in this river for chemical parameter in the 2020-21 session. The highest concentration of BOD (1.53 mg/l) was detected at upstream during after bandaling of eighth phase of the experiment and the lowest (0.45 mg/l) was found in the middle during before bandaling of the eighth phase. The highest average concentration (0.83 mg/l) was found in the upstream and the lowest (0.77 mg/l) was in the middle for this river (Fig. 5).

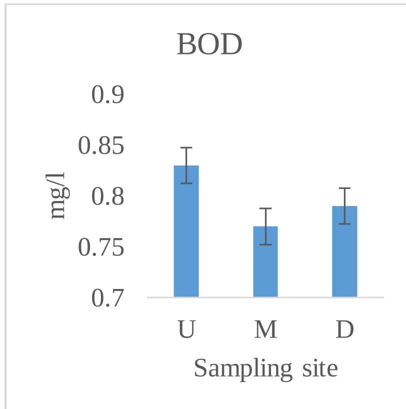


Fig. 5. Showing the average concentration of BOD of the river Kongsho (2020-2021).

Bhadra river:

A total of eight phases of experiments were done in this river for chemical parameters in the session of 2020-21. The highest concentration (1.54 mg/l) of BOD was detected at upstream during before bandaling of seventh phase of the experiment and the lowest concentration (0.33 mg/l) was found in the upstream and in the middle during before and after bandaling of the sisth phase. The highest average concentration (0.82 mg/l) was found in the upstream and the lowest (0.64 mg/l) was in the middle for this river (Fig. 6).

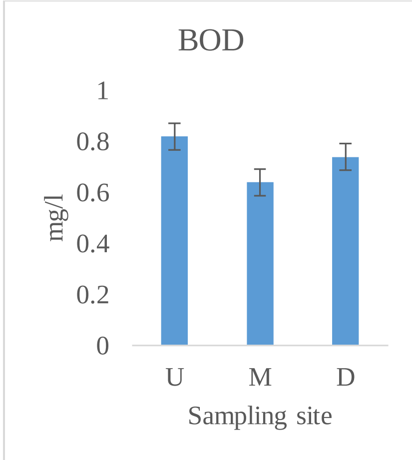


Fig. 6. Showing the average concentration of BOD of the river Bhadra (2020-2021).

Heavy metal:

Nickle (Ni):

Padma river:

No Ni was found at any phase of the experiment in this river. The concentration was always below the detection level.

Arialkha river:

No Ni was found at any phase of the experiment in this river. The concentration was always below the detection level.

Baliakandi river:

No Ni was found at any phase of the experiment in this river. The concentration was always below the detection level.

Sugondha river:

No Ni was detected at any phase of the experiment in this river. The concentration was always below the detection level.

Kongsho river:

No Ni was available at any phase of the experiment in this river. The concentration was always below the detection level.

Bhadra river:

No Ni was detected at any phase of the experiment in this river. The concentration was always below the detection level.

Chromium (Cr):

Padma river:

Chromium was found quite a few times in this river during 2020-21 session in a very low concentration (0.01 mg/l), thrice in each of the site in this river. Rest of the time the concentration was below the detection level.

Arialkha river:

Chromium was found only once in this river during 2020-21 session in a very low concentration (0.01 mg/l) in the middle during the before bandaling of the second phase in this river. Rest of the time the concentration was below the detection level.

Baliakandi river:

Chromium was found only twice in this river during 2020-21 session in a very low concentration (0.01 mg/l), once in the upstream during after bandaling of the first phase and once in the downstream during before bandaling of the second phase in this river. Rest of the time the concentration was below the detection level.

Sugondha river:

Chromium was found a few times in this river during 2020-21 session in a very low concentration (0.01 mg/l), twice in the upstream and in the middle and once in the downstream during after bandaling of the third phase of the experiment in this river. Rest of the time the concentration was below the detection level.

Kongsho river:

Chromium was found only three times in this river during 2020-21 session in a very low concentration (0.01 mg/l), once in the each site in the different phases of the experiment in this river. Rest of the time the concentration was below the detection level.

Bhadra river:

Chromium was found for two times in this river during 2020-21 session in a very low concentration (0.01 mg/l), once in the each of the up and downstream in different phases of the experiment in this river and the middle was free from Chromium. Rest of the time the concentration was below the detection level.

Arsenic (As):

Padma river:

As was found for only one time in this river in the session of 2020-21 in the downstream in very low concentration (0.002 mg/l) during the before bandaling of the tenth phase. Rest of the time arsenic was below the detection level in this river throughout the session of the experiment.

Arialkha river:

No arsenic was detected in this river during this session (2020-21) of experiment. All the time the concentration was below the detection level.

Baliakandi river:

No arsenic was detected in this river during this session (2020-21) of experiment. All the time the concentration was below the detection level.

Sugondha river:

No arsenic was detected in this river during this session (2020-21) of experiment. All the time the concentration was below the detection level.

Kongsho river:

No arsenic was detected in this river during this session (2020-21) of experiment. All the time the concentration was below the detection level.

Bhadra river:

No arsenic was detected in this river during this session (2020-21) of experiment. All the time the concentration was below the detection level.

Cadmium (Cd):

Padma river:

No Cadmium was detected in this river during this session (2020-21) of experiment. All the time the concentration was below the detection level.

Arialkha river:

No Cadmium was detected in this river during this session (2020-21) of experiment. All the time the concentration was below the detection level.

Baliakandi river:

No Cadmium was detected in this river during this session (2020-21) of experiment. All the time the concentration was below the detection level.

Sugondha river:

No Cadmium was detected in this river during this session (2020-21) of experiment. All the time the concentration was below the detection level.

Kongsho river:

No Cadmium was detected in this river during this session (2020-21) of experiment. All the time the concentration was below the detection level.

Bhadra river:

No Cadmium was detected in this river during this session (2020-21) of experiment. All the time the concentration was below the detection level.

Lead (Pb):

Padma river:

Lead (Pb) is one of the heavy metals which was found almost all the river during the session of 2020-21, in a very low concentration (0.01 mg/l). It was found for six times in this river, twice in each of the site. Rest of the times the concentrations were below the detection level.

Arialkha river:

Two phases of experiment had been carried out here in this river and Pb was found in a very low concentration (0.01 mg/l) during before bandaling of the second phase of the experiment in the middle. Upstream and downstream was totally free from Pb accumulation. Rest of the time on the different site the concentration was below the detection level.

Baliakandi river:

Two times in two phases of experiment Pb was detected in a low concentration (0.01 mg/l) which was detected in the upstream during after bandaling of the first phase and in the middle during before bandaling of the second phase of the experiment. Downstream was found free from Pb accumulation. Rest of the time the concentration was below the detection level.

Sugondha river:

Only four times in three different sites in the experiment Pb was detected, once in upstream and in downstream and twice in the middle. The concentration (0.01 mg/l) was same in every cases during the experiment. The concentration was below the detection level rest of the time.

Kongsho river:

Six phases of the experiment among ten Pb was detected in the three sites of this river for thrice in the upstream, once in the middle and two times in the downstream of the river. The concentration of this heavy metal was very low (0.01 mg/l). Rest of the time Pb concentration was below the detection level in this river.

Bhadra river:

Only two phases of the experiment among ten Pb was detected only in the middle during the session of 2020-21 in the river. The concentration was 0.01 mg/l every time. Upstream and downstream were totally free from Pb concentration and most of the time in the middle Pb concentration was below the detection level in this river.

Mercury (Hg):

Padma river:

No Hg was detected in any site of the river during the experiment. The concentration was always below the detection level.

Arialkha river:

No Hg was detected in any site of the river during the experiment. The concentration was always below the detection level.

Baliakandi river:

No Hg was detected in any site of the river during the experiment. The concentration was always below the detection level.

Sugondha river:

No Hg was detected in any site of the river during the experiment. The concentration was always below the detection level.

Kongsho river:

No Hg was detected in any site of the river during the experiment. The concentration was always below the detection level.

Bhadra river:

No Hg was detected in any site of the river during the experiment. The concentration was always below the detection level.

Soluble reactive phosphorus (SRP):

Padma River:

A total of ten phases of experiment were done in the session of 2020-21 for chemical parameters in this river. The concentration of SRP was the highest in the upstream (14.57 µg/l) during before bandaling of the ninth phase of the experiment and the lowest (2.30 µg/l) was found during before bandaling in the upstream during the third phase of the experiment. The highest average concentration of SRP (8.17 µg/l) was found in the middle and the lowest (7.15 µg/l) was detected in the upstream for this river (fig. 7).

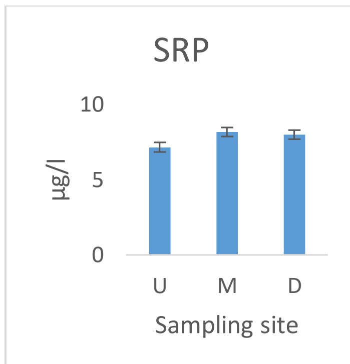


Fig. 7. Showing the average concentration of SRP of the river Padma (2020-2021).

Arialkha river:

Sampling was also carried out only for two phases in this river for this session. The highest concentration of SRP (12.33 µg/l) was found in the middle in the first phase during before bandaling of the experiment and the lowest concentration (3.34 µg/l) was also detected in the middle during after bandaling at the second phase of the experiment. The highest average concentration of SRP (8.13 µg/l) was found in the upstream and the lowest (7.24 µg/l) was found in the downstream for this river (Fig. 8).

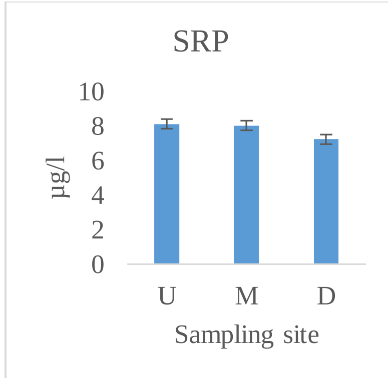


Fig. 8. Showing the average concentration of SRP of the river Arialkha (2020-2021).

Baliakandi river:

In this river sampling was also carried out for two phases during this session of 2020-21 for chemical parameters. The highest concentration of SRP (12.49 µg/l)) was found in the downstream during after bandaling in the second phase of the experiment and the lowest concentration (4.69 µg/l) was detected in the upstream during before bandaling at the second phase of the experiment. The highest average concentration of SRP (10.87 µg/l) was found in the downstream and the lowest (6.45 µg/l) was found in the middle for this river (Fig.9).

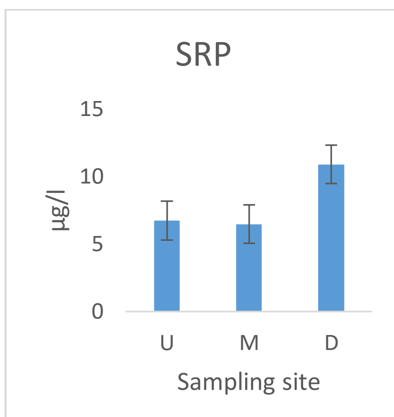


Fig. 9. Showing the average concentration of SRP of the river Baliakandi (2020-2021).

Sugondha river:

A total of eight phases of experiments were done in this river. The highest concentration (12.13 µg/l) of SRP was detected in the middle during after bandaling of fifth phase of the experiment and the lowest concentration (3.34 µg/l) was found in the upstream during after bandaling of the seventh phase. The highest average concentration of SRP (6.83 µg/l) was found in the middle and the lowest (6.67 µg/l) was in the downstream for this river (Fig. 10).

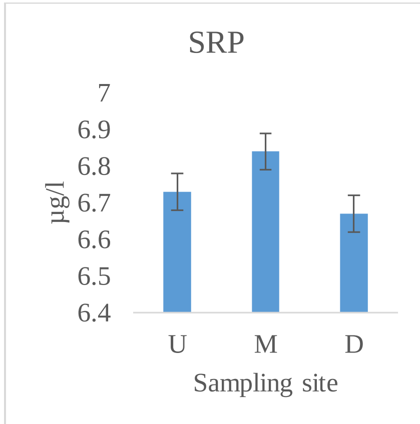


Fig. 10. Showing the average concentration of SRP of the river Sugondha (2020-2021).

Kongsho river:

A total of ten phases of experiments were done in this river during this session for chemical parameters. The highest concentration (10.58 µg/l)) of SRP was found at the middle during before bandaling of the fifth phase of the experiment and the lowest concentration (2.45 µg/l) was also found in the middle during after bandaling of the sixth phase of the experiment. The highest average concentration of SRP (6.82 µg/l) was found in the downstream and the lowest concentration (6.41 µg/l) was detected in the upstream for this river (Fig. 11).

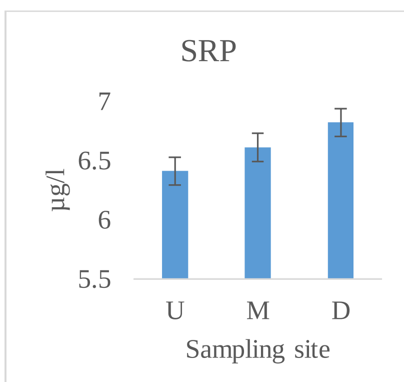


Fig. 11. Showing the average concentration of SRP of the river Kongsho (2020-2021).

Bhadra river:

A total of eight phases of experiments were done in this river for chemical parameters in this session. The highest concentration (10.43 µg/l) of SRP was detected in the upstream during after bandaling of fourth phase of the experiment and the lowest concentration (2.25 µg/l) was also found in the upstream during after bandaling period of sixth phase. The highest average concentration of SRP (6.47 µg/l) was found in the middle and the lowest concentration (5.56 µg/l) was detected in the upstream for this river (Fig. 12).

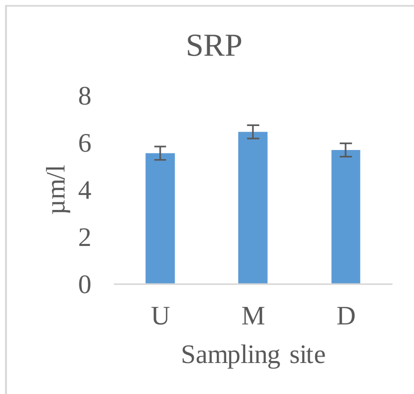


Fig. 12. Showing the average concentration of SRP of the river Bhadra (2020-2021).

Soluble reactive silicate (SRS):

Padma River:

The concentration of SRP was the highest in the downstream (12.37 mg/l) during before bandaling at the fifth phase of the experiment and the lowest concentration (0.37 mg/l) was detected during after bandaling in the upstream in the fourth phase of the experiment. The highest average concentration of SRP (5.77 mg/l) was found in the downstream and the lowest (3.48 mg/l) was detected in the upstream for this river (fig. 13).

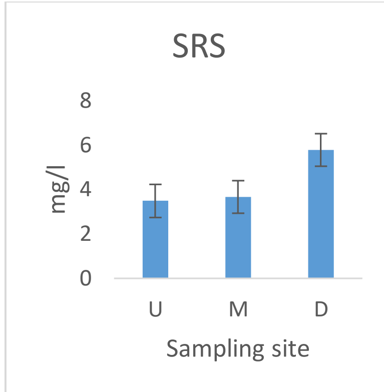


Fig. 13. Showing the average concentration of SRS of the river Padma (2020-2021).

Arialkha river:

Sampling was carried out only for two phases in this river during this session for chemical parameters. The highest concentration of SRP (11,73 mg/l) was found in the downstream in the second phase during after bandaling of the experiment and the lowest concentration (1.93 mg/l) was also detected in the upstream during before bandaling at the second phase of the experiment. The highest average concentration of SRP (8.85 mg/l) was found in the downstream and the lowest concentration (4.06 mg/l) was found in the upstream for this river (Fig. 14).

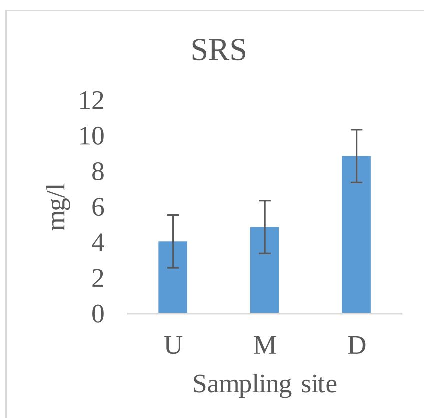


Fig. 14. Showing the average concentration of SRS of the river Arialkha (2020-2021).

Baliakandi river:

In this river sampling was also carried out only for two phases in this session for chemical parameters. The highest concentration of SRP (10.87 mg/l)) was found in the upstream during before bandaling in the first phase of the experiment and the lowest concentration (1.57 mg/l) was detected in the downstream during after bandaling at the first phase of the experiment. The highest average concentration of SRP (6.97 mg/l) was found in the upstream and the lowest average concentration (3.78 mg/l) was in the downstream for this river (Fig. 15).

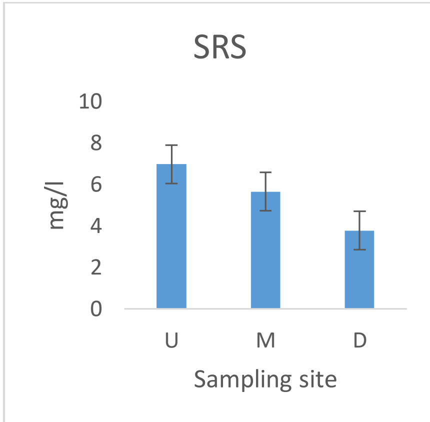


Fig. 15. Showing the average concentration of SRS of the river Baliakandi (2020-2021).

Sugondha river:

A total of eight phases of experiments were done in this river for chemical parameters in this session. The highest concentration (9.34 mg/l) of SRP was detected at middle during after bandaling of the fifth phase of the experiment and the lowest concentration (0.49 mg/l) was found at the upstream during after bandaling period of the third phase. The highest average concentration of SRP (3.69 mg/l) was found in the upstream and the lowest (3,14 mg/l) was in the downstream for this river (Fig. 16).

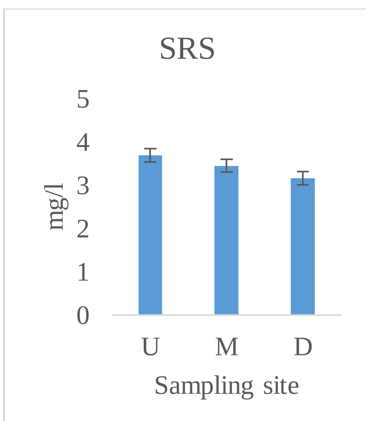


Fig. 16. Showing the average concentration of SRS of the river Sugondha (2020-2021).

Kongsho river:

A total of ten phases of experiments were done in this river for chemical parameters in the second session. The highest concentration of SRP (8.59 mg/l) was found at the upstream during after bandaling of the second phase of the experiment and the lowest concentration (0.45 mg/l) was found at the upstream during before bandaling period of the third phase of the experiment. The highest average concentration of SRP (3.41 mg/l) was found in the middle and downstream and the lowest concentration (3.31 mg/l) was in the upstream for this river (Fig. 17).

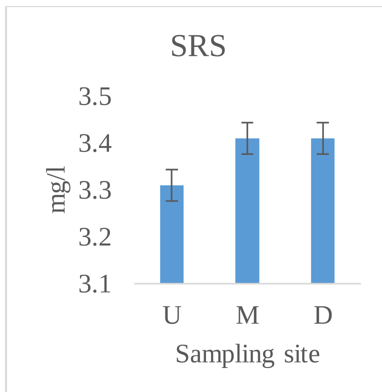


Fig. 17. Showing the average concentration of SRS of the river Kongsho (2020-2021).

Bhadra river:

A total of eight phases of experiments were done in this river for chemical parameters in the second session of the 2020-21. The highest concentration of SRP (8.45 mg/l) was detected in the middle during after bandaling of third phase of the experiment and the lowest concentration (0.91 mg/l) was found in the middle during before bandaling period of the eighth phase. The highest average concentration of SRP (3.45 mg/l) was found in the middle and the lowest (2.93 mg/l) was detected in the upstream for this river (Fig. 18).

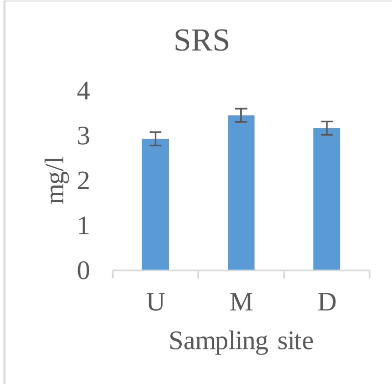


Fig. 18. Showing the average concentration of SRS of the river Bhadra (2020-2021).

Chlorophyll a (Chl a):

Padma River:

Experiment was carried out only for five phases for biological parameter in this river in the session of 2020-21. The concentration of Chl a was the highest in the middle (12.89 µg/l) during after bandaling at the fifth phase of the experiment and the lowest concentration (1.23 µg/l) was also found during after bandaling in the middle during the second phase of the experiment. The highest average concentration of Chl a (5.69 µg/l) was found in the downstream and the lowest (4.82 µg/l) was detected in the upstream for this river (fig. 19).

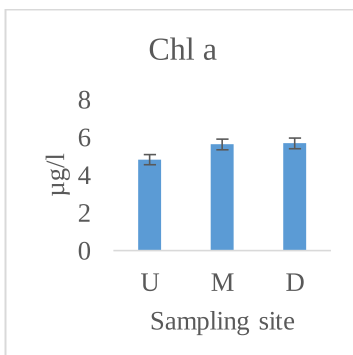


Fig. 19. Showing the average concentration of Chl a of the river Padma (2020-2021).

Arialkha river:

Sampling was carried out only for three times in this river for biological parameters, once in the before bandaling and twice in the after bandaling in the second session of 2020-21. The highest concentration of Chl a (9.46 µg/l) was found in the upstream during after bandaling of the third time and the lowest (2.36 µg/l) was also found in the middle during after bandaling in the second time of the experiment. The highest average concentration of SRP (7.10 µg/l) was found in the upstream and the lowest concentration (3.60 µg/l) was found in the downstream for this river (Fig. 20).

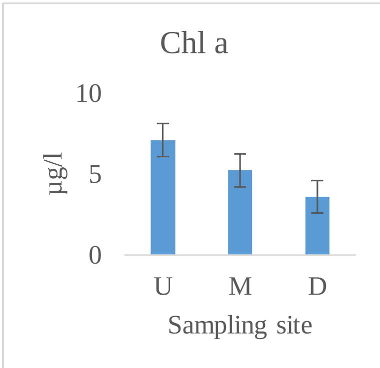


Fig. 20. Showing the average concentration of Chl a of the river Arialkha (2020-2021).

Baliakandi river:

Sampling was also carried out here only for two phases for the enumeration of the biological parameters in the second session. The highest concentration of Chl a (9.45 µg/l)) was found in the downstream during after bandaling in the second phase and the lowest concentration (1.98 µg/l) was detected in the middle during after bandaling of the second phase of the experiment. The highest average concentration of SRP (5.35 µg/l) was found in the downstream and the lowest average concentration (3.25 µg/l) was in the upstream for this river (Fig. 21).

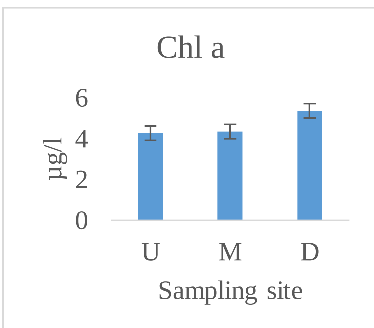


Fig. 21. Showing the average concentration of Chl a of the river Baliakandi (2020-2021).

Sugondha river:

A total of five phases of experiments were done in this river for biological parameters in the second session. The highest concentration of Chl a (6.79 µg/l) was detected at the middle during after bandaling of the fifth phase of the experiment and the lowest concentration (1.23 µg/l) was found in the upstream during after bandaling period of second phase. The highest average concentration of Chl a (5.09 µg/l) was found in the upstream and the lowest (3.39 µg/l) was in the downstream for this river (Fig. 22).

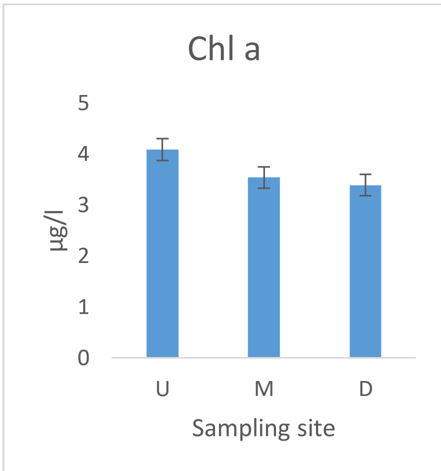


Fig. 22. Showing the average concentration of Chl a of the river Sugondha (2020-2021).

Kongsho river:

A total of five phases of experiments were done in this river for biological parameters. The highest concentration of Chl a (3.98 µg/l) was found at the middle during before bandaling of the second phase and the lowest concentration (1.08 µg/l) was also found at the middle during before bandaling of the third phase of the experiment. The highest average concentration of Chl a (2.87 µg/l) was found in the upstream and the lowest (2.50 µg/l) was in the middle for this river (Fig. 23).

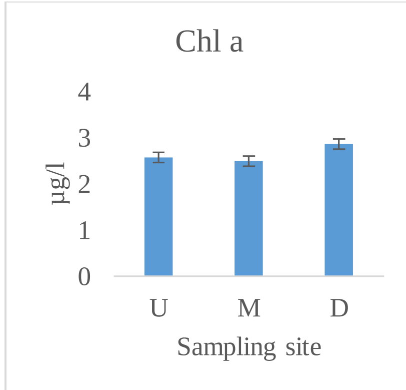


Fig. 23. Showing the average concentration of Chl a of the river Kongsho (2020-2021).

Bhadra river:

Five phases of experiments were carried out in this river for biological parameters in the second session. The highest concentration of Chl a (6.68 µg/l) was detected in the middle during before bandaling of the fourth phase and the lowest concentration (1.20 µg/l) was found in the downstream during after bandaling of the fourth phase of the experiment. The highest average concentration of Chl a (3.48 µg/l) was found in the middle and the lowest concentration (3.22 µg/l) was detected in the downstream for this river (Fig. 24).

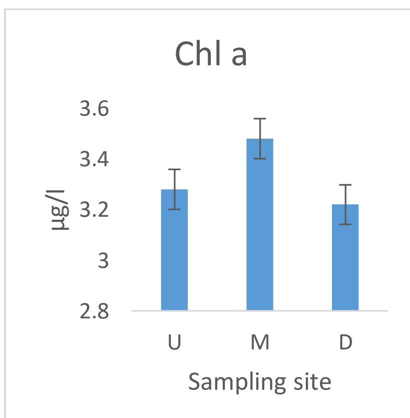


Fig. 24. Showing the average concentration of Chl a of the river Bhadra (2020-2021).

Phaeopigment:

Padma River:

Experiment was carried out only for five phases for biological parameter in this river in the 2nd session. The concentration of phaeopigment was the highest in the upstream (0.96 µg/l) during after bandaling at the first phase and the lowest concentration (0.19 µg/l) was also found during after bandaling in the upstream of the fourth phase of the experiment. The highest average concentration of phaeopigment (0.59 µg/l) was found in the middle and downstream and the lowest (0.58 µg/l) was detected in the upstream for this river (fig. 25).

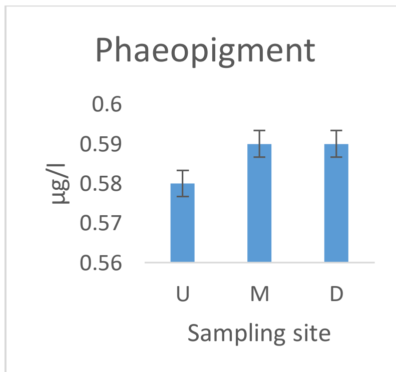


Fig. 25. Showing the average concentration of phaeopigment of the river Padma (2020-2021).

Arialkha river:

Sampling was carried out only for three times in this river, once in the before bandaling and twice in the after monsoon. The highest concentration of phaeopigment (0.77 µg/l) was found in the middle at third time during after bandaling and the lowest (0.12 µg/l) was also found in the upstream during before bandaling at the first time of experiment. The highest average concentration of phaeopigment (0.54 µg/l) was found in the middle and the lowest (0.31 µg/l) was found in the upstream for this river (Fig. 26).

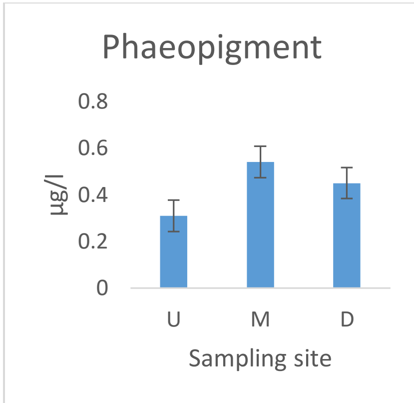


Fig. 26. Showing the average concentration of phaeopigment of the river Arialkha (2020-2021).

Baliakandi river:

In this river sampling was also carried out only for two phases. The highest concentration of phaeopigment (0.83 µg/l)) was found in the middle during after bandaling in the second and the lowest concentration (0.09 µg/l) was detected in the downstream during before bandaling of the first of the experiment. The highest average concentration of phaeopigment (0.62 µg/l) was found in the middle and the lowest (0.36 µg/l) was in the upstream for this river (Fig. 27).

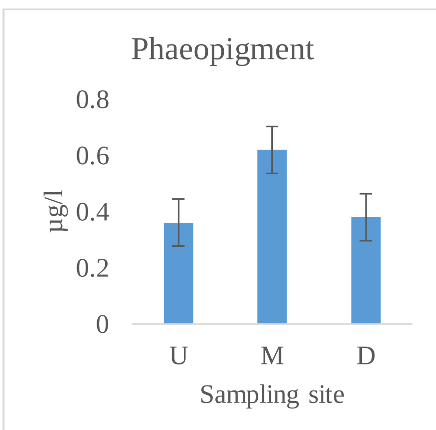


Fig. 27. Showing the average concentration of phaeopigment of the river Baliakandi (2020-2021).

Sugondha river:

A total of five phases of experiments were done in this river. The highest concentration of phaeopigment (0.92 µg/l) was detected at upstream during before bandaling of first phase of the experiment and the lowest concentration (0.03 µg/l) was found in the upstream and in the middle during after bandaling of the fourth and the third phase of the experiment. The highest average concentration of phaeopigment (0.28 µg/l) was found in the downstream and the lowest (0.16 µg/l) was in the middle for this river (Fig. 28).

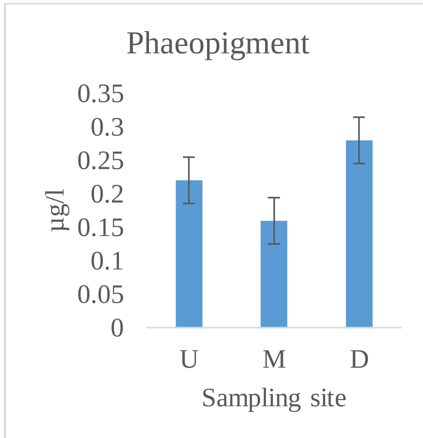


Fig. 28. Showing the average concentration of phaeopigment of the river Sugondha (2020-2021).

Kongsho river:

A total of five phases of experiments were done in this river for biological parameters. The highest concentration of phaeopigment (0.45 µg/l) was found at the downstream during before bandaling of the first phase of the experiment and the lowest concentration (0.03 µg/l) was found at the middle during before bandaling of the second phase of the experiment. The average concentration of phaeopigment (0.26 µg/l) was found the same (0.15 µg/l) for the all three sites (Fig. 29).

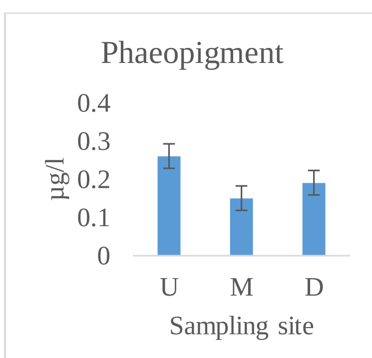


Fig. 29. Showing the average concentration of phaeopigment of the river Kongsho (2020-2021).

Bhadra river:

A total of five phases of experiments were done in this river for biological parameters. The highest concentration of phaeopigment (0.56 µg/l) was detected in the downstream during before bandaling of the first phase and the lowest (0.02 µg/l) was found in the upstream during before bandaling of the fifth phase of the experiment. The highest average concentration of phaeopigment (0.27 µg/l) was found in the downstream and the lowest (0.12 µg/l) was detected in the upstream for this river (Fig. 30).

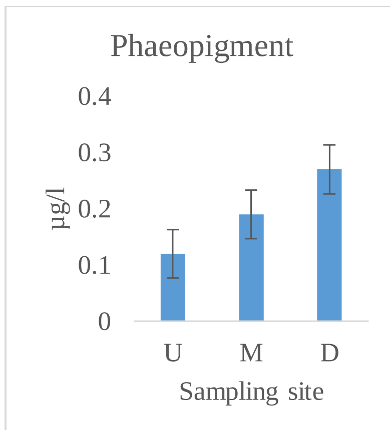


Fig. 30. Showing the average concentration of phaeopigment of the river Bhadra (2020-2021).

Numerical count of Phytoplankton (No. of ind.×10^4):

Padma River:

Sampling was carried out for five phases in this river for counting phytoplankton. The numerical count of phytoplankton was the highest in the middle (14.49 µg/l) during after bandaling in the fifth phase of the experiment and the lowest (2.46 µg/l) was also found during after bandaling in the upstream during the fourth phase of the sampling. The highest average numerical count of phytoplankton (8.94 µg/l) was found in the middle and the lowest (6.15 µg/l) was detected in the upstream for this river (fig. 31).

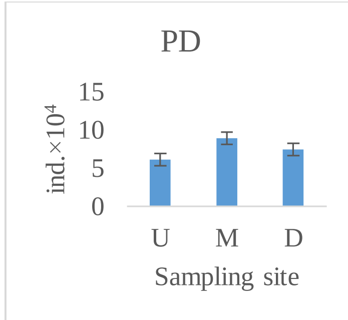


Fig. 31. Showing the average concentration of numerical count of phytoplankton of the river Padma (2020-2021).

Arialkha river:

Sampling was carried out only for three times, once in the before bandaling and twice in the after bandaling (second and third). The highest numerical count of phytoplankton (12.72 µg/l) was found in the middle in the third time of the experiment and the lowest concentration (1.79 µg/l) was also detected in the upstream during after bandaling in the second time of experiment. The highest average numerical count of phytoplankton (8.58 µg/l) was found in the middle and the lowest concentration (3.65 µg/l) was found in the downstream for this river (Fig. 32).

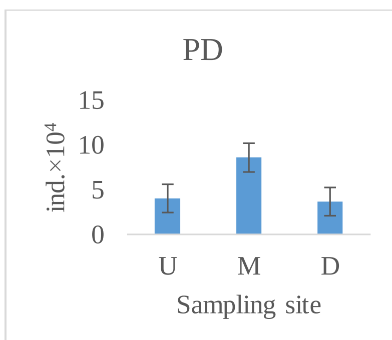


Fig. 32. Showing the average concentration of numerical count of phytoplankton of the river Arialkha (2020-2021).

Baliakandi river:

In this river sampling was also carried out only for two phases. The highest numerical count of phytoplankton (11.39 µg/l)) was found in the upstream during after bandaling in the first phase of the experiment and the lowest concentration (1.16 µg/l) was detected in the downstream during before bandaling at the second phase of the experiment. The highest average numerical count of phytoplankton (10.12 µg/l) was found in the upstream and the lowest average (5.17 µg/l) was in the downstream for this river (Fig. 33).

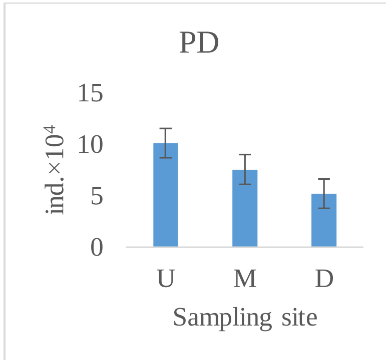


Fig. 33. Showing the average concentration of numerical count of phytoplankton of the river Baliakandi (2020-2021).

Sugondha river:

Five phases of sampling were done in this river for biological parameters in the second session. The highest numerical count of phytoplankton (11.49 µg/l) was detected in the downstream during after bandaling of first phase of the experiment and the lowest concentration (2.25 µg/l) was also found at the upstream during after bandaling period of first phase. The highest average numerical count of phytoplankton (8.15 µg/l) was found in the middle and the lowest (6.05 µg/l) was in the upstream for this river (Fig. 34).

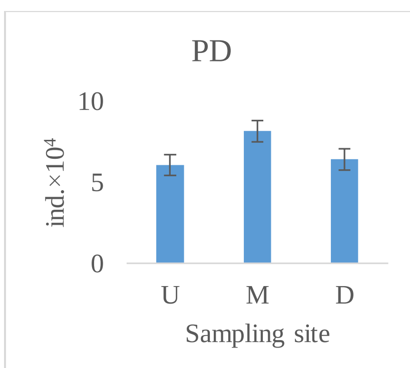


Fig. 34. Showing the average concentration of numerical count of phytoplankton of the river Sugondha (2020-2021).

Kongsho river:

A total of five phases of experiments were done in this river for biological parameters. The highest numerical count of phytoplankton (12.45 µg/l) was found at the downstream during before bandaling of first phase and the lowest (2.16 µg/l) was also found in the upstream during before bandaling of the fourth phase of the experiment. The highest average numerical count of phytoplankton (8.02 µg/l) was found in the middle and the lowest (6.11 µg/l) was in the upstream for this river (Fig. 35).

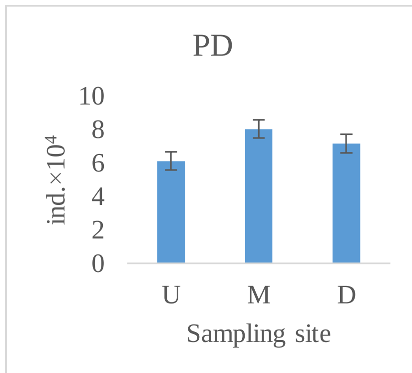


Fig. 35. Showing the average concentration of numerical count of phytoplankton of the river Kongsho (2020-2021).

Bhadra river:

A total of five phases of experiments were done in this river for biological parameters. The highest numerical count of phytoplankton (12.57 µg/l) was detected in the downstream during after bandaling of the fourth phase and the lowest (1.28 µg/l) was also found in the downstream during after bandaling of the fifth phase of the experiment. The highest average numerical count of phytoplankton (6.47 µg/l) was found in the upstream and the lowest concentration (5.48 µg/l) was detected in the downstream in the second session for this river (Fig. 30).

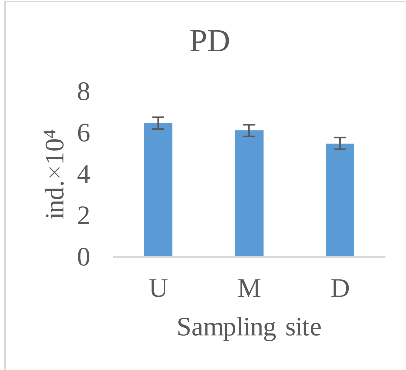


Fig. 36. Showing the average concentration of numerical count of phytoplankton of the river Bhadra (2020-2021).

Phytoplankton and macrophytes count

Phytoplankton counting:

Phytoplankton belonging to different classes has been counted and identified during this time of 2020-21. A total of 73 species of Chlorophyceae, 43 species of Bacillariophyceae, 41 species of Euglenophyceae, 18 species of Cryptophyceae, 19 species of Cyanophyceae, 14 species of Dinophyceae and 5 species of Chrysophyceae were indentified.

Macrophyte counting:

Macrophytes belonging to monocotyledons and dicotyledons were enumerated form all six sampling rivers. A total of 65 species of macrophytes were found during the second session of the experiment.

Recommendations:

The different concentrations of chemical and hydrobiological parameters were found of the studied rivers in normal range both in before and after bamboo bandaling of the river. It indicates the good river water quality of the rivers.

The contamination of water with heavy metals is another major environmental problem. Anthropogenic activities continuously increase the amount of heavy metals in the environment, especially in aquatic ecosystem. Pollution of heavy metals in aquatic system is growing at an alarming rate and has become an important worldwide problem. Some of these metals are potentially toxic or carcinogenic at high concentrations and can cause serious health hazard if they enter into the food chain. Heavy metals like Cu, Zn, Mn, Fe, Ni, Cd, Cr, Co, Pb etc. are usually present in water at low concentration. But luckily no heavy metal was detected at ppb level in any of the water samples. All the results of the studied rivers showed below detection level. This indicates that the water can easily be considered safe for fishery and recreational applications.

The experimental design and methodology of current research is prepared based on the river ecosystem of Bangladesh. The research focuses mainly on the central linkage between physical processes and biota within river corridor ecosystems which is one of the research areas of climate change related issue. More over the research project will be achieved by the application of combined knowledge of biology, geology and environmental engineering.

(Dr. Mohammed Almujaddade Alfasane)