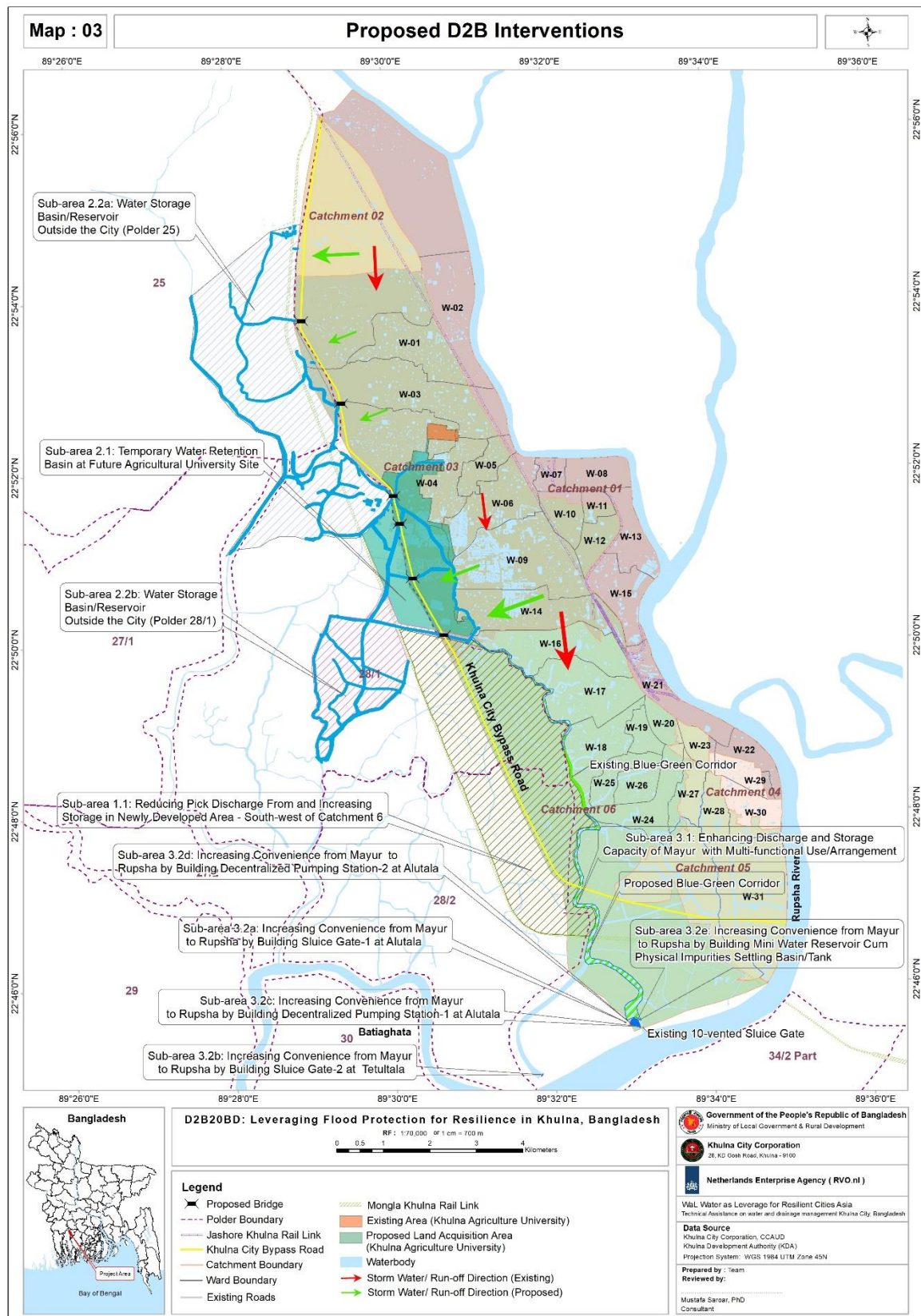


Annex 10 : Proposed interventions



Sub-project 1: Reducing peak discharges when improving drainage in urban build-up areas

Problem definition:

The most important improvement in quality of life would be expected by the residents who have been living in low-lying pockets of catchment 6. As all the excess storm water from all upper catchments such as 2, 3 and 4 (in part) ultimately found their way to Moyur via catchment 6, residents of catchment 6 used to suffer the worst. Under-privileged residents especially would benefit the most. From KCC's and private business perspective, it could be said that recurrent cost of maintenance of road infrastructure, and water and drainage infrastructures from the part of KCC would be reduced substantially.

Accumulated flood water in low-lying urban areas of Catchment 6 draining on Moyur already creates heavy peak load. The extended areas located on either banks of Moyur river have been experiencing rapid land-use transformation and development of real-estate by landfilling on low land. This would further worsen the already deteriorated water logging situation as the new build-up areas would reduce the infiltration and promote rapid surface runoff, leading to higher peak discharges. This is the main subject in sub-area 1.1

However higher peak discharges are not only coming from new build-up areas. If drainage will be improved in existing urban areas to reduce water logging and local flooding in very high rainfall events - like it is included in the CCAUD project – and there is insufficient additional storage available within that areas, the peak discharges will become higher here as well after project implementation. Possibilities to reduce increase of peak discharges is subject of sub-area 1.2.

Sub-area 1.1: Reducing peak discharges from and increasing storage in newly developed area south-west of catchment 6

The newly developed areas are expanding towards the extended area of the Khulna city. West of Moyur river, the Khulna Development Authority (KDA) has established a newly planned residential area, the government has established the new prisoner compound (jail) covering huge area. Note that this area is outside of current KCC boundary but to be included officially soon though gazette notification of Bangladesh Government. Private landowners trying to develop sprawl development. The current situation of this extended areas is shown in the map 4 below. It is time to prepare and implement a new policy instrument for controlling the unplanned development in this south-west part of the expanding areas including catchment 6. The instrument could assist legislation and enforcement and keep 30-40% areas vacant to manage its own storm water by enhancing high infiltration and reducing runoff. The key challenge is however to get Khulna Development Authority (KDA) – an autonomous specialised planning body – on board as KDA is legally entrusted to oversee the urban development control affairs. However, the window of opportunity is there. In the current Master Plan of Khulna prepared by KDA in 2001, this area is mostly shown as residential area (see yellow coloured areas in the map 5 below).

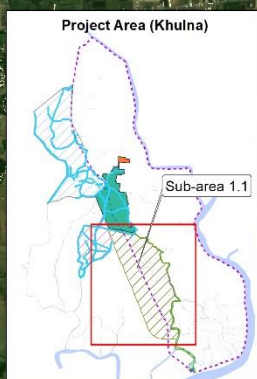
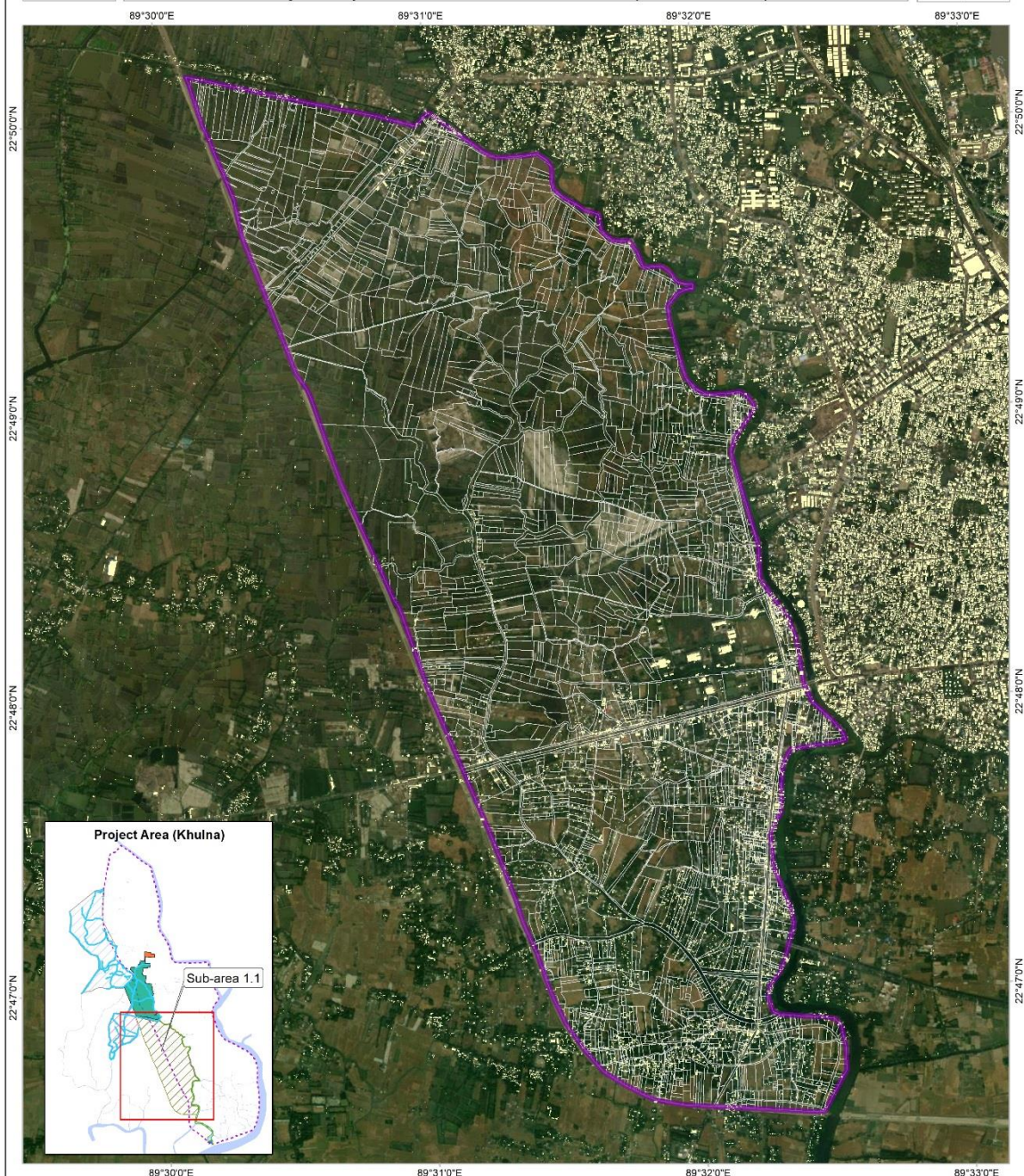
Sub-area 1.2: Improving drainage combined with water storage south of sub-catchment 11

In this subarea, which exact location still needs to be delineated, it will be investigated whether there are still options here to combine improving drainage (to reduce waterlogging and flooding) and (temporary) storage (to avoid increasing peak discharges leading to downstream flooding events), ideally using building with nature concepts in this urban setting.

For a possible location reference is made to WaL report 2019, p74 where the area in ward 16, 17 is proposed, as well as 19,20 and 26, 24. It would seem that CCAUD interventions are not targeting these specific areas

Map : 04

Sub-area 1.1: Reducing Pick Discharge From and Increasing Storage in Newly Developed Area - South-west of Catchment 6 (Current Scenario)



D2B20BD: Leveraging Flood Protection for Resilience in Khulna, Bangladesh

RF : 1:23,208 or 1 cm = 232 m
0 0.225 0.45 0.9 1.35 1.8 Kilometers

Legend

- Sub-Area
- Plot Boundary
- Existing Structure

Government of the People's Republic of Bangladesh
Ministry of Local Government & Rural Development

Khulna City Corporation
28, KZ Gosh Road, Khulna - 9100

Netherlands Enterprise Agency (RVO.nl)

W&L Water as Leverage for Resilient Cities Asia
Technical Assistance on water and drainage management Khulna City, Bangladesh

Data Source
Khulna City Corporation, CCAUD
Khulna Development Authority (KDA)
Projection System: WGS 1984 UTM Zone 45N

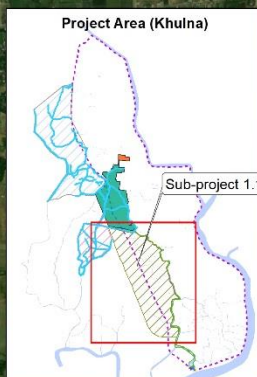
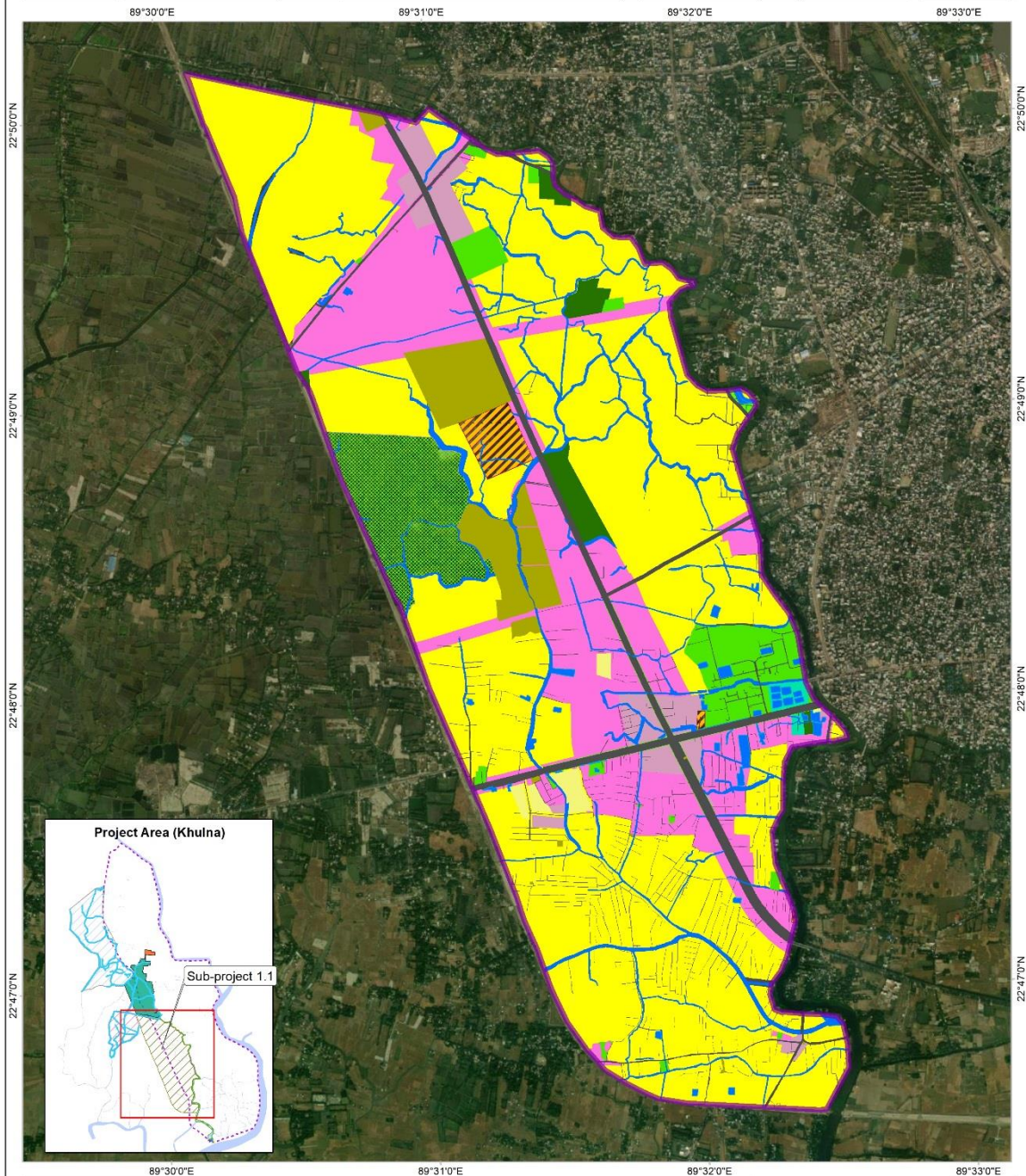
Prepared by : Team

Reviewed by :

Mustafa Sarker, PhD
Consultant

Map : 05

Sub-area 1.1: Reducing Pick Discharge From and Increasing Storage in
Newly Developed Area - South-west of Catchment 6(Proposed Land use, KDA)



D2B20BD: Leveraging Flood Protection for Resilience in Khulna, Bangladesh

RF : 1:23,208 or 1 cm = 232 m
0 0.225 0.45 0.9 1.35 1.8 Kilometers

Legend

Sub-area

Proposed Landuse (KDA)

- | | |
|---------------------------------------|-----------------------------|
| Agriculture | Mixed Use |
| Circulation Network | Recreational Facility |
| Commercial | Residential |
| Education and Research | Restricted Area |
| Government Service | Service Activity |
| Manufacturing and Processing Activity | Transport and Communication |
| Khal/Canal | Urban Green Space |
| | Waterbody |

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Technical Assistance on water and drainage management Khulna City, Bangladesh

Data Source
Khulna City Corporation, CCAUD
Khulna Development Authority (KDA)
Projection System: WGS 1984 UTM Zone 43N

Prepared by : Team

Reviewed by:

Mustafa Sarker, PhD
Consultant

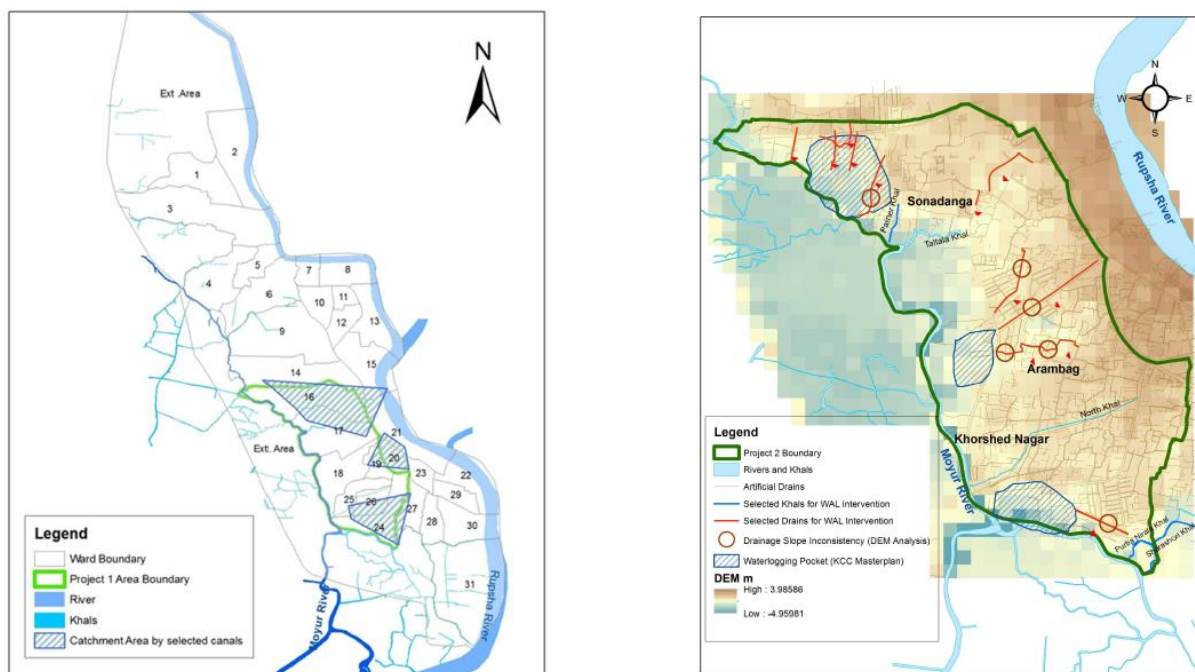


Figure of selected drainage areas proposed by WaL 2019

Sub-project 2: Increasing storage capacity (retention)

Problem definition:

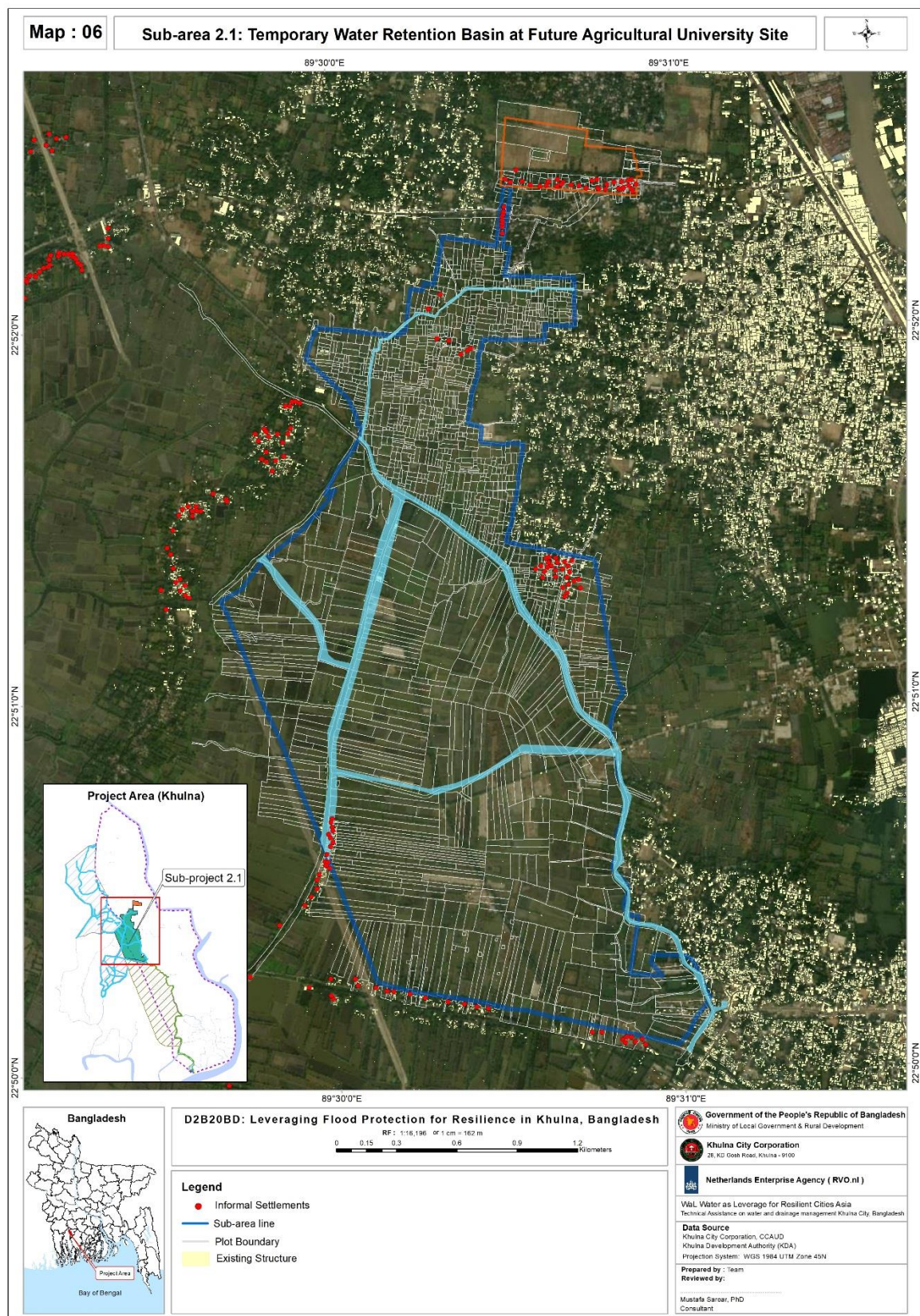
Khulna city is (officially) only about 46 sq. km, but it allows flowing of stormwater/runoff from 82 sq. km area, which includes unofficially covered KCC area (to be gazetted by Govt soon). Storm water from more than 50 sq. km area covering catchment 2, 3, 6 and 5 (in part) (see map 3) ultimately pass through the Moyur. Earlier studies estimated that Moyur can accommodate safely only about 1-1.5 lac¹ m³ of storm water/surface runoff but it receives about 3-3.5 lac m³ of surface runoff and rainfall during peak events. Moyur river cannot discharge excess stormwater to Rupsha river, which causes water level to rise in the river and back up in the khals (natural canals inside the city) and creates massive water logging as the areas adjacent to Moyur river, which are at low elevation. The volume of peak discharge to Moyur river from upper catchments need to be reduced to avoid water logging in the low lying areas of the city.

Sub-area 2.1: Creation of temporary storage at future Agricultural University site.

The WaL study (2019) and KfW's CCAUD study (2021) identified the future agriculture university to span over 1500 acres of land for temporary storage of excess storm water/surface runoff from upper catchments (catchments 2 & 3), which is set to be realised in phases. As of now, the university has

¹ 1 lac = 100.000

completed digital survey and is developing its DPP with a cost of 10 thousand crore BDT (about 100 million Euro), half of which will be used to buy 1,500 acres of land at a time within the next five years. Most land parcels are low land; about 100 acres of which would be developed as build-up areas and remaining low land (currently rice-paddies) would be field laboratories, demonstration fields/plots of stress tolerant (salinity, water logging etc) varieties of rice and aquaculture research field laboratory/demonstration ponds. Other than build up areas, low lying natural depression areas could accommodate substantial volume of overland flows from the upper catchments during the peak rainfall period /events. Second consideration is potentially linked to its strategic location. The site includes a few canals that, in earlier times, drained out water from the city before the construction of city bypass road. The proposed site of Khulna Agricultural University is shown in the map 6 below.



CCAUD (2021) proposes an 800,000 m³ storage basin to reduce the flooding in sub-catchment 11 and the peak outflows to Moyur river. The proposed basin by CCAUD will allow water from the Bastuharakhal to accumulate, and then allow gradual discharge through the Moyur river after the

storm event has passed and capacity once again becomes available. KCC has indicated that the currently proposed site is not appropriate, and the Implementation Consultant is tasked² to make a concept design including preliminary drawings and preliminary cost estimates, based on alternative location for the retention basin. In this respect, the D2B project has a similar objective, and close cooperation will be required in this regard with the IC of CCAUD.

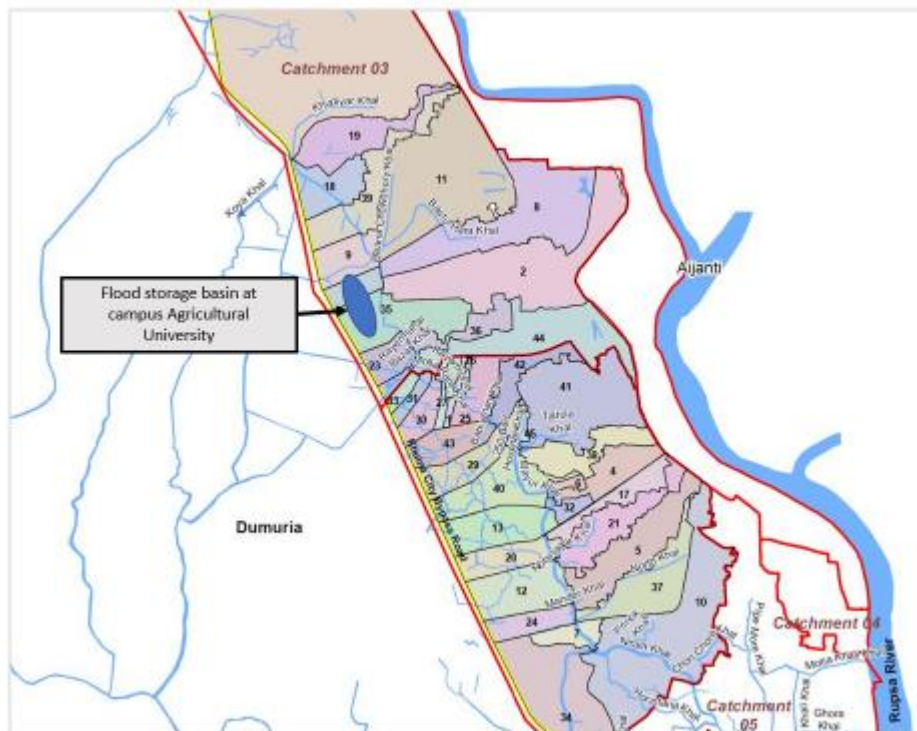


Figure with location of flood storage basin proposed by CCAUD (2021: 147)

One of the key challenge would be getting the university high authority on board. From a distant perspective, policy stability would also be a potential issue to explore further. If the future authority of the university declines to continue this potential/ongoing cooperation with KCC how the system would survive. In addition, although sparsely populated, the agricultural university will need to buy out farmers to obtain the land.

Sub-area 2.2: Creation of water storage basin/reservoir outside the city boundary

Both the WaL study and CCAUD study have indicated that the creation of multipurpose water storage basin/reservoir in land currently used as seasonal agriculture field. One way of reducing the pressure on the Moyur River is through providing flood storage in low lying areas where excess flood water can be stored and either reused as a form of rainwater harvesting or released after rainfall events. The

²“The IC shall investigate opportunities for decentralised detention storage within the sub-catchments and centralised storage along the Moyur River using innovative Blue Green Infrastructure (BGI) features, and assess suitable locations for these BGI features.” (CCAUD 2021:278)

intervention to be investigated would form a decentralised system of storm water/surface/ overland flow.

Where people of catchment 3 would not suffer from the onrush of overland flow coming from upper catchment 2 to their own catchment 3. As the water from catchment 2 would be diverted to the polder 25 located outside the city via connecting natural khals, they would enjoy better environmental quality (map 7). Similarly, as the water from catchment 3 would be diverted to the polder 28/1 located outside the city or agriculture university site via connecting natural khals, they would enjoy better environmental quality (map 8).

A potential suitable site has been identified to the west of the 4 vent regulating gates (see map 2) where the discharge from Khunde Khal can be diverted away from the Moyur river using the regulating gates. A recent site visit (early November 2020) of TA team lead by Hon'ble Mayor and accompanied by KCC Planning and Engineering unit technical officials identified that a dense network of natural huge size khals/canals (government owned) could potentially be used as storage/reservoir of water if encroachments are cleared, deepening and widening take place. They also proposed to acquire a very narrow band of land either bank of Khals to increase water storage capacity. As the canals are just outside of city boundary and the Khulna District administration (led by Deputy Commissioner) is legally entrusted with the oversee of the government owned canals, these canals are either officially leased out from DC office or illegally occupied by local people by building bamboo fence/earthen dyke along the cross-section of canals to cultivate fish.

Two prospective sites are identified adjacent to city west boundary where dense-network of canals/khals could potentially be used as water storage.

The larger site located at polder 25 could accommodate overland flow from catchment 2. This diversion of stormwater would hugely reduce downward flow to Moyur through first catchment 3 and later through catchment 6 (see map 2 & 7).

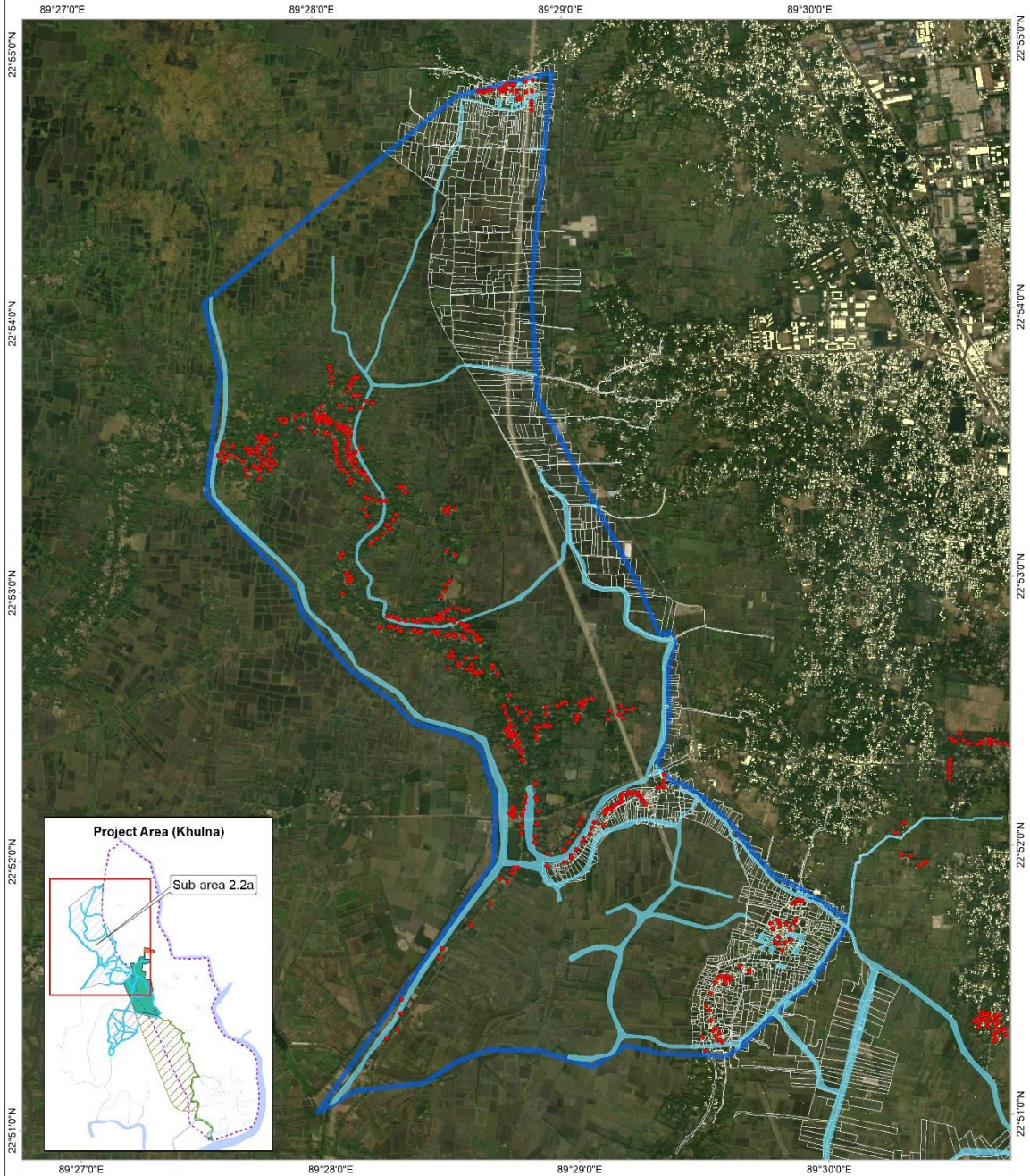
Another site located at polder 28/1 could accommodate overland flow from catchment 3 if purposefully diverted by regulating 4-vented sluice at Rayer Mohal area near Khuderkhal. This diversion of stormwater would hugely reduce downward existing flow from catchment 3 to Moyur through first catchment 6 (see map 2 & 8).

There are socio-political challenges to use dense network of khals for water diversion from the city but there are opportunities as well. Both in polder 25 and 28/1 Blue Gold programme is in operation until December '21. Under this programme Water Management Committees, Water Management Association for polder water management are permanently established. They take care of the khals. By building effective stakeholder engagement framework and effective dialogue this D2B project component that focus on use of dense-network of canal as solution to Khulna's water problem could be implemented. There is immense potential that if overland flows could be diverted from upper catchments such as 2, and 3 to these water retention/storage basin/reservoir the peak load would

reduce to Moyur and thus discharge requirement to Rupsha river would be reduced as well which eventually would lower if not completely eliminate the need for any non-gravity/mechanical pumping. This nature-based solution would have huge financial implication considering from a lifecycle perspective.

Map : 07

Sub-area 2.2a: Water Storage Basin/Reservoir Outside the City (Polder 25)



D2B20BD: Leveraging Flood Protection for Resilience in Khulna, Bangladesh

RF : 1:25,000 or 1 cm = 250 m
0 0.25 0.45 0.9 1.35 1.8 Kilometers

Legend

- Informal Settlements
- Sub-area Line
- Plot Boundary
- Existing Structure

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Netherlands Enterprise Agency (RVO.nl)

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Technical Assistance on water and drainage management Khulna City, Bangladesh

Data Source
Khulna City Corporation, CCAUD
Khulna Development Authority (KDA)
Projection System: WGS 1984 UTM Zone 45N

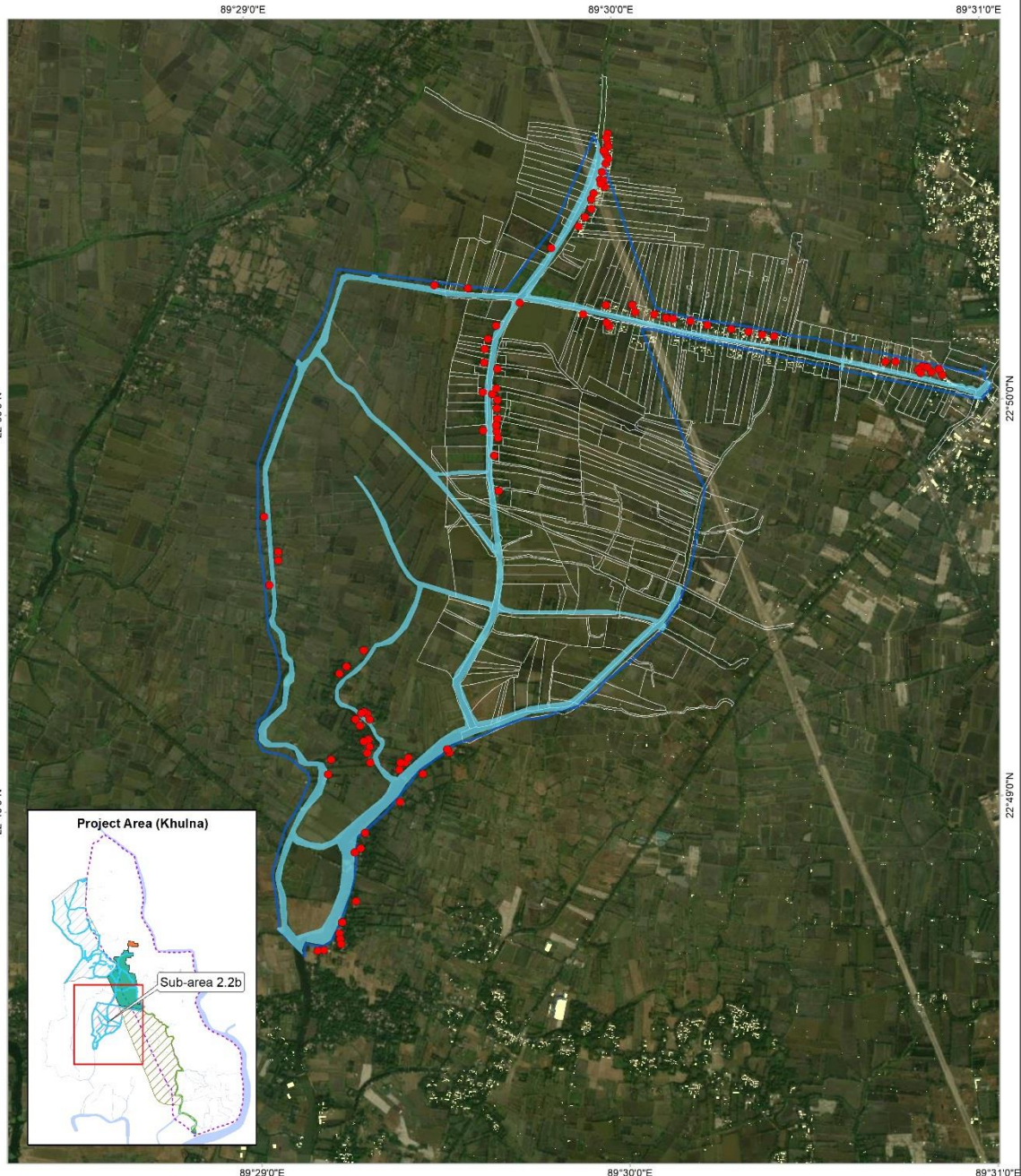
Prepared by : Team

Reviewed by :

Mustafa Sarker, PhD
Consultant

Map : 08

Sub-area 2.2b: Water Storage Basin/Reservoir Outside the City (Polder 28/1)



D2B20BD: Leveraging Flood Protection for Resilience in Khulna, Bangladesh

RF : 1:17,000 or 1 cm = 170 m
0 0.15 0.3 0.6 0.9 1.2 Kilometers

Legend

- Informal Settlements
- Sub-area Line
- Plot Boundary
- Existing Structure

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W&L Water as Leverage for Resilient Cities Asia Technical Assistance on water and drainage management Khulna City, Bangladesh	
Data Source Khulna City Corporation, CCAUD Khulna Development Authority (KDA) Projection System: WGS 1984 UTM Zone 45N	
Prepared by : Team Reviewed by : Mustafa Sarker, PhD Consultant	

Sub project 3: Downstream conveyance

Problem definition:

The Moyur river cannot fully discharge excess stormwater to Rupsha river, which causes water level to rise in the Moyur river and back up in the khals (natural canals). The solution envisaged must enhance the discharge capacity of Moyur river, which would improve the water flow at Moyur from its current stagnant condition. In fact, Moyur is the lifeline of Khulna city. Efforts to revitalise the Moyur would provide city residents not only a water logging free environment, as well as cultural and recreational amenities. Although people from all walks of life would benefit, the residents living in low-lying pockets (where, mostly poor, migrants/ settlers have built slums/poor settlements) would benefit more. Because unlike more affluent residents, who would enjoy a better environment, slum residents will be freed from confinement of stagnant water that restrict their mobility for income, schooling, even health related crisis sometimes for weeks in rainy season. It would reduce reported prevalence of localised water related diseases as well.

Sub area 3.1: Discharge capacity of Moyur from Khude Khal to confluence with Rupsha

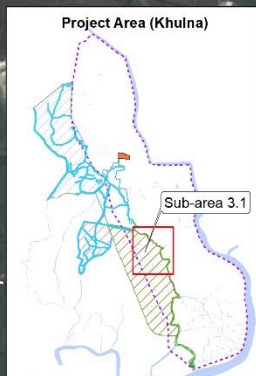
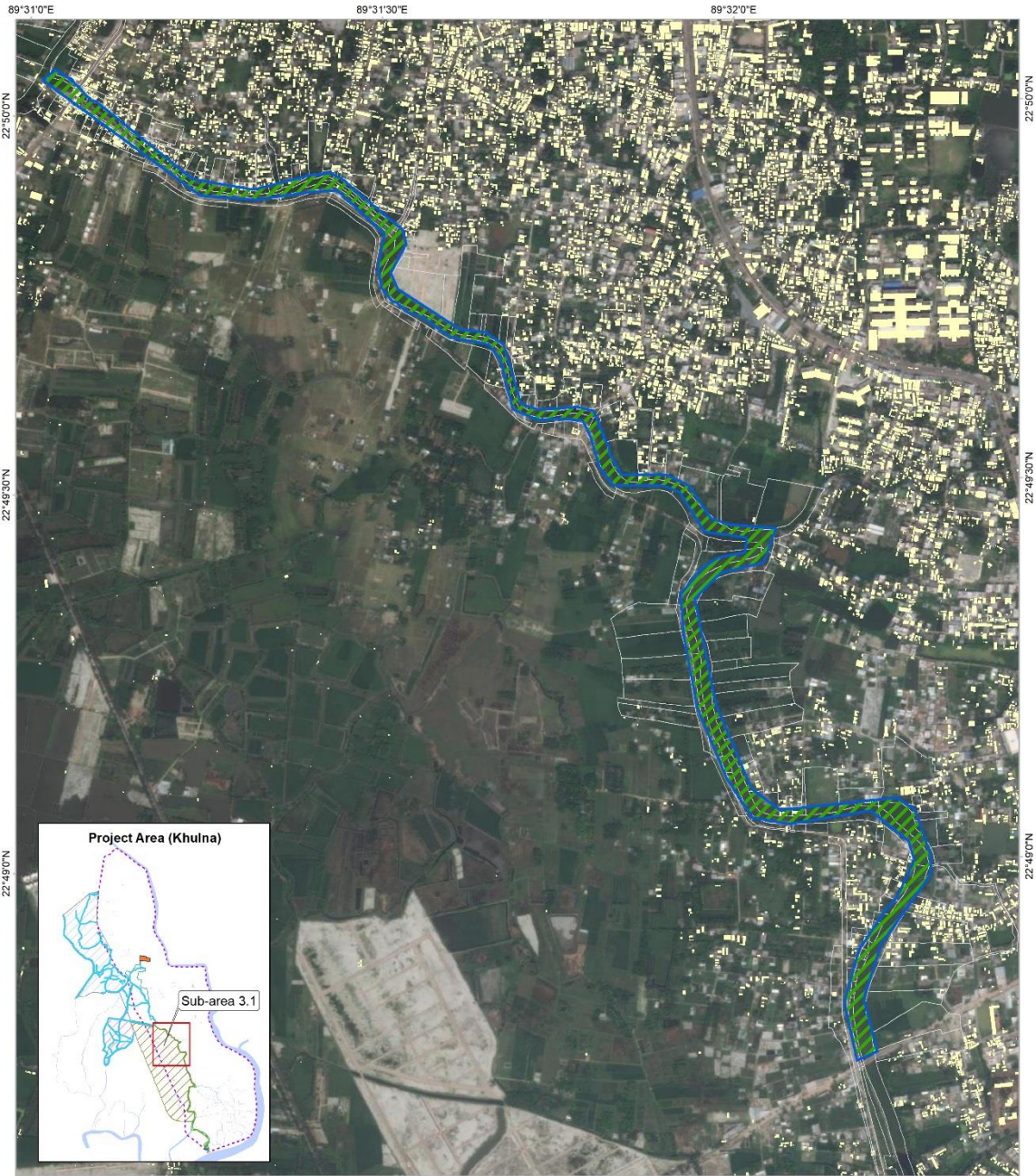
Sub area 3.1 is focusses on a sufficient discharge capacity of the Moyur river itself to transport and also temporary store water from the North of Khulna towards the confluence of the Khulna and Rupsha river, taking along the water from the various khals draining into the Moyur river.

Realizing and maintaining sufficient discharge and storage capacity entails the depth of the river, the cross section and also resistance against flow created by vegetation and also solid waste, that can seriously hamper the flow at narrowing of the cross section for instance at bridges but also at the sluices and future pumping station(s). The ongoing GoB funded drainage project of 2019 has some focus on Moyur to maintain its flow but these seem insufficient to address the issues holistically and in an integrated way.

This drainage and storage capacity should combined as much as possible with a multifunctional use, such as water storage for the dry season, recreation – possibly with income generating activities - and biodiversity conservation, using building with nature concepts where possible (see map 9).

Map : 09

Sub-area 3.1: Enhancing Discharge and Storage Capacity
of Mayur with Multi-functional Use/Arrangement (Part-2)



D2B20BD: Leveraging Flood Protection for Resilience in Khulna, Bangladesh

RF: 1:9,000 or 1 cm = 90 m
0 0.075 0.15 0.3 0.45 0.6 Kilometers

Legend

- Sub-area Line
- Plot Boundary
- Proposed Blue-Green Corridor
- Existing Structure

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Ministry of Local Government & Rural Development

Khulna City Corporation

28, KZ Gosh Road, Khulna - 9100

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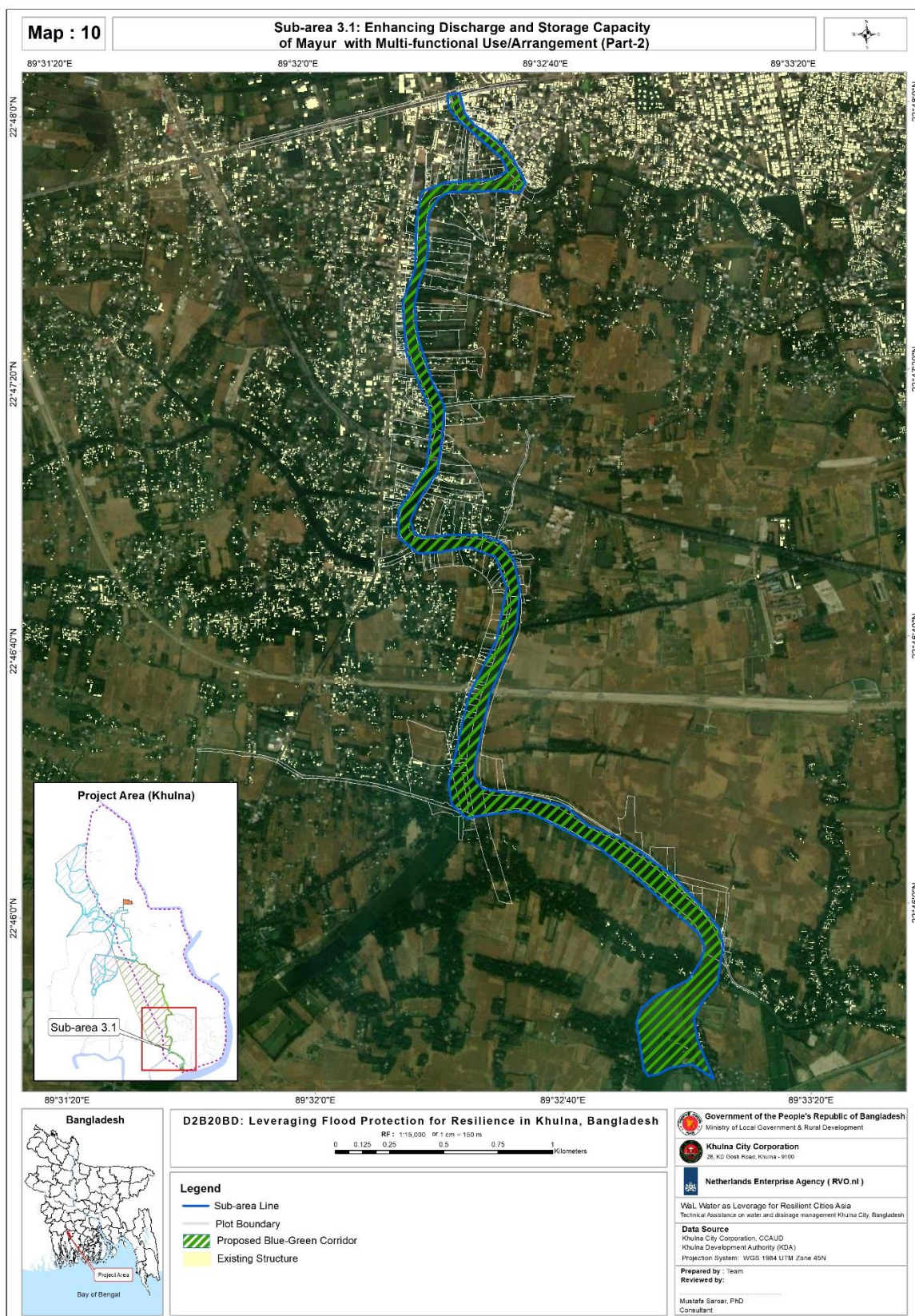
Data Source
Khulna City Corporation, CCAUD
Khulna Development Authority (KDA)
Projection System: WGS 1984 UTM Zone 45N

Prepared by: Team

Reviewed by:

Mustafa Sarker, PhD

Consultant



Sub-area 3.2: Conveyance from Moyur to Rupsha

Moyur river's discharge capacity of water towards the Rupsha river is constrained by numerous factors. During the normal hightide the water level at Rupsha river goes as high as 3m although during low tide the level is 0.5 m. But the water level at Moyur remains at 0.8 to 1 m. The Rupsha river being a tidal river experiences two times high tide in a day. The gravity flow can discharge excess storm water from Moyur river during the low tide windows only. It means that tidal blockage restricts gravity discharge for 18-20 hours a day and only during 4-6 hours water can be discharged. Hence, although the 10-vented sluice at Alutola point of Moyur river has maximum capacity (assuming constraints) to discharge about 30 cub m/s, at present it can only discharge about 9 cub m/s, equalling to one-third of its designed capacity. The CCAUD project has included the Alutola sluice gate upgrading, by making it 11 gated and with higher dimension of each gate (3m X 2.3 m). They have given a notional estimate of 364.800 euro, which includes demolition of the existing structure and reconstruction of the concrete superstructure, complete with concrete guide walls, bottom erosion protection and installation of new motorised gates.

Additionally, CCAUD Implementing Consultant will make investment proposal, including concept design and preliminary costing, for a new pumping station at Alutola. The Drainage Master Plan (DMP 2012) proposed mechanical pumping capacity of 120 cub m/s at Alutola outfall/point considering the likely impacts of climate extreme events. The CCAUD estimated a pumping capacity requirement of **75 cub m/s**. CCAUD proposed the pumping station in combination with water retention basin (see sub-area 1.1 above), and in fact relies in its hydrological models and impact assessment on the completion of both the Alutola pumping station and for the retention basin for the CCAUD measures to have significant effects³. However, 75 cub m/s pumping need is still too high and costly from a lifecycle perspective.



³"The full extent of the benefits of the CCAUD investments are [...] only achieved once the investment proposals [i.e. Alutola pumping station and detention storage basin] are also implemented. Including these two proposed projects in the analysis the number of buildings protected will increase to 10,479 [from 7,740], while the total replacement value will increase to Euro 135 million [from: euro 103 million]. The reduction in flooded area increases to 390 ha [from 204 ha], a 90% increase. The population benefiting increases to around 427,000 [from 398,000 people] (CCAUD 2021: xxii).

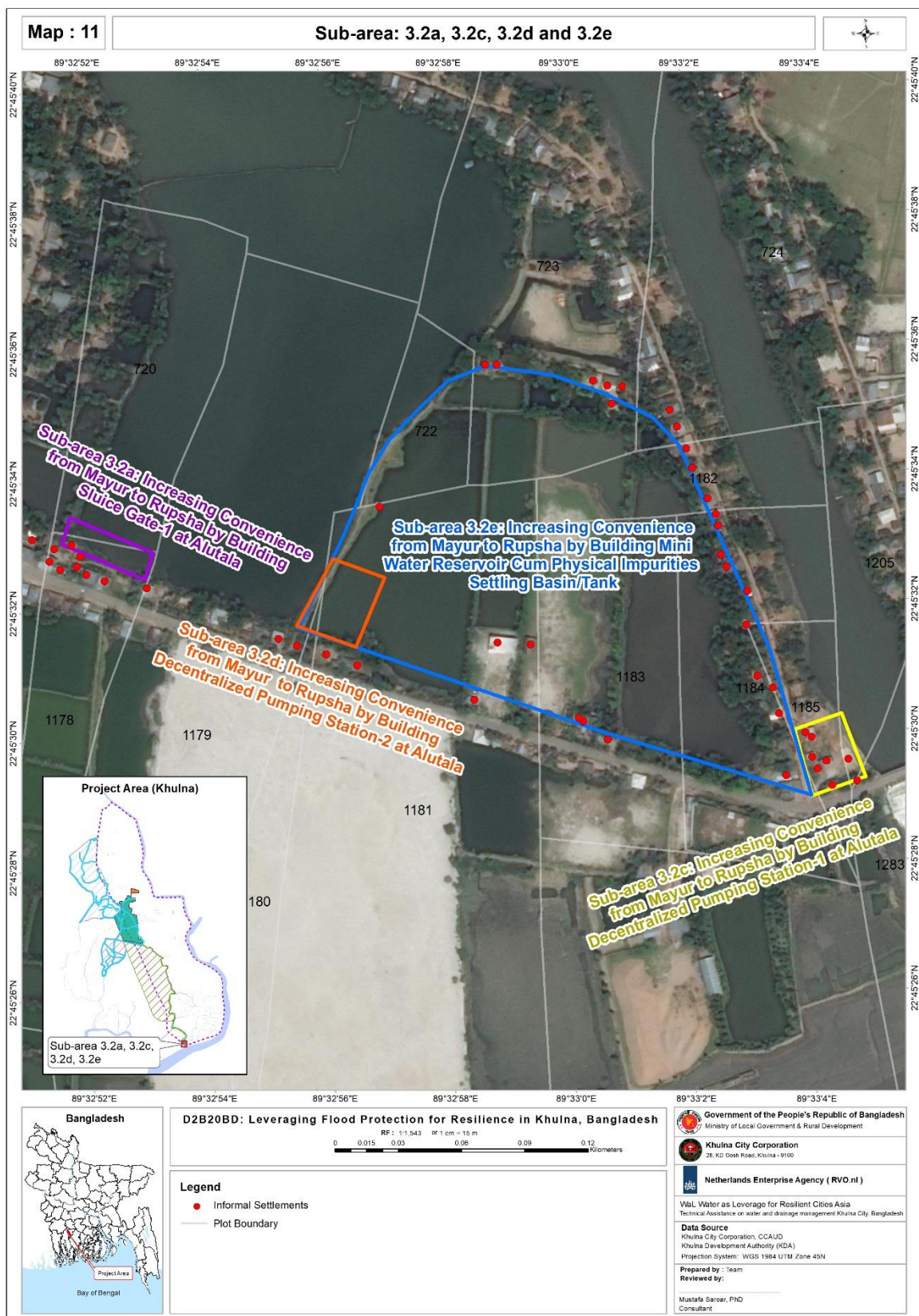
Figure with indicative location of pump houses as Alutola Gates (CCAUD 2021: 287)

CCAUD study did not consider quality of water to be pumped. As the storm water of Moyur carries huge debris, floating and suspended physical objects/impurities including solid waste, which will impede the efficiency of pumping equipment/machineries. It is urgent to filter out physical impurities from waste water before entering pump house. Construction of a mini water reservoir cum physical impurities settling basin/tank (see the map 3, 11 & 12). As the current location of pumping station (KfW's CCAUD proposal) is close to nearby clusters of human settlements, building a waste water treatment facilities (partial treatment of physical impurities) close to it might trigger unrest among local residents, therefore a new location just 500 meter south of current location is proposed for both the pumping station and newly proposed water treatment basin/plant.

The WaL study (2019) proposed complete gravity solution (part of nature-based solution package). They identified the raising of embankments of Moyur in its entire length to rise the water level for enhancing gravity flow. However WaL (2018) proposal seems too ambitious to drain out using only gravity flow. Complete avoidance of pumping could be too ambitious as well.

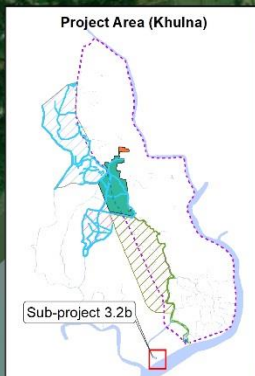
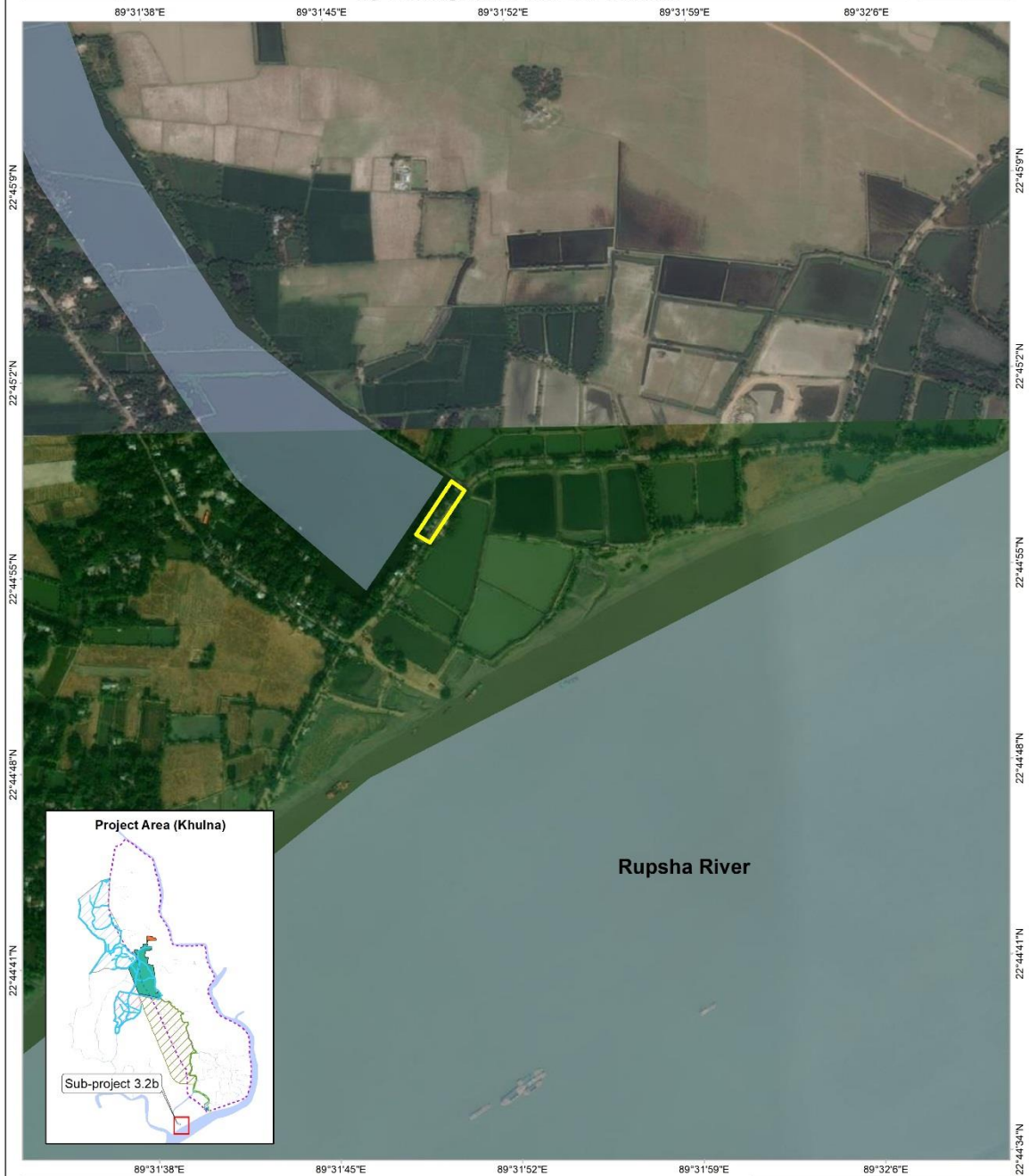
An alternative to pumping or perhaps a combination with pumping can be development of a new sluice gate. A new 10-vented sluice gate close to the existing one (see map 3, 11 & 12) can be considered and creation of multipurpose water storage/reservoir/basin to lower the heavy reliance on pumping station. The proposed 10-vented sluice, given the constraints imposed by tidal blockage, could discharge 10 cub m/s. From a lifecycle perspective this new construction has huge positive implications in terms of cost saving by avoidance of huge pumping need. To reduce resettlement issues and acquisition of new (private) land, two alternate locations, one 150 meter and another about 750 meter south of the existing sluice gate (see map 3, 11 & 12) can be investigated through the D2B study.

The land of the site proposed about 150 meter south of current Alutola sluice gate is owned by Government Agency Bangladesh Water Development Board (BWDB). The site located about 750 meter south of current Alutola sluice gate is in government owned Khas land ; this site is originally part of a moribund tract/channel of Moyur river. Government owned Khas land is recorded in a separate volume of land registry system of Bangladesh. The Deputy Commissioner (DC) office (ADC Land & ADC-revenue) oversees the land affairs. Couple of factors need to be considered; first, in the moribund tract of Moyur river (see map 12) influential people built a series of large enclosures, in order to use the section of river as large fish ponds; second, there are sporadic informal settlements in the government owned Khas land as well as in BWDB's land as well; although not dense but quietly living there for long time, i.e. more than 5-10 years. Another key limitation is that the site (Tetultola) located about 750 meter south of Alutola sluice gate is outside the future (KCC) city boundary and within the jurisdiction of BatiaghataUpazila/subdistrict land office (AC Land Batiaghata). As the BWDB has been collaborating with KCC as regards various water infrastructures, cooperation is foreseeable for the proposed new 10-vented sluice gate in 150 meter south of current one.



Map : 12

Sub-area 3.2b: Increasing Convenience from Mayur to Rupsha
by Building Sluice Gate-2 at Tetultala



D2B20BD: Leveraging Flood Protection for Resilience in Khulna, Bangladesh

RF : 1:4,000 or 1 cm = 40 m
0 0.05/5 0.07/5 0.15 0.225 0.3 Kilometers

Legend
— Sub-area Line
Waterbody

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Data Source Khulna City Corporation, CCAUD Khulna Development Authority (KDA) Projection System: WGS 1984 UTM Zone 43N	
Prepared by : Team Reviewed by : Mustafa Sarker, PhD Consultant	