

*PLANNING AND DESIGN OF
STORM WATER
MANAGEMENT SYSTEM FOR
GDH. THINADHOO*



*FINAL
DESIGN
REPORT*

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SUBMITTED BY:

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(PVT)LTD.*

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CLIENT:

MINISTRY OF ENVIRONMENT AND ENERGY

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Executive Summary

A study has been made by Male Water Supply and Sewerage Company (Pvt.) Ltd. (MWSC) for Ministry of Environment and Energy (MEE) to address the issue of Storm Water in the Island of Gdh.Thinadhoo From the study the following were identified;

- One of the main causes of flooding is due to the slopes/levels in the Roads.
- Roads have not been constructed to address the problem of Flooding.
- There is no governing rules and regulation on flood water due to roofs of the houses. It is very common that all waters from the Roof are let to the roads.
- Improper planning in the land use in allocation of ground water discharge areas.

Following are the main recommendations and solutions;

- A Design has been done using under water ground tank for storing water. This approach has been mostly described in the Design report and drawing. Water from the Gutters and Soak Pit connected with Pipe line is let to underground storage tank. From the underground water tank water could be discharged to ground or could be used. The top of the Ground could be used for other purposes such as Play Grounds.
- Control Flooding by Rules and Regulations. Normally approximately 60% of the rainwater flood is caused from the Roofs. If from governing bodies such as Council, Ministry of Housing, Ministry of Environment/EPA regulations are made such that a certain percentage is only allowed to discharge to the roads, the rain water flooding problem will become less severe. From the Gutters and down Pipe each households could connect rainwater to an inside chamber in the Household.
- Land use plan must emphasize ground water recharge areas. When land use plans are made from the Planning Department of Ministry of Housing importance should be given to allocate space for Rainwater Discharge.
- Filling of Low Lying areas. Pockets of Water are found in the roads during rainy season due to low lying areas. These areas could be filled.
- Road Construction to take account of natural and prescribed scope.
- Modify and in Future use Soak Pits under the Road with Access. It is observed that Roads that had been constructed in the Island such as Khuldhufushi already have soak pits in the middle. But the Soak Pits have no means of access. It is asphalted without cover. Overtime the soak pit gets filled by debris and during rainy period excess water come out from side road drains. Hence for maintenance purpose

and cleaning the Soak Pit need to be constructed with cover. Gorrugated shafts also could be used to construct the Soak Pit to reduce costs. This should be integrated in all road designs.

- Implementation of Rainwater Harvesting.
- Use Flap Gates for Sea-outfalls. It is observed that back-flow of water occurs from the sea-outfall that had been constructed. Flap Gates should be used to avoid such back-flow.

Four different proposal and cost estimates had been prepared (in section 2 of report) that could be used to solve the rainwater flooding problem.

- Option 1- Cost estimate using underground water tank in Flood prone area A and B.
- Option 2- Cost estimate using underground water tank in one of the flooding area.
- Option 3- Cost estimate using underground water tank in one of the flooding area.
- Option 4- Cost estimate for Rainwater harvesting in one of the flooding area.

As a Pilot project if funding is available it is recommended that Option 2 is taken. This is since it is a model that could be used in all islands of Maldives where land is scarce. Empty lands could be used in the Island for underground tank and top could be utilized for other purpose. Other cheaper option could be considered if the available budget is less.

PLANNING AND DESIGN OF STORM WATER MANAGEMENT
SYSTEM FOR THE G DH. THINADOO ISLAND
FINAL REPORT

INTRODUCTION

G Dh. Thinadoo Island (Figure 3.1) with an area of around 115.5 Hectares is densely populated with 9000 people living within the Council area. An issue that the inhabitants had been concerned about for sometime is the poor drainage. This is mainly due to geographical factors such as flat terrain and intense rainfall in the area. Apart from this, human interventions such as depressions along roads, obstruction to natural drainage pattern to the sea, frequent tide fluctuations, unplanned land use and inadequate maintenance contribute to the present situation. Having realized the need for a well-designed Storm Water Management System for the entire Island, the Ministry of Environment and Energy (MEE) has initiated a project through the Male Water Supply and Sewerage Company (Pvt) Ltd (MWSC) in September 2013 titled 'Design of Storm Water Management System' (SWMS).

The layout of the land is such, that generally the coastal belt is higher than the inland. As a result the gravity flow fails to evacuate the storm water that gets filled up within the depressions along roads. The situation gets aggravated when the capacity available for rainfall harvesting is inadequate and the excess storm water spill over to adjoining areas. All these cause a deterioration of the environment. As at present there are two existing pipe outlets to the sea and four earthen outlets as emergency outlets to the sea. There are three major locations where inundation is critical. The problem gets aggravated when there is inflow from the sea during High Tide.

There is heavy rainfall during North East Monsoon and South West Monsoon. The depressions filled up with water during this period and get dried up after weeks of evaporation to atmosphere and seepage to the ground. Seasonal variation of average rainfall at Kaadedhdhoo is summarized below. A close contour map of the G Dh. Thinadoo was prepared from the spot levels available at MWSC. This map indicates that the highest elevation of the Island is 2.0m MSL and lowest level is 0.50m MSL.

Seasonal Variation of Average Rainfall at Kaadedhdhoo			
Seson	Period	Rainfall in mm	Percentage from Annual Rainfall %
1 st Inter Monsoon	March- April	222.3	10.2
South West Monsoon	May to September	953.3	43.7
2 nd Inter Monsoon	October - November	509.3	23.3
North East Monsoon	December to February	498.7	22.8
	Annual	2183.6	100.0

With a view to utilize the funds that are already allocated by the MEE, two basins were selected on priority basis as Pilot Projects for detail design and implementation. In addition funds were utilized to investigate the storm water management system in other basins to prepare a comprehensive design report to seek funds for the balance development. During this study five distinct basins were identified. See figure (3.1).

Detail designs and hydrological analysis have been carried out along with the preparation of the required plans and bills of quantities with the objective of mitigating the inconvenience caused due to inundation, and preventing the salt water intrusion. Having considered the economic aspects and the prevailing international design criteria for similar projects, a 5 year Average Rainfall Intensity (ARI) was considered sufficient for the Detail Design to protect the G Dh. Thinadoo Island from adverse effects from rainfall.

This study has been carried out by the application of a hydraulic model simulation with the objective of arriving at an optimum solution which provides an insight to the pre and post project scenarios.

All existing emergency outfalls numbering seven discharge four basins will be rehabilitated with the provision of seven Flap Gates so as to prevent sea water intrusion. In order to ensure proper maintenance of the project after completion, suitable maintenance equipment has been proposed. Having taken to consideration all aspects of the Technical, Financial, and Socio – Economic and Environmental considerations, the consultants believe that the project would be viable.

Main items of work involved are summarized below:

STORM WATER MANAGEMENT SYSTEM FOR G. Dh. THINADHOO ISLAND, MALDIVES
LIST OF MAJOR ITEMS

No	Item description	Unit	Zone A	Zone B	Zone C	Zone D	Zone E	Total
1	HDPE pipes 200 mm dia	m	2,106.0	2,146.0	1,503.0	2824	1943	10,522.0
2	HDPE pipes 300 mm dia	m	687.0	662.0	266.0	0	0	1,615.0
3	Manholes 600 mm dia	nr	38.0	23.0	21.0	34	25	141.0
4	Gutter inlet 400x400 mm	nr	280.0	281	177	283	195	1,216.0
5	HDPE flap valve	nr	1.0	2	2	2	0	7.0
6	Outfall	nr	1.0	2	2	2	0	7.0
7	Silt trap	nr	1.0	2	2	2	0	7.0
8	Storage tank	m3	2,448.0	1424	775	1959	1518	8,124.0

The total cost of the Option 1& 2 of the pilot project Zone A and Zone B amounts to Maldivian Rufiyaa 2,136,041.00 and 228,014.00 respectively and it is proposed to commence work in January 2014.

With the completion of the project sufficient protection of urban areas ear marked under Zone A and B as shown in figure 3.2, 3.3 & 3.4 will be ensured. The overall project will safeguard 115.5ha of urban lands in G Dh. Thinadoo Island and provide flood relief for lands in Zones A, B, C, D & E as shown in 3.3, 3.4, 3.5, 3.6 & 3.7. There are several intended development activities such as roads, drinking water, and sewerage etc within the G Dh. Thinadoo Island.

Rain Water Harvesting and Improvements to the Ground Water Recharging

Buildings such as mosque, hospitals, and banks, large commercial buildings such as hotels, shops and selected individual houses with large roof areas can be utilized for the purpose of water harvesting:

Available rainfall data need to be analyzed to ascertain the availability of yield to be harvested during the rainy season. The rain water collected from the above buildings can be diverted by gravity to the most convenient and closest water tanks provided at selected locations. It will be necessary to design and implement the general layout plans of the rain fall collection system and improvements to the ground water recharging system in individual plots in consultation with community in the area.

The main design components of the rainfall harvesting and collection systems up to the treatment plant includes Transmission pipe network system, Inter connected storage tank system, supply of pumps for transmission of rain water from the storage tanks to the RO plant and design of a system to flush out the polluted roof and gutters prior to the rainy season.

Laws and regulations on Storm Water Management

Water is a scarce commodity. Every effort must be taken to utilize water prudently. The people must be apprised of the need to prevent wastage. With that in view it is essential that the existing rules and regulations pertaining to the use of water is rigidly adhered by the inhabitants. The Council must enforce the legal powers it has when necessary. As at present there are instances of wastage observed at certain locations, particularly due to the nonexistence of a network of roads where a system of pipe network could receive the excess water from the premises.

Rainwater harvesting (RWH)

People must be encouraged to harvest rainwater. They should be provided with private tanks on cost recovery basis. As against the high cost of desalination, rainwater is free resource and installation and disinfection cost is also affordable. Therefore the authorities must promote and popularize RWH as much as possible. There are several supportive factors for RWH such as sufficient rainfall, technical skills, available local resources, cost effectiveness, enthusiastic community, positive health impacts and environmentally friendly.

RWH is the most preferred source of water for domestic use especially in rural areas where living conditions too had improved due to the roof catchment system.

One of the key factors that determine the feasibility of RWH is the policy adopted in maintenance of RWH system. Regulations and guidelines for implementers and users need to be put in place to ensure the effectiveness of rainwater harvesting programme.

Public appeal

At the onset of monsoon, public needs to be alerted to get prepared for the harvesting. The families will require cleaning their system and repairing faults if any. This will help them to store maximum water and protect the quality of stored water. Government (water supply department) may consider giving public notice in the press for the benefit of people and avoiding water shortage in the dry period.

Ground water recharging wells

In addition to the proposed seepage tanks in the storm water management system, ground water recharging wells consisting of circular reinforced concrete wells of 1200mm internal diameter with 100mm of wall thickness and 1500mm height can be constructed along the main roads. (Alternatively to reduce the cost prefabricated corrugated wells of PVC/PE material could be used). These wells can be covered with G.I manhole cover to match with the finished ground levels. This will supplement the capacity of rainwater aquifers presently available in the Island. These wells can be linked by using μ PVC pipes of 160mm diameter. They should be covered using a geo textile membrane to prevent infiltration of silt into the pipe network.

With all these development activities, the Island of G Dh. Thinadoo would provide a springboard for a lot of potential projects. Therefore the Ministry of Environments and Energy can confidently provide a facelift to the G Dh. Thinadoo Island since with the completion of the project the community would benefit by the elimination of water stagnation, reduced inundation of properties, boost the morale of the people, removal of periodic access interruptions etc. On the whole the final impact would be the improved rainfall recharging system, reduction of salt water intrusion, land value enhancement, and enhanced environmental aesthetics in the area. As such the communities could be expected to cooperate in the operation and Maintenance of the new project in collaboration with the Council. In view of the above, the project is technically and socially feasible and therefore recommended for interested donors to explore the possibility of implementation of this project.

Detail Design

1.0 Introduction

The G Dh Thinadhoo Island has an approximate area of about 115.5 ha and highly urbanized settlements with over 9000 inhabitants. The location of the project area is shown in figure 3.1. One of the problems in the Island is stagnation of water at the low elevated areas. This is due to several factors and among that flat topography, intense rainfall, high tide from the sea, Unavailability of flap gates to prevent salt water intrusion into the inland areas, existing earthen outlet to sea, improper land use, variation of existing ground along the roads and less maintenance can be highlighted. See Photos page no 145 – 153.

2.0 Strategy

In order to utilize the funding already available for the project and also to derive timely benefit for the affected community, two pilot projects from each Island were identified. Based on the priorities indicated by the Island Council, Zone A and B of the each Island was selected for full investigations.

Detailed designs and preliminary estimate has already been prepared for these two pilot projects in order to commence the construction work in January 2014. This study has already complemented by a hydraulic model simulation to understand and justify the submergence of roads under pre and post project conditions.

3.0 Climate

3.1 Rainfall

Design rainfall intensities have to be derived from a set of rainfall intensity – Frequency – Duration curves which have been prepared for G dh. Thinadhoo Islands. Rainfall data collected from Metrological Department of Male at Kaadedhoo, Hanimadhoo and Hulhule gauging station were considered as representative for this study.

Daily data and 3 hourly data were readily available for the following stations with different durations.

- Daily rainfall Data:-
 - Kaadedhoo – from 1994 to 2012 – [19 yrs]
 - Hanimadhoo – from 1991 to 2012 – [22 yrs]
- 3 Hourly rainfall Data :-
 - Kaadedhoo – from 2000 to 2008 – [9 yrs]
 - Hulhule – from 2008 to 2012 – [5 yrs]
 - Hanimadhoo – 3hourly data not available



Figure 3.1 - Catchment Boundaries of Dh Thinadhoo Island

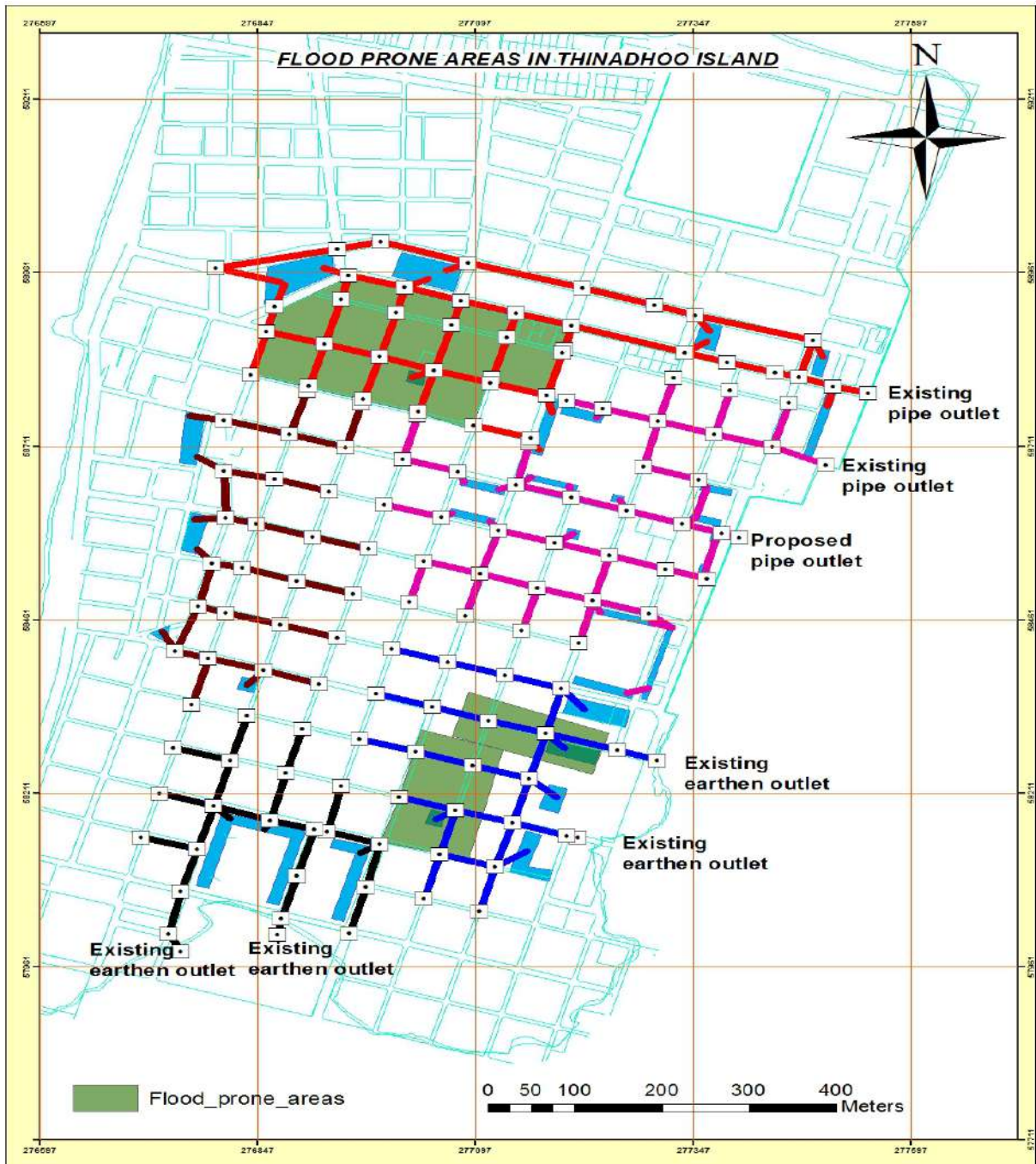


Figure 3.2 – Flood Prone areas – Thinadhoo Island

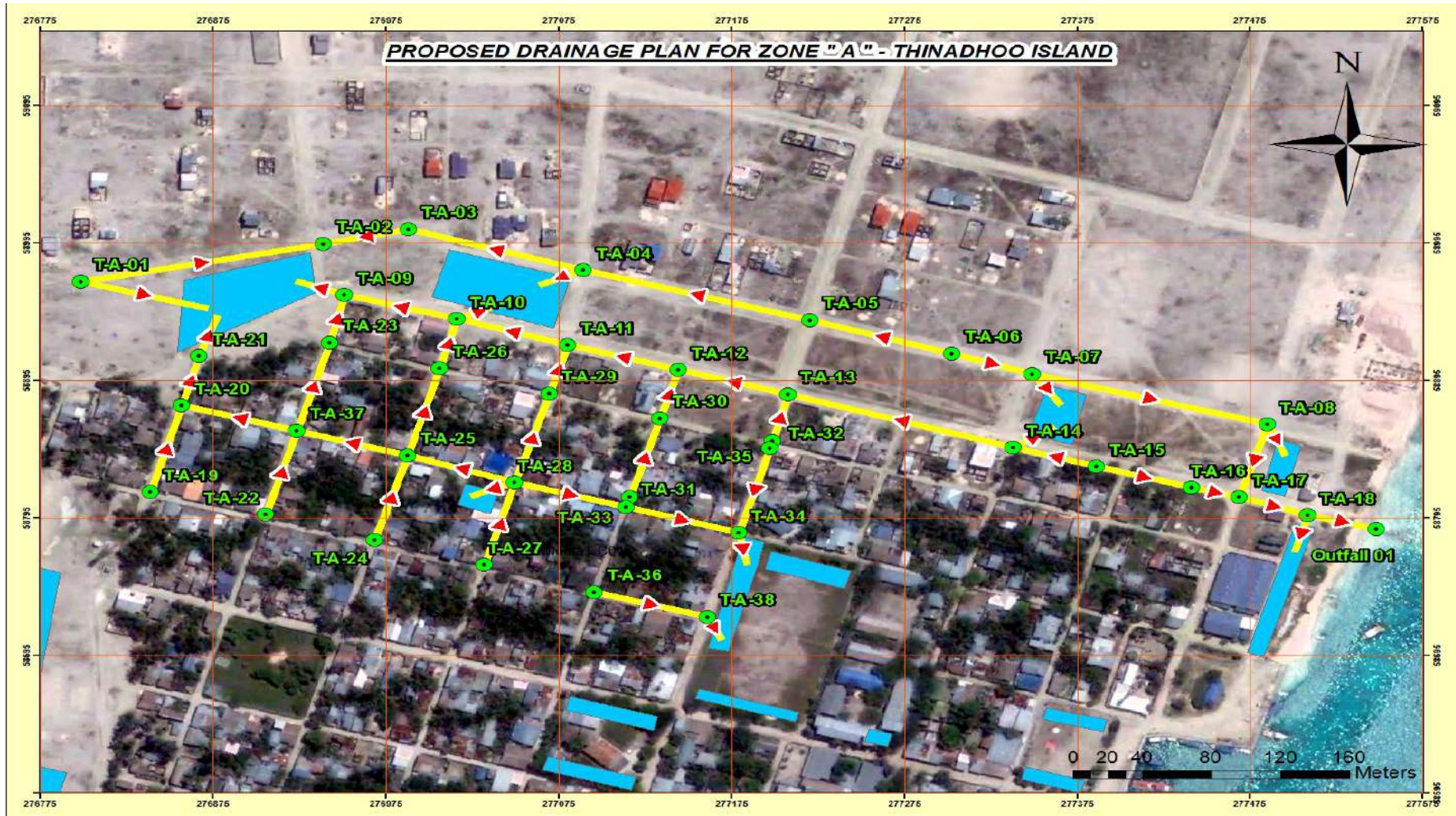


Figure 3.3 – Flood Prone areas Zone A – G Dh Thinadhoo Island



Figure 3.4 – Flood Prone areas Zone B – G Dh Thinadhoo Island

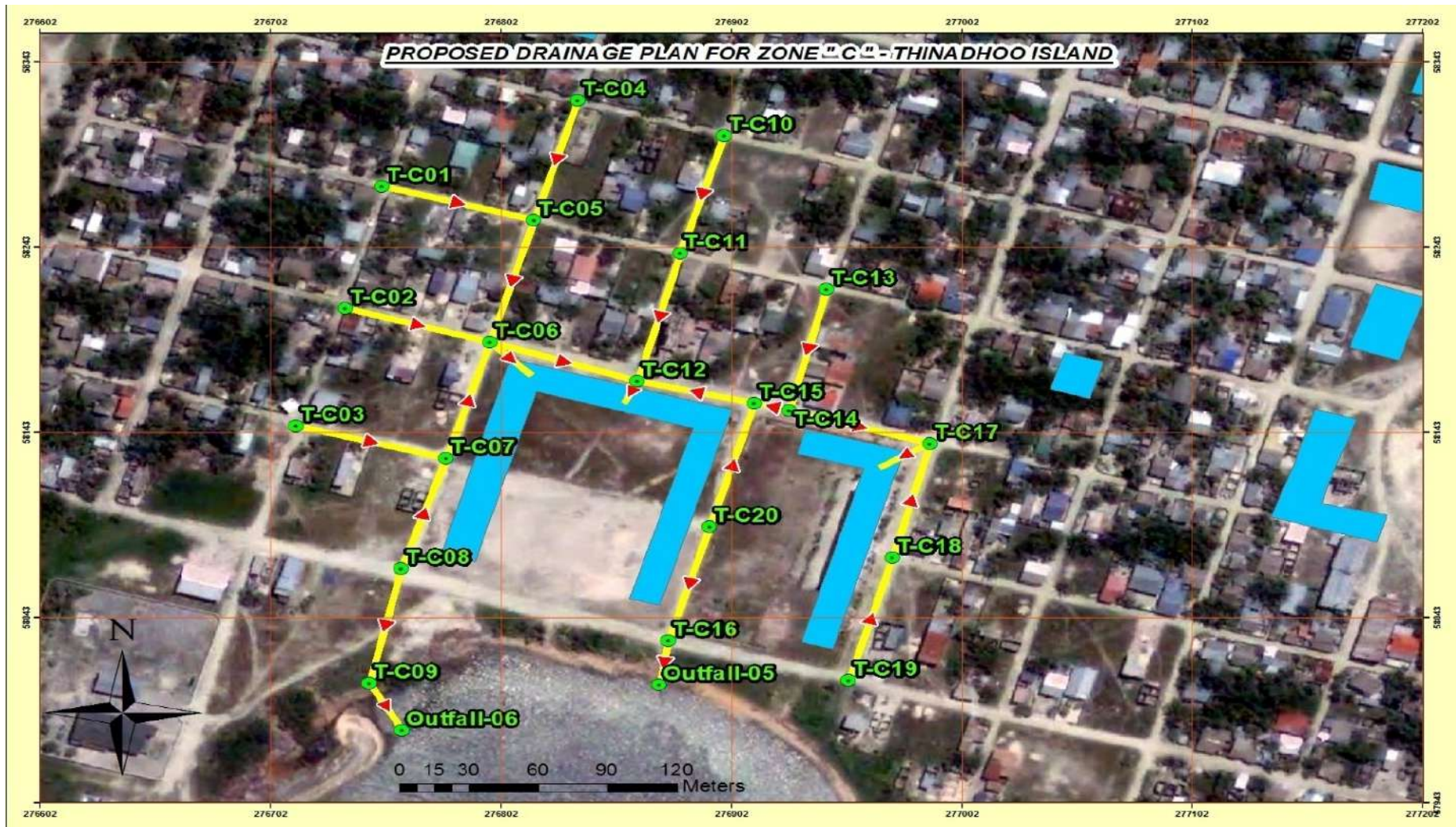


Figure 3.5 – Flood Prone areas Zone C – G Dh Thinadoo Island

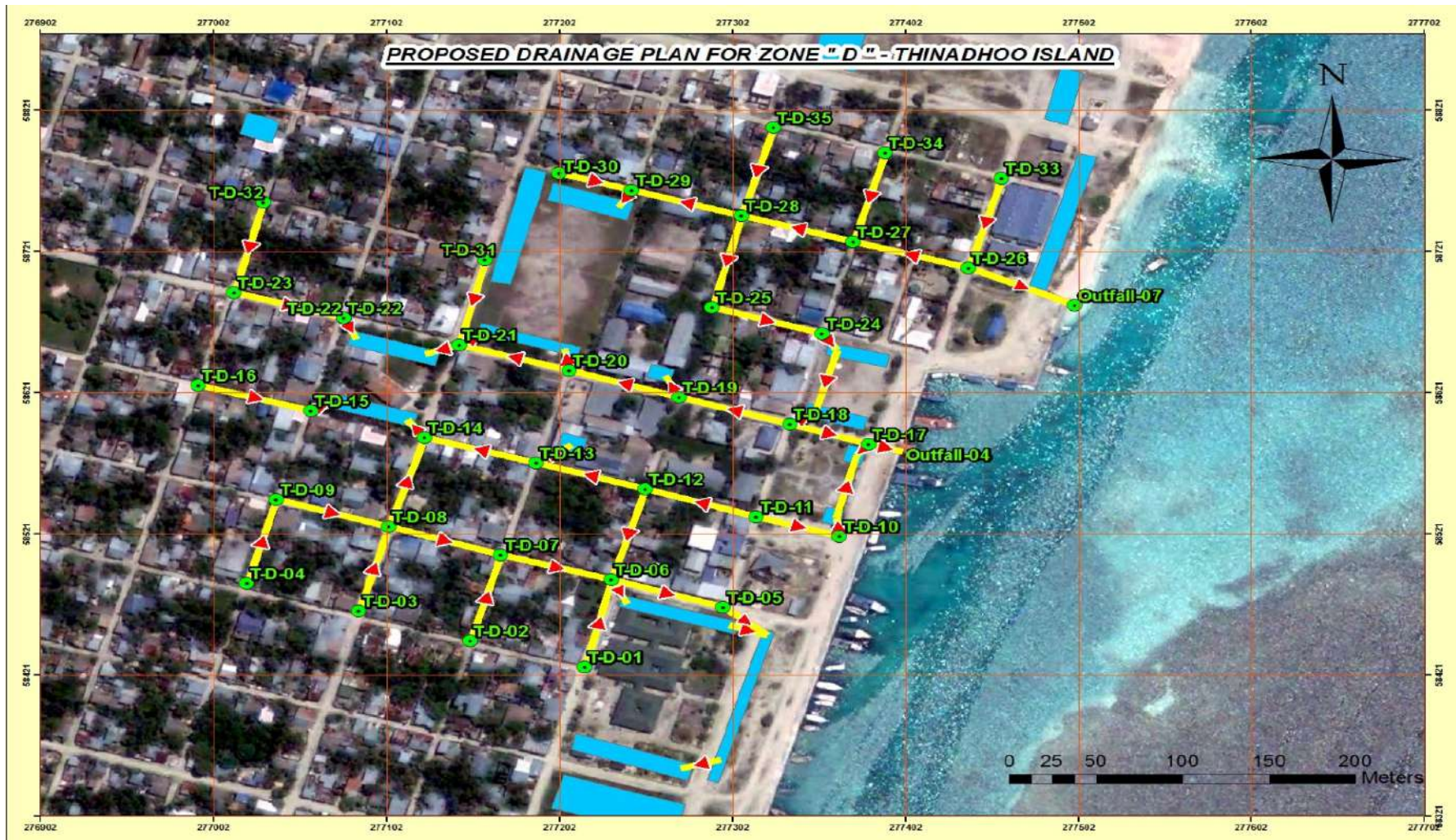


Figure 3.6 – Flood Prone areas Zone D – G Dh Thinadhoo Island



Figure 3.7 – Flood Prone areas Zone – G Dh Thinadhoo Island

3.2 Rainfall Intensity Analysis

The catchment areas of individual sub-basins in the G Dh.Thinadhoo under consideration for effective drainage are comparatively small. Therefore time of concentration, (T_c) as defined in surface hydrology is very short. The details of the basin show that the largest catchment area is limited to 115.5 ha. The time of concentration (T_c) is of the order of 30 to 60 minutes. Therefore in designing storm water management system for these small urban catchments, the rainfall intensity for short duration, such as 5,10,15,30 minutes is very important. In addition, 24 hour rainfall data of the automatic rain gauges maintained at the above weather stations were analyzed for several years.

- Development of Depth Duration and Intensity Duration Frequency (IDF) curves for Kaadedhdoo and Hulhule Weather Stations have been comprehensively studied and presented in the Inception Report that have been already submitted. Final product of this task is shown in Table (3.1) to 3.6 and Figures 3.8 to 3.11.

Duration in Hours	Return Period in Years								
	2	5	10	15	25	50	75	100	200
0	0	0	0	0	0	0	0	0	0
0.25	20.0	22.5	25.0	27.5	30.0	32.5	35.0	37.5	40.0
0.5	28.0	31.75	35.5	39.25	43.0	46.75	50.5	54.25	58.0
1	38.0	42.5	49.0	55.5	62.0	68.5	75.0	81.5	88.0
3	65.9	81.9	94.0	101.1	110.1	122.2	126.0	130.5	142.3
6	75.9	91.8	103.7	111.0	119.5	130.8	135.4	139.8	152.3
9	79.5	94.2	105.4	112.9	120.1	131.3	137.8	142.4	153.6
12	82.5	97.7	108.3	114.6	122.5	133.1	139.4	143.8	154.5
15	85.6	99.8	110.3	116.6	123.5	134.3	140.6	144.1	154.6
18	89.3	103.1	112.8	118.5	125.6	135.3	141.0	145.0	154.7
21	92.7	105.1	114.5	120.0	126.9	136.3	141.8	145.7	155.0
24	95.4	107.3	116.3	121.6	128.2	137.2	142.5	146.2	155.2

Table 3.1 - Rainfall Depth Duration Frequency Data (mm) at Hulhule

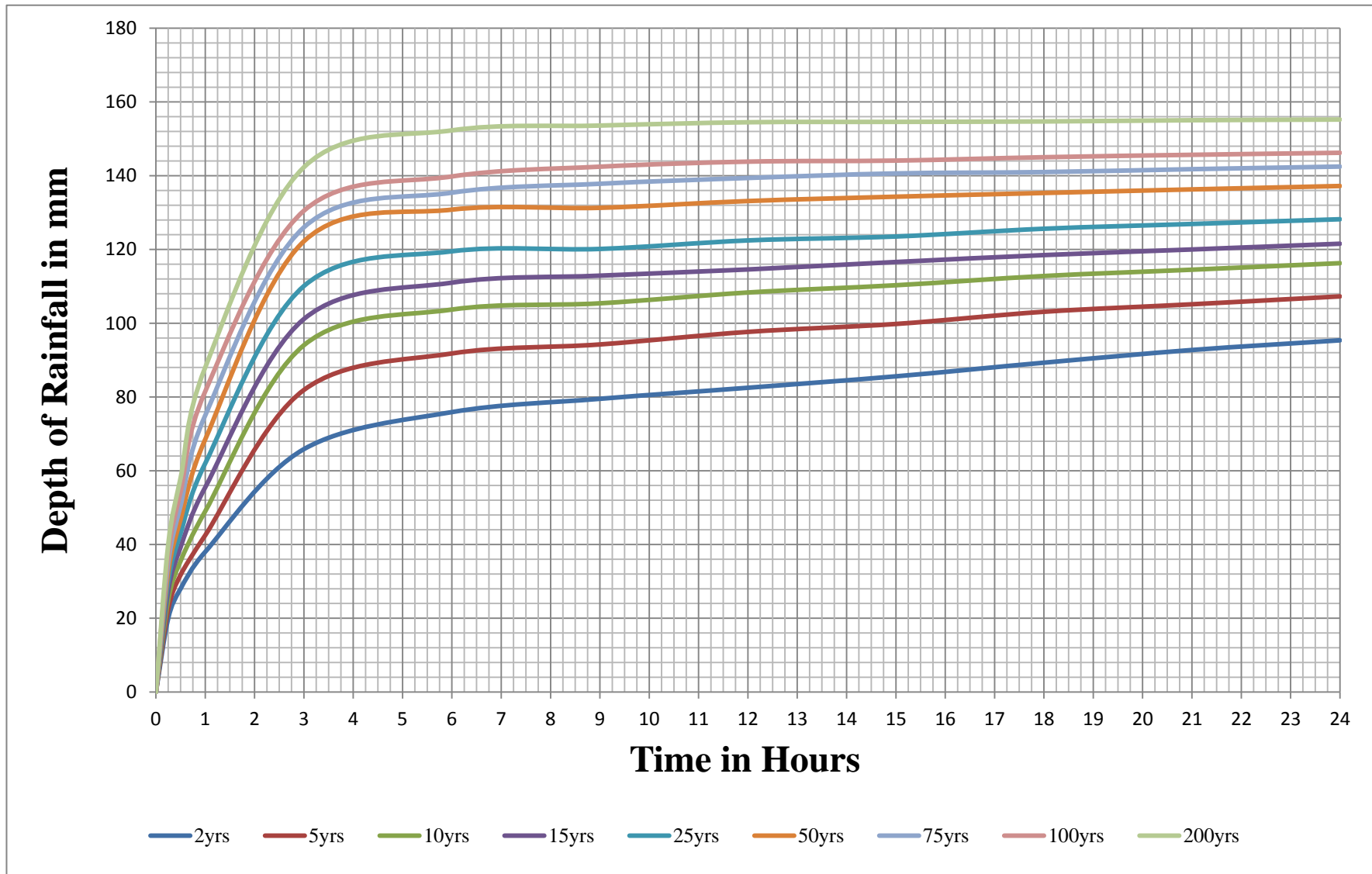


Figure 3.8 -Depth Duration Frequency Curves at Hulhule

Duration in Hours	Return Period in Years								
	2	5	10	15	25	50	75	100	200
0.25	80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0	160.0
0.5	56.0	63.5	71.0	78.5	86.0	93.5	101.0	108.5	116.0
1	38.0	42.5	49.0	55.5	62.0	68.5	75.0	81.5	88.0
3	22.0	27.3	31.3	33.7	36.7	40.7	42.0	43.5	47.4
6	12.7	15.3	17.3	18.5	19.9	21.8	22.6	23.3	25.4
9	8.8	10.5	11.7	12.5	13.3	14.6	15.3	15.8	17.1
12	6.9	8.1	9.0	9.5	10.2	11.1	11.6	12.0	12.9
15	5.7	6.7	7.4	7.8	8.2	9.0	9.4	9.6	10.3
18	5.0	5.7	6.3	6.6	7.0	7.5	7.8	8.1	8.6
21	4.4	5.0	5.5	5.7	6.0	6.5	6.8	6.9	7.4
24	4.0	4.5	4.8	5.1	5.3	5.7	5.9	6.1	6.5

Table 3.2 - Rainfall Intensity Duration Frequency Data (mm/hour) at Hulhule

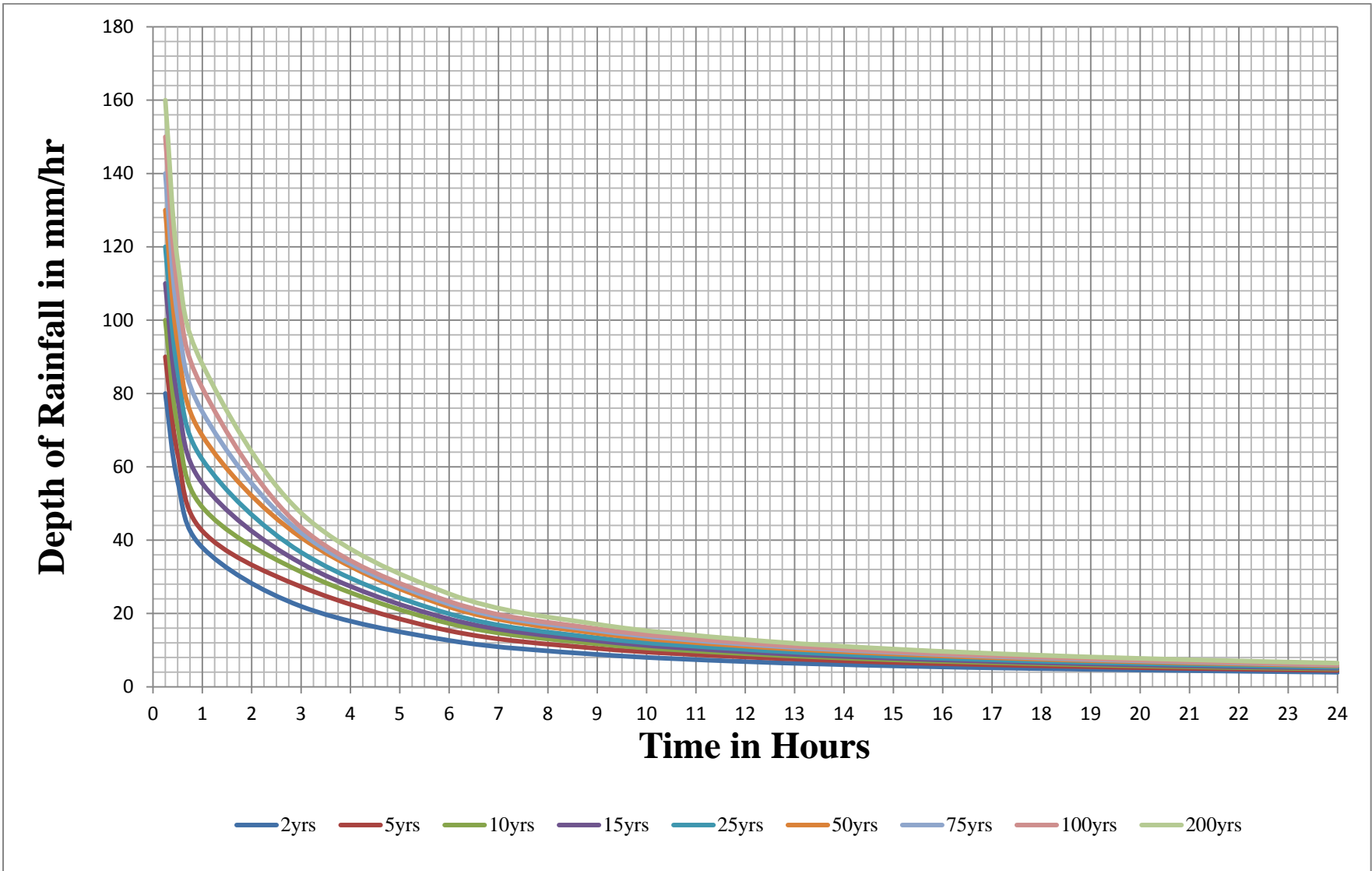


Figure 3.9 Intensity Duration Frequency Curves at Hulhule

NO	RETURN PERIOD T_R IN YEARS	EQUATION
1	2	$I = 2298.3 [T+ 25.4]^{-0.8752}$
2	5	$I = 3709.7 [T+ 26.8]^{-0.9238}$
3	10	$I = 5075.8 [T+ 26.8]^{-0.9553}$
4	15	$I = 5802.0 [T+ 25.5]^{-0.9674}$
5	25	$I = 7314.3 [T+ 28.0]^{-0.9926}$
6	50	$I = 8989.6 [T+ 29.6]^{-1.0105}$
7	75	$I = 9094.4 [T+ 29.3]^{-1.0063}$
8	100	$I = 9667.8 [T+ 29.6]^{-1.0110}$
OPTIMUM RANGE FOR T		$5 \leq T \leq 1440$

T is in minutes, I is in mm/hour

Table 3.3- Intensity Duration Frequency equations for Hulhule Station

Depth Duration Frequency Table								
Duration	Return period in years							
	2	5	10	15	25	50	75	100
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.25	22.0	22.7	23.9	26.0	27.4	33.4	39.3	45.2
0.5	29.5	30.7	32.7	36.3	38.7	48.6	58.6	68.5
1	44.6	48.8	53.0	57.0	64.0	70.8	84.4	98.0
3	85.4	101.0	113.5	127.0	136.5	150.9	157.4	163.8
6	107.5	125.3	142.5	149.8	162.3	178.9	187.5	198.5
9	112.6	133.8	153.7	161.2	177.0	197.7	207.0	216.3
12	114.2	140.2	162.3	169.5	188.6	208.5	218.5	229.1
15	116.5	148.5	171.4	180.2	198.0	221.6	232.2	242.9
18	118.0	154.0	178.9	188.3	207.9	233.6	245.2	256.7
21	119.5	158.6	185.9	197.6	220.7	243.9	255.3	267.5
24	121.9	165.8	194.9	203.2	228.7	254.2	268.0	281.8
48	146.7	200.4	236.0	253.1	277.5	314.3	330.9	347.4
72	169.1	224.5	261.2	278.8	303.9	341.9	358.9	372.2
96	190.2	240.8	274.3	290.3	313.3	348.0	363.6	381.2
120	205.3	256.2	289.9	306.0	329.1	364.0	379.6	395.3

Table 3.4 - Depth Duration Frequency at Kaadedhdoo

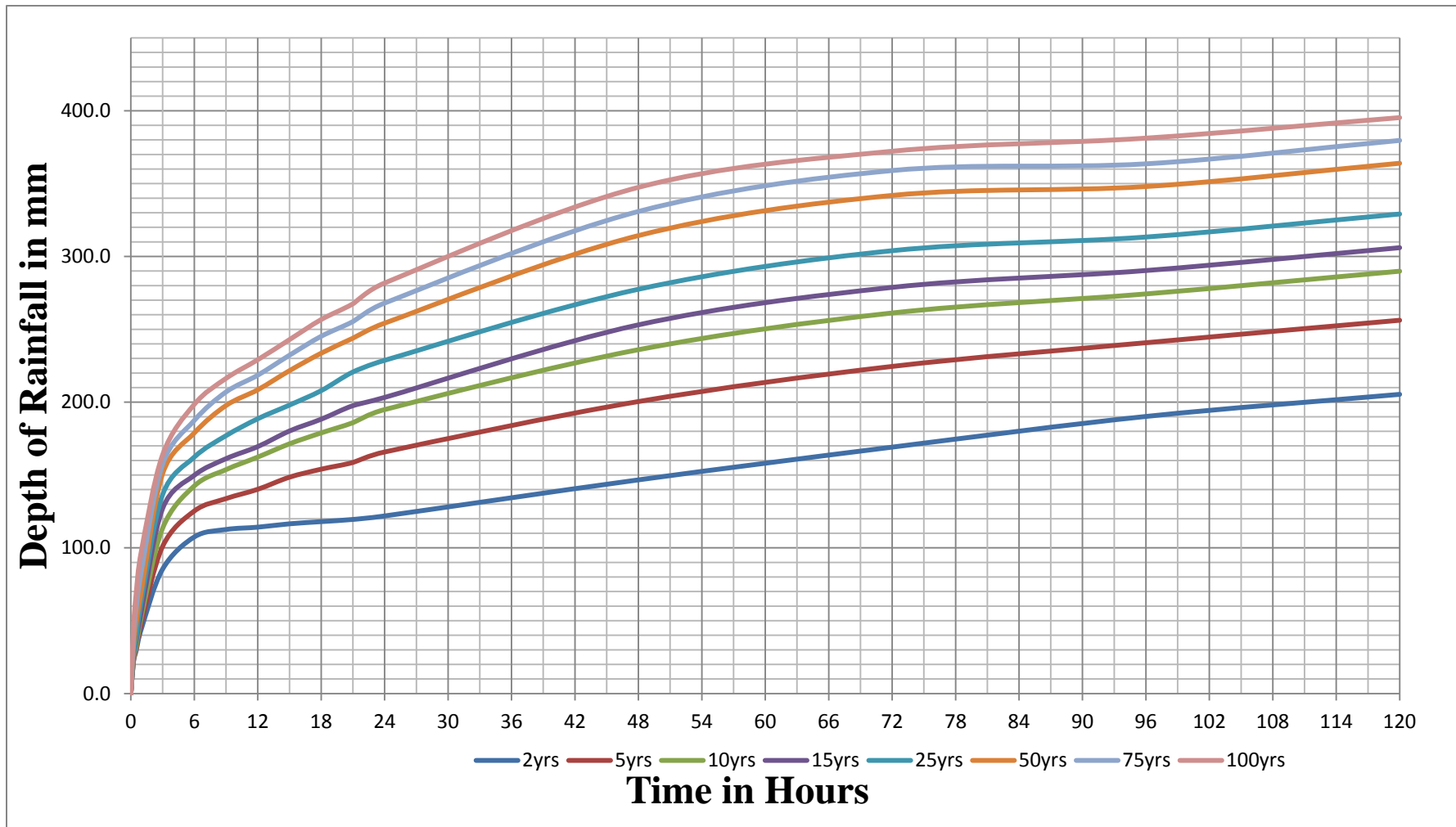


Figure 3.10- Depth Duration Frequency Curves at Kaadedhdoo

Duration	Return period in years							
	2	5	10	15	25	50	75	100
0.25	88.0	90.8	95.6	104.1	109.8	133.5	157.1	180.8
0.5	59.0	61.4	65.4	72.5	77.3	97.2	117.1	137.0
1	44.6	48.8	53.0	57.0	64.0	70.8	84.4	98.0
3	28.5	33.7	37.8	42.3	45.5	50.3	52.5	54.6
6	17.9	20.9	23.8	25.0	27.1	29.8	31.3	33.1
9	12.5	14.9	17.1	17.9	19.7	22.0	23.0	24.0
12	9.5	11.7	13.5	14.1	15.7	17.4	18.2	19.1
15	7.8	9.9	11.4	12.0	13.2	14.8	15.5	16.2
18	6.6	8.6	9.9	10.5	11.6	13.0	13.6	14.3
21	5.7	7.6	8.9	9.4	10.5	11.6	12.2	12.7
24	5.1	6.9	8.1	8.5	9.5	10.6	11.2	11.7
48	3.1	4.2	4.9	5.3	5.8	6.5	6.9	7.2
72	2.3	3.1	3.6	3.9	4.2	4.7	5.0	5.2
96	2.0	2.5	2.9	3.0	3.3	3.6	3.8	4.0
120	1.7	2.1	2.4	2.6	2.7	3.0	3.2	3.3

Table 3.5 -Intensity Duration Frequency Kaadedhdoo

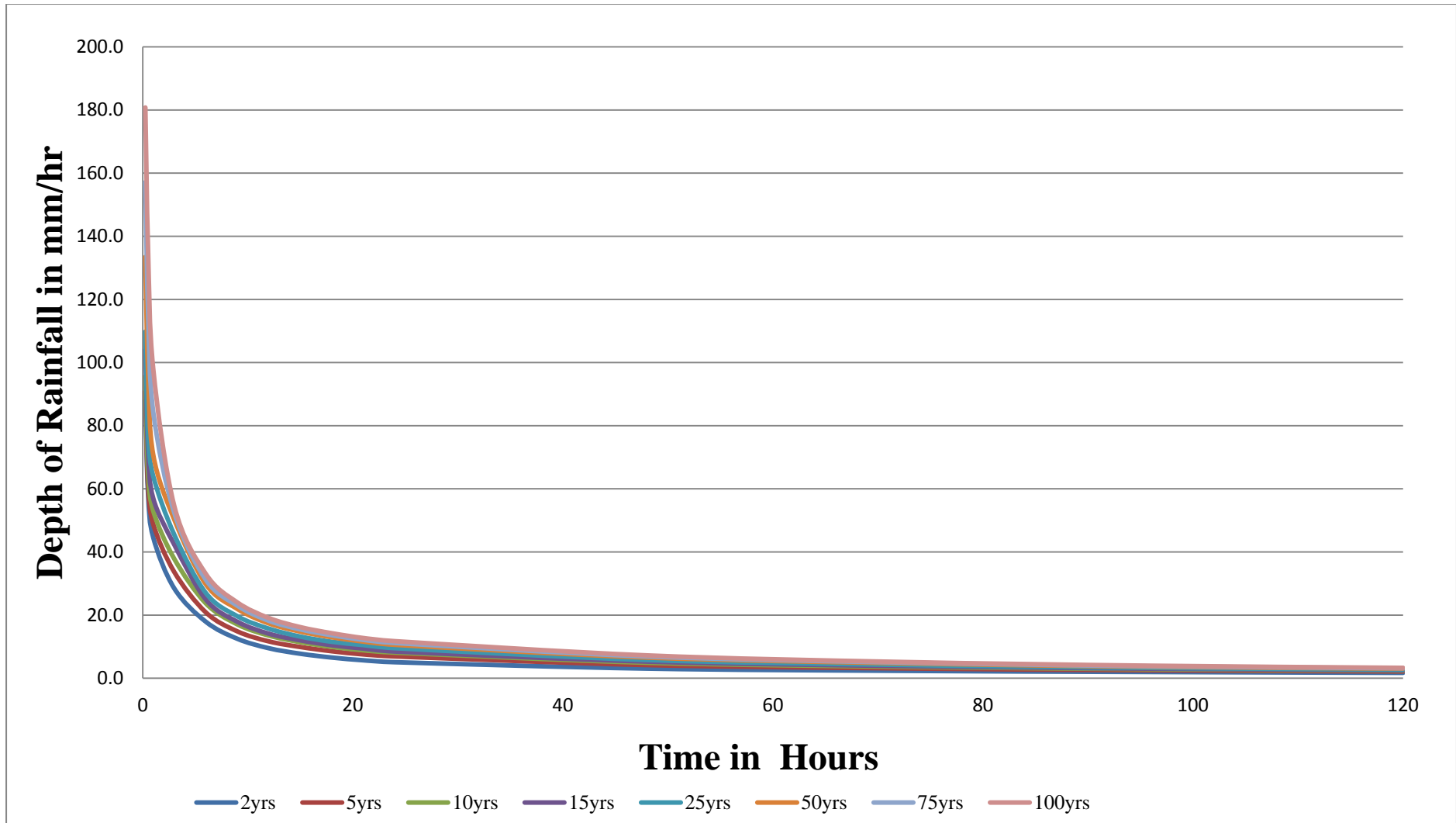


Figure 3.11 - Intensity Duration Curves at Kaadedhdoo

No	Return Period T _r in years	Equation
1	2	$I = 2009.2 [T + 29.5]^{-0.8066}$
2	5	$I = 2092.4 [T + 26.2]^{-0.7795}$
3	10	$I = 2233.1 [T + 20.5]^{-0.7693}$
4	15	$I = 2355.6 [T + 21.5]^{-0.7689}$
5	25	$I = 2734.9 [T + 24.5]^{-0.7766}$
6	50	$I = 3113.7 [T + 28.3]^{-0.7795}$
7	75	$I = 3158.9 [T + 29.0]^{-0.7742}$
8	100	$I = 3315.2 [T + 27.5]^{-0.7750}$
Optimum Range for T		$5 \leq T \leq 7200$

T is in minutes, I is in mm/hour

Table 3.6-Intensity Duration Frequency equations for Kaadedhdoo Station

3.2.2 Design storm for Five year ARI

By considering the long term continuous rain, a 12 hour design storm was developed for the model analysis for the 05 Year return period based on the rainfall analysis. Design event was derived for 15 minute intervals so that the quick response of small catchment is taken in to account.

The alternative block method was applied for the development of the design storm and the peak rainfall was placed at the middle. Since this is a 12 hour event, the depression storages may be filled within the initial few hours and the infiltration model also sufficiently saturated when the peak rainfall arrives and thereby this may be regarded as a possible worst scenario and a sufficient degree of Factor of Safety is achieved.

The calculation procedure of deriving the design rainfall is given in Table 3.7 and a graphical interpretation of the event is given in figure 3.12.

Intensity Equation for 5 Year Return Period; $I = 3709.7 (T+26.8)^{-0.9238}$

	Duration (min)	Duration (hours)	Intensity (mm/hr)	Incremental Depth (mm)	Incremental depth (Design Event) (mm)
1	15	0.25	117.95	29.49	0.23
2	30	0.5	88.85	14.94	0.25
3	45	0.75	71.56	9.24	0.26
4	60	1	60.05	6.39	0.28
5	75	1.25	51.83	4.73	0.29
6	90	1.5	45.65	3.69	0.31
7	105	1.75	40.83	2.98	0.34
8	120	2	36.96	2.47	0.36
9	135	2.25	33.78	2.09	0.39
10	150	2.5	31.13	1.80	0.43
11	165	2.75	28.87	1.58	0.47
12	180	3	26.93	1.40	0.52
13	195	3.25	25.24	1.25	0.58
14	210	3.5	23.76	1.13	0.65
15	225	3.75	22.45	1.03	0.74
16	240	4	21.28	0.94	0.86
17	255	4.25	20.23	0.86	1.03
18	270	4.5	19.29	0.80	1.25
19	285	4.75	18.43	0.74	1.58
20	300	5	17.65	0.69	2.09
21	315	5.25	16.93	0.65	2.98
22	330	5.5	16.27	0.61	4.73
23	345	5.75	15.66	0.58	9.24
24	360	6	15.10	0.54	29.49
25	375	6.25	14.58	0.52	14.94
26	390	6.5	14.09	0.49	6.39
27	405	6.75	13.64	0.47	3.69
28	420	7	13.22	0.45	2.47
29	435	7.25	12.82	0.43	1.80
30	450	7.5	12.45	0.41	1.40
31	465	7.75	12.10	0.39	1.13
32	480	8	11.77	0.38	0.94
33	495	8.25	11.45	0.36	0.80
34	510	8.5	11.16	0.35	0.69
35	525	8.75	10.88	0.34	0.61
36	540	9	10.61	0.32	0.54
37	555	9.25	10.36	0.31	0.49
38	570	9.5	10.12	0.30	0.45
39	585	9.75	9.89	0.29	0.41
40	600	10	9.67	0.28	0.38
41	615	10.25	9.46	0.28	0.35
42	630	10.5	9.26	0.27	0.32
43	645	10.75	9.07	0.26	0.30
44	660	11	8.89	0.25	0.28
45	675	11.25	8.71	0.25	0.27
46	690	11.5	8.54	0.24	0.25
47	705	11.75	8.38	0.23	0.24
48	720	12	8.22	0.23	0.23

Table 3.7– Calculation procedure for development of the design storm for 5 yr ARI

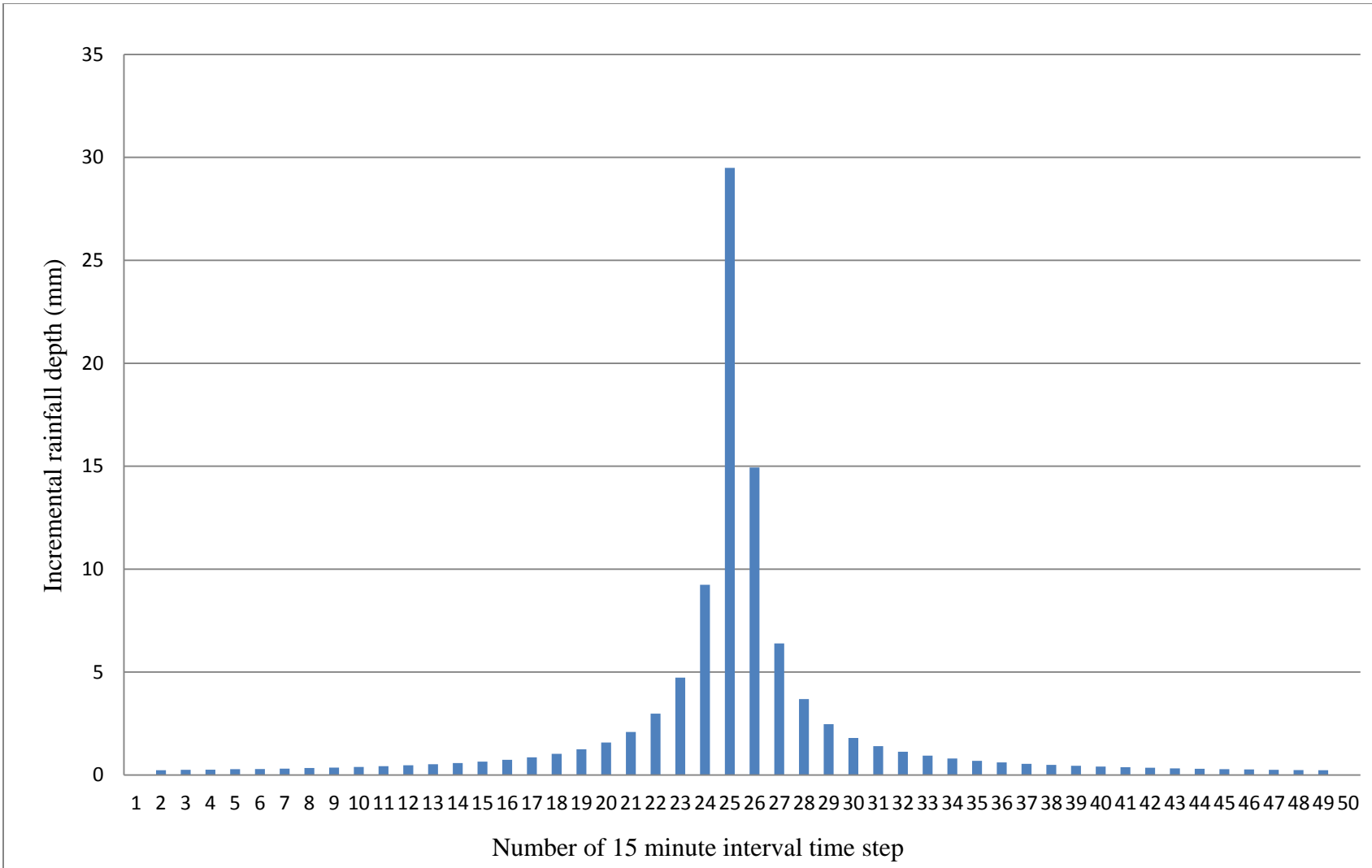


Figure 3.12 – Graphical interpretation of the design storm for 5 yr ARI

4.0 Variation of sea water levels

The variation of sea water level during high tide and low tide is important as the excess storm water from all the basins eventually discharges to the sea as an emergency out let. The exit level of all the storm water path will be designed in such a way that water level at the exit is kept at the low tide level to use as an emergency outlet. The flap gates also will be provided to close during the high tides and to open during the low tides.

4.2 G Dh Thinadhoo Coastline

G Dh Thinadhoo Island is on the west side of the atoll. Therefore the eastern coastline is facing the inside of the atoll. Due to the shallow reef about 500m offshore, wave action is limited on the east and northern sides of the island. On the west side of the Island the reef is only about 200m away from the shore and most of the waves break on the reef. Sea currents off the southern shoreline may be very high due to the narrow opening between the two Islands.

Wave and wind data at the Island is necessary to estimate the wave and wind set up which can be very high and can cause inundation in low lying area and may lead to disruption of storm water runoff.

According to the Admiralty tide tables, Tidal constituents are available at Addoo atoll (Table 4.1) which is only about 130km South from G Dh Thinadhoo. Therefore the tide that can be generated for Addhoo atoll is applicable for G Dh Thinadhoo.

Tidal constituent	Phase (deg.)	Amplitude (m)
M2	37	0.3
S2	76	0.18
K1	75	0.09
O1	86	0.05

Table 4.1: Tidal Constituents at Addoo atoll

According to the generated tide (Figure 4.1) with mean sea level at 0.66 m above the Chart Datum, tidal range is about 1.5m.

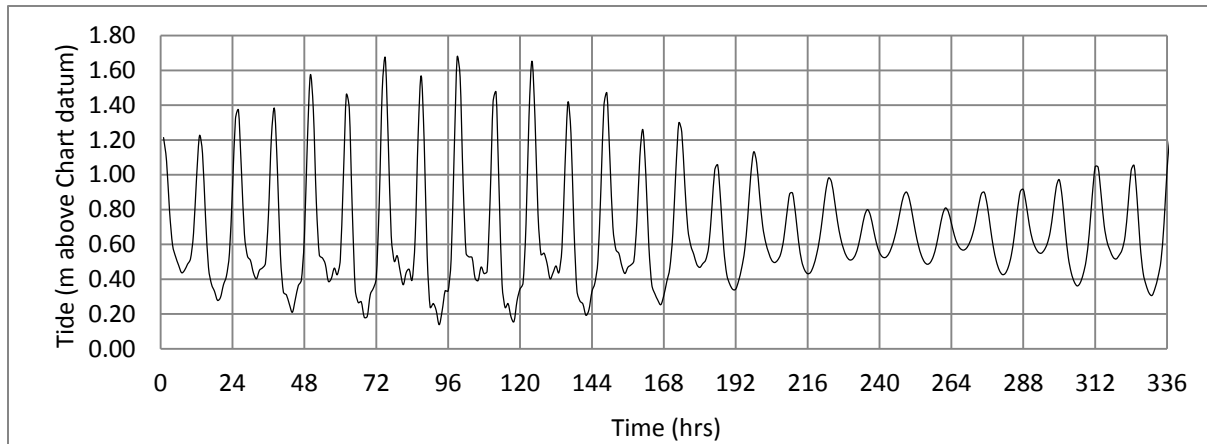


Figure 4.1 -Typical tidal levels at Thinadhoo Island

4.2.1. Sea level at G Dh Thinadhoo Island

There is no historical sea level data at G Dh Thinadhoo to establish the design sea levels around the island. Closest sea level gauging station is at Gan (Latitude: 00-41S, Longitude: 073-09E) which is about 35km South of G Dh Thinadhoo.

According to the 1 hour tide data available at the Joint Archive for Sea Level of University of Hawaii Sea Level Centre /National Oceanographic Data Centre, at Gan, the maximum water level recorded during the period March 1987 to October 2013 is 2.361m above the staff zero. It was recorded at 11.00 Hours on 19/08/2012. However, it is not possible to confirm the level of the staff zero with respect to the mean sea level or another accepted datum. Average sea level at this station during the period 1987 to 2013, is 1.588m above the staff zero. That means the maximum sea level record 2.361m is 0.773m above the average sea level. Though it is not possible to find a recurrence interval or a return period for this maximum sea level, it is the maximum sea level that has occurred during the past 26 years.

In conclusion the maximum sea level that is recorded during the past 26 years is 0.773m above the average sea level.

5.0 Methodology and design consideration

After the first meeting for the familiarization of the project in the latter part of the October, a discussion was held at MWSC office with Engineering Manager and other Engineers. First site visit has been carried out with the following officials from 6th October to 9th October at GH Thinadhoo

1. Ms .Mariyam Najfa Shaheem Razi - Ministry of Environment and Energy
2. Mr. Mohamed Imran Adnan - Manager, Planning & Design- MWSC
3. Mr. Mohomed Adam - Engineer , Planning - MWSC
4. Mr. P.P.Ghananapala - Civil Engineer , ECL

Findings are as follows;

- Based on the discussions with Island council and some of the residents, it was found that storm water issues were severe in three areas. **(Refer Figure 3.2)**
- There are emergency outlets without flap gates to control salt water intrusion. Back water will take place during high tide.
- At the lowest areas of the Island, flooding occurs during rainy season and puddles remain for 2 to 3 weeks. In these areas, ground water level raises up to ground level and the depth of puddles are more than 450mm in the most severely affected areas **(Refer Figure 3.2)**.
- Natural ground of the island has a gradient from West to East which will provide an easy water flow from all the roads to sea.
- For the purpose of providing underground storage tanks land is available within premises of school, playground, parks, mosques etc... **(Refer Figure 6.1)**
- Frequent fluctuation of water levels were examined with a view to ascertain a realistic water level that can be adopted. Existing wells and water harvesting methods were also inspected. See photos 120 and 123.

2nd site visit has been carried out in the company of Council Members from 04th November 2013 to 07th November 2013 in G Dh Thinadhoo Islands to collect more details at site for Modeling Process and to also confirm the locations selected for the Ground Tanks.

After having inspections and discussions with the relevant officials, it was decided to establish the following methodologies and design criteria to propose a sustainable storm water management system for the Island:

1. Consideration of Design Horizon as 2030.
2. Design Criteria adopted.

5.1 Return period

After considering technical, economical and social aspects of the project, it was decided to select 5year ARI for the Hydrology and Hydraulic calculations.

5.2 Consideration of Design Horizon as 2030

By considering future infrastructure developments in the Islands, design horizon was taken as 2030. Land use maps from year 2012 received from previous study has been projected to year 2030 to represent the future conditions. The main parameter from the land use maps which the proposed analytical tool (SWMM and Rational methods) used is the Runoff Coefficient. It was decided to apply the Runoff Coefficients dependent on following land use types such as Roads, Houses, Parks and Open Areas, Water Ponds and others.

The following factors have been adopted to consider 2030 scenario.

- The development of zoning map only considered storm water management aspect and not to worsening the storm water problem in the future.
- The level of urbanization is assessed through the degree of imperiousness on sub basin level and increase of pervious / impervious percentages.
- The drainage capacity is represented through the present storm water inundation pattern.

5.3 Design Criteria Adopted

5.3.1 Hydrology & Hydraulic design

The hydrology & Hydraulic design was done using the SWMM software. SWMM is free modeling software which can be used to simulate single event or long term events primarily for urban areas. SWMM has the capability of simulating the Hydrologic, Hydro dynamic & Water quality processes within urban drainage networks. The typical structure of the SWMM model is shown in figure 5.1

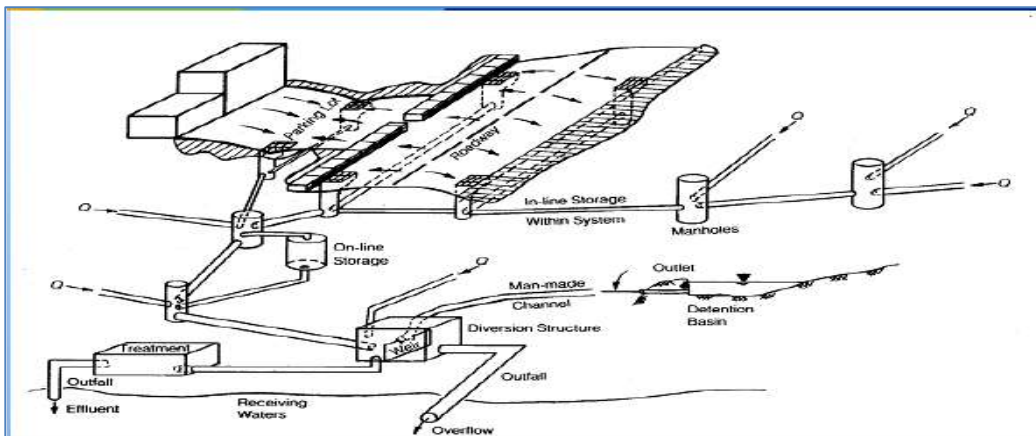


Figure 5.1 - Typical structure with in SWMM

5.3.2 Hydrology

SWMM represents catchments as single slope with kinematic wave routing. The idealization of a catchment section is shown in figure 5.2

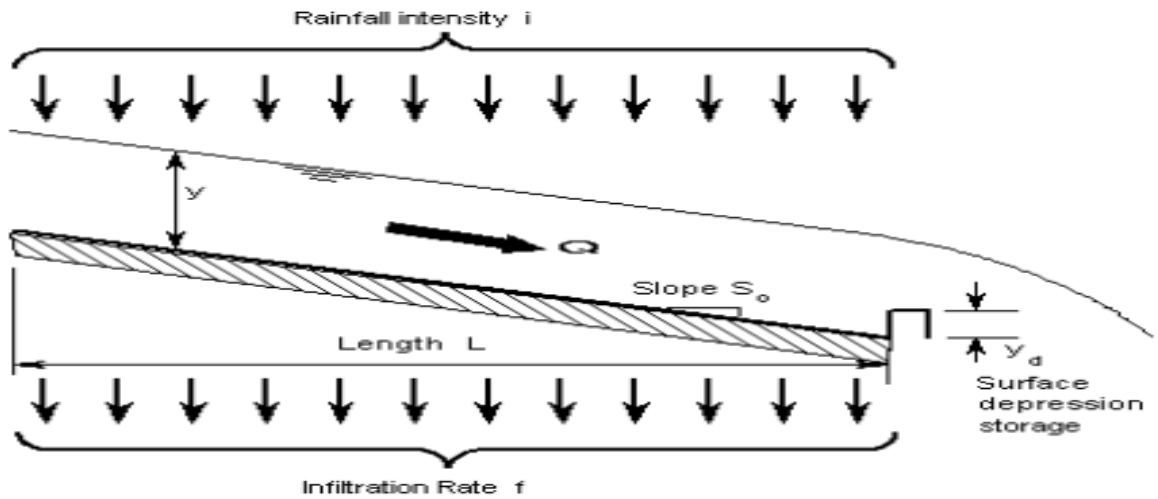


Figure 5.2 – Idealization of the Section of a sub-catchment with in SWMM

The following conceptualization is used with in SWMM to simulate the rainfall – runoff process is shown in figure 5.3.

Each sub-catchment is treated as a non-linear reservoir and inflow receives from precipitation and runoff from any upstream designated sub-catchments. There is a provision d_p (Depression storage) for maximum surface storage and which can be used to represent the interception and depression storage.

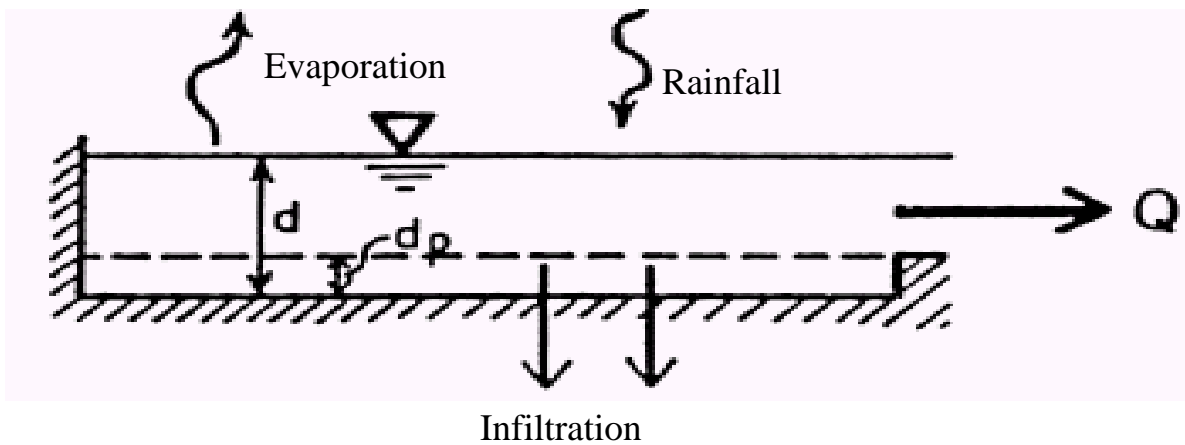


Figure 5.3 - Rainfall-Runoff model structure with in SWMM

The out flow only occurs when the $d > d_p$ and the outflow discharge is calculated by using the manning's equation. The sub-catchment is assumed as a broad rectangular channel in calculating the runoff and the following equation is used.

$$Q = W \frac{1.49}{n} (d - d_p)^{5/3} S^{1/2}$$

5.3.3. Evaporation

Evaporation value was taken as 4mm day. However, the model could be more fine-tuned with more accurate values of evaporation.

5.3.4 Characteristic width & slope of the sub-catchment

Characteristic width of a sub-catchment is normally found by dividing the catchment area by its characteristic sheet flow length. The idealization of a sub-catchment is shown in figure 5.4 .

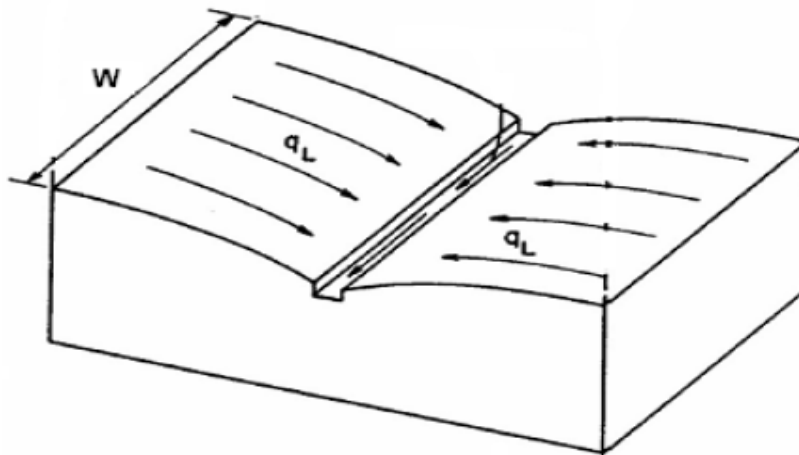


Figure 5.4 - Idealization of a sub catchment to calculate the characteristic width of the catchment

However, based on the site visits, the physical drainage process of the two Islands deviate from this assumption and the model idealization of the actual drainage process within one typical sub-catchment are presented in figure 5.5.

The runoff from individual premises is drained out to the road by pipes through the boundary walls and subsequently this runoff flows as sheet flow along the road towards the inlet point at the junction. The sheet flow routing within a sub-catchment occurs primarily along the roads. Therefore, the width of the road was taken as the width of sheet flow routing of each sub-catchment. Further, the limiting of the characteristic width to the road will enable to take account of the delay in the runoff within the household boundaries and thereby attenuation of the hydrograph. Rainfall harvesting and groundwater recharge within the premises already encountered into the model.

For the purpose of modeling, one inlet point per each sub-catchment was defined at the road intersection. However, this one inlet point was divided into number of gratings based on the catchment inflows to inlet points.

The terrain of the island is a flat terrain and therefore, minimum catchment slope of 0.1% was used.

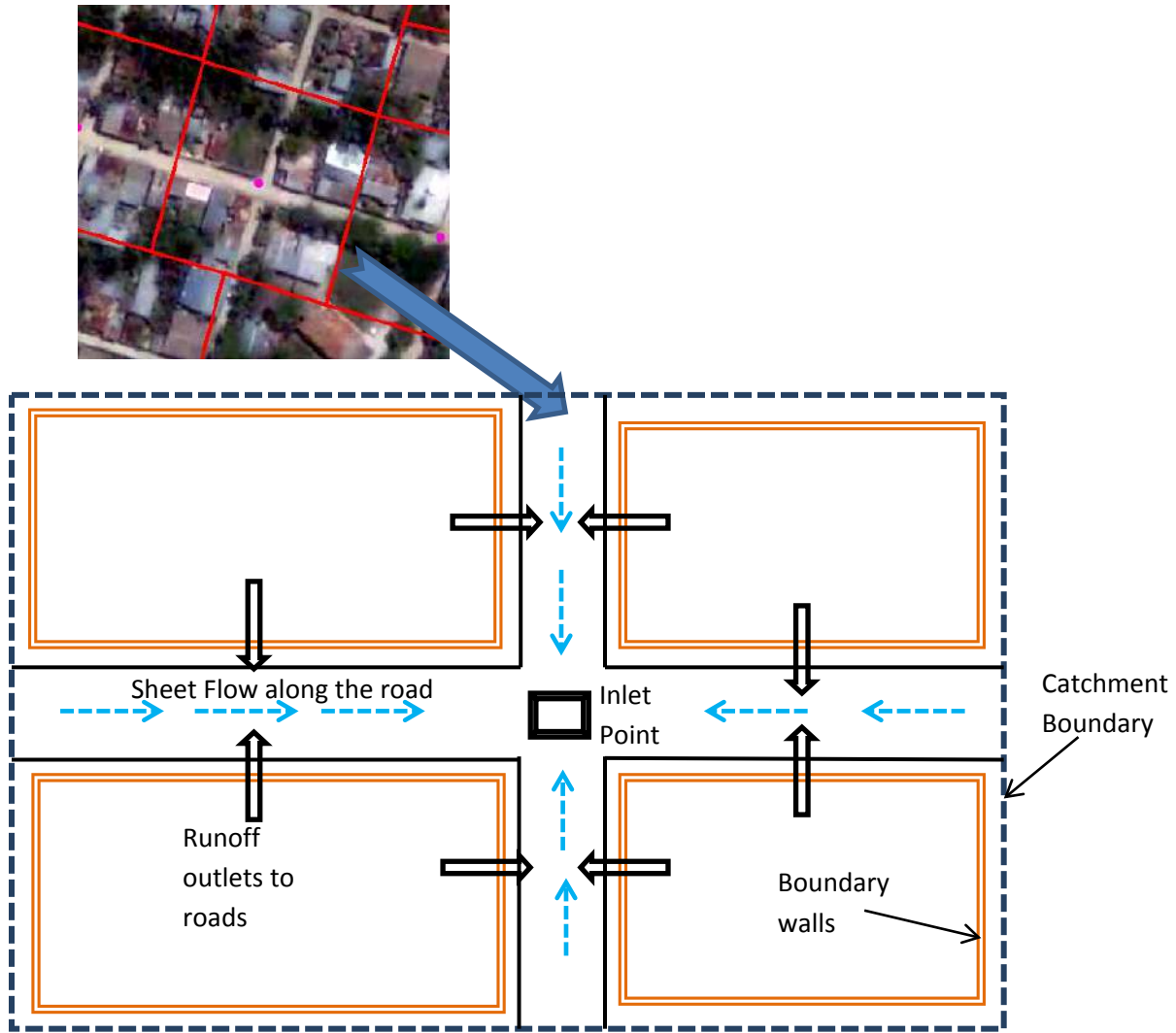


Figure 5.5 - Idealization of a typical sub catchment with in this SWMM model

5.3.5 Depression storage and interception

Parameters are available in SWMM to simulate the initial loss and this was taken as 5mm in order to model the depression filling & interception.

5.3.6 Land Use type & Soil type

The land use pattern is primarily residential as shown in the master plan & the soil type is primarily sandy. However, a 15% of each sub-catchment was defined as impervious and this will represent the paved areas and also allows a fraction for future developments.

5.3.7 Resistance for Sheet flow

Manning's equation for broad rectangular channels is used to simulate the friction of sheet flow as shown in figure 5.5 and Manning's n value of 0.05 was used for the flow in pervious areas and 0.012 was taken as the n value for impervious areas within each sub-catchment.

5.3.8 Infiltration

Infiltration is the rate at which surface water percolates into the ground. It is often expressed as cm or inches per hour, but the SI amount is $m s^{-1}$. The rate depends on a number of factors including soil type, soil moisture, vegetation, and temperature. Typically, the smaller the grains of soil, the more slowly water percolates into the ground. Also, the wetter the ground, the less room for water to infiltrate and consequently, the slower the rate.

The infiltration plays a major role in order to calculate the effective rainfall. There are several methods available to model the infiltration with in SWMM model set up. The Horton's method was selected as the infiltration method for the modeling of this project by considering actual geographical conditions of these two Islands.

Horton's theory is based on the fact that infiltration is faster in dry ground, so as rain continues and the ground becomes wetter, the infiltration rate decreases. The reason that infiltration is faster when the ground is dry is that there are more spaces for the water to fill so capillary forces that pull the water down into the ground are stronger.

Horton's Equation is the governing heuristic equation for infiltration,

$$(f - f_c) = (f_0 - f_c)e^{-kt}$$

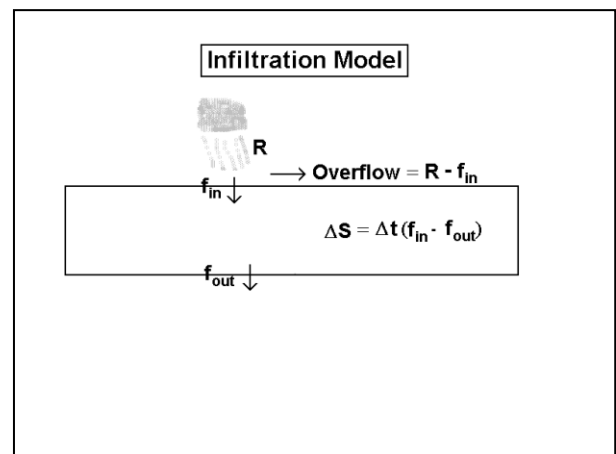
Where,

f = infiltration rate

f_0 = (initial) infiltration rate for dry ground

f_c = (asymptotic) infiltration rate for saturated ground

k = infiltration constant (Decay Constant)



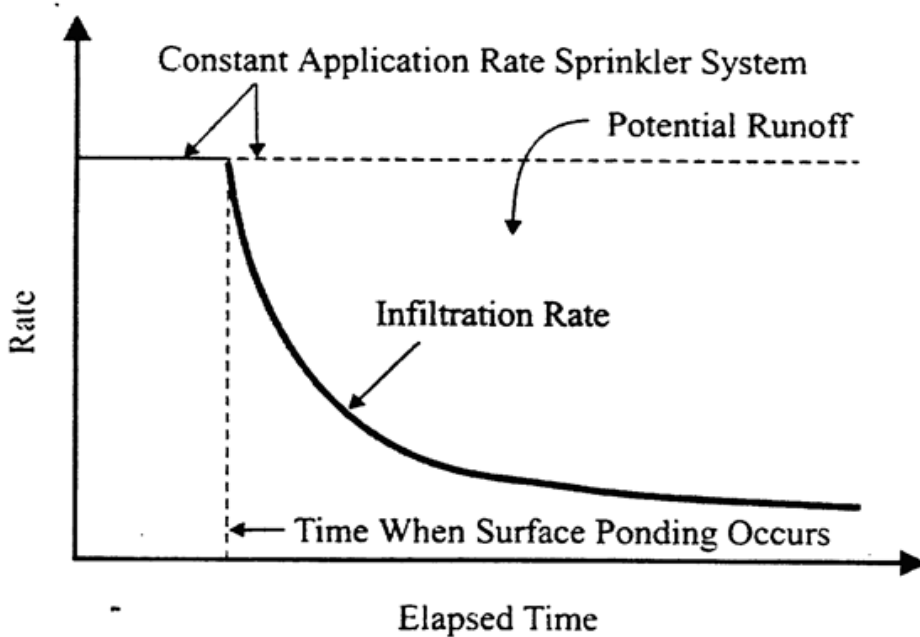


Figure 5.6 – Horton's infiltration

Horton's infiltration equation assumes the constant supply of water in excess of evaporation capacity and however, the calculation process could be modified in case of the rainfall is less than the infiltration capacity. See figure 5.6.

The maximum infiltration capacity was taken based on the following criteria

1. DRY soils (with little or no vegetation):
 Sandy soils: 5 in/hr
 Loam soils: 3 in/hr
 Clay soils: 1 in/hr
2. DRY soils (with dense vegetation):
 Multiply values given in A. by 2
3. MOIST soils
 Soils which have drained but not dried out (i.e., field capacity):
 Divide values from A and B by 3.
 Soils close to saturation:
 Choose value close to min. infiltration rate.
 Soils which have partially dried out:

Divide values from A and B by 1.5 - 2.5.

The minimum infiltration is essentially the saturated hydraulic conductivity, or "permeability", of soils. The tables 5.1, 5.2 & 5.3 were referred for better estimation of this parameter.

Minimum (Asymptotic) Infiltration Rate, F_c		
Hydrologic Soil Group	(in/hr)	(mm/hr)
A	0.30 - 0.45	7.6 - 11.4
B	0.15 - 0.30	3.8 - 7.6
C	0.05 - 0.15	1.3 - 3.8
D	0.00 - 0.05	0.0 - 1.3

Table 5.1 – Minimum Infiltration rates by Musgrave, 1955

Soil Texture Class	K	Y	f	FC	WP
Sand	4.74	1.93	0.437	0.062	0.024
Loamy Sand	1.18	2.4	0.437	0.105	0.047
Sandy Loam	0.43	4.33	0.453	0.19	0.085
Loam	0.13	3.5	0.463	0.232	0.116
Silt Loam	0.26	6.69	0.501	0.284	0.135
Sandy Clay Loam	0.06	8.66	0.398	0.244	0.136
Clay Loam	0.04	8.27	0.464	0.31	0.187
Silty Clay Loam	0.04	10.63	0.471	0.342	0.21
Sandy Clay	0.02	9.45	0.43	0.321	0.221
Silty Clay	0.02	11.42	0.479	0.371	0.251
Clay	0.01	12.6	0.475	0.378	0.265

Table 5.2 – Characteristics of various Soils

- K** = hydraulic conductivity, in/hr
- Y** = suction head, in.
- f** = porosity, fraction
- FC** = field capacity, fraction
- WP** = wilting point, fraction

Source: Rawls, W.J. et al., (1983). *J. Hyd. Engr.*, 109:1316

<u>Soil Type</u>	<u>(in/hr)</u>	<u>(mm/hr)</u>
Clay loam, silty clay loam, sandy clay, silty clay, clay	0.00 - 0.05	0.00 - 1.3
Sandy clay loam	0.05 - 0.15	1.3 - 3.8
Silt loam, loam	0.15 - 0.30	3.8 – 7.6
Sand, loamy sand, sandy loam	0.30 - 0.45	7.6 – 11.4

Table 5.3 – Minimum infiltration capacities suggested by Akan, 1993

The minimum (asymptotic) infiltration rate is often close to the saturated hydraulic conductivity of the soil.

5.3.9. Hydrodynamic modeling

Once the sub-catchment flow reaches the inlet point the hydro-dynamic flow routing occurs along the pipes up to a storage tank or emergency outlet.

5.3.9.1 Wave approximation

The flow propagation as unsteady flow and the unsteady flow is associated depending on the simplifications to the Saint Venant flow equations. The Dynamic wave option is used with in this model set up so that it solves the Complete Saint Venant flow equations for one dimensional flow and the water levels at nodes and the flow in conduits is couples together by the model. The use of dynamic wave option provides a better simulation of backwater effects, channel storage etc. and thereby enhance the accuracy.

5.3.9.2 Resistance to Flow

The routing method requires resistance equation to relate the flow rate to water depth and friction slope. The manning’s equation was used as the resistance equation when the flow is under open channel state & Hazen Williams equation was used for the pressurized flow.

Manning's Equation

Manning's equation is the most commonly used open channel flow equation. The roughness component, C, is typically assumed to be constant over the full range of flows and is represented by a Manning's roughness value, n. These 'n'- values have been experimentally determined for various materials and should not be used with fluids other than water.

Manning's equation is:

$$V = \frac{k}{n} R^{2/3} S^{1/2}$$

V = Mean velocity (m/s, ft./s)

k = 1.49 for U.S. customary Units, 1.00 for SI Units

n = Manning's roughness value

R = Hydraulic radius (m, ft.)

S = Friction slope (m/m, ft./ft.)

The Manning's Roughness Values (n) was selected as per the Table 5.4.

Hazen-Williams Equation

The Hazen-Williams equation is most frequently used in the design and analysis of pressure pipe systems. The equation was developed experimentally, and therefore should not be used for fluids other than water (and only within temperatures normally experienced in potable water systems). The Hazen-Williams equation is:

$$V = kCR^{0.63}S^{0.54}$$

Where V = Mean velocity(m/s, ft./s)

k = 1.32 for U.S. customary units, or 0.85 for SI

C = Hazen-

R = Hydraulic radius(m, ft.)

S = Friction slope(m/m, ft./ft.)

The Hazen-Williams roughness coefficient (C) was selected as per the Table 5.5.

Conduit Material	Manning n
Asbestos-cement pipe	0.011 - 0.015
Brick	0.013 - 0.017
Cast iron pipe	
- Cement-lined & seal coated	0.011 - 0.015
Concrete (monolithic)	
- Smooth forms	0.012 - 0.014
- Rough forms	0.015 - 0.017
Concrete pipe	0.011 - 0.015
Corrugated-metal pipe (1/2-in. x 2-2/3-in. corrugations)	
- Plain	0.022 - 0.026
- Paved invert	0.018 - 0.022
- Spun asphalt lined	0.011 - 0.015
Plastic pipe (smooth)	0.011 - 0.015
Vitrified clay	
- Pipes	0.011 - 0.015
- Liner plates	0.013 - 0.017

Table 5.4 – Manning’s roughness n for closed conduits

Source: ASCE (1982). *Gravity Sanitary Sewer Design and Construction*, ASCE Manual of Practice No. 60, New York, NY.

Pipe Material	Values for C		
	Range High/Low	Average Value	Typical Design Value
Plastic, PVC, Polyethylene pipe or tubing	160/150	150-155	150
Cement or mastic lined iron or steel pipe	160/130	148	140
Copper, brass, lead, tin or glass pipe or tubing	150/120	140	130
Wood Stave	145/110	120	110
Welded or Seamless Steel	150/80	130	100
Cast and ductile iron	150/80	130	100
Concrete	152/85	120	100
Corrugated steel	-	60	60

Table 5.5 – Hazen-Williams fiction factor C

5.3.10. Model Calibration

Since this is a new drainage network, proper calibration of the model is a difficult task. However, the maximum discharges in the sub-catchments were compared with the rational values and the peak values calculated from individual houses along the roads.

- ❖ As there is no intention of providing pumps, the drainage will be by gravity alone. But ground tank already provided in the vicinity of emergency outlet which can be used, if need arises for pumping or pump water to RO facility.
- ❖ Low elevated levels of the roads already considered for possible minimum filling after carrying out value engineering and possible height is 150 mm.
- ❖ There are several locations acting as ponding areas during rainy period. Some of these can be improved to increase detention capacity. Study has already been carried out to determine the functioning of these ponding areas and verified whether which locations are vulnerable to storm water storage during rainy period.
- ❖ The existing structures to the sea will be rehabilitated with automatic flap gates. Design water levels at the outlet will be the observed average low tide levels in the North East monsoon. However high tide level also be considered in design in order to check the functioning of the system under external condition. See Figure 9.1 & Table 9.1.
- ❖ Volume of water retaining on the roads within stipulated time period already compared with the maximum runoff coming from individual premises.
- ❖ Peak discharge received from model output already compared with the peak discharge calculated from rational method.

6.0 Storm water Management Plan

The entire proposed drainage network figure 6.1 for the G Dh Thinadhoo Island was modeled with in the SWMM model setup as per the design criteria stipulated in Section 05.



Figure 6.1 SWMM model set up for G Dh Thinadhoo Island

The road levels below 1.0m MSL are proposed to be raised up to 1.0m,MSL throughout the road. All the storm water runoff with in the drainage network are directed to storage tanks as much as possible and there by the outflow to the sea has been made minimal so that the people could get the maximum utilization of water while being free of inundation.

The maximum depth at nodes with in SWMM was selected such that the top of these nodes represent the ground elevation. Thereby any flooding could be identified by the longitudinal flow profile. The pipes of the drainage network were sized so that there is no flooding and the network has the capacity to drain out the water.

Typical flow hydrograph obtained by the model is shown in figure 6.2.

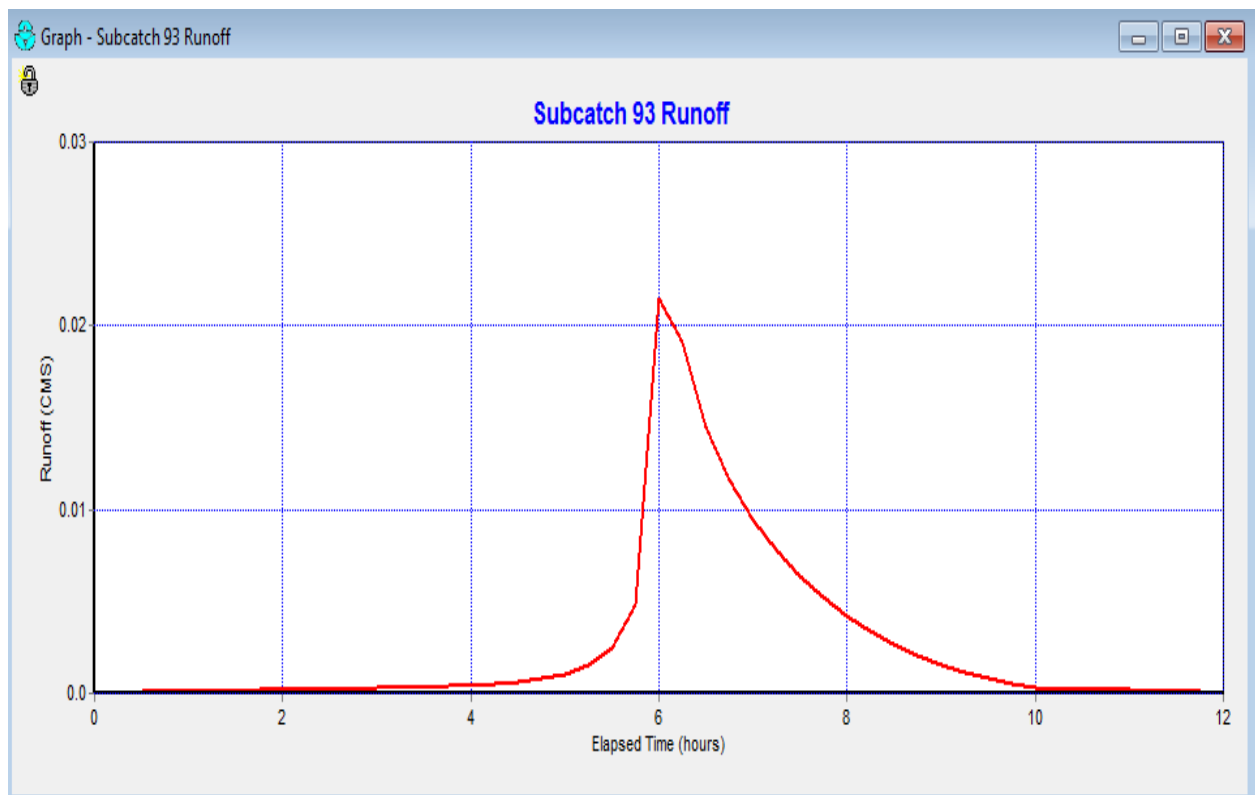


Figure 6.2 Outflow hydrograph of a typical sub catchment

Proposed pipe line network and ground tank for zone A is shown in figure 6.3.

Proposed pipe line network and ground tank for zone B is shown in Figure 6.4.

Details of summary of pipe for Zone A is shown in table 6.1

Details of summary of nodes for Zone A is shown in table 6.2

Details of summary of pipe for Zone B are shown in table 6. 3

Details of summary of nodes for Zone B is shown in table 6.4

Details of summary of pipe for Zone C is shown in table 6.5

Details of summary of nodes for Zone C is shown in table 6.6

Details of summary of pipe for Zone D is shown in table 6.7

Details of summary of nodes for Zone D is shown in table 6.8

Details of summary of pipe for Zone E is shown in table 6.9

Details of summary of nodes for Zone E is shown in table 6.10

Volume of ground storage tank for zone A is shown in table 6.11

Volume of ground storage tank for zone B is shown in table 6.12

Volume of ground storage tank for zone C is shown in table 6.13

Volume of ground storage tank for zone D is shown in table 6.14

Volume of ground storage tank for zone E is shown in table 6.15

Tripartite section of water elevation profile for zone A is shown in figure 6.9

Tripartite section of water elevation profile for zone B is shown in figure 6.12

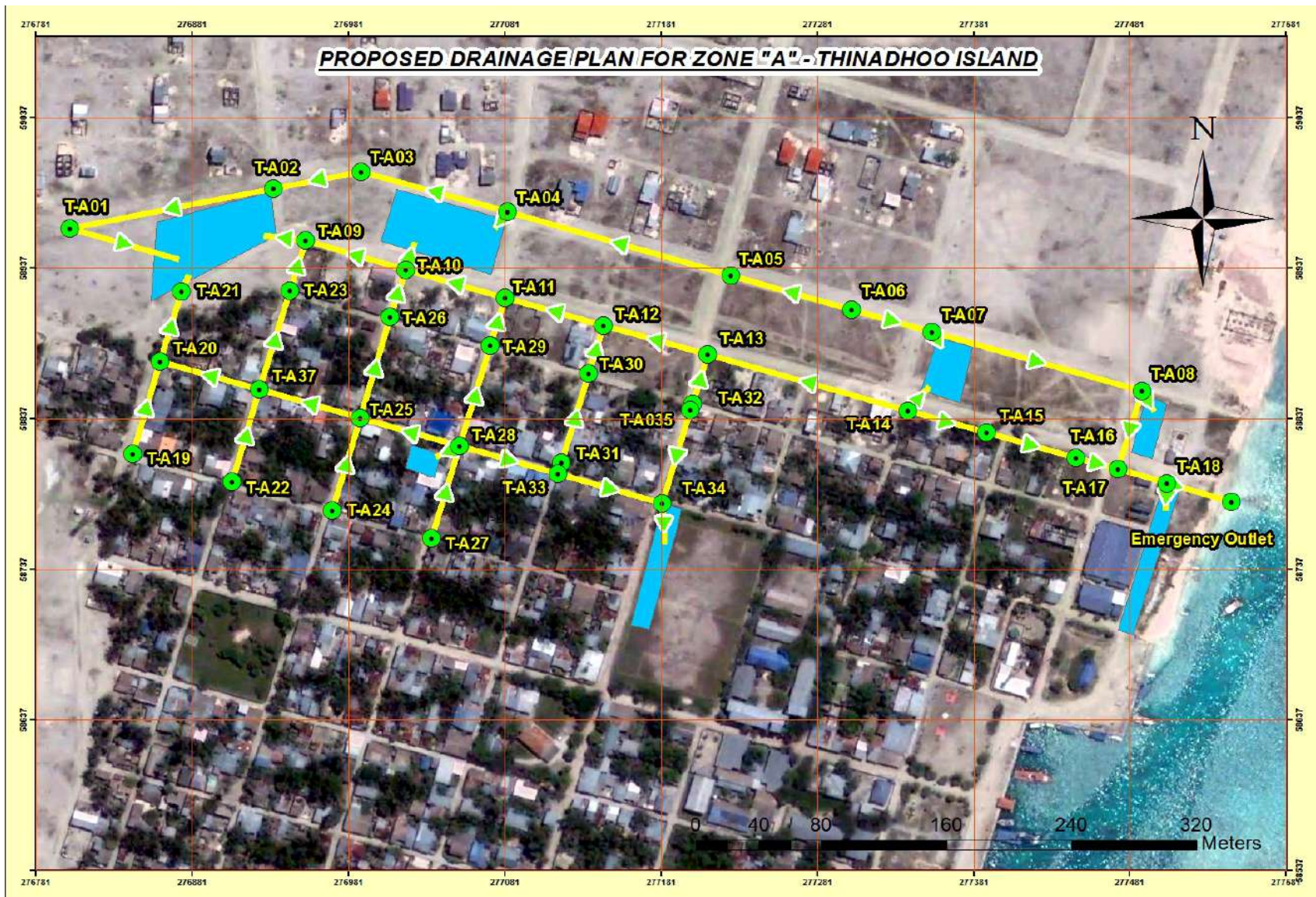


Figure 6.3 Proposed pipe line network and ground tank for zone A.

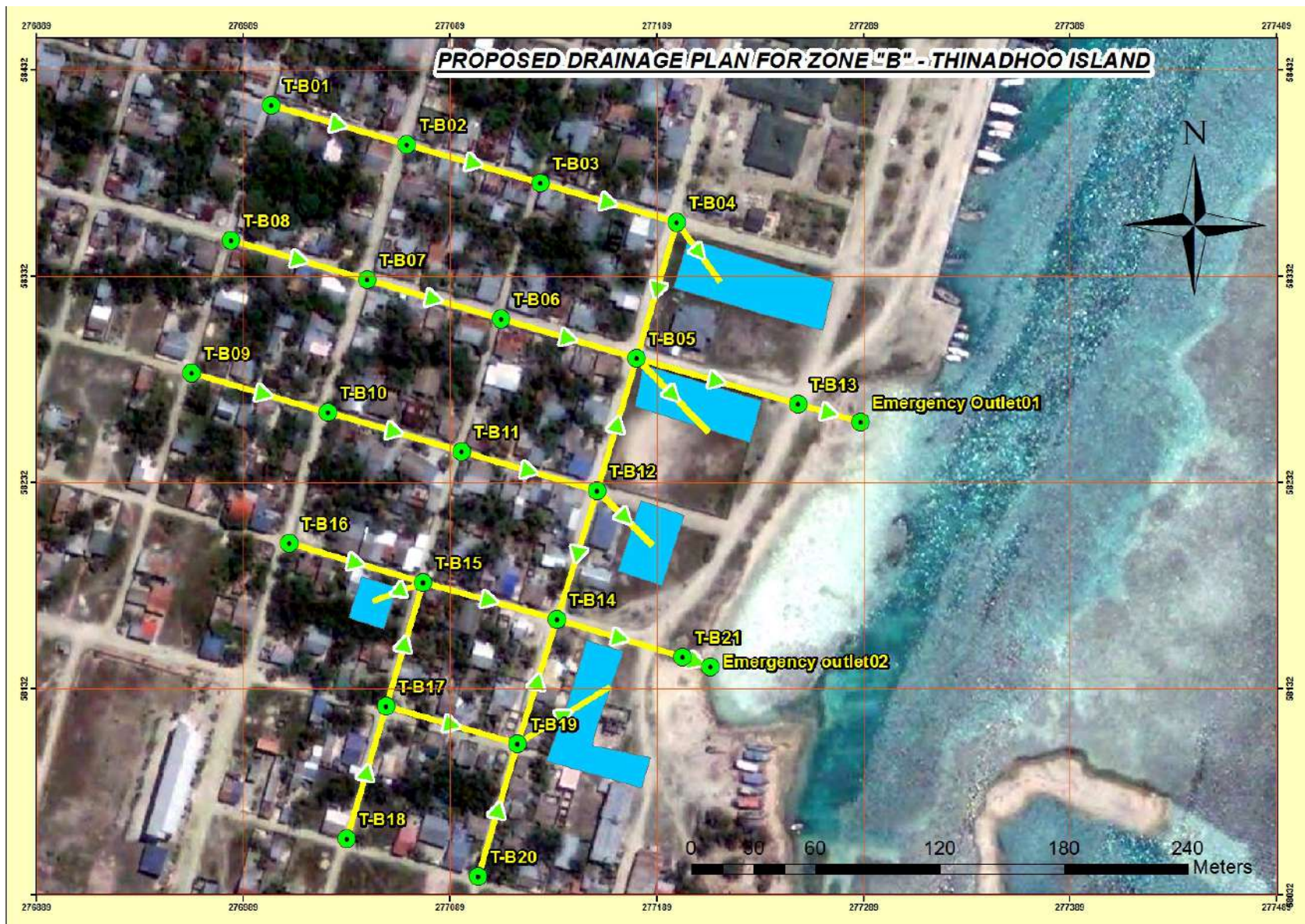


Figure 6.4 Proposed pipe line network and ground tank for zone B

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%)
T-A01	T-A02	138	0.2	1	0.001
T-A02	T-A03	50	0.2	1	0.001
T-A03	T-A04	137	0.2	1	0.001
T-A04	T-A05	108	0.2	2	0.001
T-A05	T-A06	82	0.2	1	0.001
T-A06	T-A07	52	0.2	2	0.001
T-A07	T-A08	137	0.2	1	0.001
T-A08	T-A17	53	0.2	1	0.001
T-A09	T-A10	69	0.3	1	0.001
T-A10	T-A11	65	0.3	1	0.001
T-A11	T-A12	66	0.3	1	0.001
T-A12	T-A13	67	0.3	1	0.001
T-A13	T-A14	129	0.3	1	0.001
T-A14	T-A15	57	0.3	1	0.001
T-A15	T-A16	62	0.3	1	0.001
T-A16	T-A17	22	0.3	1	0.001
T-A17	T-A18	32	0.3	2	0.001
T-A18	Outlet	43	0.3	2	0.001
T-A19	T-A20	67	0.2	1	0.002
T-A20	T-A21	36	0.2	2	0.002
T-A22	T-A37	65	0.2	1	0.0015
T-A37	T-A23	65	0.2	1	0.0015
T-A23	T-A09	40	0.2	1	0.0015
T-A24	T-A25	65	0.2	1	0.0015
T-A25	T-A26	65	0.2	1	0.0015
T-A26	T-A10	40	0.2	1	0.0015
T-A27	T-A28	65	0.2	1	0.0015
T-A28	T-A29	65	0.2	1	0.0015
T-A29	T-A11	40	0.2	1	0.0015
T-A31	T-A30	65	0.2	1	0.0015
T-A30	T-A12	40	0.2	1	0.0015
T-A32	T-A13	36	0.2	1	0.0015
T-A37	T-A20	67	0.2	1	0.0015
T-A25	T-A37	67	0.2	1	0.0015
T-A28	T-A25	67	0.2	1	0.0015
T-A28	T-A33	67	0.2	1	0.0015
T-A33	T-A34	67	0.2	1	0.0015
T-A35	T-A34	64	0.2	1	0.0015

Table 6.1 Zone A Summary of pipes

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
T-A01	0.2	0.963	0.15
T-A02	0.249	0.968	0.519
T-A03	0.299	1.085	0.586
T-A04	0.436	1.042	0.406
T-A05	0.544	0.855	0.111
T-A06	0.626	1.011	0.185
T-A07	0.574	0.969	0.195
T-A08	0.437	1.011	0.374
T-A09	0.12	0.998	0.678
T-A10	0.189	0.976	0.587
T-A11	0.254	0.691	0.507
T-A12	0.32	0.929	0.409
T-A13	0.387	0.84	0.253
T-A14	0.516	0.912	0.196
T-A15	0.459	0.955	0.296
T-A16	0.397	0.988	0.391
T-A17	0.375	0.929	0.354
T-A18	0.343	0.945	0.402
T-A19	0.287	1.09	0.603
T-A20	0.19	0.956	0.566
T-A21	0.15	0.95	0.6
T-A22	0.384	0.958	0.374
T-A23	0.189	1.057	0.668
T-A24	0.453	1.042	0.389
T-A25	0.356	0.89	0.334
T-A26	0.258	0.745	0.287
T-A27	0.518	1.056	0.338
T-A28	0.421	0.96	0.339
T-A29	0.323	0.924	0.401
T-A30	0.389	0.966	0.377
T-A31	0.487	1.078	0.391
T-A32	0.45	0.798	0.148
T-A33	0.321	1.078	0.557
T-A34	0.421	1.059	0.438
T-A35	0.274	0.798	0.324
T-A37	0.287	0.853	0.366
Outlet	0.3		

Table 6.2 Summary of Nodes Zone A

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%)
T-B01	T-B02	69	0.2	2	0.0015
T-B02	T-B03	66	0.2	2	0.0015
T-B03	T-B04	67	0.2	2	0.0015
T-B04	T-B05	68	0.3	1	0.001
T-B08	T-B07	69	0.2	2	0.001
T-B07	T-B06	66	0.2	2	0.001
T-B06	T-B05	67	0.2	2	0.001
T-B05	T-B13	86	0.3	2	0
T-B13	Outlet 01	45	0.3	2	0
T-B05	T-B12	68	0.3	1	0.001
T-B09	T-B10	69	0.2	2	0.001
T-B10	T-B11	66	0.2	2	0.001
T-B11	T-B12	67	0.2	2	0.001
T-B12	T-B14	68	0.3	1	0.001
T-B14	T-B21	68	0.3	2	0
T-B21	Outfall	30	0.3	2	0
T-B15	T-B14	66	0.2	2	0.001
T-B16	T-B15	67	0.2	2	0.001
T-B17	T-B15	67	0.2	2	0.0005
T-B18	T-B17	67	0.2	2	0.0005
T-B19	T-B14	67	0.2	2	0.001
T-B20	T-B19	67	0.2	2	0.001
T-B17	T-B19	66	0.2	2	0.001

Table 6.3 Summary of pipes Zone B

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
T-B01	0.671	1.139	0.268
T-B02	0.568	1.178	0.41
T-B03	0.469	1.037	0.369
T-B04	0.368	0.783	0.215
T-B05	0.3	0.669	0.169
T-B06	0.367	0.835	0.268
T-B07	0.433	0.9	0.267
T-B08	0.502	0.924	0.222
T-B09	0.502	1	0.298
T-B10	0.433	1	0.367
T-B11	0.367	0.882	0.305
T-B12	0.3	0.738	0.238
T-B13	0.3	0.663	0.163
T-B14	0.3	0.726	0.26
T-B15	0.366	0.775	0.209
T-B16	0.433	0.853	0.22
T-B17	0.4	0.77	0.171
T-B18	0.433	0.647	0.014
T-B19	0.367	0.701	0.134
T-B20	0.434	0.769	0.135
T-B21	0.3	0.587	0.07
Outlet 01	0.3		
Outlet 02	0.3		

Table 6.4 Summary of Nodes Zone B

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%)
Node-T-C-01	Node-T-C-05	64	0.2	1	0.15
Node-T-C-04	Node-T-C-05	67	0.2	2	0.2
Node-T-C-05	Node-T-C-06	67	0.2	2	0.2
Node-T-C-06	Node-T-C-07	67	0.2	2	0.1
Node-T-C-03	Node-T-C-07	64	0.2	1	0.1
Node-T-C-07	Node-T-C-08	66	0.2	2	0.1
Node-T-C-08	Node-T-C-09	54	0.3	2	0.1
Node-T-C-09	Outfall-06	49	0.3	2	0.1
Node-T-C-06	Node-T-C-12	64	0.2	2	0.1
Node-T-C-10	Node-T-C-11	67	0.2	1	0.15
Node-T-C-11	Node-T-C-12	67	0.2	2	0.15
Node-T-C-15	Node-T-C-12	48	0.2	1	0.15
Node-T-C-14	Node-T-C-15	18	0.2	1	0.1
Node-T-C-20	Node-T-C-15	64	0.2	1	0.15
Node-T-C-16	Node-T-C-20	56	0.2	1	0.15
Node-T-C-16	Outfall-05	30	0.3	2	0.1
Node-T-C-19	Node-T-C-18	61	0.2	1	0.15
Node-T-C-18	Node-T-C-17	65	0.2	2	0.15
Node-T-C-17	Node-T-C-14	68	0.2	1	0.15
Node-T-C-13	Node-T-C-14	67	0.2	1	0.15

Table 6.5 Summary of pipes Zone C

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
Node-T-C-01	0.436	0.879	0.243
Node-T-C-02	0.366	0.81	0.244
Node-T-C-03	0.433	0.739	0.106
Node-T-C-04	0.474	0.869	0.195
Node-T-C-05	0.34	0.85	0.31
Node-T-C-06	0.27	0.723	0.253
Node-T-C-07	0.337	0.687	0.15
Node-T-C-08	0.403	0.65	0.047
Node-T-C-09	0.349	0.7	0.151
Node-T-C-10	0.407	0.794	0.187
Node-T-C-11	0.307	0.864	0.357
Node-T-C-12	0.206	0.843	0.437
Node-T-C-13	0.437	0.766	0.13
Node-T-C-14	0.336	0.639	0.103
Node-T-C-15	0.318	0.76	0.242
Node-T-C-16	0.33	0.605	0.075
Node-T-C-17	0.234	0.702	0.268
Node-T-C-18	0.332	0.694	0.163
Node-T-C-19	0.423	0.674	0.051
Node-T-C-20	0.414	0.622	0.008
Outfall-05	0.3		
Outfall-06	0.3		

Table 6.6 Summary of Nodes Zone C

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%)
Node-T-D-01	Node-T-D-06	63	0.2	1	0.2
Node-T-D-02	Node-T-D-07	63	0.2	1	0.2
Node-T-D-03	Node-T-D-08	63	0.2	1	0.2
Node-T-D-04	Node-T-D-09	63	0.2	1	0.2
Node-T-D-09	Node-T-D-08	67	0.2	2	0.2
Node-T-D-08	Node-T-D-07	68	0.2	2	0.2
Node-T-D-07	Node-T-D-06	66	0.2	2	0.2
Node-T-D-05	Node-T-D-06	67	0.2	2	0.2
Node-T-D-12	Node-T-D-06	66	0.2	1	0.2
Node-T-D-16	Node-T-D-15	67	0.2	1	0.2
Node-T-D-13	Node-T-D-14	67	0.2	2	0.1
Node-T-D-12	Node-T-D-13	65	0.2	2	0.1
Node-T-D-11	Node-T-D-12	67	0.2	2	0.1
Node-T-D-11	Node-T-D-10	50	0.2	1	0.2
Node-T-D-10	Node-T-D-17	66	0.2	1	0.1
Node-T-D-32	Node-T-D-23	66	0.2	1	0.2
Node-T-D-23	Node-T-D-22	66	0.2	2	0.2
Node-T-D-31	Node-T-D-21	66	0.2	1	0.1
Node-T-D-20	Node-T-D-21	66	0.2	1	0.1
Node-T-D-19	Node-T-D-20	66	0.2	1	0.1
Node-T-D-18	Node-T-D-19	67	0.2	1	0.1
Node-T-D-18	Node-T-D-17	48	0.2	1	0.2
Node-T-D-17	Outfall 04	20	0.3	2	0.2
Node-T-D-28	Node-T-D-25	67	0.2	1	0.1
Node-T-D-25	Node-T-D-24	66	0.2	1	0.1
Node-T-D-27	Node-T-D-24	66	0.2	1	0.1
Node-T-D-26	Outfall 07	66	0.3	2	0.3
Node-T-D-26	Node-T-D-27	69	0.2	1	0.2
Node-T-D-27	Node-T-D-28	67	0.2	1	0.1
Node-T-D-28	Node-T-D-29	66	0.2	1	0.1
Node-T-D-30	Node-T-D-29	43	0.2	1	0.1
Node-T-D-35	Node-T-D-28	65	0.2	1	0.2
Node-T-D-34	Node-T-D-27	65	0.2	1	0.2
Node-T-D-33	Node-T-D-26	66	0.2	1	0.2
Node-T-D-08	Node-T-D-14	66	0.2	1	0.1

Table 6.7 Summary of pipes Zone D

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
Node-T-D-01	0.422	0.825	0.203
Node-T-D-02	0.554	1.108	0.354
Node-T-D-03	0.63	1.221	0.391
Node-T-D-04	0.764	1.292	0.328
Node-T-D-05	0.25	0.839	0.389
Node-T-D-06	0.3	0.933	0.433
Node-T-D-07	0.432	1.246	0.614
Node-T-D-08	0.508	1.284	0.576
Node-T-D-09	0.642	1.448	0.606
Node-T-D-10	0.334	0.71	0.176
Node-T-D-11	0.434	0.748	0.114
Node-T-D-12	0.367	0.93	0.363
Node-T-D-13	0.302	1.157	0.655
Node-T-D-14	0.25	1.478	1.028
Node-T-D-15	0.3	1.45	0.95
Node-T-D-16	0.434	1.54	0.906
Node-T-D-17	0.34	0.852	0.34
Node-T-D-18	0.434	0.774	0.14
Node-T-D-19	0.368	0.873	0.305
Node-T-D-20	0.302	1.213	0.711
Node-T-D-21	0.25	1.13	0.68
Node-T-D-22	0.3	1.34	0.84
Node-T-D-23	0.43	1.24	0.61
Node-T-D-24	0.16	0.775	0.415
Node-T-D-25	0.226	0.89	0.464
Node-T-D-26	0.498	0.672	0
Node-T-D-27	0.36	0.677	0.117
Node-T-D-28	0.293	0.938	0.445
Node-T-D-29	0.228	1.01	0.582
Node-T-D-30	0.271	1	0.529
Node-T-D-31	0.316	1.123	0.607
Node-T-D-32	0.562	1.059	0.297
Node-T-D-33	0.63	0.857	0.027
Node-T-D-34	0.492	0.864	0.172
Node-T-D-35	0.425	0.909	0.284
Outfall 04	0.3		
Outfall 07	0.3		

Table 6.8 Summary of Nodes Zone D

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%)
Node-T-E-01	Node-T-E-02	67	0.2	1	0.2
Node-T-E-02	Node-T-E-03	65	0.2	1	0.2
Node-T-E-03	Node-T-E-04	34	0.2	2	0.2
Node-T-E-05	Node-T-E-06	67	0.2	1	0.2
Node-T-E-06	Node-T-E-07	65	0.2	2	0.2
Node-T-E-07	Node-T-E-08	34	0.2	2	0.2
Node-T-E-09	Node-T-E-10	67	0.2	1	0.2
Node-T-E-10	Node-T-E-11	65	0.2	2	0.2
Node-T-E-11	Node-T-E-12	34	0.2	2	0.2
Node-T-E-13	Node-T-E-14	67	0.2	1	0.2
Node-T-E-14	Node-T-E-15	65	0.2	1	0.2
Node-T-E-15	Node-T-E-16	34	0.2	2	0.2
Node-T-E-17	Node-T-E-18	65	0.2	1	0.2
Node-T-E-18	Node-T-E-19	59	0.2	1	0.2
Node-T-E-20	Node-T-E-21	67	0.2	2	0.2
Node-T-E-21	Node-T-E-22	78	0.2	2	0.2
Node-T-E-23	Node-T-E-20	66	0.2	1	0.2
Node-T-E-24	Node-T-E-21	66	0.2	1	0.2
Node-T-E-16	Node-T-E-19	67	0.2	2	0.2
Node-T-E-08	Node-T-E-04	69	0.2	2	0.2
Node-T-E-08	Node-T-E-12	63	0.2	2	0.2
Node-T-E-25	Node-T-E-03	69	0.2	1	0.1

Table 6.9 Summary of pipes Zone E

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
Node-T-E-01	0.642	0.966	0.124
Node-T-E-02	0.51	0.973	0.263
Node-T-E-03	0.38	1.038	0.458
Node-T-E-04	0.3	1.272	0.772
Node-T-E-05	0.638	1.122	0.284
Node-T-E-06	0.506	1.102	0.396
Node-T-E-07	0.376	1.37	0.794
Node-T-E-08	0.31	1.146	0.636
Node-T-E-09	0.628	1.261	0.433
Node-T-E-10	0.496	1.403	0.707
Node-T-E-11	0.366	1.227	0.661
Node-T-E-12	0.3	1.112	0.612
Node-T-E-13	0.638	1.327	0.489
Node-T-E-14	0.506	1.477	0.771
Node-T-E-15	0.376	1.36	0.784
Node-T-E-16	0.31	1.05	0.54
Node-T-E-17	0.548	1.591	0.843
Node-T-E-18	0.418	1.489	0.871
Node-T-E-19	0.3	1.192	0.692
Node-T-E-20	0.588	1.371	0.583
Node-T-E-21	0.456	1.416	0.456
Node-T-E-22	0.3	1.096	0.596
Node-T-E-23	0.718	1.009	0.091
Node-T-E-24	0.586	1.039	0.253
Node-T-E-25	0.449	0.802	0.153

Table 6.10 Summary of Nodes Zone E

Name of the Storage Area	Volume (m ³)
Storage Area A01	900
Storage Area A02	725
Storage Area A03	200
Storage Area A04	120
Storage Area A05	120
Storage Area A06	8
Storage Area A07	375

6.11 Volume of ground storage tank ZONE A – G Dh Thinadhoo Island

Name of the Storage Area	Volume (m ³)
Storage Area B01	475
Storage Area B02	125
Storage Area B03	60
Storage Area B04	375
Storage Area B05	14

6.12 Volume of ground storage tank ZONE B – G Dh Thinadhoo Island

ZONE C

Name of the Storage Area	Volume (m ³)
Storage Area C01	300
Storage Area C02	475

6.13 Volume of ground storage tank ZONE C – G Dh Thinadhoo Island

ZONE D

Name of the Storage Area	Volume (m ³)
Storage Area D01	350
Storage Area D02	150
Storage Area D03	10
Storage Area D04	200
Storage Area D05	7
Storage Area D06	200
Storage Area D07	120
Storage Area D08	14
Storage Area D09	375
Storage Area D10	130
Storage Area D11	325
Storage Area D12	18
Storage Area D13	150

*6.14 Volume of ground storage tank ZONE D – G Dh Thinadhoo Island***ZONE E**

Name of the Storage Area	Volume (m ³)
Storage Area E01	18
Storage Area E02	425
Storage Area E03	475
Storage Area E04	600

6.15 Volume of ground storage tank ZONE E – G Dh Thinadhoo Island

6.1 Model Results Analysis

Result analysis for Zone A

The location of Zone “A” and the catchment delineation is depicted in figures 6.7 and 6.8 respectively.



Figure 6.7 -: Location of Zone “A” with in the G Dh Thinadhoo drainage network of SWMM model



Figure 6.8 -: Sub-catchment delineation in Zone A

The simulation results of SWMM model for each and every sub-catchment is shown in tabular format in table 6.16. Thereafter the pipe network was sized and invert levels were defined so that the majority of the flood water stored in the storage units while the maximum water level lies below the ground level. A maximum water level profile along node T-A-09 to T-A-22 is shown in figure 6.9

Sub-catchment	Area Hectares	Total precipitation		Total Infiltration		Total Runoff		Peak Discharge (m3/s)	Equivalent Runoff coefficient
		In mm	In m3	In mm	In m3	In mm	In m3		
Area-A-01	0.94	98.53	922.39	77.49	725.43	20.01	187.32	0.04	0.203
Area-A-02	0.48	98.53	468.15	74.94	356.07	23.58	112.04	0.02	0.239
Area-A-03	0.40	98.53	398.36	74.13	299.71	24.4	98.65	0.02	0.248
Area-A-04	0.79	98.53	782.03	77.49	615.04	20.89	165.80	0.03	0.212
Area-A-05	0.94	98.53	921.82	77.49	724.98	20.01	187.21	0.04	0.203
Area-A-06	0.50	98.53	491.20	75.18	374.79	23.34	116.36	0.02	0.237
Area-A-07	0.75	98.53	734.13	77.28	575.80	21.22	158.11	0.03	0.215
Area-A-08	0.67	98.53	656.54	76.69	511.02	21.81	145.33	0.03	0.221
Area-A-09	0.25	98.53	242.77	71.84	177.01	26.73	65.86	0.01	0.271
Area-A-10	0.19	98.53	188.77	70.81	135.66	27.77	53.20	0.01	0.282
Area-A-11	0.25	98.53	242.11	71.84	176.53	26.73	65.68	0.01	0.271
Area-A-12	0.49	98.53	481.81	75.09	367.19	23.43	114.57	0.02	0.238
Area-A-13	0.49	98.53	482.67	75.1	367.89	23.42	114.73	0.02	0.238
Area-A-14	0.30	98.53	292.21	72.66	215.49	25.9	76.81	0.02	0.263
Area-A-15	0.31	98.53	305.33	72.87	225.82	25.68	79.58	0.02	0.261
Area-A-16	0.31	98.53	305.09	72.87	225.63	25.68	79.52	0.02	0.261
Area-A-17	0.33	98.53	328.82	73.22	244.35	25.33	84.53	0.02	0.257
Area-A-18	0.49	98.53	487.40	75.15	371.74	23.37	115.60	0.02	0.237
Area-A-19	0.33	98.53	327.75	73.2	243.49	25.35	84.32	0.02	0.257
Area-A-20	0.42	98.53	416.35	74.35	314.17	24.18	102.17	0.02	0.245
Area-A-21	0.19	98.53	188.00	70.81	135.11	27.77	52.99	0.01	0.282
Area-A-22	0.49	98.53	478.47	75.06	364.50	23.47	113.97	0.02	0.238
Area-A-23	0.41	98.53	404.30	74.21	304.51	24.33	99.83	0.02	0.247
Area-A-24	0.33	98.53	320.99	73.1	238.14	25.45	82.91	0.02	0.258
Area-A-25	0.45	98.53	448.07	74.73	339.84	23.8	108.23	0.02	0.242
Area-A-26	0.19	98.53	188.50	70.81	135.47	27.77	53.13	0.01	0.282
Area-A-27	0.21	98.53	211.06	71.26	152.65	27.32	58.52	0.01	0.277
Area-A-28	0.49	98.53	480.38	75.07	366.00	23.45	114.33	0.02	0.238
Area-A-29	0.35	98.53	346.88	73.47	258.65	25.08	88.30	0.02	0.255
Area-A-30	0.33	98.53	325.33	73.16	241.57	25.39	83.83	0.02	0.258
Area-A-31	0.22	98.53	216.34	71.52	157.04	27.05	59.39	0.01	0.275
Area-A-32	0.24	98.53	233.44	71.52	169.45	27.05	64.09	0.01	0.275
Area-A-33	0.43	98.53	424.88	74.45	321.04	24.08	103.84	0.02	0.244
Area-A-34	0.19	98.53	189.64	70.83	136.32	27.75	53.41	0.01	0.282
Area-A-35	0.33	98.53	327.84	73.2	243.56	25.35	84.35	0.02	0.257
Area-A-36	0.37	98.53	365.94	73.72	273.80	24.82	92.18	0.02	0.252
Area-A-37	0.32	98.53	314.75	73	233.20	25.55	81.62	0.02	0.259

Table 6.16 -: Simulation results for sub-catchments in Zone A

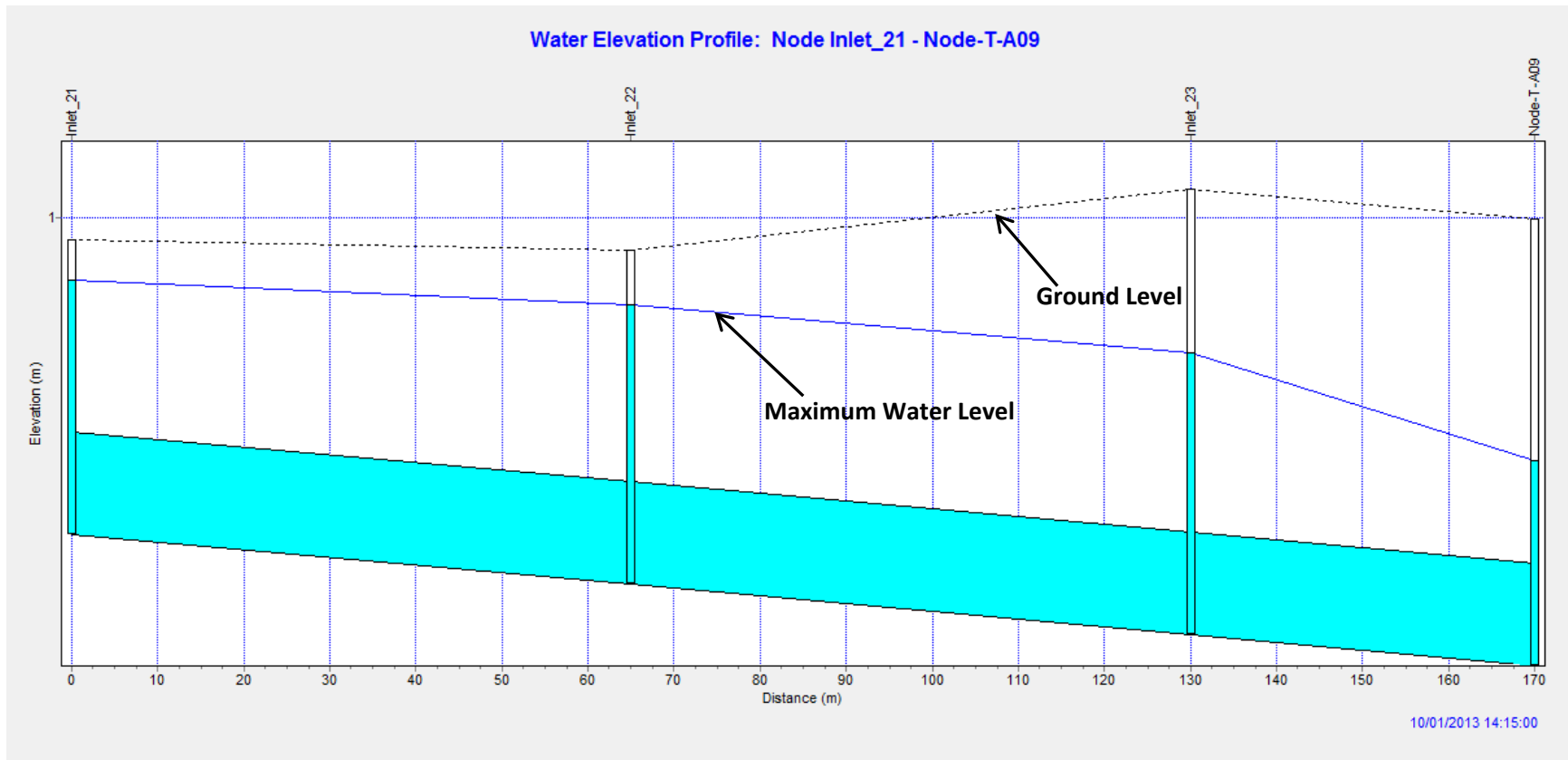


Figure 6.9 -: Maximum Water Level from Node T-A09 to T-A22 of Zone A

Results analysis for Zone “B”

The location and catchment delineation for Zone “B” are depicted in figure 6.10 and 6.11



Figure 6.10 -: Location of Zone “B” with in the G Dh Thinadhoo drainage network of SWMM model



Figure 6.11 -: Sub-catchment delineation in Zone B

The simulation results for sub-catchments in Zone “B” are shown in table 6.17.

Sub-catchment	Area Hectares	Total precipitation		Total Infiltration		Total Runoff		Peak Discharge (m ³ /s)	Equivalent Runoff coefficient
		In mm	In m ³	In mm	In m ³	In mm	In m ³		
Area-B-01	0.67	98.53	655.29	77.49	515.36	19.93	132.55	0.02	0.202
Area-B-02	0.72	98.53	709.87	77.49	558.28	19.51	140.56	0.03	0.198
Area-B-03	0.59	98.53	586.25	77.49	461.06	20.53	122.15	0.02	0.208
Area-B-04	1.14	98.53	1125.54	77.49	885.20	17.2	196.48	0.04	0.175
Area-B-05	0.44	98.53	436.47	74.56	330.29	23.97	106.18	0.02	0.243
Area-B-06	0.46	98.53	453.91	74.78	344.50	23.75	109.41	0.02	0.241
Area-B-07	0.41	98.53	403.73	75.09	307.68	23.43	96.00	0.02	0.238
Area-B-08	0.49	98.53	486.50	75.14	371.01	23.38	115.44	0.02	0.237
Area-B-09	0.34	98.53	336.79	73.33	250.65	25.22	86.20	0.02	0.256
Area-B-10	0.47	98.53	467.12	75.09	355.99	23.43	111.08	0.02	0.238
Area-B-11	0.49	98.53	481.91	75.09	367.27	23.43	114.60	0.02	0.238
Area-B-12	0.47	98.53	466.78	75.09	355.73	23.43	111.00	0.02	0.238
Area-B-13	0.31	98.53	305.13	72.87	225.67	25.68	79.53	0.02	0.261
Area-B-14	0.46	98.53	452.01	74.77	343.01	23.76	109.00	0.02	0.241
Area-B-15	0.43	98.53	428.20	74.49	323.73	24.04	104.48	0.02	0.244
Area-B-16	0.34	98.53	339.83	73.37	253.05	25.18	86.85	0.02	0.256
Area-B-17	0.15	98.53	152.70	70.04	108.55	28.56	44.26	0.01	0.29
Area-B-18	0.45	98.53	445.88	74.69	338.00	23.84	107.88	0.02	0.242
Area-B-19	0.67	98.53	662.98	76.75	516.43	21.76	146.42	0.03	0.221
Area-B-20	0.43	98.53	427.15	74.48	322.89	24.05	104.26	0.02	0.244
Area-B-21	0.84	98.53	822.85	77.49	647.14	20.61	172.12	0.03	0.209

Table 6.17 -: Simulation results for sub-catchments in Zone B

A maximum water level along the nodes T-B-09 to T-B-12 is shown in figure 6.12

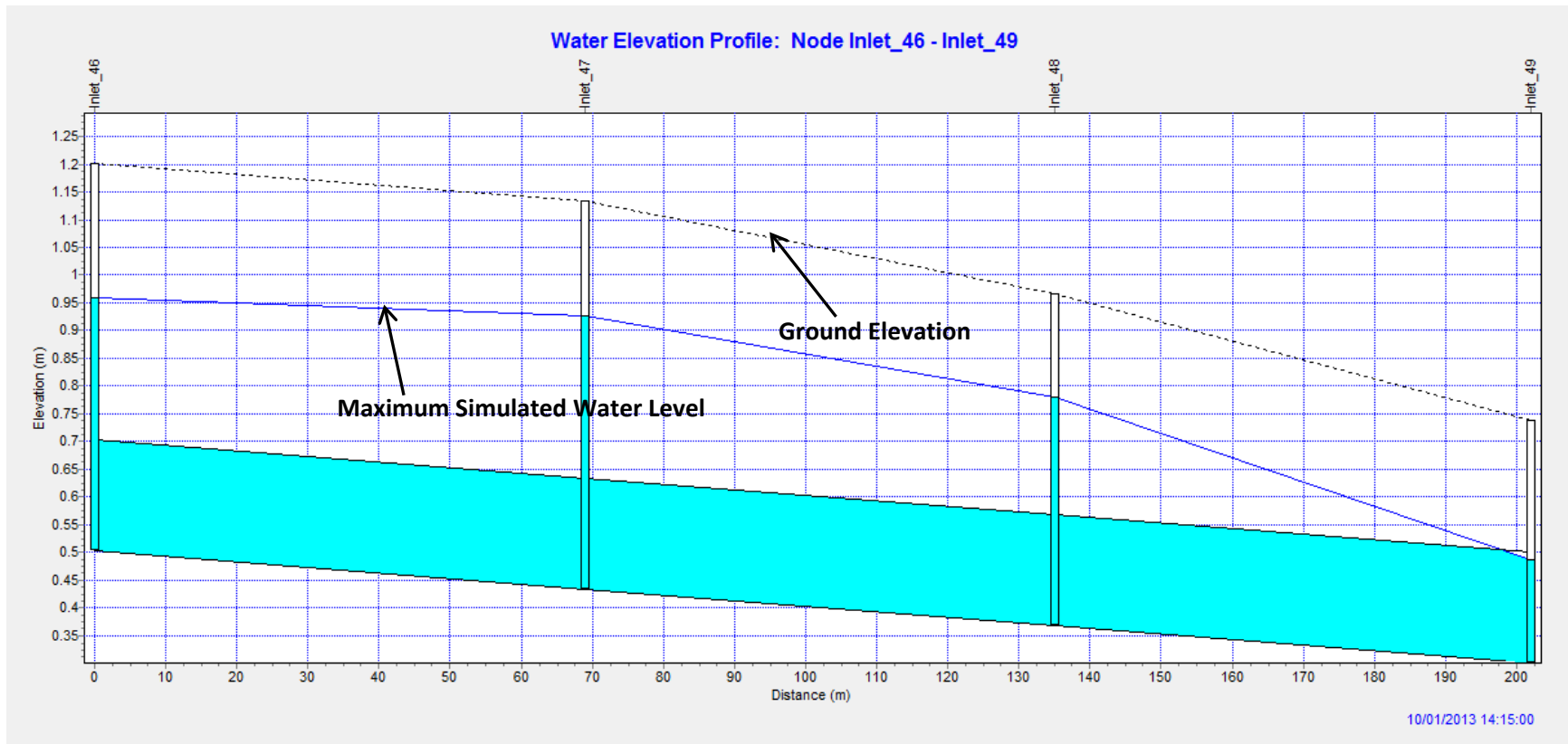


Figure 6.12 -: Maximum Water Level from Node T-B-09 to T-B-12 of Zone B

Result analysis for Zone C

The location and catchment delineation is shown in figure 6.13 and 6.14.



Figure 6.13 -: Location of Zone “C” with in the Thinadhoo drainage network of SWMM



Figure 6.14 -: Sub-catchment delineation in Zone C

The simulation results of the sub-catchments is shown in Table 6.16

Sub-catchment	Area Hectares	Total precipitation		Total Infiltration		Total Runoff		Peak Discharge (m ³ /s)	Equivalent Runoff coefficient
		In mm	In m ³	In mm	In m ³	In mm	In m ³		
Area-C-01	0.46	98.53	455.61	74.8	345.88	23.73	109.73	0.02	0.241
Area-C-02	0.43	98.53	427.07	74.48	322.83	24.05	104.24	0.02	0.244
Area-C-03	0.23	98.53	228.12	71.58	165.73	27	62.51	0.01	0.274
Area-C-04	0.46	98.53	455.16	74.8	345.54	23.73	109.62	0.02	0.241
Area-C-05	0.41	98.53	404.49	74.21	304.65	24.33	99.88	0.02	0.247
Area-C-06	0.47	98.53	459.91	74.86	349.43	23.67	110.48	0.02	0.24
Area-C-07	0.23	98.53	225.62	71.58	163.91	27	61.83	0.01	0.274
Area-C-08	0.48	98.53	472.34	74.99	359.49	23.54	112.85	0.02	0.239
Area-C-09	0.61	98.53	603.78	76.26	467.32	22.25	136.35	0.03	0.226
Area-C-10	0.18	98.53	175.26	70.54	125.48	28.05	49.90	0.01	0.285
Area-C-11	0.56	98.53	548.56	75.76	421.79	22.76	126.72	0.02	0.231
Area-C-12	0.23	98.53	227.71	71.58	165.43	27	62.40	0.01	0.274
Area-C-13	0.56	98.53	548.36	75.75	421.58	22.77	126.73	0.02	0.231
Area-C-14	0.42	98.53	415.57	74.35	313.58	24.18	101.98	0.02	0.245
Area-C-15	0.51	98.53	506.05	75.34	386.95	23.19	119.10	0.02	0.235
Area-C-16	0.29	98.53	288.87	72.61	212.88	25.94	76.05	0.02	0.263
Area-C-17	0.59	98.53	584.79	76.09	451.60	22.42	133.07	0.02	0.228
Area-C-18	0.43	98.53	424.65	74.45	320.87	24.08	103.78	0.02	0.244
Area-C-19	0.10	98.53	99.16	68.68	69.12	29.95	30.14	0.01	0.304

Table 6.16 -: Simulation results for sub-catchments in Zone C

A maximum water level profile from the node T-C-10 to T-C-12 is shown in figure 6.15 as a typical profile plot of Zone C.

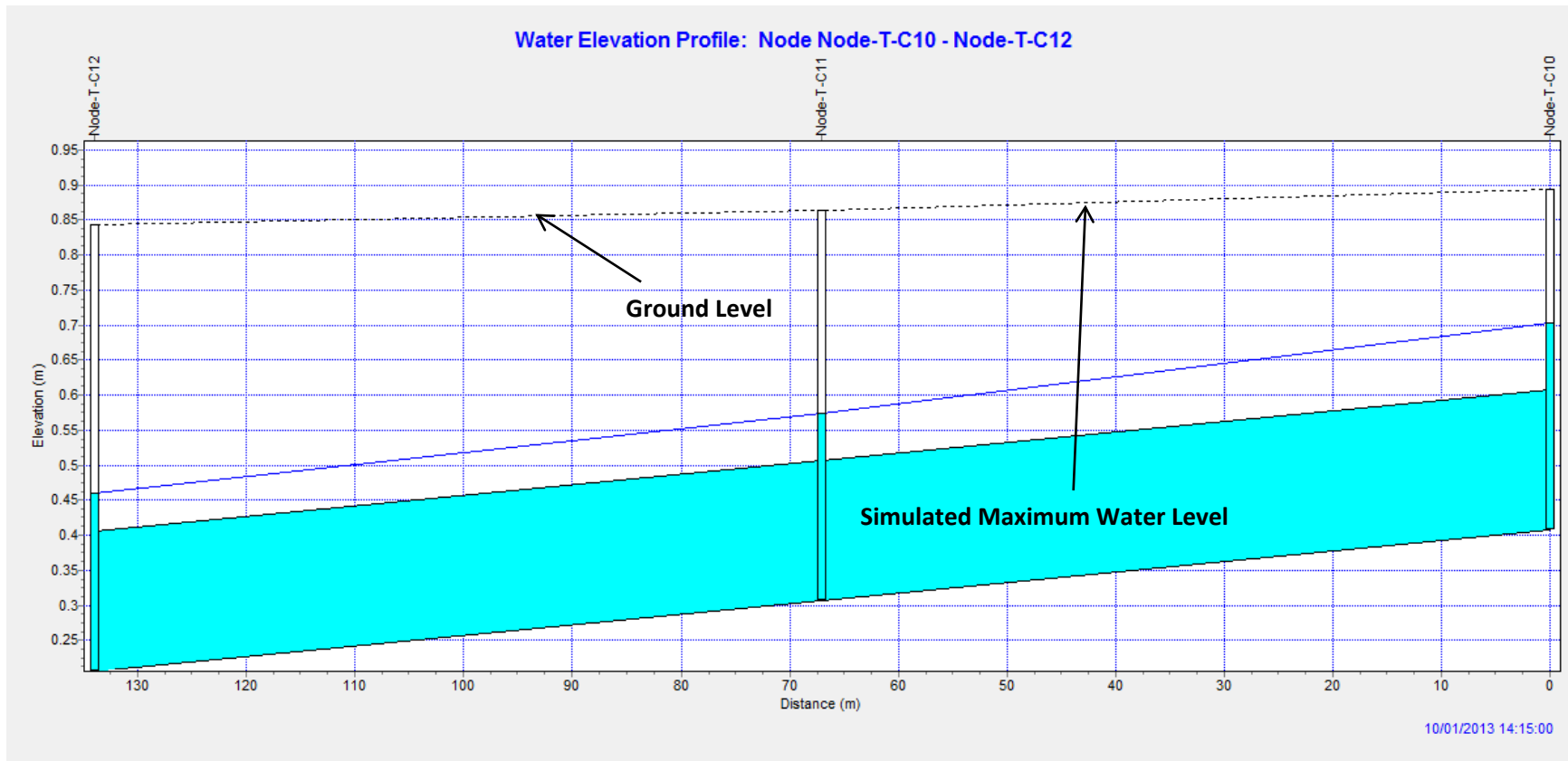


Figure 6.15 -: Maximum Water Level from Node T-C-10 to T-C-12 of Zone C

Result analysis for Zone D

The location and catchment delineation for Zone D is shown in figure 6.16 and 6.17 respectively



Figure 6.16 -: Location of Zone “D” with in the G Dh Thinadhoo drainage network of SWMM model



Figure 6.17 -: Sub-catchment delineation in Zone D

Corresponding simulation results for the sub-catchments in Zone D is tabulated in table 6.17

The maximum water level from T-D-21 to T-D-17 is shown in figure 6.18 as a profile plot for Zone D.

Sub-catchment	Area Hectares	Total precipitation		Total Infiltration		Total Runoff		Peak Discharge (m3/s)	Equivalent Runoff coefficient
		In mm	In m3	In mm	In m3	In mm	In m3		
Area-D-01	0.26	98.53	253.62	72.08	185.53	26.48	68.16	0.01	0.269
Area-D-02	0.21	98.53	204.57	71.14	147.71	27.44	56.97	0.01	0.278
Area-D-03	0.28	98.53	273.03	72.36	200.51	26.2	72.60	0.01	0.266
Area-D-04	0.24	98.53	232.17	71.66	168.85	26.91	63.41	0.01	0.273
Area-D-05	0.34	98.53	332.86	73.3	247.62	25.25	85.30	0.02	0.256
Area-D-06	0.52	98.53	514.27	75.42	393.65	23.1	120.57	0.02	0.234
Area-D-07	0.39	98.53	388.28	74.01	291.65	24.53	96.67	0.02	0.249
Area-D-08	0.47	98.53	462.69	74.89	351.68	23.64	111.01	0.02	0.24
Area-D-09	0.40	98.53	394.22	74.09	296.44	24.45	97.83	0.02	0.248
Area-D-10	0.20	98.53	195.18	70.95	140.54	27.63	54.73	0.01	0.28
Area-D-11	0.35	98.53	341.99	73.4	254.77	25.15	87.29	0.02	0.255
Area-D-12	0.50	98.53	496.93	75.25	379.52	23.27	117.36	0.02	0.236
Area-D-13	0.42	98.53	409.86	74.28	308.98	24.26	100.91	0.02	0.246
Area-D-14	0.48	98.53	474.77	75.02	361.48	23.51	113.28	0.02	0.239
Area-D-15	0.45	98.53	438.87	74.62	332.37	23.91	106.50	0.02	0.243
Area-D-16	0.44	98.53	438.15	74.61	331.78	23.92	106.37	0.02	0.243
Area-D-17	0.28	98.53	275.29	72.4	202.29	26.16	73.09	0.01	0.266
Area-D-18	0.36	98.53	356.02	73.59	265.90	24.95	90.15	0.02	0.253
Area-D-19	0.52	98.53	511.69	75.4	391.57	23.12	120.07	0.02	0.235
Area-D-20	0.48	98.53	470.99	74.98	358.41	23.55	112.57	0.02	0.239
Area-D-21	0.49	98.53	486.14	75.14	370.73	23.39	115.40	0.02	0.237
Area-D-22	0.44	98.53	436.02	74.59	330.08	23.94	105.94	0.02	0.243
Area-D-23	0.47	98.53	467.06	74.93	355.19	23.59	111.82	0.02	0.239
Area-D-24	0.41	98.53	399.85	74.16	300.95	24.38	98.94	0.02	0.247
Area-D-25	0.68	98.53	665.13	76.76	518.17	21.74	146.76	0.03	0.221
Area-D-26	0.33	98.53	324.95	73.16	241.28	25.39	83.74	0.02	0.258
Area-D-27	0.77	98.53	758.19	77.45	595.98	21.05	161.98	0.03	0.214
Area-D-28	0.42	98.53	413.27	74.32	311.73	24.22	101.59	0.02	0.246
Area-D-29	0.48	98.53	474.72	75.02	361.45	23.51	113.27	0.02	0.239
Area-D-30	0.41	98.53	399.12	74.15	300.36	24.39	98.80	0.02	0.248
Area-D-31	0.13	98.53	128.47	69.45	90.55	29.16	38.02	0.01	0.296
Area-D-32	0.39	98.53	383.92	73.96	288.19	24.58	95.78	0.02	0.249
Area-D-33	0.33	98.53	325.56	73.17	241.77	25.38	83.86	0.02	0.258
Area-D-34	0.52	98.53	511.11	75.39	391.08	23.13	119.98	0.02	0.235
Area-D-35	0.23	98.53	222.39	71.48	161.33	27.09	61.14	0.01	0.275

Table 6.17 -: Simulation results for sub-catchments in Zone D

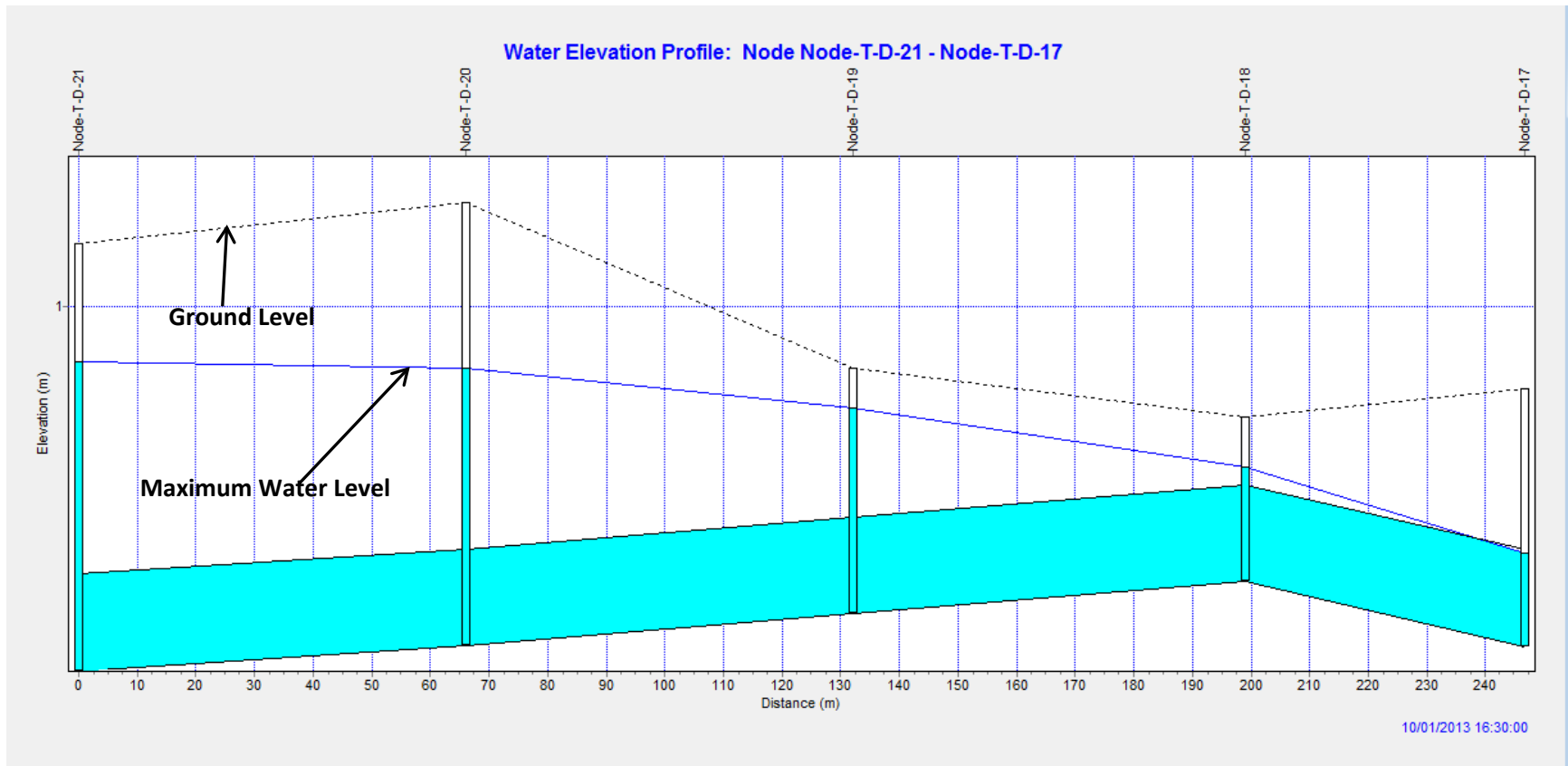


Figure 6.18 -: Maximum Water Level from Node T-D-21 to T-C-17 of Zone D

Result analysis for Zone E

All the runoff in the Zone E is stored with in the Storage units. The location and the catchment delineation for the Zone E is shown in figure 6.19 and 6.20 respectively.

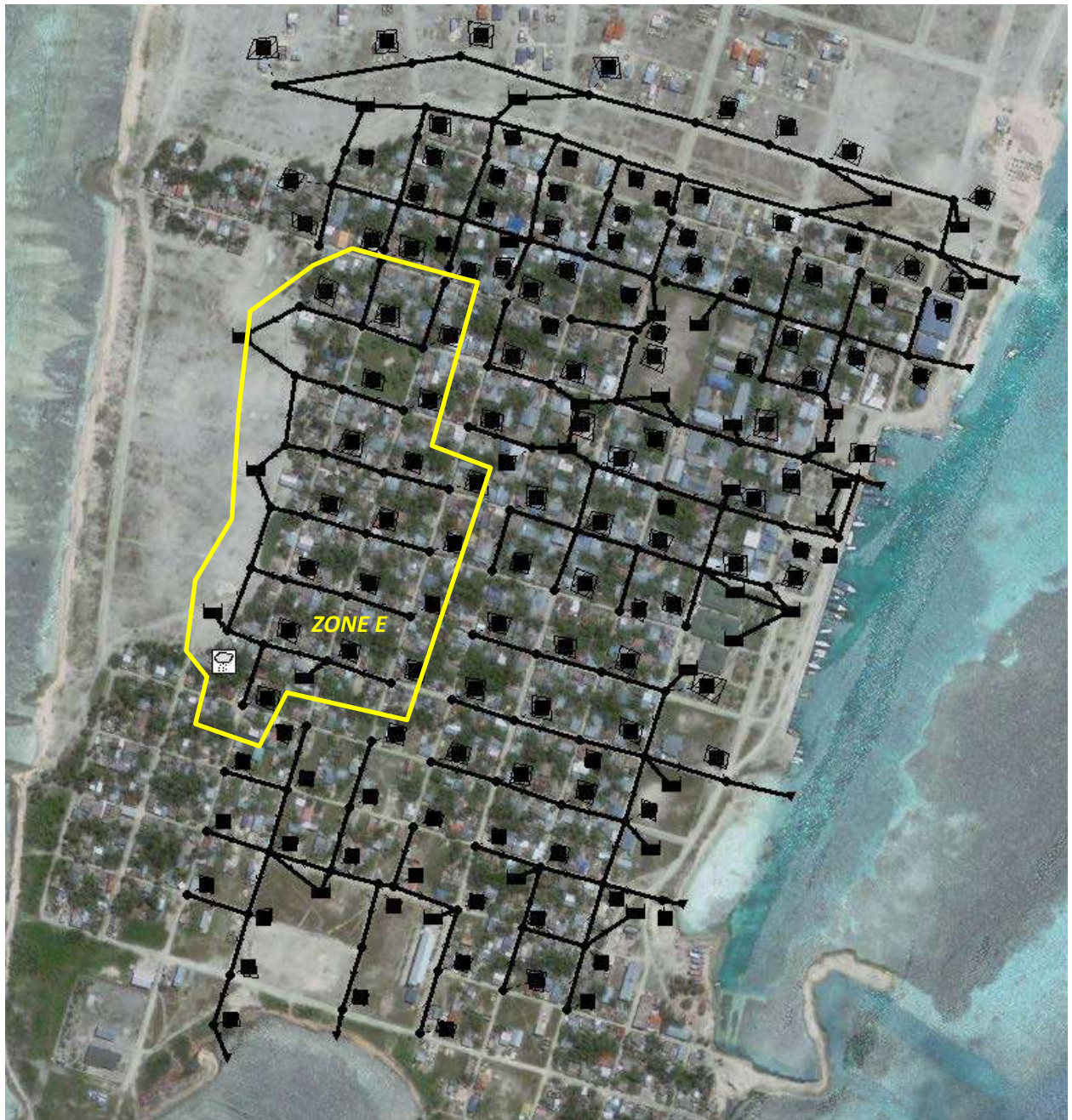


Figure 6.19 -: Location of Zone “E” with in the G Dh Thinadhoo drainage network of SWMM model



Figure 6.20 -: Sub-catchment delineation in Zone E

The simulation results for the sub-catchments in Zone E is shown in table 6.18

Additionally, the maximum water level from the node T-E-09 to T-E-12 is shown in figure 6.21 as the typical profile plot for Zone E.

Sub-catchment	Area Hectares	Total precipitation		Total Infiltration		Total Runoff		Peak Discharge (m3/s)	Equivalent Runoff coefficient
		In mm	In m3	In mm	In m3	In mm	In m3		
Area-E-01	0.43	98.53	421.27	74.41	318.14	24.12	103.13	0.02	0.245
Area-E-02	0.46	98.53	448.85	74.73	340.43	23.8	108.42	0.02	0.242
Area-E-03	0.47	98.53	464.30	74.9	352.95	23.62	111.30	0.02	0.24
Area-E-04	0.44	98.53	430.32	74.52	325.46	24.01	104.86	0.02	0.244
Area-E-05	0.44	98.53	434.78	74.57	329.05	23.96	105.73	0.02	0.243
Area-E-06	0.43	98.53	427.95	74.49	323.53	24.04	104.41	0.02	0.244
Area-E-07	0.47	98.53	458.48	74.84	348.25	23.69	110.23	0.02	0.24
Area-E-08	0.52	98.53	509.70	75.38	389.94	23.14	119.70	0.02	0.235
Area-E-09	0.48	98.53	475.41	75.02	361.98	23.5	113.39	0.02	0.239
Area-E-10	0.38	98.53	372.85	73.81	279.31	24.73	93.58	0.02	0.251
Area-E-11	0.43	98.53	426.42	74.48	322.34	24.06	104.13	0.02	0.244
Area-E-12	0.42	98.53	414.88	74.34	313.02	24.2	101.90	0.02	0.246
Area-E-13	0.48	98.53	477.58	75.05	363.77	23.48	113.81	0.02	0.238
Area-E-14	0.57	98.53	562.11	75.88	432.89	22.63	129.10	0.02	0.23
Area-E-15	0.45	98.53	441.94	74.65	334.83	23.88	107.11	0.02	0.242
Area-E-16	0.44	98.53	434.22	74.57	328.63	23.97	105.63	0.02	0.243
Area-E-17	0.45	98.53	446.95	74.71	338.90	23.82	108.05	0.02	0.242
Area-E-18	0.22	98.53	213.16	71.31	154.27	27.27	59.00	0.01	0.277
Area-E-19	0.22	98.53	219.88	71.43	159.40	27.14	60.57	0.01	0.275
Area-E-20	0.41	98.53	406.96	74.24	306.63	24.29	100.32	0.02	0.247

Table 6.18 -: Simulation results for sub-catchments in Zone D

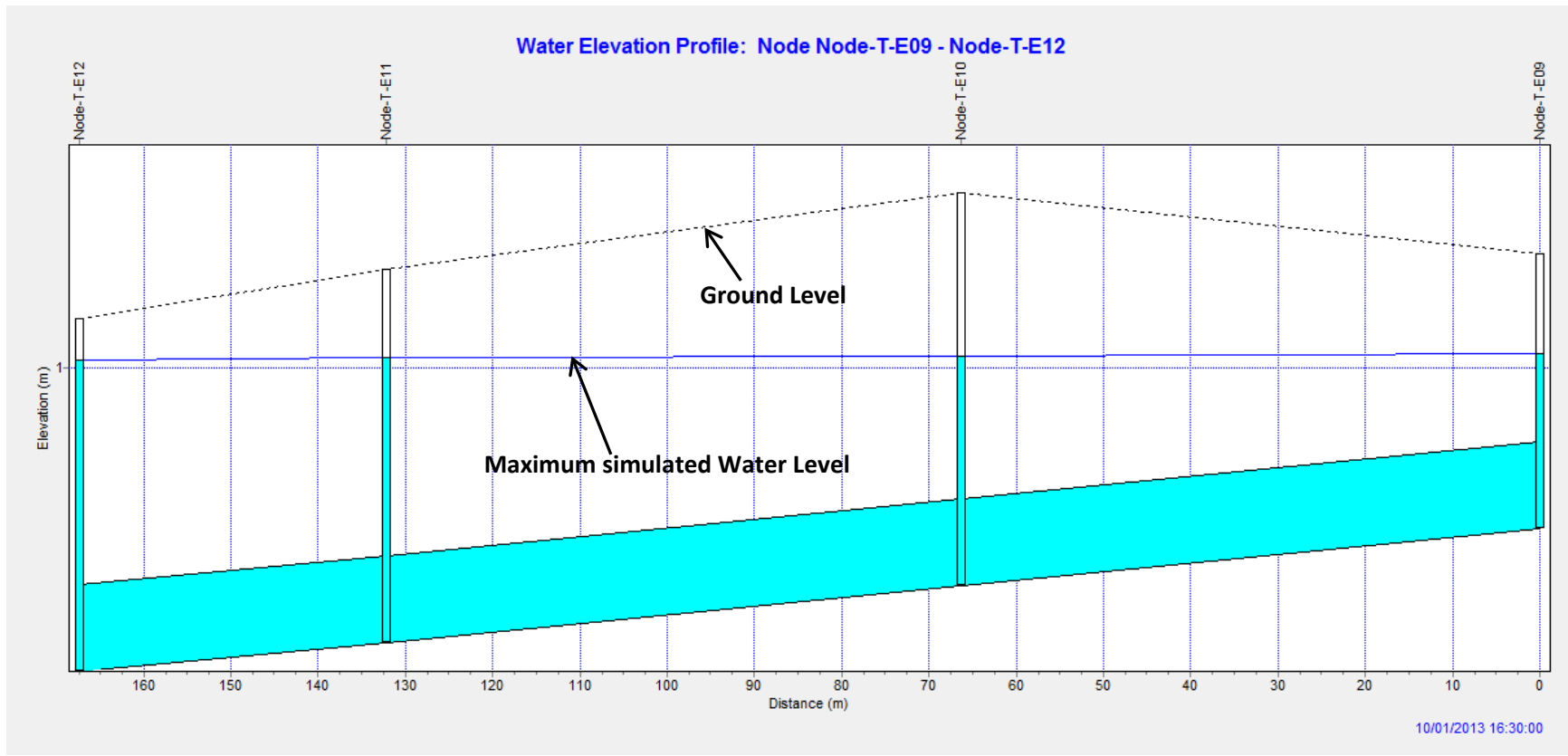


Figure 6.21 -: Maximum Water Level from Node T-E-09 to T-E-12 of Zone E

Overall Evaluation of the model results for G Dh Thinadhoo Island.

The objective of the drainage design was store the maximum amount of runoff for the benefit of the people of the island while addressing the flood issues. A summary of the Zonal model results for the G Dh Thinadhoo island is shown in table 6.19.

An interpretation in terms of a schematic diagram for the combined model results for the drainage proposal for G Dh Thinadhoo island is given in figure 6.22.

Zone	Total Catchment area (Ha)	Total Rain		Total Infiltration		Total Runoff		Total Outflow (m3)	Total stored (m3)
		In mm	In m3	In mm	In m3	In mm	In m3		
Zone A	15.16	98.53	14941	74.64	11319	23.89	3622	224	3398
Zone B	10.81	98.53	10647	75.71	8181	22.82	2465	1168	1297
Zone C	7.66	98.53	7551	74.56	5714	23.97	1837	445	1392
Zone D	14.07	98.53	13861	74.42	10470	24.11	3391	1707	1684
Zone E	8.61	98.53	8488	74.57	6424	23.96	2064	0	2064

Table 6.19 -: Summary of the Zonal model results for G Dh Thinadhoo Island

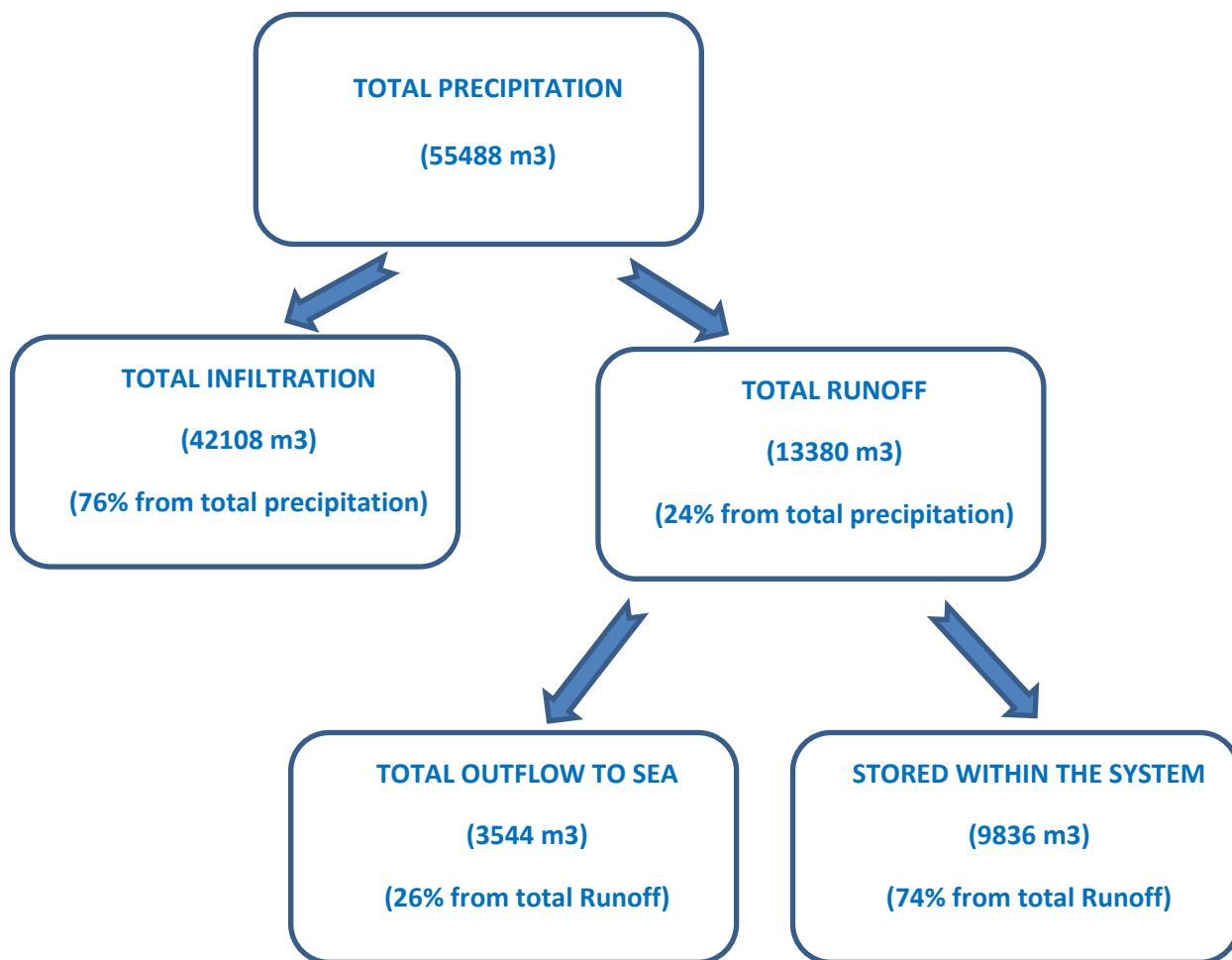


Figure 6.22 -: Interpretation of the combined model results for the G Dh Thinadhoo Island

Conclusively about 75% of runoff volume is stored within the system for the benefit of the people while addressing the flood issue.

7.0 Rain Water Harvesting and Improvements to the Ground Water Recharging

Buildings of following category that have substantial roof area can be utilized for the purpose of water harvesting:

Public buildings such as mosques, hospitals, banks etc.

Large commercial buildings such as hotels and Shops etc.

Selected individual houses with large roof areas.

Available rainfall data need to be analyzed to ascertain the availability of yield to be harvested during the rainy season. The rain water collected from the above buildings can be diverted by gravity to the most convenient and closest water tanks provided at selected locations. The water stored in this manner can then be sent to the RO plant for treatment and disinfection. Mobile pumps can be used to pump water from the storage tanks to the RO Plant when the need arises.

It will be necessary to design and implement the general layout plans of the rain fall collection system and improvements to the ground water recharging system in individual plots in consultation with community in the area.

The following are the main design components of the rainfall harvesting and collection systems up to the treatment plant.

Transmission pipe network system.

Inter connected storage tank system.

Supply of pumps for transmission of rain water from the storage tanks to the RO plant.

Design of a system to flush out the polluted roof and gutters prior to the rainy season.

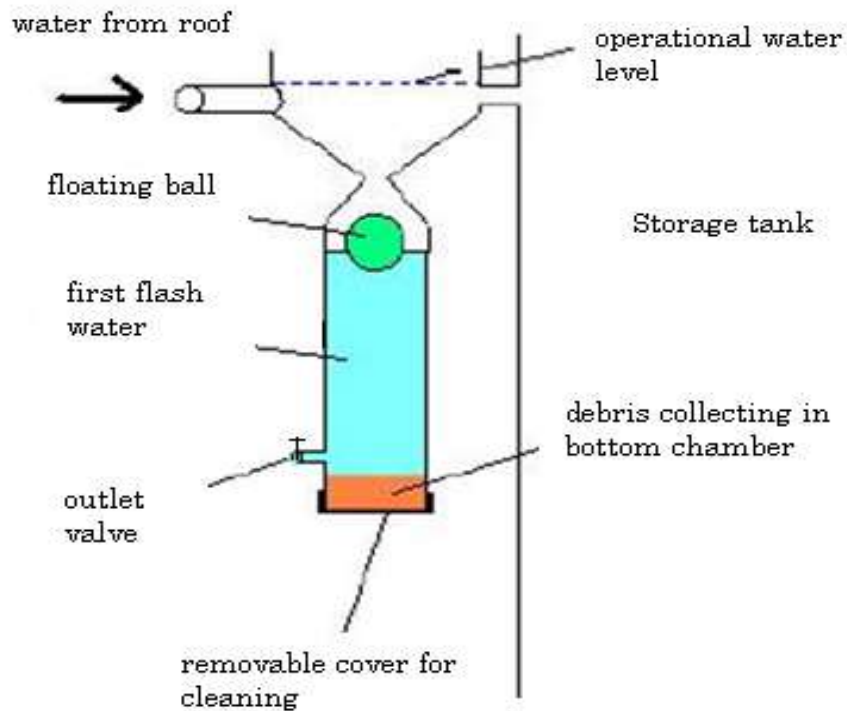
Proposed method to be adopted in getting the system cleaned to prevent contamination of water

First – Flash System

The method is called the first – flash system and the objective is to divert first raindrops from storage tanks. During dry periods of weather the roof gets covered in a fine coating of dust together with leaves, bird droppings, and other debris. When it starts to rain these objects are washed straight off the roof and down the guttering. Up to the first 1mm of rainfall is so heavily contaminated that it cannot be recommended even for non-drinking uses. Therefore, first-flash rainwater must be eliminated from catchment.

The capacity of the first- flash system depends on the catchment area and amount of rain to be eliminated. In this study, a roof area of 50m² was considered as a catchment.

Further, the amount of rainfall to be eliminated was 2-3mm. Therefore, a 50 liters capacity first- flash system is sufficient for diverting contaminated rainwater. Locally available plastic cones can be used for this purpose. Further, a plastic ball should be introduced for shutting off the system automatically. A typical drawing of a first-flash system is shown in annex-1. This system can easily be produced using locally available materials and it dose not require highly skilled persons. However, the proposed first-flash system needs to be emptied manually before next rain starts.



Leaf screen and wire basket

Gutters should have a leaf screen to prevent leaves and other debris from cluttering the system. The study recommends installation of a leaf screen made of quarter –inch wire mesh in a frame along the entire length of the gutter and a screen or wire basket at the head of the downspout. Length of the wire screen for a roof area of 50m² is calculated from the following assumption.

Assuming the dimensions of the roofs are 10m x 5m (one side)

Total length of the screen = $2(10 + 5) = 30\text{m}$

Accordingly, the study considered a 30m long leaf screen for the analysis.

Plan for preventive maintenance

The major concern of RWH is the prevention of contamination of harvested rainwater. Bacterial contamination can be minimized by keeping roof surfaces and drains clean. However, it cannot be eliminated. Therefore, a maintenance plan is necessary in the operation of RWH systems. A RWH system does not require expensive tools for maintenance. Further, it can be maintained by its users with ordinary level of skill. In reality, components of RWH system can easily be repaired or replaced. The reason is that the rainwater systems usually experience lower pressure than municipal or other piped water supply system. If the RWH system is installed properly, it may run for a long time without pipe burst or repairs.

The plan for preventive maintenance consists of annual cleaning of the storage tank, regular inspection of gutters and downpipes, and removal of dirt, leaves and other accumulated materials. Such cleaning should be carried out annually before the start of the major rainfall season. However, cracks in the tanks should be repaired immediately to avoid contamination of the collected rainwater. Cleaning procedures of the storage tanks consists of through scrubbing of the inner walls and floors. Use of a chlorine solution is recommended for cleaning. Gutters and downpipes needs to be periodically inspected and cleaned carefully. Further, roof catchments should be cleaned regularly to remove dust, leaves, and bird droppings to maintain the quality of rainwater. The pumps also should be serviced periodically. Table 05 describes the plan for preventive maintenance of a RWH system. Accordingly, total labor-hours required for the maintenance is 5.5 per year.

Description		Frequency	Labour Hours
1.0	Washing storage tank	Once a year (Preferably in November)	2
2.0	Cleaning roof and downpipe	Twice a year	2
3.0	Repair to the distribution	Once a year	0.5
4.0	Pump service	Once a year	1

Laws and regulations on Storm Water Management

Water is a scarce commodity. Every effort must be taken to utilize water prudently. The people must be apprised of the need to prevent wastage. With that in view it is essential that the existing rules and regulations pertaining to the use of water is rigidly adhered by the inhabitants. The Council must enforce the legal powers it has when necessary. As at present there are instances of wastage observed at certain locations, particularly due to the non existence of a network of roads where a system of pipe network could receive the excess water from the premises.

Rainwater harvesting (RWH)

People must be encouraged to harvest rainwater. They should be provided with private tanks on cost recovery basis. As against the high cost of desalination, rainwater is free resource and installation and disinfection cost is also affordable. Therefore the authorities must promote and popularize RWH as much as possible. There are several supportive factors for RWH such as sufficient rainfall, technical skills, available local resources, cost effectiveness, enthusiastic community, positive health impacts and environmentally friendly.

RWH is the most preferred source of water for domestic use especially in rural areas where living conditions too had improved due to the roof catchment system.

One of the key factors that determine the feasibility of RWH is the policy adopted in maintenance of RWH system. Regulations and guidelines for implementers and users need to be put in place to ensure the effectiveness of rainwater harvesting programme

- a) Rain harvesting should be made mandatory for all government buildings including schools, hospitals and other offices. These systems should be a model for public to follow.
- b) It should also be mandatory for private buildings with more than 100sq.m floor area. Necessary provision can be made in national building code.
- c) Children going to school carry water with them (mostly mineral water bottle). It should be made mandatory for the school to maintain their water system in good

condition and children should be encouraged to drink safety collected rain water at schools

- d) School education and public education/awareness need to be intensified
- e) Ground water recharge through rain water harvesting and rain water use for agricultural uses should be encouraged
- f) Government should accord priority to this program and provide incentives to the community for popularizing the system
- g) Rain water harvesting cell/unit need to be created within the ministry of Environment and Energy to coordinate and monitor the program and provide technical guidance to community.
- h) Instead of providing 2500L storage tank per family, it should be provided according to the size of the family. It is recommended to provide 500L storage capacity tank per person. There is no adequate space for keeping additional water tanks at household. So underground tanks need to be considered.

As per the Model Study minimum quantity of water that needs to be preserved within each household is 6000 Litres as computed below:

The anticipated runoff percentage would be 34.53% and an additional 10.53% has been increased than the design condition. Therefore this quantity may be considered as the water volume to be retained in housing units.

Calculation

$$\begin{aligned} \text{Volume to be retained in housing units} &= 10.53\% \text{ of total rain} \\ &= 0.1053 \times 0.099 \times 0.46 \times 10000 \\ &= 48 \text{ m}^3 \end{aligned}$$

Assuming that one sub-catchment consists of 08 housing units,

$$\text{Volume to be retained in one housing unit} = 6 \text{ m}^3$$

Public appeal

At the onset of monsoon, public needs to be alerted to get prepared for the harvesting. The families will require cleaning their system and repairing faults if any. This will help them to store maximum water and protect the quality of stored water. Government (water supply department) may consider giving public notice in the press for the benefit of people and avoiding water shortage in the dry period. The draft of such appeal is given below for ready reference.

Get prepared to harvest rain water:

It is time again to welcome the rains and get ready for storing precious rain water for our drinking and other domestic needs. Maldives is blessed with sufficient rains to meet with our requirements provided we store and use it wisely. We get rain water free from nature that is of pure quality. Also it is available at our home and we can store as much as we want. Wise people say that “we must make best use of every drop of rain water before it reaches the sea.” There are many benefits of storing rain water in addition to making us self-reliant. Salient benefits of storing rain water at household level can be enumerated as below,

1. Provide good quality water
2. Save water charges to be paid for public supplies
3. Reduces exploitation and contamination of ground water
4. Water is available during disasters and emergencies

The ministry of water wish to alert you and urge to cooperate in storing rain water and help mitigate the water shortage of the country. You can follow the checklist provided here below to get ready for harvesting the rains.

1. Provide rain water harvesting system with adequate design and proper materials
2. Maintain the system in a good condition to get sufficient quantity and good quality of water
3. Clean the system before onset of monsoon to prevent contamination of water
4. Repair the system (leakages and damages)
5. Procure necessary chemicals

Ground water recharging wells

In addition to the proposed seepage tanks in the storm water management system, ground water recharging wells consisting of circular reinforced concrete wells of 1200mm internal diameter with 100mm of wall thickness and 1500mm height can be constructed along the main roads. . (Alternatively to reduce the cost prefabricated corrugated wells of PVC/PE material could be used). These wells can be covered with G.I manhole cover to match with the finished ground levels. This will supplement the capacity of rainwater aquifers presently available in the Island. These wells can be linked by using perforated μ PVC pipes of 160mm diameter. They should be covered using a geo textile membrane to prevent infiltration of silt into the pipe network.

General guide lines for rainfall harvesting

- 1 Plan showing proposal how to collect rainwater in the individual premises.
- 2 If the building is having upper flow with roof slab comprehensive plan to be prepared showing size of the inlet pipe , outlet pipe , storage tank and groundwater storage tank and storage tank should be protected from external activities.
- 3 Increase the seepage rate by constructing possible small bund within the garden area.
- 4 Removal of first rainfall event to remove dirty material etc.
- 5 Possible method to maximum use of rain water collection by using ground tank and other method should be constructed as follows to suit the ground location.
 - Above ground level
 - On the ground
 - Underneath the ground
 - Collection pit to collect overflow water
 - Increase pervious areas.
 - Existing well
 - Bore holes.

Wherever the possible places local filtration method to be adopted.

Storing percentage of rain water depend on storage capacity and seepage rate of the ground due to following reasons.

1. Location of the land
2. Ground water level fluctuation of the land
3. Extent of the land.
4. Type of the material of the ground.

To maintain vulnerability of ground water aquifers and the Ecological balance of the area at least 75% of the water quantity to be stored within the individual premise. But exact percentage has to be decided by the Local Authority depend on the above factors.

Ground Water recharge areas

The Planning Department of the Ministry of Housing is entrusted with the function of preparing Land Use Plans, and when they are being prepared, it is essential that due importance is given to the need for allocating sufficient space for surface and ground water storage / recharge areas. With the objective of achieving an environmentally sustainable society the planners must recognise the priority that should be given to the storm water management aspect. Few guide lines that could be followed are given below:

Proposed Public out Door Recreational Plan

All open areas can be utilised for the storage and recharge facilities

- Open Space : 1000 Person for 1.5 ha
- Pocket Parks Town Centre every 100 met (6-8) perches
- Mini park : 200 met playground every 200met
- Local park }
Urban park } 400 met Play

- 30 met buffer lane around the Island
- Residential area 35-40%
- Commercial 04-06%
- Open Space every 1000 people 1.5 ha

8.0 Proposed Improvements

Complete set of plans showing the proposed Improvements are presented in a separate Volume and a Sample drawing which indicates the principal dimensions of pipe network, man holes, gully gratings, storm water storage tank, details of emergency outfalls and there design levels is shown in Figure 8.1, Figure 8.2 and 8.3.

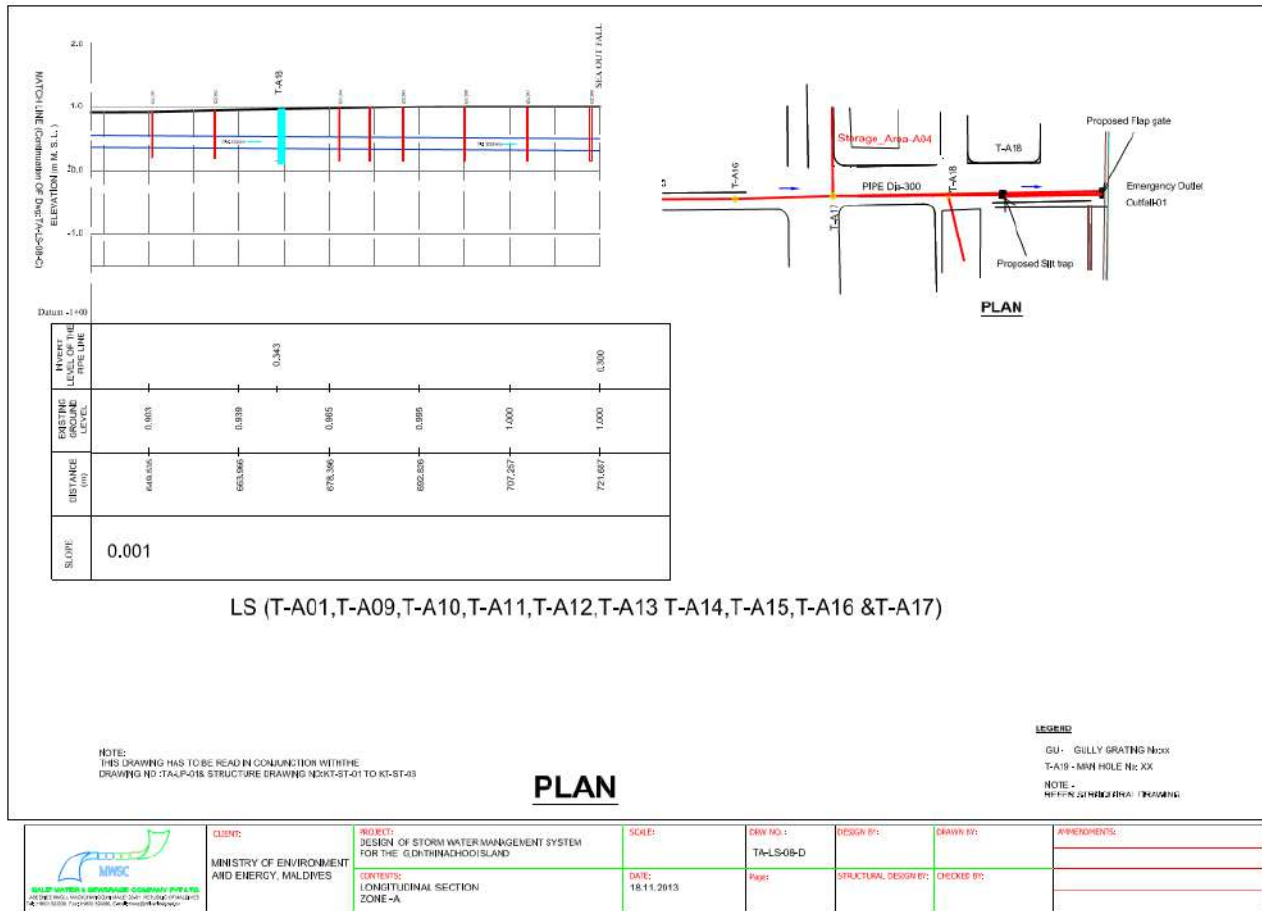


Figure 8.1 Sample drawings

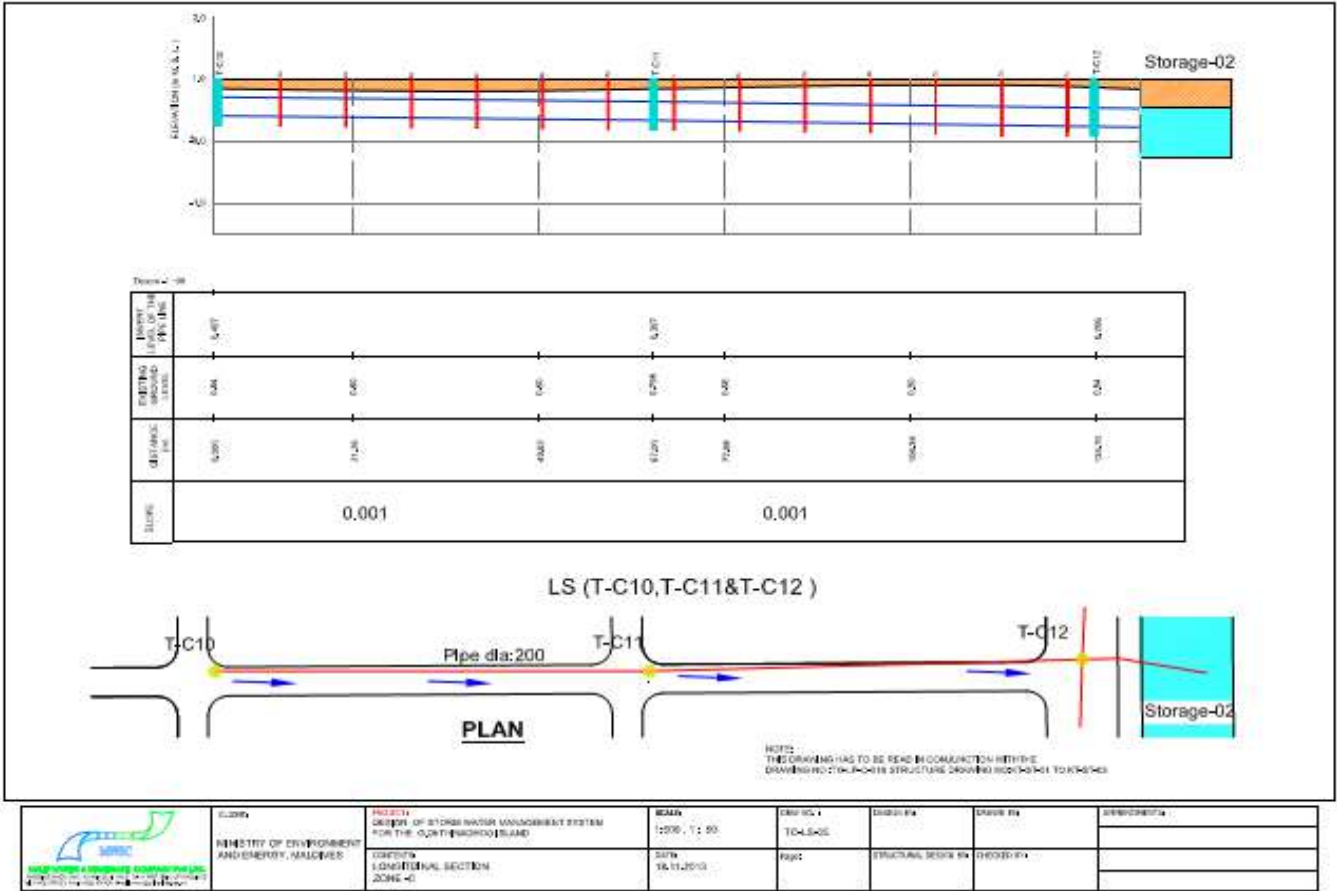
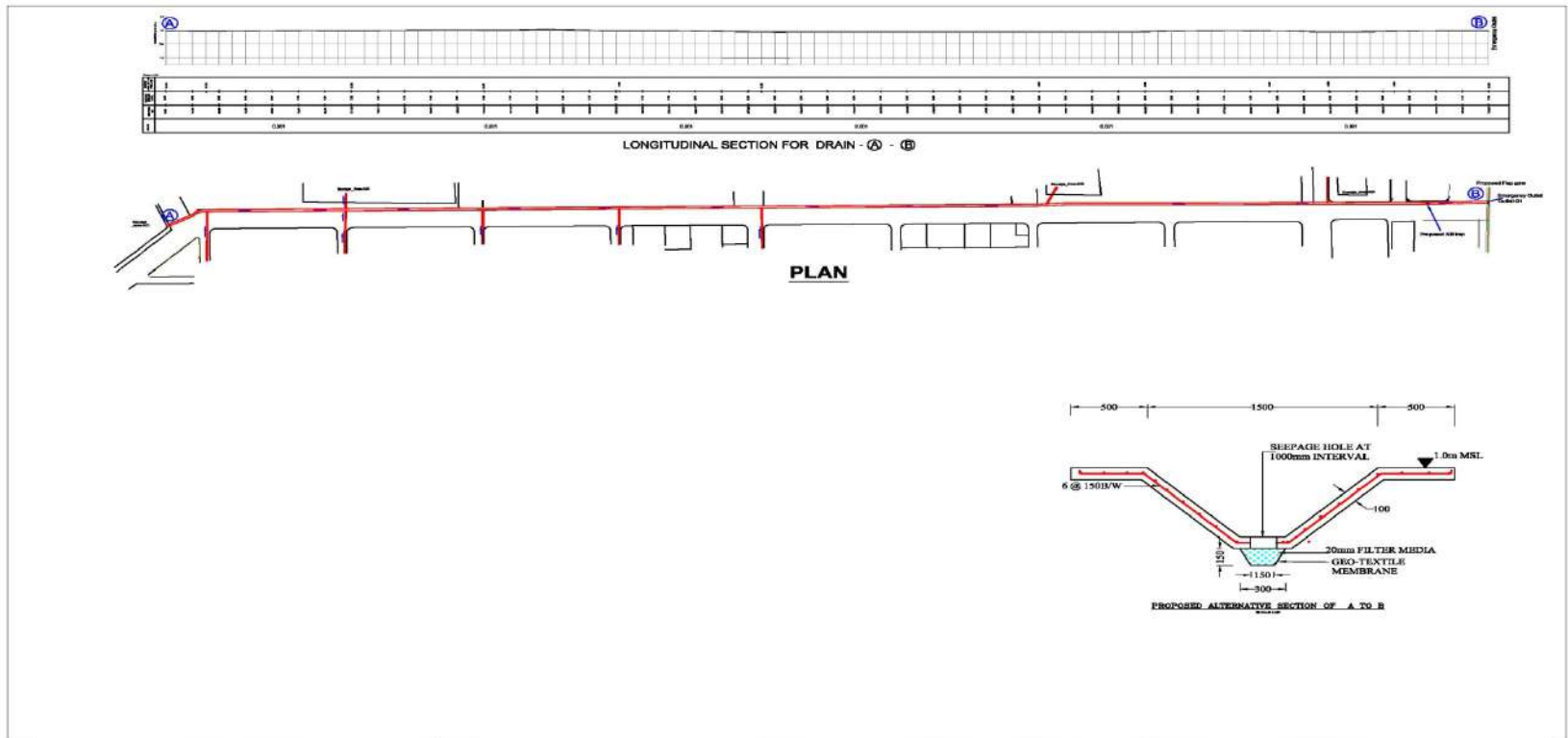


Figure 8.2 Sample drawings



 <p>MWSC MALDIVIAN WATER & SEWERAGE CORPORATION PVT LTD. APARTMENT 2004, HANU-GUMMUDAH ROAD, 2011, NERUPA ATUF, MALDIVES TEL: 960 2333 3333 FAX: 960 2333 3333 EMAIL: info@mwsc.com.mv</p>	<p>CLIENT: MINISTRY OF ENVIRONMENT AND ENERGY, MALDIVES</p>	<p>PROJECT: DESIGN OF STORM WATER MANAGEMENT SYSTEM FOR THE G.DRITHINADHOO ISLAND</p>	<p>SCALE:</p>	<p>DRW NO.: TA-LS-10</p>	<p>DESIGN BY:</p>	<p>DRAWN BY:</p>	<p>AMMENDMENTS:</p> <table border="1"> <tr><td> </td></tr> <tr><td> </td></tr> <tr><td> </td></tr> </table>			
<p>CONTENTS: ALTERNATIVE SECTION A TO B ZONE -A</p>	<p>DATE: 20.12.2013</p>	<p>Page:</p>	<p>STRUCTURAL DESIGN BY:</p>	<p>CHECKED BY:</p>						

Figure 8.3 Sample drawings

9.0 Flap Gate

Normally the flap gates made locally do not function properly. Therefore it is proposed provide flap gates for which specification are below.



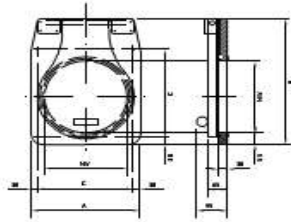
Figure 9.1 Proposed Flap Gate

HDPE Wall Mounted

Flap Valves: Wall mounted flap valves are made from high quality HDPE materials or a combination of HDPE material and stainless steel reinforcements. The materials are highly corrosion resistant with a longevity and low maintenance cost. **Available in sizes ranging from 100mm up to 1000mm.**

Mounting Kit : Mounting kit includes self adhesive neoprene seal to seal to the wall & 316 Stainless Steel chemical anchor fixing bolts.

SPECIFICATIONS TKV SERIES DN125-DN1000 TYPE WALL MOUNTED



TKV SERIES DN 125 - 300

ØNW	A	B	C	Pressure	Weight
125	235	295	175	6 mwc	4
150	260	325	200	6 mwc	4
200	310	378	250	6 mwc	5
250	360	430	300	6 mwc	7
300	410	480	300	6 mwc	8

INDUSTRIAL STANDARD DIN 19569-4

PRESSURE CHARACTERISTICS
6 mwc

STANDARD CONSTRUCTION MATERIALS

Frame: HDPE -300
 Valve: HMPE - 500 or HDPE - 300
 Valve hinge pin: Stainless steel AISI 316
 Sealing: EPDM

OPTIONS

Other sizes up to 1000 mm
 Square, rectangular or oval

Table 9.1: Dimensional Data

10.0 Environmental Impacts

Existing Environment

There is a need for enhancement of the environment within the island of G Dh Thinadhoo due to non-availability of a proper storm water management system. People undergo some inconvenience during the rainy season due to inundation of their environs. Existing earthen natural outfalls are cut opened when the need arises for the discharge of excess runoff from the affected area. However there is a negative impact to the environment due to the opening created for the discharge of storm water as there is a possibility for the sea water to enter the lands through these openings. However the proposed improvements will enhance the environment with improved drainage.

Land Use is semi urban and there are no significant sensitive or unique ecological resources such as rare or endangered species that would be affected by the project.

Environmental benefits:

Implementation of the SWMS will bring relief to these affected people and enhance their economic conditions.

During the construction stage there will be some adverse impacts such as noise, dust, unsightly conditions, traffic congestions and difficulty in access to premises. Necessary precautions will have to be taken to minimize these impacts. As the project will ultimately benefit the people they have to be apprised of the need to undergo temporary hardship.

Project Benefits:

1. Reduce rainwater flooding / inundation.
2. Improved aesthetic environment.
3. Reduce traffic delays.
4. Reduce inconvenience to people.
5. Improved rainfall recharging system.
6. Reduce saltwater intrusion into the Island.

Mitigatory Measures

Negative impacts expected during the construction phase would be controlled or minimized through proper construction planning as follows:

- a) Proper arrangement for diversion of traffic, if necessary and work programming to minimize the negative impacts of such construction works.
- b) Proper sorting and disposal of excavated material in an environmentally accepted manner.
- c) Planning of construction activities to minimize nuisance to general public and the community. Avoidance of night work in residential areas.
- d) Adoption of all necessary safety measures, such as placing of sign boards, night lights and warning lights, for the safety of residents and road users. The workers will be advised on safety measures and precautions that need to be adhered.
- e) Adoption of appropriate safety measures for the safety of workers from accidents at work sites.
- f) Identification of properties to be affected by constructions, if any, and design of structures to minimize any adverse impacts on private properties as much as possible.

During the Operation Phase

Proper institutional planning and cooperation will overcome the impacts expected during the operation phase. Further, vigilance and law enforcement by the local authorities will minimize any adverse impacts on the maintenance of the facilities by the residents. During the planning stage of the project, all the adverse impacts of the project on physical, ecological and socio-economic environments have been carefully considered to ensure that any potential significant impact is avoided or minimized. Constructional impacts were found to be temporary and minor in nature and could be overcome by mitigatory measures proposed. On completion of the project, the community would benefit by minimized or eliminated water stagnation, reduced inconvenience on water stagnation to properties, removal of periodic access interruption, etc.

11.0 Operations and maintenance guidelines

With a view to keep the entire drainage network in topping condition it is necessary give high priority for the maintenance aspect and at the outset the equipment necessary for this task is described below:

Cleaning of 200mm Drainage Pipes.

The cleaning of drain pipes could be done by using high pressure water jettors or applying chemical drain cleaners.

Use of chemical drain cleaners cause most of the environmental hazards and lack of effectiveness for removing clogs far from the drain opening. Sometimes this method may be dangerous. The danger arises from their potential to injure eyes, lungs, skins and damage to cloths. Sometimes it may be explosive. In any case this can't be used due to social and environmental aspects of these locations. The use of chemical methods is completely out of the question as the people living in these areas are in contact with water throughout their lives.

Therefore the most suitable method for cleaning of drain pipes is by using high pressure water jet machine.

The **water jetter** is composed of a controlled high-pressure water source such as a pressure washer or reciprocating displacement pump, a flexible high pressure line (called a jetter hose) of up to hundreds of meters (several hundred feet) in length, and a nozzle that uses hydraulic force to pull the line into water drains, clean the sides of pipes, and flush out residue.

The performance of drainage system could easily be affected by many factors. Mud and silt carried by storm flow could deposit gradually inside drains and channels and affect their effective capacity. Therefore continual efforts are required to keep drainage system in good working order and to achieve this the following are essential.

- I. Carrying out regular Preventive Maintenance.
- II. Addressing local drainage improvement needs.

Preventive Maintenance

Maintaining catch basins, storm water inlets, and other storm water conveyance structures on a regular basis will keep the system in good working order.

Catch Basins / Inlet Structures

Maintenance staff should regularly inspect facilities to ensure the following:-

- I. Immediate repair of any deterioration threatening structural integrity.
 - II. Catch basins should be cleaned as frequently as possible.
 - III. Stenciling of catch basins and inlets Handling and Disposal.
 - IV. Clean catch basins, storm drain inlets, and other conveyance.
- Conduct inspections more frequently during the wet season for problem areas where sediment or trash accumulates more often. Clean and repair as needed.
 - Keep accurate logs of the number of catch basins cleaned.
 - Record the amount of waste collected.

Storm Drain Conveyance System

- Locate reaches of storm drain with deposit problems and develop a flushing schedule that keeps the pipe clear of excessive buildup.

Maintenance of Storm water Storage tank

General:

Storm water Storage tank is an important component within the SWMS providing storage for the detention or infiltration of runoff. With varying shapes, sizes and configurations these tanks receive water either prior to treatment. Systems without pre-treatment require greater attention to system functionality and may require additional maintenance. In order to sustain system functionality the following general maintenance guidelines need to be followed.

Precautions:

1. Prior to & During Construction - Siltation prevention of the storm water system.
 - a. Conform to all local, environmental regulations for sediment and erosion control during Construction.
 - b. Install site erosion and sediment 'Best Management Practices' required prevent siltation of the storm water system.
 - c. Inspect and maintain erosion and sediment 'Best Management Practices' during construction.
2. Post Construction - Prior to commissioning
 - a. Remove and properly dispose of construction erosion as per all local, environmental regulations.

Care should be taken during removal as not to allow collected sediment or debris into the storm water system.

- b. Flush the system to remove any sediment.

Inspections:

Follow all local and environmental regulations regarding storm water 'Best Management Practices' inspection requirements. The following recommendations need to be followed

1. Frequency
 - a. During the first service year a visual inspection should be completed during and after each major rainfall event, in addition to semi-annually, to establish a pattern of sediment.
 - b. Adjacent Area: soil runoff, gravel removal.
 - c. Establish an annual inspection frequency based on the information collected during the first year. At a minimum an inspection should be performed semi-annually.
2. Inspect:
 - a. Inspection points.
 - b. Inflow and outflow points including the inlet/manhole and pipes.
 - c. Discharge area.
3. Identify and Report maintenance required:
 - a. Sediment accumulation.
 - b. System backing up.
 - c. Flow rate change.

Maintenance Procedures:

1. Conform to all local, environmental regulations.
2. Determine if maintenance is required. If a pre-treatment device is installed, follow manufacturer recommendations.
3. Using a vacuum pump to evacuate sediment from the inflow and outflow points.
4. Flush the system with clean water forcing debris from the system. Take care to avoid direct water pressure when flushing the system.
5. Repeat steps 3 and 4 until no debris is evident.

Preventive Maintenance of Flap gate

The storm water conveyance system collects and transports urban runoff that may contain certain pollutants. Maintaining catch basins, storm water inlets, and other storm water conveyance structures on a regular basis will remove pollutants, prevent clogging of the downstream conveyance system, restore catch basins' sediment trapping capacity, and ensure the system functions properly hydraulically to avoid flooding.

Details of suggested feasible machine

KJ-3100 Water Jetter

- ❖ Cost of the machine is around 5000 US\$



The RIDGID® Model KJ-3100 portable water jetter gives you 3000 psi (205bar) actual working pressure to handle large commercial and industrial applications. This jetter propels a highly flexible and lightweight hose through 2" (50 mm) to 10" (250 mm) lines blasting through sludge, soap, grease, and sediment blockages. As you pull the hose back, it power scrubs the line flushing debris away and restoring drain lines to their full, free-flowing capacity – all without the use of harmful chemicals.

FEATURES

- **Powerful** - Actual working pressure of 3000 psi (205bar) and flow of 5.5 GPM (21 l/min) for fast, effective cleaning of lines.
- **Lightweight Hose** - Hose with nylon braid provides significant weight reduction and increased flexibility – all without reducing strength. Allows the thrust to propel the hose further down the line.
- **Complete** - With the Model KJ-3100's removable hose reel, there is no need to purchase expensive portable hose reels. Standard packages come equipped to handle indoor and remote applications.
- **Convenient** - Completely remove the hose reel to ease loading onto service trucks. Simply rotate the hose reel forward to gain full access to the engine's gas tank and air filter.
- **Maneuverable** - In the heavy-duty 3000 psi (205bar) jetter category, the RIDGID KJ-3100 is one of the most maneuverable jetters on the market. The unit, on its unique two-wheeled cart, easily fits through standard size doors and can negotiate tight turns with the greatest of ease.
- **Pulse Action** - Activate the Model KJ-3100's pulse action to easily negotiate difficult bends and traps.
- **Quality & Dependability** - Triplex pump with corrosion-resistant, forged brass head. Gear reducer allows pump to run at slower (optimal) speed. Reduced number of fittings, hoses and parts minimizes leaks and downtime – keeping you on the job.
- **Versatile** - Power wash package and chemical injector system cleans cables, tools, and other heavily soiled equipment.

- **Quick Start** - 16 HP Recoil start gasoline engine starts easily. Features: ON/OFF switch; fuel shutoff; choke and throttle controls; easy access oil fill and dip stick.

MACHINE OPTIONES

Catalog Number	Model No.	Description	Weight	
			lb.	kg
37413	KJ-3100	KJ-3100 Jetter with Pulse – H-111 and H-112 1/4" NPT Nozzles – H-38 Hose Reel with 200' (61 m) x 3/8" ID Jet Hose – 50' (15 m) x 3/8" ID Jet/Wash Hose – FV-1 Foot Valve – Nozzle Cleaning Tool – HW-30 Wash Wand – Root Ranger Root Cutting Nozzle – HF-4 Quick Connect Hose	272	125

JETTER HOSES

Catalog Number	Model No.	Description	Hose I.D. (in.)	Hose O.D. (in.)	Male NPT Thread (in.)
47597	H-1435	3/16" x 35' (11 m)	3/16	1/4	1/8
47602	H-1450	3/16" x 50' (15 m)	3/16	1/4	1/8
49272	H-1475	3/16" x 75' (23 m)	3/16	1/4	1/8
49277	H-1400	3/16" x 100' (30 m)	3/16	1/4	1/8
64732	H-1415	3/16" x 150' (45,5 m)	3/16	1/4	1/8
64832	H-3850	3/8" ID x 50' (15 m) Jet/Wash Hose	3/8	5/8	1/4
64837	H-3810	3/8" ID x 100' (30 m) Jet Hose	3/8	5/8	1/4
64842	H-3815	3/8" ID x 150' (45,5 m) Jet Hose	3/8	5/8	1/4
64847	H-3820	3/8" ID x 200' (61 m) Jet Hose	3/8	5/8	1/4
64857	H-3830	3/8" ID x 300' (91 m) Jet Hose	3/8	5/8	1/4

ACCESSORIES

Catalog Number	Model No.	Description
62882	H-5	Mini Hose Reel
64862	H-38	Hose Reel (Fits KJ-3000)
64902	H-38 WH	Hose Reel with 200' (61 m) x 3/8" ID Hose (Fits KJ-3100)
64797	HW-30	Wash Wand, KJ-3000
48367	H-25	Winterizing Kit
48157	FV-1	Foot Valve
66732	HF-4	Quick Connect Hose (Reel to Foot Valve)
47542	H-21	Nozzle Cleaning Tool
67187	H-32	Jet Vac
70032		RIDGID PVC Drain Cleaning Gloves
41937		RIDGID Leather Drain Cleaning Gloves

12.0 Cost Estimate (Blank BOQ for Full Island, using underground tank)

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES BILL OF QUANTITIES					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
-	<u>STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES</u>				
-	<u>GRAND SUMMARY</u>				
A	General Items				
B	Zone A works				
C	Zone B works				
D	Zone C works				
E	Zone D works				
F	Zone E works				
	GRAND TOTAL			USD	
	TAXES				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
GENERAL ITEMS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	- <u>GENERAL ITEMS</u>				
A	Supply of performance bond as per the contract requirement	Item	1.0		
B	Insurance of the Works as per the contract	Item	1.0		
C	Third party insurance as per the contract	Item	1.0		
D	Office for the Engineer's staff including , portable water, electricity and sanitary facilities	Item	1.0		
E	Testing of materials	Item	1.0		
F	Testing of Works completed	Item	1.0		
G	Temporary traffic diversions and access roads	Item	1.0		
H	Contractor's site office including sanitary facilities.	Item	1.0		
J	Contractor's site storage	Item	1.0		
K	Contractor's site staff / workers accommodation	Item	1.0		
L	Electricity for Works including connection and maintenance.	Item	1.0		
M	Water for Works including connection and maintenance.	Item	1.0		
N	Security for Works	Item	1.0		
P	Transport for Workers	Item	1.0		
Q	Ground investigation report	Item	1.0		
R	Environment Impact Assessment report	Item	1.0		
	Total general items carried to summary			USD	

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
ZONE A WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
<u>STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES</u>					
-					
<u>SUMMARY - ZONE A WORKS</u>					
A	Earthworks				
B	Pipe works - Pipes				
C	Pipe works - Manholes and Pipe work Ancillaries				
D	Storage tanks				
Total Zone A works carried to grand summary				USD	
<u>EARTHWORKS</u>					
<u>Earth filling</u>					
A	Filling and compaction of earth (imported), in 150 mm layers for road works ; all in accordance with drawings and specifications.	m ³	1,600.0		
B	Filling and compaction of earth (imported), in 150 mm layers for storage tanks , minimum total thickness 300 mm ; all in accordance with drawings and specifications.	m ³	1,836.0		
<u>Road reinstatement</u>					
C	Reinstatement of roads along pipe laying as per road works specifications	Item	1.0		
Total earthworks carried to summary					

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
ZONE A WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>PIPEWORK - MANHOLES AND PIPEWORK ANCILLARIES</u>				
	<u>Manholes</u>				
	<u>PE inspection manholes, including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb; all in accordance with drawings and specifications.</u>				
A	600 mm diameter	nr	38.0		
	<u>Gutter inlet</u>				
	<u>PE infiltration gutter inlet, including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb; all in accordance with drawings and specifications.</u>				
B	400 x 400 mm	nr	280.0		
	<u>Grade 25 concrete pipe encasing including formwork, concrete and reinforcement; all in accordance with drawings and specifications.</u>				
C	200 mm diameter pipes	m	359.0		
D	300 mm diameter pipes	m	248.0		
	<u>Valves</u>				
	<u>HDPE flap valve including jointing; all in accordance with drawings and specifications.</u>				
E	300 mm diameter	nr	1.0		
F	Rehabilitation of existing silt trap; all in accordance with drawings and specifications.	nr	1.0		
	<u>Construction of outfall; all in accordance with drawings and specifications</u>				
A	Outfall 1	nr	1.0		
	<u>Silt trap</u>				
B	Silt trap: including excavation, backfilling, concrete, formwork, reinforcements covering and gratings; all in accordance with drawings and specifications.	nr	1.0		
	Total pipe works - manholes and pipe work ancillaries carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
ZONE A WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>STORAGE TANK</u>				
	<u>PP module cells storage tank, effective water depth 400 mm, minimum compressive strength 0.45N/mm2, including excavation, anti-infiltration eathen cloth, one way infiltration earthen cloth ; all in accordance with drawings and specifications (earth fill measured separately)</u>				
A	Storage area A-1 (Volume 900 m3)	Item			
B	Storage area A-2 (Volume 725 m3)	Item			
C	Storage area A-3 (Volume 200 m3)	Item			
D	Storage area A-4 (Volume 120 m3)	Item			
E	Storage area A-5 (Volume 120 m3)	Item			
F	Storage area A-6 (Volume 8 m3)	Item			
G	Storage area A-7 (Volume 375 m3)	Item			
	Total storage tank carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
ZONE B WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
<u>STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES</u>					
<u>SUMMARY - ZONE B WORKS</u>					
A	Earthworks				
B	Pipe works - Pipes				
C	Pipe works - Manholes and Pipe work Ancillaries				
D	Storage tanks				
Total Zone B works carried to grand summary				USD	
<u>EARTHWORKS</u>					
<u>Earth filling</u>					
A	Filling and compaction of earth (imported), in 150 mm layers for road works ; all in accordance with drawings and specifications.	m ³	1,500.0		
B	Filling and compaction of earth (imported), in 150 mm layers for storage tanks , minimum total thickness 300 mm ; all in accordance with drawings and specifications.	m ³	787.0		
C	Salt water intrusion bunt, width 3.0 m ; all in accordance with drawings and specifications.	m	10.0		
<u>Road reinstatement</u>					
D	Reinstatement of roads along pipe laying as per road works specifications	Item	1.0		
<u>Demolition</u>					
E	Removing of existing earthen outfall	Item	1.0		
Total earthworks carried to summary					

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES

BILL OF QUANTITIES

ZONE B WORKS

Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<p><u>PIPEWORK - PIPES</u></p> <p><u>Pipes</u></p> <p><u>HDPE pipes including excavation, concrete bedding, pipe laying, jointing, pipe specials, dewatering, earthworks support and back filling, minimum depth to the top of the pipe is 500 mm ; all in accordance with drawings and specifications.</u></p>				
A	nominal diameter 200 mm	m	2,146.0		
B	nominal diameter 300 mm	m	662.0		
	Total pipe works - pipes carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
ZONE B WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
<u>PIPEWORK - MANHOLES AND PIPEWORK ANCILLARIES</u>					
<u>Manholes</u>					
<u>PE inspection manholes, including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb; all in accordance with drawings and specifications.</u>					
A	600 mm diameter	nr	23.0		
<u>Gutter inlet</u>					
<u>PE infiltration gutter inlet, including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb; all in accordance with drawings and specifications.</u>					
B	400 x 400 mm	nr	281.0		
<u>Grade 25 concrete pipe encasing including formwork, concrete and reinforcement; all in accordance with drawings and specifications.</u>					
C	200 mm diameter pipes	m	1,474.0		
D	300 mm diameter pipes	m	596.0		
<u>Valves</u>					
<u>HDPE flap valve including jointing; all in accordance with drawings and specifications.</u>					
E	300 mm diameter	nr	2.0		
<u>Construction of outfall; all in accordance with drawings and specifications</u>					
F	Outfall 2	nr	1.0		
G	Outfall 3	nr	1.0		
<u>Silt trap</u>					
A	Silt trap : including excavation, backfilling, concrete, formwork, reinforcements covering and gratings; all in accordance with drawings and specifications.	nr	2.0		
Total pipe works - manholes and pipe work ancillaries carried to summary					

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES BILL OF QUANTITIES ZONE B WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<p><u>STORAGE TANK</u></p> <p><u>PP module cells storage tank, effective water depth 400 mm, minimum compressive strength 0.45N/mm2, including excavation, anti-infiltration earthen cloth, one way infiltration earthen cloth ; all in accordance with drawings and specifications (earth fill measured separately)</u></p>				
A	Storage area B-1 (Volume 475 m3)	Item			
B	Storage area B-2 (Volume 125 m3)	Item			
C	Storage area B-3 (Volume 60 m3)	Item			
D	Storage area B-4 (Volume 375 m3)	Item			
E	Storage area B-5 (Volume 14 m3)	Item			
	Total storage tank carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
ZONE C WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
<u>STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES</u>					
<u>SUMMARY - ZONE C WORKS</u>					
A	Earthworks				
B	Pipe works - Pipes				
C	Pipe works - Manholes and Pipe work Ancillaries				
D	Storage tanks				
Total Zone C works carried to grand summary				USD	
<u>EARTHWORKS</u>					
<u>Earth filling</u>					
A	Filling and compaction of earth (imported), in 150 mm layers for road works ; all in accordance with drawings and specifications.	m ³	1,300.0		
B	Filling and compaction of earth (imported), in 150 mm layers for storage tanks , minimum total thickness 300 mm ; all in accordance with drawings and specifications.	m ³	581.0		
<u>Road reinstatement</u>					
C	Reinstatement of roads along pipe laying as per road works specifications	Item	1.0		
Total earthworks carried to summary					

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES**BILL OF QUANTITIES****ZONE C WORKS**

Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>PIPEWORK - PIPES</u> <u>Pipes</u> <u>HDPE pipes including excavation, concrete bedding, pipe laying, jointing, pipe specials, dewatering, earthworks support and back filling, minimum depth to the top of the pipe is 500 mm ; all in accordance with drawings and specifications.</u>				
A	nominal diameter 200 mm	m	1,503.0		
B	nominal diameter 300 mm	m	266.0		
	Total pipe works - pipes carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
ZONE C WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>PIPEWORK - MANHOLES AND PIPEWORK ANCILLARIES</u>				
	<u>Manholes</u>				
	<u>PE inspection manholes, including excavation, concrete bedding, jointing, dewatering, earthworks support , back filling , paving and concrete curb; all in accordance with drawings and specifications.</u>				
A	600 mm diameter	nr	21.0		
	<u>Gutter inlet</u>				
	<u>PE infiltration gutter inlet , including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb ; all in accordance with drawings and specifications.</u>				
B	400 x 400 mm	nr	177.0		
	<u>Grade 25 concrete pipe encasing including formwork, concrete and reinforcement ; all in accordance with drawings and specifications.</u>				
C	200 mm diameter pipes	m	1,503.0		
D	300 mm diameter pipes	m	266.0		
	<u>Valves</u>				
	<u>HDPE flap valve including jointing ; all in accordance with drawings and specifications.</u>				
E	300 mm diameter	nr	2.0		
	<u>Construction of outfall ; all in accordance with drawings and specifications</u>				
A	Outfall 5	nr	1.0		
B	Outfall 6	nr	1.0		
	<u>Silt trap</u>				
C	Silt trap : including excavation, backfilling , concrete, formwork, reinforcements covering and gratings ; all in accordance with drawings and specifications.	nr	2.0		
	Total pipe works - manholes and pipe work ancillaries carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES**BILL OF QUANTITIES****ZONE C WORKS**

Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>STORAGE TANK</u>				
	<u>PP module cells storage tank, effective water depth 400 mm, minimum compressive strength 0.45N/mm2, including excavation, anti-infiltration earthen cloth, one way infiltration earthen cloth ; all in accordance with drawings and specifications (earth fill measured separately)</u>				
A	Storage area C-1 (Volume 300 m3)	Item			
B	Storage area C-2 (Volume 475 m3)	Item			
	Total storage tank carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
ZONE D WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES</u>				
	<u>SUMMARY - ZONE D WORKS</u>				
A	Earthworks				
B	Pipe works - Pipes				
C	Pipe works - Manholes and Pipe work Ancillaries				
D	Storage tanks				
	Total Zone D works carried to grand summary			USD	

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES**BILL OF QUANTITIES****ZONE D WORKS**

Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>EARTHWORKS</u>				
A	<u>Earth filling</u> Filling and compaction of earth (imported), in 150 mm layers for road works ; all in accordance with drawings and specifications.	m ³	1,800.0		
B	Filling and compaction of earth (imported), in 150 mm layers for storage tanks , minimum total thickness 300 mm ; all in accordance with drawings and specifications.	m ³	1,537.0		
	<u>Road reinstatement</u>				
C	Reinstatement of roads along pipe laying as per road works specifications	Item	1.0		
	Total earthworks carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
ZONE D WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
A	<p><u>PIPEWORK - PIPES</u></p> <p><u>Pipes</u> <u>HDPE pipes including excavation, concrete bedding, pipe laying, jointing, pipe specials, dewatering, earthworks support and back filling, minimum depth to the top of the pipe is 500 mm ; all in accordance with drawings and specifications.</u></p> <p>nominal diameter 200 mm</p>	m	2,824.0		
	Total pipe works - pipes carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
ZONE D WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>PIPEWORK - MANHOLES AND PIPEWORK ANCILLARIES</u>				
	<u>Manholes</u>				
	<u>PE inspection manholes, including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb; all in accordance with drawings and specifications.</u>				
A	600 mm diameter	nr	34.0		
	<u>Gutter inlet</u>				
	<u>PE infiltration gutter inlet, including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb; all in accordance with drawings and specifications.</u>				
B	400 x 400 mm	nr	283.0		
	<u>Grade 25 concrete pipe encasing including formwork, concrete and reinforcement; all in accordance with drawings and specifications.</u>				
C	200 mm diameter pipes	m	790.0		
	<u>Valves</u>				
	<u>HDPE flap valve including jointing; all in accordance with drawings and specifications.</u>				
D	200 mm diameter	nr	2.0		
	<u>Construction of outfall; all in accordance with drawings and specifications</u>				
E	Outfall 6	nr	1.0		
F	Outfall 7	nr	1.0		
	<u>Silt trap</u>				
A	Silt trap : including excavation, backfilling, concrete, formwork, reinforcements covering and gratings; all in accordance with drawings and specifications.	nr	1.0		
	Total pipe works - manholes and pipe work ancillaries carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES

BILL OF QUANTITIES

ZONE D WORKS

Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>STORAGE TANK</u>				
	<u>PP module cells storage tank, effective water depth 400 mm, minimum compressive strength 0.45N/mm², including excavation, anti-infiltration eathen cloth, one way infiltration earthen cloth ; all in accordance with drawings and specifications (earth fill measured separately)</u>				
A	Storage area D-1 (Volume 350 m3)	Item			
D	Storage area D-2 (Volume 150 m3)	Item			
C	Storage area D-3 (Volume 10 m3)	Item			
D	Storage area D-4 (Volume 200 m3)	Item			
E	Storage area D-5 (Volume 7 m3)	Item			
F	Storage area D-5 (Volume 200 m3)	Item			
G	Storage area D-5 (Volume 120 m3)	Item			
H	Storage area D-5 (Volume 14 m3)	Item			
J	Storage area D-5 (Volume 375 m3)	Item			
K	Storage area D-5 (Volume 130 m3)	Item			
L	Storage area D-5 (Volume 235 m3)	Item			
M	Storage area D-5 (Volume 18 m3)	Item			
N	Storage area D-5 (Volume 150 m3)	Item			
	Total storage tank carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
ZONE E WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES</u> <u>SUMMARY - ZONE E WORKS</u>				
A	Earthworks				
B	Pipe works - Pipes				
C	Pipe works - Manholes and Pipe work Ancillaries				
D	Storage tanks				
	Total Zone E works carried to grand summary			USD	
	<u>EARTHWORKS</u>				
	<u>Earth filling</u>				
A	Filling and compaction of earth (imported), in 150 mm layers for road works ; all in accordance with drawings and specifications.	m ³	1,200.0		
B	Filling and compaction of earth (imported), in 150 mm layers for storage tanks , minimum total thickness 300 mm ; all in accordance with drawings and specifications.	m ³	1,139.0		
	<u>Road reinstatement</u>				
C	Reinstatement of roads along pipe laying as per road works specifications	Item	1.0		
	Total earthworks carried to summary				
	<u>PIPEWORK - PIPES</u>				
	<u>Pipes</u>				
	<u>HDPE pipes including excavation, concrete bedding, pipe laying, jointing, pipe specials, dewatering, earthworks support and back filling, minimum depth to the top of the pipe is 500 mm ; all in accordance with drawings and specifications.</u>				
A	nominal diameter 200 mm	m	1,943.0		
	Total pipe works - pipes carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES					
BILL OF QUANTITIES					
ZONE E WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>PIPEWORK - MANHOLES AND PIPEWORK ANCILLARIES</u>				
	<u>Manholes</u>				
	<u>PE inspection manholes, including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb; all in accordance with drawings and specifications.</u>				
A	600 mm diameter	nr	25.0		
	<u>Gutter inlet</u>				
	<u>PE infiltration gutter inlet, including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb; all in accordance with drawings and specifications.</u>				
B	400 x 400 mm	nr	195.0		
	<u>Grade 25 concrete pipe encasing including formwork, concrete and reinforcement; all in accordance with drawings and specifications.</u>				
C	200 mm diameter pipes	m	262.0		
	Total pipe works - manholes and pipe work ancillaries carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR THINADHOO ISLAND, MALDIVES**BILL OF QUANTITIES****ZONE E WORKS**

Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>STORAGE TANK</u> <u>PP module cells storage tank, effective water depth 400 mm, minimum compressive strength 0.45N/mm2, including excavation, anti-infiltration eathen cloth, one way infiltration earthen cloth ; all in accordance with drawings and specifications (earth fill measured separately)</u>				
A	Storage area E-1 (Volume 18 m3)	Item			
B	Storage area E-2 (Volume 425 m3)	Item			
C	Storage area E-3 (Volume 475 m3)	Item			
D	Storage area E-4 (Volume 600 m3)	Item			
	Total storage tank carried to summary				

13.0 Conclusion and Recommendations

Every available option has been taken into consideration in deciding on the most suitable solution in addition there are 8 isolated locations where improvements are necessary that has been adopted. The cost factor also has been considered, and it has been observed that the engineering solution that has been proposed at each of the locations is in agreement with the suggestions made by the community living in the respective area.

The improvements that have been proposed are of conventional nature and within the capabilities of the local construction industry.

The problems identified and the solutions suggested are derived mainly from the experience of the beneficiaries and the concerned people living in the locality. Their views and suggestions along with those of the Municipal Council members and staff have been taken into consideration in evolving these proposals for improving the storm water drainage system.

With regard to the SWMS that has been proposed in the foregoing paragraphs, there are few items that need to be reiterated with a view to achieve the objectives of the Designer and they are described in detail as follows:

- All development activities must be carried out in such a manner that high priority is given for the preservation of the water resources. It is essential that the developers of land should reserve space for storage and ground recharge purposes. Prior to approval of development plans it is necessary to examine whether these requirements have been fulfilled.
- Storm water harvesting is an activity that ideally be carried out within each household premises. The Down pipes that carry the water should flow directly into the ground water well. Every effort must be taken to store the entire quantity within the ground water well and only in rare instances should water be allowed to spill over to the road.
- Road construction activities that are presently in progress should continue with the Infiltration Galleries incorporated to the system with provision for cleaning at regular intervals.
- All Manholes along the road need to be provided with GI covers in such a manner that they flush with road surface.
- As proposed in the Master Plan it is proposed to use Aqua Cells as ground storage tanks.
- In the event of heavy rainfall discharge to the sea is inevitable and for this purpose the excess water should be diverted to the collection sump and from there pumping should be carried out to the optimum level so as to prevent any adverse effect within inland.
- Buildings such as mosques, hospitals, banks, large commercial buildings such as hotels, shops and selected individual houses with large roof areas should be utilized for the purpose of water harvesting
- Available rainfall data need to be analyzed to ascertain the availability of yield to be harvested during the rainy season. The rain water collected from the above buildings can be diverted by gravity to the most convenient and closest water tanks provided at selected

locations. It will be necessary to design and implement the general layout plans of the rain fall collection system and improvements to the ground water recharging system in individual plots in consultation with community in the area.

- The main design components of the rainfall harvesting and collection systems up to the treatment plant includes transmission pipe network system, inter connected storage tank system, supply of pumps for transmission of rain water from the storage tanks to the Ro plant and design of a system to flush out the polluted roof and gutters prior to the rainy season.
- Laws and regulations on Storm Water Management
Water is a scarce commodity. Every effort must be taken to utilize water prudently. The people must be apprised of the need to prevent wastage. With that in view it is essential that the existing rules and regulations pertaining to the use of water is rigidly adhered by the inhabitants. The Council must enforce the legal powers it has when necessary. As at present there are instances of wastage observed at certain locations, particularly due to the non existence of a network of roads where a system of pipe network could receive the excess water from the premises.
- Rainwater harvesting (RWH)
People must be encouraged to harvest rainwater. They should be provided with private tanks on cost recovery basis. As against the high cost of desalination, rainwater is free resource and installation and disinfection cost is also affordable. Therefore the authorities must promote and popularize RWH as much as possible. There are several supportive factors for RWH such as sufficient rainfall, technical skills, available local resources, cost effectiveness, enthusiastic community, positive health impacts and environmentally friendly. RWH is the most preferred source of water for domestic use especially in rural areas where living conditions too had improved due to the roof catchment system. One of the key factors that determine the feasibility of RWH is the policy adopted in maintenance of RWH system. Regulations and guidelines for implementers and users need to be put in place to ensure the effectiveness of rainwater harvesting programme.
- Public appeal
At the onset of monsoon, public needs to be alerted to get prepared for the harvesting. The families will require cleaning their system and repairing faults if any. This will help them to store maximum water and protect the quality of stored water. Government (water supply department) may consider giving public notice in the press for the benefit of people and avoiding water shortage in the dry period.

The overall impact of the project on the environment is very positive and will not entail any significant negative impacts.

Having taken into consideration all aspects of the Technical, Financial, Socio-Economic and Environmental conditions, it is recommended that the Storm Water Drainage Improvement Project be implemented.

14.0 Photos



Actual site condition even for small rainfall



Well water level during rainy period



Storm water flow along the earthen drain



Water collected areas even for small rainfall



Water collected areas for small rain



Opening across the playground boundary wall to collect storm water runoff during rainy period



Inlet condition of the newly constructed shallow box culvert



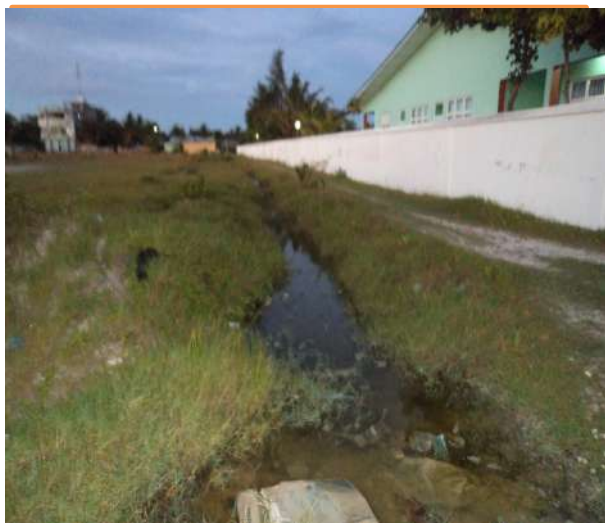
Inlet of the existing pipe culvert into sea – pilot project A



Downstream section of the earthen drain along the main road- Zone B



Existing condition of the earthen outlet during rainy period – pilot project Zone B



Water collected location by the side of the playground- Zone C



Existing earthen outfall Zone C



Downstream view of the existing earthen outfall Zone C



Water Level in the well during rainy period



Water collected areas during small rainfall



Water collected areas during small rainfall



Storm water flowing along the main road



Water collected areas even for small rain
Zone A



Existing emergency outlet location 01 Zone A



Existing emergency outlet location 02
Zone D

SECTION 2

INTRODUCTION

Price BOQ for the Island of Gdh.Thinadhoo have been prepared with four (04) Options. Although much emphasis had been made on the report for draining the storm water to underground tanks in available empty space (option 1), additional pricing option are given so that within an available budget and condition any methods in the option could be selected. The four Options are as follows;

OPTION 1

Price BOQ using under Ground Tank in empty available space for drainage/storage of storm water. Details of this is given in report and drawings of the project. Zone A and Zone B are selected as test project as these were found to be most problematic. (Refer drawings in Design report and Drawings for details).

OPTION 2

Price BOQ using under Ground Tank in empty available space for drainage/storage of storm water. This is same method as in option 1 but a small area is selected so that a Pilot Project could be conducted with a minimum budget. (Refer drawings attached with the BOQ for detail).

OPTION 3

Price BOQ for pumping out Storm water by means of Sump. Two Alternatives are given in this option which is as follows;

Alternative 1

In Alternative 1, storm water is collected from Storm water prone area to a Sump by means of collection Chamber and Pipe network. From the Sump the water is pumped to the sea. (Refer drawings attached with the BOQ for detail).

Alternative 2

In Alternative 1, storm water is collected from Storm water prone area to a Sump by means of collection Chamber and Pipe network. From the Sump the water is pumped to water distribution center in the Island. The water could be stored in a water tank in the distribution center and with filtration/treatment could be re-used. (Refer drawings attached with the BOQ for detail).

OPTION 4

Price BOQ using under rainwater harvesting. Importance of rainwater harvesting was already discussed in the report. Approximately 60% of the rainwater flood is caused from the Roofs (particularly since the roads of the Islands is very narrow and with lesser area compared with the roofs). Much of the problem of flooding could be solved if the rainwater is not allowed to flow to the roads. In this options rainwater is collected from the roofs of a storm water prone area (through gravity) by means of pipe network and chambers. From the network the Rainwater enters into a Lift Station and from the lift station(after sand removal), the water is collected in Storage Tank. Rainwater could be re-used after filtration/treatment (Refer drawings attached with the BOQ for detail).

OPTION 1
(USING UNDERGROUND TANKS)

OPTION 1

BILL OF QUANTITIES

Item No	Description	Unit	Qty	Rate	Amount
	Bill No. 1				
	General & Preliminaries				
1.1	General & Preliminaries Cost consisting the following: <ul style="list-style-type: none">• Provision and Maintenance of Equipments such as Excavators, Leveling Equipment ..etc needed in the project.• Material Transportation• Material Storage• Contractors Accommodation and administrative works	item	1	750,000	750,000
	Bill No. 2				
	ZONE A				
2.1	<i>Earth Works</i>				
2.1.1	Filling and compaction of sand , in 150 mm layers for road works ; all in accordance with drawings and specifications.	m ³	1,600	295	472,000
2.1.2	Filling and compaction of sand , in 150 mm layers for storage tanks , minimum total thickne 300 mm ; all in accordance with drawings and specifications.	m ³	1,836	295	541,620
2.2	<i>Pipe Works, Manholes & Gutters</i>				
2.2.1	Diameter 200 mm Pipe <ul style="list-style-type: none">• UPVC pipes including excavation, , pipe laying, jointing, pipe fitting, dewatering, earthworks support and back filling, minimum depth to the top of the pipe is 500 mm ; all in accordance with drawings and specifications.	m	2,106	1,200	2,527,200
2.2.1a	Diameter 300 mm Pipe	m	687	1,300	893,100

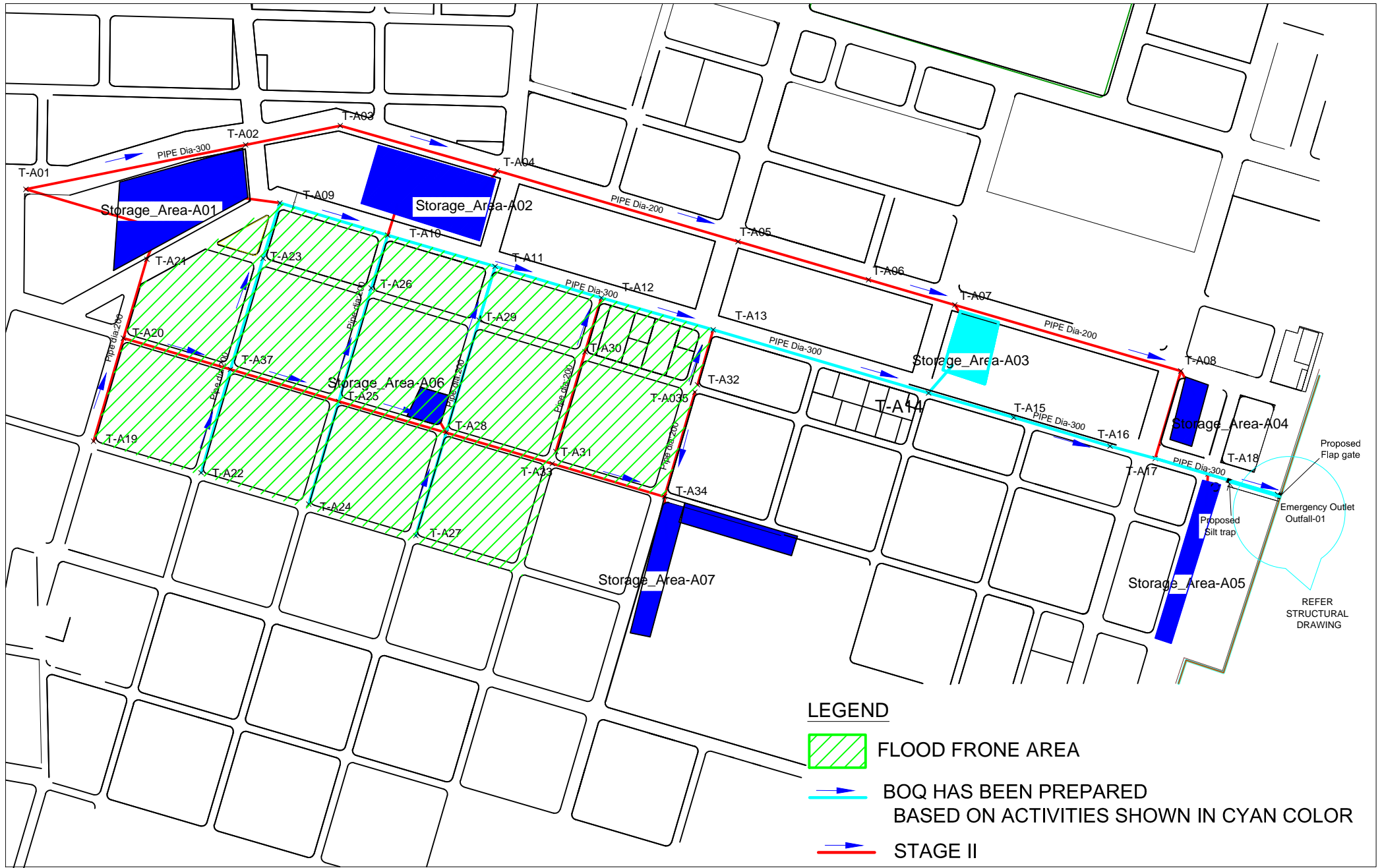
2.2.1	600mm Diameter Manholes <ul style="list-style-type: none"> PE inspection manholes, including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb; all in accordance with drawings and specifications. 	nos	38	25,000	950,000
2.2.3	Gutter Inlet 400mm x 400mm <ul style="list-style-type: none"> PE infiltration gutter inlet, including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb; all in accordance with drawings and specifications. 	nos	280	5,420	1,517,600
2.3	<i>FLIP GATE INSTALLATION</i>				
2.3.1	Installation of Flap Gate and bringing the needed modification to Sea-outfall	item	150,000	150,000	150,000
2.4	<i>STORAGE TANK</i> <ul style="list-style-type: none"> PP module cells storage tank, effective water depth 400 -800 mm, minimum compressive strength 0.45N/mm², including excavation, anti-infiltration earthen cloth, one way infiltration earthen cloth; all in accordance with drawings and specifications (earth fill measured separately) 				
2.4.1	Storage area A-1 (Volume 900 m ³)	m ³	900	5,550	4,995,000
2.4.2	Storage area A-2 (Volume 725 m ³)	m ³	725	5,550	4,023,750
2.4.3	Storage area A-3 (Volume 200 m ³)	m ³	200	5,550	1,110,000
2.4.4	Storage area A-4 (Volume 120 m ³)	m ³	120	5,550	666,000
2.4.5	Storage area A-5 (Volume 120 m ³)	m ³	120	5,550	666,000
2.4.6	Storage area A-6 (Volume 8 m ³)	m ³	8	5,550	44,400
2.4.7	Storage area A-6 (Volume 375 m ³)	m ³	375	5,550	2,081,250

Bill No. 3					
ZONE B					
3.1	<i>Earth Works</i>				
3.1.1	Filling and compaction of sand , in 150 mm layers for road works ; all in accordance with drawings and specifications.	m ³	1,500	295	442,500
3.1.2	Filling and compaction of sand , in 150 mm layers for storage tanks , minimum total thickne 300 mm ; all in accordance with drawings and specifications.	m ³	787	295	232,165
3.1.3	Salt water intrusion bunt, width 3.0 m ; all in accordance with drawings and specifications.	item	1	475,000	475,000
3.2	<i>Pipe Works, Manholes & Gutters</i>				
3.2.1	Diameter 200 mm Pipe <ul style="list-style-type: none"> UPVC pipes including excavation, , pipe laying, jointing, pipe fitting, dewatering, earthworks support and back filling, minimum depth to the top of the pipe is 500 mm ; all in accordance with drawings and specifications. 	m	2,146	1,200	2,575,200
3.2.2	Diameter 300 mm Pipe	m	662	1,300	860,600
3.2.1	600mm Diameter Manholes <ul style="list-style-type: none"> PE inspection manholes, including excavation, concrete bedding, jointing, dewatering, earthworks support , back filling , paving and concrete curb; all in accordance with drawings and specifications. 	nos	23	25,000	575,000
3.2.3	Gutter Inlet 400mm x 400mm <ul style="list-style-type: none"> PE infiltration gutter inlet , including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb ; all in accordance with drawings and specifications. 	nos	281	5,420	1,523,020
3.3	<i>FLIP GATE INSTALLATION</i>				
3.3.1	Installation of Flap Gate and bringing the needed	item	300,000	300,000	300,000




	modification to Sea-outfall (2nos)				
3.4	STORAGE TANK <ul style="list-style-type: none"> PP module cells storage tank, effective water depth 400 -800 mm, minimum compressive strength 0.45N/mm2, including excavation, anti-infiltration earthen cloth, one way infiltration earthen cloth ; all in accordance with drawings and specifications (earth fill measured separately) 				
3.4.1	Storage area B-1 (Volume 475 m3)	m ³	475	5,550	2,636,250
3.4.2	Storage area B-2 (Volume 125 m3)	m ³	125	5,550	693,750
3.4.3	Storage area B-3 (Volume 60 m3)	m ³	60	5,550	333,000
3.4.4	Storage area B-4 (Volume 375 m3)	m ³	375	5,550	2,081,250
3.4.5	Storage area B-6 (Volume 14 m3)	m ³	14	5,550	77,700
	TOTAL				34,193,355


OPTION 2

(USING UNDERGROUND TANKS)



LEGEND

-  FLOOD FRONE AREA
-  BOQ HAS BEEN PREPARED
BASED ON ACTIVITIES SHOWN IN CYAN COLOR
-  STAGE II

 MALÉ WATER & SEWERAGE COMPANY PVT LTD. <small>AMEENEE MAGU, MACHCHANGOLHI MALÉ - 20-01 REPUBLIC OF MALDIVES Tel: (+960) 323209, Fax: (+960) 324306, E-mail: mwsc@dhthinad.net.mv</small>	CLIENT: MINISTRY OF ENVIRONMENT AND ENERGY, MALDIVES	PROJECT: DESIGN OF STORM WATER MANAGEMENT SYSTEM FOR THE G.DhTHINADHOO ISLAND	SCALE: AS SHOWN	DRW NO. : TA-LP-A-01	DESIGN BY:	DRAWN BY:	AMMENDMENTS:
	CONTENTS: LAYOUT PLAN ZONE -A	DATE: 14.12.2013	Page:	STRUCTURAL DESIGN BY:	CHECKED BY:		

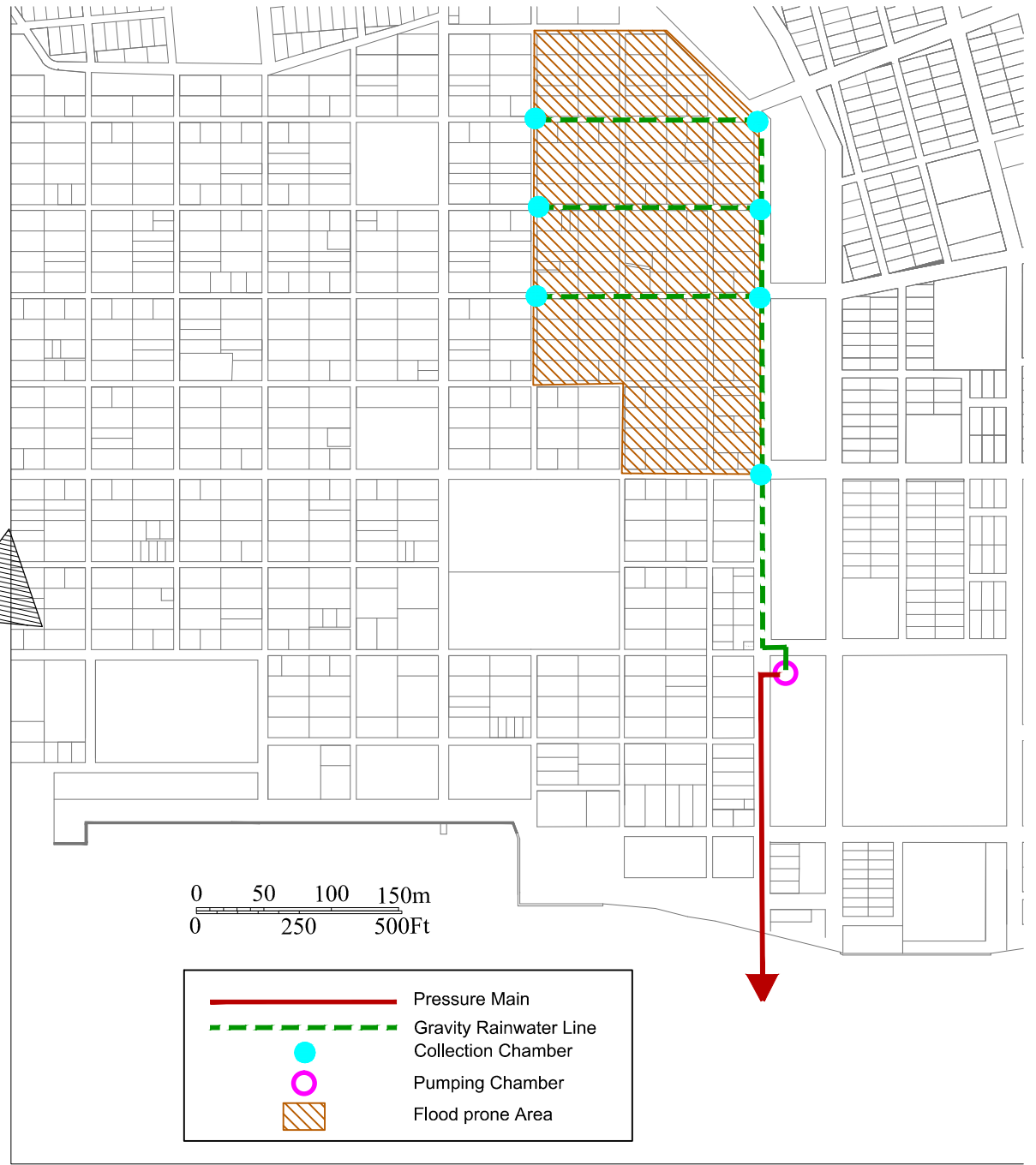
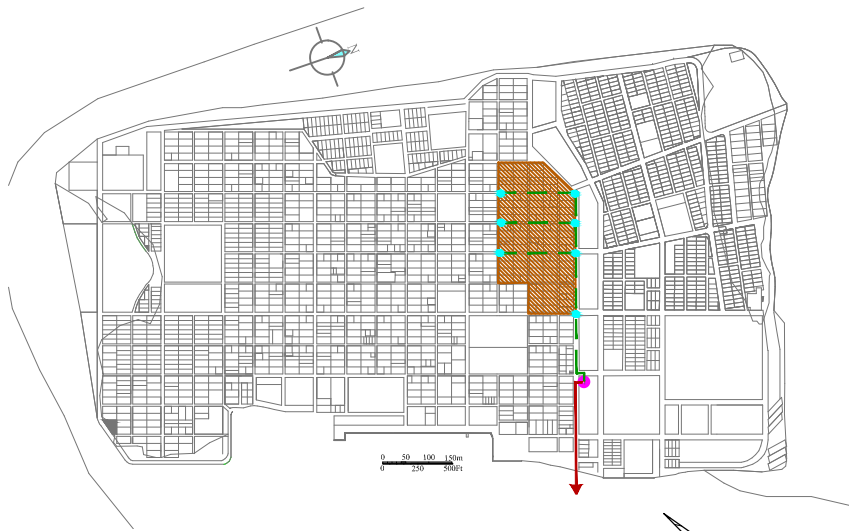
OPTION 2

BILL OF QUANTITIES

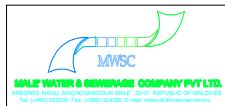
Item No	Description	Unit	Qty	Rate	Amount
	Bill No. 1				
	General & Preliminaries				
1.1	General & Preliminaries Cost consisting the following: <ul style="list-style-type: none">• Provision and Maintenance of Equipments such as Excavators, Leveling Equipment ..etc needed in the project.• Material Transportation• Material Storage• Contractors Accommodation and administrative works	item	1	500,000	500,000
	Bill No. 2				
2.1	<i>Earth Works</i>				
2.1.1	Filling and compaction of sand , in 150 mm layers for road works ; all in accordance with drawings and specifications.	m ³	865	295	255,175
2.2	<i>Pipe Works, Manholes & Gutters</i>				
2.2.1	Diameter 200 mm Pipe <ul style="list-style-type: none">• UPVC pipes including excavation, , pipe laying, jointing, pipe fitting, dewatering, earthworks support and back filling, minimum depth to the top of the pipe is 500 mm ; all in accordance with drawings and specifications.	m	510	1,200	612,000
2.2.1a	Diameter 300 mm Pipe	m	687	1,300	893,100
2.2.1	600mm Diameter Manholes <ul style="list-style-type: none">• PE inspection manholes, including excavation, concrete bedding, jointing, dewatering, earthworks support , back filling , paving and concrete curb; all in accordance with drawings and specifications.	nos	14	25,000	350,000

2.2.3	Gutter Inlet 400mm x 400mm <ul style="list-style-type: none">PE infiltration gutter inlet , including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb ; all in accordance with drawings and specifications.	nos	120	5,420	650,400
2.3	<i>FLIP GATE INSTALLATION</i>				
2.3.1	Installation of Flap Gate and bringing the needed modification to Sea-outfall	item	150,000	150,000	150,000
2.4	<i>STORAGE TANK</i> <ul style="list-style-type: none">PP module cells storage tank, effective water depth 400 -800 mm, minimum compressive strength 0.45N/mm2, including excavation, anti-infiltration eathen cloth, one way infiltration earthen cloth ; all in accordance with drawings and specifications (earth fill messured separatly)				
2.4.1	Storage area A-3 (Volume 200 m3)	m ³	200	5,550	1,110,000
	TOTAL				4,520,675

OPTION 3
(ALTERNATIVE 1)
(USING PUMP STATION TO PUMP TO SEA)



	Pressure Main
	Gravity Rainwater Line
	Collection Chamber
	Pumping Chamber
	Flood prone Area



PROJECT: Design of Storm water Management System for G.Dh.Thinadhoo Island

CONTENTS: Conceptual Layout - Option IV (Alternative 1)

SCALE: NTS

DATE: 25 - 12 - 2013

DRW NO. : TSW/C-4A

DESIGN BY: ---

STRUCTURAL DESIGN BY: --

DRAWN BY: HAPPY

CHECKED BY: MIA

AMMENDMENTS:

OPTION 3 (ALTERNATIVE 1)

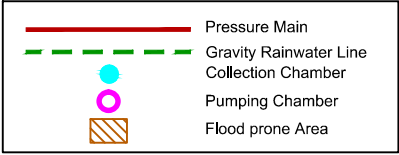
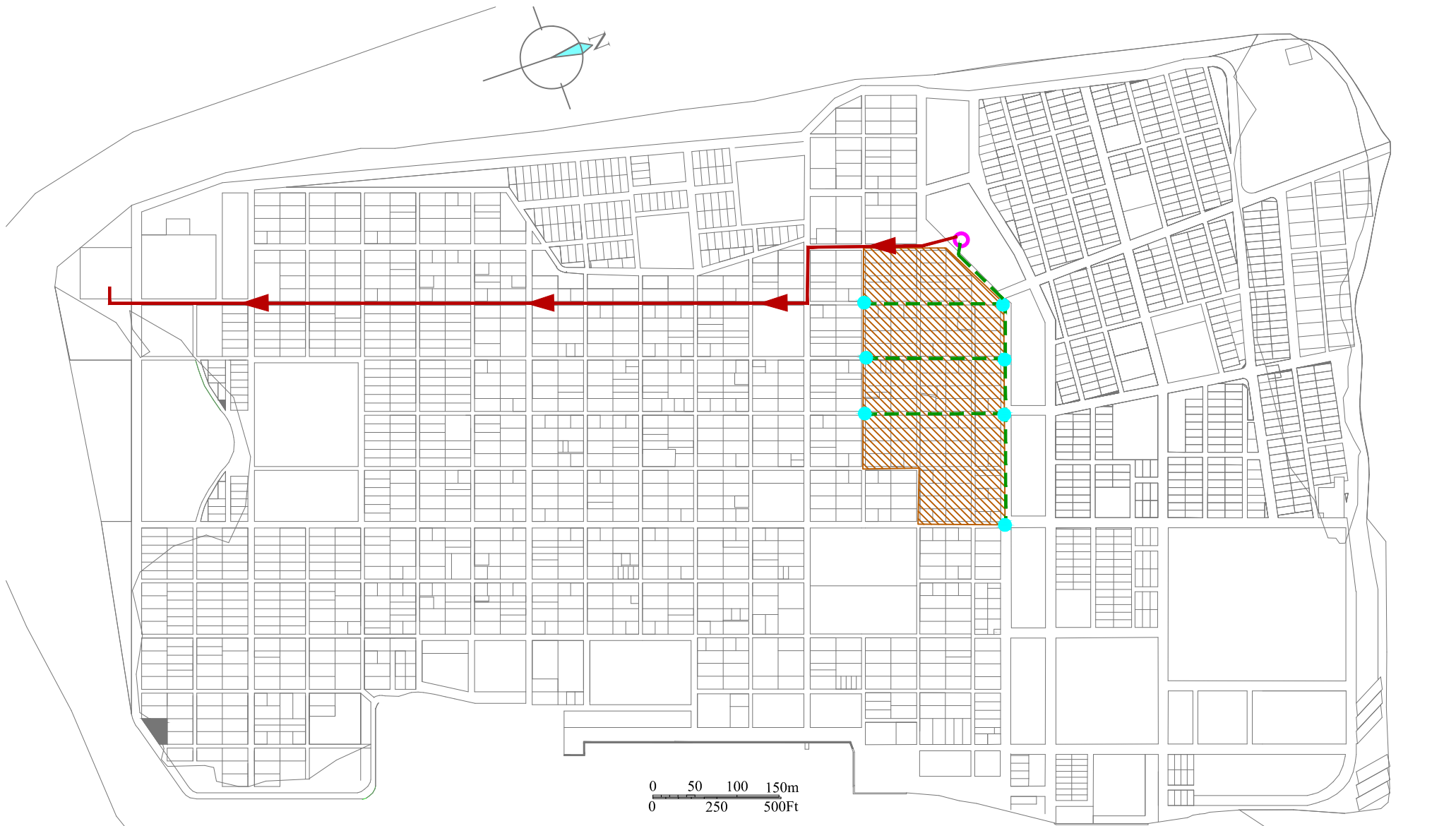
BILL OF QUANTITIES

Item No	Description	Unit	Qty	Rate	Amount
	Bill No. 1				
	General & Preliminaries				
1.1	General & Preliminaries Cost consisting the following: <ul style="list-style-type: none">• Provision and Maintenance of Equipments such as Excavators, Leveling Equipment, ..etc needed in the project.• Material Transportation• Material Storage• Contractors Accommodation and administrative works	item	1	500,000	500,000
	Bill No. 2				
2.1	<i>PIPE LAYING</i>				
2.1.1	Laying of 160mm Ø PE Forcemain pipe line (material and labour)	m	256	1,250	320,000
2.1.2	Laying of 200mm Ø Upvc gravity pipe line (material and labour)	m	851	1,200	1,021,200
2.2	<i>LIFTING STATION & COLLECTION CHAMBERS</i>				
2.2.1	Pump stations	nos	1	700,000	500,000
2.2.2	Collection chambers	nos	7	25,000	175,000
2.2.3	Pumps	nos	1	150,000	150,000
	TOTAL				2,666,200

OPTION 3

(ALTERNATIVE 2)

**(USING PUMP STATION TO PUMP TO
WATER DISTRIBUTION OPERATION
CENTER)**



PROJECT: Design of Storm water Management System for G.Dh.Thinadhoo Island

CONTENTS: Conceptual Layout - Option IV (Alternative 2)

SCALE:
NTS

DATE:
25 - 12 - 2013

DRW NO. :
TSW/C-04B

DESIGN BY:

STRUCTURAL DESIGN BY:
--

DRAWN BY:
HAPPY

CHECKED BY:
MIA

AMMENDMENTS:

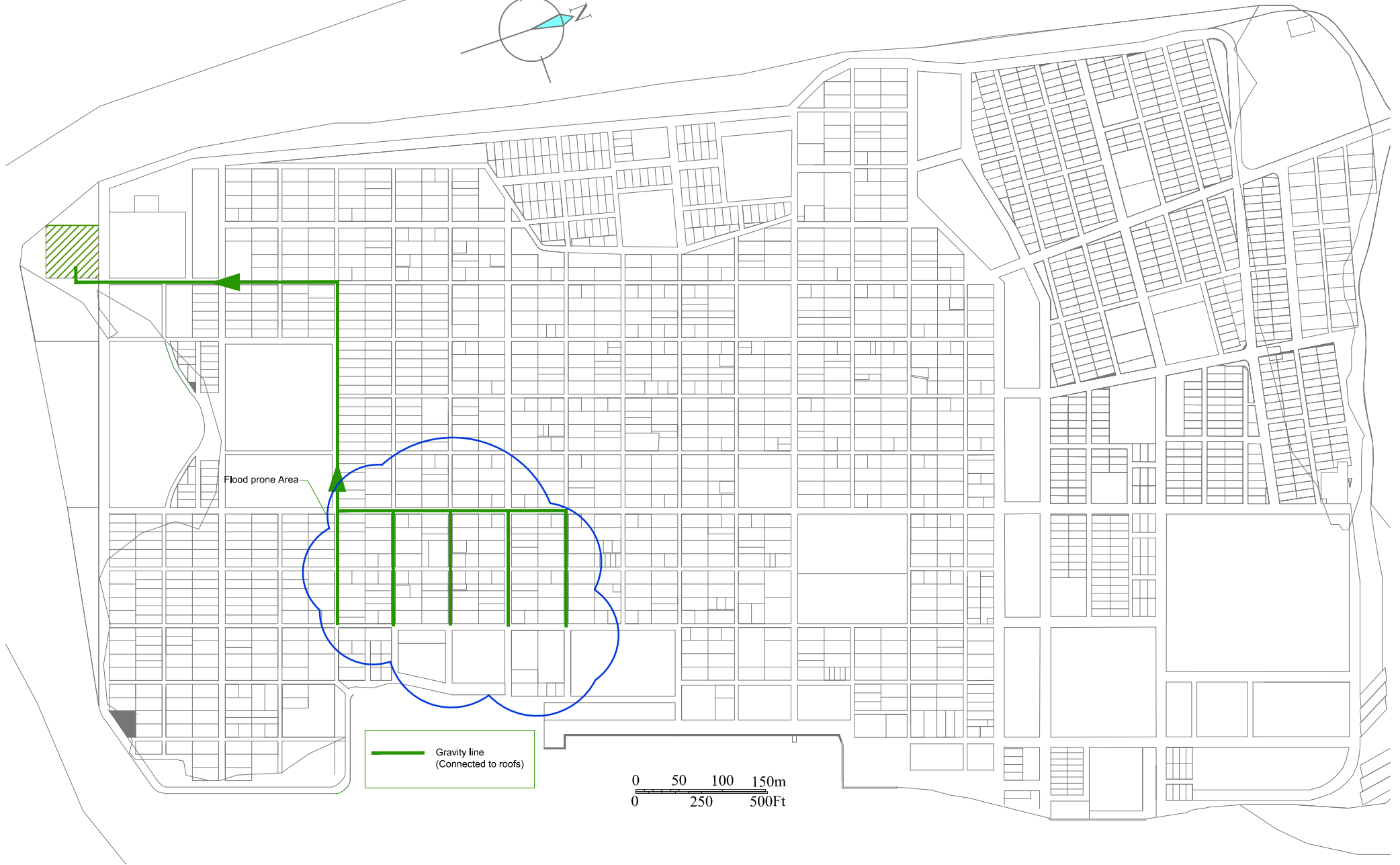
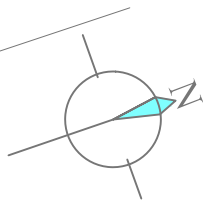
OPTION 3 (ALTERNATIVE 2)

BILL OF QUANTITIES

Item No	Description	Unit	Qty	Rate	Amount
	Bill No. 1				
	General & Preliminaries				
1.1	General & Preliminaries Cost consisting the following: <ul style="list-style-type: none">• Provision and Maintenance of Equipments such as Excavators, Leveling Equipment, ..etc needed in the project.• Material Transportation• Material Storage• Contractors Accommodation and administrative works	item	1	500,000	500,000
	Bill No. 2				
2.1	<i>PIPE LAYING</i>				
2.1.1	Laying of 160mm Ø PE Forcemain pipe line	m	1100	1,250	1,375,000
2.1.2	Laying of 200mm Ø Upvc gravity pipe line	m	851	1,200	1,021,200
2.2	<i>LIFTING STATION & COLLECTION CHAMBERS</i>				
2.2.1	Pump stations	nos	1	700,000	500,000
2.2.2	Collection chambers	nos	7	25,000	175,000
2.2.3	Pumps	nos	1	200,000	200,000
	TOTAL				3,771,200

OPTION 4

(RAINWATER HARVESTING)



Flood prone Area

— Gravity line
(Connected to roofs)

0 50 100 150m
0 250 500Ft



PROJECT: Design of Storm water Management System for the G.Dh.Thinadhoo Island

CONTENTS: Conceptual Layout - Option III

SCALE:
NTS

DATE:
25 - 12 - 2013

DRW NO. :

TSW/C-03

DESIGN BY:

STRUCTURAL DESIGN BY:

--

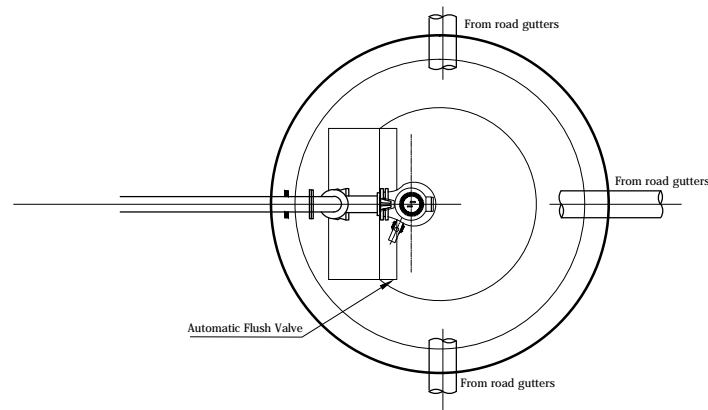
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HAPPY

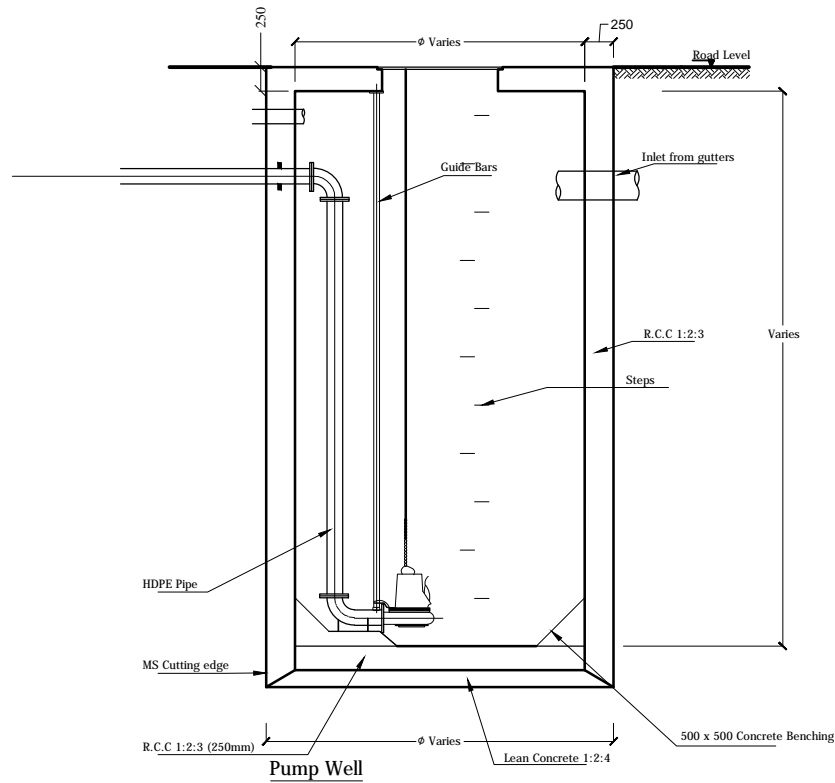
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MIA


AMMENDMENTS:

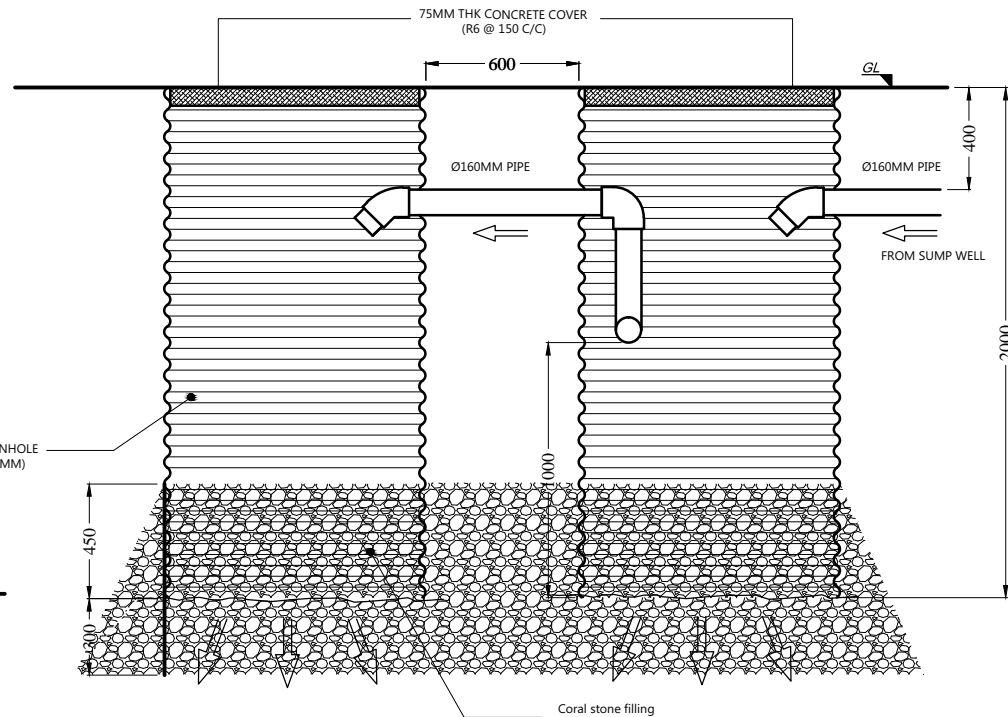
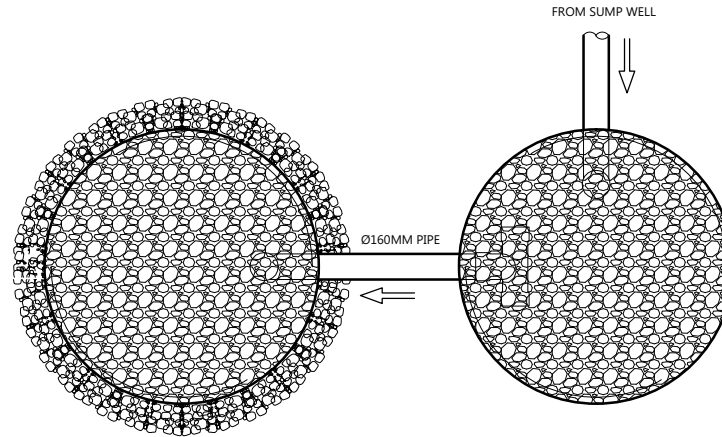


SECTIONAL PLAN VIEW



SECTIONAL ELEVATION (SUMP)

 <p>MWSC MALDIVIAN WATER & SEWERAGE COMPANY PVT LTD. ARENTEE MAGU, MACHCHANGOLU MALÉ 20-01, REPUBLIC OF MALDIVES Tel: (995) 323276, Fax: (995) 324026, E-mail: mwsc@divnet.net.mv</p>	<p>PROJECT: Design of Storm water Management System for H.Dh.Kulhudhuffushi and G DH.Thinadhoo Island</p>	<p>SCALE: As Given</p>	<p>DRW NO. : KTSW/TD-05</p>	<p>DESIGN BY: ---</p>	<p>DRAWN BY: HAPPY</p>	<p>AMMENDMENTS:</p> <hr/> <hr/> <hr/>
	<p>CONTENTS: Typical Pump Station</p>	<p>DATE: 25 - 12 - 2013</p>	<p>STRUCTURAL DESIGN BY: --</p>	<p>CHECKED BY: MIA</p>		

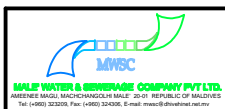


Ø1000MM CORRUGATED MANHOLE
WITHOUT BASE (DEPTH: 2000MM)
2 Nr's

SECTIONAL ELEVATION
SCALE 1:25

SETTLING CHAMBER

Coral stone filling



PROJECT:
Design of Storm water Management System
for H.Dh.Kulhudhuffushi and G DH.Thinadhoo Island

CONTENTS: Typical Settling Chamber

SCALE:
As Given

DATE:
25 - 12 - 2013

DRW NO. :
KTSW/TD-04

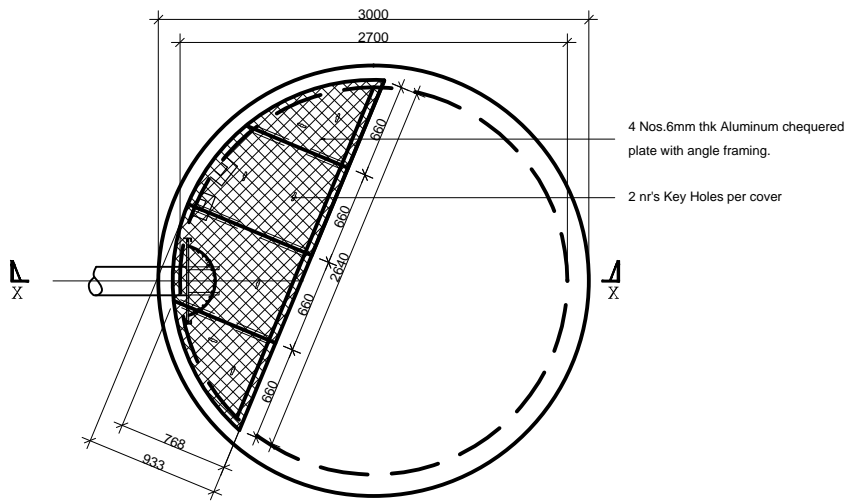
DESIGN BY:

STRUCTURAL DESIGN BY:
--

DRAWN BY:
HAPPY

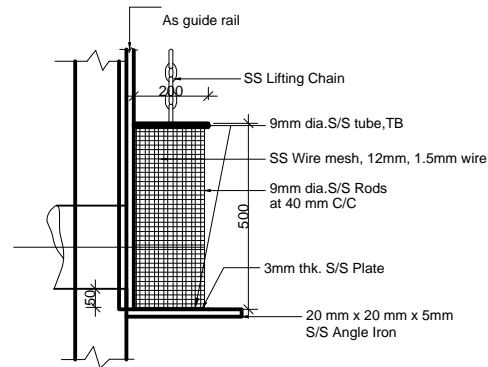
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AMMENDMENTS:



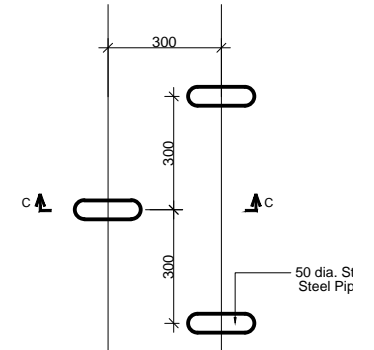
PLAN - LIFT STATION

NTS

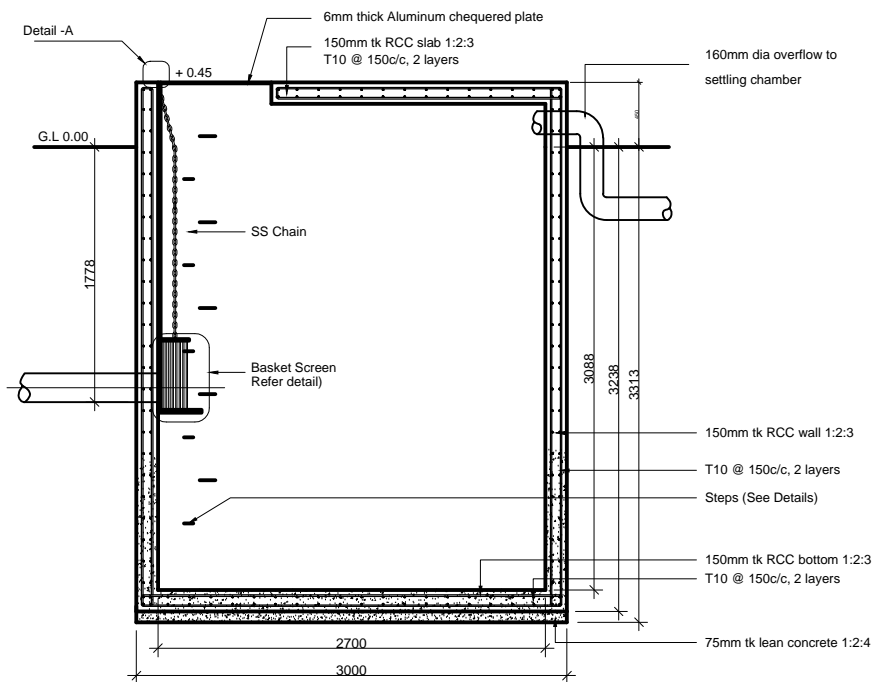


Section

20mm C-Channel

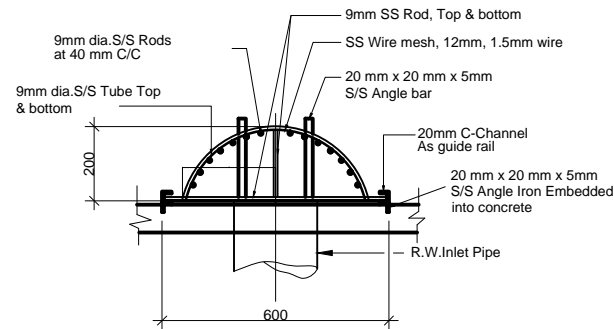


Elevation



SECTION X-X

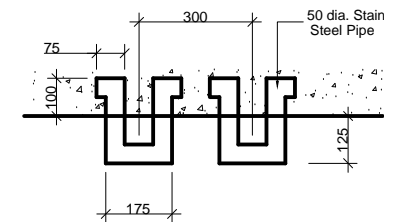
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Plan View

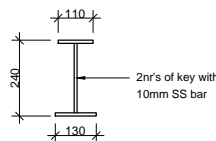
Detail of Basket Screen

Scale - 1:20



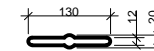
Section C-C
Detail of Steps

Scale - 1:20



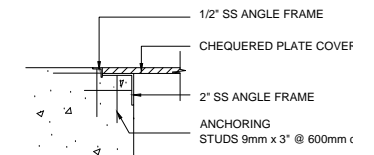
KEY DETAIL

NTS




KEY HOLE DETAIL

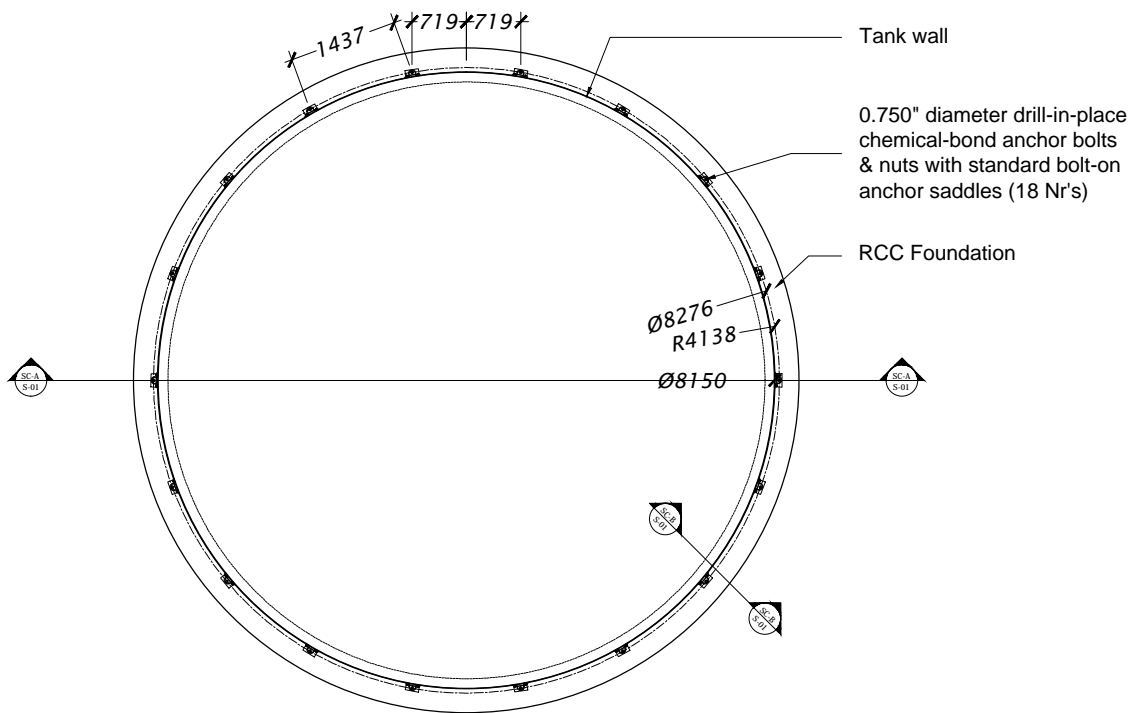
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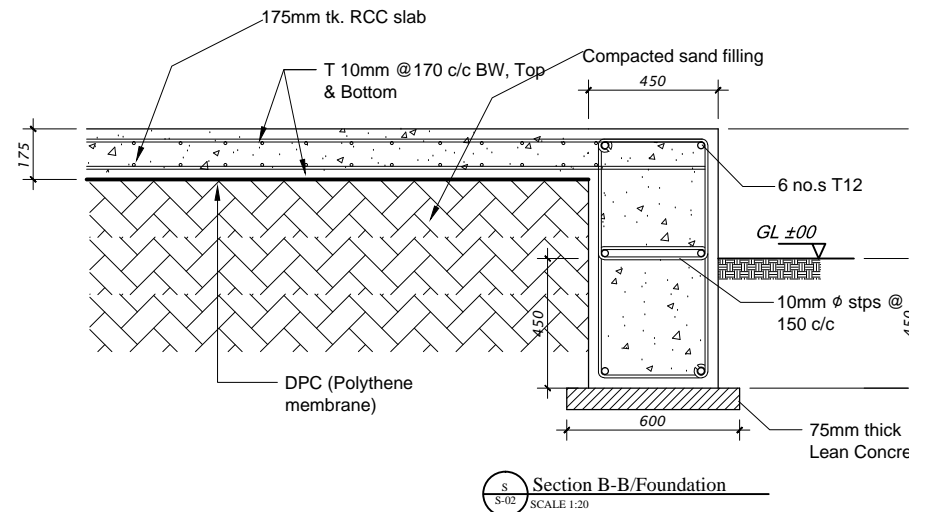
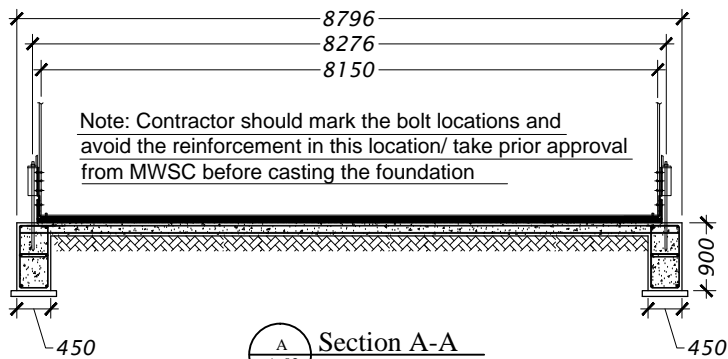
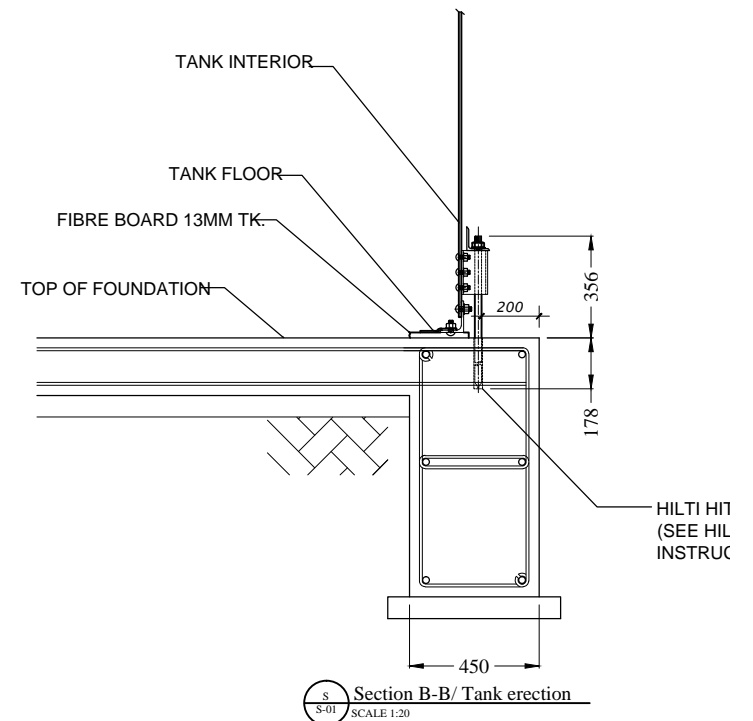
DETAIL-A


NTS

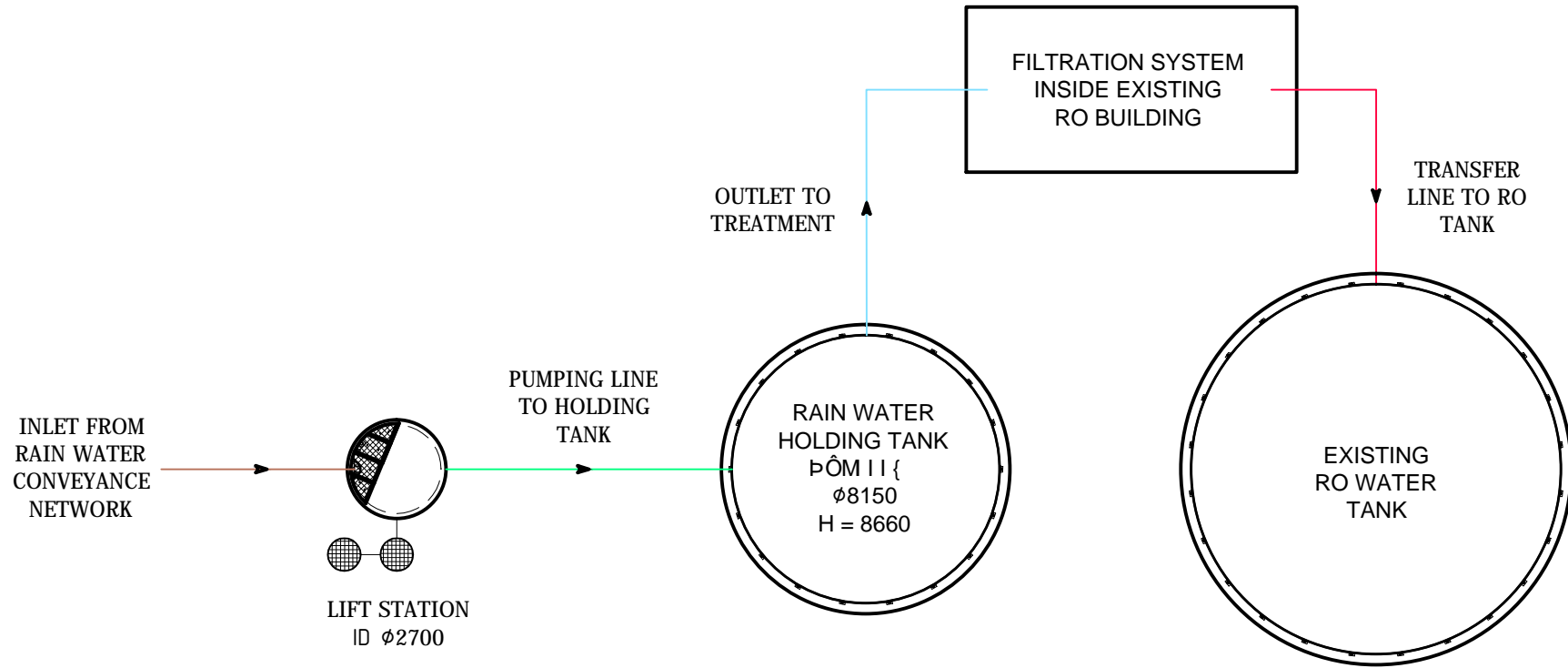
 <p>MWSB MALDIVIAN WATER & SEWERAGE COMPANY PVT. LTD. ARENTEE MAGU, MACHCHANGOLU MALÉ 2001, REPUBLIC OF MALDIVES Tel: (995) 323278, Fax: (995) 324026, E-mail: mwsb@divnet.net.mv</p>	<p>PROJECT: Design of Storm water Management System for H.Dh.Kulhudhuffushi and G DH.Thinadhoo Island</p>	<p>SCALE: As Given</p>	<p>DRW NO. : KTSW/TD-03</p>	<p>DESIGN BY: ---</p>	<p>DRAWN BY: HAPPY</p>	<p>AMENDMENTS:</p>
	<p>CONTENTS: Typical Lift Station</p>	<p>DATE: 25 - 12 - 2013</p>	<p>STRUCTURAL DESIGN BY: --</p>	<p>CHECKED BY: MIA</p>		




Plan
A
A-01
SCALE 1:100



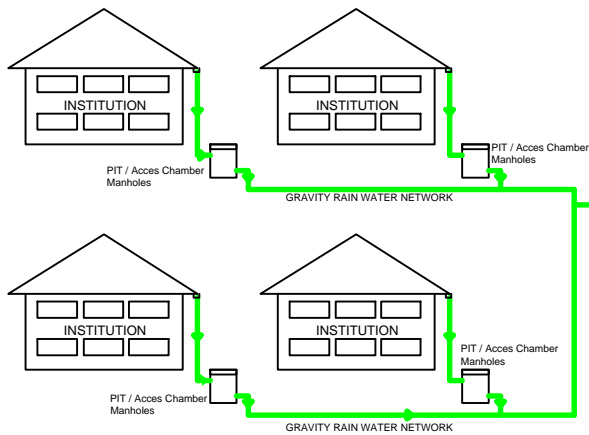
 <p>MWSC MALDIVIAN WATER & SEWERAGE COMPANY PVT. LTD. ARENREE MAGU, MACHCHANGOLU MALÉ, 20-01, REPUBLIC OF MALDIVES Tel: (9953) 323378, Fax: (9953) 324038, E-mail: mwsc@divnet.net.mv</p>	<p>PROJECT: Design of Storm water Management System for H.Dh.Kulhudhuffushi and G DH.Thinadhoo Island</p>	<p>SCALE: As Given</p>	<p>DRW NO. : KTSW/TD-02</p>	<p>DESIGN BY: ---</p>	<p>DRAWN BY: HAPPY</p>	<p>AMMENDMENTS:</p>
	<p>CONTENTS: Typical Storage Tank</p>	<p>DATE: 25 - 12 - 2013</p>	<p>STRUCTURAL DESIGN BY: ---</p>	<p>CHECKED BY: MIA</p>		



 MW&S <small>MALE WATER & SEWERAGE COMPANY PVT. LTD.</small> <small>ARENTERE MOOI MAACHINGOOLA MALE' 2011 REPUBLIC OF MALDIVES</small> <small>Tel: (+960) 322209, Fax: (+960) 324300, E-mail: mwsc@dhuvetel.net.mv</small>	PROJECT: Design of Storm water Management System for H.Dh.Kulhudhufushi and G DH.Thinadhoo Island	SCALE: NTS	DRW NO. : ---	DESIGN BY: ---	DRAWN BY: HAPPY	AMMENDMENTS: _____ _____ _____
	CONTENTS: Typical Flow Diagram	DATE: 25 - 12 - 2013	KT SW/TD-01	STRUCTURAL DESIGN BY: --	CHECKED BY: MIA	
	_____ _____ _____					

STAGE-1 (RAIN WATER COLLECTION)

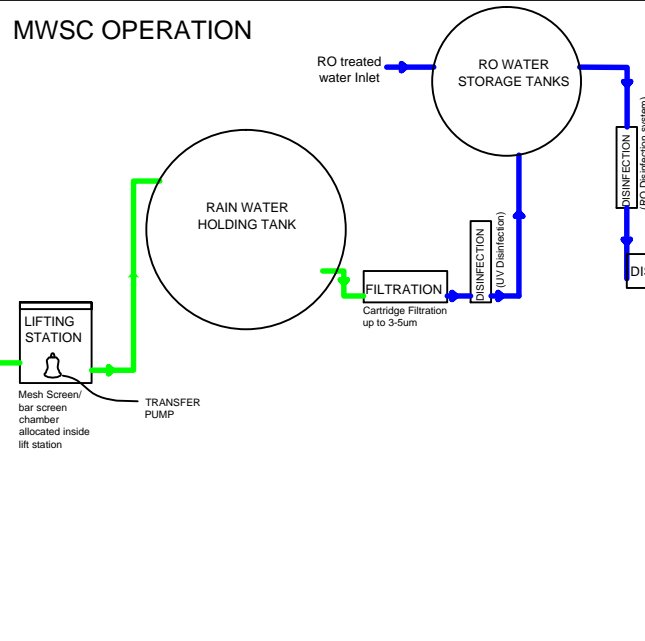
INSTITUTIONS



RAIN WATER IS COLLECTED FROM THE ROOF OF DIFFERENT INSTITUTIONS AND COLLECTED TO A SMALL PIT.
COLLECTED WATER THEN TRAVELS THROUGH FROM A GRAVITY PIPELINE TO A LIFTING STATION LOCATED AT MWSC PROCESSING AREA

STAGE-2 (RAIN WATER PROCESSING)

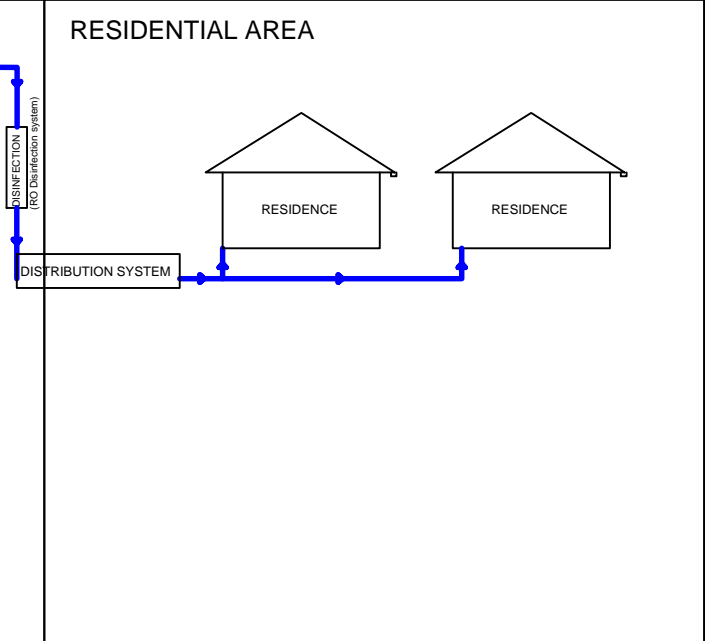
MWSC OPERATION



LIFTING STATION WILL THEN PUMP THE WATER TO A HOLDING TANK.
WATER FROM THE HOLDING TANK IS THEN FILTERED AND SEND TO THE DISINFECTION
DISINFECTED WATER IS STORED IN THE RO WATER STORAGE TANKS
WATER FROM STORAGE TANKS ARE AGAIN DISINFECTED PRIOR DISTRIBUTION

STAGE-3 (DISTRIBUTION)

RESIDENTIAL AREA



DISINFECTED WATER FROM THE FILTRATION SYSTEM AND RO PLANT WILL BE PUMP TO THE MWSC MAIN DISTRIBUTION NETWORK AND TO THE END CUSTOMERS

OPTION 4

BILL OF QUANTITIES

Item No	Description	Unit	Qty	Rate	Amount
	Bill No. 1				
	General & Preliminaries				
1.1	General & Preliminaries Cost consisting the following: <ul style="list-style-type: none">• Provision and Maintenance of Equipments such as Excavators, Leveling Equipment, ..etc needed in the project.• Material Transportation• Material Storage• Contractors Accommodation and administrative works	item	1	500,000	500,000
	Bill No. 2				
2.1	<i>PIPE LAYING</i>				
2.1.2	Laying of 200mm Ø Upvc gravity pipe line (material and labour)	m	1550	1,200	1,860,000
2.2	<i>ROOF CONNECTIONS</i>				
2.2.1	Roof Connections	nos	95	20,000	1,900,000
2.3	<i>LIFTING STATION & COLLECTION CHAMBERS</i>				
2.3.1	Lift stations	nos	1	500,000	500,000
2.3.2	Collection chambers	nos	28	25,000	700,000
2.3.3	Pumps	nos	1	200,000	200,000
2.3	<i>RAINWATER STORAGE TANK</i>				
	Foundation & Erection	nos	1	500,000	500,000
	400 m3 Water Tank	nos	1	1,200,000	1,200,000

3.0	<i>FILTRATION SYSTEM</i>				
3.1	<p>Filtration system (Filtration System which consist of UV System,Filter, pumps..etc needed)</p> <p>Note</p> <p>It is assumed that the Filtration System is placed in an existing RO Building and hence cost of a separate Building is not provided.</p>	item	1	720,000	720,000
	TOTAL				8,080,000