Blue Gold Programme

Planning, design and monitoring of community based water management systems in Polder 30

Final Design Report
January 2014

Acknowledgement

This publication was made possible with a financial contribution of the Netherlands Government. We would like to express our gratefulness to Bangladesh Water Development Board (BWDB) to support us in providing guideline at different stages of implementing this project. We also acknowledge the contribution of Blue Gold TA team in designing and implementation of this project in a more integrated way with Water Management Groups (WMGs). We would also like to express gratitude to Mr. Mofazzal Ahmed, Water Resource Management (WRM) leader and all WRM team for their scholastic guidance. Heartfelt gratitude is expressed to farmers and WMG members, who helped to make the project successful. We are also thankful to anonymous reviewers for their constructive criticism and advice to improve the report.

Disclaimer

These are the views and expressions of the author, and do not necessarily represent the view of the Netherlands Embassy in Dhaka or the Blue Gold program.

Table of Contents

List of Figures

List of Tables

1. Introduction

The productivity of a polder can be improved through proper water management. It is more applicable for a polder like 30 with large land level variation, interconnected regulators by khals and different tidal characteristics in the peripheral rivers. The conflict between high-low land owners is always present in every crop period in this polder. To improve drainage condition for increasing crop yield and removing conflict,subpoldering and Water Management Units (WMU) are required. Moreover to ensure proper connectivity in between khals and flood plain small field channel need to be constructed.

Blue Gold assigned Institute of Water Modelling (IWM) to select, design and monitor two pilot WMUs in Polder 30. This report contains the selection of WMUs, design and assessment of the efficiency of proposed improved drainage system.

2. Objectives

a) To delineate WMUs within a sub-polder, and select 2 WMUs for piloting, based on hydrology, existing infrastructure and community preferences for water management and cropping system options
b) Planning and design of an improved drainage system for selected WMUs.
c) Planning and design for renovation ofthe existing drainage system and new small levees, drains and drainage outlets in the WMUs
d) To monitor water management practicesin the 2 WMUs and other parts of the sub-polder

3. Selection of WMUs and present drainage system

Two water management units (WMU) has been selected for implementation of community based improved drainage system involving local farmer, LGI, representative from Blue Gold. Theseunits are situated in Phultola village, east side of Polder 30 near Kazibacha River. Three focus group discussion (FGD) have been conducted with farmers and water management committee of the Phultola village to identify existing drainage systems, cropping pattern, drainage related problems, crop damage and probable solutions. A map showing the selected WMUs, land elevation (DEM) and existing drainage systems is presented in**Figure 1**.This area currently drained through two regulator (Katakhali and Khoria) to Kazibacha river. The renovated one vent Katakhali regulator is in the north and connected by Konar khal, Poschim Khal, Saduria khal, Vorakhali khal and Katakhali khal. The drainage route to this regulator is 5.5 Km long and there are 4-5 blockages with small pipes and pata for fish cultivation in the Saduria khal.Figure 2 shows the photographs of blockage in the Saduria Khal. On the other hand the two vent Khoria regulator in the south and connected through Poschim khal, Vorakhali khal and Khoria khal. The length of drainage route to this regulator is arounf 4.0 Km with two blockages with very small culvert in the vorakhali khal.

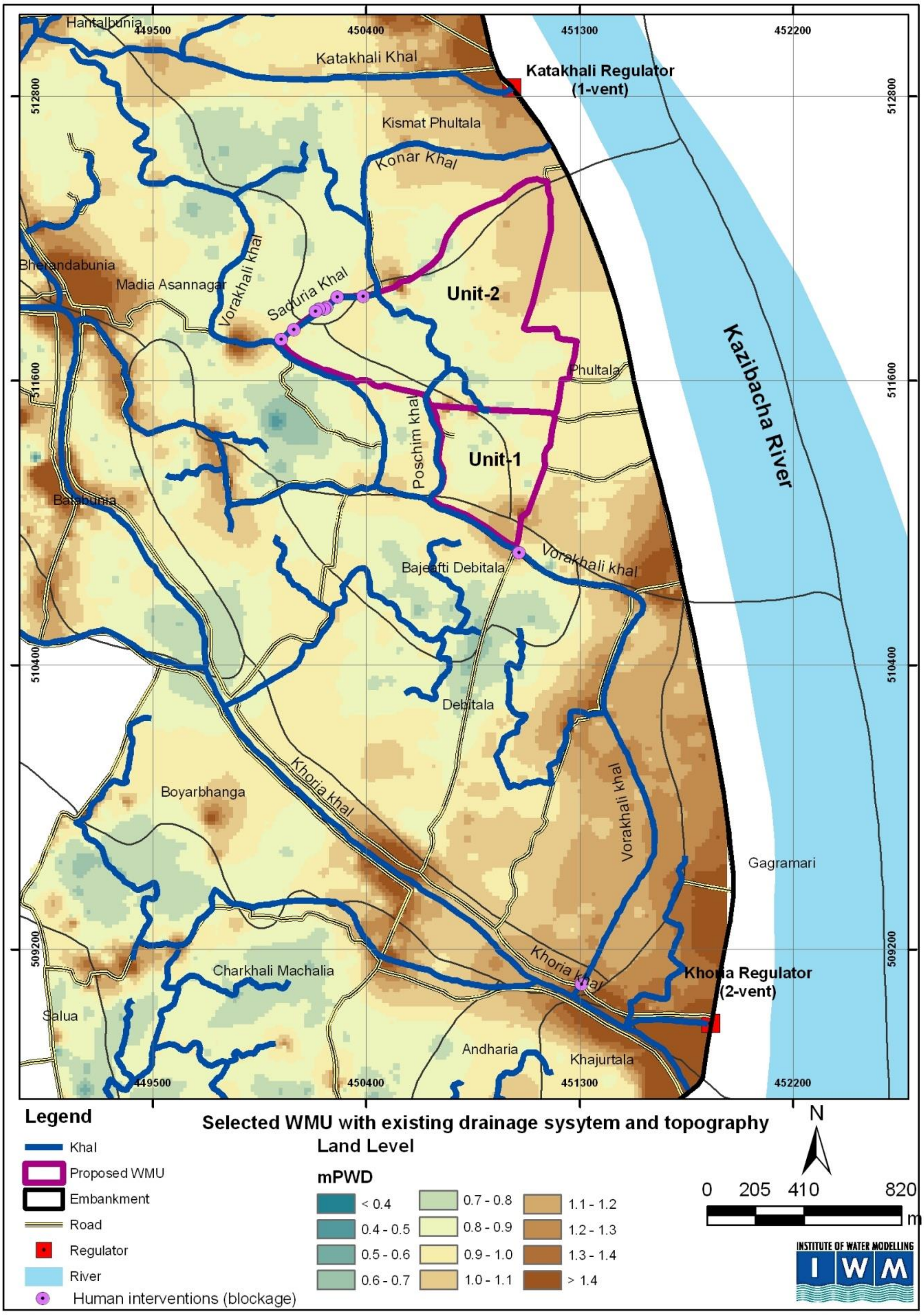


Figure 1: Study area map of selected water management units with existing drainage system

Figure 2: Photographs of blockage in Saduria khal

So the existing drainage systems of the selected WMUs are not working effectively. Farmers in this area cannot grow HYV Aman because of high water depth during monsoon. And in the Rabi period sesame cultivation is delayed because the land remain wet until February. Last two years the sesame crop got damaged by the early monsoon rainfall in May. So the main objectives of improved drainage system are to cultivate HIV aman rice in monsoon and early sesame cultivation in the Rabi period. Both of this change will result in high yield of rice and sesame.

4. Gravity drainage opportunity

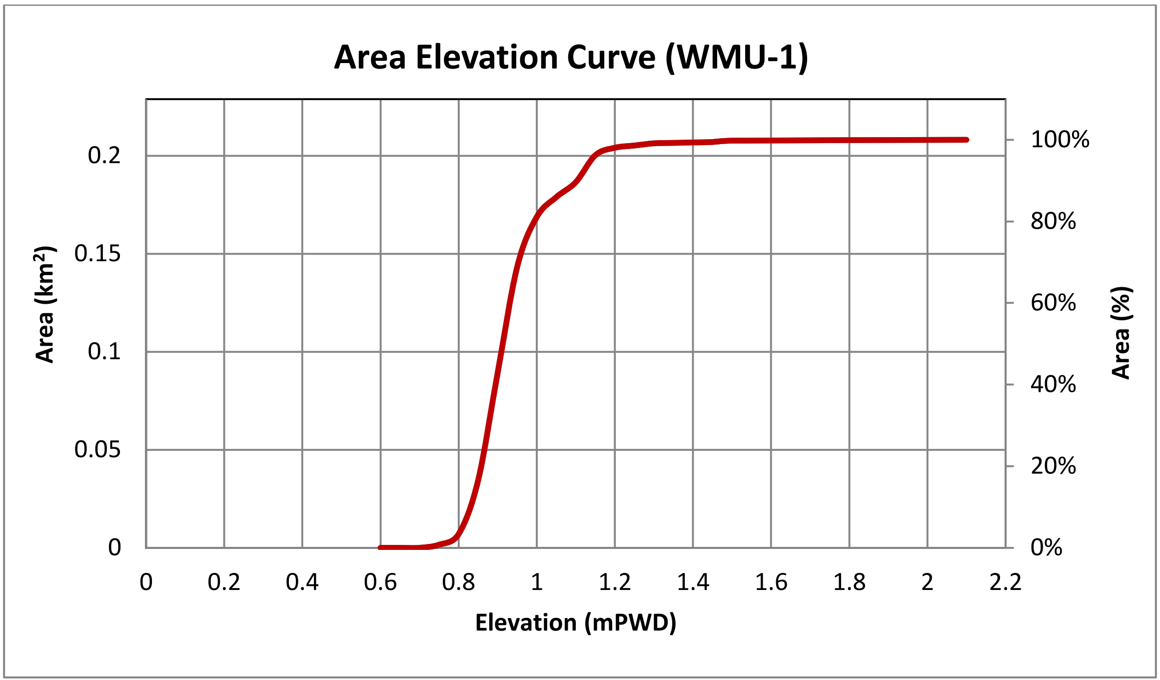
Gravity drainage depends on the land level of the area to be drained and tidal level of the peripheral river. Water can be drained twice a day during low tide. Here lend elevation of two selected units is compared with the tidal level of Kazibacha river where the Katakhali regulator is connected.

Area elevation curve of two WMUs are shown in Figure 3. These areas are moderately flat compare to the other areas in Polder-30.

Table 1 shows the distribution of land elevation in two selected water management units. More than 80% area of unit-1 is varied from 0.8 to 1.0 mPWD. In Unit-2 around 98% areas are in between 0.7 and 1.0 mPWD. Average land elevation of Unit-1 and Unit-2 are 0.9 and 0.8 mPWD respectively.

Table 1: Area-Elevation table of two selected units

Level (mPWD)	Unit-1			Unit-2		
	Area (Hectares)	Area below this level (Hectares)	% Area below this level	Area (Hectares)	Area below this level (Hectares)	% Area below this level
0.6	0.00	0.00	0.00%	0.14	0.14	0.21%
0.7	0.00	0.00	0.00%	2.18	2.32	3.63%
0.8	0.70	0.70	3.35%	31.48	33.80	52.94%
0.9	8.24	8.93	42.92%	19.15	52.94	82.94%
1	7.94	16.88	81.08%	10.15	63.09	98.84%
1.1	1.78	18.65	89.62%	0.47	63.56	99.58%
1.2	1.76	20.41	98.05%	0.02	63.59	99.61%
1.3	0.23	20.63	99.14%	0.14	63.72	99.82%
1.4	0.05	20.68	99.35%	0.02	63.74	99.86%
1.5	0.14	20.81	100.00%	0.09	63.83	100.00%



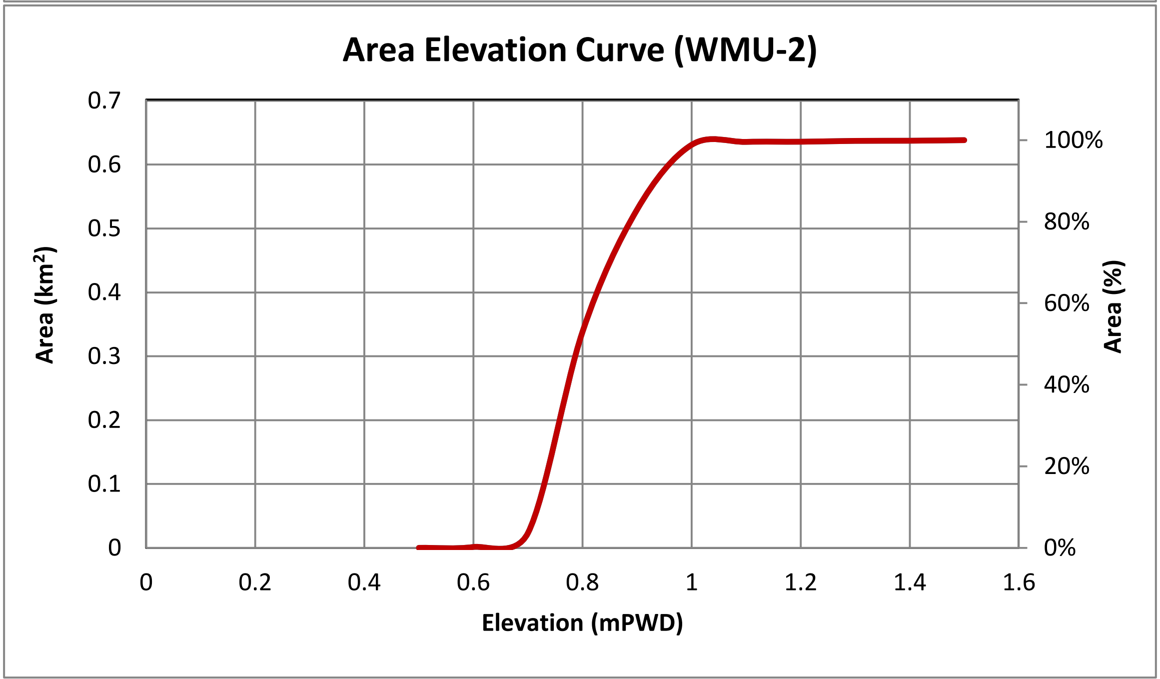


Figure 3: Area-elevation curve of selected WMUs

Figure 4shows the measured tidal water level in Kazibacha River in the month of September and October. Average water level in this period is around 1.3 mPWD. Here low tide level varies from -0.5 mPWD to 0.5 mPWD from spring to neap tide respectively.This tidal level is lower than the average land elevation of WMUs. So water can be drained to this river from the WMUs twice a day during monsoon. In the post-monsoon (November & December) tidal level in the river is lower than monsoon period. Gravity drainage opportunity is also increase in post-monsoon period.

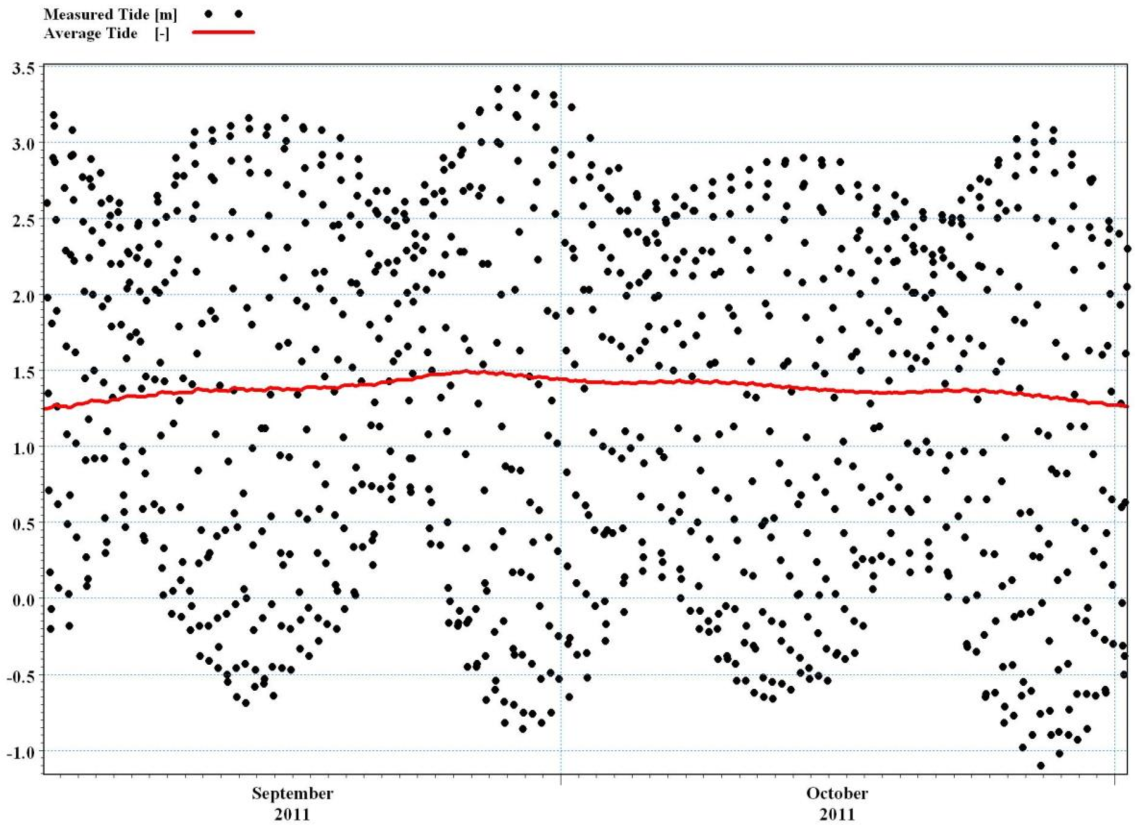


Figure 4: Tidal level in Kazibacha River during monsoon

5. Improved drainage options

Analyzing the present drainage system, khals, regulators, roads, culverts and land level three options has been considered for improved drainage of WMUs. These options are given in Table 2

Table 2: Proposed drainage improvement Plan

Option	Connecting Khals	Drainage route length (Km)	Drainage Regulator	River
Option-1	Konar khal, 350m new khal, Katakhali Khal	2.4	Katakhali Regulator	Kazibacha
Option-2	Saduria khal, Vorakhali Khal, Katakhali Khal	5.5	Katakhali Regulator	Kazibacha
Option-3	Poschim Khal, Vorakhali Khal, Khoria Khal	4	Khoria Regulator	Kazibacha

After consulting with the local farmer the Option-3 was discarded because they don’t have control over Khoria regulator. Moreover there are two blockages with permanent religious structure and very small culvert. In Figure 5photograph of FGD in Fultola village and constrains in Vorakhali khal has been shown.

Figure 5: FGD in the Fultola village (Left) and constraint in the Vorakhali Khal

InFigure 6 the schematic map of drainage system under option-1 is shown. To connect the Konar khal with Katakhali khal a 350 m long new khal will be excavated in Kismot-fultola village. The drainage route length in this option is around 2.4 Kilometers.

Figure 7present the schematic map of option-2 drainage system.The blockage in Saduria khal will be removed by constructing 3 footbridges. The drainage route length in this option is around 5.5 Kilometers much higher than Option-1.

Two new culverts with control fallboard are proposed in two units to control the water movement in the outlets. Field channels in two units will be connected to the main channel for good connection and quicker drainage. In Unit-1 two pipes is proposedto connect the low, remote land to Paschim khal and Vorakhali khal. Modelling technique has used to find the effectiveness of the drainage options and design criteria of the required elements. Detailed design of the field channel, new khals, culverts and foot bridgesare included in this report.

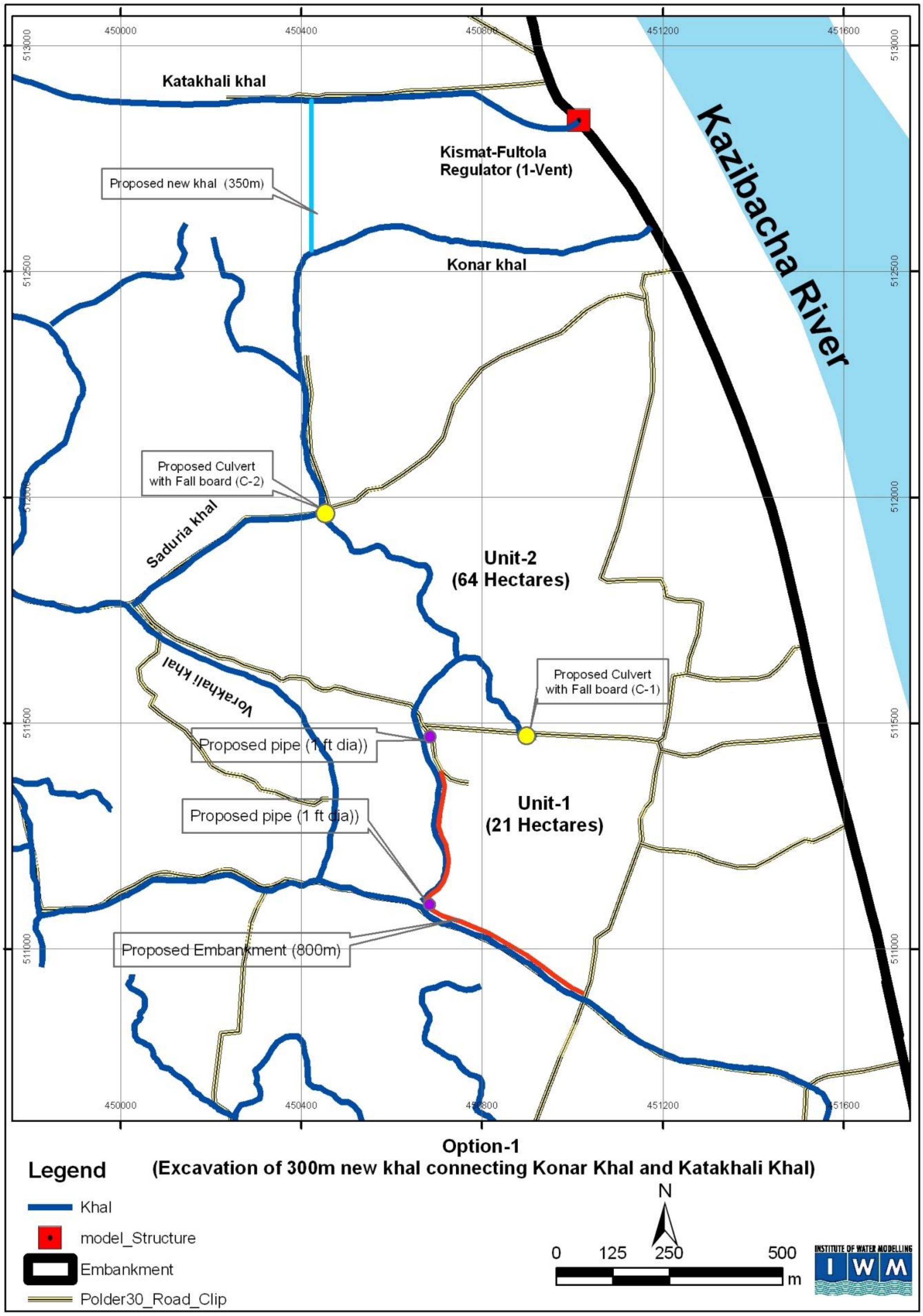


Figure 6: Map showing the proposed improved drainage system in Option-1

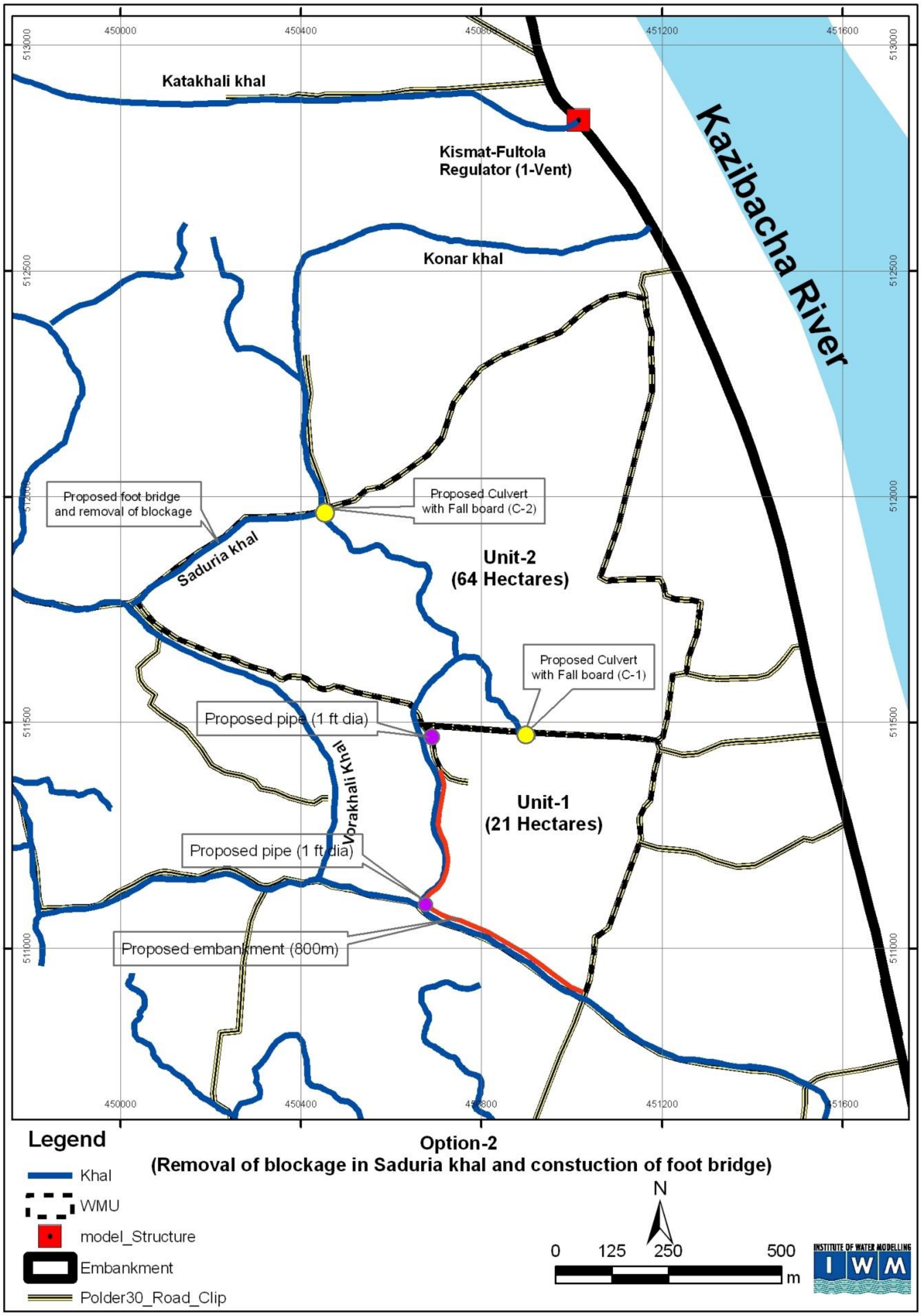


Figure 7: Map showing the proposed improved drainage system in Option-2

6. Approach and Methodology

6.1 Statistical analysis of rainfall

Data collection

The improved drainage system is designed to improve the drainage conditions consequently would be increased the yield of Aman rice and Rabi crop in the WMUs. Extreme value analysis has been carried out to calculate 10 year, 25 year and 30 year return period monthly maximum rainfall from July to December.

Daily precipitation data is collected from Bangladesh Meteorological Department (BMD) at Khulna(220 47’’N Latitude, 890 32’’E Longitude). Daily rainfall data is available for about 48 years (1961-2008). Consecutive 5-day maximum rainfall forthe selected months at Khulna is presented in Table 3for 48 years’ (1961-2008) time period.

Table 3: 5-day maximum rainfall for the period of (1961-2008)

Year/Month	5-day maximum rainfall (mm)					
	July	August	September	October	November	December
1961	64	186	71	44	--	--
1962	3	89	112	179	73	--
1963	101	80	89	68	1--	--
1964	179	79	55	165	18	9
1965	285	179	143	58	1	8
1966	69	126	**NA**	**NA**	**NA**	**NA**
1967	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
1968	299	102	21	17	--	--
1969	72	226	421	64	28	--
1970	209	121	117	107	13	--
1971	32	104	63	115	6	--
1972	63	**NA**	**NA**	**NA**	**NA**	**NA**
1973	88	70	41	0	--	4
1974	262	197	220	170	1	1
1975	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
1976	117	187	122	72	11	11
1977	**NA**	112	34	**NA**	15	11
1978	130	105	288	291	1	--
1979	296	521	145	83	--	29
1980	109	182	57	104	--	1
1981	127	108	91	37	--	65
1982	64	234	89	28	29	3
1983	**NA**	234	106	138	6	6
1984	115	126	97	61	--	6
1985	59	95	42	132	12	--
1986	177	77	657	516	152	1
1987	171	292	89	38	48	7
1988	148	115	25	42	14--	14--

Year/Month	5-day maximum rainfall (mm)					
	July	August	September	October	November	December
1989	79	72	88	133	--	1
1990	111	101	72	119	77	4
1991	132	140	152	93	41	47
1992	92	62	44	53	--	--
1993	155	97	70	76	14	--
1994	89	103	89	53	3	--
1995	131	228	112	93	14--	--
1996	115	141	33	220	215	--
1997	204	100	139	168	2	15
1998	209	85	169	63	125	--
1999	141	200	221	55	17	--
2000	295	116	198	135	128	--
2001	91	61	98	102	31	--
2002	189	143	165	56	148	--
2003	109	120	51	220	16	18
2004	73	99	430	163	--	--
2005	198	109	159	224	--	--
2006	295	96	428	55	1	--
2007	256	79	197	133	93	--
2008	74	57	279	208	2	--

Frequency Analysis

Frequency or probability distribution helps to relatethe magnitude of extreme hydrologic events like floods,droughts and severe storms with their number ofoccurrences such that their chance of occurrence withtime can be predicted successfully. Observed values ofADMR can be obtained statistically through the use ofthe Chow's general frequency formula. The formulaexpresses the frequency of occurrence of an event interms of a frequency factor,K_T which depends upon thedistribution of particular event investigated. Chow (1951)has shown that many frequency analyses can be reducedto the form

$X_T = \bar{X}(1 + C_V K_T)$ …………………………………. (1)

Where, XT is maximum value of event corresponding to return period T; X is mean of the annual maximum series of the data of length N years, C_V is the coefficient of variation and K_T is the frequency factor which depends upon the return period T and the assumed frequency distribution. The expected value of annual maximum daily rainfall for the same return periods were computed for determining the best probability distributions. Gumbel, normal, log normal and log Pearson type –III are adopted for frequency analysis.

Testing the goodness of fit

The goodness of fit of a statistical distribution defines how well it fits a set of observations. Measures of goodness of fit typically summarize the discrepancy between observed values and the values expected under the model. Most commonly used testing methods for goodness of fit are chi-square test (χ^2 test), Kolmogorov–Smirnov test (K-S test), Anderson–Darling test, Shapiro–Wilk test, Hosmer–Lemeshow test, Akaike information criterion (AIC) and Hosmer–Lemeshow test. However in this study, χ^2 test and K-S test are adopted to check the goodness of fit as they are very popular and frequently used. Goodness of fit test for 5-day maximum rainfall is provided in Table 4

Table 4: Goodness of fit test for maximum 5-day consecutive rainfall.

Distribution	Chi-square	Kolmogorov-Smirnov
Gamma-pearson-3	3.64	0.07
Normal	13.45	0.15
Log-normal	2.91	0.08
Gumbel	3.64	0.08

Analysis of Results

It is evident from analysis that, extreme value distribution for 5-day maximum rainfall is best fitted with log-normal distribution especially during July, August and September. On the other hand, Gumbel distribution is more fitted for October, November and December. However, 5-day maximum rainfall for July to December at 10 years, 25 years and 30 years recurrence interval is shown in Table 5

Table 5: Monthlymaximum 5-day rainfall at 10, 25 and 30 years of return period.

Distribution	Log-normal	Log-normal	Log-normal	Gumbel	Gumbel	Gumbel
Return period (year)/ 5-day maximum rainfall (mm)	July	August	September	October	November	December
10	241.38	237.22	288.74	232.00	108.87	39.98
25	307.10	306.46	413.26	299.00	149.74	57.65
30	319.10	323.40	438.82	312.50	157.73	61.12

6.2 Drainage modelling

Model set up

A dedicated polder drainage model is developed using Rainfall-Runoff (NAM) and Hydrodynamic (Mike11 HD) models. Recent surveyed (2012) data- khal and river cross sections, regulator dimensions and land level is used in the modelling tools. Boundary condition was taken from well calibrated south west regional model (SWRM).InFigure 8schematic diagram of modelling technique of drainage model was explained.

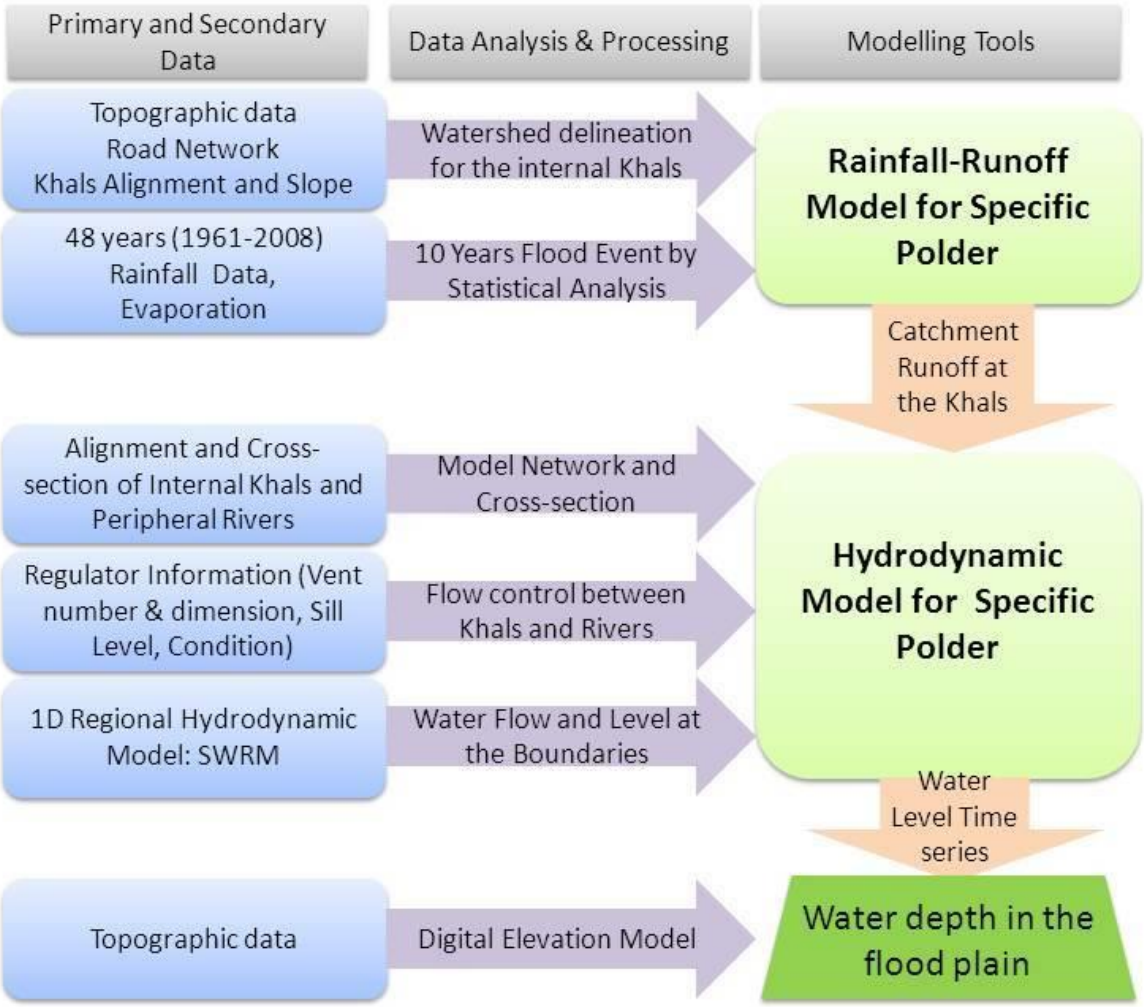


Figure 8: Schematic diagram of modelling techniques to analysis the performance of drainage system.

Figure 9presents the network system of dedicated model for Polder-30. For the selected units flood plains was included in dynamic calculation in the model.

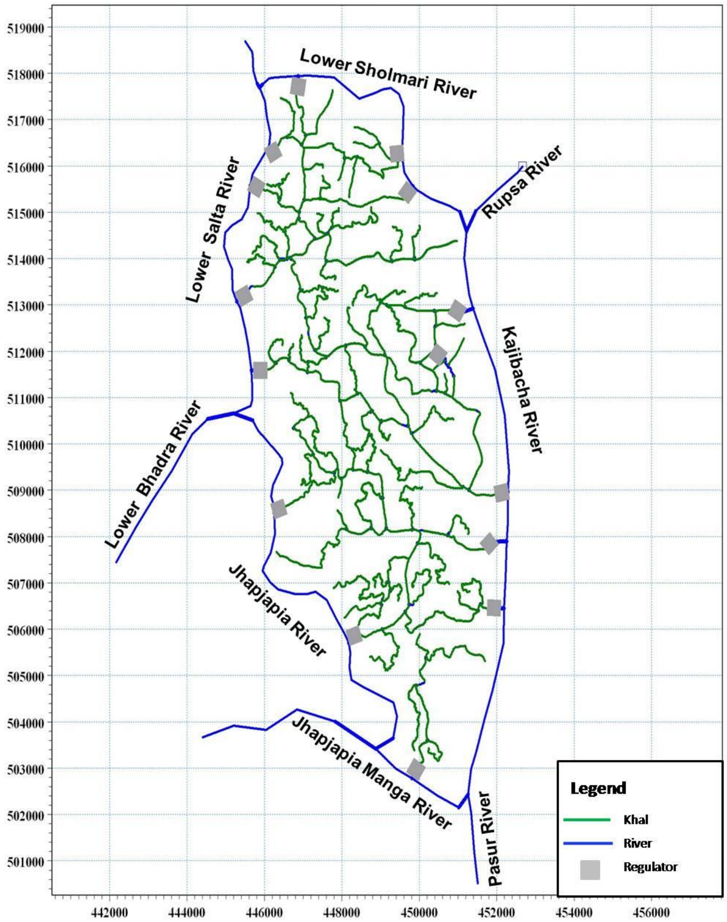


Figure 9: Network diagram of Polder 30 dedicate drainage model

Model calibration

The performance of drainage system of a polder depends on the water level of the peripheral river system. To discharge out water from polder by gravitational force the water level in the river should be lower than the khals water level. So the calibration of water level in the peripheral river is very important for drainage model. Boundary condition of the dedicated polder model was taken from the regional model. The south west regional model was calibrated properly for the peripheral river of Polder 30. In Figure 10calibration of the regional model in Kazibacha and Lower Sholmari river has been shown.

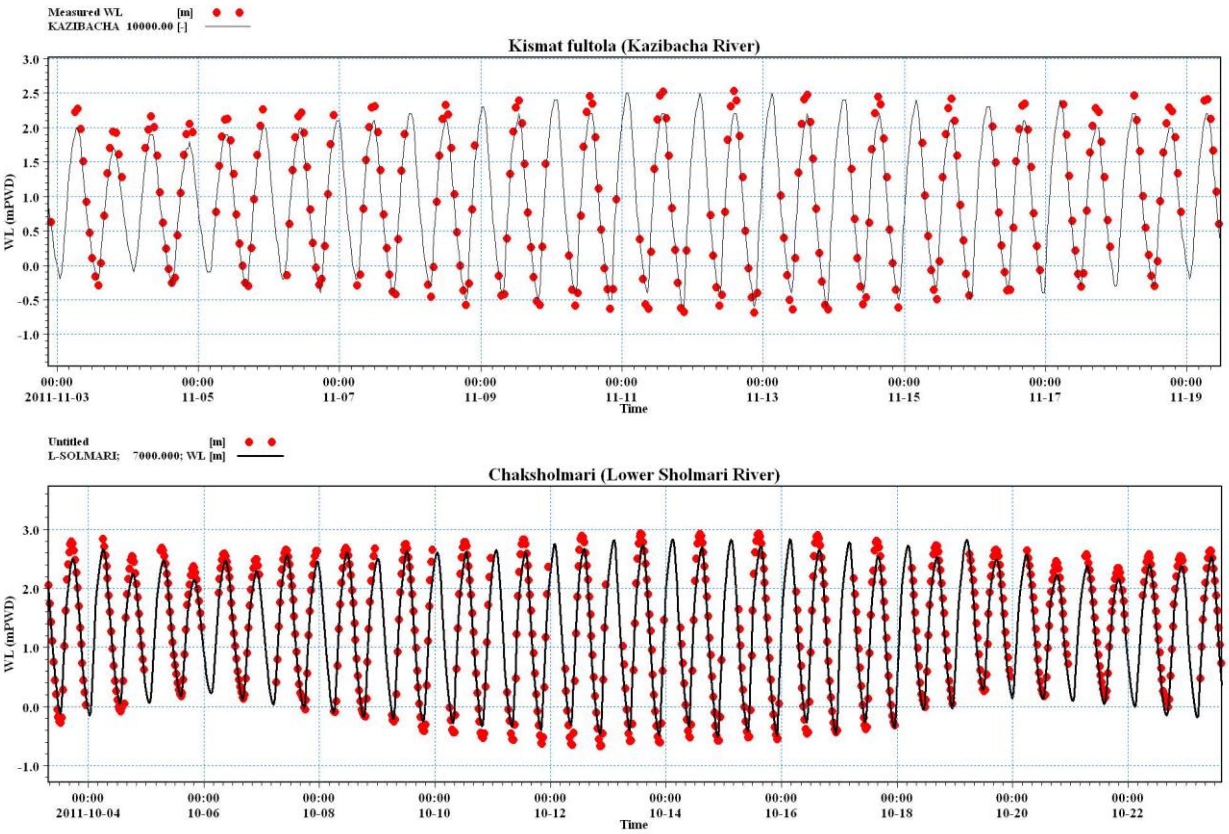


Figure 10: Water Level calibration in Kazibacha River (top) and Lower Sholmari River (bottom)

Model result

The model was simulated for 10 years rainfall event.Design flow of field channels, khals and culverts have been obtained from model result. They are given in Table 6.

Table 6: Design criteria for Khals, Culverts and Field Channel

Item	Design length (m)	Design flow (m3/s)
Khal	350	0.75
Culvert-1	N/A	0.2
Culvert-2	N/A	0.47

The model is also used to evaluate drainage performance of the two proposed option.Figure 11shows the comparison of water depth for two options. From this figure,water depth in option-1 is much lower than option-2. Maximum depth can be reduced from 0.70m to 0.48m by excavating a new 350m khal in Option-1.

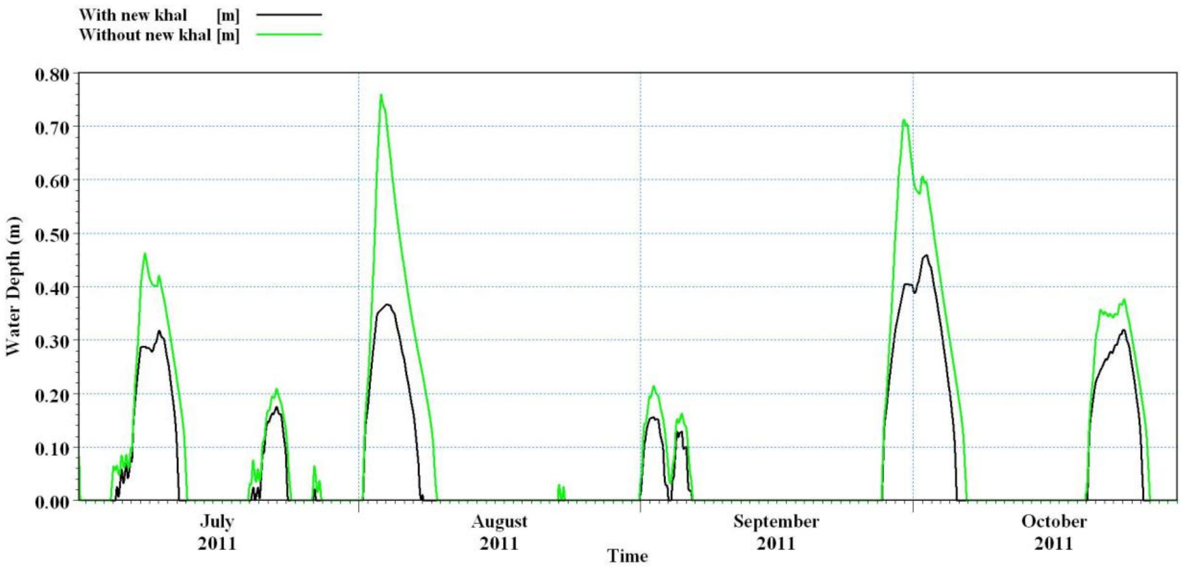


Figure 11: Comparison of water depth in floodplains by two drainage improvement options.

Figure 12shows water depth in September for two options. It is evident from figure that effectiveness of drainage system in Option-1 is better compared to Option-2. The 3 day depth in Option-1 is 26cm much lower than Option-2 which is 35 cm.

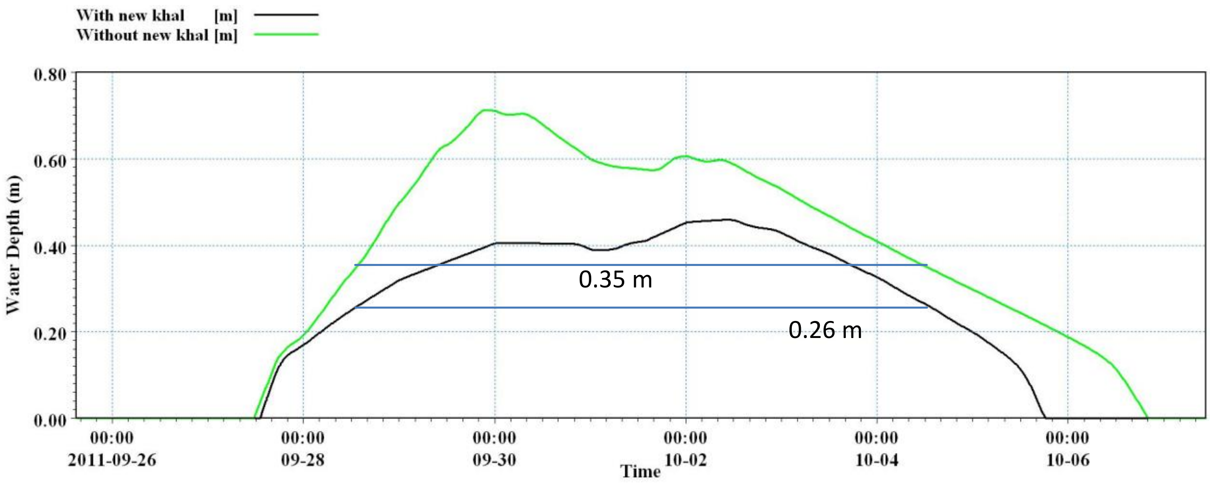


Figure 12:Comparison of water depth in floodplains by two drainage improvement options in September

Inundation map

Depth duration inundation map was generated by from model result using high resolution DEM. Figure 13, Figure 14 and Figure 15 shows the flood map under present drainage condition, improved Option-1 and Option-1 respectively. From these 3 day depth duration map, it is evident that Option-1 and Option-2 improves the drainage condition of the WMUs and surrounding areas greatly from existing situation. Also the Option-1 is giving far better improvement when compared with Option-2.

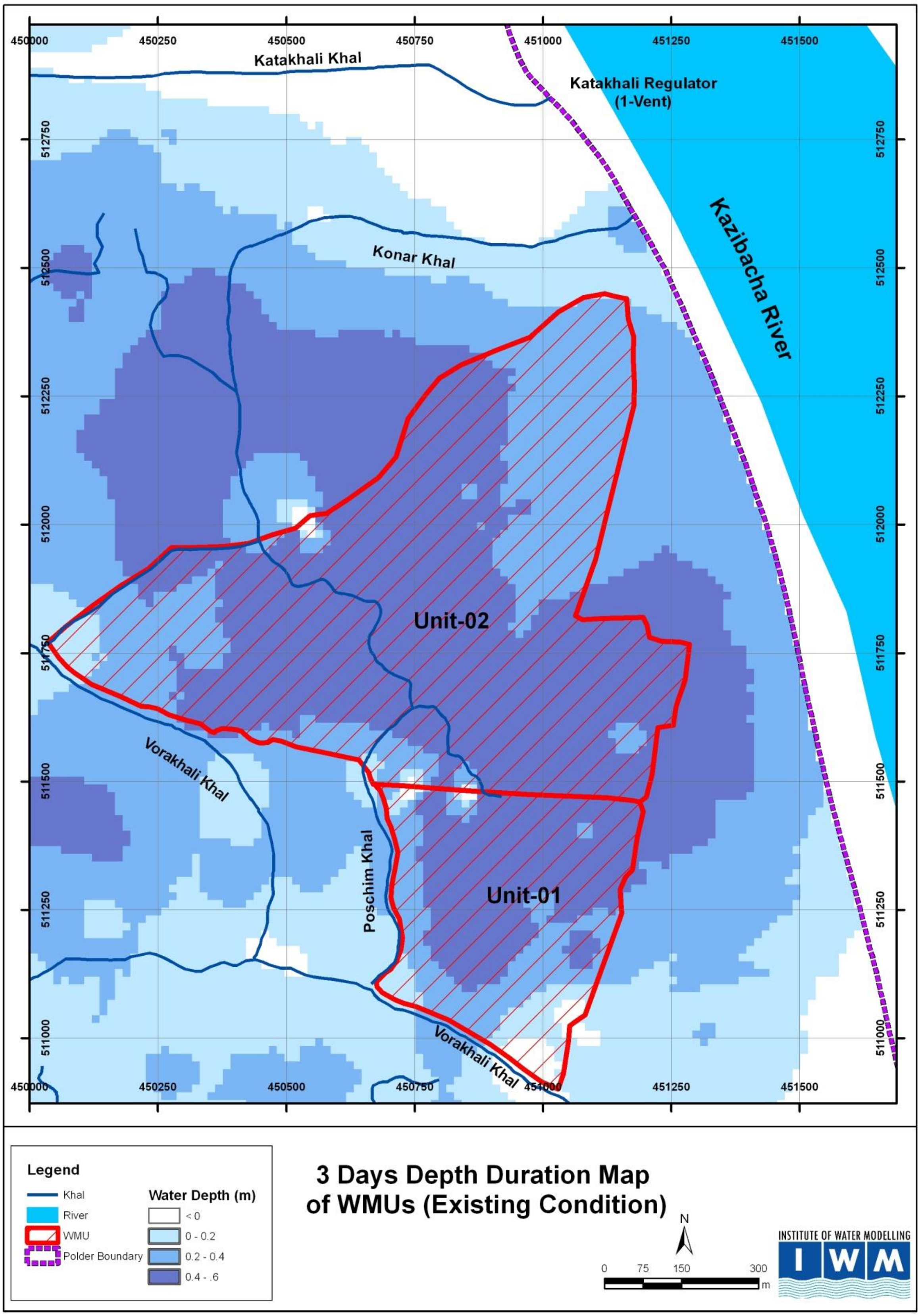


Figure 13: 3 day Depth-Duration inundation map of WMUs in Existing condition

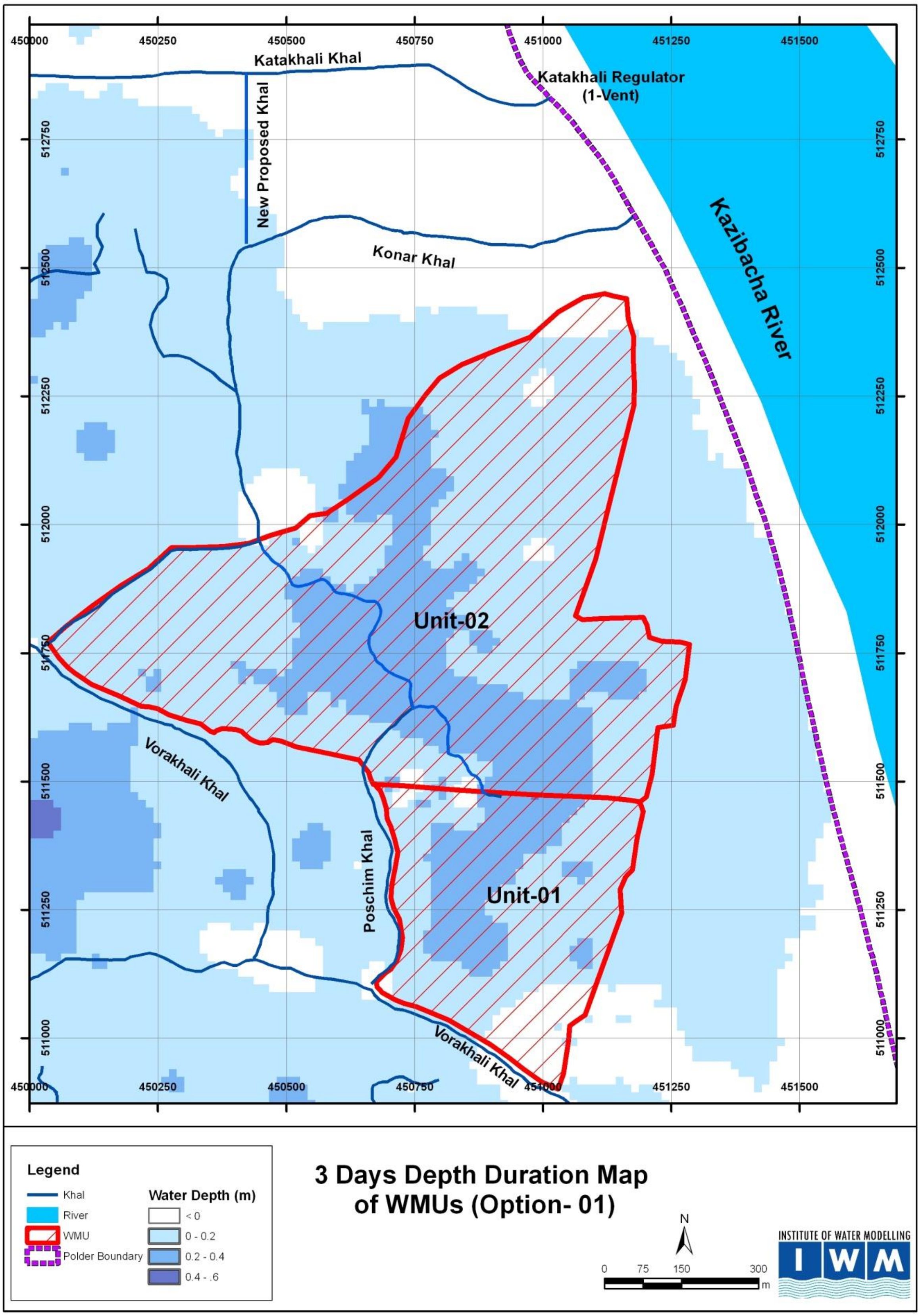


Figure 14: 3 day depth-duration inundation map under improvement option-1

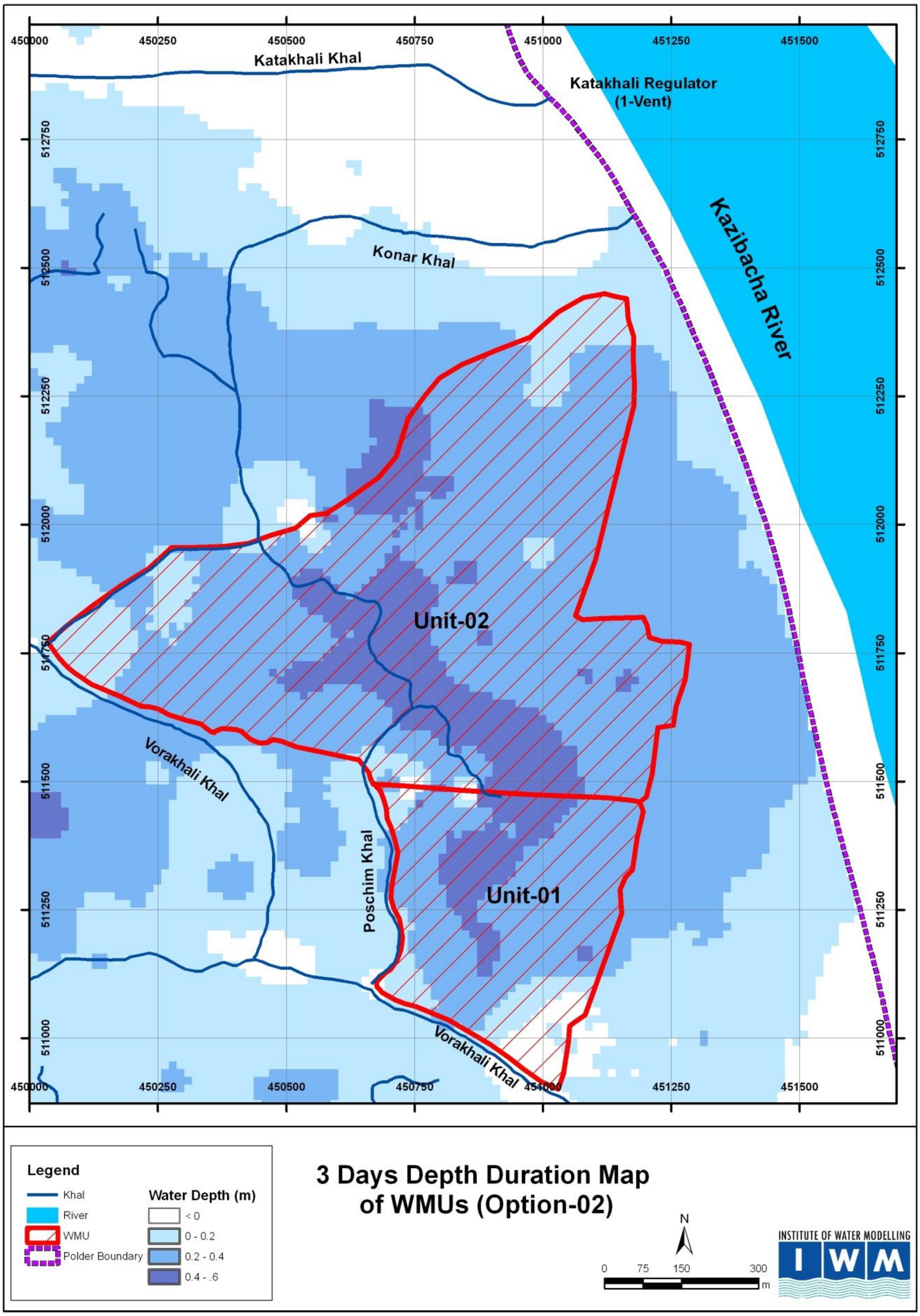


Figure 15: 3 day depth-duration inundation map under improvement option-2

6.3 Design and Cost estimation

6.3.1 Design of internal field channel

Internal field channel layout should allow drainage from every slice of land in the WMUs. It is a great challenge to ensure the connectivity between high-low land and drainage khals. IWM has done a GPS survey to identify the land boundary inside two units. This GPS alignment data also checked with Mouza map and high resolution satellite image. Figure 16 shows the collected GPS alignment overlays over mouza map in the two units.

Field channel layout of WMUs is shown in Figure 17. Most of the time field channel alignment is selected along the boundary of the land. So these channels can ensure connectivity with most of the farm land and use less space. There is two pockets of low and remote land in Unit-1, where drainage thorough main system is difficult. For these small pockets two additional pipe (1foot diameter with control fall board) is used. These two pipes are connected to Paschim khal and Vorakhali khal. During heavy monsoon farmers can drain additional water through this pipe. There is one big channel (cannel-03) in Unit-1 along the road side is used. This channel will carry water from other field channel to the outlet. In Unit-2 to big channel is planned, one in the middle replacing the dead khal and the other is located along the road side in the north. These two bigger channels will carry water from the small field channel to the outlet.

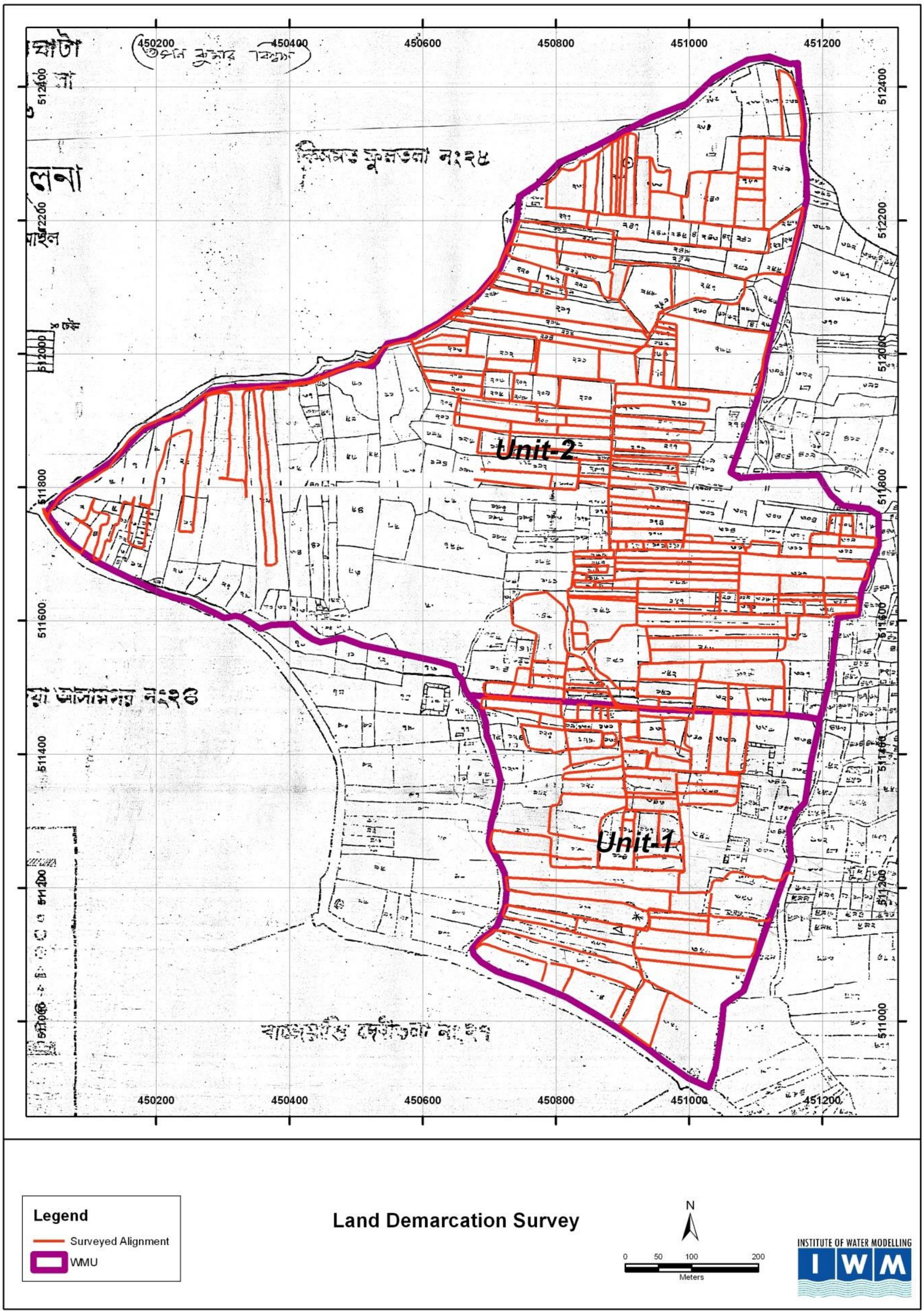
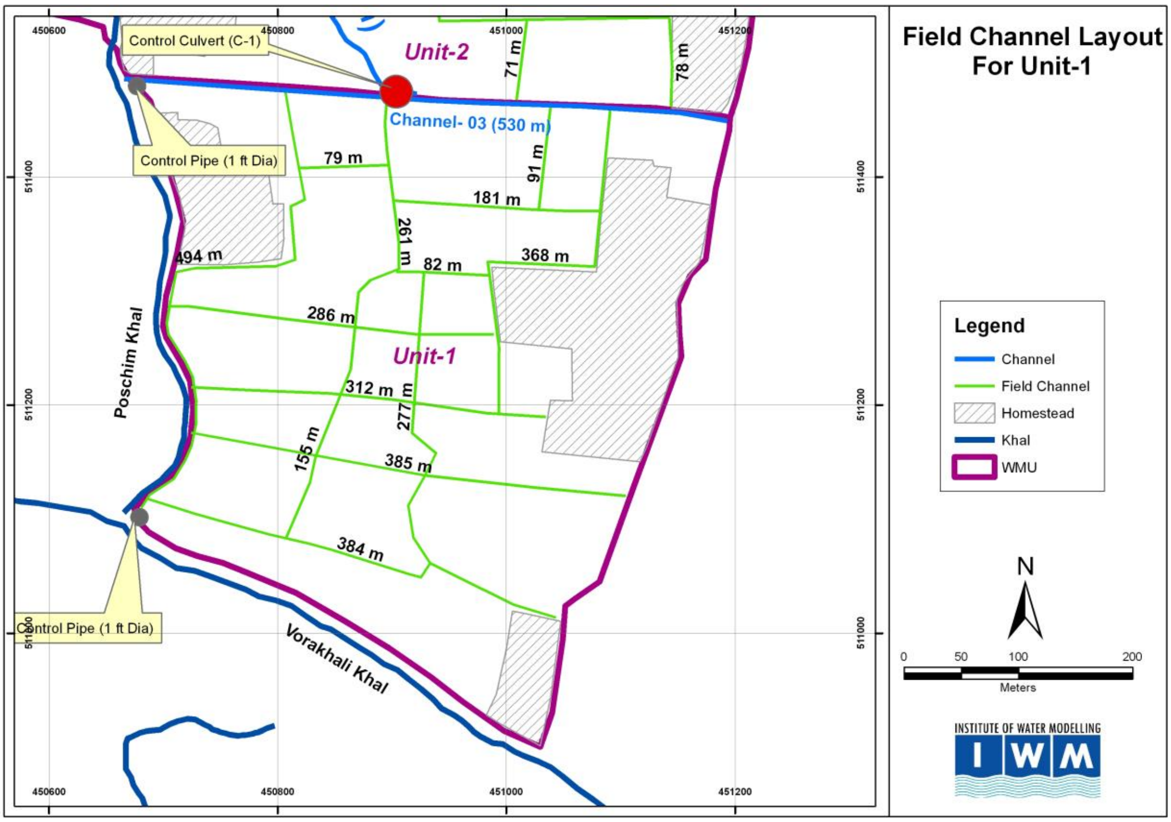


Figure 16: Map showing the GPS alignment data with the mouza map.



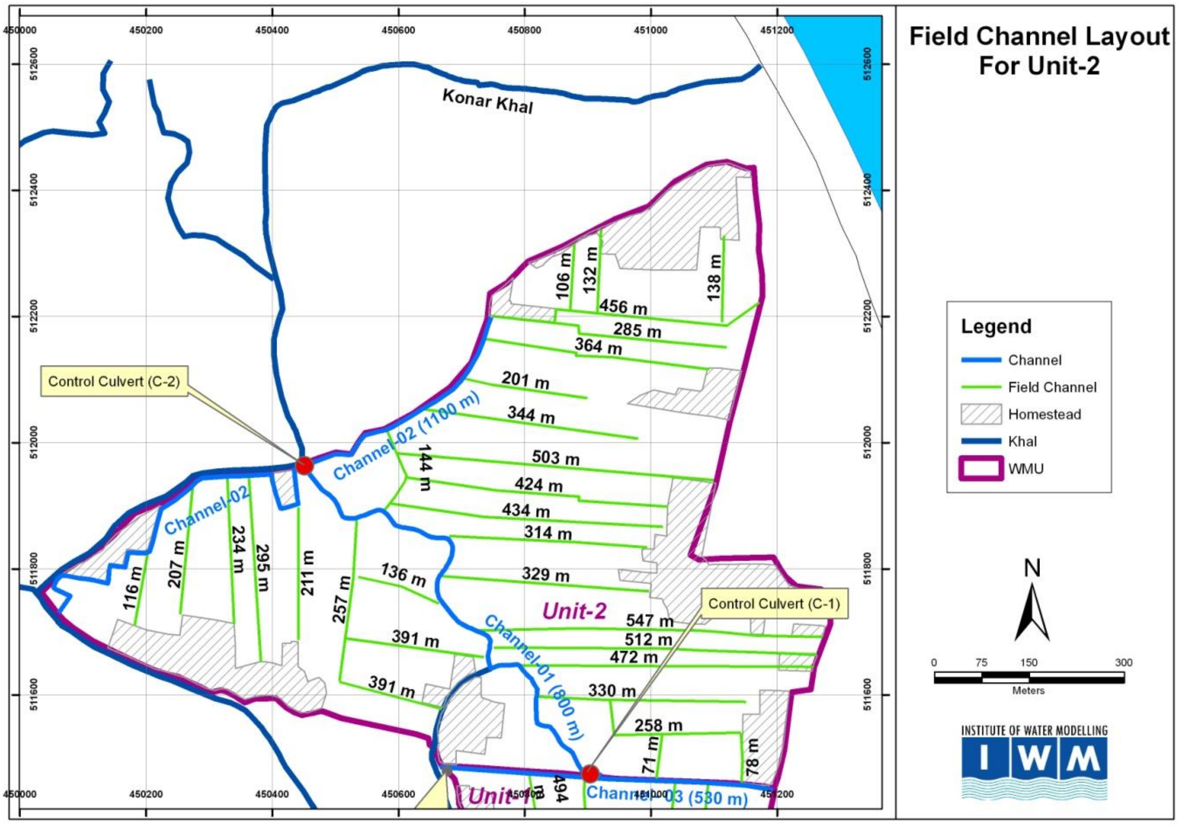


Figure 17: Field channel layout of Unit-1 (top) and Unit-2 (bottom)

The field channel is designed using thefollowing considerations:

- Design flow has been derived from mathematical modelling
- Section has been designed using Manning's formula considering following criteria:
    - Manning's roughness coefficient : 0.035
    - Bed slope : 1/2500
    - Side slope: 1:1

The design sections of field channels are shown in the following Table

Table 7: Design Section of Khals and Field Channel

Sl. No.	Name of Khal	Bed width (m)	Depth (m)	Side slope
1	Channel-01	0.75	0.75	1:1
2	Channel-02, Channel-03	0.45	0.45	1:1
3	Unit 1 Field Channel	0.15	0.15	1:1
4	Unit 2 Field Channel	0.15	0.15	1:1

In Figure 18 design section of Channels and field channels is shown.

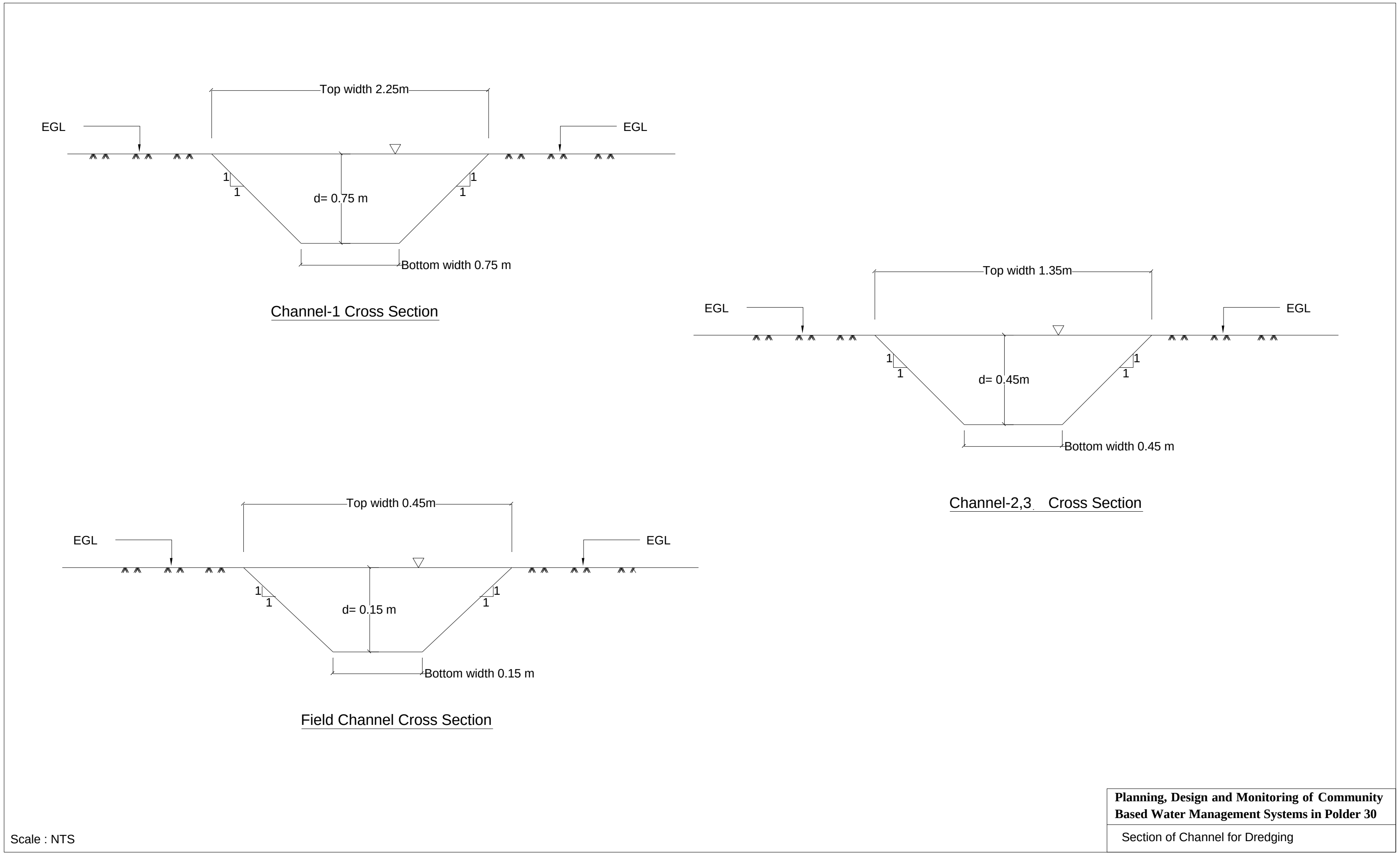


Figure 18: Design cross section of Channel-01,02,03 and field channel in two units

6.3.2 Design of improved drainage system

A connecting Khal- 350m between Konar khal and Katakhali khal have been proposed for new excavation. Two control culvert (C-1 and C-2) have been proposed in two units to control the outlets. Additional two pipes also proposed in Unit-1 connected to Paschim khal and Vorakhali khal (see Figure 17). Three foot bridges are proposed to replace the existing blockage in Saduria khal.One embankment (800m) in the south and west part of Unit-1 is proposed to isolate the Unit. This embankment will restrict the water to enter into Unit-1from Vorakhali khal and Paschim Khal during monsoon.

Design consideration:

- Design flowfor khal, culverts & pipesand water level for embankment has been derived from mathematical modelling.
- Section has been designed using Manning's formula considering following criteria:
  - Manning's roughness coefficient : 0.035
  - Bed slope : 1/2500
  - Side slope : 1:1
  - Depth of canal with respect to existing bed level of khal and ground level

Design Sections:

The design sections of khal are as follows:

- Length: 350 m
- Bed width: 1.05 m
- Depth: 1.00 m
- Sideslope: 1:1

The design sections of culverts are as follows:

Culvert 1(C1): Clear width = 0.75 m, Clear height = 0.55 m
Culvert 2(C2): Clear width = 1.00 m, Clear height = 0.80 m

The design sections of rcc pipes are as follows:

Pipe diameter: 300 mm (1 foot) as BWDB standard

The design sections of embankment are as follows:

- Length: 800 m
- Crest width: 300mm
- Height: 700mm
- Sideslope: 1:2 (both side)
- The grass turfing may be used as slope protection

The size /length of foot bridges are as follows:

Length: 11.00m
Width: 1.20 m

Design drawings of Khals, culverts, embankments and foot bridges are shown in Figure 19, Figure 20, Figure 21, Figure 22, Figure 23, Figure 24, Figure 25.

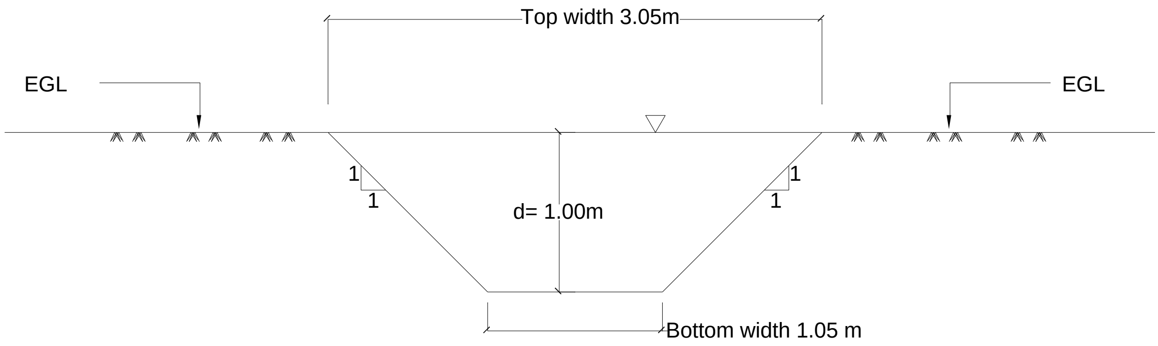


Figure 19: Design section of new khal

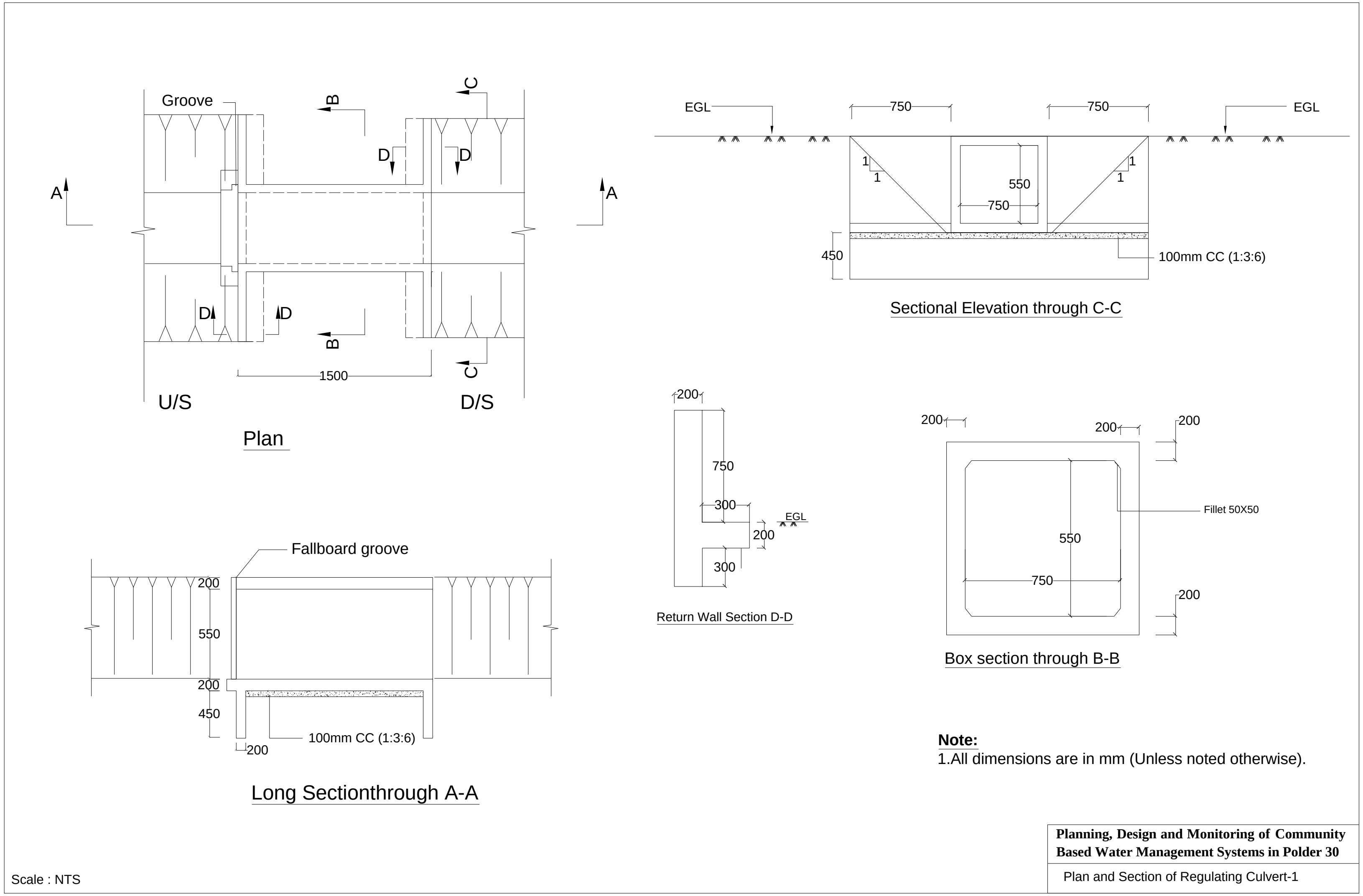


Figure 20: Plan and section of Culvert-1

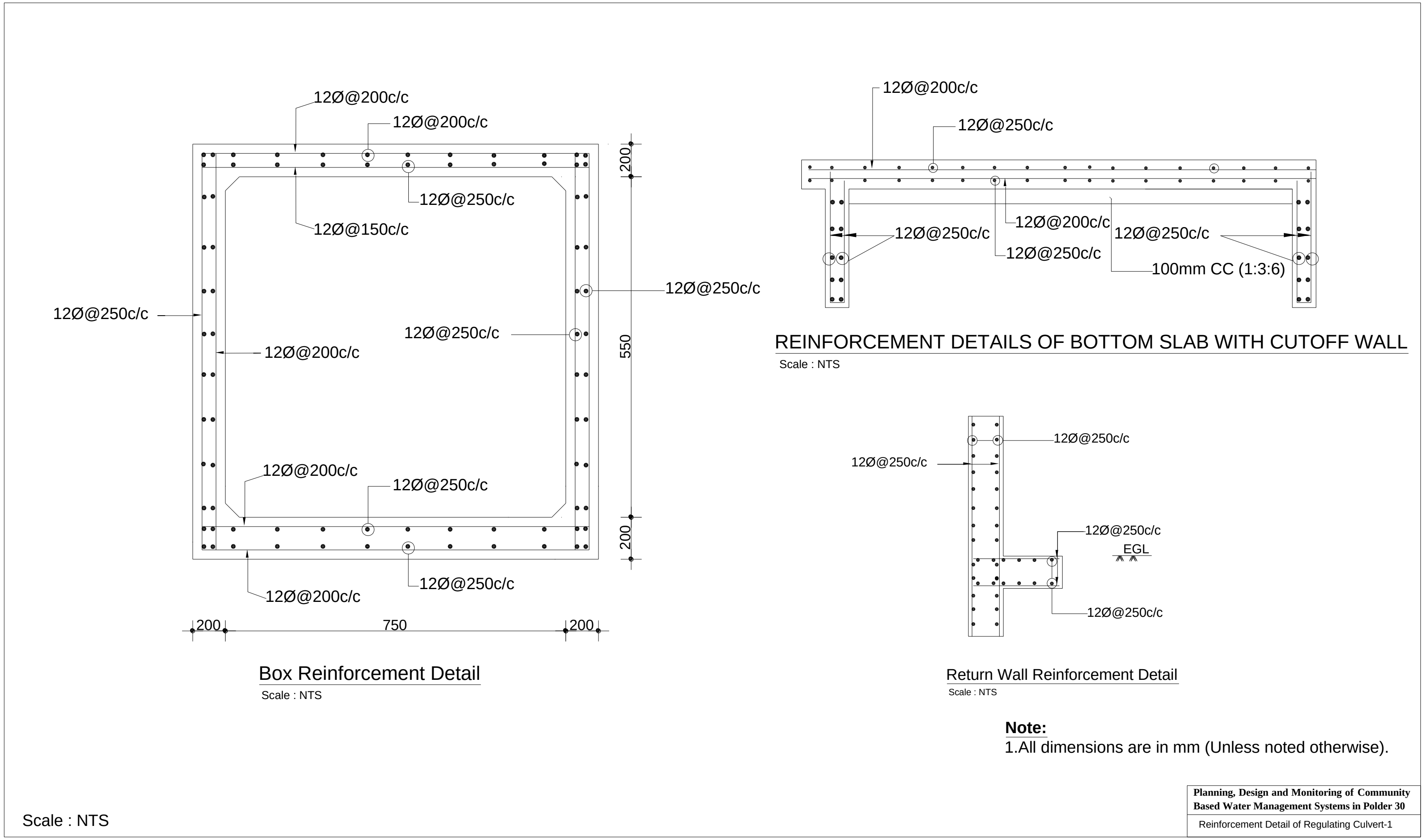


Figure 21: Reinforcement detail of Culvert-1

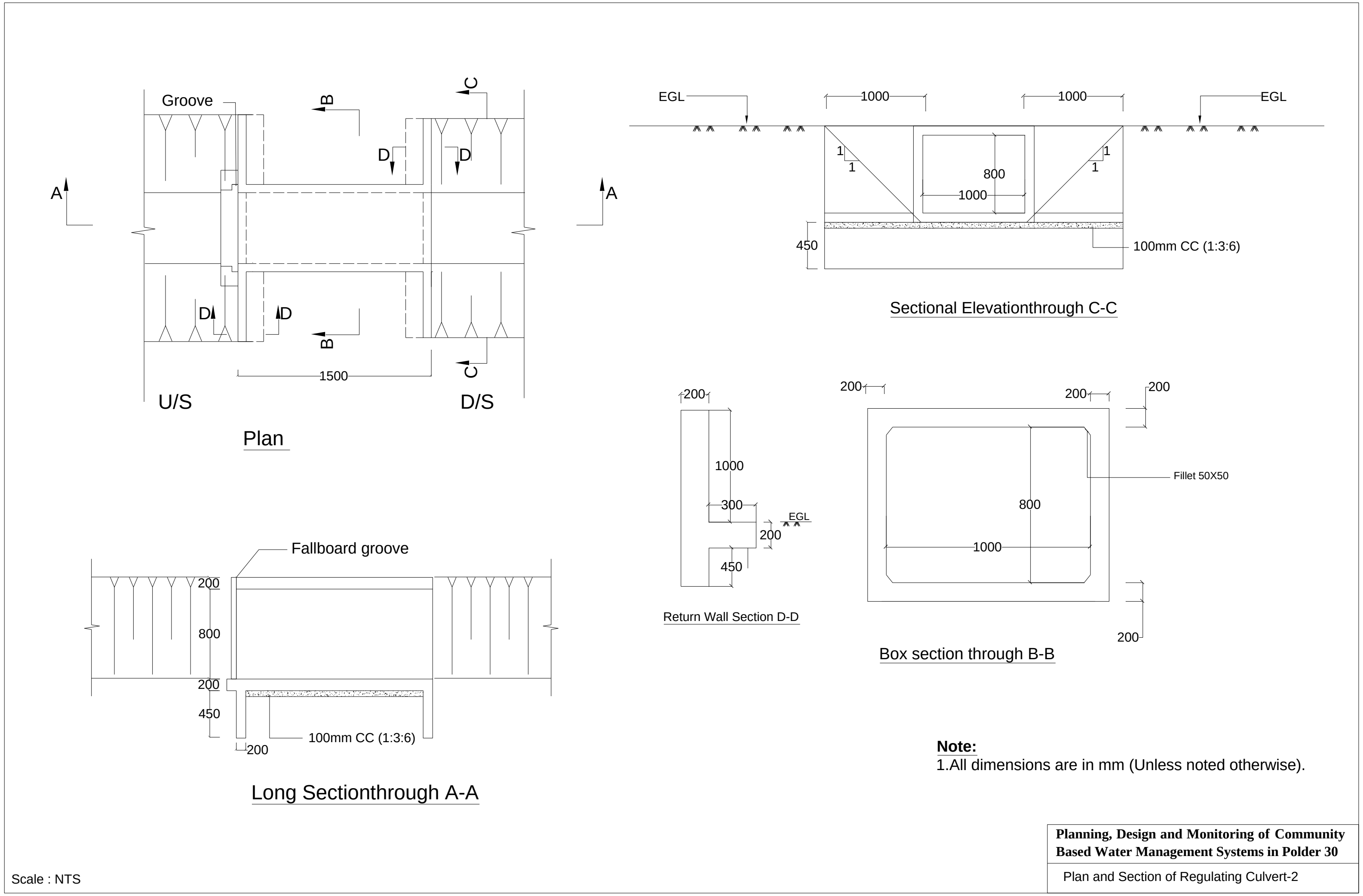


Figure 22: Plan and section of Culvert-2

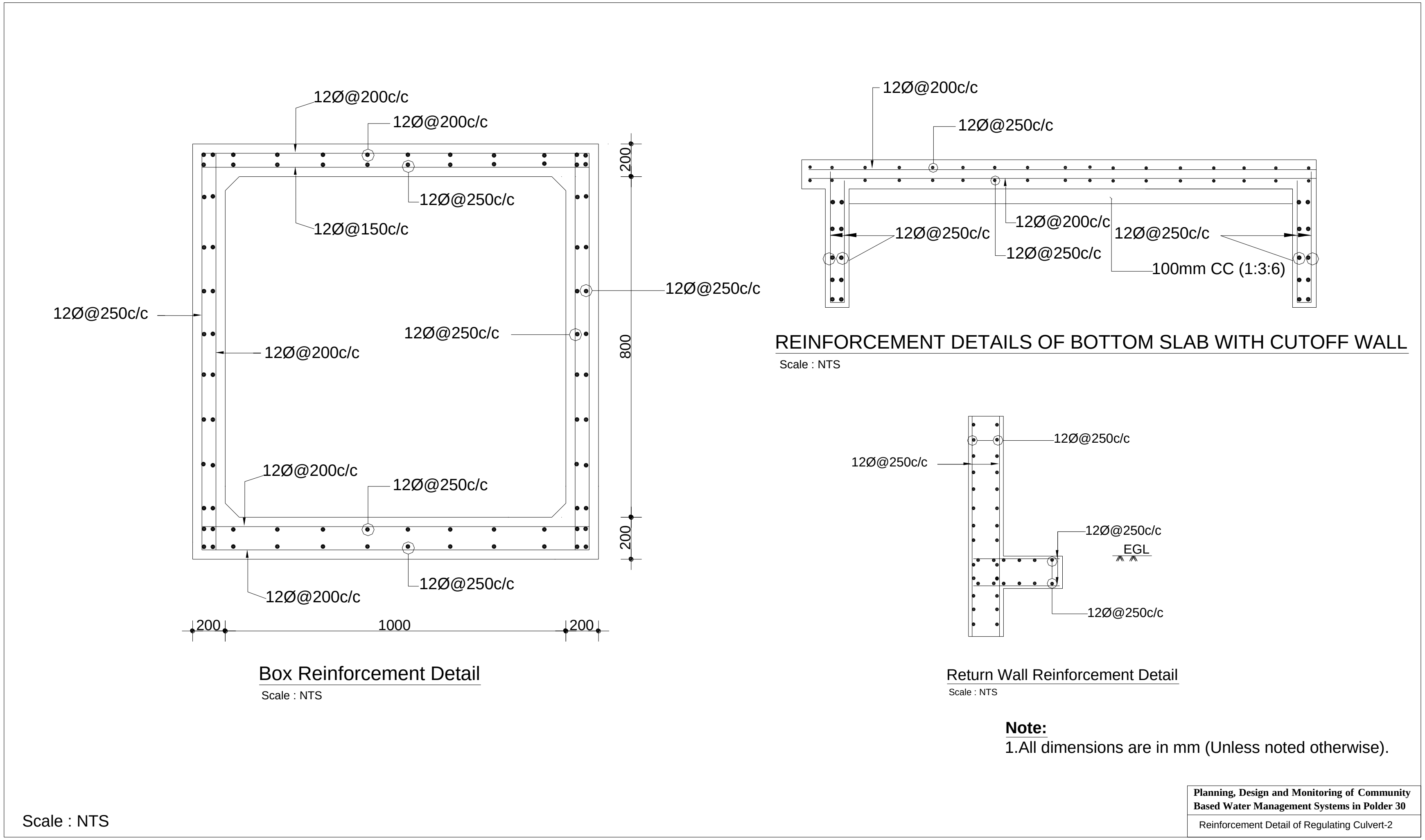
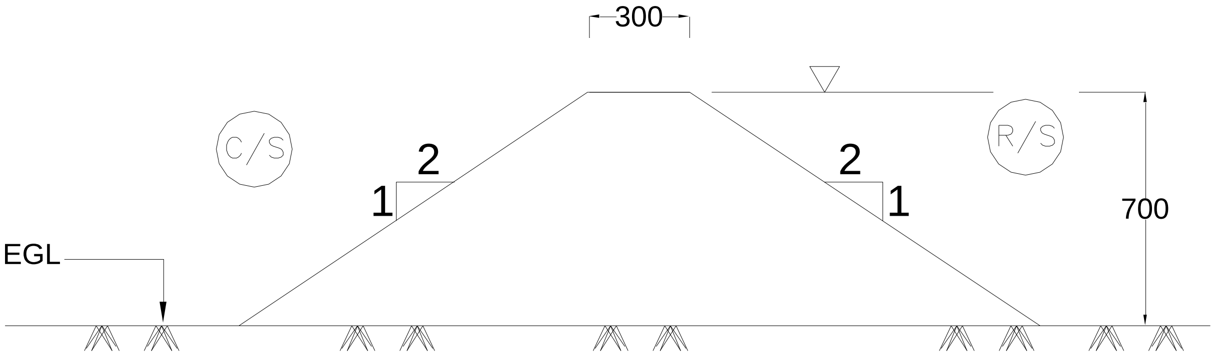


Figure 23: Reinforcement detail of Culvert-2



Embankment Cross Section

Scale : NTS

Notes:

1. The filling earth shall be compacted to 85% maximum dry density at optimum moisture content.
2. All dimension are in mm (Unless noted otherwise).
3. The construction drawing of embankment will modify according the field condition and after taking cross section datas along the alingment.

Scale : NTS

Planning, Design and Monitoring of Community Based Water Management Systems in Polder 30
Embankment Section

Figure 24: Design section of embankment

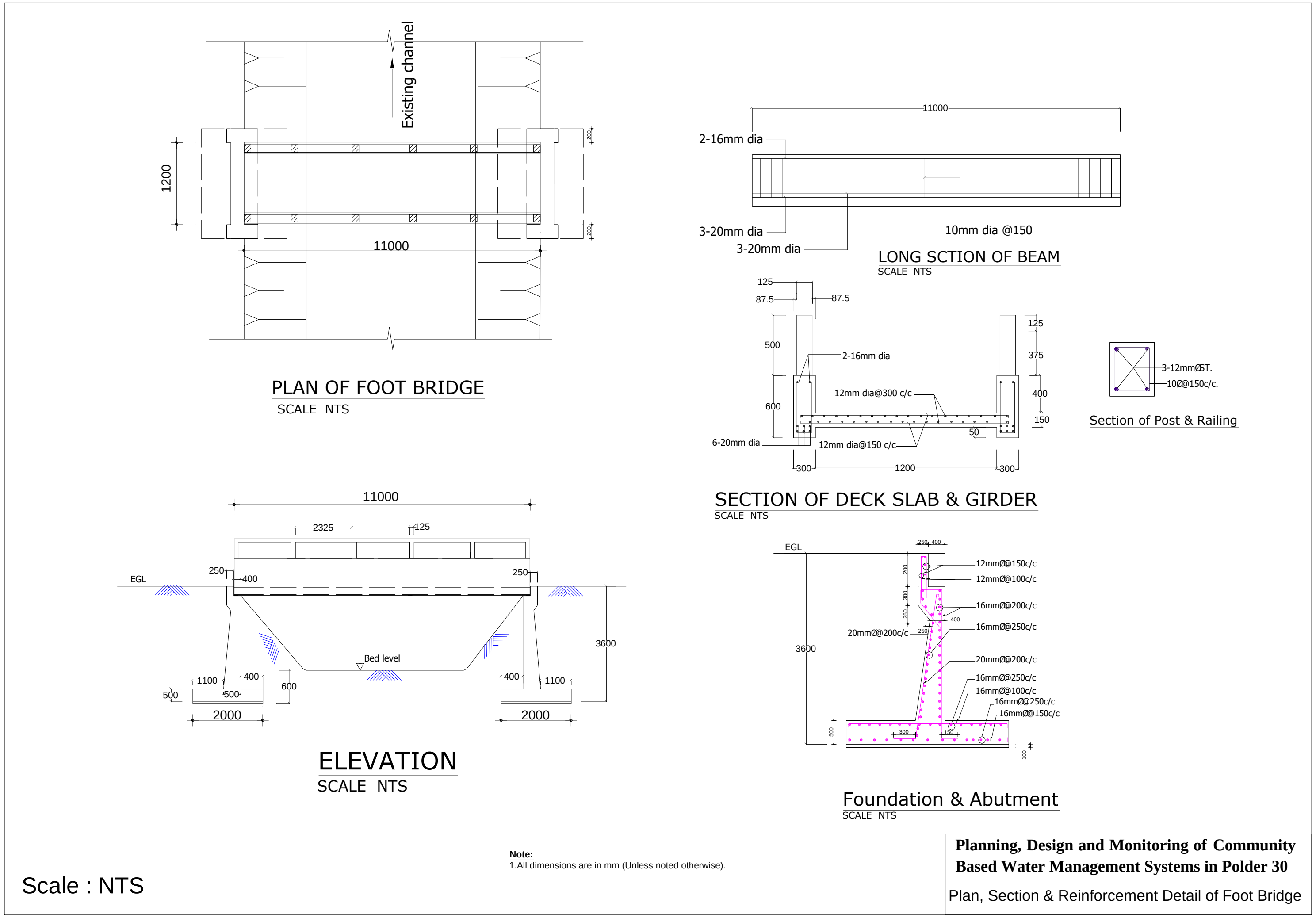


Figure 25: Plan, Section and reinforcement detail of Foot Bridge

6.3.3 Cost estimate

Khal Excavation

The rate has been taken from available BWDB O & M schedule item rate. The khaland the field channel manual excavation rate has been taken 110 TK per cum and the total cost is as below,

Khal: Length = 350m, Area per meter length= 2.05 m^2

Cost = 38,725.50 TK

Channel 01: Cross-sectional area = 1.125 m^2

Cost per 100 meter length = 12375 tk

Channel 02 & 03: Cross-sectional area = 0.405 m^2

Cost per 100 meter length = 4455 tk

Field Channel: Cross-sectional area = 0.045 m^2

Cost per 100 meter length = 495 tk

Embankment: Cross-sectional area = 1.19 m^2

Cost per 100 meter length = 14875 tk

Table 8: Cost estimation of Culverts with controlling gate

SL. No.	Item Code No.	Item Description	Unit	Quantity	Rate (TK)	Amount (TK)
1	16-150	Earthwork in excavation of foundation trench	cum	3.90	100	390.00
2	16-530	Backfilling of hydraulic structure	cum	2.75	95	261.25
3	28-120-60	Cement Concrete in leanest mix 1:3:6	cum	1.80	6350	11430.00
4	28-170-10	Reinforced cement concrete in leanest mix 1:2:4	cum	3.90	6700	26130.00
5	76-110-10	M.S work for reinforcement	kg	460.00	80	36800.00
6	36-150-10	Formwork for centering & shuttering	sqm	4.25	315.27	1339.90
7	68-130	Supplying wooden fall boards/stop logs	cum	0.16	56752	9080.32
					Total tk. =	**85431.47**

Table 9: Cost estimation for Footbridge (One bridge)

SL. No.	Item Code No.	Item Description	Unit	Quantity	Rate (TK)	Amount (TK)
1	16-150	Earthwork in excavation of foundation trench	cum	12.25	110	1347.50
2	16-530	Backfilling of hydraulic structure	cum	5.25	98	514.50
3	28-120-60	Cement Concrete in leanest mix 1:3:6	cum	1.00	6550	6550.00
4	28-170-10	Reinforced cement concrete in leanest mix 1:2:4	cum	13.56	6850	92886.00
5	76-110-10	M.S work for reinforcement	kg	1,600.00	80	128000.00
6	36-150-10	Formwork for centering & shuttering	sqm	23.73	350	8305.50
					Total tk. =	**237603.50**

6 Conclusion

Drainage performance is much better in the drainage improvement Option-1. However implementation of this option is largely depends on the farmer of Kismat-fultoa village. Blue Gold needs to convince the land owners to provide land for new Khal excavation to connect Konar khal and Katakhali khal. Though this improvement plan is for WMUs in Fultola village, this new khal will also improve water logging in Kismat-fultola agricultural land. At present drainage route from Kismat-fultola is around 5.5 kilometers by Konar khal, Vorakhali khal and Katakhali khal. With the proposed new khal this distance is reduced to 2.4 kilometer and consequently drainage will be improved that would reducethe crop damage.

In Option-2, drainage route length is quite high but performance is satisfactory for the selected WMUs. But this will not improve the water logging problem in surrounding area that much as by Option-1.

Actual number, length and alignment of Field channel can be varied during the time of construction according to farmers' choice.