Bangladesh Economic Zones Authority
Prime Minister's Office

DETAIL STUDY ON TOTAL WATER DEMAND AND WATER AVAILABILITY FOR SABRANG AND NAF TOURISM PARK

☑ Volume-1: Main Report

☐ Volume-2: Geotechnical Investigation Report

Revised Final Report (Phase-2)

April, 2022

INSTITUTE OF WATER MODELLING (IWM)

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LIST OF ACRONYMS AND ABBREVIATIONS

ADCP	Acoustic Doppler Current Profiler
AE	Assistant Engineer
APHA	American Public Health Association
BEZA	Bangladesh Economic Zone Authority
BIWTA	Bangladesh Inland Water Transport Authority
BM	Bench Mark
BMD	Bangladesh Meteorological Department
BNBC	Bangladesh National Building Code
BOD	Biological Oxygen Demand
BOD_5	5 Day BOD
BOQ	Bill of Quantities
BOT	Build-operate-transfer
BTM	Bangladesh Transverse Mercator projection
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
BWRO	Brackish Water Reverse Osmosis
CIP	Clean-In-Place
COD	Chemical Oxygen Demand
CTFB	Chittagong Tripura Fold Belt
DAF	Dissolved Air Flotation
DBO	Design-build-operate
DEM	Digital Elevation Model
DFR	Draft Final Report
DHI	Danish Hydraulic Institute
DI	Ductile Iron
DO	Dissolved Oxygen
DPHE	Department of Public Health Engineering
EC	Electrical Conductivity
EZ	Economic Zone
FAP	Flood Action Plan
FC	Fecal Coliform
GoB	Government of Bangladesh
GPS	Global Positioning System
GIS	Geographic information system
GDEM	Global Digital Elevation Model
GNSS	Global Navigation Satellite System
GSB	Geological Survey of Bangladesh
GW	Groundwater
HD	Hydrodynamic
HDPE	High density polyethylene
IBR	Indo-Burman Ranges
IRP	Iron Removal Plant
IWM	Institute of Water Modelling
Km	Kilometre
kWh	Kilowatt hour
m	Metre
lcpd	Litre per Capita per Day
MED	Multi-effect Distillation

MF	Microfiltration
MGD	Million Gallon per Day
MLD	Million Litter Per Day
MSF	Multi-stage Flash Evaporation
MSL	Mean Sea Level
O&M	Operation and Maintenance
PTW	Production Tube Well
PwC	PricewaterhouseCoopers Pvt Ltd
PWD	Public Works Department
PWL	Piezometric Water Level
Q	Discharge
REB	Bangladesh Rural Electrification Board
RO	Reverse Osmosis
RR	Rainfall-Runoff
RTK	Real Time Kinematic
RWHS	Rainwater harvesting System
RWH	Rainwater harvesting
SE	Superintendent Engineer
SoB	Survey of Bangladesh
SPV	Special Purpose Vehicle
SW	Surface Water
SWL	Shallow Water Level
SWRO	Sea Water Reverse Osmosis
SWTP	Surface Water Treatment Plant
TBM	Temporary Bench Mark
TC	Total Coliform
TDS	Total dissolved solids
TP	Tourism Park
TSS	Total suspended solids
TTW	Test Tube Well
TRDI	Teledyne RD Instruments
UGR	Underground reservoir
UGWR	Underground water reservoir
UTM	Universal Transverse Mercator
UF	Ultrafiltration
UWF	Unaccounted For Water
WL	Water Level
WMP	Water Management Plan
WS	Water Supply
WQ	Water Quality
WRP	Water Recourses Planning
WTP	Water Treatment Plant

EXECUTIVE SUMMARY

E.1 Introduction

With a view to encourage rapid economic development Bangladesh Economic Zones Authority (BEZA) has selected Naf and Sabrang area in Teknaf upazila of Cox's Bazar district to develop as economic zones for recreational and tourism purposes. The proposed Sabrang Tourism Park comprise an area of 1048 acres (424 hectares), 96km away from Cox's Bazar town and runs parallel to Teknaf-Shahparirdwip highway (Z1099). The proposed Naf Tourism Park is an Island to be designated as economic zone with covering an area of 271.93 acres (110 hectares) approximately 80 kms from the Cox's Bazar and besides Cox's Bazar-Teknaf National Highway (N1). The study area is shown in **Figure E.1**.

Figure E.1: Location map of the study area

The main objective of this study is to prepare a water supply master plan to fulfill water demand for Naf and Sabrang Tourism Park in the context with water availability and demand. The study work is divided in two phases. The objective of Phase-1 is to assess groundwater availability in and around the EZs particularly in Nhila, Teknaf. In Phase-2 water management plan including design of water supply related works has been completed.

The detail water demand estimation, groundwater resource assessment, assessment of roof top rainwater harvesting, desalination plant & bottling water plant, dam & reservoir analysis in Teknaf have been completed in Phase-1 and presented in Final Report of Phase-1.

The activities accomplished in Phase-2 is listed below:

- Topographic and Engineering survey along the proposed transmission main;
- Outline design of transmission main and related structures for use of groundwater ;
- Outline design of distribution line and related other structures;
- Sub-soil investigation;
- use of the proposed lake water as reservoir;
- Prepare a water zoning and phasing plan for the project area;
- Prepare a water management plan;
- Cost estimation and documentation.

The Draft Final Report of Phase-2 was submitted on 31 March 2021 and workshop was held on zoom platform on 22 April 2021. Considering the feedback from client the Final Report (Phase-2) has been prepared and submitted on 18 June 2021. Presentation meeting on the Final Report Phase-2 was held on 01 November 2021. Incorporating all the feedback from the client the Final Report has been upgraded. The response comment tables on Draft Final Report and Final Report are given in **Annex-T** and **Annex-V** respectively.

According to the feedback from client and discussion with BEZA officials, water supply system development plan is divided into two phases as shown in **Table E.1**.

Table E.1: Phasing of water supply system development plan

Phases	Period	Time
Phase -1	2022-2027	5 year
Phase -2	2031-2036	5 year

E.2 Option Analysis for Preparing Water management plan for Sabrang

Based on water availability and cost different options has been analysis for fulfilling water demand in Naf and Sabrang Tourism Park as presented in **Table E.2.**

Table E.2: Source of water under different options

Options	**Source of water**	
	Sabrang Tourism Park	**Naf Tourism Park**
Option-1	• Groundwater • Water stored in dam in Teknaf • Rainwater harvesting in the roof top of buildings • Desalination plant	• Groundwater
Option-2	• Groundwater • Rainwater harvesting in the roof top of buildings • Rainwater harvesting in lake area • Desalination plant	• Groundwater
Option-3	• Rainwater harvesting in the roof top of buildings • Rainwater harvesting in lake area • Desalination plant	• Rainwater harvesting in the roof top of buildings • Desalination plant
Option-4	• Groundwater • Rainwater harvesting in the roof top of buildings • Rainwater harvesting in lake area • Desalination plant	• Rainwater harvesting in the roof top of buildings • Desalination plant

SWOT analysis has been carried out for the three options and it has been found that Option-4 is most suitable and sustainable for water supply.

E.3 SWOT Analysis

SWOT analysis for different water supply management plant of this study is presented in **Table E.3** and **Table E.4.** From the SWOT analysis of different options, it is observed that all options have some strength, weakness, opportunity and threat. Among the options, Option-3 is most advantageous option. So, water supply through conjunctive use of desalination, rain water harvesting from roof top and lake as shown in Option-3 are most preferable.

Table E.3: SWOT analysis of water management plan

 **for** **Sabrang Tourist Park**	**Strengths (S)** ✓ Rainwater harvesting ✓ Lake water reservoir ✓ Desalination of sea water ✓ Fund availability for capital investment ✓ Assurance of water tariff	**Weakness (W)** ○ Low yield of groundwater resources ○ GW availability far away from Sabrang ○ Cost of transmission line through hilly terrain ○ Highly skill resource is required for operating desalination plant ○ High O&M cost for desalination plant
Opportunities (O) ➢ Availability of groundwater in deep aquifer ➢ Possibility of creation of small rainwater reservoir in the hilly water shade ➢ Dependency increases for desalination of sea water ➢ Partial capital cost may be imposed to the investors ➢ Efficient and economic use of all possible water resources	**Opportunity-Strength Strategies** ✚ Limited use of groundwater ✚ Small quantity from rainwater resources ✚ Desalination of sea water can meet the demand ✚ Fund available for capital investment	**Opportunity-Weakness Strategies** ✚ Monitoring of GW & cost of transmission not favorable ✚ Skill resource development for O&M of desalination plant
Threats (T) ❖ Reduce groundwater resource in future ❖ Social unrest due to carry groundwater to long distance ❖ Inconsistence annual rainfall due to climate change ❖ Deforestation in the Hilly watershed area	**Threat-Strength Strategies** ✚ Threatening to annual quantification of GW & rainwater resources ✚ New PTW need to installed for domestic usage	**Threat-Weakness Strategies** ✚ Inconsistence availability of GW & rainwater storage

Table E.4: Comparison of SWOT analysis of different water management plan options

Options	Components	S	W	O	T	Strategy
Option-1	GW from Whykhong		✓	✓	✓	➢ Highly dependent on groundwater ➢ Partial support from rainwater ➢ desalination (partial) is an opportunity in future
	Teknaf reservoir	Not ensured				
	Rainwater	✓		✓	✓	
	Desalination	✓	✓	✓		

Options	Components	S	W	O	T	Strategy
Option-2	GW from Whykhong		✓	✓	✓	➢ High dependency on groundwater ➢ Partial support from rainwater ➢ desalination (Partial) is an opportunity in future
	Rainwater from rooftop	✓		✓	✓	
	Rainwater from lake	✓		✓	✓	
	Desalination	✓	✓	✓		
Option-3	Rainwater from rooftop	✓		✓	✓	➢ Highly dependent on desalination ➢ Partial support from rainwater
	Rainwater from lake	✓		✓	✓	
	Desalination	✓	✓	✓		
Option-4	GW from Whykhong		✓	✓	✓	➢ High dependency on groundwater ➢ desalination (partial) is an opportunity in future Partial support from rainwater ➢ **Advantageous option**
	Rainwater from rooftop	✓		✓	✓	
	Rainwater from lake	✓		✓	✓	
	Desalination	✓	✓	✓		

E.4 Financial and economic Analysis

For financial and economic analysis the cost for PTW, transmission & distribution system, desalination plant, rainwater harvesting in lake, land acquisition & development has been considered.

To estimate the economic benefits from investment in water supply to the tourism parks, we have used the following parameters presented in **Table E.5**.

Table E.5: Parameters used to estimate economic benefits and costs of the project

Parameters	Value	Assumptions or unit of measurement
Price of Water per cub meter	65	taka
Systematic increase in water prices	3%	per year
Cost increase for O&M inputs	3%	per year
Elasticity of Water Demand	-0.05	Curtis, John A., 2003 "Demand for Water-based Leisure Activity", *Journal of Environmental Planning and Management*, 46(1), 65–77, Taylor and Francis Publishing.
Choke price of water	2	times the market price

Table E.6 presents the summary of the financial and economic analysis for the project.

Table E.6: Summary of Financial and economic Analysis

Items	Financial Analysis			Economic Analysis		
	Option-2	Option-3	Option-4	Option-2	Option-3	Option-4
	Million BDT			Million BDT		
Total Initial Investment	4,993.23	2,321.91	4,165.57	3,899.73	2,286.49	3,390.27
O&M Costs per year	73.80	103.04	69.85	58.48	81.65	55.35

Items	**Financial Analysis**			**Economic Analysis**		
	Option-2	**Option-3**	**Option-4**	**Option-2**	**Option-3**	**Option-4**
	Million BDT			**Million BDT**		
Present Value						
Benefits from selling water	1,240.18	1,240.18	1,240.18	1,240.18	1,240.18	1,240.18
Indirect benefits - contribution to Tourism sector				228.42	228.42	228.42
Costs of the project	3,465.21	1,559.00	3,081.96	2,715.44	1,452.66	2,482.04
NPV	(2,225.03)	(318.82)	(1,841.78)	(1,246.83)	15.94	(1,013.43)
Benefit Cost Ratio	0.36	0.80	0.40	0.54	1.01	0.59
IRR	2.66%	8.72%	3.82%	6.30%	12.15%	7.18%
Discount rate	12%	12%	12%	12%	12%	12%

It is observed that:

1. While Investment Option-3 has the least initial costs (which is 2321.9 Million BDT) its average annual O&M is the highest (which is 103.04 Million BDT per year).
2. The analysis is done up to 2051 – the life of the project assumed.
3. At price 65 taka per cubic meter of water the project is economically feasible in case of Investment Option-3 but it is not financially viable. Investment Option-3 is financially viable at a water price of 81.8 taka per cubic meter (see **Table E.7**).
4. Investment Option-2 is viable at a price of 182 Taka price per cubic meter (financially) while it is economically viable at a price of 109 taka per cubic meter of water (see **Table E.7**).
5. Investment Option-4 is viable at a price of 162 Taka price per cubic meter (financially) while it is economically viable at a price of 101.2 taka per cubic meter of water (see **Table E.7**).
6. Sensitivity of financial and economic analysis has been simulated which also shows changes in the value of parameters makes all the investment options financially infeasible except for the option-3.

Table E.7: Sensitivity of Financial and economic Analysis Results on price of water

Price of Water	**Financial Analysis**			**Economic Analysis**		
	Option-2	**Option-3**	**Option-4**	**Option-2**	**Option-3**	**Option-4**
65	0.36	0.80	0.40	0.54	**1.01**	0.59
65	0.36	0.80	0.40	0.54	**1.01**	0.59
81.8	0.45	**1.00**	0.51	0.71	**1.32**	0.77
101.2	0.56	**1.24**	0.63	0.91	**1.71**	**1.00**
109	0.60	**1.33**	0.67	**1.00**	**1.87**	**1.10**
162	0.89	**1.98**	**1.00**	**1.66**	**3.10**	**1.82**
182	**1.00**	**2.23**	**1.13**	**1.94**	**3.62**	**2.12**
190	**1.05**	**2.33**	**1.18**	**2.05**	**3.84**	**2.25**

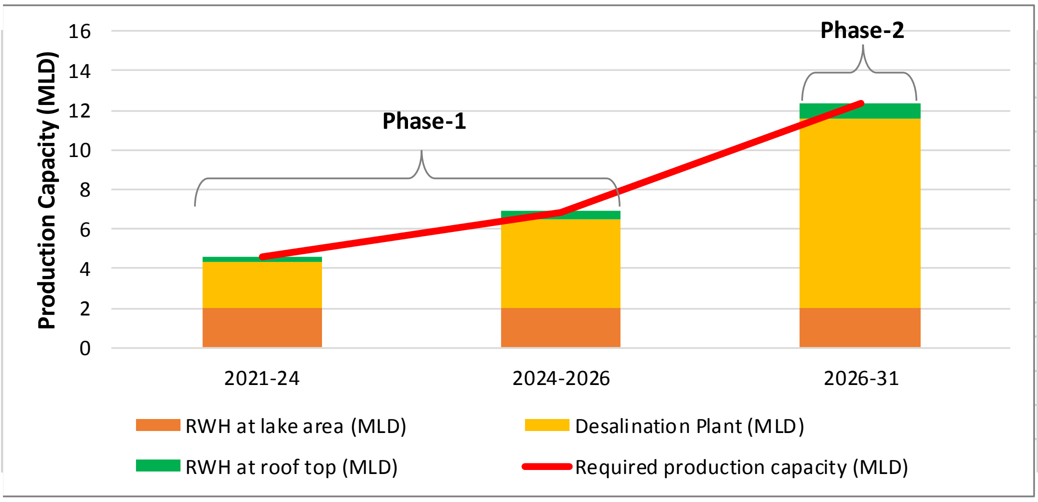
Investment Option-3 that includes desalinization plants and rainwater harvest is the most viable option for supplying water in the two EZs for developing tourism parks. The initial price of water shall be set at 82 taka per cubic meter which is about a dollar per cubic meter of water. This will ensure that there is no subsidy required for supplying water into the tourism facilities.

E.5 Preferable Water management plan for Sabrang

The different water sources that have been analyzed as most suitable area below:

- Rainwater harvesting in the roof top of building area
- Rainwater harvesting in lake area
- Desalination plant

Water supply system for different phases under Option-3 has been planned as shown in **Figure E.2**.



Planning hoizon	2021-24	2024-2026	2026-31
Water demand at user end (MLD)	3.72	5.53	9.98
Water lossess (MLD)	0.87	1.30	2.34
Required production capacity (MLD)	**4.60**	**6.83**	**12.33**
RWH at roof top (MLD)	0.24	0.38	0.73
RWH at lake area (MLD)	2.00	2.00	2.00
Gap (MLD)	2.35	4.45	9.60
Desalination Plant (MLD)	**2.35**	**4.50**	**9.60**
Production capacity (MLD)	**4.59**	**6.88**	**12.33**

Figure E.2: Preferable sources and water allocation plan for Sabrang Tourism Park

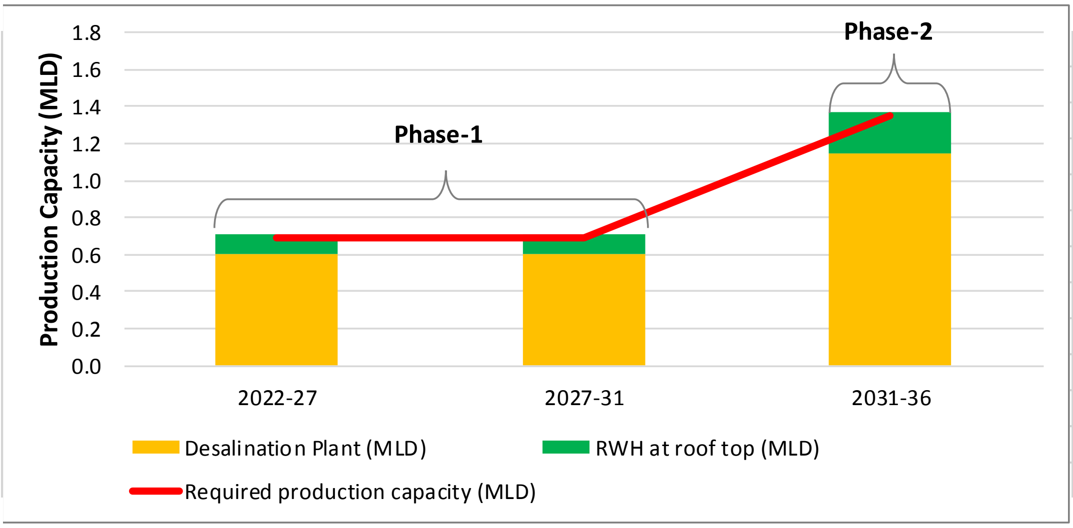
E.6 Water management plan for Naf

The different water sources that have been analyzed as most suitable area below:

- Rainwater harvesting in the roof top of building area

- Desalination plant

Water supply system for different phases under Option-3 has been planned as shown in **Figure E.3**.



Planning hoizon	2022-27	2027-31	2031-36
Water demand at user end (MLD)	0.56	0.56	**1.10**
Water lossess (MLD)	0.13	0.13	0.26
Required production capacity (MLD)	**0.69**	**0.69**	**1.35**
RWH at roof top (MLD)	0.11	0.11	0.22
Gap (MLD)	0.58	0.58	1.13
Desalination Plant (MLD)	**0.60**	**0.60**	**1.15**
Production capacity (MLD)	**0.71**	**0.71**	**1.37**

Figure E.3: Preferable sources and water allocation plan for Naf Tourism Park

E.7 Distribution Network in Naf Tourism Park

The total length of distribution network is about 10.1km in Naf Tourism Park and diameter varies from 75 to 160mm (**Figure E.4**). HDPE pipe material would be used for distribution line. Two numbers of underground water reservoir are required to store water for 2 days and supply different plots. Each reservoir will have 2 chambers. The 1st reservoir (N_ UGWR-1) will be used to supply water in Phase-1 area and the 2nd reservoir (N_ UGWR-2) in Phase-2 area. The size of reservoir N_ UGWR-1 is 18.2mx 18.2mx 5m and reservoir N_ UGWR-1 is 17.8m x 17.8m x 5m including 0.5m freeboard. 2 nos. pumps (1 on duty, 1 stand by) at 2 reservoirs will be required. The pumps will be operated for maximum 16 hour depending on demand on each phase. Moreover, for maintenance, repairing or replacement facilities one mobile pump will be kept stand by in each Tourism Park. The capacity of each pump is 0.5cusec.

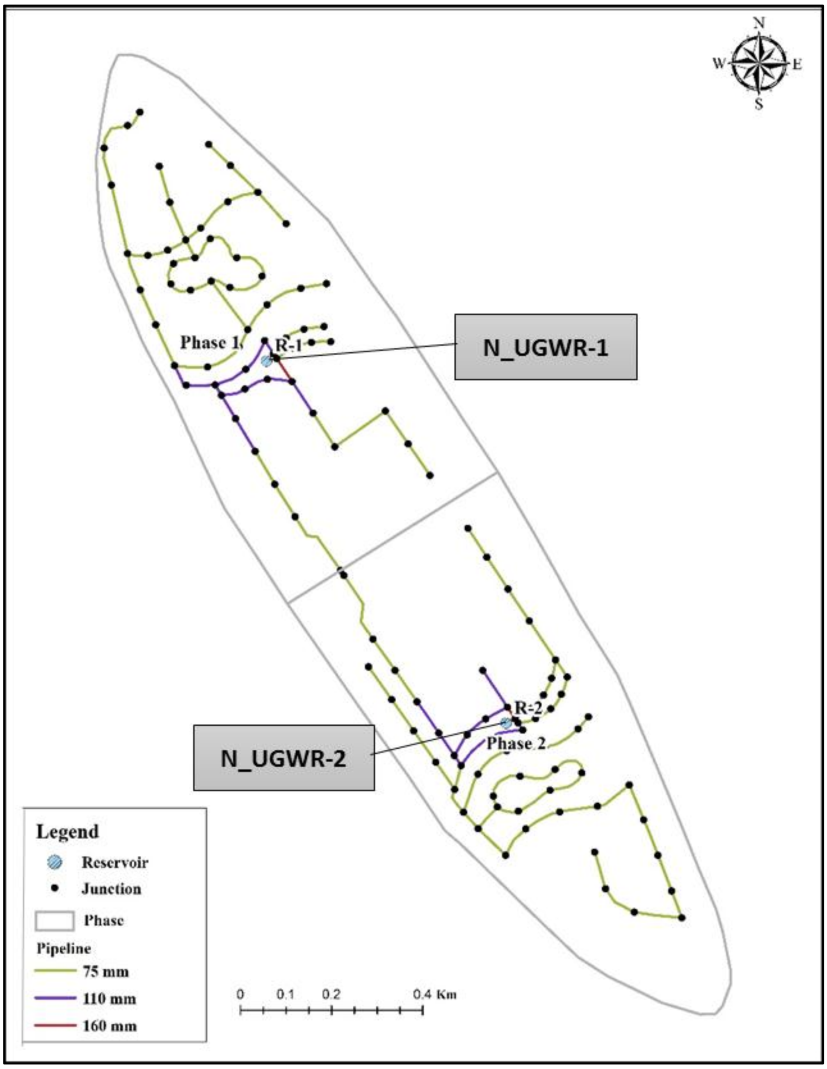


Figure E.4: Distribution network in Naf Tourism Park

E.8 Distribution Network in Sabrang Tourism Park

The total length of distribution network is about 12.11km in Sabrang Tourism Park and diameter varies from 75 to 355mm (**Figure E.5**). HDPE pipe material would be used for distribution line. Three numbers of underground water reservoir are required to store water for 2 days and supply different plots. Each reservoir will have 2 chambers. The 1st reservoir (S_ UGWR-1) will be used to supply water in Phase-1 area, 2nd reservoir (S_ UGWR-2) in Phase-2 area area and 3rd reservoir (S_ UGWR-3) in Phase-3 area. The size of reservoir S_UGWR-1 is 46.9m x 46.9m x 5m, reservoir S_ UGWR-2 is 46.4m x 46.4m x 5m and reservoir S_ UGWR-3 is 43m x 43m x 5m including 0.5m freeboard. 5 nos. pump units (4 on duty, 1 stand by) at 3 reservoirs will be required. The pumps will be operated for maximum 14 hour depending on demand on each phase. Moreover, for maintenance, repairing or replacement facilities one mobile pump will be kept stand by in each Tourism Park. The capacity of each pump is 1.0cusec.

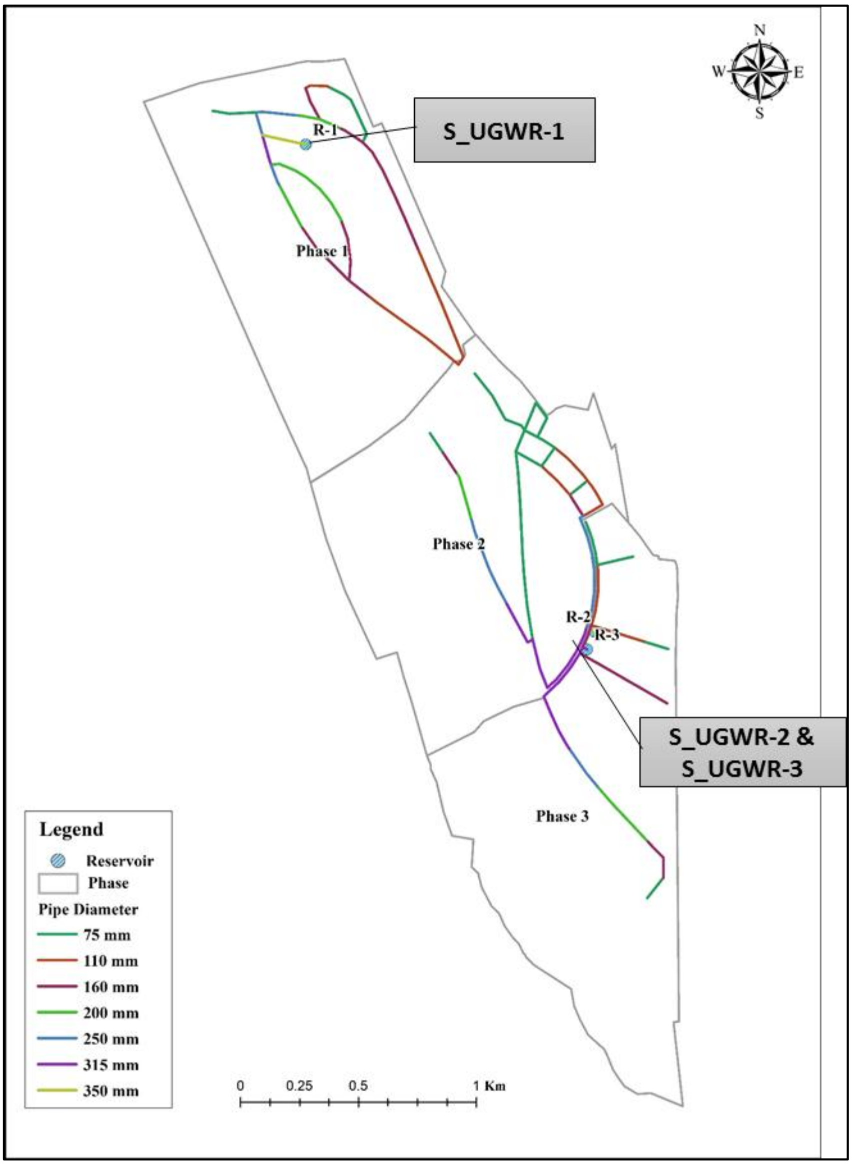


Figure E.5: Distribution network in Sabrang Tourism Park

E.9 Phase Wise Development Plan

The summary of water supply development plan for the preferable option (Option-3) at different phases are presented in **Table E.8**.

Table E.8: Phase-wise water supply development plan

Phase	Sl. No.	Interventions
Phase-1 2022-27	1	Construction/installation of 1 no desalination plant of 4.5 MLD production capacity in Sabrang TP
	2	Construction/installation of 1 no desalination plant of 0.6 MLD production capacity in Naf TP
	3	Construction of 2 nos. underground reservoir (S_UWRW-1 & S_UWRW-2) in Sabrang of dimension 45.6 mx 45.6 mx 5 m and 44.9m x 44.9m x 5m
	4	Installation of 5 nos. pumps in reservoir S_UWRW-1 of capacity 1 cusec each

Phase	Sl. No.	Interventions
	5	Installation of 3 nos. pumps in reservoir S_UWRW-2 of capacity 1 cusec each
	6	Construction of 1 no underground reservoir in Naf (N_UGRW-1) of dimension 17.8 mx 17.8 mx 5 m
	7	Installation of 2 nos. pumps in reservoir N_UWRW-1 of capacity 0.5 cusec each
	8	Laying of 6.92 km distribution line in Sabrang Tourism Park
	9	Laying of 5.14 km distribution line in Naf Tourism Park
	10	Constriction of 1no bottling water plant of capacity 4,000 liter /hour
	11	Construction of lake/water reservoir & treatment plant of capacity 2MLD
Phase-2 2031-36	1	Increase the capacity of the desalination plant by additional 5.1 MLD production capacity in Sabrang TP
	2	Increase the capacity of the desalination plant by additional 0.55 MLD production capacity in Naf TP
	3	Construction of 1 no underground reservoir (S-UGWR-3) in Sabrang of dimension 38.4 mx 38.4 mx 5 m
	4	Installation of 2 nos. pumps in reservoir S_UWRW-2 of capacity 1 cusec each
	5	Installation of 5 nos. pumps in reservoir S_UWRW-3 of capacity 1 cusec each
	6	Construction of 1 no underground reservoir in Naf (N_UGRW-2) of dimension 17.4 mx 17.4 mx 5 m
	7	Installation of 2 nos. pumps in reservoir N_UWRW-2 of capacity 0.5 cusec each
	8	Laying of 4.94 km distribution line in Naf Tourism Park
	9	Laying of 5.2 km distribution line in Sabrang Tourism Park
	10	Constriction of 1no bottling water plant of capacity 3,500 liter /hour

E.10 Cost Estimation

The tentative project cost to meet the water requirement in Sabrang and Naf Tourism Park is about 2,893 Million BDT which will be required in two phase upto full development in 2036. About 1,621 Million BDT is required in Phase-1 and 1,272 Million BDT is required in Phase-2. The summary of tentative costs in different phases are shown in **Table E.9**. The cost of reservoirs and necessary plumbing system for roof top rain water harvesting system will be carried out by the land leaser/developer.

Table E.9: Tentative cost for full filled the total water demand (Option-3)

Item No.	Description	Phase-1 (2022-27)	Phase-2 (2031-36)	Total
		Price in Million BDT		
1	Distribution network	38.0	32.1	70.2
2	Underground Water Reservoir in Tourism Parks including pump units	203.2	88.9	201.8
3	Desalination plants	871.9	887.8	1,759.8

Item No.	Description	Phase-1 (2022-27)	Phase-2 (2031-36)	Total
		Price in Million BDT		
4	Bottling water plants	227.3	191.0	418.2
5	Treatment plant for lake water	200.0	-	200.0
6	Consultancy (6%)	80.4	72.0	147.0
	Total Project Cost (Current price)	**1,621**	**1,272**	**2,893**

E.11 Summary Findings

Common findings

- Groundwater assessment in Whykhong well field has been conducted with the following findings:
  - About 6.2 MLD groundwater may be extracted from the Whykhong well field by constructing 8 nos. production tube wells.
  - Total about 42.3 km transmission main of ductile iron (DI) pipe material 400 mm is required to carry groundwater from Whykhong well field to Sabrang Tourism Park.
  - Two booster pumps would be required along the transmission main to guarantee water pressure to the desired level for uninterrupted supply.
  - Collection pipe 1 & 2 is required to carry water from the 8 nos. PTWs to booster pump station at Whykhong (BPS-1). The total length of collection pipe is 8 km and HDPE pipe would be used with diameter 200 to 315 mm.
  - As the water transmission from groundwater sources is too much high so groundwater use is not preferable for water supply in the Tourism Parks.
- To meet the drinking water requirement bottle water industry can be developed in Sabrang Tourism Park.
- Four different options has been analysis for water supply in Naf and Sabrang Tourism Park. After SWOT analysis and economic & financial analysis, option-3 has became the most viable option.
- Tentative total project cost to meet the water requirement in Sabrang and Naf Tourism Park is about 2,893 (Option-3) Million BDT which will be required in two phase upto full development in 2036. In Phase-1 1,621 Million BDT and in Phase-2 1,272 Million BDT is required.
- The O&M cost of the distribution system is about 10.23 Million BDT per year in Phase-1 and 13.23 Million BDT per year in Phase-2.
- The initial price of water under Option-3 shall be set at 82 taka per cubic meter which is about a dollar per cubic meter of water. This will ensure that there is no subsidy required for supplying water into the tourism facilities.
- Investment Option-3 is the least risk in terms of the changing financial and economic conditions.

Findings for Sabrang Tourism Park

- Under Option-3, roof top rainwater harvesting, desalination plant and water reserve in the lake are considered for fulfilling water demand in Sabrang Tourism Park.
- From roof top rainwater harvesting about 0.73 MLD can be made available for Sabrang Tourism Park and recommended for water supply.
- From the proposed lake of 50acre area about 2.0 MLD water can be available throughout the year.
- Desalination RO plant of capacity 4.5 MLD and 5.1 MLD is required in phase 1 & 2 for the preferable option (Option-3) respectively to fulfill the total water requirement in Sabrang Tourism Park.
- The length of distribution network is 12.11 km and diameter varies from 75 to 355mm.
- Three reservoirs with pump units are proposed for Sabrang Tourism Park to store water of different phases for 2 days.
- The tentative cost of roof top rain water harvesting system is 3,208 Million BDT which would be carried out by land leaser/developer.
- The O&M cost of the desalination plants for the preferable option (Option-3) is about 45 Million BDT in Phase-1 and 48 Million BDT in Phase-2

Findings for Naf Tourism Park

- Under Option-3, roof top rainwater harvesting and desalination plant are considered for fulfilling water demand in Naf Tourism Park.
- From roof top rainwater harvesting about 0.22 MLD can be made available for Naf Tourism Park.
- Two desalination RO plant of capacity 0.6 MLD and 0.55 MLD is required in phase 1 & 2 to fulfill the total water requirement in Naf Tourism Park.
- The length of distribution network is 10.1 km and diameter varies from 75 to 160mm.
- Three reservoirs with pump units are proposed for Sabrang Tourism Park to store water of different phases for 2 days.
- The O&M cost of the desalination plants for the preferable option (Option-3) is about 8 Million BDT in Phase-1 and 7 Million BDT in Phase-2

E.12 Recommendations

Recommendations for Sabrang Tourism Park

- The provision of roof top rainwater harvesting shall be kept in each building area of roof area >300m^2 from the very beginning. Otherwise, extra costing will be needed for re-designing of the plumbing system.
- The availability of water from the dam-reservoir in Teknaf is uncertain due to high water requirement of Teknaf city. So this option can be considered as supplementary only.

- Metering system shall be installed with the water supply pipeline at every buildings. In that case, BEZA should establish and follow the rules & regulations prepared and approved by the Government of Bangladesh best on WASA Act 1996.

Recommendations for Naf Tourism Park

- The provision of roof top rainwater harvesting shall be kept in each building area of roof area >300m^2 from the very beginning. Otherwise, extra costing will be needed for re-designing of the plumbing system.
- Metering system shall be installed with the water supply pipeline at every buildings. In that case, BEZA should establish and follow the rules & regulations prepared and approved by the Government of Bangladesh best on WASA Act 1996.

Recommendations for both Sabrang and Naf Tourism Park

- Water transmission from Whykhog well field is very costly due to long distance water travel. So, water supply from groundwater sources is not preferable. If water need to abstract from groundwater the following recommendation are made
  - Monitoring of water level is required to ascertain its decline at different phase of development. Monitoring of water quality is also required to ascertain any risk of salinity intrusion with development.
  - Recharge and safe limit of abstraction is required to be updated reviewing the monitoring as mentioned above.
  - Development of production tube wells in phases need to be reviewed based on the groundwater level and quality monitoring data.
  - If the shallow tube wells in the surrounding influenced area of PTW's cannot uplift water due to water table drawdown, BEZA need to construct a new PTW for domestic usage to avoid conflict. The supply system of this PTW should be operated and maintained through local administration or under respective authority.
- Power supply for underground reservoirs and BPS-2 need to be ensure during designing power supply of the Tourism Parks.
- Desalination plant is a new technology for Bangladesh, so after construction/implementation of desalination plant, its operation should be done for at least three years by the installation company. In the meanwhile, BEZA have to develop its own O&M mechanism.
- Detail field survey long the proposed distribution pipeline and design of the distribution system is required before implementation.
- A conventional treatment plant is required for using the water from the proposed lake. After constructing the reservoir the water quality of the lake has to be measure for designing the process diagram of the treatment plant and detail design.

1 INTRODUCTION

1.1 Background

With a view to encourage rapid economic development, Bangladesh Economic Zones Authority (BEZA) is establishing Economic Zones (EZs) throughout Bangladesh under the Bangladesh Economic Zones Act, 2010. BEZA aims to establish economic zones in all potential areas in Bangladesh including backward and under developed regions through increase and diversification of industry, employment, production and export. BEZA aims to establish about 100 economic zones in the country over the next fifteen years. They have selected two economic zones, Naf and Sabrang in Teknaf upazila of Cox's Bazar district. The aim to develop Jaliar Dip and Sabrang area as economic zones are to enhance recreational facilities and tourism.

Present water supply system in the surrounding area is groundwater, but comprehensive assessment of groundwater resources to ensure safe, affordable and sustainable water supply is yet to be carried out. Moreover, in dry season there is scarcity of water in many of constructed water wells and the constructed more water wells might become inoperable.

Another important observation is that the existing surface water system (khal/chhara) are not being considered for water supply to its potential mainly due to the lack of data and assessment about sustainability of water availability of these sources. In the vicinity of proposed Sabrang and Naf Tourism Park, there is no potential source of surface water which may be used to supply water. Thus, ensuring water supply become a challenge.

To ensure water supply in these two economic zones, BEZA engage Institute of Water Modelling (IWM) for water availability assessment from different potential sources and prepare water management and development plan.

1.2 Objective of the Study

The main objective of the study is to prepare a Water Supply Master Plan to fulfill water demand for Naf Tourism Park and Sabrang Tourism Park (TP) in the context with water availability and demand. The study work is divided in two phases. The objective of Phase-1 is to assess groundwater availability in and around the EZs particularly in Nhila, Teknaf. In Phase-2 water management plan including design of water supply related works will be completed.

1.3 Scope of the Study

The scope of work of the study includes, but not limited to the followings:

Phase-1

1) Examine the project site and existing situation analysis;
2) Hydrogeological investigation for groundwater resources assessment;
3) Hydraulic data collection and analysis;

4) Surface water quality assessment;
5) GIS mapping;
6) Identify possible groundwater source with relevant water quality and validate water availability in the context of development program for the project area;
7) Conduct a stakeholder workshop to share the groundwater condition for the project area and obtain feedback.

Phase-2

1) Topographic and Engineering survey;
2) Sub-soil investigation;
3) Prepare a water zoning and phasing plan for the project area;
4) Prepare a water management plan for the project on the point of environmental context;
5) Outline design of transmission and distribution line;
6) Cost estimation and documentation;
7) Conduct a training program to transfer the knowledge and capacity building of the client;
8) Conduct a stakeholder workshop to share the water supply related utility planning for the project area and obtain feedback.

1.4 Study Phasing

The study was planned to be implemented in two phases. During the study, close coordination was maintained with BEZA office in the collection of all past studies, development works of BEZA in the proposed economic zones, different water supply option analysis and interaction with relevant stakeholders.

1.4.1 Progress Achieved in Phase-1

Under the Phase-1 study emphasis has been given for water supply to the tourism park areas by harnessing mainly groundwater resources. The activities accomplished under Phase-1 are given below:

- Water demand estimation for the two tourism parks;
- Secondary lithological data collection of the study area;
- Test tube wells construction and lithological analysis at 17 locations;
- Construction of two production tube wells and two long term aquifer tests;
- Water level and discharge measurement in Naf river and analysis;
- Surface water quality sampling, testing and analysis of Naf River;
- Assessment of roof top rainwater harvesting;
- Dam and reservoir analysis in Teknaf;
- Analysis of desalination plant;
- Prepare water management plan in Sabrang and Naf tourism park;
- Tentative cost estimation.

1.4.2 Works done in Phase-2

Under the Phase-2 study the following works has been completed:

- Topographic and engineering survey along the proposed transmission main (considering groundwater as source);
- Sub-soil investigation for construction of different water supply infrastructures;
- Analysis of water availability from the proposed lake in Sabrang Tourism Park;
- Outline design of water transmission main (considering groundwater as source);
- Outline design of water distribution system;
- Zoning and phasing plan for water supply system;
- Project cost estimation.

The Draft Final Report (DFR) of Phase-2 was submitted on 31 March 2021 and workshop was held on zoom platform due to COVID situation on 22 April 2021. Officials and Consultants from BEZA and Officials from DPHE attended the workshop, and representative of IWM gave presentation of the DFR. Participates commented on the DFR and gave their suggestions to improve the report. Considering the feedback and comments from clients the Final Report (Phase-2) has been prepared and submitted on 18 June 2021. Presentation meeting on the Final Report Phase-2 was held on 01 November 2021. Incorporating all the feedback from client the Final Report has been upgraded. The response comment tables on Draft Final Report and Final Report are given in **Annex-T** and **Annex-V** respectively.

2 PRIMARY DATA COLLECTION: TOPOGRAPHIC & ENGINEERING SURVEY

2.1 Introduction

Topographic data has been collected along the transmission main as proposed in Phase-1. The data is required for outline design of transmission main, booster pump, river/khal crossing etc.

2.2 Reconnaissance Survey

Reconnaissance visit has been made in the project area and the proposed transmission main along the Cox's Bazar-Teknaf highway. The field visit took place during 15-16 November, 2020. Survey Specialist, hydrologist and water distribution network modeler visited the sites. The team visited the proposed PTW sites, reservoir area, Naf & Sabrang Tourism Park area and Cox's Bazar-Teknaf highway. Some snaps take during the visit is presented in **Figure 2.1**. The main observations during the visit are given below:

- There are many khals crossing along the Cox's Bazar-Tennaf highway.
- Most of area along the highway is flat except 0.5km road which is very steep and there is hill in one side and in another side, there is Naf River.
- In some area there is small drain along the highway.
- Near bazar areas, both sides are occupied with small katcha shops.

Figure 2.1: Some snaps take during the reconnaissance visit

2.3 Topographic & Engineering Survey

2.3.1 Survey Specification

Topographic survey has be carried out for about 48 km transmission main. Some snaps taken during the survey is presented in **Figure 2.2.** Based on the reconnaissance survey the topographic survey speciation has been made as follows:

- In flat area, road cross section @ 20m interval extended to 10m on both sides from the road line.
- In hilly area road cross section interval minimum 2 m and maximum 10 m extended to 10m on both sides from the road line.
- Cross section of khal at all khal crossing of road on both side of road.
- Structural information survey alone the road.
- Main features survey along the transmission main within the cross-section distance.

The detail survey data are presented in **Appendix A**.

Figure 2.2: Some snaps take during the engineering survey

2.3.2 Bench Mark Flying Survey

Before mobilization of the survey team, a reconnaissance survey has been conducted. Based on the reconnaissance survey, a detailed survey plan has been prepared in consultation with the team. Survey of Bangladesh (SOB) has a number of Geodetic Bench Mark in and around the project area. These BM pillars are being used as reference for the cross-section survey in Mean Sea level (MSL) datum.

For establishing vertical datum in the project area in reference of SOB pillars, experienced surveyors were deployed for BM fly using optical level. To avoid reading error three cross hair staff readings are being taken during leveling survey (BM fly) and recorded in the field book. Equal distance from the instrument for back reading and fore reading has been maintained for minimizing error. Survey has been closed from BM to BM to ensure the elevation established for TBM is consistent. These BM and TBM pillars will be used as reference for conducting cross sections and land level survey in Phase-2 of the study. List of BMs and TBM pillars kept at different locations are given in **Table 2.1**.

Table 2.1: List of SoB BM Pillars and established TBM Pillar

Sl no	ID	Location	Latitude	Longitude	RL of BM (mMSL)
1	GPS 342	The pillar is situated in the compound of Nazir Para Community Health center. It is about 200 m east of Teknaf -Shahparir Dwip road. Vill: Nazir Para, Upazila: Teknaf, District: Cox's Bazar	20°51'11.46"	92°18'11.13"	5.099
2	GPS 330	The pillar is situated west bank of a pond in front of Palongkhali Pukurpar Mosque. It is about 150m east of Taknaf- Cox's Bazar road and east side of Palangkhali Bazar. Vill: Palongkhali, Upazila: Ukhia, District: Cox's Bazar	21°08'37.80"	92°09'37.19"	5.0089
3	GPS 344	The pillar is situated in the compound of Khunkar Para Cyclone Shelter. It is 27 m north-east from the south end of the entrance stair of the cyclone shelter and 800 m south from sea beach. Vill: Khunkar Para, Upazila: Teknaf, District: Cox's Bazar	20°50'37.23"	92°16'52.72"	3.0522
4	BM 1416	The pillar is situated in the compound of BWDB Office, about 12.5m east side of Teknaf - Cox's Bazar road and 1m north of south boundary wall. Vill: Barai Tali, Upazila: Teknaf, District: Cox's Bazar	20°53'32.48"	92°17'28.80"	4.5219
5	BM 1417	The pillar is situated in the compound of Damdamia Jame Mosque, north west corner of Damdamia BDR check post and west side of Teknaf - Cox's Bazar road	20°55'43.69"	92°15'51.00"	6.6862
6	BM 1418	The pillar is situated about 3.5m north from southern building of Nhaikong Khali Govt. Primary School & 5.5m east from northern building, which is north west corner of Moulovi Bazar. Vill: Nhaikong Khali, Upazilla: Teknaf, District: Cox's Bazar	21° 1'55.87"	92°14'27.06"	2.0185

Sl no	ID	Location	Latitude	Longitude	RL of BM (mMSL)
7	BM 1420	The pillar is situated in the compound of Whaikong School & College. The pillar position is east side of pond, middle of Primary school building & college office. North side of Whaikong- Shaplapur road, Vill: Whaikong, Upazilla: Teknaf	21° 6'56.26"	92°11'43.70"	5.5767

Projection System

Bangladesh Transverse Mercator (BTM) projection has been used during the survey. The parameters used in BTM projection system are shown below:

Conversion parameter from WGS-84 Ellipsoid to Local Ellipsoid (Everest 1830)

Everest-1830 ellipsoid

Semi-major axis a = 6,377,276.34518 m

Semi-minor axis b = 6,356,075.41511 m

Inverse flattening 1/f = 300.8017

Datum Transformation Parameters

Method	:	Seven Parameters
Rotation X	:	0
Rotation Y	:	0
Rotation Z	:	0
Translation X	:	-283.729 m
Translation Y	:	-735.942 m
Translation Z	:	-261.143 m
Scale	:	0 ppm

Projection parameter

Projection method	:	Transverse Mercator
Latitude of origin	:	0° N
Central meridian	:	90° E
False Northing	:	-2,000,000 m
False Easting	:	500,000 m
Scale factor	:	0.9996

2.3.3 Cross section survey of Road

According to the specification mentioned above (sec. 2.3.1), about 1078 nos. of road cross section along the proposed transmission line has been surveyed (**Figure 2.3**). The longitudinal profile of road center line, left and right edge of road is presented in **Figure 2.4**. The elevation of road center line along the proposed transmission line varies from 2.04 to 24.78mMSL. The higher elevation area represents hilly areas along the proposed transmission line. The hill area is located about 1.5 km north of Teknaf Pourashava.

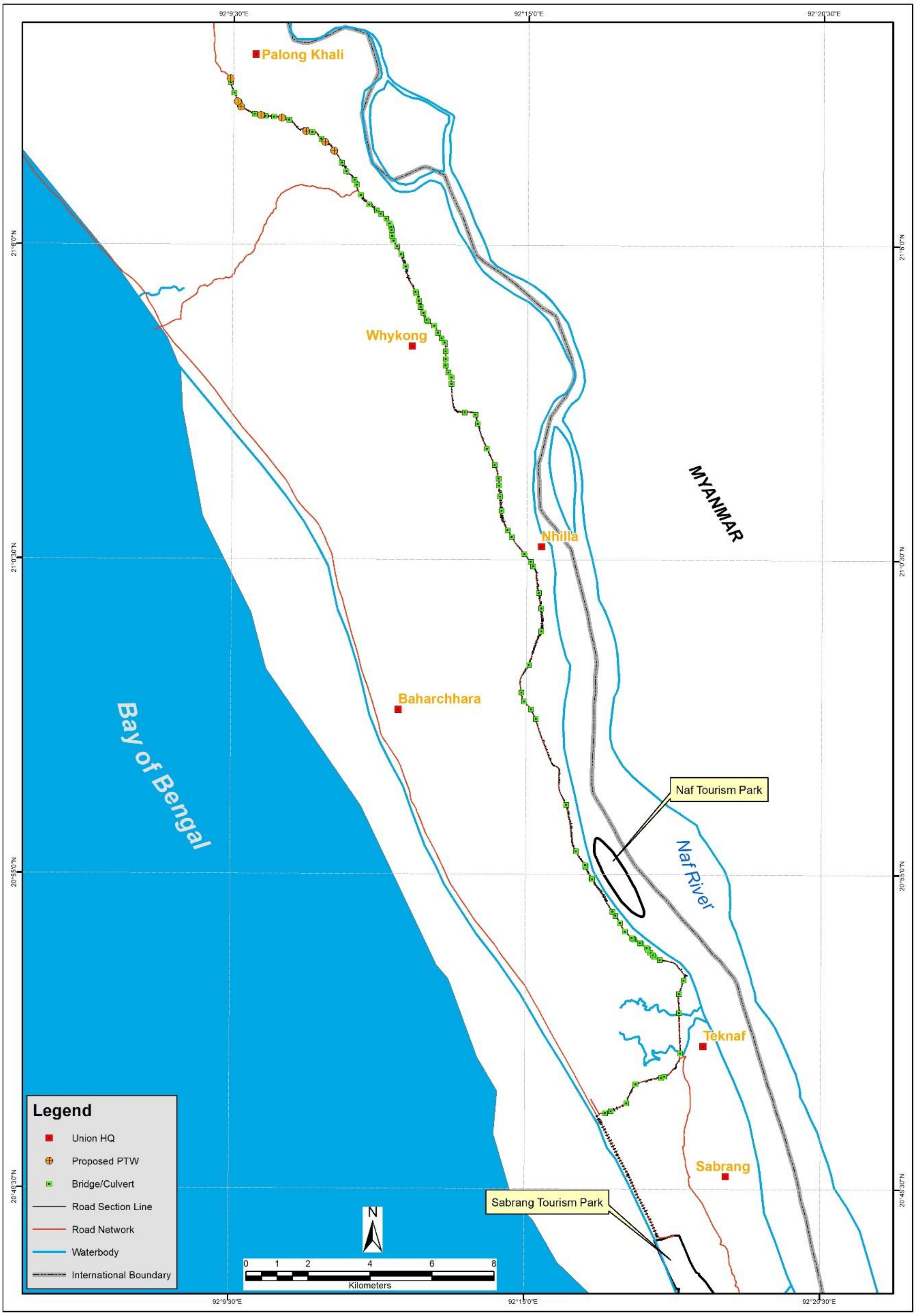


Figure 2.3: Engineering survey location map

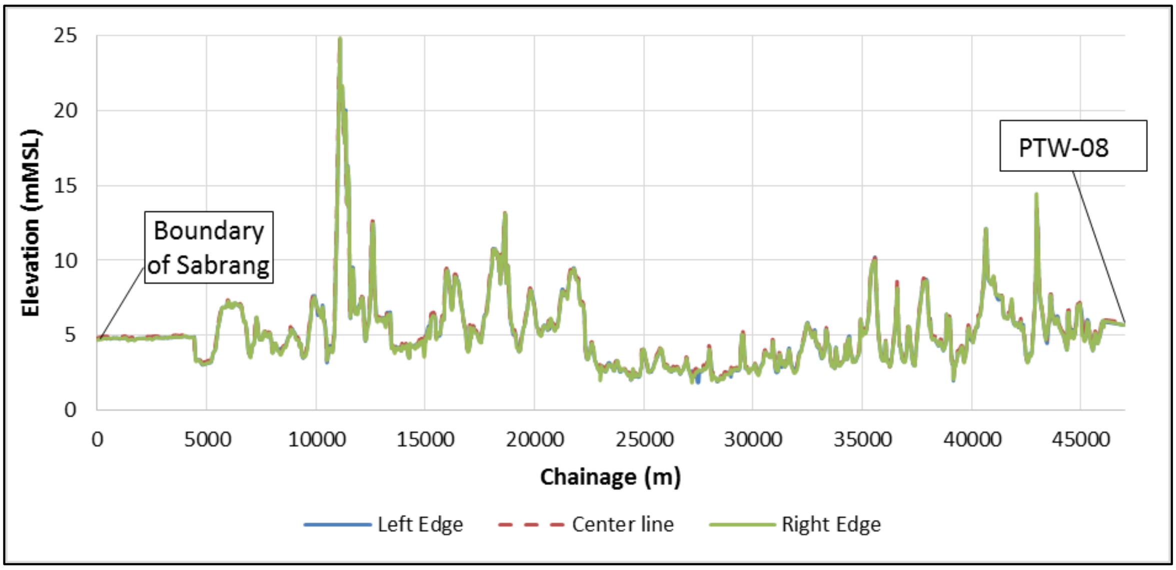


Figure 2.4: Longitudinal profile of road from Sabrang to PTW-08

2.3.4 Structural information survey

Along the proposed transmission line, the survey team identified 107 nos. of structures. Among these structures there are 73 nos. of box culvert and 34 nos. of bridge. The inventory of structures is given in **Appendix B**.

2.3.5 Cross section survey of Khals

Along the proposed transmission line, the survey team has identified about 61 nos. of khals. On each khal there exists box culver or bridge. The cross section of each khal near the structure has been surveyed. Some cross sections are given in **Figure 2.5**. The list of khals and cross sections are given in **Appendix C**

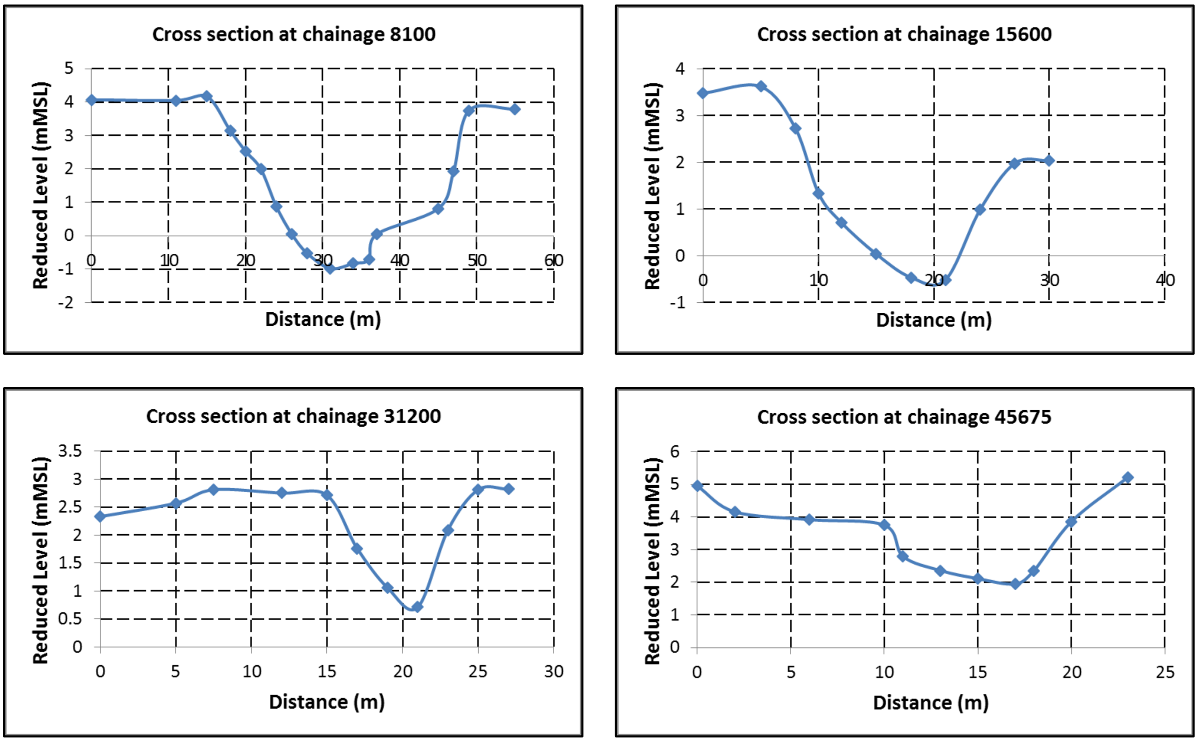


Figure 2.5: Some cross section of khal

2.3.6 Features survey

Along the proposed transmission line, the survey team has surveyed the features on both sides of the roads up to 10m from road edges. Within this boundary, there is no squatters/house, commercial structures (except some shops), office building or school/college. The features that have been identified are given in **Table 2.2**.

Table 2.2: List of features identified along proposed transmission line

Feature Type	Structure Count	Remarks
Electric Pole	1239 nos.	
Mobile tower	5 nos.	
Mosque/Ojukhana/Madrasa	5 nos.	
Manhole	23 nos.	
Boundary Wall	81 nos.	Total length=6445m
Road protection wall	14 nos.	Total length=831m
HPB (Pacca shop)	31 nos.	
HTS (Tin shed shop)	93 nos.	
HSP (Semi pacca shop)	54 nos.	
Tree	1234 nos.	
Tube well	7 nos.	
Telephone pole	19 nos.	
Lamp post	83 nos.	
Submerged pump	4 nos.	
Drain	34 nos.	Total length=2767.7m
Dustbin	4 nos.	
Grave yard	3 nos.	
Pond	13 nos.	
Box culvert/bridge	107 nos.	
BGB check post	3 nos.	

3 DESIGN OF WATER TRANSMISSION MAIN FOR GROUNDWATER USE

3.1 Introduction

The potential groundwater source was explored at Whykhong, Teknaf to supply water in Sabrang and Naf Tourism Park. This well field area is about 30 km and 45 km away from Naf and Sabrang Tourism Park respectively. In order to facilitate potable water in these Tourism Parks, water have to transmit from Whykhong to Naf and Sabrang Tourism Park. The water is planned to store in underground water reservoirs (UGWR) to be built in proposed area of Naf and Sabrang Tourism Park first and then distributed at different user nodes through distribution system.

For carrying water to the designated underground water reservoirs (UGWR) in the tourism park areas total about 56 Km transmission pipe line including collection pipe line for the proposed 8nos. production wells (PTW) will be required along with two (2) booster pumping stations (**Figure 3.1**). This chapter describes all the aspects about modelling and design of this water transmission main including the collection system.

Figure 3.1: Base Map of Transmission Main

3.2 Water Sources and Demand Allocation

The proposed eight (08) Production Tube wells (PTWs) at Whykhong well field area will be the main source of water for Naf and Sabrang Tourism Park. This well field will produce about 6.20 MLD water. Moreover, Teknaf SWTP will be another source which will supplement 1.48 MLD water for only Sabrang Tourism Park. The transmission main will supply about 1.04 MLD water to the Naf Tourism Park and about 6.6 MLD water to the Sabrang Tourism Park. The schematic of the sources and demand allocation is shown in **Figure 3.2**.

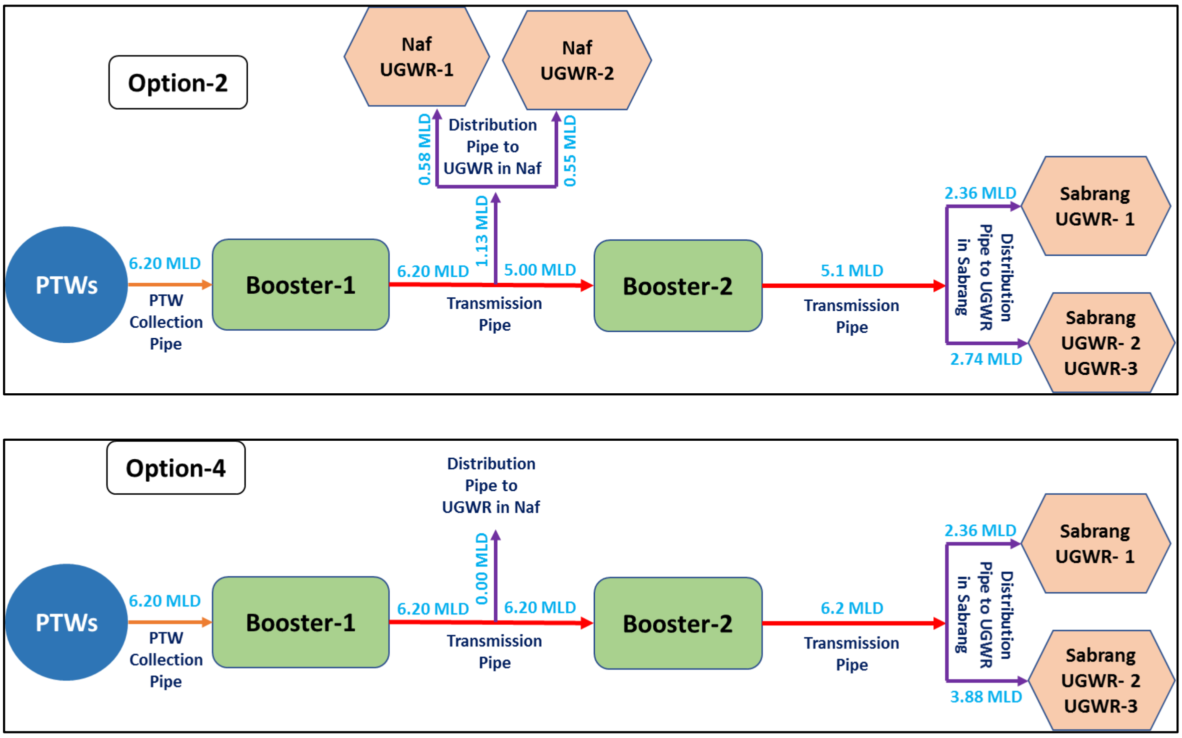


Figure 3.2: Schematic of the Sources and Demand Allocation

However, **Table 3.1** shows phase wise flow requirement for Tourism Parks in transmission main.

Table 3.1: Phase-wise Flow Requirement for Tourism Parks in Transmission Main

Particular	Development Horizon		
	Phase 1	Phase 2	Total
	2022-2027	2031-2036	2022-2036
Production from PTWs (MLD)	3.1	3.1	6.2
Flow for Naf and Sabrang (MLD)	3.1	3.1	6.2
Flow to NAF (MLD)	0.58	0.55	1.13
Flow to Sabrang (MLD)	2.53	2.56	5.1

3.3 Design Philosophy

The transmission main will facilitate about 1.04 MLD in Naf Tourism Park and 6.6 MLD water in Sabrang Tourism Park. But these tourism parks need water in different phases. Such as Naf Tourism Park requires about 1 MLD water in 3 (three) phases where about 0.53 MLD water is required in 2020-2029. On the other hand, Sabrang Tourism Park requires 6.51 MLD water in 6 (six) phases where about 1.33 MLD water is required in 2020-2024 and 1.38 MLD water is required in 2025-2029. But, full development in Naf and Sabrang will be finished in 2049.

So up to year 2029, the two-tourism parks require only about 1.9 MLD water. The remaining amount of water will be supplied phase by phase within year 2049. That's why it will be wise to plan 2 (two) nos. PTW collection line for different phases. The collection line-1 will collect the water from PTW 4, 5, 7, 8 and collection line-2 will collect the water from PTW 1, 2, 3, 6.

For that instance, it seems to plan different transmission lines for different phases but it will not be a wise decision as construction of phase-wise transmission lines will be difficult in Cox's Bazar-Teknaf highway where about 107 nos. natural water bodies and local depressions will need to be crossed and phase-wise transmissions will be costlier than a single transmission line. Beside this, O&M of transmissions will be a difficult task. For these reasons, a single transmission line from Whykhong to Sabrang with 2 (two) booster pumping station is planning for the water transmission. For different phases water will be supplied by controlling operation hours of booster pumping stations.

So, total 6.2 MLD water from Whykhong well field will be transmitted ultimately in the year 2049. That's why the design horizon for the transmission line will be 2049.

3.4 Modelling Principles and Objective

The aim of modelling is to prepare a lay-out design for water transmission main form Whykhong to Naf and Sabrang Tourism Park. Basic principles are:

- Ensure continuous supply of safe drinking water of enough quantity to the consumers
- Be economically and financially viable, ensuring sufficient income for the upkeep and extension of the system
- In addition to these major concerns there are some secondary priorities which have also been considered for the design which are-
  - The system should have enough spare capacity to operate in an emergency
  - The system should have an enough degree of "flexibility"
  - The capacity of the major components of the system should be such that it can perform satisfactorily at least up to 50 years.
  - Design Model should carefully consider the significant constructions difficulties and provide tangible solution.

3.5 Design Considerations

Considerations for the transmission model are as follows.

- Design Horizon for Transmission Line: 50 years
- Design Horizon for PTW Collection Line: 2027 for PTW 4, 5, 7, 8
  2036 for PTW 1, 2, 3, 6
- Pipe material: Ductile Iron (DI) and High-Density Polyethylene Pipe (HDPE)
- Wall Roughness co-efficient of DI pipe: 0.5 mm

- Hazen-William co-efficient: 100 in transmission and 110 in collection line
- Maximum head available at treated water pump station: 6 bar
- Maximum permissible velocity: 1.5 m/s
- Maximum head loss in Transmission Line: 2 m/km
- Maximum head loss in PTW Collection Line: 5 m/km
- Minimum head near Booster Pumping Stations: 0.3 bars
- For design purpose model will consider following range of design pressure gradients and pipe velocity provides in **Table 3.2.**

Table 3.2: Design Pressure Gradient and Velocity for the Distribution Network

Pipe Diameter (mm)	Design Pressure Gradient (m/km)	Design Velocity (m/s)
150	4 – 5	≈ 0.5
200	2 – 5	≈ 0.5
250	1.5 – 5	≈ 0.5
300	1 – 5	0.5-1.0
≥400	0.5 – 2	0.5-1.5

3.6 Criteria for Selection of Transmission Route

Route of treated water transmission main should be selected based on following considerations:

- Avoid land acquisition
- Avoid busy roads so that disturbance to traffic movement is minimized
- Minimum under and above ground obstruction
- Follow wider roads so that the line can be laid by not disturbing existing other utilities
- Minimum disturbance of traffic movement
- Straightness of pipeline to minimize head loss

The water transmission lines will follow Cox’s bazar-Teknaf Highway and Marin Drive Road from Teknaf-Sabrang. In this alignment around 107 nos. natural water bodies and local depressions will need to be crossed and there is a hilly region near Teknaf.

3.7 Design Parameters

3.7.1 Pipe Material for Transmission Line

The pipe materials considered for treated water transmission main (diameter ≥350 mm) are as follows:

- Ductile iron (DI)
- Steel
- Glass fiber reinforced plastic (GRP)

These pipes are not locally available but available in international market. The summary of the advantages and disadvantages of different proposed types of pipes are follows:

Ductile Iron Pipe

- High mechanical strength and toughness, easy jointing, flexible joints can tolerate some deflection, easy to repair
- Can be cut in the field
- Restrained can be accomplished with restrained joints
- Required little support from pipe surround materials
- Possibility of corrosion if internal and external protection system are damaged

Steel Pipe

- High mechanical strength and toughness
- Flexible
- Welded joints require skilled welders and special equipment
- Susceptible to corrosion if protection system is damaged
- Require cathodic protection
- Reliant on stable soil support

Glass Fiber Reinforced Plastic Pipe

- Corrosion resistant
- Relatively light weight
- Easy of jointing
- Flexible joint can tolerate some deflection
- Susceptible to impact damage
- Reliant on support soil
- Retrospective installation of fittings/ repair complicated
- Susceptible to structural degradation by certain organic contaminants

Recommendation: Ductile Iron (DI) pipe has been considered for design of transmission main as these pipes are semi rigid pipes, characteristically strong and tough and able to withstand earth and live loads with little support from soils. On the other GRP and steel pipes are both flexible pipes and rely heavily on soil support and are therefore not recommended for the project. However, in case of cannel/culvert and other crossings steel pipes may be used.

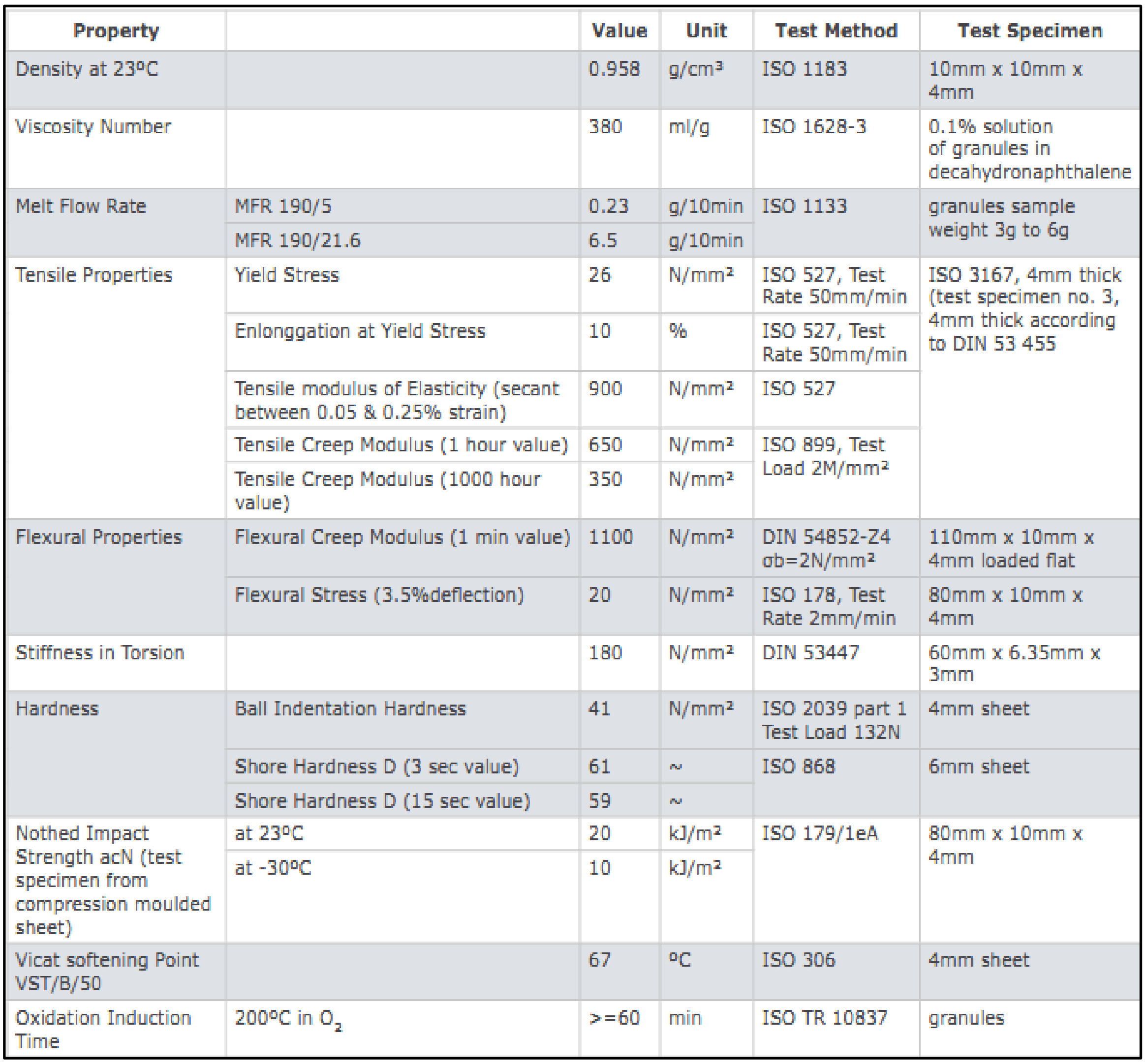
Diameter of DI Pipes in the model are considered as per standard of ISO 2531 with thickness class of K9. Again, flanged pipes shall be used for exposed pipe and shall conform to ISO 2531 with thickness class of K12.

3.7.2 Pipe Material for PTW Collection Line and Distribution Lines

HDPE and uPVC pipe are in active consideration for PTW collection line and transmission lines in tourism parks (diameter < 350 mm). uPVC pipe is locally available but have some disadvantage like lack of sustainability and this pipe is leak prone. On the other hand, HDPE pipe has more flexibility and sustainability than uPVC pipe. Moreover, horizontal directional drilling (HDD) pipe laying method can be adopted by using HDPE pipe which requires less time of implementation than the open excavation pipe laying method.

Recommendation: Considering project perspectives, HDPE pipe has been considered for development of hydraulic model for PTW collection lines and distribution lines. In selection of HDPE pipe, other issues such as design life, tensile strength, joint strengths etc. were also considered.

Figure 3.3 shows Engineering properties of HDPE pipe.



Property		Value	Unit	Test Method	Test Specimen
Density at 23ºC		0.958	g/cm³	ISO 1183	10mm x 10mm x 4mm
Viscosity Number		380	ml/g	ISO 1628-3	0.1% solution of granules in decahydronaphthalene
Melt Flow Rate	MFR 190/5	0.23	g/10min	ISO 1133	granules sample weight 3g to 6g
	MFR 190/21.6	6.5	g/10min		
Tensile Properties	Yield Stress	26	N/mm²	ISO 527, Test Rate 50mm/min	ISO 3167, 4mm thick (test specimen no. 3, 4mm thick according to DIN 53 455
	Enlonggation at Yield Stress	10	%	ISO 527, Test Rate 50mm/min	
	Tensile modulus of Elasticity (secant between 0.05 & 0.25% strain)	900	N/mm²	ISO 527	
	Tensile Creep Modulus (1 hour value)	650	N/mm²	ISO 899, Test Load 2M/mm²	
	Tensile Creep Modulus (1000 hour value)	350	N/mm²		
Flexural Properties	Flexural Creep Modulus (1 min value)	1100	N/mm²	DIN 54852-Z4 σb=2N/mm²	110mm x 10mm x 4mm loaded flat
	Flexural Stress (3.5%deflection)	20	N/mm²	ISO 178, Test Rate 2mm/min	80mm x 10mm x 4mm
Stiffness in Torsion		180	N/mm²	DIN 53447	60mm x 6.35mm x 3mm
Hardness	Ball Indentation Hardness	41	N/mm²	ISO 2039 part 1 Test Load 132N	4mm sheet
	Shore Hardness D (3 sec value)	61	~	ISO 868	6mm sheet
	Shore Hardness D (15 sec value)	59	~		
Nothed Impact Strength acN (test specimen from compression moulded sheet)	at 23ºC	20	kJ/m²	ISO 179/1eA	80mm x 10mm x 4mm
	at -30ºC	10	kJ/m²		
Vicat softening Point VST/B/50		67	ºC	ISO 306	4mm sheet
Oxidation Induction Time	200ºC in O_2	>=60	min	ISO TR 10837	granules

Figure 3.3: Engineering Properties of HDPE Pipe

Accurate internal Diameter of different sizes of HDPE Pipes of specification PE 100 (PN 10) SDR 17 as per the standard ISO 4427-2: 2007(E) was used in the model, which is presented in **Table 3.3**.

Table 3.3: HDPE PE 100 (PN 10) Internal Diameter in (mm)

HDPE Piped Dimensions				
Nominal outside Diameter	Mean outside Diameter	Nominal wall thickness (mm) SDR 17 (S 8) PE 100 (PN 10)		Internal Diameter (mm)
DN	dim, min	e min	e max	
75	75	4.5	5.1	65.4
110	110	6.6	7.4	96
160	160	9.5	10.6	139.9
200	200	11.9	13.2	174.9
250	250	14.8	16.4	218.8
315	315	18.7	20.7	275.6

3.7.3 Roughness Coefficient and Minor Loss

The standard Hazen-William Coefficient (C) for HDPE and DI pipe is 150 for new and smoother pipes. Generally, it is considered that HDPE and DI pipe has a smooth internal diameter and maintains its flow capability over time. Hazen Williams's factor remains 150, even after years of use. Nevertheless, the aging effect on the roughness might get come along, so this fact should be taken into consideration. The losses in the pipes comes not just from the friction between water and internal wall but also on local points along the pipe network such as tees, elbows, valves and etc. These losses are called minor losses. Minor losses have not been counted within model, but their effect has been incorporated in final value for Hazen - William's coefficient C. In this stage, it's not possible to calculate exact value for coefficient C, because the exact value can only be estimated by calibrating the model using observed data on the field. These observed data now don't exist, thus, an approximate value of Hazen Williams co-efficient has been used. In the modelling, Hazen Williams C value has been considered as 110 for HDPE pipe considering the pipe friction with the inclusion of all sort of minor losses are possible. For DI pipe in transmission line, Hazen Williams C value has been considered as 100 to address minor losses in about 110 nos. water body crossings.

3.8 Model Development

3.8.1 Network Digitization

The pipe network has been digitized from available road network information. Network data describes all physical components of the water supply system and defines how those elements are interconnected. Networks are made up of nodes and links. Nodes represent water system features at specific locations and links define relationships between nodes. Network data can include traditional data mainly composed of two primary types – pipe and node data.

3.8.2 Nodal Elevation data

Nodal elevation has been assigned from topographic survey data. For design purpose, the proposed road crest level has been considered as base. For pipe sizing, pipe is considered to be laid 1.5m below of road surface level. Generally, a gradient of 0.2% to 0.3% in ascending sections and 0.4% to 0.6% in descending sections is recommended for transmission line. However, pipe gradient should be addressed properly during detailed designing.

3.8.3 Source Assign and Nodal Demand

Two collection lines will carry separately 3.10 MLD each from eight PTW. That's why these PTWs are the sources for PTW collection lines. These PTWs will feed to an underground water reservoir with necessary boosting arrangement at Whykhong. From this reservoir 6.2 MLD water will be transmitted to designated UGWR in Naf and Sabrang Tourism Park by about 45 Km transmission pipe line. The Booster Pumping Station-1 at Whykhong will be the source of transmission line. Another source for the transmission line is Teknaf SWTP which will supplement 1.48 water in transmission line near Teknaf Truck Stand. In order to alleviate pressure for pipe head loss, in transmission line the second booster i.e., Booster Pumping Station-2 with an underground water reservoir will be required near the Teknaf ferry ghat. The UGWR at Booster Pumping Station-2 will reserve the transmitted water of Booster Pumping Station-1 and will feed the transmission line later on.

Demands can be allocated to the junctions using various methods. In the hydraulic model for transmission line, nodal demand has been allocated considering the phases' demand of Naf and Sabrang Tourism Parks. Details of nodal demand allocation in Model is provided in **Table 3.4.**

Table 3.4: Details of Nodal Demand Allocation

Demand Node Description	Location	Nodal Demand (MLD)
UGWR-1 for Phase-1 area	Naf Tourism Park	0.58
UGWR-2 for Phase-2 area	Naf Tourism Park	0.55
UGWR-1 for Phase-1 area	Sabrang Tourism Park	2.36
UGWR-2 for Phase-2 area UGWR-3 for Phase-3 area	Sabrang Tourism Park	2.74

3.8.4 Pump Data

In model, 0.5 cusec flow capacity is considered for each PTW. Based on aquifer test information of the Pumping well at Katakhali, Whykhong, Teknaf, pumping level in model is considered as 40 m below from ground level. As each collection pipe lines will collect water from series of four nos. DTWs, discharging head of pumps will be variable in order to maintain efficient pressure platform. Details of pump head considered in model for PTWs is provided in **Table 3.5.**

Table 3.5: Details Pump Head Considered in Model for PTWs

PTW No.	Pump Head (mH_2O)	Minimum Discharging Head (mH_2O)
PTW-1	45.00	5.00
PTW-2	45.00	5.00
PTW-3	45.00	5.00
PTW-4	50.00	10.00
PTW-5	50.00	10.00

PTW No.	Pump Head (mH_2O)	Minimum Discharging Head (mH_2O)
PTW-6	55.00	15.00
PTW-7	55.00	15.00
PTW-8	55.00	15.00

For Booster Pumping Station at Whykhong (BPS-1), pump head is considered as 50 mH_2O while minimum discharging head is 45 mH_2O. For Booster Pumping Station near Teknaf Ferry Ghat (BPS-2), pump head is considered as 45 mH_2O while minimum discharging head is 40 mH_2O.

3.9 Output of Hydraulic Model

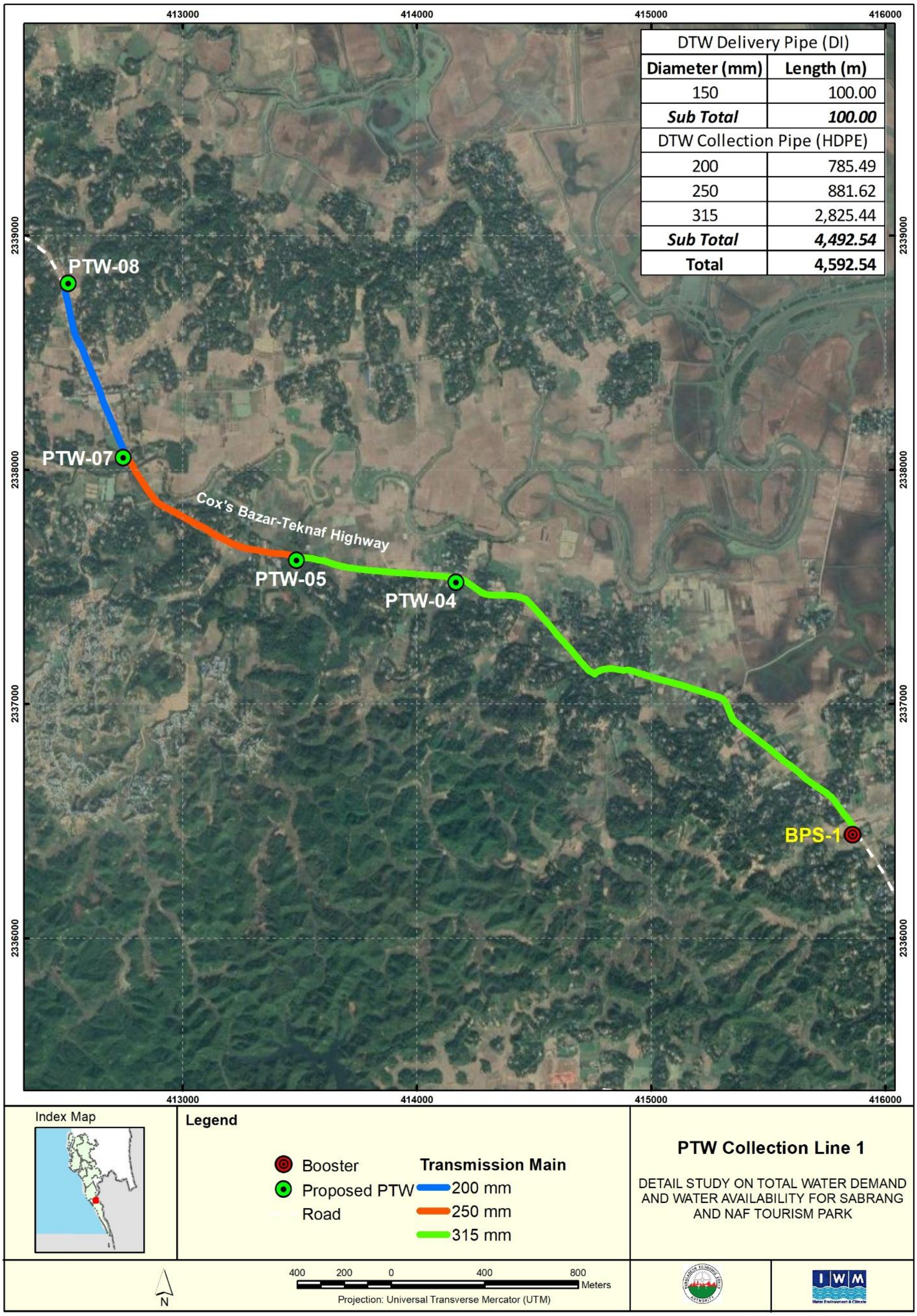
Networks pipe sizing have been done for specific hydraulic criteria and improved by giving several trials. The final pipe size found from model for PTW collection lines and transmission main are provided in **Table 3.6** and **Table 3.7.** The Pipeline layout is shown in **Figure 3.4** to **Figure 3.8**. However, pipe lengths may vary during construction period based on field condition.

Table 3.6: Diameter wise Pipe size found from Model for PTW Collection Line

DTW Delivery Pipe (DI)	
Diameter (mm)	**Length (m)**
150	171.79
Sub Total	***171.79***
DTW Collection Pipe (HDPE)	
200	3,123.84
250	1,634.15
315	3,253.38
Sub Total	***8,011.36***
Total	**8,183.16**

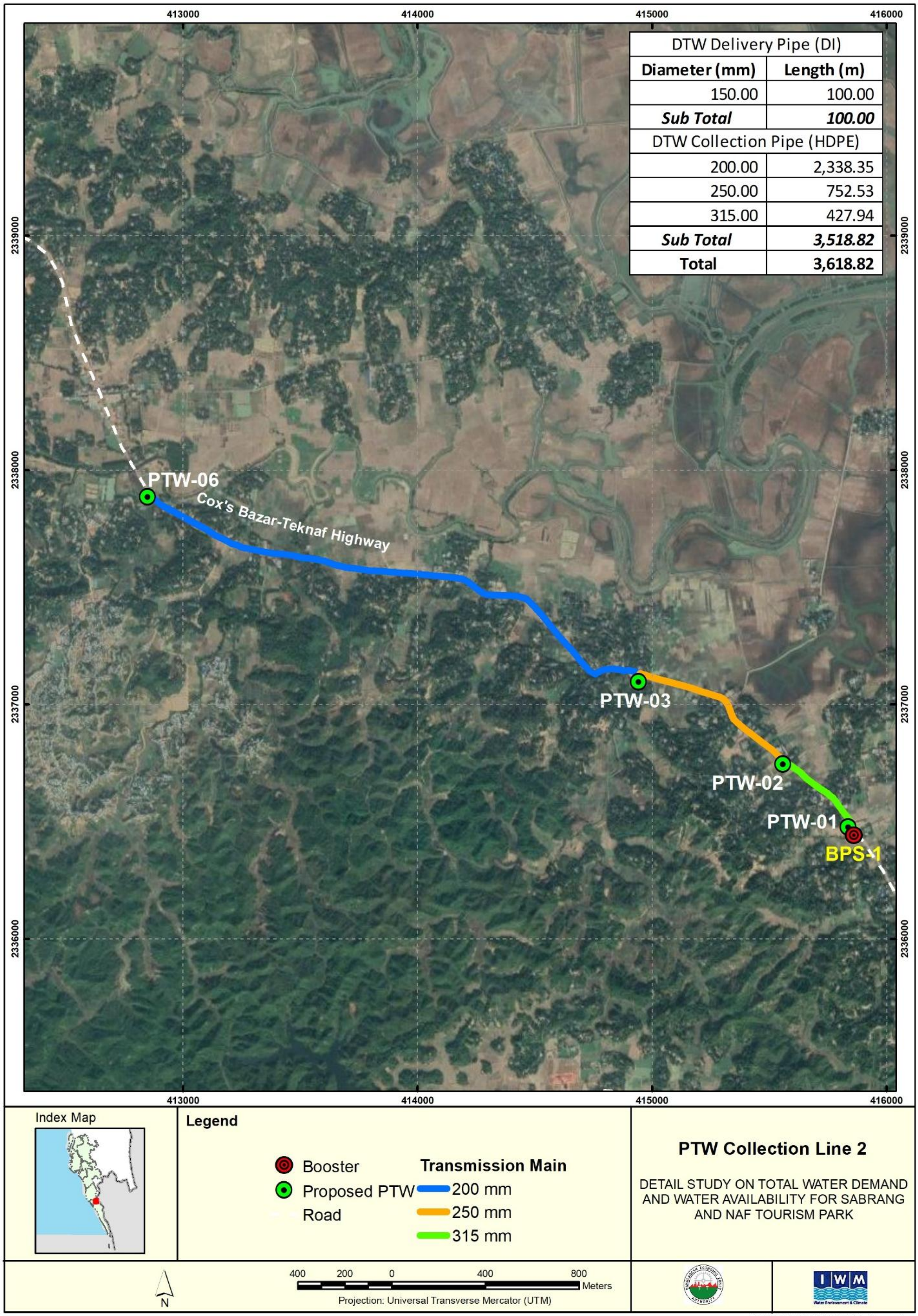
Table 3.7: Diameter wise Pipe size found from Model for Transmission Main

Transmission Line (DI)	
Diameter (mm)	**Length (m)**
400	42,249.85
Sub Total	***42,249.85***
Transmission in Naf (HDPE)	
160	1,593.09
200	959.83
Sub Total	***2,552.92***
Transmission in Sabrang (HDPE)	
250	178.06
3150	2,701.42
Sub Total	***2,879.48***
Total	**47,682.25**



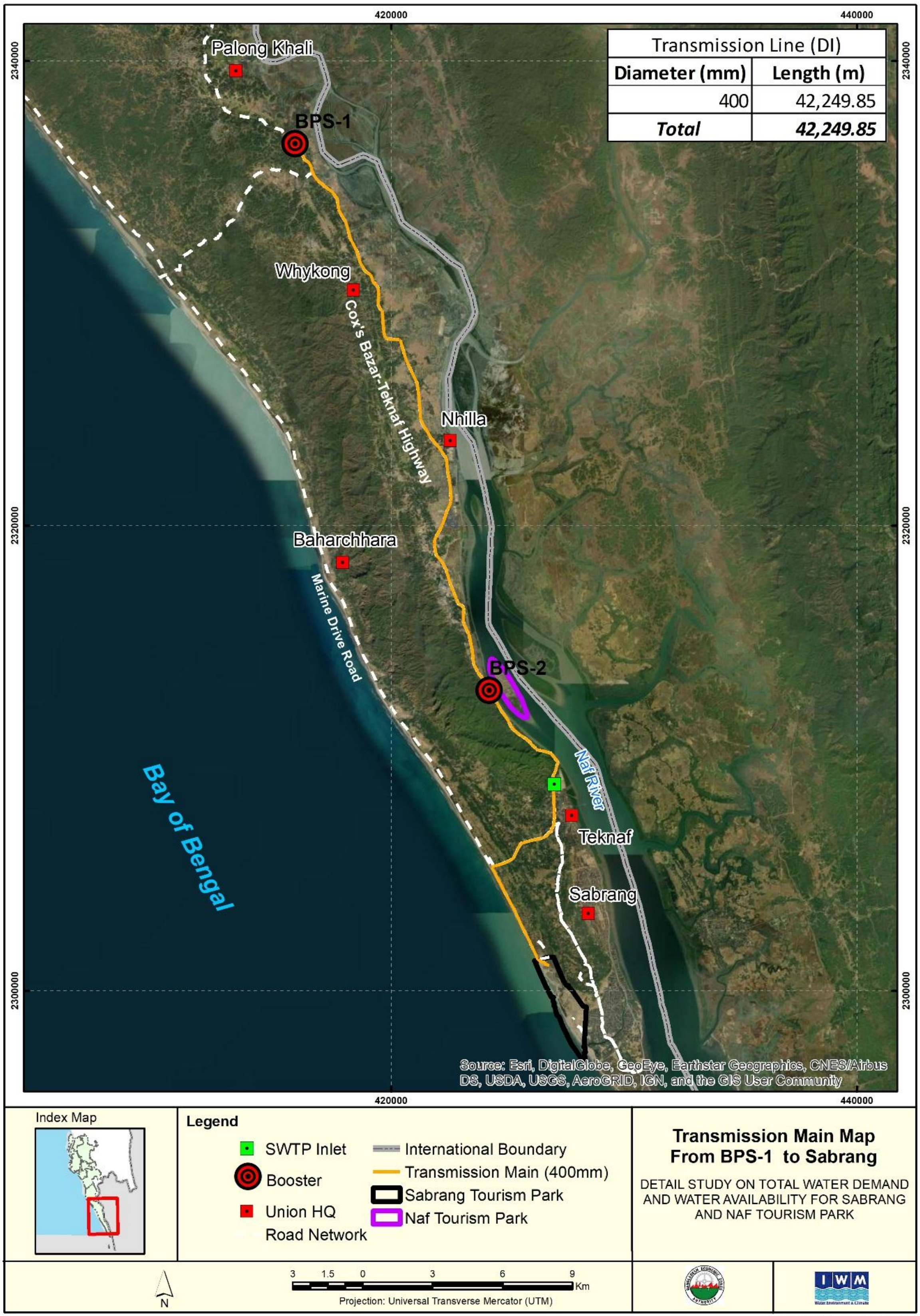
DTW Delivery Pipe (DI)	
Diameter (mm)	**Length (m)**
150	100.00
Sub Total	***100.00***
DTW Collection Pipe (HDPE)	
200	785.49
250	881.62
315	2,825.44
Sub Total	***4,492.54***
Total	**4,592.54**

Figure 3.4: Map of PTW Collection Line-1



DTW Delivery Pipe (DI)	
Diameter (mm)	**Length (m)**
150.00	100.00
Sub Total	***100.00***
DTW Collection Pipe (HDPE)	
200.00	2,338.35
250.00	752.53
315.00	427.94
Sub Total	***3,518.82***
Total	**3,618.82**

Figure 3.5: Map of PTW Collection Line-2



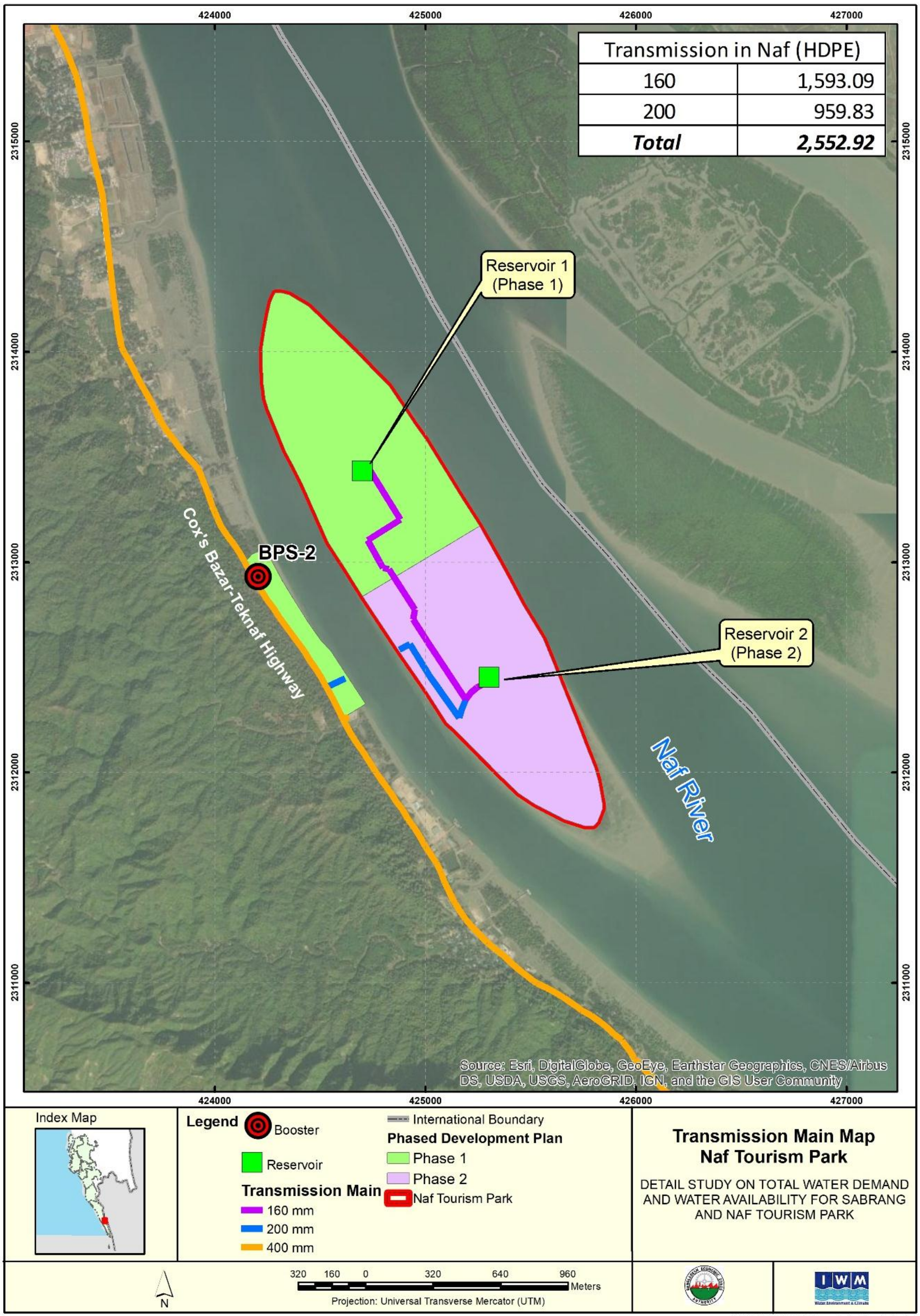
Transmission Line (DI)	
Diameter (mm)	Length (m)
400	42,249.85
Total	*42,249.85*

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Transmission Main Map From BPS-1 to Sabrang

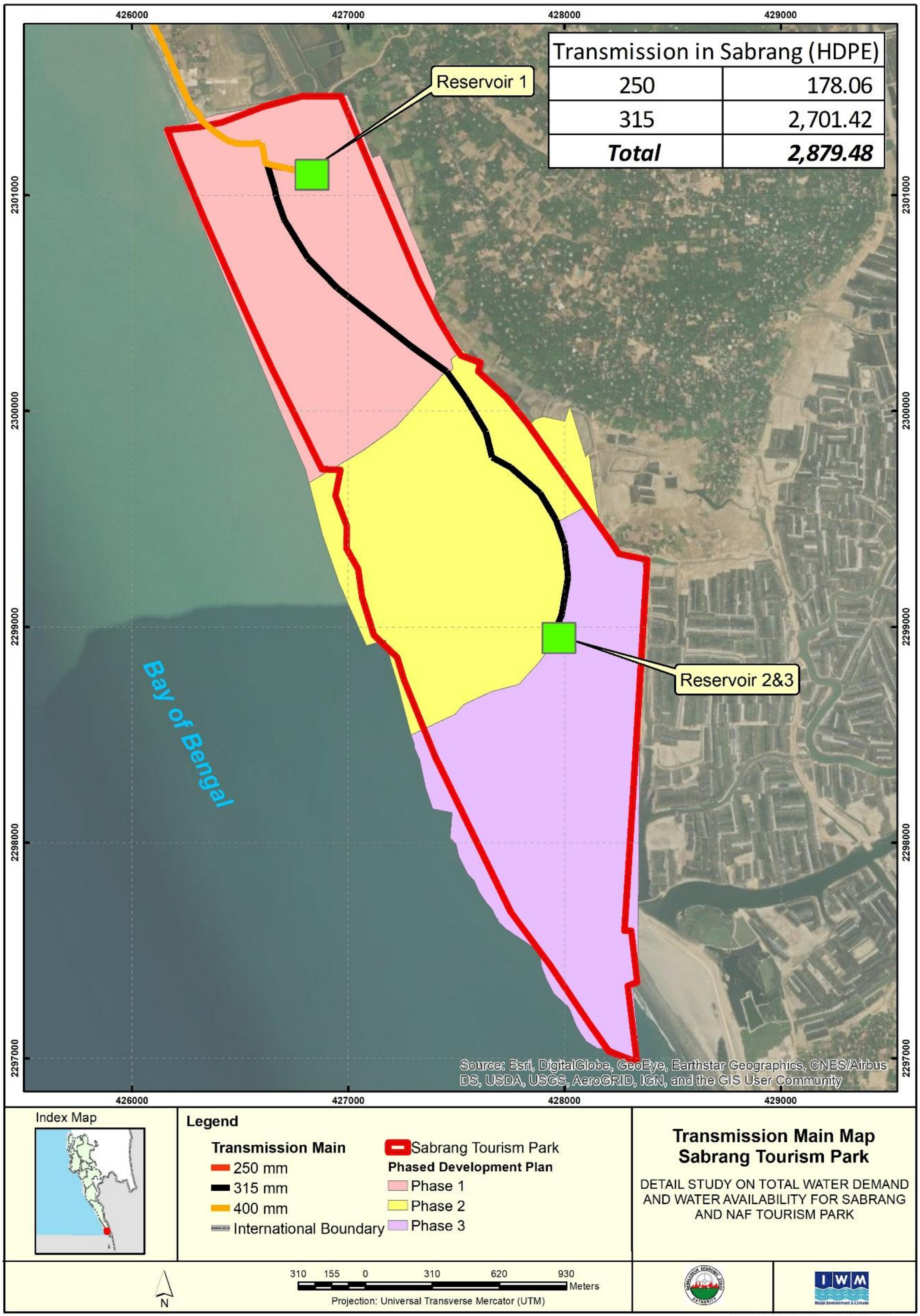
DETAIL STUDY ON TOTAL WATER DEMAND AND WATER AVAILABILITY FOR SABRANG AND NAF TOURISM PARK

Figure 3.6 Map of Transmission Main from BPS-1 to Sabrang



Transmission in Naf (HDPE)	
160	1,593.09
200	959.83
Total	***2,552.92***

Figure 3.7: Map of Transmission in Naf Tourism Park



Transmission in Sabrang (HDPE)	
250	178.06
315	2,701.42
Total	***2,879.48***

Figure 3.8: Map of Transmission in Sabrang Tourism Park

3.10 Outline Design of Booster Pumping Station

3.10.1 Water Reservoirs

A water reservoir with a capacity of 560m^3 will be required for BPS-1 at Whykhong. Detention period for collected PTW water has been considered 2 hour which includes 0.5 hour for chlorine contact basin. The size of clear water reservoir with chlorine contact basin will be 14m x 10m x 5m including freeboard of 0.5m.

Similarly, a water reservoir with a capacity of 480m^3 will be required for BPS-2 near Teknaf Ferry Ghat. Detention period for collected PTW water has been considered 2 hour which includes 0.5 hour for chlorine contact basin. The size of clear water reservoir with chlorine contact basin will be 12m x 10m x 5m including freeboard of 0.5m.

The water reservoirs shall be sub-divided into two compartments, so that one compartment can be out of service for cleaning. The tank will also be constructed with baffle walls to prevent short circuiting. Other considerations are,

- Turfing should be provided at the top of reservoir
- Necessary ventilation arrangements should be provided at the top of reservoir
- Bottom level of pump sump should be minimum 1.23 m below the bottom level of reservoir

The clear well serves water to a pump station which is constructed adjacent to the clear water reservoir. The pump station is a structure that houses pumps, piping and auxiliary equipment such as pump controls, spare parts and accessories.

3.10.2 Characteristics of Pumping Station

Booster Pump Station-1

Design flow for booster pumping station has been considered 6.2MLD. In total 5 pumps of 1 cusec capacity each will need to be installed. Three Pumps (2 fixed head and 1 VFD) will be on duty and the other two will be kept standby (1 fixed and 1 VFD) for safe operation and maintenance.

Characteristics of Booster Pump Units are

- Total Discharge: 0.072 m^3/s (6.2MLD)
- Pumping Head: 5.5 bars
- Discharge Capacity of each Pumps: 1 cusec (0.0283 m^3/s)
- Nos. of Pump: 5 (3 on duty, 2 standby)
- Water Reservoir Size: 14 m x 10 m x 5 m
- Power requirement: 54 kWh

The electricity power for BPS-1 has to be connected from existing Bangladesh Rural Electrification Board (REB) electricity line along the Cox's Bazar-Teknaf highway. Due to high power requirement a sub-station at the closed electricity pole need to be installed.

Booster Pump Station -2

Design flow for booster pumping station has been considered 5.16MLD. In total 3 pumps of 1 cusec capacity each will need to be installed. Three Pumps (2 fixed head and 1 VFD) will be on duty and the other two will be kept standby for safe operation and maintenance.

Characteristics of Booster Pump Units are:

- Total Discharge: 0.06 m^3/s (5.16 MLD) to 0.072 m^3/s (6.2MLD)
- Pumping Head: 4.0 bars
- Discharge Capacity of each Pumps: 1 cusec (0.0283 m3/s)
- Nos. of Pump: 5 (3 on duty, 2 standby)
- Water Reservoir Size: 12 m x 10 m x 5 m
- Power requirement: 60 kWh

The electricity power for BPS-2 has to be connected to the proposed electricity line designed for Naf Tourism Park.

3.11 Considerations during Construction

3.11.1 Pipe Laying

For pipe laying the trench location, depth, pipe cover, etc. should be analysed during the final designing. A safer margin of 2 bars for surcharge over pressure should be used to size the pipe and appurtenances. Again, for surge protection air valves will be used at different locations as required. These air valves will release great quantities of air under low pressure when filling the mains and lower quantities of air under pressure during normal operation. Such air valves will also play an important role in the field surge protection by preventing any water column separation in case of power failure occurs in Booster pumping station. Water column separation can also occur during the operation of valves by creating vacuum conditions. Therefore, to operate under low and normal pressures double air valves with a large orifice for low pressure and a small orifice for normal pressure will be used. In addition, surge vessels will also be installed in delivery of treated water pumping station, delivery of booster pumping stations and different locations of transmission main. In the location where air valves will not sufficient, surge vessels will be used. In addition to these isolating valves, washout valves will be provided with the pipeline depending on the requirements. Clear cover between the crest of the pipe & the road surface should be a minimum of 1 m.

Trenches for pipe laying by excavating paved road will be necessary. To minimize disturbance to traffic movement, the works should need to be executed during low traffic movement period i.e., night time. Necessary access by leveling and dressing may be needed for equipment movement.

The following geotechnical problems may be encountered during the laying of pipe:

3.11.1.1 Unstable slopes

An unstable slope may be observed along the transmission main. The instability can be influenced by scouring near water bodies, change in groundwater and drainage conditions and increase of additional surface loads (building construction) on a subsoil with a low shearing resistance.

Al some locations constructions need to be done near steep slopes and at some places, the underground will consist of cohesive soils with a low shearing resistance. The design need to be proceed with a preliminary stability analysis based on conservatively estimated soil parameters.

The stability of cut slopes of a certain depth must also be analyzed, using at first estimated parameters in a preliminary calculation, to make sure that the intended layout will not present severe problems.

3.11.1.2 Danger of erosion

Erosion problems are mainly expected at the pipelines, particularly, where khal/low lying areas have to be crossed.

To prevent erosion of soil and backfill in the area of the pipeline installation, the following erosion protection measures may be applied.

(i) Surface Drainage System

To avoid the concentration of runoff water, construction should be done in pre-monsoon or dry period when rainfall is very less.

For construction in rainy period, the backfill area of the pipeline at steep slopes must be kept free from concentration of runoff water. Near the upper edge of the slope a reasonably dimensioned stormwater ditch would be provided. If the height of the slope is more than approximately 10 m, the slope should be intersected by one or more additional ditches. The ditches will collect the stormwater before more concentrated streams develop. The surface of the ditches and the intermediate slopes shall be protected by planted vegetation, as outlined below. To stabilize very steep slopes, a sequence of gabions can be installed which will provide secure protection at the hillside part of the berm.

(ii) Surface Protection by Rockfill Layers

In difficult areas, where water flows cannot be diverted easily or where traffic conditions may not allow a successful vegetation planting, a special protection layer may be prepared by use of rockfill material. The grain size distribution of this material must be carefully selected in accordance with the inclination and the expected water flow.

(iii) Surface Protection by Vegetation

The most adequate protection against erosion consists in planting of grass or small bushes. The surface to be protected will need certain care and maintenance particularly immediately after planting of grass, but later the cultivated areas will remain safe with minimum maintenance.

(iv) Erosion Protection at Khal/Bridge/ Culvert Crossings

For Khal crossings, we consider hanging with the Bridge/Culvert or under-bed micro tunnelling method during dry period. The pipe will be installed during the dry season in a trench excavated into the riverbed.

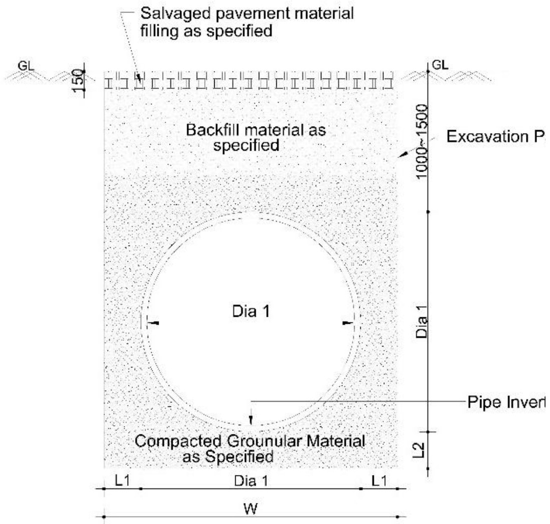
The banks at both ends of crossings through under bed need to be protected by the construction of gabions at the adjacent slope up to the expected maximum water level.

3.11.1.3 Stability of trench walls

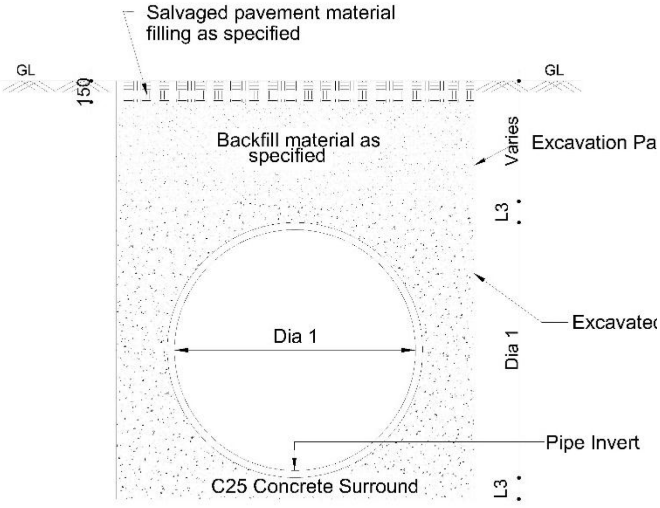
Where the pipe trenches will be excavated with vertical cuts deeper than 1.50 m the walls would require temporary support for safety reasons. Near roads or places with public traffic any cut steeper inclined than 1V:1H shall be supported.

3.11.1.4 Low bearing capacity at the trench bottom

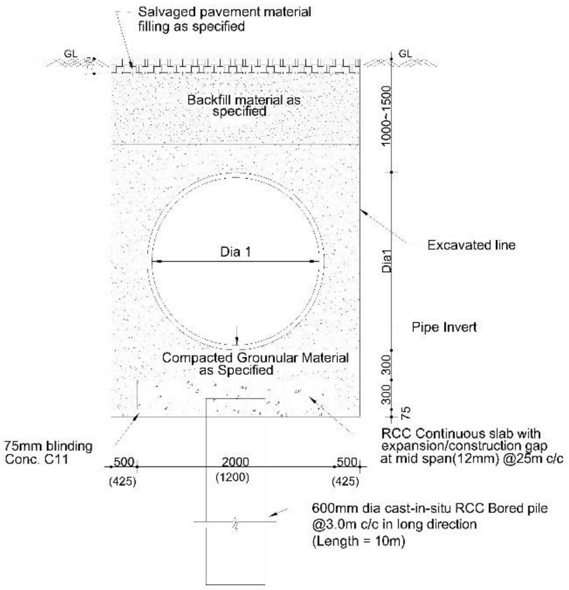
If the subsoil at any place is found to have a low natural density, is related to a low compression modulus. To avoid unacceptable settlement values and settlement differences, the design will try to reduce the new load by increasing the depth of excavation. It would also be possible to remove soft soil from the trench bottom beyond the allowable depth and the trench will be filled up with compacted selected filling materials and the trench bottom bearing capacity can be increased by concreting.



PIPE INSTALLATION TYPE A



PIPE INSTALLATION TYPE B



PIPE INSTALLATION TYPE C

Figure 3.9: Pipe installation at different types of soil

3.11.1.5 Low lateral bearing capacity in trenches

Anchor blocks at pipe bends and valves would need to react on the laterally located undisturbed soil to transmit the forces from the pipe to the underground without displacements.

The lateral bearing capacity of soils along the pipeline depends mainly on the soil composition, density and the shearing resistance prevailing at the sidewall of the trench. These values will be investigated in regular distances and used to establish the admissible lateral loads on the trench walls.

At some places, the horizontal bearing capacity may be low, due to the presence of soft cohesive soils, or due to high temporary groundwater levels. The pipe may then be designed to be installed deeper under the ground surface; the bearing capacity generally increases with depth, due to the increase of soil volume reacting laterally and very often also due to a better soil quality at a greater depth.

3.11.1.6 High bedrock level

Bedrock is observed near the hilly region in Teknaf along the transmission main. The excavation of trenches in rock material must be carried out mechanically, e.g., by excavator, ripping dozer, hydraulic hammer in co-operation with a track drill machine and/or pneumatic hammers. The use of explosives will not be possible besides the roads.

The final quantities for the different excavation classes need to be estimated during detailed design or construction period.

3.11.2 Pipe Gradient

The presence of a pocket of air is detrimental to a good performance of a pumping main. Thus, pipeline layout must be planned in a manner facilitating air accumulation at well-defined high spots, where venting equipment must be installed. The treated water transmission main would be provided with a gradient to facilitate upward movement of the air. If the pipeline profile is flat, artificial high and low spots should be created by applying a gradient. Generally, a gradient of 0.2% to 0.3% in ascending sections and 0.4% to 0.6% in descending sections is recommended. Profiles of this type, with gradual ascents and rapid descents, facilitate air collection at high spots, whilst preventing any air entrainment. Air release valves should be installed at every high spot and a wash-out should be installed at every low spot.

From an idealistic point of view, providing pipe gradient of 4 mm/km or more may result in pipe installation in higher depth which will increase pipe installation cost. A more flexible guideline (minimum grade of 0.2%) recommended by Watercare, Auckland may be adopted from the viewpoint of installation cost minimization.

3.11.3 Bedding

Determination of pipe bedding will be made on case-to-case basis during final design depending on the soil condition. However, following bedding can be used:

- Backfill material will be soil removed from the trenches or any materials suggested or directed by engineer in charge
- Pipe bedding will consist of either gravel or crushed bricks
- Pipe surround material will be crushed bricks.

3.11.4 Valves and Chambers

Valve Chamber or Manholes

All valves and appurtenances will be installed in valve chamber or manholes, the type of each of them would be chosen among standardized types. Isolating valves on the treated water transmission main will be of the butterfly type, however, these valves should be provided only in selected locations like after a washout, inlet and outlet of boosters, in the beginning of tourism park transmission pipe etc. Besides butterfly valves non return valves will be required in washout and in the beginning of PTW collection lines to avoid back water flow.

Air Release/Vacuum Valves

Air release valves (ARVs) remove any small-scale air that might occur, while air vacuum valves (AVVs) generally allow for large-scale removal/admission of air during filling/draining scenarios. Moreover, ARVs are often activated during transient conditions, such as pump failure, admitting air into pipes to counter sub atmospheric conditions and removing the admitted air once pressure increases.

Based on the guidelines of AWWA (2001) it is recommended to install air valves at intervals of 400 m to 800 m along ascending, descending, and horizontal lines and at all the high points along the treated water transmission main.

Washout Arrangements

For cleaning of the transmission main washout chambers with necessary valve will need to be provided at the low points where there is a nearby water body to flush out the water from the pipeline.

3.11.5 Thrust Block Arrangements

Thrust blocks are required to prevent fittings from moving when hydrostatic pressure is applied to the pipeline. Their function is to transmit the loads imposed on them to the adjacent soil or rock. Thrust blocks should be provided wherever the pipeline: changes direction, changes diameter, terminates or other. Lack of thrust blocks may damage the pipe from forces from the water when the direction of the pipe changes.

A thrust block shall be installed wherever the above conditions arise on the transmission line. Location and sized of thrust blocks should be investigated during detailed design. Thrust blocks should be constructed in reinforced concrete with due regard to pipe forces and ground conditions.

3.11.6 Method of Khal/Bridge/ Culvert Crossings

According to the field investigation, treated water transmission main will cross bridges/culverts and canals in 107 number of locations. Among 107 nos. 73 nos. bridge/culvert are on khals/charas/waterbodies. Remaining 34 nos. bridges/culverts are on plain land/paddy field. Again, there are 73 nos. box culverts and 34 nos. bridges. Depending on the bridge/culvert condition pipe can be crossed by hanging in bridge/culvert structure or pipe can be laid under the bed level by open excavation during dry period to cross khals/canals/waterbodies. However, for crossing of pipe in waterbodies, trenchless technologies are recommended for avoiding disturbance of structures. Based on structural information it is assumed that hanging of pipe in bridge/culvert will be provided if length of the structure is greater or equal to 30.00 m, depth of the crossing waterbody is greater or equal to 4.00 m and vent nos. for box culvert is greater or equal to 3. Details of crossings are provided in **Table 3.8.** The detail list of structures with crossing of khal/bridge/culvert is given in **Appendix-D**. However, type of crossing can be changed depending on field conditions.

Table 3.8: Detail of Crossings

Crossing Type	Nos.	Length (m)
Box Culvert		
Hanging	2	24.2
Under Bed	71	675.25
Subtotal	***73***	***699.45***
Bridge		
Hanging	26	1046.25
Under Bed	8	121.05
Subtotal	***34***	***1167.3***
Total	**107**	**1866.75**

Several trenchless methods could be envisaged to cross water body. Amongst the widely used methods all over the world, Pipe Jacking (PJ) or Micro-tunnelling (MT) method is recommended (**Figure 3.10** and **Figure 3.11**).

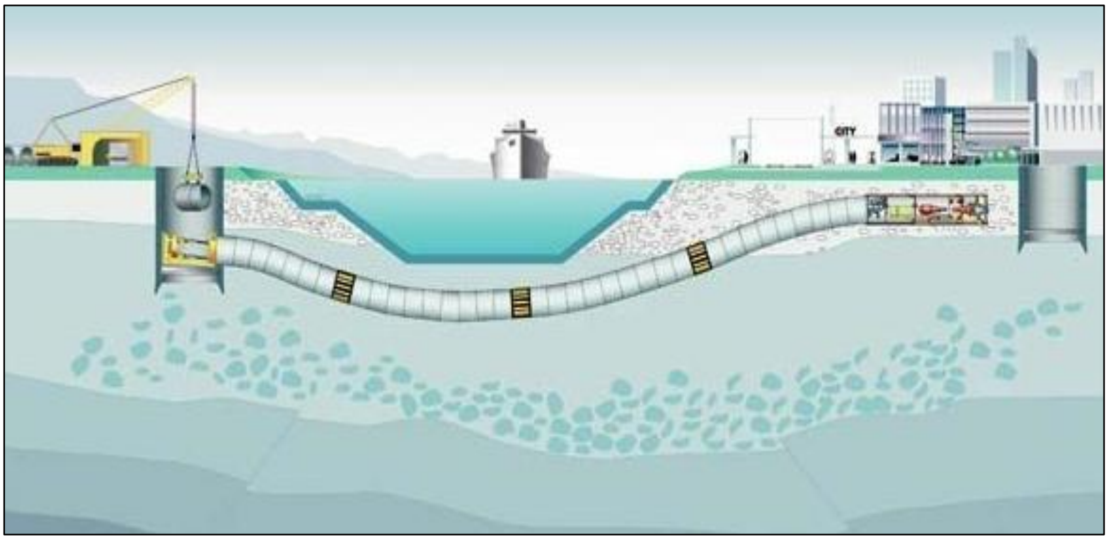


Figure 3.10: Schematic of Micro-Tunneling (MT)

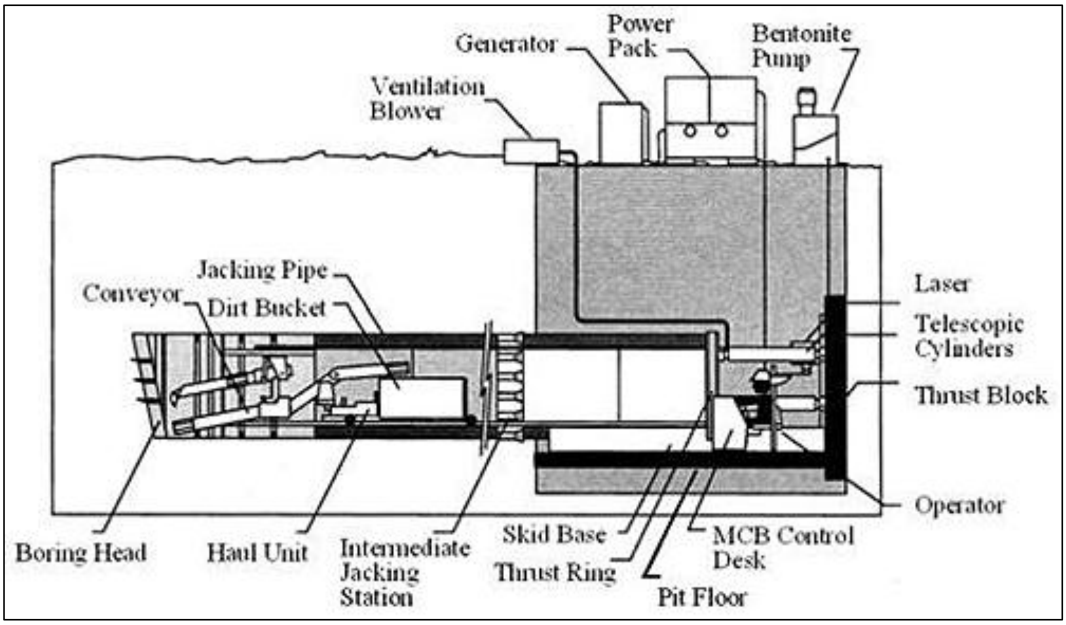


Figure 3.11: Schematic of Pipe jacking (PJ)

3.12 Risks and Control Measures in Transmission Main

Risks associated with transmission system are-

- Contamination during construction of new transmission main.
- Corrosion leading to loss of structural integrity due to pipe ageing.
- Contamination from leaky water transmission main in areas of low pressure or intermittent water supply due to backflow through leaky joints. Contaminants enter the drinking-water system when the pressure of the contaminant source exceeds the pressure of the water system. This is known as backflow. The lower the system

pressure and/or the increased instances of leakage in the piping network, the greater the probability of contaminant increases.

- Accumulation of biofilms, sediments and particles in transmission main due to low flow velocities in pipes and resuspension during high-flow events.
- Excessive chlorine above health-based guideline value (5 mg/L) or underdosing of chlorine leading to inadequate protection against increase of microbial contamination or growth of biofilms.
- Possible hazardous events that may pose a risk to drinking-water quality in storage reservoirs due to-
    - damage of roofs
    - gaps between the roof structure and the tank wall
    - cracks in concrete tank walls or corrosion of metal tanks
    - gaps at entry points of pipework
- Security breaches at transmission assets

Table 3.9 provides a list of control measures for typical risk events in the transmission system. Some of the control measures are applied during the design and construction of the water distribution system, whereas others involve a range of operational and maintenance procedures.

Table 3.9: Risk Events and Control Measures in Transmission Main

Risk Event	Control Measure
Contamination during construction	• Construction standards and specifications (including materials – storage, handling, transport, flushing, disinfection, contact time and water quality testing) • Disinfection prior to commissioning
Corrosion leading to loss of structural integrity	• Approved product standards for materials in contact with water • Leak detection program during operation • Pipe and fittings replacement program
Contamination from leaky water mains in areas of low pressure or intermittent water supply	• Maintain positive pressure (must ensure design pumping head) • provide continuous supply (in case of intermittent supply for different phases, sufficient air release valves should be provided to control low pressures) • Maintain minimum chlorine residuals in the network • Leak detection and repair program • Pipe and fittings replacement program • Construction standards and specifications
Accumulation of biofilms, sediments and particles in transmission main	• Design standards to achieve self-cleaning pipe velocities (transmission main model has

Risk Event	Control Measure
	been developed considering design standards) • Operate valves and pumps to avoid rapid surges in flows • Routine water main cleaning program • Maintain minimum chlorine residuals in the network
Excessive or underdosing of chlorine	• Monitor chlorine residuals so that chlorine residuals stay within limits (receiving reservoirs at tourism parks at least 0.2 mg/L)
Possible hazardous events in storage reservoir	• Reservoir inspection and maintenance program, including repair of faults/gaps • Disinfect tank after repairs • Design and construction standards
Security breaches at transmission assets	• Security fencing, locked gates, access hatches, alarms, routine security patrols, closed-circuit cameras etc.

3.13 Cost Estimate

Tentative cost estimate of the transmission main has been assessed based on following consideration.

- The cost estimate for the DI 400 mm pipelines is prepared based on material rates from Kubota, Japan. A profit of 10% is included in the pipe rates.
- Cost for fittings and valves for DI 400 mm has been estimated as 15% of the pipe material cost. Cost for pipeline construction is estimated as 50% of the overall material cost including fittings and valves.
- The cost estimate for the HDPE pipelines is prepared based on material rates from the Draft Rate Schedule-2021 of DWASA.
- Cost for fittings and valves for HDPE has been estimated as 15% of the pipe material cost. Cost for pipeline construction is estimated as 33% of the overall material cost including fittings and valves.
- Cost for road restoration charges payable to road owning agencies RHD (Cox’s Bazar-Teknaf Highway, Marine Drive Road) and LGED (Internal Road in Teknaf) has been estimated based on per m2 rate analysis considering the RHD Rate Schedule-2018 and LGED Rate Schedule-2018.
- Cost of general items has been estimated as 5% of the material and construction cost.
- Custom Duty and other taxes for the pipe materials has been estimated as 60.31% of the material cost including fittings and valves following the tariff schedule of 2018-19.
- Custom Duty and other taxes for electro-mechanical equipment’s vary within a range of 25% to 40% (e.g., for 27.55% for pumps and motors, 38.47% for transformer). Depending on the variations of the CD &VAT on electro-mechanical equipment, a rate of 40% has been considered as CD &VAT for electro-mechanical equipment’s.

The cost estimate for transmission main is provided in **Table 3.10.**

Table 3.10: Cost Estimate of the Transmission Main

SL No.	Item	Unit	Quantity	Rate (BDT)	Amount* (Million BDT)
1	**Transmission Pipe from Whykhong to Sabrang Tourism Park** includes procurement and transportation of material & necessary appurtenances and installation of the same (DI Pipe)				
1.1	DN 400 mm	m	42,249.85	31,568.08	1,333.75
2	**Transmission Pipe in Naf Tourism Park** includes procurement and transportation of material & necessary appurtenances and installation of the same (HDPE Pipe)				
2.1	DN 160 mm	m	1,593.09	3,241.49	5.16
2.2	DN 200 mm	m	959.83	4,817.40	4.62
3	**Transmission Pipe in Sabrang Tourism Park** includes procurement and transportation of material & necessary appurtenances and installation of the same (HDPE Pipe)				
3.1	DN 250 mm	m	178.06	7,134.72	1.27
3.2	DN 300 mm	m	2,701.42	10,700.35	28.91
4	**PTW Collection Pipe-1 in Whykhong Well Field to BPS-1** includes procurement and transportation of material & necessary appurtenances and installation of the same (HDPE Pipe)				
4.1	DN 200 mm	m	785.49	4,817.40	3.78
4.2	DN 250 mm	m	881.62	7,134.72	6.29
4.3	DN 315 mm	m	2,825.44	10,700.35	30.23
5	**PTW Collection Pipe-2 in Whykhong Well Field to BPS-1** includes procurement and transportation of material & necessary appurtenances and installation of the same (HDPE Pipe)				
5.1	DN 200 mm	m	2,338.35	4,700.77	10.99
5.2	DN 250 mm	m	752.53	6,961.98	5.24
5.3	DN 315 mm	m	427.94	10,441.28	4.47
6	**PTW Delivery Pipe in Whykhong Well Field** includes procurement and transportation of material & necessary appurtenances and installation of the same (DI Pipe)				
6.1	DN 150 mm for Collection Pipe-1	m	100.00	4,456.25	0.45
6.2	DN 150 mm for Collection Pipe-2	m	100.00	3,823.75	0.38
7	**Bridge Crossings/Waterbody Crossing:** Design, supply and installation of pipes, steel casing, fittings, conduits and all temporary and permanent arrangements to connect the pipelines, and other equipment necessary including all necessary pipe supports	Nos.	107.00	–	10.00

SL No.	Item	Unit	Quantity	Rate (BDT)	Amount* (Million BDT)
8	**Booster pumping station-1 (BPS-1) at Whykhong** includes water reservoir, pumping station, with necessary pumps and motors, control cubicles, boundary wall, operator room with necessary above ground and underground works for construction	–	–	–	45.00
9	**Booster pumping station-2 (BPS-2) near Teknaf Ferry Ghat** includes water reservoir, pumping station, with necessary pumps and motors, control cubicles boundary wall, operator room with necessary above ground and underground works for construction	–	–	–	40.00
	Sub Total (Item 1 - Item 9)				***1,530.55***
10	**General Item**	L.S.	–	–	**76.53**
11	**Road Restoration charges**				
11.1	Road Restoration charges payable to RHD	sqm	45,934.79	9,500.00	436.38
11.2	Road Restoration charges payable to LGED	sqm	3,180.00	6,000.00	19.08
	Sub Total (Item 11)				***455.46***
12	**CD VAT and Other Taxes**				
12.1	Pipeline Material	–	–	–	519.30
12.2	Electro-mechanical equipment	–	–	–	82.00
	Grand Total				***601.30***
13	**Physical and price contingencies**				***133.19***
	Grand Total				**2,797.03**

*Price is without price escalation

4 DESIGN OF DISTRIBUTION NETWORK

Water from the transmission main will be initially stored in the underground water reservoir (UGWR) in both Naf and Sabrang Tourism Park and then will be distributed through distribution network. Several types of network analysis are also carried out to increase the robustness of the system. Moreover, underground reservoirs are also designed to store water for at least 2 days. Cost of each item related to the distribution network is also provided in this chapter.

4.1 Introduction of Hydraulic Network Modelling

Naf and Sabrang Tourism Park is located at Teknaf Upazilla in Cox's Bazar district, undertaken by Bangladesh Economic Zone Authority (BEZA), the country's first tourism-based special economic zone (SEZ). Naf Tourism Park will be developed in two (2) phases and Sabrang Tourism Park in three (3) phases (Detailed Master Plan, December 2020) within a tentative development period as given in **Table 4.1** and **Table 4.2**.

Table 4.1: Naf Tourism Park Development Periods

Phase	Development Period
1	2021-2024
2	2024-2031

Table 4.2: Sabrang Tourism Park Development Periods

Phase	Development Period
1	2021-2026
2	2026-2031
3	2031-2036

The proposed eight (08) Production Tubewells (PTWs) at Whykhong well field area will be the main source of water for Naf and Sabrang Tourism Park. Teknaf SWTP will be another source of water to supply only at Sabrang Tourism Park. The water will be carried through about 45 km transmission main upto Sabrang Tourism Park. In the middle path after travelling 26km the transmission main will supply water in Naf Tourism Park. At first, the supplied water from the PTWs and reservoir (for Sabrang only) will be stored in the under-ground water reservoirs (UGWRs), then the water will be distributed to each user.

The water distribution network has been modelled and analysed for Naf and Sabrang Tourism Park only.

The water supply pipe network has been analysed in three distinct folds:

- Accumulation of water from production tube wells to a UGWR near the well field.
- The water will be pumped from the UGWR to transmission main and then stored underground water reservoir (UGWR) within the Tourism Park;
- The water distribution network from UGWR to the consumer;

Following input data is required for detailed network analysis:

- The design capacity of the production tube wells;

- Topographic information with land use plan;
- Population and water demand projections;

A schematic diagram of staged approach for water distribution modelling is shown in **Figure 4.1**. The water distribution system for Naf and Sabrang Tourism Park has been modelled following this schematic diagram.

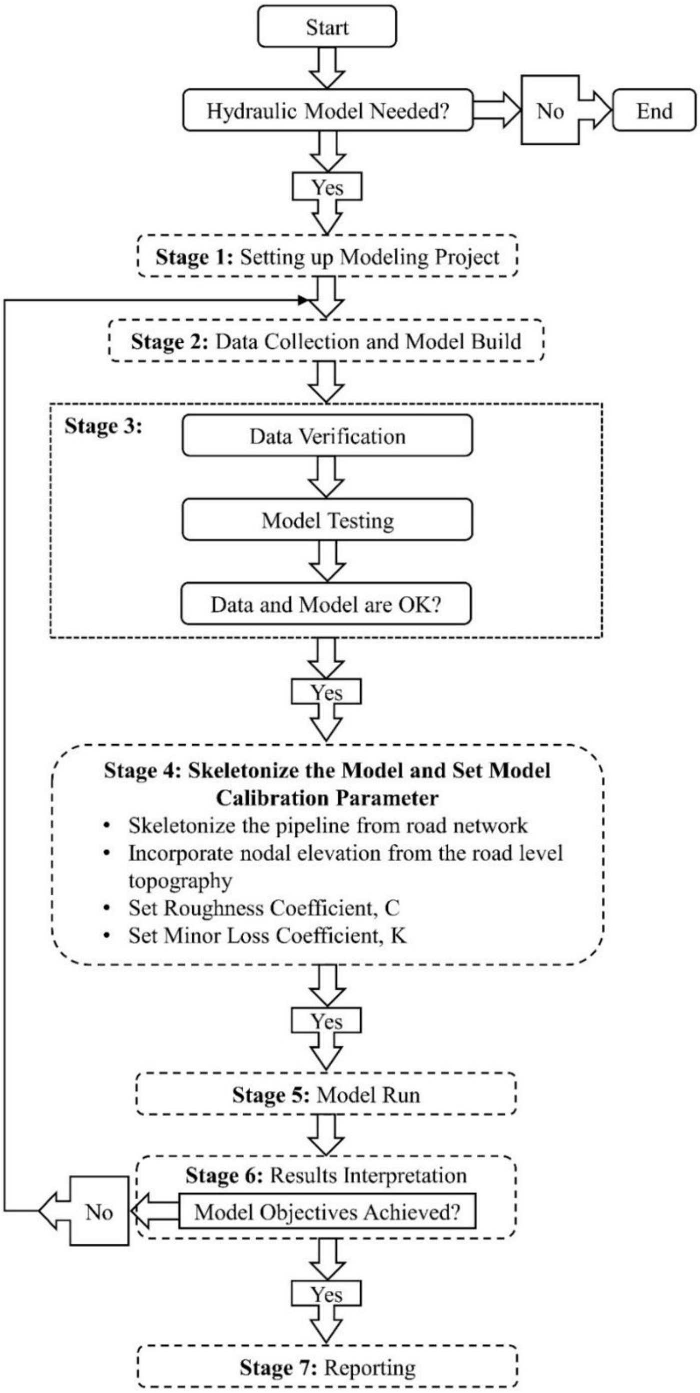


Figure 4.1: Staged Approach for Water Distribution System Modelling

4.2 Methodology

For Naf and Sabrang Tourism Park, the methodology adopted for the Water Supply Network Modelling to identify, select, process, and analyse data and model is shown in **Figure 4.2**.

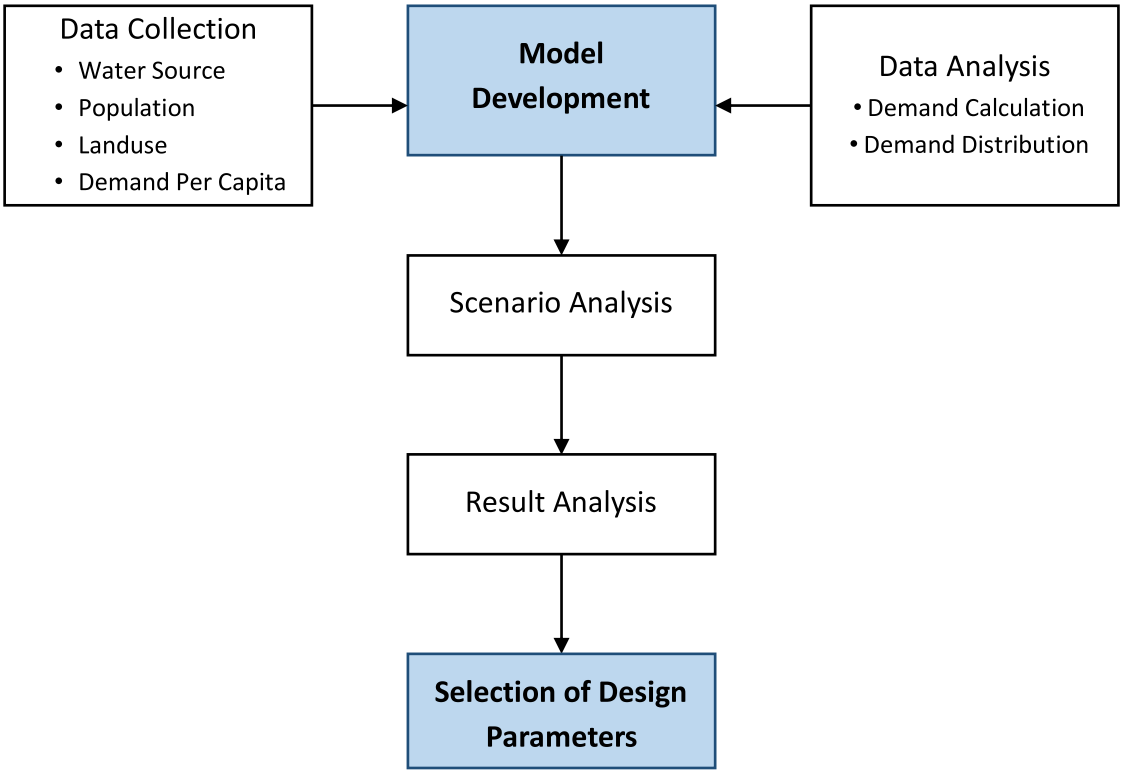


Figure 4.2: Proposed Methodology of the Hydraulic Modelling

4.3 Design Criteria of Hydraulic Model

Considering optimum energy consumption of the water supply sources, least possible minimum head losses through the pipes have been considered. The minimum pressure at any node of water distribution system is considered about 1 bar (10m H_2O). The road crest level found from the topographic survey along the transmission main is 7.0 mPWD. The nodal elevation is assumed to be 1 m below the road surface. Pipe sizing had been done considering following range of design pressure gradients as shown in **Table 4.3**.

Table 4.3: Design Criteria of Hydraulic Model

Pipe Diameter (mm)	Design Pressure Gradient (m/km)	Design Velocity (m/s)
100	4 – 5	up to 0.5
150	2 – 3	up to 0.5
200	1.5 – 2.5	up to 0.5
250	1 – 2	0.5-1.0
300	1 – 1.5	0.5-1.0
≥400	0.5 – 1.0	0.5 – 1.5

For determining the pipe sizes of water distribution system, the Under Ground Reservoirs (UGRs) are considered as the water source. To minimize the overall construction cost, pipe alignment was determined keeping consistency with road pattern. Experiences of field surveys, effects of infrastructure development were incorporated in the model to get the best design of the system. Considering the head loss gradient criteria and understanding implementation risks, pipe sizing has been determined to minimize the overall cost. To ensure further the robustness of the model, sensitivity & criticality analysis will be performed, and it will be endeavored to optimize the model until it is satisfactory.

4.4 Design Parameter

The standard Hazen-William Coefficient (C) for HDPE pipe is 150 for new and smoother pipes. Generally, it is considered that HDPE pipe has a smooth internal diameter and maintains its flow capability over time. The aging effect on the roughness might get come along, so this fact should be taken into consideration. The losses in the pipes comes not just from the friction between water and internal wall but also on local points along the pipe network such as tees, elbows, valves etc. These losses are called minor losses. Minor losses have not been counted within model but their effect has been incorporated in final value for Hazen - William's coefficient C. In this stage it's not possible to calculate exact value for coefficient C, because the exact value can only be estimated by calibrating the model using observed data on the field. These observed data now don’t exist, thus an approximate value of Hazen Williams co-efficient has been used. In the modelling, Hazen-Williams C value has been considered as 110 considering the pipe friction with the inclusion of all sorts of minor losses are possible.

4.5 Model Building and Data Entry

Model is assembled applying two basic data entry procedures. Data entry process accomplished in the following two methods:

- Manually creating data by typing it into the model
- **Transferring data between various files** by simply import data from one file to another, which also requires some additional manual editing.

4.5.1 Model Build up

In Hydraulic network model design, sizing of pipe network has taken into consideration where water flow transits from one steady state to another based on head loss, velocity & pressure. In this project one of the sophisticated hydraulic modeling tools known as Bentley WaterGEMS has been used. Network data describes all physical components of the water distribution system and defines how those elements are interconnected. Networks are made up of nodes and links. Nodes represent water system features at specific locations and links define relationships between nodes. Network data can include traditional data mainly composed of two primary types – pipe and node data. Network geometry data are now generally available in the Geographical Information System (GIS) format.

4.5.2 Pipe Data

The pipe network has been digitized from the information available in “Detailed Master Plan for Naf Tourism Park” (December, 2020) and “Detailed Master Plan for Sabrang Tourism Park” (December, 2020) project. Network was digitized along major roads of the scheme area. It was also ensured that there are different beach resorts, hotels, apartments along the network. Location of amusement park, picnic zone, restaurants, Echo Park were also considered during network digitization. The layout of Water Supply Distribution Network for Naf and Sabrang Tourism Park is shown in **Figure 4.3** and **Figure 4.4.**

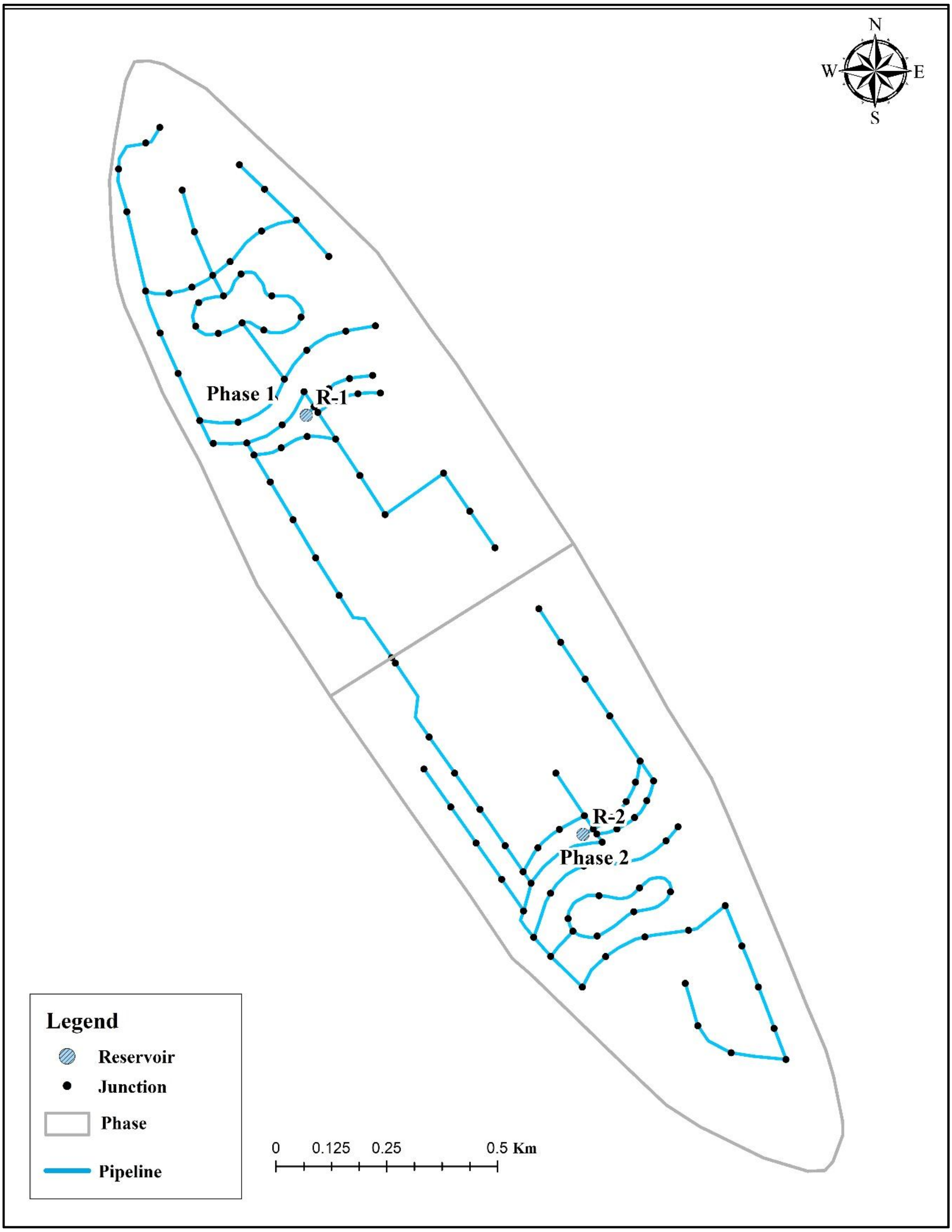


Figure 4.3: Naf Water Supply Distribution Network Layout

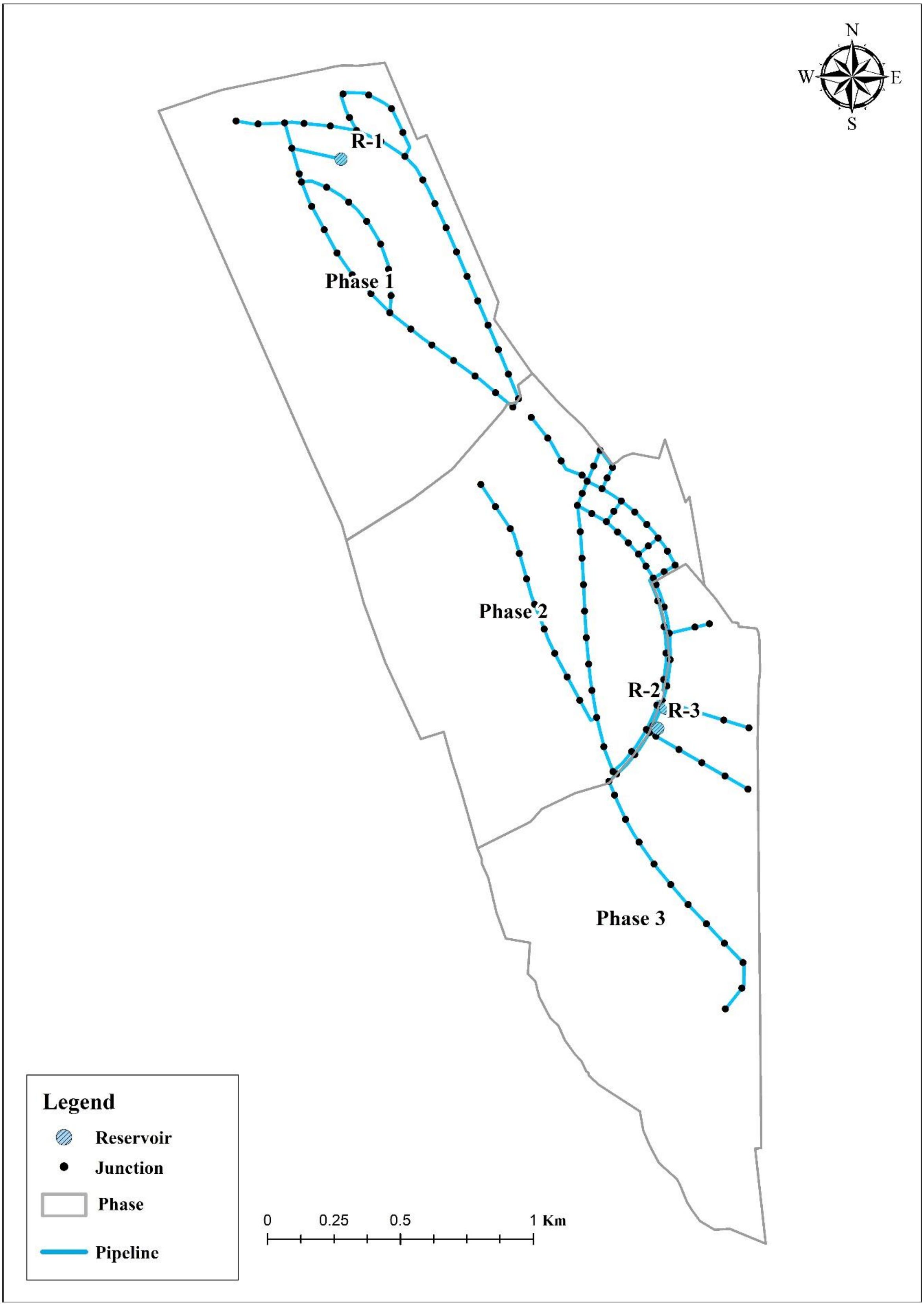


Figure 4.4: Sabrang Water Supply Distribution Network Layout (Scenario 1)

4.5.3 Nodal Elevation data

For design purpose, the proposed road crest level has been considered as baseline nodal elevation of the distribution network. Pipe is considered to be aligned 1m below of road surface level. Crest of Pipe intersection & end points of the pipe has been considered as mandatory nodal elevation data with some design nodal points.

4.5.4 Nodal Demand

Demands can be allocated to the junctions using various methods in WaterGEMS software. Demand calculation methods such as billing meters aggregation, nearest Pipe or node method can be used to determine flows in certain points of the network, where data based on mainly population allocation.

To determine nodal demand assessment for water supply in the Naf and Sabrang Tourism Park, land use pattern, assessment of plot number and population_is used. Linking all these spatial and non-spatial data has been done by using the spatial analysis of ArcGIS toolkit. Adjacent nodal area has been identified and assigned manually for each demand node. To account for the losses occurring in water supply process 15% leakage were considered and a peak factor of 1.25 were included in the demand calculation for the peak demand scenario. Water demand for each node has been calculated considering land use pattern and plot wise density factor. Details of water demand, the model hydraulics at each node different phases are shown in **Appendix F** and **Appendix J** for Naf and Sabrang respectively.

4.6 Network model discussion for Naf Tourism Park

4.6.1 Water demand

Water demand of Naf Tourism Park has been calculated as 1.52 MLD including all loses and design peak factor. The distribution hour has also been considered as 10-12 hours. The phase-wise water demands are given below in **Table 4.4** and detail demand in given in **Appendix-E**.

Table 4.4: Phase-wise Water Demand

Development Phase	Demand (L/s)	Demand (MLD)
1	9.0	0.78
2	8.7	0.75
Total	**17.6**	**1.52**

4.6.2 Network model Scenarios

For Naf Tourism Park only one scenario has been simulated to evaluate efficient the water supply networks efficiency and implementation feasibility. The details of the scenario for different development periods for Naf Tourism Park distribution modelling are given below in **Table 4.5** and the detail layout of pipe and reservoirs have been shown in **Figure 4.5.**

Table 4.5: Description of Network Model Scenarios

Development period	Description	Scenarios
2021-2024	The 1st URWG will be constructed and supply to Phase 1 area	**Scenario-1**
2024-2031	The 2nd URWG will be constructed and supply to Phase 2 area	

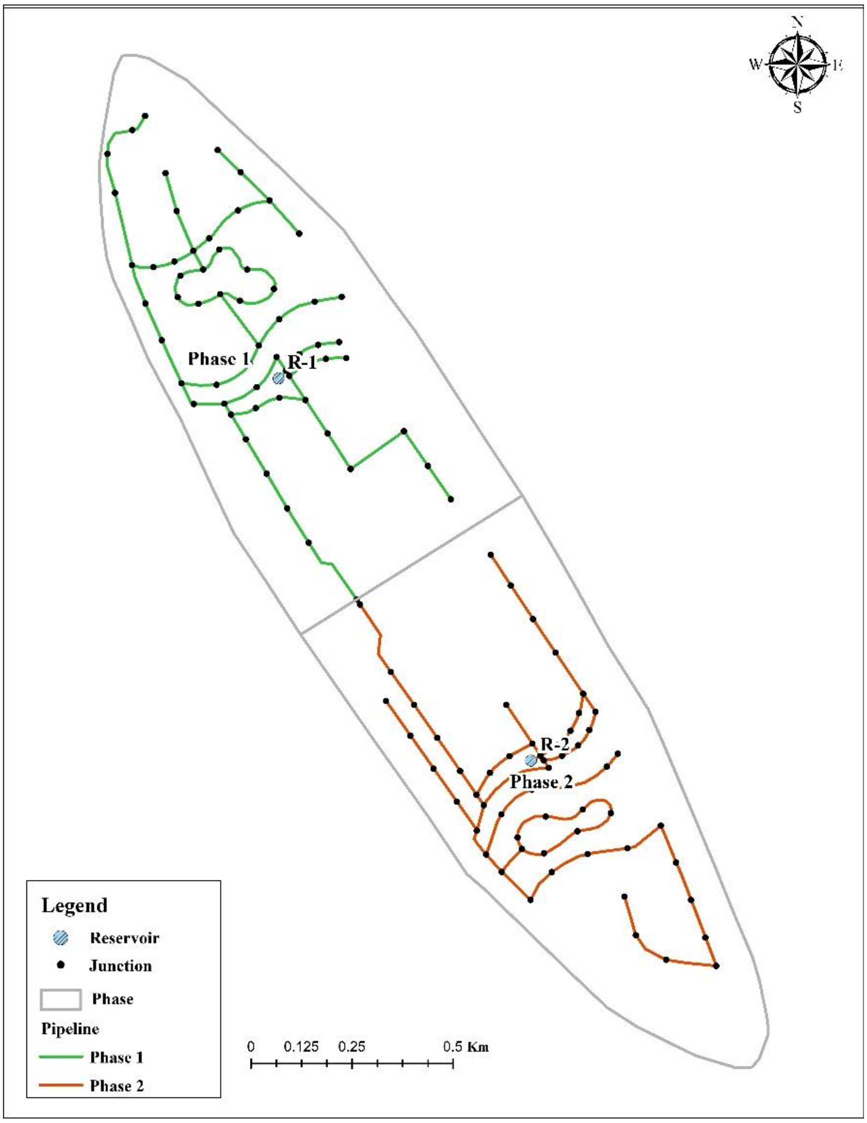


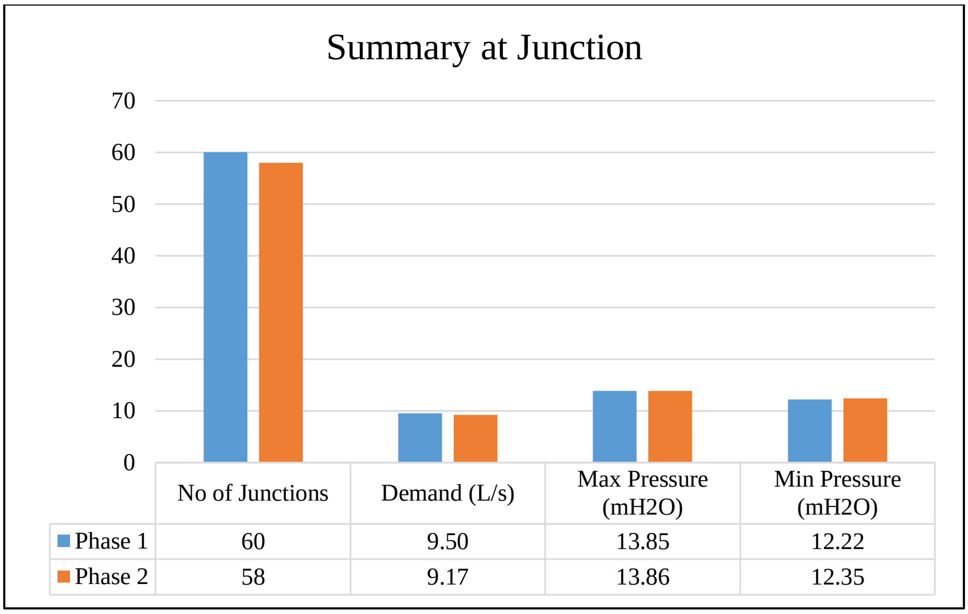
Figure 4.5: Reservoir and pipeline layout for Scenario 1

4.6.3 Distribution Network Model for Naf Tourism Park

A water supply model generally consists of reservoirs, pumps, junctions and pipe network. The detail description of distribution network modelling for Sabrang Tourism Park as derived from the model is describe below.

4.6.3.1 Description of Junction (Node) Data

Each junction (node) is verified for corresponding design parameters specially the residual pressure. Summary of model output at different junctions for Scenario 1 are presented in **Figure 4.6** (tabular form) and **Figure 4.7** and the detail data such as junction label, demand and residual Pressure are stated in **Appendix F.** it is observed that the pressure varies between 12.22 to 13.85 m H_2O in Phase-1 and 12.35 to 13.86 m H_2O in Phase-2 which is above the design minimum pressure at each junction.



	No of Junctions	Demand (L/s)	Max Pressure (mH2O)	Min Pressure (mH2O)
🟦 Phase 1	60	9.50	13.85	12.22
🟧 Phase 2	58	9.17	13.86	12.35

Figure 4.6: Summary of model output at different junctions

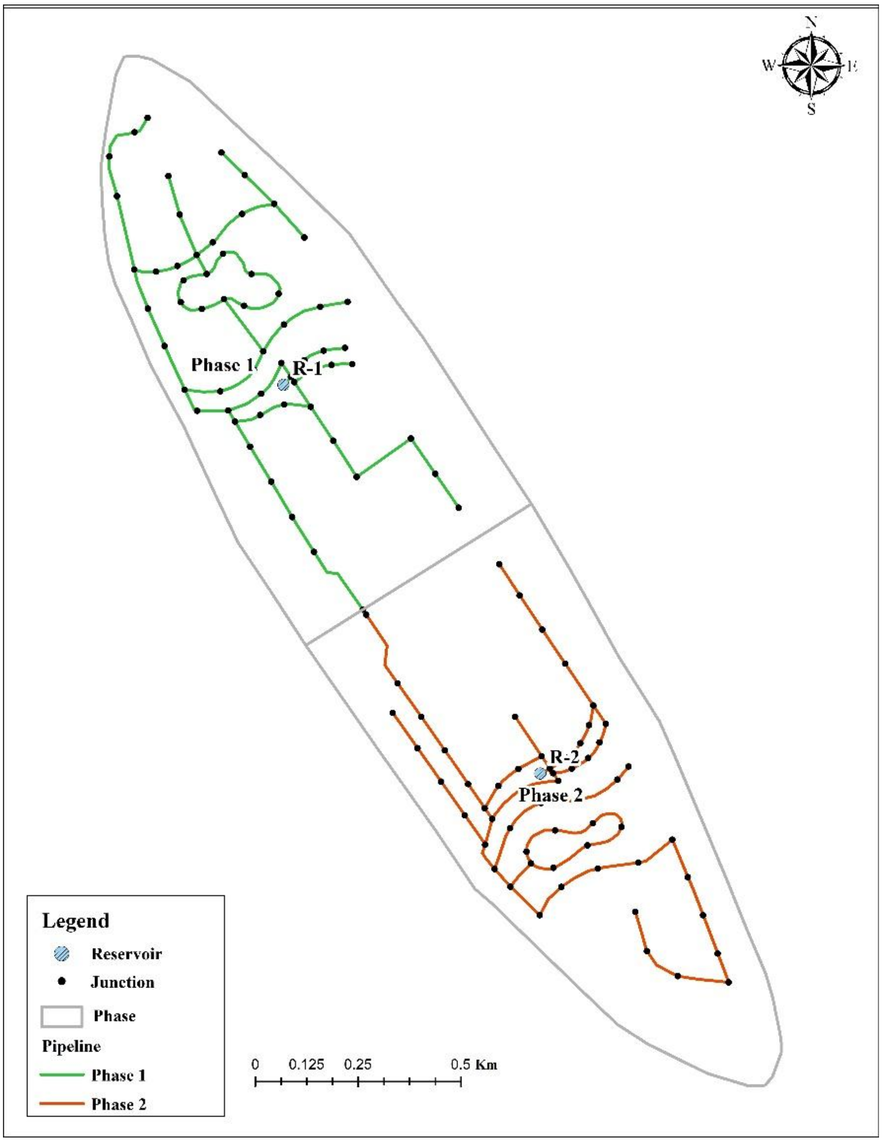
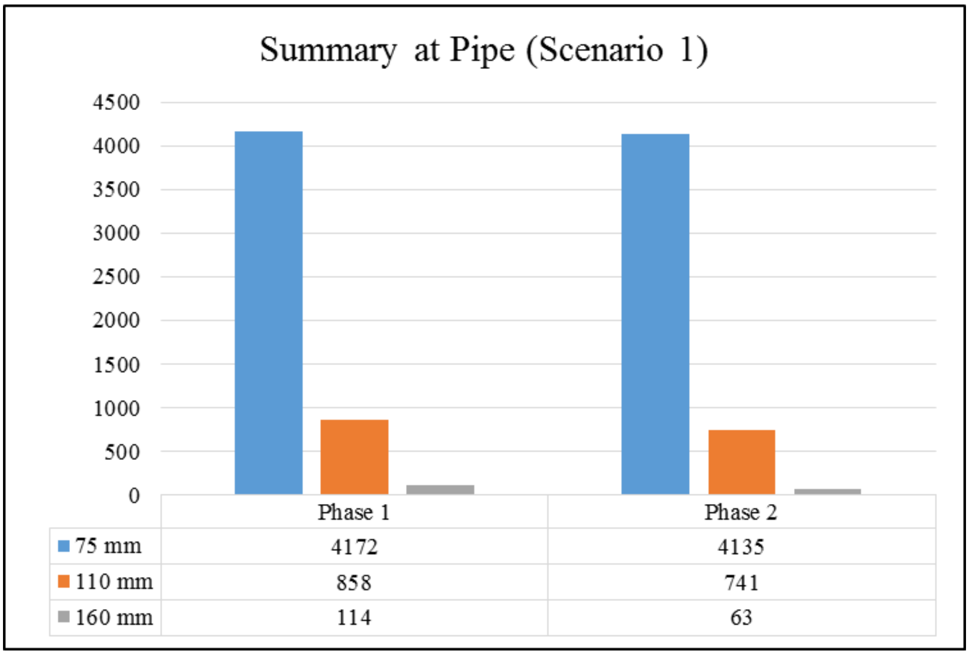


Figure 4.7: Pressure at different junction for Water Supply Model (Scenario 1)

4.6.3.2 Description of Network Data

Network data describes all physical components of the water distribution system and defines how those elements are interconnected. Networks are made up of nodes and links. Nodes represent water system features at specific locations and links define relationships between nodes. Network data can include traditional data mainly composed of two primary types – pipe and node data.

In scenario-1, the total length of network is about 10.0 km and pipe diameter varies from 75 to 110mm. The length of pipes for different diameter are summarize in **Figure 4.8** and **Figure 4.9**. It is observed that the head loss gradient is within the range of design criteria of pressure gradient (**Table 4.3**). The length of pipes considered in different scenario are describe in **Appendix G**. The detailed results of pipes with selected hydraulic properties (diameter, velocity, head loss gradient, head-loss and flow) are provided for design in **Appendix H.**



	Phase 1	Phase 2
75 mm	4172	4135
110 mm	858	741
160 mm	114	63

Figure 4.8: Summary of Pipe Data

Figure 4.9: Map of Model Output for Pipe Diameter

In pipeline design criteria, it is suggested that maximum velocity of flow in the pipes should be up to 1.5 m/s. The maximum velocity found from model is shown in **Table 4.6.** As it can be seen that the pipe velocities are well below the maximum design limit.

Table 4.6: Maximum Velocity (m/s) in Pipes

Phase	Scenario 1	
	Pipe	Velocity (m/s)
1	P-2	0.62
2	P-66	0.60

But it is observed that during modelling the minimum velocity cannot be ensured. The velocity of flow is inversely proportional to the diameter of pipe. If the velocity of the pipe flow required to be increased, the diameter of the pipe needs to be decreased. But according to design criteria, minimum diameter of the pipe must be 75mm. In order to satisfy the minimum diameter criteria, the minimum velocity cannot be ensured.

4.7 Network Analysis for Naf Tourism Park

Criticality, sensitivity and flushing analysis were carried out to ensure the robustness of designed model and interpret the behavior of the network in different condition.

4.7.1 Criticality Analysis

To ensure the optimum behavior of the system during reparation or maintenance work, isolation valves are necessary in the network. By incorporation of isolation valves in the network and by performing criticality analysis, it is possible to identify the customers whose connections will be interrupted during isolation events. The valves that are needed to be closed for isolating any segment can be identified also. Number and location of isolation valves of Naf Tourism Park has been determined and optimized by criticality analysis which was performed by using the WaterGEMS software.

4.7.1.1 Assumptions and Approaches

- Complete isolation from the network is the first criteria for putting isolation valves in the pipes.
- Isolation valves must be located such that during operation and maintenance work, possible stoppage of sources can be avoided as much as possible.
- Minimize the offline areas as much as possible considering the maintenance work at network.
- Minimize the number and length of outage segments in the network.
- Minimize the number of valves that need to be closed for isolating a segment. The more no. of valves required closing at a time decreases the network reliability during the operation of those valves.
- Total cost considerations.

4.7.1.2 Additional Considerations

- Maximum length of one segment below 1000 m
- Avoid larger diameters (≥ 200 mm) as many as possible.
- Maximum number of GV for one segment closure is within 10.
- Maximum length of outage segment is within 1000 m (except dead end branch) at the downstream of network
- Special Consideration (if any) which must be approved by BEZA.

4.7.1.3 Segmentation of the Network

At first, a tentative number of isolation valves were digitized in the model. Isolation valve diameter was modified to conform to corresponding pipe diameter. After that criticality analysis were carried out for entire network to check the isolation and isolated segment properties in the system. Finally, the number and location of isolation valves were optimized to obtain the desirable outputs. **Figure 4.10** shows different isolated segments.

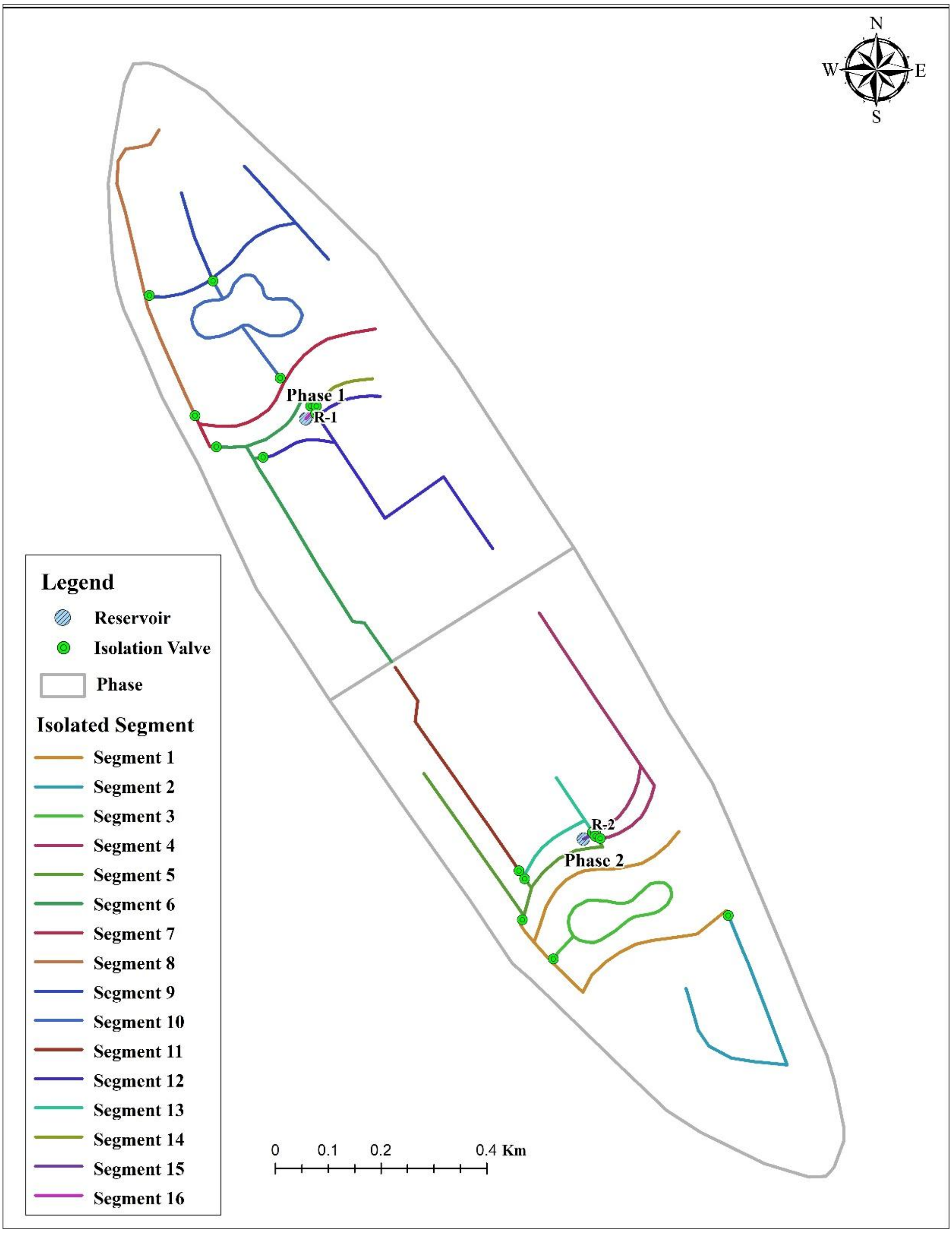


Figure 4.10: Different Isolated Segments

4.7.1.4 Outputs of Criticality Analysis

The output results of the criticality analysis are shown in **Table 4.7**.

Table 4.7: Summary of Criticality Analysis

Item Description	Value
a) No. of Proposed Gate Valves	18
b) No. of Isolated Segments	16
c) Maximum Segment Length (m)	1077
d) Average Length of all Segments(m)	630

Item Description	Value
e) Average Length of segments related to service connections (m)	714
f) Maximum No. of Valves Needed to be Closed	4

Total isolation valves have been selected 18 nos. and segments became 16 nos. Out of these 16 segments, 14 of them are related to service connections and the rest are related to operation of water sources near UGWRs. In case of major segments which are related to the service connections for undelivered water during segment shutoff, the average segment length has been found as 714 m. On the contrary, for all segments either these are for water source operation or related to the service connection, average segment length has been found as 630 m. So maximum segment length during reparation or maintenance work is within the design consideration (1000m). Moreover, it is found that maximum number of valves need to be closed for repairing and maintenance work is 3nos. which also satisfied design considerations.

The total length of outage segments and demand shortfall for repairing and maintenance at different segments are stated in **Table 4.8**. It is observed that maximum outage segment length is about 5.1 km and demand shortfall is about 50.9%. Moreover, if any repairing or maintenance is required in any segments connected to the reservoirs (UGWR), the network system connected to these reservoirs will be under shortfall of water. Precaution is needed to avoid the situation as stated below.

Table 4.8: Isolated Segment Properties

Segment	Segment Length (m)	Isolation Nodes	Outage Segment Length (m)	System Demand Shortfall (%)
Related to Operation of Sources				
Segment - 15	39	3	4,900	49.1
Segment - 16	41	3	5,102	50.9
Related to Service Connection				
Segment - 1	1,077	3	1,345	6.9
Segment - 2	686	1	0	0.2
Segment - 3	660	1	0	1.4
Segment - 4	846	2	0	1.2
Segment - 5	722	4	2,423	7.3
Segment - 6	887	3	3,068	29.5
Segment - 7	586	3	2,481	8.9
Segment - 8	745	2	0	1.6
Segment - 9	886	2	0	1.5
Segment - 10	850	2	0	1.7
Segment - 11	556	1	0	20.1
Segment - 12	993	2	0	20.9
Segment - 13	353	3	556	40.6
Segment - 14	154	1	0	0.4

4.7.2 Sensitivity Analysis

The water supply distribution network model of Naf Tourism Park satisfies all the hydraulic requirement which is suitable to meet the demand 18.68 L/s considering loses and peak factor

1.25. The model has been tested again for different sensitivity analysis as describe below. Network pipe sizing has been optimized considering the output of these analysis.

As it is said earlier in this report, minor losses have not been directly incorporated in the model, but in actual case there will be some minor losses in the water distribution system, the common minor losses and its corresponding head loss coefficient are shown below:

- **1.5 - Elbow, Threaded Regular 90°**
- **1.0 - Tee, Flanged, Branched Flow**
- **0.5 - Elbow, Threaded Regular 45°**

For sensitivity analysis of the model, the model has been simulated for various values for Hazen-Williams Coefficient (C) and Minor Loss Coefficient (K). It has been checked with different C values as 120, 110 & 100 and for three minor loss coefficients (1, 0.75 & 0.5) whether the model is robust irrespective of such changes. The minimum pressure and maximum head loss gradient variation due to different C and K values is shown in **Table 4.9**.

Table 4.9: Pressure Variation with Hazen-Williams Coefficient (C) and Minor Loss Coefficient (K)

Phase	Hazen-Williams C	Minor Loss Coefficient, K	Pipe Maximum Head loss Gradient (m/km)	Pipe Label	Diameter (mm)	Junction Minimum Pressure (m H_2O)	Junction Label
1	**100**	**0.00**	6.27	P-29	110	11.88	J-120
		0.50	6.37	P-29	110	11.84	J-120
		0.75	6.41	P-29	110	11.82	J-120
		1.00	6.46	P-29	110	11.80	J-120
	110	**0.00**	5.25	P-29	110	12.22	J-100
		0.50	5.35	P-29	110	12.18	J-100
		0.75	5.40	P-29	110	12.16	J-100
		1.00	5.45	P-29	110	12.14	J-100
	120	**0.00**	4.47	P-29	110	12.48	J-100
		0.50	4.57	P-29	110	12.44	J-100
		0.75	4.62	P-29	110	12.42	J-100
		1.00	4.67	P-29	110	12.40	J-100
2	**100**	**0.00**	6.17	P-88	110	12.03	J-17
		0.50	6.26	P-88	110	12.00	J-16
		0.75	6.31	P-88	110	11.99	J-16
		1.00	6.36	P-88	110	11.97	J-16
	110	**0.00**	5.17	P-88	110	12.35	J-16
		0.50	5.27	P-88	110	12.32	J-16
		0.75	5.31	P-88	110	12.30	J-16
		1.00	5.36	P-88	110	12.28	J-16
	120	**0.00**	4.40	P-88	110	12.59	J-16
		0.50	4.50	P-88	110	12.56	J-16
		0.75	4.54	P-88	110	12.54	J-16
		1.00	4.59	P-88	110	12.53	J-16

From the table above it seen that pressure variation is insignificant in these cases. Due to aging effect on the pipe caused by formation of deposits on the inside wall of the pipe, the pressure will drop and it is likely that roughness coefficient will decrease. The pressures variation seen on the **Table 4.9** for the C values 120, 110 and 100 are smaller. For safety consideration, incorporation of minor losses and taking into consideration previous experiences on modeling for similar other projects, Hazen - Williams coefficient C have been taken 110 as appropriate.

4.7.3 Flushing Analysis

Flushing analysis of total water distribution system (WDS) has been carried out to determine the time required for flushing event of distribution pipe that is connected with wash out. Required water for washing WDS has been assumed to be supplied from underground water reservoirs (UGWRs). The total volume of the water required for distribution pipe was approximately 21,976 L for phase 1, 20,231 L for phase 2. The total volume of the water required for distribution pipe flushing, velocity at Washouts (WO) pipe and the corresponding required flushing time have been shown in **Table 4.10**.

Table 4.10: Flushing Analysis of Total Water Distribution System

Pipe Label	Flushing Layout	Diameter of WO Pipe (mm)	WO Flow Rate/Segment Flushing Rate (L/s)	Velocity (m/s) at WO Pipe	Segment Volume (L)	Flushing Time Req. (min)
P-WO-1	Total Network	110	13.99	2.04	21,976	26.18
P-WO-2		75	9.09	2.76	20,231	37.09

The following **Table 4.11** lists the pipes which satisfy minimum flushing velocity threshold of 1.0 m/s during flushing through the proposed 2 (two) washout valves for scenario 2.

Table 4.11: Pipes with Flushing Velocity above 1.0 m/s

Label	Length (m)	Diameter (mm)	Velocity (Maximum Flushing) (m/s)	Flushing Event
P-86	65	75	2.88	Event [WO-2]
P-WO-2	3	75	2.76	Event [WO-2]
P-31	75	110	2.1	Event [WO-1]
P-23	63	110	2.1	Event [WO-1]
P-WO-1	1	110	2.04	Event [WO-1]
P-4	41	110	1.15	Event [WO-1]
P-40	91	110	1.15	Event [WO-1]
P-41	91	110	1.15	Event [WO-1]
P-2	26	160	1.14	Event [WO-1]
P-27	65	110	1.11	Event [WO-1]
P-26	65	110	1.11	Event [WO-1]
P-25	65	110	1.11	Event [WO-1]

Though two washouts were proposed but several local and temporary flushing arrangements may be required during O&M to satisfy minimum flushing velocity criteria for other pipes.

Again, some additional washouts may need to be installed based on variations in the as-built pipe profile. **Figure 4.11** shows flushing velocity in different pipes in the model network.

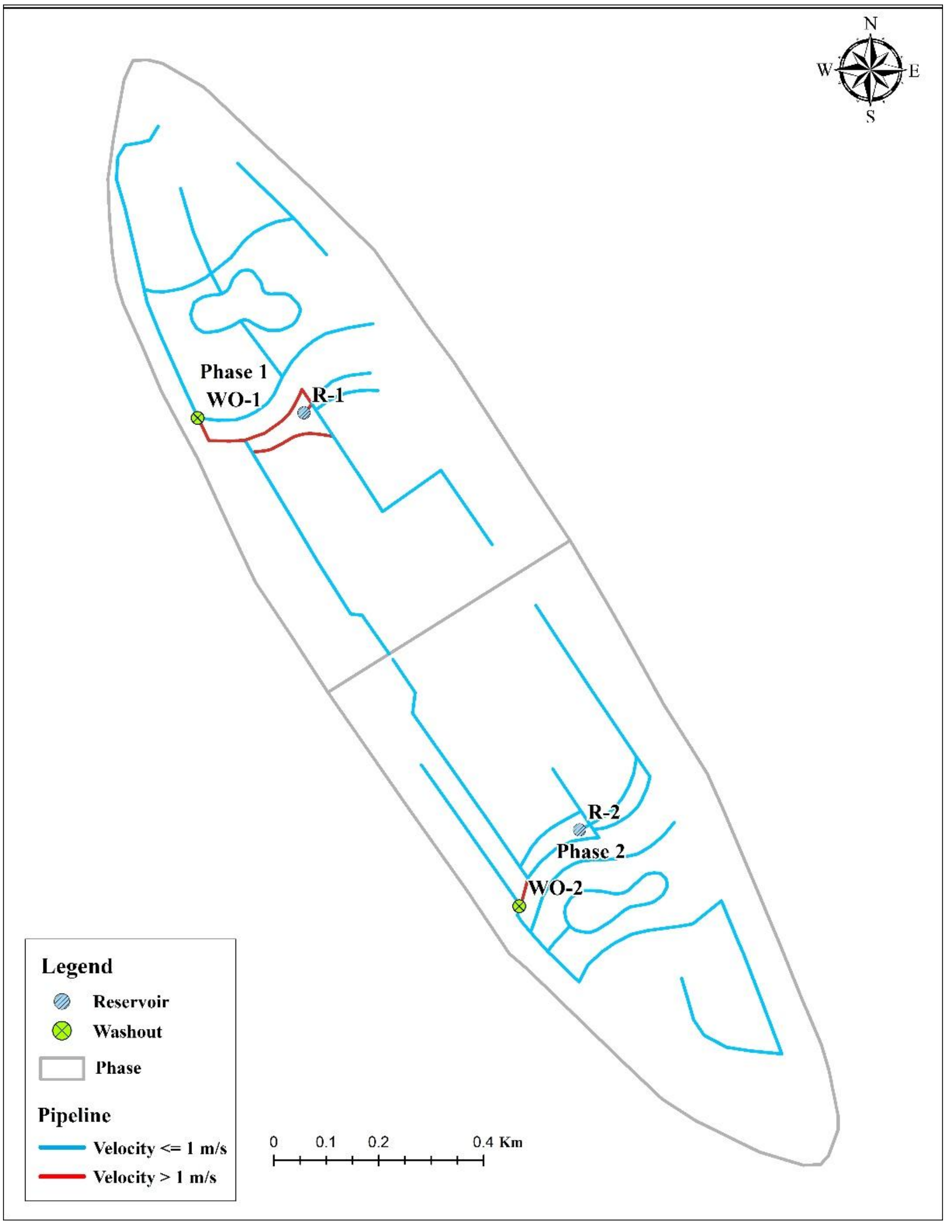


Figure 4.11: Pipes Showing Flushing Velocity

4.8 Under Ground Water Reservoir for Naf Tourism Park

4.8.1 Water Reservoir

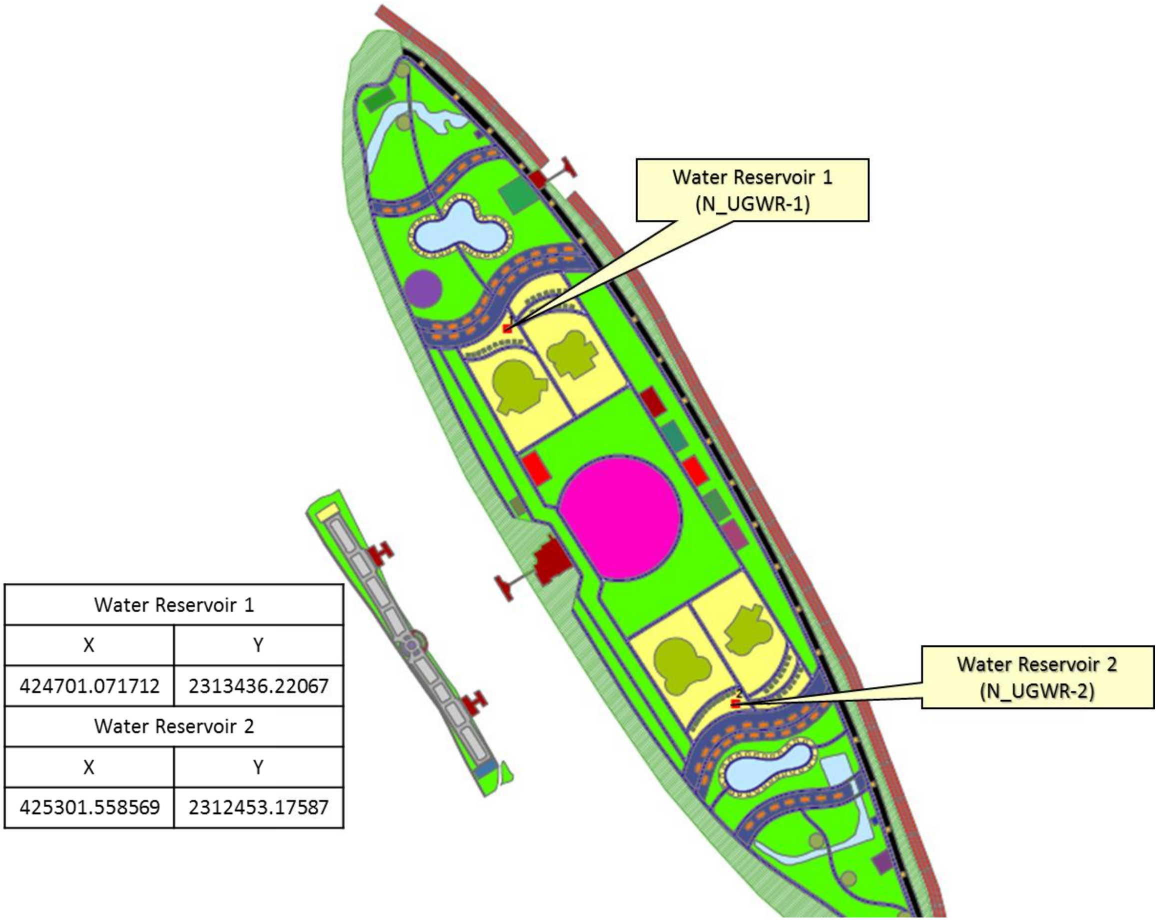
The underground water reservoirs (UGWR) is proposed in Naf Tourism Parks that would receive water from production tube well through the transmission main. The water will be stored in these UGWRs and then will be diverted through distribution network into each plot by pumping. The capacity of the Underground Water Reservoir (CUGWR) would be made adequate to store 2 days water demand. Two days storage has been suggested to ensure availability of uninterrupted water supply during any maintenance or repairing works.

Water Reservoir capacity = Volume of daily water demand x 2

Two numbers of underground water reservoir are good enough in Naf Tourism Park to optimize the cost and operation facilities. Each reservoir will have 2 chambers. The 1st reservoir (N_UGWR-1) will be used to supply water in Phase-1 area. The 2nd reservoir (N_UGWR-2) will be used to supply water in Phase-2 area. The locations of the reservoirs in Tourism Park area are provided from BEZA. The capacity, size and required head of each reservoir is given in **Table 4.12** and the locations are shown in **Figure 4.12**.

Table 4.12: Underground water reservoir capacity and size in Naf Tourism Park

	Unit	N_UGWR-1	N_UGWR-2
Maximum Water Requirement in the Distribution System	MLD	0.66	0.63
Required reservoir capacity for 2 days	m^3	1,240	1,200
Planned Reservoir Capacity	m^3	1,243	1,203
	Million Litre	1.24	1.2
Size of reservoir	mXmXm	17.8 x 17.8 x 5	17.4 x 17.4 x 5



Water Reservoir 1	
X	Y
424701.071712	2313436.22067
Water Reservoir 2	
X	Y
425301.558569	2312453.17587

Figure 4.12: Proposed underground water reservoir locations in Naf Tourism Park

4.8.2 Pump Station

Design flow of pumps in N_UGWR-1 and N_UGWR-2 0.58 and 0.55 MLD respectively and the pumps will be operated for 14-16 hours. Characteristics of Pump Units in each reservoir locations are given in **Table 4.13.** In both reservoirs 1 pumps of 0.5 cusec capacity each will need to be installed. Moreover, one Pumps need to be kept standby at each reservoir location for safe operation and maintenance.

Table 4.13: Characteristics of Pump Units

Reservoir	unit	N_UGWR-1	N_UGWR-2
Discharge	m^3/s	0.014	0.014
	cusec	0.58	0.55
Pump head	bar	2.30	2.30
Discharge Capacity of each Pumps	cusec	0.5	0.5
Nos. of Pump	no	2 (1 on duty, 1 standby)	2 (1 on duty, 1 standby)
Power requirement	kWh	5.0	5.0

4.9 Network model discussion for Sabrang Tourism Park

4.9.1 Water demand

Water demand of Sabrang Tourism Park has been calculated as 13.87 MLD considering loses and peak factor 1.25. The distribution hour has also been considered as 10-12 hours. The phase-wise water demands are given below in **Table 4.14** and detail demand in given in **Appendix-I**.

Table 4.14: Phase-wise Water Demand

Phase	Water Demand (L/s)	Water Demand (MLD)
1	60	5.17
2	59	5.01
3	50	3.68
Total	**169**	**13.87**

4.9.2 Network model Scenarios

To evaluate the water supply networks efficiency, implementation feasibility and to choose a more economic system, different scenarios were considered. The description of the scenarios for Sabrang Tourism Park distribution modelling are presented in **Table 4.15**. The reservoirs and layout of nearby pipes are shown in **Figure 3.13** and **Figure 3.14**.

Table 4.15: Description of Network Model Scenarios

Scenario	Description
Scenario 1	Water will be distributed from 3 reservoirs through partially connected pipelines along the path. • 1st reservoir is connected to phase 1; • 2nd reservoir is connected to phase 2; • 3rd reservoir is connected to phase 3.

Scenario	Description
Scenario 2	Water will be distributed from 2 reservoirs through partially connected pipelines along the path. • 1st reservoir is connected to phase 1; • 2nd reservoir is connected to phase 2 & 3 and they are partially connected.

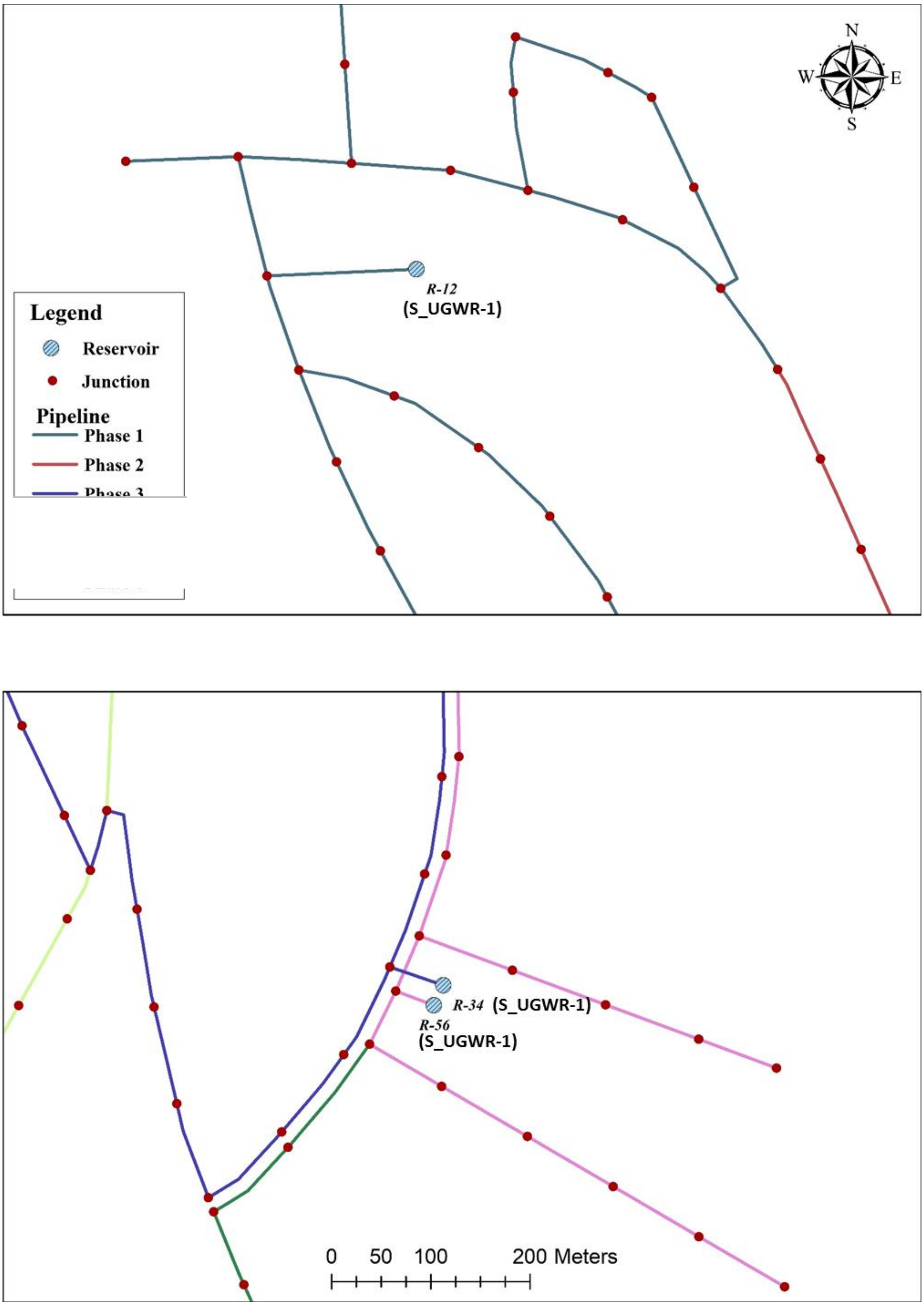


Figure 4.13: Reservoir and nearby Pipeline Layout (Scenario 1)

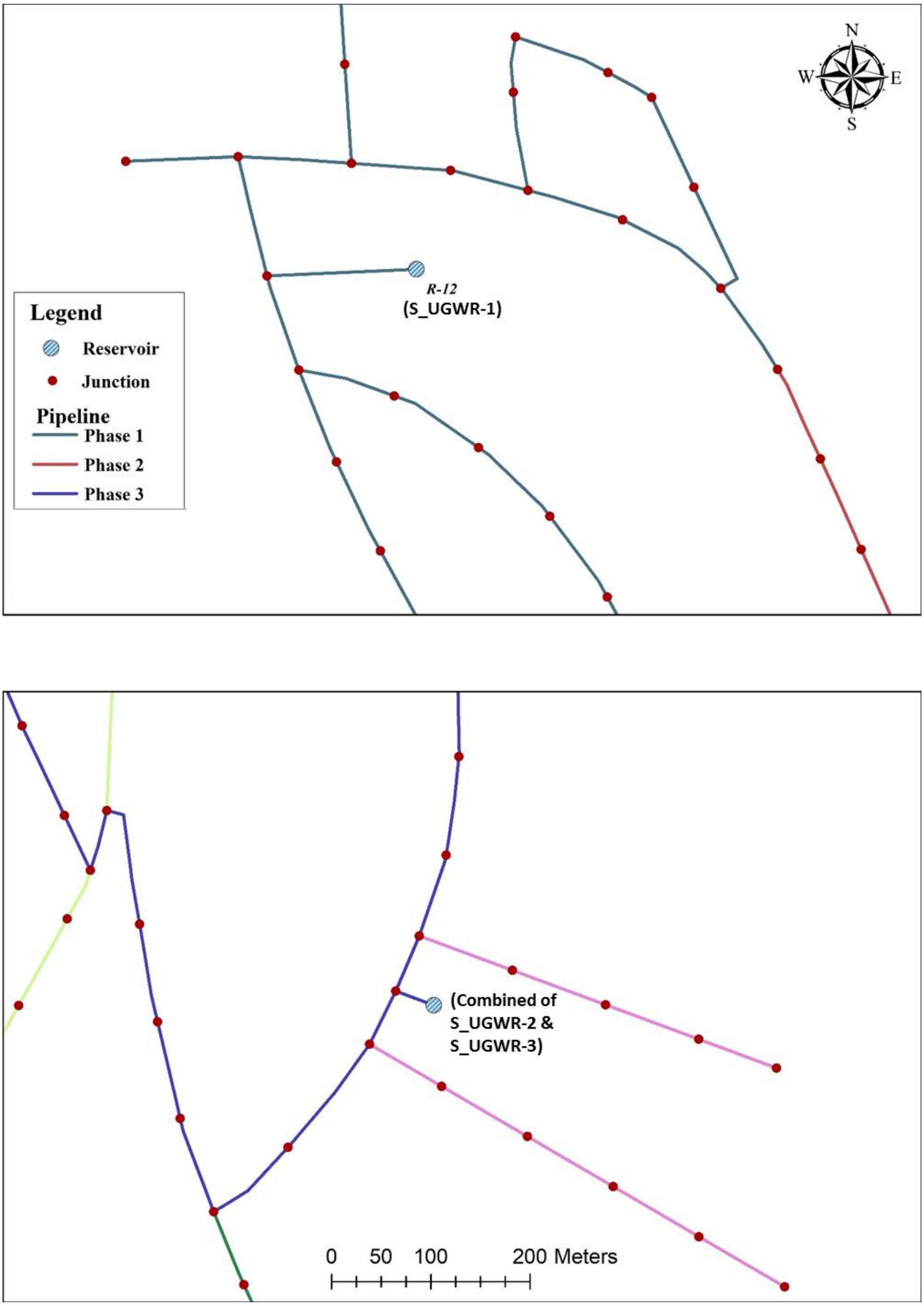


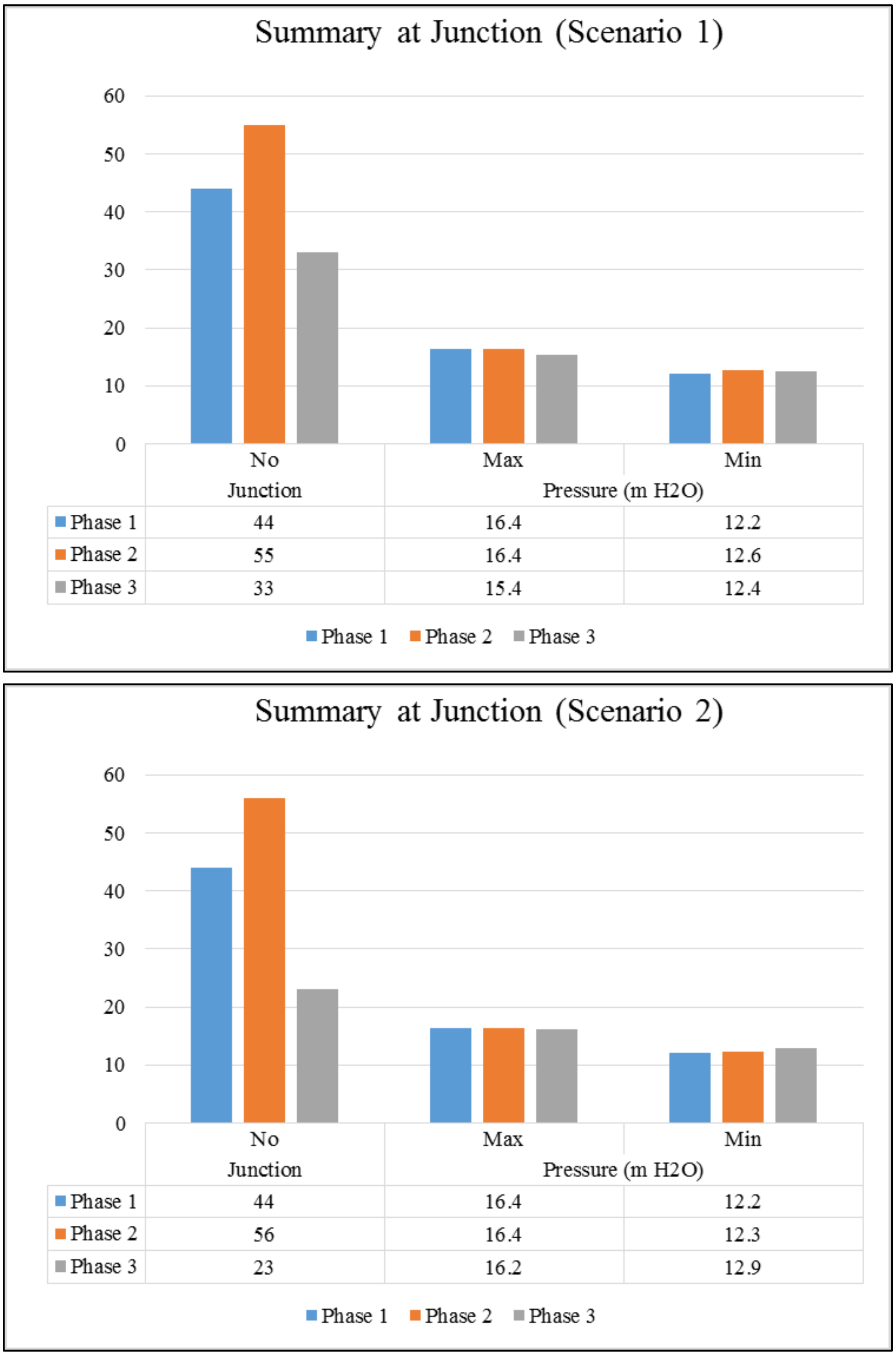
Figure 4.14: Reservoir and nearby Pipeline Layout (Scenario 2)

4.9.3 Distribution Network Model for Sabrang Tourism Park

The detail description of distribution network modelling for Sabrang Tourism Park as derived from the model is describe below.

4.9.3.1 Description of Junction (Node) Data

Each junction (node) is verified for corresponding design parameters specially the residual pressure. Summary of model output at different junctions for Scenario 1 and 2 are presented in **Figure 4.15** (tabular form) and **Figure 4.16** and the detail data such as junction label, demand and residual Pressure are stated in **Appendix J.** it is observed that the pressure varies between 12.2 to 16.4 m H_2O in scenario-1 and scenario-2 which is above the design minimum pressure at each junction.



Summary at Junction (Scenario 1)

	No	Max	Min
	Junction	Pressure (m H2O)	
■ Phase 1	44	16.4	12.2
■ Phase 2	55	16.4	12.6
■ Phase 3	33	15.4	12.4

Summary at Junction (Scenario 2)

	No	Max	Min
	Junction	Pressure (m H2O)	
■ Phase 1	44	16.4	12.2
■ Phase 2	56	16.4	12.3
■ Phase 3	23	16.2	12.9

Figure 4.15: Summary of Model Output at Junctions

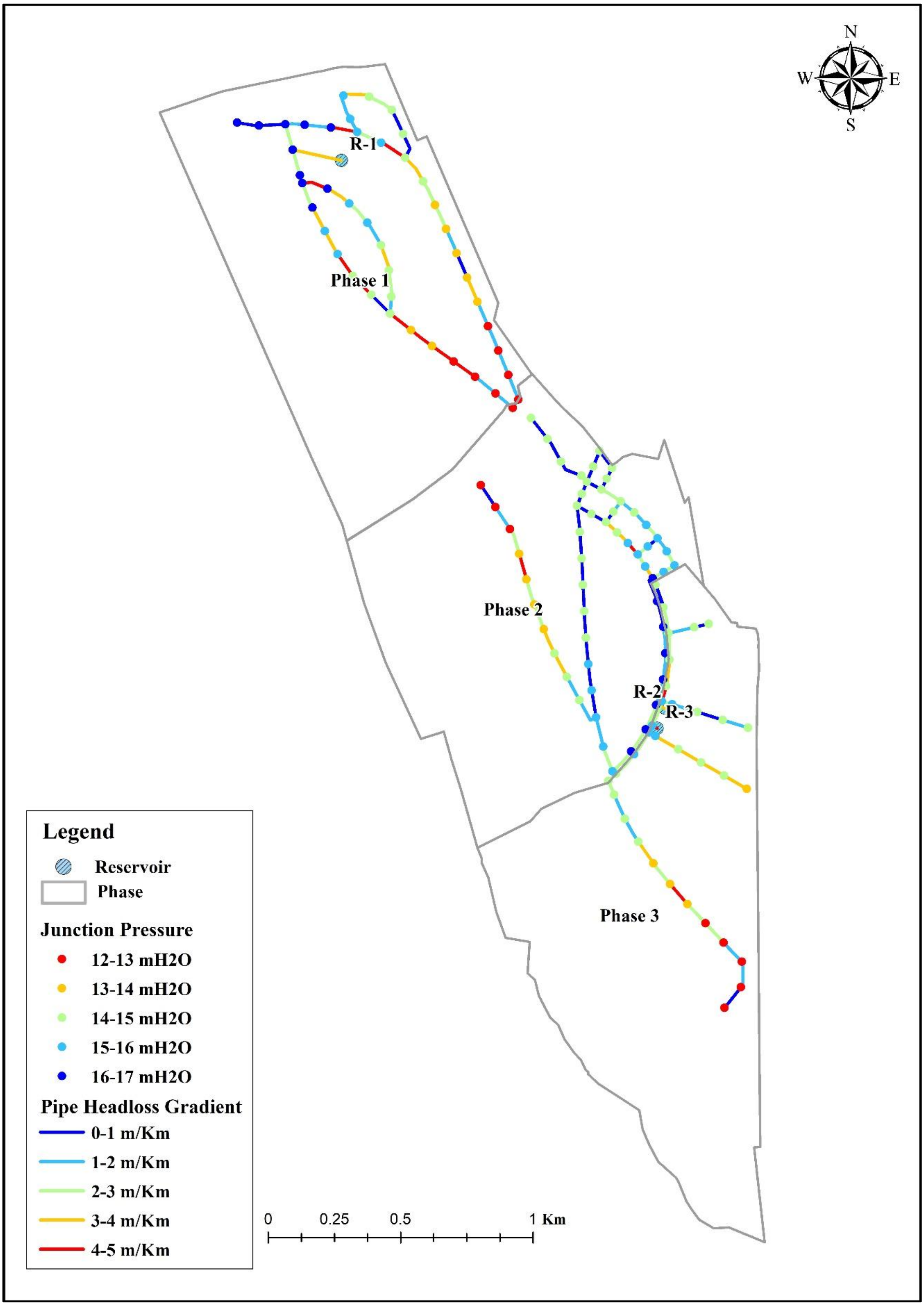
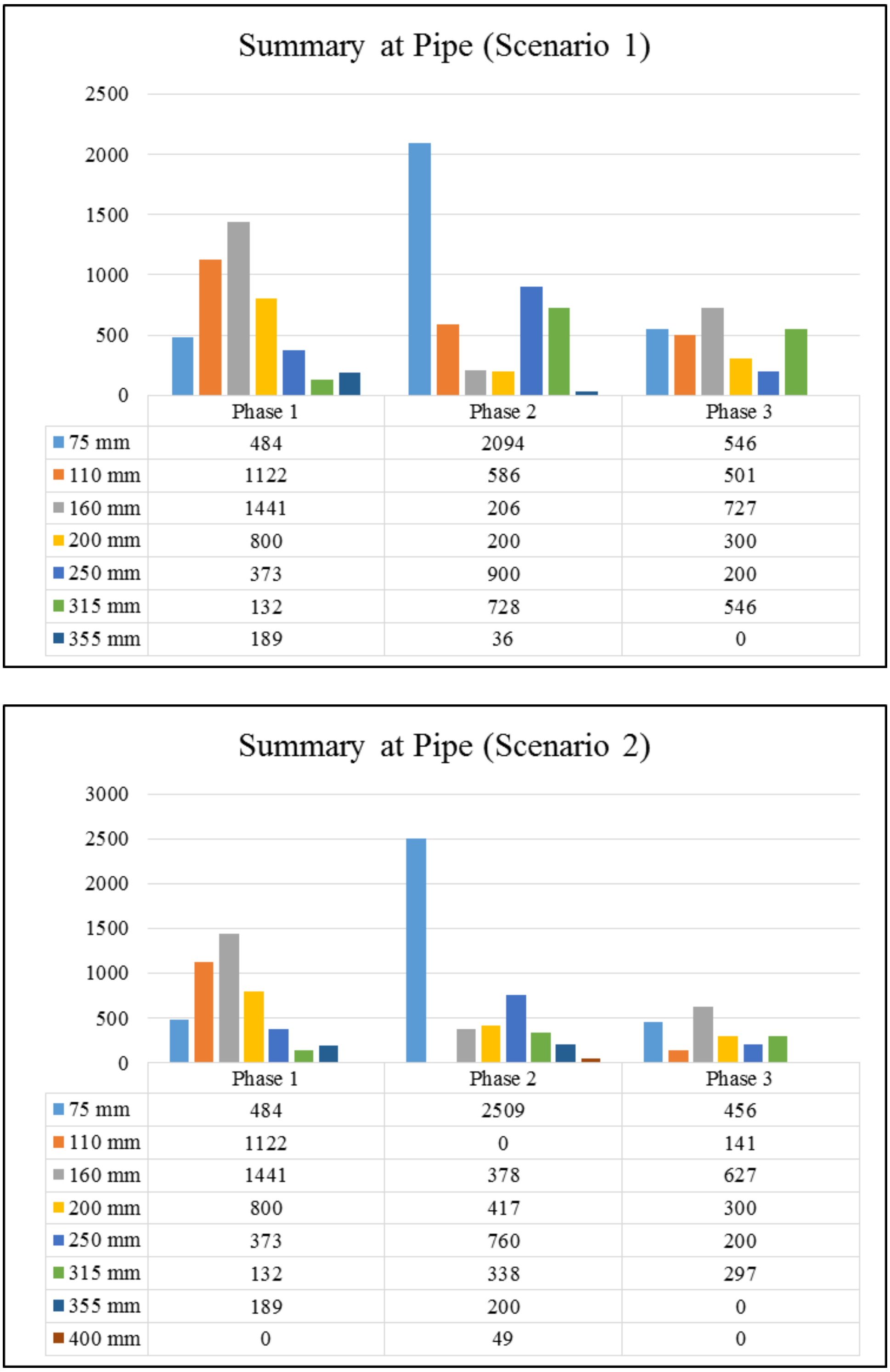


Figure 4.16: Profile of particular Parameter in Selected Junctions for Water Supply Model (Scenario 1)

4.9.3.2 Description of Network Data

In scenario-1, the total length of network is about 12.1 km and pipe diameter vary from 75 to 355mm, while in scenario-2 total length of network becomes 11.2 km and pipe diameter varies from 75 to 400mm. The length of pipes for different diameter are summarize in **Figure 4.17** and **Figure 4.18**. It is observed that the head loss gradient is within the range of design criteria of pressure gradient (**Table 4.3**). The length of pipes considered in different scenario are describe in **Appendix K**. The detailed results of pipes with selected hydraulic properties (diameter, velocity, head loss gradient, head-loss and flow) are provided for design in **Appendix L.**



Summary at Pipe (Scenario 1)

	Phase 1	Phase 2	Phase 3
■ 75 mm	484	2094	546
■ 110 mm	1122	586	501
■ 160 mm	1441	206	727
■ 200 mm	800	200	300
■ 250 mm	373	900	200
■ 315 mm	132	728	546
■ 355 mm	189	36	0

Summary at Pipe (Scenario 2)

	Phase 1	Phase 2	Phase 3
■ 75 mm	484	2509	456
■ 110 mm	1122	0	141
■ 160 mm	1441	378	627
■ 200 mm	800	417	300
■ 250 mm	373	760	200
■ 315 mm	132	338	297
■ 355 mm	189	200	0
■ 400 mm	0	49	0

Figure 4.17: Summary of Pipe Data

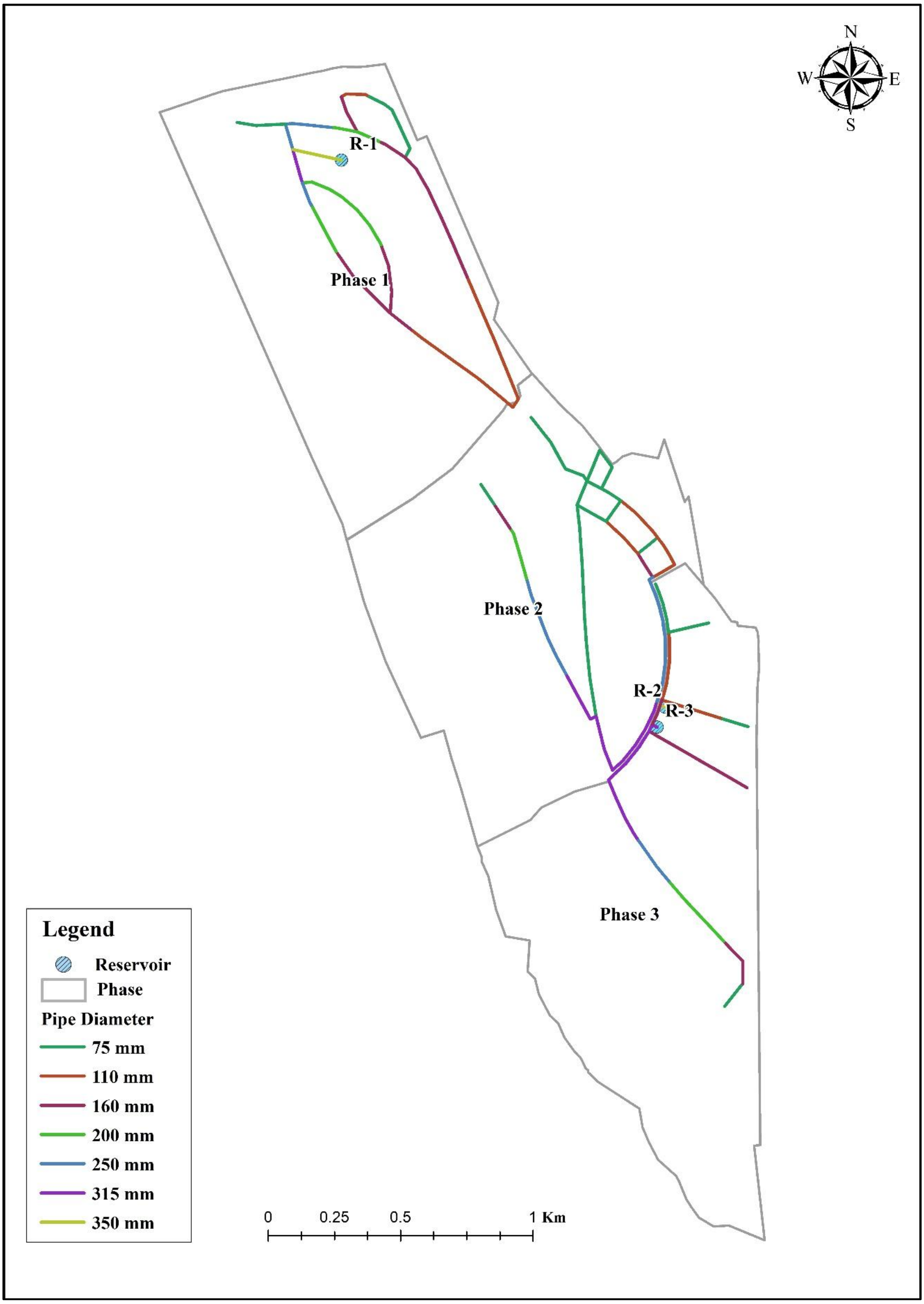


Figure 4.18: Map of Model Output for Pipe Diameter (Scenario 1)

In pipeline design criteria, it is suggested that maximum velocity of flow in the pipes should be up to 1.5 m/s. The maximum velocity found from model is shown in **Table 4.16.** As it can be seen that the pipe velocities are well below the maximum design limit.

Table 4.16: Maximum Velocity (m/s) in Pipes

Phase	Scenario 1		Scenario 2	
	Velocity (m/s)	Label	Velocity (m/s)	Label
1	0.84	P-47	0.84	P-47
2	0.82	P-49	1.2	P-48
3	0.89	P-108	0.74	P-120

But it is observed that during modelling the minimum velocity cannot be ensured. The velocity of flow is inversely proportional to the diameter of pipe. If the velocity of the pipe flow required to be increased, the diameter of the pipe needs to be decreased. But according to design criteria, minimum diameter of the pipe must be 75mm. In order to satisfy the minimum diameter criteria, the minimum velocity cannot be ensured.

4.9.3.3 Selection of model scenario

For selection of model scenario, there are practical issues should be taken into account such as operation and maintenance of reservoir and pump station; technical hindrances like maintaining the required amount of pressure at the consumer end in pipe with large diameter when all the phases are not functioning which are really a challenging task.

As per “Detailed Master Plan for Sabrang Tourism Park” (December, 2020), the phases will be developed in different time period mentioned in **Table 4.2**. If scenario-2 is selected, the 2nd reservoirs and pump units have to be constructed 10 years prior to reaching their fully functioned state. It will require huge financial investment at earlier which may not be a rational planning to make. Keeping all these factors in mind and applying a sound judgment, we have preliminarily chosen Scenario-1 for this assessment as the most viable network for Sabrang Tourism Park water supply.

4.10 Network Analysis

As we have recommended Scenario-1 for implementation, so several types of network analysis have been varied out for Scenario-1 only.

4.10.1 Criticality Analysis

Number and location of isolation valves of Sabrang Tourism Park has been determined and optimized by criticality analysis which was performed by using the WaterGEMS software.

4.10.1.1 Assumptions and Approaches

- Complete isolation from the network is the first criteria for putting isolation valves in the pipes.
- Isolation valves must be located such that during operation and maintenance work, possible stoppage of sources can be avoided as much as possible.
- Minimize the offline areas as much as possible considering the maintenance work at network.
- Minimize the number and length of outage segments in the network.

- Minimize the number of valves that need to be closed for isolating a segment. The more no. of valves required closing at a time decreases the network reliability during the operation of those valves.
- Total cost considerations.

4.10.1.2 Additional Considerations

- Maximum length of one segment below 1000 m
- Avoid larger diameters (≥ 200 mm) as many as possible.
- Maximum number of GV for one segment closure is within 10.
- Maximum length of outage segment is within 1000 m (except dead end branch) at the downstream of network
- Special Consideration (if any) which must be approved by BEZA.

4.10.1.3 Segmentation of the Network

At first, a tentative number of isolation valves were digitized in the model. Isolation valve diameter was modified to conform to corresponding pipe diameter. After that criticality analysis were carried out for entire network to check the isolation and isolated segment properties in the system. Finally, the number and location of isolation valves were optimized to obtain the desirable outputs. **Figure 4.19** shows different isolated segments.

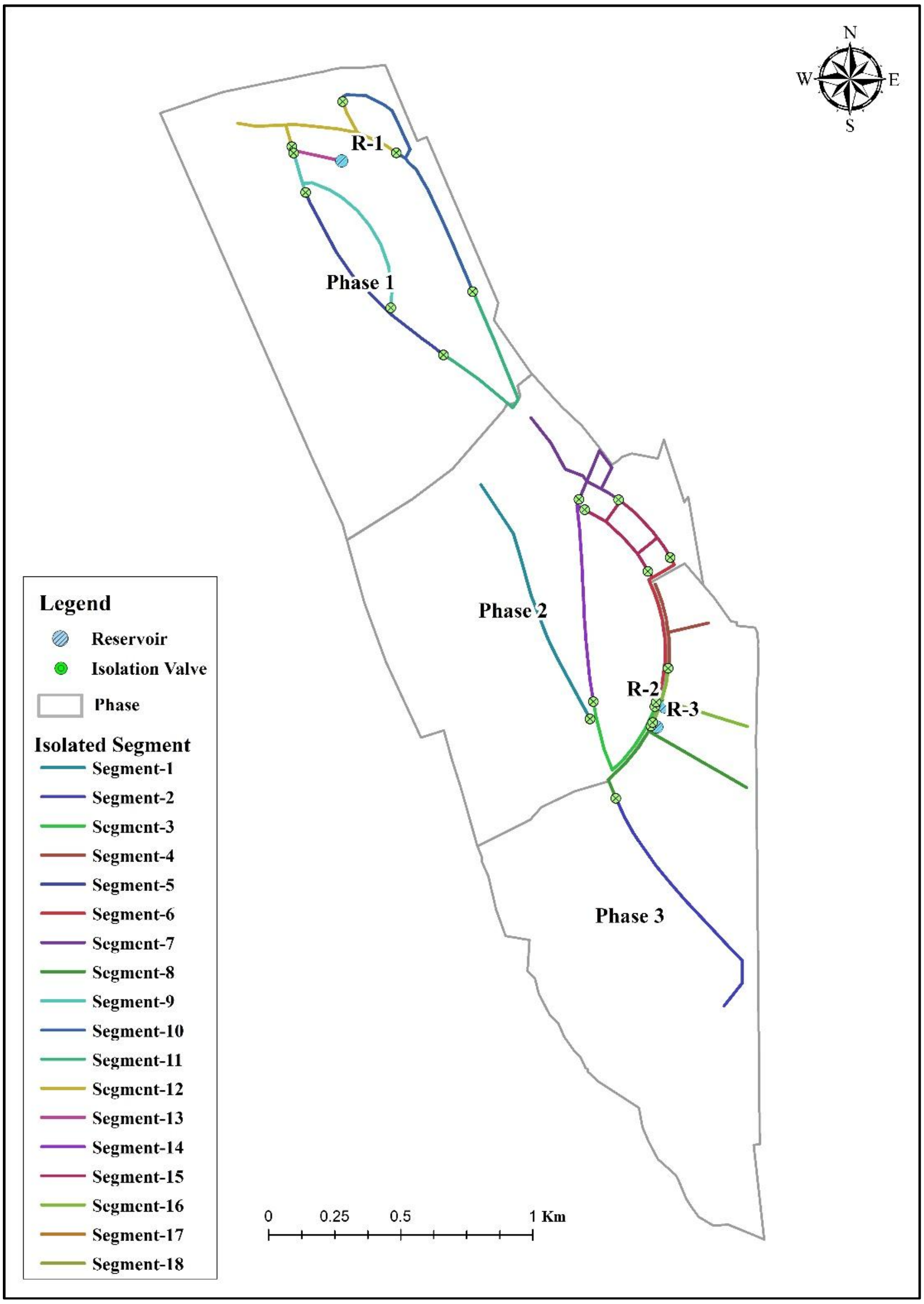


Figure 4.19: Different Isolated Segments in Scenario 2

4.10.1.4 Outputs of Criticality Analysis

The output results of the criticality analysis for scenario 1 are shown in **Table 4.17**.

Table 4.17: Summary of Criticality Analysis

Item Description	Value
a) No. of Proposed Gate Valves	21
b) No. of Isolated Segments	18
c) Maximum Segment Length (m)	1035
d) Average Length of all Segments(m)	787
e) Average Length of segments related to service connections (m)	672
f) Maximum No. of Valves Needed to be Closed	4

Total isolation valves have been selected 21 nos. and segments became 18nos. Out of these 18 segments, 15 of them are related to service connections and the rest are related to operation of water sources near UGWRs. In case of major segments which are related to the service connections for undelivered water during segment shutoff, the average segment length has been found as 787 m. On the contrary, for all segments either these are for water source operation or related to the service connection, average segment length has been found as 672 m. So maximum segment length during reparation or maintenance work is within the design consideration (1000m). Moreover, it is found that maximum number of valves need to be closed for repairing and maintenance work is 3nos. which also satisfied design considerations.

It is also observed (**Table 4.17**) that, in the network no of outage segments is 18 which is refers repairing or maintenance work near the reservoir location.

The total length of outage segments and demand shortfall for repairing and maintenance at different segments are stated in **Table 4.18**. It is observed that maximum outage segment length is about 4.7 km and demand shortfall is about 35.40%. Moreover, if any repairing or maintenance is required in any segments connected to the reservoirs (UGWR), the network system connected to this reservoir will be under shortfall of water. Precaution is needed to avoid the situation as stated below.

Table 4.18: Isolated Segment Properties

Segment	Segment Length (m)	No of Isolation Nodes	Outage Segment Length (m)	System Demand Shortfall (%)
Related to Operation of Sources (UGWR)				
Segment - 13	214	2	4,327	35.40
Segment - 17	53	2	4,698	34.80
Segment - 18	36	2	2,783	29.80
Related to Service Connection				
Segment - 1	986	1	0	19.10
Segment - 2	980	1	0	18.70
Segment - 3	587	3	986	23.80
Segment - 4	482	1	0	1.70
Segment - 5	843	3	0	12.50
Segment - 6	648	3	0	5.10
Segment - 7	842	2	0	0.80
Segment - 8	766	2	980	26.40
Segment - 9	798	3	0	6.80
Segment - 10	1036	3	0	6.20
Segment - 11	810	2	0	3.70
Segment - 12	839	3	0	3.10
Segment - 14	806	3	0	0.10
Segment - 15	829	4	0	4.90
Segment - 16	556	2	482	3.40

4.10.1.5 Precautions needed during repairing or maintenance work

Precautions needed to minimize demand shortfall during repairing or maintenance work are as follows:

4.10.2 Sensitivity Analysis

The water supply distribution network model of Sabrang Tourism Park satisfies all the hydraulic requirement which is suitable to meet the demand 178.89 L/s considering loses and peak factor 1.25. The model has been tested again for different sensitivity analysis as describe below. Network pipe sizing has been optimized considering the output of these analysis.

As it is said earlier in this report, minor losses have not been directly incorporated in the model, but in actual case there will be some minor losses in the water distribution system, the common minor losses and its corresponding head loss coefficient are shown below

- 1.5 - Elbow, Threaded Regular 90^o
- 1.0 - Tee, Flanged, Branched Flow
- 0.5 - Elbow, Threaded Regular 45^o

For sensitivity analysis of the model, the model has been simulated for various values for Hazen-Williams Coefficient (C) and Minor Loss Coefficient (K). It has been checked with different C values as 120, 110 & 100 and for three minor loss coefficients (1, 0.75 & 0.5) whether the model is robust irrespective of such changes. The minimum pressure and maximum head loss gradient variation due to different C and K values is shown in **Table 4.19**.

Table 4.19: Pressure Variation with Hazen-Williams Coefficient (C) and Minor Loss Coefficient (K)

Phase	Hazen-Williams Coefficient (C) Values	Minor Loss Coefficient, K	Maximum Head loss Gradient (m/km) at Pipe	Pipe Label	Pipe Diameter (mm)	Minimum Pressure (m H_2O) at Junction	Junction Label
1	100	0.00	5.94	P-24	110	11.25	J-30
		0.50	5.99	P-24	110	11.13	J-30
		0.75	6.03	P-45	160	11.08	J-30
		1.00	6.08	P-45	160	11.02	J-30
	110	0.00	4.98	P-24	110	12.17	J-30
		0.50	5.03	P-24	110	12.06	J-30
		0.75	5.08	P-45	160	12.00	J-30
		1.00	5.13	P-45	160	11.95	J-30
	120	0.00	4.24	P-24	110	12.88	J-30
		0.50	4.30	P-45	160	12.77	J-30
		0.75	4.34	P-45	160	12.72	J-30
		1.00	4.39	P-45	160	12.66	J-30
2	100	0.00	5.55	P-64	110	11.89	J-98
		0.50	5.66	P-64	110	11.74	J-98

Phase	Hazen-Williams Coefficient (C) Values	Minor Loss Coefficient, K	Maximum Head loss Gradient (m/km) at Pipe	Pipe Label	Pipe Diameter (mm)	Minimum Pressure (m H_2O) at Junction	Junction Label
		0.75	5.71	P-64	110	11.66	J-98
		1.00	5.76	P-64	110	11.58	J-98
	110	0.00	4.65	P-64	110	12.63	J-98
		0.50	4.76	P-64	110	12.48	J-98
		0.75	4.81	P-64	110	12.40	J-98
		1.00	4.86	P-64	110	12.32	J-98
	120	0.00	3.96	P-64	110	13.20	J-98
		0.50	4.06	P-64	110	13.05	J-98
		0.75	4.12	P-64	110	12.97	J-98
		1.00	4.17	P-64	110	12.89	J-98
3	100	0.00	5.83	P-115	110	11.84	J-114
		0.50	5.94	P-24	110	11.69	J-114
		0.75	6.38	P-108	315	11.62	J-114
		1.00	6.87	P-108	315	11.55	J-114
	110	0.00	4.89	P-115	110	12.43	J-114
		0.50	5.10	P-108	315	12.28	J-114
		0.75	5.59	P-108	315	12.21	J-114
		1.00	6.07	P-108	315	12.13	J-114
	120	0.00	4.16	P-115	110	12.88	J-30
		0.50	4.49	P-108	315	12.73	J-114
		0.75	4.97	P-108	315	12.66	J-30
		1.00	5.46	P-108	315	12.59	J-114

From the table above it seen that pressure variation is insignificant in this case. Due to aging effect on the pipe caused by formation of deposits on the inside wall of the pipe, the pressure will drop and it is likely that roughness coefficient will decrease. The pressure variations for the C values 120, 110 and 100 are smaller. For safety consideration, incorporation of minor losses and taking into consideration previous experiences on modeling for similar other projects, Hazen - Williams coefficient C have been taken 110 as appropriate.

4.10.3 Flushing Analysis

Flushing analysis of total water distribution system (WDS) was carried out to determine the time required for flushing event of distribution pipe that is connected with wash out. Required water for washing WDS has been assumed to be supplied by existing underground reservoirs (UGRs). The total volume of the water required for distribution pipe was approximately 87,288L for phase 1, 99,235 L for phase 2 and 63,926 L for phase 3. For flushing analysis of Sabrang Tourism Park, 30% of total water demand has been considered in design nodes. The total volume of the water required for distribution pipe flushing, velocity at Washouts (WO) pipe and the corresponding required flushing time have been shown in **Table 4.20** for scenario 1.

Table 4.20: Flushing Analysis of Total Water Distribution System

Pipe Label	Flushing Layout	Diameter of WO Pipe (mm)	WO Flow Rate/Segment Flushing Rate (L/s)	Velocity (m/s) at WO Pipe	Total Flushing Rate (L/s)	Segment Volume (L)	Flushing Time Req. (min)
P-WO-11	Total Network	160	33.0	3.1	46.7	87,288	31.2
P-WO-12		110	13.6	2.0			
P-WO-21		160	33.1	2.9	69.5	99,235	23.8
P-WO-22		160	36.4	3.6			
P-WO-31		110	12.0	1.7	44.2	63,926	24.1
P-WO-32		160	32.2	2.9			

The following **Table 4.21** listed the pipes which satisfy minimum flushing velocity threshold of 1.0 m/s during flushing through the proposed 6 (six) washout valves for scenario 1.

Table 4.21: Pipes with Flushing Velocity above 1.0 m/s

Label	Length (m)	Diameter (mm)	Velocity (Maximum Flushing) (m/s)	Flushing Event
P-WO-22	1.90	160	3.57	Event [WO-3]
P-WO-11	2.00	160	3.05	Event [WO-1]
P-WO-21	2.93	160	2.92	Event [WO-2]
P-WO-32	2.78	160	2.88	Event [WO-4]
P-60	53.12	160	2.54	Event [WO-2]
P-61	53.12	160	2.53	Event [WO-2]
P-21	100.00	200	2.3	Event [WO-1]
P-28	100.00	200	2.15	Event [WO-1]
P-126	100.00	200	2.05	Event [WO-4]
P-WO-12	2.00	110	1.99	Event [WO-6]
P-132	100.00	200	1.98	Event [WO-4]
P-115	59.54	110	1.87	Event [WO-5]
P-120	100.00	110	1.85	Event [WO-5]
P-122	100.00	110	1.82	Event [WO-5]
P-WO-31	2.00	110	1.72	Event [WO-5]
P-90	100.00	250	1.69	Event [WO-3]
P-92	100.00	250	1.69	Event [WO-3]
P-100	100.00	250	1.64	Event [WO-3]
P-31	100.00	250	1.49	Event [WO-1]
P-5	73.38	250	1.49	Event [WO-1]
P-32	100.00	250	1.48	Event [WO-1]
P-49	35.51	355	1.41	Event [WO-3]
P-129	100.00	250	1.4	Event [WO-4]
P-24	100.00	110	1.39	Event [WO-6]
P-34	100.00	110	1.39	Event [WO-6]
P-33	100.00	110	1.39	Event [WO-6]
P-125	100.00	250	1.35	Event [WO-4]
P-85	100.00	250	1.3	Event [WO-2]

Label	Length (m)	Diameter (mm)	Velocity (Maximum Flushing) (m/s)	Flushing Event
P-81	100.00	250	1.28	Event [WO-2]
P-83	100.00	250	1.28	Event [WO-2]
P-84	100.00	250	1.25	Event [WO-2]
P-77	100.00	250	1.23	Event [WO-2]
P-108	20.97	315	1.21	Event [WO-4]
P-7	84.49	110	1.16	Event [WO-6]
P-22	100.00	110	1.16	Event [WO-6]
P-87	100.00	315	1.15	Event [WO-3]
P-86	100.00	315	1.14	Event [WO-3]
P-106	103.96	315	1.14	Event [WO-3]
P-88	100.00	315	1.14	Event [WO-3]
P-107	113.55	315	1.11	Event [WO-3]
P-55	47.92	75	1.09	Event [WO-2]
P-78	110.87	315	1.09	Event [WO-3]
P-99	100.00	315	1.09	Event [WO-3]
P-54	47.92	75	1.06	Event [WO-2]
P-47	188.64	355	1.03	Event [WO-1]

Though four washouts were proposed but several local and temporary flushing arrangements may be required during O&M to satisfy minimum flushing velocity criteria for other pipes. Again, some additional washouts may need to be installed based on variations in the as-built pipe profile. **Figure 4.20** shows flushing velocity in different pipes in the model network.

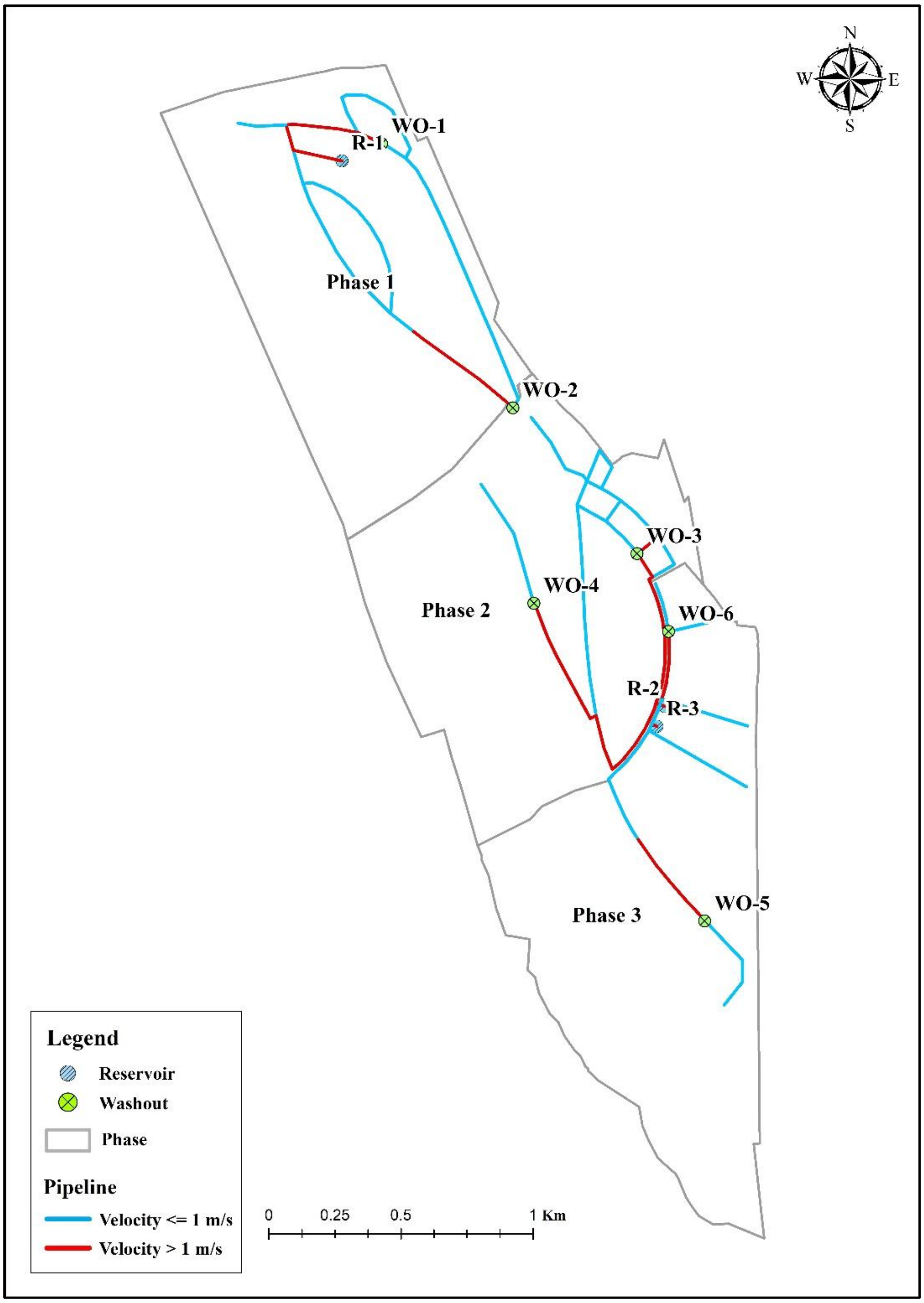


Figure 4.20: Pipes Showing Flushing Velocity in Scenario 1

4.11 Under Ground Water Reservoir for Sabrang Tourism Park

4.11.1 Water Reservoir

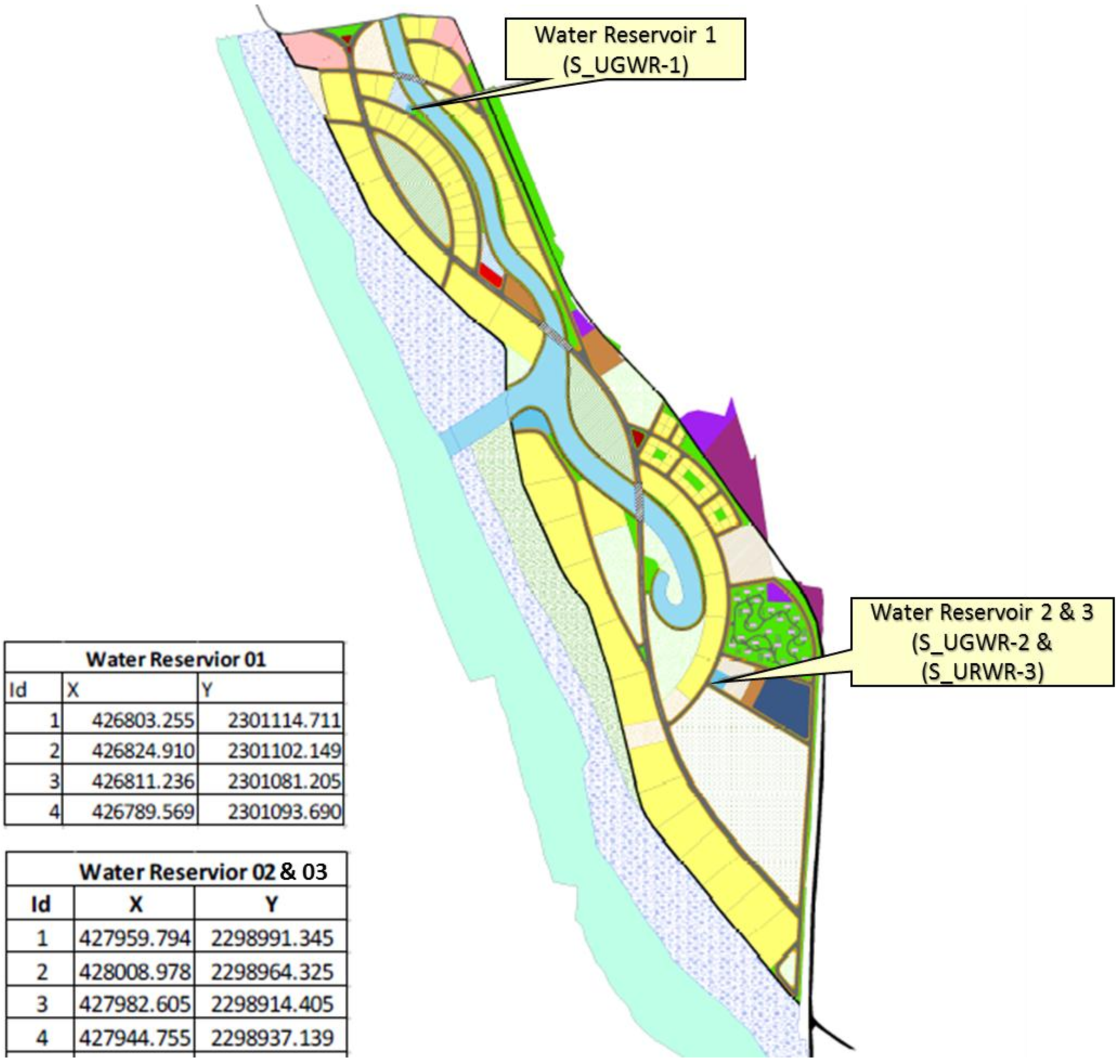
The underground water reservoirs (UGWR) are proposed in Sabrang Tourism Parks that would receive water from production tube well, Teknaf reservoir through the transmission main and from desalination plant. The water will be stored in these UGWRs and then will be diverted through distribution network into each plot by pumping. The capacity of the Underground Water Reservoir (CUGWR) would be made adequate to store 2 days water demand. Two days storage has been suggested to ensure availability of uninterrupted water supply during any maintenance or repairing works.

Water Reservoir capacity = Volume of daily water demand x 2

Three numbers of underground water reservoir are good enough in Sabrang Tourism Park to optimize the cost and operation facilities. Each reservoir will have 2 chambers. The 1st reservoir (S_UGWR-1) will be used to supply water in areas Phase-1. The 2nd reservoir (S_UGWR-2) will be used to supply water in areas Phase-2. And the 3rd reservoir (S_UGWR-3) will be used to supply water in areas Phase-3. The locations of the reservoirs in Tourism Park area are provided from BEZA. The capacity, size and required head of each reservoir is given in **Table 4.22** and the locations are shown in **Figure 4.21**.

Table 4.22: Underground water reservoir capacity and size in Sabrang Tourism Park

	Unit	S_UGWR-1	S_UGWR-2	S_UGWR-3
Maximum Water Requirement in the Distribution System	MLD	4.14	4.01	2.94
Required reservoir capacity for 2 days	m^3	8,280	8,002	5,880
Planned Reservoir Capacity	m^3	8,300	8,040	5,893
	Million Litre	8.3	8.04	5.89
Size of reservoir	mXmXm	45.6 x 45.6 x 5	44.9 x 44.9 x 5	38.4 x 38.4x 5



Water Reservior 01

Id	X	Y
1	426803.255	2301114.711
2	426824.910	2301102.149
3	426811.236	2301081.205
4	426789.569	2301093.690

Water Reservior 02 & 03

Id	X	Y
1	427959.794	2298991.345
2	428008.978	2298964.325
3	427982.605	2298914.405
4	427944.755	2298937.139

Figure 4.21: Proposed underground water reservoir locations in Sabrang Tourism Park

4.11.2 Pump Station

Design flow of pumps in S_UGWR-1, S_UGWR-2 and S_UGWR-3 are 3.85, 3.77 and 3.24 MLD respectively and the pumps will be operated for 12-14 hours. Characteristics of Pump Units in each reservoir locations are given in **Table 4.23**. For all the reservoirs 1 pumps of 1.0 cusec capacity need to be kept standby for safe operation and maintenance.

Table 4.23: Characteristics of Pump Units

Reservoir	unit	S_UGWR-1	S_UGWR-2	S_UGWR-3
Discharge	m^3/s	0.11	0.11	0.09
	cusec	3.85	3.77	3.24
Pump head	bar	2.65	2.60	2.50
Discharge Capacity of each Pumps	cusec	1	1	1
Nos. of Pump	no	5 (4 on duty, 1 standby)	5 (4 on duty, 1 standby)	5 (4 on duty, 1 standby)
Power requirement	kWh	11.1	10.9	8.6

4.12 Distribution Network Cost estimation

Tentative cost estimate of the distribution network has been assessed based on following consideration.

- The cost estimate for the HDPE mm pipelines includes material cost as well as supply and installation cost.
- The cost of valves and wash outs include material cost as well as supply and installation cost.

4.12.1 Distribution Network Cost for Naf Tourism Park

The cost of distribution network includes cost of pipe materials, reservoir and pumping unit cost including supply and installation cost which is about 62.59 Million BDT. The cost estimate is provided in **Table 4.24.**

Table 4.24: Cost Estimate of distribution network in Naf Tourism Park

Item No.	Description of Items	Diameter (mm)	Unit	Total Quantity	Rate in BDT	Amount* (Million BDT)
1	**Supply and Installation of Water Pipes using Open Trench Method**					
	Includes pipe material cost, excavating/trench cutting, pipe laying, sand bedding, labour charges, backfilling and restoration	75	m	8307	1,670	13.88
		110	m	1599	2,094	3.35
		160	m	177	2,954	0.52
	Sub-Total of Item No. 1					**17.75**
2	**Supply and Installation of Valves and Equipment**					
2.1	Gate valve (GV)	75	Nos.	10	8,527	0.09
		100	Nos.	6	15,159	0.09
		150	Nos.	2	29,847	0.06
	Sub-Total of Item No. 2.1					***0.24***
2.2	Washout Set (WO)	75	Nos	1	22,500	0.02
		100	Nos	1	40,000	0.04
	Sub-Total of Item No. 2.2					***0.06***
2.3	Air Release Valve (ARV)	100	Nos	2	42,530	0.09
	Sub-Total of Item No. 2.3					***0.09***
2.4	Fire Hydrant	100	Nos	2	120,000	0.24
	Sub-Total of Item No. 2.4					***0.24***
	Sub-Total of Item No. 2 (Summation of 2.1 to 2.4)					***0.67***
3	**Chambers and Surface Box**					
3.1	Gate valve (GV)					
3.1.1	Surface Box (GV upto 250mm diameter)		Nos.	18	120,000	2.16
	Sub-Total of Item No. 3.1					***2.16***
3.2	ARV Chamber (100mm~150mm)		Nos.	2	120,000	0.24
	Sub-Total of Item No. 3.2					***0.24***
3.3	Washout Chamber		Nos.	2	150,000	0.30
	Sub-Total of Item No. 3.3					***0.30***
3.4	Fire Hydrant Chamber		Nos.	2	120,000	0.24
	Sub-Total of Item No. 3.4					***0.24***
	Sub-Total of Item No. 3 (Summation of 3.1 to 3.4)					***3.06***
4	Underground water reservoirs includind water reservoirs, pumping units with necessary above ground and underground works for construction					**41.28**

	Sub-Total of Item No. 4					***41.28***
	Grand Total					**62.59**

*Price is without price escalation

4.12.2 Distribution Network Cost for Sabrang Tourism Park

The cost of distribution network includes cost of pipe materials, reservoir and pumping unit cost including supply and installation cost which is about 325.44 Million BDT. The cost estimate is provided in **Table 4.25.**

Table 4.25: Cost Estimate of distribution network in Sabrang Tourism Park

Item No.	Description of Items	Diameter (mm)	Unit	Total Quantity	Rate in BDT	Amount* (Million BDT)
1	**Supply and Installation of Water Pipes using Open Trench Method**					
1.1	Includes pipe material cost, excavating/trench cutting, pipe laying, sand bedding, labour charges, backfilling and restoration	75	m	3123	1,670	5.22
		110	m	2209	2,094	4.63
		160	m	2374	2,954	7.01
		200	m	1300	3,883	5.05
		250	m	1473	5,261	7.75
		315	m	1406	7,584	10.66
		355	m	224	9,632	2.16
	Sub-Total of Item No. 1					***42.48***
2	**Supply and Installation of Valves and Equipment**					
2.1	Gate valve (GV)	100	Nos.	4	15,159	0.06
		150	Nos.	4	29,847	0.12
		200	Nos.	5	41,598	0.21
		250	Nos.	3	68,743	0.21
		300	Nos.	5	135,916	0.68
	Sub-Total of Item No. 2.1					***1.27***
2.2	Washout Set (WO)	100	Nos.	2	40,000	0.08
		150	Nos.	4	60,000	0.24
	Sub-Total of Item No. 2.2					***0.32***
2.3	Air Release Valve (ARV)	100	Nos.	3	42,530	0.13
	Sub-Total of Item No. 2.3					***0.13***
2.4	Fire Hydrant	100	Nos.	3	120,000	0.36
	Sub-Total of Item No. 2.4					***0.36***
	Sub-Total of Item No. 2 (Summation of 2.1 to 2.4)					***2.08***
3	**Chambers and Surface Box**					
3.1	Gate valve (GV)					
3.1.1	Surface Box (GV upto 250mm diameter)		Nos.	16	120,000	1.92
			Nos.	5	150,000	0.75
	Sub-Total of Item No. 3.1					***2.67***

Item No.	Description of Items	Diameter (mm)	Unit	Total Quantity	Rate in BDT	Amount* (Million BDT)
3.2	ARV Chamber (100mm~150mm)		Nos.	3	120,000	0.36
	Sub-Total of Item No. 3.2					***0.36***
3.3	Washout Chamber		Nos.	6	150,000	0.90
	Sub-Total of Item No. 3.3					***0.90***
3.4	Fire Hydrant Chamber		Nos.	3	120,000	0.36
	Sub-Total of Item No. 3.4					***0.36***
	Sub-Total of Item No. 3 (Summation of 3.1 to 3.4)					***4.29***
4	Underground water reservoirs including water reservoirs, pumping units with necessary above ground and underground works for construction					276.59
	Sub-Total of Item No. 4					**276.59**
	Grand Total					**325.44**

*Price is without price escalation

5 GEOTECHNICAL INVESTGIGATION

5.1.1 Exploratory Work

The exploratory work involves drilling through cohesive and non-cohesive soil on firm ground with recovery of samples. Standard penetration tests and permeability tests have been executed in the boreholes located at proposed booster pump stations (BPS-1 & BPS-2) reservoir locations at Naf and Sabrang Tourism Park. Booster pump station BPS-2 will be located within the acquired land of BEZA for Naf Tourism Park and for fixing the exact locations two areas are posed and according soil test has been conducted. A summary of the exploratory work is given in **Table 5.1**.

Table 5.1: Summary of Exploratory Work

Location	Reservoir/Pump ID	Bore Hole ID	Depth of Bore Hole (m)
Whykhong	BPS-1	01	20
Whykhong	BPS-1	02	20
Whykhong	BPS-1	03	20
Whykhong	BPS-1	04	20
Naf Tourism Park	N_UGWR-1	05	20
Naf Tourism Park	N_UGWR-1	06	20
Naf Tourism Park	N_UGWR-2	07	20
Naf Tourism Park	N_UGWR-2	08	20
Sabrang Tourism Park	S_UGWR-1	09	20
Sabrang Tourism Park	S_UGWR-1	10	20
Sabrang Tourism Park	S_UGWR-2	11	20
Sabrang Tourism Park	S_UGWR-2	12	20
Sabrang Tourism Park	S_UGWR-3	13	20
Sabrang Tourism Park	S_UGWR-3	14	20
Teknaf Ferry Ghat	BPS-2 (Option-1)	15	20
Teknaf Ferry Ghat	BPS-2 (Option-1)	16	20
Teknaf Ferry Ghat	BPS-2 (Option-1)	17	20
Teknaf Ferry Ghat	BPS-2 (Option-2)	18	20
Teknaf Ferry Ghat	BPS-2 (Option-2)	19	20

The structure wise locations of Bore holes are shown in Site Plan Maps in **Figure 5.1** to **Figure 5.7.** Some Snaps taken during the field investigation area given in **Figure 5.8**. The Detail analysis of the test results is given in Volume II of the Final Report (Phase-2).

Figure 5.1: Bore hole location Map at BPS-1, Whykhong

Figure 5.2: Bore hole location Map at N_UGWR-1, Naf Tourism Park

Figure 5.3: Bore hole location Map at N_UGWR-2, Naf Tourism Park

Figure 5.4: Bore hole location Map at S_UGWR-1, Sabrang Tourism Park

Figure 5.5: Bore hole location Map at S_UGWR-2 & S_UGWR-3 Sabrang Tourism Park

Figure 5.6: Bore hole location Map at BPS-2 (Option-1), Teknaf Ferry Ghat

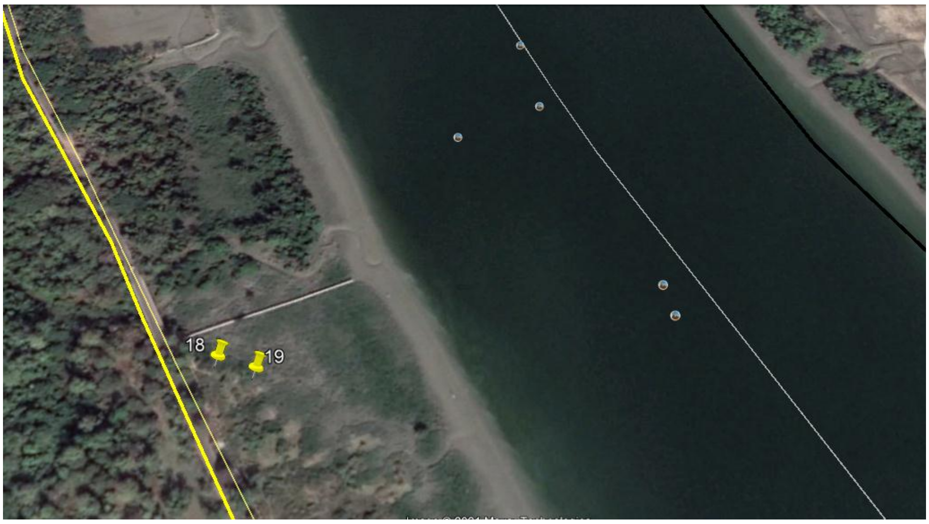


Figure 5.7: Bore hole location Map at BPS-2 (Option-2), Teknaf Ferry Ghat

Figure 5.8: Some snaps taken during the field test

5.1.2 General Interpretation of Soil and Required Type of Foundation

The Bore logs for reservoir and booster pumping station-1 (BPS-1) at Whykhong shows grey soft to medium stiff silty clay soil with SPT values within 3-6 at shallow depth up to 8 m below the ground level and beyond that SPT less than 30 up to a depth of 16.5 is available. The bearing layer consisting of medium dense to dense silty fine sand is available below 15.0 m depth and the required length of the bored pile will be greater than 18.0 m.

From the bore logs at the Naf Tourism Park site, Borehole BH-05 to BH-06 for N_UGWR-1 and BH-07 to BH-08 for N_UGWR-2 have been done. It is observed that foundation soil consists of dark grey very soft to soft silty clay with SPT values within 1-3 at depth up to 6.0 m below the ground level. Most of the bore logs have STP less than 30 up to a depth of 18.0 m is available. The bearing layer consisting of dense silty fine sand is available below depth 16.5 m and the required length of the bored pile will be greater than 20.0 m.

To know the sub-soil properties for three (3) reservoirs (S_UGWR-1, S_UGWR-2 and S_UGWR-3) at Sabrang Tourism Park total 6 nos. borehole have been investigated. For S_UGWR-1, STP greater than 30 up to a depth of 7.5 m is available of borehole BH-09 and BH-10. The bearing layer consisting of medium dense to dense silty fine sand is available below depth 3.0 m and the required length of the bored pile will be greater than 10.5 m. On the other hand, for S_UGWR-2 and S_UGWR-3, borehole BH-11 to BH-14 have been investigated. It is observed that foundation soil consists of very loose to loose silty fine sand with SPT values within 1-5 at depth up to 4.5 m below the ground level. Most of the bore logs have STP less than 30 up to a depth of 10.5 m is available. The bearing layer consisting of medium dense to dense silty fine sand is available below depth 4.5 m and the required length of the bored pile will be greater than 12.0 m.

The Bore logs for booster pumping station-2 (BPS-2) at Teknaf Ferry Ghat, Borehole BH-15 to BH-17 BPS-2 (Option-1) and BH-18 to BH-19 for BPS-2 (Option-2) have been investigated.

From the observation it is shows that, loose silty fine sand to medium stiff clayey silt with fine soil with SPT values within 4-7 at shallow depth up to 4.5 m below the ground level at BPS-2 (Option-1) and beyond that SPT less than 30 up to a depth of 12.0 is available. The bearing layer consisting of medium dense to dense silty fine sand is available below 5.0 m depth and the required length of the bored pile will be greater than 16.0 m.

On the other hand, for BPS-2 (Option-2), loose silty fine sand to medium stiff clayey silt with fine soil with SPT values within 2-10 at shallow depth up to 4.5 m below the ground level at and beyond that SPT less than 30 up to a depth of 7.5 is available. The bearing layer consisting of medium dense to dense silty fine sand is available below 5.0 m depth and the required length of the bored pile will be greater than 13.5 m.

Recommendation:

Booster pumping station-1 (BPS-1) at Whykhong: Borehole BH-01 to BH-04 has been done. According to the geotechnical report, for piles cast in situ of 50cm diameter, the average ultimate pile capacity is 1089 KN at 15m depth.

Naf Tourism Park: For underground reservoir Borehole BH-05 to BH-08 has been done. According to the geotechnical report, for cast in situ piles of 50cm diameter, the average ultimate pile capacity is 1020 KN at 20.0 m depth.

Sabrang Tourism Park: According to the geotechnical report, for S_UGWR-1 it is observed that shallow foundations at a depth of 4.5 m may be appropriate or cast in situ piles of 50cm diameter, the average ultimate pile capacity is 1021 KN at 10.5 m depth.

For S_UGWR-2 and S_UGWR-2, it is recommended that cast in situ piles of 50cm diameter, the average ultimate pile capacity is 1035 KN at 15.0 m depth.

Teknaf Ferry Ghat Booster pumping station-2: According to the geotechnical report, for BPS-2 (Option-1) it is observed that cast in situ piles of 50cm diameter, the average ultimate pile capacity is 1171 KN at 16.5 m depth.

For BPS-2 (Option-2), it is recommended that cast in situ piles of 50cm diameter, the average ultimate pile capacity is 1265 KN at 13.5 m depth.

6 LAND ACQUISITION QUANTIFICATION

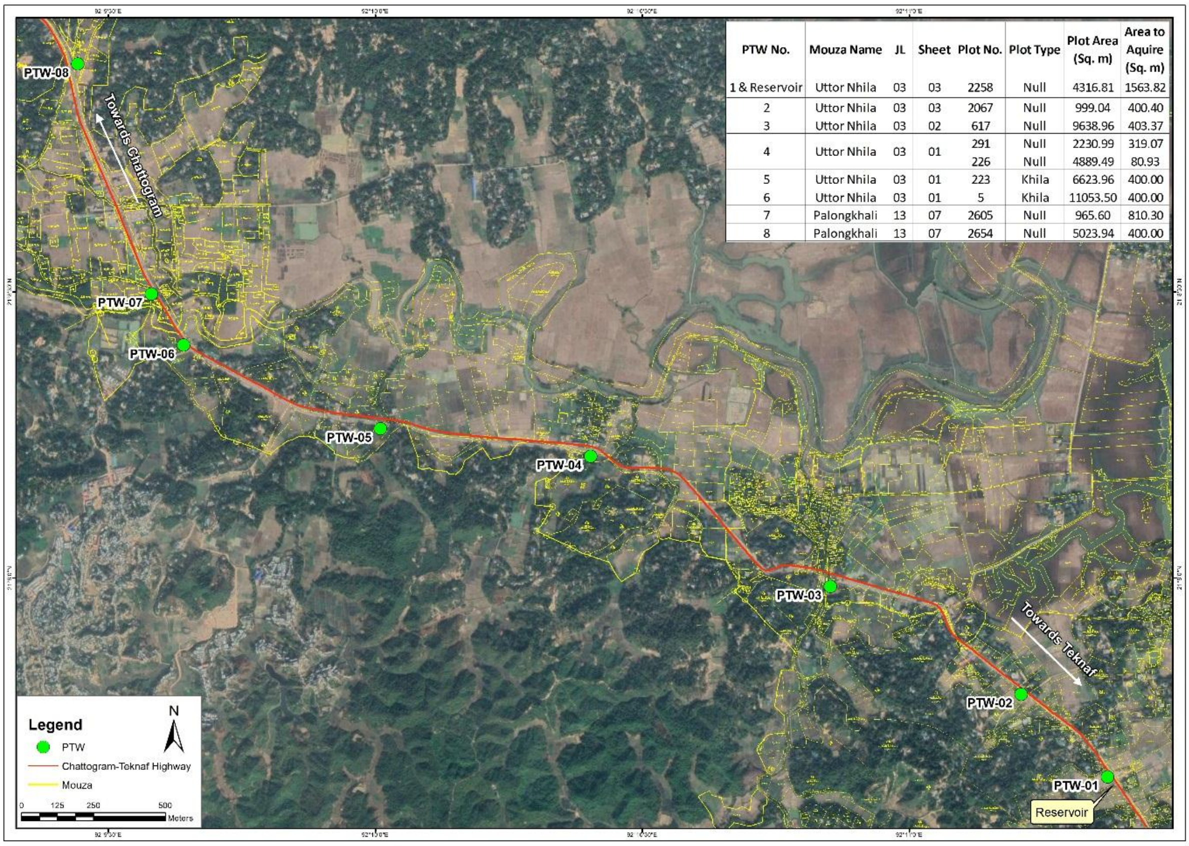
6.1 Land acquisition

Land outside the tourism park areas is required for installation of 8 nos. production tube wells in Whykhong and the booster pumps including reservoir in Whykhong and Teknaf along the transmission main.

The required area for each production tube well is about 400m^2 (20mX20m) and for booster pumps including reservoir is 900m^2 (30mX30m). Moreover, a rest room is required near one of the PTW for visiting the sites or maintenance by expertise and other purposes, so additional 400m^2 area is required. Thus, total about 4,778 m^2 (1.4 acre) of land will be required. Booster pump BPS-2 is selected at already acquired land of BEZA near the Teknaf Ferry Ghat. The estimation of required additional land acquisition is based on required RoW. The land acquisition for the production tube wells and BPS-1 at Whykhong are given in **Table 6.1** and presented in **Figure 6.1** to **Figure 6.9**.

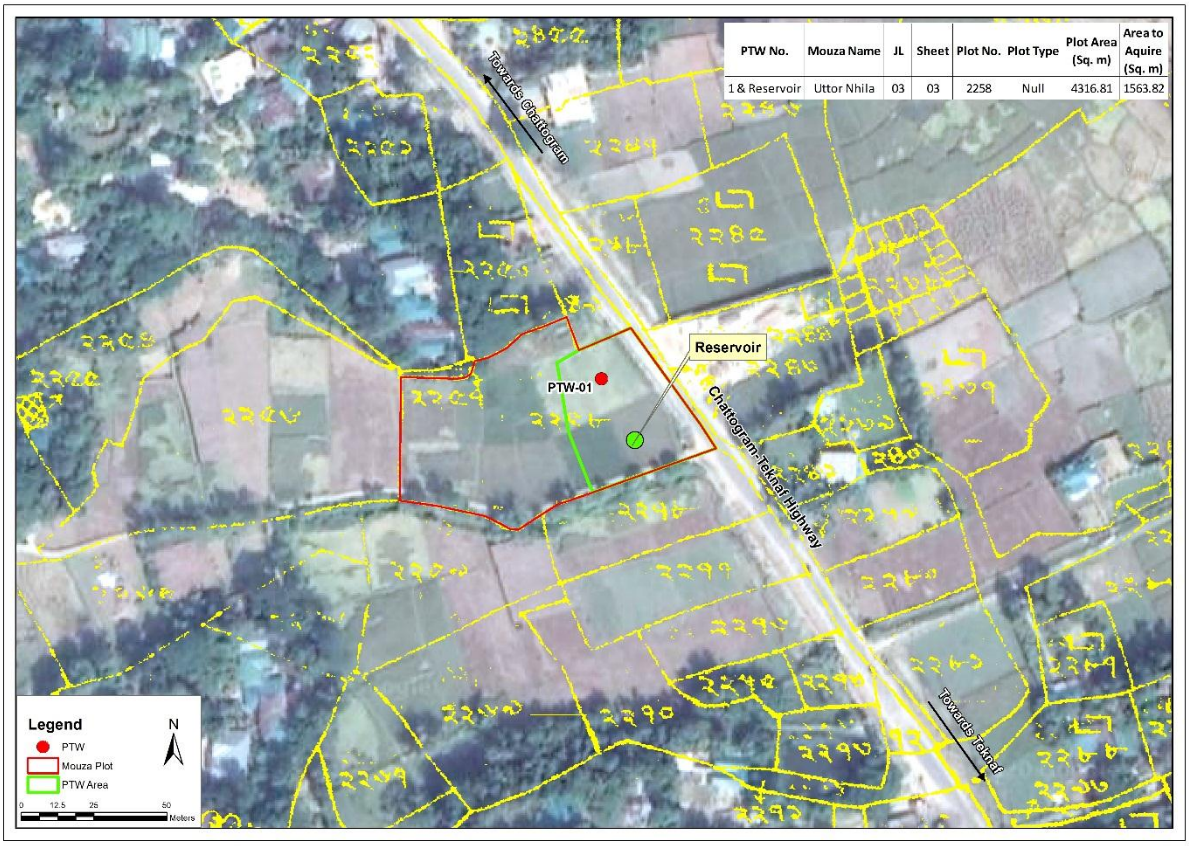
Table 6.1: Land Acquisition estimation

Production well ID	Mouza Name	JL No.	Sheet No.	Plot No.	Plot Type	Plot Area (Sq. m)	Area to be Acquired (Sq. m)
PTW-01 & BPS-1	Uttor Nhila	03	03	2258	Null	4316.81	1563.82
PTW-02	Uttor Nhila	03	03	2067	Null	999.04	400.40
PTW-03	Uttor Nhila	03	02	617	Null	9638.96	403.37
PTW-04	Uttor Nhila	03	01	291	Null	2230.99	319.07
				226	Null	4889.49	80.93
PTW-05	Uttor Nhila	03	01	223	Khila	6623.96	400.00
PTW-06	Uttor Nhila	03	01	5	Khila	11053.50	400.00
PTW-07	Palongkhali	13	07	2605	Null	965.60	810.30
PTW-08	Palongkhali	13	07	2654	Null	5023.94	400.00
Total							**4,778**



PTW No.	Mouza Name	JL	Sheet	Plot No.	Plot Type	Plot Area (Sq. m)	Area to Aquire (Sq. m)
1 & Reservoir	Uttor Nhila	03	03	2258	Null	4316.81	1563.82
2	Uttor Nhila	03	03	2067	Null	999.04	400.40
3	Uttor Nhila	03	02	617	Null	9638.96	403.37
4	Uttor Nhila	03	01	291	Null	2230.99	319.07
				226	Null	4889.49	80.93
5	Uttor Nhila	03	01	223	Khila	6623.96	400.00
6	Uttor Nhila	03	01	5	Khila	11053.50	400.00
7	Palongkhali	13	07	2605	Null	965.60	810.30
8	Palongkhali	13	07	2654	Null	5023.94	400.00

Figure 6.1: Land acquisition plan of 8 nos. production wells

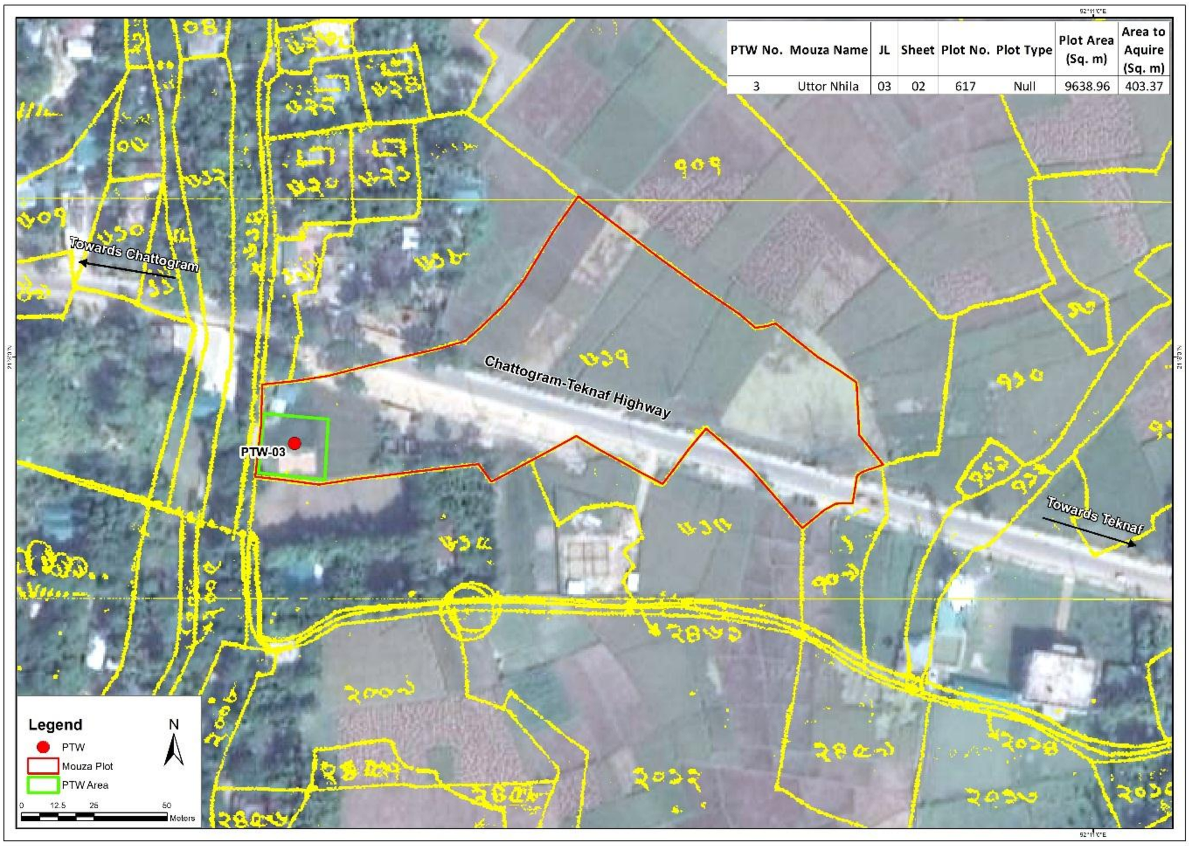


PTW No.	Mouza Name	JL	Sheet	Plot No.	Plot Type	Plot Area (Sq. m)	Area to Aquire (Sq. m)
1 & Reservoir	Uttor Nhila	03	03	2258	Null	4316.81	1563.82

Figure 6.2: Land acquisition plan of PTW-01 & reservoir at Whykhong

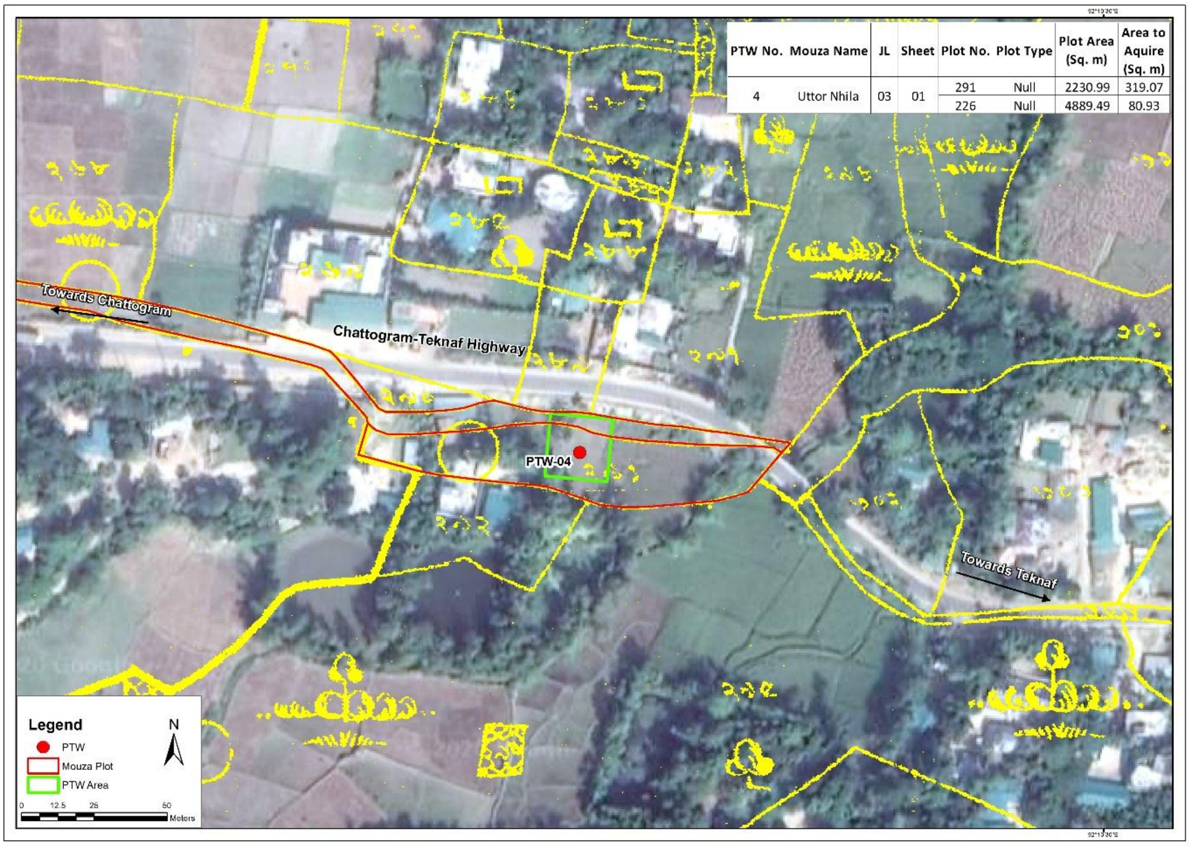
PTW No.	Mouza Name	JL	Sheet	Plot No.	Plot Type	Plot Area (Sq. m)	Area to Aquire (Sq. m)
2	Uttor Nhila	03	03	2067	Null	999.04	400.40

Figure 6.3: Land acquisition plan of PTW-02



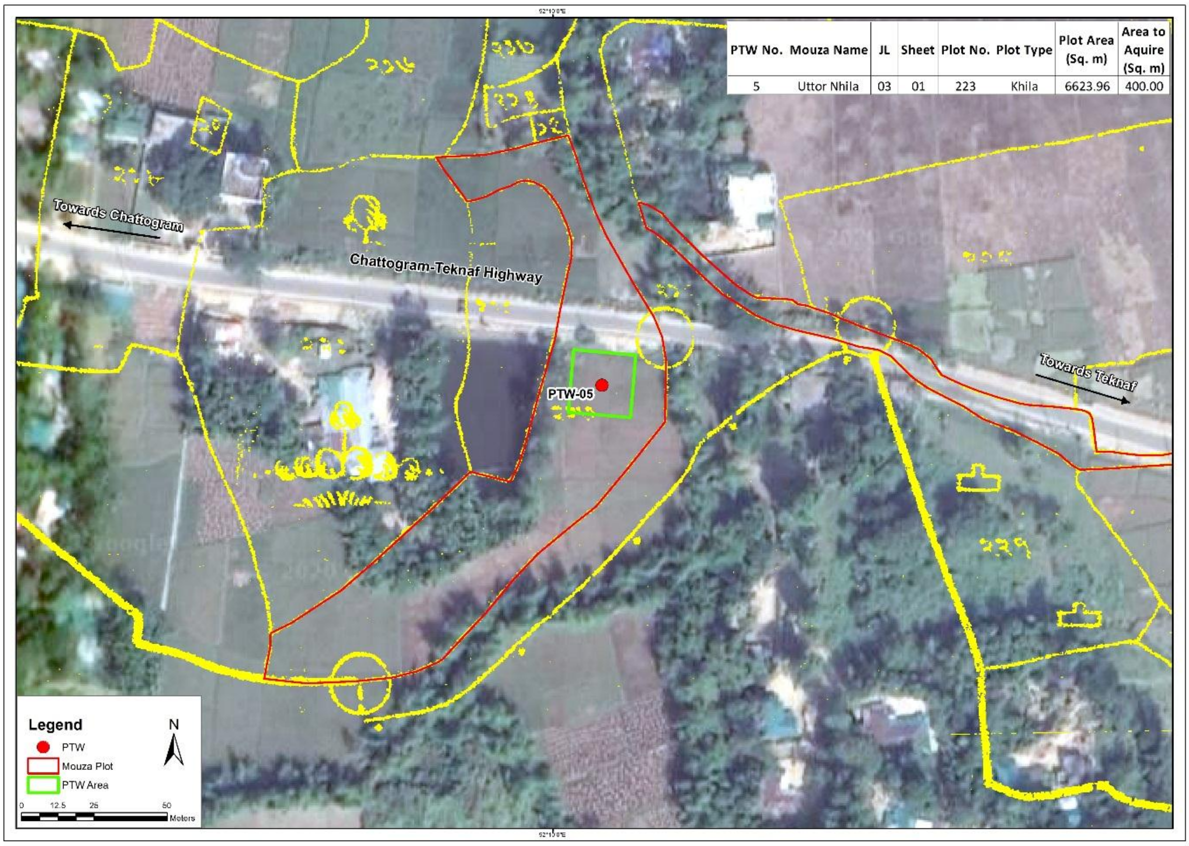
PTW No.	Mouza Name	JL	Sheet	Plot No.	Plot Type	Plot Area (Sq. m)	Area to Aquire (Sq. m)
3	Uttor Nhila	03	02	617	Null	9638.96	403.37

Figure 6.4: Land acquisition plan of PTW-03



PTW No.	Mouza Name	JL	Sheet	Plot No.	Plot Type	Plot Area (Sq. m)	Area to Aquire (Sq. m)
4	Uttor Nhila	03	01	291	Null	2230.99	319.07
				226	Null	4889.49	80.93

Figure 6.5: Land acquisition plan of PTW-04

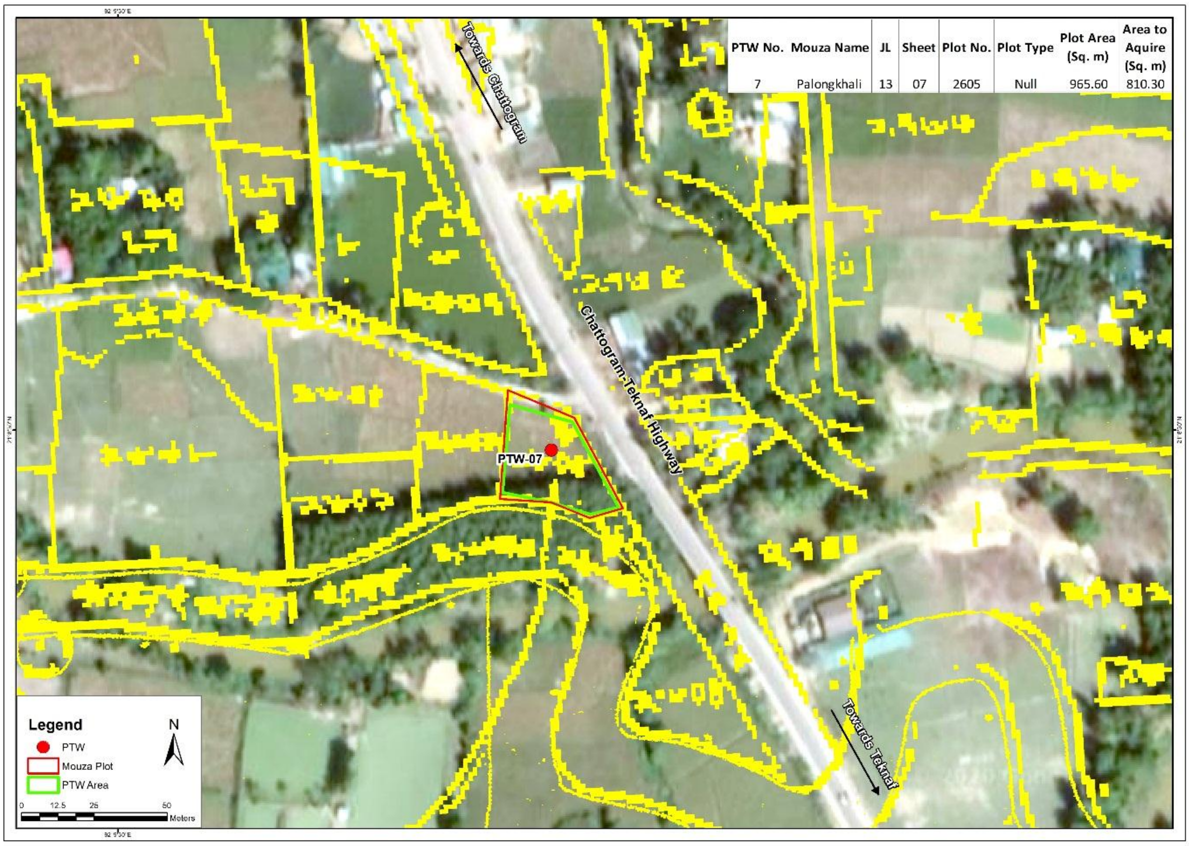


PTW No.	Mouza Name	JL	Sheet	Plot No.	Plot Type	Plot Area (Sq. m)	Area to Aquire (Sq. m)
5	Uttor Nhila	03	01	223	Khila	6623.96	400.00

Figure 6.6: Land acquisition plan of PTW-05

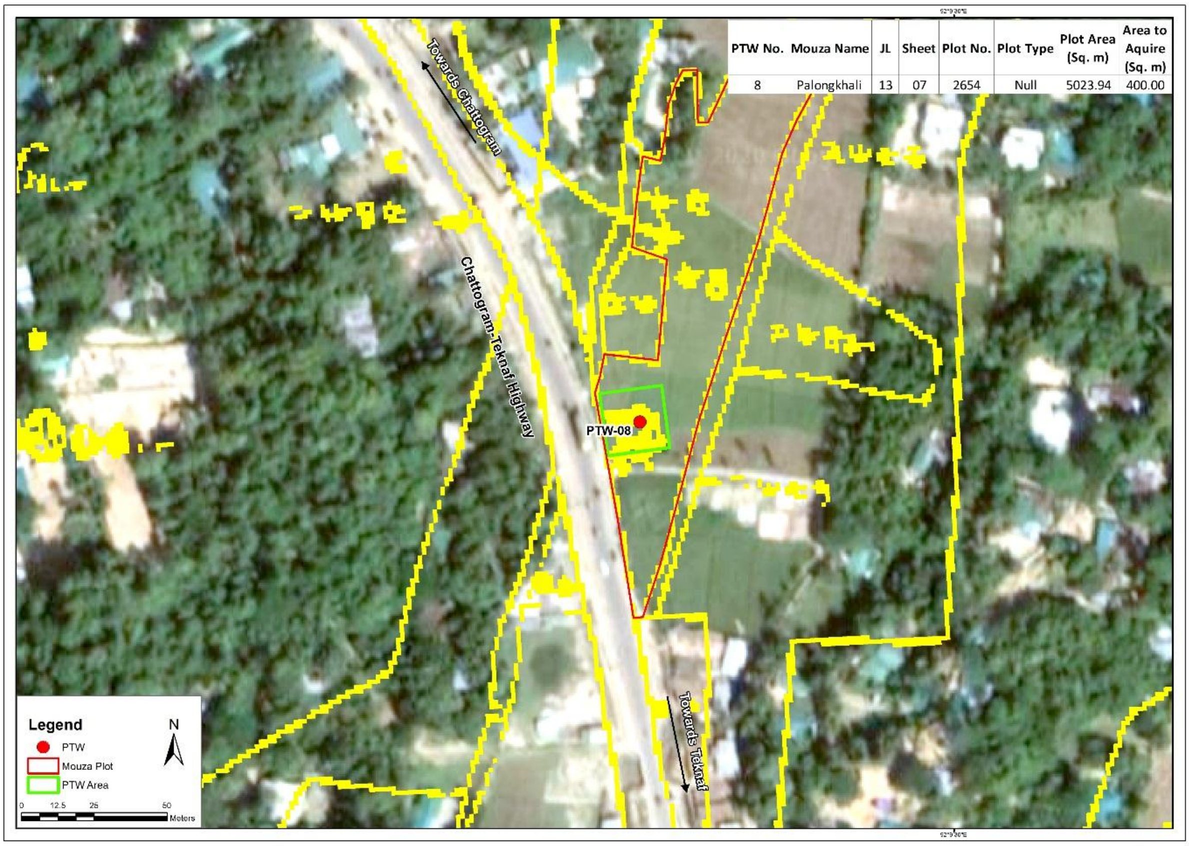
PTW No.	Mouza Name	JL	Sheet	Plot No.	Plot Type	Plot Area (Sq. m)	Area to Aquire (Sq. m)
6	Uttor Nhila	03	01	5	Khila	11053.50	400.00

Figure 6.7: Land acquisition plan of **PTW-06**



PTW No.	Mouza Name	JL	Sheet	Plot No.	Plot Type	Plot Area (Sq. m)	Area to Aquire (Sq. m)
7	Palongkhali	13	07	2605	Null	965.60	810.30

Figure 6.8: Land acquisition plan of **PTW-07**



PTW No.	Mouza Name	JL	Sheet	Plot No.	Plot Type	Plot Area (Sq. m)	Area to Aquire (Sq. m)
8	Palongkhali	13	07	2654	Null	5023.94	400.00

Figure 6.9: Land acquisition plan of PTW-08

6.2 Working Easement for Pipe Laying

For the transmission main pipe easement is required for the purpose of laying, constructing, installing, maintaining, inspecting, operating, protecting, repairing, replacing, altering, changing the size of, relocating (but only within the existing easement), substituting and/ or removing water lines and any appurtenant.

The transmission main is proposed to be laid along the existing roads owning by RHD (Cox's Bazar-Teknaf Highway, Marine Drive Road) and LGED (Internal Road in Teknaf). About 47.1km transmission main is planned to be laid along RHD road and 3.2 km along LGED road. Waterline easement is required and road restoration charge need to be paid to RHD and LGED.

From the features survey it is observed that, there are some electric pole, telephone pole, dustbin, manhole, tree, tube well, lamp post within 2 m from edges of the road. Moreover, some portion of mosque, shop, boundary wall, drain, graveyard, pond fall within 2 m from edges of the road. The list of features within 2 m are given in **Table 6.2** and **Table 6.3**. During detail these features need to be considered.

Table 6.2: Lost of features within 2 m from right edge of the road

Feature Type	Structure Count	Remarks
Electric Pole	330 nos.	
Telephone pole	3 nos.	
Submerged pump	1 no.	

Feature Type	Structure Count	Remarks
Mosque	3 nos.	Partial area
Manhole	9 nos.	
Boundary Wall	31 nos.	total length=6303m
Drain	9 nos.	total length=2582m
Dustbin	3 nos.	
Grave yard	1 no.	Partial area
Road protection wall	5 nos.	total length=816m
HPB (Pacca shop)	4 nos.	Partial area
HTS (Tin shed shop)	30 nos.	Partial area
HSP (Semi pacca shop)	13 nos.	Partial area
Tree	367 nos.	
Tube well	2 nos.	
Pond	7 nos.	Partial area
Lamp post	19 nos.	

Table 6.3: Lost of features within 2 m from left edge of the road

Feature Type	Structure Count	Remarks
Electric Pole	60 nos.	
Mobile tower	1 no.	
Mosque	2 nos.	Partial area
Manhole	2 nos.	
Boundary Wall	1 no.	total length=142m
Road protection wall	3 nos.	total length=119m
HPB (Pacca shop)	1 no.	Partial area
HTS (Tin shed shop)	1 no.	Partial area
HSP (Semi pacca shop)	4 nos.	Partial area
Tree	54 nos.	
Tube well	1 no.	

6.3 Right of Way

The pipeline right of way is the corridor of land above the pipeline which is permanently dedicated to the pipeline. Therefore, no structures or roads can be constructed within the limits of the right of way without first obtaining the permission of the pipeline owner. This enables the pipeline agency to review any changes in loading on the pipeline and, if necessary, allows for inclusion of additional protective measures to prevent any damage to the pipeline from the new construction, both during and after construction. It also allows the pipeline agency to ensure that access to critical locations for operation and maintenance purposes is maintained.

The required width of the right of way is dependent on several criteria. It must be wide enough to accommodate all normal operations and maintenance activities. It must also be wide enough to allow for any emergency activities. For example, if there is a leak or rupture in the pipeline, the right of way should be wide enough to allow for the excavation and repair or replacement of the defective section of the pipeline.

For the proposed transmission main of 400mm diameter which would be laid along the existing highways the width of roadway right-of-way would be 3-5m. The width of right of way needs to be finalized during the detail design depending on available space besides the existing roads. For the distribution network the right of way needs to be kept 2-4m.

6.4 Cost of Land Acquisition and Land Development

If khas land is not available near the proposed locations for PTW, BPS-1 and reservoir, then land acquisition will be required. The cost of land is collected from AC Land Office of Ukhia and Teknaf and land rate is Tk. 19,080/- and Tk. 18,285/- per decimal respectively. All land acquisition should be completed before any implementation work.

The tentative cost required for land acquisition and land development is given in **Table 6.4**.

Table 6.4: Tentative cost of land acquisition and land development

Sl. No.	**Item**	**Unit**	**Total Amount**	
			Uttor Nhila Mouza	Palongkhali Mouza
1	Required amount of land	m^2	3568	1210
2	Land Costing	million BDT	5.1	1.6
3	Development costing	million BDT	2.5	0.8
	Total		***7.6***	***2.4***
	Grand total		**10.0**	

7 IMPOUNDING RESERVOIR PLANNING & DESIGN

7.1 Suitable Site for Impounding Reservoir

Due to water scarcity, the proposed lake (**Figure 7.1**) in Sabrang Tourism Park can be used as impounding reservoir for supplying water. The area of the reservoir is around 50acre. Rainwater in monsoon can be stored in this reservoir which can be used throughout the year. This option is relatively environment friendly and a best option to utilize rain water.

Figure 7.1: Proposed lake/reservoir location in Sabrang Tourism Park

Following criteria have been considered for the reservoir:

- The sill level of the regulator at the downstream of the lake is at 0 mMSL;
- A wide and deep reservoir (around 5.0m depth) of 50 acre is preferred instead of shallow one considering the less evaporation loss and less possibility of weed growth;
- The geological formation of the reservoir banks, walls etc. have been planned to design to entail minimum leakage, minimum water losses through absorption and percolation;
- Intake channel have been planned to design by avoiding too much silt as much as possible.
- The reservoir water will be free from any contamination of solid waste and sewerage water from upstream and surrounding area.

7.2 Planning concept of off-channel reservoir

Following steps have been followed in planning stage of off-channel reservoir:

- The reservoir/lake banks have been planned with a side slope 2:1 and 2.5 m berm to stabilize the 5.0 m deep reservoir bank with 0.5m freeboard. Walkway (**Figure 7.2**) is preferred along the periphery of the reservoir.
- Generated flood volume including time and duration of monsoon along the peripheral river:
    - The generated rainfall (from 1977 to 2018) from Teknaf rainfall data have been analyzed.
    - The existing khal system would be re-sectioned/re-excavated to accommodate rainwater as proposed in the Detail master Plan (December 2020) and banks would be protected with walkway.
    - The reservoir is planned to fill-up by gravity flow during monsoon, post-monsoon season and protected from saline water by sluice gate at the mouth of the lake. The gate should be closed during dry season to attain the full reservoir level during post-monsoon. For facilitating drainage system the gate should be open during ebb tide in monsoon.

Figure 7.2: Lake side walkway and bi-cycle lane in Sabrang Tourism Park

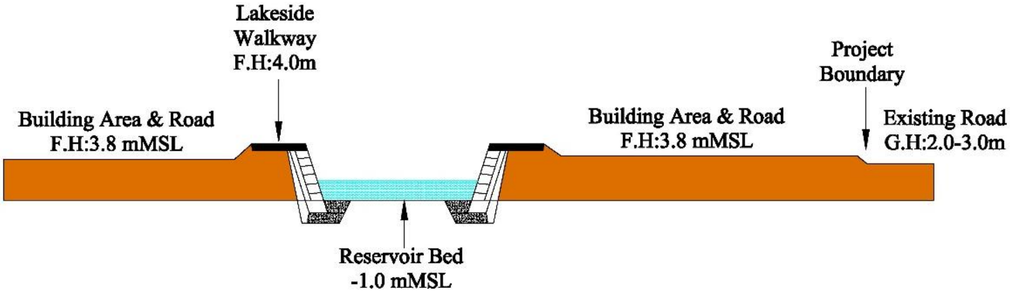


Figure 7.3: Plan elevation of proposed lake/reservoir location in Sabrang Tourism Park

- Fixation of elevation of the crest level (height) of the proposed reservoir:

  - The crest level (height) of the proposed reservoir bank with walkway have been fixed at +4.0 m,MSL while the proposed building area and road would be developed at +3.8 m,MSL (**Figure 7.3**).

- Fixation of bed elevation of the proposed reservoir:
  - The minimum bed level of the proposed reservoir has been fixed at -1.00 m,MSL to maintain the total active storage depth at least 3.0m including dead storage depth around 1.5m and freeboard 0.5m. A gentle slope need to be maintained from the sill level to the lake bottom. The reservoir bed would be treated depending on the permeability test results of soil properties.

- Live storage capacity of the proposed reservoir:
  - Live storage capacity of each proposed off-channel reservoir has been analysed based on two criteria: (i) average potential evaporation rate at Chittagong hydro-meteorological station data – 6mm/day, (ii) deep percolation losses – 4mm/day (considering existing soil condition and treated reservoir bed).

- Protecting the reservoir from sediment:
  - To protect the reservoir from siltation a sediment trap can be constructed at the inlet of the khal into the Tourism Park area. White passing through the sediment trap, the sediment will be settled at the bottom of the sediment trap. After2-3 years the sediment trap need to be excavated for continuous settlement of sediments.

7.3 Typical plan of off-channel reservoir

Typical plan and cross section of off-channel reservoir with bank protection work is shown in **Figure 7.4** and **Figure 7.5**. The typical plan of the off-channel reservoir near the regulator is also given is **Figure 7.6**. The characteristics features of the proposed reservoir is:

- Reservoir banks (2:1 slope) would be protected by CC block at two stages and in between gabion box would be placed at 3m wide berm;
- The difference in elevation between the lake bottom and sill level of regulator is considered 1 m. In typical design the sill level regulator should be kept 0.6-1.0 m above the bed of the canal on upstream.
- Banks under water part (dead storage part) would be protected by geo-bag which would be connected with CC block by another 3m wide berm;
- Reservoir bed would be treated based on permeability test results of soil samples;
- 3m wide walkway with bi-cycle lane on the crest of the reservoir is proposed which can also be used for operation and maintenance of reservoir;
- Each reservoir will provide individual archeological aesthetic outlook where peoples can spend their leisure time in the morning, afternoon and evening;

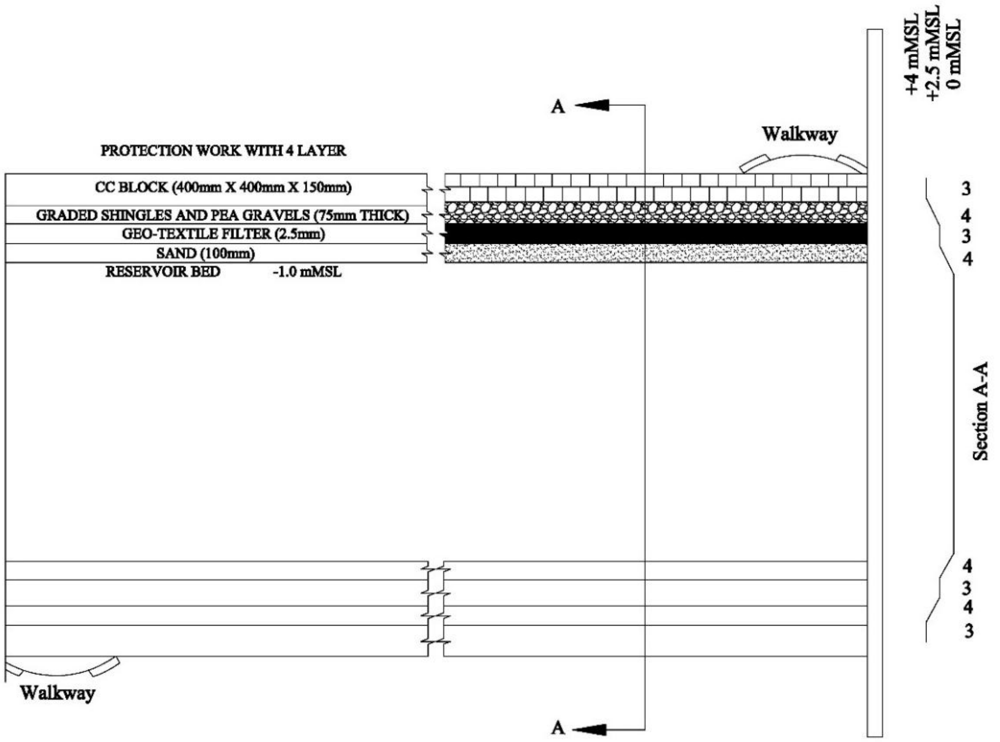


Figure 7.4: Typical plan of reservoir with bank protection

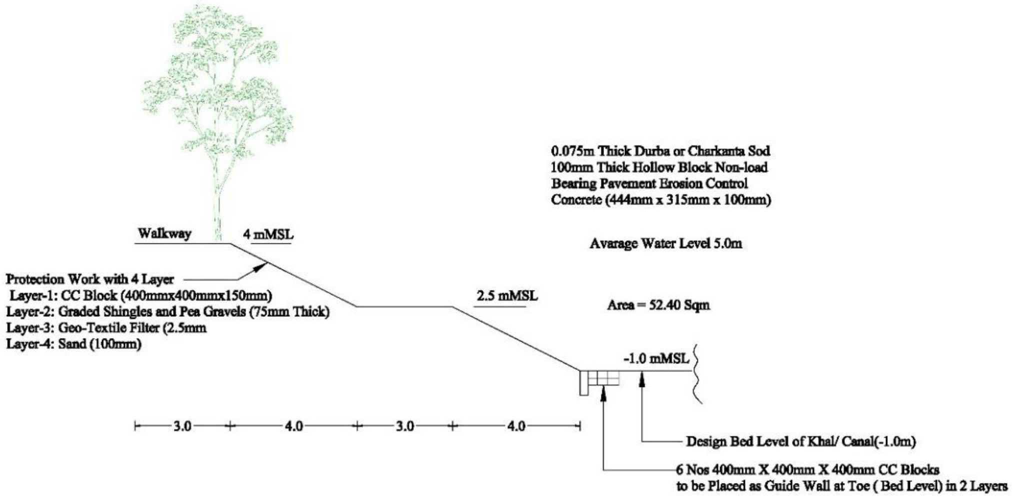


Figure 7.5: Cross section of reservoir with bank protection

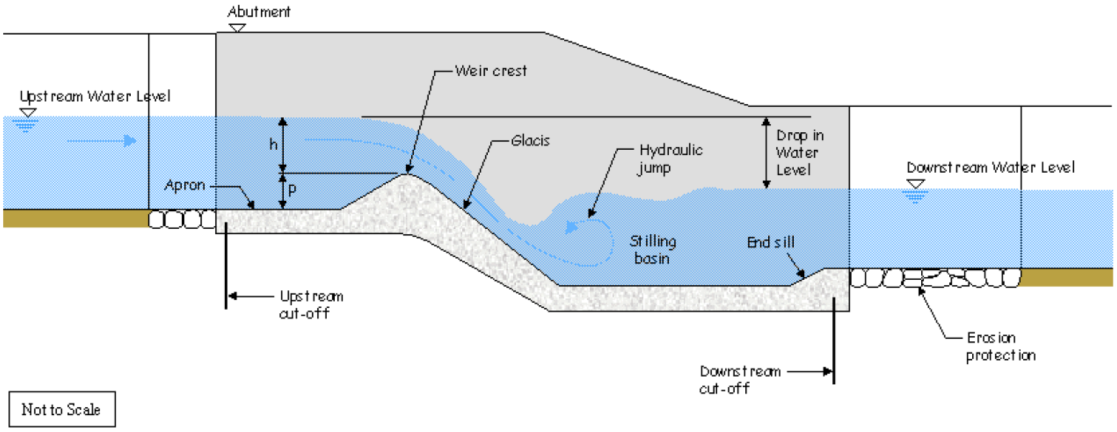


Figure 7.6: Typical plan of reservoir with bank protection near the regulator

7.4 Reservoir Storage Capacity

The proposed reservoir supply capacity per day have been estimated (**Table 7.1**) considering following criteria:

- Pumping duration: 6 months in the dry season from November to April
- Pumping time: 18 hours per day
- Evaporation losses: 6 mm/day
- Percolation losses: 4 mm/day

It is estimated that maximum of 2.0 MLD water would be available from the reservoir in the dry months (November to April). In monsoon the available water would be more as rain flow will be continuous from upstream and open area of the tourism park.

Table 7.1: Estimation of water supply through reservoir

Month	RF	Storage rainwater	Cumulative storage	Evaporation & percolation loss	Possible storage in lakes	Supply from reservoir	
	mm	Million lt	Million lt	Million lt	Million lt	Million lt	MLD
May	287.45	52.3	52.3			-	-
Jun	997.17	181.6	233.9			-	-
Jul	1095.88	199.6	433.5			-	-
Aug	879.45	160.2	593.7			-	-
Sep	439.88	80.1	673.8			-	-
Oct	245.50	44.7	718.5				
Nov	58.83	0.0	718.5	48.6	607.0	60.70	2.0
Dec	6.83	0.0	669.9	48.6	558.5	60.70	2.0
Jan	5.24	0.0	626.2	48.6	509.9	60.70	2.0
Feb	10.57	0.0	582.5	48.6	461.3	60.70	2.0
Mar	16.24	0.0	538.8	48.6	412.8	60.70	2.0
Apr	65.14	0.0	495.1	48.6	364.2	60.70	2.0

A treatment plant may be required for treating the reservoir water before supplying. The design of the treatment plant will depend on the water quality of the reserved water. After constructing the reservoir, the water quality has to be measured for designing the process diagram of the treatment plant and detail design.

8 WATER MANAGEMENT PLAN

8.1 Phasing of Plan

Three development phases for Sabrang Tourism Park and Two for Naf Tourism Park have been proposed in its Detailed Master Plan (December, 2020). In order to be consistent with the Master Plan, earlier water supply system development plan was divided into four phases (**Table 8.1**). It was decided in the Final Report (Phase-2) report presentation workshop to revise the implementation period to make it consistent with current development works. After discussion with BEZA Officials the implementation phases are considered as shown in **Table 8.1**.

Table 8.1: Phasing of water supply system implementation plan

Earlier proposed implementation plan			Finally proposed implementation plan		
Phases	**Period**	**Time**	**Phases**	**Period**	**Time**
Phase-1	2021-2024	3 years	Phase -1	2022-2027	5 years
Phase-2	2024-2026	2 years	Phase -2	2031-2036	5 years
Phase-3	2026-2031	5 years			
Phase-4	2031-2036	5 years			

It is considered that under Project-1 all water system to supply water in the proposed Phase-1 and 2 area in Sabrang and Phase-1 area in Naf tourism Park will be implemented.

8.2 Different Water Management Plan Options

Different options have been analysis for fulfilling water demand in Naf and Sabrang Tourism Park based on the following issues:

- Selected groundwater well is far enough from the project area and thus the cost of transmission is very high;
- The availability of water from Teknaf reservoir is supplementary and not certain;
- Usage of rain water more efficiently by storing at lake area in Sabrang Tourism Park.

The source of water under different option are presented in **Table 8.2**.

Table 8.2: Source of water under different options

Options	Source of water	
	Sabrang Tourism Park	**Naf Tourism Park**
Option-1	• Groundwater • Water stored in dam in Teknaf • Rainwater harvesting in the roof top of buildings • Desalination plant	• Groundwater
Option-2	• Groundwater • Rainwater harvesting in the roof top of buildings • Rainwater harvesting in lake area	• Groundwater

Options	Source of water	
	Sabrang Tourism Park	Naf Tourism Park
	• Desalination plant	
Option-3	• Rainwater harvesting in the roof top of buildings • Rainwater harvesting in lake area • Desalination plant	• Rainwater harvesting in the roof top of buildings • Desalination plant
Option-4	• Groundwater • Rainwater harvesting in the roof top of buildings • Rainwater harvesting in lake area • Desalination plant	• Rainwater harvesting in the roof top of buildings • Desalination plant

8.3 Water Management Plan for Sabrang Tourism Park

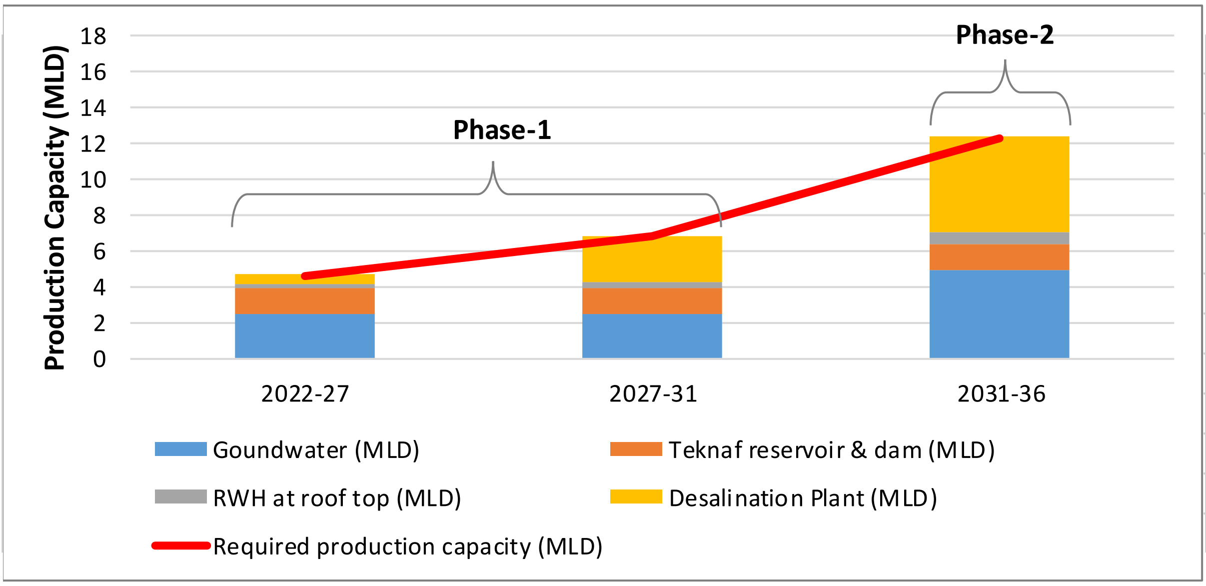
The water demand in Sabrang Tourism Park was estimated and submitted in the Final Report of Phase-1 based on the total number of tourist and work force required to run the public facilities, utilities, administrations and transportations etc. as mentioned in the Master Plan (Draft Final Report, August 2019). Further the Master Plan has been finalized in December 2020. Accordingly, water demand has been updated (Appendix-E & Appendix-I). The total production capacity required, however, considers physical loss or leakage from the water transmission and distribution pipelines and appurtenances. The estimated total required production capacity will be 12.98 MLD after the completion of full development in 2036. To fulfill water requirement three different options has been analyzed as describe below.

8.3.1 Water Management Plan for Sabrang Tourism Park Option-1

Under Option-1 following different water sources has been considered in fulfilling the estimated water demand:

- Groundwater extracted from Whykhong well field
- Water stored in dam in Teknaf
- Rainwater harvesting in the roof top of building area
- Desalination plant

Water supply system for different phases as mentioned in **Table 8.1** has been planned under Option-1 as shown in **Figure 8.1**.



Planning hoizon	2022-27	2027-31	2031-36
Water demand at user end (MLD)	3.72	5.53	9.98
Water lossess (MLD)	0.87	1.30	2.34
Required production capacity (MLD)	**4.60**	**6.83**	**12.33**
Goundwater (MLD)	2.42	2.42	4.88
Teknaf reservoir & dam (MLD)	1.48	1.48	1.48
RWH at roof top (MLD)	0.24	0.38	0.73
Gap (MLD)	0.45	2.54	5.24
Desalination Plant (MLD)	**0.50**	**2.55**	**5.25**
Production capacity (MLD)	**4.65**	**6.83**	**12.34**

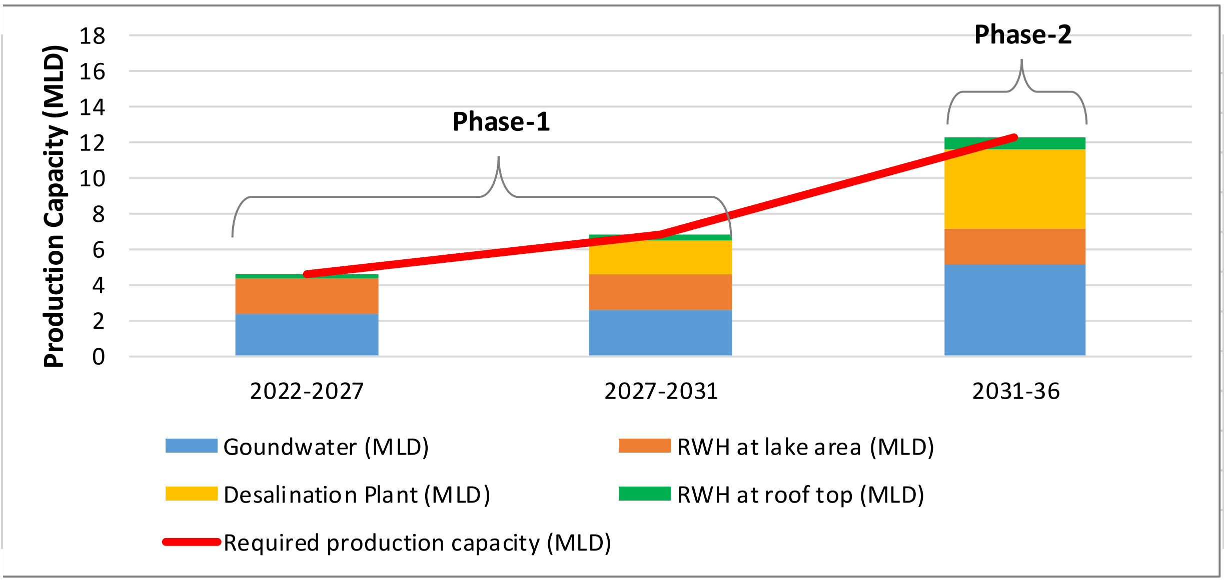
Figure 8.1: Future Sources of Supply for Sabrang Tourism Park under Option-1

8.3.2 Water Management Plan for Sabrang Tourism Park Option-2

The supply of water from Teknaf dam-reservoir is considered as supplementary. In this option rainwater harvesting at the lake area in Sabrang Tourism Park is considered as potential option. So under Option-2 following different water sources has been considered:

- Groundwater extracted from Whykhong well field
- Rainwater harvesting in the roof top of building area
- Rainwater harvesting in lake area
- Desalination plant

Water supply system for different phases under Option-2 has been planned as shown in **Figure 8.2**.



Planning hoizon	**2022-2027**	**2027-2031**	**2031-36**
Water demand at user end (MLD)	3.72	5.53	9.98
Water lossess (MLD)	0.87	1.30	2.34
Required production capacity (MLD)	**4.60**	**6.83**	**12.33**
Goundwater (MLD)	2.36	2.53	5.10
RWH at roof top (MLD)	0.24	0.38	0.73
RWH at lake area (MLD)	2.00	2.00	2.00
Gap (MLD)	0.00	1.91	4.50
Desalination Plant (MLD)	**0.00**	**1.90**	**4.50**
Production capacity (MLD)	**4.60**	**6.81**	**12.33**

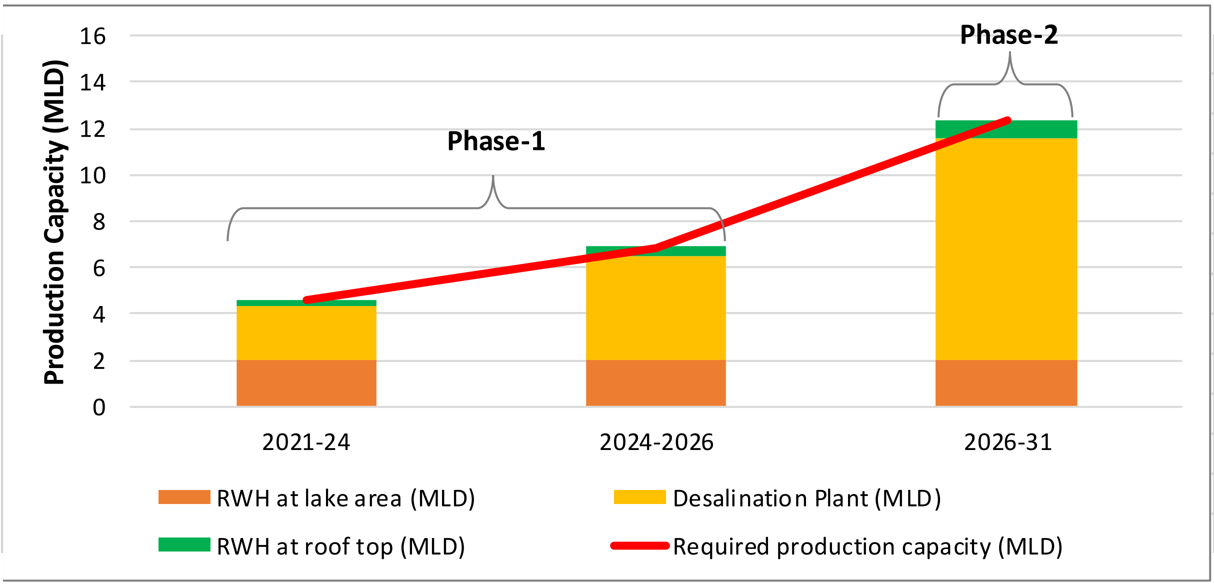
Figure 8.2: Future Sources of Supply for Sabrang Tourism Park under Option-2

8.3.3 Water Management Plan for Sabrang Tourism Park Option-3

Due to long distance transmission main, water supply from groundwater becomes very costly. So, under Option-3 no groundwater source is considered. To fulfilling water demand more use of saline water through desalination is considered as major source. So, under Option-3 water sources has been considered as below:

- Rainwater harvesting in the roof top of building area
- Rainwater harvesting in lake area
- Desalination plant

Water supply system for different phases under Option-3 has been planned as shown in **Figure 8.3**.



Planning hoizon	**2021-24**	**2024-2026**	**2026-31**
Water demand at user end (MLD)	3.72	5.53	9.98
Water lossess (MLD)	0.87	1.30	2.34
Required production capacity (MLD)	**4.60**	**6.83**	**12.33**
RWH at roof top (MLD)	0.24	0.38	0.73
RWH at lake area (MLD)	2.00	2.00	2.00
Gap (MLD)	2.35	4.45	9.60
Desalination Plant (MLD)	**2.35**	**4.50**	**9.60**
Production capacity (MLD)	**4.59**	**6.88**	**12.33**

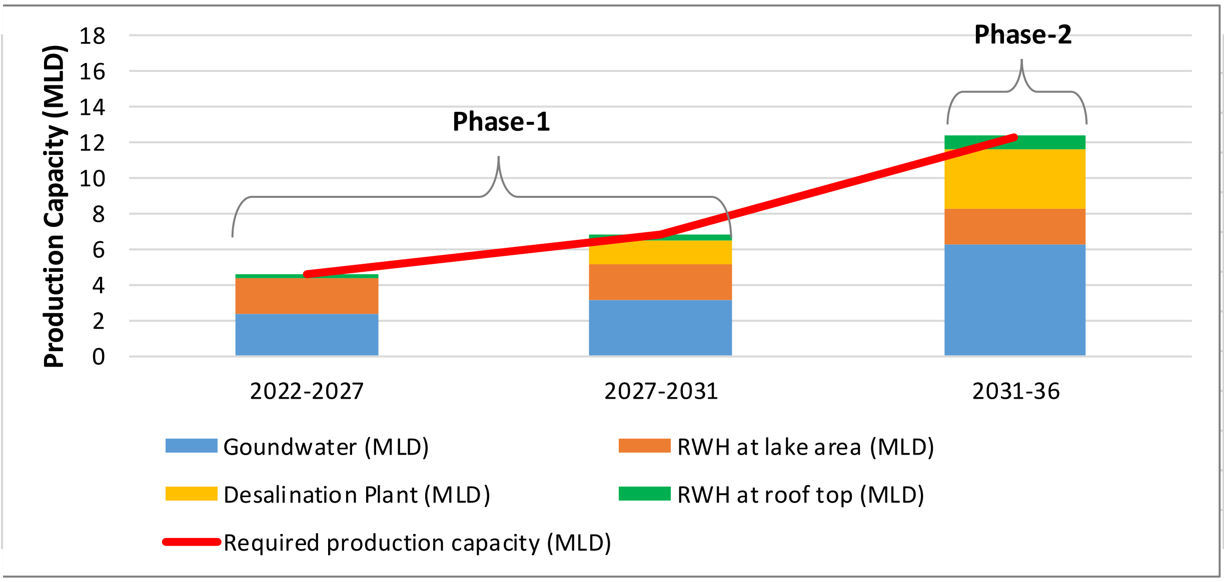
Figure 8.3: Future Sources of Supply for Sabrang Tourism Park under Option-3

8.3.4 Water Management Plan for Sabrang Tourism Park Option-4

In Option-4 water sources for Sabrang Tourism Park are considered as like Option-2 whereas the sources are:

- Groundwater extracted from Whykhong well field
- Rainwater harvesting in the roof top of building area
- Rainwater harvesting in lake area
- Desalination plant

Water supply system for different phases under Option-4 is shown in n **Figure 8.4**.



Planning hoizon	**2022-2027**	**2027-2031**	**2031-36**
Water demand at user end (MLD)	3.72	5.53	9.98
Water lossess (MLD)	0.87	1.30	2.34
Required production capacity (MLD)	**4.60**	**6.83**	**12.33**
Goundwater (MLD)	2.35	3.11	6.23
RWH at roof top (MLD)	0.24	0.38	0.73
RWH at lake area (MLD)	2.00	2.00	2.00
Gap (MLD)	0.01	1.33	3.37
Desalination Plant (MLD)	**0.00**	**1.35**	**3.40**
Production capacity (MLD)	**4.59**	**6.84**	**12.36**

Figure 8.4: Future Sources of Supply for Sabrang Tourism Park under Option-4

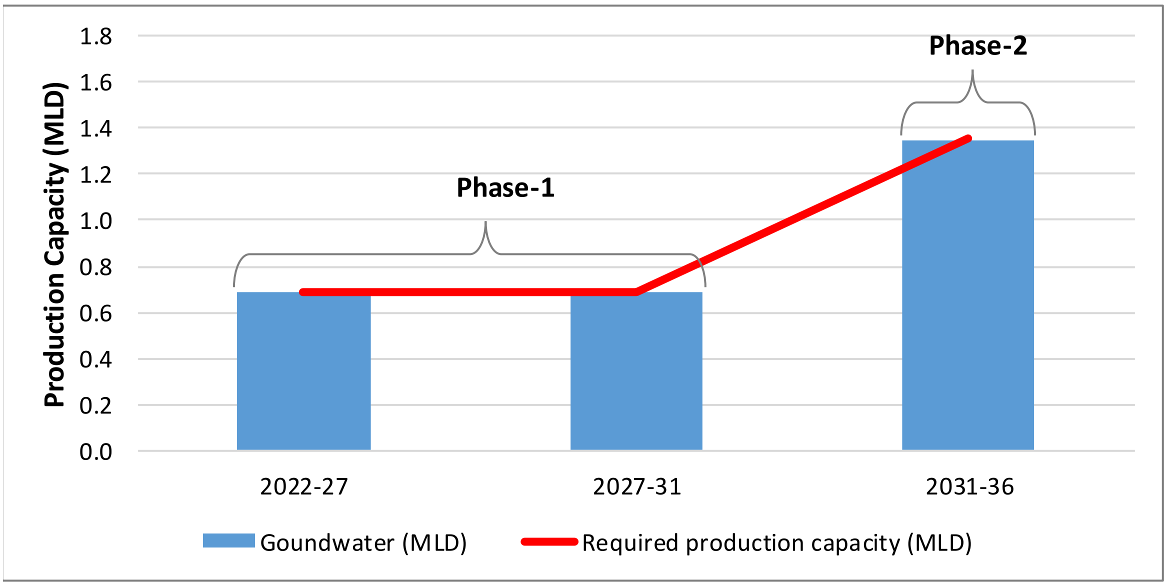
8.4 Water Management Plan for Naf Tourism Park

The water demand in Naf Tourism Park was estimated and submitted in the Final Report of Phase-1 based on the total number of tourist and work force required in different accommodations like hotels, cottages, apartments and central plaza as mentioned in the Master Plan (Draft Final Report, August 2019). Further the Master Plan has been finalized in December 2020. Accordingly, water demand has been updated (Appendix-E). The total production capacity required, however, considers physical loss or leakage from the water transmission and distribution pipelines and appurtenances. The estimated total required production capacity will be 1.35 MLD after the completion of full development in 2036. To fulfill water requirement three different options has been analyzed as describe below.

8.4.1 Water Management Plan for Naf Tourism Park Option-1

Under-1 only groundwater is considered as source for fulfilling the estimated water demand.

Water supply system for different phases as mentioned in **Table 8.1** under Option-1 is shown in **Figure 8.5**.



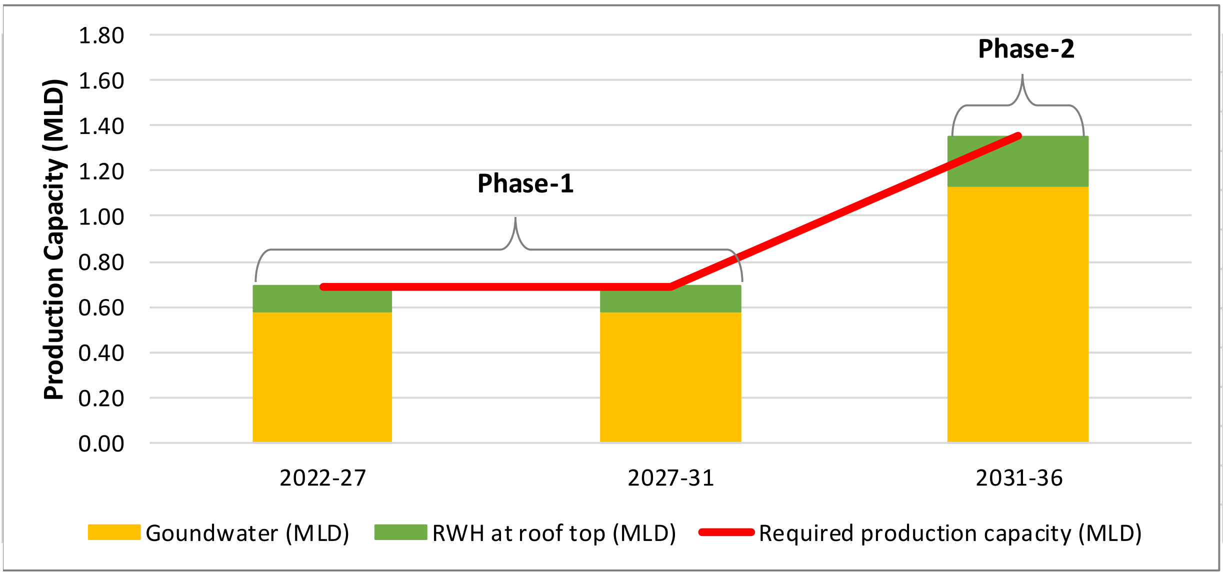
Planning hoizon	2022-27	2027-31	2031-36
Water demand at user end (MLD)	0.56	0.56	1.10
Water lossess (MLD)	0.13	0.13	0.26
Required production capacity (MLD)	**0.69**	**0.69**	**1.35**
Goundwater (MLD)	**0.69**	**0.69**	**1.35**
Production capacity (MLD)	**0.69**	**0.69**	**1.35**

Figure 8.5: Future Sources of Supply for Naf Tourism Park under Option-1

8.4.2 Water Management Plan for Naf Tourism Park Option-2

Under Option-2 groundwater well as rainwater harvesting from roof top is considered as source for fulfilling the estimated water demand.

Water supply system for different phases as mentioned in **Table 8.1** under Option-2 is shown in **Figure 8.6**.



Planning hoizon	2022-27	2027-31	2031-36
Water demand at user end (MLD)	0.56	0.56	1.10
Water lossess (MLD)	0.13	0.13	0.26
Required production capacity (MLD)	**0.69**	**0.69**	**1.35**
Goundwater (MLD)	**0.58**	**0.58**	**1.13**
RWH at roof top (MLD)	0.11	0.11	0.22
Desalination plant/RWH (MLD)	0.00	0.00	0.00
Production capacity (MLD)	**0.69**	**0.69**	**1.35**

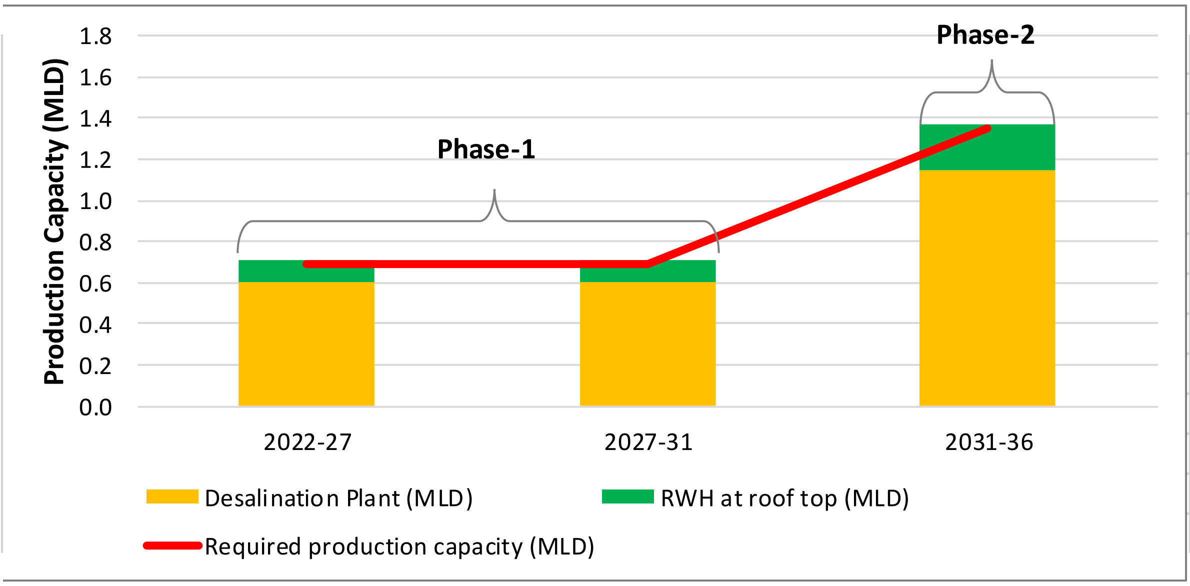
Figure 8.6: Future Sources of Supply for Naf Tourism Park under Option-2

8.4.3 Water Management Plan for Naf Tourism Park Option-3

Under Option-3 no groundwater source is considered and the water sources considered are given below:

- Rainwater harvesting in the roof top of buildings
- Desalination plant

Water supply system for different phases under Option-3 is shown in **Figure 8.7**.



Planning hoizon	**2022-27**	**2027-31**	**2031-36**
Water demand at user end (MLD)	0.56	0.56	**1.10**
Water lossess (MLD)	0.13	0.13	0.26
Required production capacity (MLD)	**0.69**	**0.69**	**1.35**
RWH at roof top (MLD)	0.11	0.11	0.22
Gap (MLD)	0.58	0.58	1.13
Desalination Plant (MLD)	**0.60**	**0.60**	**1.15**
Production capacity (MLD)	**0.71**	**0.71**	**1.37**

Figure 8.7: Future Sources of Supply for Naf Tourism Park under Option-3 & Option-4

8.4.4 Water Management Plan for Naf Tourism Park Option-3

Option-4 is similar as Option-3 for Naf Tourism Park where the water sources considered are:

- Rainwater harvesting in the roof top of buildings
- Desalination plant

Water supply system for different phases under Option-4 are similar as is shown in **Figure 8.7**.

8.5 Phasing Plan of Different Components

8.5.1 Production Tube well

Groundwater is the main source of water supply for Sabrang (Option-1 & 2) and Naf Tourism Park (Option-1 & 2). Total 8 nos. of production tube well can be installed in Whykhong well field area with production capacity 14.42 l/s (0.5 cusec) each as shown in **Figure 8.8**. The locations of these proposed locations were selected with BEZA officials as given in **Table 8.3**. The total production would be 6.2 MLD considering maximum of 15 hours operating period.

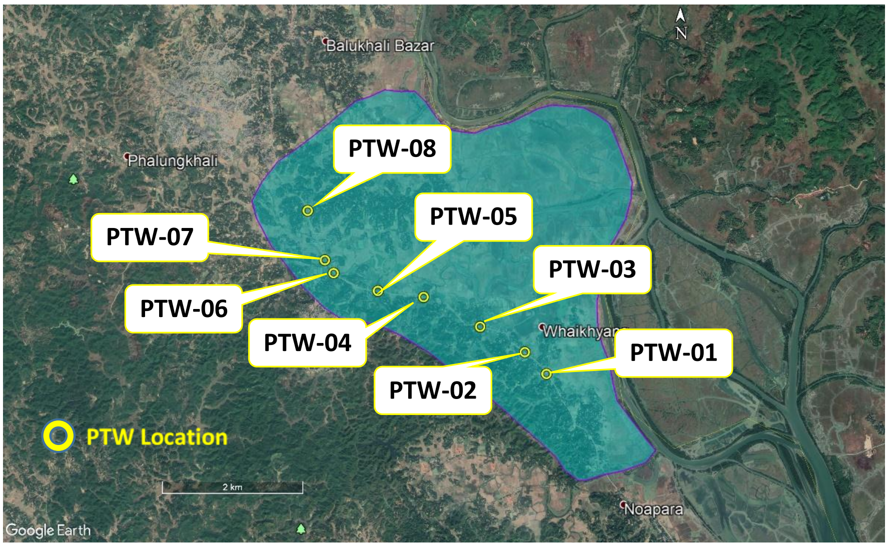


Figure 8.8: Proposed production tube well locations in Whykhong

Table 8.3: Locations of proposed production wells in Whykhong

Sl. no.	Well ID	Latitude	Longitude
1	PTW-01	21° 7'39.16"N	92°11'22.27"E
2	PTW-02	21° 7'48.30"N	92°11'12.70"E
3	PTW-03	21° 7'59.90"N	92°10'50.80"E
4	PTW-04	21° 8'13.40"N	92°10'23.10"E
5	PTW-05	21° 8'16.20"N	92°10'0.70"E
6	PTW-06	21° 8'24.30"N	92° 9'39.00"E
7	PTW-07	21° 8'30.20"N	92° 9'34.70"E
8	PTW-08	21° 8'52.70"N	92° 9'26.30"E

After the installation of PTW, the shallow tube wells in the surrounding influenced area of about 100m radius may be abandoned due to water table drawdown. To observe the influenced of shallow tube wells and drawdown, monitoring is needed. A groundwater monitoring plan is given in **Appendix-M**. If the shallow tube wells cannot uplift water, conflict with the existing local water use may arise. In order to avoid conflict BEZA need to construct a new PTW for domestic usage. The supply system of this PTW should be operated and maintained through local administration or under respective authority.

In order to fulfill the water demand into different development phase, the no of PTW, its operation hour and power requirement has been optimized as shown in **Table 8.4**. The electricity power has to be connected from existing Bangladesh Rural Electrification Board (REB) electricity line along the Cox's Bazar-Teknaf highway.

Table 8.4: Production tube wells in different phases

Phase	Phase-1	Phase-2	Total
	2022-27	2031-36	2022-2036
Total no of PTW	4	4	8
PTW ID to be developed (Figure 8.8)	PTW-08, PTW-07, PTW-05 & PTW-04	PTW-08, PTW-07, PTW-05 & PTW-04	PTW-01 to 08
Operating Hour	15	15	15

Phase	Phase-1	Phase-2	Total
	2022-27	2031-36	2022-2036
Total Production for Tourism Parks (MLD)	3.11	3.11	6.2
Power requirement: electricity (kWh)	8.4	8.4	16.8

8.5.1.1 Guidelines for Installation and Operation of Production Tube Well

Good production tube well depends on drilling method, well design, proper gravel packing and well development. Development work to be started within 24 hours after completion of lowering fixture and gravel packing. PTW design to be done by experienced hydrogeologist. The following guideline should be followed for getting better production from production tube well.

8.5.1.1.1 During drilling the following task is to be ensured:

- Production Tube Well drilling work should be done using hydraulic rig (not Rotary set or any other local device) capable of making an open borehole at least 600 mm diameter and up to a depth of 250 m.
- Reverse circulation method should be used for drilling.
- Proper sampling procedure to be ensured.
- Cutting samples to be kept in a sample box at every 3 m interval with proper leveling of depth.

8.5.1.1.2 After drilling during design, installation the following task is to be ensured:

- Sand sample and gravel sample should be sieve analyzed.
- Find out D_{10}, D_{3o}, D_{6o} and D_{50} value from sand and gravel samples.
- Identify Uniform coefficient (U_c) and Pack Aquifer (P-A) ratio properly.
- The production tube well design should be carried out by expert Hydrogeologist.
- Proper gravel which is clean, hard and rounded (not crushes or angular shaped) should be selected.
- After selection of gravel materials gravel packing will be continued up to depth 15 m below the ground surface.

8.5.1.1.3 Development procedure of production tube well:

Development procedure of production well should be supervised by expert Hudrogeologist following the headings below:

1) **50% designed discharge test**: The test should be carried out by submersible pump and with minimum 50% of PTW designed capacity. Duration of test should be minimum 3 hours.
2) **Development by compressed air**: The test should be carried out by high capacity compressor of minimum capacity 250 psi.
3) **Washing with dispersant Chlorination**: Total volume of water of the production tube well need to be calculated and 15 kg Sodium Hexa Metaphosphate and 1.25 kg dry loose calcium hypochlorite Ca(OCl)Cl (65% chlorine) per cubic meter water should be used.

4) **High pressure water Jetting**: The test needs to be carried out by jetting machine (minimum water pressure 600 to 700 psi) and compressor. Minimum duration of test should be 4 to 6 hours for six (6) meter strainer length.
5) **Development by over pumping**: The test should be carried out using submersible pump with discharge capacity 150% of the designed capacity of production tube well. Over pumping should be carried out by back wash method and maintaining minimum three steps. Duration of every step should be minimum 1.5 hours. Over pumping should consist of step pumping at 75% to 150% of design capacity of the production well.
6) **Step drawdown test**: A step draw down test should be carried out at 75%, 100%, 125% and 150% of the production well design capacity. During each test pumping should be continued for 90 minutes and be increased to the next rate without stopping the switch. After completion of step drawdown test water level recovery need to be measured. Step drawdown test should be carried out using orifice manometer method. Final static water level (SWL), pumping water level (PWL), drawdown (DD), specific capacity, discharge (Q), well loss percentage, aquifer loss percentage to be find out from the step draw down test.
7) **Constant discharge test**: The test should be carried out with design capacity of the production well. Duration of the test should be 6 hours without any break.
8) **Verticality test**: A good production well depend on straightness of the production well. The deviations of Pump Housing Pipe (PHP) should not more than 1 mm per 1 meter length of Pump Housing Pipe (PHP) in any direction.

8.5.1.1.4 Production Tube Well Maintenance during operation period:

- Regular checking of discharge rate by flow meter and note it on register book.
- Checking of water quality parameter with regular interval.
- Regular measurement of static water level before starting pump and to be noted in register book.
- Measurement of pumping water level during pump operation every day.
- Regular checking of control panel specially volt meter during pump operation

8.5.2 Desalination Plant

Desalination plant is a vital source of water for Sabrang (in all options) and Naf Tourism Park (Option-3). The required production capacity from desalination plant under different option and planning horizon are given in **Table 8.5**.

Table 8.5: Production capacity of desalination plant in different phases

Tourism park	Option	Phase-1	Phase-2	Total
		2022-27	2031-36	2022-36
		Production capacity (MLD)		
Sabrang	Option-1	2.55	2.7	5.25
	Option-2	1.9	2.6	4.5
	Option-3	4.5	5.1	9.6
	Option-4	1.35	2.05	3.4

Tourism park	Option	Phase-1	Phase-2	Total
		2022-27	2031-36	2022-36
		Production capacity (MLD)		
Naf	Option-3 & Option-4	0.60	0.55	1.15

To fulfill water demand in Sabrang Tourism Park it has been planned to install/construct desalination plants of total production capacity 5.25MLD in Option-1, 4.5 MLD in Option-2, 9.6 MLD in Option-3 and 3.4 MLD in Option-4. In each option, the production capacity of the desalination plant will be increase phase by phase with common administrative and utility facilities.

In Naf Tourism Park desalination plant of total 1.15 MLD capacity in Option-3 as well as Option-4 has been estimated as shown in **Table 8.5.** The production capacity will be increase phase by phase with common administrative and utility facilities.

The office building for desalination plants would be common for all phases in both Sabrang and Naf Tourism Park and production units would be installed according to increase of water demand with development.

The source of water for desalination plant is Bay-of-Bengal River in Sabrang and Naf River in Naf and the intake should be constructed near the tourism park area. Treated water from the desalination plants would be first reserve in the underground water reservoir and then distributed through the proposed distribution network. Some portion of the water would be used in the bottling water plants. About 5 acre land is required to construct the desalination plants. The location of proposed desalination plants is designated by BEZA officials as shown in **Figure 8.9**. The transmission main of the desalination plant would be separated from the transmission line for groundwater as shown in **Figure 8.10.**

Figure 8.9: Proposed locations of desalination plant and bottling water plant in Sabrang Tourism Park

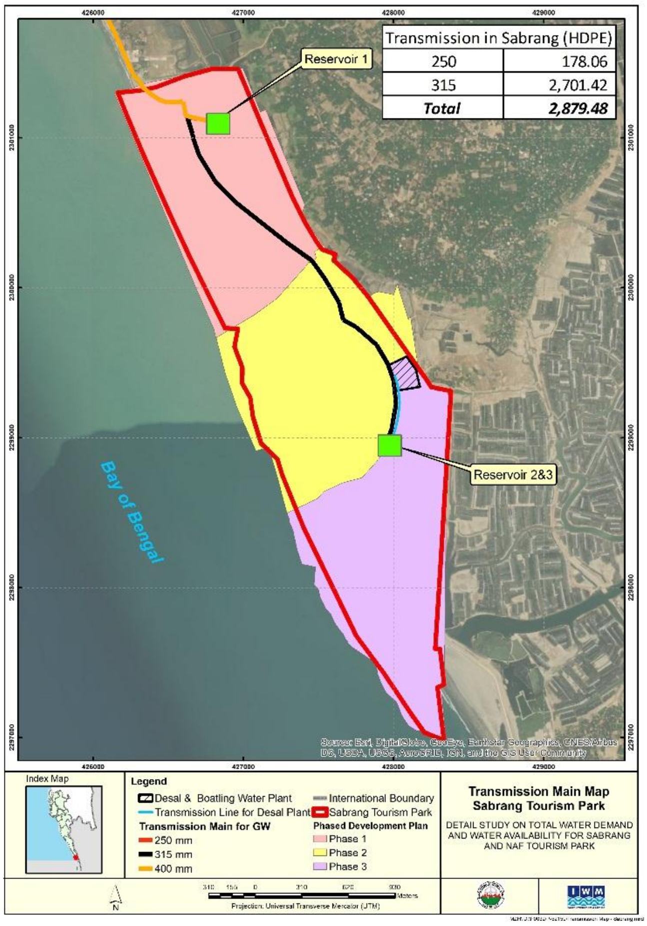


Figure 8.10: Transmission line for desalination plant in Sabrang

8.5.3 Roof top Rainwater Harvesting

Roof top rainwater harvesting is considered in Sabrang Tourism Park for all options and in Naf Tourism Park for Option 2, 3 & 4. Total 0.73 MLD and 0.22 MLD water can be made available in Sabrang and Naf Tourism Park respectively after full development. About 180 nos. reservoir will be required in Sabrang and 63 nos. in Naf Tourism Park to store the rainwater and use throughout the year. The size of each reservoir in Sabrang and Naf Tourism Park would be 15.7mX15.7mX4m and 15.4mX15.4mX4m (including 0.5m freeboard) respectively. The no of tanks that could be construct in each phase is given in **Table 8.6**.

Table 8.6: Rainwater harvesting in different phases

Tourism park	**Items**	**Phase-1**	**Phase-2**	**Total**
		2021-24	2024-26	2021-36
Sabrang	Total Harvested water (MLD)	0.38	0.35	0.73
	No of tanks	94	86	180
Naf	Total Harvested water (MLD)	0.11	0.11	0.22
	No of tanks	32	31	63

8.5.4 Lake/Reservoir water

About 2.0 MLD water can be supply from the proposed lake/water reservoir in Sabrang Tourism Park. The lake area is planned to be re-sectioned in Phase-1. After developing the lake, it can be used as water reservoir after some treatment.

8.5.5 Underground Water Reservoir

The underground water reservoirs (UGWR) are proposed in the Tourism Parks that would receive water from different water sources first, and then water will be diverted through distribution network into each plot by pumping. The capacity of the Underground Water Reservoir (CUGWR) would be made adequate to store 2 days water demand. Two days storage has been suggested in the Master Plan to ensure availability of uninterrupted water supply during any maintenance or repairing works.

Water Reservoir capacity = Volume of daily water demand x 2

Moreover, two additional reservoirs with booster pump stations have been proposed for head generation for travelling a long distance through transmission main. The first reservoir and booster pump station (BPS-1) is prosed at Whykhong near PTW-01 which will receive water from the 8 nos. production tube wells. Another reservoir and booster pump station (BPS-2) is proposed near the Teknaf Ferry Ghat. The capacity of the reservoir would be made adequate to store water for 2 hours only.

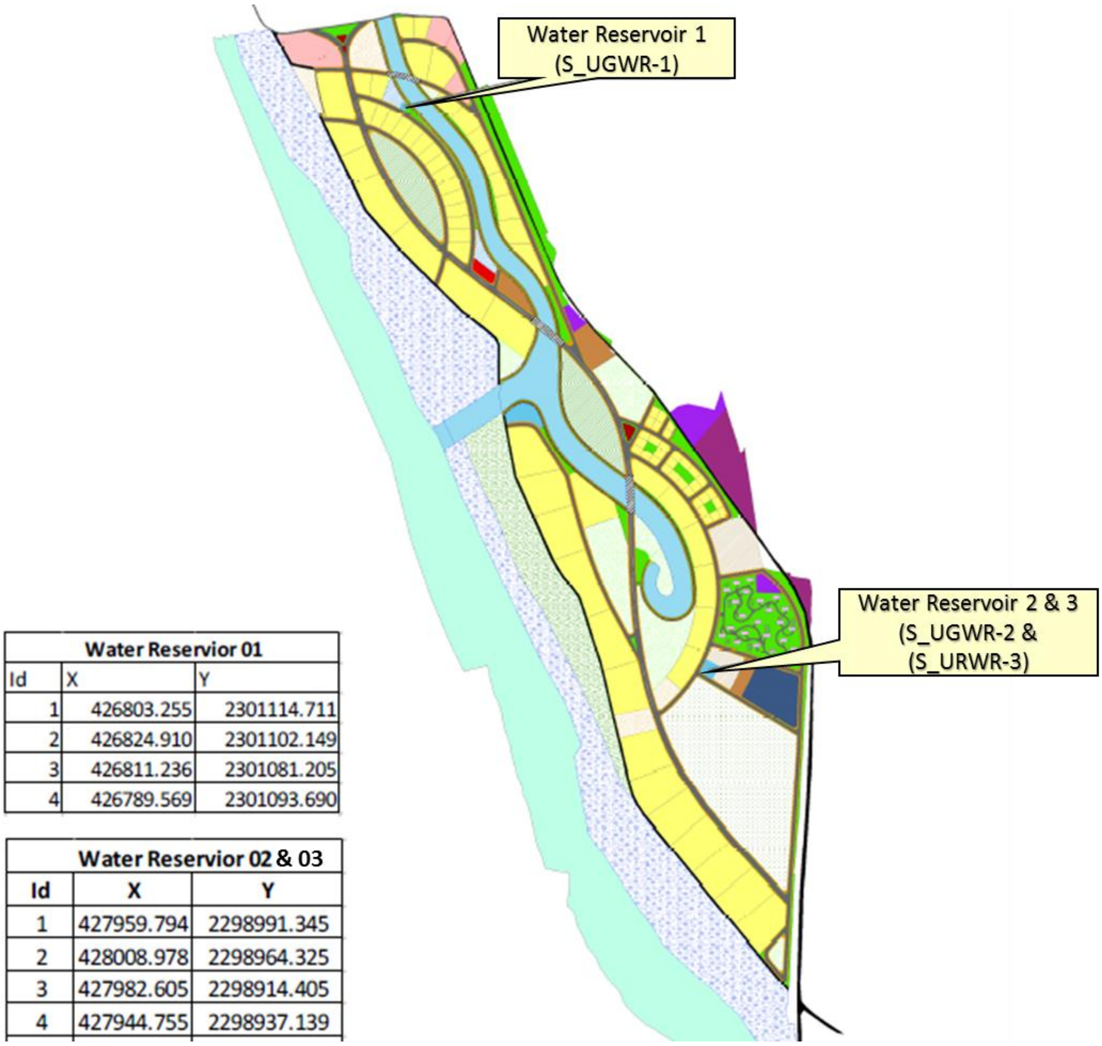
8.5.5.1 Underground Water Reservoirs in Sabrang Tourism Park

Three number of underground water reservoirs is considered in Sabrang Tourism Park to optimize the cost and operation facilities. Each reservoir will have 2 chambers. Two reservoirs will be developed in Phase 1 and remaining one in Phase-2. The locations of the reservoirs in

Tourism Park area are provided from BEZA. The capacity and size of reservoir is given in **Table 8.7** and the locations are shown in **Figure 8.11**.

Table 8.7: Underground water reservoir capacity and size in Sabrang tourism Park

Item	**unit**	**Phase-1**		**Phase-2**
Reservoir ID		S_UGWR-1	S_UGWR-2	S_UGWR-3
Planned Capacity	m^3	8,300	8,040	5,893
Size of reservoir (height including freeboard)		45.6m x 45.6m x 5m	44.9m x 44.9m x 5m	38.4m x 38.4m x 5m



Water Reservior 01		
Id	X	Y
1	426803.255	2301114.711
2	426824.910	2301102.149
3	426811.236	2301081.205
4	426789.569	2301093.690

Water Reservior 02 & 03		
Id	X	Y
1	427959.794	2298991.345
2	428008.978	2298964.325
3	427982.605	2298914.405
4	427944.755	2298937.139

Figure 8.11: Proposed reservoir locations in Sabrang Tourism Park

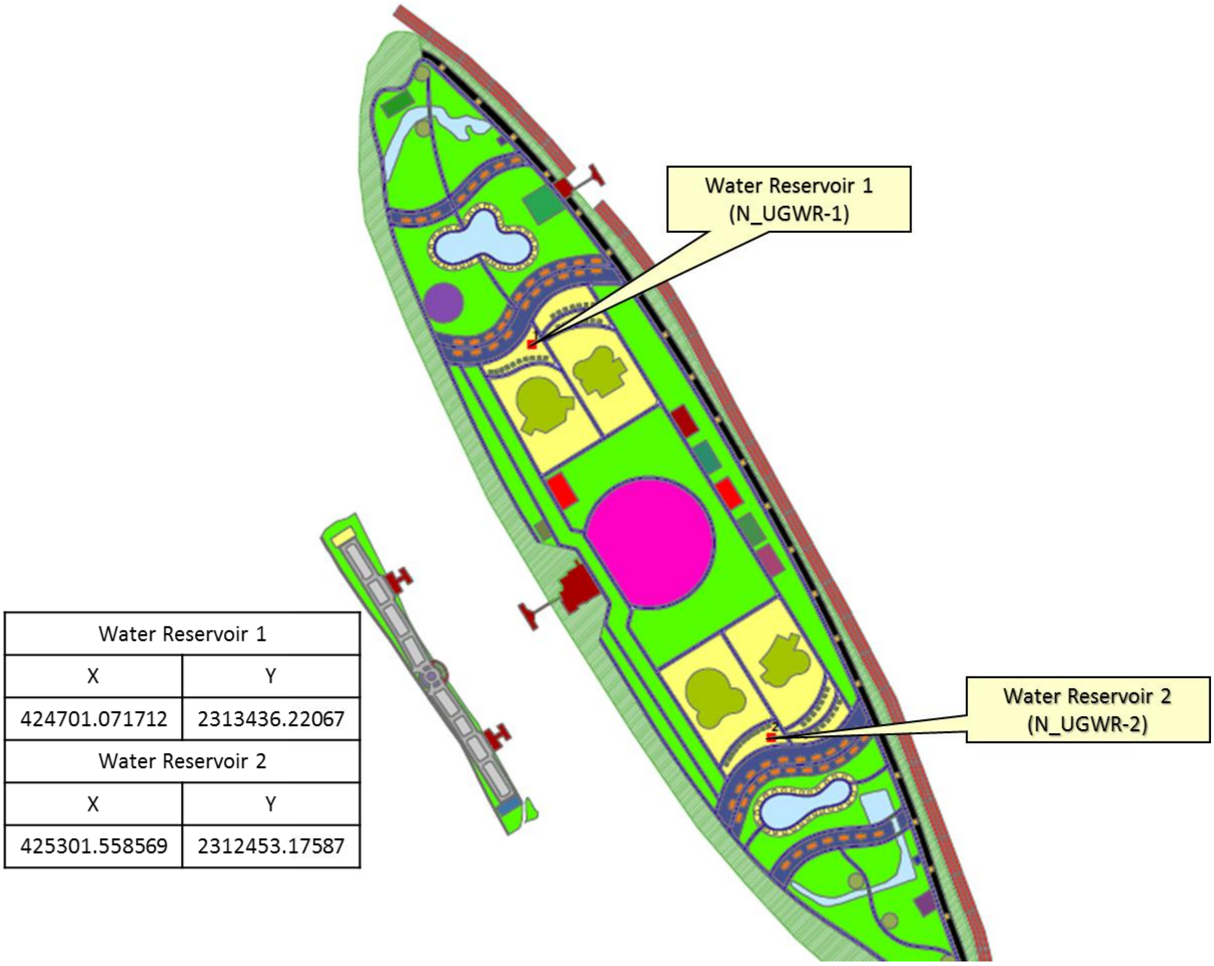
8.5.5.2 Underground Water Reservoir in Naf Tourism Park

Two number of underground water reservoirs are considered in Naf Tourism Park to optimize the cost and operation facilities. Each reservoir will have 2 chambers. The 1st reservoir (N_ UGWR-1) will be used to supply water in Phase-1 development area. The 2nd reservoir (N_ UGWR-2) will be used to supply water in Phase-2 development area. The locations of the reservoirs in Tourism Park area are provided from BEZA. The reservoirs will be developed in

Phase 1 & 2 of water supply plan. The capacity and size of reservoir is given in **Table 8.8** and the locations are shown in **Figure 8.12**.

Table 8.8: Underground water reservoir capacity and size in Naf Tourism Park

Item	unit	Phase-1	Phase-2
Reservoir ID		N_UGWR-1	N_UGWR-2
Planned Capacity	m^3	1,240	1,200
Size of reservoir (height including freeboard)		17.8 x 17.8 x 5m	17.4m x 17.4m x 5m



Water Reservoir 1	
X	Y
424701.071712	2313436.22067
Water Reservoir 2	
X	Y
425301.558569	2312453.17587

Figure 8.12: Proposed reservoir locations in Naf Tourism Park

8.5.5.3 Underground Water Reservoir at BPS-1, Whykhong

A water reservoir with a capacity of 560m^3 will be required for BPS-1 at Whykhong for detention of about 2 hours which includes 0.5 hour for chlorine contact basin. The size of clear water reservoir with chlorine contact basin will be 14m x 10m x 5m including freeboard of 0.5m. The reservoir would have 2 chambers and need to be developed in Phase-1.

8.5.5.4 Underground Water Reservoir at BPS-2, Teknaf Ferry Ghat

A water reservoir with a capacity of 480m^3 will be required for BPS-1 near Teknaf Ferry Ghat for detention of about 2 hours which includes 0.5 hour for chlorine contact basin. The size of clear water reservoir with chlorine contact basin will be 12m x 10m x 5m including freeboard of 0.5m. The reservoir would have 2 chambers and need to be developed in Phase-1.

8.5.6 Water Supply Pump Stations/Units

8.5.6.1 Booster pump stations

The length of transmission line from the well field to Sabrang Tourism Park is about 43.5 km (from PTW-01). In order to carry the water through this long transmission pipe line, at two booster pumps will be required to guarantee water pressure to the desired level for uninterrupted supply. The first booster pump (BPS-01) is planned to installed at Whykhong at location just north of PTW-01 and the second one (BPS-02) is near Teknaf Ferry Ghat. The characteristics of Booster Pumps are described in sec. 3.10.2. The phase wise installation and operation of the pumps are given in **Table 8.9**.

Table 8.9: Pump operating hour in different period

Particular	Phases	
	Phase-1	Phase-2
Production from PTWs (MLD)	3.11	6.22
NAF water Demand (MLD)	0.58	1.13
Flow in BPS-1 (MLD)	3.11	6.22
no of pump to be installed in BPS-1	3 (2 on duty, 1 stand by)	4 (3 on duty, 1 stand by)
Capacity of each pump (m^3/s)	0.0283	0.0283
Operating Hour of BPS-1	15.3	20.4
Flow in BPS-2 (MLD)	2.53	5.10
no of pump to be installed in BPS-2	3 (2 on duty, 1 stand by)	4 (3 on duty, 1 stand by)
Operating Hour of BPS-2	12.4	16.7

8.5.6.2 Pumps at Underground Water Reservoirs in Naf Tourism Park

The capacity of water supply pumps at underground water reservoirs in Naf Tourism Park need to be sufficient enough to meet peak water demand. For Naf Tourism Park 2 nos. pumps at 2 reservoirs will be required. The pumps will be operated for maximum 16 hour depending on demand on each phase. Moreover, for maintenance, repairing or replacement facilities one mobile pump will be kept stand by in each Tourism Park. The capacity of each pump is 0.5cusec. The operating hour of these pumps in different phases in given in **Table 8.10**.

Table 8.10: Pump capacity in Naf Tourism Park

Particular	Phases	
	Phase-1	Phase-2
Pump Unit at N_UGRW-1		
No of pump to be installed	2	2
	(1 on duty, 1 stand by)	
Capacity of pump unit (m^3/s)	0.0142	0.0142
Operating Hour	16	16
Pump Unit at N_UGRW-2		
No of pump to be installed	-	2

		(1 on duty, 1 stand by)
Capacity of pump unit (m^3/s)	-	0.0142
Operating Hour	-	16

8.5.6.3 *Pumps at Underground Water Reservoirs in Sabrang Tourism Park*

The capacity of water supply pumps at underground water reservoirs in Sabrang Tourism Park need to be sufficient enough to meet peak water demand. For Sabrang Tourism Park 3 nos. pump units at 3 reservoirs will be required. The pumps will be operated for maximum 14 hour depending on demand on each phase. Moreover, for maintenance, repairing or replacement facilities one mobile pump will be kept stand by in each Tourism Park. The capacity of each pump is 1.0cusec. The operating hour of these pumps in different phases in given in **Table 8.11**.

Table 8.11: Pump capacity in Sabrang tourism Park

Particular	Phase	
	Phase-1	Phase-2
Pump Unit at S_UGRW-1		
No of pump to be installed	5	5
	(4 on duty, 1 stand by)	
Capacity of pump unit (m3/s)	0.11	0.11
Operating Hour	14	14
Pump Unit at S_UGRW-2		
No of pump to be installed	3	5
	(2 on duty, 1 stand by)	(4 on duty, 1 stand by)
Capacity of pump unit (m3/s)	0.11	0.11
Operating Hour	14	14
Pump Unit at S_UGRW-3		
No of pump to be installed	-	5
		(4 on duty, 1 stand by)
Capacity of pump unit (m3/s)	-	0.09
Operating Hour	-	14

8.5.7 Water Supply Transmission Main

The water supply transmission main from Whykhong well field (BPS-1) to Sabrang Tourism Park including is about 42.3km which would have DI pipe with 400mm diameter. The transmission line to be developed in Phase-1. Moreover, collection line-1 of 4.5 km will collect the water from PTW 4, 5, 7, 8 and collection line-2 of 3.5 km from PTW 1, 2, 3, 6. Collection line-1 need to lay in Phase-1 and Collection line-2 in Phase-2. The diameter of collection system varies from 200 to 315 mm and HDPE pipe material would be used.

To divert from the main transmission main to Naf Tourism Park Naf River need to be cross. In this regard river cross or large water carrier will be needed to carry the water from the transmission main to the reservoir sites. Considering cost effectiveness water carries tankers are suggested to carry water to Naf Tourism Park. In Phase-1, 1 no General purpose tanker and in Phase-2 another General purpose tanker may be required.

The length of the pipe transmission main in Naf Tourism Park upto reservoirs N_UGWR-1 & 2 will be about 2.5 km HDPE pipe with diameter 160 to 200mm. About 1.1 km line will be laid in Phase-1 and 1.4 km in Phase-2.

The length of transmission main in Sabrang Tourism Park up to the reservoirs is about 2.9 km HDPE pipe and diameter varies from 250 to 315 mm. About 200m line will be laid in Phase-1 and 2.7km in Phase-2.

8.5.8 Water Supply Distribution Line in Sabrang Tourism Park

The alignment of the pipe lines for different development phases is taken from the Detailed Master Plan (December 2020). The total length of distribution network is about 12.11km and diameter varies from 75 to 355mm. HDPE pipe material would be used for distribution line. The required length of distribution line for different phase in Sabrang Tourism Park is given in **Table 8.12.**

Table 8.12: Water Supply Distribution Line in Sabrang tourism Park

Diameter (mm)	Phase 1	Phase 2	Total
75	1,531	1,593	3123
110	1,415	794	2209
160	1,544	831	2374
200	900	400	1300
250	823	650	1473
315	496	910	1406
355	206	18	224
Grand Total	**6,916**	**5,195**	**12,110**

8.5.9 Water Supply Distribution Line in Naf Tourism Park

Naf tourism park area will be developed in 3 planning horizons and the alignment of the pipe lines in these three phases is taken from the Detailed Master Plan (December, 2020). The total length of distribution network is about 10.1km and diameter varies from 75 to 160mm. HDPE pipe material would be used for distribution line. The required length of distribution line for different phase in Naf Tourism Park is given in **Table 8.13**.

Table 8.13: Water Supply Distribution Line in Naf tourism Park

Diameter (mm)	Phase-1	Phase-2	Total
75	4172	4135	8307
110	858	741	1599
160	114	63	177
Grand Total	**5,144**	**4,939**	**10,083**

8.5.10 Land Acquisition and Land Development

Land will be required outside the tourism park areas for installation of 8 nos. production tube well and 1 no. booster pump stations including underground reservoirs in Whykhong along the transmission line. About 1.4 acres of land acquisition is required. Other structures will be constructed at already acquired land of BEZA. The locations of production tube wells and booster pumps are selected and finalized concerning BEZA officials. All land acquisition should be completed in development Phase-1. The detail land acquisition quantifications are stated in Chapter 6.

8.5.11 Bottling Water Plant

Considering average number of tourists, the drinking water requirement in Sabrang and Naf Tourism Parks are about 41,000liter/day and 4,000liter/day respectively. To meet only the drinking water requirement 2 nos. of bottling water plant can be installed in two phases as shown in **Table 8.14**.

Table 8.14: Production capacity of bottling water plant in different phases

Phases	Production Capacity (liter/day)	Production Capacity (liter /hour)
Phase-1	25,000	4,000
Phase-3	21,000	3,500
Total	**46,000**	**7,500**

About 2 acres land is required to construct the bottling water plants. The location of proposed bottling water plants is selected from BEZA as shown in **Figure 8.9**. Power is one of the major requirement to run a bottling water plant. The approximate power requirement may be 330volt/60Hz.

8.6 Environmental and Social guidelines, concerns, challenges

(i) **Social unrest** – Due to installation and operation of the proposed production wells in Whykhong well field, shallow tube wells of the surrounding 100m radius areas may get effected. The shallow tube wells can have less or no uplift water. In this situation, social unrest situation may arise. In order to avoid this conflict BEZA need to construct a new PTW for domestic usage. The supply system of this PTW should be operated and maintained through local administration or under respective authority.

(ii) **Safe yield quantification of groundwater abstraction** – In absence of site-specific detail information about soil, lithology and land, indirect approach has been applied to estimate specific yield over the area. A good groundwater management under the condition requires monitoring of abstraction (by local use and/or Tourism Park), review of recharge estimate, water quality and groundwater water level fluctuations as the development goes on. The area is in geologically complex (folding and faulting), having very low yield. Therefore, increase in abstraction under future development scenario needs close monitoring to understand aquifer response and bring the safe limit within a narrow range of confidence limit. A groundwater monitoring plan is given in **Appendix-M**.

(iii) **Easement** – Easement is a key element of the water supply projects. Easement agreement is required with R&H and LGED for laying the transmission main. Permission and road restoration charge will be required. Easement involves documents submission, regulatory authority review, and approval. Delayed submittals and incomplete or wrong applications can significantly slow down the approval process and subsequent construction work. Close communications with regulatory staff and understanding of permit requirements along with the submission of relevant forms, fees, and supporting documents can greatly expedite the process.

(iv) **Budget challenges** – Project costs are typically estimated at the planning stage and get regularly revised as more design specifics become available. Detailed drawings and specs generated for bidding provide a high degree of confidence in finalizing cost estimates. Moreover, as the project will be implied for long period, the actual inflation may vary as considered during project cost estimation.

(v) **Traffic management and mobilization needs** – Traffic management is a big issue, during project construction at congested areas and urban surroundings with high traffic zones. Transportation of heavy equipment, construction tools, materials, establishment of the site office, and other activities require proper access to the project site. Coordination with local transportation department, allocation of sufficient manpower, and ensuring public safety becomes crucial. Selecting correct traffic patterns can avoid blockage, traffic jams, accidents, and casualties. Traffic management during construction activities is indeed a challenging task.

(vi) **Unexpected subsurface conditions** – Excavation is an integral part of the water supply project. For pipelines, underground tanks or other components, excavation activities need to be performed at the site. Boring logs, rock cores, geotechnical investigation report, topographical data/maps, and other subsurface data provide an idea about the underground conditions and expected excavation needs. Some guidelines during the construction phase are describe in Sec. 3.11.

(vii) **Construction sequence difficulties** –Well-seasoned professionals are required to develop an effective construction sequence for proper system operations. A lot of coordination is required between the contractor, operators, and engineers to execute the construction sequence effectively during the project span.

(viii) **Coordination and communication issues** – The construction process is intense and involves a lot of coordination and communication between the contractor, sub-contractor, client, engineer, surveyors, regulators, and other members involved with the project. Project schedules, daily progress, milestones, and challenges get discussed among the teams on a regular basis. However, lack of communication, miscommunication, ignorance, assumptions, and other actions can create conflicts, disagreements, and an unpleasant atmosphere. This can adversely affect project goals. To meet project needs and keep everyone on the same page at every stage, effective communication and coordination is a must.

(ix) **Change order disputes** –Due to unknowns or unexpected situations in the field, planned works may get added or deleted based on actual site conditions. In such cases, change orders are typically issued to acknowledge project scope changes and are agreed upon by the contractor, client, and other responsible entities. These contract alterations are also associated with project pricing and schedule changes.

8.7 Operation and Maintenance of Water Supply System

For operation and maintenance of the production tube wells including transmission main and distribution system, BEZA will setup a Unit for operation and maintenance (O&M) by an Executive Engineer. The O&M unit will be responsible for-

a) Procurement of chemicals, operation and maintenance of

- groundwater wells
- Collection system
- water transmission main
- distribution network

b) Providing service connection to the consumers

c) Receive complains and provide emergency services

Proposed Organizational Structure for O&M unit of the overall water supply system is shown in **Figure 8.13.**

Moreover, the operation and maintenance of the desalination plant will be carried out by the contractor (BOOT method will be used for procurement) for at least 3 years. Gradually the O&M system need to be handed over to BEZA after capacity building of the O&M unit of BEZA and proper training.

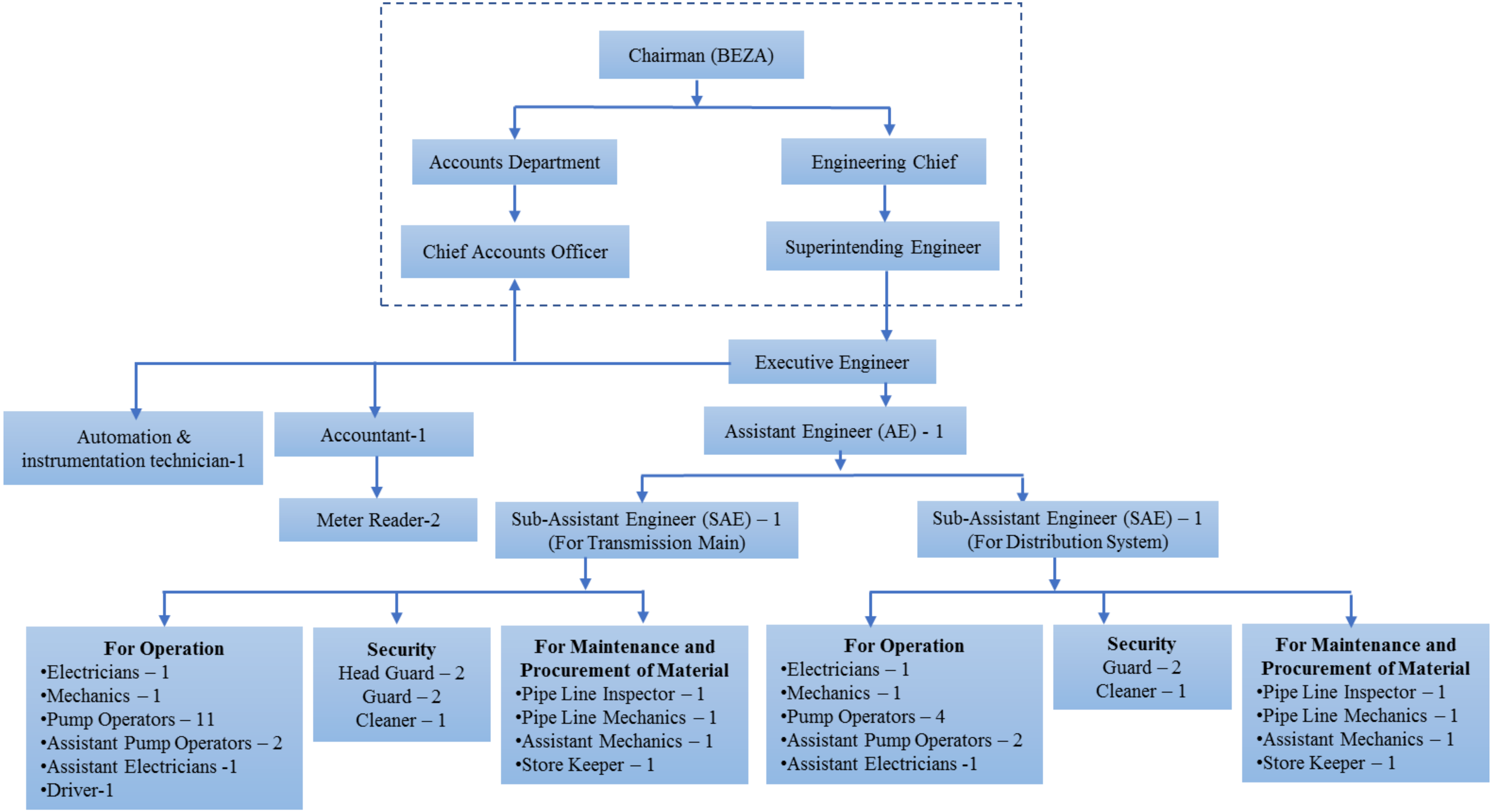


Figure 8.13: Proposed Organogram for O&M Unit of Water Supply system

8.7.1 Staff Position and Duties

Operation and Maintenance Unit will be operated under an Executive Engineer. He will be sole responsible for operation and maintenance (O&M) of the pipelines and maintenance of accounts.

Executive engineer will be assisted by following officers and staffs for O&M and procurement of chemicals, use and preservation of the chemicals:

a) Executive Engineer
b) Assistant Engineer
c) Sub Assistant Engineer
d) Accountant
e) Electricians
f) Mechanics
g) Meter Reader
h) Pipeline Inspector
i) Assistant Mechanics
j) Head Guard, Guard
k) Pump operator
l) Store Keeper
m) Cleaner
n) Driver.

Duty of the Assistant Engineer are to engage the staffs & operators in different units of the water supply system. The schedule of the O&M staffs will be prepared in such a way so that each and every staff will be on duty at least for 8 hours.

Depending on the construction of reservoir and pumps, no of the pump operator will be vary for both PTWs including transmission system, and distribution system.

Under Executive Engineer, revenue officer with revenue inspectors will be engaged for billing & collection of revenue. The revenue officer will be liable to maintain all records of billing and collection of the revenue. He will work under the Executive Engineer.

Under Executive Engineer, one Accountant with two Meter Reader will be worked for maintenance of the accounts.

8.8 SWOT Analysis

SWOT analysis is a decision making method that has been widely used in identifying and solving problems related to water resource management and plan which often involve interdisciplinary issues that are difficult to quantify. SWOT analysis for different water supply management plant of this study is presented in **Table 8.15** and **Table 8.16.**

Table 8.15: SWOT analysis of water management plan

 **for** **Sabrang Tourist Park**	**Strengths (S)** ✓ Rainwater harvesting ✓ Lake water reservoir ✓ Desalination of sea water ✓ Fund availability for capital investment ✓ Assurance of water tariff	**Weakness (W)** ○ Low yield of groundwater resources ○ GW availability far away from Sabrang ○ Cost of transmission line through hilly terrain ○ Highly skill resource is required for operating desalination plant ○ High O&M cost for desalination plant
Opportunities (O) ➢ Availability of groundwater in deep aquifer ➢ Possibility of creation of small rainwater reservoir in the hilly water shade ➢ Dependency increases for desalination of sea water ➢ Partial capital cost may be imposed to the investors ➢ Efficient and economic use of all possible water resources	**Opportunity-Strength Strategies** ✣ Limited use of groundwater ✣ Small quantity from rainwater resources ✣ Desalination of sea water can meet the demand ✣ Fund available for capital investment	**Opportunity-Weakness Strategies** ✣ Monitoring of GW & cost of transmission not favorable ✣ Skill resource development for O&M of desalination plant
Threats (T) ❖ Reduce groundwater resource in future ❖ Social unrest due to carry groundwater to long distance ❖ Inconsistence annual rainfall due to climate change ❖ Deforestation in the Hilly watershed area	**Threat-Strength Strategies** ✣ Threatening to annual quantification of GW & rainwater resources ✣ New PTW need to installed for domestic usage	**Threat-Weakness Strategies** ✣ Inconsistence availability of GW & rainwater storage

Table 8.16: Comparison of SWOT analysis of different water management plan options

Options	Components	S	W	O	T	Strategy
Option-1	GW from Whykhong		✓	✓	✓	➢ Highly dependent on groundwater ➢ Partial support from rainwater ➢ desalination (partial) is an opportunity in future
	Teknaf reservoir	Not ensured				
	Rainwater	✓		✓	✓	
	Desalination	✓	✓	✓		

Options	Components	S	W	O	T	Strategy
Option-2	GW from Whykhong		✓	✓	✓	➢ High dependency on groundwater ➢ Partial support from rainwater ➢ desalination (Partial) is an opportunity in future
	Rainwater from rooftop	✓		✓	✓	
	Rainwater from lake	✓		✓	✓	
	Desalination	✓	✓	✓		
Option-3	Rainwater from rooftop	✓		✓	✓	➢ Highly dependent on desalination ➢ Partial support from rainwater
	Rainwater from lake	✓		✓	✓	
	Desalination	✓	✓	✓		
Option-4	GW from Whykhong		✓	✓	✓	➢ High dependency on groundwater ➢ desalination (partial) is an opportunity in future Partial support from rainwater ➢ **Advantageous option**
	Rainwater from rooftop	✓		✓	✓	
	Rainwater from lake	✓		✓	✓	
	Desalination	✓	✓	✓		

From the SWOT analysis of different options, it is observed that all options have some strength, weakness, opportunity and threat. Among the options, Option-3 is most advantageous option. Moreover, from cost estimation (Sec. 9.1) and financial and economic analysis (Chapter 10) it is observed that Option-3 is requires lest amount of budget for investment and most viable economically and financially. So, water supply through conjunctive use of desalination, rain water harvesting from roof top and lake as shown in Option-3 are most preferable.

8.9 Summary of Phase Wise Development Plan

The different components for fulfilling water demand in Sabrang and Naf Tourism Park has been describe in sec. 8.5. The summary of development plans at different phases for Option-2, Option-3 & Option-4 is presented in **Table 8.17** to **Table 8.19**.

Table 8.17: Phase-wise water supply development plan under Option-2

Phase	Sl. No.	Interventions
Phase-1 2022-27	1	Installation of 4 nos. production tube wells with production capacity 0.5 cusec each
	2	Laying of 4.5 km collection line-1 from PTW-08 to BPS-2
	3	Laying of 42.3 km transmission main from Whykhong to Sabrang Tourism Park
	4	Laying of 2.9 km transmission main inside Sabrang Tourism Park
	5	Laying of 1.1 km transmission main inside Naf Tourism Park
	6	Construction of 1 no underground reservoir (BPS-1) at whykhong of dimension 14m x 10m x 5m
	7	Installation of 3 nos. pumps in reservoir (BPS-1) of capacity 1 cusec each
	8	Construction of 1 no underground reservoir (BPS-2) near Teknaf Ferry Ghat of dimension 12m x 10m x 5m
	9	Installation of 3 nos. pumps in reservoir (BPS-2) of capacity 1 cusec each

Phase	Sl. No.	Interventions
	10	Purchase of 1 no. water tank for Naf Tourism Park
	11	Construction of 2 nos. underground reservoir (S_UWRW-1 & S_UWRW-2) in Sabrang of dimension 45.6 mx 45.6 mx 5 m and 44.9m x 44.9m x 5m
	12	Installation of 5 nos. pumps in reservoir S_UWRW-1 of capacity 1 cusec each
	13	Installation of 3 nos. pumps in reservoir S_UWRW-2 of capacity 1 cusec each
	14	Construction of 1 no underground reservoir in Naf (N_UGRW-1) of dimension 17.8 mx 17.8 mx 5 m
	15	Installation of 2 nos. pumps in reservoir N_UWRW-1 of capacity 0.5 cusec each
	16	Construction/installation of 1 no desalination plant of 1.9 MLD production capacity in Sabrang TP
	17	Laying of 6.92 km distribution line in Sabrang Tourism Park
	18	Laying of 5.14 km distribution line in Naf Tourism Park
	19	Constriction of 1no bottling water plant of capacity 4,000 liter /hour
	20	Construction of lake/water reservoir & treatment plant of capacity 2MLD
Phase-2 2031-36	1	Installation of 4 nos. production tube wells with production capacity 0.5 cusec each
	2	3.5 km collection line-2 from PTW-06 to BPS-2
	3	Laying of 1.4 km transmission main inside Naf Tourism Park
	4	Installation of 1 no. pumps in reservoir (BPS-1) of capacity 1 cusec each
	5	Installation of 1 no. pumps in reservoir (BPS-2) of capacity 1 cusec each
	6	Purchase of another 1 no. water tank for Naf Tourism Park
	7	Construction of 1 no underground reservoir (S-UGWR-3) in Sabrang of dimension 38.4 mx 38.4 mx 5 m
	8	Installation of 2 nos. pumps in reservoir S_UWRW-2 of capacity 1 cusec each
	9	Installation of 5 nos. pumps in reservoir S_UWRW-3 of capacity 1 cusec each
	10	Construction of 1 no underground reservoir in Naf (N_UGRW-2) of dimension 17.4 mx 17.4 mx 5 m
	11	Installation of 2 nos. pumps in reservoir N_UWRW-2 of capacity 0.5 cusec each
	12	Increase the capacity of desalination plant by additional 2.6 MLD in Sabrang TP
	13	Laying of 4.94 km distribution line in Naf Tourism Park
	14	Laying of 5.2 km distribution line in Sabrang Tourism Park
	15	Constriction of 1no bottling water plant of capacity 3,500 liter /hour

Table 8.18: Phase-wise water supply development plan under Option-3

Phase	Sl. No.	Interventions
Phase-1 2022-27	1	Construction/installation of 1 no desalination plant of 4.5 MLD production capacity in Sabrang TP
	2	Construction/installation of 1 no desalination plant of 0.6 MLD production capacity in Naf TP
	3	Construction of 2 nos. underground reservoir (S_UWRW-1 & S_UWRW-2) in Sabrang of dimension 45.6 mx 45.6 mx 5 m and 44.9m x 44.9m x 5m
	4	Installation of 5 nos. pumps in reservoir S_UWRW-1 of capacity 1 cusec each

Phase	Sl. No.	Interventions
	5	Installation of 3 nos. pumps in reservoir S_UWRW-2 of capacity 1 cusec each
	6	Construction of 1 no underground reservoir in Naf (N_UGRW-1) of dimension 17.8 mx 17.8 mx 5 m
	7	Installation of 2 nos. pumps in reservoir N_UWRW-1 of capacity 0.5 cusec each
	8	Laying of 6.92 km distribution line in Sabrang Tourism Park
	9	Laying of 5.14 km distribution line in Naf Tourism Park
	10	Constriction of 1no bottling water plant of capacity 4,000 liter /hour
	11	Construction of lake/water reservoir & treatment plant of capacity 2MLD
Phase-2 2031-36	1	Increase the capacity of the desalination plant by additional 5.1 MLD production capacity in Sabrang TP
	2	Increase the capacity of the desalination plant by additional 0.55 MLD production capacity in Naf TP
	3	Construction of 1 no underground reservoir (S-UGWR-3) in Sabrang of dimension 38.4 mx 38.4 mx 5 m
	4	Installation of 2 nos. pumps in reservoir S_UWRW-2 of capacity 1 cusec each
	5	Installation of 5 nos. pumps in reservoir S_UWRW-3 of capacity 1 cusec each
	6	Construction of 1 no underground reservoir in Naf (N_UGRW-2) of dimension 17.4 mx 17.4 mx 5 m
	7	Installation of 2 nos. pumps in reservoir N_UWRW-2 of capacity 0.5 cusec each
	8	Laying of 4.94 km distribution line in Naf Tourism Park
	9	Laying of 5.2 km distribution line in Sabrang Tourism Park
	10	Constriction of 1no bottling water plant of capacity 3,500 liter /hour

Table 8.19: Phase-wise water supply development plan under Option-4

Phase	Sl. No.	Interventions
Phase-1 2022-27	1	Installation of 4 nos. production tube wells with production capacity 0.5 cusec each
	2	Laying of 4.5 km collection line-1 from PTW-08 to BPS-2
	3	Laying of 42.3 km transmission main from Whykhong to Sabrang Tourism Park
	4	Laying of 2.9 km transmission main inside Sabrang Tourism Park
	5	Laying of 1.1 km transmission main inside Naf Tourism Park
	6	Construction of 1 no underground reservoir (BPS-1) at whykhong of dimension 14m x 10m x 5m
	7	Installation of 3 nos. pumps in reservoir (BPS-1) of capacity 1 cusec each
	8	Construction of 1 no underground reservoir (BPS-2) near Teknaf Ferry Ghat of dimension 12m x 10m x 5m
	9	Installation of 3 nos. pumps in reservoir (BPS-2) of capacity 1 cusec each
	10	Construction of 2 nos. underground reservoir (S_UWRW-1 & S_UWRW-2) in Sabrang of dimension 45.6 mx 45.6 mx 5 m and 44.9m x 44.9m x 5m

Phase	Sl. No.	Interventions
	11	Installation of 5 nos. pumps in reservoir S_UWRW-1 of capacity 1 cusec each
	12	Installation of 3 nos. pumps in reservoir S_UWRW-2 of capacity 1 cusec each
	13	Construction of 1 no underground reservoir in Naf (N_UGRW-1) of dimension 17.8 mx 17.8 mx 5 m
	14	Installation of 2 nos. pumps in reservoir N_UWRW-1 of capacity 0.5 cusec each
	15	Construction/installation of 1 no desalination plant of 1.35 MLD production capacity in Sabrang TP
	16	Construction/installation of 1 no desalination plant of 0.6 MLD production capacity in Naf TP
	17	Laying of 6.92 km distribution line in Sabrang Tourism Park
	18	Laying of 5.14 km distribution line in Naf Tourism Park
	19	Constriction of 1no bottling water plant of capacity 4,000 liter /hour
	20	Construction of lake/water reservoir & treatment plant of capacity 2MLD
Phase-2 2031-36	1	Installation of 4 nos. production tube wells with production capacity 0.5 cusec each
	2	3.5 km collection line-2 from PTW-06 to BPS-2
	3	Laying of 1.4 km transmission main inside Naf Tourism Park
	4	Installation of 1 no. pumps in reservoir (BPS-1) of capacity 1 cusec each
	5	Installation of 1 no. pumps in reservoir (BPS-2) of capacity 1 cusec each
	6	Construction of 1 no underground reservoir (S-UGWR-3) in Sabrang of dimension 38.4 mx 38.4 mx 5 m
	7	Installation of 2 nos. pumps in reservoir S_UWRW-2 of capacity 1 cusec each
	8	Installation of 5 nos. pumps in reservoir S_UWRW-3 of capacity 1 cusec each
	9	Construction of 1 no underground reservoir in Naf (N_UGRW-2) of dimension 17.4 mx 17.4 mx 5 m
	10	Installation of 2 nos. pumps in reservoir N_UWRW-2 of capacity 0.5 cusec each
	11	Increase the capacity of the desalination plant by additional 2.05 MLD in Sabrang TP
	12	Increase the capacity of the desalination plant by additional 0.55 MLD in Naf TP
	13	Laying of 4.94 km distribution line in Naf Tourism Park
	14	Laying of 5.2 km distribution line in Sabrang Tourism Park
	15	Constriction of 1no bottling water plant of capacity 3,500 liter /hour

9 COST ASSESSMENT

9.1 Project Cost Estimation

Project cost include the tentative cost requires for constructing water supply infrastructures to mitigate total water demand of proposed Sabrang and Naf Tourism Park. Initial cost estimation was submitted in Final Report of Phase-1, which is revised based on different water supply options as describe in Chapter 8. Phase-wise costing has been estimated as per the development plan indicated in **Table 8.17** to **Table 8.18**. The cost estimation does not consider price escalation. The current price escalation is about 5.5% annually based on current trend of inflation rate (https://www.statista.com/statistics/438363/inflation-rate-in-bangladesh/).

Option-1 would require total 5,655 Million BDT, Option-2 5,724 Million BDT, Option-3 2,893 Million BDT and Option-4 4,846 Million BDT as shown in **Table 9.1** to **Table 9.4**. It is observed that Option-3 estimated the lowest cost. Option-1, 2 & 4 estimated more due to higher cost for 42.3 km long transmission main. For selecting the most cost-effective option, cast analysis is done for Option-2, Option-3 & Option-4. Option-1 is discarded from cost analysis as the availability of water from dam in Teknaf.

Moreover, the reservoir cost for roof top rain water harvesting including the plumbing system is estimated about 3,208 Million BDT (**Table 9.5**) for Sabrang Tourism Park and 1,084 Million BDT (**Table 9.6**) for Naf Tourism Park. This costing would be carried out by the land leaser/developer and not a part of the project cost of BEZA.

Moreover, the cost of earthen dam and associated raw water transmission pipeline, surface water treatment plant and water office in Teknaf will be financed by the GoB/Donor agencies and implemented by DPHE. The feasibility study and cost of this dam is yet to finalization under *Emergency Multi-Sector Rohingya Crisis Response Project (EMCRP)* of DPHE.

Table 9.1: Tentative project cost under Option-1

Item No.	Description	Phase-1 (2022-27)	Phase-2 (2031-36)	Total
		Price in Million BDT		
1	Production Tube wells	70.5	70.5	141.0
2	Distribution network	38.0	32.1	70.2
3	Transmission Main, booster pump station & related other structures	2605.4	58.4	2663.8
4	Water transport to Naf	425.0	425.0	850.0
5	Underground Water Reservoir in Tourism Parks including pump units	203.2	88.9	292.1
6	Desalination plants	439.1	451.4	890.5
7	Bottling water plants	227.3	191.0	418.2
8	Land Acquisition & development	10.0	0.0	10.0
9	Consultancy (6%)	240.5	79.0	319.5
	Total Project Cost (Current price)	**4,259**	**1,396**	**5,655**

Table 9.2: Tentative project cost under Option-2

Item No.	Description	Phase-1 (2022-27)	Phase-2 (2031-36)	Total
		Price in Million BDT		
1	Production Tube wells	70.5	70.5	141.0
2	Distribution network	38.0	32.1	70.2
3	Transmission Main, booster pump station & related other structures	2,605.4	58.4	2,663.8
4	Water transport to Naf	425.0	425.0	850.0
5	Underground Water Reservoir in Tourism Parks including pump units	203.2	88.9	292.1
6	Desalination plants	331.4	434.8	766.2
7	Bottling water plants	227.3	191.0	418.2
8	Treatment plant for lake water	200.0	-	200.0
9	Land Acquisition & development	10.0	-	10.0
10	Consultancy (6%)	234.0	78.0	312.1
	Total Project Cost (Current price)	**4,345**	**1,379**	**5,724**

Table 9.3: Tentative project cost for under Option-3

Item No.	Description	Phase-1 (2022-27)	Phase-2 (2031-36)	Total
		Price in Million BDT		
1	Distribution network	38.0	32.1	70.2
2	Underground Water Reservoir in Tourism Parks including pump units	203.2	88.9	201.8
3	Desalination plants	871.9	887.8	1,759.8
4	Bottling water plants	227.3	191.0	418.2
5	Treatment plant for lake water	200.0	-	200.0
6	Consultancy (6%)	80.4	72.0	147.0
	Total Project Cost (Current price)	**1,621**	**1,272**	**2,893**

Table 9.4: Tentative project cost for under Option-4

Item No.	Description	Phase-1 (2022-27)	Phase-2 (2031-36)	Total
		Price in Million BDT		
1	Production Tube wells	70.5	70.5	141.0
2	Distribution network	38.0	32.1	70.2
3	Transmission Main, booster pump station & related other structures	2,605.4	58.4	2,663.8
4	Underground Water Reservoir in Tourism Parks including pump units	203.2	88.9	292.1
5	Desalination plants	349.8	438.7	788.5
6	Bottling water plants	227.3	191.0	418.2

Item No.	Description	Phase-1 (2022-27)	Phase-2 (2031-36)	Total
		Price in Million BDT		
7	Treatment plant for lake water	200.0	-	200.0
8	Land Acquisition & development	10.0	-	10.0
9	Consultancy (6%)	209.7	52.8	262.4
	Total Project Cost (Current price)	**3,914**	**932**	**4,846**

Table 9.5: Tentative cost for roof top rainwater harvesting system in Sabrang Tourism Park

Item No.	Description	Phase-1 (2022-27)	Phase-2 (2031-36)	Total
		Price in Million BDT		
1	Roof Top RWH	1580.5	1446.0	3026.5
2	Consultancy (6%)	94.8	86.8	181.6
	Total Project Cost	**1,675**	**1,533**	**3,208**

Table 9.6: Tentative cost for roof top rainwater harvesting system in Naf Tourism Park

Item No.	Description	Phase-1 (2022-27)	Phase-2 (2031-36)	Total
		Price in Million BDT		
1	Roof Top RWH	515.4	507.2	1022.6
2	Consultancy (6%)	30.9	30.4	61.4
	Total Project Cost	**546**	**538**	**1,084**

9.2 Operation and Maintenance Cost Estimation

9.2.1 Operation and Maintenance Cost for PTW and Transmission Main

Operation and maintenance (O&M) cost of production tube wells including transmission main will vary for different phases due to continuous development of the whole system phase by phase. The O&M cost of production tube wells including transmission main for different phases are presented in **Table 9.7**.

Table 9.7: Summary of O&M cost of production tube wells including transmission main

Item No.	Description	Phase-1 (2022-27 & onward)	Phase-2 (2031-36 & onward)
		Cumulative Price in Million BDT	
1	Manpower cost	3.85	4.86
2	Chemicals (Chlorine)	0.10	0.20
3	Electricity Cost	4.75	5.22
4	Spare Parts	0.25	0.50
	Total Cost	**8.94**	**10.79**

Moreover, to carry the water to Naf Tourism Park about 5.5 Million BDT per year is required for each water carries tankers.

9.2.2 Operation and Maintenance Cost for Distribution System

Operation and maintenance (O&M) cost of the distribution system in Naf and Sabrang Tourism Park will be different in different phases due to step by step construction of distribution pipelines and reservoirs with pumping units. The O&M cost of the distribution system for different phases are presented in **Table 9.8**.

Table 9.8: Summary of O&M cost of distribution system

Item No.	Description	Phase-1 (2022-27 & onward)	Phase-2 (2031-36 & onward)
		Cumulative Price in Million BDT	
1	Manpower cost	5.64	6.61
2	Chemicals (Chlorine)	0.15	0.26
3	Electricity Cost	4.24	6.06
4	Spare Parts	0.20	0.30
	Total Cost	**10.23**	**13.23**

9.2.3 Operation and Maintenance Cost for Desalination Plant

Operation and maintenance (O&M) cost of the desalination plant for different phases and different options are given in **Table 9.9**.

Table 9.9: Summary of O&M cost of desalination plant

Tourism Park	Option	Phase-1 (2022-27 & onward)	Phase-2 (2031-36 & onward)
		Cumulative Price in Million BDT	
Sabrang	Option-1	33	32
	Option-2	24	26
	Option-3	45	48
	Option-4	17	24
Naf	Option-3 & Option-4	8	7

9.2.4 Cost of Metering system

The full distribution system needs to be connected by flow meter for accounting the amount of water used by. The flow meter needs to be installed at each building in Naf and Sabrang Tourism Park. The price of each meter is about Tk. 6,000/-. The specification of the meter is given below:

Manufacturer Standard:	:	• Manufacturer should have OHSAS-18001 Certificate or equivalent certificate. • Manufacturer should have CE (EC declaration of conformity and compliance with relative EC directives) or equivalent certificate
Type	:	Woltman
Nominal diameter	:	75mm
Length	:	225 mm

Height	:	279 mm
Outside diameter	:	200
Connecting flange	:	160
Maximum working temperature	:	60°C
Body	:	Electrostatic painted body made of corrosion resistant brass
Connecting bolts	:	8-M16
Normal flow rate	:	78.75 m^3/h
Over flow rate	:	63 m^3/h
Boundary flow rate	:	2 m^3/h
Min flow rate	:	1.26 m^3/h
Min reading	:	0.0005 m^3
Max reading	:	999,9999m^3

9.3 Cost Comparison

Long term cost comparison among Option-2, 3 & 4 have been conducted for selecting the best option. The analysis hereafter assumes the following parameters.

a. Installation period of the PTWs are 3years in each phase.
b. Construction period of the transmission main is 3 years.
c. Installation/construction period of each desalination plant is 3 years.
d. Construction period of each reservoir is mot more than 2 years.
e. Construction period of the lake and its treatment plant is 3 years.

Cost comparison is done for investment cost, operating cost and total cost for 50 years period as shown in **Figure 9.1**. It is observed that though investment cost for Option-3 is the lowest but O&M cost is the highest, but in long run Option-3 required the least budget considering both investment and O&M cost.

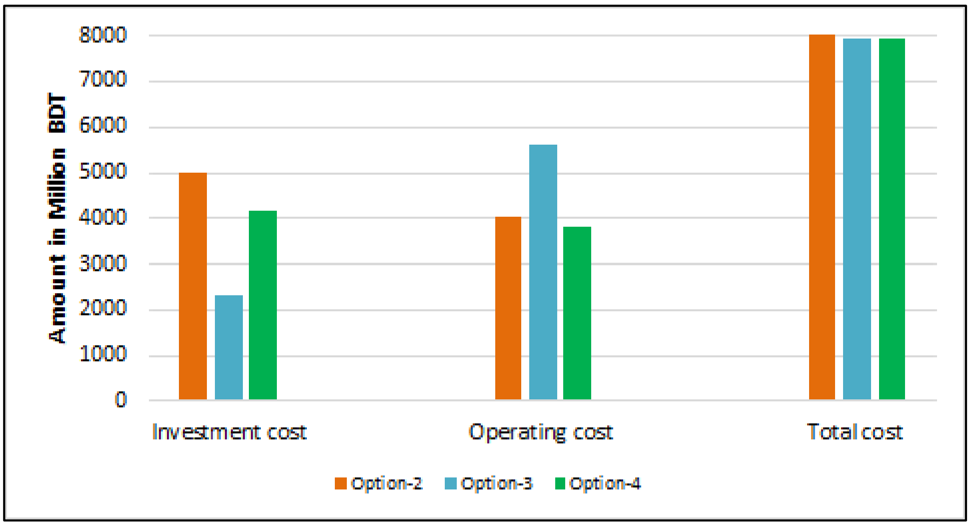


Figure 9.1: Cost Comparison for 50 years period

10 FINANCIAL AND ECONOMIC ANALYSIS

Naf and Sabrang Tourism Park to be established by BEZA for facilitate private investments and promote tourism sector in Bangladesh. Tourism as an economic development strategy will create opportunities for business growth in both Naf and Sabrang Tourism Park. To supply water in these tourism parks 4 nos. options have been analysis (Chapter 8) and cost has been estimated (Chapter 9). As water availability from dam in Teknaf as mentioned in Option-1 in uncertain financial and economic analysis has been done for Option-2, 3 & 4 for selecting the best option.

For financial and economic analysis, the estimated cost under the following items has been considered:

- Installation of production tube wells
- Water transmission main to carry groundwater including booster pump stations & related other structures
- Distribution network including underground water reservoirs inside Naf and Sabrang Tourism Park
- Desalination plant
- Rainwater harvesting in lake area in Sabrang
- Land Acquisition & land development

Considering the above items, the total cost of investment under these options are shown in **Table 10.1**.

Table 10.1: Initial Investments and O&M Costs under different Options

Items	Amount in Million BDT		
	Option-2	Option-3	Option-4
Initial Investment			
Phase 1	3,883.47	1,313.07	3,476.90
Phase 2	11,09.76	1,008.84	688.66
Total Investment	**4,993.23**	**2,321.91**	**4,165.57**
Annual O&M Costs	73.80	103.35	69.72

Clearly, the options are designed with a view to find the best options for developing Water Supply to make the two Tourism Parks sustainable.

10.1 Investment & Benefits for Economic and Financial Analysis

Water Supply development facilities in the two tourism park areas are part of a necessity to make the two tourism sites sustainable. Without a stable and sustainable supply of water the economic zone for tourism development will not a viable option. Considering these, we consider the following assumptions while designing the investment in water supply facilities for these two tourism parks:

a. It is part of the essential facilities for development of the tourism parks and so investment in this is not independent of the overall investment for tourism parks.

b. Fetching private investments in these sites will not be possible without a viable and sustainable water supply facilities.

c. Since the area is part of world class facilities designed to attract international tourists and generate foreign exchange for Bangladesh, its water supply infrastructure must also adhere to the global standards required for such facilities including waste disposal and economizing the use of water.

Given these, benefits include revenue earned for the supply of water to the tourism parks to facilitate financial and economic activities. For economic activities, contribution of water as an input in developing surplus for tourism activities – an indirect benefit from use of water for tourism is also considered.

10.1.1 Economic Estimation of Benefits

Direct and indirect benefits from supply of water to the tourism parks are obtained using the following diagrams shown in **Figure 10.1**. The following diagram shows that besides generating revenue for supply water to the two tourism parks, the amount of water used in tourism activities also contribute towards generating surplus for its users. Private investors who invest in these sites to facilitate tourism activities will have surplus from using water as their input for tourism services. Economically, this is estimated by the area under the demand (input demand) curve and above the price which they pay for inputs. This is shown by the trapezium shaped area in the **Figure 10.1**. The rectangle below the trapezium is the revenue which is accrued to suppliers of water. These are the Total Benefits of water used in the tourist area. Option 1 and 3 includes extraction of ground water from distance location and according to the international norms, local communities must be given access to such water as it is taken out of their ground water aquifer. Since such provisions are not planned, we have not included benefits to local communities as indirect benefits of the projects.

In terms of costs to the project; the investment cost includes a) construction costs; b) operation and maintenance costs; and c) mitigation costs to avoid any negative external impacts.

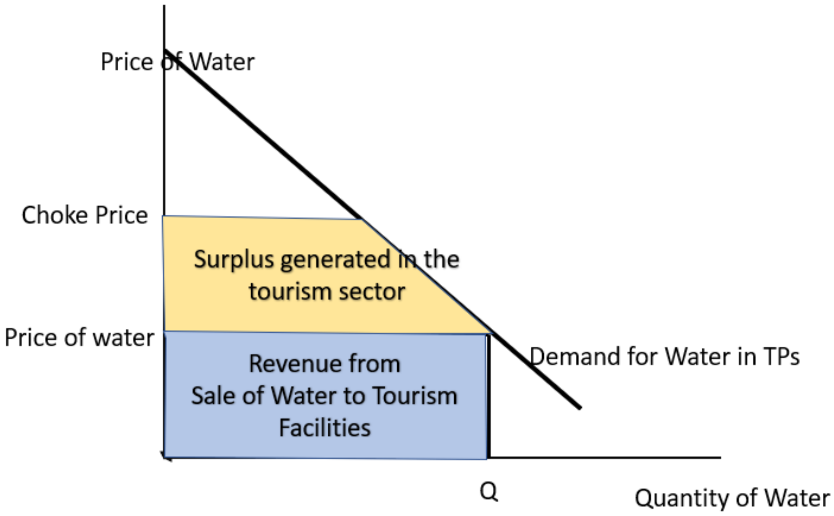


Figure 10.1: Understanding of the Benefits from Water Supply in Tourism Parks

To estimate the two shaded areas, we need the following information; a) the volume of water needed to ensure full servicing of the tourism facilities (Q in the diagram); b) price of water at which the investment will be financially viable (will be estimated); c) a choke price – which is a price at which private investors will refrain from investing in these TPs (simulated under several assumptions), and d) an estimate of the elasticity of water demand for tourism activities.

10.1.2 Assumptions

To estimate the financial benefits from investment in water supply to the tourism parks, we have used the following parameters presented in **Table 10.2**.

Table 10.2: Parameters used to estimate economic benefits and costs of the project

Parameters	Value	Assumptions or unit of measurement
Systematic increase in water prices	3%	per year
Cost increase for O&M inputs	3%	per year
Elasticity of Water Demand	-0.05	Curtis, John A., 2003 "Demand for Water-based Leisure Activity", *Journal of Environmental Planning and Management*, 46(1), 65–77, Taylor and Francis Publishing.
Choke price of water	3	times the market price

10.2 Summary of Financial and economic Analysis

Table 10.3 presents the summary of the financial and economic analysis for the project. The detail financial and economic analysis is given in **Annex-Q**

Table 10.3: Summary of Financial and economic Analysis

Items	Financial Analysis			Economic Analysis		
	Option-2	Option-3	Option-4	Option-2	Option-3	Option-4
	Million BDT			Million BDT		
Total Initial Investment	4,993.23	2,321.91	4,165.57	3,899.73	2,286.49	3,390.27
O&M Costs per year	73.80	103.04	69.85	58.48	81.65	55.35
Price of Water per cub meter	**182**	**81.8**	**162**	**93.2**	**57.6**	**88**
Present Value						
Benefits from selling water	34,725.08	15,607.21	30,909.14	17,782.29	10,989.92	16,790.15
Indirect benefits - contribution to Tourism sector				9,392.34	3,587.46	8,373.51
Costs of the project	34,652.14	15,590.03	30,819.62	27,154.37	14,526.60	24,820.36
NPV	**72.94**	**17.17**	**89.51**	**20.26**	**50.78**	**343.30**

Benefit Cost Ratio	1.00	1.00	1.00	1.00	1.00	1.01
IRR	12.02%	12.02%	12.03%	12.01%	12.05%	12.13%
Discount rate	12%	12%	12%	12%	12%	12%

The summary in **Table 10.3** shows that

1. While Investment Option-3 has the least initial costs (which is 2321.9 Million BDT) its average annual O&M is the highest (which is 103.04 Million BDT per year).
2. The analysis is done up to 2051 – the life of the project assumed.
3. At price 57.6 taka per cubic meter of water the project is economically feasible in case of Investment Option-3 but it is not financially viable. Investment Option-3 is financially viable at a water price of 81.8 taka per cubic meter.
4. Investment Option-2 is viable at a price of 182 Taka price per cubic meter (financially) while it is economically viable at a price of 93.2 taka per cubic meter of water.
5. Investment Option-4 is viable at a price of 162 Taka price per cubic meter (financially) while it is economically viable at a price of 88 taka per cubic meter of water.

10.3 Sensitivity of Financial and economic Analysis

We have used an excel simulation model to understand the impact on the financial and economic feasibility of the different investment options considering assumptions given in Table 10.2 and feasible water price of 81.8 Taka per cubic meter estimated under Option-3 to identify risk factors. These are shown in **Table 10.4** to **Table 10.6**. The sensitivity analysis is also done for current water price of DWASA (2021) which is 42 Taka per cubic meter for commercial usage. According to **Table 10.4** to **Table 10.6**, changes in the value of parameters makes all the investment options financially more feasible for the option-3.

Table 10.4: Sensitivity for BCR under Financial and economic Analysis Results

	Financial Analysis			**Economic Analysis**		
Price of Water	**Option 2**	**Option 3**	**Option 4**	**Option 2**	**Option 3**	**Option 4**
42	0.23	0.51	0.26	0.37	0.68	0.40
57.6	0.32	0.70	0.36	0.54	**1.00**	0.59
81.8	0.45	**1.00**	0.51	0.84	**1.57**	0.92
88	0.48	**1.08**	0.54	0.93	**1.73**	**1.01**
93.2	0.51	**1.14**	0.58	**1.00**	**1.87**	**1.09**
162	0.89	**1.98**	**1.00**	**2.18**	**4.08**	**2.39**
182	**1.00**	**2.23**	**1.13**	**2.60**	**4.86**	**2.84**
190	**1.05**	**2.33**	**1.18**	**2.77**	**5.18**	**3.03**
	Financial Analysis			**Economic Analysis**		
Annual rise in water price	**Option 2**	**Option 3**	**Option 4**	**Option 2**	**Option 3**	**Option 4**
3.0%	0.45	**1.00**	0.51	0.84	**1.57**	0.92
4.5%	0.56	**1.23**	0.62	**1.14**	**2.12**	**1.24**
6.5%	0.74	**1.65**	0.84	**1.80**	**3.36**	**1.97**
10.0%	**1.27**	**2.83**	**1.43**	**4.80**	**8.97**	**5.25**

	Financial Analysis			Economic Analysis		
Input price rise	Option 2	Option 3	Option 4	Option 2	Option 3	Option 4
3%	0.45	**1.00**	0.51	0.84	**1.57**	0.92
4.5%	0.45	1.00	0.51	0.84	**1.57**	0.92
6.5%	0.45	0.99	0.50	0.84	**1.56**	0.92
10.0%	0.45	0.98	0.50	0.84	**1.55**	0.91
	Financial Analysis			Economic Analysis		
Elasticity of water demand	Option 2	Option 3	Option 4	Option 2	Option 3	Option 4
-0.05	0.45	**1.00**	0.51	0.84	**1.57**	0.92
-0.08	0.45	**1.00**	0.51	0.84	**1.57**	0.92
-0.1	0.45	**1.00**	0.51	0.84	**1.57**	0.92
-0.2	0.45	**1.00**	0.51	0.84	**1.57**	0.92
-0.4	0.45	**1.00**	0.51	0.84	**1.57**	0.92
-0.5	0.45	**1.00**	0.51	0.84	**1.57**	0.92

Table 10.5: Sensitivity for VPV under Financial and economic Analysis Results

	Financial Analysis			Economic Analysis		
Price of Water	Option 2	Option 3	Option 4	Option 2	Option 3	Option 4
42	(26,639)	(7,577)	(22,806)	(17,234)	(4,606)	(14,899)
57.6	(23,662)	(4,600)	(19,830)	(12,577)	**51**	(10,243)
81.8	(19,045)	**17**	(15,212)	(4,312)	**8,316**	(1,978)
88	(17,862)	**1,200**	(14,029)	(1,991)	**10,637**	**343**
93.2	(16,870)	**2,192**	(13,037)	**20**	**12,648**	**2,354**
162	(3,743)	**15,319**	**90**	**32,132**	**44,760**	**34,466**
182	**73**	**19,135**	**3,905**	**43,387**	**56,015**	**45,721**
190	**1,599**	**20,661**	**5,432**	**48,132**	**60,759**	**50,466**
	Financial Analysis			Economic Analysis		
Annual rise in water price	Option 2	Option 3	Option 4	Option 2	Option 3	Option 4
3.0%	(19,045)	**17**	(15,212)	(4,312)	**8,316**	(1,978)
4.5%	(15,404)	**3,658**	(11,571)	**3,711**	**16,339**	**6,045**
6.5%	(8,903)	**10,159**	(5,071)	**21,635**	**34,262**	**23,969**
10.0%	**9,477**	**28,539**	**13,309**	**103,135**	**115,762**	**105,469**
	Financial Analysis			Economic Analysis		
Input price rise	Option 2	Option 3	Option 4	Option 2	Option 3	Option 4
3.0%	(19,045)	**17**	(15,212)	**(4,312)**	**8,316**	**(1,978)**
4.5%	(19,088)	**(43)**	(15,253)	**(4,346)**	**8,268**	**(2,010)**
6.5%	(19,146)	**(123)**	(15,308)	**(4,392)**	**8,205**	**(2,054)**
10.0%	(19,246)	**(262)**	(15,404)	**(4,472)**	**8,094**	**(2,129)**
	Financial Analysis			Economic Analysis		

Elasticity of water demand	Option 2	Option 3	Option 4	Option 2	Option 3	Option 4
-0.05	(19,045)	**17**	(15,212)	(4,312)	**8,316**	(1,978)
-0.08	(19,045)	**17**	(15,212)	(4,312)	**8,316**	(1,978)
-0.1	(19,045)	**17**	(15,212)	(4,312)	**8,316**	(1,978)
-0.2	(19,045)	**17**	(15,212)	(4,312)	**8,316**	(1,978)
-0.4	(19,045)	**17**	(15,212)	(4,312)	**8,316**	(1,978)
-0.5	(19,045)	**17**	(15,212)	(4,312)	**8,316**	(1,978)

Table 10.6: Sensitivity for IRR under Financial and economic Analysis Results

	Financial Analysis			Economic Analysis		
Price of Water	**Option 2**	**Option 3**	**Option 4**	**Option 2**	**Option 3**	**Option 4**
42	-1%	3%	0%	3%	7%	4%
57.6	2%	7%	3%	6%	**12%**	7%
81.8	5%	**12%**	6%	10%	**19%**	11%
88	5%	**13%**	6%	11%	**20%**	**12%**
93.2	6%	**14%**	7%	**12%**	**21%**	**13%**
162	11%	**24%**	**12%**	**21%**	**38%**	**22%**
182	**12%**	**26%**	**13%**	**23%**	**43%**	**24%**
190	**12%**	**27%**	**14%**	**24%**	**45%**	**25%**
	Financial Analysis			**Economic Analysis**		
Annual rise in water price	**Option 2**	**Option 3**	**Option 4**	**Option 2**	**Option 3**	**Option 4**
3%	5%	**12%**	6%	10%	**19%**	11%
5%	7%	**15%**	8%	**13%**	**22%**	**14%**
7%	9%	**19%**	10%	**17%**	**27%**	**18%**
10%	**14%**	**25%**	**15%**	**24%**	**36%**	**25%**
	Financial Analysis			**Economic Analysis**		
Input price rise	**Option 2**	**Option 3**	**Option 4**	**Option 2**	**Option 3**	**Option 4**
3%	5%	**12%**	6%	10%	**19%**	11%
5%	5%	12%	6%	10%	**19%**	11%
7%	5%	12%	6%	10%	**19%**	11%
10%	5%	12%	6%	10%	**18%**	11%
	Financial Analysis			**Economic Analysis**		
Elasticity of water demand	**Option 2**	**Option 3**	**Option 4**	**Option 2**	**Option 3**	**Option 4**
-0.05	5%	**12%**	6%	10%	**19%**	11%
-0.08	5%	**12%**	6%	10%	**19%**	11%
-0.10	5%	**12%**	6%	10%	**19%**	11%
-0.20	5%	**12%**	6%	10%	**19%**	11%
-0.40	5%	**12%**	6%	10%	**19%**	11%
-0.50	5%	**12%**	6%	10%	**19%**	11%

10.4 Recommendations

Based on the analysis presented above we conclude the following.

1. Investment Option-3 that includes desalinization plants and rainwater harvest is the most viable option for supplying water in the two EZs for developing tourism parks.
2. Price of water shall be fixed at 81.8 taka per cubic meter in order to make this financially viable and it shall rise at a rate of 3% annually to cover a similar rising in the costs of operations and maintenance.
3. We have tested the sensitivity of the assumptions used in the calculation of NPV, BCR and IRR and it shows that for investment Option-3, the BCR remains 1 or above – implying the investment remains economic viable.
4. For Investment Option-2 to be viable economically and financially, price of water shall be set at 182 taka per cubic meter.
5. For Investment Option-4 to be viable economically and financially, price of water shall be set at 162 taka per cubic meter.
6. Finally, in case of ground water extraction, the investment Option-2 and Option-4 shall be modified to allow for local supply of water since it is extracted from another location and there are local inhabitants who will be deprived of precious water resources.
7. Considering all of these options, we recommend selection Investment Option-3 the supply of water to Sabrang and Naf Tourism Parks and the initial price of water shall be set at 82 taka per cubic meter which is about a dollar per cubic meter of water. This will ensure that there is no subsidy required for supplying water into the tourism facilities.
8. Furthermore, investment Option-3 is the least risk in terms of the changing financial and economic conditions as it has been shown in **Table 10.4**.

11 TRAINING AND CAPACITY BUILDING

A training program to transfer the knowledge and capacity building of the BEZA officials has been conducted from 02-05 October 2021 at Hotel The Cox Today, Cox's Bazar. Mr. Shaikh Yusuf Harun, Executive Chairman, BEZA was the Chief Guest and Paban Chowdhury, Former Executive Chairman, BEZA was the Special Guest of the training and capacity building program. The list of other participants from BEZA is given in **Table 11.1** and the training schedule in given in **Table 11.2**. Some taken during the program is presented in **Figure 11.1**.

Table 11.1: List of participants from BEZA in the training and capacity building program

Sl. No.	Names of the Officials	Designation
1.	Mohammed Erfan Sharif	Executive Member (Planning & Development) (Additional Secretary)
2.	Md. Moniruzzaman	General Manager (Investment Promotion) (Joint Secretary)
3.	Mohammad Hasan Arif	General Manager (Administration & Finance) (Joint Secretary)
4.	Doyananda Debnath	General Manager (Planning & Development) (Joint Secretary)
5.	Md. Khurshid Alam Patwary	Manager (Administration) (Deputy Secretary)
6.	Md. Helal Ahmed	Manager (Planning & Development-5) (Deputy Secretary)
7.	Abu Hena Md. Mustafa Kamal	Manager (Investment Promotion-1) (Deputy Secretary)
8.	Md. Mahbubur Rahman	Manager (Planning & Development-1) (Deputy Secretary)
9.	Mohammad Rezaul Houque	Manager (Finance & Budget) (Deputy Secretary)
10.	Mustafizur Rahman	Manager (OSS & Co-ordination) (Deputy Secretary)
11.	Md. Nazmul Alam	Manager (Planning & Development-4)
12.	Md. Ahsan Ullah	Manager (Investment Promotion)
13.	Md. Abdus Salam Chowdhury	PS to Executive Chairman (Senior Assistant Secretary)
14.	Farjana Alam	Deputy Manager (Planning & Development) (Senior Assistant Secretary)
15.	Mirza Abuzar Shuvo	Assistant Manager (Sabrang Tourism Park)
16.	Nasir Chowdhury	Infrastructure Consultant
17.	Shenjuti Barua (as Coordinator)	Deputy Manager

18.	Md. Abdul Quader Khan (as Coordinator)	Social Development Consultant

Table 11.2: List of participants from BEZA in the training and capacity building program

Day	Time	Details	Resource person
02/10/2021 Saturday	8:00	Travel from Dhaka to Cox's Bazar	
	10:00-17:00	Field Visit along the proposed transmission main & Sabrang Tourism Park	Guided by Rafiqul Islam, Hydrogeologist, IWM
03/10/2021 Sunday	9:00-9:30	Inauguration session	*Chief Guest:* *Shaikh Yusuf Harun, Executive Chairman, BEZA*
	9:30-10:30	Presentation & Discussion on Final Report	Ismat Ara Pervin, Senior Specialist, IWM
	10:30 - 11:30	Guidelines during construction of production tubewell	Murshed Alam/ Rafiqul Islam, Hydrogeologist, IWM
	11:30 -11:50	Break	
	11:50 - 12:50	Guidelines for development and completion of production tubewell	Murshed Alam/ Rafiqul Islam, Hydrogeologist, IWM
	15:50 - 2:00	Lunch Break	
	2:00-3:00	Guidelines for installation of transmission main & distribution system	Md. Serajuddin, Sr. Water Supply & Sanitation Specialist, IWM
	3:00-4:00	Guidelines for operation and maintenance of transmission main & distribution system	Md. Serajuddin , Sr. Water Supply & Sanitation Specialist, IWM
	4:00 - 5:00	Operation and maintenance of production tubewell	Murshed Alam/ Rafiqul Islam, Hydrogeologist, IWM
04/10/2021 Monday	9:00-10:30	Plant and design built contract for international procurement methods	Harunur Rashid, Procurement Specialist
	10:30-10:50	Break	
	10:50-11:50	Continue previous session	Harunur Rashid, Procurement Specialist
	11:50-01:00	Bottling water plant: Its future for industrial/tourism hub in Bangladesh	Tajuddin Ahmed, CEO Optimus Technology Limited
	01:00- 02:30	Lunch Break	
	02:30-04:00	Desalination plant: Its challenges and procurement method	David Khan, Senior Water Management Specialist, Esolve International Limited
	04:00-05:00	Closing Session	*Special Guest:* *Paban Chowdhury, (Former Executive Chairman, BEZA)* *Chief Advisor, City Group*

Day	Time	Details	Resource person
05/10/2021 Tuesday	09:00-15:00	Field Visit	
	17:00	Return to Dhaka	

Figure 11.1: Some snaps taken during the training & capacity building program

12 FINDINGS AND RECOMMENDATIONS

12.1 Findings

12.1.1 Common findings

- Groundwater assessment in Whykhong well field has been conducted with the following findings:
    - About 6.2 MLD groundwater may be extracted from the Whykhong well field by constructing 8 nos. production tube wells.
    - Total about 42.3 km transmission main of ductile iron (DI) pipe material 400 mm is required to carry groundwater from Whykhong well field to Sabrang Tourism Park.
    - Two booster pumps would be required along the transmission main to guarantee water pressure to the desired level for uninterrupted supply.
    - Collection pipe 1 & 2 is required to carry water from the 8 nos. PTWs to booster pump station at Whykhong (BPS-1). The total length of collection pipe is 8 km and HDPE pipe would be used with diameter 200 to 315 mm.
    - As the water transmission from groundwater sources is too much high so groundwater use is not preferable for water supply in the Tourism Parks.
- To meet the drinking water requirement bottle water industry can be developed in Sabrang Tourism Park.
- Four different options has been analysis for water supply in Naf and Sabrang Tourism Park. After SWOT analysis and economic & financial analysis, option-3 has became the most viable option.
- Tentative total project cost to meet the water requirement in Sabrang and Naf Tourism Park is about 2,893 (Option-3) Million BDT which will be required in two phase upto full development in 2036. In Phase-1 1,621 Million BDT and in Phase-2 1,272 Million BDT is required.
- The summary of budget and demand allocation development plan is presented below:

Table 12.1: Summary of budget and demand allocation plan

Phase	Period	Budget (Million BDT)	Source of water	
			Sabrang	Naf
Phase-1	2022-27	1,621	• Rainwater harvesting in the roof top of buildings • Rainwater harvesting in lake area • Desalination plant	• Rainwater harvesting in the roof top of buildings • Desalination plant
Phase-2	2027-36	1,272		
Total		**2,893**		

- The O&M cost of the distribution system is about 10.23 Million BDT per year in Phase-1 and 13.23 Million BDT per year in Phase-2.

- The initial price of water under Option-3 shall be set at 82 taka per cubic meter which is about a dollar per cubic meter of water. This will ensure that there is no subsidy required for supplying water into the tourism facilities.
- Investment Option-3 is the least risk in terms of the changing financial and economic conditions.

12.1.2 Findings for Sabrang Tourism Park

- Under Option-3, roof top rainwater harvesting, desalination plant and water reserve in the lake are considered for fulfilling water demand in Sabrang Tourism Park.
- From roof top rainwater harvesting about 0.73 MLD can be made available for Sabrang Tourism Park and recommended for water supply.
- From the proposed lake of 50acre area about 2.0 MLD water can be available throughout the year.
- Desalination RO plant of capacity 4.5 MLD and 5.1 MLD is required in phase 1 & 2 for the preferable option (Option-3) respectively to fulfill the total water requirement in Sabrang Tourism Park.
- The length of distribution network is 12.11 km and diameter varies from 75 to 355mm.
- Three reservoirs with pump units are proposed for Sabrang Tourism Park to store water of different phases for 2 days.
- The tentative cost of roof top rain water harvesting system is 3,208 Million BDT which would be carried out by land leaser/developer.
- The O&M cost of the desalination plants for the preferable option (Option-3) is about 45 Million BDT in Phase-1 and 48 Million BDT in Phase-2

12.1.3 Findings for Naf Tourism Park

- Under Option-3, roof top rainwater harvesting and desalination plant are considered for fulfilling water demand in Naf Tourism Park.
- From roof top rainwater harvesting about 0.22 MLD can be made available for Naf Tourism Park.
- Two desalination RO plant of capacity 0.6 MLD and 0.55 MLD is required in phase 1 & 2 to fulfill the total water requirement in Naf Tourism Park.
- The length of distribution network is 10.1 km and diameter varies from 75 to 160mm.
- Three reservoirs with pump units are proposed for Sabrang Tourism Park to store water of different phases for 2 days.
- The O&M cost of the desalination plants for the preferable option (Option-3) is about 8 Million BDT in Phase-1 and 7 Million BDT in Phase-2.

12.2 Recommendations

12.2.1 Recommendations for Sabrang Tourism Park

- The provision of roof top rainwater harvesting shall be kept in each building area of roof area >300m^2 from the very beginning. Otherwise, extra costing will be needed for re-designing of the plumbing system.

- The availability of water from the dam-reservoir in Teknaf is uncertain due to high water requirement of Teknaf city. So, this option can be considered as supplementary only.
- Metering system shall be installed with the water supply pipeline at every building. In that case, BEZA should establish and follow the rules & regulations prepared and approved by the Government of Bangladesh best on WASA Act 1996.

12.2.2 Recommendations for Naf Tourism Park

- The provision of roof top rainwater harvesting shall be kept in each building area of roof area >300m^2 from the very beginning. Otherwise, extra costing will be needed for re-designing of the plumbing system.
- Metering system shall be installed with the water supply pipeline at every building. In that case, BEZA should establish and follow the rules & regulations prepared and approved by the Government of Bangladesh best on WASA Act 1996.

12.2.3 Recommendations for both Sabrang and Naf Tourism Park

- Water transmission from Whykhog well field is very costly due to long distance water travel. So, water supply from groundwater sources is not preferable. If water need to abstract from groundwater the following recommendation are made
  - Monitoring of water level is required to ascertain its decline at different phase of development. Monitoring of water quality is also required to ascertain any risk of salinity intrusion with development.
  - Recharge and safe limit of abstraction is required to be updated reviewing the monitoring as mentioned above.
  - Development of production tube wells in phases need to be reviewed based on the groundwater level and quality monitoring data.
  - If the shallow tube wells in the surrounding influenced area of PTW's cannot uplift water due to water table drawdown, BEZA need to construct a new PTW for domestic usage to avoid conflict. The supply system of this PTW should be operated and maintained through local administration or under respective authority.
- Power supply for underground reservoirs and BPS-2 need to be ensure during designing power supply of the Tourism Parks.
- Desalination plant is a new technology for Bangladesh, so after construction/implementation of desalination plant, its operation should be done for at least three years by the installation company. In the meanwhile, BEZA have to develop its own O&M mechanism.
- Detail field survey long the proposed distribution pipeline and design of the distribution system is required before implementation.
- A conventional treatment plant is required for using the water from the proposed lake. After constructing the reservoir, the water quality of the lake has to be measured for designing the process diagram of the treatment plant and detail design.

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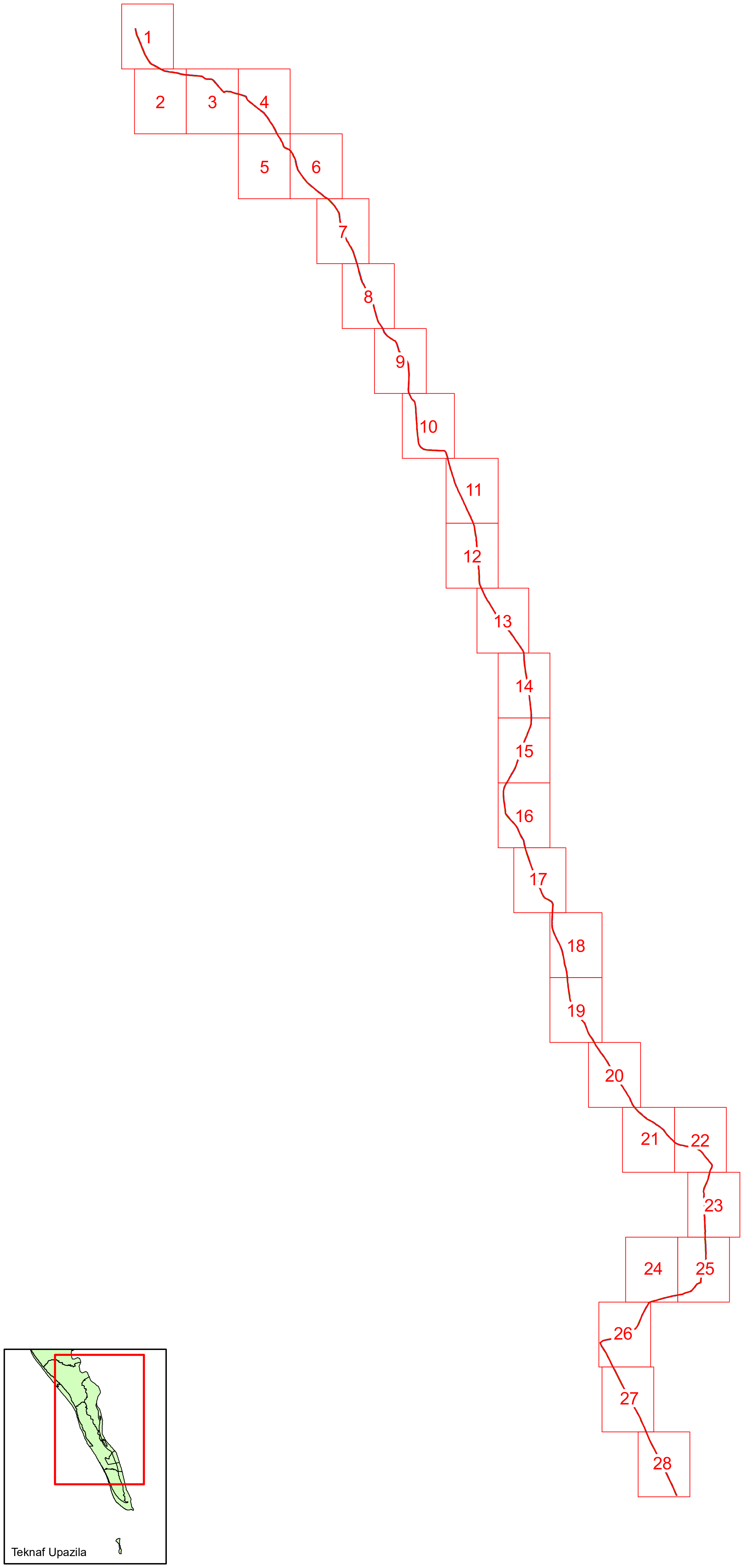
APPENDIX

Appendix A: Engineering Survey Data



Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

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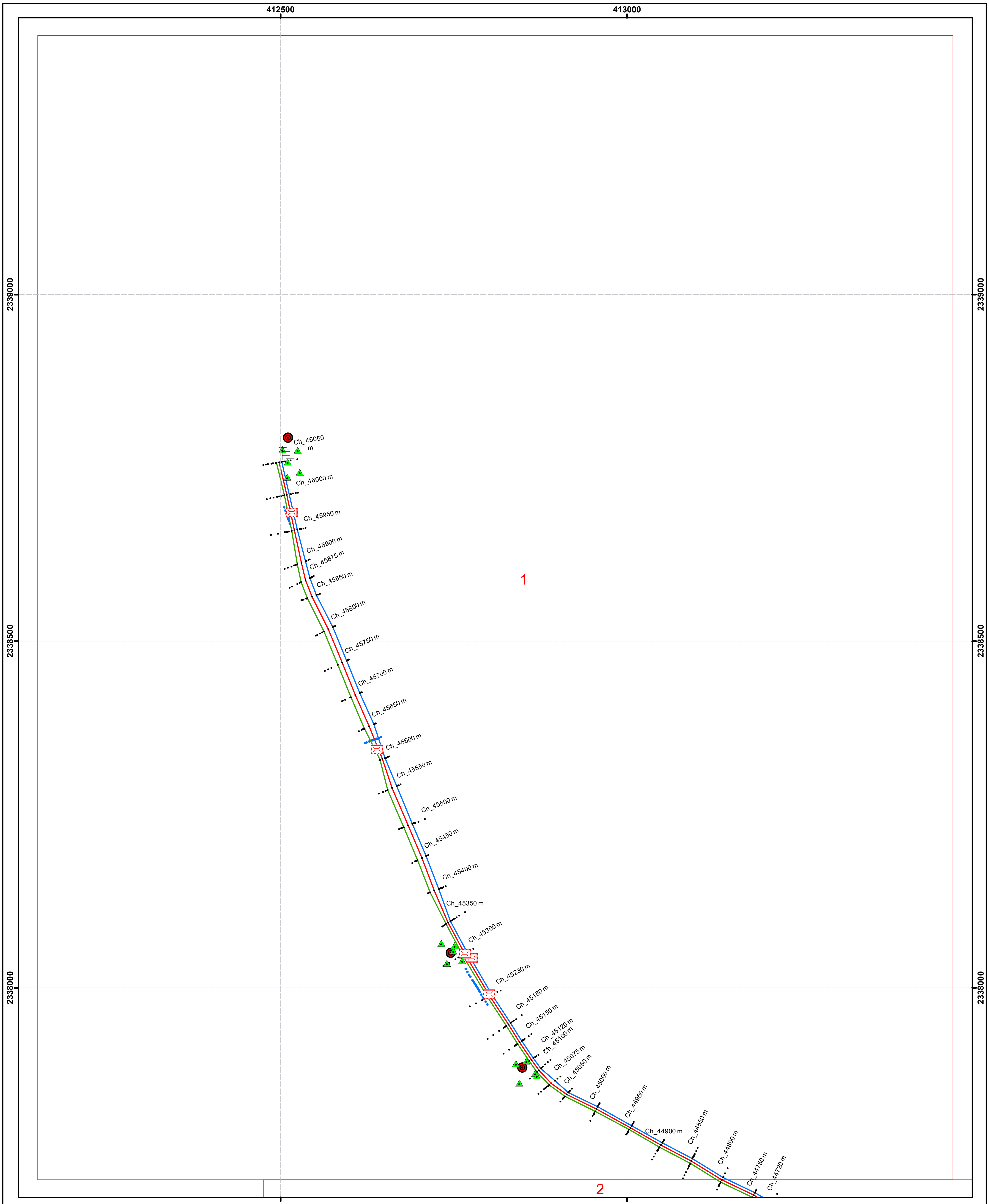
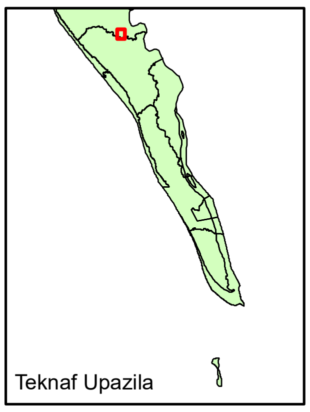
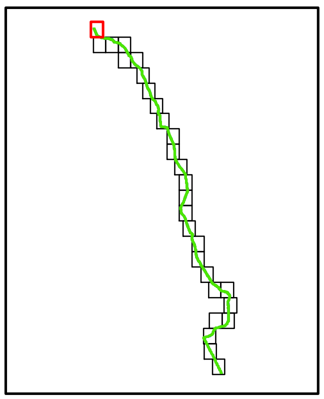


Legend

- 🟥 Union HQ
- ◎ Proposed PTW
- ⊠ Bridge/Culvert
- · Khal Section
- · Road Section
- ▬ Waterbody
- ▬ International Boundary
- ▬ Road Centerline
- ▬ Road Left Edge
- ▬ Road Right Edge
- ▭ Sabrang Tourism Park
- ▭ Naf Tourism Park
- ⁝ Boundary Wall
- ┼ Electric Pole
- ⬟ Graveyeard
- ⊕ Road Intersection
- ● Light Post
- ◎ Manhole
- ★ Mosque
- ⌂ House/Office
- ⌂ Shop
- ☎ Telephone Pole
- ♣ Tree
- ▲ Tubewell





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Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

0 25 50 100 150 200 250
Meters

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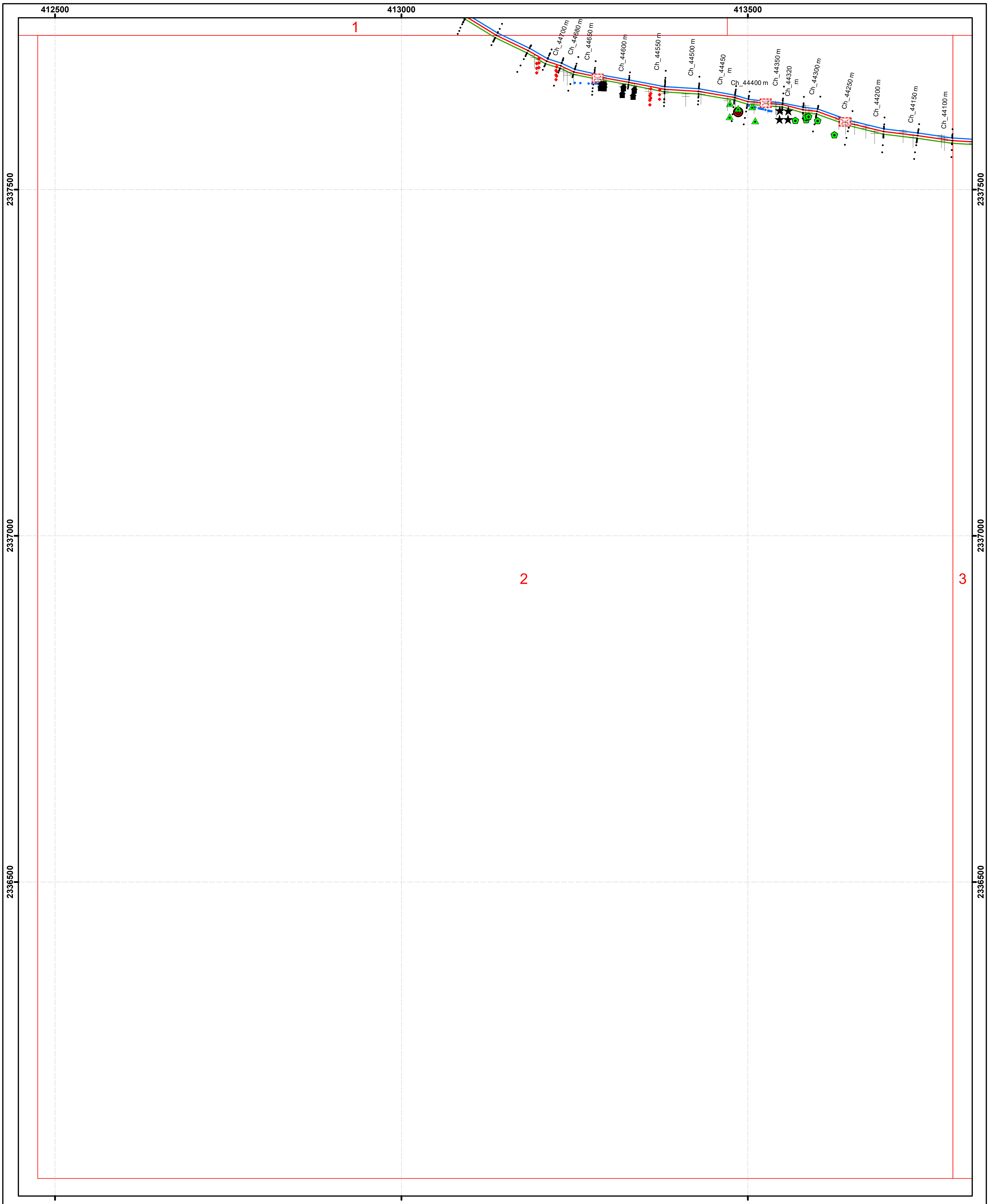

Legend

Union HQ
Proposed PTW
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Road Right Edge
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Naf Tourism Park

Boundary Wall
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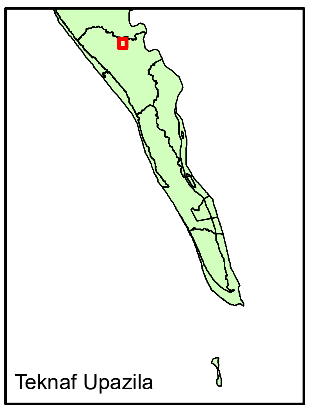

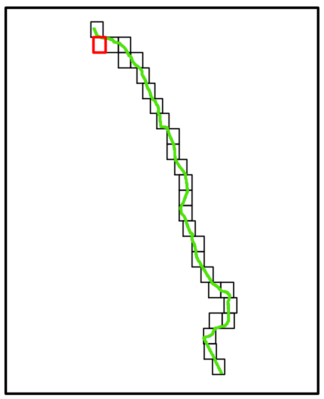

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Sabrang and Naf Tourism Park Water Assessment

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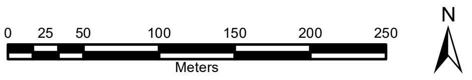

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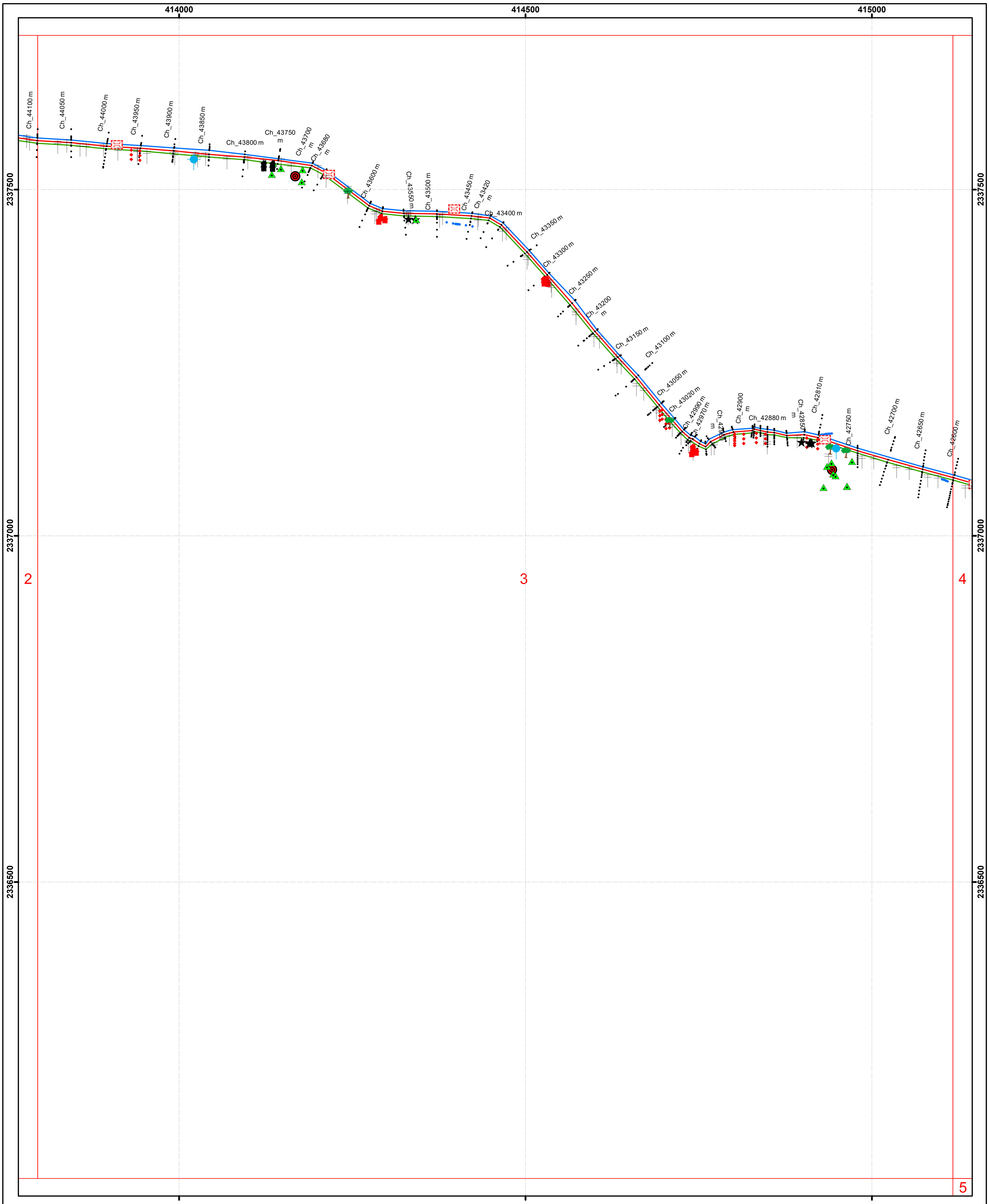

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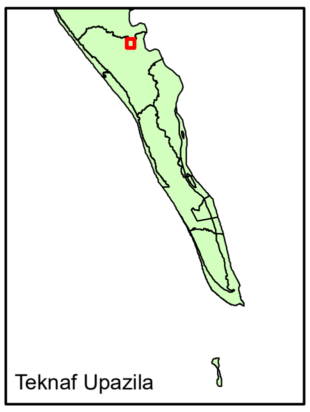

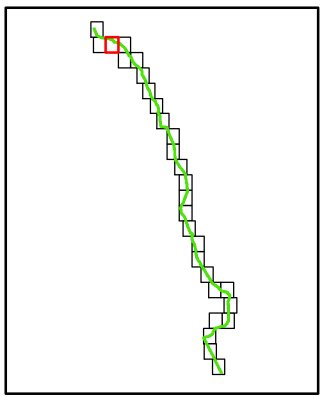

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Sabrang and Naf Tourism Park Water Assessment

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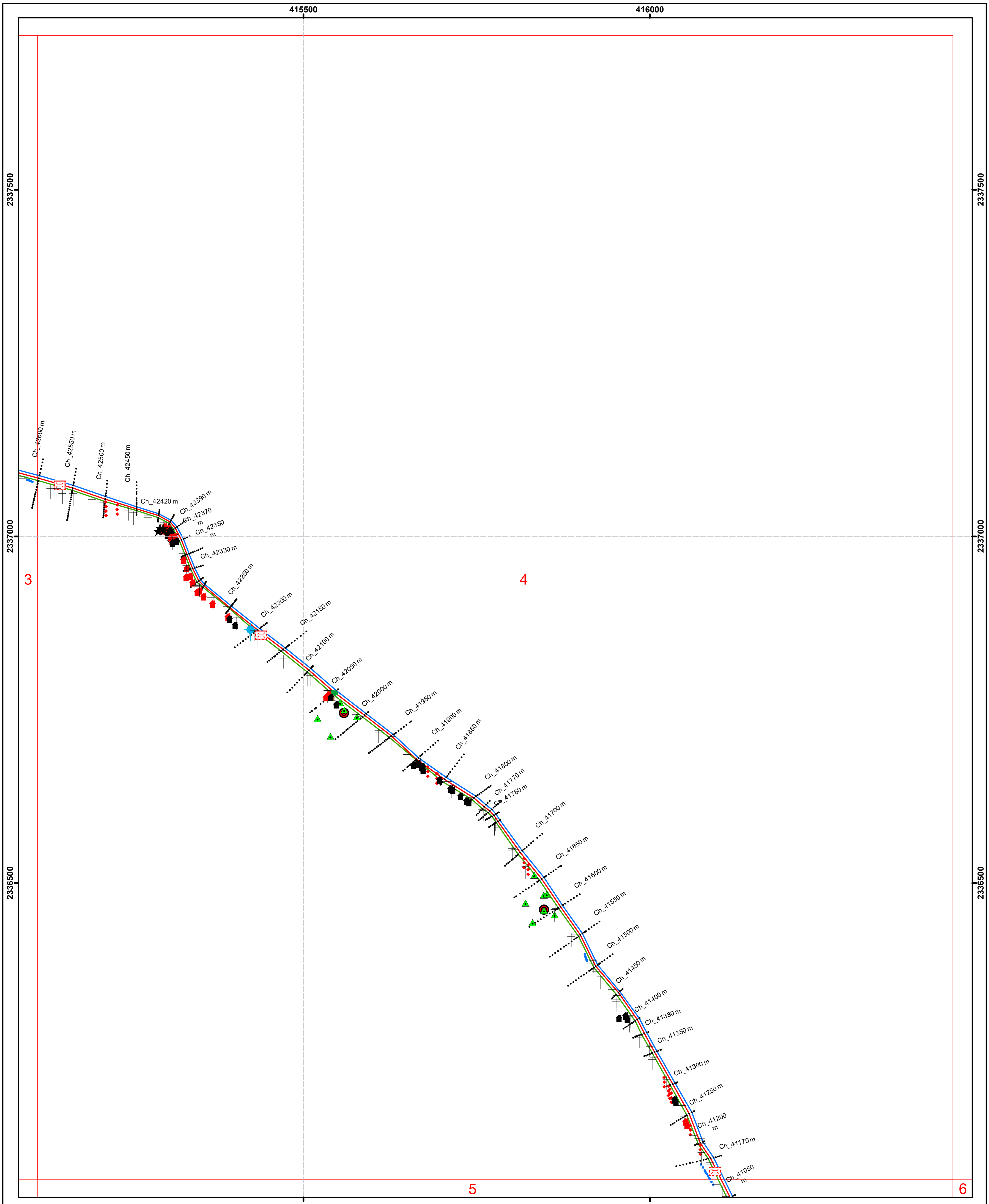

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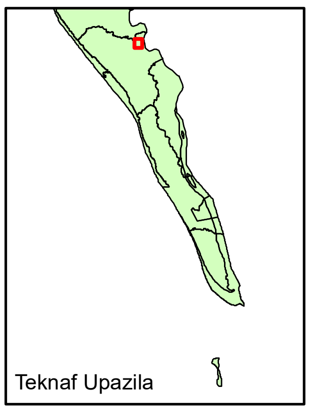

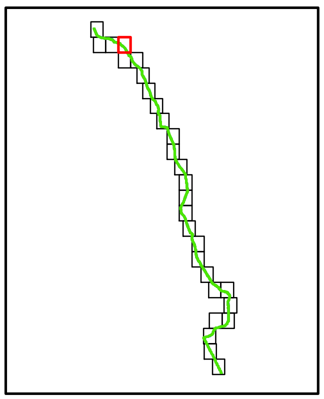

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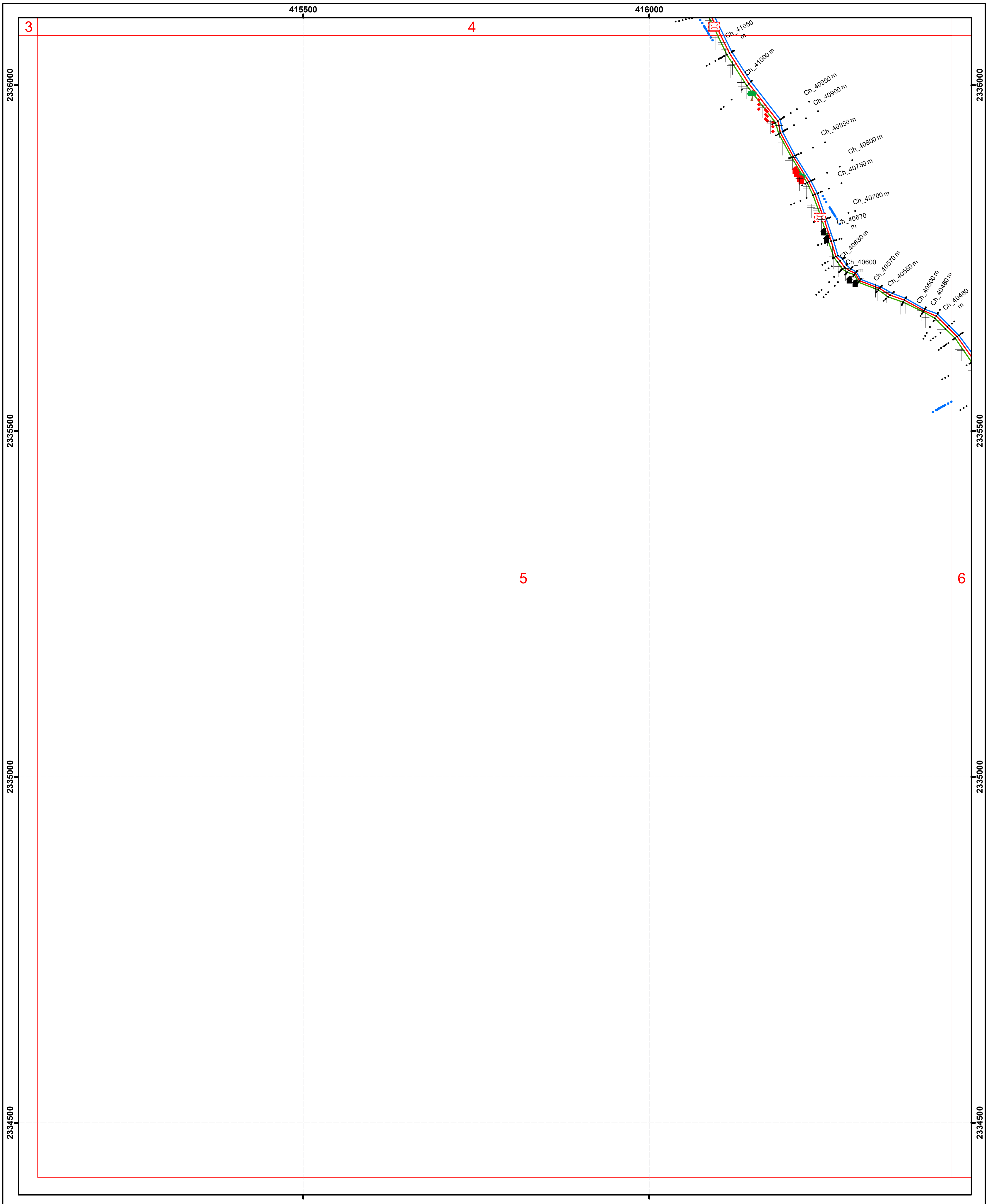

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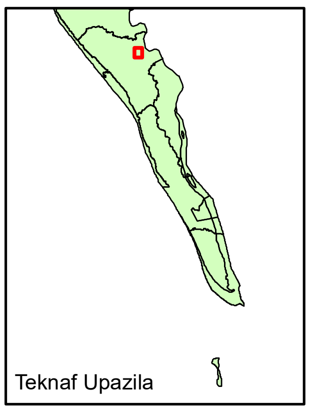

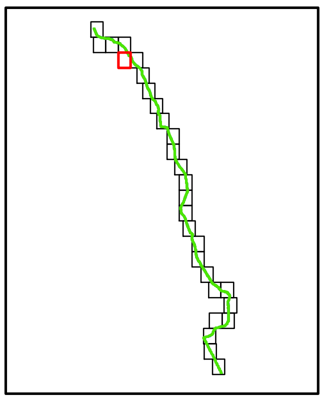

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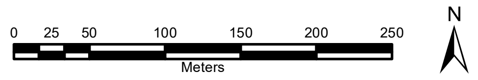
Scale: 1:5000



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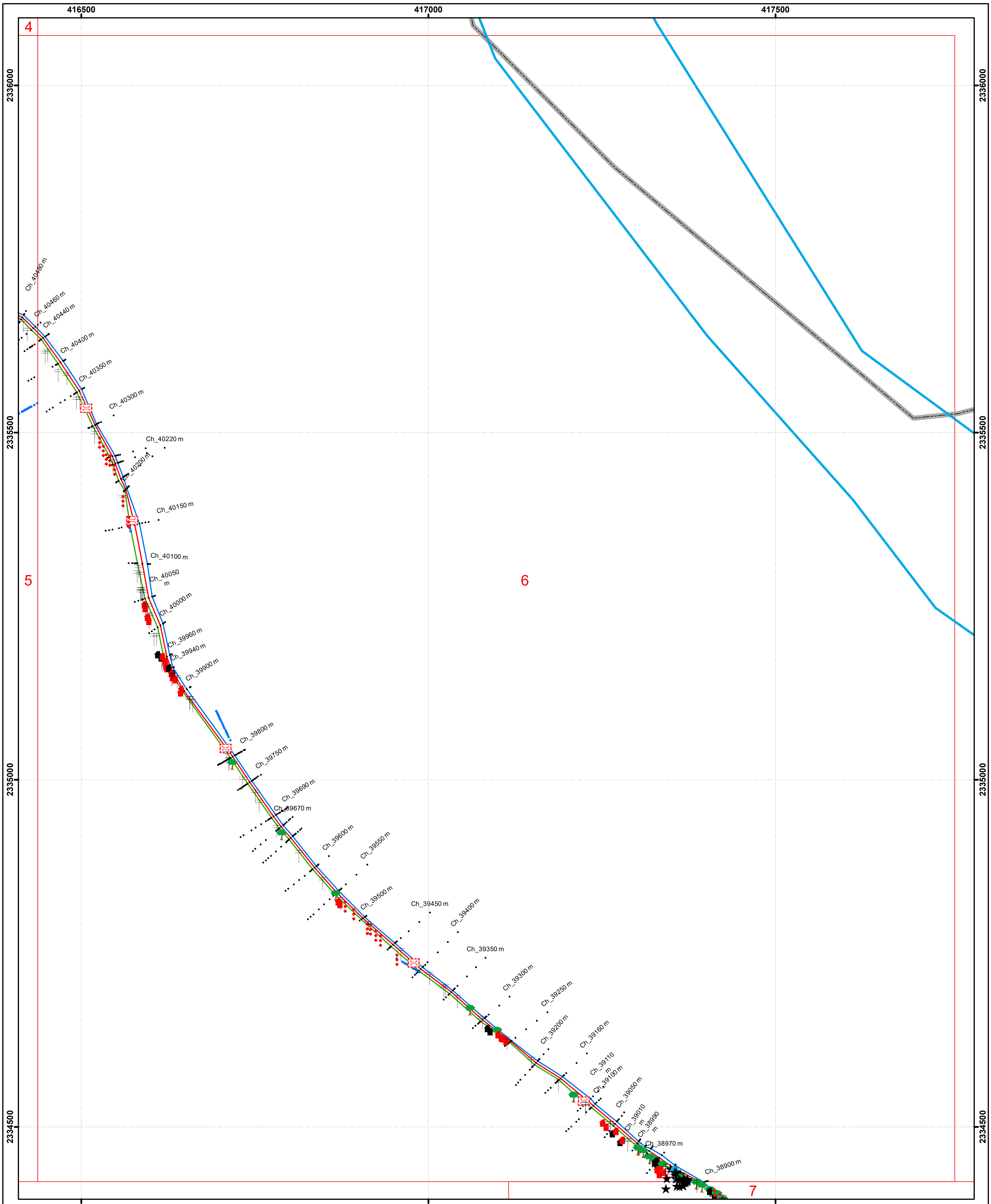

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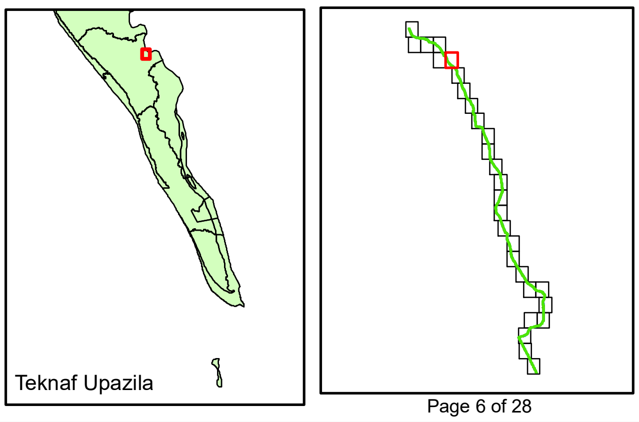

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Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
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Scale: 1:5000

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Meters

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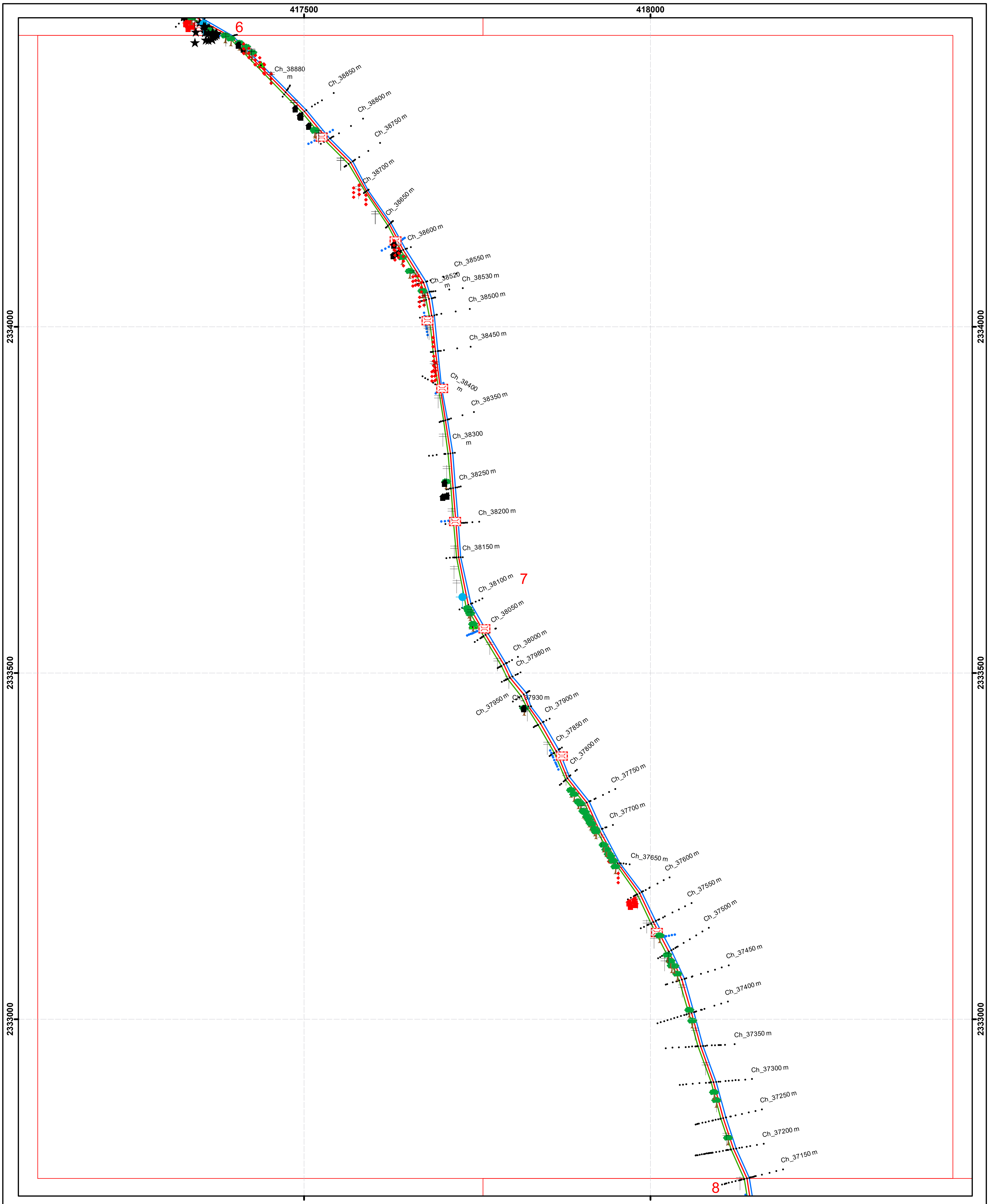

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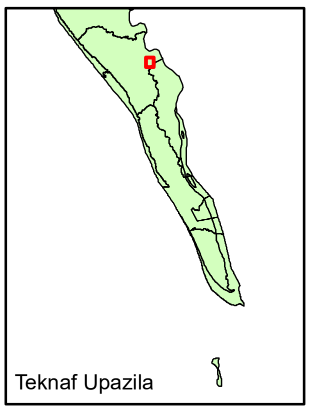
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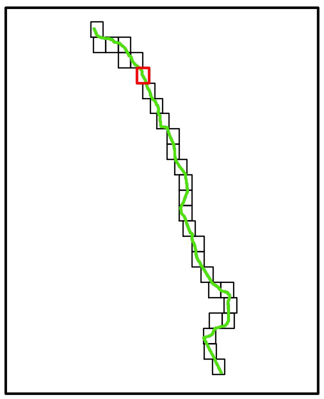
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Sabrang and Naf Tourism Park Water Assessment

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Data Source: Field Survey, IWM
Scale: 1:5000

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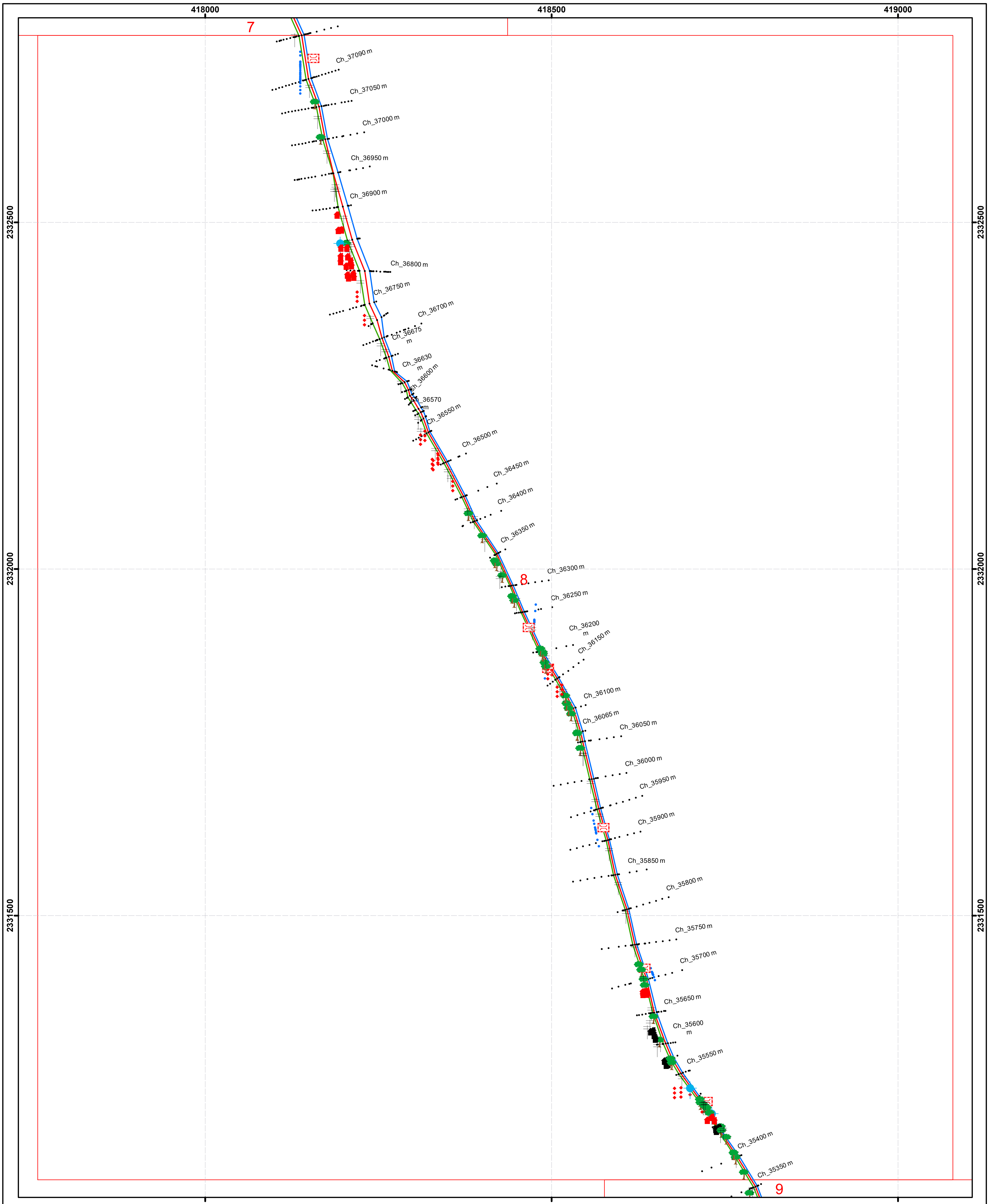

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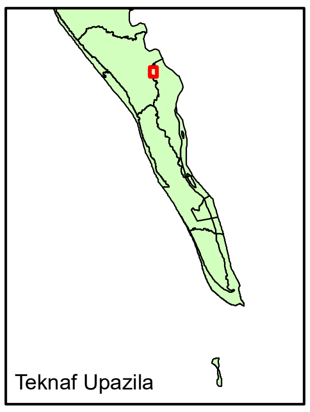
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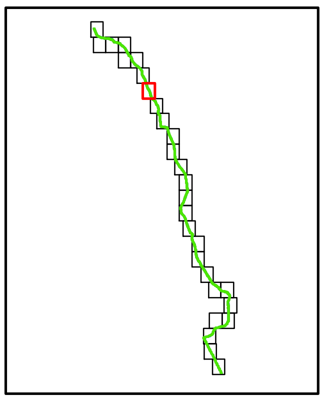
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Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
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Scale: 1:5000

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Meters

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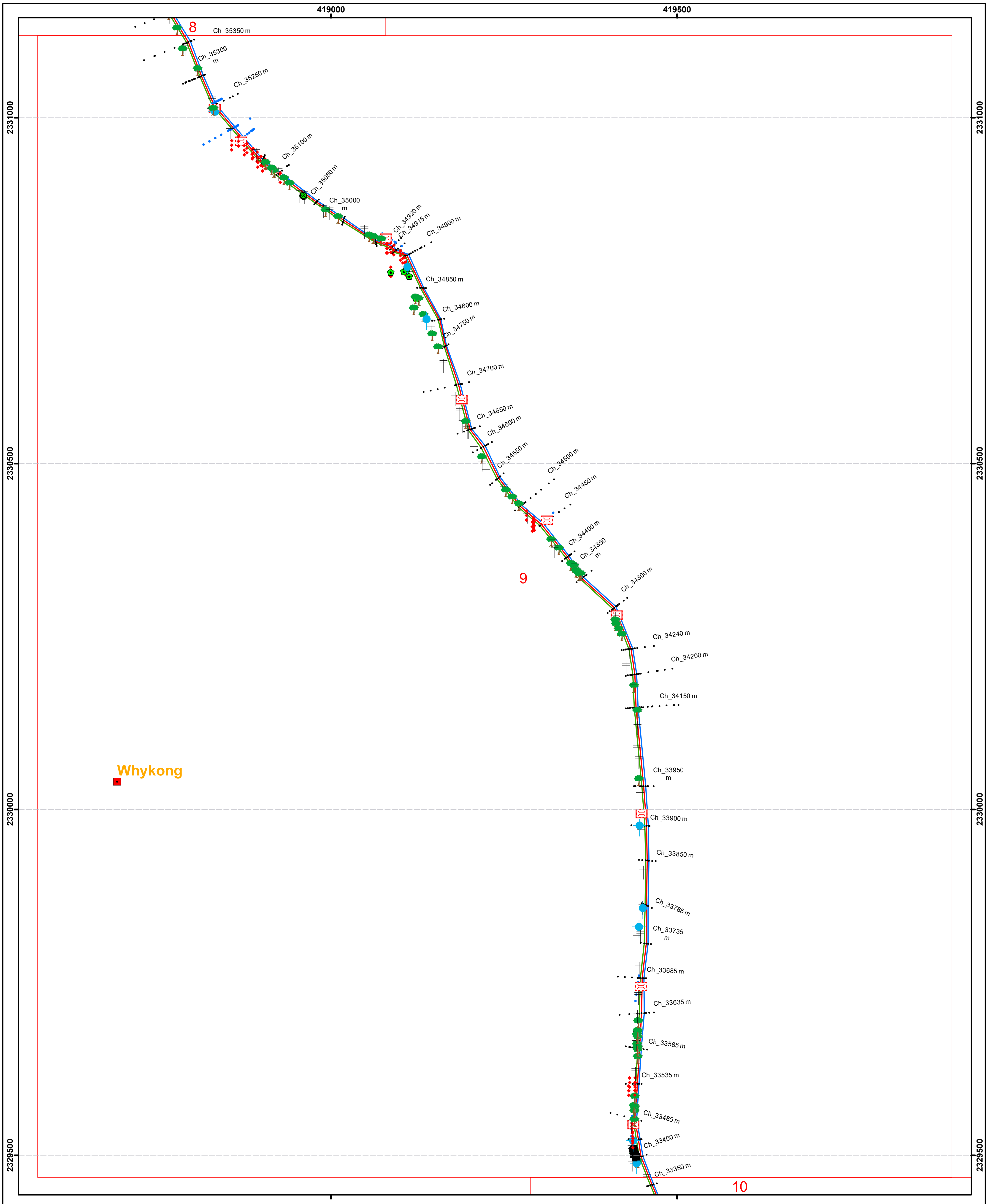

Legend

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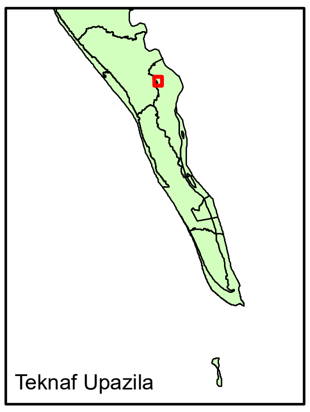

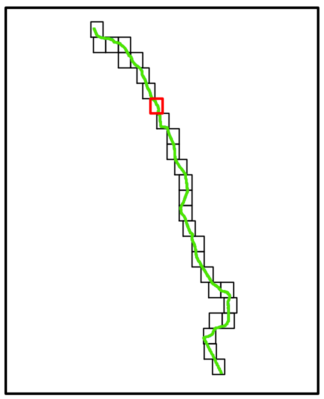

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Sabrang and Naf Tourism Park Water Assessment

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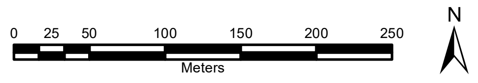

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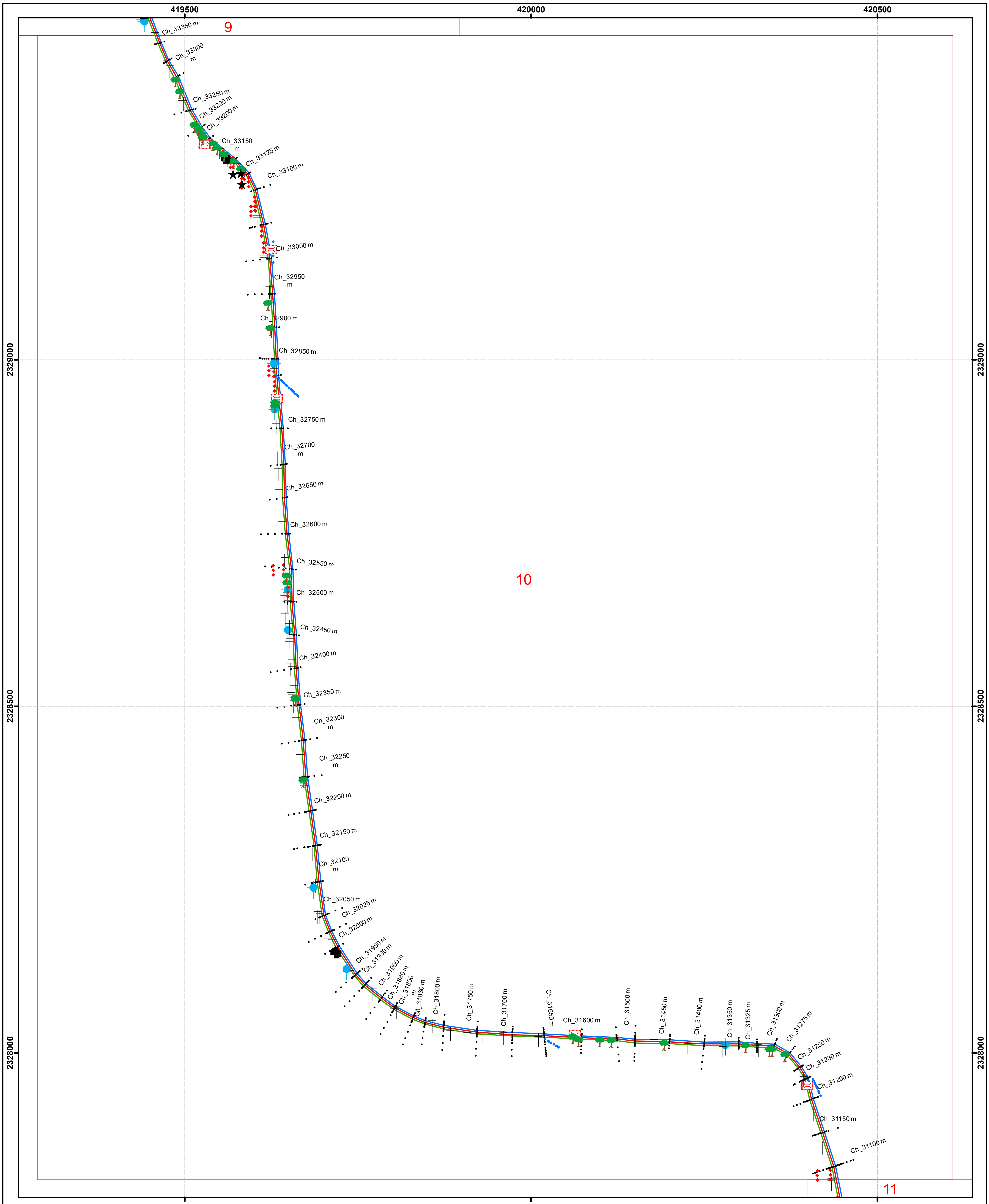

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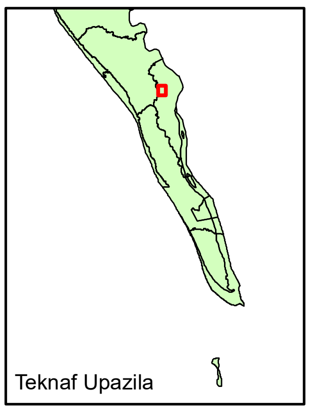

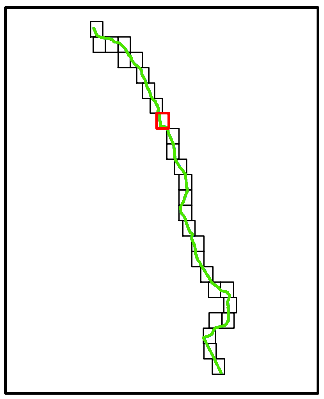

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Sabrang and Naf Tourism Park Water Assessment

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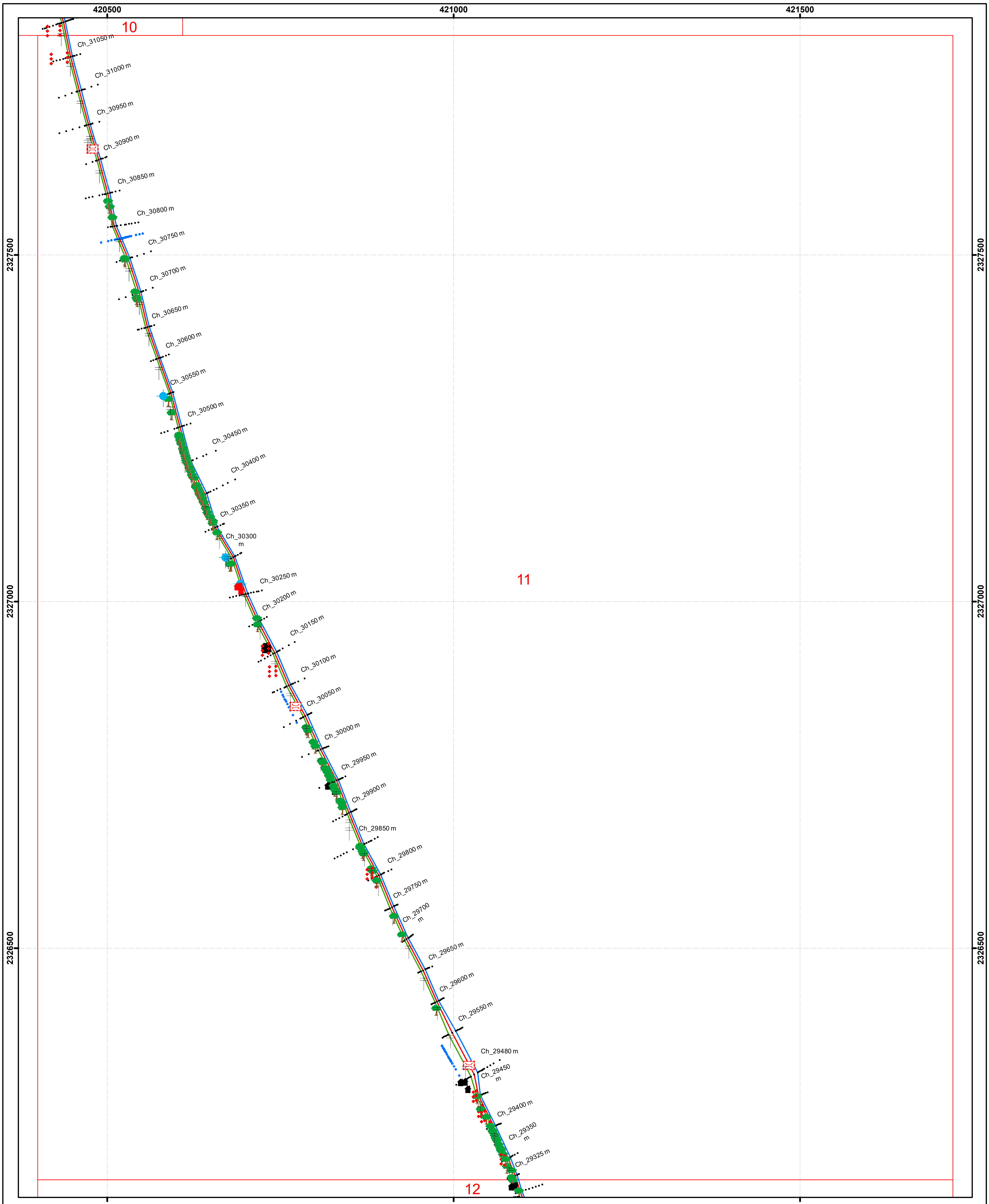

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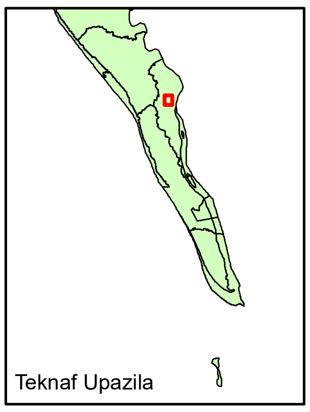

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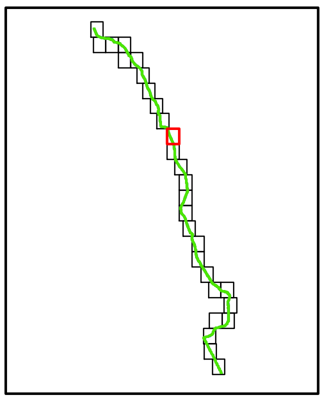

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Sabrang and Naf Tourism Park Water Assessment

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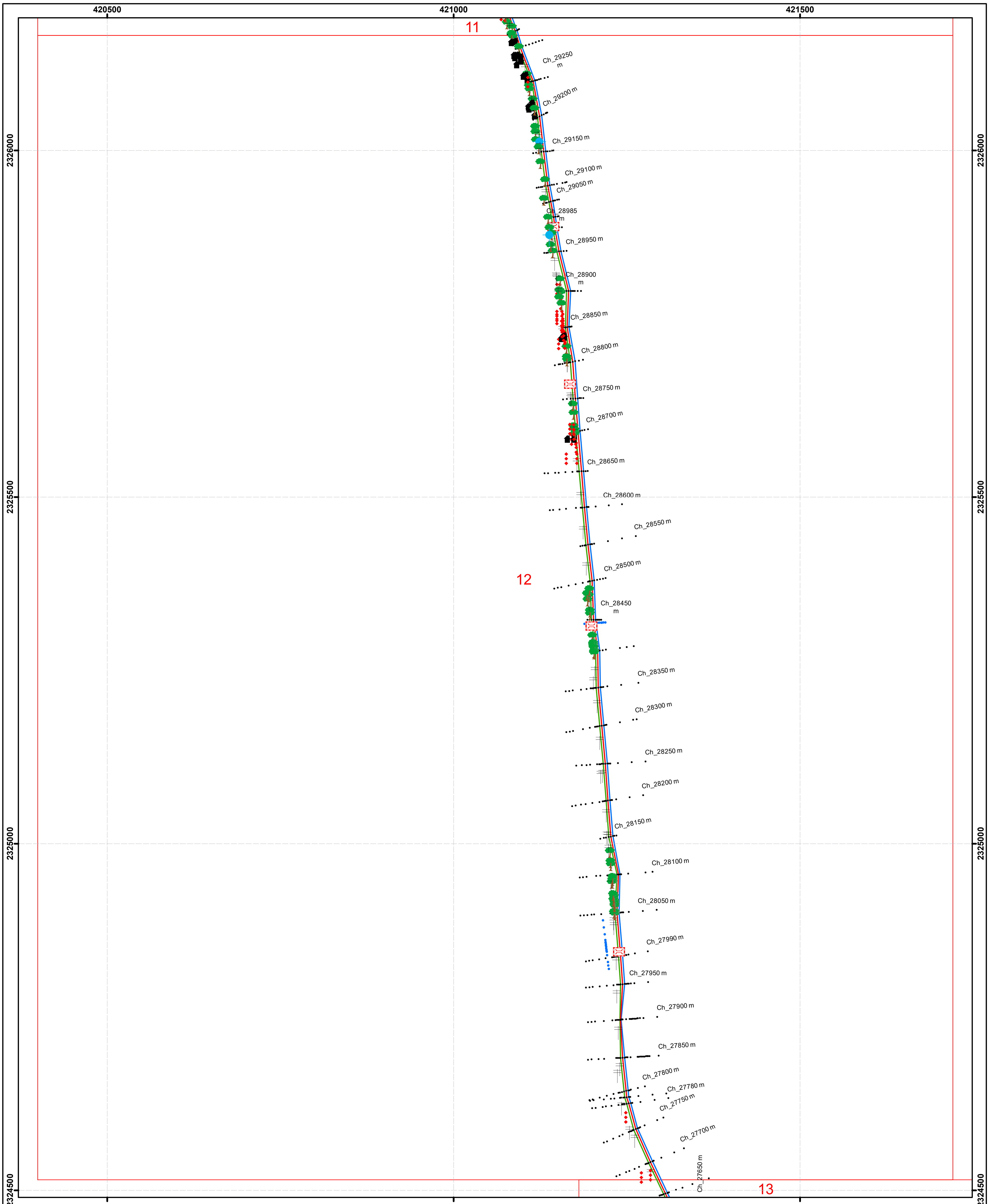

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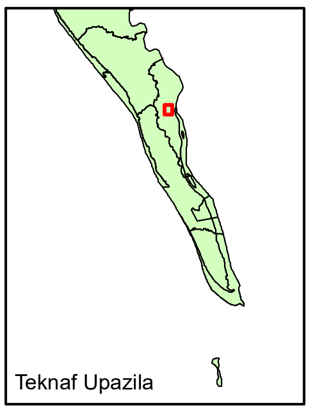

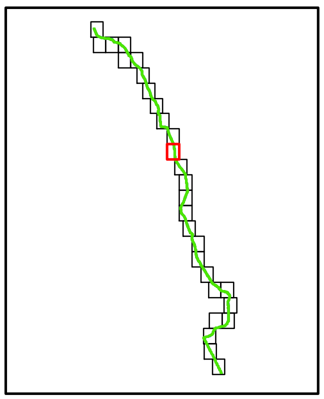

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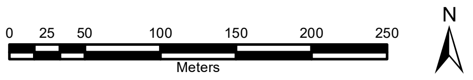

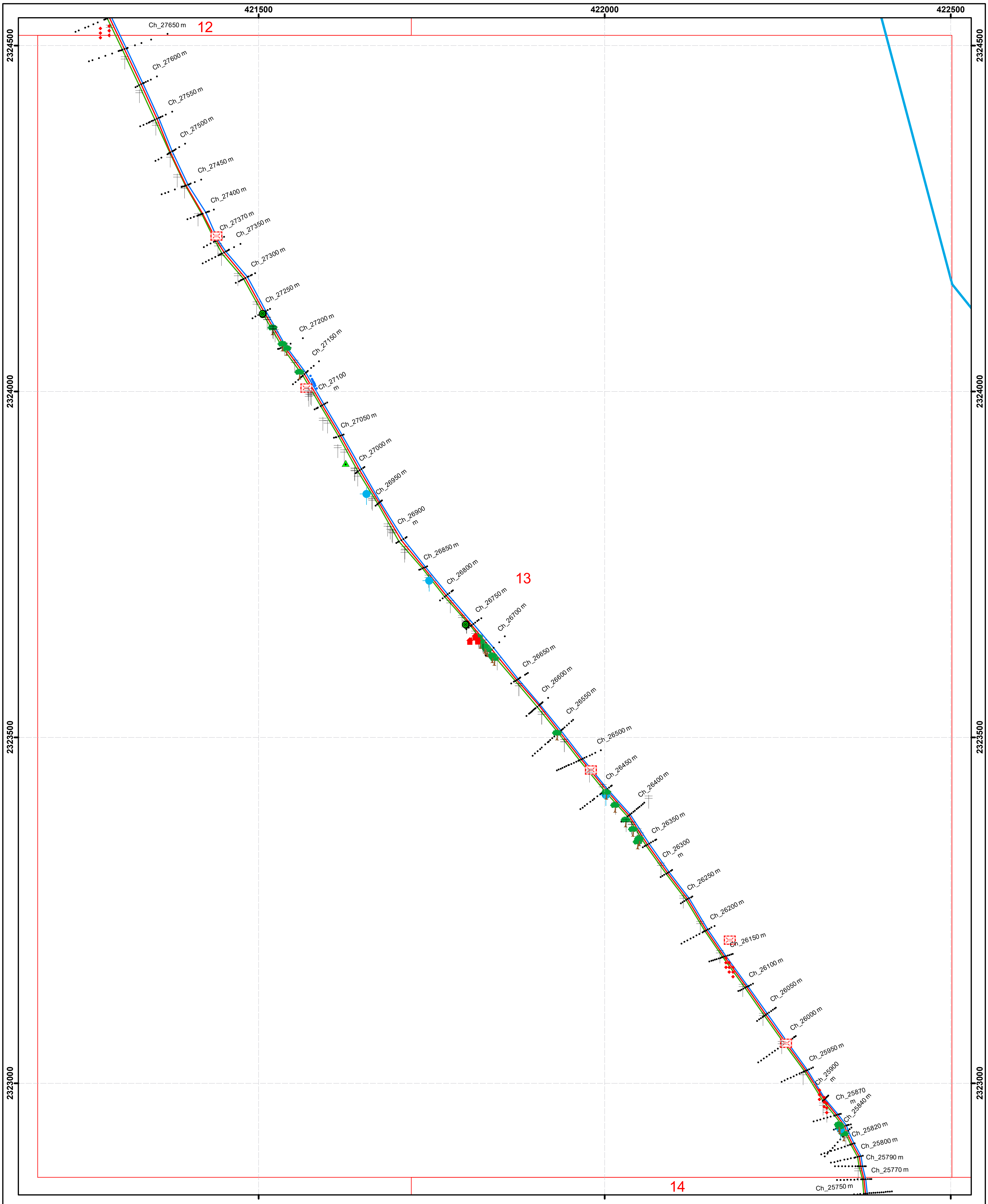

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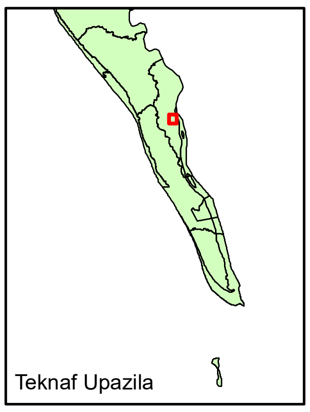

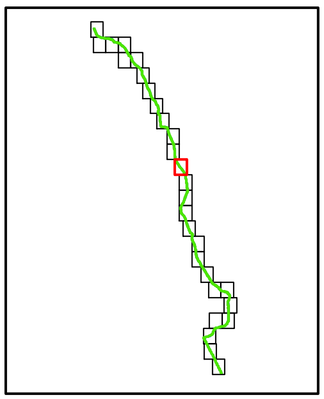

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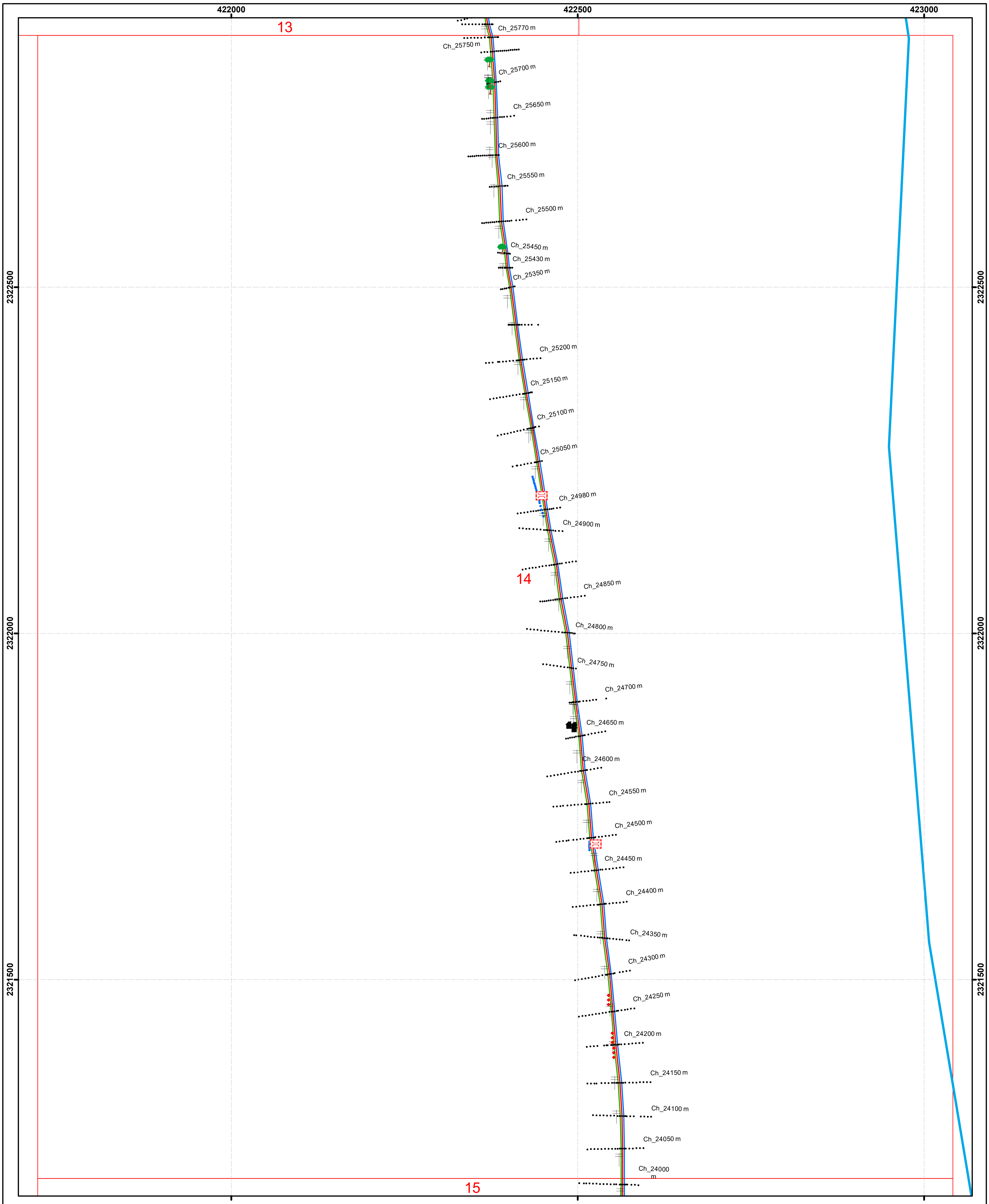

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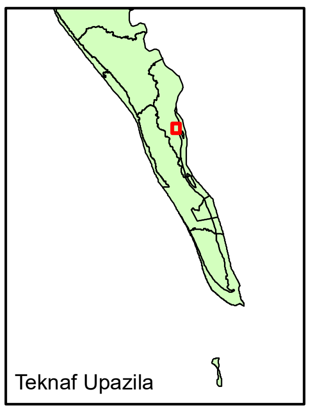
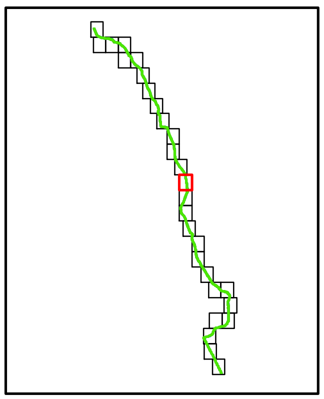
- Road Right Edge
- Sabrang Tourism Park
- Naf Tourism Park
- Boundary Wall
- Electric Pole
- Graveyeard
- Road Intersection
- Light Post
- Manhole
- Mosque
- House/Office
- Shop
- Telephon Pole
- Tree
- Tubewell





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Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

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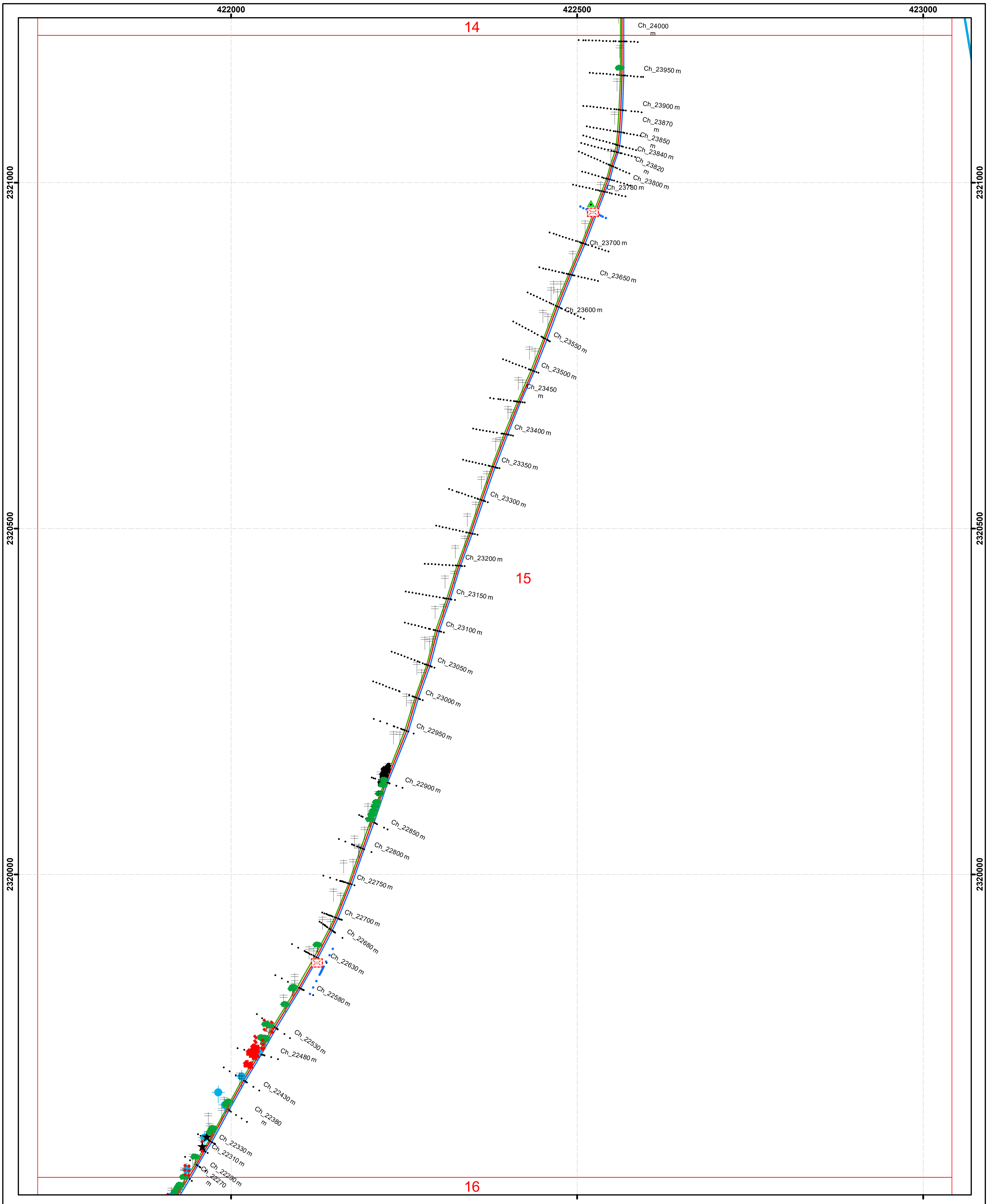
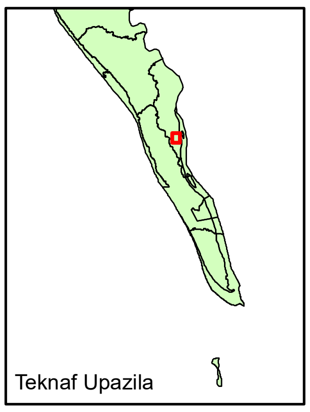
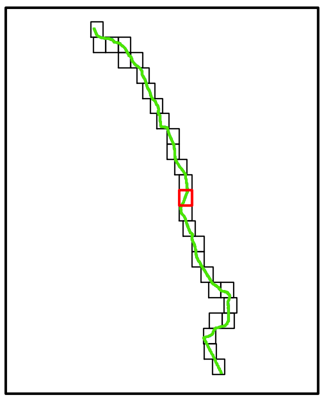


Legend

- 🟥 Union HQ
- ◎ Proposed PTW
- ▨ Bridge/Culvert
- • Khal Section
- • Road Section
- — Waterbody
- — International Boundary
- — Road Centerline
- — Road Left Edge
- — Road Right Edge
- ☐ Sabrang Tourism Park
- ☐ Naf Tourism Park
- ◆ Boundary Wall
- ┼ Electric Pole
- ⬠ Graveyeard
- ⊕ Road Intersection
- ● Light Post
- ◎ Manhole
- ★ Mosque
- ⌂ House/Office
- ⌂ Shop
- ☎ Telephon Pole
- ♣ Tree
- ▲ Tubewell





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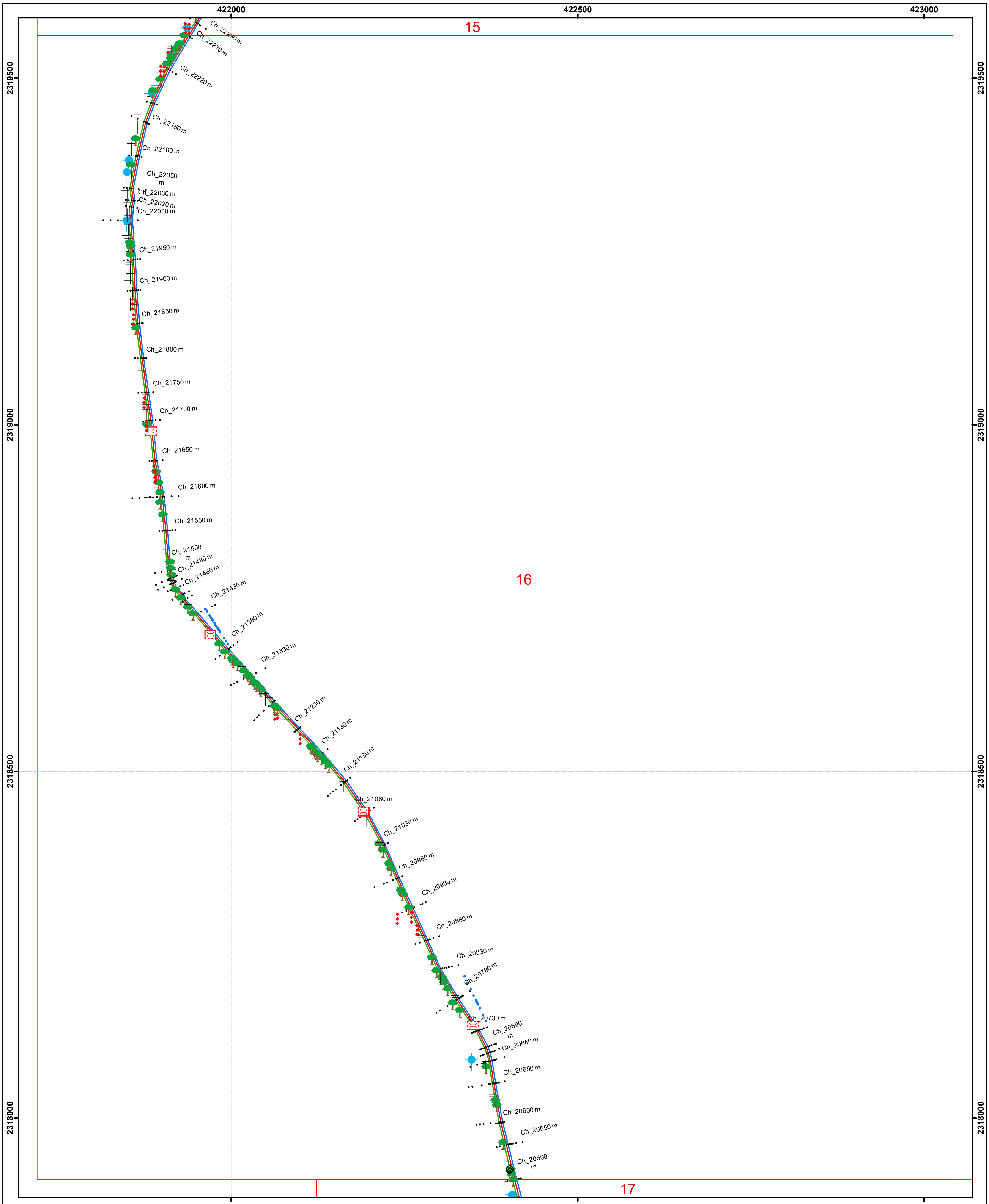
Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

0 25 50 100 150 200 250
Meters

N

Document Path: MZH\\D:\P0032\P-52159\A3 Grid Map.mxd



Legend

- ■ Union HQ
- ◎ Proposed PTW
- ▨ Bridge/Culvert
- • Khal Section
- · Road Section
- — Waterbody
- — International Boundary
- — Road Centerline
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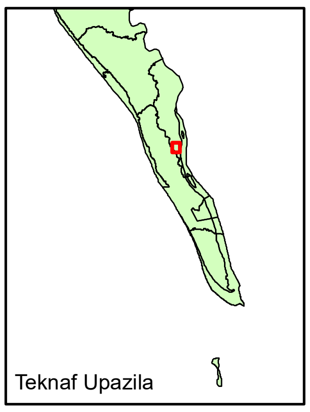
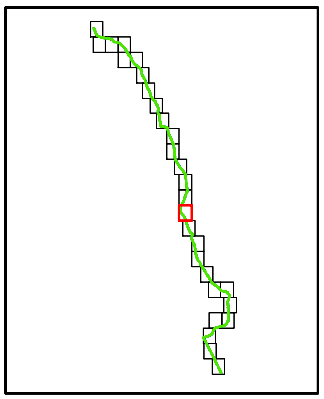
- ● Light Post
- ◎ Manhole
- ★ Mosque
- ⌂ House/Office
- ⌂ Shop
- ☎ Telephon Pole
- ♣ Tree
- ▲ Tubewell

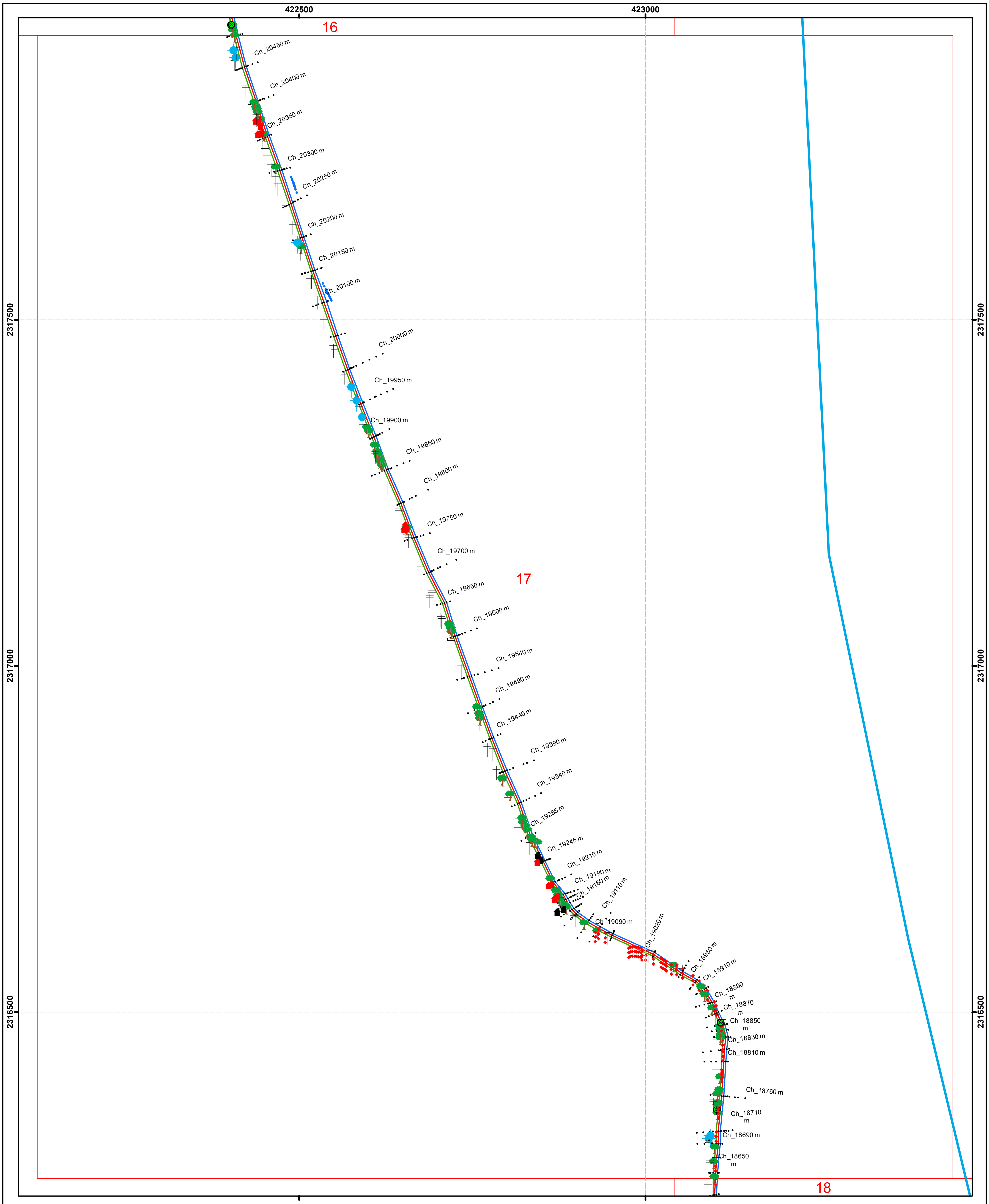




Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

IWM



Legend

- 🟥 Union HQ
- ◎ Proposed PTW
- ▨ Bridge/Culvert
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- ☎ Telephon Pole
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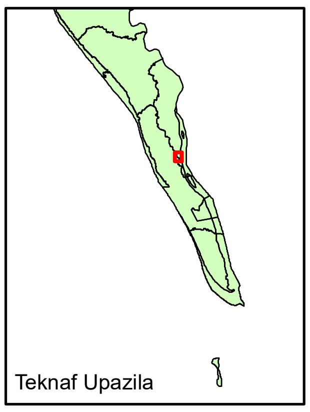
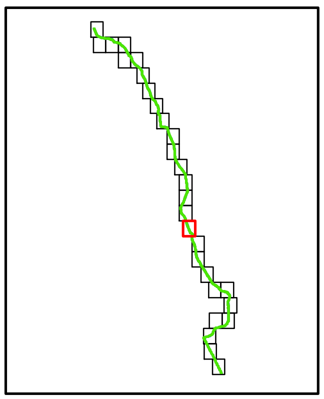
- ▲ Tubewell





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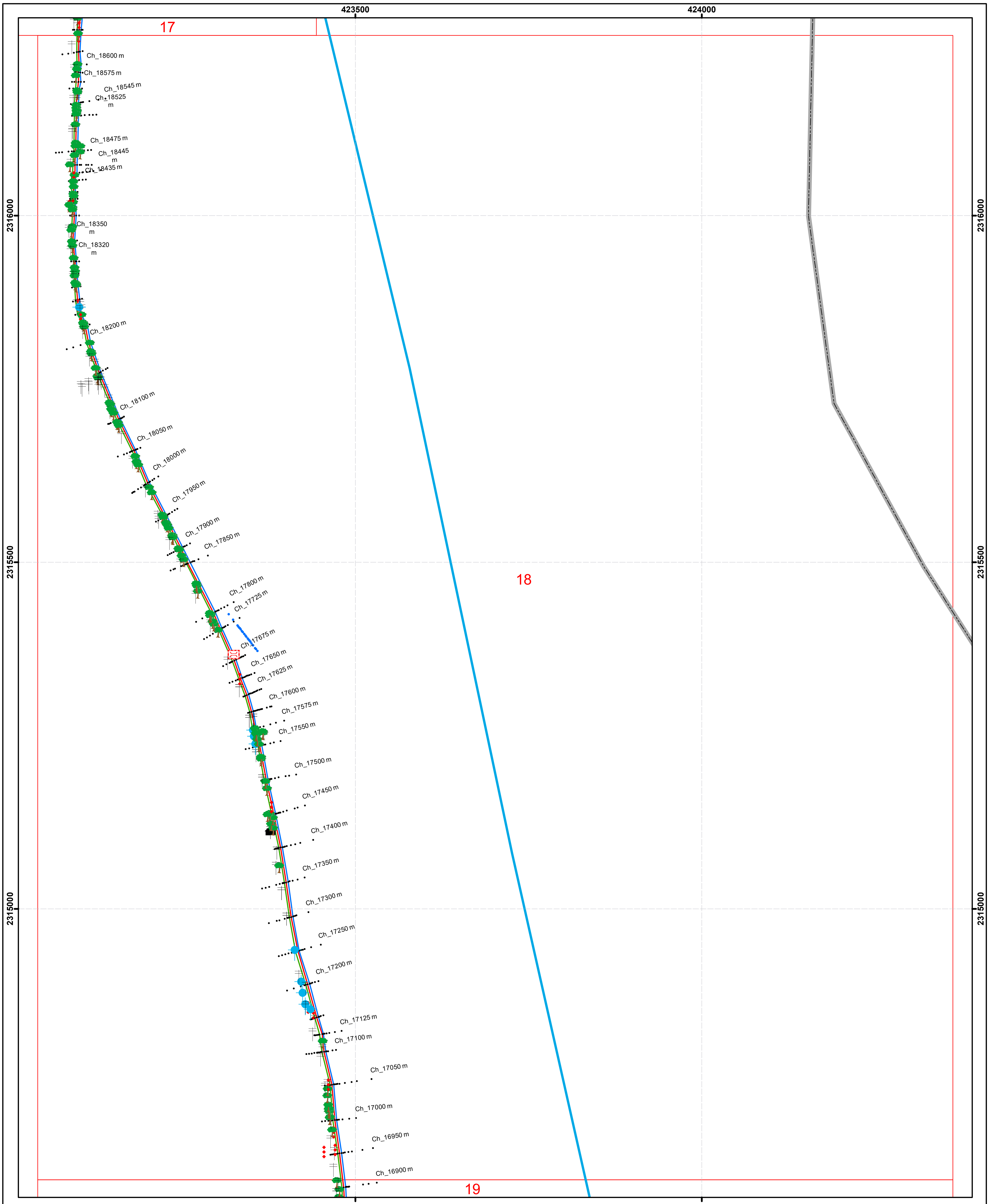
Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000



Legend

- 🟥 Union HQ
- ◎ Proposed PTW
- ▨ Bridge/Culvert
- · Khal Section
- · Road Section
- — Waterbody
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- ▭ Naf Tourism Park
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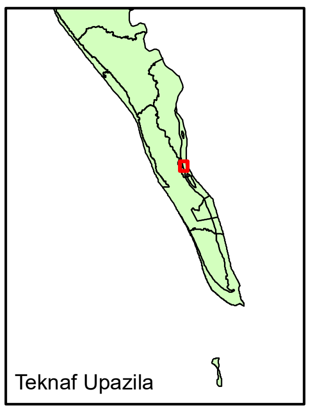
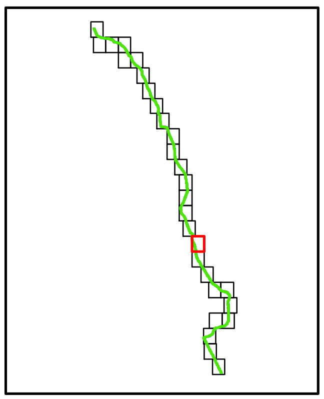
- ◎ Manhole
- ★ Mosque
- ☗ House/Office
- ☗ Shop
- ☎ Telephon Pole
- ♣ Tree
- ▲ Tubewell

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Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

0 25 50 100 150 200 250
Meters

N

IWM

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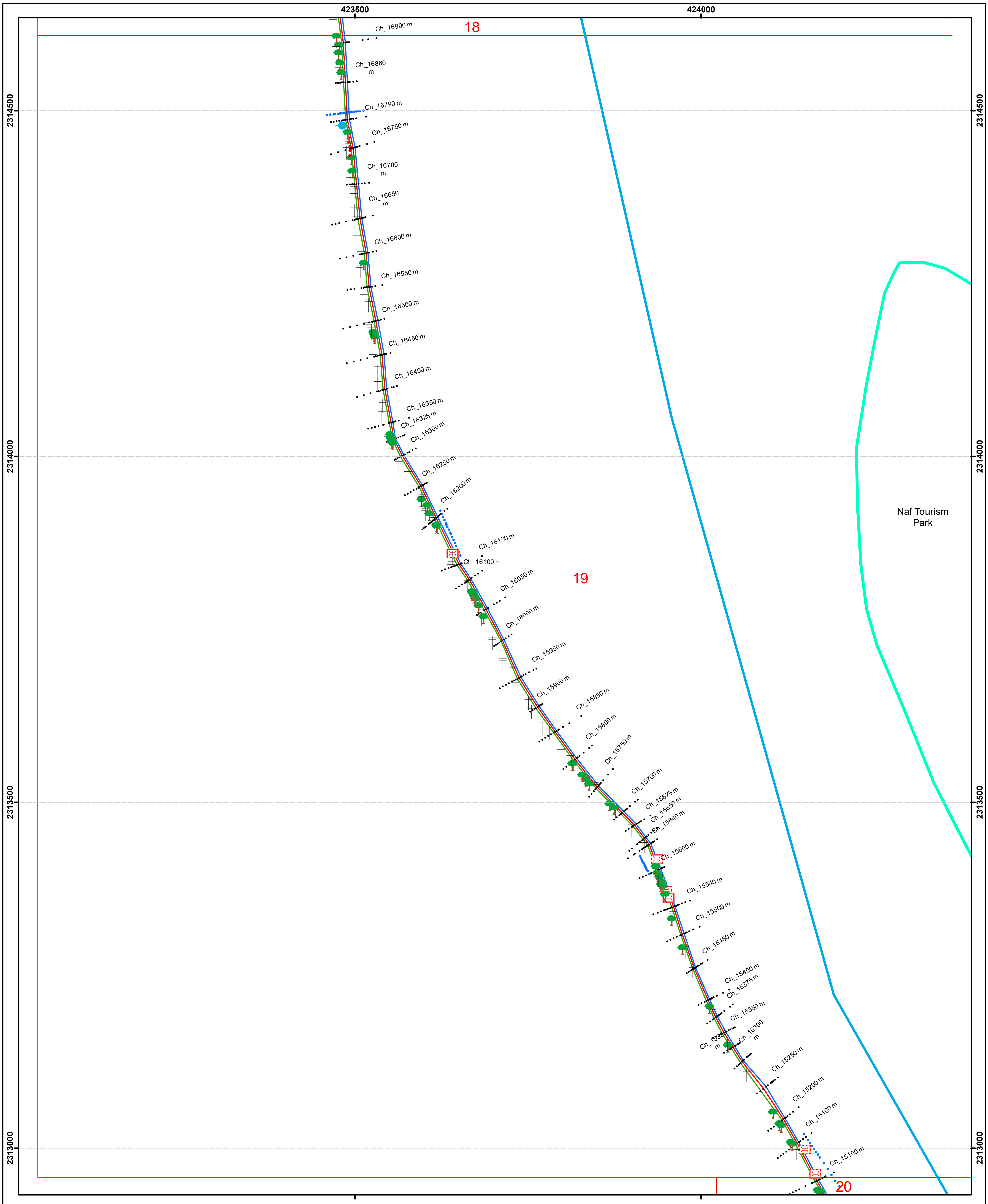

Legend

- 🟥 Union HQ
- ◎ Proposed PTW
- ▨ Bridge/Culvert
- • Khal Section
- • Road Section
- — Waterbody
- — International Boundary
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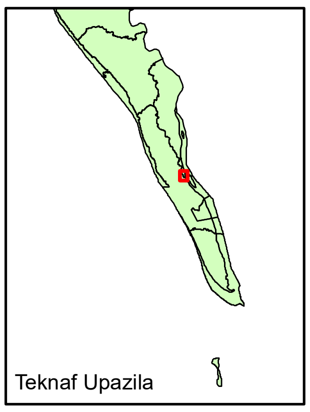
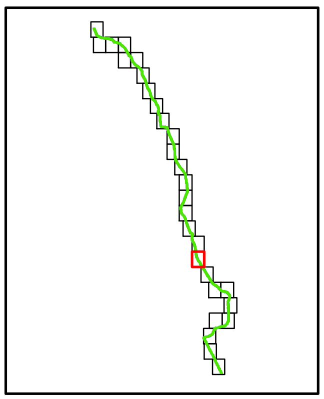
- ☐ Sabrang Tourism Park
- ☐ Naf Tourism Park
- ⋮ Boundary Wall
- ┼ Electric Pole
- ⬟ Graveyeard
- ⊕ Road Intersection
- ● Light Post
- ◎ Manhole
- ★ Mosque
- ■ House/Office
- ■ Shop
- ☎ Telephon Pole
- ▲ Tree
- ▲ Tubewell





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Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

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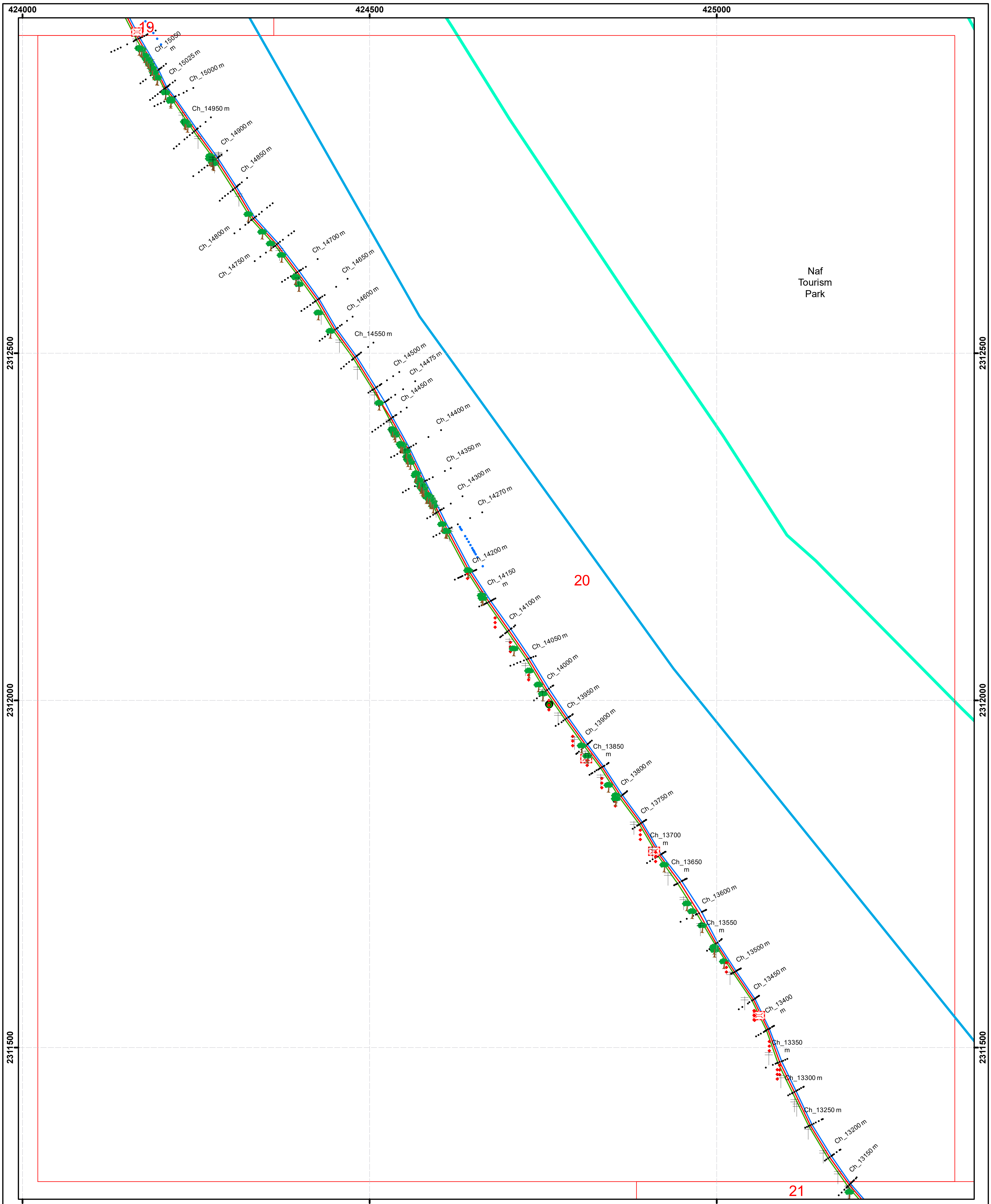
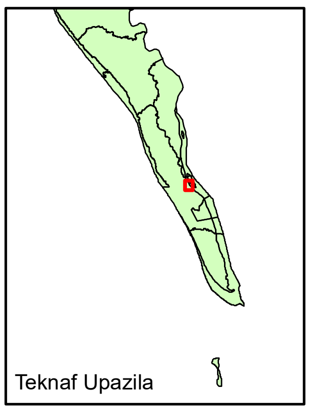


Legend

- 🟥 Union HQ
- ◎ Proposed PTW
- ▨ Bridge/Culvert
- · Khal Section
- · Road Section
- — Waterbody
- — International Boundary
- — Road Centerline
- — Road Left Edge
- — Road Right Edge
- ▭ Sabrang Tourism Park
- ▭ Naf Tourism Park
- ⁝ Boundary Wall
- ┬ Electric Pole
- ⬟ Graveyeard
- ⊕ Road Intersection
- ● Light Post
- ◎ Manhole
- ★ Mosque
- ⌂ House/Office
- ⌂ Shop
- ☎ Telephon Pole
- ♣ Tree
- ▲ Tubewell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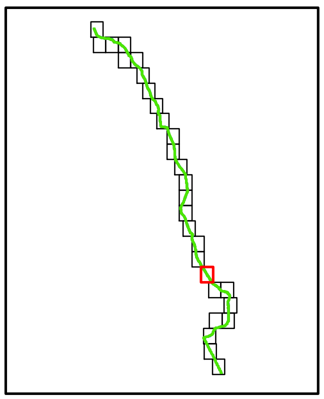
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Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

0 25 50 100 150 200 250
Meters

N

IWM

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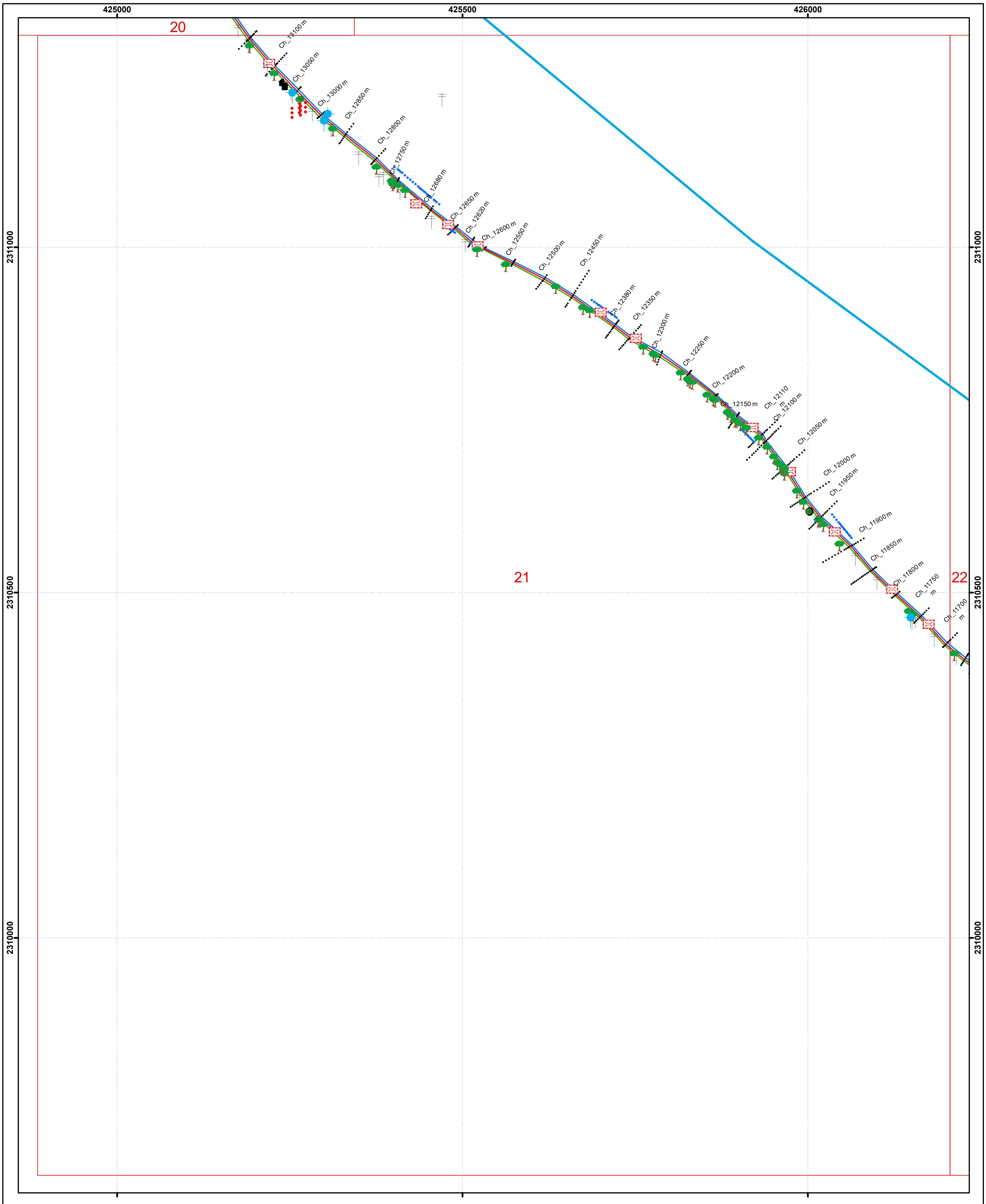

Legend

- Union HQ
- Proposed PTW
- Bridge/Culvert
- Khal Section
- Road Section
- Waterbody
- International Boundary
- Road Centerline
- Road Left Edge
- Road Right Edge
- Sabrang Tourism Park
- Naf Tourism Park
- Boundary Wall
- Electric Pole
- Graveyeard
- Road Intersection
- Light Post
- Manhole
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- House/Office
- Shop
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- Tree
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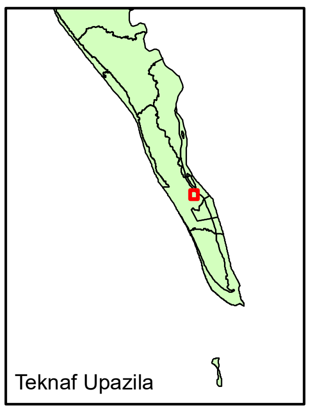
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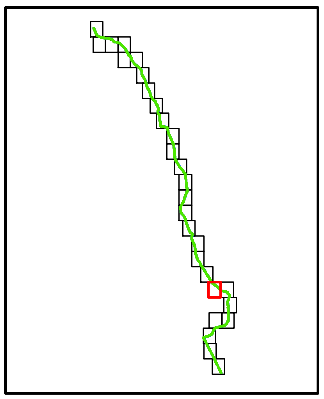
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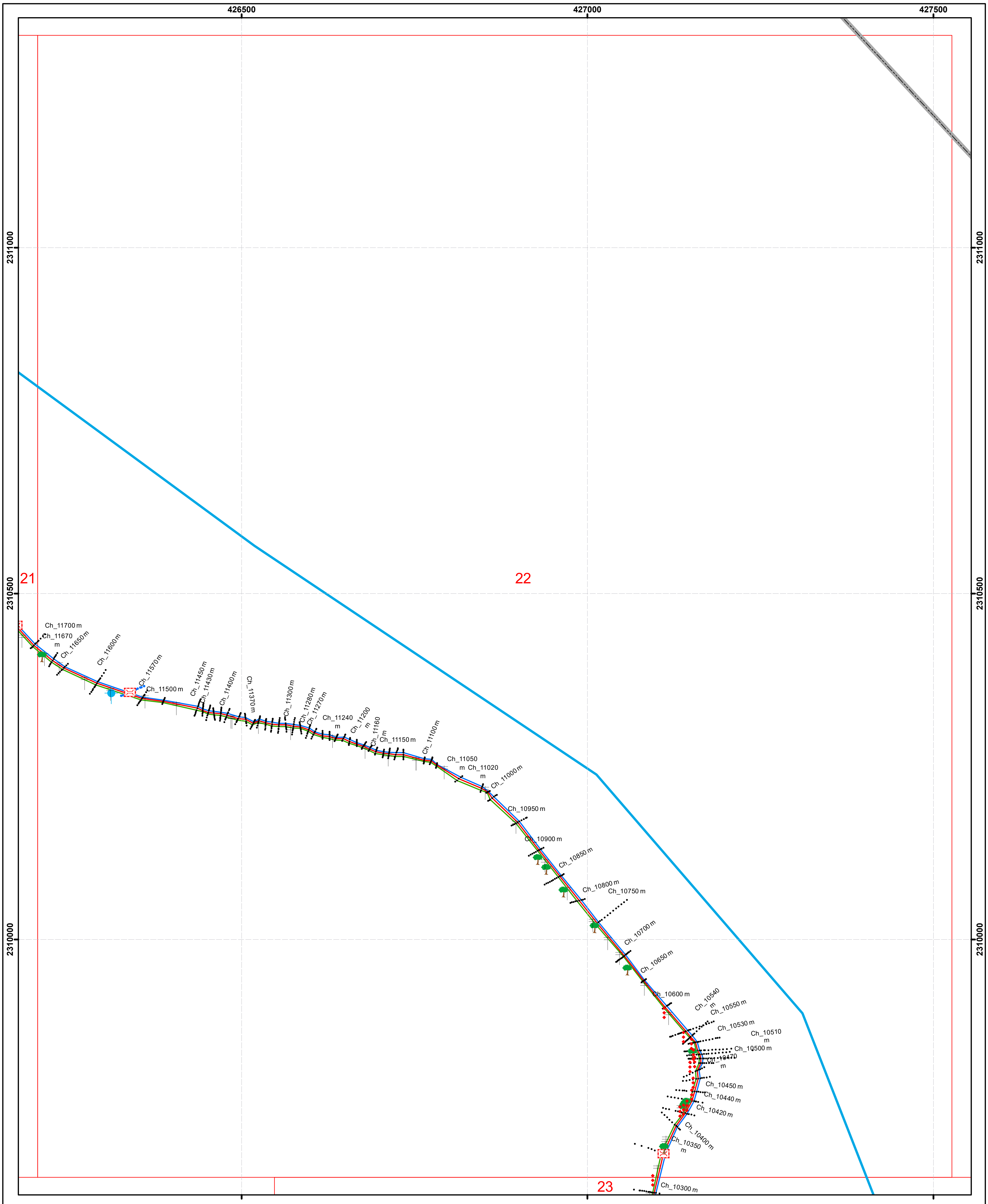
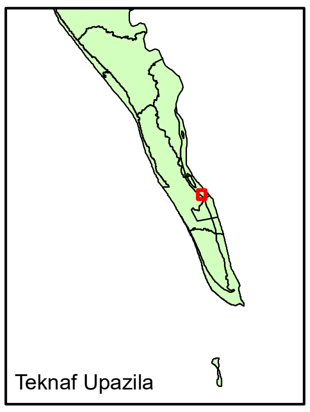
Sabrang and Naf Tourism Park Water Assessment

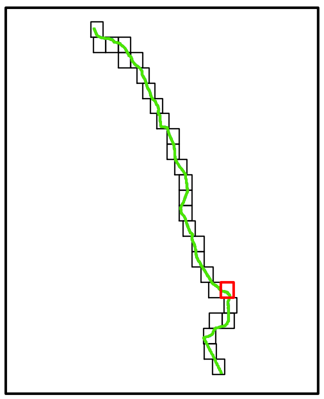
Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000



Legend

🟥	Union HQ
◎	Proposed PTW
▨	Bridge/Culvert
•	Khal Section
·	Road Section
━	Waterbody
━	International Boundary
━	Road Centerline
━	Road Left Edge
━	Road Right Edge
▭	Sabrang Tourism Park
▭	Naf Tourism Park
⁞	Boundary Wall
┼	Electric Pole
⬟	Graveyeard
⊕	Road Intersection
●	Light Post
◎	Manhole
★	Mosque
⌂	House/Office
⌂	Shop
☎	Telephon Pole
♣	Tree
▲	Tubewell





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Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

0 25 50 100 150 200 250
Meters

N

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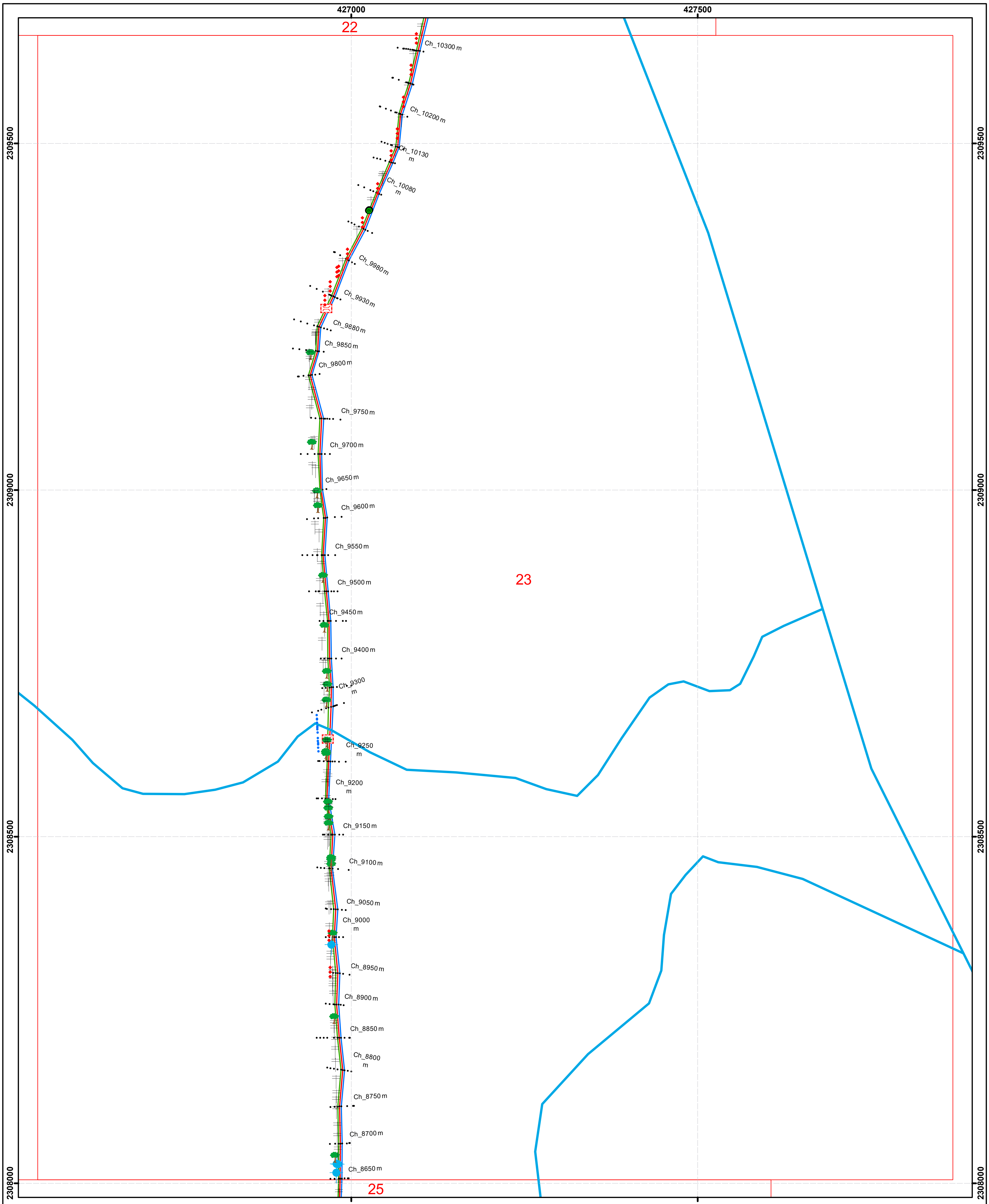
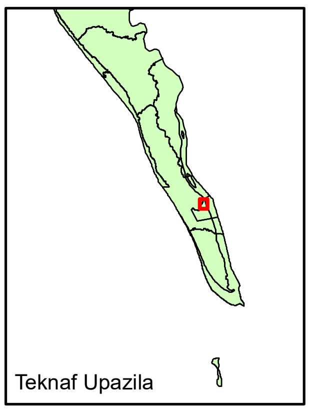


Legend

- ■ Union HQ
- ◎ Proposed PTW
- ▨ Bridge/Culvert
- · Khal Section
- · Road Section
- — Waterbody
- — International Boundary
- — Road Centerline
- — Road Left Edge
- — Road Right Edge
- ☐ Sabrang Tourism Park
- ☐ Naf Tourism Park
- ⁝ Boundary Wall
- † Electric Pole
- ⬟ Graveyeard
- ⊕ Road Intersection
- ● Light Post
- ◎ Manhole
- ★ Mosque
- ■ House/Office
- ■ Shop
- ☎ Telephon Pole
- ♣ Tree
- ▲ Tubewell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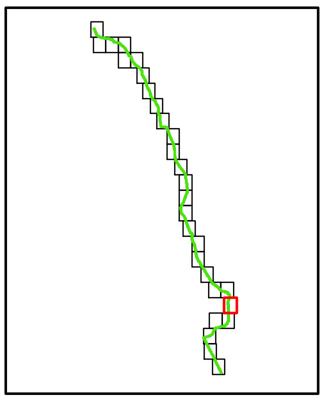
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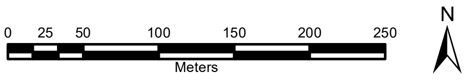
Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000



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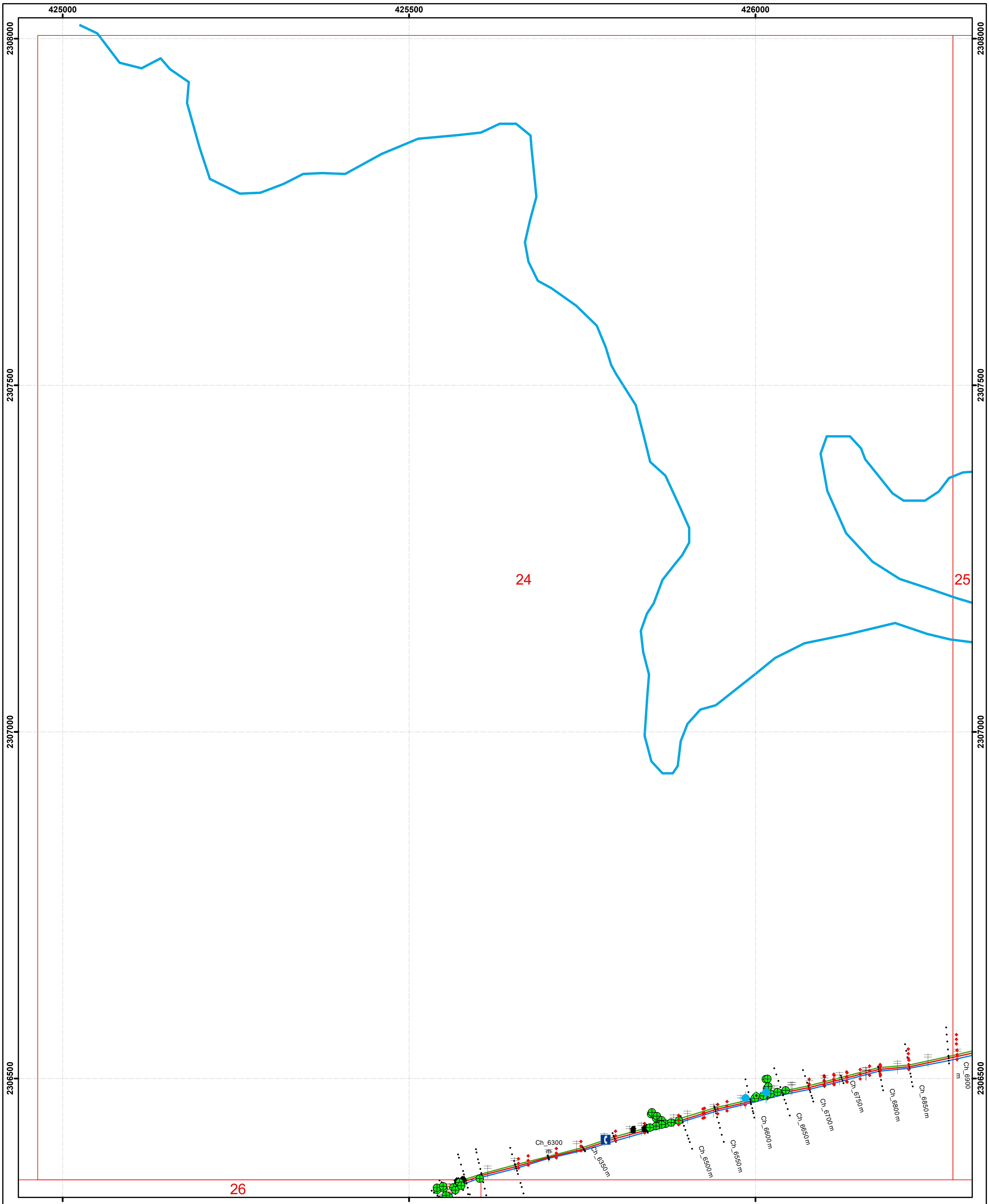

Legend

- 🟥 Union HQ
- ◎ Proposed PTW
- ▨ Bridge/Culvert
- • Khal Section
- · Road Section
- ━ Waterbody
- ━ International Boundary
- ━ Road Centerline
- ━ Road Left Edge
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- ⌂ Shop
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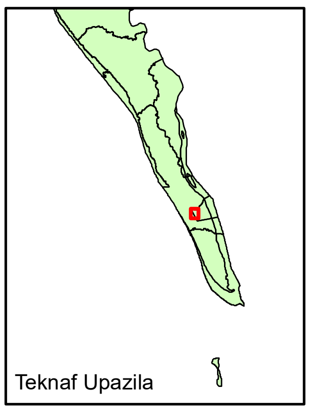

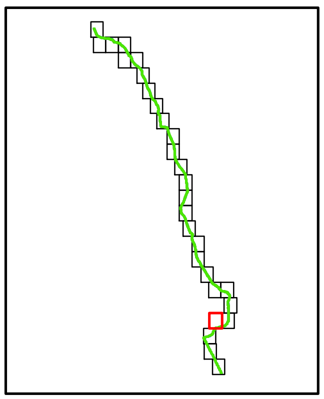

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Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

0 25 50 100 150 200 250
Meters

N

IWM

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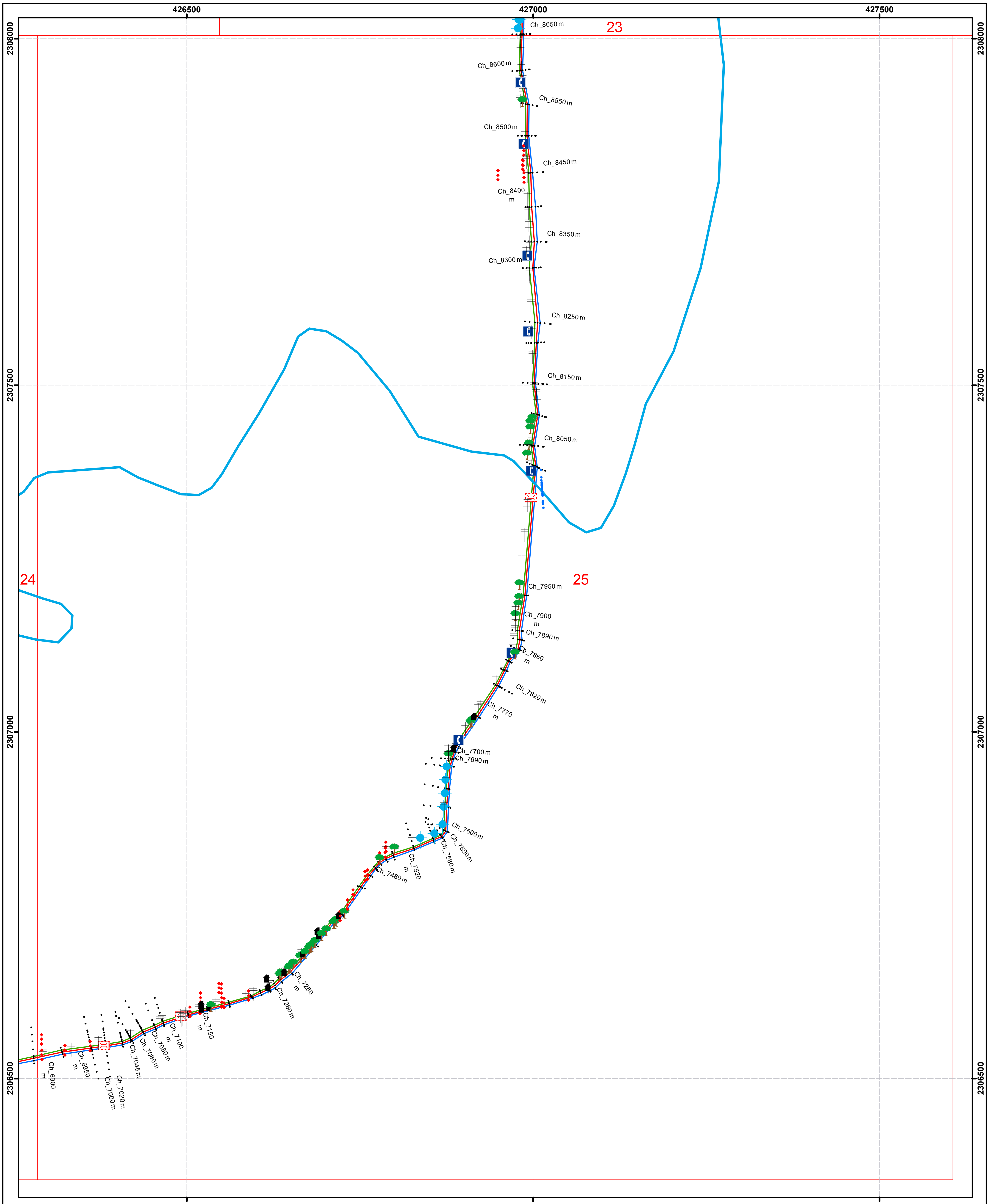

Legend

- Union HQ
- Proposed PTW
- Bridge/Culvert
- Khal Section
- Road Section
- Waterbody
- International Boundary
- Road Centerline
- Road Left Edge
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- Tree
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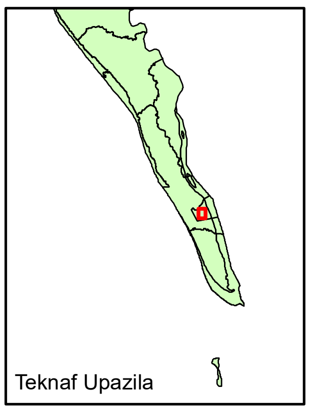

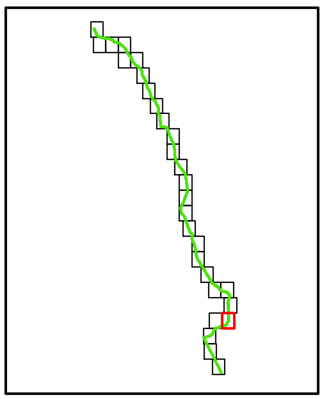

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Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

0 25 50 100 150 200 250
Meters
N

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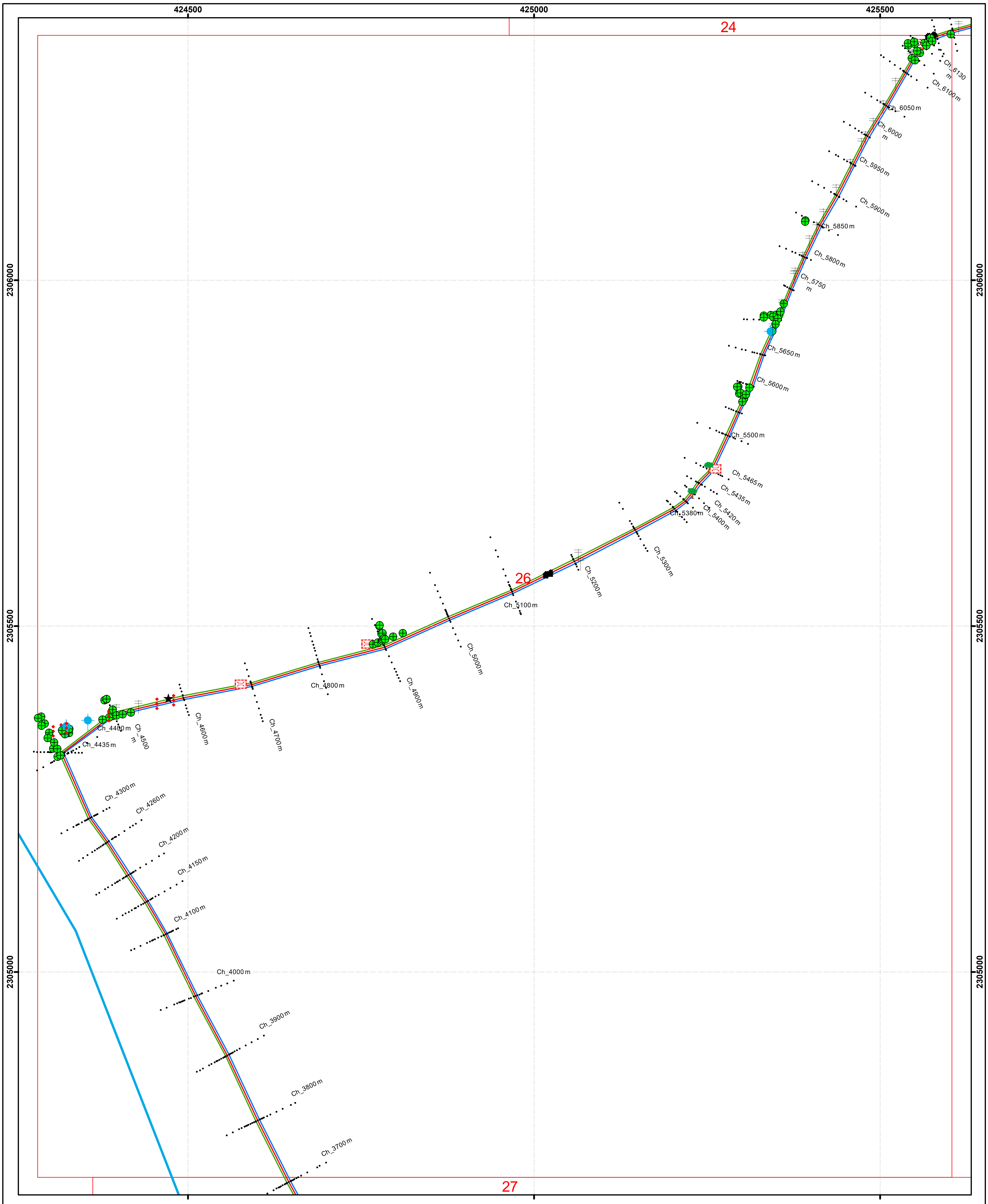

Legend

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- ◎ Manhole
- ★ Mosque
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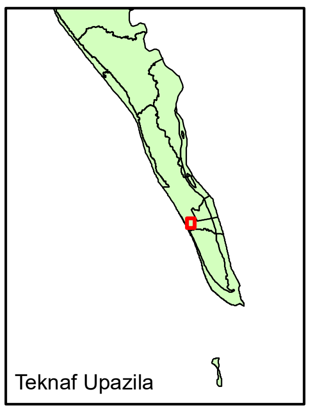
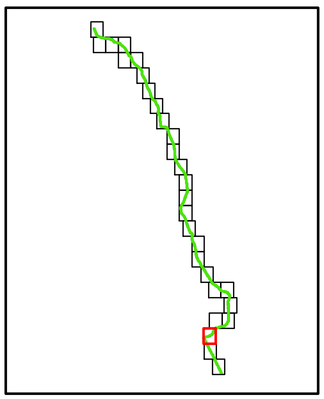
- ■ Shop
- ☎ Telephon Pole
- 🌳 Tree
- ▲ Tubewell





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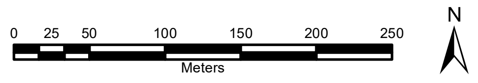
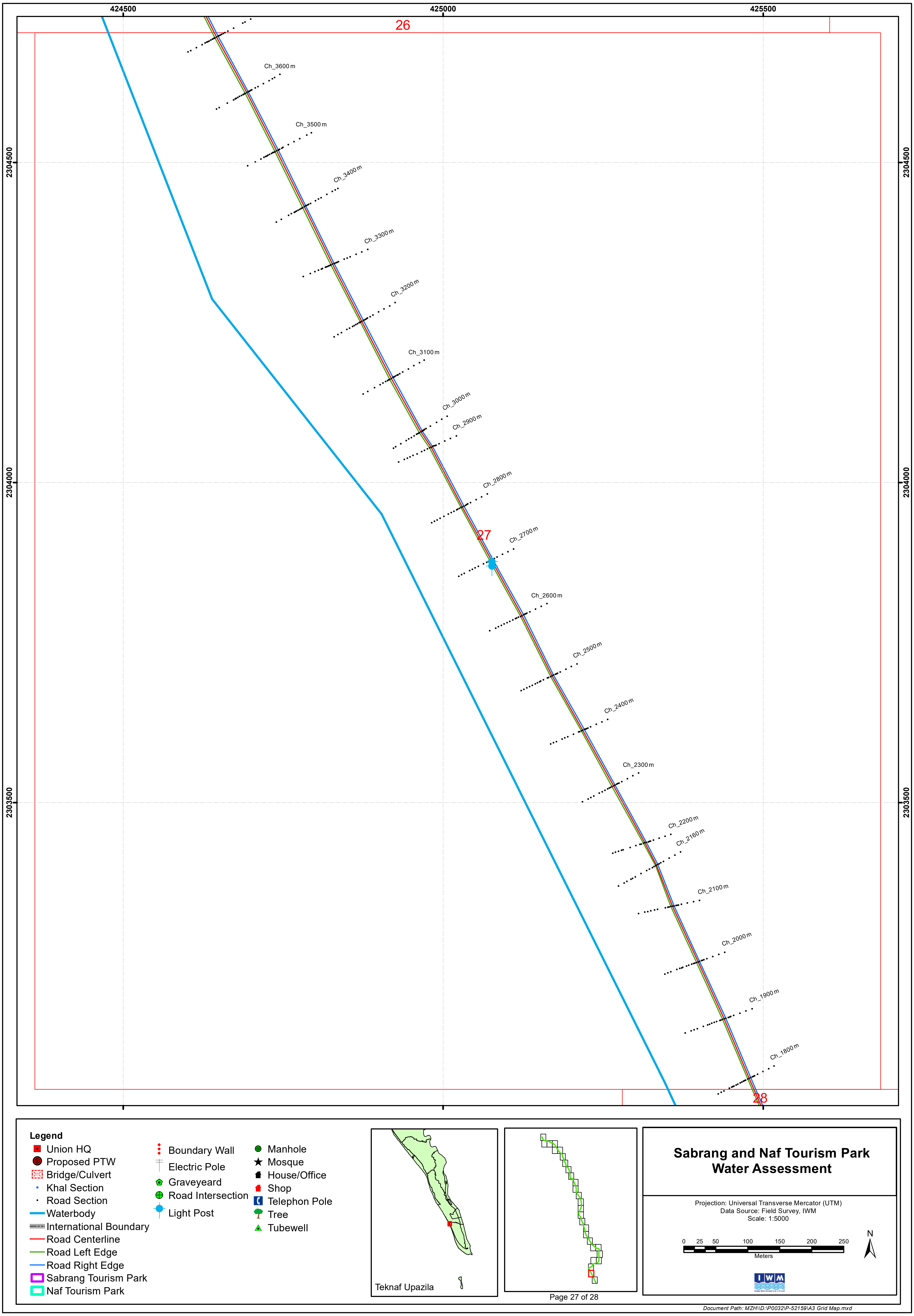
Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000





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Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

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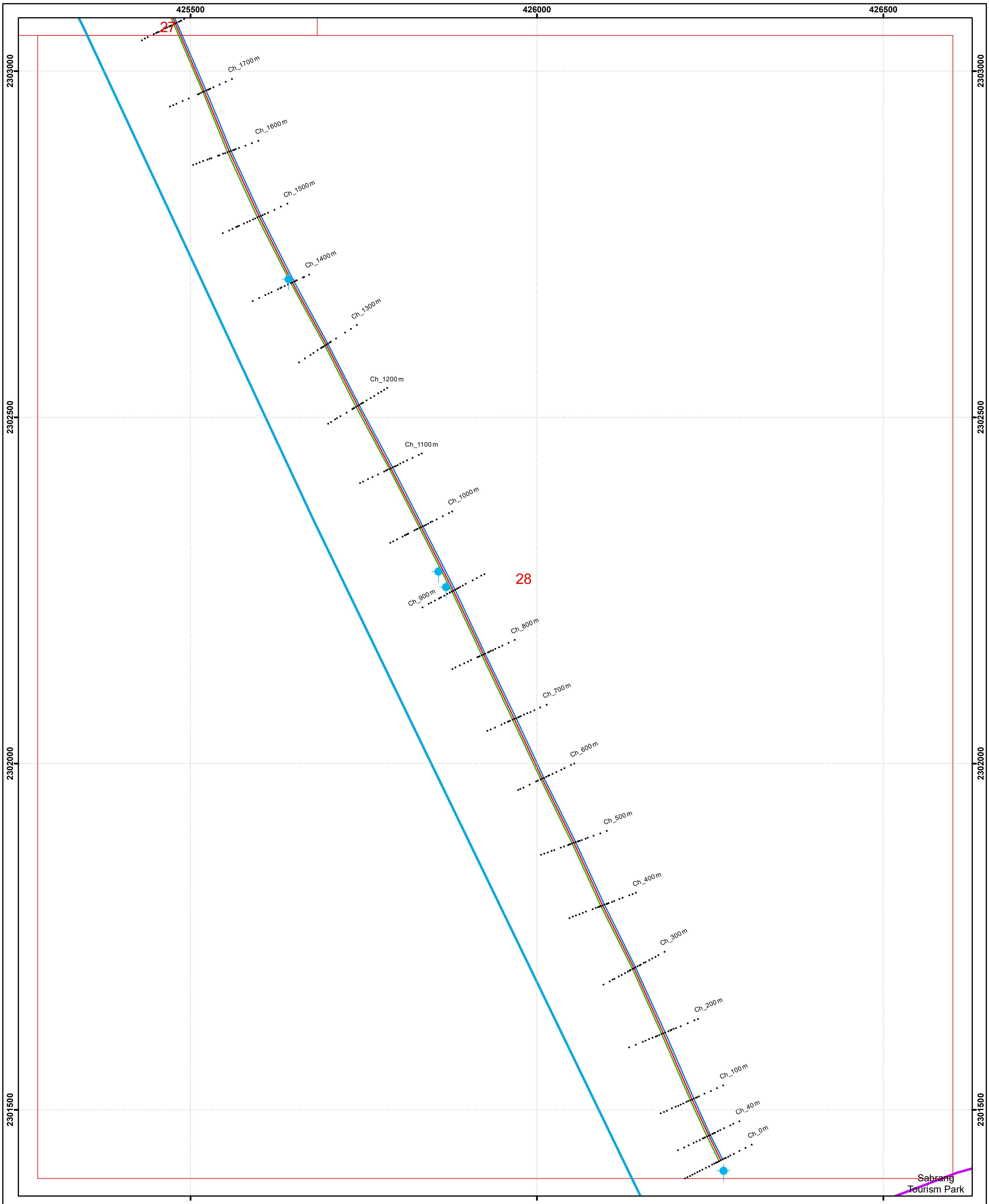

Legend

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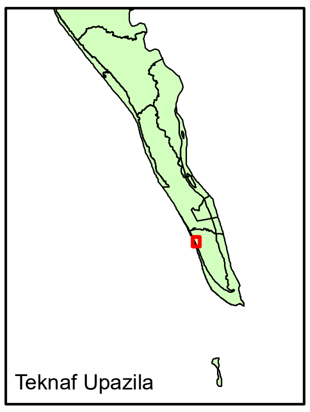
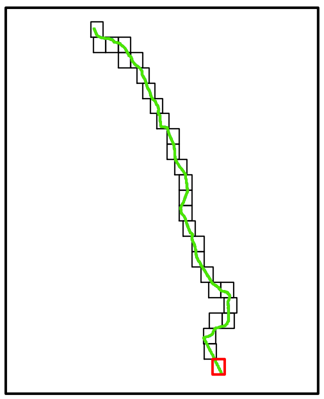

Teknaf Upazila


Page 28 of 28

Sabrang and Naf Tourism Park Water Assessment

Projection: Universal Transverse Mercator (UTM)
Data Source: Field Survey, IWM
Scale: 1:5000

0 25 50 100 150 200 250
Meters

N

IWM

Appendix B: Inventory of Structures along the Proposed Transmission Line

SL	Structure Type	No. of Vent	Barel Length (m)	Opening		Reduced Level (mMSL)			Position (UTM)	
				Height (m)	Width (m)	Sill (m)	Soffit (m)	Deck (m)	Northing (m)	Easting (m)
1	Box Culvert	1	10.5	0.8	1.35	3.087	3.88	4.23	2330281	419413
2	Box Culvert	1	10	1.34	1.2	2.15	3.49	3.82	2330418	419312
3	Box Culvert	1	10	1.38	1.2	1.74	3.12	3.31	2330592	419189
4	Bridge	1	14.2	1.88	13.6	2.281	4.16	5.79	2330826	419079
5	Box Culvert	1	10.5	1.74	1.82	3.24	4.98	5.09	2330966	418870
6	Box Culvert	1	10	1.65	2.7	3.81	5.46	5.71	2331013	418832
7	Box Culvert	1	10.5	1.49	1.2	-	9.34	9.51	2331232	418724
8	Box Culvert	1	10.5	1.49	2.7	3.64	5.13	5.41	2331424	418634
9	Box Culvert	1	10.2	1.75	4.25	1.3	3.05	3.37	2331627	418575
10	Box Culvert	1	10.5	0.87	2.2	2.8	3.07	3.23	2331857	418495
11	Box Culvert	1	10.5	0.88	2.8	1.81	2.69	2.97	2331916	418467
12	Bridge	3	37	6.08	7.2	-1.71	4.37	5.69	2332737	418156
13	Box Culvert	1	10	1.23	1.2	3.5	4.73	5.06	2333125	418009
14	Box Culvert	1	10	1.86	1.2	6.12	7.98	8.31	2333380	417872
15	Box Culvert	1	10	1.32	2.8	3.94	5.26	5.84	2333564	417760
16	Bridge	3	39	3.72	36.6	6.8	3.08	4.76	426966	2308641
17	Box Culvert	1	9.2	3.3	8.6	3.67	6.97	7.7	426964	2309262
18	Box Culvert	1	9.35	2.51	8.75	2.86	5.37	6.14	427110	2309690
19	Bridge	3	30	4.61	27.6	0.14	4.75	6.37	422349	2318133
20	Box Culvert	1	9.6	2.64	9	3	5.64	6.06	422191	2318442
21	Bridge	3	38	5	35.6	1.61	6.61	7.86	421970	2318698
22	Box Culvert	1	10	0.82	9.4	8.29	9.11	9.49	421884	2318991
23	Bridge	3	30	1.89	28.9	1.08	2.97	4.84	422124	2319872
24	Bridge	3	31.5	3.09	29.4	0.17	3.26	4.19	420063	2328026
25	Box Culvert	1	18	4.45	17.4	0.67	5.12	5.85	419633	2328944
26	Box Culvert	1	7	1.72	6.4	2.17	3.89	4.2	419625	2329159
27	Box Culvert	1	10	0.69	9.4	2.56	3.25	3.52	419529	2329311
28	Box Culvert	1	7	1.19	6.4	2.79	3.98	4.21	419437	2329544
29	Box Culvert	1	7.3	1.62	6.7	1.23	2.85	3.16	419448	2329744
30	Box Culvert	1	10	0.88	9.4	1.84	2.77	3.07	419449	2329994
31	Box Culvert	1	12.2	2.36	11.6	1.95	4.31	5.71	414397	2337472
32	Bridge	3	30.2	4.37	28.7	0.65	5.02	6.07	414216	2337522
33	Box Culvert	1	9.5	1.11	8.9	2.01	3.12	3.56	413910	2337565
34	Box Culvert	1	9.5	0.85	8.9	3.05	3.9	4.3	413640	2337598
35	Box Culvert	1	10.45	2.94	9.85	2.23	5.17	6.28	413526	2337625
36	Box Culvert	1	7.9	1.52	7.3	2.2	3.64	3.86	426380	2306548
37	Bridge	3	35.3	2.8	33.8	1.81	4.61	6.38	425220	2311266
38	Bridge	3	37.2	1.68	36	0.91	2.59	4.36	426997	2307338
39	Box Culvert	1	6.1	1.12	5.5	2.91	4.03	4.25	426492	2306590
40	Box Culvert	1	4.3	0.75	3.7	6.14	6.89	7.11	425561	2306342
41	Box Culvert	1	8.2	0.57	7.6	4.38	4.95	5.25	425262	2305727
42	Box Culvert	1	6.2	7.6	5.6	10.58	2.98	3.23	424759	2305474
43	Box Culvert	1	7.9	1.33	7.3	1.81	3.14	3.49	424576	2305416
44	Box Culvert	1	10	1.26	9.4	2.54	3.8	4.23	425061	2311546
45	Box Culvert	1	7.3	0.88	6.7	2.89	3.69	4.64	424910	2311783
46	Box Culvert	1	7.3	2.68	6.7	0.73	3.41	4.38	414812	2311916
47	Bridge	2	23.8	3.87	7.4	0.656	4.528	6.175	2310357	426339
48	Box Culvert	1	7.5	0.527	7	6.073	6.606	7.601	2310454	426175
49	Box Culvert	1	8.2	0.911	8.25	4.529	5.44	6.373	2310505	426122
50	Bridge	1	22.5	5.062	19	0.214	5.276	6.676	2310588	426039

SL	Structure Type	No. of Vent	Barel Length (m)	Opening		Reduced Level (mMSL)			Position (UTM)	
				Height (m)	Width (m)	Sill (m)	Soffit (m)	Deck (m)	Northing (m)	Easting (m)
51	Box Culvert	1	10	2.362	3	4.716	7.078	7.545	2310675	425974
52	Box Culvert	1	10.25	2.568	2.75	4.66	7.228	7.68	2310739	425920
53	Box Culvert	1	10.2	1.418	2.7	4.028	5.446	5.837	2310868	425751
54	Bridge	3	30.4	4.896	28.4	0.063	4.959	5.737	2310906	425700
55	Box Culvert	1	10.9	2.59	6.6	8.92	11.49	12.52	2311002	425522
56	Box Culvert	1	9.4	2.269	6.7	7.54	9.809	10.58	2311033	425479
57	Bridge	3	41.7	4.861	38.5	0.947	5.808	7.817	2311063	425433
58	Bridge	2	13.25	2.906	11.95	-0.94	3.849	4.501	2320957	422523
59	Box Culvert	1	9.5	1.682	3.05	0.55	2.232	2.65	2321696	422526
60	Bridge	3	47.75	1.863	45.55	1.13	2.993	4.37	2322199	422448
61	Bridge	2	10.3	3.903	9	3.064	6.967	7.564	2336084	416094
62	Box Culvert	1	9.6	1.198	2.9	3.328	4.526	5.52	2336858	415439
63	Box Culvert	1	10.3	1.52	1.95	0.93	2.45	2.863	2323058	422262
64	Box Culvert	1	9.5	1.244	2.85	1.056	2.3	2.723	2323207	421581
65	Box Culvert	1	11.4	1.602	2.95	0.723	2.325	2.751	2323453	421980
66	Box Culvert	1	9.6	1.233	4.2	1.456	2.689	3.88	2337074	415148
67	Bridge	1	15	3.065	15.2	1.282	4.347	6.084	2337139	414932
68	Box Culvert	1	11	0.92	4	1.09	2.01	2.4	421569	2324005
69	Box Culvert	1	9.2	1.45	5.4	0.78	2.23	2.67	421439	2324225
70	Bridge	3	32	5.43	6.7	-2.46	2.97	4.44	421239	2324844
71	Box Culvert	1	11	2.91	6.7	-1.22	1.69	2.1	421199	2325314
72	Box Culvert	1	9	1.2	2	1.21	2.32	2.6	421168	2325663
73	Box Culvert	1	10	0.69	2	1.8	2.49	2.77	421144	2325890
74	Box Culvert	1	10	1.4	3.4	1.12	2.52	3.01	417224	2334537
75	Box Culvert	1	9	1.19	3.75	2.25	3.44	3.89	416979	2334736
76	Bridge	3	77	6.06	7	-1.06	5	6.54	416708	2335045
77	Box Culvert	1	9	1.44	3.2	3.52	4.96	5.37	416573	2335373
78	Box Culvert	1	7	2.73	6.3	3.09	5.82	6.1	416507	2335535
79	Box Culvert	1	9	2.03	2	6.15	8.18	8.55	416247	2335809
80	Box Culvert	1	12.2	3.35	8	1.58	4.93	6.15	417349	2334433
81	Box Culvert	1	10	0.75	3.2	2.78	3.53	4.11	417525	2334274
82	Box Culvert	1	9.2	0.48	2	3.65	4.13	4.54	417632	2334124
83	Box Culvert	1	10	1.24	2	2.58	3.82	4.26	417678	2334009
84	Box Culvert	1	10.25	1.29	1.95	2.87	4.16	4.56	417699	2333911
85	Box Culvert	1	10.2	1.46	3.3	2.81	4.27	4.77	417718	2333719
86	Bridge	3	37	3.85	7.3	94.02	97.87	5.61	2312998	424150
87	Bridge	3	37	3.85	7.3	94.02	99.16	5.61	2312963	424165
88	Bridge	3	37	3.85	7.3	94.02	98.87	5.61	2313373	423949
89	Bridge	1	14.5	3.43	7.4	0.16	3.59	5.2	2313362	423953
90	Bridge	1	14	3.75	7.4	0.03	3.78	5.34	2313418	423936
91	Bridge	5	50	4.52	7.3	2.19	6.71	7.48	2313860	423641
92	Bridge	3	36	5	7.4	-0.64	4.36	6.51	2315367	423324
93	Bridge	1	40	3.6	10.5	-0.88	2.72	5.25	2326331	421022
94	Box Culvert	1	10.3	2.3	2	0.7	3	3.14	2326849	420772
95	Bridge	1	16	4.23	8	-0.89	3.342	4.689	420479	2327653
96	Box Culvert	1	9.6	2.29	7.3	0.67	2.96	3.83	420399	2327953
97	Box Culvert	1	10	0.37	7.3	4.38	4.75	5.55	422516	2338686
98	Bridge	1	16	3.68	7.3	0.64	4.32	5	412639	2338344
99	Bridge	3	59	5.4	7.3	5.4	4.69	5.83	412776	2338043
100	Bridge	3	59	5.4	7.3	5.4	3.75	6.58	412801	2337991
101	Bridge	3	59	5.4	7.3	5.4	4.53	5.71	412766	2338049
102	Box Culvert	1	9.6	0.99	3.35	2.87	3.86	4.84	413283	2337661
103	Box Culvert	1	10.2	1.574	3.5	3.853	5.427	5.712	418841	2331018

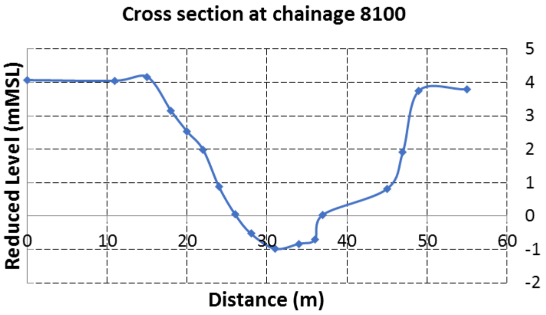
SL	Structure Type	No. of Vent	Barel Length (m)	Opening		Reduced Level (mMSL)			Position (UTM)	
				Height (m)	Width (m)	Sill (m)	Soffit (m)	Deck (m)	Northing (m)	Easting (m)
104	Box Culvert	1	9.65	2.04	4.8	2.72	4.76	6.21	415919	2336395
105	Box Culvert	1	12.6	3.582	7.4	-0.291	3.291	4.583	420488	2327648
106	Box Culvert	1	7.4	2.579	8.4	2.325	4.904	5.734	422537	2317535
107	Box Culvert	1	10.2	1.498	1.3	3.396	4.894	5.042	422476	2317692
108	Bridge	3	34	2.91	7	1.97	4.55	5.52	423494	2314505
109	Bridge	3	38.7	7.4	3.17	0.51	3.07	3.88	424641	2312199

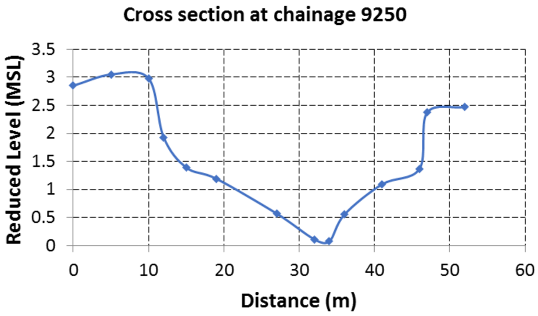
Appendix C: List of Khals and Cross Section along the Transmission Main

Khal ID	Chainage* (m)	X-coordinate (UTM)	Y-coordinate (UTM)
Khal#01	8100	427013	2307349
Khal#02	9250	426951	2308650
Khal#03	11600	426341	2310358
Khal#04	12030	426050	2310594
Khal#05	12110	425912	2310728
Khal#06	12600	425520	2311000
Khal#07	12650	425482	2311026
Khal#08	12700	425466	2311062
Khal#09	14270	424630	2312250
Khal#10	15150	424149	2313020
Khal#11	15600	423925	2313396
Khal#12	16150	423652	2313857
Khal#13	16800	423459	2314493
Khal#14	17700	423317	2315425
Khal#15	20115	422534	2317553
Khal#16	20275	422497	2317684
Khal#17	20770	422337	2318204
Khal#18	21430	421995	2318684
Khal#19	22680	422114	2319827
Khal#20	23750	422471	2320875
Khal#21	24500	422517	2321687
Khal#22	25000	422435	2322226
Khal#23	27990	421224	2324819
Khal#24	28440	421189	2325317
Khal#25	29500	420983	2326359
Khal#26	30050	420751	2326870
Khal#27	30900	420491	2327518
Khal#28	31200	420418	2327938
Khal#29	31730	420040	2328008
Khal#30	32910	419664	2328947
Khal#31	33110	419628	2329140
Khal#32	33430	413534	2337613
Khal#33	33530	419434	2329527
Khal#34	33750	419440	2329723
Khal#35	34460	419311	2330417
Khal#36	34940	419102	2330814
Khal#37	35200	418863	2330962
Khal#38	35225	418816	2330961
Khal#39	35235	418828	2331020
Khal#40	35710	418649	2331407
Khal#41	35930	418568	2331600
Khal#42	36170	418490	2331842
Khal#43	36240	418475	2331920
Khal#44	37100	418137	2332686

Khal ID	Chainage* (m)	X-coordinate (UTM)	Y-coordinate (UTM)
Khal#45	37520	418018	2333119
Khal#46	37820	417855	2333388
Khal#47	38040	417735	2333554
Khal#48	38150	417698	2333719
Khal#49	38300	417701	2333919
Khal#50	38450	417678	2333988
Khal#51	38560	417612	2334110
Khal#52	38760	417506	2334264
Khal#53	39460	416988	2334723
Khal#54	40280	416411	2335528
Khal#55	41550	415906	2336397
Khal#56	42850	414942	2337148
Khal#57	43520	414423	2337447
Khal#58	44670	413290	2337653
Khal#59	45325	412799	2337976
Khal#60	45675	412622	2338353
Khal#61	46030	412505	2338693

*Chainage are measured at Sabrang zero point with coordinate 426270, 2301426


Cross section at chainage 8100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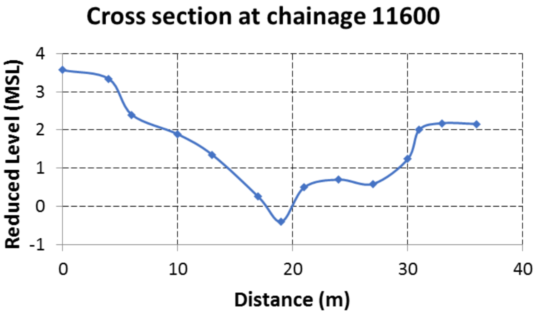
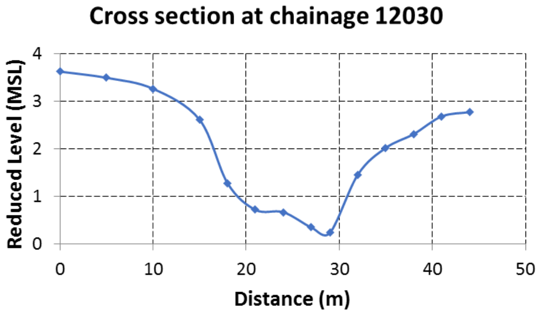

Cross section at chainage 11600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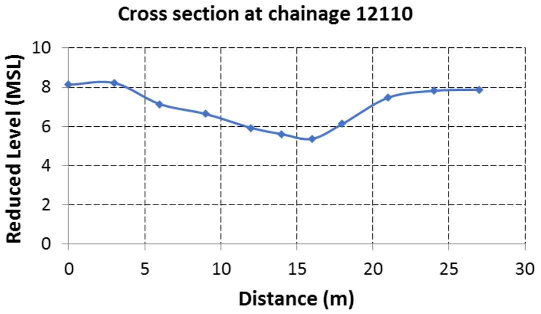
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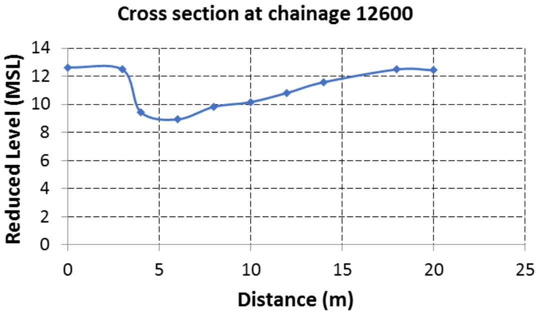
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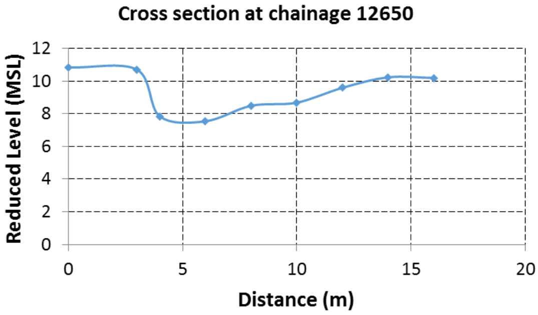
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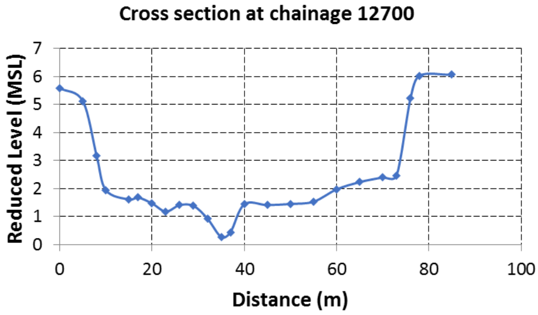
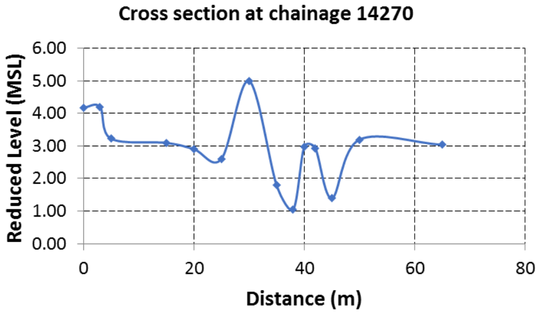
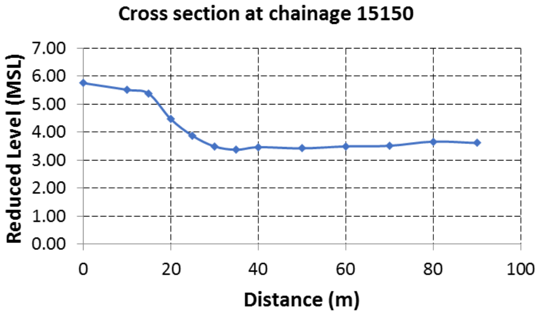
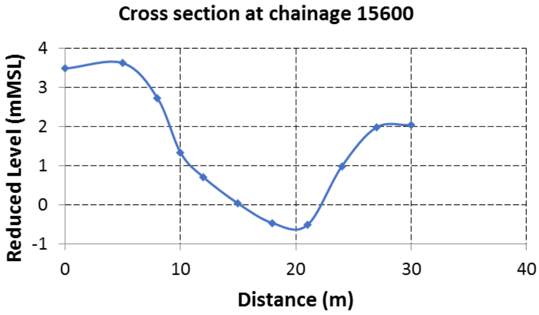

Cross section at chainage 12700


Cross section at chainage 14270


Cross section at chainage 15150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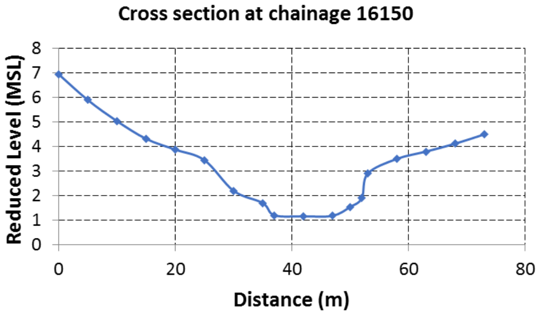
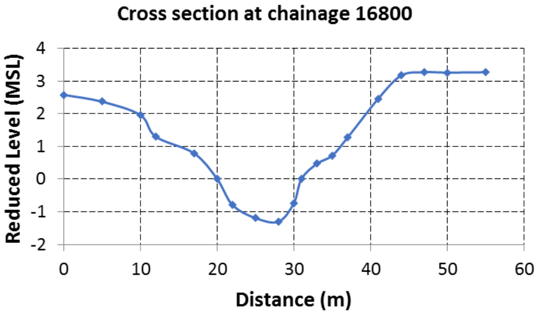
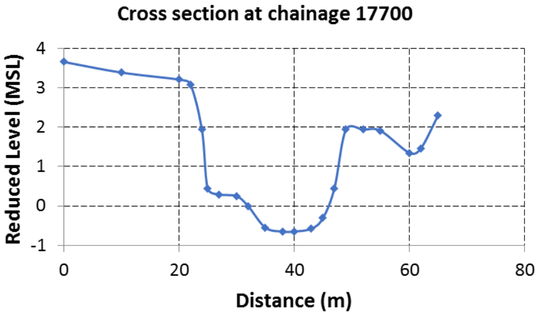
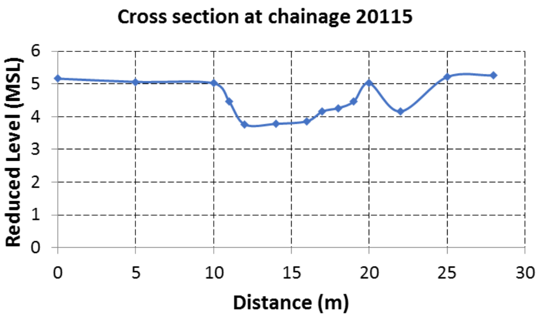
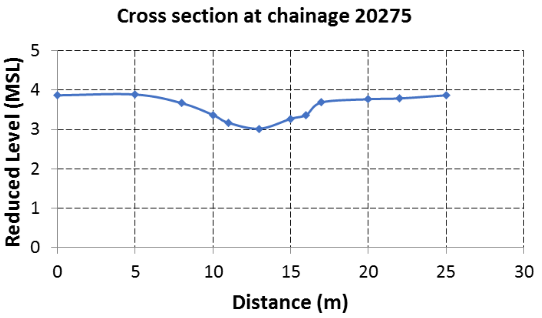
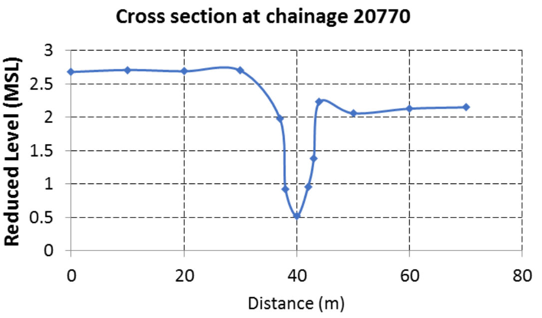

Cross section at chainage 16150


Cross section at chainage 16800


Cross section at chainage 17700


Cross section at chainage 20115
Reduced Level (MSL)
Distance (m)
0
1
2
3
4
5
6
0
5
10
15
20
25
30


Cross section at chainage 20275
Reduced Level (MSL)
Distance (m)
0
1
2
3
4
5
0
5
10
15
20
25
30


Cross section at chainage 20770
Reduced Level (MSL)
Distance (m)
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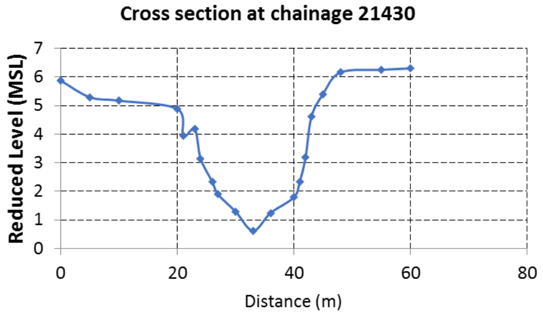
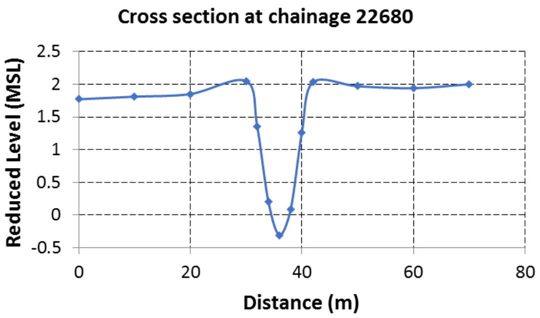
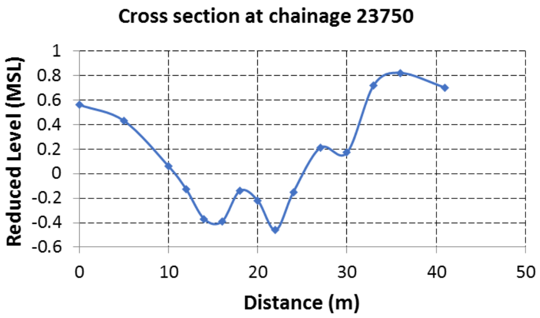
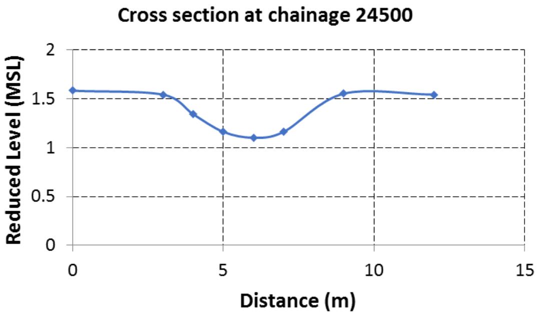
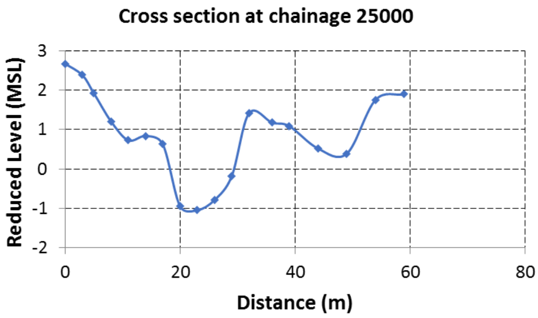
0.5
1
1.5
2
2.5
3
0
20
40
60
80

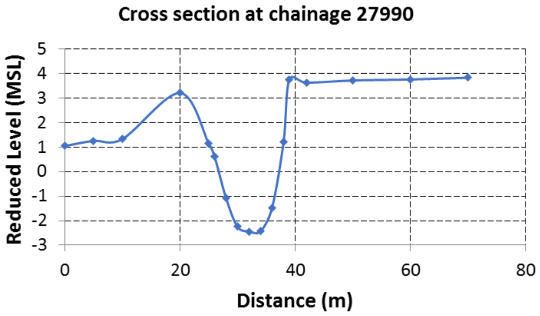

Cross section at chainage 21430
Reduced Level (MSL)
Distance (m)
0
1
2
3
4
5
6
7
0
20
40
60
80

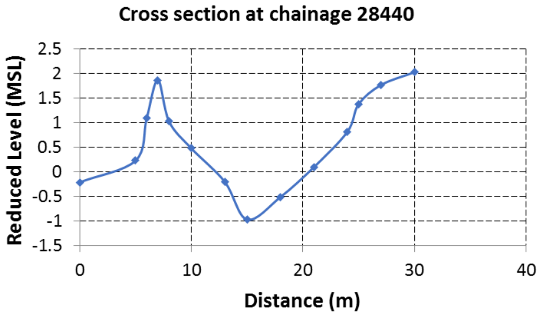

Cross section at chainage 22680
Reduced Level (MSL)
Distance (m)
-0.5
0
0.5
1
1.5
2
2.5
0
20
40
60
80

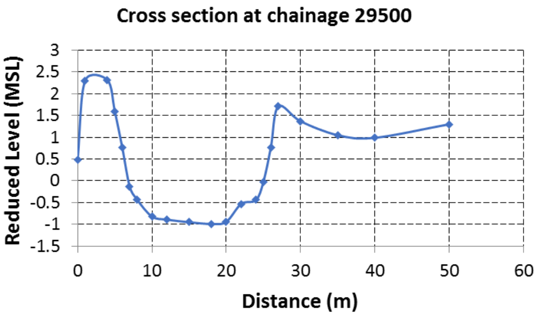

Cross section at chainage 23750
Reduced Level (MSL)
Distance (m)
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
0
10
20
30
40
50

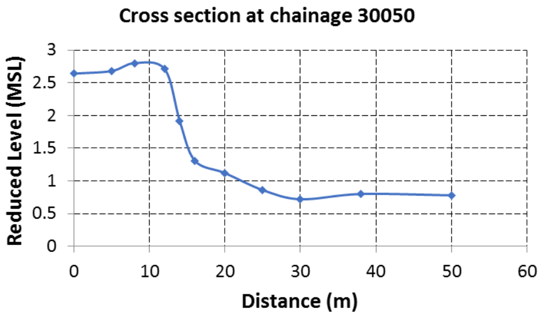

Cross section at chainage 24500
Reduced Level (MSL)
Distance (m)
0
0.5
1
1.5
2
0
5
10
15

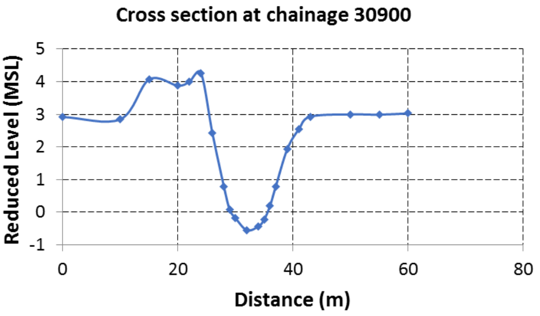

Cross section at chainage 25000
Reduced Level (MSL)
Distance (m)
-2
-1
0
1
2
3
0
20
40
60
80

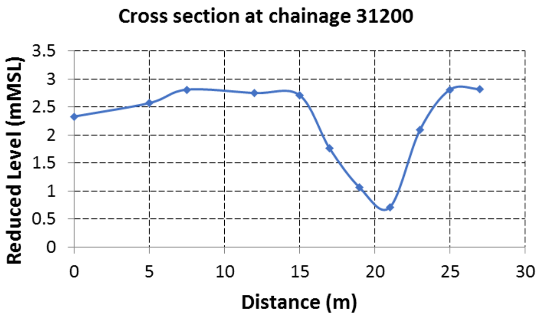

Cross section at chainage 27990
Reduced Level (MSL)
Distance (m)
-3
-2
-1
0
1
2
3
4
5
0
20
40
60
80

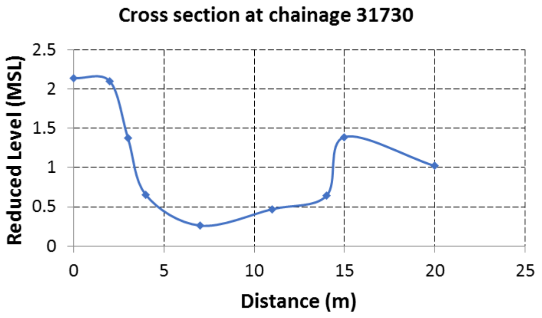

Cross section at chainage 28440
Reduced Level (MSL)
Distance (m)
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
0
10
20
30
40

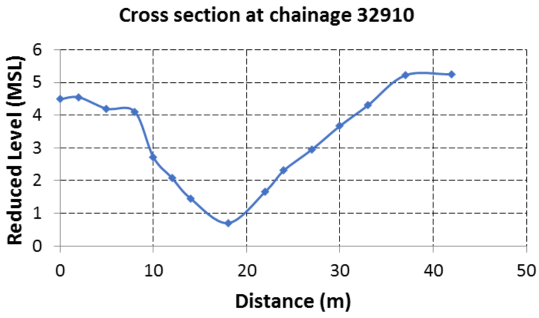

Cross section at chainage 29500
Reduced Level (MSL)
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
10
20
30
40
50
60
Distance (m)

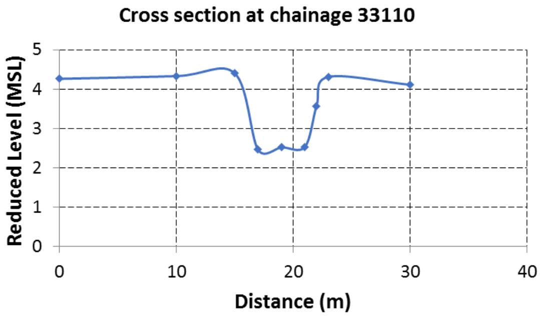

Cross section at chainage 30050
Reduced Level (MSL)
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
Distance (m)

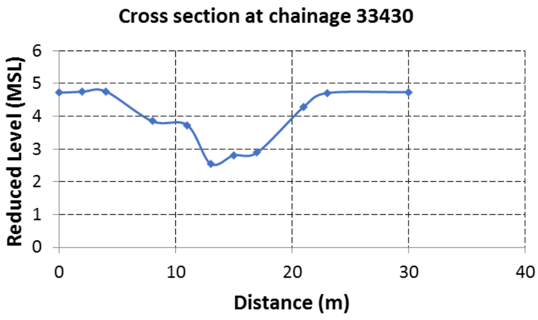

Cross section at chainage 30900
Reduced Level (MSL)
5
4
3
2
1
0
-1
0
20
40
60
80
Distance (m)

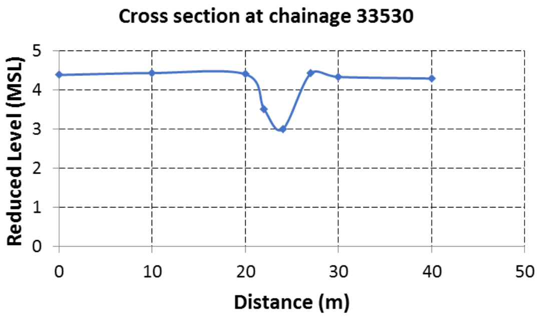

Cross section at chainage 31200
Reduced Level (mMSL)
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
Distance (m)

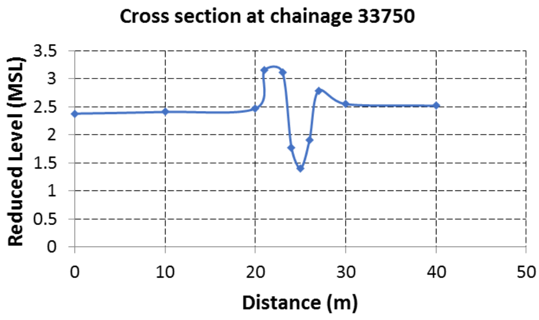

Cross section at chainage 31730
Reduced Level (MSL)
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
Distance (m)

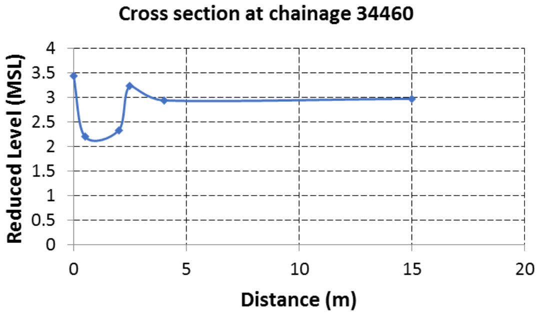

Cross section at chainage 32910
Reduced Level (MSL)
6
5
4
3
2
1
0
0
10
20
30
40
50
Distance (m)

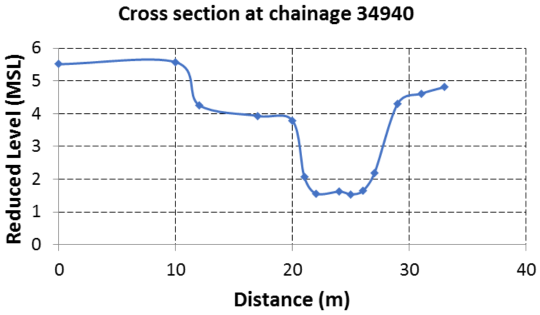

Cross section at chainage 33110
Reduced Level (MSL)
5
4
3
2
1
0
0
10
20
30
40
Distance (m)

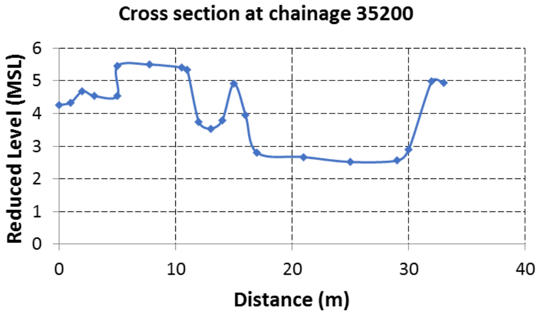

Cross section at chainage 33430
Reduced Level (MSL)
6
5
4
3
2
1
0
0
10
20
30
40
Distance (m)

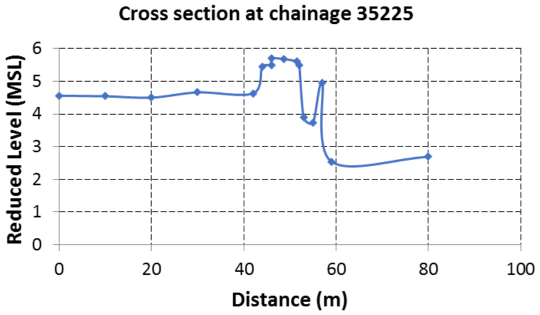

Cross section at chainage 33530
Reduced Level (MSL)
5
4
3
2
1
0
0
10
20
30
40
50
Distance (m)

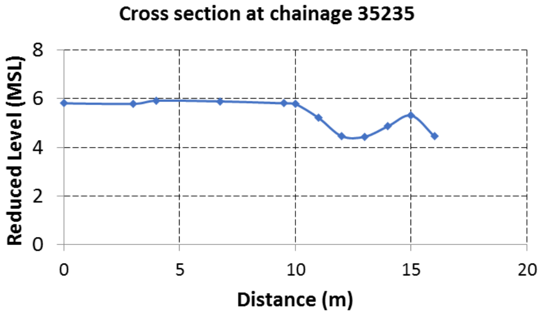

Cross section at chainage 33750
Reduced Level (MSL)
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
Distance (m)

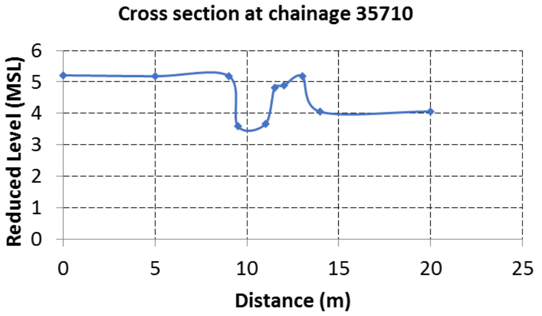

Cross section at chainage 34460
Reduced Level (MSL)
Distance (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
5
10
15
20

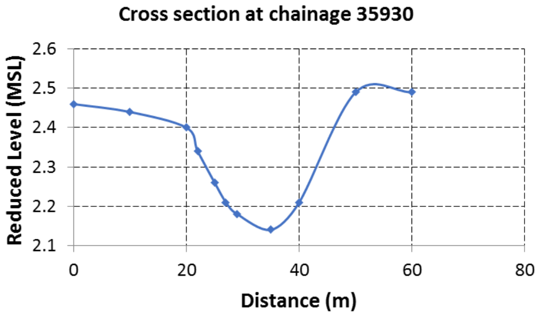

Cross section at chainage 34940
Reduced Level (MSL)
Distance (m)
0
1
2
3
4
5
6
0
10
20
30
40

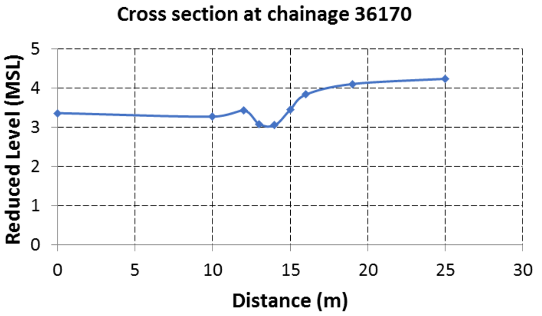

Cross section at chainage 35200
Reduced Level (MSL)
Distance (m)
0
1
2
3
4
5
6
0
10
20
30
40

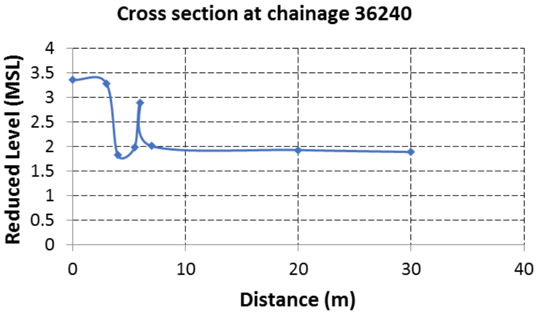

Cross section at chainage 35225
Reduced Level (MSL)
Distance (m)
0
1
2
3
4
5
6
0
20
40
60
80
100

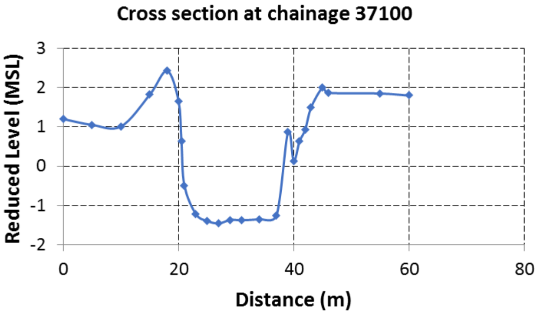

Cross section at chainage 35235
Reduced Level (MSL)
Distance (m)
0
2
4
6
8
0
5
10
15
20

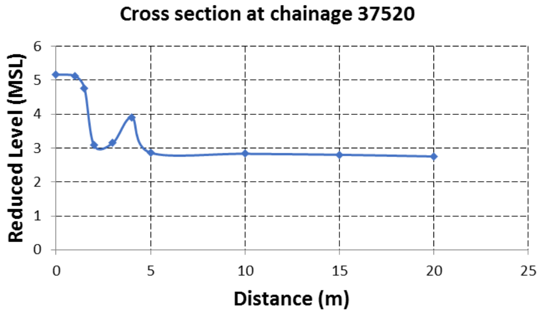

Cross section at chainage 35710
Reduced Level (MSL)
Distance (m)
0
1
2
3
4
5
6
0
5
10
15
20
25

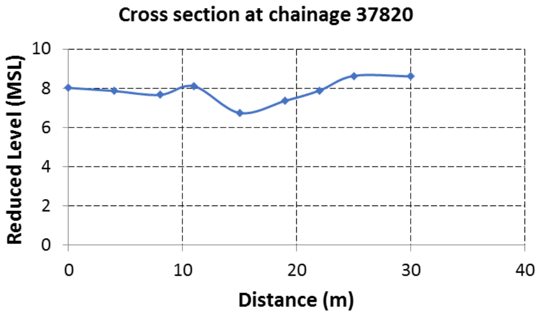

Cross section at chainage 35930
Reduced Level (MSL)
Distance (m)
2.1
2.2
2.3
2.4
2.5
2.6
0
20
40
60
80

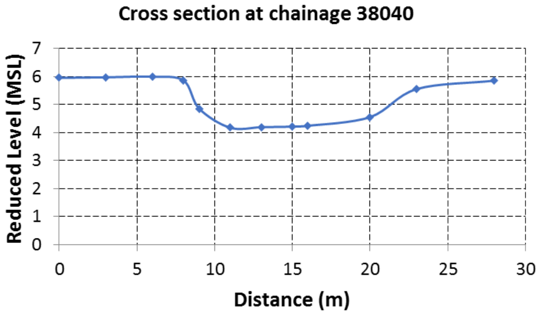

Cross section at chainage 36170
Reduced Level (MSL)
Distance (m)
0
1
2
3
4
5
0
5
10
15
20
25
30

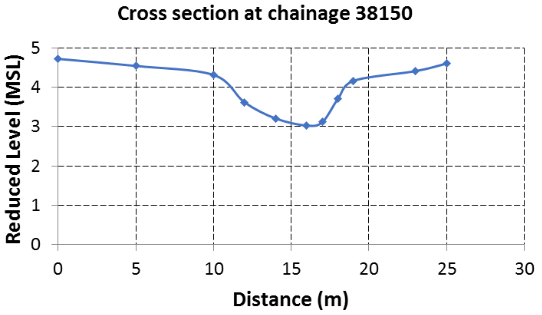

Cross section at chainage 36240
Reduced Level (MSL)
Distance (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
10
20
30
40

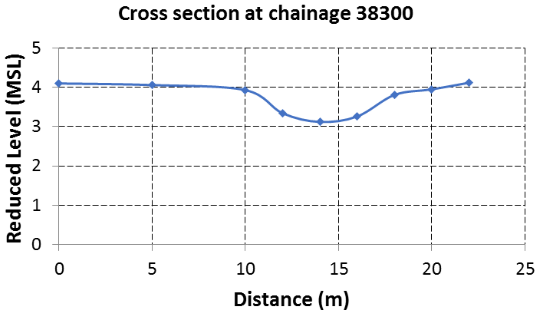

Cross section at chainage 37100
Reduced Level (MSL)
Distance (m)
-2
-1
0
1
2
3
0
20
40
60
80

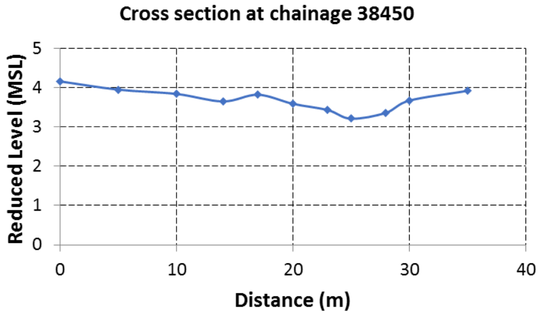

Cross section at chainage 37520

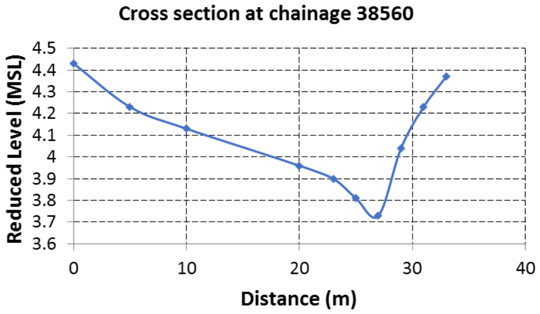

Cross section at chainage 37820

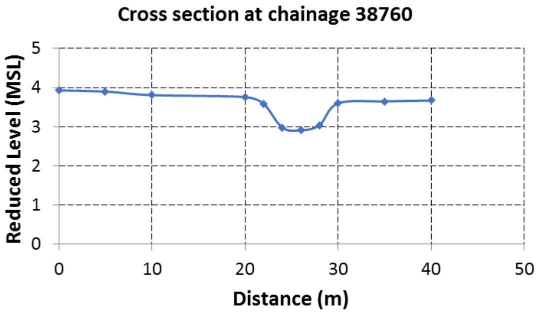

Cross section at chainage 38040

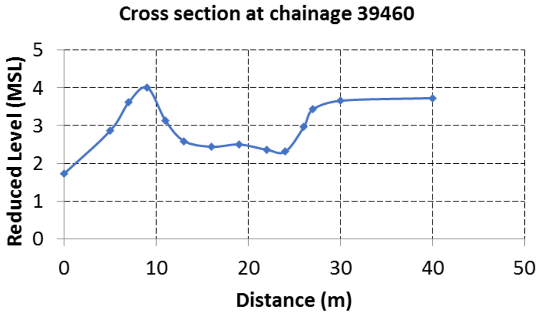

Cross section at chainage 38150

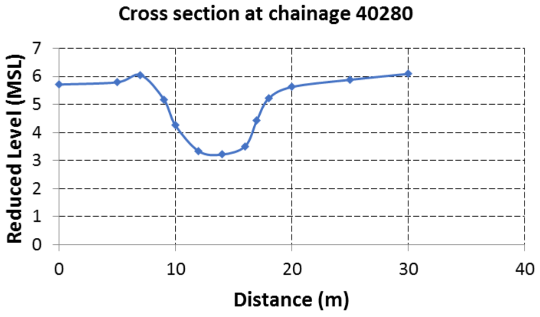

Cross section at chainage 38300

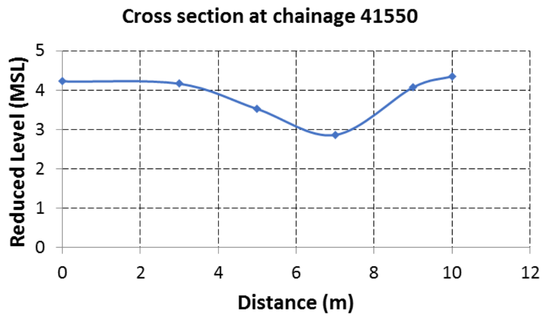

Cross section at chainage 38450

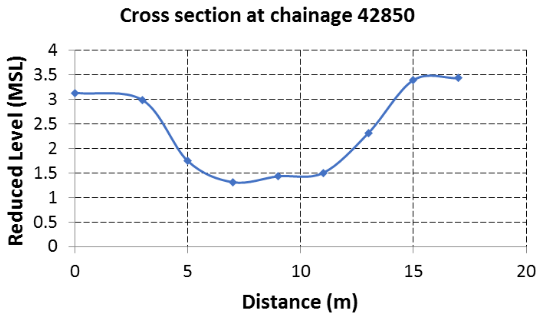

Cross section at chainage 38560

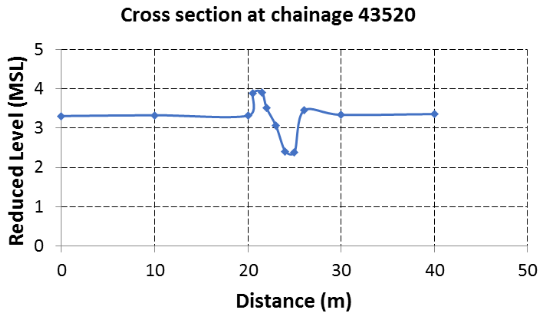

Cross section at chainage 38760

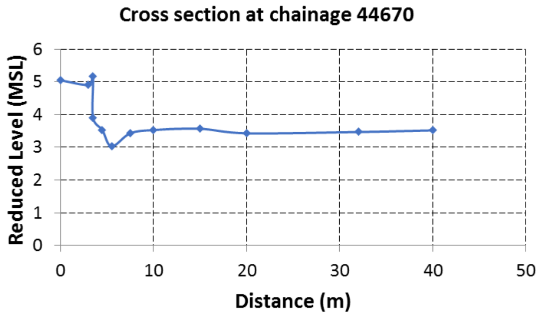

Cross section at chainage 39460

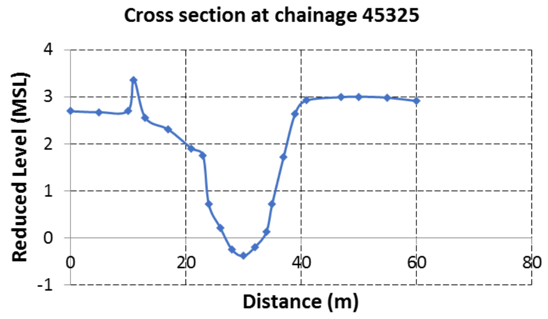

Cross section at chainage 40280

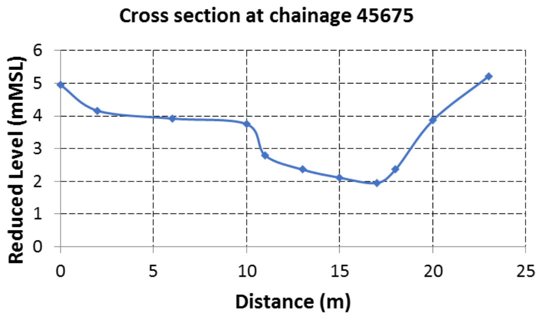

Cross section at chainage 41550

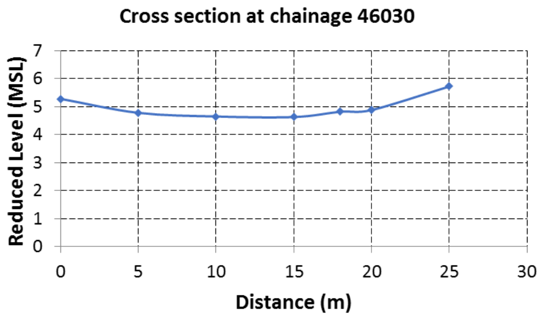

Cross section at chainage 42850


Cross section at chainage 43520


Cross section at chainage 44670


Cross section at chainage 45325


Cross section at chainage 45675


Cross section at chainage 46030

Appendix D: List of structures with crossing of khal/bridge/culvert

SL No.	Structure Type	No. of Vent	Barel Length (m)	Height (m)	Sill (m)	Soffit (m)	Northing	Easting	Crossing Type
1	Box Culvert	1	10.50	0.80	3.09	3.88	2330281	419413	Under Bed
2	Box Culvert	1	10.20	1.574	3.853	5.43	2331018	418841	Under Bed
3	Box Culvert	1	10.00	1.340	2.150	3.49	2330418	419312	Under Bed
4	Box Culvert	1	9.65	2.040	2.720	4.76	2336395	415919	Under Bed
5	Box Culvert	1	10.00	1.38	1.74	3.12	2330592	419189	Under Bed
6	Box Culvert	1	12.60	3.582	0.291	3.29	2327648	420488	Under Bed
7	Bridge	1	14.20	1.88	2.28	4.16	2330826	419079	Under Bed
8	Box Culvert	1	7.40	2.579	2.325	4.90	2317535	422537	Under Bed
9	Box Culvert	1	10.20	1.498	3.396	4.89	2317692	422476	Under Bed
10	Box Culvert	1	10.50	1.740	3.240	4.98	2330966	418870	Under Bed
11	Bridge	3	34.00	2.91	1.97	4.55	2314505	423494	Hanging
12	Box Culvert	1	10.50	1.49	-	9.34	2331232	418724	Under Bed
13	Bridge	3	38.70	7.40	0.51	3.07	2312199	424641	Hanging
14	Box Culvert	1	10.50	1.490	3.640	5.13	2331424	418634	Under Bed
15	Box Culvert	1	10.20	1.750	1.300	3.05	2331627	418575	Under Bed
16	Box Culvert	1	10.50	0.870	2.800	3.07	2331857	418495	Under Bed
17	Box Culvert	1	10.50	0.880	1.810	2.69	2331916	418467	Under Bed
18	Bridge	3	37.00	6.08	-1.71	4.37	2332737	418156	Hanging
19	Box Culvert	1	10.00	1.230	3.500	4.73	2333125	418009	Under Bed
20	Box Culvert	1	10.00	1.860	6.120	7.98	2333380	417872	Under Bed
21	Box Culvert	1	10.00	1.320	3.940	5.26	2333564	417760	Under Bed
22	Bridge	3	39.00	3.72	6.80	3.08	2308641	426966	Hanging
23	Box Culvert	1	9.20	3.30	3.67	6.97	2309262	426964	Under Bed
24	Box Culvert	1	9.35	2.51	2.86	5.37	2309690	427110	Under Bed
25	Bridge	3	30.00	4.61	0.14	4.75	2318133	422349	Hanging
26	Box Culvert	1	9.60	2.64	3.00	5.64	2318442	422191	Under Bed
27	Bridge	3	38.00	5.00	1.61	6.61	2318698	421970	Hanging
28	Box Culvert	1	10.00	0.82	8.29	9.11	2318991	421884	Under Bed
29	Bridge	3	30.00	1.89	1.08	2.97	2319872	422124	Hanging
30	Bridge	3	31.50	3.09	0.17	3.26	2328026	420063	Hanging
31	Box Culvert	1	18.00	4.450	0.670	5.12	2328944	419633	Hanging
32	Box Culvert	1	7.00	1.720	2.170	3.89	2329159	419625	Under Bed
33	Box Culvert	1	10.00	0.69	2.56	3.25	2329311	419529	Under Bed
34	Box Culvert	1	7.00	1.190	2.790	3.98	2329544	419437	Under Bed
35	Box Culvert	1	7.30	1.620	1.230	2.85	2329744	419448	Under Bed
36	Box Culvert	1	10.00	0.88	1.84	2.77	2329994	419449	Under Bed
37	Box Culvert	1	12.20	2.360	1.950	4.31	2337472	414397	Under Bed
38	Bridge	3	30.20	4.37	0.65	5.02	2337522	414216	Hanging
39	Box Culvert	1	9.50	1.11	2.01	3.12	2337565	413910	Under Bed
40	Box Culvert	1	9.50	0.85	3.05	3.90	2337598	413640	Under Bed
41	Box Culvert	1	10.45	2.940	2.230	5.17	2337625	413526	Under Bed
42	Box Culvert	1	7.90	1.52	2.20	3.64	2306548	426380	Under Bed
43	Bridge	3	35.30	2.80	1.81	4.61	2311266	425220	Hanging

SL No.	Structure Type	No. of Vent	Barel Length (m)	Height (m)	Sill (m)	Soffit (m)	Northing	Easting	Crossing Type
44	Bridge	3	37.20	1.68	0.91	2.59	2307338	426997	Hanging
45	Box Culvert	1	6.10	1.12	2.91	4.03	2306590	426492	Under Bed
46	Box Culvert	1	4.30	0.75	6.14	6.89	2306342	425561	Under Bed
47	Box Culvert	1	8.20	0.57	4.38	4.95	2305727	425262	Under Bed
48	Box Culvert	1	6.20	7.60	10.58	2.98	2305474	424759	Hanging
49	Box Culvert	1	7.90	1.33	1.81	3.14	2305416	424576	Under Bed
50	Box Culvert	1	10.00	1.26	2.54	3.80	2311546	425061	Under Bed
51	Box Culvert	1	7.30	0.88	2.89	3.69	2311783	424910	Under Bed
52	Box Culvert	1	7.30	2.68	0.73	3.41	2311916	424812	Under Bed
53	Bridge	2	23.80	3.87	0.66	4.53	2310357	426339	Under Bed
54	Box Culvert	1	7.50	0.53	6.07	6.61	2310454	426175	Under Bed
55	Box Culvert	1	8.20	0.91	4.53	5.44	2310505	426122	Under Bed
56	Bridge	1	22.50	5.06	0.21	5.28	2310588	426039	Hanging
57	Box Culvert	1	10.00	2.36	4.72	7.08	2310675	425974	Under Bed
58	Box Culvert	1	10.25	2.568	4.660	7.23	2310739	425920	Under Bed
59	Box Culvert	1	10.20	1.42	4.03	5.45	2310868	425751	Under Bed
60	Bridge	3	30.40	4.90	0.06	4.96	2310906	425700	Hanging
61	Box Culvert	1	10.90	2.590	8.920	11.49	2311002	425522	Under Bed
62	Box Culvert	1	9.40	2.269	7.540	9.81	2311033	425479	Under Bed
63	Bridge	3	41.70	4.86	0.95	5.81	2311063	425433	Hanging
64	Bridge	2	13.25	2.91	-0.94	3.85	2320957	422523	Under Bed
65	Box Culvert	1	9.50	1.682	0.550	2.23	2321696	422526	Under Bed
66	Bridge	3	47.75	1.86	1.13	2.99	2322199	422448	Hanging
67	Bridge	2	10.30	3.90	3.06	6.97	2336084	416094	Under Bed
68	Box Culvert	1	9.60	1.20	3.33	4.53	2336858	415439	Under Bed
69	Box Culvert	1	10.30	1.52	0.93	2.45	2323058	422262	Under Bed
70	Box Culvert	1	9.50	1.24	1.06	2.30	2323207	422181	Under Bed
71	Box Culvert	1	11.40	1.60	0.72	2.33	2323453	421980	Under Bed
72	Box Culvert	1	9.60	1.233	1.456	2.69	2337074	415148	Under Bed
73	Bridge	1	15.00	3.07	1.28	4.35	2337139	414932	Under Bed
74	Box Culvert	1	11.00	0.920	1.090	2.01	2324005	421569	Under Bed
75	Box Culvert	1	9.20	1.45	0.78	2.23	2324225	421439	Under Bed
76	Bridge	3	32.00	5.43	-2.46	2.97	2324844	421239	Hanging
77	Box Culvert	1	11.00	2.910	-1.22	1.69	2325314	421199	Under Bed
78	Box Culvert	1	9.00	1.20	1.21	2.32	2325663	421168	Under Bed
79	Box Culvert	1	10.00	0.69	1.80	2.49	2325890	421144	Under Bed
80	Box Culvert	1	10.00	1.40	1.12	2.52	2334537	417224	Under Bed
81	Box Culvert	1	9.00	1.190	2.250	3.44	2334736	416979	Under Bed
82	Bridge	3	77.00	6.06	-1.06	5.00	2335045	416708	Hanging
83	Box Culvert	1	9.00	1.440	3.520	4.96	2335373	416573	Under Bed
84	Box Culvert	1	7.00	2.730	3.090	5.82	2335535	416507	Under Bed
85	Box Culvert	1	9.00	2.030	6.150	8.18	2335809	416247	Under Bed
86	Box Culvert	1	12.20	3.350	1.580	4.93	2334433	417349	Under Bed
87	Box Culvert	1	10.00	0.750	2.780	3.53	2334274	417525	Under Bed
88	Box Culvert	1	9.20	0.480	3.650	4.13	2334124	417632	Under Bed

SL No.	Structure Type	No. of Vent	Barel Length (m)	Height (m)	Sill (m)	Soffit (m)	Northing	Easting	Crossing Type
89	Box Culvert	1	10.00	1.240	2.580	3.82	2334009	417678	Under Bed
90	Box Culvert	1	10.25	1.290	2.870	4.16	2333911	417699	Under Bed
91	Box Culvert	1	10.20	1.460	2.810	4.27	2333719	417718	Under Bed
92	Bridge	3	37.00	3.85	94.02	97.87	2312998	424150	Hanging
93	Bridge	3	37.00	3.85	94.02	99.16	2312963	424165	Hanging
94	Bridge	3	37.00	3.85	94.02	98.87	2313373	423949	Hanging
95	Bridge	1	14.50	3.43	0.16	3.59	2313362	423953	Under Bed
96	Bridge	1	14.00	3.75	0.03	3.78	2313418	423936	Under Bed
97	Bridge	5	50.00	4.52	2.19	6.71	2313860	423641	Hanging
98	Bridge	3	36.00	5.00	-0.64	4.36	2315367	423324	Hanging
99	Bridge	1	40.00	3.60	-0.88	2.72	2326331	421022	Hanging
100	Box Culvert	1	10.30	2.300	0.700	3.00	2326849	420772	Under Bed
101	Box Culvert	1	9.60	2.290	0.670	2.96	2327953	420399	Under Bed
102	Box Culvert	1	10.00	0.370	4.380	4.75	2338686	412516	Under Bed
103	Bridge	1	16.00	3.68	0.64	4.32	2338344	412639	Under Bed
104	Bridge	3	59.00	5.40	5.40	4.69	2338043	412776	Hanging
105	Bridge	3	59.00	5.40	5.40	3.75	2337991	412801	Hanging
106	Bridge	3	59.00	5.40	5.40	4.53	2338049	412766	Hanging
107	Box Culvert	1	9.60	0.990	2.870	3.86	2337661	413283	Under Bed

Appendix E: Water Demand Estimation in Naf Tourism Park

Population Projection

In the Detailed Master Plan (DMP) of Naf Tourism Park (December, 2020), it is proposed that maximum about 4,163 nos. of tourist will visit and may stay at night in the Tourism Park daily. To serve and facilitate the tourists, about 1,719 nos. employee is required in different land usages. Thus, total population projected for the tourism park is about 5,880 nos. The population projection for different facilities is presented in **Table E.1**.

Table E.1: Population projection of Naf Tourism Park

Facilities	Tourist (Nos.)	Work Force (Nos.)	Total population (Nos.)
Hotel	2831	755	3586
Service Studio Apartment	912	114	1026
Cottage	420	168	588
Central Plaza		185	185
Cable Car and Fire Station		21	21
Electrical Sub-station		17	17
Fire Safety Staff		17	17
Helipad		20	20
Jetty		43	43
Law Enforcement		30	30
Parking Area		32	32
Power House		14	14
Pump and Gas Station		17	17
Rest Room		17	17
Restaurant		61	61
Security Staff		54	54
Service Staff		55	55
Solid waste and e-waste plants		67	67
STPs		18	18
Water Reservoir		20	20
Total	**4,163**	**1,719**	**5,882**

Water Demand

Water demand is calculated based on the per capita demand recommended in BNBC and population projection for Naf Tourism Park as shown in **Table E.1**. Considering water availability, full facilities is considered only for the Hotels and restricted facilities for other usages. Thus, the total water required is estimated as 1.35 MLD after completing all structural development and full operation of Tourism Park in 2031 as mentioned in DMP of Naf Tourism Park (December, 2020). The water requirement at different phases as mentioned in the DMP is presented in **Table E.2.** The detailed water demand estimation is stated in **Table E.3** to **Table E.4.**

Table E.2: Estimated water demand for Naf Tourism Park

Usage	Water Requirement (Litre/day)		
	Phase-1 2021-24*	Phase-2 2024-31*	Total
Total demand at user end	0.56	0.54	1.10
Maximum Day Water Requirement for Distribution System	0.62	0.60	1.22
Water Treatment Capacity to be Installed	0.69	0.67	1.35

Duration of phases is taken from DMP of Naf Tourism Park (December, 2020)

10% loss of water is considered in the transmission main and in the distribution network.

Table E.3: Estimated water demand for Naf Tourism Park in Phase-1 (2021-2024)

Sl. No.	Facilities	Area (Acre)	Number of Plots	Tourist per Plot (Nos.)	Work force per category (Nos.)	Total Population (Nos.)	Water Demand (lpcd)	Tourist Demand (L/d)	Work force Demand (L/d)	Total water demand (L/d)
1	Hotel	21.71	2	1416	378	1793	300	424650	11325	435975
2	Service Studio Apartment	11.22	29	464	58	522	135	62640	1740	64380
3	Cottage	7.69	54	216	173	389	135	29160	5184	34344
4	Central Plaza	9.33	0.5	0	93	93	30	0	2775	2775
5	Cable Car and Fire Station	1.03	1	0	21	21	30	0	630	630
6	Electrical Sub-station	0.83	1	0	17	17	30	0	510	510
7	Fire Safety Staff	0.82	1	0	17	17	30	0	510	510
8	Helipad	1.94	1	0	20	20	30	0	600	600
9	Jetty	4.21	1	0	43	43	30	0	1290	1290
10	Law Enforcement	1.49	1	0	30	30	30	0	900	900
11	Parking Area	0.00	0	0	0	0	30	0	0	0
12	Power House	0.71	1	0	14	14	30	14000	420	14420
13	Pump and Gas Station	0.82	1	0	17	17	30	0	510	510
14	Rest Room	0.00	0	0	0	0	30	0	0	0
15	Restaurant	0.61	2	0	24	24	30	0	732	732
16	Security Staff	0.00	0	0	0	0	30	0	0	0
17	Service Staff	0.00	0	0	0	0	30	0	0	0
18	Solid waste and e-waste Plant-1	0.00	0	0	0	0	30	0	0	0
19	Solid waste and e-waste plant-2	0.00	0	0	0	0	30	0	0	0
20	STP-1	0.08	1	0	6	6	30	0	180	180
21	STP-2	0.00	0	0	0	0	30	0	0	0
22	Water Reservoir	0.15	1	0	10	10	30	0	300	300
	Total			**2,096**	**920**	**3,016**				**558,056**

Table E.4: Estimated water demand for Naf Tourism Park in Phase-1 (2024-2031)

ID	Facilities	Area (Acre)	Number of Plots	Tourist per Plot (Nos.)	Work force per category (Nos.)	Total Population (Nos.)	Water Demand (lpcd)	Tourist Demand (L/d)	Work force Demand (L/d)	Total water demand (L/d)
1	Hotel	21.71	2	1416	378	1793	300	424650	11325	435975
2	Service Studio Apartment	10.83	28	448	56	504	135	60480	1680	62160
3	Cottage	7.27	51	204	163	367	135	27540	4896	32436
4	Central Plaza	9.33	0.5	0	93	93	30	0	2775	2775
5	Cable Car and Fire Station	0.00	0	0	0	0	30	0	0	0
6	Electrical Sub-station	0.00	0	0	0	0	30	0	0	0
7	Fire Safety Staff	0.00	0	0	0	0	30	0	0	0
8	Helipad	0.00	0	0	0	0	30	0	0	0
9	Jetty	0.00	0	0	0	0	30	0	0	0
10	Law Enforcement	0.00	0	0	0	0	30	0	0	0
11	Parking Area	0.00	0	0	0	0	30	0	0	0
12	Power House	0.00	0	0	0	0	30	0	0	0
13	Pump and Gas Station	0.00	0	0	0	0	30	0	0	0
14	Rest Room	0.00	0	0	0	0	30	0	0	0
15	Restaurant	0.91	3	0	37	37	30	0	1098	1098
16	Security Staff	0.80	1	0	54	54	30	0	1620	1620
17	Service Staff	0.81	1	0	55	55	30	0	1650	1650
18	Solid waste and e-waste Plant-1	0.00	0	0	0	0	30	0	0	0
19	Solid waste and e-waste plant-2	0.58	1	0	39	39	30	0	1170	1170
20	STP-1	0.08	1	0	6	6	30	0	180	180
21	STP-2	0.00	0	0	0	0	30	0	0	0
22	Water Reservoir	0.15	1	0	10	10	30	0	300	300
	Total			**2,068**	**890**	**2,957**				**539,364**

Appendix F: Details of Model Output at Junctions for Naf Tourism Park

Table F.1: Details of Model Output at Junctions for Scenario 1

Phase	Label	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H_2O)
1	J-3	0.00	13.84	13.82
1	J-4	0.01	13.88	13.85
1	J-10	0.02	13.15	13.13
1	J-11	0.00	13.17	13.14
1	J-15	0.00	13.75	13.72
1	J-20	0.25	12.48	12.45
1	J-21	0.01	12.48	12.45
1	J-28	0.00	12.49	12.47
1	J-29	0.08	12.49	12.46
1	J-30	0.03	13.84	13.81
1	J-31	0.03	13.84	13.81
1	J-32	0.11	12.52	12.50
1	J-33	0.08	12.60	12.58
1	J-34	0.01	13.84	13.81
1	J-35	0.04	12.49	12.47
1	J-36	0.01	12.50	12.47
1	J-37	0.02	13.88	13.85
1	J-38	0.03	13.88	13.85
1	J-39	0.02	12.49	12.47
1	J-40	0.02	13.88	13.85
1	J-41	0.04	12.56	12.54
1	J-42	0.04	12.53	12.51
1	J-43	0.03	12.49	12.47
1	J-44	0.04	12.49	12.47
1	J-45	0.03	12.49	12.47
1	J-46	0.04	12.51	12.49
1	J-50	0.04	13.08	13.06
1	J-51	0.00	13.01	12.99
1	J-52	0.05	12.49	12.47
1	J-53	0.04	13.32	13.30
1	J-56	0.04	13.50	13.47
1	J-58	0.00	13.68	13.65
1	J-59	0.08	12.46	12.44
1	J-60	0.15	12.47	12.44
1	J-64	0.00	12.78	12.75
1	J-67	0.00	12.48	12.45
1	J-68	0.00	12.48	12.45
1	J-69	0.04	12.49	12.47
1	J-70	0.04	12.49	12.47
1	J-71	0.08	12.48	12.45
1	J-72	0.04	12.48	12.45

Phase	Label	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H_2O)
1	J-73	0.15	12.48	12.46
1	J-74	0.00	12.50	12.47
1	J-75	0.15	12.79	12.76
1	J-80	0.04	13.46	13.43
1	J-89	0.00	12.49	12.47
1	J-90	0.01	12.49	12.47
1	J-94	0.00	12.52	12.50
1	J-96	3.71	13.17	13.15
1	J-100	0.00	12.25	12.22
1	J-101	0.01	12.25	12.22
1	J-105	0.01	12.85	12.82
1	J-106	0.00	12.70	12.68
1	J-107	3.71	12.25	12.23
1	J-112	0.01	13.17	13.15
1	J-113	0.01	13.17	13.15
1	J-115	0.00	13.17	13.15
1	J-116	0.01	13.17	13.15
1	J-117	0.02	12.48	12.45
1	J-120	0.07	12.24	12.22
2	J-1	0.00	13.85	13.82
2	J-2	0.01	13.89	13.86
2	J-5	0.04	13.79	13.77
2	J-8	0.03	12.58	12.55
2	J-9	0.02	12.58	12.55
2	J-12	0.00	13.31	13.28
2	J-13	0.02	13.29	13.26
2	J-14	0.01	13.81	13.78
2	J-16	0.15	12.37	12.35
2	J-17	0.08	12.37	12.35
2	J-18	0.03	13.85	13.82
2	J-19	0.03	13.85	13.82
2	J-22	0.02	13.85	13.82
2	J-23	0.00	13.85	13.83
2	J-24	0.02	13.88	13.85
2	J-25	0.03	13.87	13.84
2	J-26	0.02	13.86	13.83
2	J-27	0.00	13.86	13.83
2	J-47	0.04	12.58	12.55
2	J-48	0.00	12.60	12.57
2	J-49	0.04	12.66	12.63
2	J-54	0.04	13.46	13.43
2	J-55	0.04	13.63	13.60
2	J-57	0.04	12.99	12.97
2	J-61	0.03	12.57	12.55

Phase	Label	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H_2O)
2	J-62	0.04	12.57	12.55
2	J-63	0.00	12.92	12.90
2	J-65	0.01	12.52	12.49
2	J-66	0.00	12.52	12.49
2	J-76	0.04	12.57	12.55
2	J-77	0.00	12.99	12.97
2	J-78	0.11	12.54	12.51
2	J-79	0.00	12.57	12.54
2	J-81	0.00	13.57	13.54
2	J-82	0.03	13.85	13.82
2	J-83	0.03	13.85	13.82
2	J-84	0.05	12.57	12.55
2	J-85	0.01	12.52	12.49
2	J-86	0.00	12.52	12.49
2	J-87	0.19	12.51	12.48
2	J-88	0.15	12.43	12.41
2	J-91	0.11	12.39	12.37
2	J-92	0.00	12.52	12.49
2	J-93	0.00	12.52	12.49
2	J-95	0.08	12.53	12.50
2	J-97	0.08	12.52	12.49
2	J-98	0.01	12.52	12.49
2	J-99	0.02	12.52	12.49
2	J-102	0.00	13.85	13.83
2	J-103	0.00	13.85	13.83
2	J-104	3.71	12.41	12.38
2	J-108	0.00	12.99	12.97
2	J-109	0.00	12.99	12.97
2	J-110	0.00	12.41	12.38
2	J-111	0.00	12.40	12.38
2	J-114	0.00	12.99	12.97
2	J-118	3.71	13.22	13.20
2	J-119	0.05	12.40	12.38

Appendix G: Summary of Pipe Diameter for Naf Tourism Park

Diameter (mm)	Pipe Length (m)		
	Phase 1	**Phase 2**	**Total**
75 mm	4172	4135	8307
110 mm	858	741	1599
160 mm	114	63	177
Total	5144	4939	10,083

Appendix H: Details of Model Output of Pipes for Naf Tourism Park

Table H.1: Details of Model Output of Pipes for Scenario 1

Phase Area	Label	Start Node	Stop Node	Diameter (mm)	Head loss Gradient (m/km)	Length (Scaled) (m)	Flow (L/s)	Velocity (m/s)
1	P-1	J-3	J-4	160	2.3	15.0	-6.5	0.4
1	P-2	R-1	J-4	160	4.6	26.0	9.5	0.6
1	P-3	J-10	J-11	110	0.6	32.0	-1.2	0.2
1	P-4	J-4	J-15	110	3.2	41.0	2.9	0.4
1	P-5	J-20	J-21	75	0.0	50.0	0.0	0.0
1	P-6	J-28	J-29	75	0.2	50.0	0.2	0.1
1	P-7	J-30	J-31	75	0.0	51.0	0.0	0.0
1	P-8	J-32	J-33	75	1.6	50.0	-0.7	0.2
1	P-9	J-31	J-34	75	0.0	51.0	0.0	0.0
1	P-10	J-3	J-30	75	0.0	51.0	0.1	0.0
1	P-11	J-35	J-36	75	0.1	54.0	-0.1	0.0
1	P-12	J-37	J-38	75	0.0	53.0	0.1	0.0
1	P-13	J-39	J-28	75	0.0	52.0	-0.1	0.0
1	P-14	J-4	J-37	75	0.0	53.0	0.1	0.0
1	P-15	J-38	J-40	75	0.0	53.0	0.0	0.0
1	P-16	J-41	J-42	75	0.5	54.0	0.4	0.1
1	P-17	J-43	J-44	75	0.0	59.0	0.0	0.0
1	P-18	J-45	J-43	75	0.0	59.0	0.1	0.0
1	P-19	J-42	J-46	75	0.4	54.0	0.4	0.1
1	P-20	J-46	J-28	75	0.3	54.0	0.3	0.1
1	P-21	J-44	J-39	75	0.0	59.0	0.0	0.0
1	P-22	J-36	J-45	75	0.0	59.0	0.1	0.0
1	P-23	J-50	J-51	110	1.1	63.0	1.6	0.2
1	P-24	J-39	J-52	75	0.0	65.0	0.1	0.0
1	P-25	J-10	J-53	110	2.7	65.0	-2.6	0.4
1	P-26	J-53	J-56	110	2.7	65.0	-2.7	0.4
1	P-27	J-56	J-58	110	2.8	65.0	-2.7	0.4
1	P-28	J-59	J-60	75	0.0	68.0	-0.1	0.0
1	P-29	J-64	J-10	110	5.3	71.0	-3.8	0.5
1	P-30	J-58	J-3	160	2.2	73.0	-6.4	0.4
1	P-31	J-11	J-50	110	1.2	75.0	1.7	0.2
1	P-32	J-67	J-68	75	0.0	80.0	0.0	0.0
1	P-33	J-69	J-70	75	0.0	100.0	0.0	0.0
1	P-34	J-71	J-72	75	0.0	83.0	0.1	0.0
1	P-35	J-73	J-32	75	0.5	83.0	-0.4	0.1
1	P-36	J-52	J-69	75	0.0	100.0	0.0	0.0
1	P-37	J-74	J-20	75	0.2	100.0	0.3	0.1
1	P-38	J-75	J-51	75	2.6	87.0	-0.9	0.3
1	P-39	J-70	J-35	75	0.0	100.0	-0.1	0.0
1	P-40	J-15	J-80	110	3.2	91.0	2.9	0.4
1	P-41	J-80	J-11	110	3.1	91.0	2.9	0.4

Phase Area	Label	Start Node	Stop Node	Diameter (mm)	Head loss Gradient (m/km)	Length (Scaled) (m)	Flow (L/s)	Velocity (m/s)
1	P-42	J-33	J-75	75	1.9	100.0	-0.8	0.2
1	P-43	J-89	J-90	75	0.0	98.0	0.0	0.0
1	P-44	J-60	J-73	75	0.2	100.0	-0.2	0.1
1	P-45	J-94	J-74	75	0.2	100.0	0.3	0.1
1	P-46	J-29	J-71	75	0.1	100.0	0.1	0.0
1	P-47	J-96	J-58	110	5.1	99.0	-3.7	0.5
1	P-48	J-100	J-101	75	0.0	100.0	-0.1	0.0
1	P-49	J-105	J-106	75	1.4	100.0	0.7	0.2
1	P-50	J-107	J-64	110	5.3	100.0	-3.8	0.5
1	P-51	J-72	J-67	75	0.0	100.0	0.0	0.0
1	P-52	J-112	J-113	75	0.0	100.0	0.0	0.0
1	P-53	J-101	J-107	75	0.0	100.0	-0.1	0.0
1	P-54	J-106	J-41	75	1.4	101.0	0.7	0.2
1	P-55	J-115	J-96	75	0.0	105.0	0.0	0.0
1	P-56	J-113	J-116	75	0.0	105.0	0.0	0.0
1	P-57	J-28	J-89	75	0.0	107.0	0.0	0.0
1	P-58	J-72	J-117	75	0.0	110.0	0.0	0.0
1	P-59	J-51	J-105	75	1.5	117.0	0.7	0.2
1	P-60	J-32	J-36	75	0.2	159.0	0.2	0.1
1	P-61	J-116	J-115	75	0.0	162.0	0.0	0.0
1	P-62	J-41	J-94	75	0.2	184.0	0.3	0.1
1	P-63	J-120	J-100	75	0.0	192.0	-0.1	0.0
2	P-64	J-1	J-2	110	2.5	14.0	-2.5	0.4
2	P-65	J-5	J-1	110	2.6	22.0	-2.6	0.4
2	P-66	R-2	J-2	160	4.3	27.0	9.2	0.6
2	P-67	J-8	J-9	75	0.1	31.0	-0.1	0.0
2	P-68	J-12	J-13	110	0.6	32.0	1.2	0.2
2	P-69	J-2	J-14	160	2.2	36.0	6.4	0.4
2	P-70	J-16	J-17	75	0.0	42.0	0.1	0.0
2	P-71	J-18	J-19	75	0.0	48.0	-0.1	0.0
2	P-72	J-22	J-18	75	0.0	48.0	0.0	0.0
2	P-73	J-1	J-22	75	0.0	48.0	0.0	0.0
2	P-74	J-19	J-23	75	0.0	48.0	-0.1	0.0
2	P-75	J-24	J-25	75	0.2	49.0	0.2	0.1
2	P-76	J-26	J-27	75	0.1	49.0	0.2	0.1
2	P-77	J-2	J-24	75	0.2	49.0	0.2	0.1
2	P-78	J-25	J-26	75	0.1	49.0	0.2	0.1
2	P-79	J-23	J-27	75	0.0	54.0	-0.1	0.0
2	P-80	J-9	J-47	75	0.1	58.0	0.1	0.0
2	P-81	J-48	J-49	75	1.0	58.0	-0.6	0.2
2	P-82	J-54	J-55	110	2.7	64.0	-2.6	0.4
2	P-83	J-49	J-57	75	4.7	71.0	-1.3	0.4
2	P-84	J-13	J-54	110	2.6	64.0	-2.6	0.4
2	P-85	J-55	J-14	110	2.8	64.0	-2.7	0.4

Phase Area	Label	Start Node	Stop Node	Diameter (mm)	Head loss Gradient (m/km)	Length (Scaled) (m)	Flow (L/s)	Velocity (m/s)
2	P-86	J-57	J-12	75	4.9	65.0	-1.3	0.4
2	P-87	J-61	J-62	75	0.0	100.0	0.0	0.0
2	P-88	J-13	J-63	110	5.2	71.0	3.8	0.5
2	P-89	J-65	J-66	75	0.0	75.0	0.0	0.0
2	P-90	J-48	J-9	75	0.3	76.0	0.3	0.1
2	P-91	J-76	J-8	75	0.0	100.0	-0.1	0.0
2	P-92	J-57	J-77	75	0.0	87.0	0.0	0.0
2	P-93	J-78	J-79	75	0.3	88.0	-0.3	0.1
2	P-94	J-81	J-5	110	2.5	91.0	-2.5	0.4
2	P-95	J-82	J-83	75	0.0	90.0	0.0	0.0
2	P-96	J-62	J-76	75	0.0	100.0	-0.1	0.0
2	P-97	J-84	J-61	75	0.0	100.0	0.0	0.0
2	P-98	J-85	J-86	75	0.0	100.0	0.0	0.0
2	P-99	J-87	J-88	75	0.8	100.0	0.5	0.2
2	P-100	J-91	J-16	75	0.2	100.0	0.2	0.1
2	P-101	J-92	J-93	75	0.0	99.0	0.0	0.0
2	P-102	J-95	J-78	75	0.1	100.0	-0.2	0.1
2	P-103	J-47	J-84	75	0.0	100.0	0.1	0.0
2	P-104	J-93	J-97	75	0.0	101.0	0.0	0.0
2	P-105	J-79	J-48	75	0.3	100.0	-0.3	0.1
2	P-106	J-88	J-91	75	0.4	100.0	0.3	0.1
2	P-107	J-98	J-85	75	0.0	100.0	0.0	0.0
2	P-108	J-97	J-95	75	0.1	100.0	-0.1	0.0
2	P-109	J-99	J-92	75	0.0	100.0	0.0	0.0
2	P-110	J-102	J-103	75	0.0	100.0	0.1	0.0
2	P-111	J-63	J-104	110	5.2	100.0	3.8	0.5
2	P-112	J-66	J-99	75	0.0	100.0	0.0	0.0
2	P-113	J-108	J-109	75	0.0	100.0	0.0	0.0
2	P-114	J-103	J-82	75	0.0	100.0	0.1	0.0
2	P-115	J-104	J-110	75	0.0	100.0	0.1	0.0
2	P-116	J-77	J-108	75	0.0	100.0	0.0	0.0
2	P-117	J-110	J-111	75	0.0	100.0	0.1	0.0
2	P-118	J-12	J-81	110	2.5	104.0	-2.5	0.4
2	P-119	J-109	J-114	75	0.0	105.0	0.0	0.0
2	P-120	J-49	J-87	75	1.4	107.0	0.7	0.2
2	P-121	J-14	J-118	110	5.1	115.0	3.7	0.5
2	P-122	J-27	J-102	75	0.0	123.0	0.1	0.0
2	P-123	J-86	J-65	75	0.0	125.0	0.0	0.0
2	P-124	J-111	J-119	75	0.0	192.0	0.1	0.0

Appendix I: Water Demand Estimation in Sabrang Tourism Park

Population Projection

In the Detailed Master Plan (DMP) of Naf Tourism Park (December, 2020), it is proposed that maximum about 41,360 nos. of tourist will visit and may stay at night in the Tourism Park daily. To serve and facilitate the tourists, about 14,638 nos. employee is required in different land usages. Thus, total population projection for the tourism park is about 56,000 nos. The population projection for different land use pattern is given in **Table I.1**.

Table I.1: Population projection of Sabrang Tourism Park

Broad Land use	Types	Tourist (Nos.)	Work Force (Nos.)	Total Population (Nos.)
Residential/ Hospitality	Beach Side Resort and Hotel	20967	8387	29354
	Lake Side Resort & Hotel (South)	3296	1268	4564
	Lake Side Resort & Hotel (North)	12326	3006	15332
	Economy Hotel	1978	742	2720
	Service Studio Apartment	1998	266	2264
Institutional Zone	Welfare Centre	271	54	325
	Old Age Home	524	87	611
Common Facilities	Park-1		50	50
	Park-2		70	70
	Amphitheatre		12	12
	Amusement Park		100	4100
	Golf Course		50	50
	Food Zone		7	7
	Boating and Shopping		5	5
	Liberation War and Amusement Museum		15	15
	Watch Tower and Restaurant		30	30
	Shopping District		100	100
	Rest Room & Wash Room		5	5
	South Watch Tower		5	5
Administrative Zone	Disaster Management Centre		15	15
	Hospital		18	18
	Security and Service Zone		10	10
	Security Zone		5	5

Broad Land use	Types	Tourist (Nos.)	Work Force (Nos.)	Total Population (Nos.)
	Tourist Police Station and Fire Station		100	100
	Administrative Area		50	50
Transportation Zone	Bus Depot		25	25
	Helipad Station		10	10
	Jetty Area		16	16
	Transportation Hub		5	5
Utility Zone	Electrical Sub-station 2		9	9
	Electrical Sub-station-1		9	9
	Bio-Gas Plant		7	7
	Power Plant and Gas Station		20	16020
	Solid Waste Centre		32	32
	STP 1		10	10
	STP 2		15	15
	STP-3		10	10
	Water Reservoir		8	8
Water body and Green	Farming Area		5	5
Total		**41,360**	**14,638**	**56,000**

Water Demand

Water demand is calculated based on the per capita demand recommended in BNBC and population projection for Sabrang Tourism Park as shown in **Table I.1**. Considering water availability, full facilities in considered only for the plots allocated for accommodations where the plot size in >= 3acre. For the other usage restricted facilities is considered. Thus the total water required is estimated as 12.33 MLD completing all structural development and full operation of Tourism Park in 2036 as mentioned in DMP of Sabrang Tourism Park (December, 2020). The water requirement at different phases as mentioned in the DMP is presented in **Table I.2.** The detailed water demand estimation is stated in **Table I.3** to **Table I.5.**

Table I.2: Estimated water demand for Sabrang Tourism Park

Usage	Water Requirement (Litre/day)			
	Phase-1	Phase-2	Phase-3	Total
	2021-26*	2026-31*	2031-36*	
Total demand at user end	3.72	3.61	2.65	9.98
Maximum Day Water Requirement for Distribution System	4.14	4.01	2.94	11.09
Water Treatment Capacity to be Installed	4.60	4.46	3.27	12.33

**Duration of phases is taken from DMP of Naf Tourism Park (December, 2020)*

10% loss of water is considered in the transmission main and in the distribution network.

Table I.3: Estimated water demand for Sabrang Tourism Park in Phase-1 (2021-26)

Broad Land use	Types	Category	Number	Area (Acre)	Water Demand (lpcd)	Tourist (Nos.)	Work force (Nos.)	Total Population (Nos.)	Tourist Demand (l/d)	Work force Demand (l/d)	Total (L/d)
Residential/ Hospitality	Beach Side Resort and Hotel	1A	6	35.46	300	6290	2516	8806	1887030	75483	1962513
	Lake Side Resort & Hotel (South)	1B	0	0.00	300	0	0	0	0	0	0
	Lake Side Resort & Hotel (North)	1C	27	38.07	135	12326	3006	15332	1664010	90180	1754190
	Economy Hotel	1D	0	0.00	135	0	0	0	0	0	0
	Service Studio Apartment	24	0	0.00	135	0	0	0	0	0	0
Institutional Zone	Welfare Centre	22	0	0.00	100	0	0	0	0	0	0
	Old Age Home	25	0	0.00	100	0	0	0	0	0	0
Common Facilities	Park-1	9A	1	10.57	10	0	50	50	0	500	500
	Park-2	9B	0	0.00	10	0	0	0	0	0	0
	Amphitheatre	17	0	0.00	10	0	0	0	0	0	0
	Amusement Park	15	0	0.00	10	0	0	0	0	0	0
	Golf Course	21	0	0.00	10	0	0	0	0	0	0
	Food Zone	30	1	0.51	30	0	7	7	0	210	210
	Boating and Shopping	29	1	2.29	10	0	5	5	0	50	50
	Liberation War and Amusement Museum	16	0	0.00	10	0	0	0	0	0	0
	Watch Tower and Restaurant	18	0	0.00	10	0	0	0	0	0	0
	Shopping District	13	0	0.00	30	0	0	0	0	0	0
	Rest Room & Wash Room	31	1	2.07	10	0	5	5	0	50	50

Broad Land use	Types	Category	Number	Area (Acre)	Water Demand (lpcd)	Tourist (Nos.)	Work force (Nos.)	Total Population (Nos.)	Tourist Demand (l/d)	Work force Demand (l/d)	Total (L/d)
	South Watch Tower	36	0	0.00	10	0	0	0	0	0	0
Administrative Zone	Disaster Management Centre	5	1	0.94	30	0	15	15	0	450	450
	Hospital	4	1	1.32	135	0	18	18	0	540	540
	Security and Service Zone	28A	0	0.00	30	0	0	0	0	0	0
	Security Zone	28B	0	0.00	30	0	0	0	0	0	0
	Tourist Police Station and Fire Station	3	1	1.96	30	0	100	100	0	3000	3000
	Administrative Area	2	1	5.97	30	0	50	50	0	1500	1500
Transportation Zone	Bus Depot	8	1	4.40	10	0	25	25	0	250	250
	Helipad Station	11	0	0.00	10	0	0	0	0	0	0
	Jetty Area	20	1	2.27	30	0	16	16	0	480	480
	Transportation Hub	19	0	0.00	10	0	0	0	0	0	0
Utility Zone	Electrical Sub-station 2	10B	0	0.00	30	0	0	0	0	0	0
	Electrical Sub-station-1	10A	1	1.21	30	0	9	9	0	270	270
	Bio-Gas Plant	7	1	1.04	30	0	7	7	0	210	210
	Power Plant and Gas Station	23	0	0.00	30	0	0	0	0	0	0
	Solid Waste Centre	12	0	0.00	10	0	0	0	0	0	0
	STP 1	6A	1	1.96	30	0	10	10	0	300	300
	STP 2	6B	0	0.00	30	0	0	0	0	0	0

Broad Land use	Types	Category	Number	Area (Acre)	Water Demand (lpcd)	Tourist (Nos.)	Work force (Nos.)	Total Population (Nos.)	Tourist Demand (l/d)	Work force Demand (l/d)	Total (L/d)
	STP-3	6C	0	0.00	30	0	0	0	0	0	0
	Water Reservoir	14	1	2.05	10	0	8	8	0	80	80
Water body and Green Area	Farming Area	37	1	6.24	100	0	5	5	0	150	150
Total				**118.33**		**18,616**	**5,852**	**24,468**			**3,724,743**

Table I.4: Estimated water demand for Sabrang Tourism Park in Phase-2 (2026-31)

Broad Land use	Types	Category	Number	Area (Acre)	Water Demand (lpcd)	Tourist (Nos.)	Work force (Nos.)	Total Population (Nos.)	Tourist Demand (l/d)	Work force Demand (l/d)	Total (L/d)
Residential/ Hospitality	Beach Side Resort and Hotel	1A	7	41.37	300	7338	2935	10274	2201535	88064	2289599
	Lake Side Resort & Hotel (South)	1B	6	17.82	300	3296	1268	4564	988800	38040	1026840
	Lake Side Resort & Hotel (North)	1C	0	0.00	135	0	0	0	0	0	0
	Economy Hotel	1D	32	9.40	135	1978	742	2720	267030	22260	289290
	Service Studio Apartment	24	0	0.00	135	0	0	0	0	0	0
Institutional Zone	Welfare Centre	22	0	0.00	100	0	0	0	0	0	0
	Old Age Home	25	0	0.00	100	0	0	0	0	0	0
Common Facilities	Park-1	9A	0	0.00	10	0	0	0	0	0	0
	Park-2	9B	1	13.04	10	0	70	70	0	700	700
	Amphitheatre	17	1	2.16	10	0	12	12	0	120	120
	Amusement Park	15	1	10.49	10	0	100	100	0	1000	1000

Broad Land use	Types	Category	Number	Area (Acre)	Water Demand (lpcd)	Tourist (Nos.)	Work force (Nos.)	Total Population (Nos.)	Tourist Demand (l/d)	Work force Demand (l/d)	Total (L/d)
	Golf Course	21	0	0.00	10	0	0	0	0	0	0
	Food Zone	30	0	0.00	30	0	0	0	0	0	0
	Boating and Shopping	29	0	0.00	10	0	0	0	0	0	0
	Liberation War and Amusement Museum	16	1	2.23	10	0	15	15	0	150	150
	Watch Tower and Restaurant	18	1	9.80	10	0	30	30	0	300	300
	Shopping District	13	1	7.70	30	0	100	100	0	3000	3000
	Rest Room & Wash Room	31	0	0.00	10	0	0	0	0	0	0
	South Watch Tower	36	0	0.00	10	0	0	0	0	0	0
Administrative Zone	Disaster Management Centre	5	0	0.00	30	0	0	0	0	0	0
	Hospital	4	0	0.00	135	0	0	0	0	0	0
	Security and Service Zone	28A	1	11.12	30	0	10	10	0	300	300
	Security Zone	28B	0	0.00	30	0	0	0	0	0	0
	Tourist Police Station and Fire Station	3	0	0.00	30	0	0	0	0	0	0
	Administrative Area	2	0	0.00	30	0	0	0	0	0	0
Transportation Zone	Bus Depot	8	0	0.00	10	0	0	0	0	0	0
	Helipad Station	11	1	2.61	10	0	10	10	0	100	100
	Jetty Area	20	0	0.00	30	0	0	0	0	0	0

Broad Land use	Types	Category	Number	Area (Acre)	Water Demand (lpcd)	Tourist (Nos.)	Work force (Nos.)	Total Population (Nos.)	Tourist Demand (l/d)	Work force Demand (l/d)	Total (L/d)
	Transportation Hub	19	1	1.81	10	0	5	5	0	50	50
Utility Zone	Electrical Sub-station 2	10B	0	0.00	30	0	0	0	0	0	0
	Electrical Sub-station-1	10A	0	0.00	30	0	0	0	0	0	0
	Bio-Gas Plant	7	0	0.00	30	0	0	0	0	0	0
	Power Plant and Gas Station	23	0	0.00	30	0	0	0	0	0	0
	Solid Waste Centre	12	1	4.54	10	0	32	32	0	320	320
	STP 1	6A	0	0.00	30	0	0	0	0	0	0
	STP 2	6B	1	3.57	30	0	15	15	0	450	450
	STP-3	6C	0	0.00	30	0	0	0	0	0	0
	Water Reservoir	14	1	2.05	10	0	8	8	0	80	80
Water body and Green Area	Farming Area	37	0	0.00	100	0	0	0	0	0	0
Total				**139.71**		**12,612**	**5,352**	**17,965**			**3,612,299**

Table I.5: Estimated water demand for Sabrang Tourism Park in Phase-3 (2031-36)

Broad Land use	Types	Category	Number	Area (Acre)	Water Demand (lpcd)	Tourist (Nos.)	Work force (Nos.)	Total Population (Nos.)	Tourist Demand (l/d)	Work force Demand (l/d)	Total (L/d)
Residential/ Hospitality	Beach Side Resort and Hotel	1A	7	41.37	300	7338	2935	10274	2201535	88064	2289599
	Lake Side Resort & Hotel (South)	1B	0	0.00	300	0	0	0	0	0	0

	Lake Side Resort & Hotel (North)	1C	0	0.00	135	0	0	0	0	0	0
	Economy Hotel	1D	0	0.00	135	0	0	0	0	0	0
	Service Studio Apartment	24	1	19.75	135	1998	266	2264	269730	7980	277710
Institutional Zone	Welfare Centre	22	1	4.02	100	271	54	325	27100	1620	28720
	Old Age Home	25	1	7.76	100	524	87	611	52400	2610	55010
Common Facilities	Park-1	9A	0	0.00	10	0	0	0	0	0	0
	Park-2	9B	0	0.00	10	0	0	0	0	0	0
	Amphitheatre	17	0	0.00	10	0	0	0	0	0	0
	Amusement Park	15	0	0.00	10	0	0	0	0	0	0
	Golf Course	21	1	55.94	10	0	50	50	0	500	500
	Food Zone	30	0	0.00	30	0	0	0	0	0	0
	Boating and Shopping	29	0	0.00	10	0	0	0	0	0	0
	Liberation War and Amusement Museum	16	0	0.00	10	0	0	0	0	0	0
	Watch Tower and Restaurant	18	0	0.00	10	0	0	0	0	0	0
	Shopping District	13	0	0.00	30	0	0	0	0	0	0
	Rest Room & Wash Room	31	0	0.00	10	0	0	0	0	0	0
	South Watch Tower	36	1	1.18	10	0	5	5	0	50	50
Administrative Zone	Disaster Management Centre	5	0	0.00	30	0	0	0	0	0	0
	Hospital	4	0	0.00	135	0	0	0	0	0	0
	Security and Service Zone	28A	0	0.00	30	0	0	0	0	0	0
	Security Zone	28B	1	1.81	30	0	5	5	0	150	150

	Tourist Police Station and Fire Station	3	0	0.00	30	0	0	0	0	0	0
	Administrative Area	2	0	0.00	30	0	0	0	0	0	0
Transportation Zone	Bus Depot	8	0	0.00	10	0	0	0	0	0	0
	Helipad Station	11	0	0.00	10	0	0	0	0	0	0
	Jetty Area	20	0	0.00	30	0	0	0	0	0	0
	Transportation Hub	19	0	0.00	10	0	0	0	0	0	0
Utility Zone	Electrical Sub-station 2	10B	1	1.33	30	0	9	9	0	270	270
	Electrical Sub-station-1	10A	0	0.00	30	0	0	0	0	0	0
	Bio-Gas Plant	7	0	0.00	30	0	0	0	0	0	0
	Power Plant and Gas Station	23	1	8.45	30	0	20	20	0	600	600
	Solid Waste Centre	12	0	0.00	10	0	0	0	0	0	0
	STP 1	6A	0	0.00	30	0	0	0	0	0	0
	STP 2	6B	0	0.00	30	0	0	0	0	0	0
	STP-3	6C	1	1.75	30	0	10	10	0	300	300
	Water Reservoir	14	1	2.05	10	0	8	8	0	80	80
Water body and Green Area	Farming Area	37	0	0.00	100	0	0	0	0	0	0
Total				**145.41**		**10,131**	**3,449**	**13,581**			**2,652,989**

Appendix J: Details of Model Output at Junctions for Sabrang Tourism Park

Table J.1: Details of Model Output at Junctions for Scenario 1

Phase Area	Label	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H_2O)
1	J-1	0.00	16.11	16.08
1	J-2	1.11	16.18	16.14
1	J-3	0.00	12.52	12.49
1	J-4	0.00	12.46	12.44
1	J-5	0.00	15.39	15.36
1	J-6	1.11	15.30	15.27
1	J-7	0.00	14.12	14.10
1	J-8	2.21	14.22	14.19
1	J-9	0.00	16.20	16.17
1	J-10	1.11	16.05	16.02
1	J-11	0.03	16.20	16.17
1	J-12	0.00	16.20	16.17
1	J-13	0.00	12.34	12.32
1	J-14	0.01	14.60	14.58
1	J-15	1.11	14.62	14.59
1	J-16	1.11	15.20	15.17
1	J-17	2.26	14.82	14.79
1	J-18	2.21	15.69	15.66
1	J-19	1.11	15.37	15.34
1	J-20	1.11	14.59	14.56
1	J-21	2.21	15.09	15.06
1	J-22	1.11	14.52	14.49
1	J-23	2.21	14.90	14.87
1	J-24	5.57	15.89	15.86
1	J-25	1.11	14.20	14.17
1	J-26	1.11	13.91	13.88
1	J-27	5.57	14.22	14.19
1	J-28	0.00	14.69	14.66
1	J-29	1.11	15.87	15.84
1	J-30	5.57	12.20	12.17
1	J-31	5.58	15.15	15.12
1	J-32	0.00	15.52	15.49
1	J-33	0.00	13.19	13.16
1	J-34	5.57	13.69	13.66
1	J-35	1.11	13.69	13.66
1	J-36	0.00	12.95	12.93
1	J-37	0.00	12.81	12.78
1	J-38	2.22	15.15	15.12
1	J-39	1.11	13.54	13.51
1	J-40	5.57	16.40	16.37
1	J-41	0.01	12.69	12.67

Phase Area	Label	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H_2O)
1	J-42	1.11	13.44	13.41
1	J-43	1.11	13.10	13.07
1	J-44	0.00	12.66	12.64
2	J-45	0.15	14.62	14.59
2	J-46	0.00	14.62	14.59
2	J-47	0.00	16.39	16.36
2	J-48	0.16	14.59	14.56
2	J-49	0.46	14.59	14.56
2	J-50	0.15	14.64	14.61
2	J-51	0.15	15.76	15.73
2	J-52	0.15	15.63	15.60
2	J-53	0.15	15.52	15.49
2	J-54	3.07	15.44	15.41
2	J-55	0.31	15.33	15.30
2	J-56	0.15	15.29	15.25
2	J-57	0.31	14.78	14.75
2	J-58	0.31	14.87	14.84
2	J-59	3.07	14.74	14.71
2	J-60	0.15	14.64	14.61
2	J-61	0.15	14.68	14.65
2	J-62	0.15	15.60	15.57
2	J-63	0.15	14.95	14.92
2	J-64	0.31	15.17	15.14
2	J-65	0.15	15.40	15.37
2	J-66	0.31	14.69	14.66
2	J-67	0.31	14.59	14.56
2	J-68	0.00	14.59	14.56
2	J-69	0.31	15.12	15.09
2	J-70	0.15	14.99	14.96
2	J-71	2.91	15.82	15.79
2	J-72	0.01	15.16	15.13
2	J-73	0.00	14.96	14.93
2	J-74	0.01	14.62	14.59
2	J-75	5.57	13.04	13.01
2	J-76	5.57	12.83	12.80
2	J-77	2.91	16.20	16.17
2	J-78	0.00	16.06	16.03
2	J-79	0.05	14.62	14.59
2	J-80	2.91	15.92	15.89
2	J-81	0.00	15.87	15.84
2	J-82	2.91	16.11	16.08
2	J-83	0.00	15.62	15.58
2	J-84	5.57	15.37	15.34
2	J-85	0.00	13.73	13.70

Phase Area	Label	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H_2O)
2	J-86	5.57	13.48	13.45
2	J-87	0.00	14.38	14.35
2	J-88	6.27	13.98	13.96
2	J-89	0.00	15.10	15.07
2	J-90	0.00	15.04	15.01
2	J-91	5.57	14.78	14.75
2	J-92	0.00	14.74	14.71
2	J-93	0.00	14.98	14.95
2	J-94	0.00	14.86	14.83
2	J-95	0.00	14.80	14.77
2	J-96	0.00	14.92	14.89
2	J-97	0.01	14.62	14.59
2	J-98	5.57	12.66	12.63
2	J-99	0.00	12.66	12.63
3	J-100	0.00	15.41	15.38
3	J-101	0.00	15.32	15.29
3	J-102	0.00	15.23	15.20
3	J-103	0.00	14.76	14.74
3	J-104	0.00	14.86	14.83
3	J-105	0.00	15.21	15.18
3	J-106	0.49	15.11	15.08
3	J-107	0.68	14.23	14.20
3	J-108	0.01	14.23	14.20
3	J-109	5.57	14.64	14.61
3	J-110	0.68	14.92	14.89
3	J-111	0.94	14.12	14.09
3	J-112	0.00	14.12	14.09
3	J-113	0.00	12.63	12.60
3	J-114	5.57	12.45	12.43
3	J-115	0.01	15.09	15.06
3	J-116	0.68	14.58	14.55
3	J-117	0.68	14.37	14.35
3	J-118	0.00	14.46	14.43
3	J-119	5.57	14.29	14.26
3	J-120	5.57	13.91	13.88
3	J-121	5.57	13.65	13.63
3	J-122	5.57	13.21	13.19
3	J-123	5.57	12.80	12.77
3	J-124	0.00	13.00	12.98
3	J-125	0.00	12.45	12.43
3	J-126	0.68	14.94	14.91
3	J-127	0.68	14.86	14.83
3	J-128	0.68	14.72	14.69
3	J-129	0.00	14.53	14.50

Phase Area	Label	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H_2O)
3	J-130	0.00	14.18	14.15
3	J-131	0.00	14.88	14.85
3	J-132	8.18	13.83	13.80

Table J.2: Details of Model Output at Junctions for Scenario 2

Phase Area	Label	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H_2O)
1	J-1	0.00	16.11	16.08
1	J-2	1.11	16.18	16.14
1	J-3	0.00	12.52	12.49
1	J-4	0.00	12.46	12.44
1	J-5	0.00	15.39	15.36
1	J-6	1.11	15.30	15.27
1	J-7	0.00	14.12	14.10
1	J-8	2.21	14.22	14.19
1	J-9	0.00	16.20	16.17
1	J-10	1.11	16.05	16.02
1	J-11	0.03	16.20	16.17
1	J-12	0.00	16.20	16.17
1	J-13	0.00	12.34	12.32
1	J-14	0.01	14.60	14.58
1	J-15	1.11	14.62	14.59
1	J-16	1.11	15.20	15.17
1	J-17	2.26	14.82	14.79
1	J-18	2.21	15.69	15.66
1	J-19	1.11	15.37	15.34
1	J-20	1.11	14.59	14.56
1	J-21	2.21	15.09	15.06
1	J-22	1.11	14.52	14.49
1	J-23	2.21	14.90	14.87
1	J-24	5.57	15.89	15.86
1	J-25	1.11	14.20	14.17
1	J-26	1.11	13.91	13.88
1	J-27	5.57	14.22	14.19
1	J-28	0.00	14.69	14.66
1	J-29	1.11	15.87	15.84
1	J-30	5.57	12.20	12.17
1	J-31	5.58	15.15	15.12
1	J-32	0.00	15.52	15.49
1	J-33	0.00	13.19	13.16
1	J-34	5.57	13.69	13.66
1	J-35	1.11	13.69	13.66
1	J-36	0.00	12.95	12.93

Phase Area	Label	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H_2O)
1	J-37	0.00	12.81	12.78
1	J-38	2.22	15.15	15.12
1	J-39	1.11	13.54	13.51
1	J-40	5.57	16.40	16.37
1	J-41	0.01	12.69	12.67
1	J-42	1.11	13.44	13.41
1	J-43	1.11	13.10	13.07
1	J-44	0.00	12.66	12.64
2	J-45	0.00	16.39	16.35
2	J-46	2.91	16.29	16.26
2	J-47	0.15	13.96	13.93
2	J-48	0.00	13.96	13.93
2	J-49	0.00	15.33	15.30
2	J-50	0.00	16.07	16.04
2	J-51	0.16	13.92	13.89
2	J-52	0.46	13.92	13.89
2	J-53	0.15	13.96	13.93
2	J-54	3.07	14.89	14.86
2	J-55	0.15	14.71	14.68
2	J-56	0.15	14.57	14.55
2	J-57	3.07	14.45	14.43
2	J-58	0.31	14.38	14.36
2	J-59	0.15	14.36	14.33
2	J-60	0.31	14.13	14.10
2	J-61	0.31	14.08	14.05
2	J-62	3.07	14.23	14.20
2	J-63	0.15	14.02	13.99
2	J-64	0.15	14.10	14.07
2	J-65	0.15	14.67	14.64
2	J-66	0.15	14.30	14.27
2	J-67	0.31	14.37	14.34
2	J-68	3.59	15.91	15.88
2	J-69	0.15	14.45	14.42
2	J-70	0.31	14.14	14.11
2	J-71	0.31	13.92	13.89
2	J-72	0.00	13.92	13.89
2	J-73	0.31	14.20	14.17
2	J-74	0.15	14.12	14.10
2	J-75	0.94	15.22	15.19
2	J-76	0.01	14.84	14.81
2	J-77	0.00	14.64	14.61
2	J-78	0.01	13.95	13.93
2	J-79	5.57	12.71	12.69
2	J-80	5.57	12.51	12.48

Phase Area	Label	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H_2O)
2	J-81	0.01	15.81	15.78
2	J-82	0.05	13.95	13.92
2	J-83	0.68	15.72	15.69
2	J-84	3.59	15.55	15.52
2	J-85	5.57	15.05	15.02
2	J-86	0.00	13.41	13.38
2	J-87	5.57	13.15	13.13
2	J-88	0.00	14.06	14.03
2	J-89	6.27	13.66	13.63
2	J-90	0.00	14.75	14.72
2	J-91	0.00	14.65	14.62
2	J-92	5.57	14.46	14.43
2	J-93	0.00	14.19	14.17
2	J-94	0.00	14.56	14.53
2	J-95	0.00	14.38	14.35
2	J-96	0.00	14.29	14.26
2	J-97	0.00	14.47	14.44
2	J-98	0.01	13.95	13.92
2	J-99	5.57	12.33	12.31
2	J-100	0.00	12.33	12.31
3	J-101	0.00	16.20	16.16
3	J-102	0.00	15.24	15.21
3	J-103	0.49	15.97	15.94
3	J-104	0.68	15.40	15.37
3	J-105	0.01	15.40	15.37
3	J-106	5.57	15.11	15.08
3	J-107	0.00	13.10	13.07
3	J-108	5.57	12.93	12.90
3	J-109	0.00	14.93	14.90
3	J-110	5.57	14.76	14.73
3	J-111	5.57	14.38	14.35
3	J-112	5.57	14.12	14.10
3	J-113	5.57	13.68	13.66
3	J-114	5.57	13.27	13.24
3	J-115	0.00	13.48	13.45
3	J-116	0.00	12.93	12.90
3	J-117	0.68	15.80	15.77
3	J-118	0.68	15.30	15.27
3	J-119	0.68	15.16	15.13
3	J-120	0.00	15.50	15.47
3	J-121	0.00	15.15	15.12
3	J-122	0.00	15.85	15.82
3	J-123	8.18	14.80	14.77

Appendix K: Summary of Pipe Diameter for Sabrang Tourism Park

Table K.1: Summary of Pipe Diameter for Scenario 1

Diameter (mm)	Phase 1 area	Phase 2 area	Phase 3 area	Total
75	484	2094	546	3123
110	1122	586	501	2209
160	1441	206	727	2374
200	800	200	300	1300
250	373	900	200	1473
315	132	728	546	1406
355	189	36	0	224
Total	4,540	4,751	2,819	12,110

Table K.2: Summary of Pipe Diameter for Scenario 2

Diameter (mm)	Phase 1 area	Phase 2 area	Phase 3 area	Total
75	484	2509	456	3448
110	1122	0	141	1263
160	1441	378	627	2446
200	800	417	300	1517
250	373	760	200	1333
315	132	338	297	766
355	189	200	0	389
400	0	49	0	49
Total	4,540	4,650	2,021	11,211

Appendix L: Details of Model Output of Pipes for Sabrang Tourism Park

Table L.1: Details of Model Output of Pipes for Scenario 1

Phase Area	Label	Start Node	Stop Node	Diameter (mm)	Head loss Gradient (m/km)	Length (Scaled) (m)	Flow (L/s)	Velocity (m/s)
1	P-1	J-1	J-2	315	2.10	31.60	-37.02	0.62
1	P-2	J-3	J-4	110	1.45	37.57	1.89	0.26
1	P-3	J-5	J-6	160	1.60	55.63	5.37	0.35
1	P-4	J-7	J-8	160	1.53	64.27	-5.24	0.34
1	P-5	J-9	J-10	250	2.00	73.38	19.67	0.52
1	P-6	J-11	J-12	75	0.00	83.67	0.00	0.00
1	P-7	J-4	J-13	110	1.45	84.49	1.89	0.26
1	P-8	J-14	J-15	75	0.18	100.00	-0.23	0.07
1	P-9	J-6	J-16	160	1.04	100.00	4.27	0.28
1	P-10	J-16	J-17	110	3.75	100.00	3.16	0.44
1	P-11	J-18	J-1	200	4.21	100.00	-16.30	0.68
1	P-12	J-19	J-18	200	3.22	100.00	-14.09	0.59
1	P-13	J-17	J-20	75	2.36	100.00	0.90	0.27
1	P-14	J-21	J-19	200	2.76	100.00	-12.98	0.54
1	P-15	J-22	J-23	160	3.79	100.00	-8.56	0.56
1	P-16	J-23	J-21	200	1.96	100.00	-10.77	0.45
1	P-17	J-8	J-22	160	2.93	100.00	-7.45	0.48
1	P-18	J-24	J-1	250	2.21	100.00	-20.72	0.55
1	P-19	J-25	J-26	160	2.92	100.00	7.43	0.48
1	P-20	J-27	J-28	160	4.67	100.00	-9.58	0.62
1	P-21	J-29	J-5	200	4.78	100.00	17.45	0.73
1	P-22	J-13	J-30	110	1.45	100.00	1.89	0.26
1	P-23	J-31	J-32	200	3.68	100.00	-15.16	0.63
1	P-24	J-33	J-34	110	4.98	100.00	-3.68	0.51
1	P-25	J-26	J-35	160	2.16	100.00	6.32	0.41
1	P-26	J-20	J-14	75	0.17	100.00	-0.22	0.06
1	P-27	J-36	J-37	110	1.46	100.00	1.90	0.26
1	P-28	J-5	J-38	200	2.42	100.00	12.08	0.50
1	P-29	J-35	J-39	160	1.51	100.00	5.21	0.34
1	P-30	J-2	J-40	315	2.22	100.00	-38.13	0.64
1	P-31	J-40	J-9	250	2.01	100.00	19.70	0.52
1	P-32	J-10	J-29	250	1.80	100.00	18.56	0.49
1	P-33	J-30	J-41	110	4.96	100.00	-3.68	0.51
1	P-34	J-41	J-33	110	4.98	100.00	-3.68	0.51
1	P-35	J-34	J-7	160	4.38	100.00	-9.25	0.60
1	P-36	J-42	J-43	110	3.41	100.00	3.00	0.41
1	P-37	J-9	J-11	75	0.01	100.00	0.03	0.01
1	P-38	J-44	J-3	110	1.45	100.00	1.89	0.26
1	P-39	J-39	J-42	160	0.97	100.00	4.11	0.27
1	P-40	J-37	J-44	110	1.46	100.00	1.90	0.26

Phase Area	Label	Start Node	Stop Node	Diameter (mm)	Head loss Gradient (m/km)	Length (Scaled) (m)	Flow (L/s)	Velocity (m/s)
1	P-41	J-43	J-36	110	1.46	100.00	1.90	0.26
1	P-42	J-32	J-24	200	3.68	100.00	-15.16	0.63
1	P-43	J-28	J-31	160	4.67	100.00	-9.58	0.62
1	P-44	J-7	J-27	160	0.93	101.13	-4.01	0.26
1	P-45	J-38	J-15	160	4.93	107.02	9.86	0.64
1	P-46	J-15	J-25	160	3.77	112.78	8.53	0.56
1	P-47	J-40	R-1	355	3.18	188.64	-63.40	0.84
2	P-48	J-45	J-46	75	0.02	31.58	0.07	0.02
2	P-49	J-47	R-3	355	3.07	35.51	-62.16	0.82
2	P-50	J-48	J-49	75	0.04	45.16	-0.10	0.03
2	P-51	J-49	J-50	75	0.98	45.16	-0.56	0.17
2	P-52	J-51	J-52	110	2.63	47.78	2.61	0.36
2	P-53	J-52	J-53	110	2.35	47.78	2.45	0.34
2	P-54	J-54	J-55	75	2.23	47.92	0.87	0.26
2	P-55	J-55	J-56	75	0.99	47.92	0.56	0.17
2	P-56	J-57	J-58	75	1.94	48.00	-0.81	0.24
2	P-57	J-59	J-57	75	0.80	48.00	-0.50	0.15
2	P-58	J-60	J-61	75	0.76	48.87	-0.49	0.14
2	P-59	J-45	J-60	75	0.38	48.87	-0.33	0.10
2	P-60	J-62	J-51	160	3.07	53.12	-7.64	0.50
2	P-61	J-54	J-62	160	2.96	53.12	-7.49	0.49
2	P-62	J-63	J-64	110	3.94	57.31	-3.24	0.45
2	P-63	J-59	J-63	110	3.60	57.31	-3.09	0.43
2	P-64	J-64	J-54	110	4.65	57.31	-3.55	0.49
2	P-65	J-65	J-56	110	1.83	60.62	2.15	0.30
2	P-66	J-53	J-65	110	2.08	60.62	2.30	0.32
2	P-67	J-50	J-45	75	0.24	62.27	0.26	0.08
2	P-68	J-66	J-59	75	0.86	62.78	-0.52	0.16
2	P-69	J-61	J-66	75	0.16	62.78	-0.21	0.06
2	P-70	J-45	J-67	75	0.46	63.13	0.37	0.11
2	P-71	J-67	J-68	75	0.02	63.13	0.06	0.02
2	P-72	J-56	J-69	110	2.53	65.90	2.56	0.35
2	P-73	J-69	J-70	110	1.99	65.90	2.24	0.31
2	P-74	J-70	J-58	110	1.74	65.90	2.09	0.29
2	P-75	J-68	J-48	75	0.02	79.44	0.06	0.02
2	P-76	J-58	J-50	75	2.75	85.94	0.97	0.29
2	P-77	J-71	J-51	250	0.62	100.00	10.40	0.28
2	P-78	J-72	J-73	315	1.80	110.87	34.10	0.57
2	P-79	J-46	J-74	75	0.02	100.00	0.07	0.02
2	P-80	J-75	J-76	200	2.08	100.00	11.13	0.46
2	P-81	J-77	J-78	250	1.40	100.00	16.23	0.43
2	P-82	J-74	J-79	75	0.02	100.00	0.06	0.02
2	P-83	J-78	J-80	250	1.40	100.00	16.23	0.43

Phase Area	Label	Start Node	Stop Node	Diameter (mm)	Head loss Gradient (m/km)	Length (Scaled) (m)	Flow (L/s)	Velocity (m/s)
2	P-84	J-80	J-71	250	0.97	100.00	13.32	0.35
2	P-85	J-47	J-77	250	1.91	100.00	19.14	0.51
2	P-86	J-81	J-82	315	2.44	100.00	-40.11	0.67
2	P-87	J-82	J-47	315	2.78	100.00	-43.02	0.72
2	P-88	J-83	J-84	315	2.44	100.00	40.11	0.67
2	P-89	J-85	J-86	250	2.52	100.00	22.27	0.59
2	P-90	J-87	J-88	250	3.99	100.00	28.53	0.76
2	P-91	J-89	J-90	75	0.61	100.00	0.43	0.13
2	P-92	J-91	J-87	250	3.99	100.00	28.53	0.76
2	P-93	J-92	J-61	75	0.60	100.00	0.43	0.13
2	P-94	J-90	J-93	75	0.61	100.00	0.43	0.13
2	P-95	J-94	J-95	75	0.60	100.00	0.43	0.13
2	P-96	J-93	J-96	75	0.61	100.00	0.43	0.13
2	P-97	J-86	J-75	200	4.41	100.00	16.70	0.70
2	P-98	J-79	J-97	75	0.00	100.00	0.01	0.00
2	P-99	J-73	J-91	315	1.80	100.00	34.10	0.57
2	P-100	J-88	J-85	250	2.52	100.00	22.27	0.59
2	P-101	J-98	J-99	75	0.00	100.00	0.00	0.00
2	P-102	J-76	J-98	160	1.71	100.00	5.57	0.36
2	P-103	J-95	J-92	75	0.60	100.00	0.43	0.13
2	P-104	J-96	J-94	75	0.61	100.00	0.43	0.13
2	P-105	J-72	J-89	75	0.61	103.15	0.43	0.13
2	P-106	J-83	J-81	315	2.44	103.96	-40.11	0.67
2	P-107	J-84	J-72	315	1.85	113.55	34.54	0.58
3	P-108	J-100	R-2	315	4.13	20.97	-53.32	0.89
3	P-109	J-101	J-102	160	3.49	27.38	8.18	0.53
3	P-110	J-101	J-100	315	3.29	28.01	-47.16	0.79
3	P-111	J-103	J-104	315	2.31	40.65	-38.97	0.65
3	P-112	J-105	J-106	110	2.47	41.04	2.52	0.35
3	P-113	J-107	J-108	75	0.00	55.71	0.01	0.00
3	P-114	J-103	J-109	315	2.31	56.19	38.97	0.65
3	P-115	J-105	J-110	110	4.89	59.54	3.64	0.50
3	P-116	J-111	J-112	75	0.00	89.88	0.00	0.00
3	P-117	J-113	J-114	160	1.71	100.00	5.57	0.36
3	P-118	J-104	J-115	315	2.31	100.00	-38.97	0.65
3	P-119	J-100	J-105	160	2.07	100.00	6.16	0.40
3	P-120	J-110	J-116	110	3.34	100.00	2.97	0.41
3	P-121	J-117	J-111	75	2.56	100.00	0.94	0.28
3	P-122	J-116	J-117	110	2.07	100.00	2.29	0.32
3	P-123	J-115	J-101	315	2.31	100.00	-38.98	0.65
3	P-124	J-118	J-119	315	1.74	100.00	33.40	0.56
3	P-125	J-120	J-121	250	2.52	100.00	22.27	0.59
3	P-126	J-121	J-122	200	4.41	100.00	16.70	0.70

Phase Area	Label	Start Node	Stop Node	Diameter (mm)	Head loss Gradient (m/km)	Length (Scaled) (m)	Flow (L/s)	Velocity (m/s)
3	P-127	J-109	J-118	315	1.74	100.00	33.40	0.56
3	P-128	J-123	J-113	160	1.71	100.00	5.57	0.36
3	P-129	J-119	J-120	250	3.81	100.00	27.84	0.74
3	P-130	J-124	J-123	200	2.08	100.00	11.14	0.46
3	P-131	J-114	J-125	75	0.00	100.00	0.00	0.00
3	P-132	J-122	J-124	200	2.08	100.00	11.14	0.46
3	P-133	J-117	J-107	75	1.42	100.00	0.68	0.20
3	P-134	J-126	J-127	110	0.78	100.00	1.35	0.19
3	P-135	J-106	J-126	110	1.65	100.00	2.03	0.28
3	P-136	J-127	J-128	75	1.40	100.00	0.68	0.20
3	P-137	J-129	J-130	160	3.49	100.00	8.18	0.53
3	P-138	J-102	J-131	160	3.49	100.00	8.18	0.53
3	P-139	J-131	J-129	160	3.49	100.00	8.18	0.53
3	P-140	J-130	J-132	160	3.49	100.00	8.18	0.53

**(-) flow denotes only opposite director as considered in the model*

Table L.2: Details of Model Output of Pipes for Scenario 2

Phase Area	Label	Start Node	Stop Node	Diameter (mm)	Head loss Gradient (m/km)	Length (Scaled) (m)	Flow (L/s)	Velocity (m/s)
1	P-1	J-1	J-2	315	2.10	31.60	-37.02	0.62
1	P-2	J-3	J-4	110	1.45	37.57	1.89	0.26
1	P-3	J-5	J-6	160	1.60	55.63	5.37	0.35
1	P-4	J-7	J-8	160	1.53	64.27	-5.24	0.34
1	P-5	J-9	J-10	250	2.00	73.38	19.67	0.52
1	P-6	J-11	J-12	75	0.00	83.67	0.00	0.00
1	P-7	J-4	J-13	110	1.45	84.49	1.89	0.26
1	P-8	J-14	J-15	75	0.18	100.00	-0.23	0.07
1	P-9	J-6	J-16	160	1.04	100.00	4.27	0.28
1	P-10	J-16	J-17	110	3.75	100.00	3.16	0.44
1	P-11	J-18	J-1	200	4.21	100.00	-16.30	0.68
1	P-12	J-19	J-18	200	3.22	100.00	-14.09	0.59
1	P-13	J-17	J-20	75	2.36	100.00	0.90	0.27
1	P-14	J-21	J-19	200	2.76	100.00	-12.98	0.54
1	P-15	J-22	J-23	160	3.79	100.00	-8.56	0.56
1	P-16	J-23	J-21	200	1.96	100.00	-10.77	0.45
1	P-17	J-8	J-22	160	2.93	100.00	-7.45	0.48
1	P-18	J-24	J-1	250	2.21	100.00	-20.72	0.55
1	P-19	J-25	J-26	160	2.92	100.00	7.43	0.48
1	P-20	J-27	J-28	160	4.67	100.00	-9.58	0.62
1	P-21	J-29	J-5	200	4.78	100.00	17.45	0.73
1	P-22	J-13	J-30	110	1.45	100.00	1.89	0.26
1	P-23	J-31	J-32	200	3.68	100.00	-15.16	0.63

Phase Area	Label	Start Node	Stop Node	Diameter (mm)	Head loss Gradient (m/km)	Length (Scaled) (m)	Flow (L/s)	Velocity (m/s)
1	P-24	J-33	J-34	110	4.98	100.00	-3.68	0.51
1	P-25	J-26	J-35	160	2.16	100.00	6.32	0.41
1	P-26	J-20	J-14	75	0.17	100.00	-0.22	0.06
1	P-27	J-36	J-37	110	1.46	100.00	1.90	0.26
1	P-28	J-5	J-38	200	2.42	100.00	12.08	0.50
1	P-29	J-35	J-39	160	1.51	100.00	5.21	0.34
1	P-30	J-2	J-40	315	2.22	100.00	-38.13	0.64
1	P-31	J-40	J-9	250	2.01	100.00	19.70	0.52
1	P-32	J-10	J-29	250	1.80	100.00	18.56	0.49
1	P-33	J-30	J-41	110	4.96	100.00	-3.68	0.51
1	P-34	J-41	J-33	110	4.98	100.00	-3.68	0.51
1	P-35	J-34	J-7	160	4.38	100.00	-9.25	0.60
1	P-36	J-42	J-43	110	3.41	100.00	3.00	0.41
1	P-37	J-9	J-11	75	0.01	100.00	0.03	0.01
1	P-38	J-44	J-3	110	1.45	100.00	1.89	0.26
1	P-39	J-39	J-42	160	0.97	100.00	4.11	0.27
1	P-40	J-37	J-44	110	1.46	100.00	1.90	0.26
1	P-41	J-43	J-36	110	1.46	100.00	1.90	0.26
1	P-42	J-32	J-24	200	3.68	100.00	-15.16	0.63
1	P-43	J-28	J-31	160	4.67	100.00	-9.58	0.62
1	P-44	J-7	J-27	160	0.93	101.13	-4.01	0.26
1	P-45	J-38	J-15	160	4.93	107.02	9.86	0.64
1	P-46	J-15	J-25	160	3.77	112.78	8.53	0.56
1	P-47	J-40	R-1	355	3.18	188.64	-63.40	0.84
2	P-48	J-45	R-2	400	5.39	20.97	-115.5	1.20
2	P-49	J-46	J-45	400	3.42	28.01	-90.29	0.94
2	P-50	J-47	J-48	75	0.02	31.58	0.07	0.02
2	P-51	J-51	J-52	75	0.01	45.16	-0.06	0.02
2	P-52	J-52	J-53	75	0.86	45.16	-0.52	0.16
2	P-53	J-54	J-55	75	3.73	47.78	1.15	0.34
2	P-54	J-55	J-56	75	2.85	47.78	0.99	0.30
2	P-55	J-57	J-58	75	1.46	47.92	0.69	0.21
2	P-56	J-58	J-59	75	0.49	47.92	0.38	0.11
2	P-57	J-60	J-61	75	0.94	48.00	0.54	0.16
2	P-58	J-62	J-60	75	2.15	48.00	0.85	0.25
2	P-59	J-63	J-64	75	1.80	48.87	-0.77	0.23
2	P-60	J-47	J-63	75	1.19	48.87	-0.62	0.18
2	P-61	J-65	J-54	160	4.16	53.12	-8.99	0.59
2	P-62	J-57	J-65	160	4.03	53.12	-8.84	0.58
2	P-63	J-66	J-67	160	1.29	57.31	-4.77	0.31
2	P-64	J-62	J-66	160	1.21	57.31	-4.62	0.30
2	P-65	J-67	J-57	160	1.44	57.31	-5.08	0.33
2	P-66	J-50	J-68	250	2.61	59.54	22.68	0.60
2	P-67	J-69	J-59	75	1.44	60.62	0.69	0.20
2	P-68	J-56	J-69	75	2.09	60.62	0.84	0.25

Phase Area	Label	Start Node	Stop Node	Diameter (mm)	Head loss Gradient (m/km)	Length (Scaled) (m)	Flow (L/s)	Velocity (m/s)
2	P-69	J-53	J-47	75	0.00	62.27	0.01	0.00
2	P-70	J-70	J-62	75	1.49	62.78	-0.70	0.21
2	P-71	J-64	J-70	75	0.51	62.78	-0.39	0.12
2	P-72	J-47	J-71	75	0.54	63.13	0.41	0.12
2	P-73	J-71	J-72	75	0.04	63.13	0.10	0.03
2	P-74	J-59	J-73	75	2.46	65.90	0.92	0.27
2	P-75	J-73	J-74	75	1.13	65.90	0.60	0.18
2	P-76	J-74	J-61	75	0.66	65.90	0.45	0.13
2	P-77	J-72	J-51	75	0.04	79.44	0.10	0.03
2	P-78	J-61	J-53	75	1.44	85.94	0.69	0.20
2	P-79	J-75	J-54	200	2.85	117.09	13.21	0.55
2	P-80	J-76	J-77	315	1.80	110.87	34.10	0.57
2	P-81	J-48	J-78	75	0.02	100.00	0.07	0.02
2	P-82	J-79	J-80	200	2.08	100.00	11.13	0.46
2	P-83	J-49	J-81	355	4.81	100.00	-79.19	1.05
2	P-84	J-78	J-82	75	0.02	100.00	0.06	0.02
2	P-85	J-45	J-50	250	3.17	100.00	25.20	0.67
2	P-86	J-68	J-83	250	1.90	100.00	19.09	0.51
2	P-87	J-84	J-75	200	3.24	100.00	14.14	0.59
2	P-88	J-83	J-84	250	1.77	100.00	18.41	0.49
2	P-89	J-81	J-46	355	4.81	100.00	-79.20	1.05
2	P-90	J-49	J-85	315	2.45	113.26	40.22	0.67
2	P-91	J-86	J-87	250	2.52	100.00	22.27	0.59
2	P-92	J-88	J-89	250	3.99	100.00	28.53	0.76
2	P-93	J-90	J-91	75	0.93	100.00	0.54	0.16
2	P-94	J-92	J-88	250	3.99	100.00	28.53	0.76
2	P-95	J-93	J-64	75	0.91	100.00	0.54	0.16
2	P-96	J-91	J-94	75	0.93	100.00	0.54	0.16
2	P-97	J-95	J-96	75	0.91	100.00	0.54	0.16
2	P-98	J-94	J-97	75	0.92	100.00	0.54	0.16
2	P-99	J-87	J-79	200	4.41	100.00	16.70	0.70
2	P-100	J-82	J-98	75	0.00	100.00	0.01	0.00
2	P-101	J-77	J-92	274.6	1.84	100.00	34.10	0.58
2	P-102	J-89	J-86	250	2.52	100.00	22.27	0.59
2	P-103	J-99	J-100	75	0.00	100.00	0.00	0.00
2	P-104	J-80	J-99	160	1.71	100.00	5.57	0.36
2	P-105	J-96	J-93	75	0.91	100.00	0.54	0.16
2	P-106	J-97	J-95	75	0.92	100.00	0.54	0.16
2	P-107	J-76	J-90	75	0.93	103.15	0.54	0.16
2	P-108	J-85	J-76	315	1.86	113.55	34.65	0.58
3	P-109	J-46	J-101	160	3.49	27.38	8.18	0.53
3	P-110	J-102	J-49	315	2.31	40.65	-38.97	0.65
3	P-111	J-50	J-103	110	2.47	41.04	2.52	0.35
3	P-112	J-104	J-105	75	0.00	55.71	0.01	0.00
3	P-113	J-102	J-106	315	2.31	56.19	38.97	0.65

Phase Area	Label	Start Node	Stop Node	Diameter (mm)	Head loss Gradient (m/km)	Length (Scaled) (m)	Flow (L/s)	Velocity (m/s)
3	P-114	J-107	J-108	160	1.71	100.00	5.57	0.36
3	P-115	J-109	J-110	315	1.74	100.00	33.40	0.56
3	P-116	J-111	J-112	250	2.52	100.00	22.27	0.59
3	P-117	J-112	J-113	200	4.41	100.00	16.70	0.70
3	P-118	J-106	J-109	315	1.74	100.00	33.40	0.56
3	P-119	J-114	J-107	160	1.71	100.00	5.57	0.36
3	P-120	J-110	J-111	250	3.81	100.00	27.84	0.74
3	P-121	J-115	J-114	200	2.08	100.00	11.14	0.46
3	P-122	J-108	J-116	75	0.00	100.00	0.00	0.00
3	P-123	J-113	J-115	200	2.08	100.00	11.14	0.46
3	P-124	J-84	J-104	75	1.42	100.00	0.68	0.20
3	P-125	J-117	J-118	75	5.04	100.00	1.35	0.40
3	P-126	J-103	J-117	110	1.65	100.00	2.03	0.28
3	P-127	J-118	J-119	75	1.40	100.00	0.68	0.20
3	P-128	J-120	J-121	160	3.49	100.00	8.18	0.53
3	P-129	J-101	J-122	160	3.49	100.00	8.18	0.53
3	P-130	J-122	J-120	160	3.49	100.00	8.18	0.53
3	P-131	J-121	J-123	160	3.49	100.00	8.18	0.53

**(-) flow denotes only opposite director as considered in the model*

Appendix M: Groundwater Monitoring Plan

The foundation of any good groundwater analyses requires high quality monitoring data and appropriate understanding of aquifer to evaluate groundwater resource utilization and management strategies. Similarly study of regional and local hydrogeological situation for understanding of target area aquifer system requires good design and establishment of groundwater monitoring system.

Benefit of the Monitoring Network

Project would be benefited on the following aspects from the outcome of the groundwater monitoring system:

- Present and future groundwater scenario for aquifer management
- Optimum utilization of groundwater resource and project facilities
- Protection on degradation of aquatic environment
- Development of valuable reference for research and study on groundwater technology

Essential Components of Water-Level Monitoring Programs

Essential components of water-level monitoring program include:

- Distribution of monitoring well and construction
- Water level measuring instruments
- Frequency of GWL Measurements
- Installation of Rain gauge
- Base line and Seasonal water quality checking
- Quality Assurance and Data Checking

Distribution of monitoring well and construction

The project area is in the valley located between Inani and Olat anticline. Naf River crosses the area from north to south and fall into Bay of Bengal. This river has tidal impact and salinity issue. Monitoring of groundwater level, water quality, rainfall measurements are important factors for a sustainable management plan of the proposed well field which is situated in Whykhong area. Monitoring wells consist of multi-level groundwater monitoring wells (multi-level, one shallow and one deep) and line wells perpendicular to west bank of Naf river. To observe groundwater-surface water interaction, rain gauge stations are also proposed.

Multi-level Monitoring Well

Multi-level monitoring wells installation are proposed at 8 locations as shown in **Figure M.1**. Depth for shallow well is up to 300 feet and deep well is up to 600 feet. Diameter of the monitoring well would be 2 inch or 50 mm. The tentative locations of multi-level groundwater monitoring wells are given in **Table M.1**.

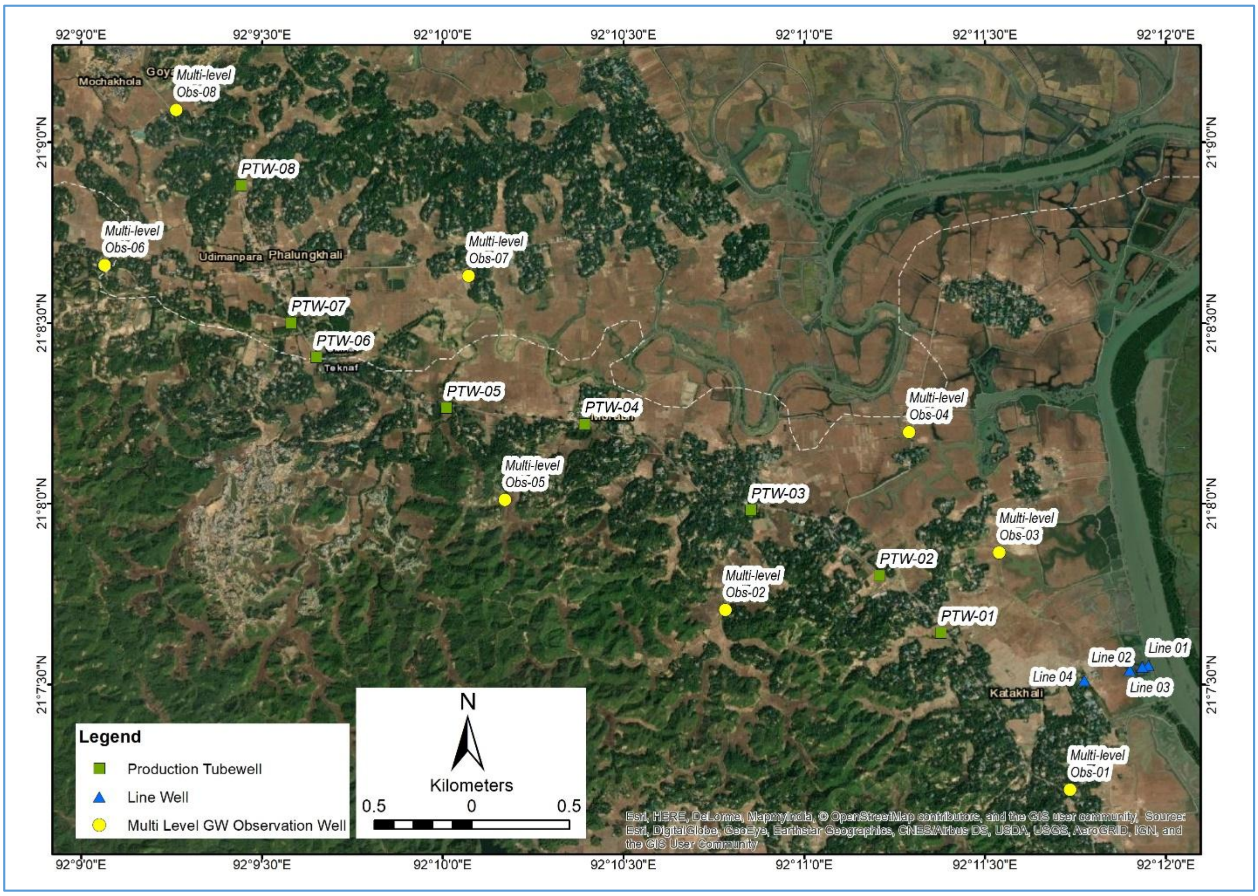


Figure M.1: Location of Multi Level Groundwater Monitoring wells and Line Wells

Table M.1: Tentative locations of Multi-level Groundwater monitoring wells, Line Well and Rain Gauge Station

Sl No	Well ID/Station ID	Latitude	Longitude
1	Multi-level Obs-01	21° 7'12.53"N	92°11'44.16"E
2	Multi-level Obs-02	21° 7'42.41"N	92°10'46.93"E
3	Multi-level Obs-03	21° 7'51.90"N	92°11'32.37"E
4	Multi-level Obs-04	21° 8'11.91"N	92°11'17.40"E
5	Multi-level Obs-05	21° 8'0.68"N	92°10'10.30"E
6	Multi-level Obs-06	21° 8'39.63"N	92° 9'3.85"E
7	Multi-level Obs-07	21° 8'37.85"N	92°10'4.28"E
8	Multi-level Obs-08	21° 9'5.42"N	92° 9'15.78"E
9	Line 01	21° 7'33.17"N	92°11'57.16"E
10	Line 02	21° 7'32.93"N	92°11'56.11"E
11	Line 03	21° 7'32.42"N	92°11'54.04"E
12	Line 04	21° 7'30.70"N	92°11'46.52"E
13	Rain Gauge Station (Ukhiya)	21°14'37.56"N	92° 8'40.48"E
14	Rain Gauge Station (Whykhong, Teknaf)	21° 8'20.37"N	92° 9'57.50"E

Note: All the locations are tentative, locations may be changed based on actual field condition

Different Component of Monitoring Well for this project:

50mm diameter uPVC pipe can be used as casing pipe except upper 1.5 m, which would be 50mm GMS pipe. Out of this 1.5 m GI pipe, 0.60 m would remain above the ground surface as standpipe. 6 meter long 10 slot screens need to be installed in the target aquifer. At the bottom of the screen, 3 m UPVC casing need to be fixed as bail sump. At top of the monitoring wells, there should be arrangement for the provision of closing with threaded cap. Standpipes should be fixed with 0.6m x 0.6m x 0.6 m cement concrete platform. A schematic diagram for different components of a groundwater monitoring wells is illustrated in **Figure M.2**.

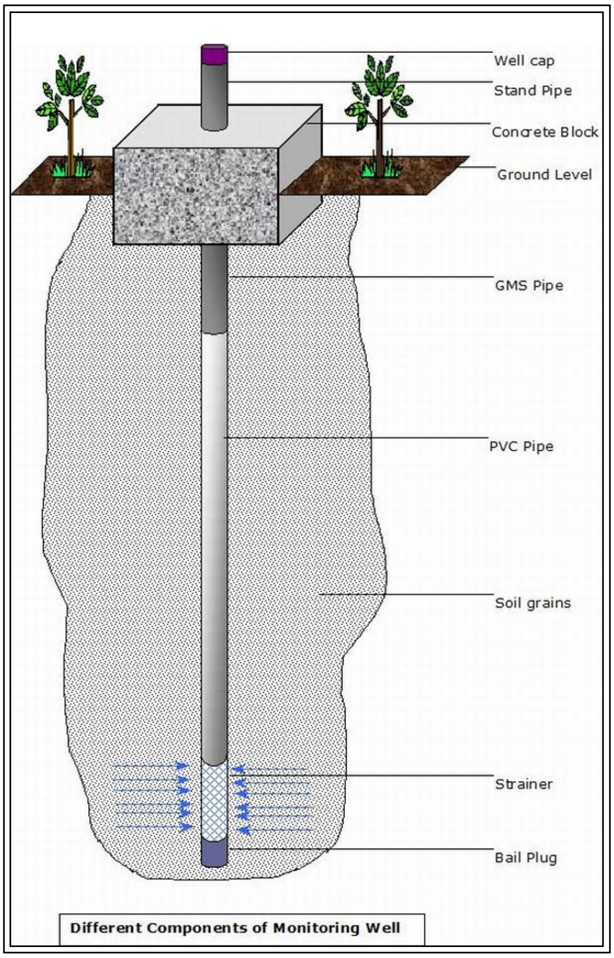


Figure M.2: Different Component of Monitoring Well

Line Well for Surface and Ground water interaction

At the west bank of Naf River, line wells need to be installed to observe the possibility of surface water and groundwater interaction. Line well consists of at least 4 nos. shallow monitoring wells. Distance of the well would be 0, 30, 90, 300 meters towards land from the high tide point of the west bank of Naf River for a particular location. Depth of the wells would be within 100 feet. The tentative locations of line wells are presented in **Figure M.1** and listed in **Table M.1**.

Rain gauge

Two rain gauges are proposed to be installed for measuring rainfall. Automatic rain gauge with data logger is preferred. The suitable locations for rain gauge installation are: (i) at north of the well field area in Ukhiya upazila and (ii) in the well field area (Whykhong union of Teknaf).

Tentative locations for rain gauge installation are presented in **Figure M.3** and listed in **Table M.1**.

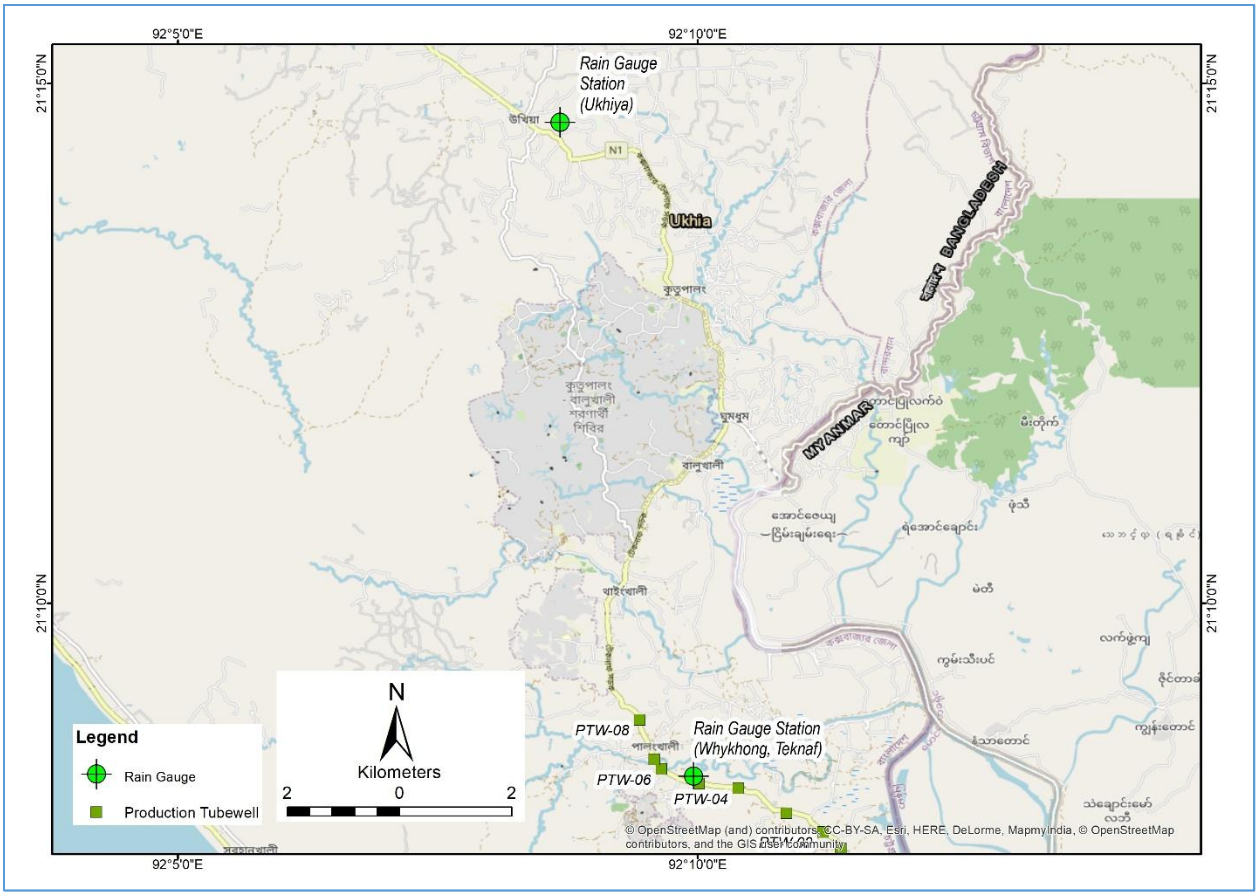


Figure M.3: Rain Gauge Station for Rainfall Measurement

Frequency of Groundwater level Measurement

The frequency of water-level measurements is the most important components of a water level monitoring program. Water-level monitoring may involve **"continuous"** or **"periodic"** measurements. Continuous monitoring involves the installation of automatic water-level sensing and recording instruments that are programmed to make measurements in observation wells at a specified frequency. Continuous monitoring provides the highest level of resolution of water-level fluctuations. **Figure M.4** represent the selection method of data collection frequency for any groundwater water project based on data requirement and management purpose.

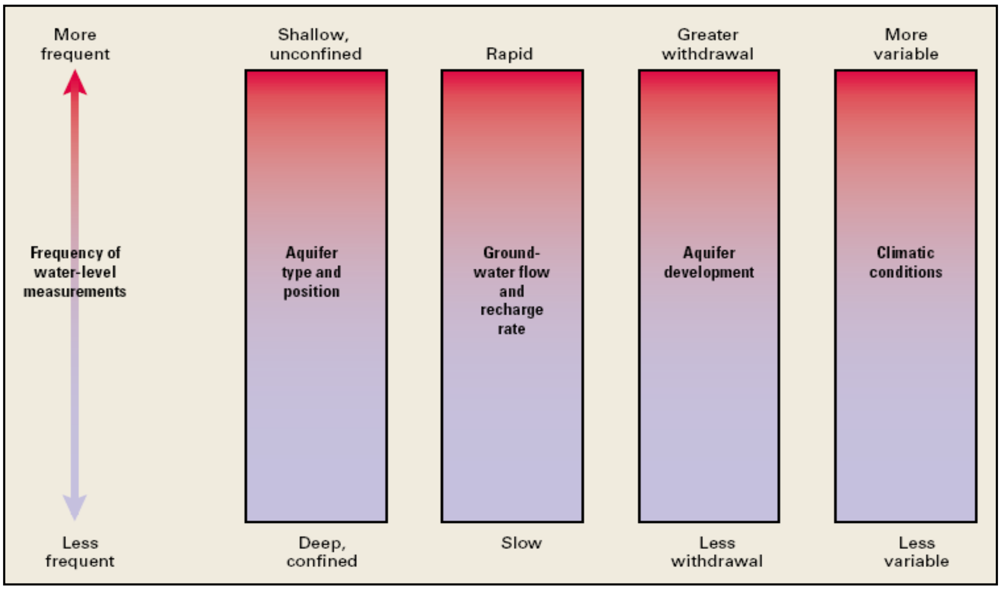


Figure M.4: Frequency of groundwater monitoring data recording

Groundwater level and electrical conductivity of the area need to be measured as Naf River course is very close to the Well field area and connected with the Bay of Bengal. Therefore, automatic data recorder with capability of measuring both water level and electrical conductivity (EC) need to be installed.

Water level and change of EC (if any) in aquifer can be measure hourly (shorter period also possible) through automatic data recorder to understand the groundwater situation during and after production hour. Data can be collected manually from each site through data reading device in fortnightly/ monthly or when as required.

If telemetry module connected (GPRS/Radio link) with data logger, this data can directly integrate with SCADA or view in web/data server and view real time data.

Base Line and Seasonal Water Quality Check

To understand groundwater quality situation the following parameters, need to be checked for establishment of base line condition before starting groundwater abstraction from the well field area. Sample needs to be collected and tested from all the monitoring well installed under this project.

Physical analysis required: Color, Odour, Temp, pH, EC, Salinity, TDS

Chemical analysis Principal ions: Ca, Mg, Na, K, CO_3, HCO_3, SO_4, Cl, NO_3.

Other ions: P, Fe, Mn, As, F, Al, B, Cd, Pb, Si, Zn, Si and hardness

Analysis required for seasonal monitoring (Dry season and wet season): Fe, Mn, As, B, Zn, Cl, NO_3 and F

Installation date of the well, depth of individual well and date of sampling must be attached with the quality data sheet.

Quality Assurance and Data Checking

Good quality-assurance practices help maintaining accuracy and precision of water-level measurements to ensure that observation wells reflect actual conditions in the aquifer being monitored, and provide reliable data for many intended uses.

Some important field practices that can ensure the quality of ground-water-level data include:

- the establishment of permanent datum (reference points for water-level measurements) for monitoring wells;
- Well structure and monitoring well should be checked periodically for ensuring its hydraulic connection with the aquifer and capacity to indicate the aquifer response through the static water level inside the well casing. For checking groundwater, water level in the pipe should be measured and then fresh water should be poured (**Figure M.5**) into the pipe up to top of the monitoring well and take measurement of groundwater level (GWL) at an interval of 5 minutes until GWL lowered down to original level. After that a pump head should be fitted into the GI standpipe and continue pumping for one hour. After removing the pump head from the pipe, measurement of static water level should be taken. Fresh water should be poured and measurement of GWL should be taken at an interval of 5 minutes until groundwater level reaches to the original level. Development should continue till the hydraulic characteristics of the filter pack and the geologic formation adjacent to the well screen improved and continues until groundwater level falls quickly after pouring of water into the pipe. This exercise should be carried out at least once in year.

Figure M.5: Monitoring well hydraulic connectivity test

To maintain and assure quality of monitoring, a permanent file need be maintained that should contain the followings:

- a physical description of well construction,
- location coordinates,
- the datum used for water-level measurements,
- Results of hydraulic tests for each monitoring well.

Recent water-level measurements should be compared with previous measurements under similar hydrologic conditions to identify potential anomalies in water-level fluctuations that may indicate a malfunction of measuring equipment or a defect in monitoring well construction. To eliminate human error of collected data, any abrupt or sudden change in hydrograph can be an indication. The monitoring well should be free from any influence of production well.

Tentative Cost

For the groundwater monitoring system tentative establishment cost is around 16.2 Million BDT. Annually 1.96 Million BDT would be required for the operation of total 20 monitoring wells (8 nos. Deep well, 8 nos. shallow well and 4 nos. monitoring well). Moreover, about 1.2 million BDT would be required after every 3 years for rehabilitation of the wells. The detail costing is given in **Table M.2** to **Table M.4**.

Table M.2: Tentative establishment cost of the monitoring system

Sl No	Description	Unit	Unit cost (Taka)	Quantity	Total (Taka)
1	Monitoring Well (Deep)	Pc	300,000	8	2,400,000
2	Monitoring Well (Shallow)	Pc	200,000	8	1,600,000
3	Line Well	4 Pc (1 set)	800,000	1	800,000
4	Data logger (Temp, Depth, EC)	Pc	430,000	22	9,460,000
5	Digital/Automatic Rain Gauge	Pc	85,000	2	170,000
6	Laptop (For Data Collection from Field)	Pc	70,000	1	70,000
7	Water Quality Multiparameter	Pc	410,000	1	410,000
8	Groundwater Sampler (Submersible Pump with +/- 30 meter head)	**Pc**	70,000	4	280,000
9	Flow-Through Cell for GW sampling	**Pc**	70,000	1	70,000
10	Base line Water Quality test	Per sample	45,000	20	900,000
Total Cost for Establishment					**16,160,000**

Table M.3: Tentative annual operation cost of the monitoring system

Sl No	Description	Unit	Unit cost (Taka)	Quantity	Total (Taka)
1	Water Quality Test				
1.1	Dry Season	Per sample	30,000	20	600,000
1.2	Wet Season	Per sample	30,000	20	600,000
2	Well Observer (Salary)for 1 year	Per Month	15,000	12	180,000
3	Data Engineer (Salary) for 1 year	Per Month	40,000	12	480,000
4	Annual Rehabilitation.	Per Well	5,000	20	100,000
Annual Cost for Monitoring					**1,960,000**

Table M.4: Tentative maintenance cost at every 3 years of the monitoring system

Sl No	Description	Unit	Unit cost (Taka)	Quantity	Total (Taka)
1	3 years Rehabilitation work (Development, Regeneration)	Per Well	60,000	20	1,200,000

Appendix N: Cost Assessment for Desalination Plant

To fulfill water demand in Sabrang and Naf Tourism Park, desalination plant is one of the Major source. The capacity of desalination plant varies in different water supply Options and thus cost also varies. The summary of cost estimation of desalination plant for different Options are presented in **Table N.1** to **Table N.6.**

Table N.1: Cost summary of desalination plant in Sabrang Tourism Park for Option-1

Item	Phase-1		Phase-2	
	Million USD	Million BDT	Million USD	Million BDT
Capacity	**2.55 MLD**		**2.65 MLD**	
Equipment cost with installation	3.8	325.1	4.1	344.3
CD & VAT	1.1	97.5	1.2	103.3
Transmission main with installation		3.9		3.9
Office building		12.6		
Total		**439.1**		**451.4**

Table N.2: Cost summary of desalination plant in Sabrang Tourism Park for Option-2

Item	Phase-1		Phase-2	
	Million USD	Million BDT	Million USD	Million BDT
Capacity	**1.9 MLD**		**2.6 MLD**	
Equipment cost with installation	2.85	242.3	3.90	331.5
CD & VAT	0.86	72.7	1.17	99.5
Transmission main with installation		3.856		3.856
Office building		12.6		
Total		**331.4**		**434.8**

Table N.3: Cost summary of desalination plant in Sabrang Tourism Park for Option-3

Item	Phase-1		Phase-2	
	Million USD	Million BDT	Million USD	Million BDT
Capacity	**4.5 MLD**		**5.1 MLD**	
Equipment cost with installation	6.75	573.8	7.14	606.9
CD & VAT	2.03	172.1	2.14	182.1
Transmission main with installation		3.86		3.856
Office building		12.6		
Total		**762.3**		**792.8**

Table N.4: Cost summary of desalination plant in Naf Tourism Park for Option-3

Item	Phase-1		Phase-2	
	Million USD	Million BDT	Million USD	Million BDT
Capacity	**0.6 MLD**		**0.55 MLD**	
Equipment cost with installation	0.9	76.5	0.83	70.1
CD & VAT	0.27	23.0	0.25	21.0
Transmission main with installation		3.86		3.86
Office building		6.3		
Total		**109.6**		**95.0**

Table N.5: Cost summary of desalination plant in Sabrang Tourism Park for Option-4

Item	Phase-1		Phase-2	
	Million USD	Million BDT	Million USD	Million BDT
Capacity	**1.35 MLD**		**2.05 MLD**	
Equipment cost with installation	2.025	172.1	3.08	261.4
CD & VAT	0.61	51.6	0.92	78.4
Transmission main with installation		3.856		3.856
Office building		12.6		
Total		**240.2**		**343.6**

Table N.6: Cost summary of desalination plant in Naf Tourism Park for Option-4

Item	Phase-1		Phase-2	
	Million USD	Million BDT	Million USD	Million BDT
Capacity	**0.6 MLD**		**0.55 MLD**	
Equipment cost with installation	0.9	76.5	0.83	70.1
CD & VAT	0.27	23.0	0.25	21.0
Transmission main with installation		3.856		3.856
Office building		6.3		
Total		**109.6**		**95.0**

Appendix O: Cost Assessment for Bottling Water Plant

The summary of cost estimation of bottling water plant is stated in **Table O.1.**

Table O.1: Cost summary of bottling water plant

Item	Phase-1		Phase -2	
	USD	Million BDT	USD	Million BDT
Capacity	**4000 lt/hr**		**3500 lt/hr**	
Equipment cost				
Treatment plant unit	31,250	2.7	27,500	2.3
Semiautomatic Bottle Unscrambler	2,750	0.2	2,420	0.2
3 In1 High Speed Water Filling Machine	23,125	2.0	20,350	1.7
Downstream Auxiliary Packing Machines	35,625	3.0	31,350	2.7
Bottle blowing machine	48,750	4.1	42,900	3.6
CD & VAT				
TP unit	18,853	1.6	16,591	1.4
other unit	30,374	2.6	26,729	2.3
Transportation				
Sea Fred	8,000	0.7	8,000	0.7
Local transportation		0.4		0.5
Installation	28,300	2.4	24,904	2.1
Sludge management unit		15.0		15.0
Civil works				
Factory building		180.0		158.4
Office building		12.6		
Total		**227.3**		**191.0**

Appendix P: Year wise cost under different options

Table P.1: Year wise investment, operating and total cost in Option-2

Year #	Year	Investment cost (Million BDT)	Operating cost (Million BDT)	Total cost (Million BDT)
1	2022-2023	667.48	0.00	667.48
2	2023-2024	1297.30	0.00	1297.30
3	2024-2025	1723.62	0.00	1723.62
4	2025-2026	193.00	24.96	217.96
5	2026-2027	247.04	26.21	273.25
6	2027-2028	224.20	35.11	259.31
7	2028-2029	0.00	82.84	82.84
8	2029-2030	0.00	86.98	86.98
9	2030-2031	0.00	91.33	91.33
10	2031-2032	144.74	85.64	230.38
11	2032-2033	251.94	89.92	341.86
12	2033-2034	841.34	94.41	935.76
13	2034-2035	195.37	113.69	309.06
14	2035-2036	379.16	125.61	504.77
15	2036-2037	379.16	131.89	511.05
16	2037-2038	0.00	223.29	223.29
17	2038-2039	0.00	234.45	234.45
18	2039-2040	0.00	246.18	246.18
19	2040-2041	0.00	258.48	258.48
20	2041-2042	0.00	271.41	271.41
21	2042-2043	0.00	284.98	284.98
22	2043-2044	0.00	299.23	299.23
23	2044-2045	0.00	314.19	314.19
24	2045-2046	0.00	329.90	329.90
25	2046-2047	0.00	346.39	346.39
26	2047-2048	0.00	363.71	363.71
27	2048-2049	0.00	381.90	381.90
28	2049-2050	0.00	400.99	400.99
29	2050-2051	0.00	421.04	421.04
30	2051-2052	0.00	442.10	442.10
31	2052-2053	0.00	464.20	464.20
32	2053-2054	0.00	487.41	487.41
33	2054-2055	0.00	511.78	511.78
34	2055-2056	0.00	537.37	537.37
35	2056-2057	0.00	564.24	564.24
36	2057-2058	0.00	592.45	592.45
37	2058-2059	0.00	622.07	622.07
38	2059-2060	0.00	653.18	653.18
39	2060-2061	0.00	685.84	685.84
40	2061-2062	0.00	720.13	720.13
41	2062-2063	0.00	756.13	756.13
42	2063-2064	0.00	793.94	793.94

Year #	Year	Investment cost (Million BDT)	Operating cost (Million BDT)	Total cost (Million BDT)
43	2064-2065	0.00	833.64	833.64
44	2065-2066	0.00	875.32	875.32
45	2066-2067	0.00	919.09	919.09
46	2067-2068	0.00	965.04	965.04
47	2068-2069	0.00	1013.29	1013.29
48	2069-2070	0.00	1063.96	1063.96
49	2070-2071	0.00	1117.15	1117.15
50	2071-2072	0.00	1173.01	1173.01
Total		**6,544**	**21,156**	**27,700**

Table P.2: Year wise investment, operating and total cost in Option-3

Year #	Year	Investment cost (Million BDT)	Operating cost (Million BDT)	Total cost (Million BDT)
1	2022-2023	156.03	0.00	156.03
2	2023-2024	338.50	0.00	338.50
3	2024-2025	265.10	0.00	265.10
4	2025-2026	115.53	50.48	166.01
5	2026-2027	286.20	53.00	339.20
6	2027-2028	311.88	63.25	375.13
7	2028-2029	0.00	101.40	101.40
8	2029-2030	0.00	106.47	106.47
9	2030-2031	0.00	111.79	111.79
10	2031-2032	86.66	117.38	204.04
11	2032-2033	313.91	123.25	437.15
12	2033-2034	373.61	129.41	503.03
13	2034-2035	540.15	135.88	676.03
14	2035-2036	712.48	148.91	861.39
15	2036-2037	0.00	289.51	289.51
16	2037-2038	0.00	303.99	303.99
17	2038-2039	0.00	319.19	319.19
18	2039-2040	0.00	335.15	335.15
19	2040-2041	0.00	351.91	351.91
20	2041-2042	0.00	369.50	369.50
21	2042-2043	0.00	387.98	387.98
22	2043-2044	0.00	407.38	407.38
23	2044-2045	0.00	427.75	427.75
24	2045-2046	0.00	449.13	449.13
25	2046-2047	0.00	471.59	471.59
26	2047-2048	0.00	495.17	495.17
27	2048-2049	0.00	519.93	519.93
28	2049-2050	0.00	545.92	545.92
29	2050-2051	0.00	573.22	573.22
30	2051-2052	0.00	601.88	601.88
31	2052-2053	0.00	631.97	631.97
32	2053-2054	0.00	663.57	663.57

Year #	Year	Investment cost (Million BDT)	Operating cost (Million BDT)	Total cost (Million BDT)
33	2054-2055	0.00	696.75	696.75
34	2055-2056	0.00	731.59	731.59
35	2056-2057	0.00	768.17	768.17
36	2057-2058	0.00	806.58	806.58
37	2058-2059	0.00	846.91	846.91
38	2059-2060	0.00	889.25	889.25
39	2060-2061	0.00	933.71	933.71
40	2061-2062	0.00	980.40	980.40
41	2062-2063	0.00	1029.42	1029.42
42	2063-2064	0.00	1080.89	1080.89
43	2064-2065	0.00	1134.93	1134.93
44	2065-2066	0.00	1191.68	1191.68
45	2066-2067	0.00	1251.27	1251.27
46	2067-2068	0.00	1313.83	1313.83
47	2068-2069	0.00	1379.52	1379.52
48	2069-2070	0.00	1448.50	1448.50
49	2070-2071	0.00	1520.92	1520.92
50	2071-2072	0.00	1596.97	1596.97
Total		**3,500**	**28,887**	**32,387**

Table P.3: Year wise investment, operating and total cost in Option-4

Year #	Year	Investment cost (Million BDT)	Operating cost (Million BDT)	Total cost (Million BDT)
1	2022-2023	691.88	0.00	691.88
2	2023-2024	1346.09	0.00	1346.09
3	2024-2025	1299.38	0.00	1299.38
4	2025-2026	169.38	28.15	197.53
5	2026-2027	199.80	29.56	229.36
6	2027-2028	176.96	38.63	215.59
7	2028-2029	0.00	73.24	73.24
8	2029-2030	0.00	76.90	76.90
9	2030-2031	0.00	80.74	80.74
10	2031-2032	178.98	84.78	263.76
11	2032-2033	320.42	89.02	409.44
12	2033-2034	143.94	93.47	237.41
13	2034-2035	164.88	115.67	280.55
14	2035-2036	318.18	127.69	445.87
15	2036-2037	318.18	134.07	452.25
16	2037-2038	0.00	211.83	211.83
17	2038-2039	0.00	222.42	222.42
18	2039-2040	0.00	233.54	233.54
19	2040-2041	0.00	245.22	245.22
20	2041-2042	0.00	257.48	257.48

Year #	Year	Investment cost (Million BDT)	Operating cost (Million BDT)	Total cost (Million BDT)
21	2042-2043	0.00	270.35	270.35
22	2043-2044	0.00	283.87	283.87
23	2044-2045	0.00	298.06	298.06
24	2045-2046	0.00	312.97	312.97
25	2046-2047	0.00	328.62	328.62
26	2047-2048	0.00	345.05	345.05
27	2048-2049	0.00	362.30	362.30
28	2049-2050	0.00	380.41	380.41
29	2050-2051	0.00	399.43	399.43
30	2051-2052	0.00	419.41	419.41
31	2052-2053	0.00	440.38	440.38
32	2053-2054	0.00	462.39	462.39
33	2054-2055	0.00	485.51	485.51
34	2055-2056	0.00	509.79	509.79
35	2056-2057	0.00	535.28	535.28
36	2057-2058	0.00	562.04	562.04
37	2058-2059	0.00	590.15	590.15
38	2059-2060	0.00	619.65	619.65
39	2060-2061	0.00	650.64	650.64
40	2061-2062	0.00	683.17	683.17
41	2062-2063	0.00	717.33	717.33
42	2063-2064	0.00	753.19	753.19
43	2064-2065	0.00	790.85	790.85
44	2065-2066	0.00	830.39	830.39
45	2066-2067	0.00	871.91	871.91
46	2067-2068	0.00	915.51	915.51
47	2068-2069	0.00	961.29	961.29
48	2069-2070	0.00	1009.35	1009.35
49	2070-2071	0.00	1059.82	1059.82
50	2071-2072	0.00	1112.81	1112.81
Total		**5,328**	**20,104**	**25,432**

Appendix Q: Financial and Economic Analysis

Table Q.1: Economic Analysis

(all cost in Lakh BDT)

Table Q.2: Financial Analysis

(all cost in Lakh BDT)

Appendix R: Comments from Clients on Draft Final Report

Comments received from Dr. Tanveer Ahmed, Environment Specialist, BEZA through e-mail

1. Review comments of BEZA on the draft interim and final report and their respective response by IWM should be included in the final presentation and revised report;
2. Unit rate of the proposed project interventions and the required quantity, operation/maintenance cost of the proposed project interventions should be included along the source of reference of the quoted price in the cost assessment section;
3. Required land area and cost of the land for underground reservoir under BPS-02 should be included in the land acquisition plan of the project;
4. Topographic & Engineering survey sections should detail the topographic implications and guideline for laying out the proposed transmission line in the hilly terrain of the project area;
5. Number and types of major natural and socio-economic features identified along the buffer area of the proposed transmission line at certain interval should be detailed in section 2.3.6;
6. Proposed location of the desalination plant inside Sabrang Tourism park along with its intake point of raw water main and distribution network should be discussed as part of the integrated water transmission system for Sabrang and NAF tourism park;
7. Environmental and Social guidelines, concerns, challenges should be discussed in separate section as part of the construction and operation risk of the entire project;
8. Geo-technical and Sub-soil investigation report along with its implication and recommendations for laying out the proposed water transmission system should be completed in section 05.
9. Feedback from the stakeholder consultations to share the proposed water supply related utility planning for the project area with the respective local administrative office, agencies, NGO’s and community representatives, PAPs along with the list of state holders and recommendations from IWM should be included in separate sections.

Comments received from Mr. Md. Abdul Quader Khan, Social Specialist, BEZA through e-mail.

1. The consultancy firm has suggested 06 Phases development based on initial finding. According to current situation, most of the tourism industry will be built by 2030. With this in mind, it is better to build between 4 phases by omitting the 5 and 6 phases. Based on phasing plan 4th Phase total costing only BDT. 4 million which we can be construct at the 3rd phase.

2. The consultant should use separate paragraph for overall social impact in the executive summary of the report including in the details report.
3. Total 107 nos. of structures has been identified along the proposed transmission main. Among these structures there are 73 nos. of box culvert and 34 nos. of bridge. Moreover about 69 nos. of khals are found along the transmission main. The information of structures, cross section of all khals and features on both sides of the roads are taken during the survey works. According to your survey report there is no commercial structure, squatters or Houses, please check it and confirm the issues in the final report. Please provide the list of Khals and bridges in the annexure in the final report. Consultant should support BEZA to take permission form BWDB, LGED and RHD for the use of Khals and Bridges. The procedures of use of Khals and bridges needs to be mentioned in the report
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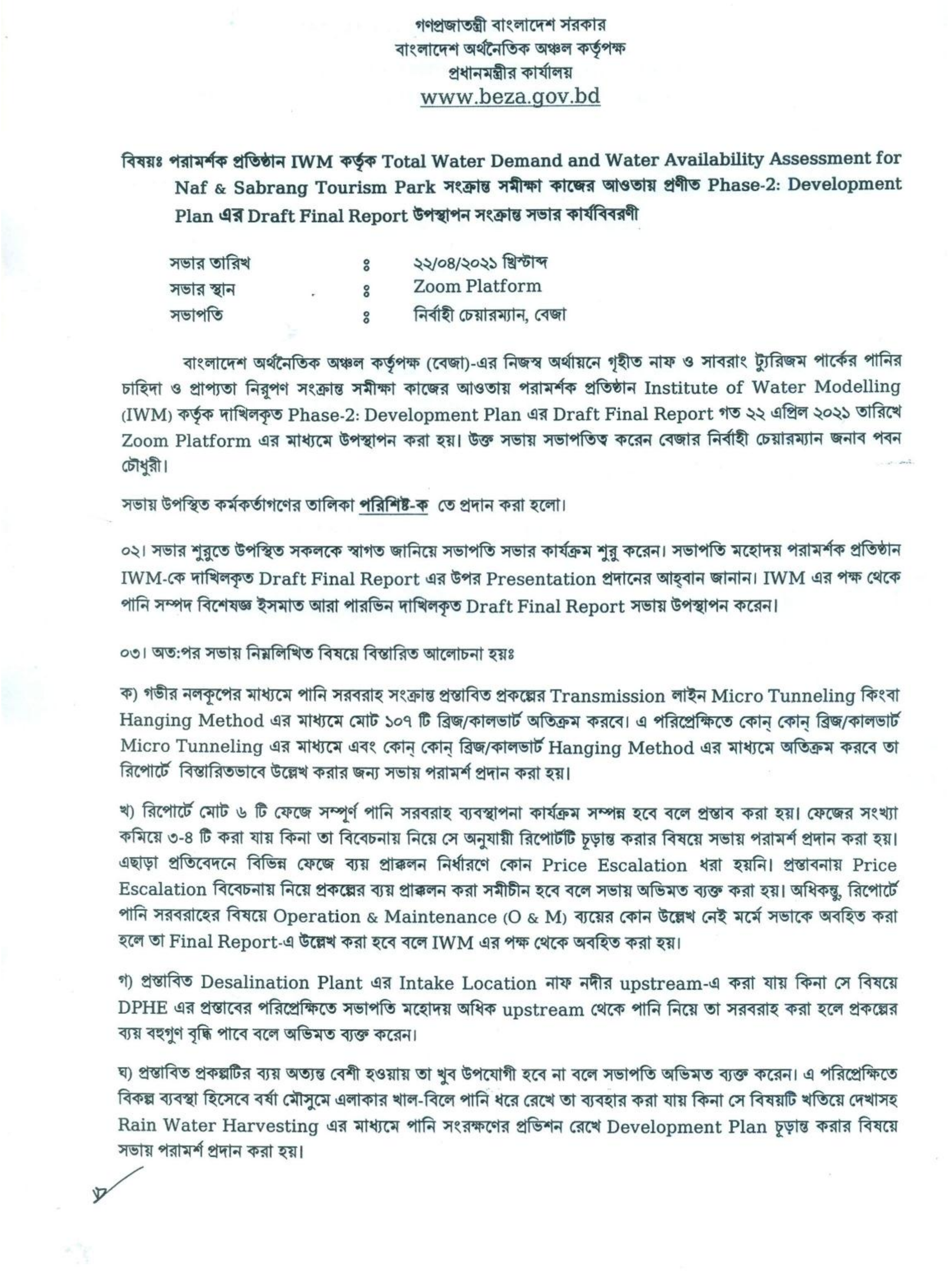
5. Land acquisition cost considered BDT 24 million (Please provide the details in the report). The detailed land acquisition cost needs to be incorporated in the budget part.
6. As we know that DPHE is one of the important stakeholders for this project. So, report should be verified from the DPHE officially.
7. The tentative cost of roof top rain water harvesting system is 4,793 Million BDT which would be carried out by land leaser/developer. Whereas total project cost 5,196 million for 10.68 MLD. Please provide the cost analysis for rain water harvesting or how we can minimize the cost of rain water harvesting please suggest us.
8. As per report the water supplied from Teknaf reservoir shall be considered as supplementary water source, as due to rainfall variation in very dry year the storage volume could be lower than design storage volume but in the **Figure E.6**, Consultant consider this is one of the main source of water. This is very misleading information. If it supplementary water source, how we will ensure targeted water please suggest us.
9. Water management plan for Sabrang and Naf Tourism Park: I don't found any difference between **Figure E.5** and **Figure E.6**. Please check it and update the separate table for Sabrnag and Naf Tourism Park.
10. According to report Desalination RO plant is required in phase 2, 5 & 6 to fulfill the total water requirement in Sabrang Tourism Park. The capacity of the desalination plant would be 1 MLD but in the same line in report consultant mentioned 1.05 and 1.42 MLD respectively. Is it separate 2 Desalination RO plant or initial capacity will be 1.05 MLD and future up gradation plan will be 1.42 MLD. Please give your clarification.

Appendix S: Meeting Minutes of Draft Final Report (Phase-2) Presentation Workshop



গণপ্রজাতন্ত্রী বাংলাদেশ সরকার
বাংলাদেশ অর্থনৈতিক অঞ্চল কর্তৃপক্ষ
প্রধানমন্ত্রীর কার্যালয়
www.beza.gov.bd

বিষয়ঃ পরামর্শক প্রতিষ্ঠান IWM কর্তৃক Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park সংক্রান্ত সমীক্ষা কাজের আওতায় প্রণীত Phase-2: Development Plan এর Draft Final Report উপস্থাপন সংক্রান্ত সভার কার্যবিবরণী

সভার তারিখ ঃ ২২/০৪/২০২১ খ্রিস্টাব্দ
সভার স্থান ঃ Zoom Platform
সভাপতি ঃ নির্বাহী চেয়ারম্যান, বেজা

বাংলাদেশ অর্থনৈতিক অঞ্চল কর্তৃপক্ষ (বেজা)-এর নিজস্ব অর্থায়নে গৃহীত নাফ ও সাবরাং ট্যুরিজম পার্কের পানির চাহিদা ও প্রাপ্যতা নিরূপণ সংক্রান্ত সমীক্ষা কাজের আওতায় পরামর্শক প্রতিষ্ঠান Institute of Water Modelling (IWM) কর্তৃক দাখিলকৃত Phase-2: Development Plan এর Draft Final Report গত ২২ এপ্রিল ২০২১ তারিখে Zoom Platform এর মাধ্যমে উপস্থাপন করা হয়। উক্ত সভায় সভাপতিত্ব করেন বেজার নির্বাহী চেয়ারম্যান জনাব পবন চৌধুরী।

সভায় উপস্থিত কর্মকর্তাগণের তালিকা **পরিশিষ্ট-ক** তে প্রদান করা হলো।

০২। সভার শুরুতে উপস্থিত সকলকে স্বাগত জানিয়ে সভাপতি সভার কার্যক্রম শুরু করেন। সভাপতি মহোদয় পরামর্শক প্রতিষ্ঠান IWM-কে দাখিলকৃত Draft Final Report এর উপর Presentation প্রদানের আহ্বান জানান। IWM এর পক্ষ থেকে পানি সম্পদ বিশেষজ্ঞ ইসমাত আরা পারভিন দাখিলকৃত Draft Final Report সভায় উপস্থাপন করেন।

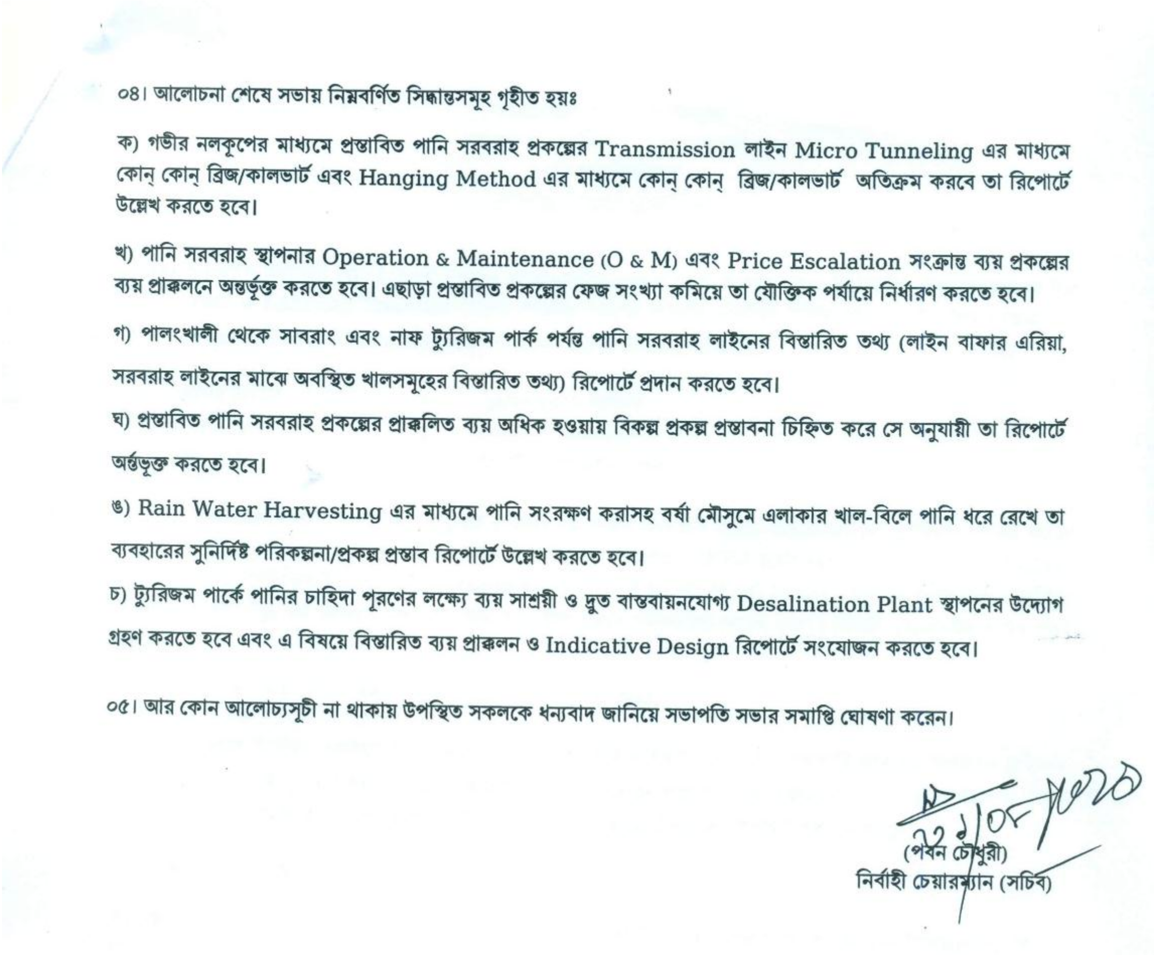
০৩। অত:পর সভায় নিম্নলিখিত বিষয়ে বিস্তারিত আলোচনা হয়ঃ

ক) গভীর নলকূপের মাধ্যমে পানি সরবরাহ সংক্রান্ত প্রস্তাবিত প্রকল্পের Transmission লাইন Micro Tunneling কিংবা Hanging Method এর মাধ্যমে মোট ১০৭ টি ব্রিজ/কালভার্ট অতিক্রম করবে। এ পরিপ্রেক্ষিতে কোন্ কোন্ ব্রিজ/কালভার্ট Micro Tunneling এর মাধ্যমে এবং কোন্ কোন্ ব্রিজ/কালভার্ট Hanging Method এর মাধ্যমে অতিক্রম করবে তা রিপোর্টে বিস্তারিতভাবে উল্লেখ করার জন্য সভায় পরামর্শ প্রদান করা হয়।

খ) রিপোর্টে মোট ৬ টি ফেজে সম্পূর্ণ পানি সরবরাহ ব্যবস্থাপনা কার্যক্রম সম্পন্ন হবে বলে প্রস্তাব করা হয়। ফেজের সংখ্যা কমিয়ে ৩-৪ টি করা যায় কিনা তা বিবেচনায় নিয়ে সে অনুযায়ী রিপোর্টটি চূড়ান্ত করার বিষয়ে সভায় পরামর্শ প্রদান করা হয়। এছাড়া প্রতিবেদনে বিভিন্ন ফেজে ব্যয় প্রাক্কলন নির্ধারণে কোন Price Escalation ধরা হয়নি। প্রস্তাবনায় Price Escalation বিবেচনায় নিয়ে প্রকল্পের ব্যয় প্রাক্কলন করা সমীচীন হবে বলে সভায় অভিমত ব্যক্ত করা হয়। অধিকন্তু, রিপোর্টে পানি সরবরাহের বিষয়ে Operation & Maintenance (O & M) ব্যয়ের কোন উল্লেখ নেই মর্মে সভাকে অবহিত করা হলে তা Final Report-এ উল্লেখ করা হবে বলে IWM এর পক্ষ থেকে অবহিত করা হয়।

গ) প্রস্তাবিত Desalination Plant এর Intake Location নাফ নদীর upstream-এ করা যায় কিনা সে বিষয়ে DPHE এর প্রস্তাবের পরিপ্রেক্ষিতে সভাপতি মহোদয় অধিক upstream থেকে পানি নিয়ে তা সরবরাহ করা হলে প্রকল্পের ব্যয় বহগুণ বৃদ্ধি পাবে বলে অভিমত ব্যক্ত করেন।

ঘ) প্রস্তাবিত প্রকল্পটির ব্যয় অত্যন্ত বেশী হওয়ায় তা খুব উপযোগী হবে না বলে সভাপতি অভিমত ব্যক্ত করেন। এ পরিপ্রেক্ষিতে বিকল্প ব্যবস্থা হিসেবে বর্ষা মৌসুমে এলাকার খাল-বিলে পানি ধরে রেখে তা ব্যবহার করা যায় কিনা সে বিষয়টি খতিয়ে দেখাসহ Rain Water Harvesting এর মাধ্যমে পানি সংরক্ষণের প্রভিশন রেখে Development Plan চূড়ান্ত করার বিষয়ে সভায় পরামর্শ প্রদান করা হয়।



০৪। আলোচনা শেষে সভায় নিম্নবর্ণিত সিদ্ধান্তসমূহ গৃহীত হয়ঃ

ক) গভীর নলকূপের মাধ্যমে প্রস্তাবিত পানি সরবরাহ প্রকল্পের Transmission লাইন Micro Tunneling এর মাধ্যমে কোন্ কোন্ ব্রিজ/কালভার্ট এবং Hanging Method এর মাধ্যমে কোন্ কোন্ ব্রিজ/কালভার্ট অতিক্রম করবে তা রিপোর্টে উল্লেখ করতে হবে।

খ) পানি সরবরাহ স্থাপনার Operation & Maintenance (O & M) এবং Price Escalation সংক্রান্ত ব্যয় প্রকল্পের ব্যয় প্রাক্কলনে অন্তর্ভূক্ত করতে হবে। এছাড়া প্রস্তাবিত প্রকল্পের ফেজ সংখ্যা কমিয়ে তা যৌক্তিক পর্যায়ে নির্ধারণ করতে হবে।

গ) পালংখালী থেকে সাবরাং এবং নাফ ট্যুরিজম পার্ক পর্যন্ত পানি সরবরাহ লাইনের বিস্তারিত তথ্য (লাইন বাফার এরিয়া, সরবরাহ লাইনের মাঝে অবস্থিত খালসমূহের বিস্তারিত তথ্য) রিপোর্টে প্রদান করতে হবে।

ঘ) প্রস্তাবিত পানি সরবরাহ প্রকল্পের প্রাক্কলিত ব্যয় অধিক হওয়ায় বিকল্প প্রকল্প প্রস্তাবনা চিহ্নিত করে সে অনুযায়ী তা রিপোর্টে অর্ন্তভূক্ত করতে হবে।

ঙ) Rain Water Harvesting এর মাধ্যমে পানি সংরক্ষণ করাসহ বর্ষা মৌসুমে এলাকার খাল-বিলে পানি ধরে রেখে তা ব্যবহারের সুনির্দিষ্ট পরিকল্পনা/প্রকল্প প্রস্তাব রিপোর্টে উল্লেখ করতে হবে।

চ) ট্যুরিজম পার্কে পানির চাহিদা পূরণের লক্ষ্যে ব্যয় সাশ্রয়ী ও দ্রুত বাস্তবায়নযোগ্য Desalination Plant স্থাপনের উদ্যোগ গ্রহণ করতে হবে এবং এ বিষয়ে বিস্তারিত ব্যয় প্রাক্কলন ও Indicative Design রিপোর্টে সংযোজন করতে হবে।

০৫। আর কোন আলোচ্যসূচী না থাকায় উপস্থিত সকলকে ধন্যবাদ জানিয়ে সভাপতি সভার সমাপ্তি ঘোষণা করেন।

২২/০৫/২০২০

(পবন চৌধুরী)
নির্বাহী চেয়ারম্যান (সচিব)

Appendix T: Response to the Comments on Draft Final Report (Phase-2)

Table T.1: Response of Comments received from Dr. Tanveer Ahmed, Environment Specialist, BEZA.

Sl. No.	Comments	Response
1.	Review comments of BEZA on the draft interim and final report and their respective response by IWM should be included in the final presentation and revised report	Reviewing the comments on Interim Report, Phase-2 and Final Report, Phase-1 the following remaining issues has been address in this Final Report (Phase-2) • Groundwater monitoring Plan has been prepared and incorporate in Appendix M, Final Report (Phase-2) • The cost of metering system is included in Sec. 9.2, Final Report (Phase-2).
2.	Unit rate of the proposed project interventions and the required quantity, operation/ maintenance cost of the proposed project interventions should be included along the source of reference of the quoted price in the cost assessment section;	Operation and maintenance cost of the proposed project are included in Sec. 9.2 of Final Report (Phase-2).
3.	Required land area and cost of the land for underground reservoir under BPS-02 should be included in the land acquisition plan of the project	Required land area for BPS-2 is already incorporated in the Report (Sec 6.1). BPS-2 will be constructed in land which is already acquired by BEZA, so no additional land acquisition plan is not required.
4.	Topographic & Engineering survey sections should detail the topographic implications and guideline for laying out the proposed transmission line in the hilly terrain of the project area	Topographic implications and guideline for laying out the proposed transmission line is given in Sec. 3.11.
5.	Number and types of major natural and socio-economic features identified along the buffer area of the proposed transmission line at certain interval should be detailed in section 2.3.6	Major natural and socio-economic features identified during survey along the buffer area of the proposed transmission line are already given in Annex-1 and also summarized in Table 2.2, 6.2 & 6.3 in Final Report, Phase-2.
6.	Proposed location of the desalination plant inside Sabrang Tourism park along with its intake point of raw water main and distribution network should be discussed as part of the integrated water transmission system for Sabrang and NAF tourism park	The location for desalination plant is provided from BEZA (given in Figure 8.4). The exact location of intake will be selected during construction. The water from the desalination plant will first stored

Sl. No.	Comments	Response
		in the underground water reservoir and will be supplied through the distribution line as describe in Chapter 4.
7.	Environmental and Social guidelines, concerns, challenges should be discussed in separate section as part of the construction and operation risk of the entire project	Environmental and Social guidelines, concerns, challenges during construction and operation phase are given in Sec. 8.8 of Final Report, Phase-2.
8.	Geo-technical and Sub-soil investigation report along with its implication and recommendations for laying out the proposed water transmission system should be completed in section 05.	Geo-technical and sub-soil investigation report is incorporate in Volume-II and summary report is given in Chapter 5.
9.	Feedback from the stakeholder consultations to share the proposed water supply related utility planning for the project area with the respective local administrative office, agencies, NGO's and community representatives, PAPs along with the list of state holders and recommendations from IWM should be included in separate sections	Stakeholder consultation is out of scope of this current study and should be done during EIA study.

Table T.2: Response of Comments received from Mr. Md. Abdul Quader Khan, Social Specialist, BEZA

Sl. No.	Comments	Response
1.	The consultancy firm has suggested 06 Phases development based on initial finding. According to current situation, most of the tourism industry will be built by 2030. With this in mind, it is better to build between 4 phases by omitting the 5 and 6 phases. Based on phasing plan 4th Phase total costing only BDT. 4 million which we can be construct at the 3rd phase	Water supply plan has been revised based on Detailed Master Plan, December 2020 for both Sabrang and Naf Tourism Park.
2.	The consultant should use separate paragraph for overall social impact in the executive summary of the report including in the details report	Social impact assessment is out of scope of the current study. But one social issue has been incorporated which can be arise due to abandon of surrounding shallow tube well for construction of PTWs in Sec. 8.5.1.

Sl. No.	Comments	Response
3.	Total 107 nos. of structures has been identified along the proposed transmission main. Among these structures there are 73 nos. of box culvert and 34 nos. of bridge. Moreover about 69 nos. of khals are found along the transmission main. The information of structures, cross section of all khals and features on both sides of the roads are taken during the survey works. According to your survey report there is no commercial structure, squatters or Houses, please check it and confirm the issues in the final report. Please provide the list of Khals and bridges in the annexure in the final report. Consultant should support BEZA to take permission form BWDB, LGED and RHD for the use of Khals and Bridges. The procedures of use of Khals and bridges needs to be mentioned in the report.	• Major natural and socio-economic features identified during survey along the buffer area of the proposed transmission line are already given in Annex-1 and also summarized in Table 2.2, 6.2 & 6.3 in Final Report, Phase-2. • List of structures are already incorporate in Appendix-B. List of khal and cross section are given in Appendix D. • The methods of Khal/culvert/bridge crossing methods are given in Appendix-C. • Consultants will support BEZA to seek permission form BWDB, LGED and RHD.
4.	The budget consider without price escalation (Please consider the escalation according to phasing plan)	All price are given considering price escalation Price escalation of 5.5% (ttps://www.statista.com)
5.	Land acquisition cost considered BDT 24 million (Please provide the details in the report). The detailed land acquisition cost needs to be incorporated in the budget part	Land acquisition cost is verified with AC land office and updated and incorporated in Sec. 6.4 of Final Report (Phase-2).
6.	As we know that DPHE is one of the important stakeholders for this project. So, report should be verified from the DPHE officially	DPHE officials gave comments on Draft Final Report, Phase-2 during the presentation workshop that detail design is required for implementation. Consultant's responses that detail design is out of scope of current study.
7.	The tentative cost of roof top rain water harvesting system is 4,793 Million BDT which would be carried out by land leaser/developer. Whereas total project cost 5,196 million for 10.68 MLD. Please provide the cost analysis for rain water harvesting or how we can minimize	We have revised the cost for roof top rainwater harvesting and it becomes 3,208 Million BDT. The cost will be carried out by land

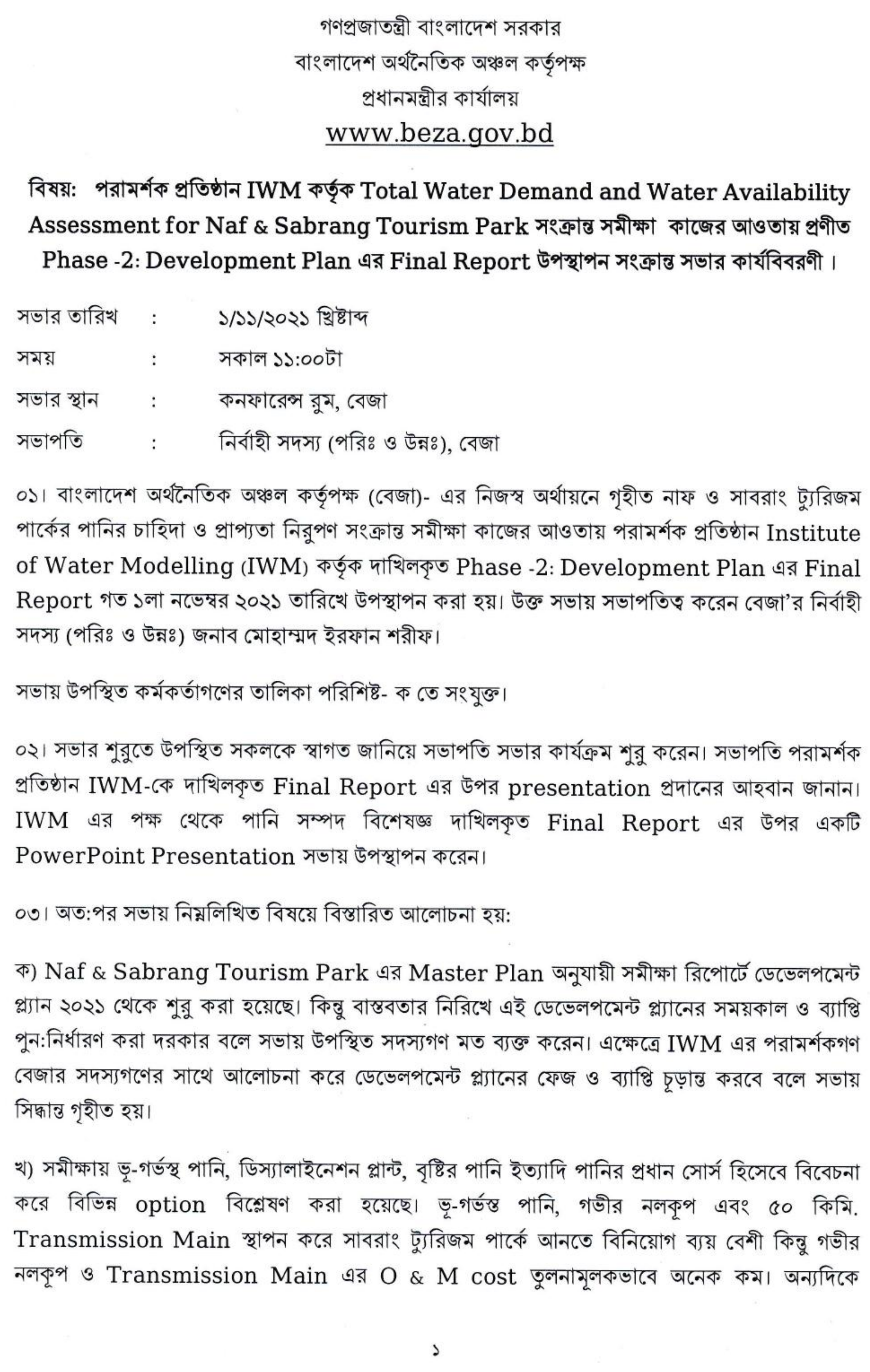
Sl. No.	Comments	Response
	the cost of rain water harvesting please suggest us.	leaser/developer and it will not influence the project cost of BEZA.
8.	As per report the water supplied from Teknaf reservoir shall be considered as supplementary water source, as due to rainfall variation in very dry year the storage volume could be lower than design storage volume but in the Figure E.6, Consultant consider this is one of the main source of water. This is very misleading information. If it supplementary water source, how we will ensure targeted water please suggest us	Considering water supply from Teknaf reservoir as supplementary, we have analysis two different other options to ensure targeted water in Chapter 8 of Final Report (Phase-2).
9.	Water management plan for Sabrang and Naf Tourism park: I don't found any difference between Figure E.5 an E.6. Please check it and update the separate table for Sabrang and Naf Tourism Park	In the Final Report, Phase-2 the Figures has been upgraded.
10.	According to report Desalination RO plant is required in phase 2, 5 & 6 to fulfill the total water requirement in Sabrang Tourism Park. The capacity of the desalination plant would be 1 MLD but in the same line in report consultant mentioned 1.05 and 1.42 MLD respectively. Is it separate 2 Desalination RO plant or initial capacity will be 1.05 MLD and future up gradation plan will be 1.42 MLD. Please give your clarification	The requirement of desalination plant has been upgraded according to Detailed master Plan, December 2020 and incorporate in this report Sec 8.5.2.

Table T.3: Response to the comments given in DFR presentation meeting

গত ২২ অক্টোবর ২০২ তারিখে বেজা'র সম্মেলন কক্ষে অনুষ্ঠিত Workshop-এ গৃহীত সিদ্বান্ত মোতাবেক পরামর্শক প্রতিষ্ঠান কর্তৃক প্রয়োজনীয় পরিবর্তন এবং সংশোধন করা হয়েছে । নিম্নে ছক আকারে সিদ্বান্তসমূহের উপর গৃহীত কার্যক্রম সদয় অবাগতির জন্য প্রদত্ত হলোঃ

Sl. No.	Comments	Response
ক)	গভীর নলকূপের মাধ্যমে প্রস্তাবিত পানি সরবরাহ প্রকল্পের Transmission লাইন Micro Tunneling এর মাধ্যমে কোন কোন ব্রিজ / কালভার্ট এবং Hanging Method এর মাধ্যমে কোন কোন ব্রিজ / কালভার্ট অতিক্রম করবে তা রিপোর্টে উল্লেখ করতে হবে।	এ বিষয়ে তথ্য Final Report (Phase 2) এর Appendix –D তে উল্লেখ করা হয়েছে।
খ)	পানি সরবরাহ স্থাপনার Operation & Maintenance (O & M) এবং Price Escalation সংক্রান্ত ব্যয় প্রকল্পের ব্যয় প্রাক্কলনে অর্ন্তভূক্ত করতে হবে। এছাড়া প্রস্তাবিত প্রকল্পের ফেজ সংখ্যা কমিয়ে তা যৌক্তিক পর্যায়ে নির্ধারিণ করতে হবে।	• পানি সরবরাহ স্থাপনার O & M ব্যয় OSec.9.2, Final Report (Phase-2) তে অর্ন্তভূক্ত করা হয়েছে। • Price Escalation বিবেচনা করে প্রকল্পের ব্যয় প্রাক্কলনে অর্ন্তভূক্ত করা হয়েছে। • প্রস্তাবিত প্রকল্পের ফেজ সংখ্যা Detailed Master Plan (December 2020) এর সাথে সমন্বয় করে Sec. 8.1এ পূন:নির্ধারণ করা হয়েছে।
গ)	পালংখালী থেকে সাবরাং এবং নাফ ট্যুরিজম পার্ক পর্যন্ত পানি সরবরাহ লাইনের বিস্তারিত তথ্য (লাইন বাফার এরিয়া, সরবরাহ লাইনের মাঝে অবস্থিত খালসমূহের বিস্তারিত তথ্য) রিপোর্টে প্রদান করতে হবে।	পানি সরবরাহ লাইনের বিস্তারিত তথ্য Final Report (Phase 2) এর Appendix –A, B, C তে প্রদান করা হয়েছে।
ঘ)	প্রস্তাবিত পানি সরবরাহের প্রকল্পের প্রাক্কলিত ব্যয় অধিক হওয়ায় বিকল্প প্রস্তাবনা চিহ্নিত করে সে অনুযায়ী তা রিপোর্টে অর্ন্তভূক্ত করতে হবে।	Draft Final Report (Phase 2) তে উল্লেখিত প্রকল্পের প্রাক্কলিত ব্যয় অধিক হওয়ায় বিকল্প প্রস্তাবনা চিহ্নিত করে Chapter 8, Final Report (Phase 2) তে অর্ন্তভূক্ত করা হয়েছে।
ঙ)	Rain Water Harvesting এর মাধ্যমে পানি সংরক্ষণ করাসহ বর্ষা মৌসুমে এলাকার খাল-বিলে পানি ধরে রেখে তা ব্যবহারের সুনির্দিষ্ট পরিকল্পনা /প্রকল্প প্রস্তাব রিপোর্টে উল্লেখ করতে হবে।	
চ)	ট্যুরিজম পার্কে পানির চাহিদা পূরণের লক্ষ্যে ব্যয় সাশ্রয়ী ও দ্রুত বাস্তবায়নযোগ্য Desallination Plant স্থাপনের উদ্যোগ গ্রহন করতে হবে এবং এ বিষয়ে বিস্তারিত ব্যয় প্রাক্কলন ও Indicative Design রিপোর্টে সংযোজন করতে হবে।	• বিভিন্ন ফেজে প্রয়োজনীয় Desalination Plant এর ধারন ক্ষমতা Sec.8.5.2 তে এবং সম্ভাব্য ব্যয় Chapter 8 এ উল্লেখ করা হয়েছে। • De Salination Plant এর তথ্য Final Report (Phase- 1) উল্লেখ করা হয়েছে। • Desalination Plant স্থাপনা Build –own-operate -transfer (BOOT) প্রক্রিয়ায় হয় বিধায় এর Indicative design দেয়া সম্ভব নয়।

Appendix U: Meeting Minutes of Final Report (Phase-2) Presentation Workshop



গণপ্রজাতন্ত্রী বাংলাদেশ সরকার
বাংলাদেশ অর্থনৈতিক অঞ্চল কর্তৃপক্ষ
প্রধানমন্ত্রীর কার্যালয়
www.beza.gov.bd

বিষয়: পরামর্শক প্রতিষ্ঠান IWM কর্তৃক Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park সংক্রান্ত সমীক্ষা কাজের আওতায় প্রণীত Phase -2: Development Plan এর Final Report উপস্থাপন সংক্রান্ত সভার কার্যবিবরণী।

সভার তারিখ : ১/১১/২০২১ খ্রিষ্টাব্দ
সময় : সকাল ১১:০০টা
সভার স্থান : কনফারেন্স রুম, বেজা
সভাপতি : নির্বাহী সদস্য (পরিঃ ও উন্নঃ), বেজা

০১। বাংলাদেশ অর্থনৈতিক অঞ্চল কর্তৃপক্ষ (বেজা)- এর নিজস্ব অর্থায়নে গৃহীত নাফ ও সাবরাং ট্যুরিজম পার্কের পানির চাহিদা ও প্রাপ্যতা নিরুপণ সংক্রান্ত সমীক্ষা কাজের আওতায় পরামর্শক প্রতিষ্ঠান Institute of Water Modelling (IWM) কর্তৃক দাখিলকৃত Phase -2: Development Plan এর Final Report গত ১লা নভেম্বর ২০২১ তারিখে উপস্থাপন করা হয়। উক্ত সভায় সভাপতিত্ব করেন বেজা'র নির্বাহী সদস্য (পরিঃ ও উন্নঃ) জনাব মোহাম্মদ ইরফান শরীফ।

সভায় উপস্থিত কর্মকর্তাগণের তালিকা পরিশিষ্ট- ক তে সংযুক্ত।

০২। সভার শুরুতে উপস্থিত সকলকে স্বাগত জানিয়ে সভাপতি সভার কার্যক্রম শুরু করেন। সভাপতি পরামর্শক প্রতিষ্ঠান IWM-কে দাখিলকৃত Final Report এর উপর presentation প্রদানের আহবান জানান। IWM এর পক্ষ থেকে পানি সম্পদ বিশেষজ্ঞ দাখিলকৃত Final Report এর উপর একটি PowerPoint Presentation সভায় উপস্থাপন করেন।

০৩। অত:পর সভায় নিম্নলিখিত বিষয়ে বিস্তারিত আলোচনা হয়:

ক) Naf & Sabrang Tourism Park এর Master Plan অনুযায়ী সমীক্ষা রিপোর্টে ডেভেলপমেন্ট প্ল্যান ২০২১ থেকে শুরু করা হয়েছে। কিন্তু বাস্তবতার নিরিখে এই ডেভেলপমেন্ট প্ল্যানের সময়কাল ও ব্যাপ্তি পুন:নির্ধারণ করা দরকার বলে সভায় উপস্থিত সদস্যগণ মত ব্যক্ত করেন। এক্ষেত্রে IWM এর পরামর্শকগণ বেজার সদস্যগণের সাথে আলোচনা করে ডেভেলপমেন্ট প্ল্যানের ফেজ ও ব্যাপ্তি চূড়ান্ত করবে বলে সভায় সিদ্ধান্ত গৃহীত হয়।

খ) সমীক্ষায় ভূ-গর্ভস্থ পানি, ডিস্যালাইনেশন প্লান্ট, বৃষ্টির পানি ইত্যাদি পানির প্রধান সোর্স হিসেবে বিবেচনা করে বিভিন্ন option বিশ্লেষণ করা হয়েছে। ভূ-গর্ভস্ত পানি, গভীর নলকূপ এবং ৫০ কিমি. Transmission Main স্থাপন করে সাবরাং ট্যুরিজম পার্কে আনতে বিনিয়োগ ব্যয় বেশী কিন্তু গভীর নলকূপ ও Transmission Main এর O & M cost তুলনামূলকভাবে অনেক কম। অন্যদিকে

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Desalination Plant এর O & M cost অত্যাধিক বেশী। এই বিবেচনায় সমীক্ষায় আলোচিত Option – 2 & 3 এর O&M সহ সর্বমোট ব্যয় বিশ্লেষণ করে সেরা Option টিকে চূড়ান্ত করতে হবে বলে সভায় মতামত প্রদান করা হয়।

গ) প্রস্তাবিত গভীর নলকূপ ও Booster Pump চালনার জন্য কতটুকু বিদ্যুৎ সরবরাহের প্রয়োজন হবে তা সমীক্ষায় উল্লেখ থাকতে হবে। এছাড়া বিদ্যুৎ সরবরাহের উৎস নিশ্চিত করতে উক্ত স্থানসমুহে বর্তমান ও ভবিষ্যৎ পরিকল্পনা কি আছে তা খতিয়ে দেখতে হবে। এ কাজে বেজা'র কনসালটেন্টের সাথে পরামর্শ করে সমীক্ষা চূড়ান্ত করতে হবে।

ঘ) বিল্ডিং এর ছাদে বৃষ্টির পানি সংরক্ষন করে তা বিভিন্ন Non-potable কাজে ব্যবহার করার জন্য plumbing ব্যবস্থা দ্বৈত করতে হবে এবং বিল্ডিং নির্মাণের শুরুতেই সেই অনুযায়ী Plumbing design ও construction করতে হবে বলে সভায় মত প্রদান করা হয়।

ঙ) সমীক্ষায় সাবরাং ট্যুরিজম পার্কে অবস্থিত লেকে বৃষ্টির পানি বর্ষা মৌসুমে ধরে রেখে তা সারা বছর ব্যবহার করার জন্য লেকের Bottom level (-) 1m MSL এ নির্ধারণ করা হয়েছে। পার্কে অবস্থিত লেকটির downstream এ একটি রেগুলেটর নির্মান করা হয়েছে যার Bottom level o m MSL এ রাখা হয়েছে। এমতাবস্থায় স্লুইজ গেট দিয়ে বর্ষাকালে পানি নিষ্কাষন করতে কোন সমস্যা আছে কিনা তা খতিয়ে দেখতে হবে।

০৪। আলোচনা শেষে সভায় নিম্নবর্ণিত সিদ্ধান্তসমূহ গৃহীত হয়:

(ক) সাবরাং ট্যুরিজম পার্কে প্রাক্কলিত পর্যটকের সংখ্যা পুনরায় ন্যায়সঙ্গতভাবে বিবেচনা করে পানির সঠিক চাহিদা নিরুপন করতে হবে এবং বিভিন্ন পানির উৎসের মধ্যে Ground Water কে প্রধান্য দিয়ে পানি সরবরাহ মহাপরিকল্পনা পুর্নগঠন করতে হবে।

(খ) হোয়াইকং থেকে সাবরাং এবং নাফ ট্যুরিজম পার্ক পর্যন্ত পানি সরবরাহ লাইনের বিস্তারিত তথ্য (লাইন বাফার এরিয়া, সরবরাহ লাইনের মাঝে অবস্থিত খালসমূহের বিস্তারিত তথ্য) রিপোর্টে উল্লেখ থাকতে হবে।

(গ) বেজার সদস্যগণের সাথে আলোচনা করে পানি সরবরাহ মহাপরিকল্পনা বাস্তবায়নের ১ম ফেজ ২০২২-২০২৭ বিবেচনা করে পরবর্তী তিন ফেজ পুন:নির্ধারণ করতে হবে এবং রিপোর্ট পুর্নগঠন করতে হবে।

(ঘ) সমীক্ষায় উল্লেখিত পানি সরবরাহের জন্য প্রস্তাবিত Option – 2 & 3 এর O&M সহ সর্বমোট ব্যয় বিশ্লেষণ করে সেরা Option টিকে চূড়ান্ত করতে হবে। বিভিন্ন বিকল্প প্রস্তাবনার Cost Benefit Analysis রিপোর্টতে সংযোজন করতে হবে।

(ঙ) প্রস্তাবিত গভীর নলকূপ ও Booster Pump এর প্রয়োজনীয় বিদ্যুতের পরিমান ও এর উৎস বেজার কনসালটেন্টগণের সাথে আলোচনা করা সমীক্ষায় উল্লেখ করতে হবে।

(চ) লেকের প্রস্তাবিত bottom levelটি লেকের downstream এর রেগুলেটরের silt level বিবেচনায় নিয়ে চূড়ান্ত করতে হবে।

(ছ) পরামর্শক প্রতিষ্ঠান IWM উল্লেখিত সিদ্ধান্তসমূহ যথাযথভাবে অনুসরণ করে পুর্নগঠিত চূড়ান্ত প্রতিবেদন বেজাতে দাখিল করার প্রয়োজনীয় ব্যবস্থা গ্রহণ করবে।

০৫। আর কোন আলোচ্যসূচী না থাকায় উপস্থিত সকলকে ধন্যবাদ জানিয়ে সভার সমাপ্তি ঘোষনা করেন।

১৬.০৭.২০২১
(মোহাম্মদ ইরফান শরীফ)
অতিরিক্ত সচিব
নির্বাহী সদস্য (পরিকল্পনা ও উন্নয়ন)
বাংলাদেশ অর্থনৈতিক অঞ্চল কর্তৃপক্ষ

Appendix V: Response to the Comments on Final Report

Table V.1: Response to the comments given in FR presentation meeting

গত ১ নভেম্বর ২০২১ তারিখে বেজা'র সম্মেলন কক্ষে অনুষ্ঠিত Workshop- এ গৃহীত সিদ্ধান্ত মোতাবেক পরামর্শক প্রতিষ্ঠান কর্তৃক প্রয়োজনীয় পরিবর্তন এবং সংশোধন করা হয়েছে। নিম্নে ছক আকারে সিদ্ধান্ত সমূহের উপর গৃহীত কার্যক্রম সদয় অবগতির জন্য প্রদত্ত হলো:

Sl. No.	Comments	Response
ক)	সাবরাং ট্যুরিজম পার্কে প্রাক্কলিত পর্যটকের সংখ্যা পুনরায় ন্যায়সঙ্গতভাবে বিবেচনা করে পানির সঠিক চাহিদা নিরুপণ করতে হবে এবং বিভিন্ন পানির উৎসের মধ্যে Ground Water কে প্রাধান্য দিয়ে পানি সরবরাহ মহাপরিকল্পনা পুর্নগঠন করতে হবে।	সাবরাং ট্যুরিজম পার্কের সংখ্যা BEZA কর্তৃক অনুমোদিত Detailed Master Plan (December 2020) হতে নেওয়া হয়েছে। পর্যটকের সংখ্যা পুনরায় প্রাক্কালন করার অন্য কোনো উৎস না থাকায় তা এই সমীক্ষার Detailed Master Plan (Dec 2020) অনুসরণ করা হয়েছে। পানির চাহিদাপূরণে বিভিন্ন Option বিশ্লেষণ করে সবচেয়ে কার্যকরী ব্যবস্থা বিবেচনা করে মহাপরিকল্পনা পুর্নগঠন করা হয়েছে এবং তা সমীক্ষার Sec. 8.8 ও 8.9 এ উল্লেখ করা হয়েছে।
খ)	হোয়াইকং থেকে সাবরাং এবং নাফ ট্যুরিজম পার্ক পর্যন্ত পানি সরবরাহ লাইনের বিস্তারিত তথ্য (লাইন বাফার এরিয়া, সরবরাহ লাইনের মাঝে অবস্থিত খালসমূহের বিস্তারিত তথ্য) রির্পোটে উল্লেখ থাকতে হবে।	হোয়াইকং থেকে সাবরাং এবং নাফ ট্যুরিজম পার্ক পর্যন্ত পানি সরবরাহ লাইনের বিস্তারিত তথ্য (লাইন বাফার এরিয়া, সরবরাহ লাইনের মাঝে অবস্থিত খালসমূহের বিস্তারিত তথ্য) রিপোর্টের Chapter 2 এবং Apppendix A, B, C, D তে উল্লেখ করা হয়েছে।
গ)	বেজার সদস্যগণের সাথ আলোচনা করে পানি সরবরাহ মহাপরিকল্পনা বাস্তবায়নের ১ম ফেজ ২০২২-২০২৭ বিবেচনা করে পরবর্তী তিন ফেজ পুন:নির্ধারণ করতে হবে এবং রিপোর্ট পুর্নগঠন করতে হবে।	বেজার সদস্যগণের সাথ আলোচনা করে পানি সরবরাহ মহাপরিকল্পনা বাস্তবায়নের ১ম ফেজ ২০২২-২০২৭ বিবেচনা করে ফেজ পুন:নির্ধারণ করা হয়েছে এবং তা রিপোর্টের Section 8.1 এ উল্লেখ করা হয়েছে।
ঘ)	সমীক্ষায় উল্লেখিত পানি সরবরাহের জন্য প্রস্তাবিত Option -2 & 3 এর O & M সহ সর্বমোট ব্যয় বিশ্লেষণ করে সেরা Option টিকে চুড়ান্ত করতে হবে। বিভিন্ন বিকল্প প্রস্তাবনার Cost Benefit Analysis রিপোর্ট টিতে সংযোজন করতে হবে।	পানি সরবরাহের জন্য প্রস্তাবিত Option -2 & 3 সহ আরও একটি Option - 4 এবং O & M সহ সর্বমোট ব্যয় বিশ্লেষণ করে Cost Benefit Analysis রিপোর্টের Chapter 10 এ সংযোজন করা হয়েছে।
ঙ)	প্রস্তাবিত গভীর নলকূপ ও Booster Pump এর প্রয়োজনীয় বিদ্যুতের পরিমান ও এর উৎস বেজার কনসালটেন্টগণের সাথে আলোচনা করা সমীক্ষায় উল্লেখ করতে হবে।	প্রস্তাবিত গভীর নলকূপ ও Booster Pump এর প্রয়োজনীয় বিদ্যুতের পরিমান ও এর উৎস বেজার কনসালটেন্টগণের সাথে আলোচনা করে যথাক্রমে সমীক্ষার Section 8.5.1 ও 8.10.2 এ উল্লেখ করা হয়েছে।

Sl. No.	Comments	Response
চ)	লেকের প্রস্তাবিত bottom level টি লেকের downstream এর রেগুলেটরের silt level বিবেচনায় নিয়ে চুড়ান্ত করতে হবে।	লেকের প্রস্তাবিত bottom level -1m MSL এবং লেকের downstream এর রেগুলেটরের silt level Om, MSL ধরা হয়েছে। বিশেষজ্ঞ পরামর্শদাতার পরামর্শ মতে -1m, MSL এ লেকের bottom level রাখা যুক্তিযুক্ত, যা সমীক্ষার Section 7.3 এ উল্লেখ করা হয়েছে। ।
ছ)	পরামর্শক প্রতিষ্ঠান IWM উল্লেখিত সিদ্ধান্তসমূহ যথাযথভাবে অনুসরণ করে পুর্নগঠিত চুড়ান্ত প্রতিবেদন বেজাতে দাখিল করার প্রয়োজনীয় ব্যবস্থা গ্রহণ করবে।	উল্লেখিত সিদ্ধান্তসমূহ যথাযথভাবে বিবেচনা করে চুড়ান্ত প্রতিবেদন (Revised Final Report) বেজাতে দাখিল করার প্রয়োজনীয় ব্যবস্থা গ্রহন করা হয়েছে।

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Prime Minister’s Office

DETAIL STUDY ON TOTAL WATER DEMAND AND WATER AVAILABILITY FOR SABRANG AND NAF TOURISM PARK

☐ Volume-1: Main Report
☑ Volume-2: Geotechnical Investigation Report

Final Report (Phase-2)

June, 2021

INSTITUTE OF WATER MODELLING (IWM)

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INSTITUTE OF WATER MODELLING

Table of Contents

1 INTRODUCTION

The exploratory work involves drilling through cohesive and non-cohesive soil on firm ground with recovery of samples. Standard penetration tests and permeability tests have been executed in the boreholes located at proposed booster pump stations (BPS-1 & BPS-2) reservoir locations at Naf and Sabrang Tourism Park. Booster pump station BPS-2 will be located within the acquired land of BEZA for Naf Tourism Park and for fixing the exact locations two areas are posed and according soil test has been conducted. A summary of the exploratory work is given in **Table 1**.

Table 1: Summary of Exploratory Work

Location	Reservoir/Pump ID	Bore Hole ID	Depth of Bore Hole (m)
Whykhong	BPS-1	01	20
Whykhong	BPS-1	02	20
Whykhong	BPS-1	03	20
Whykhong	BPS-1	04	20
Naf Tourism Park	N_UGWR-1	05	20
Naf Tourism Park	N_UGWR-1	06	20
Naf Tourism Park	N_UGWR-2	07	20
Naf Tourism Park	N_UGWR-2	08	20
Sabrang Tourism Park	S_UGWR-1	09	20
Sabrang Tourism Park	S_UGWR-1	10	20
Sabrang Tourism Park	S_UGWR-2	11	20
Sabrang Tourism Park	S_UGWR-2	12	20
Sabrang Tourism Park	S_UGWR-3	13	20
Sabrang Tourism Park	S_UGWR-3	14	20
Teknaf Ferry Ghat	BPS-2 (Option-1)	15	20
Teknaf Ferry Ghat	BPS-2 (Option-1)	16	20
Teknaf Ferry Ghat	BPS-2 (Option-1)	17	20
Teknaf Ferry Ghat	BPS-2 (Option-2)	18	20
Teknaf Ferry Ghat	BPS-2 (Option-2)	19	20

2 OBJECTIVE OF WORKS

The main scope of this investigation works are:

a. Execution of exploratory borings, recording of sub-soil stratification and position of ground water level.

b. Execution of standard penetration test (SPT) at an interval of 1.5m (5ft.) depth with collection of disturbed soil samples upto the final depth of exploration of each boring.

c. Collection of undisturbed soil samples by thin walled shelby tubes from each hole.

d. Execution of laboratory tests on soil samples to determine the physical and mechanical characteristics of the underlying soil deposit.

e. Preparation of final report with all works including bearing capacity and skin friction values of sub-soil.

3 FIELD INVESTIGATION WORKS

The field investigation was carried out on 21-03-2021 to 28-03-2021 by two sets of boring rig and execution of a total of four borings each upto the depth of 20.0 m from the existing ground surface. The holes were made by driving the casing of 10 cm (4") diameter upto 1.83m (6'-0") depth. The disturbed samples were collected by driving split spoon sampler of 3.15 cm (1-3/8") inner diameter with a hammer of 63.5 kg (140 lbs.) weight falling freely a height of about 76.2 cm (30") in average and the number of blows required to drive the sampler for every 0.15m (6") penetration over 0.45m (1.5 ft.) depth was recorded to measure the standard penetration resistance-N per 0.30m (foot.). Disturbed samples were collected at an interval of 1.5m (5 ft.) depth. The undisturbed samples were collected in 7.62 cm (3") diameter shelby tubes. Ground water table was recorded 24 hours after completion of each hole.

4 LABORATORY TESTINGS

The disturbed samples collected in polythene bags and undisturbed samples in Shellby Tubes and were brought to soil mechanics Laboratory for testing. All the samples were visually examined and all undisturbed and representative disturbed samples were selected for necessary testing. The tests performed on the selected samples are shown in **Table 2**.

Table 2: Tests performed

Name of the test	**No of samples**
Location: BPS-1 at Whykhong	
Natural Moisture Content	14
Liquid & Plastic Limit	8
Specific Gravity	1
Grain Size Analysis	12
Wet & Dry Density	4
Unconfined Compression Test	4
Consolidation Test	1
Direct Shear Test	2
Location: Naf Tourism Park	
Natural Moisture Content	11
Liquid & Plastic Limit	5
Specific Gravity	2
Grain Size Analysis	12
Wet & Dry Density	4
Unconfined Compression Test	4
Consolidation Test	2
Direct Shear Test	2

Location: Sabrang Tourism Park	
Natural Moisture Content	4
Specific Gravity	3
Grain Size Analysis	18
Wet & Dry Density	4
Direct Shear Test	4
Location: BPS-2 near Teknaf Ferry Ghat	
Natural Moisture Content	10
Liquid & Plastic Limit	5
Specific Gravity	2
Grain Size Analysis	15
Wet & Dry Density	4
Unconfined Compression Test	4
Consolidation Test	2
Direct Shear Test	4

5 DISCUSSION ON TEST RESULTS

5.1 Discussion on test results at BPS-1, Whykhong

5.1.1 Soil Profile

The stratification of materials around the holes at the site consists of an upper cohesive deposit of soft to stiff silty-clay and clayey-silt mixed with varying amount of fine sand upto the maximum depth of about 15.5 m from the existing ground surface. The deposit below upto the depth of exploration consists of noncohesive deposit of medium dense to dense silty fine sand mixed with trace amount of mica.

The standard penetration test (SPT) results have been shown in the respective boring log and the results vary between 3 and 13 in cohesive deposit and 23 and 40 in the non-cohesive deposit. The detailed information on stratification have been shown in the laboratory boring logs of **attachment-II**.

5.1.2 Range of Values of Test Results

Name of Tests/Parameters	Range of Values
Natural Moisture Content (%)	25.9 to 32.8
Liquid Limit (%)	36 to 50
Plastic Limit (%)	24 to 28
Specific Gravity	2.676
Wet Density (kN/m^3)	17.75 to 18.41
Dry Density (kN/m^3)	13.38 to 14.32
Unconfined Compressive Strength (kN/m^2)	32.8 to 52.5
Compression Index, C_c	0.220
Void Ratio, e_o	0.835
Angle of Internal Friction, ϕ (degree)	33.0 to 35.0
Cohesion, C (kN/m^2)	0.0

5.2 Discussion on test results at Reservoirs in Naf Tourism Park

5.2.1 Soil Profile

The stratification of materials around the holes at the site consists of an upper cohesive deposit of very soft to medium stiff silty-clay mixed with varying amount of fine sand upto the maximum depth of about 15.5 m from the existing ground surface. The deposit below upto the depth of exploration consists of noncohesive deposit of medium dense sandy-silt and dense silty fine sand mixed with trace amount of mica.

The standard penetration test (SPT) results have been shown in the respective boring log and the results vary between 1 and 8 in cohesive deposit and 11 and 39 in the non-cohesive deposit. The detailed information on stratification have been shown in the laboratory boring logs of attachment-II.

5.2.2 Range of Values of Test Results

Name of Tests/Parameters	Range of Values
Natural Moisture Content (%)	28.3 to 35.9
Liquid Limit (%)	44 to 50
Plastic Limit (%)	23 to 25
Specific Gravity	2.675 to 2.678
Wet Density (kN/m^3)	17.71 to 17.97
Dry Density (kN/m^3)	13.04 to 13.55
Unconfined Compressive Strength (kN/m^2)	26 to 32.5
Compression Index, C_c	0.3 to 0.31
Void Ratio, e_o	0.937 to 0.995
Angle of Internal Friction, ϕ (degree)	32 to 34
Cohesion, C (kN/m^2)	0.0

5.3 Discussion on test results at Reservoirs in Sabrang Tourism Park

5.3.1 Soil Profile

The stratification of materials around the holes at the site consists of an upper noncohesive deposit of very loose to loose silty fine sand mixed with trace amount of mica upto the maximum depth of about 5.0 m from the existing ground surface. The deposit below upto the depth of exploration consists of noncohesive deposit of medium dense to very dense silty fine sand mixed with trace amount of mica.

The standard penetration test (SPT) results have been shown in the respective boring log and the results vary between 1 and >50 in the non-cohesive deposit. The detailed information on stratification have been shown in the laboratory boring logs of attachment-II.

5.3.2 Range of Values of Test Results

Name of Tests/Parameters	Range of Values
Natural Moisture Content (%)	28.3 to 26.6
Specific Gravity	2.653 to 2.666
Wet Density (kN/m^3)	18.36 to 18.53
Dry Density (kN/m^3)	14.58 to 14.83
Angle of Internal Friction, ϕ (degree)	32 to 39
Cohesion, C (kN/m^2)	0.0

5.4 Discussion on test results at BPS-2 near Teknaf Ferry Ghat

5.4.1 Soil Profile

The stratification of materials around the holes at the site consists of an upper cohesive deposit of soft to stiff silty-clay and clayey-silt mixed with varying amount of fine sand upto the maximum depth of about 15.5 m from the existing ground surface. The deposit below upto the depth of exploration consists of noncohesive deposit of medium dense to dense silty fine sand mixed with trace amount of mica.

The standard penetration test (SPT) results have been shown in the respective boring log and the results vary between 3 and 13 in cohesive deposit and 23 and 40 in the non-cohesive deposit. The detailed information on stratification have been shown in the laboratory boring logs of **attachment-II**.

5.4.2 Range of Values of Test Results

Name of Tests/Parameters	Range of Values
Natural Moisture Content (%)	27.1 to 34.3
Liquid Limit (%)	34 to 38
Plastic Limit (%)	24 to 28
Specific Gravity	2.67 to 2.672
Wet Density (kN/m^3)	18.05 to 18.75
Dry Density (kN/m^3)	13.87 to 17.73
Unconfined Compressive Strength (kN/m^2)	42.7 to 77.6
Compression Index, C_c	0.15 to 0.18
Void Ratio, e_o	0.777 to 0.819
Angle of Internal Friction, ϕ (degree)	33 to 37
Cohesion, C (kN/m^2)	0.0

6 BEARING CAPACITY FOR SHALLOW & DEEP FOUNDATION

6.1 Bearing Capacity for BPS-1, Whykhong

6.1.1 Bearing Capacity for Shallow Foundation

The allowable bearing capacities in kg/cm^2 of sub-soil for square and strip footing for shallow foundation have been calculated with F.S.3 and is shown in **Table 3**.

Table 3: Allowable bearing capacities in kg/cm2 with F.S.3 at BPS-1 location

Bore Hole No.	Depth in (m)	Allowable bearing capacities for	
		Sq. Footing	Strip Footing
BH - 1	1.5	0.51	0.41
	3.0	0.87	0.69
	4.5	0.92	0.74
BH - 2	1.5	0.67	0.53
	3.0	0.72	0.58
	4.5	0.92	0.74
BH - 3	1.5	0.51	0.41
	3.0	0.72	0.58
	4.5	0.61	0.51
BH - 4	1.5	0.51	0.41
	3.0	0.56	0.46
	4.5	0.77	0.63

6.1.2 Cast In-situ Pile Capacity for Deep Foundation

Table 4: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-1

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m $Q_S=0.45*Cu*A_S$ (Clay),$1.0*N'*A_S$ (sand) kN	Ultimate End Bearing $Qe=9*Cu*A_c$ (Clay),$120*N'*A_c$ (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	C	3	3	2.356	18.394	19.50	32.505	19.50	52.01	17.34	20.80
3.0	C	5	5	2.356	30.656	32.50	54.174	52.01	106.18	35.39	42.47
4.5	C	5	5	2.356	30.656	32.50	54.174	84.51	138.69	46.23	55.47
6.0	C	7	7	2.356	42.919	45.51	75.844	130.02	205.86	68.62	82.34
7.5	C	6	6	2.356	36.788	39.01	65.009	169.02	234.03	78.01	93.61
9.0	C	6	6	2.356	36.788	39.01	65.009	208.03	273.04	91.01	109.21
10.5	C	7	7	2.356	42.919	45.51	75.844	253.53	329.38	109.79	131.75
12.0	C	8	8	2.356	49.050	52.01	86.679	305.54	392.22	130.74	156.89
13.5	C	7	7	2.356	42.919	45.51	75.844	351.05	426.89	142.30	170.76
15.0	C	9	9	2.356	55.181	58.51	97.514	409.56	507.07	169.02	202.83
16.5	S	28	21.5	2.356		50.66	506.583	460.21	966.80	322.27	386.72
18.0	S	32	23.5	2.356		55.37	553.707	515.58	1069.29	356.43	427.72
20.0	S	40	27.5	2.356		64.80	647.955	580.38	1228.34	409.45	491.33

Table 5: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-2

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m $Qs=0.45*Cu*A_S$ (Clay),$1.0*N'*A_S$ (sand) kN	Ultimate End Bearing $Qe=9*Cu*A_c$ (Clay),$120*N'*A_c$ (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	C	4	4	2.356	24.525	26.00	43.339	26.00	69.34	23.11	27.74
3.0	C	4	4	2.356	24.525	26.00	43.339	52.01	95.35	31.78	38.14
4.5	C	5	5	2.356	30.656	32.50	54.174	84.51	138.69	46.23	55.47
6.0	C	6	6	2.356	36.788	39.01	65.009	123.52	188.53	62.84	75.41
7.5	C	7	7	2.356	42.919	45.51	75.844	169.02	244.87	81.62	97.95
9.0	C	11	11	2.356	67.444	71.51	119.183	240.53	359.72	119.91	143.89
10.5	C	8	8	2.356	49.050	52.01	86.679	292.54	379.22	126.41	151.69
12.0	C	9	9	2.356	55.181	58.51	97.514	351.05	448.56	149.52	179.42
13.5	C	13	13	2.356	79.706	84.51	140.853	435.56	576.41	192.14	230.56
15.0	S	23	19.0	2.356		44.77	447.678	480.33	928.01	309.34	371.20
16.5	S	28	21.5	2.356		50.66	506.583	530.99	1037.57	345.86	415.03
18.0	S	37	26.0	2.356		61.26	612.612	592.25	1204.86	401.62	481.94
20.0	S	40	27.5	2.356		64.80	647.955	657.04	1305.00	435.00	522.00

Table 6: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-3

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m Qs=0.45*Cu*A_S (Clay),1.0*N'*A_S (sand) kN	Ultimate End Bearing Qe=9*Cu*A_c (Clay),120*N'*A_c (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	C	3	3	2.356	18.394	19.50	32.505	19.50	52.01	17.34	20.80
3.0	C	4	4	2.356	24.525	26.00	43.339	45.51	88.85	29.62	35.54
4.5	C	3	3	2.356	18.394	19.50	32.505	65.01	97.51	32.50	39.01
6.0	C	3	3	2.356	18.394	19.50	32.505	84.51	117.02	39.01	46.81
7.5	C	4	4	2.356	24.525	26.00	43.339	110.52	153.85	51.28	61.54
9.0	C	5	5	2.356	30.656	32.50	54.174	143.02	197.19	65.73	78.88
10.5	C	7	7	2.356	42.919	45.51	75.844	188.53	264.37	88.12	105.75
12.0	C	6	6	2.356	36.788	39.01	65.009	227.53	292.54	97.51	117.02
13.5	C	5	5	2.356	30.656	32.50	54.174	260.04	314.21	104.74	125.68
15.0	C	11	11	2.356	67.444	71.51	119.183	331.55	450.73	150.24	180.29
16.5	S	30	22.5	2.356		53.01	530.145	384.56	914.70	304.90	365.88
18.0	S	36	25.5	2.356		60.08	600.831	444.64	1045.47	348.49	418.19
20.0	S	39	27.0	2.356		63.62	636.174	508.26	1144.43	381.48	457.77

Table 7: Skin friction and end bearing capacity of cast in-situ pile and allowable working load at bore hole BH-4

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m $Qs=0.45*Cu*A_S$ (Clay),$1.0*N'*A_S$ (sand) kN	Ultimate End Bearing $Qe=9*Cu*A_c$ (Clay),$120*N'*A_c$ (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	C	3	3	2.356	18.394	19.50	32.505	19.50	52.01	17.34	20.80
3.0	C	3	3	2.356	18.394	19.50	32.505	39.01	71.51	23.84	28.60
4.5	C	4	4	2.356	24.525	26.00	43.339	65.01	108.35	36.12	43.34
6.0	C	5	5	2.356	30.656	32.50	54.174	97.51	151.69	50.56	60.68
7.5	C	4	4	2.356	24.525	26.00	43.339	123.52	166.86	55.62	66.74
9.0	C	4	4	2.356	24.525	26.00	43.339	149.52	192.86	64.29	77.14
10.5	C	6	6	2.356	36.788	39.01	65.009	188.53	253.53	84.51	101.41
12.0	C	5	5	2.356	30.656	32.50	54.174	221.03	275.20	91.73	110.08
13.5	C	5	5	2.356	30.656	32.50	54.174	253.53	307.71	102.57	123.08
15.0	C	9	9	2.356	55.181	58.51	97.514	312.04	409.56	136.52	163.82
16.5	S	27	21.0	2.356		49.48	494.802	361.52	856.32	285.44	342.53
18.0	S	37	26.0	2.356		61.26	612.612	422.78	1035.40	345.13	414.16
20.0	S	38	26.5	2.356		62.44	624.393	485.22	1109.62	369.87	443.85

6.2 Bearing Capacity for Reservoirs in Naf Tourism Park

6.2.1 Bearing Capacity for Shallow Foundation

The allowable bearing capacities in kg/cm^2 of sub-soil for square and strip footing for shallow foundation have been calculated with F.S.3 and is shown in **Table 8**.

Table 8: Allowable bearing capacities in kg/cm2 with F.S.3 in Naf Tourism Park

Bore Hole No.	Depth in (m)	Allowable bearing capacities for	
		Sq. Footing	Strip Footing
BH - 5	1.5	0.36	0.29
	3.0	0.41	0.34
	4.5	0.61	0.51
BH - 6	1.5	0.36	0.29
	3.0	0.25	0.20
	4.5	0.61	0.51
BH - 7	1.5	0.36	0.29
	3.0	0.41	0.34
	4.5	0.46	0.39
BH - 8	1.5	0.36	0.29
	3.0	0.25	0.20
	4.5	0.46	0.39

6.2.2 Cast In-situ Pile Capacity for Deep Foundation

Table 9: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-5

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m $Qs=0.45*Cu*A_S$ (Clay),$1.0*N'*A_S$ (sand) kN	Ultimate End Bearing $Qe=9*Cu*A_c$ (Clay),$120*N'*A_c$ (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	C	2	2	2.356	12.263	13.00	21.670	13.00	34.67	11.56	13.87
3.0	C	2	2	2.356	12.263	13.00	21.670	26.00	47.67	15.89	19.07
4.5	C	3	3	2.356	18.394	19.50	32.505	45.51	78.01	26.00	31.20
6.0	C	5	5	2.356	30.656	32.50	54.174	78.01	132.18	44.06	52.87
7.5	C	3	3	2.356	18.394	19.50	32.505	97.51	130.02	43.34	52.01
9.0	C	2	2	2.356	12.263	13.00	21.670	110.52	132.18	44.06	52.87
10.5	C	4	4	2.356	24.525	26.00	43.339	136.52	179.86	59.95	71.94
12.0	C	5	5	2.356	30.656	32.50	54.174	169.02	223.20	74.40	89.28
13.5	C	4	4	2.356	24.525	26.00	43.339	195.03	238.37	79.46	95.35
15.0	C	6	6	2.356	36.788	39.01	65.009	234.03	299.04	99.68	119.62
16.5	S	11	11	2.356		25.92	259.182	259.95	519.13	173.04	207.65
18.0	S	33	24.0	2.356		56.55	565.488	316.50	881.99	294.00	352.79
20.0	S	38	26.5	2.356		62.44	624.393	378.94	1003.33	334.44	401.33

Table 10: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-6

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m Qs=0.45*Cu*A_S (Clay),1.0*N'*A_S (sand) kN	Ultimate End Bearing Qe=9*Cu*A_c (Clay),120*N'*A_c (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	C	2	2	2.356	12.263	13.00	21.670	13.00	34.67	11.56	13.87
3.0	C	1	1	2.356	6.131	6.50	10.835	19.50	30.34	10.11	12.14
4.5	C	3	3	2.356	18.394	19.50	32.505	39.01	71.51	23.84	28.60
6.0	C	4	4	2.356	24.525	26.00	43.339	65.01	108.35	36.12	43.34
7.5	C	4	4	2.356	24.525	26.00	43.339	91.01	134.35	44.78	53.74
9.0	C	3	3	2.356	18.394	19.50	32.505	110.52	143.02	47.67	57.21
10.5	C	6	6	2.356	36.788	39.01	65.009	149.52	214.53	71.51	85.81
12.0	C	7	7	2.356	42.919	45.51	75.844	195.03	270.87	90.29	108.35
13.5	C	5	5	2.356	30.656	32.50	54.174	227.53	281.71	93.90	112.68
15.0	C	8	8	2.356	49.050	52.01	86.679	279.54	366.22	122.07	146.49
16.5	S	14	14	2.356		32.99	329.868	312.52	642.39	214.13	256.96
18.0	S	34	24.5	2.356		57.73	577.269	370.25	947.52	315.84	379.01
20.0	S	37	26.0	2.356		61.26	612.612	431.51	1044.12	348.04	417.65

Table 11: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-7

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m Qs=0.45*Cu*A_S (Clay),1.0*N'*A_S (sand) kN	Ultimate End Bearing Qe=9*Cu*A_c (Clay),120*N'*A_c (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	C	2	2	2.356	12.263	13.00	21.670	13.00	34.67	11.56	13.87
3.0	C	2	2	2.356	12.263	13.00	21.670	26.00	47.67	15.89	19.07
4.5	C	2	2	2.356	12.263	13.00	21.670	39.01	60.68	20.23	24.27
6.0	C	4	4	2.356	24.525	26.00	43.339	65.01	108.35	36.12	43.34
7.5	C	2	2	2.356	12.263	13.00	21.670	78.01	99.68	33.23	39.87
9.0	C	4	4	2.356	24.525	26.00	43.339	104.01	147.35	49.12	58.94
10.5	C	3	3	2.356	18.394	19.50	32.505	123.52	156.02	52.01	62.41
12.0	C	5	5	2.356	30.656	32.50	54.174	156.02	210.20	70.07	84.08
13.5	C	7	7	2.356	42.919	45.51	75.844	201.53	277.37	92.46	110.95
15.0	S	13	13	2.356		30.63	306.306	232.16	538.46	179.49	215.39
16.5	S	34	24.5	2.356		57.73	577.269	289.88	867.15	289.05	346.86
18.0	S	32	23.5	2.356		55.37	553.707	345.26	898.96	299.65	359.58
20.0	S	39	27.0	2.356		63.62	636.174	408.87	1045.05	348.35	418.02

Table 12: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-8

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m Qs=0.45*Cu*A_S (Clay),1.0*N'*A_S (sand) kN	Ultimate End Bearing Qe=9*Cu*A_c (Clay),120*N'*A_c (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	C	2	2	2.356	12.263	13.00	21.670	13.00	34.67	11.56	13.87
3.0	C	1	1	2.356	6.131	6.50	10.835	19.50	30.34	10.11	12.14
4.5	C	2	2	2.356	12.263	13.00	21.670	32.50	54.17	18.06	21.67
6.0	C	3	3	2.356	18.394	19.50	32.505	52.01	84.51	28.17	33.80
7.5	C	4	4	2.356	24.525	26.00	43.339	78.01	121.35	40.45	48.54
9.0	C	3	3	2.356	18.394	19.50	32.505	97.51	130.02	43.34	52.01
10.5	C	2	2	2.356	12.263	13.00	21.670	110.52	132.18	44.06	52.87
12.0	C	3	3	2.356	18.394	19.50	32.505	130.02	162.52	54.17	65.01
13.5	C	4	4	2.356	24.525	26.00	43.339	156.02	199.36	66.45	79.74
15.0	C	8	8	2.356	49.050	52.01	86.679	208.03	294.71	98.24	117.88
16.5	S	17	16.0	2.356		37.70	376.992	245.73	622.72	207.57	249.09
18.0	S	32	23.5	2.356		55.37	553.707	301.10	854.81	284.94	341.92
20.0	S	38	26.5	2.356		62.44	624.393	363.54	987.93	329.31	395.17

6.3 Bearing Capacity for Reservoirs in Sabrang Tourism Park

6.3.1 Bearing Capacity for Shallow Foundation

The allowable bearing capacities in kg/cm^2 of sub-soil for square and strip footing for shallow foundation have been calculated with F.S.3 and is shown in **Table 13**.

Table 13: Allowable bearing capacities in kg/cm2 with F.S.3

Bore Hole No.	Depth in (m)	Allowable bearing capacities for	
		Sq. Footing	Strip Footing
BH - 9	1.5	0.36	0.32
	3.0	1.34	1.15
	4.5	2.93	2.44
BH - 10	1.5	1.13	0.93
	3.0	1.18	1.03
	4.5	6.33	5.15
BH - 11	1.5	0.36	0.32
	3.0	1.03	0.91
	4.5	1.54	1.37
BH - 12	1.5	0.51	0.46
	3.0	0.87	0.79
	4.5	0.77	0.68
BH - 13	1.5	0.51	0.46
	3.0	0.72	0.63
	4.5	0.92	0.81
BH - 14	1.5	0.20	0.17
	3.0	0.72	0.63
	4.5	1.54	1.37

6.3.2 Cast In-situ Pile Capacity for Deep Foundation

Table 14: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-9

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m $Q_S=0.45*Cu*A_S$ (Clay),$1.0*N'*A_S$ (sand) kN	Ultimate End Bearing $Qe=9*Cu*A_c$ (Clay),$120*N'*A_c$ (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	S	2	2	2.356		4.71	47.124	4.71	51.84	17.28	20.73
3.0	S	8	8	2.356		18.85	188.496	23.56	212.06	70.69	84.82
4.5	S	18	16.5	2.356		38.88	388.773	62.44	451.21	150.40	180.48
6.0	S	27	21.0	2.356		49.48	494.802	111.92	606.72	202.24	242.69
7.5	S	32	23.5	2.356		55.37	553.707	167.29	721.00	240.33	288.40
9.0	S	33	24.0	2.356		56.55	565.488	223.84	789.33	263.11	315.73
10.5	S	41	28.0	2.356		65.97	659.736	289.81	949.55	316.52	379.82
12.0	S	40	27.5	2.356		64.80	647.955	354.61	1002.56	334.19	401.02
13.5	S	50	32.5	2.356		76.58	765.765	431.18	1196.95	398.98	478.78
15.0	S	50	32.5	2.356		76.58	765.765	507.76	1273.52	424.51	509.41
16.5	S	50	32.5	2.356		76.58	765.765	584.34	1350.10	450.03	540.04
18.0	S	50	32.5	2.356		76.58	765.765	660.91	1426.68	475.56	570.67
20.0	S	50	32.5	2.356		76.58	765.765	737.49	1503.25	501.08	601.30

Table 15: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-10

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m $Qs=0.45*Cu*A_S$ (Clay),$1.0*N'*A_S$ (sand) kN	Ultimate End Bearing $Qe=9*Cu*A_c$ (Clay),$120*N'*A_c$ (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	S	7	7	2.356		16.49	164.934	16.49	181.43	60.48	72.57
3.0	S	7	7	2.356		16.49	164.934	32.99	197.92	65.97	79.17
4.5	S	40	27.5	2.356		64.80	647.955	97.78	745.74	248.58	298.29
6.0	S	45	30.0	2.356		70.69	706.860	168.47	875.33	291.78	350.13
7.5	S	45	30.0	2.356		70.69	706.860	239.15	946.01	315.34	378.41
9.0	S	39	27.0	2.356		63.62	636.174	302.77	938.94	312.98	375.58
10.5	S	46	30.5	2.356		71.86	718.641	374.63	1093.28	364.43	437.31
12.0	S	42	28.5	2.356		67.15	671.517	441.79	1113.30	371.10	445.32
13.5	S	50	32.5	2.356		76.58	765.765	518.36	1284.13	428.04	513.65
15.0	S	50	32.5	2.356		76.58	765.765	594.94	1360.70	453.57	544.28
16.5	S	50	32.5	2.356		76.58	765.765	671.52	1437.28	479.09	574.91
18.0	S	50	32.5	2.356		76.58	765.765	748.09	1513.86	504.62	605.54
20.0	S	50	32.5	2.356		76.58	765.765	824.67	1590.43	530.14	636.17

Table 16: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-11

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0											
Depth in m	**Type of Sample**	**Field SPT N**	**Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15**	**Surface area for 1.5m segment m^2 A_S**	**Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN**	**Ultimate skin friction for 1.5m Q_S=0.45*Cu*A_S (Clay),1.0*N'*A_S (sand) kN**	**Ultimate End Bearing Qe=9*Cu*A_c (Clay),120*N'*A_c (sand) kN**	**Total Cumulitve Ultimate Skin Friction kN**	**Total Ultimate Load Capacity kN**	**Allowable Load Capacity with FS 3.0 kN**	**Allowable Load Capacity with FS 2.5 kN**
1.5	S	2	2	2.356		4.71	47.124	4.71	51.84	17.28	20.73
3.0	S	6	6	2.356		14.14	141.372	18.85	160.22	53.41	64.09
4.5	S	9	9	2.356		21.21	212.058	40.06	252.11	84.04	100.85
6.0	S	20	17.5	2.356		41.23	412.335	81.29	493.62	164.54	197.45
7.5	S	19	17.0	2.356		40.06	400.554	121.34	521.90	173.97	208.76
9.0	S	24	19.5	2.356		45.95	459.459	167.29	626.75	208.92	250.70
10.5	S	27	21.0	2.356		49.48	494.802	216.77	711.57	237.19	284.63
12.0	S	32	23.5	2.356		55.37	553.707	272.14	825.85	275.28	330.34
13.5	S	39	27.0	2.356		63.62	636.174	335.76	971.93	323.98	388.77
15.0	S	42	28.5	2.356		67.15	671.517	402.91	1074.43	358.14	429.77
16.5	S	50	32.5	2.356		76.58	765.765	479.49	1245.25	415.08	498.10
18.0	S	50	32.5	2.356		76.58	765.765	556.06	1321.83	440.61	528.73
20.0	S	50	32.5	2.356		76.58	765.765	632.64	1398.40	466.13	559.36

Table 17: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-12

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m² A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m Qs=0.45*Cu*A_S (Clay),1.0*N'*A_S (sand) kN	Ultimate End Bearing Qe=9*Cu*A_c (Clay),120*N'*A_c (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	S	3	3	2.356		7.07	70.686	7.07	77.75	25.92	31.10
3.0	S	5	5	2.356		11.78	117.810	18.85	136.66	45.55	54.66
4.5	S	4	4	2.356		9.42	94.248	28.27	122.52	40.84	49.01
6.0	S	16	15.5	2.356		36.52	365.211	64.80	430.01	143.34	172.00
7.5	S	18	16.5	2.356		38.88	388.773	103.67	492.45	164.15	196.98
9.0	S	28	21.5	2.356		50.66	506.583	154.33	660.91	220.30	264.37
10.5	S	33	24.0	2.356		56.55	565.488	210.88	776.37	258.79	310.55
12.0	S	41	28.0	2.356		65.97	659.736	276.85	936.59	312.20	374.64
13.5	S	47	31.0	2.356		73.04	730.422	349.89	1080.32	360.11	432.13
15.0	S	46	30.5	2.356		71.86	718.641	421.76	1140.40	380.13	456.16
16.5	S	45	30.0	2.356		70.69	706.860	492.44	1199.30	399.77	479.72
18.0	S	47	31.0	2.356		73.04	730.422	565.49	1295.91	431.97	518.36
20.0	S	50	32.5	2.356		76.58	765.765	642.06	1407.83	469.28	563.13

Table 18: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-13

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m $Qs=0.45*Cu*A_S$ (Clay),1.0*N'*A_S (sand) kN	Ultimate End Bearing $Qe=9*Cu*A_c$ (Clay),120*N'*A_c (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	S	2	2	2.356		4.71	47.124	4.71	51.84	17.28	20.73
3.0	S	4	4	2.356		9.42	94.248	14.14	108.39	36.13	43.35
4.5	S	5	5	2.356		11.78	117.810	25.92	143.73	47.91	57.49
6.0	S	14	14	2.356		32.99	329.868	58.90	388.77	129.59	155.51
7.5	S	15	15.0	2.356		35.34	353.430	94.25	447.68	149.23	179.07
9.0	S	24	19.5	2.356		45.95	459.459	140.19	599.65	199.88	239.86
10.5	S	27	21.0	2.356		49.48	494.802	189.67	684.48	228.16	273.79
12.0	S	30	22.5	2.356		53.01	530.145	242.69	772.83	257.61	309.13
13.5	S	33	24.0	2.356		56.55	565.488	299.24	864.72	288.24	345.89
15.0	S	32	23.5	2.356		55.37	553.707	354.61	908.31	302.77	363.33
16.5	S	42	28.5	2.356		67.15	671.517	421.76	1093.28	364.43	437.31
18.0	S	40	27.5	2.356		64.80	647.955	486.55	1134.51	378.17	453.80
20.0	S	50	32.5	2.356		76.58	765.765	563.13	1328.90	442.97	531.56

Table 19: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-14

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m Qs=0.45*Cu*A_S (Clay),1.0*N'*A_S (sand) kN	Ultimate End Bearing Qe=9*Cu*A_c (Clay),120*N'*A_c (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	S	1	1	2.356		2.36	23.562	2.36	25.92	8.64	10.37
3.0	S	4	4	2.356		9.42	94.248	11.78	106.03	35.34	42.41
4.5	S	9	9	2.356		21.21	212.058	32.99	245.04	81.68	98.02
6.0	S	13	13	2.356		30.63	306.306	63.62	369.92	123.31	147.97
7.5	S	17	16.0	2.356		37.70	376.992	101.32	478.31	159.44	191.32
9.0	S	23	19.0	2.356		44.77	447.678	146.08	593.76	197.92	237.50
10.5	S	28	21.5	2.356		50.66	506.583	196.74	703.33	234.44	281.33
12.0	S	32	23.5	2.356		55.37	553.707	252.11	805.82	268.61	322.33
13.5	S	32	23.5	2.356		55.37	553.707	307.48	861.19	287.06	344.48
15.0	S	40	27.5	2.356		64.80	647.955	372.28	1020.23	340.08	408.09
16.5	S	48	31.5	2.356		74.22	742.203	446.50	1188.70	396.23	475.48
18.0	S	49	32.0	2.356		75.40	753.984	521.90	1275.88	425.29	510.35
20.0	S	50	32.5	2.356		76.58	765.765	598.47	1364.24	454.75	545.70

6.4 Bearing Capacity for Reservoirs in BPS-2 near Teknaf Ferry Ghat

6.4.1 Bearing Capacity for Shallow Foundation

The allowable bearing capacities in kg/cm^2 of sub-soil for square and strip footing for shallow foundation have been calculated with F.S.3 and is shown in **Table 20**.

Table 20: Allowable bearing capacities in kg/cm2 with F.S.3

Bore Hole No.	Depth in (m)	Allowable bearing capacities for	
		Sq. Footing	Strip Footing
BH - 15	1.5	1.13	0.88
	3.0	0.87	0.69
	4.5	0.92	0.74
BH - 16	1.5	0.82	0.64
	3.0	0.72	0.58
	4.5	1.08	0.86
BH - 17	1.5	0.98	0.76
	3.0	0.87	0.69
	4.5	1.08	0.86
BH - 18	1.5	0.36	0.29
	3.0	1.34	1.05
	4.5	1.67	1.34
BH - 19	1.5	1.29	1.00
	3.0	1.65	1.44
	4.5	5.09	4.25

6.4.2 Cast In-situ Pile Capacity for Deep Foundation

Table 21: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-15

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m² A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m $Qs=0.45*Cu*A_S$ (Clay),$1.0*N'*A_S$ (sand) kN	Ultimate End Bearing $Qe=9*Cu*A_c$ (Clay),$120*N'*A_c$ (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	S	7	7	2.356		16.49	164.934	16.49	181.43	60.48	72.57
3.0	C	5	5	2.356	30.656	32.50	54.174	49.00	103.17	34.39	41.27
4.5	C	5	5	2.356	30.656	32.50	54.174	81.50	135.68	45.23	54.27
6.0	S	18	16.5	2.356		38.88	388.773	120.38	509.15	169.72	203.66
7.5	S	15	15.0	2.356		35.34	353.430	155.72	509.15	169.72	203.66
9.0	S	22	18.5	2.356		43.59	435.897	199.31	635.21	211.74	254.08
10.5	S	26	20.5	2.356		48.30	483.021	247.61	730.63	243.54	292.25
12.0	S	25	20.0	2.356		47.12	471.240	294.74	765.98	255.33	306.39
13.5	S	47	31.0	2.356		73.04	730.422	367.78	1098.20	366.07	439.28
15.0	S	35	25.0	2.356		58.90	589.050	426.68	1015.73	338.58	406.29
16.5	S	37	26.0	2.356		61.26	612.612	487.95	1100.56	366.85	440.22
18.0	S	50	32.5	2.356		76.58	765.765	564.52	1330.29	443.43	532.11
20.0	S	50	32.5	2.356		76.58	765.765	641.10	1406.86	468.95	562.75

Table 22: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-16

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m $Qs=0.45*Cu*A_S$ (Clay),1.0*N'*A_S (sand) kN	Ultimate End Bearing $Qe=9*Cu*A_c$ (Clay),120*N'*A_c (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	S	5	5	2.356		11.78	117.810	11.78	129.59	43.20	51.84
3.0	C	4	4	2.356	24.525	26.00	43.339	37.78	81.12	27.04	32.45
4.5	C	6	6	2.356	36.788	39.01	65.009	76.79	141.80	47.27	56.72
6.0	S	16	15.5	2.356		36.52	365.211	113.31	478.52	159.51	191.41
7.5	S	18	16.5	2.356		38.88	388.773	152.19	540.96	180.32	216.38
9.0	S	24	19.5	2.356		45.95	459.459	198.13	657.59	219.20	263.04
10.5	S	20	17.5	2.356		41.23	412.335	239.37	651.70	217.23	260.68
12.0	S	26	20.5	2.356		48.30	483.021	287.67	770.69	256.90	308.28
13.5	S	35	25.0	2.356		58.90	589.050	346.57	935.62	311.87	374.25
15.0	S	37	26.0	2.356		61.26	612.612	407.84	1020.45	340.15	408.18
16.5	S	48	31.5	2.356		74.22	742.203	482.06	1224.26	408.09	489.70
18.0	S	50	32.5	2.356		76.58	765.765	558.63	1324.40	441.47	529.76
20.0	S	50	32.5	2.356		76.58	765.765	635.21	1400.97	466.99	560.39

Table 23: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-17

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m $Qs=0.45*Cu*A_S$ (Clay),1.0*N'*A_S (sand) kN	Ultimate End Bearing $Qe=9*Cu*A_c$ (Clay),120*N'*A_c (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	S	6	6	2.356		14.14	141.372	14.14	155.51	51.84	62.20
3.0	C	5	5	2.356	30.656	32.50	54.174	46.64	100.82	33.61	40.33
4.5	C	6	6	2.356	36.788	39.01	65.009	85.65	150.66	50.22	60.26
6.0	S	17	16.0	2.356		37.70	376.992	123.35	500.34	166.78	200.14
7.5	S	28	21.5	2.356		50.66	506.583	174.00	680.59	226.86	272.23
9.0	S	23	19.0	2.356		44.77	447.678	218.77	666.45	222.15	266.58
10.5	S	24	19.5	2.356		45.95	459.459	264.72	724.18	241.39	289.67
12.0	S	24	19.5	2.356		45.95	459.459	310.66	770.12	256.71	308.05
13.5	S	36	25.5	2.356		60.08	600.831	370.75	971.58	323.86	388.63
15.0	S	42	28.5	2.356		67.15	671.517	437.90	1109.42	369.81	443.77
16.5	S	43	29.0	2.356		68.33	683.298	506.23	1189.53	396.51	475.81
18.0	S	46	30.5	2.356		71.86	718.641	578.09	1296.73	432.24	518.69
20.0	S	50	32.5	2.356		76.58	765.765	654.67	1420.43	473.48	568.17

Table 24: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-18

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m $Qs=0.45*Cu*A_S$ (Clay),1.0*N'*A_S (sand) kN	Ultimate End Bearing $Qe=9*Cu*A_c$ (Clay),120*N'*A_c (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	C	2	2	2.356	12.263	13.00	21.670	13.00	34.67	11.56	13.87
3.0	C	8	8	2.356	49.050	52.01	86.679	65.01	151.69	50.56	60.68
4.5	C	10	10	2.356	61.313	65.01	108.348	130.02	238.37	79.46	95.35
6.0	S	30	22.5	2.356		53.01	530.145	183.03	713.18	237.73	285.27
7.5	S	28	21.5	2.356		50.66	506.583	233.69	740.27	246.76	296.11
9.0	S	35	25.0	2.356		58.90	589.050	292.60	881.65	293.88	352.66
10.5	S	34	24.5	2.356		57.73	577.269	350.32	927.59	309.20	371.04
12.0	S	37	26.0	2.356		61.26	612.612	411.58	1024.19	341.40	409.68
13.5	S	35	25.0	2.356		58.90	589.050	470.49	1059.54	353.18	423.82
15.0	S	50	32.5	2.356		76.58	765.765	547.06	1312.83	437.61	525.13
16.5	S	50	32.5	2.356		76.58	765.765	623.64	1389.41	463.14	555.76
18.0	S	50	32.5	2.356		76.58	765.765	700.22	1465.98	488.66	586.39
20.0	S	50	32.5	2.356		76.58	765.765	776.79	1542.56	514.19	617.02

Table 25: Skin friction and end bearing capacity of cast in-situ pile and allowable working load for 500 mm dia pipe at bore hole BH-19

Pile diameter D= 0.5 m, Cross Sectional Area, A_c = 0.19635 m^2, F. Safety = 3.0

Depth in m	Type of Sample	Field SPT N	Corrected SPT N'=N,N<15 N'=15+(N-15)/2,N>15	Surface area for 1.5m segment m^2 A_S	Undrained Cohesion for Cohesive Soil, Cu=6.13125*N' kN	Ultimate skin friction for 1.5m $Qs=0.45*Cu*A_S$ (Clay),1.0*N'*A_S (sand) kN	Ultimate End Bearing $Qe=9*Cu*A_c$ (Clay),120*N'*A_c (sand) kN	Total Cumulitve Ultimate Skin Friction kN	Total Ultimate Load Capacity kN	Allowable Load Capacity with FS 3.0 kN	Allowable Load Capacity with FS 2.5 kN
1.5	C	8	8	2.356	49.050	52.01	86.679	52.01	138.69	46.23	55.47
3.0	S	18	16.5	2.356		38.88	388.773	90.88	479.66	159.89	191.86
4.5	S	32	23.5	2.356		55.37	553.707	146.25	699.96	233.32	279.98
6.0	S	30	22.5	2.356		53.01	530.145	199.27	729.41	243.14	291.77
7.5	S	32	23.5	2.356		55.37	553.707	254.64	808.35	269.45	323.34
9.0	S	28	21.5	2.356		50.66	506.583	305.30	811.88	270.63	324.75
10.5	S	34	24.5	2.356		57.73	577.269	363.02	940.29	313.43	376.12
12.0	S	42	28.5	2.356		67.15	671.517	430.18	1101.69	367.23	440.68
13.5	S	38	26.5	2.356		62.44	624.393	492.62	1117.01	372.34	446.80
15.0	S	41	28.0	2.356		65.97	659.736	558.59	1218.32	406.11	487.33
16.5	S	45	30.0	2.356		70.69	706.860	629.27	1336.13	445.38	534.45
18.0	S	50	32.5	2.356		76.58	765.765	705.85	1471.62	490.54	588.65
20.0	S	50	32.5	2.356		76.58	765.765	782.43	1548.19	516.06	619.28

7 RECOMMNDATION

The Design Engineer shall choose suitable and appropriate type of foundation considering the overall structural load, loading pattern etc. of the proposed booster pumps and water reservoirs at different locations for supplying water in Naf and Sabrang Tourism Park.

Attachment-I: LOCATION OF BORE HOLE

The structure wise location of Bore holes are shown in Site Plan Maps in **Figure 1** to **Figure 7.**

Figure 1: Bore hole location Map at BPS-1, Whykhong

Figure 2: Bore hole location Map at N_UGWR-1, Naf Tourism Park

Figure 3: Bore hole location Map at N_UGWR-2, Naf Tourism Park

Figure 4: Bore hole location Map at S_UGWR-1, Sabrang Tourism Park

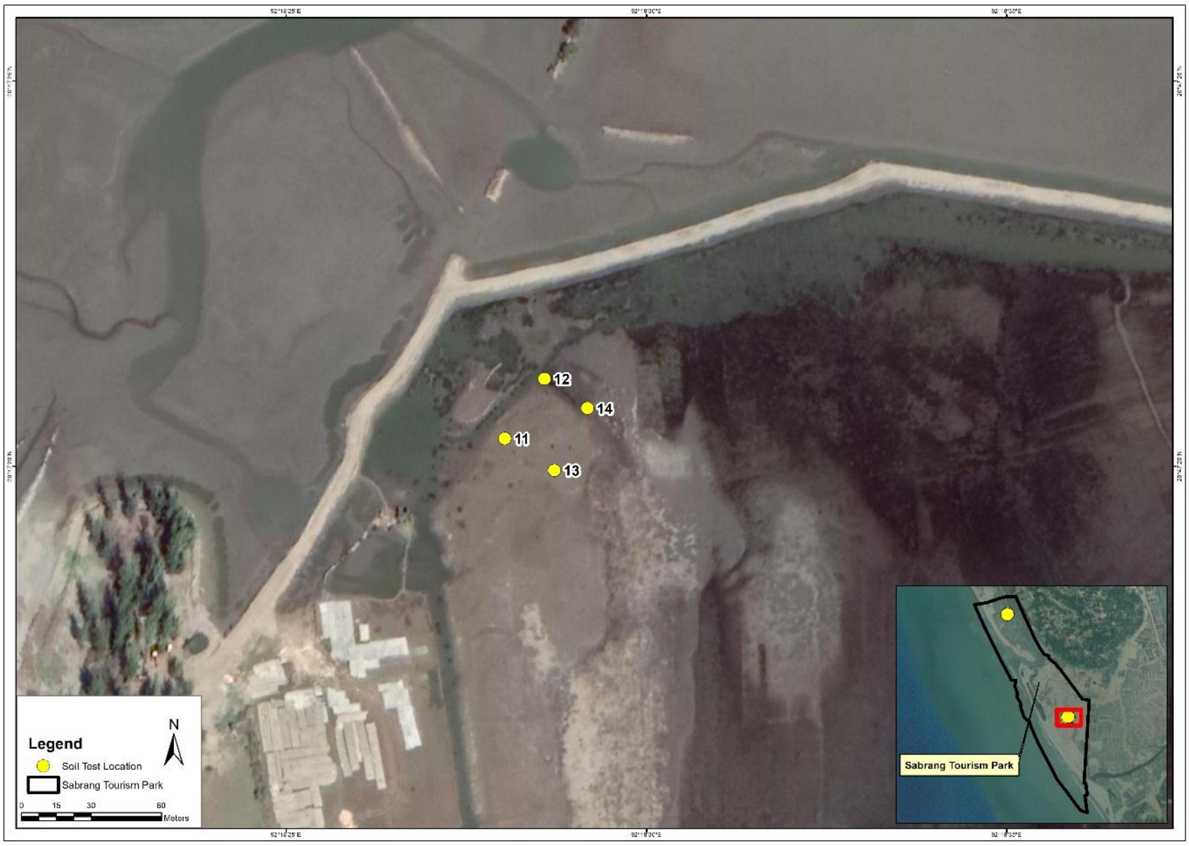


Figure 5: Bore hole location Map at S_UGWR-2 & S_UGWR-3 Sabrang Tourism Park

Figure 6: Bore hole location Map at BPS-2 (Option-1), Teknaf Ferry Ghat

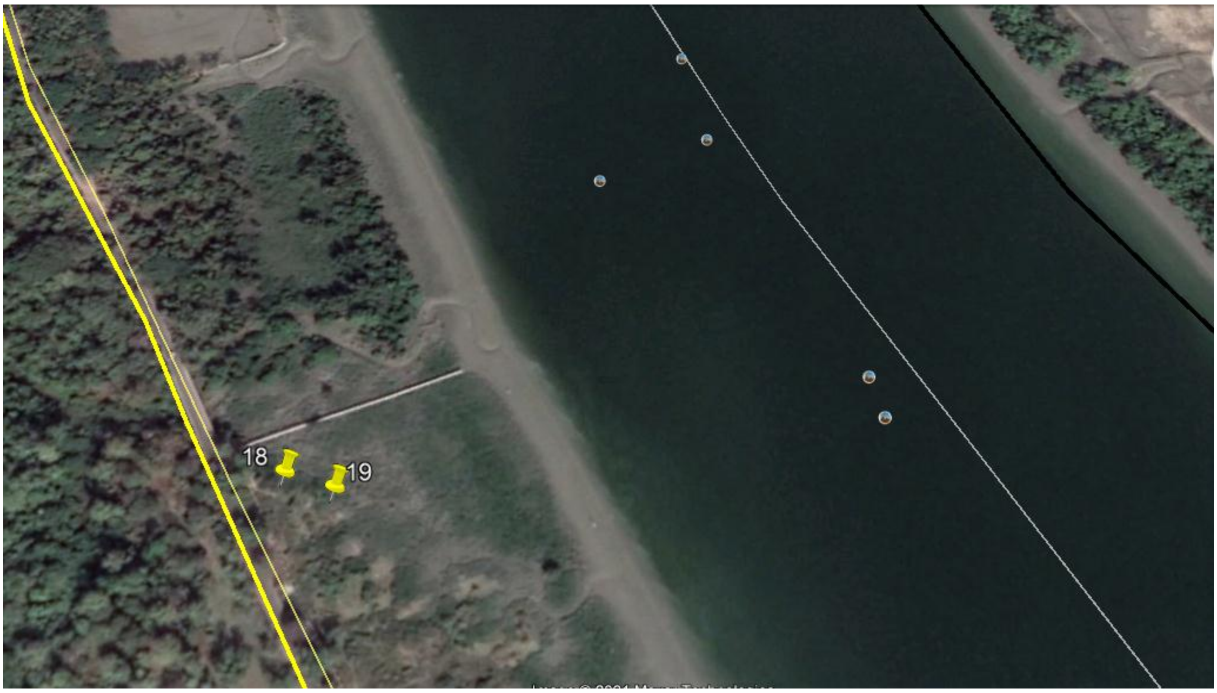
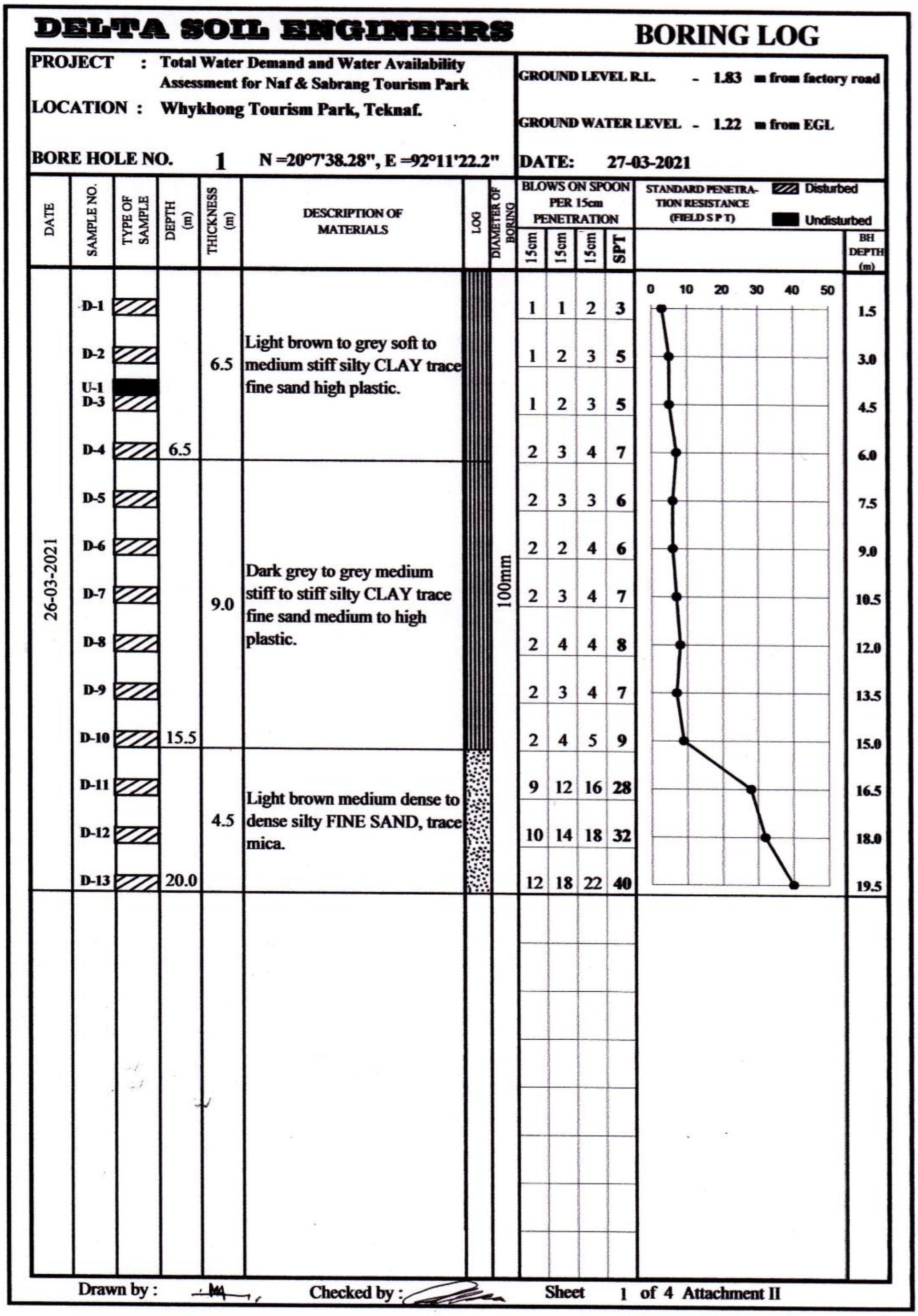


Figure 7: Bore hole location Map at BPS-2 (Option-2), Teknaf Ferry Ghat

Attachment-II: BORING LOGS



DELTA SOIL ENGINEERS

BORING LOG

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park

LOCATION : Whykhong Tourism Park, Teknaf.

BORE HOLE NO. 1 N =20°7'38.28", E =92°11'22.2"

GROUND LEVEL R.L. - 1.83 m from factory road

GROUND WATER LEVEL - 1.22 m from EGL

DATE: 27-03-2021

▨ Disturbed

■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	BH DEPTH (m)
26-03-2021	D-1	▨		6.5	Light brown to grey soft to medium stiff silty CLAY trace fine sand high plastic.	100mm	1	1	2	3	1.5
	D-2	▨					1	2	3	5	3.0
	U-1 D-3	■ ▨					1	2	3	5	4.5
	D-4	▨	6.5				2	3	4	7	6.0
	D-5	▨		9.0	Dark grey to grey medium stiff to stiff silty CLAY trace fine sand medium to high plastic.		2	3	3	6	7.5
	D-6	▨					2	2	4	6	9.0
	D-7	▨					2	3	4	7	10.5
	D-8	▨					2	4	4	8	12.0
	D-9	▨					2	3	4	7	13.5
	D-10	▨	15.5				2	4	5	9	15.0
	D-11	▨		4.5	Light brown medium dense to dense silty FINE SAND, trace mica.		9	12	16	28	16.5
	D-12	▨					10	14	18	32	18.0
	D-13	▨	20.0				12	18	22	40	19.5

Drawn by : Checked by : Sheet 1 of 4 Attachment II

DELTA SOIL ENGINEERS

BORING LOG

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park

LOCATION : Whykhong Tourism Park, Teknaf.

BORE HOLE NO. 2 N =20°7'38.28", E =92°11'22.92"

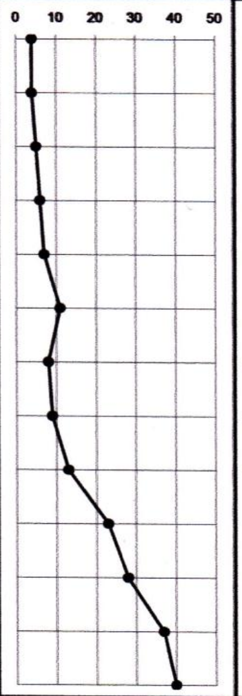
GROUND LEVEL R.L. - 1.83 m from factory road

GROUND WATER LEVEL - 1.52 m from EGL

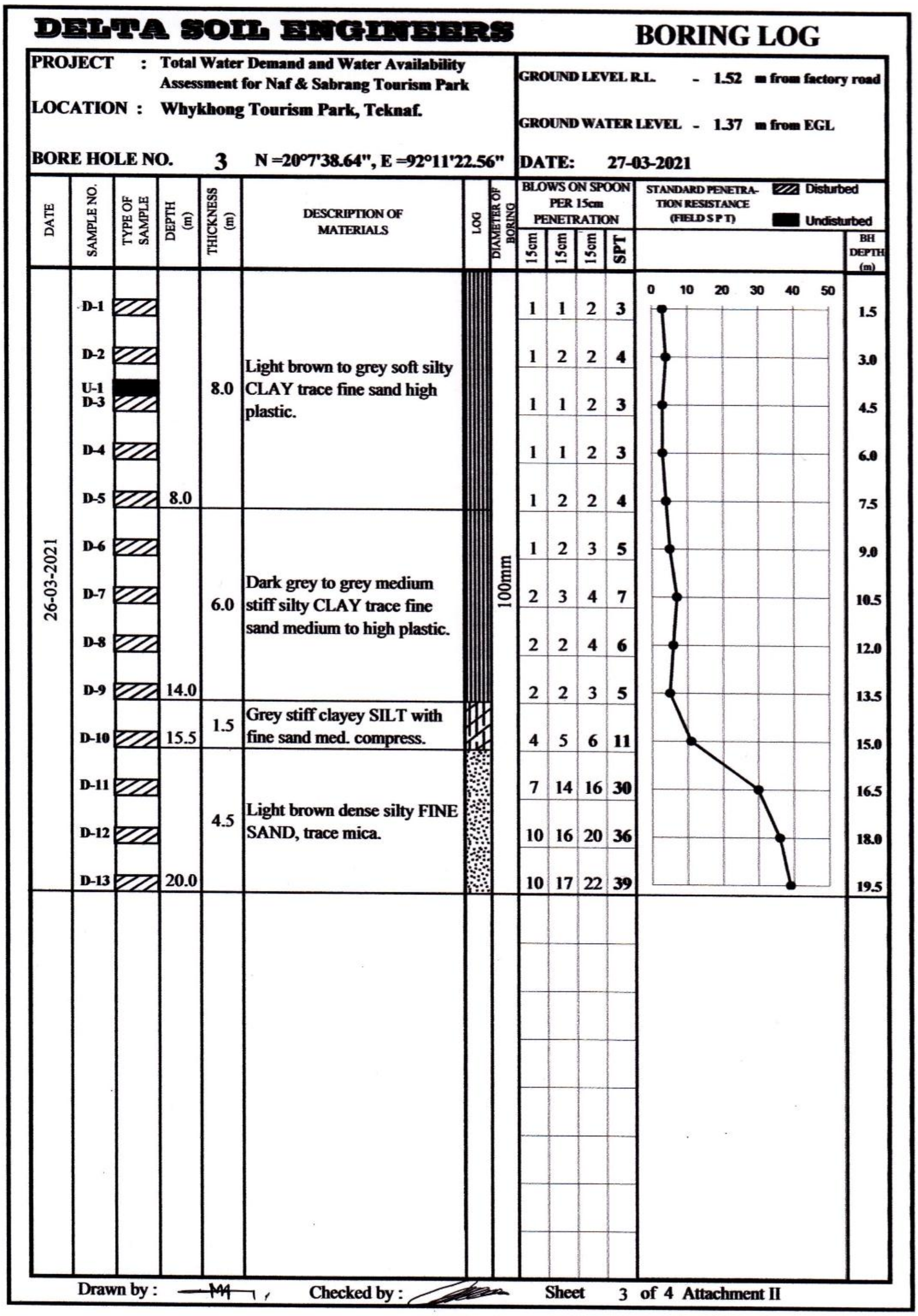
DATE: 27-03-2021

STANDARD PENETRATION RESISTANCE (FIELD S P T) ▨ Disturbed ■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION				BH DEPTH (m)
								15cm	15cm	15cm	SPT	
26-03-2021	D-1	▨		6.5	Light brown to grey soft to medium stiff silty CLAY trace fine sand high plastic.		100mm	2	2	2	4	1.5
	D-2	▨						2	2	2	4	3.0
	U-1 D-3	■ ▨						2	2	3	5	4.5
	D-4	▨	6.5					2	3	3	6	6.0
	D-5	▨		6.0	Dark grey to grey medium stiff to stiff silty CLAY trace fine sand medium to high plastic.			2	3	4	7	7.5
	D-6	▨						3	5	6	11	9.0
	D-7	▨						2	3	5	8	10.5
	D-8	▨	12.5					3	4	5	9	12.0
	D-9	▨	14.0	1.5	Grey stiff clayey SILT with fine sand med. compress.			4	6	7	13	13.5
	D-10	▨		6.0	Light brown medium dense to dense silty FINE SAND, trace mica.			5	9	14	23	15.0
	D-11	▨						8	14	14	28	16.5
	D-12	▨						10	17	20	37	18.0
	D-13	▨	20.0					10	18	22	40	19.5



Drawn by : Checked by : Sheet 2 of 4 Attachment II



DELTA SOIL ENGINEERS **BORING LOG**

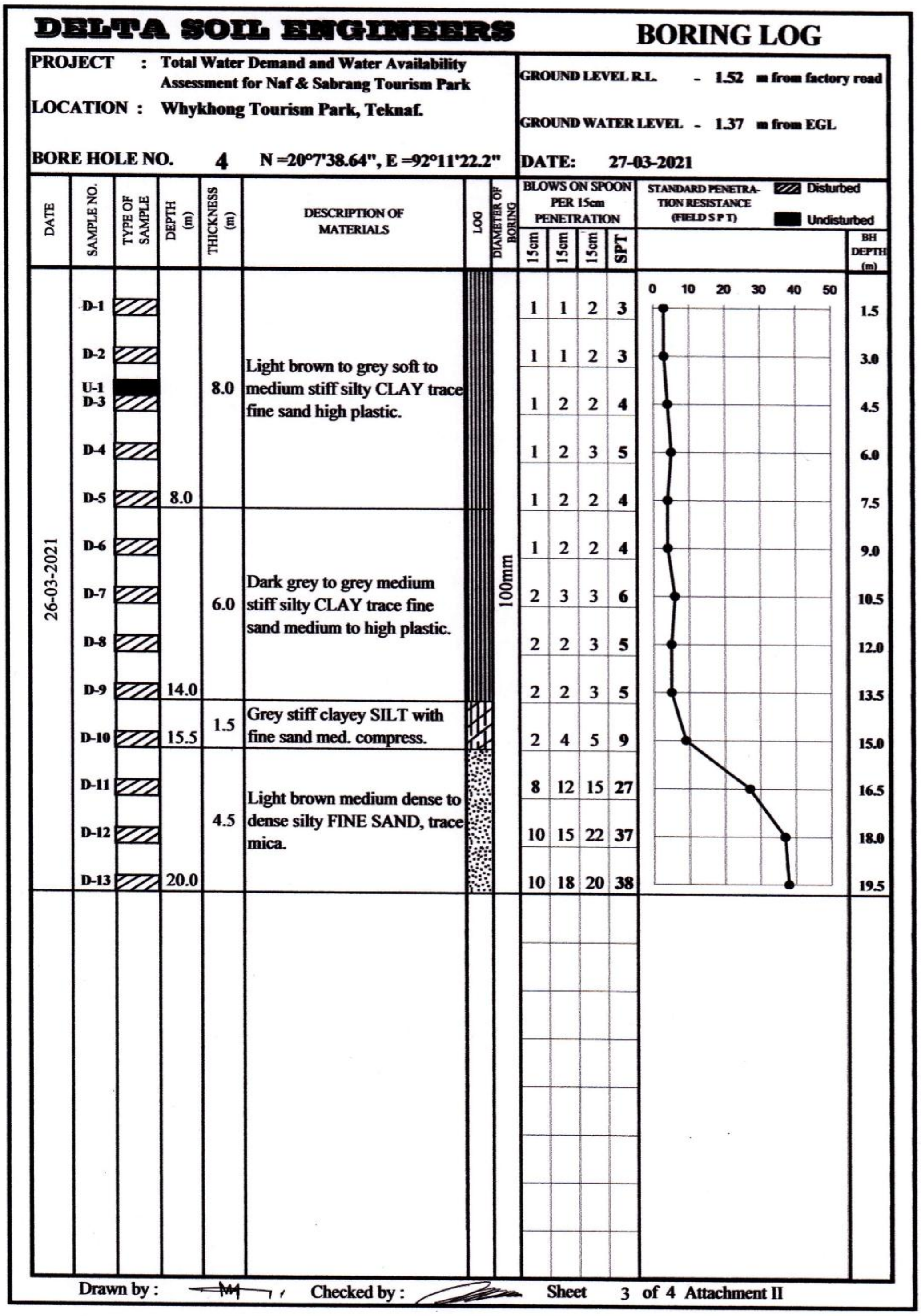
PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park
LOCATION : Whykhong Tourism Park, Teknaf.
BORE HOLE NO. 3 N =20°7'38.64", E =92°11'22.56"

GROUND LEVEL R.L. - 1.52 m from factory road
GROUND WATER LEVEL - 1.37 m from EGL
DATE: 27-03-2021

STANDARD PENETRATION RESISTANCE (FIELD S P T)
▨ Disturbed
■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	BH DEPTH (m)
26-03-2021	D-1	▨		8.0	Light brown to grey soft silty CLAY trace fine sand high plastic.		100mm	1	1	2	3	1.5
	D-2	▨						1	2	2	4	3.0
	U-1 D-3	■ ▨						1	1	2	3	4.5
	D-4	▨						1	1	2	3	6.0
	D-5	▨	8.0					1	2	2	4	7.5
	D-6	▨		6.0	Dark grey to grey medium stiff silty CLAY trace fine sand medium to high plastic.			1	2	3	5	9.0
	D-7	▨						2	3	4	7	10.5
	D-8	▨						2	2	4	6	12.0
	D-9	▨	14.0					2	2	3	5	13.5
	D-10	▨	15.5	1.5	Grey stiff clayey SILT with fine sand med. compress.			4	5	6	11	15.0
	D-11	▨		4.5	Light brown dense silty FINE SAND, trace mica.			7	14	16	30	16.5
	D-12	▨						10	16	20	36	18.0
	D-13	▨	20.0					10	17	22	39	19.5

Drawn by : M4 Checked by : Sheet 3 of 4 Attachment II



DELTA SOIL ENGINEERS **BORING LOG**

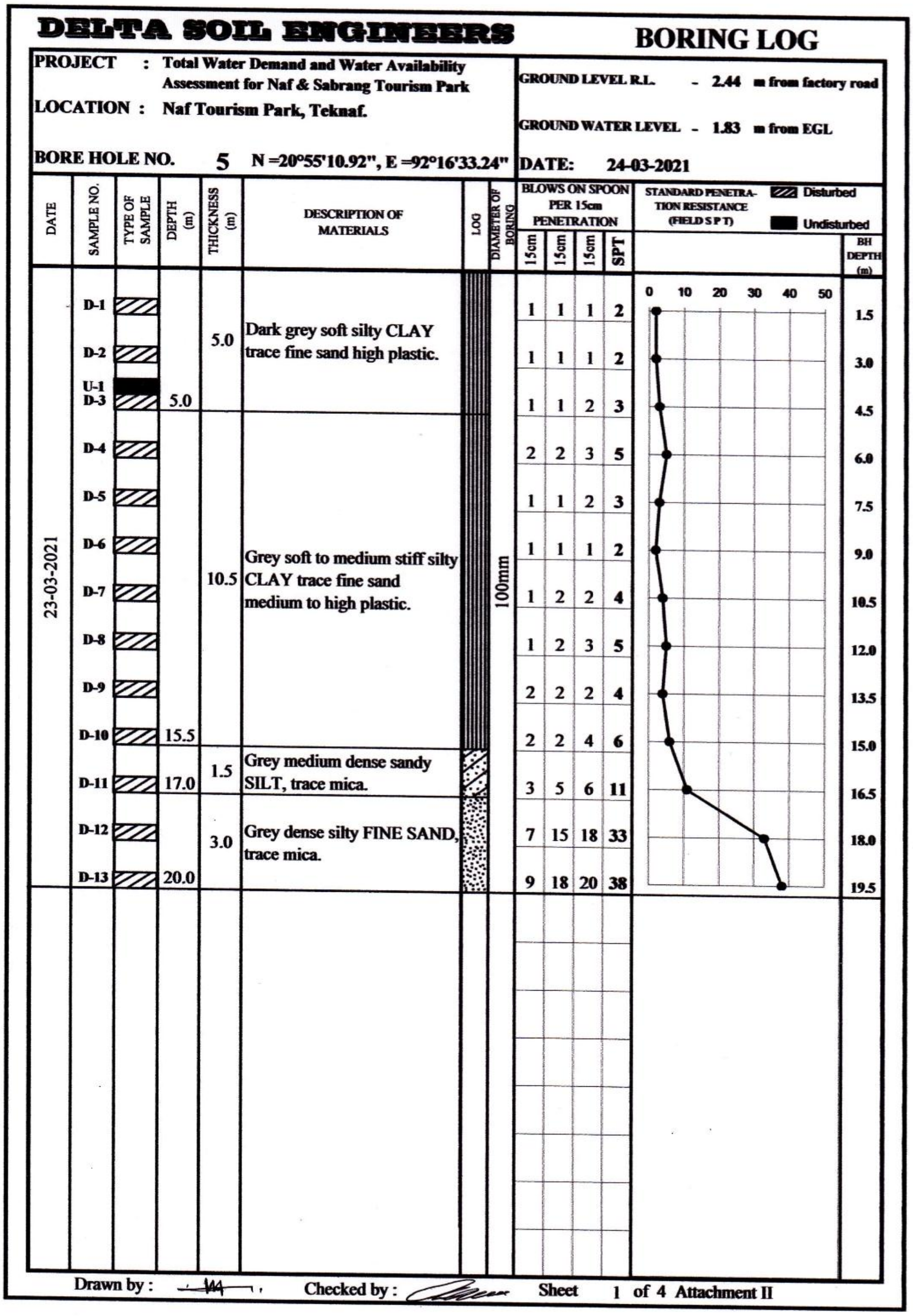
PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park
LOCATION : Whykhong Tourism Park, Teknaf.
BORE HOLE NO. 4 N =20°7'38.64", E =92°11'22.2"

GROUND LEVEL R.L. - 1.52 m from factory road
GROUND WATER LEVEL - 1.37 m from EGL
DATE: 27-03-2021

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	BH DEPTH (m)
26-03-2021	D-1	▨				100mm	1	1	2	3	1.5
	D-2	▨					1	1	2	3	3.0
	U-1 D-3	■ ▨		8.0	Light brown to grey soft to medium stiff silty CLAY trace fine sand high plastic.		1	2	2	4	4.5
	D-4	▨					1	2	3	5	6.0
	D-5	▨	8.0				1	2	2	4	7.5
	D-6	▨					1	2	2	4	9.0
	D-7	▨		6.0	Dark grey to grey medium stiff silty CLAY trace fine sand medium to high plastic.		2	3	3	6	10.5
	D-8	▨					2	2	3	5	12.0
	D-9	▨	14.0				2	2	3	5	13.5
	D-10	▨	15.5	1.5	Grey stiff clayey SILT with fine sand med. compress.		2	4	5	9	15.0
	D-11	▨					8	12	15	27	16.5
	D-12	▨		4.5	Light brown medium dense to dense silty FINE SAND, trace mica.		10	15	22	37	18.0
	D-13	▨	20.0				10	18	20	38	19.5

STANDARD PENETRATION RESISTANCE (FIELD S P T) ▨ Disturbed ■ Undisturbed

Drawn by : Checked by : Sheet 3 of 4 Attachment II



DELTA SOIL ENGINEERS

BORING LOG

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park

LOCATION : Naf Tourism Park, Teknaf.

BORE HOLE NO. 5 N =20°55'10.92", E =92°16'33.24"

GROUND LEVEL R.L. - 2.44 m from factory road

GROUND WATER LEVEL - 1.83 m from EGL

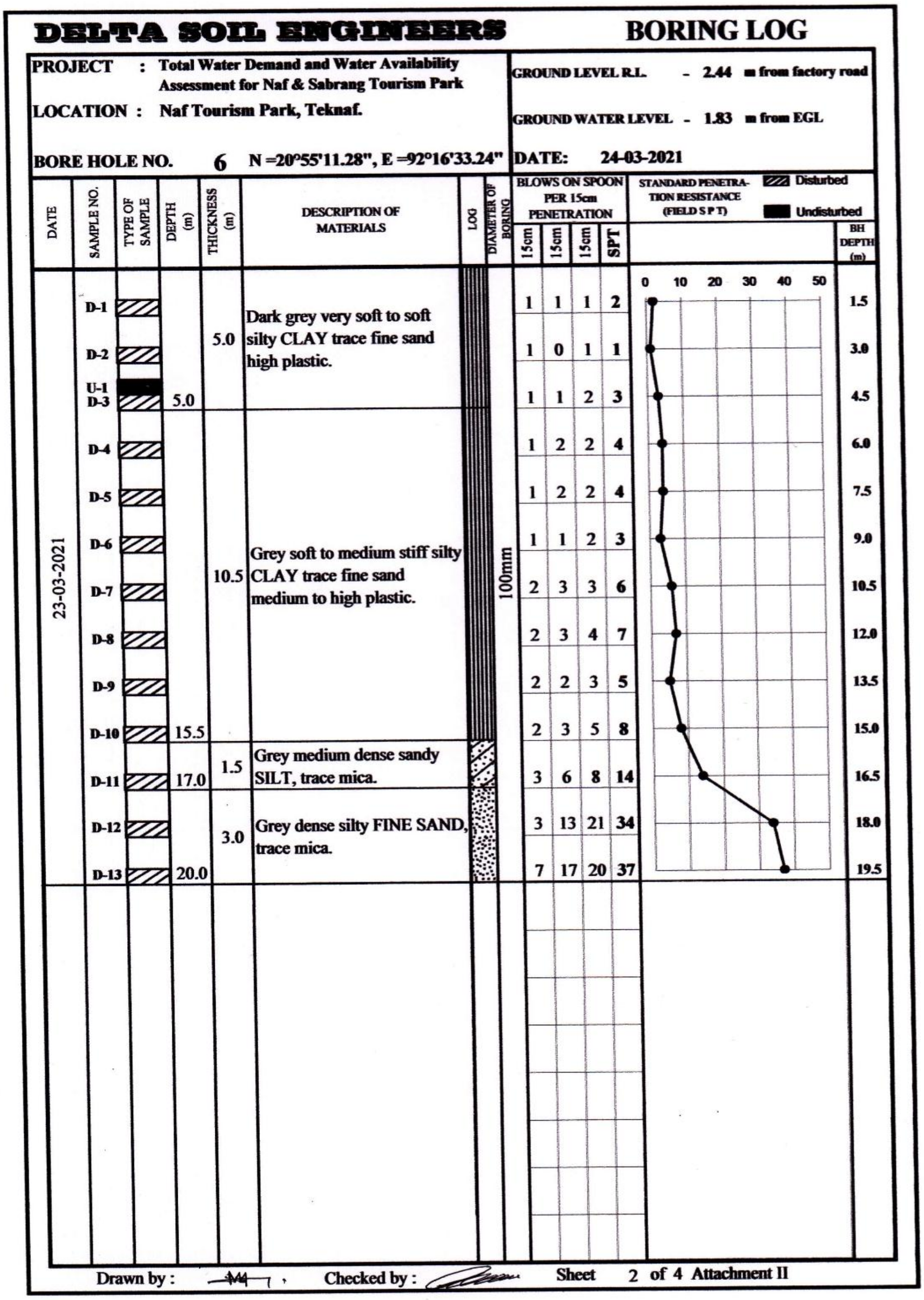
DATE: 24-03-2021

STANDARD PENETRATION RESISTANCE (FIELD S P T)

▨ Disturbed
■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	BH DEPTH (m)
23-03-2021	D-1	▨		5.0	Dark grey soft silty CLAY trace fine sand high plastic.		100mm	1	1	1	2	1.5
	D-2	▨						1	1	1	2	3.0
	U-1	■										
	D-3	▨	5.0					1	1	2	3	4.5
	D-4	▨		10.5	Grey soft to medium stiff silty CLAY trace fine sand medium to high plastic.			2	2	3	5	6.0
	D-5	▨						1	1	2	3	7.5
	D-6	▨						1	1	1	2	9.0
	D-7	▨						1	2	2	4	10.5
	D-8	▨						1	2	3	5	12.0
	D-9	▨						2	2	2	4	13.5
	D-10	▨	15.5					2	2	4	6	15.0
	D-11	▨	17.0	1.5	Grey medium dense sandy SILT, trace mica.			3	5	6	11	16.5
	D-12	▨		3.0	Grey dense silty FINE SAND, trace mica.			7	15	18	33	18.0
	D-13	▨	20.0					9	18	20	38	19.5

Drawn by : Checked by : Sheet 1 of 4 Attachment II



DELTA SOIL ENGINEERS **BORING LOG**

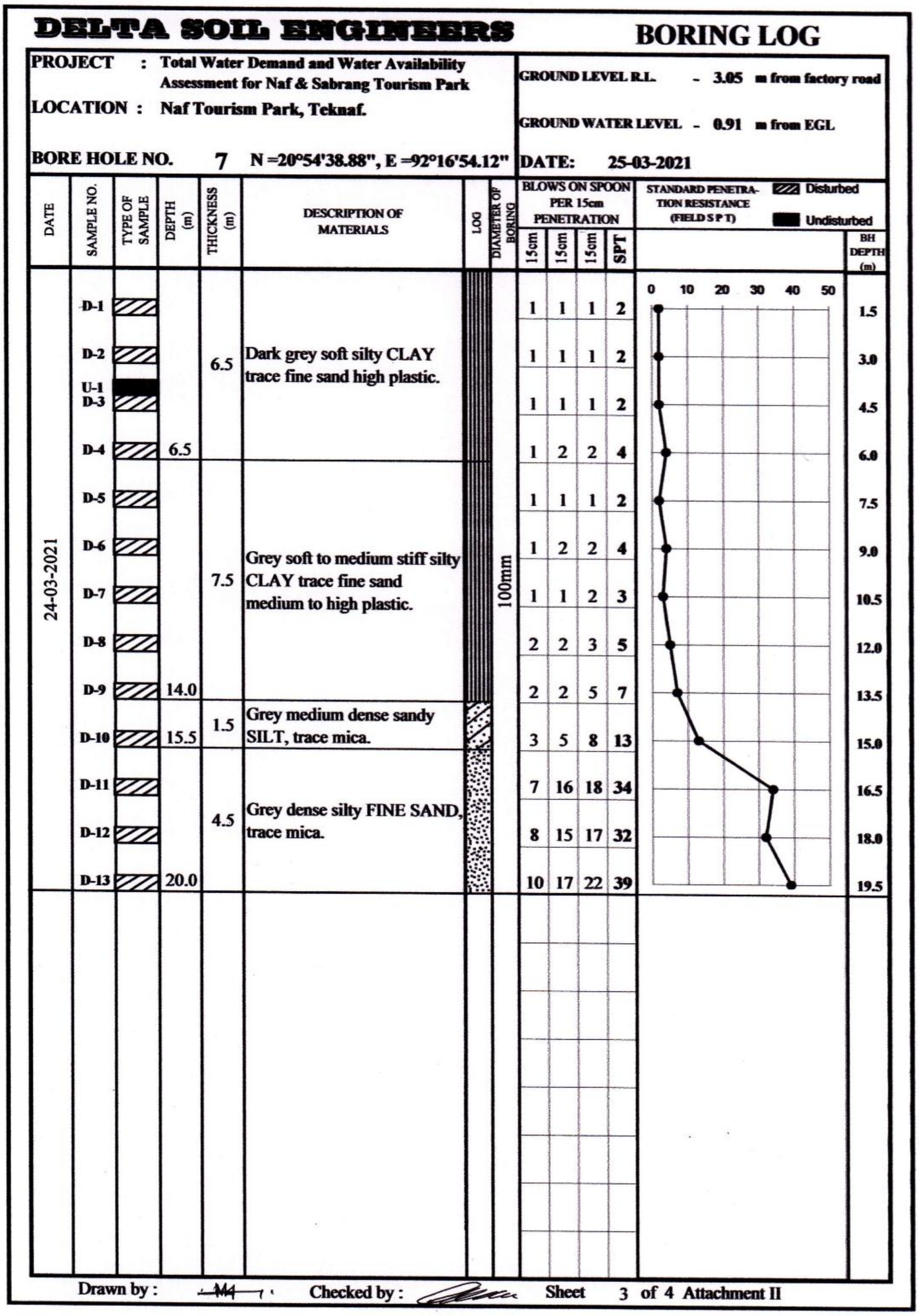
PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park
LOCATION : Naf Tourism Park, Teknaf.
BORE HOLE NO. 6 N =20°55'11.28", E =92°16'33.24"

GROUND LEVEL R.L. - 2.44 m from factory road
GROUND WATER LEVEL - 1.83 m from EGL
DATE: 24-03-2021

STANDARD PENETRATION RESISTANCE (FIELD S P T)
▨ Disturbed
■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	BH DEPTH (m)
23-03-2021	D-1	▨		5.0	Dark grey very soft to soft silty CLAY trace fine sand high plastic.		100mm	1	1	1	2	1.5
	D-2	▨						1	0	1	1	3.0
	U-1 D-3	■ ▨	5.0					1	1	2	3	4.5
	D-4	▨		10.5	Grey soft to medium stiff silty CLAY trace fine sand medium to high plastic.			1	2	2	4	6.0
	D-5	▨						1	2	2	4	7.5
	D-6	▨						1	1	2	3	9.0
	D-7	▨						2	3	3	6	10.5
	D-8	▨						2	3	4	7	12.0
	D-9	▨						2	2	3	5	13.5
	D-10	▨	15.5					2	3	5	8	15.0
	D-11	▨	17.0	1.5	Grey medium dense sandy SILT, trace mica.			3	6	8	14	16.5
	D-12	▨		3.0	Grey dense silty FINE SAND, trace mica.			3	13	21	34	18.0
	D-13	▨	20.0					7	17	20	37	19.5

Drawn by : Checked by : Sheet 2 of 4 Attachment II



DELTA SOIL ENGINEERS **BORING LOG**

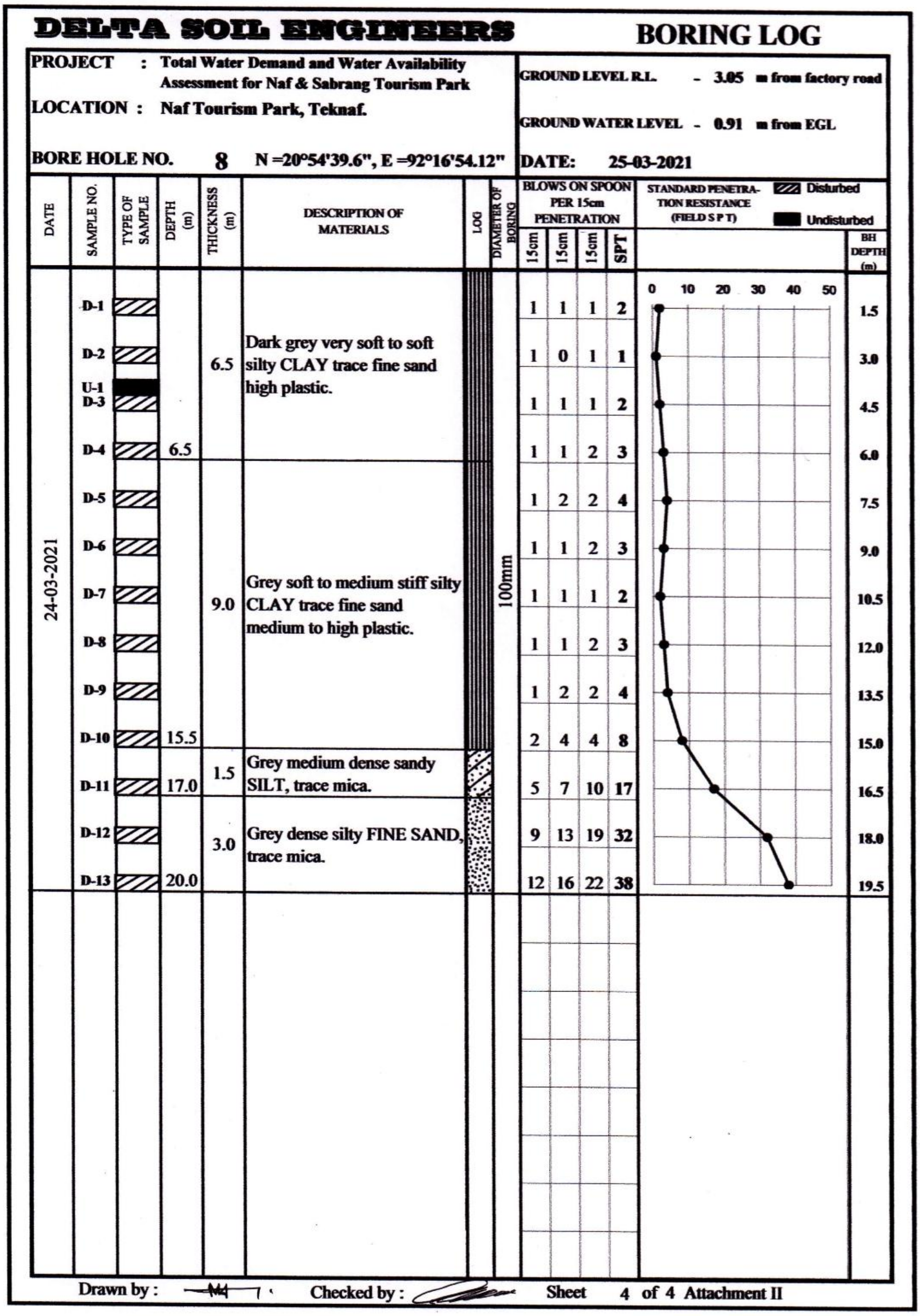
PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park
LOCATION : Naf Tourism Park, Teknaf.
BORE HOLE NO. 7 N =20°54'38.88", E =92°16'54.12"

GROUND LEVEL R.L. - 3.05 m from factory road
GROUND WATER LEVEL - 0.91 m from EGL
DATE: 25-03-2021

STANDARD PENETRATION RESISTANCE (FIELD S P T) ▨ Disturbed ■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	BH DEPTH (m)
24-03-2021	D-1	▨		6.5	Dark grey soft silty CLAY trace fine sand high plastic.		100mm	1	1	1	2	1.5
	D-2	▨						1	1	1	2	3.0
	U-1	■										
	D-3	▨						1	1	1	2	4.5
	D-4	▨	6.5					1	2	2	4	6.0
	D-5	▨		7.5	Grey soft to medium stiff silty CLAY trace fine sand medium to high plastic.			1	1	1	2	7.5
	D-6	▨						1	2	2	4	9.0
	D-7	▨						1	1	2	3	10.5
	D-8	▨						2	2	3	5	12.0
	D-9	▨	14.0					2	2	5	7	13.5
	D-10	▨	15.5	1.5	Grey medium dense sandy SILT, trace mica.			3	5	8	13	15.0
	D-11	▨		4.5	Grey dense silty FINE SAND, trace mica.			7	16	18	34	16.5
	D-12	▨						8	15	17	32	18.0
	D-13	▨	20.0					10	17	22	39	19.5

Drawn by : Checked by : Sheet 3 of 4 Attachment II



DELTA SOIL ENGINEERS **BORING LOG**

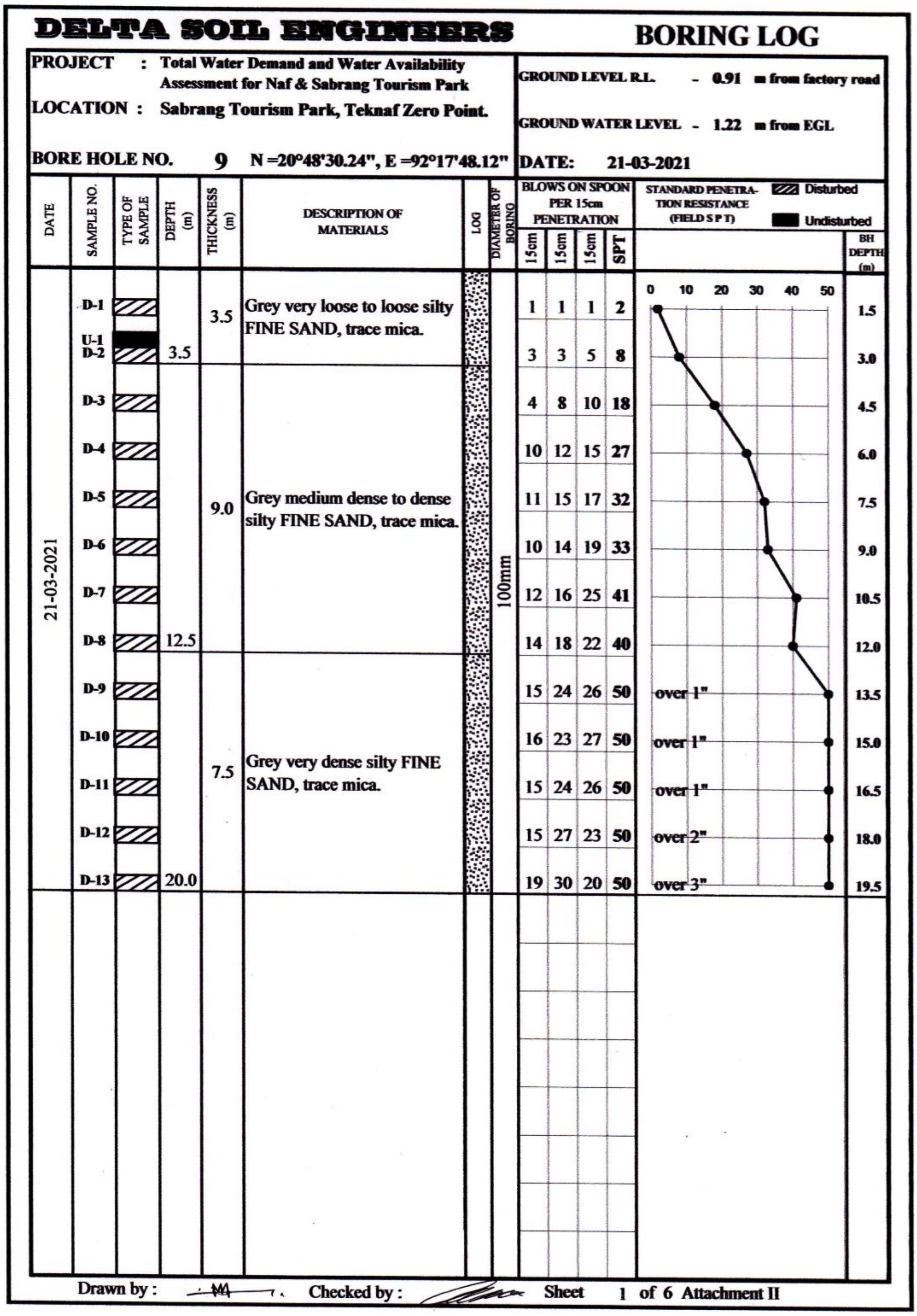
PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park
LOCATION : Naf Tourism Park, Teknaf.
BORE HOLE NO. 8 N =20°54'39.6", E =92°16'54.12"

GROUND LEVEL R.L. - 3.05 m from factory road
GROUND WATER LEVEL - 0.91 m from EGL
DATE: 25-03-2021

▨ Disturbed
■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION				STANDARD PENETRATION RESISTANCE (FIELD S P T)	BH DEPTH (m)
								15cm	15cm	15cm	SPT		
24-03-2021	D-1	▨		6.5	Dark grey very soft to soft silty CLAY trace fine sand high plastic.		100mm	1	1	1	2		1.5
	D-2	▨						1	0	1	1		3.0
	U-1	■											
	D-3	▨						1	1	1	2		4.5
	D-4	▨	6.5					1	1	2	3		6.0
	D-5	▨		9.0	Grey soft to medium stiff silty CLAY trace fine sand medium to high plastic.			1	2	2	4		7.5
	D-6	▨						1	1	2	3		9.0
	D-7	▨						1	1	1	2		10.5
	D-8	▨						1	1	2	3		12.0
	D-9	▨						1	2	2	4		13.5
	D-10	▨	15.5					2	4	4	8		15.0
	D-11	▨	17.0	1.5	Grey medium dense sandy SILT, trace mica.			5	7	10	17		16.5
	D-12	▨		3.0	Grey dense silty FINE SAND, trace mica.			9	13	19	32		18.0
	D-13	▨	20.0					12	16	22	38		19.5

Drawn by : Checked by : Sheet 4 of 4 Attachment II



DELTA SOIL ENGINEERS **BORING LOG**

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park

LOCATION : Sabrang Tourism Park, Teknaf Zero Point.

BORE HOLE NO. 9 N =20°48'30.24", E =92°17'48.12"

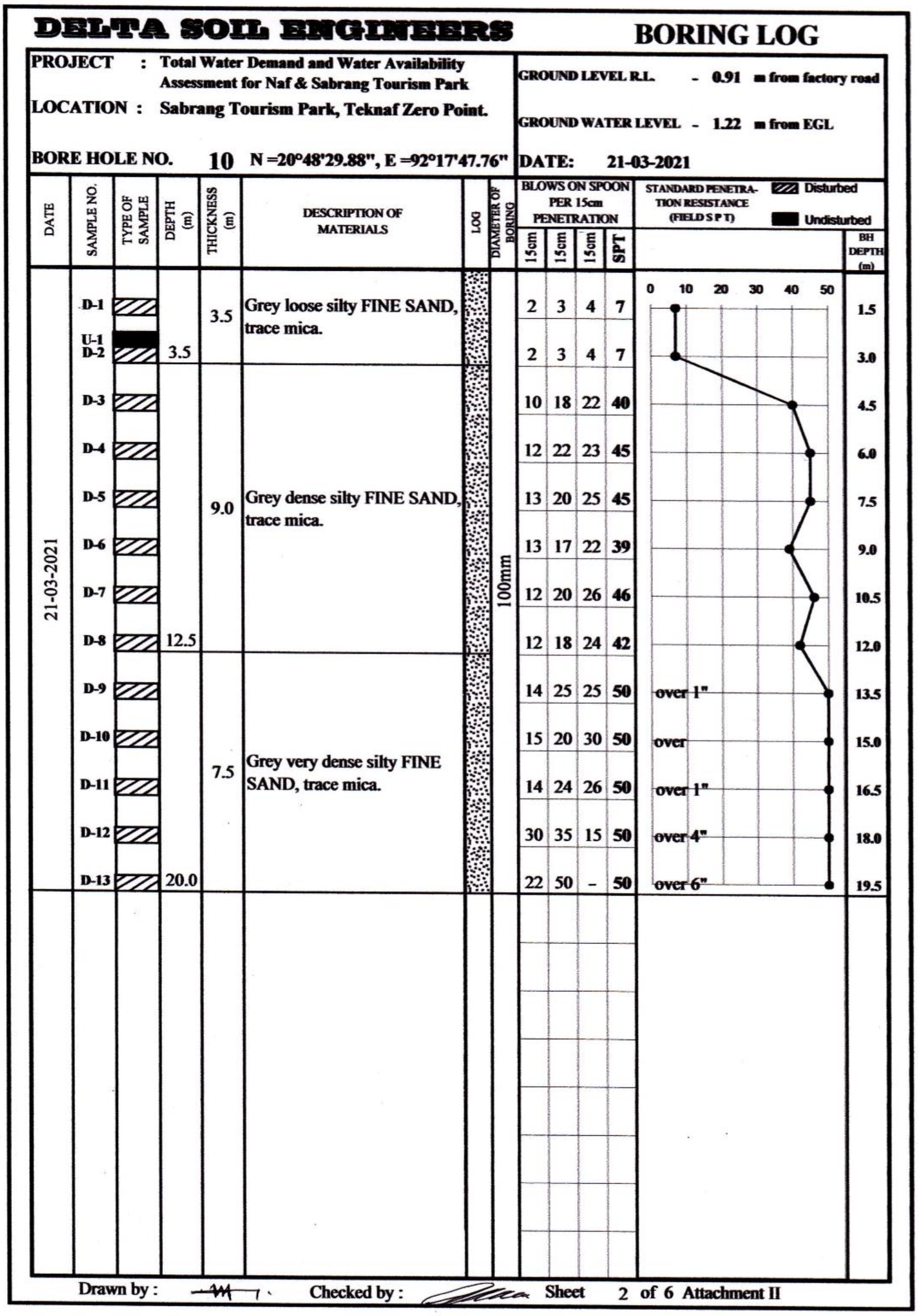
GROUND LEVEL R.L. - 0.91 m from factory road

GROUND WATER LEVEL - 1.22 m from EGL

DATE: 21-03-2021

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	STANDARD PENETRATION RESISTANCE (FIELD S P T) ▨ Disturbed ■ Undisturbed	BH DEPTH (m)
21-03-2021	D-1	▨		3.5	Grey very loose to loose silty FINE SAND, trace mica.		100mm	1	1	1	2		1.5
	U-1 D-2	■ ▨	3.5					3	3	5	8		3.0
	D-3	▨						4	8	10	18		4.5
	D-4	▨						10	12	15	27		6.0
	D-5	▨		9.0	Grey medium dense to dense silty FINE SAND, trace mica.			11	15	17	32		7.5
	D-6	▨						10	14	19	33		9.0
	D-7	▨						12	16	25	41		10.5
	D-8	▨	12.5					14	18	22	40		12.0
	D-9	▨						15	24	26	50	over 1"	13.5
	D-10	▨						16	23	27	50	over 1"	15.0
	D-11	▨		7.5	Grey very dense silty FINE SAND, trace mica.			15	24	26	50	over 1"	16.5
	D-12	▨						15	27	23	50	over 2"	18.0
	D-13	▨	20.0					19	30	20	50	over 3"	19.5

Drawn by : Checked by : Sheet 1 of 6 Attachment II



DELTA SOIL ENGINEERS **BORING LOG**

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park

LOCATION : Sabrang Tourism Park, Teknaf Zero Point.

BORE HOLE NO. 10 N =20°48'29.88", E =92°17'47.76"

GROUND LEVEL R.L. - 0.91 m from factory road

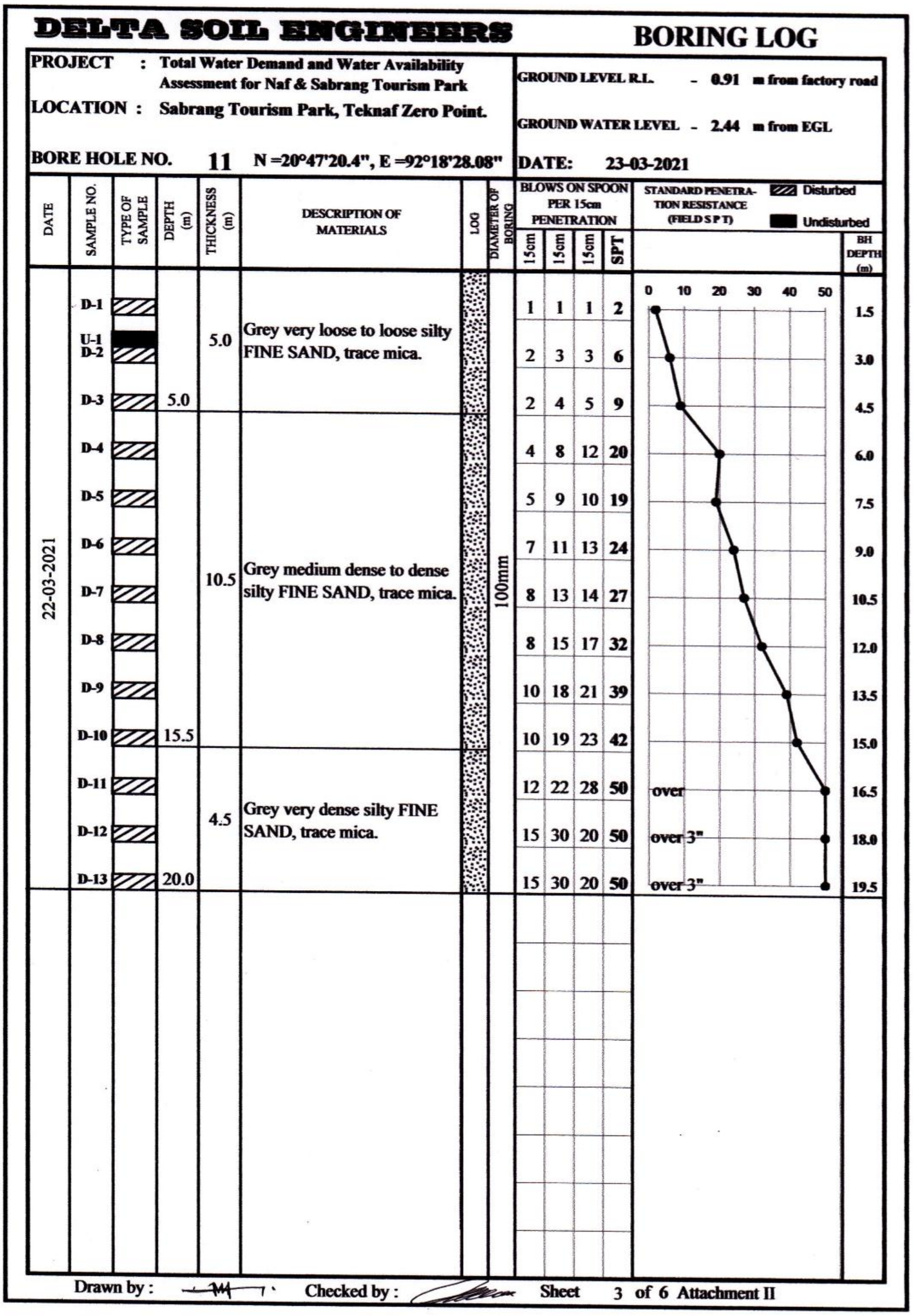
GROUND WATER LEVEL - 1.22 m from EGL

DATE: 21-03-2021

▨ Disturbed
■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	STANDARD PENETRATION RESISTANCE (FIELD S P T)	BH DEPTH (m)
21-03-2021	D-1	▨		3.5	Grey loose silty FINE SAND, trace mica.		100mm	2	3	4	7		1.5
	U-1 D-2	■ ▨	3.5					2	3	4	7		3.0
	D-3	▨		9.0	Grey dense silty FINE SAND, trace mica.			10	18	22	40		4.5
	D-4	▨						12	22	23	45		6.0
	D-5	▨						13	20	25	45		7.5
	D-6	▨						13	17	22	39		9.0
	D-7	▨						12	20	26	46		10.5
	D-8	▨	12.5					12	18	24	42		12.0
	D-9	▨		7.5	Grey very dense silty FINE SAND, trace mica.			14	25	25	50	over 1"	13.5
	D-10	▨						15	20	30	50	over	15.0
	D-11	▨						14	24	26	50	over 1"	16.5
	D-12	▨						30	35	15	50	over 4"	18.0
	D-13	▨	20.0					22	50	-	50	over 6"	19.5

Drawn by : Checked by : Sheet 2 of 6 Attachment II



DELTA SOIL ENGINEERS

BORING LOG

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park

LOCATION : Sabrang Tourism Park, Teknaf Zero Point.

BORE HOLE NO. 11 N =20°47'20.4", E =92°18'28.08"

GROUND LEVEL R.L. - 0.91 m from factory road

GROUND WATER LEVEL - 2.44 m from EGL

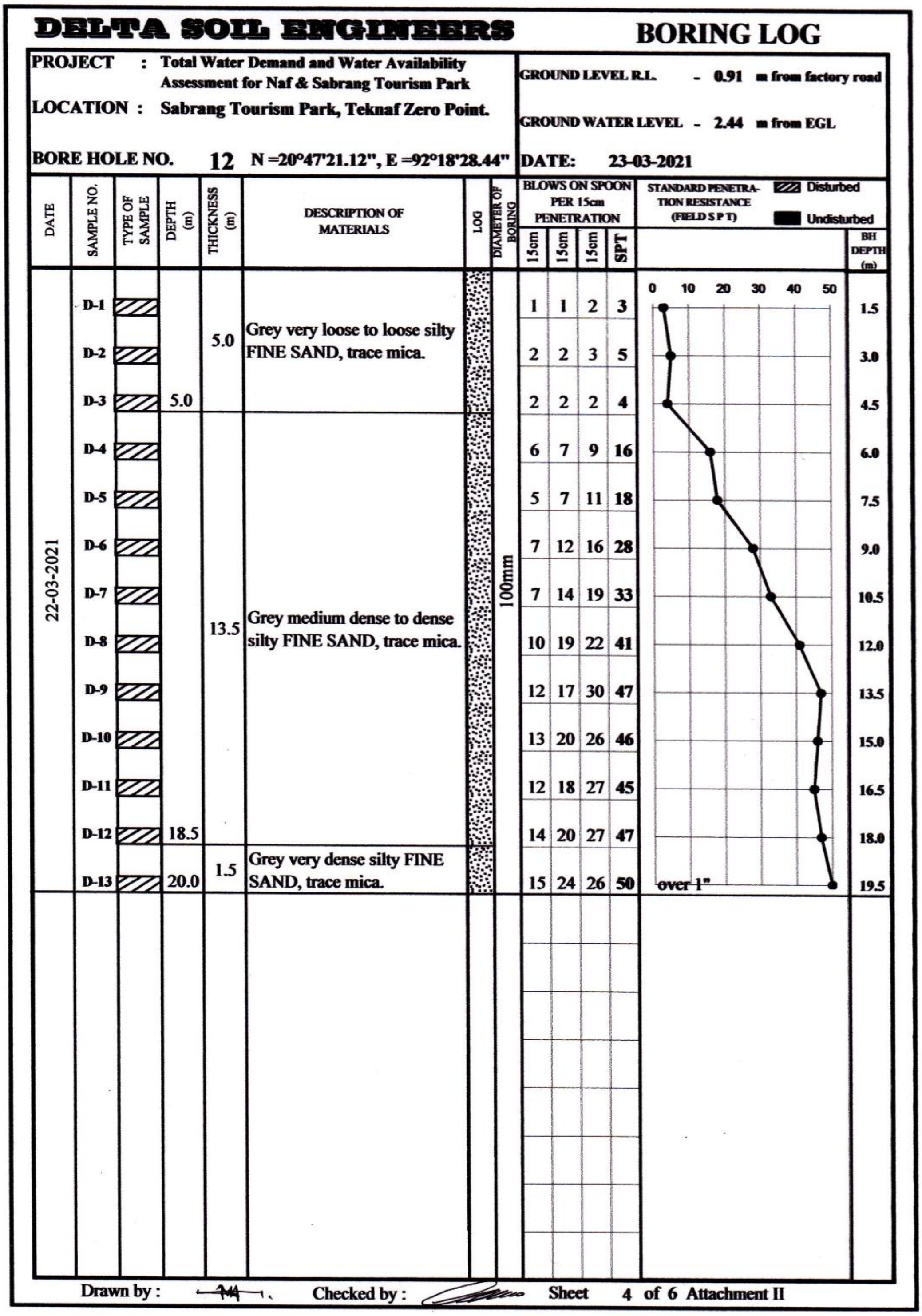
DATE: 23-03-2021

▨ Disturbed

■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	STANDARD PENETRATION RESISTANCE (FIELD S P T)	BH DEPTH (m)
22-03-2021	D-1	▨		5.0	Grey very loose to loose silty FINE SAND, trace mica.		100mm	1	1	1	2		1.5
	U-1 D-2	■ ▨						2	3	3	6		3.0
	D-3	▨	5.0					2	4	5	9		4.5
	D-4	▨		10.5	Grey medium dense to dense silty FINE SAND, trace mica.			4	8	12	20		6.0
	D-5	▨						5	9	10	19		7.5
	D-6	▨						7	11	13	24		9.0
	D-7	▨						8	13	14	27		10.5
	D-8	▨						8	15	17	32		12.0
	D-9	▨						10	18	21	39		13.5
	D-10	▨	15.5					10	19	23	42		15.0
	D-11	▨		4.5	Grey very dense silty FINE SAND, trace mica.			12	22	28	50	over	16.5
	D-12	▨						15	30	20	50	over 3"	18.0
	D-13	▨	20.0					15	30	20	50	over 3"	19.5

Drawn by : Checked by : Sheet 3 of 6 Attachment II



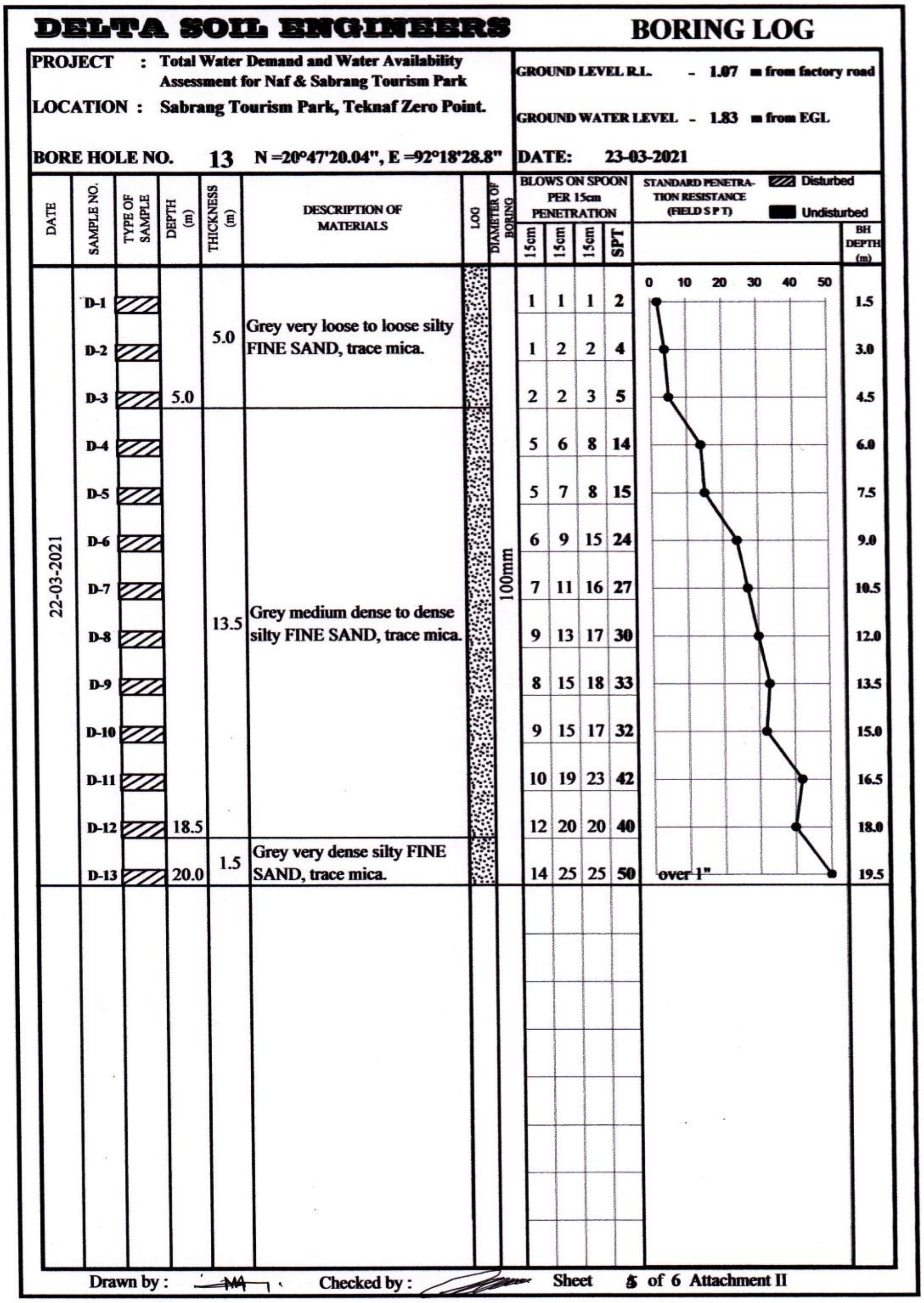
DELTA SOIL ENGINEERS **BORING LOG**

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park
LOCATION : Sabrang Tourism Park, Teknaf Zero Point.
BORE HOLE NO. 12 N =20°47'21.12", E =92°18'28.44"

GROUND LEVEL R.L. - 0.91 m from factory road
GROUND WATER LEVEL - 2.44 m from EGL
DATE: 23-03-2021

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION				STANDARD PENETRATION RESISTANCE (FIELD S P T) ▨ Disturbed ■ Undisturbed	BH DEPTH (m)
								15cm	15cm	15cm	SPT	0 10 20 30 40 50	
22-03-2021	D-1	▨		5.0	Grey very loose to loose silty FINE SAND, trace mica.		100mm	1	1	2	3		1.5
	D-2	▨						2	2	3	5		3.0
	D-3	▨	5.0					2	2	2	4		4.5
	D-4	▨		13.5	Grey medium dense to dense silty FINE SAND, trace mica.			6	7	9	16		6.0
	D-5	▨						5	7	11	18		7.5
	D-6	▨						7	12	16	28		9.0
	D-7	▨						7	14	19	33		10.5
	D-8	▨						10	19	22	41		12.0
	D-9	▨						12	17	30	47		13.5
	D-10	▨						13	20	26	46		15.0
	D-11	▨						12	18	27	45		16.5
	D-12	▨	18.5					14	20	27	47		18.0
	D-13	▨	20.0	1.5	Grey very dense silty FINE SAND, trace mica.			15	24	26	50	over 1"	19.5

Drawn by : Checked by : Sheet 4 of 6 Attachment II



DELTA SOIL ENGINEERS **BORING LOG**

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park

LOCATION : Sabrang Tourism Park, Teknaf Zero Point.

BORE HOLE NO. 13 N =20°47'20.04", E =92°18'28.8"

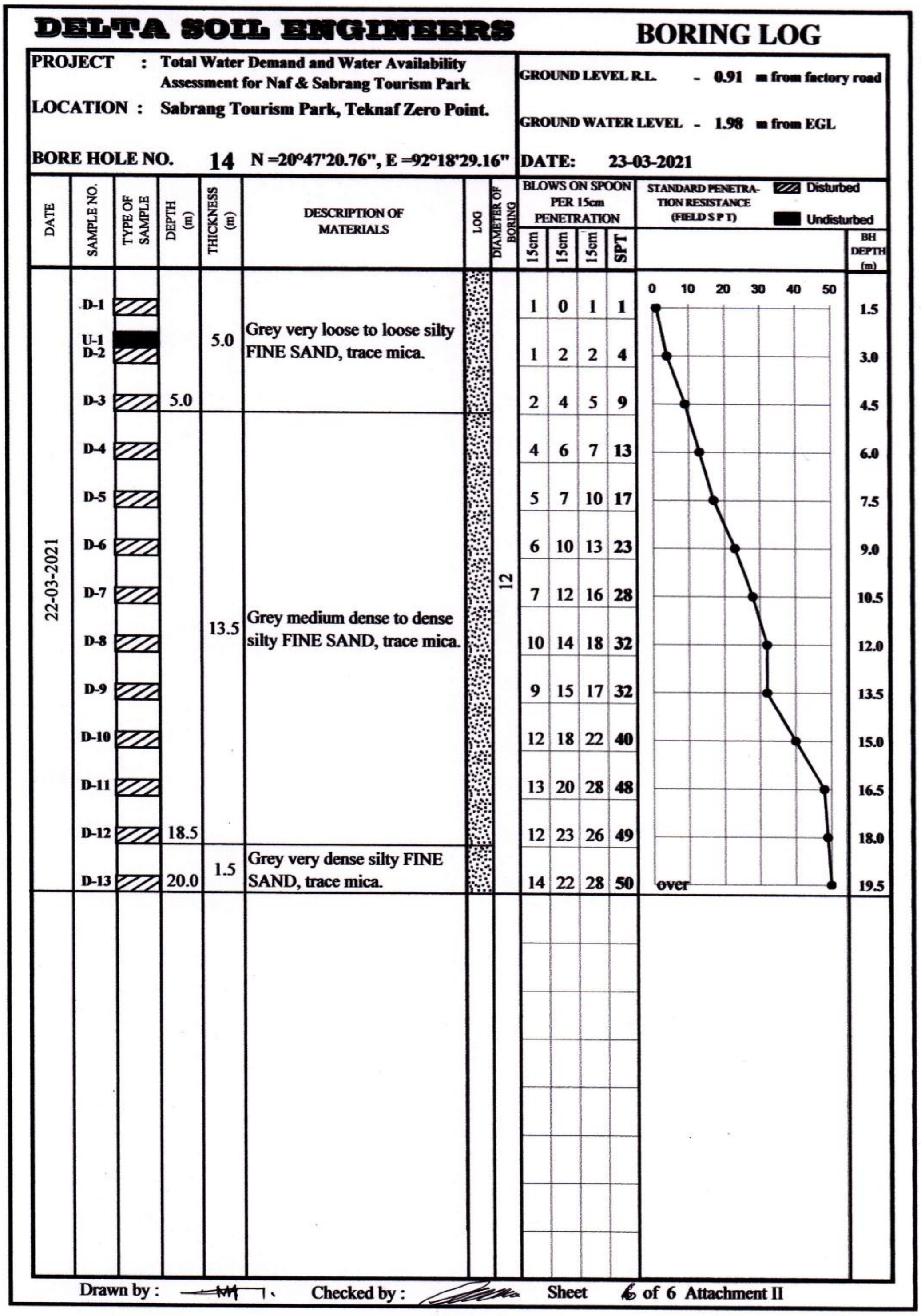
GROUND LEVEL R.L. - 1.07 m from factory road

GROUND WATER LEVEL - 1.83 m from EGL

DATE: 23-03-2021

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	STANDARD PENETRATION RESISTANCE (FIELD S P T) ▨ Disturbed ■ Undisturbed	BH DEPTH (m)
22-03-2021	D-1	▨		5.0	Grey very loose to loose silty FINE SAND, trace mica.		100mm	1	1	1	2		1.5
	D-2	▨						1	2	2	4		3.0
	D-3	▨	5.0					2	2	3	5		4.5
	D-4	▨		13.5	Grey medium dense to dense silty FINE SAND, trace mica.			5	6	8	14		6.0
	D-5	▨						5	7	8	15		7.5
	D-6	▨						6	9	15	24		9.0
	D-7	▨						7	11	16	27		10.5
	D-8	▨						9	13	17	30		12.0
	D-9	▨						8	15	18	33		13.5
	D-10	▨						9	15	17	32		15.0
	D-11	▨						10	19	23	42		16.5
	D-12	▨	18.5					12	20	20	40		18.0
	D-13	▨	20.0	1.5	Grey very dense silty FINE SAND, trace mica.			14	25	25	50	over 1"	19.5

Drawn by : Checked by : Sheet 5 of 6 Attachment II



DELTA SOIL ENGINEERS

BORING LOG

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park

LOCATION : Sabrang Tourism Park, Teknaf Zero Point.

BORE HOLE NO. 14 N =20°47'20.76", E =92°18'29.16"

GROUND LEVEL R.L. - 0.91 m from factory road

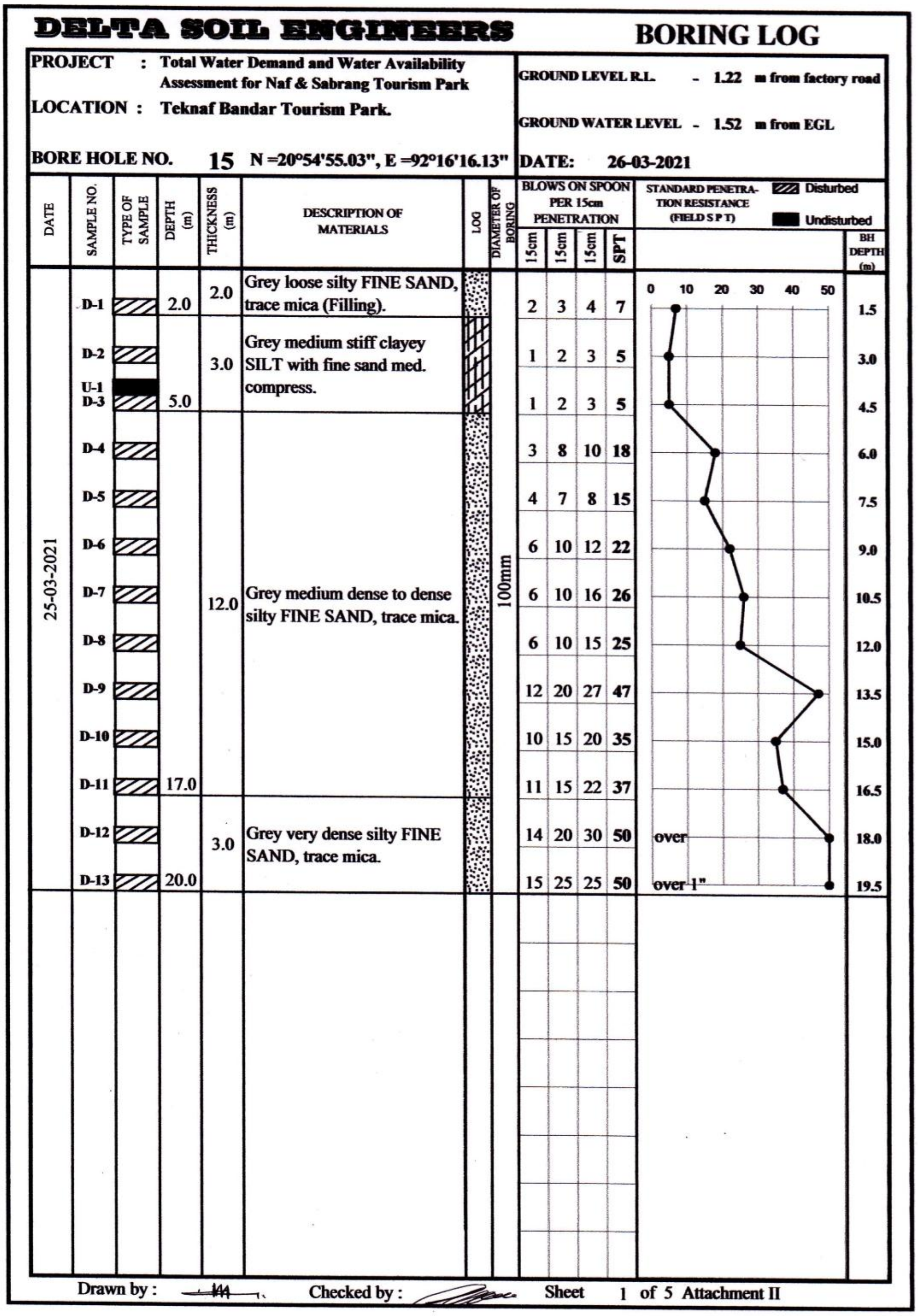
GROUND WATER LEVEL - 1.98 m from EGL

DATE: 23-03-2021

▨ Disturbed
■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	BH DEPTH (m)
22-03-2021	D-1	▨		5.0	Grey very loose to loose silty FINE SAND, trace mica.		12	1	0	1	1	1.5
	U-1	■										
	D-2	▨						1	2	2	4	3.0
	D-3	▨	5.0					2	4	5	9	4.5
	D-4	▨		13.5	Grey medium dense to dense silty FINE SAND, trace mica.			4	6	7	13	6.0
	D-5	▨						5	7	10	17	7.5
	D-6	▨						6	10	13	23	9.0
	D-7	▨						7	12	16	28	10.5
	D-8	▨						10	14	18	32	12.0
	D-9	▨						9	15	17	32	13.5
	D-10	▨						12	18	22	40	15.0
	D-11	▨						13	20	28	48	16.5
	D-12	▨	18.5					12	23	26	49	18.0
	D-13	▨	20.0	1.5	Grey very dense silty FINE SAND, trace mica.			14	22	28	50	19.5

Drawn by : Checked by : Sheet 6 of 6 Attachment II



DELTA SOIL ENGINEERS

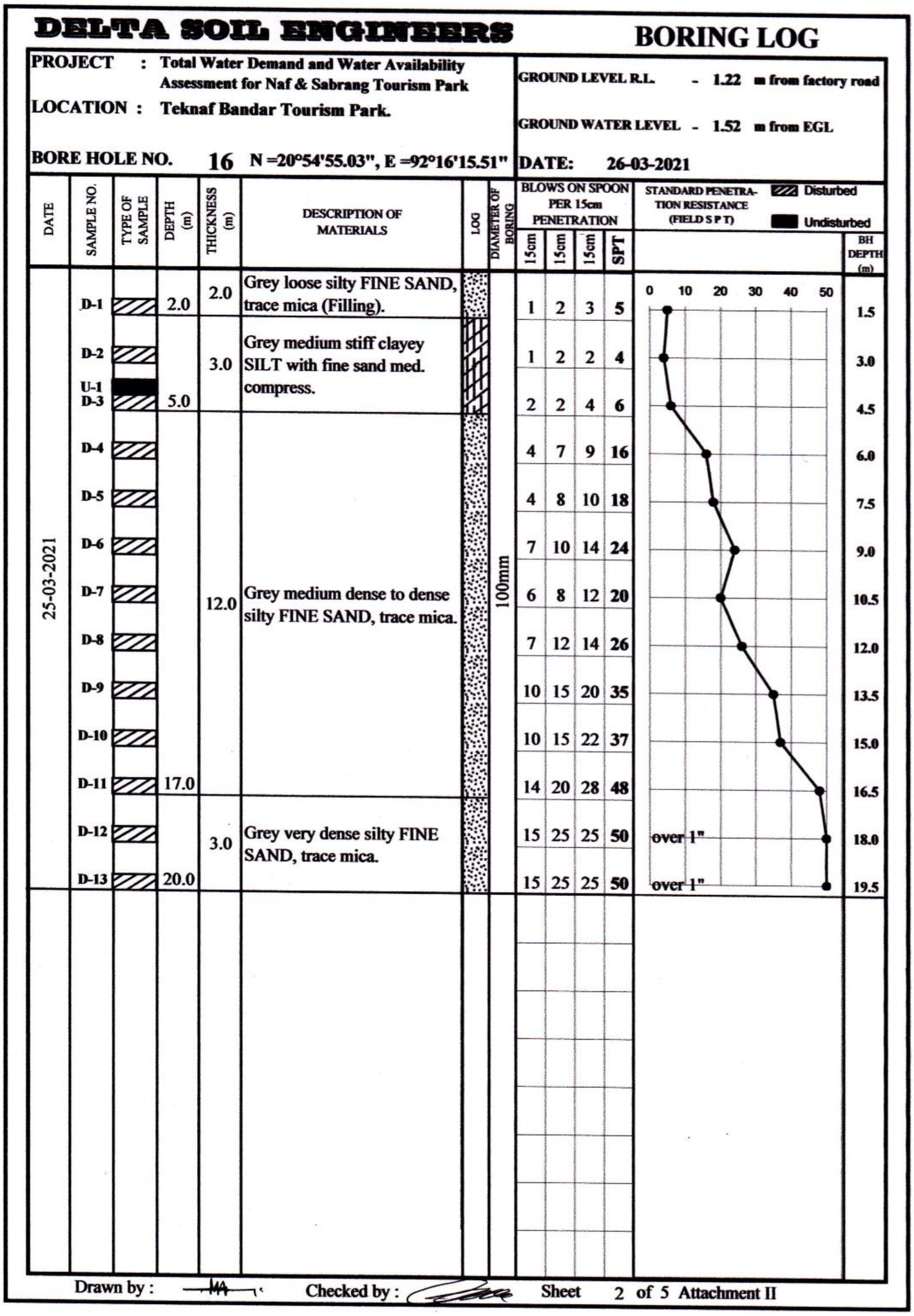
BORING LOG

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park
LOCATION : Teknaf Bandar Tourism Park.
BORE HOLE NO. 15 N =20°54'55.03", E =92°16'16.13"
GROUND LEVEL R.L. - 1.22 m from factory road
GROUND WATER LEVEL - 1.52 m from EGL
DATE: 26-03-2021

STANDARD PENETRATION RESISTANCE (FIELD S P T) ▨ Disturbed ■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	STANDARD PENETRATION RESISTANCE (FIELD S P T)	BH DEPTH (m)
25-03-2021	D-1	▨	2.0	2.0	Grey loose silty FINE SAND, trace mica (Filling).		100mm	2	3	4	7		1.5
	D-2	▨		3.0	Grey medium stiff clayey SILT with fine sand med. compress.			1	2	3	5		3.0
	U-1	■											
	D-3	▨	5.0					1	2	3	5		4.5
	D-4	▨		12.0	Grey medium dense to dense silty FINE SAND, trace mica.			3	8	10	18		6.0
	D-5	▨						4	7	8	15		7.5
	D-6	▨						6	10	12	22		9.0
	D-7	▨						6	10	16	26		10.5
	D-8	▨						6	10	15	25		12.0
	D-9	▨						12	20	27	47		13.5
	D-10	▨						10	15	20	35		15.0
	D-11	▨	17.0					11	15	22	37		16.5
	D-12	▨		3.0	Grey very dense silty FINE SAND, trace mica.			14	20	30	50	over	18.0
	D-13	▨	20.0					15	25	25	50	over 1"	19.5

Drawn by : Checked by : Sheet 1 of 5 Attachment II



DELTA SOIL ENGINEERS

BORING LOG

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park

LOCATION : Teknaf Bandar Tourism Park.

BORE HOLE NO. 16 N =20°54'55.03", E =92°16'15.51"

GROUND LEVEL R.L. - 1.22 m from factory road

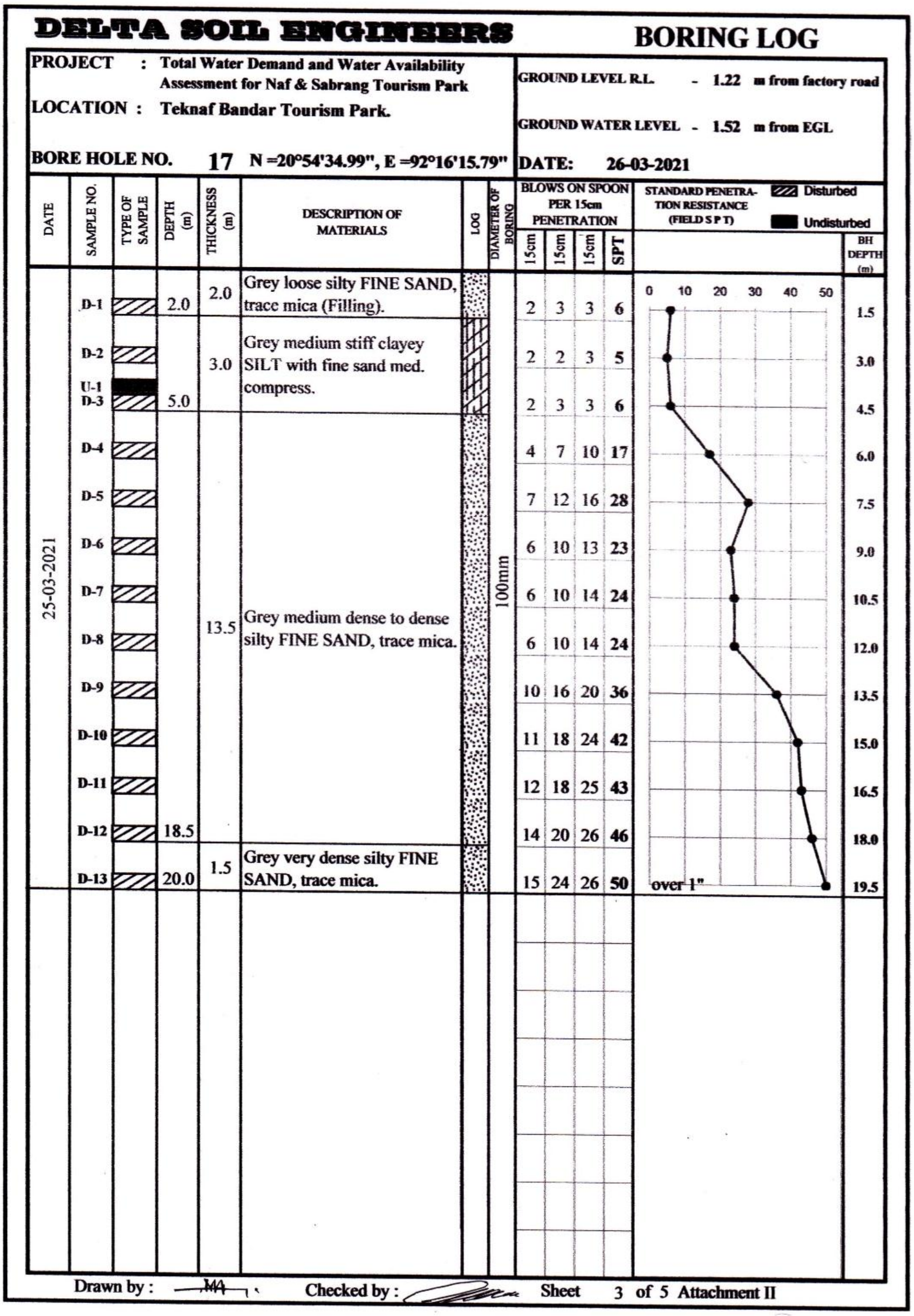
GROUND WATER LEVEL - 1.52 m from EGL

DATE: 26-03-2021

▨ Disturbed
■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	STANDARD PENETRATION RESISTANCE (FIELD S P T)	BH DEPTH (m)
25-03-2021	D-1	▨	2.0	2.0	Grey loose silty FINE SAND, trace mica (Filling).		100mm	1	2	3	5		1.5
	D-2	▨		3.0	Grey medium stiff clayey SILT with fine sand med. compress.			1	2	2	4		3.0
	U-1	■											
	D-3	▨	5.0					2	2	4	6		4.5
	D-4	▨		12.0	Grey medium dense to dense silty FINE SAND, trace mica.			4	7	9	16		6.0
	D-5	▨						4	8	10	18		7.5
	D-6	▨						7	10	14	24		9.0
	D-7	▨						6	8	12	20		10.5
	D-8	▨						7	12	14	26		12.0
	D-9	▨						10	15	20	35		13.5
	D-10	▨						10	15	22	37		15.0
	D-11	▨	17.0					14	20	28	48		16.5
	D-12	▨		3.0	Grey very dense silty FINE SAND, trace mica.			15	25	25	50	over 1"	18.0
	D-13	▨	20.0					15	25	25	50	over 1"	19.5

Drawn by : Checked by : Sheet 2 of 5 Attachment II

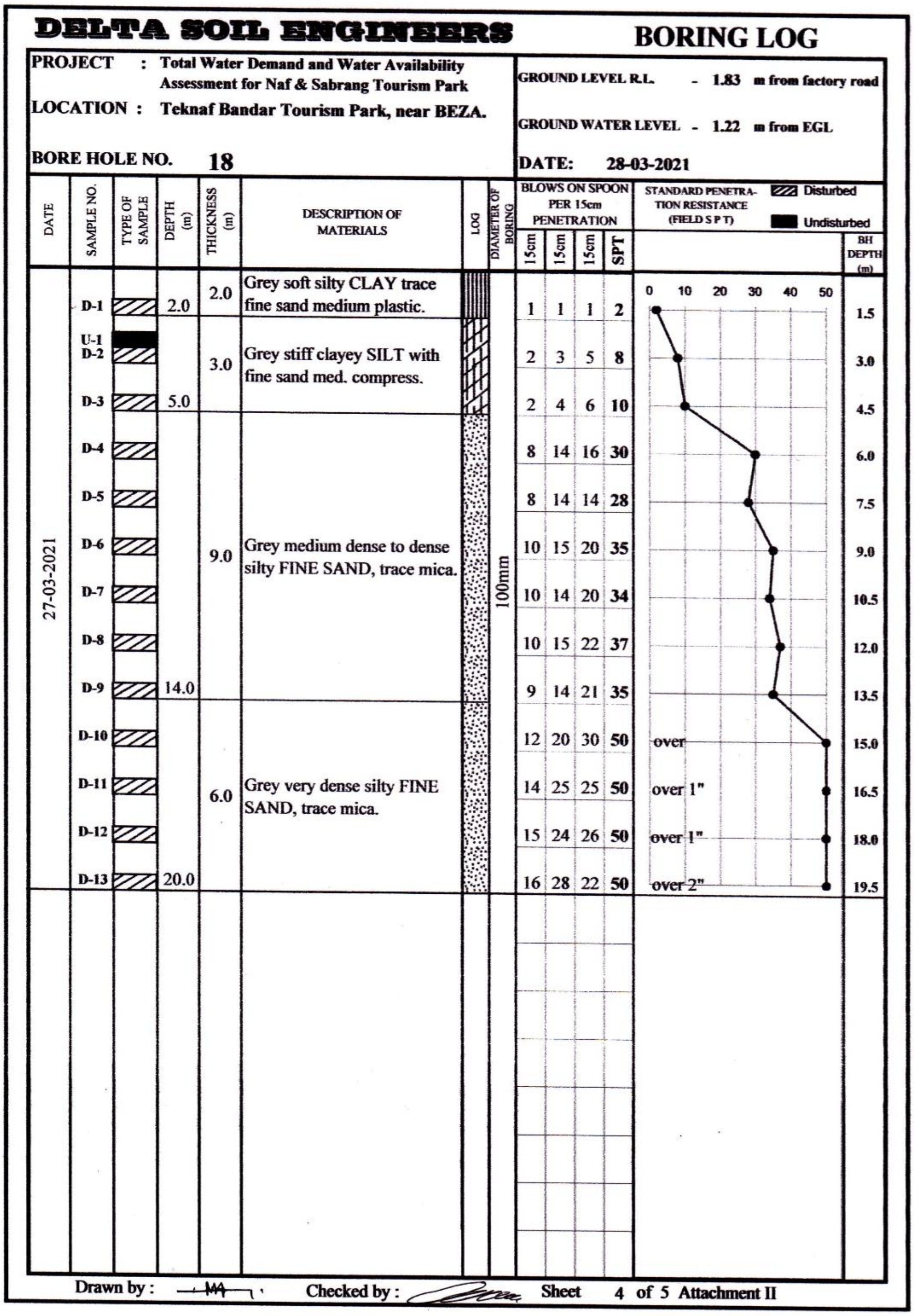


DELTA SOIL ENGINEERS **BORING LOG**

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park
LOCATION : Teknaf Bandar Tourism Park.
BORE HOLE NO. 17 N =20°54'34.99", E =92°16'15.79"
GROUND LEVEL R.L. - 1.22 m from factory road
GROUND WATER LEVEL - 1.52 m from EGL
DATE: 26-03-2021

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	STANDARD PENETRATION RESISTANCE (FIELD SPT) ▨ Disturbed ■ Undisturbed 0 10 20 30 40 50	BH DEPTH (m)
25-03-2021	D-1	▨	2.0	2.0	Grey loose silty FINE SAND, trace mica (Filling).		100mm	2	3	3	6		1.5
	D-2	▨		3.0	Grey medium stiff clayey SILT with fine sand med. compress.			2	2	3	5		3.0
	U-1 D-3	■ ▨	5.0					2	3	3	6		4.5
	D-4	▨		13.5	Grey medium dense to dense silty FINE SAND, trace mica.			4	7	10	17		6.0
	D-5	▨						7	12	16	28		7.5
	D-6	▨						6	10	13	23		9.0
	D-7	▨						6	10	14	24		10.5
	D-8	▨						6	10	14	24		12.0
	D-9	▨						10	16	20	36		13.5
	D-10	▨						11	18	24	42		15.0
	D-11	▨						12	18	25	43		16.5
	D-12	▨	18.5					14	20	26	46		18.0
	D-13	▨	20.0	1.5	Grey very dense silty FINE SAND, trace mica.			15	24	26	50	over 1"	19.5

Drawn by : MA Checked by : Sheet 3 of 5 Attachment II



DELTA SOIL ENGINEERS

BORING LOG

PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park

LOCATION : Teknaf Bandar Tourism Park, near BEZA.

BORE HOLE NO. 18

GROUND LEVEL R.L. - 1.83 m from factory road

GROUND WATER LEVEL - 1.22 m from EGL

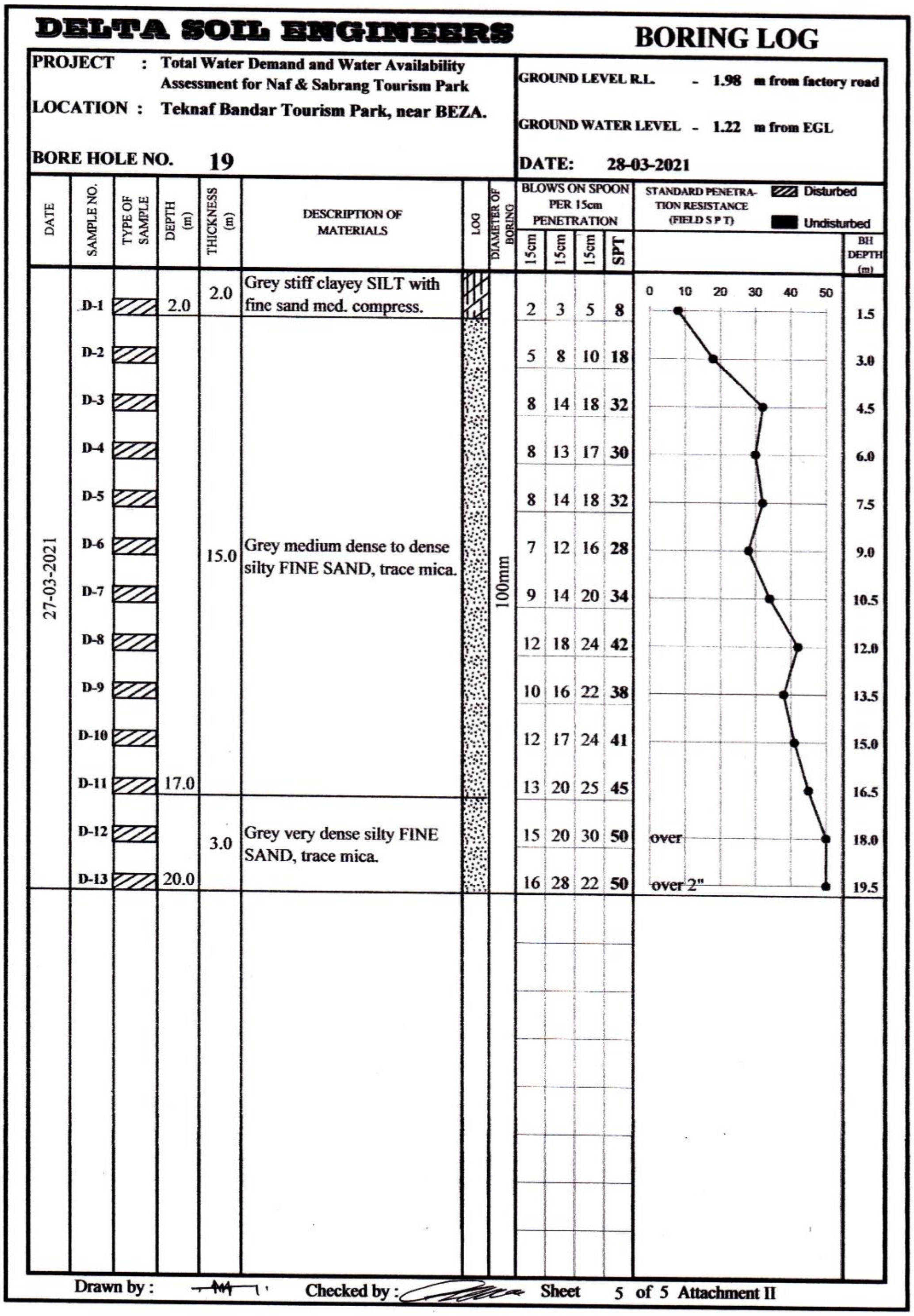
DATE: 28-03-2021

▨ Disturbed

■ Undisturbed

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	STANDARD PENETRATION RESISTANCE (FIELD S P T) 0 10 20 30 40 50	BH DEPTH (m)
27-03-2021	D-1	▨	2.0	2.0	Grey soft silty CLAY trace fine sand medium plastic.		100mm	1	1	1	2		1.5
	U-1	■		3.0	Grey stiff clayey SILT with fine sand med. compress.								
	D-2	▨						2	3	5	8		3.0
	D-3	▨	5.0					2	4	6	10		4.5
	D-4	▨		9.0	Grey medium dense to dense silty FINE SAND, trace mica.			8	14	16	30		6.0
	D-5	▨						8	14	14	28		7.5
	D-6	▨						10	15	20	35		9.0
	D-7	▨						10	14	20	34		10.5
	D-8	▨						10	15	22	37		12.0
	D-9	▨	14.0					9	14	21	35		13.5
	D-10	▨		6.0	Grey very dense silty FINE SAND, trace mica.			12	20	30	50	over	15.0
	D-11	▨						14	25	25	50	over 1"	16.5
	D-12	▨						15	24	26	50	over 1"	18.0
	D-13	▨	20.0					16	28	22	50	over 2"	19.5

Drawn by : Checked by : Sheet 4 of 5 Attachment II



DELTA SOIL ENGINEERS

BORING LOG

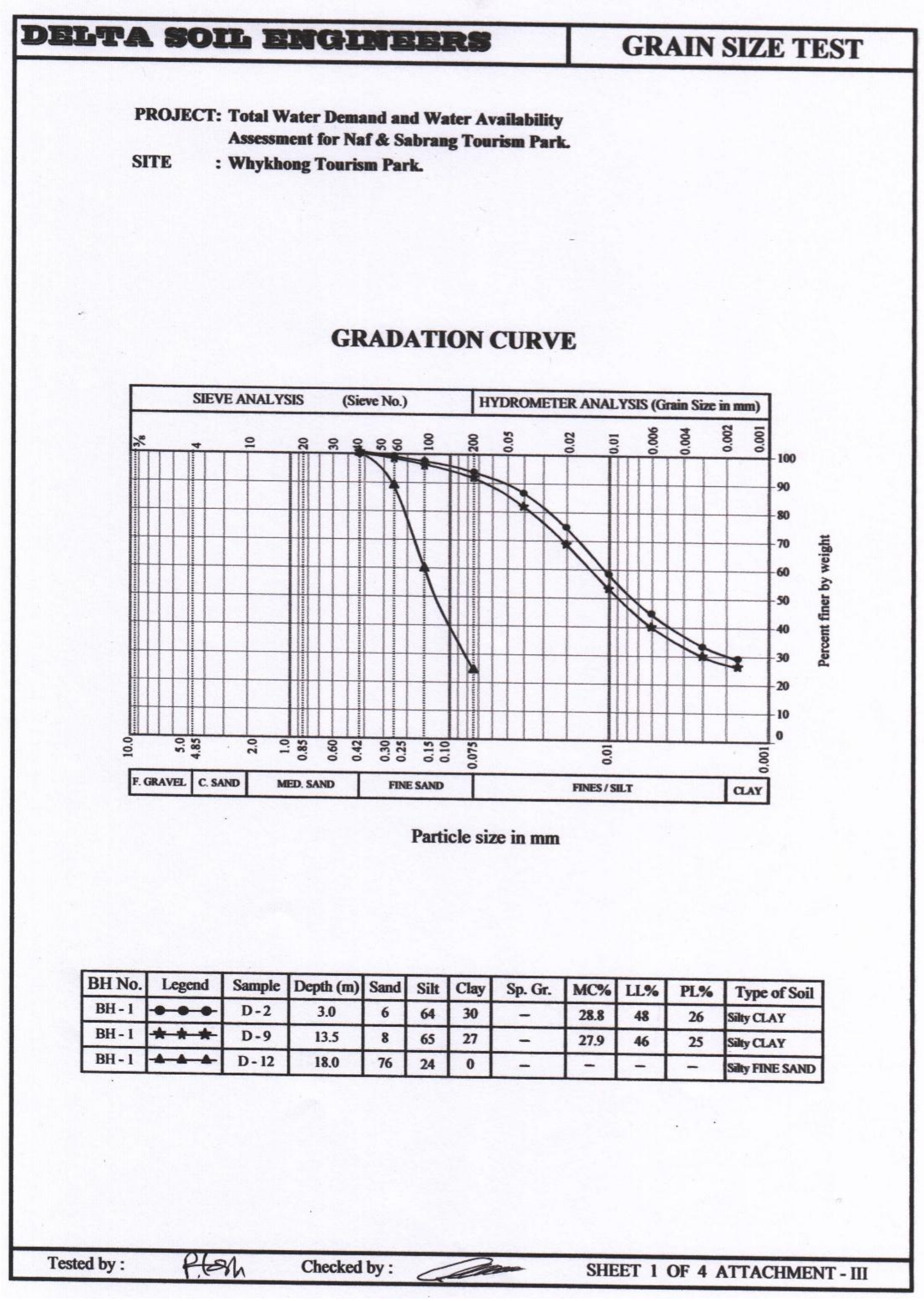
PROJECT : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park
LOCATION : Teknaf Bandar Tourism Park, near BEZA.
BORE HOLE NO. 19

GROUND LEVEL R.L. - 1.98 m from factory road
GROUND WATER LEVEL - 1.22 m from EGL
DATE: 28-03-2021

DATE	SAMPLE NO.	TYPE OF SAMPLE	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	LOG	DIAMETER OF BORING	BLOWS ON SPOON PER 15cm PENETRATION 15cm	15cm	15cm	SPT	STANDARD PENETRATION RESISTANCE (FIELD S P T) ▨ Disturbed ■ Undisturbed	BH DEPTH (m)
27-03-2021	D-1	▨	2.0	2.0	Grey stiff clayey SILT with fine sand med. compress.		100mm	2	3	5	8		1.5
	D-2	▨		15.0	Grey medium dense to dense silty FINE SAND, trace mica.			5	8	10	18		3.0
	D-3	▨						8	14	18	32		4.5
	D-4	▨						8	13	17	30		6.0
	D-5	▨						8	14	18	32		7.5
	D-6	▨						7	12	16	28		9.0
	D-7	▨						9	14	20	34		10.5
	D-8	▨						12	18	24	42		12.0
	D-9	▨						10	16	22	38		13.5
	D-10	▨						12	17	24	41		15.0
	D-11	▨	17.0					13	20	25	45		16.5
	D-12	▨		3.0	Grey very dense silty FINE SAND, trace mica.			15	20	30	50	over	18.0
	D-13	▨	20.0					16	28	22	50	over 2"	19.5

Drawn by : **Checked by :** **Sheet 5 of 5 Attachment II**

Attachment-III: GRADATION CURVE



DELTA SOIL ENGINEERS | **GRAIN SIZE TEST**

PROJECT: Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park.
SITE : Whykhong Tourism Park.

GRADATION CURVE

BH No.	Legend	Sample	Depth (m)	Sand	Silt	Clay	Sp. Gr.	MC%	LL%	PL%	Type of Soil
BH - 1	●—●—●	D - 2	3.0	6	64	30	–	28.8	48	26	Silty CLAY
BH - 1	★—★—★	D - 9	13.5	8	65	27	–	27.9	46	25	Silty CLAY
BH - 1	▲—▲—▲	D - 12	18.0	76	24	0	–	–	–	–	Silty FINE SAND

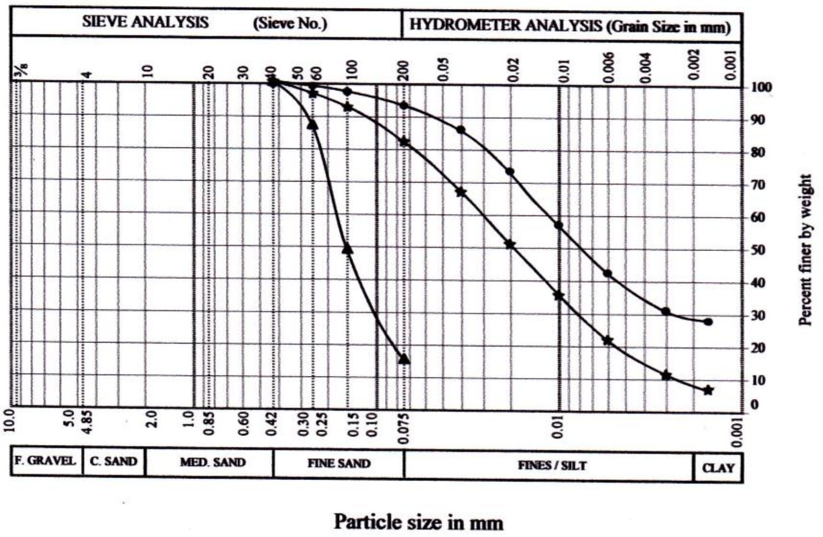
Tested by : Checked by : SHEET 1 OF 4 ATTACHMENT - III

DELTA SOIL ENGINEERS

GRAIN SIZE TEST

PROJECT: **Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park.**
SITE : Whykhong Tourism Park.

GRADATION CURVE



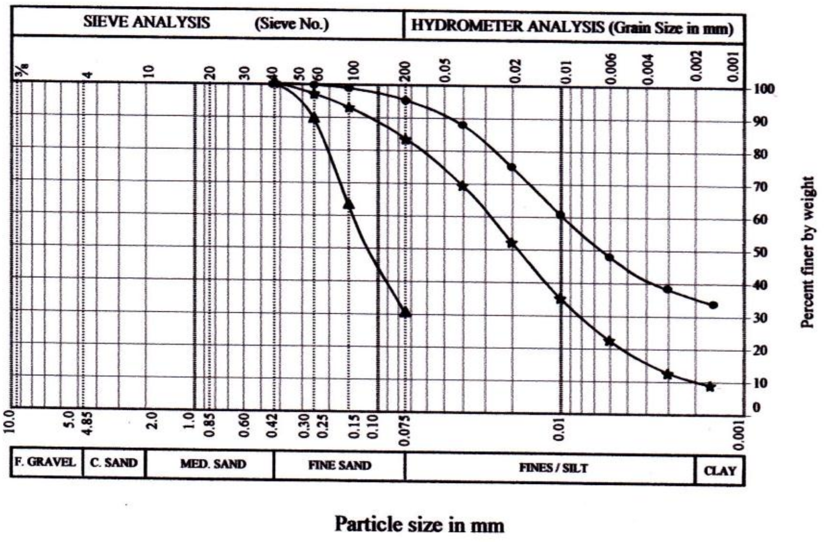
BH No.	Legend	Sample	Depth (m)	Sand	Silt	Clay	Sp. Gr.	MC%	LL%	PL%	Type of Soil
BH - 2	●—●—●	D - 5	7.5	7	65	28	–	28.1	45	25	Silty CLAY
BH - 2	★—★—★	D - 9	13.5	18	74	8	–	25.9	37	27	Clayey SILT
BH - 2	▲—▲—▲	D - 13	20.0	85	15	0	–	–	–	–	Silty FINE SAND

Tested by : Checked by : SHEET 2 OF 4 ATTACHMENT - III

DELTA SOIL ENGINEERS | **GRAIN SIZE TEST**

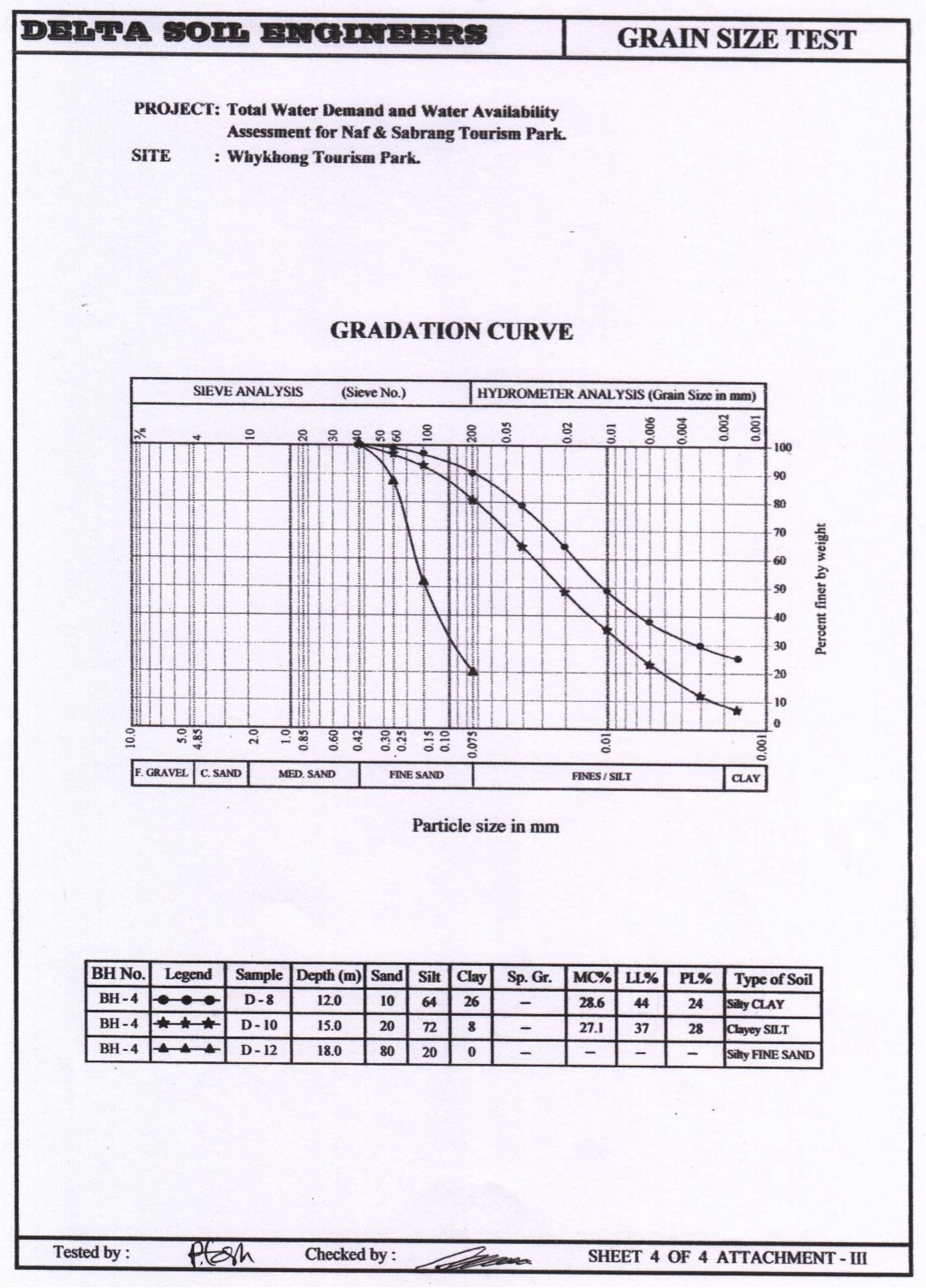
PROJECT: **Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park.**
SITE **: Whykhong Tourism Park.**

GRADATION CURVE



BH No.	Legend	Sample	Depth (m)	Sand	Silt	Clay	Sp. Gr.	MC%	LL%	PL%	Type of Soil
BH - 3	●—●—●	D - 4	6.0	5	60	35	–	32.8	50	26	Silty CLAY
BH - 3	★—★—★	D - 10	15.0	17	73	10	–	26.2	36	28	Clayey SILT
BH - 3	▲—▲—▲	D - 11	16.5	70	30	0	–	–	–	–	Silty FINE SAND

Tested by : Checked by : SHEET 3 OF 4 ATTACHMENT - III



DELTA SOIL ENGINEERS

GRAIN SIZE TEST

PROJECT: **Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park.**

SITE : Whykhong Tourism Park.

GRADATION CURVE

Particle size in mm

BH No.	Legend	Sample	Depth (m)	Sand	Silt	Clay	Sp. Gr.	MC%	LL%	PL%	Type of Soil
BH - 4	●—●—●	D - 8	12.0	10	64	26	–	28.6	44	24	Silty CLAY
BH - 4	★—★—★	D - 10	15.0	20	72	8	–	27.1	37	28	Clayey SILT
BH - 4	▲—▲—▲	D - 12	18.0	80	20	0	–	–	–	–	Silty FINE SAND

Tested by : Pt.Sh Checked by :

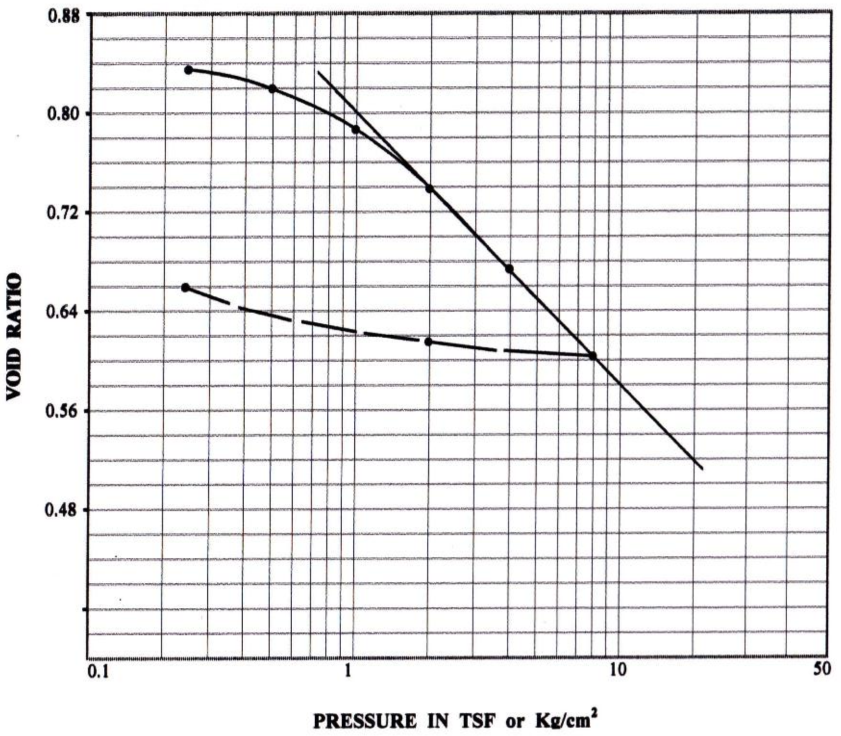
SHEET 4 OF 4 ATTACHMENT - III

Attachment-IV: VOID RATIO-LOG PRESSURE CURVE OF CONSOLIDATION TEST

DELTA SOIL ENGINEERS

CONSOLIDATION TEST
VOID RATIO-LOG PRESSURE CURVE

Project : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park.
Site : Whykhong Tourism Park.



BORING NO. :	2
SAMPLE NO. :	U - 1
SAMPLE DEPTH (m.) :	4.05 to 4.50
DESCRIPTION :	Silty CLAY
DIAMETER :	6.35 cm
INITIAL HEIGHT :	2.54 cm
SOLID HEIGHT :	1.382 cm
INITIAL M.C. :	28.6%
DRY DENSITY (kN/m^3) :	14.25
INITIAL VOID RATIO (e_0) :	0.838
SPECIFIC GRAVITY :	2.676
COMPRESSION INDEX (Cc) :	0.220

Tested by :

Checked by :

SHEET 1 OF 1 ATTACHMENT - IV

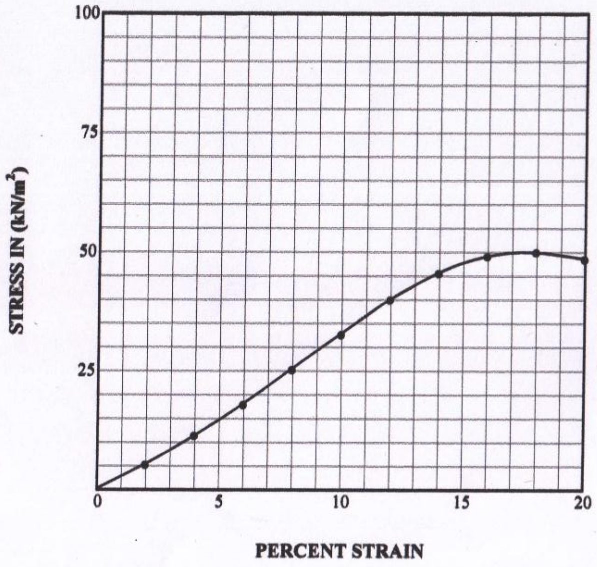
Attachment-V: STRESS-STRAIN CURVES OF UNCONFINED COMPRESSION TEST

DELTA SOIL ENGINEERS

UNCONFINED COMPRESSION TEST

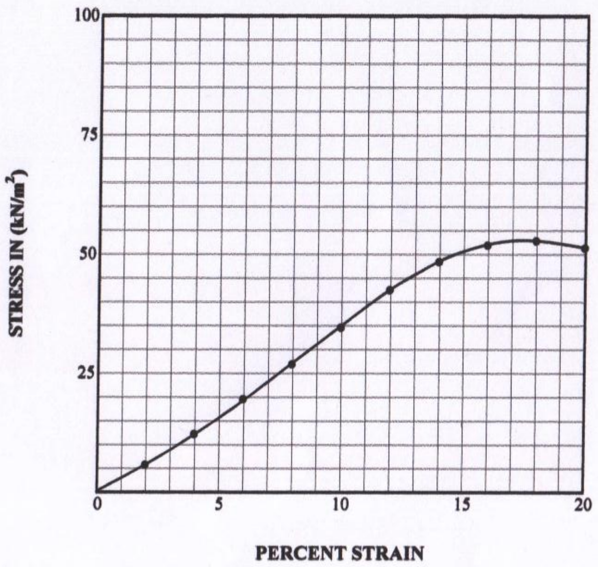
Project : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park.
Site : Whykhong Tourism Park.

Bore Hole No. 1 Sample No. U-1 Sample Depth 4.05 to 4.50 m



Unconfined Compressive Strength (kN/m²)	49.8
Percent Strain at Failure	18.0
Moisture Content (%)	28.6
Wet Density (kN/m³)	18.41
Dry Density (kN/m³)	14.32

Bore Hole No. 2 Sample No. U-1 Sample Depth 4.05 to 4.50 m



Unconfined Compressive Strength (kN/m²)	52.5
Percent Strain at Failure	18.0
Moisture Content (%)	28.8
Wet Density (kN/m³)	18.35
Dry Density (kN/m³)	14.25

Tested by : PESh

Checked by :

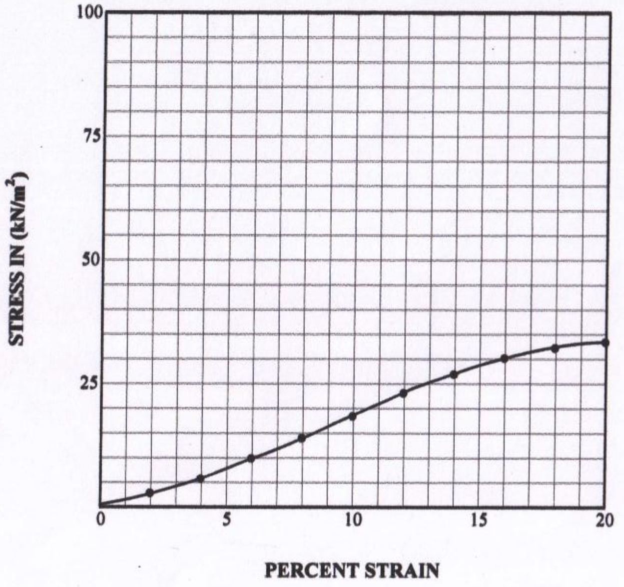
SHEET 1 OF 2 ATTACHMENT - V

DELTA SOIL ENGINEERS

UNCONFINED COMPRESSION TEST

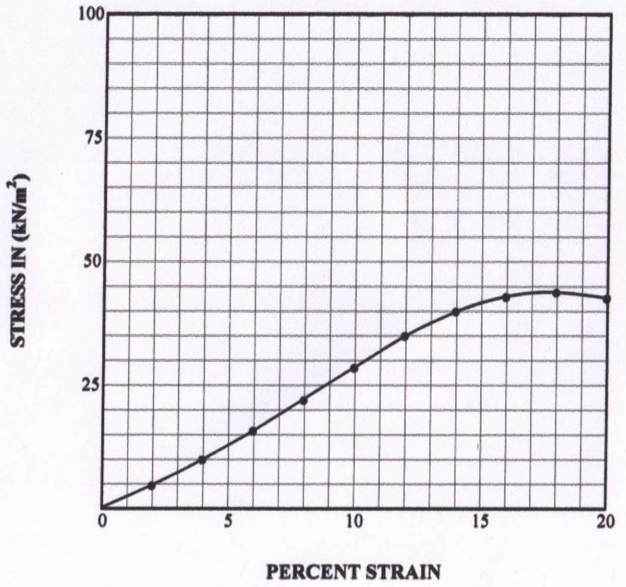
Project : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park.
Site : Whykhong Tourism Park.

Bore Hole No. 3 Sample No. U-1 Sample Depth 4.05 to 4.50 m



Unconfined Compressive Strength (kN/m^2)	32.8
Percent Strain at Failure	20.0
Moisture Content (%)	32.7
Wet Density (kN/m^3)	17.75
Dry Density (kN/m^3)	13.38

Bore Hole No. 4 Sample No. U-1 Sample Depth 4.05 to 4.50 m



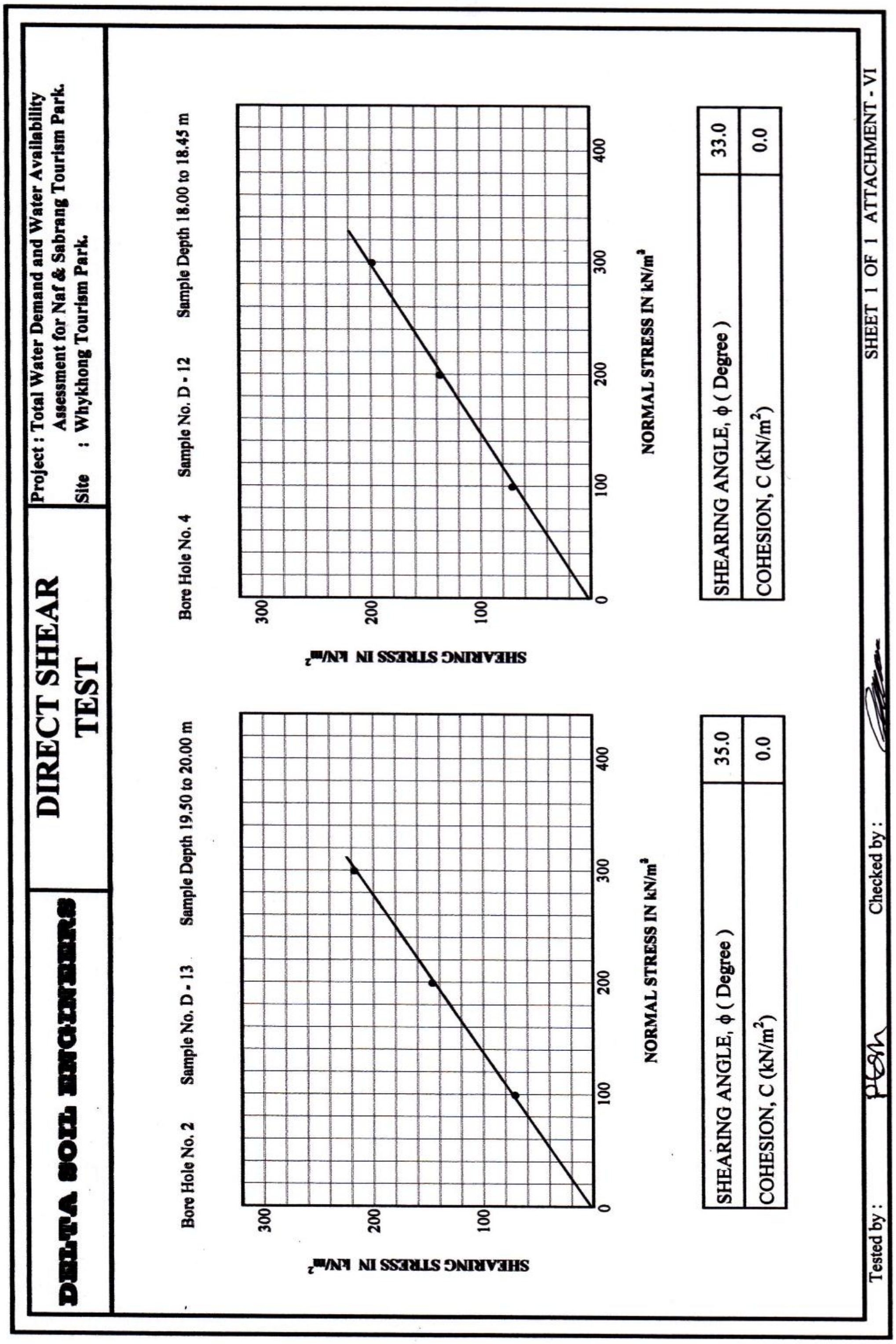
Unconfined Compressive Strength (kN/m^2)	43.8
Percent Strain at Failure	18.0
Moisture Content (%)	30.4
Wet Density (kN/m^3)	17.98
Dry Density (kN/m^3)	13.80

Tested by :

Checked by :

SHEET 2 OF 2 ATTACHMENT - V

Attachment-VI: SHEARING STRESS Vs. NORMAL STRESS CURVES OF DIRECT SHEAR TEST



DELTA SOIL ENGINEERS

DIRECT SHEAR TEST

Project : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park.
Site : Whykhong Tourism Park.

Bore Hole No. 2 Sample No. D - 13 Sample Depth 19.50 to 20.00 m

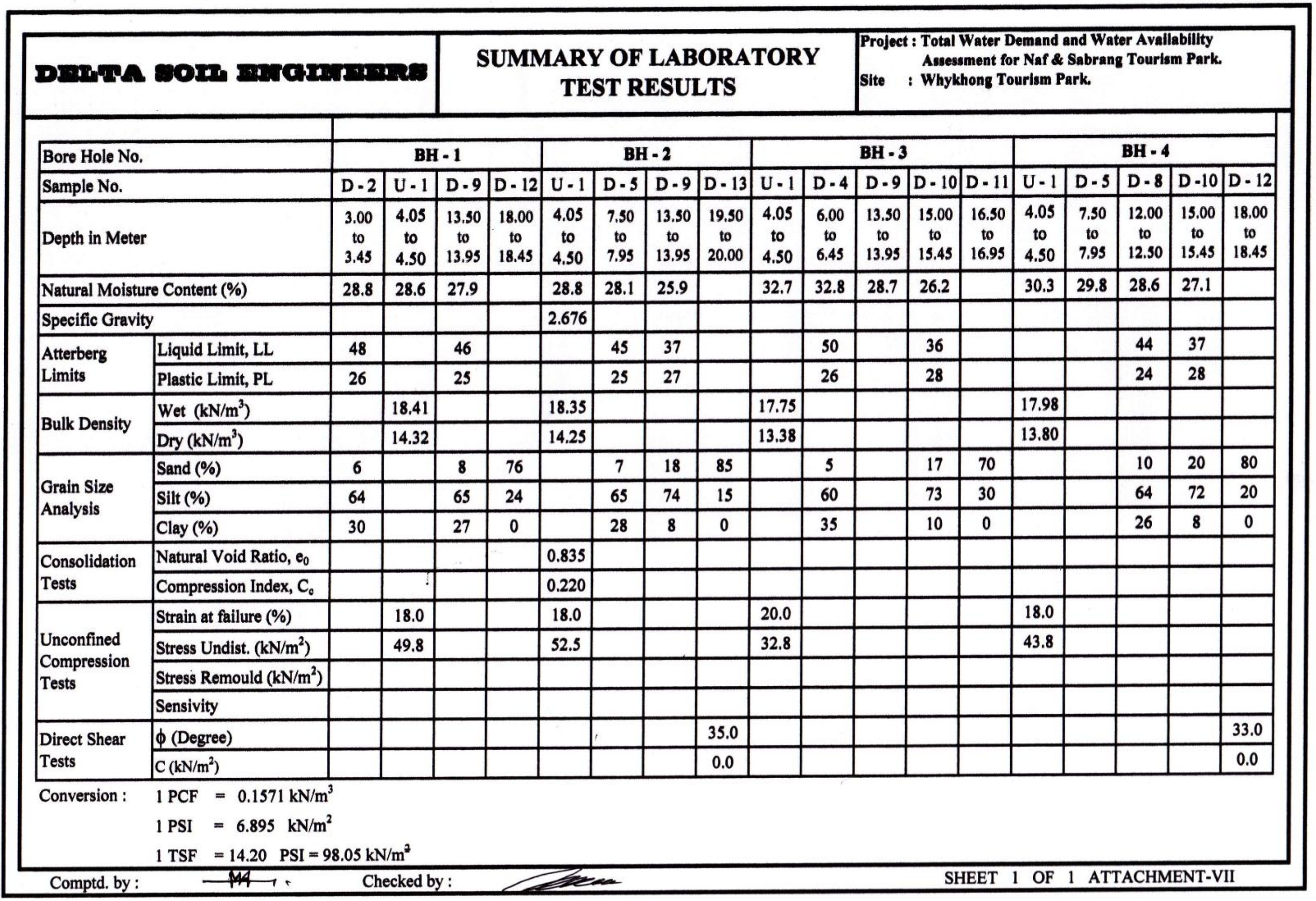
SHEARING ANGLE, ϕ (Degree)	35.0
COHESION, C (kN/m^2)	0.0

Bore Hole No. 4 Sample No. D - 12 Sample Depth 18.00 to 18.45 m

SHEARING ANGLE, ϕ (Degree)	33.0
COHESION, C (kN/m^2)	0.0

Tested by : Checked by : SHEET 1 OF 1 ATTACHMENT - VI

Attachment-VII: SUMMARY OF TEST RESULTS



DELTA SOIL ENGINEERS

SUMMARY OF LABORATORY TEST RESULTS

Project : Total Water Demand and Water Availability Assessment for Naf & Sabrang Tourism Park.
Site : Whykhong Tourism Park.

Bore Hole No.		BH - 1				BH - 2				BH - 3					BH - 4				
Sample No.		D - 2	U - 1	D - 9	D - 12	U - 1	D - 5	D - 9	D - 13	U - 1	D - 4	D - 9	D - 10	D - 11	U - 1	D - 5	D - 8	D -10	D - 12
Depth in Meter		3.00 to 3.45	4.05 to 4.50	13.50 to 13.95	18.00 to 18.45	4.05 to 4.50	7.50 to 7.95	13.50 to 13.95	19.50 to 20.00	4.05 to 4.50	6.00 to 6.45	13.50 to 13.95	15.00 to 15.45	16.50 to 16.95	4.05 to 4.50	7.50 to 7.95	12.00 to 12.50	15.00 to 15.45	18.00 to 18.45
Natural Moisture Content (%)		28.8	28.6	27.9		28.8	28.1	25.9		32.7	32.8	28.7	26.2		30.3	29.8	28.6	27.1	
Specific Gravity						2.676													
Atterberg Limits	Liquid Limit, LL	48		46			45	37			50		36				44	37	
	Plastic Limit, PL	26		25			25	27			26		28				24	28	
Bulk Density	Wet (kN/m³)		18.41			18.35				17.75					17.98				
	Dry (kN/m³)		14.32			14.25				13.38					13.80				
Grain Size Analysis	Sand (%)	6		8	76		7	18	85		5		17	70			10	20	80
	Silt (%)	64		65	24		65	74	15		60		73	30			64	72	20
	Clay (%)	30		27	0		28	8	0		35		10	0			26	8	0
Consolidation Tests	Natural Void Ratio, e_0					0.835													
	Compression Index, C_c					0.220													
Unconfined Compression Tests	Strain at failure (%)		18.0			18.0				20.0					18.0				
	Stress Undist. (kN/m²)		49.8			52.5				32.8					43.8				
	Stress Remould (kN/m²)																		
	Sensivity																		
Direct Shear Tests	ϕ (Degree)								35.0										33.0
	C (kN/m²)								0.0										0.0

Conversion : 1 PCF = 0.1571 kN/m³
1 PSI = 6.895 kN/m²
1 TSF = 14.20 PSI = 98.05 kN/m²

Comptd. by : M4 Checked by :

SHEET 1 OF 1 ATTACHMENT-VII

Attachment-VII: SITE PHOTOGRAPHS

SITE PHOTOGRAPHS (BPS-2, WHYKHONG)

SITE PHOTOGRAPHS (NAF TOURISM PARK)

SITE PHOTOGRAPHS (SABRANG TOURISM PARK)

SITE PHOTOGRAPHS (BPS-2, TEKNAF FERRY GHAT)

Water Environment & Climate

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