Understanding Natural Capital and Flood Resilience in Bangladesh

Lessons from the FRMC – August 2020




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Captions for photos on front cover, clockwise from top left: (1) Netted small pond beside banana trees, crop filed, famed vegetation and bamboo thickets beside local houses, Dhubni village, Singimari Union, Hatibanda, Lalmonirhat, 2019. (2) Taros growing by a drying pond with little remaining discoloured water, Purbo Dauabari village, Dauabari Union, Hatibanda, Lalmonirhat 2019. (3) Ducks swimming in a communal village pond, with litter visible, Kani Charitabari village, Haripur Union, Sundarganj, Gaibandha, 2019. (4) Makeshift wooden bridge on a dried canal, linking two villages, Kani Charitabari village, Haripur Union, Sundarganj, Gaibandha, 2019. All photos taken by K.A. Shahed, eSolve International.

Key Findings

This report shares the findings from the Natural Capital assessment work carried out to date by Concern as part of its contribution to the Zurich Flood Resilience Alliance programming in Bangladesh to apply the Flood Resilience Measurement Framework to support community-based pre-event flood resilience. This work was carried out with the support of eSolve consultancy services and the raw data and maps supporting this report are drawn from eSolve findings in the communities in which Concern is working. The principal learning points arising from this research project fall into the following categories:

Relevance of the flooding environment to the community's experience of flooding. The assessment of natural capital suggest that communities do not associate natural capital to a role in flood management, but experience natural capital in relation only to productive livelihoods. Land elevation is significant in relation to the experience of severe flooding, while the interactions between land use, land elevation, natural capital and flooding intensity is important to understand.

Upstream and downstream interactions can affect flood control options. The natural capital work did not present solutions, but indicated that approaches to modify flooding in one location could have significant unexpected consequences for downstream locations. This is to be assessed in the project in relation to natural capital clusters.

Business as Usual is not working. The continued use of natural capital for the use of productive livelihoods is no longer a viable solution, while land geared to cultivation and livestock introduces its own challenges in relation to flood control management. While conventional approaches to water flow management are too expensive, such as dredging, embankments and revetments, this points to the need for a more balanced and nuanced approach looking at the relative values of green, blue and grey infrastructure to assist in community based pre-event flood resilience.

Building innovative solutions, the FRMC is leading to new solutions to address the problems in flooding, such as Natural Capital Community Clusters and new insights into land use management practices, such as seasonal planting in dry riverbeds (Nala).

Need for a coherent natural capital strategy. The FRMC asks the question whether natural capital solutions are appropriate and are of the right combination of green, blue and grey to address flooding risk, this assessment should be based on a clear natural capital management strategy.

Executive Summary

This report is a key output from the Concern Bangladesh implemented flood resilience project, which is part of the Z-Zurich Foundation funded Zurich Flood Resilience Alliance (ZFRA or The Alliance); this is a multi-year global interdisciplinary collaboration of nine member organisations from the private sector, international development and humanitarian sectors, and academia. The Alliance focuses on finding practical ways to help communities strengthen their resilience to floods – and save lives. As part of this global initiative, Concern is implementing the Zurich Flood Resilience Project (ZFRP) in 22 flood-vulnerable communities from two Districts located on the floodplains of the Jamuna and Teesta Rivers in Bangladesh. The ZFRP is currently in Phase 2 of building a measurement approach for resilience in communities vulnerable to the risk of flooding, which was piloted in Phase 1. The approach views flood resilience through the lenses of five capitals (5Cs from the Sustainable Livelihoods Framework) and the 4Rs[1], built into the Flood Resilience Measurement for Communities tool (FRMC) as the input into the framework. The intention behind this approach is via community-led assessments on flood resilience to develop a perspective on community

[1] 5Cs are Social, Human, Physical, Financial and Natural Capitals; 4Rs are the properties of a resilient system: redundancy, resourcefulness, rapidity and responsiveness – see Development and Testing of a Community Flood Resilience Measurement Tool Keating, A. *et al* (2017).

flood resilience that can yield sustainable interventions in a way that can be quantified, measured, and assessed. Concern did participate in Phase 1 of the FRMC, and a key learning from this was that the understanding of the role of natural capital in building flood resilience was constrained. To address this challenge, Concern sought to investigate further the relationship of natural capital to flooding and understand how that learning can better influence the FRMC. The work involved an analysis of the flooding context affecting the programme areas, a characterisation of natural capital units in the environment in those areas, and key observations for flood control management that will be taken forward in the programme. This report presents the key findings from this initial work[2]. The natural capital assessment also includes implications for the FRMC itself, though this is not a direct focus of this report.

The key aspects raised in this report

This section considers some of the more relevant aspects of natural capital study as relating to flood resilience, brought out by the work carried out on natural capital units in the Bangladesh context to date.

A. Understanding Natural Capital

The FRMC has deliberately not at this point, taken the route of looking at ecosystem or flood ecosystem services, rather it looks at how the community perceives natural capital and thereby looks to influence that perception to modify behaviour, which is a valid approach. That said it is, however, helpful to position understanding of Natural Capital within such a framework, especially looking at Flood Ecosystem Services. Flood ecosystem services take the following form:

These services (Annex 1) relate to:

- **Peak flow attenuation and flood wave travel times,** while flooding is strongly related to rainfall, the severity of flooding is determined primarily by the catchment topography and land use influencing the flood flow, from soil water content to urbanisation. This report takes the view that actively modulating the peak flow and flood flow transit is as important in flood control, as a key input to pre-event resilience, as is reducing the likelihood of flooding.
- **Flood flow diversion/dissipation**, logic tends to dictate at times that the way to manage flooding is to focus on flood conveyance, increasing the speed of transit of the water column out of the affected area. This is often achieved through channel bank protection and channel straightening. As important, however, are the strategies that reduce the peak flow through dispersion and dissipation, such as marsh land, retention ponds and absorption ponds. These can connect to existing natural capital structures in the landscape.

Natural capital has a prominent role in the effectiveness of these services in the flood environment. Natural capital, therefore, needs to be understood not only in relation to the ecosystem benefits they bring[3] but also the influence they have on flood flow. This was explored in the FRMC study through the Natural Capital Guide. The expression of natural capital in the FRMC may, however, require further elaboration and clarification for this capital source to reflect the issues specific to flooding. This relates to the capture and expression of key concepts within the natural capital sections. The most notable area of focus, especially for Bangladesh as flooding drivers are very context specific, is the relationship of natural capital to productive livelihoods; which is not clearly explored in the FRMC. The landscape in the floodplains of the Brahmaputra River are highly managed and this issue is important for flood resilience. Further, while the FRMC does not include a characterisation of natural capital, the work carried out by Concern show that natural capital can easily be characterised by the community; the names of natural capital units are locally

[2] Esolve is credited with the field data and maps in the report; the report is compiled by the technical advisor for Concern, Richard Bold.

[3] Millennium Ecosystem Assessment defines the four services as regulating, provisioning, supporting and cultural.

specific but the roles of natural capital in relation to flooding need not be and as such the natural capital approach taken by Concern would be transferable to different contexts and easily integrated into the FRMC itself, without conducting a separate natural capital study. Generally, the observations from the FRMC suggest that communities have not looked at natural capital through the lens of its role in flooding but look at natural capital through its role in productive livelihoods. As such, solutions for flooding as they relate to green/blue and grey infrastructure are relatively poorly understood in these contexts and these differences are not well captured in the FRMC.

B. Topography

The second issue of relevance is catchment topography, different river processes occur for highland, midland and Floodplain Rivers. In the latter case, a clear catchment is difficult to determine as for the case of Bangladesh, the floodplain is filled with tributaries and distributaries, while the channel avulses frequency. In upland areas, catchment may be easier to determine. As the rivers in Bangladesh are Floodplain Rivers, the key topographical issue is variation in land elevation, where small variations in elevation can have significant influence on flooding. The maximum elevation in the study locations rarely achieves >40 mPWD4, so variations in land height can also have a significant impact on the nature of the flooding experienced... In Bangladesh, early warning for flooding is triggered by water reaching the Danger Level, which is the height of the water column beyond which flooding is imminent, this is not set locally, the Danger Level is set in relation to the average water levels corresponding to flooding from the national water gaging data. This has clear local implications, meaning that areas with lower land elevation experience flooding before it is recognised at the National level... What is also clear is that in a given year if one community is lower lying, even though at a National level, flooding is characterised as normal (1 in 2 year flood), certain locations may experience a 1 in 5 year flood and this has implications for response planning. The work that Concern is doing is mapping these minor land elevation variations and building this into a revised assessment of a locally specific Danger Level. Such land elevation variations, especially in locations with high hydraulic connectivity, has implications for land use management and therefore has implications for flooding. Concern holds that flooding is caused as much by changes in land use as it is by variations in rainfall. Although flooding and rainfall have a complex relationship in Bangladesh as flooding is influenced also by upstream Snow Melt, as such it can be difficult to connect flooding to climate change influencing rainfall patterns

C. Land use

Flooding is caused in part by increasing rainfall which can be related to climate change; yet, flooding severity (duration and intensity) is also influenced by water/land interactions mediated through topography i.e. land elevation, with the **land use** further influencing the flooding. Floodplain agriculture can be highly profitable, but the conversion of land to accommodate pasture and arable farming, can increase the vulnerability of areas to flooding and lead to a worse flooding impact. These flooding relationships are controlled in large part by the productive use of resources and understanding how that influences flooding is important in this context. There are also additional considerations to focus on in the characterisation of the natural capital components in the FRMC. These relate to the description of aspects of natural capital pertinent to flooding, such as the degree of pristineness of the natural landscape as well as limits of viable productive potential which are difficult to assess, though relevant, within the FRMC.

D. Hydrologic Connectivity

This is an area of focus that is not as prominent in the FRMC, Simply put it is the degree of isolation of specific natural capital units in the landscape, or the degree to which these units are connected through a unifying element, such as a lake pond, river etc. The nature of the natural capital configuration in the areas of study lends itself to looking at specific natural capital clusters in the environment, as the floodplain is interspersed with river tributaries, connectors, canals and the like. One perspective regarding connectivity, is a grouping of communities positioned in the landscape where they are likely to exhibit similar flooding and hydrologic characteristics. For example in Bangladesh, *Nalas* (these are distributaries of a flood plain river) may run through two or more villages in one cluster,

[4] >40 mPWD (mean public water depth) which means 40 metres above sea level, gradated to Bangladesh Public Water Depth classification

and/or may influence river flow in downstream clusters, suggesting that flood control in one location may have unintended consequences for another if viewed in isolation from the flood flow interactions with land use and elevation. *Nalas* can also be seasonal, due to reduced flow caused by seasonal changes and also through the effects of the upstream Teesta Dam. The dry *Nalas* provide important farming land during reduced annual flow conditions; this is a further connection between natural capital and livelihoods as expressed above.

E. Natural Clusters

This approach provides a decision-making framework, similar to catchment boundaries, or administrative boundaries. The clusters approach presents an interesting development for the project to use as a vehicle to promote more **inclusive localised decision-making** in flood control management in the areas, with the potential to extend this initiative further into government policy.

F. Natural Capital perceptions

The environment where there is flooding is highly farmed and largely denuded of **natural capital** due in part to the high population density. Many hydraulic units, such as natural ponds and man-made ponds are, however, not maintained and there is considerable potential for enhancing the water storage and conveyancing capacity of these structures, in terms of the efficiency of water flow and transit out of the system under investigation, though this needs to be considered within a wider natural capital management strategy. Furthermore, studies suggest that under more severe flood flow regimes the role of natural capital may be highly constrained in managing the flood flow. Currently government policy is fixed on physical engineering solutions to flooding, that are rather expensive and which can still fail; these are levee construction and reinforcement. As important as these solutions is the view point that by modifying the natural capital in a way favourable to improved flood flow mitigation through correct application of green and blue solutions, these can complement for grey infrastructure, thus reducing that budget allocation and encouraging a redirection of budget to more complementary natural capital solutions.

This report is not presenting any specific conclusions regarding natural capital and its relationship to the flooding context in Bangladesh that may provide insight into specific mitigation measures at this time. More research is needed and that will be a feature of the continued work of Concern in the Alliance programme. What this report does do, however, is illustrate that **natural capital does not currently have a central focus in flood risk management in Bangladesh**, at least in the programme areas of intervention, and that from a policy and community perspective there is a **limited understanding of the role of natural capital to enable communities to better cope with flooding**.

The work Concern has done under the auspices of the Zurich Flood Resilience Alliance, illustrates the point that **the function of natural capital elements, such as ponds, vegetation, canals, etc. changes in relation to the type of flooding experienced**. This means that under more severe flood flow regimes than normal flooding, the role of natural capital in mitigating flooding is likely to reduce. As such, an understanding of the return period for given flood levels is important. An increase in the flood frequency of higher intensity flooding may suggest green and blue solutions need to be supported by more engineered solutions to accommodate the change in flow conditions. The work also suggests that there will be opportunities for exploiting the blue infrastructure in the study areas to better manage flooding in a way that has not been applied before, with the typical over-reliance on grey infrastructure. It is also widely known that flooding is caused, in part by land use patterns and changes in land use while flooding in the study areas, located as they are in a complex sub catchment river network located in the floodplain, is also strongly influenced by relatively small changes in land elevation. This in turn interacts with land use to derive more or less flooding impact on flood free high land (F0 categorisation – Bangladesh Water Board) which can be as low as 25% spatial coverage in many areas. The flood free high land is therefore prioritised for critical infrastructure such as clinics and schools, but looking at how land use is controlled in relation to the flooding environment is something that needs more attention in flood control policy.

The key learning from this study lies in emphasising the **relationship between flooding and land use** and the **relationship between the flood danger level and land elevation**, while also pointing to critical potential roles the green and blue infrastructure can have. Typically, flood control management is focused on the grey infrastructure, but this report argues for a more **balanced approach between grey, green and blue infrastructure** to do one or more of three things:

- First, increased flood water conveyance in a targeted way, such that the peak flow transit time and peak discharge is managed to reduce flood impact.
- Secondly, to increase flood water retention through flow diversion and to increase flood impact absorption
- Thirdly, reducing levels of erosion into the rivers through appropriate land use management and conservation.

What this all points to is the need for a natural capital strategy for flood risk management in the area of intervention and this process will be facilitated through two new social innovations in the project. Firstly, the creation of Citizen's Action Groups to strengthen inter community dialogue for flood risk management and secondly through Cluster Consultative Groups, who will discuss appropriate options for flood risk management and use that to influence flood decision making. The cluster groups as explained in the report recognise the interdependence between communities from a hydraulic perspective and are designed to focus on appropriate land use management and reducing unintended consequences of isolated flood control options in the community, such as dredging which will have negative downstream consequences. The role of the strategy will be to manage these relationships in a holistic way that can provide guidance to policy makers on the deployment of appropriate grey, green and blue infrastructure to improve flood resilience.

How to work with Natural Capital in the FRMC

Readers are referred to the learning paper 'Natural Capital – reflections of the FRMC', for further details on key issues to consider when assessing natural capital in applying the FRMC study. This section provides a brief overview of that paper. This section is written from the perspective of a user who has already applied the FRMC, though some reflections in the Natural Capital paper may be useful for refining the FRMC itself.

The FRMC sections on Natural Capital are in fact very broad in scope and are set up with the intention of users being able to be locally specific. In different contexts, one set of natural capital elements will have different roles and uses than the same element in a different context. As such there is no one size fits all for natural capital, making it tricky to specify in the FRMC; although there are some principles that will work across different contexts.

The key findings from the work on Natural Capital that are relevant to the FRMC are as follows:

- Communities may not see the value of natural capital in terms of assisting flood control
- Natural capital value is more in terms of productive value, which can be an entry point for promoting more flood risk aware approaches
- Blue capital is not recognised in communities, in terms of the value it provides for ecosystem services, that communities benefit from
- Communities value certain forms of flooding, so are promoting land use in flood prone areas that lead to higher vulnerability when there is severe flooding, which needs to be taken into account when planning for nature-based solutions to flooding.

Credits

The author (Richard Bold, Disaster Risk Reduction Advisor, Concern Worldwide) would like to credit Esolve International, who provided important technical input on the natural capital assessments and is to be credited for the maps and key remote sensing data in this report, which is consolidated from earlier report findings, cited at appropriate places in this overview. The author would also like to cite ASOD, who is the field implementation partner of Concern Bangladesh. ASOD facilitated the community engagement aspects of this work and carried out the FRMC study in the areas of operation. Finally, the author would like to credit the Concern Bangladesh team for enabling this detailed study on natural capital and overseeing the implementation of the overall project.

Glossary of Terms

Term	Definition
'1 in 2 year' flood, '1 in 10' year flood etc.	Based on a flood frequency analysis, the return period for flood levels associated with a 2 year , 5 year and 10 year flood
Anthropocene	Period in earth geological cycles overtly influenced by human activity
ASOD	Assistance for Social Organization and Development, Concern's local implementing partner in Bangladesh
Beel	Small Natural Ponds
Blue infrastructure	Water based units, such as Nalas which can influence flood flows
BWDB	Bangladesh Water Development Board
Clusters	These are geographical areas, where communities have similar hydrologic characteristics (such as those that are located in or near a specific hydraulic unit) that exists within a specific local network. For example, two communities located in one Nala can form a cluster.
Conveyance capacity	The transit time of a water column existing in one or more hydraulic units
Discharge	The volume of water moving over a given time (Cumecs or $m^3.s^{-1}$)
Doba	Natural Pond
FRMC	Flood Resilience Measurement for Communities tool
FRMF	Flood Resilience Measurement Framework
Green infrastructure	Natural units, such as treescapes, that can influence flood flows
Grey infrastructure	Engineering solutions such as levee construction or revetments or, in the urban environment, canalizing, drainage, channelizing etc.
Hydraulic units	Any natural unit connected to or within river channels, or any water body
Khal	Canal structure
mPWD	Metres Public Water Depth (water level height above sea level)
Nala	Seasonal river channel
Pisciculture	Fish farming
River movement	Avulsion – lateral shift in channel form and morphology over time
ZFRA	Zurich Flood Resilience Alliance

Background to the programme

The intention of the ZFRP project is to support flood resilience in communities that can both improve outcomes and inform policy decisions to improve pre-event flood resilience[5]. It is widely recognised that flooding is the most significant extensive hazard risk globally[6], yet the Alliance notes that the vast proportion of funding goes to post-event flood recovery rather than pre-event flood resilience. The aim is to create empirical evidence to shift this narrative towards pre-event resilience, so that flooding does not have a significant negative effect on lives and livelihoods and to increase funding to flood resilience, either through new funding or reallocating existing funding, to the tune of $1Bn, in 5 years. The primary driver of this change is that there is no universally accepted way of measuring flood resilience that can better understand the characteristics of a resilient community and can better able to measure changes, helping to determine how to better build flood resilient communities, to influence the funding commitments. The methodology for this centres on the Flood Resilience Measurement Framework[7] (FRMF), which has led to the development of the Flood Resilience Measurement for Communities tool (FRMC)[8]. Based on evidenced based advocacy from the application of the FRMC, the Alliance aims to build a global footprint and an established system for building resilience. The project is being applied in nine countries and is currently undergoing scale-up across organisations and countries[9], while learning and observation from the Bangladesh work will inform higher-level policy objectives[10]. The global ambition is to achieve a critical mass in terms of changing approaches towards pre-event flood resilience, increase the funding levels committed to this and ultimately develop a system applicable to wider hazards than flooding.

By applying the FRMF, and investigating the five capitals and how they interact with the 4Rs[11] in terms of the community resilience expectations (together with other lenses, such as disaster risk management cycles), the community can better analyse the sources of resilience and identify those that are most relevant to reducing negative loss as a result of flooding and thereby build interventions to meet those requirements. In this way, the process is described as a tool called the Flood Resilience Measurement for Communities (FRMC) tool, which captures data and provides a benchmark for the current level of resilience and also provides an entry point for improving decision-making to develop interventions that can strengthen that purpose further.

Rationale for a more in-depth natural capital assessment

Flooding is caused fundamentally by a combination of excess rainfall, which is driven in part by the changing climate that we are experiencing in the 'Anthropocene', together with changes to land use, which modifies land-soil and water interactions affecting sediment capture by the river and affecting its capacity to convey water, leading to channel overflow, or flooding. In order to better understand how the flooding is experienced, it is important to have an understanding of how natural capital interacts with productive livelihoods in flood prone regions and also in respect of the flooding environment. It is also worth mentioning that the intention of the work was not to conduct a bio-diversity assessment, nor an analysis of flood ecosystem services; it rather seeks to better understanding community perspectives on how natural capital interacts with flooding as an insight to community flood management approaches.

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[5] Currently ZFRP Alliance states that for every $1 invested in prevention saves $5 in future losses, yet only 13% of spending on aid goes into pre-event resilience and risk reduction, with 87% allocated to post-event relief.
[6] Currently floods affect more people globally than any other type of natural hazard, while the global trend is for increasing temperature rise, global floods and extreme rainfall events have surged by more than 50% this decade and are occurring at a rate four times higher than in the 1980s, while climate related loos and damage events have risen by 92% since 2010 (Easac, 2018)
[7] FRMF Principles
[8] FRMC user guide
[9] See scale up strategy
[10] See Theory of Change for the ZFRA
[11] These are redundancy, robustness, rapidity and resourcefulness, see op cit for discussion on these.

The natural capital elements as stated in the FRMC are a little abstract in respect of their presentation and requires a degree of unpacking to assess properly. It was considered, specifically for the household survey question, that the natural capital questions tended to evoke an 'I don't know' response from the households. The risk then becomes that a set of I don't know responses is not really helpful in trying to understand natural capital interactions and how they correspond with flooding, given its importance in this respect. Although during the intervention selection phase, such issues may be investigated further, how this is to be completed without insight from the FRMC is unclear. To partly address this, The Alliance provided a very useful Natural Capital Guide[12], to aid understanding of these points in the FRMC and this anticipated a community process to better understand how to look at natural capital. Nonetheless, it was observed that only if the whole community was involved in such preparatory work required through this Guide, would the Natural Capital aspects in the FRMC be adequately understood by the community. For large communities, this was unlikely and as the selection of the households to include in the study is randomly assigned, it was unclear that there would have been a sufficient knowledge of natural capital to answer the questions clearly without more guidance built into the FRMC tool itself. **Note that this is a perspective of Concern Worldwide, not necessarily that of the wider Alliance.**

Concern therefore commissioned a consultancy to help understand the issues in working with the natural environment in the context of flood resilience building. The focus of our work on natural capital therefore became as follows[13]:

a) To better understand the natural capital elements present in the catchment.
b) Understand their likely role in with respect to flooding in the environment.
c) To conduct effective natural capital community assessments, which will look at how natural capital is perceived, used and managed.
d) To identify any synergistic effects between natural capital elements in the environment and livelihoods as relates to a community's position in the river network and the flooding context.

Topography

The starting point to unpack natural capital is to understand the river environment of interest. Flooding is first and foremost affected by the nature of the landscape, the catchment size, drainage density, river network, gradient, river order and so on. The position of the community within the river network is important to understand. A community in a large catchment, with high river density of a dendritic nature positioned downstream, will experience flooding of a different nature than an upstream community in the same catchment, or another community, where the drainage density is lower. The situation of the floodplain of the Jamuna River in Bangladesh is particular, there are no clear catchments as such, the land elevation is low, the river network is a complex array of tributaries and distributaries in an alluvial basin, so channel migration and instability is high. Nonetheless, a community in steeper upper reaches will experience flooding differently than communities at confluence sites, or estuarine communities. As such, site selection is critical in beginning the investigation on natural capital and how this interacts with the flooding context.

[12] Project set up, study set up, data collection and grading
[13] Note, this is not unique to Concern, all Alliance partners need to look at these issues, this report just presents the findings as understood by Concern

Site Selection

The site selection process that Concern used is well documented[14]. This was done initially through remote mapping via GIS and then later through more direct remote natural capital assessments, going on to ground truthing and community verification to achieve a clear picture of the natural capital assets in the landscape and their potential role in influencing flooding. The site selection process and outcomes previously documented, led to two Districts being selected, covering three Upazila, six Unions and 22 Communities, including one municipality in the study build (Figure 1). This selection was based on a triangulation process between the flood vulnerability assessment[15], based on secondary source reviews and direct community observation.

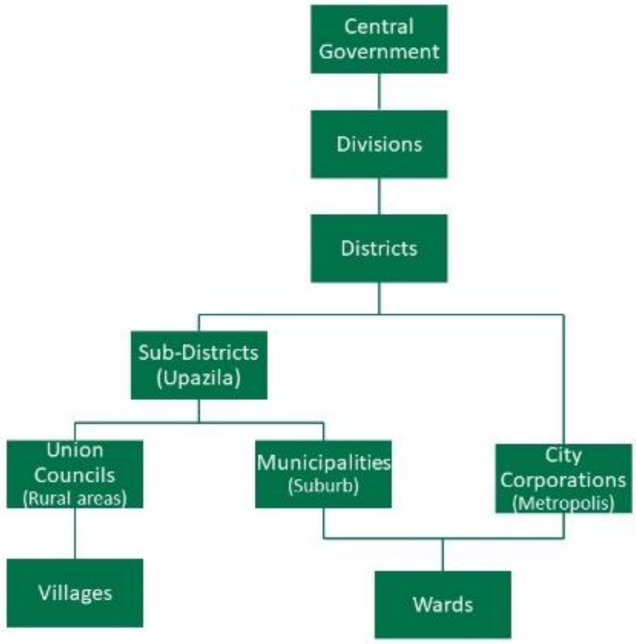

Figure 1: Administrative units in Bangladesh

Description of Gaibandha District

There were 11 selected communities spanning four Unions and one municipality in Sundarganj Upazila, Gaibandha District.

a) The major rivers that flow through Gaibandha district are Jamuna, Teesta, Ghaghot, Nalua and Karatoa (Figure 2). The hydrology and inundation cycles of the rivers and flood plains of the district are dominated by the Jamuna River as all the rivers in the District are tributaries/distributaries of the Jamuna. Drainage is often impeded in these rivers by backwash caused by high water levels along the Jamuna River. The impact of this effect is to increase the duration of floods especially when localized storm runoff coincides with high stages of the Jamuna River. In the most vulnerable Upazila, Sundarganj, the Teesta and Jamuna are the two principal rivers that are flowing through it with an approximate surface area of 5,255 km^2 and 27,965 km^2 respectively in this Upazila.

b) The Jamuna has an annual average discharge of around 20,000 m^3/s^{-1}. Over 75% of the discharge of the Jamuna River is generated from rainfall and snowmelt from upstream countries; as a result, the flow pattern is not strongly related to local precipitation. The mean monthly flow discharges of Jamuna are shown in Figure 3 taken from the Bahadurabad Gauging point. The river usually peaks in July when the average maximum discharge is about 50,000 m^3/s^{-1} and flow reduces in the dry season with average lowest in February at 4,700 m^3/s^{-1}. Historical analysis displays an increasing trend of average annual peak flows of The Jamuna. The lowest and highest flows recorded during 1976 to 2011 are 3,178 m^3/s^{-1} on 24th February 2001 and 102,535 m^3/s^{-1} on 9th September 1998.

c) The braided Teesta River, which crosses Gaibandha District, is the largest fan river in Bangladesh originating in Sikkim, India and avulsed into its present course at the end of the 18th century. Its new course is moving South Westward, with a maximum-recorded movement of 5km between 1943 and 2010 and joins the Brahmaputra/Jamuna near Chilmari. As a consequence of its systematic movement, riverbank protection is found mostly along the right (southwestern) riverbank. The channel is on average 3km wide however widely variable between 0.3 and 5km. The 40km long lower reach from Kaunia Bridge to the Brahmaputra-Jamuna River has changed in average width from 2.5 to 3.5 km. Since the early 2000s, very low overall erosion rates have been recorded. The flow pattern of the Teesta is significantly affected by the

[14] Concern Worldwide Bangladesh Community Selection Protocol
[15] See site selection report op cit 10

upstream dam, which introduces an additional dimension into understanding flow patterns and often high flow is not caused by excess rain, but opening of the dam, illustrating the importance of transboundary arrangements in controlling flooding.

d) Figure 3 provides the discharge pattern for 2017, which was the date of the last severe flood in the district. It shows that water level increased up to +1m above the danger level of 23.7m above sea level. The danger level is highlighted below

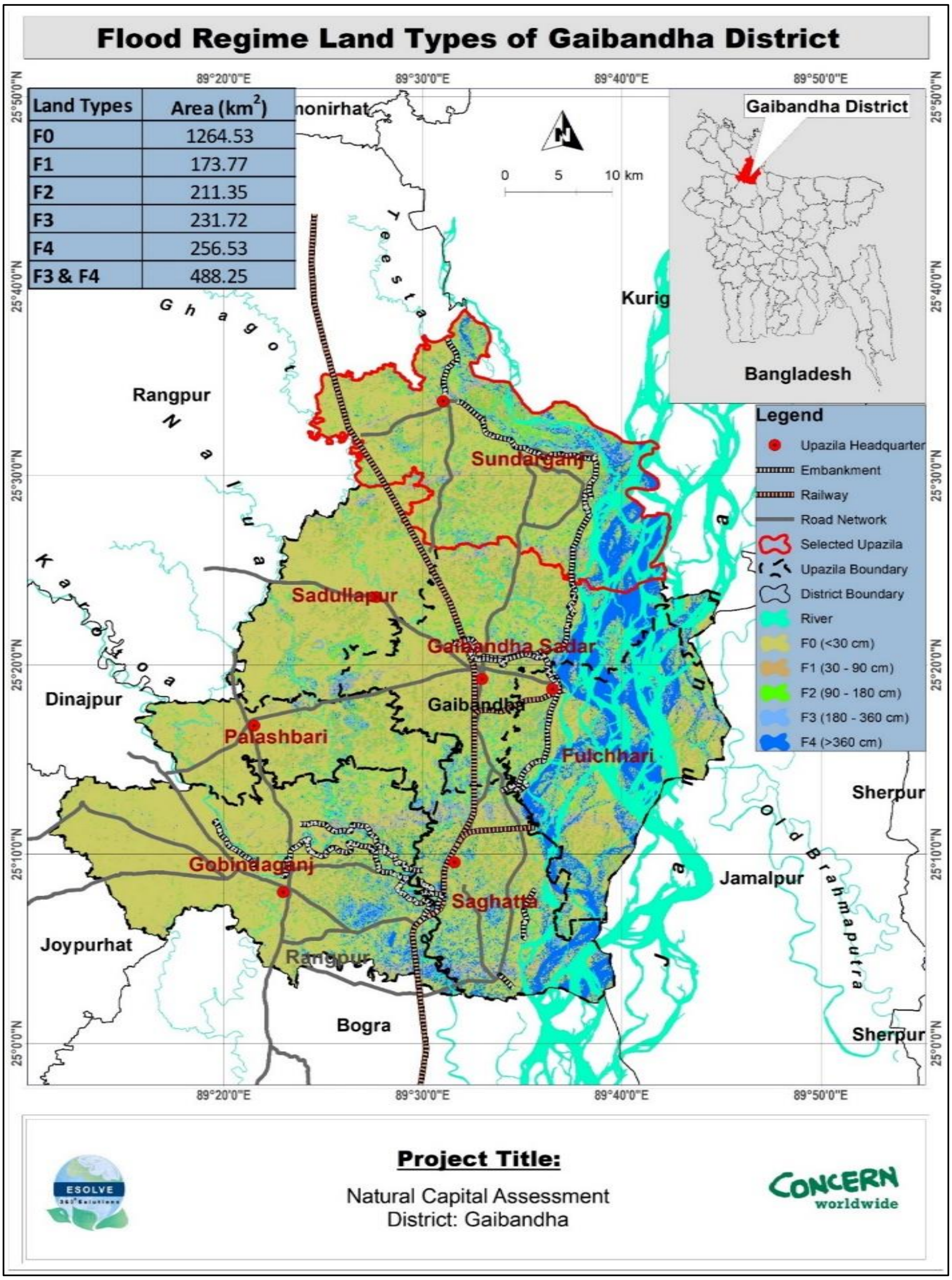

Figure 2: Land type classification for Gaibandha District, prepared by Esolve International.

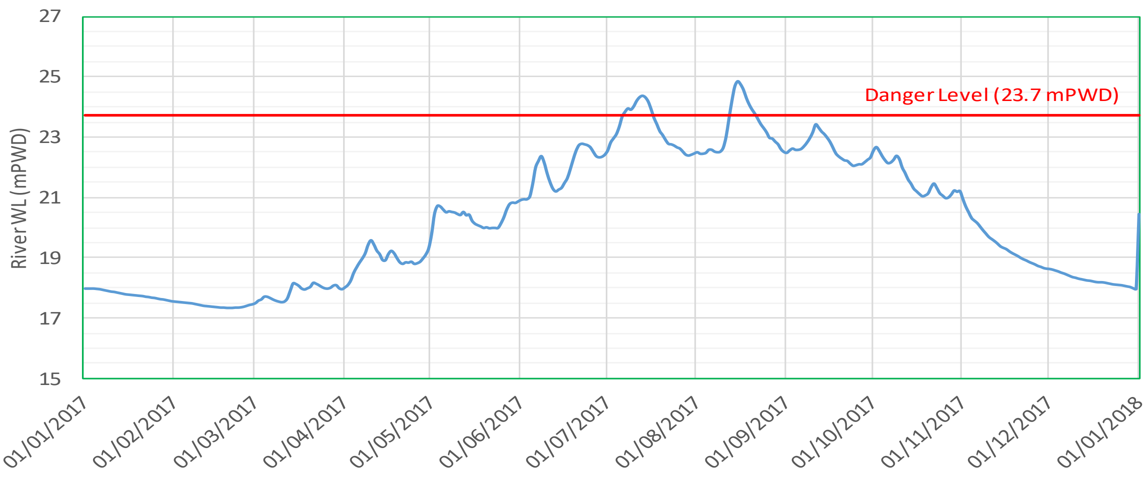

Figure 3: The discharge pattern for an annual period in 2017 for the Jamuna River, prepared by Esolve International.

Note: mPWD means mean public water depth; this is water elevation above sea level at the gauging point. Water height above the designated danger level indicates imminent flooding.

a) Table 1 states the danger level at each gauging point provided by mean water depth (water height above sea level) for each site and indicates the duration for which the water level is at or above the danger level. The Table provides data for the 1 in 2 year flood, the 1 in 5 year and the 1 in 10 year floods. For example, the danger level at Belka is 20.4m; the 1 in 10 year flood lasts for 2 days at a water height of +4.1m (mPWD). Belka also had the highest number of days where there water level was at the danger level at 159 days, compared to only 37 days for Kapashia and 22 days for Haripur, the other two unions in the project. It is worth stating at this point that a danger level recorded at Belka gauge of 20.4 may not indicate flooding at that point in the river, but due to variations in land elevation, flooding may occur lower than the officially designated danger level. This issue needs addressing in any community based flood early warning system.

Table 1: Duration of Flooding for Different Water Levels for Selected Unions in Gaibandha in 2017

Union	Distance from Chilmari	Danger Level		1:2yr		1:5yr		1:10yr	
	km	wl (Mpwd)	days	wl (Mpwd)	days	wl (Mpwd)	days	wl (Mpwd)	days
Belka	3	20.4	159	23.9	12	24.3	4	24.5	2
Chandnipur	6	23.3	23	23.6	17	24.1	8	24.3	4
Haripur	4	23.4	22	23.8	13	24.2	4	24.4	3
Kapashia	13	22.8	37	23.1	26	23.5	19	23.8	13
Sreepur	15	22.6	47	23.0	30	23.4	22	23.6	18
Tarapur	-3	23.9	11	24.3	4	24.7	0	24.9	0

Note: Chilmari is that nearest Bangladesh Water Development Board (BWDB) gauge station to the sites. Interpolation was used between the upstream and downstream gauging station at Bahadurpur to define the DLs at each site. Tarapur site is 3km upstream from

The second point to note is that increments in the DL between the 1 in 2 and 5 year flood levels are apparently small; this is due to the width of the river at the gauging station points, so a small increment in height corresponds to a large increment in discharge at that point.

Description of Lalmonirhat District

a) The location of Lalmonirhat is shown in Figure 2; Lalmonirhat is situated in the North West hydrological region of Bangladesh. Compared to the rest of the country this region receives less rainfall, and is considered the driest region in Bangladesh. Analysis of rainfall data for the period 1997-2017 of Rangpur station shows that the average annual rainfall is 2,171 mm for Lalmonirhat District. The average annual rainfall of the country is 2,700 mm. Similar to the rest of Bangladesh 80% of this rainfall occurs in the monsoon season (June–September).

b) The major rivers that flow through this district are Dharla and Teesta; both are transboundary Rivers originating in India and tributaries of the Brahmaputra/Jamuna. Smaller rivers are the Swati, Saniajan and Kharpa rivers, which are tributaries of the Dharla and Teesta respectively. Other types of surface water resources include beels, wetlands and natural canals or khals. The total catchment area of the Teesta and Dharla within Lalmonirhat District are 707 km^2 and 543 km^2 respectively. The Dharla catchment is situated in the northern part of the district near the international boundary, and apart from Patgram Upazila, settlement pattern is very thin in this catchment. On the other hand, the catchment of the Teesta is much larger and most of the settlement of the district occurs in this catchment. Thus, the Teesta has more influence on the lives and livelihoods of the communities of Lalmonirhat.

Dharla River

c) The Dharla River originates in West Bengal, India and flows through a comparatively new course since the 20th century. The rivers flow in the northern part of the district. The fairly stable channel is around 1 km wide and meandering, with the typical erosion pattern of downstream moving meander bends. The annual average erosion rate is 120 ha/year. This erosion affects the embankments protecting the Kurigram Irrigation Project. Maximum and minimum daily average discharges vary between 1,744 and 74 m^3/s^{-1} at Kurigram town.

d) The Teesta has the steepest slope amongst the flood plain Rivers of Bangladesh. The water level slope is 0.28m/km during the monsoon season compared to around 0.10m/km for the Brahmaputra-Jamuna River. As a result, the Teesta is a flashy river especially in the northern reaches, illustrated in Figure 4 showing the erratic changes in peak monthly flow. The danger level was exceeded once in 2017.

e) Two dams along the Teesta regulate river discharge. There is the dam at Gojoldoba in India West Bengal, built in 1985; but currently there is no agreement between Bangladesh and India on water sharing on the Teesta, controlling spillway management. There is also a dam, built in 1990 in Bangladesh at Dahlia in Lalmonirhat District; this dam does attenuate the severity of these flash floods. Despite this, severe floods are reported to impact the lives and livelihoods of the people in the district especially during wet years, especially if the dam spillway release at Gojoldoba coincides with high flow in upstream of the Dahlia dam.

f) The average maximum discharge of Teesta has not changed significantly over time, with the highest recorded peak reaching 8,710 m^3/s^{-1} in 1987, but the dry season flow has drastically reduced as result of the dam. The maximum monthly average discharge of the Teesta at Dahlia for 1973-1985 was 2,459 m^3/s^{-1} and for the 2000-2009 period, the maximum average discharge reduced to 1,499 m^3/s^{-1}. There is also an increasing sediment load due to the extraction of water for irrigation purposes, further complicating land use and flooding interactions in this area. High irrigation leads to river structures becoming exposed in dry conditions, which are used by communities for farming, while during high flow events, the river erodes the unprotected banks, increasing the sedimentation and affecting further flood flows.

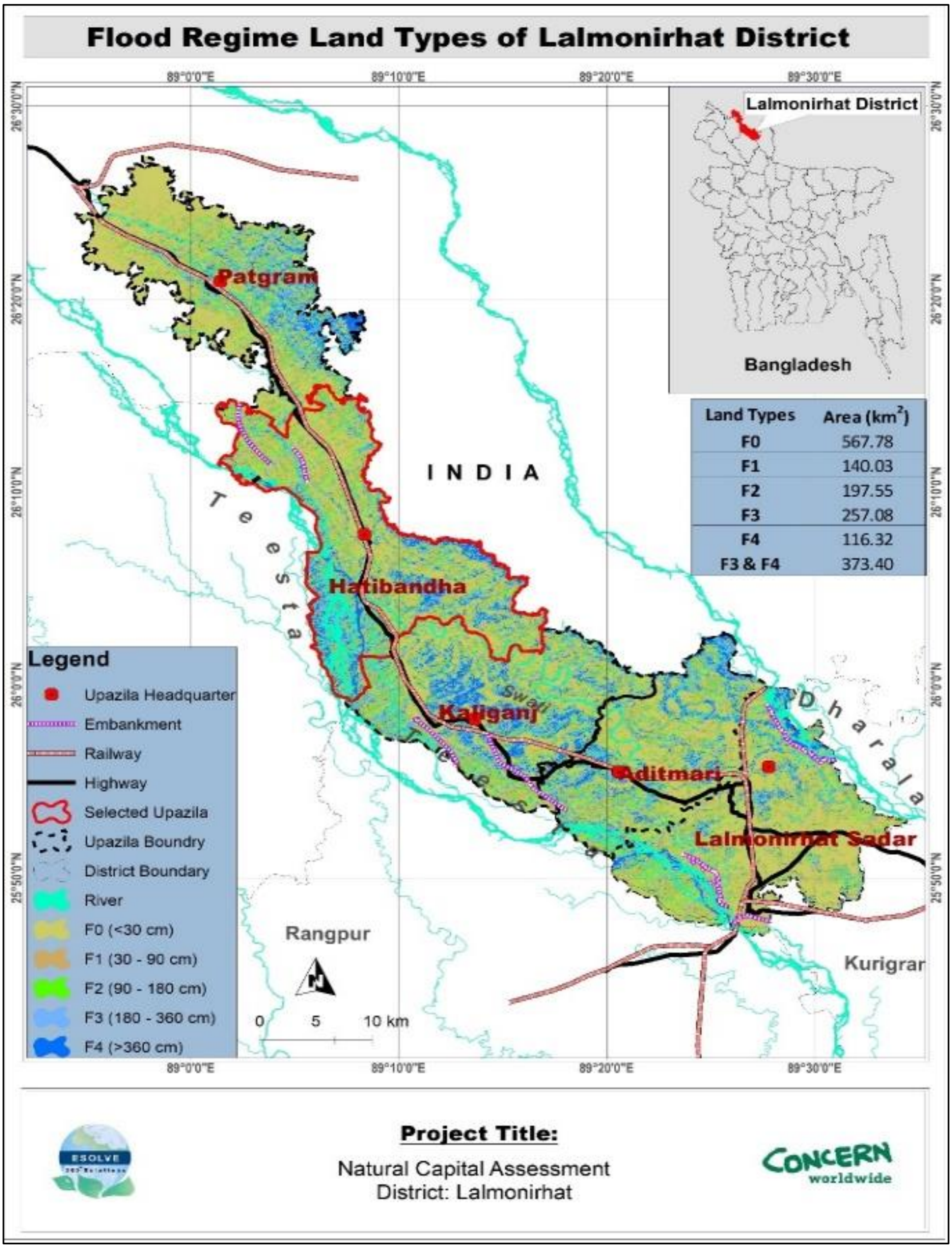

Figure 4: Land type classification for Lalmonirhat District, prepared by Esolve International.

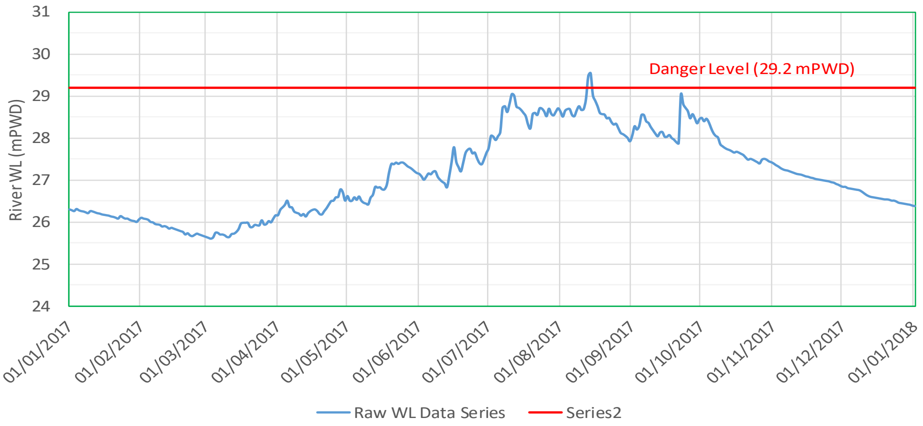

Figure 5: Water level of the Teesta River at Kaunia in 2017, prepared by Esolve International.

g) Table 2 illustrates the danger level (DL), provided by mean water depth (water height above sea level) for each site, and indicates the duration for which the water level is at or above the danger level. The Table provides data for the 1 in 2 year flood, the 1 in 5 year and the 1 in 10 year floods. For example, the danger level at Goddimari is 54.2m.

Table 2: Duration of Flooding for Different Water Levels for Selected Unions in Lalmonirhat in 2017

Union	Distance from Dalia	Danger Level		1:2yr		1:5yr		1:10yr	
	km	wl (Mpwd)	days	wl (Mpwd)	days	wl (Mpwd)	days	wl (Mpwd)	days
Goddimari	-4	54.2	0	53.8	0	54.0	0	54.1	0
Singimari	0	52.6	0	52.3	0	52.5	0	52.6	0
Sindurna	5	50.7	1	50.4	4	50.6	1	50.7	1
Patika Para	8	49.5	1	49.3	4	49.5	1	49.6	0
Dauabari	12	47.9	1	47.8	3	48.0	1	48.1	0

Note Dalia is the BWDB gauging station in Lalmonirhat.

There are some notable differences in DL between sites, for example, the DL at Goddimari is 52.2, but for the 1 in 5 years flood is lower at 54. In Bangladesh, danger level at a river location is the level above which it is likely that the flood may cause damages to nearby crops and homesteads. In a river having no embankment, danger level is about annual average flood level. In an embanked river, danger level is fixed slightly below design flood level of the embankment. The danger level at a given location needs continuous verification as e.g. embankments may be breached, whereby some danger levels may be not precise[16].

Furthermore, there are only slight incremental differences in water height between sites. There are possible two reasons for this: 1) the wide nature of the river, which means small increase in water levels equate to large increase in flows, 2) a longer range of data would increase the resolution of the statistical analyses (this data set extends for 10 years only).

[16] http://www.ffwc.gov.bd/index.php/definitions

Bangladesh flood characterisation

There are three aspects to characterising flooding in Bangladesh. First, is the danger level, as discussed above, second is the land type characterisation and third is the classification of normal, moderate or severe flooding. Table 3 identifies these additional elements.

Table 3: Flooding characteristics in Bangladesh

Flood Category	Land Type that is Inundated	Description of Land Type
Normal	F4 & F3 (always)	F4 – Low to Very Low Land, F3 – Low Land, F2 – Medium Low Land, F1 – Medium High Land, F0 – High Land
Moderate	F4, F3, & F2 (sometime)	
Severe	F4, F3, F2 & F1 (very briefly)	

Flood Affected Area	Flood Category
All F2, F3 and F4 lands inundated + about 40% of F1 land area also inundated.	Severe
All F4 area inundated and up to 40% of F2+F3 land area also inundated.	Moderate
100% F4 area is inundated and less than 30% of F2+F3 land area inundated.	Normal

What this table broadly states is that during normal flooding, where approximately 30% of the F2 and F3 land area is flooded, duration is less of a factor it is unlikely that F0 and F1 land will be affected. Only under severe flooding is F1 land affected, but F2 and F3 land is affected under moderate flooding conditions. The implication is that if one community has a low proportion of F1 and F0 land than another, and most agriculture is on F4 and F3 land, then in normal flood conditions, that community may experience more difficult flooding conditions and may experience flooding earlier. Moderate flooding, as with normal flooding F0 and F1 is not generally affected, but more land is under water. Consequently, if most farming is undertaken on F4 land, then this may be under water for a longer period than farming in the F2 category. Finally, for severe flooding, it is possible that F1 land is affected. As such, the more severe the flooding, the longer that the F4 land will be inundated.

Concern will be building the database of flood duration, along with a more precise analysis of land elevation and flood type in relation to danger levels in Phase 2 of the ZFRP project. In Sundarganj Upazila for example, F0 accounts for 24.8% of the land area and F2-4 categories account for 44.9% of the land area. In Belka Union, the respective values are 12% and 46.3%, so Belka has comparatively less high land than other areas in the Upazila. A key factor in relation to flooding is therefore the proportion of land in each F-Category, how it is used, and the duration of inundation attributable to it (at this point the study has not analysed this feature in detail). As such it is not possible without extensive research to associate specific mPWD to flood severity and natural environment in each location and we need to rely on community observation; this being part of the future work on natural capital assessments.

Summary

The key points to take away from the above assessment that will have a bearing on the FRMC are as follows:

a) Site selection is critical in flooding assessments, as this dictates not only the nature of flooding, but that different communities will experience flooding in different ways.
b) Land elevation is quite critical in affecting flood severity, especially in floodplain locations and as such to better manage flooding and work with bio-engineering approaches, a clear understanding of the interaction between the flooding and land elevation is important.

c) The specific land, water interactions alluded to in the previous sections are not captured well within the FRMC, this needs to be looked at as without a detailed characterisation of natural capital, it is unlikely that the FRMC can pinpoint appropriate solutions to address this issue.
d) Finally, while the Alliance does have an approach to considering natural capital, this is looked at in a micro way; while flooding issues are macro scale by definition as such, a system to connect macro to micro is needed in the Alliance to address flood management effectively to generate improved resilience.

Natural Capital Assessments

Prior to explaining in more detail the natural capital work undertaken, the next point to mention is the process for building the FRMC study. The starting point for Concern, this is detailed in full elsewhere , was that once the sites were assessed and selected, to prepare outcome mapping assessments, in essence these were mini PERC's, but a full PERC methodology was not followed. The Outcome Mapping was used for two fundamental reasons:

a) First, to better characterise the problem in the community in relation to flood resilience, so Concern could better design the survey and analyse the results.
b) Second, to provide a platform for the community feedback process. It was recognised early on that the results from the study would be complicated for the community to understand, while equally it would be important to ensure that the community owned the results, so the Outcome Mapping process was seen as the best route for this.

To better understand the historical events, through horizon scanning, typically women and men recall events differently so this was accounted for in the process. Through community discussion, the key events were identified and characterised. Once this was done, the principal issues were described and an issue map created for each event. The process also included stakeholder mapping to understand who was involved and had a role in addressing the issues. This assisted in defining the core stakeholders to build into the study. The final step was to collate all this information and bring it together in one resilience outcome vision statement. This statement was then agreed by the community and used to structure the FRMC results. This process is detailed in a related report. Once the resilience outcome statements were realised, the next step was to better understand the natural capital in the community, how the community understood it and what its potential role looked like in relation to flooding, the research did not look at flood ecosystem services.

Methodology

The first step was to undertake a remote assessment of the natural capital units[17] in the areas of study[18]. What this stage looked at was a characterisation of the specific natural capital units that can be observed in the study area. The next stage included community visits and ground truthing of the natural capital observed[19], this was to verify that what is characterised, was in fact accurate and recognised as such by the community in question, this also aided community identification of the natural capital units so recognised. The next stage was to undertake a natural capital unit assessment in the communities, to understand how the community interacted with that specific unit, this stage of the work drew on the Alliance guidance on natural capital.

[17] In fact the word unit may not be the most helpful here, as there will be connectivity between individual units identified, for example connection between Khal and Nala, or between Nala and tree cover (see below)
[18] The Remote Assessment reports for Gaibandha and Lalmonirhat developed by Esolve can be found here.
[19] Refer to the TOR for the Natural Capital Assessment undertaken by Esolve with ASOD

The process for the identification of the natural capital units in the areas of work led to the following categories, as presented in Table 4, photo's 1-5 provide some visual examples.

Table 4: Characterisation of Natural Capital Units

No.	NCEs	Features
1	Pond	• A pond is usually a constructed water body (with sides raised above ground level) used for washing clothes, bathing, collecting water for domestic use, etc. • Ponds can store water during heavy rains and often used during floods to collect drinking water when tube wells are not accessible
2	Doba	• A doba is a natural water body, usually smaller than ponds. Since dobas are not always clean, the water is not used for domestic purposes. Dobas may dry up in the dry season, which limit irrigation usage. • Dobas can store water during heavy rains
3	Kura	• Kura, a local term, is a natural water body created by erosion by whirlpool in the riverbed. Kuras are very deep and even if the river dries up, they still have water. • Kuras retain flood waters
4	Natural Khal	• Natural khals are canals which have connections to rivers on one side only, i.e. flows either originate or fall into the river or nala mainly during the wet season. • Khals are essential to retain flood flows during normal floods.
5	Nala	• Nalas are essentially small tributaries which originate and fall into the same river; they can be seasonal. • Nalas are essential to carry flood flows during normal floods.
6	Ground Water Table (Tube-well)	• Aquifer system stores floodwater through infiltration • Contributes to base flow during dry season
7	Flood Free High Land	• The F0 or high land is usually above normal flood level. • Shallow flooding of less than 30cm may occur occasionally in the rainy season. Communities take shelter on flood free high land during extreme floods.
8	Vegetation	• Cluster of trees or small forest. • Interception of rainwater, reduces erosion when flood waters recede, reduces velocity of flow during high floods, helps with infiltration
9	Bamboo Bush	• Grows quickly • Interception of rainwater, reduces erosion when flood waters recede, reduces velocity of flow during high floods, helps with infiltration

Photo 1 – Kura

Kura, a local term, is a natural water body created by erosion by whirlpool in the riverbed. Kuras are very deep and even if the river dries up, Kuras still have water. Kuras retain floodwaters.
This is showing a Kura in the river channel, not the principal channel, but a Nala during low flow (or normal but irrigated) conditions

Photo 2 – Doba

A doba is a natural water body, usually smaller than ponds. Since dobas are not always clean, the water is not used for domestic purposes. Dobas may dry up in the dry season, which limit irrigation usage. Dobas can store water during heavy rains

Photo 3- Nala

Nalas are essentially small tributaries that originate and fall into the same river.
Nalas are essential to carry flood flows during normal floods
Clearly, this picture depicts low flow conditions. Nala are also a valuable livelihood resource and communities use these locations to plant groundnut and herbs. Note that even though this is a river channel in the Monsoon, this land is owned by private landowners, which complicates how to work with the Nala to improve floodwater retention and conveyance.

Photo 4- Pond

A pond is usually a constructed water body (with sides raised above ground level) used for washing clothes, bathing, collecting water for domestic use, etc.
Ponds can store water during heavy rains and often used during floods to collect drinking water when tubewells are not accessible

Photo 5- Khal

Natural khals are canals that have connections to rivers on one side only, i.e. flows either originate or fall into the river or nala mainly during the wet season.

Khals are essential to carry flood flows during normal floods.

The idealised cross sectional area of a typical community in Gaibandha and Lalmonirhat District is provided in Figure 6. The key point to note from this figure is the similarity between Beel, Doba, Pond, which is due to their purpose and size, see Table 4. A key area of interest for any flood risk management strategy will be to enhance the flood connectivity and storage capacity of these structures.

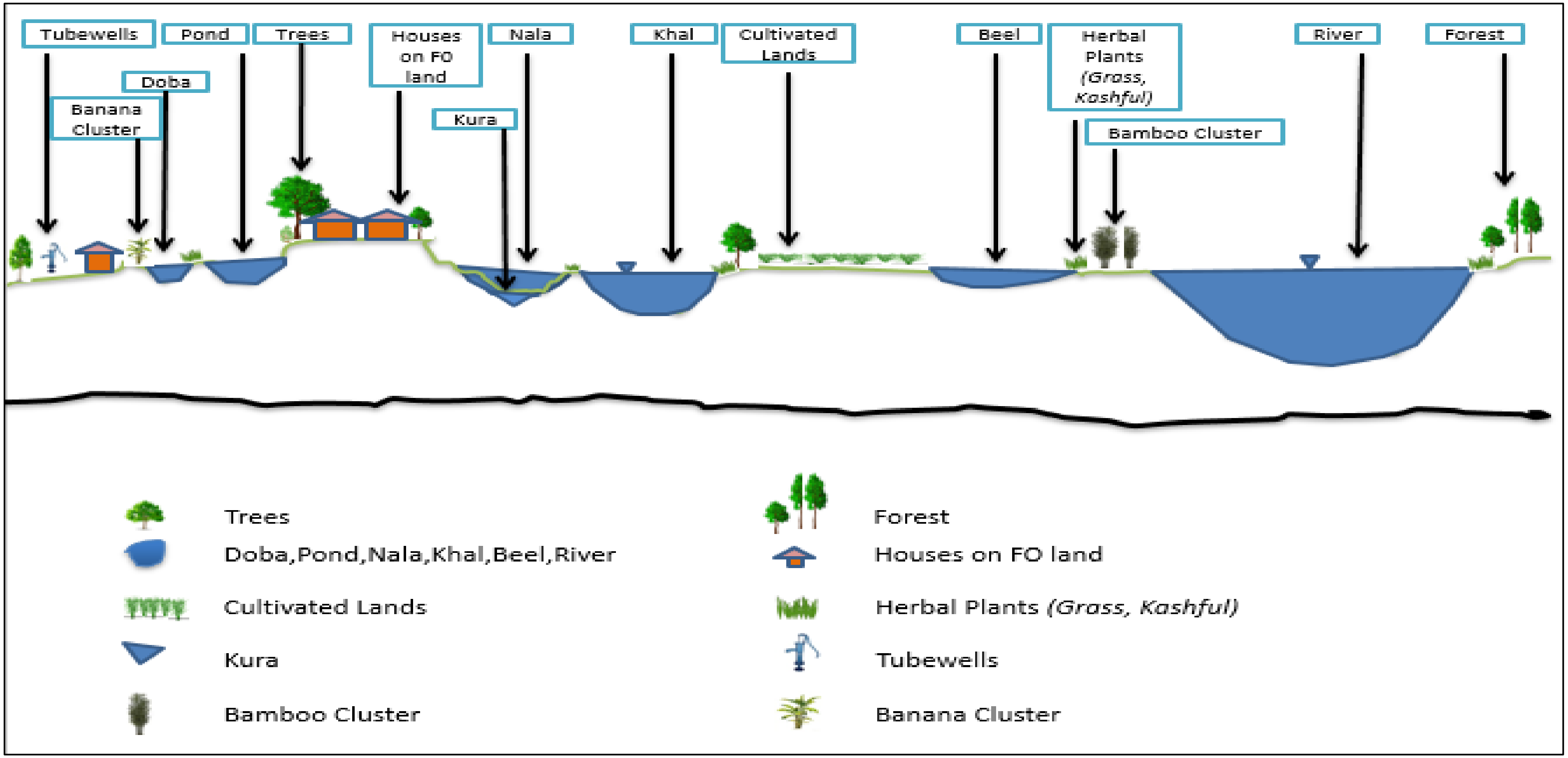

Figure 6: Juxtaposition of the natural capital units in an idealised cross sectional area of the landscape in question, prepared by Esolve International.

An example of the natural capital assessment is shown in Figure 7, which is for Belka Nabobganj community in Belka Union, Sundarganj Upazila in Gaibandha District. What this map shows is that the hydraulic environment is very interconnected and dominated by the Teesta River and its associated channels. This figure provides some quantitative analysis of the natural capital (blue capital) units in this location, with eight principal Nala and one Khal, with Nala 2 being the most significant in terms of length and overall area. The other issue of note is that the Nala are located on higher land than the main river channel (F2+) and over 90% of the vegetation cover is on F2-, with some areas of higher land. Doba, are principally located in the lower lying lands. There is also limited Bamboo bush in these locations.

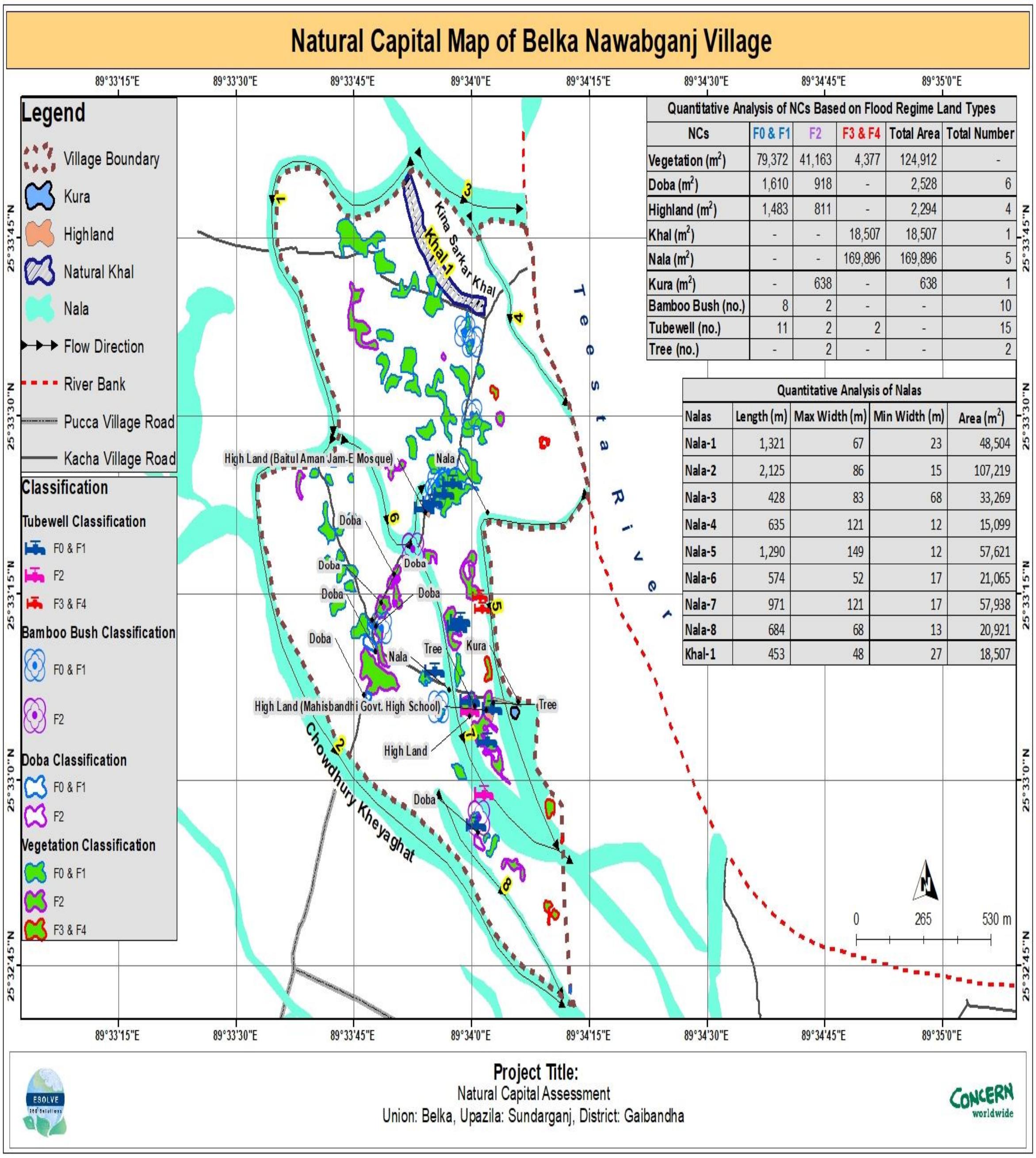

Figure 7: Natural Capital Map of Belka Nawabganj Village, prepared by Esolve International.

This recognition of hydraulic connectivity in the communities, led to the concept of natural capital clusters that could show similar hydraulic characteristics between communities. This work entailed the definition of natural capital clusters in the river network.

Natural Capital Clusters

The concept of clusters derives from integrated floodplain risk management, which recognises the interplay between landscape processes, land use and economic value. Increasingly there is a drive for green solutions for flood management that recognise the inherent value of the riverine landscape in regulating flooding. This can be seen with the approaches to increase channel form variability in the river, or approaches for natural riparian zone management[20], increasing channel roughness through the use of debris dams[21] and considering approaches that control flood flow and velocities, either through conveyance, or retention systems. The effectiveness of these approaches will change according to their application at different points in the river network, for example increasing channel roughness is more appropriate in lower order reaches than higher order reaches. Therefore, river management must be seen holistically and not only at the point of interest. This interaction between environments in the river network and therefore increasing habitat diversity recognises the interdependence along the river environment and this needs considering in the FRMC. The concept of clusters in the FRMC builds on this and starts to consider how locations in the upstream and downstream environments can have something to contribute in relation to how the natural environment is managed in relation to flood control to support flood resilience. For example, how can flood retention upstream have an impact on downstream decision making for flood control and whether there is an inherent value in changing land uses in clusters that exhibit certain hydrologic characteristics that can lead to better solutions to work with flooding; reduce exposure to flooding, or encourage flooding in lower value land assets? Furthermore, it can ask the question, given potential limitations in flood control management in one location, what can be done differently in other locations to benefit that location?

A further aspect that was presented to the project was the issue that if a flood mitigation option of either a green, blue or grey characteristic was applied in one location upstream of another location, without considering the potential consequence of that on downstream locations, there would be unintended negative impacts of this. For example, if in Belka Nabobganj a decision was taken to dredge the main river channel, this could lead to increased water flood and worse flooding in a downstream location, if their decision was to widen a Nala, which is situated on higher land than the main river channel; this could then make flooding matters worse in the downstream location. The concept of clusters is to try to solve this conundrum by promoting holistic decision making on the floodplain. As such, the Clusters present an interesting opportunity for creating a new decision making framework for flood control management in floodplain locations.

The ZFRP has created Cluster Consultative Groups (CCG). The CCG is a higher-level group that would still need to work with Community Action Groups, also created by the project, but would operate at Union level, or across different Unions as required by the Cluster demarcation. The focus of the CCG collates observations on natural capital and implications for flood control at cluster level, consulting with the Union Disaster Management Committees. However, it also needs to work across Clusters to feed into Upazila decision making. To do this effectively, a further group is formed called the District Cluster Coordination Team[22].

[20] This refers to the land/river border zone typically 0-10m from the river bank, this zone presents a supply of carbon to the river that aids in regulating river flow and increasing channel roughness, while the tree cover increases the stability of the river bank actively preventing bank erosion, the supply of sediment to a river is a key factor in its propensity to flood.

[21] Debris Dams are natural dams created by tree fall into a river that affects water flood direction, increasing bed roughness and attenuates types of dams, floodwater transition.

[22] The technical review report provides the details of this system

Gaibandha District Clusters

This cluster covers 11 communities representing four Unions and one municipality. Only Cluster 3 represents more than one Union.

- Cluster 1: West bank Teesta, this includes three villages, Kani Charitabari, Char Charitabari and Charitabari in Haripur Union.
- Cluster 2: Kapashia, this includes three villages (Vati Kapashia, Ujan Borail, Ton Gram), this covers Kapashia Union.
- Cluster 3: Confluence, this includes four villages across two Unions; Char Khodda in Tarapur Union and Taluk Belka, Belka Nabobganj, Kisamat Sadar in Belka Union.
- Cluster 4: Municipality

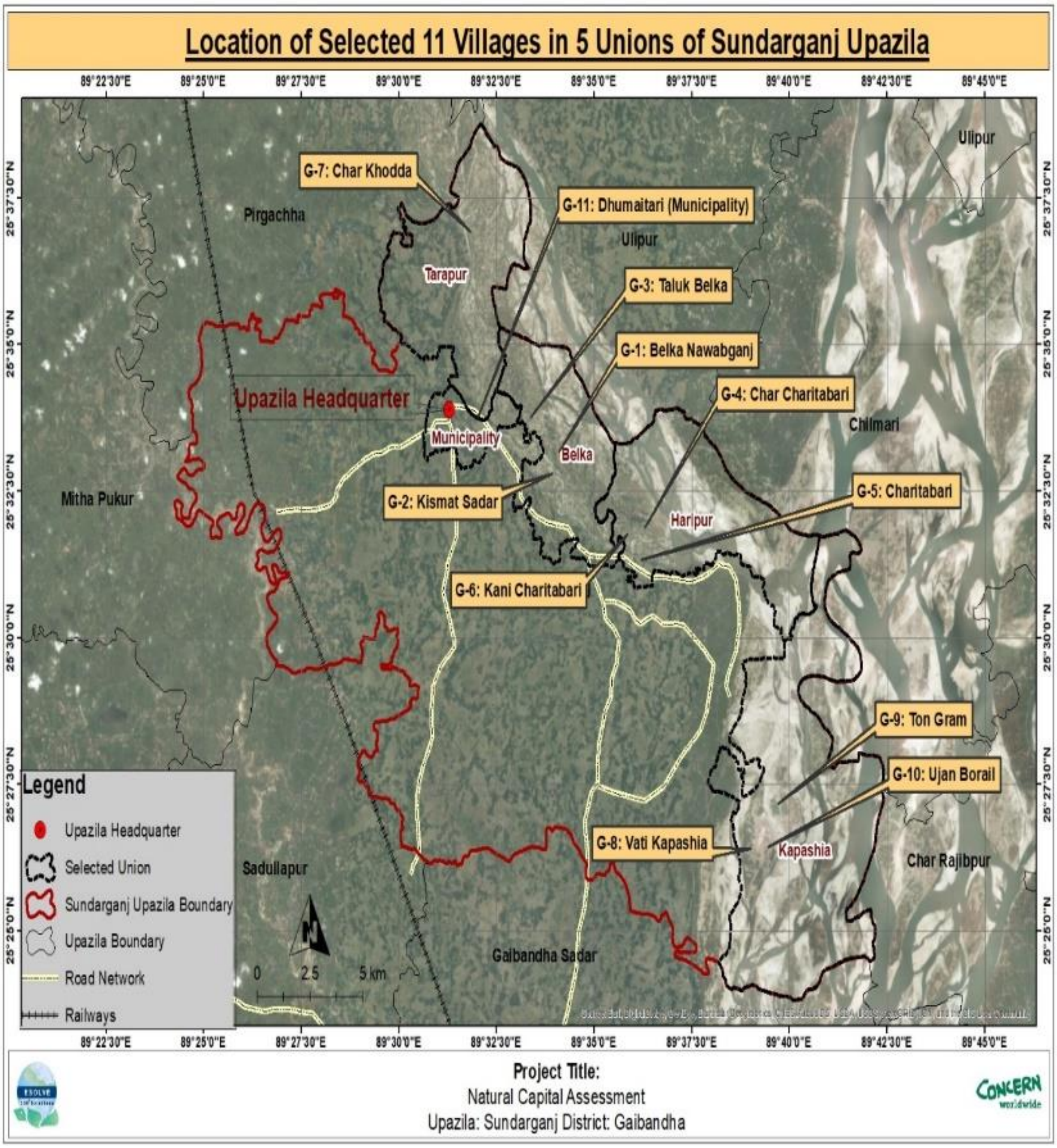

Figure 8: Programme locations in Gaibandha, prepared by Esolve International.

Lalmonirhat District Clusters

This Cluster cover 11 communities in six Unions and this makes it more complicated from a cluster perspective than for Gaibandha. For example, Sindurna union will cover two Clusters, (1 and 2) with two villages. As such, the set-up of the Clusters in Lalmonirhat needs to be carefully considered to avoid too much overlap.

- Cluster 1: Lower, this includes six villages across three Unions, namely Purba Dauabari; Dakkhin Dauabari; Uttar Dauabari in Dauabari Union: Purba Holdbari, Paschim Holdbari in Patika Para Union and Char Sindurna in Sindurna Union.
- Cluster 2: Midstream, this includes two villages, in two Unions, spanning the Teesta; Dakkhin Sindurna in Sindurna Union and Dhubni in Singimari Union.
- Cluster 3: Upstream left bank, this includes three villages in two Unions, namely Nich Goddimari and Doani in Goddimari Union and Nich Goddimari in Saniajan Union.

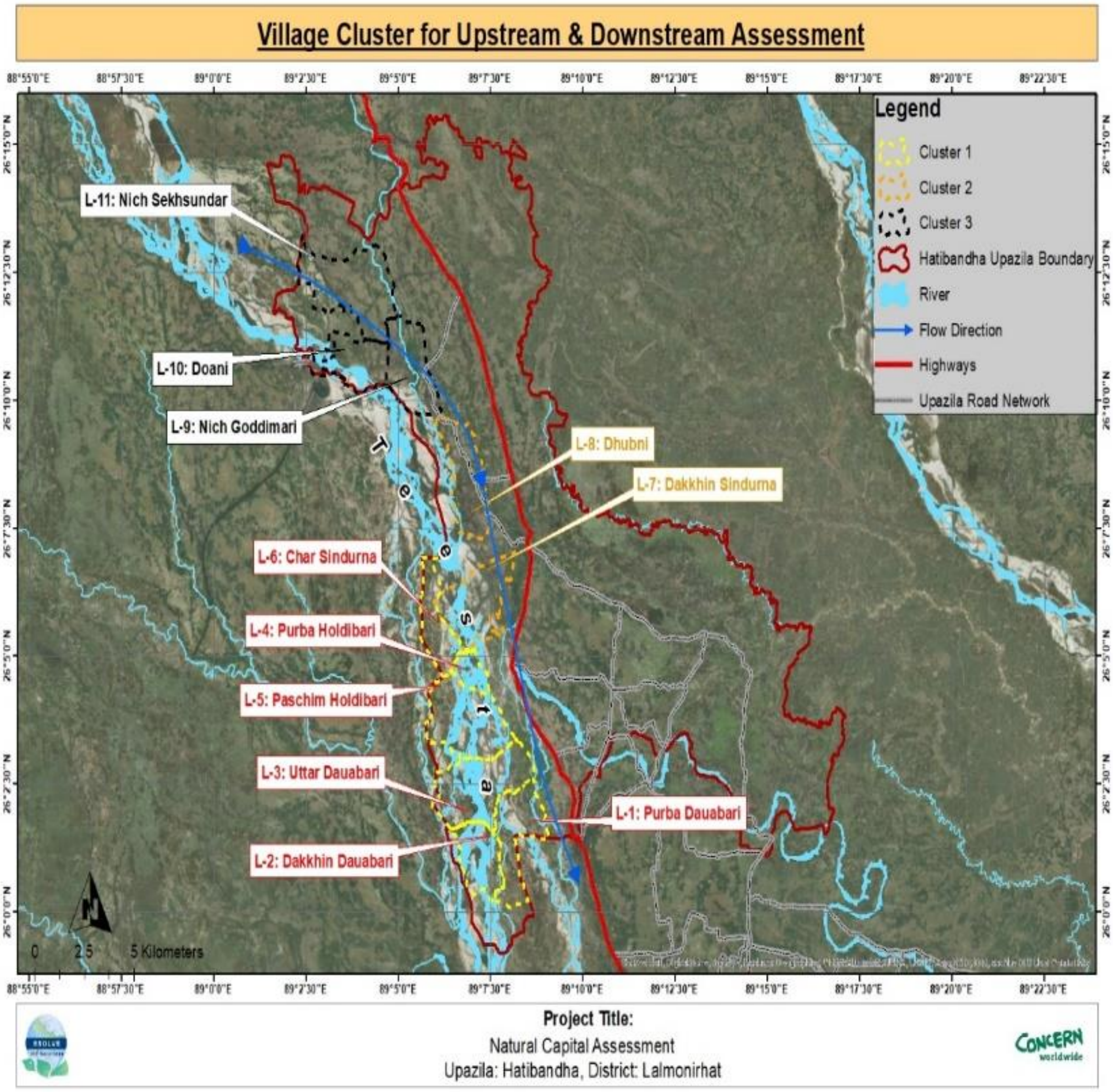

Figure 9: Programme locations in Lalmonirhat, prepared by Esolve International.

There are three key issues that need to be looked at in flood control management in communities in the study location.

1) The first is the issue of the Danger Level and how this informs flood forecasting and early warning as mentioned above.
2) The second issue is that of complementing the work of the Bangladesh Water Board and working with communities. Concern recognises the value of understanding natural capital and sees potential in developing natural capital in the study locations, and beyond. This should complement the work of the Bangladesh Water Board in working with communities to protect them against flooding and reinforce sections of the river to manage flooding in a way that can increase effectiveness of, or even suggest cost effective alternatives to the same. The cluster system is one way to try to build a common approach to influence the decision-making process on flood mitigation options. Furthermore, the clusters are premised on the assumption that flood mitigation works in an upstream location, due to the hydraulic connectivity in the environment, will automatically affect flood control options on the downstream location.
3) The further issue that is explored further in the next section is that the role of natural capital in flood control changes in relation to flood severity. The upstream dam along the Teesta has regulated flooding, but not entirely, as such it is important to understand how to consider different options for flood mitigation in relation to the recognised wisdom of engineering solutions to flood control. As such this work deals with Nature Based Solutions, using an Eco-DRR approach to address flooding, looking specifically at the relationship between green, blue and grey infrastructure (Box 1) but hopefully connecting this to ecosystem-based adaptation approaches.

What are grey, green and blue solutions?

Grey solutions, these are engineering solutions to control flooding and the most notable example of this would be levee construction or revetments or, in the urban environment, canalizing, drainage, channelizing and so on. The issue with these solutions is that they are expensive to construct and may not accommodate all design considerations, such as are built for the 1 in 100 year flood, not the 1 in 200 year flood. The other issue with grey infrastructure is cost, maintenance and failure. If a levee is constructed for the 1 in 100 year flood and the 1 in 150 year flood occurs in the next 10 years, it is likely that the levee would fail and cause even more damage. It is equally important, however, to not say that grey infrastructure is not required, but how green and blue infrastructure can work with the grey infrastructure to minimise the risk of the 1 in 150 year flood not overpowering the levee.

Green solutions, these are design solutions that can work in conjunction with grey solutions, to mitigate the impact of flooding and would cover all of the expected solutions, such as reforestations, landscape preservation, land use management, conservation and so on.

Blue solutions, these are solutions that directly work with the water, so these would be increasing channel sinuosity, creating retention ponds, aquaculture and would include natural drainage solutions as well.

Often it is not the use of one of these categories only that provides the solution, but the correct configuration of the options in relation to the catchment characteristics that leads to an appropriate mix of interventions to arrive at a flooding solution. This is the question that the work Concern is doing is going to answer.

The principal takeaway at this point is that by looking at the hydrological environment as a network it can raise alternative options for flood mitigation but which need to consider specific land/water interactions to define the right option. The issue is working holistically with environmental resources to define the appropriate mix of solutions that can either provide an alternative to the more costly engineering solutions, enable more cost effective pre-event budgeting for resilience, or increase the longevity of the engineering solutions, and therefore value for money by considering the principle of complementarity. The cluster system being established in the project, as opposed to traditional catchment, or administrative demarcations, intends to build this more **holistic floodplain risk management approach for Bangladesh** and which will ultimately influence budgeting decisions for flood management as typically the ask from Upazila authorities for such work is in excess of the allocation provided to those Upazilas. This is considered further in later sections.

Natural Capital Units (NCU) in the environments

The list of identified NCUs in Gaibandha and Lalmonirhat District were highlighted in Table 4, while a graphical presentation of these natural capital units in Gaibandha was provided in Figure 6. The key findings from the Phase II Remote Assessment Report (eSolve International, 2019) has been summarized in this section to determine the nature and role of the existing natural capital units in the selected 11 communities of Sundarganj Upazila of Gaibandha District.

Gaibandha District NCUs

Cluster 1 (Jamuna Chars)

This cluster includes three villages of Kapashia Union: Vati Kapashia, Ton Gram and Ujan Borail, Figure 7 (p21). The sites are located relatively close to each other therefore, there is likely to be little hydrologic difference between them. However, given that the sites have different elevations, they are likely to have different level of flood exposure and consequential vulnerabilities. The remote assessment indicated that Ton Gram and Ujan Borail do not have any Nalas or Khals but the former community is located on higher level land and the latter on low lying land; this suggests that Ujan Borail is more vulnerable to flood risks. However, Ujan Borail has more Dobas, located in F3 and F4 lands, which would help absorb some flood waters, especially during normal events. Both sites face challenges with regards to cultivated land, Ton Gram has a more limited cultivable area (probably due to soil infertility issues) and all cultivated lands of Ujan Borail are located on flood prone (F3 and F4) areas. The two sites also have limited number of tube wells, with Ujan Borail particularly vulnerable as all tube wells are in F3 and F4 lands. Thus, in this cluster, it seems Vati Kapashia is likely to be better off in terms of flood exposure as it has more highland, more Nalas and Khals. Although it has the highest amount of cultivated land these are in F3 and F4 locations. Given that this cluster of communities are in the most downstream part of Sundarganj Upazila, any measures to attenuate or absorb flood flows in any of the upstream clusters would be beneficial. Increases in vegetation areas and Doba would potentially reduce flood impacts in this cluster.

Given the large volumes of flood water in the Teesta and Jamuna Rivers, it is, however, unlikely that significant changes in the flood exposure can be achieved given that this cluster of villages is located within the Jamuna River Chars. Another important connectivity issue between this cluster and the other clusters (especially Cluster 2, which is nearest) is that Cluster 1 sites seem to be particularly vulnerable to damage to crops during the monsoon season, therefore, increasing cultivated lands in F0, F1 and F2 lands in the other Clusters can help provide rice and other crop products to Cluster 1 sites during flood events. Addressing issues such as this is one of the key functions of the Cluster Consultative Groups. These observations from Cluster 1 reinforce the need to consider the relationship between natural capital and flooding events holistically and understand how land management practice contributes to or reduces the impact of flood flow.

Cluster 2 (Jamuna-Teesta Confluence)

This includes three villages of Haripur Union: Char Charitabari, Charitabari and Kani Charitabari, Figure 7. All three villages are situated on the right bank of the Teesta River. The villages are mostly flooded by Teesta waters, but Jamuna water levels also influence the flood duration and drainage pattern of these villages. Char Charitabari is more exposed to flooding than the other two sites in the cluster, as it is located nearest to the main river channel. Although it has a good number of Nalas and Khals, their conveyance capacities seem to be limited, but could be potentially be increased to allow easier passage of flood flows from upstream areas; however, this is likely to have a detrimental effect on Cluster 1 sites as it can lead to Teesta River peak flood wave moving faster to those sites. An alternative option would be to increase the number of Dobas or their specific storage volumes, especially on F0, F1 and F2 lands as these play a more important role for higher than normal floods; this reasoning applies to all the sites in this cluster, such as Charitabari, which already has a good number of dobas in these high land level areas. As alluded to in the Cluster 1 assessment, increasing Monsoon season food production in this Cluster could help increase flood resilience in Cluster 1. Measures to attenuate flood flows in Cluster 2 sites can therefore be beneficial to Cluster 1 sites. However, these measures can have detrimental effects to Cluster 3 (Teesta Chars) sites, as these measures can hamper recession of the flood wave from upstream areas.

Cluster 3 (Teesta Chars)

This cluster includes three villages of Belka Union: Belka Nawabganj, Kisomat Sadar and Taluk Belka and one village, Char Khodda, of Tarapur Union (Figure 7). In this Cluster, Char Khodda is the most upstream site. Therefore, measures to increase conveyance capacities of Nalas and Khals at this site would need to be done carefully in order to avoid unwanted impacts at downstream sites and also at Clusters 1 and 2; however, there is considerable vegetation in low lying lands at this site. Further improvements to natural capital in this cluster can assist in attenuating flood flows. This measure could potentially have beneficial impacts on downstream sites as well as at Clusters 1 and 2. As with Char Khodda, improvements in conveyance capacities of Khals and Nalas in Taluk Belka (to allow easier passage of flood flows) can have detrimental effects on Belka Nawabganj and Kisomat Sadar and other downstream sites (in Clusters 1 and 2). Therefore, improvements to these structures should start from the downstream end and move upwards in phases. Measures to store, disperse or attenuate flood flows at Taluk Belka are likely to have beneficial effects on the downstream sites also. Vegetation areas, including bamboo bushes, can be increased along the Nalas and Khals to help attenuate flood flows and to reduce erosion rates in this Cluster. This can also have beneficial effects at the downstream Clusters. At Kisomat Sadar, there is considerable vegetation in low lying lands, which can assist in attenuating flood flows at this site and have positive impacts on downstream Clusters. However, Attenuation of flood flows at this site should be carefully considered, as it can have unwanted drainage congestion at upstream sites (Belka Nabobganj and Taluk Belka).

Cluster 4 (Municipality)

This cluster has two sites, which are Dhumaitari and Ram Dakua, which is located along the right bank of the Teesta River. Most of this site area is above normal flood levels. Furthermore, the site has a wide nala (44m to 77m) that can pass flood waters through the site. However, encroachment of this nala and dumping of solid wastes can reduce flood resilience at this site. This cluster has conveyance capacity, but most land is above flood water levels.

Natural Capital Units

To look in a little more detail at the natural capital units present in each of the Clusters in Gaibandha, Table 5 provides the count of units; it does not provide the spatial extent of these units. The table also includes average inundation period for the severe flood events only. The data in the table has considered flooding between 2007 and 2018. Only two communities exhibit fewer than three severe flooding events, being Kani Charitabari and Kisamot Sadar. It would be interesting to understand why these communities only experience two events, but Vati Kapashia and Char Charitabari for example experience four. That said, despite more severe events, the average inundation period is approximately 1 week.

The community under water for the longest period is Belka Nabobganj, averaging 34 days for the severe flooding events. In terms of community based early warning, it would be useful to understand better these differences and what that means for land use. There are four communities with a high number of severe events and long average inundation period, being Ton Gram Cluster 1, Charitabari, Cluster 2 and Belka Nabobganj and Taluk Belka in Cluster 3.

A further interesting observation from Table 5 is the comparison between Belka Nabobganj, Vati Kapashia in Cluster 1 and Charitabari in Cluster 2. All these communities have similar extent of cultivated land, but Belka is much more severely affected by flooding, while Belka has fewer blue capital resources than either Vati Kapashia or Charitabari. This raises an interesting question which can be explored by the Cluster Consultative Groups as to whether the configuration of land use vis a vis the locations more severely affected by flooding is the correct configuration to minimise impact and if not what needs to change?

Table 5: Summary of NCUs observed in Gaibandha communities

NCE	Cluster 1			Cluster 2			Cluster 3				Cluster 4	
	VK	TG	UB	CC	C	KC	BN	KS	TB	CK	Dh	RD
Pond	3	0	2	4	20	0	0	2	5	2	4	3
Beel	0	0	100	0	0	0	0	0	0	0	0	0
Doba	13	8	9	25	33	12	3	4	20	15	13	5
Kura	2	0	0	4	0	9	1	11	0	0	0	2
Khal	0	0	50	0	0	0	0	1	0	0	0	0
Nala	2	0	1	2	2	3	3	2	5	1	1	0
FFHL		0	12	0	15	1	7	5	1	42	0	1.5
Cultivated	1500	450	300	300	1200	600	1200	1500	900	4800	25	150
Forest	0	0	0	0	0	0	0	0	0	0	0	0
Tree cluster	115	45	1	65	220	170	122	345	550	300	25	25
Ave. Inundation period	7	**13**	10	8	**13**	6	**34**	8	**14**	6	7.6	6.5
Severe flood events	4	**3**	3	4	**3**	2	**3**	2	**3**	3	4	3

Note: This table is counting the number of visible units, it does not indicate size, so looking at tree cluster, in Cluster 1 VK, there are 1,500 clusters of trees, not 1,500 trees and in Cluster 1 VK, there are 13 Dobas.

Key observations

- The communities which on average suffer the greatest number of days underwater is Cluster 3, with 56 days over the last 12 flooding events, with Belka Nabobganj (BN) demonstrating on average 34 days inundation over all flooding events over the last 10 years. Conversely, Cluster 4, Municipality, has the fewest number of days underwater. This is likely due to the impact of the Levee protecting Sundarganj (principal town in the Upazila).
- The villages with the higher number of severe flooding events (those that reach F2 and above) correspond largely to fewer days under water. This may reflect the more flashy nature of flooding along the Teesta.
- No forested areas exist in any of the clusters, although Cluster 3 is relatively better endowed with tree clusters than Cluster 1 or 2.
- Flood free high land is relatively sparse but some sites are available in each of the clusters, this could suggest that there is some further analysis needed in terms of land use and land use interactions in these locations.
- There is a mix of water retention sites, such as ponds and canals across the clusters. For example, cluster 2 has relatively more ponds than seen in Cluster 1, while Cluster 1 has relatively more Khal than the other clusters and cluster 2 has more Doba than the other clusters. Nala are relatively uncommon across clusters, but more investigation is needed on whether these water retention systems can be further exploited to accommodate more floodwater, increase the livelihood options and generate greater environmental diversity.
- Finally, Cluster 3 indicates the highest levels of cultivated land than cluster 1 and 2, with 3,600 Bigha, approximately 900Ha, with 2,250B in Cluster 1 and 2,100B in Cluster 2, so the most cultivated areas experienced the highest average number of days underwater during flooding.

The principal comment from Table 5 is that while there are apparent opportunities to manage land use in a way that is more attentive of flooding and control flood water flows, further study is needed to understand the capacity, limitations and opportunities for working with the blue and green infrastructures built in a natural capital strategy. This strategy can then facilitate improved flood risk management and consequently flood resilience; this will be taken forward in the next stages of the project.

Lalmonirhat District NCUs

Cluster 1 (Teesta Chars)

This cluster includes six villages which are Purba Dauabari, Dakkhin Dauabari and Uttar Dauabari of Dauabari Union, Purba Holdibari and Paschim Holdibari of Patika Para Union and Char Sindurna of Sindurna Union (Figure 8). All these villages are located on Chars in the Teesta River and located relatively close to each other. Therefore, there is likely to be little hydrologic difference between the three sites. However, given that the three sites are located on different land levels, they will have different flood vulnerability and resilience characteristics. For example, Char Sindurna is located at the upstream most section of the river while Dakkhin Dauabari is situated at the downstream end; thus, the flood waters will affect Char Sindurna, before the other villages. Dakkhin Dauabari and Uttar Dauabari are located on the main channel of the Teesta River, while the other villages are located on the banks of the tributaries. Most of the villages have a large number of Nalas flowing through the villages, with the Teesta River or its tributaries bordering the village. The Teesta River or its tributaries flows through three of the villages that is Purba Dauabari, Uttar Dauabari and Purba Holdibari bisecting the administrative boundary into two parts, it is unclear how this will impact on flood flow management. Additionally, Uttar Dauabari, Purba Holdibari and Char Sindurna have significant number of Kuras which are created by erosion within the river or tributary bed. This shows that the river system is still quite active and erosion and sedimentation occurring frequently along different river sections.

None of the villages have considerable amount of F0-F1 land and most of the cultivable area of all the villages are situated in F3-F4 land. Of the villages, Paschim Dauabari has the smallest area (0.43 km^2) and population and also the lowest amount of natural capital units. Paschim Dauabari also has very little cultivable land compared to other villages in this cluster. Given that this cluster of villages are located in the most downstream part of Hatibanda Upazila, any measures to attenuate or absorb flood flows in any of the upstream clusters would be beneficial. In particular, increase in vegetation areas and doba areas would potentially reduce flood impacts in this cluster. Additionally, vegetation areas, including bamboo bushes, can be increased along the Nalas and khals to help attenuate flood flows and also to reduce erosion rates in this cluster.

Cluster 2 (Teesta Mid-Section)

This cluster includes Dakkhin Sindurna of Sindurna Union and Dhubni of Singimari Union. Both villages are located on the left bank of the Teesta River and are located quite a distance from the main channel of the Teesta River, 8.1m and 1.3m respectively. As a result, both villages have only one khal or nala. Dakkhin Sindurna can be considered to be more vulnerable in the cluster, as it is located nearest to the main river channel. The conveyance capacity of the Khal is also quite limited, as it narrows to 4m in some places, meaning it is more liable to flood. On the other hand, Dhubni, does not have any Nala within the village, rather it is bordered by a Nala and tributary. The conveyance capacities of these Nalas and Khal could be increased to allow easier passage of flood flows from upstream areas. Measures to attenuate flood flows in Cluster 2 sites can be beneficial to Cluster 1 sites if both measures are taken up in a planned way. There is considerable vegetation in low lying lands in all the villages of this cluster. Further improvements in this vegetation could also assist in attenuating flood flows, though this will be considered in the next phase of the natural capital work of Concern, and is not considered further in this report.

Cluster 3 (Teesta North)

This cluster includes three villages which are situated in the left bank of Teesta River at the northern part of Lalmonirhat District. The villages are Nich Goddimari and Doani of Goddimari Union and Nich Sekhsundar of Saniajan Union. This cluster has the highest elevation and the slope in this section of the river is also quite high. Nich Goddimari and Nich Sekhsundar have numerous Nalas and Khals; only Doani has two Nalas has a small Beel. Beels are very important for flood retention, groundwater recharge and provision of water in dry season. In this Cluster, Nich Sekhsundar is the most upstream site. Therefore, measures to increase conveyance capacities of Nalas and Khals at this site should be considered carefully in order to avoid unwanted impacts at downstream sites and also at Clusters 1 and 2. Further improvements to natural capital can assist in attenuating flood flows. This measure can have beneficial impacts on downstream sites as well as at Clusters 1 and 2. At Nich Goddimari and

Doani, there is considerable vegetation in low lying lands, which can assist in attenuating flood flows at this site and also have positive impacts on downstream Clusters. However, attenuation of flood flows at this site needs to be carefully considered, as it can have unwanted drainage congestion at upstream sites.

Key Points

a) There is hydrologic connectivity between natural capital units in each Cluster and attenuation in any one cluster can have downstream impacts in other clusters, so ameliorative actions need to be viewed holistically. To address this flood resilience planning at the cluster level would be appropriate.
b) Flooding severity is caused by the relationship between duration, water depth and land elevation and this then has implications on land use planning and management to better manage flood attenuation.
c) The natural capital units have different roles in flooding, which is explored below, but there is potentially a limit to what can be achieved under severe flood conditions in working with the existing natural capital units.
d) To better manage flooding, we need to look at appropriate flood retention structures sited at specific nodes in the landscape to best attenuate flood flow and look to greater inter dependency between communities within clusters.

Natural Capital Units

To look in a little more detail at the natural capital units present in each of the Clusters in Lalmonirhat, Table 6 provides the count of units; it does not provide the spatial extent of these units. What is notable about this Table in relation to Table 5 (Gaibandha) is the increased frequency of severe floods, with Char Sindurna boasting seven severe flood events, while four communities have experienced five or more severe events in the time period 2007 to 2018. Table 6, as 5, includes average inundation period for the severe flood events only and communities in Lalmonirhat may tend to be inundated for longer periods, than Gaibandha with a few notable exceptions.

Table 6: Breakdown of natural capital units in Lalmonirhat

NCE	Cluster 1 - Teesta						Cluster 2 – Teesta Mid		Cluster 3 – Teesta N		
	PD	DD	UD	PH	PsH	CS	DS	D	NG	Do	NS
Pond*	72	5	65	20	10	39	61	144	102	85	27
Kura	3	0	0	1	1	7	2	2	3	4	1
Khal	1	0	0	0	0	0	0	0	0	0	1
Nala	9	3	7	4	8	6	3	1	1	2	2
GW	40	204		81			250	300	32	400	77
FFHL	3	1	0	50	0.5	2	0	2	2	1	5
Cultivated	2500	990	300	736	650	6000	160	1500	5700	200	830
Forest	0	0	0	0	0	0	0	0	0	0	0
Tree cluster	27	80	70	3045	3547		50	330	110	190	3572
Ave. Inundation period	7.1	26	9.3	10	11.1	27	9.5	12	14.5	8.7	10.6
Severe flood events	2	6	1	4	3	7	1	5	6	1	3

Note: In this table, ponds refer to Beel, Doba and Ponds.

Key observations

a) The patter of flooding is highly varied in Lalmonirhat; Table 6 indicates that Lalmonirhat suffers more severe events than in Gaibandha, with four locations experiencing more than four severe flood events, compared to no communities in Gaibandha experiencing more than four severe events. The range for Lalmonirhat in terms of average inundation period for severe flood events is between 7 days and 27 days, for Gaibandha (Table 5) the range is 6 to 34 days. As such, generally Lalmonirhat suffer more severe floods corresponding to a lower inundation period than for Gaibandha. This is consistent with the Upper Teesta being relatively more flashy.

b) As with Gaibandha locations, no forested areas exist in any of the clusters, although Cluster 1 is relatively better endowed with tree clusters, at least in the PH and PsH locations than either Cluster 2 or 3.

c) Flood free high land is relatively sparse in all clusters, with the notable exemption of Cluster 1 PH.

d) In relation to water retention sites, such as ponds and canals across the clusters, Cluster 2 and 3 have the highest number of ponding sites. For example, cluster 2 has relatively more ponds than seen in Cluster 1. The presence of Beels and Khals are limited in the area, though there are Nala present. As such, strategies to enhance water storage potential should focus more on enhancing pond capacity than reinforcing natural canal systems.

e) In Lalmonirhat, there is much more cultivated land than in Gaibandha. Cluster 1 indicates the highest levels of cultivated land than cluster 1 and 2, with 11,176 Bigha, approximately 2,794Ha, and as with Gaibandha, the pattern is similar, as in Cluster 1 CS, this the most number of flooding days with the highest level of cultivation at 6,000B (1,500Ha).

f) The principal comment from Table 6 is similar to that for Table 5, in that further study is needed to understand the capacity, limitations and opportunities for working with the blue and green infrastructures to facilitate improved flood risk management and consequently flood resilience, this will be taken forward in the next stages of the project. There is considerably more cultivated land in the Lalmonirhat sites than Gaibandha and the reasons for this need exploring, as well as the potential impact of shorter duration more intense flooding on cultivation potential in Lalmonirhat and the implications for land use management vis a vis the potential for natural capital solutions for improved flood mitigation.

Natural capital and flooding interactions

Gaibandha

As part of the natural capital studies, communities were asked to consider what role they perceived the identified natural capital units had in the environment in relation to the buffering, coping and recovery capacity[23] in relation to flooding and whether these capacities altered under different flood flow regimes; normal, moderate and severe flooding events were used to categorise the responses. Referring to the aforementioned Natural Capital Guide, the community work looked at the role of different natural capital units in relation to the socio-economic function it provides as being:

1) **Buffering**, this looks to see whether the natural capital may have a role in attenuating flood flows, or mitigating the impact of the flood in any way.
2) **Coping**, this refers to whether the natural capital is used to assist households during a flooding event to better withstand the flood.
3) **Recovery**, this refers to whether the natural capital is used to support household income recovery following the flood.
4) **Prevention**, this is a term used in the Practical Action natural capital guidance, but this was seen as too complicated an issue to address at the community level in relation to likely flood ecosystem services, to be of value, so this was not considered. The rationale is that in a highly degraded landscape it is unlikely that

[23] The Alliance Natural Capital Guide, which was used as a base for this work, also looks at prevention, but this was not considered in the study, as it is quite a complex issue. Flood prevention and communities are unlikely to differentiate between prevention and buffering, so the categorisation was simplified.

natural capital can effectively prevent a flooding situation. In the next phase of the work, Concern will look in more detail at perceptions of natural capital and consider what options the community would cite in terms of natural capital preventing flooding in the first place

The way in which natural capital was reviewed and how this was considered is summarised in Table 7 and the efficacy of these roles for flood attenuation, were assessed, albeit subjectively, as High, Medium and Low, though this needs further refinement, which will be part of the next phase of the work. There are a few points to draw out from this analysis.

Table 7: Description of potential natural capital unit roles in the environment with respect to flooding

Role of NCE	Description of Role	Effectiveness of Role
Buffer	NCUs play a role in lessening the impact of a flood on the community	High: NCU is very effective and useful Medium: NCU provides some help Low: NCU provides little assistance in flood
Coping	NCUs help community to get through the initial days of the flooding	
Recovery	NCUs help community to re-build, repair, re-grow what has been lost or damaged in the flood	

Table 8 provides results of the investigation and the following text refers to the observations from each community in Gaibandha Cluster 3 only. Only Gaibandha Cluster 3 is shown at this point, the more detailed assessment of the other clusters will be undertaken in Phase 2 of the project, but unlikely that there will be substantial difference in the underlying issues affecting those Clusters as the ones affecting Cluster 3.

Table 8: Results of Focus Group Discussions in GC3 Belka Nobabganj regarding community perception of functionality of natural capital elements present in the community

	NCE	BN			KS			TB			CK				
		Buffering	Coping	Recovery	Buffering	Coping	Recovery	Buffering	Coping	Recovery	Buffering	Coping	Recovery	Comment	
Normal	Pond	H	L	H	H	M	H	H	L	M	H	L	H	BN	High buffering potential for water and land resources, coping is low for water resources, recovery is higher for water resurces
	Doba	H	L	H	H	L	M	M	L	M	H	L	M	KS	Similar to BN, but some coping potential for ponds
	Nala	H	L	M	H	L	H	H	L	M	H	L	M	TB	Weak coping potential for water resources, better recovery potential
	GW	L	M	H	L	M	H				L	M	L	CK	Strong buffering potential for water resources, weak for coping, land and trees for recovery
	FFHL	L	H	L	L	H	M	L	H	L	L	H	L		
	Land	H	M	H	H	L	H	H	L	H	H	L	H		
	Tree cluster	H	H	M	H	H	M	H	M	M	M	M	H		
Moderate		BN			KS			TB			CK				
		Buffering	Coping	Recovery	Buffering	Coping	Recovery	Buffering	Coping	Recovery	Buffering	Coping	Recovery		
	Pond	H	L	M	H	M	M	H	L	M	M	L	M	BN	Similar to normal flood, but better recovery potential for Nala
	Doba	H	L	M	M	L	M	H	L	M	M	L	M	KS	Slightly reduced buffering and coping potential to normal flooding stronger recovery potential for water and land resources
	Nala	H	L	H	H	L	H	M	L	M	M	L	M	TB	Coping for water resources is low, stronger recovery potential
	GW	M	L	H	M	L	H				M	L	L	CK	Buffering capacity under moderate flood more limited, limited coping and some recovery potential of water and land resources
	FFHL	L	H	L	M	L	L	L	H	L	M	M	L		
	Land	H	L	H	M	L	H	M	M	H	M	L	M		
	Tree cluster	L	M	M	M	M	L	L	M	M	M	L	M		
Severe		BN			KS			TB			CK				
		Buffering	Coping	Recovery	Buffering	Coping	Recovery	Buffering	Coping	Recovery	Buffering	Coping	Recovery		
	Pond	L	L	L	L	L	L	L	L	M	L	L	L	BN	Gnerally low capability under severe flood, but Nala and land pose recovery potential
	Doba	L	L	L	L	L	M				L	L	L	KS	FFHL has a strong role in coping under severe flooding
	Nala	L	L	M	M	L	M	L	L	L	L	L	M	TB	FFHL has a strong role in coping under severe flooding
	GW	L	L	M	L	L	H	L	L	L	L	L	L	CK	FFHL has a strong role in coping under severe flooding
	FFHL				L	H	L	L	M	L	L	M	L		
	Land	L	L	M	M	L	H	L	H	H	L	M	M		
	Tree cluster	L	L	M	L	M	L	L	L	M	L	L	M		

The key observations

Looking at normal flood flow conditions, Table 5 indicates that there is a high perception that both blue and green capital provide a buffering role in mitigating floods. However, it is not clear in what way, whether the speed of floodwater is reduced, or the depth of the flooding is mitigated. This needs further study in the project. Interestingly the blue capital provides little coping capacity during flooding, indicating that these resources are not used to support livelihoods during the flood, which stands somewhat to reason, as households will be concerned with weathering the flood itself. For the recovery aspect, blue capital appears to offer more for recovery in Belka Nabobganj and Kisomot Sadar, than for Taluk Belka and Char Khodda. The green capital seems to provide more opportunity. Though it is not yet clear exactly how this manifests in the communities and needs further research.

Under moderate flood flow, the situation changes, this is where up to 40% of land in F2 and higher are affected. We can still see a positive role of blue capital in buffering the flood flow impacts, the situation is a little more varied for the green capital, for example in Char Khodda the green capital appears to provide more benefit under moderate than normal floods. The more significant change is for coping where there is limited potential across the board, so communities do not use natural capital well to cope with the floods, this may be because the communities see the role of natural capital as supporting livelihoods and not flood flow management, so do not see the benefit when the land is flooded. For the recovery aspect, it is generally more positive, this will mean that after flood recession, the natural capital can be brought more under productive use. This insight, though it needs more investigation, may suggest that there is a need to change perceptions of communities to see positive benefit from using blue capital better to manage floods than for productive livelihoods.

Under severe flood flow conditions, it is as we would expect, where there are many more fewer instances of a positive benefit seen from either blue and or green capital in buffering and coping, with a couple of exceptions, such as Belka Nabobganj and Kisomot Sadar, where there are more benefits perceived in the Nala than other communities.

To investigate further, Table 9 looks at the distribution of land in the different land categories. Looking back to Table 5, Cluster 3 has the most cultivated land, being 8,400Bg, compared to 2,250 for Cluster 1 (Haripur Union) and 2,100 for Cluster 2 (Kapashia Union). Most of the cultivable land is in the F4-F2 categories across the Clusters, so highly liable to flooding. Generally, in Cluster 3 sites more than 50% of cultivated land is lying in the heavily flooded F3/4 locations, which accounts for only 9.4% of the spatial area in the Union. Cluster 1 sites (Haripur Union) are a little different with 72% of cultivated land in Charitabari in the F2 and above categories, unlike Char Charitabari where 100% is in the F3/4, which accounts for most of the land allocation (Table 9). In Kapashia, Ton Gram has 100% of cultivated land in the F3/4 category, with only 100% for Ujan Borail. Finally, Table 10 indicates that Sundarganj Upazila is water rich with Nala amounting to 58km in length with over 170 ponds, this indicates a significant potential for enhancing water storage and delay flood impacts through the correct management of blue capital in the system.

One aspect to research further is the distribution of productive value in the higher land elevation areas, if most cultivation is on the relatively lower land more susceptible to flooding, can land practices be considered to shift cultivation from these locations into less exposed sites? This will be a key question for the forthcoming natural capital management strategy for the project.

Table 9: Distribution of land elevation across the land categories for each Union in Sundarganj Upazila, Gaibandha District

	Unions														
Land Category	Belka (C3)			Tarapur (C3)			Municipality			Haripur (C1)			Kapashia (C2)		
	DEM	Area	%	DEM	Area	%	DEM	Area	%	DEM	Area	%	DEM	Area	%
F4	11 - 19	0.2	0.8%	11 - 19	0.15	0.7%	17-19	0.02	0.1%	11 - 19	1.75	7.2%	11 - 19	35.6	57.0%
F3	19-22	2.1	8.6%	19-22	2.2	9.6%	19-22	0.14	0.7%	19-22	5.76	23.5%	19-22	15.4	24.6%
F2	22-24	9	36.9%	22-24	4.76	20.8%	22-24	0.97	4.8%	22-24	9.33	38.1%	22-24	8.1	13.0%
F1	24-26	10.1	41.4%	24-26	11.48	50.1%	24-26	3.2	15.7%	24-26	6.88	28.1%	24-26	2.9	4.6%
F0	26-35	3	12.3%	26-35	14.31	62.5%	26-35	15.99	78.7%	26-35	0.75	3.1%	26-35	0.5	0.8%
Totals		24.4			22.9			20.32			24.47			62.5	

Table 10: Blue capital characterisation for the Unions in Sundarganj Upazila

		Nala			Khal			Pond
Union	Village	No.	Total Length	Ave	No.	Total Length	Ave	No.
Belka	Belka Nabobganj	8	8,078	1,010	1	453	453	6
	Taluk Belka	9	5,003	556	0	0	0	2
	Kisomat Sadar	8	5,935	742	0	0	0	6
Tarapur	Char Khodda	5	9,881	1,976	0	0	0	12
Municipality	Dhumaitari	1	524	524	0	0	0	0
	Ram Dauka	0	0	0	0	0	0	8
Haripur	Char Charitabari	7	7,151	1,022	2	354	177	27
	Charitabari	1	3,820	3,820	3	2,625	875	41
	Kani Charitabari	11	11,963	1,088	0	0	0	48
Kapashia	Vati Kapashia	6	6,565	1,094	1	1,392	1,392	13
	Ton Gram	0	0	0	0	0	0	12
	Ujan Borail	0	0	0	0	0	0	1
Total		56	58,920	1,052	7	4,824	689	176

Lalmonirhat

As with Gaibandha, this section follows the same format, looking at the potential roles of the natural capital with respect to the flooding environment first (Lalmonirhat presents all clusters, unlike Gaibandha, which presents cluster 3). Then, this section considers the relationship of topography and land use to flooding.

Table 11 provides the findings from the community perceptions of the role of natural capital under different flood flow regimes. The Table considers Normal, Moderate and Severe flow conditions.

Table 11: Results of Focus Group Discussions on the community perceptions of natural capital in Lalmonirhat

		Purbo Daubari			Purba Holdibari			Uttar Duabari			Paschim Holdibari			Dakkhin Dauabari			Char Sindurna			Comment
	NCE	Buffering	Coping	Recovery	Buffering	Coping	Recovery	Buffering	Coping	Recovery	Buffering	Coping	Recovery	Buffering	Coping	Recovery	Buffering	Coping	Recovery	
Normal	Pond	H	M	M	H	M	M	H	M	H	H	M	H	H	M	H	H	H	H	The blue capital have a significant role in buffering flood impacts, but are more imactful for communities for recovery. The land and green resources are generally more impactful for coping and recovery in normal flooding
	Doba	H	M	H	H	M	H	H	M	H	H	M	H	H	M	H	H	M	H	
	Kura	H	M	H	H	M	H	H	M	H	H	M	H				H	M	H	
	K/Nala	H	M	H	H	M	H				H	M	H	H	L	H	H	M	H	
	GW	M	H	M	M	H	M	M	M	H	M	M	H	M	L	H	L	M	H	
	FFHL	M	H	M	M	H	M				L	M	L	M	L	L	L	M	L	
	Land	H	M	H	H	M	H	H	H	H	H	M	H	H	M	H	H	L	H	
	Tree	H	H	H	H	H	H	H	H	H	H	M	M	H	M	H	H	M	H	
Moderate	Pond	M	L	M	M	L	M	H	M	M	H	M	M	M	M	H	H	L	M	There appears to be under moderate flood conditions a difference between PD,PH and UD sites sites, where natural capital has a relatively more significant role in strategies, as oppsoed to PH, DD na dCS, where the capacity is lower across the board
	Doba	M	M	M	M	M	M	H	M	M	M	M	M	M	M	H	M	L	H	
	Kura	M	M	M	M	M	M	H	L	M	M	L	M				M	L	H	
	K/Nala	H	M	H	H	M	H				M	L	H	H	L	H	M	M	H	
	GW	M	H	M	M	H	M	M	H	H	L	L	M	M	L	H	L	M	H	
	FFHL	M	M	M	M	M	M				L	M	L	M	L	L	L	H	L	
	Land	H	M	H	H	M	H	H	M	M	M	M	H	M	M	H	H	L	M	
	Tree	H	M	H	H	M	H	H	H	M	M	M	L	M	M	H	M	M	H	
Severe	Pond	L	L	L	L	L	L	L	L	L	L	L	L	L	L	M	L	L	L	Generally, as observed in the report, under severe flood conditions the role of natural capital is significantly less across the board.
	Doba	L	L	M	L	L	M	L	L	M	L	L	M	L	L	M	L	L	M	
	Kura	L	L	M	L	L	M	L	L	M	L	L	M				L	L	H	
	K/Nala	M	L	H	M	L	H				L	L	H	L	L	H	L	L	H	
	GW	M	L	L	M	L	L	L	M	H	L	M	H	L	L	M	L	L	H	
	FFHL	L	M	L	L	M	L				L	H	L	L	L	M	L	M	L	
	Land	M	L	H	M	L	H	L	L	H	L	L	H	L	L	H	L	L	H	
	Tree	M	L	L	M	L	L	L	L	M	L	L	L	L	L	L	L	L	L	

Cluster 1 - Teesta Chars

Normal flooding: Overall, what can be stated for all locations is that blue capital can have a significant role in buffering flood impacts, but are more impactful for communities during recovery. The land and green resources are generally more impactful for coping and recovery in normal flooding. During normal flooding, up to 30% of land is underwater principally in the F4-3 category suggest that highest damage occur due to river erosion. Flooding, is however, very useful for crop production in mid land and high land area. Ponds become suitable for pisciculture (fish farming). During normal flood, people build platform in their house indicating that green resources are highly used to buffer the impact of flooding. The deposition of alluvial soil increases the fertility level of cultivated lands, which is very useful for sapling and vegetation; as such, the communities tend to appreciate normal flooding during the monsoon seasons.

Moderate flooding: There appears to be a difference under moderate flood conditions between PD, PH and UD sites, where natural capital has a relatively more significant role in buffering and coping strategies, as opposed to PH, DD and CS, where the capacity is lower across the board. This may be due to relatively fewer blue capital units in these latter locations in Cluster 1. In 2015 and 2018, moderate flooding took place and it was found that around 90% area of Cluster 1 was affected by the flood and around 80% crops were damaged. Essentially social systems were unable to cope with the extent of the flooding, while the knowledge of the community on how to use and work with blue and green capital was not present. This indicates that there is a need to work closely with the community to better understand the limitations and opportunities in strengthening green and blue capital in these locations.

Severe flows: Generally, as observed earlier, under severe flood conditions the role of natural capital is significantly less across the board. It is also found that in 2008, 2014, 2016 and 2017 severe flood occurred. In 2007, most severe flood attacked three times repeatedly. The first flood started during the end of Ashar[24] and remained four days. Next day flood water recedes and returned again. This time the height of water level was 1' to 2' higher than the previous one and stayed for seven days. After seven days, the flood hit the area for third time and remained for 13 to 14 days. This cycle of flood waves reflects the flashy nature of the Teesta River.

Cluster 2 – Teesta Mid-Section

Normal flooding: During floods Doba water is used for irrigation, ponds are also used for pisciculture. Although the low land area become damaged, due to alluvial soil deposition crop production of the area can increase due to increased fertility of the soil. Some roads are inundated during normal flood but make the lands fertile. Local fishes come into the canal/ river. Normal flood is useful for the villagers. In this location, the communities generally do not need to irrigate the lands.

Moderate flooding: From investigation, it was found that in 2013 and 2018 moderate flood occurred in this area. Floodwater enter into the village and inundate houses and fish can escape from ponds. Roads and dams are also badly affected. Under moderate flood conditions, there is a significant negative impact on the community in terms of health, damages, crop loss etc.

Severe flood: Severe flood occurred in this location 3 times in the last 10 years, 2008, 2014 and 2017; the flood can stay for several weeks (Table 5). During the severe flood events, roads and Teesta barrage collapse. People are displaced and take shelter at their relative's houses with cattle. Crops are also destroyed and thousands of cattle are killed. Due to unemployment, people spend their day by fasting and the price of products double and people do not get sufficient space for shelter. Houses float into the river and toilets sink and pollute the environment. Villagers do not get proper treatment and medicine. Different diseases take place due to the lack of portable water.

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[24] Ashar in Bangla means June-July

Cluster 3 – Teesta North

Normal flooding: There is a similar situation in Cluster 3 as the other clusters, normal floods are beneficial, enable livelihood options such as pisciculture and improve agriculture. There is limited damage during the flood, but the benefits generally outweigh the costs. Normal day-to-day activity can still proceed, such as education, water access and communications.

Moderate flooding: In the study period, there have been four moderate flooding events. Roads are damaged so communication education system become hampered. Crop are also damaged so people face financial crisis. They also suffer from food starvation. Fuel energy is not available during flood. Although considerable damage occurs in moderate flood but it has some benefits such as deposition of alluvial soil increases the soil production, fish enter into ponds and Doba so people catch fish and sell them to become benefitted economically.

Severe flood: During the last severe flood event, the water pressure of Teesta river causes the collapse of Saniajan Dam and road of Adarsha Village. Floodwater remained for three months. The first time the water lasted for 15 days. After one day, the water receded to one and half feet and again increased. This time the water remained for 13 days. Approximately ten people died during the severe flood. The older people and children also died due to diarrhoea. People made platforms, as they could not take shelter during the flood period. Thousands of animals were killed. Treatment and medicine facility were not available. Lake of safe drinking water and proper sewerage system increased.

Key observations

Flooding is a significant issue in Cluster 3, especially as there are over 11,000Bg of land under cultivation (Table 6), more than any other cluster in the study. To indicate the scale of the issue Table 12 maps the land elevation measured in metres above sea level and estimates the proportion of total land coverage in the union (Km^2) attributable to each land category, measured as F0-F4. Table 12 shows that the smallest Union is Saniajan with 19.5 Km^2 and the largest is Dauabari and Singimari with 24.4 Km^2 each. Cluster 1 is clearly the largest cluster, with 67.6 Km^2, followed by Cluster 2 (44.7 Km^2) and Cluster 3 (42.7 Km^2). The Union with the largest amount of land in the F1 and F0 is Sindurna with 94% of land in this category; the lowest Union is Singimari with 30% of land in the F3 and F4 category. To compound the issue over 95% of all cultivated land in this Cluster is located across all communities in the F3/F4 category. Under severe flood events over 40% of all land in the F4-F1 category is under water, creating a significant issue for livelihoods. Also significant is the relative frequency of severe flood events, which this study can not indicate as the database only covers 10 years, so the return period will be distorted unless extended over a longer time period, which is the subject of the more detailed land use study being planned.

Cluster investigations will need to look at the type of land use in Singimari as this has relatively higher proportions of high land compared to others and to look at the type of blue capital in the lower lying unions. A quick assessment shows that the unions have the following numbers and lengths of Nala and Khal in Table 13. Dhubni has the longest Nala, but Sekhsundar has the most Nala with 13 of an average length of 1.4km. In terms of Ponds, Sekhsundar has the most pod structures with 120.

Overall, what the study findings are pointing to is that the critical issue when working with natural capital is to identify ways to reduce the frequency of the severe floods, since these are highly damaging, affect all land types and occur in waves, rather than one single event.

Using green and blue capital in ways that mitigate flood impacts and increase recovery times will enable communities to cope better with moderate floods. Managing the flood flows through natural capital in different ways – through pond development, flow direction or enhancement – will enable communities to use the floodwaters of normal floods to support stronger livelihoods.

As mentioned in the earlier sections, if the trend is for an increasing frequency of the severe flooding, this will affect policy decisions on how to manage flooding and this is the focus on phase 2 of the work on natural capital.

Clusters and flood flow regimes

A. Normal flooding (where up to 30% of F2 and higher land is inundated)

As would be expected, the hydraulic role natural capital is stronger or perhaps more obvious, under normal flood flow conditions in terms of buffering flood impacts. There is no specific data to substantiate this, however, but it can be observed in the capture of excess runoff in Nala and Khals, meaning that for normal floods the flood impact is delayed perhaps while the presence of these structures may affect duration of flooding under normal conditions, this does need to be quantified, however. This observation may provide some insight into increasing this retentive capacity of these structures, yet this needs to be set against the recognised beneficial impacts of a normal flood condition. Generally, the communities do not use hydraulic/blue capital resources for coping strategies during normal flooding conditions but may generate some benefit during recovery. The presence of trees is also seen in a positive way for buffering flood impacts and for coping, such as in the manufacture of roofing materials or boats. As such, a line of enquiry is needed when building the natural capital management strategy being that, under normal flood flow conditions what mix/configuration of natural capital is required in relation to the land use management, to better regulate flood flow characteristics that will minimise impacts but realise the expected flooding benefits accruing from normal flooding.

B. Moderate flooding (where up to 40% of F2 and higher land is inundated)

The situation during moderate flooding is similar to that for normal flood flow conditions, overall there is a slightly reduced buffering and coping potential than was apparent under normal flood conditions, but it is unclear whether this can be further enhanced by modifications to the water carrying structures (blue infrastructure) in the environment. Generally, households do not use blue assets for coping capacity, only during the recovery stage. It is not precisely clear why this is but may be due to access and definition issues in that under moderate and severe flood flow it is not possible to distinguish a Nala from a Khal or the main river channel.

Table 12: Distribution of land elevation across the land categories for each Union in Lalmonirhat District

	Cluster 1																	
							Cluster 2											
													Cluster 3					
Land Category	Unions																	
	Dauabari			Patika Para			Sindurna			Singimari			Goddimari			Saniajan		
	DEM	Area	%	DEM	Area	%	DEM	Area	%	DEM	Area	%	DEM	Area	%	DEM	Area	%
F4	29-40	0.2	0.8%	36-40	0.07	0.3%	36-40	0.02	0.1%	33-51	1.75	7.2%	39-46	0.14	0.6%	48-53	0.76	3.9%
FE	40-43	2.1	8.6%	40-43	1.78	7.8%	40-43	0.14	0.7%	51-53	5.76	23.6%	46-49	1.98	8.5%	53-54	1.59	8.2%
F2	43-45	9	36.9%	43-45	5.49	24.0%	43-45	0.97	4.8%	53-55	9.33	38.2%	49-51	6.27	27.0%	54-55	3.55	18.2%
F1	45-47	10.1	41.4%	45-47	9.43	41.2%	45-47	3.2	15.8%	55-58	6.88	28.2%	51-53	9.27	40.0%	55-57	9.4	48.2%
F0	47-57	3	12.3%	47-57	6.18	27.0%	47-57	15.99	78.8%	58-80	0.75	3.1%	53-59	5.61	24.2%	58-62	4.27	21.9%
Totals		24.4			22.9			20.3			24.4			23.2			19.5	

Table 13: Summary of Nala and Pond units in each of the study villages of Lalmonirhat District

		Nala			Pond
Union	Village	No.	Total Length	Ave	No.
Dauabari	Purba Dauabari	9	11,728	1,303	72
	Dakkhin Dauabari	3	4,856	1,619	5
	Uttar Dauabari	7	5,895	842	65
Patika Para	Purba Holdibari	4	2,433	608	20
	Paschim Holdibari	8	6,925	866	10
Sindurna	Char Sindurna	6	6,217	1,036	39
	Dakkhin Sindurna	2	5,697	2,849	24
Singimari	Dhubni	1	3,933	3,933	43
Saniajan	Goddimari	7	6,001	857	63
	Doani	3	3,291	1,097	26
	Sekhsundar	13	18,897	1,454	120
Total		63	75,873	1,204	487

C. Severe flooding (where 40 % of F1 and higher land is inundated)

As may be expected under sever flood flow conditions, there is a lower apparent capability of natural capital to buffer and enable improved coping from flooding, but relatively improved capability to assist during recovery phases. However, this does not mean that there is no role in affecting flooding under severe flow conditions. More understanding is needed as to what this means, but if the frequency of severe flooding events in increasing in the area of investigation, this may have certain consequences for the type of flood control interventions required to better manage flooding for increased flood resilience.

Key Points

a) What the natural capital assessment tells us so far is that there is a need to better understand the land/productive value and flooding relationships in relation to natural capital. At this point, generally, the role of natural capital in buffering flooding is lower under severe flooding for all communities. For all communities, in general there is high buffering and recovery potential for water and land based resources under normal flooding, slightly less for moderate flooding.

b) Mostly, the communities derive more benefit from using land based e.g. trees, natural resources in all phases of the flooding cycle than the water based resources e.g. ponds. Communities do not generally use water and land based resources for coping with flooding.

c) Changing the use of land resources may further increase the buffering potential for normal and moderate flooding. Flood Free High Land and cultivable land has a role to play in coping in Kisamot Sadar (KS), Taluk Belka (TB) and Char Khodda (CK) that could be further explored, while this is not seen as an issue in Belka Nabobganj (BN).

d) The flood vulnerability is likely to be controlled by land elevation, Bangladesh Water Board use the F0 (Higher land) to F5 (Low lying land) classification, so the proportion of land in each of these categories significantly influences the degree of flooding. This has implications for the point at which the Danger Level is set. Secondly, as there is a likely connection between flooding and natural capital in these locations, it is likely that locations with fewer natural capital units and a high value land use in the higher F (F3 and above) categories is likely to be more vulnerable to flooding. This does have implications for land use planning in respective locations and are the type of questions that the Cluster Consultative Groups would investigate.

e) While it is tempting to state that by removing water from the flood system through retention can have beneficial impacts on attenuating flood severity, the relative value of approaches to re-engineer blue infrastructure needs to be weighed against the overall negative impact of flood flow deflection and enhancement in specific areas that are valuable for land use. As such, any specification for enhancing blue and green infrastructure should be set within an overall natural capital enhancement strategy for flood flow management.

Community engagement with the FRMC and Natural Capital

Community Feedback Process

All of the work undertaken by Concern regarding Natural Capital would mean nothing if it is not done in conjunction with the communities. There is an inherent challenge in applying the FRMC as it is by nature an extractive process and generates a complex result package. It was recognised early on by Concern that it would not be correct to run the FRMC and then provide a comprehensive feedback and expect the communities to take on board and more importantly own the results. Concern's position is that for the FRMC to work, the community must know 100% what the FRMC is, does, can do and how the community can work with it. To do this, the results feedback needs careful management. This section goes into the process that Concern applied to achieve this.

The process that was used is detailed in this report[25] in brief, once the results are assessed, they are mapped back to the resilience vision and packaged to feedback to the community, to agree areas identified for attention. A Community Resilience Action Group (CRAG) is identified to take ownership of the results and help disseminate to the wider community. This group is presented with the results of the FRMC by theme and also according to the resilience source area, looking at the grades that were provided. Ideally, there is a process of discussion with the community to analyse the results and this is supported by a second follow up meeting to provide an opportunity to explore the meaning of those results. The alternative to run through all the results in one go with the community not fully aware of the full purpose of the FRMC was not seen as a useful approach.

The next steps, once the community has understood the meaning behind the results, is a further meeting with the CRAG to start investigating options to address the issues identified. It is important to stress two points at this juncture. First, in the feedback Concern is not forming an opinion on relative level of flood risk awareness in the community, either within results or between communities, in fact, Concern is not in agreement with the Alliance that the FRMC exposes strengths and weaknesses per se; rather we look at results as being an issue or element is relatively more or less flood risk aware/sensitive. The second point to mention is that at no point does Concern, before the full feedback has been provided, make any suggestions or preconceptions or decisions on community interventions to address the matters raised through the FRMC result analysis phase. The first stage of the options definition is issue refinement; this is an internal process, where the practitioners filter the observations through the sources to clarify issues. Note, Concern adopts a slightly different approach when planning interventions than that stated in the guidance (ref 32), in that interventions are not discussed with the community until all feedback is completed and the community have sourced the relevant interventions themselves. The second stage is the scenario based community options finder, includes the range of possibilities to work with the community. This stage considers the need for, ongoing work, stakeholders, outcomes, costs of the interventions and these are then ranked with a final list. On the basis of this list, Concern can then confirm which actions can be proceeded and whether they are advocacy based, need referral or are direct intervention. These actions are then placed into a Community Action Plan, which the CRAG group takes ownership of.

[25] Technical Grading Assessment Report Bangladesh 2019

Finally, Concern is working on the Governance system in the project to ensure that the community action plans are connected into the Union and Upazila planning system, but this is not the subject of this report.

Community Perceptions

To complement the FRMC, based on the cluster system developed for the studies, we undertook additional survey questions to illuminate the FRMC Natural Capital units more clearly and add richness to the data. From this, we were able to observe the following attributes that need further exploration in any intervention programming. From this further investigation we found the following:

- 100% households do not connect education level to ability to prepare for floods, but they say that they do not know enough about it.
- Very few households associate natural capital units with flood management i.e. don't realise the impact of their livelihoods on the flooding context, while many say the additional benefit, they get from natural capital units is diminishing.
- There are no community centred disaster risk management plans effective.
- Centrally held plans that are not well communicated. The issue is therefore to unlock this system rather than pumping more money into a non-functioning system.
- 100% of the community says that without action flooding will only get worse, but don't know how to protect the community from this, only how to protect individual assets, as such there is a clear need to strengthen both formal and informal community mutual networks and strengthen community perspectives, which is the idea behind the community action groups and the cluster resilience committees.
- The Key Informant Interviews (KII) consistently either over or under-estimate the figures than those provided by household (HH) surveys and focus group discussions (FGD), so either FGD/HH are not accurate, or the KII are not up to date on what is happening, either way this is a key issue to resolve for social governance in the flood sector.

Key learning

There are two key learning elements arising from the approach that was taken to understand natural capital in the FRMC – the role of natural capital in flood management and flood decision-making.

Role of Natural Capital in flood management

While the research cannot be specific in this regard a couple of points on investigation emerge, that will be explored further to develop a flood sensitive natural capital management strategy.

a) Firstly, the relationship between flood free high land, natural capital and flooding events is critical to understand.
b) There is a connection between land use management and the flooding environment that needs to be explored to better see how flood control solutions can be developed.
c) The natural capital work is pinpointing areas of interest to strengthen hydraulic connectivity in the clusters and improve water carrying capacity of critical infrastructures, which can then be connected to productive livelihoods.
d) The overlay between specific natural capital elements in the environment and the flood intensity to determine the correct relationship between blue, green and grey infrastructures, which will create the correct balance of solutions as referred in the introductory sections of this paper.
e) Better understanding of land use practices and how this interacts with flooding will also be a clear learning for the programme.

Flood Decision-Making

To understand flooding, the starting point is to understand catchments, this being the normal unit of study. The catchment controls the drainage density, river slope, network and land typology all of which have a role in the affecting the storm hydrograph. Essentially, denuded land cover, exposed soils increases the propensity for soil erosion, soil water loss and increased overland flow meaning that, due to sedimentation processes, for a given level of rainfall, the river channel is less able to carry water creating the conditions for flooding. This paper does not go further on the nature of the storm hydrograph at this point. The issue for Bangladesh is that the catchments are not present as a unit of study for flood control management. In Bangladesh, the floodplain of the Ganges is a highly dense network of tributaries and distributaries with no clear delineation, to address this, in Bangladesh the network is divided into administrative boundaries, which are operated discretely. In common approaches, the unit of study for the FRMC is a community, an administrative boundary or a naturally induced barrier that creates sub administrative units, such as when a community is divided by a river. In this way, a community defines itself. The approach of this work is to say that there is another approach to look at this, to overcome these constraints, by looking at clusters. This is where a group of communities are included in a decision-making framework, this grouping is defined naturally.

The concept of clusters derives from integrated floodplain risk management, which recognises the interplay between landscape processes, land use and economic value. Increasingly there is a drive for green solutions for flood management, that recognise the inherent value of the riverine landscape in regulating flooding, this can be seen with the approaches to increase channel form variability in the river, or approaches for natural riparian zone management[26], increasing channel roughness through the use of debris dams[27] and considering approaches that control flood flow and velocities, either through conveyance, or retention systems. This interaction between environments in the river network and therefore increasing habitat diversity recognises the interdependence along the river environment.

The concept of clusters in the FRMC take this recognition and starts to consider how locations in the upstream and downstream environments can have something to say in relation to how the natural environment is managed in relation to flood control. For example, how can flood retention upstream have an impact on downstream decision making for flood control and whether there is an inherent value in changing land uses in clusters that exhibit certain hydraulic characteristics that can lead to better solutions to work with flooding, reduce exposure to flooding or encourage flooding in lower value land assets? From the analysis of natural capital to date, Esolve suggested that certain community juxtapositions facilitated the creation of the following clusters. As such, for locations that have relatively lower proportions of flood free high land may be more significantly impacted by measures to attenuate flood flow upstream, while land use management decisions may be relatively more significant for locations with higher proportion of low-lying land. How these issues interplay within a cluster is the area of enquiry for this project.

The intention of the cluster group CCG has three roles:

1. To guide choices related to flood resilience decision making in the ZFRP relating to the selection of green/blue and grey infrastructure development.
2. To start building linkages between communities within and between clusters to bolster common approaches to consider flood resilience decision making
3. Actively influence flood resilience decision-making at the Upazila and Union levels.

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[26] This refers to the land/river border zone typically 0-10m from the river bank, this zone presents a supply of carbon to the river that aids in regulating river flow and increasing channel roughness, while the tree cover increases the stability of the river bank actively preventing bank erosion, the supply of sediment to a river is a key factor in its propensity to flood.
[27] Debris Dams are natural dams created by tree fall into a river that affects water flood direction, increasing bed roughness and attenuates, for certain types of dams, floodwater transition.

Guidance for Alliance projects in addressing natural capital in the FRMC

The work Concern has invested in for a clearer understanding of Natural Capital in the environment and its relationship to flooding has been in-depth and focused, but what can be taken from this experience that can be applied easily into other flood resilience projects without the considerable time, energy and efforts required to arrive at this point?

The exploration of the natural capital context in Gaibandha and Lalmonirhat has provided a rich resource in categorising and clarifying the natural capital units that could not have been identified before without extensive understanding of the local context. The categorisation of natural capital pinpointed the issue in the communities that they had never before considered natural capital in relation to flood control, only in relation to productive livelihoods. Interestingly, the relationship between natural capital and productive livelihoods is not clear in the FRMC, which comes more from the perspective of natural capital in relation to flood ecosystem services, but this this not the key point for communities. For the FRMC, the key question is rather to understand how changing livelihoods can impact on the ability of a natural system to become more resilient. This merging of perspectives is very interesting for the programme as it opens the natural capital element to consider both land and water interactions in relation to productive livelihoods, which will lend itself more to understanding the environment as an entirety rather than as a resource to exploit. This understanding of natural capital, which is hoped to be promulgated through the new innovation of cluster resilience committees will hopefully lead to new ways of considering the natural environment in relation to flood control management, the extent to which this is realised will remain to be seen.

1) For users starting with the Natural Capital questions in the FRMC to prepare a list of natural capital units and include these as local questions in the database. The key units which need to be identified are ponds, lakes, canals, outflow rivers, marsh, woodland and so on. A simple review with the communities would easily identify these specific units to include in the study and this then provides a frame of reference for the study. Further information is included in the FRMC report. For users who have already progressed into interventions the following suggestions can be provided:
2) If conversations have not been held with the community on natural capital, to start working these into the community dialogue sessions. What we have seen from the work with communities is that there is the knowledge in the community on the range of natural capital units and through community recall and triangulation methods it is possible to understand better how these natural capital units operate during normal, moderate and severe flooding events. It may also be helpful to identify a point person in the community to liaise with the project and other stakeholders when investigating options for flood control management. One key issue to address in Bangladesh is that flood mitigation decisions are taken without community consultation; this is a key intervention to start connecting the community into these flood decisions. The key questions that could be considered in this discussed are as follows:
    a. During normal flooding year (2016 for example) at what point did you see the Nala/water body filling up and how fast did this occur?
    b. Once the Nala was full, what did you notice about the behaviour of the water then?
    c. How soon did the flooding occur after this?
    d. Where in your community did you notice flooding occurring earlier than other places?
    e. At what point did you know that flooding is imminent?
    f. Were any communities cut off during this period and if so why?
    g. How fast were the ponds and other water bodies filling up?
    h. Did you find any productive value from these water bodies during the flooding, in a normal year and any productive value from the flood itself?
    i. Repeat these questions for moderate and severe floods.

These questions can then provide key information about weak points in the river network and provide some idea of how the flooding occurs.

3) One observation that we see from the FRMC is that there is a high level of flood risk awareness, but this is from the basis that yes, we know that there will be a flood and we probably will expect a flood in the next few years. This is only part of being flood risk aware. As important is knowing how flooding occurs and the role of individual and community actions in encouraging that flooding, communities and individuals are less aware about the causes of the flooding. Many people may not make the link between using natural resources for livelihoods and flooding; or, if they do have limited choice to modify that behaviour. It is important to have those discussions with the community. It will be important to engage in conversations with communities and also decision makers at Union/Upazila and District levels to discuss why flooding occurs and what solutions there may be. The key points being:
    a. Upstream land erosion supplies sand to the river that reduces the capacity of the channel to convey water, protecting the river bank from erosion is an easy win. An infographic, attached can illustrate the key issues.
    b. The impact of fast overland flow due to high rainfall, these are managed by river bank protection.
    c. River channel morphology is important, so reducing the erosive potential, changing fast flow channels, increasing channel sinuosity to increase Kura and reduce travel times of peak flows. These need discussion with the community.
    d. There should be discussion with the communities on the flood management options. For example, dredging is a popular solution, but deepening the nala may lead to increased erosion, as there is more water in flowing into the nala and create additional unintended impacts, so creating river channels within the nala may be preferred rather than whole bed removal. Dredging unless done on a massive scale will not be that impactful. As such a meaningful discussion with the community on appropriate options is preferred and for this to be supported and costed out.
4) The community also need to understand the relative importance of the different flooding options, looking at conveyance, storage and absorption approaches to flood flow and to consider appropriate land sites that can accommodate this. Conveyance options are solutions that shift water out of an area and reduce the impact of the peak discharge, so this can be channel straightening, or protection. Storage options are retaining water upstream in structures such as ponds and marshes. Absorption options are when an area of land is demarcated for flooding. In reality a combination of the conveyance, storage and absorption options are desirable, but situated properly along the river network.
5) Finally, it would be worthwhile discussing with the community what sacrifices they would make to reduce the impact of flooding, especially in terms of land management and what alternatives should be considered to support livelihoods that do not put more pressure on resources that protect the environment from the impacts of excess flooding. Looking more to alternative livelihoods from blue capital than green capital. Where alternatives are available, these should be pursued, where they are not a more locally specific early warning and response system is needed, based on the intricacies of land elevation and water depth.

Conclusion

The assessment of natural capital carried out has revealed several interesting aspects regarding the role of natural capital in flood resilience. These can be summarised as follows:

- Sensitivity of flooding to land elevation as opposed to topography in general, especially for floodplain locations
- High proportion of cultivation on highly exposed land areas, partly to exploit the beneficial aspects of flooding, but with limited alternatives sustain high impacts during more severe events.
- Lack of awareness in the communities of the roles of different landscape components in flooding control, with natural capital awareness centred on the issue of productive value.
- Clear hydraulic connectivity between sites that communities and planners are unaware of, or do not focus on, can provide additional insights into how to manage flooding.
- Different design strategies vis a vis blue, green and grey infrastructure are required according to the nature of the flooding experienced.
- Further investigation is needed into how communities can, through appropriate land use management best prevent the worst flooding impacts.

This presentation does not provide any specific conclusions as to how natural capital influences flooding, but what it does is to point to potential areas of interest that can be explored in understanding better the relationship between natural capital and the environment. These can be of use in building a strategy and approach for more holistic flood control management that looks at the correct suite of options taken from the grey, green and blue infrastructure solutions that can then improve community flood resilience.

About the Zurich Flood Resilience Alliance

The Zurich Flood Resilience Alliance is a cross-sector collaboration, which focuses on building community flood resilience in both developed and developing countries. We help people measure their resilience to floods and identify appropriate solutions before disaster strikes. Our vision is that floods should have no negative impact on people's ability to thrive. To achieve this, we are working to increase funding for flood resilience; strengthen global, national and subnational policies; and improve flood resilience practice.

Find out more: www.floodresilience.net

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