PLANNING AND DESIGN OF STORM WATER MANAGEMENT SYSTEM FOR HDH. KULHUDHUFFUSHI

Final Detail Design Report

December, 2013

Submitted by:

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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 Hdh. Kulhudhuffushi. 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.
- The only road constructed(main road Ameenee magu) was constructed with soak pit without any access of cleaning.
- 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 HDH. KULHUDHUFFUSHI

FINAL REPORT

Introduction

Hdh. Kulhudhuffushi Island (Figure 1.1) with an area of around 236 Hectares is densely populated with 8974 people living within the council area. An issue that the inhabitants had been concerned about for some time 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.

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 Kaadedhdoo is summarized below.

Seasonal Variation of Average Rainfall at Kaadedhdhoo

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

A close contour map of the Hdh. Kulhudhuffushi was prepared from the spot levels available at MWSC. This map indicates that the highest elevation of the Island is 3.0m MSL along the coast line and lowest level is 0.50m MSL.

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. Additionally 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, four distinct basins were identified. Figure (1.1)

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 Hdh. Kulhudhuffushi Island from adverse effects from rainfall.

There are three ponds having large water spread areas within the Island and these will be rehabilitated and improved with a view to act as flood retention areas while maintaining for domestic, aesthetic and environmental purposes. 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.

Emergency outfalls that discharge three basins in to three ponds will be rehabilitated with the provision of three flap gates in order to prevent sea water intrusion. The capacity of the ponds will be enhanced by dredging and cleaning. In order to ensure proper maintenance of the project after completion, maintenance guide lines and suitable maintenance equipment has been proposed. Considering all the aspects of the Technical, Financial, Socio-Economic and Environmental considerations, the consultants believe that the project would be viable.

Main items of work involved

Zone A, Zone B, Zone C & Zone D

STORM Water Management System For Hdh. Kulhudhuffushi Island, Maldives

No	Item Description	Unit	Zone A	Zone B	Zone C	Zone D	Total
1	Hdpe Pipes 200 Mm Dia	M	2,774.0	3,255.0	13,430.0	1,440.0	**20,899.0**
2	Hdpe Pipes 300 Mm Dia	M	-				**-**
3	Manholes 600 Mm Dia	Nr	26.0	43.0	245.0	33.0	**347.0**
4	Gutter Inlet 400x400 Mm	Nr	278.0	325.0	1,343.0	144.0	**2,090.0**
5	Hdpe Flap Valve	Nr	1.0	1.0	1.0	-	**3.0**
6	Outfall	Nr	1.0	1.0	1.0	-	**3.0**
7	Silt Trap	Nr	1.0	1.0	1.0	-	**3.0**
8	Storage Tank	M3	3,425.0	3,755.0	8,908.0	2,450.0	**18,538.0**

The total cost of the option 1 and 2 of the pilot project for Zone A and Zone B amounts to Maldivian Rufiyaa 2,676,071.00(MVR) and 222,453.50(MVR) respectively and it is proposed to commence the work in January 2014.

With the completion of the project sufficient protection of urban areas earmarked under zone A and B as shown in figure 1.3 and 1.4 will be ensured. The overall project will safeguard 200ha of urban lands in Hdh. Kulhudhuffushi Island and provide flood relief for lands in zone A, B, C & D. There are several ongoing development activities such as roads, drinking water, and sewerage etc. within the Hdh. Kulhudhuffushi 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 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 program.

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.

With all these development activities, the island of Hdh. Kulhudhuffushi would provide a springboard for a lot of potential projects. Therefore the Ministry of Environment and Energy can confidently provide a facelift to the Hdh. Kulhudhuffushi 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 O&M 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.

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 µPVC pipes of 160mm diameter. They should be covered using a geo textile membrane to prevent infiltration of silt into the pipe network.

Detail Design

1 Introduction

1.1 Hdh. Kulhudhuffushi

The Hdh. Kulhudhuffushi Island has an approximate area of above 236 ha and a large concentration of people (8974) living in the Hdh. Kulhudhuffushi council area. The location of the project area is shown in figure 1.1. One of the major problems in the island is stagnation of water at the low elevated areas. This is due to several factors and among them flat topography, intense rainfall, high tide from the sea, improper land use, variation of existing ground along the roads and less maintenance can be highlighted as main reasons. See Photos Page No. 177 & 182.

The area that requires drainage facilities under the project is administered by the Island Council. Contour map has been prepared by the consultant by using the available spot level maps, to identify specific flood prone areas in order to prepare a Storm Water Management System (SWMS) for the island. An investigation / examination of land use pattern specific to the elevation above mean sea level has been studied during the design stage. Figure No1.3, 1.4, 1.5 & 1.6 show areas subject to localized flooding within the basins.

A proper storm water management system and protection from high tide has been a long felt need experienced by the council and the residents in the island. In order to meet these objectives the implementation of a SWMS has been discussed in the Inception Report and presented to the Ministry of Environment and Energy and relevant stakeholders on 26th October 2013.

It was observed that high tides of the sea exceeded 0.30m MSL during monsoonal rains during November and December. In addition, during the North East Monsoon, heavy rain storms occurred, resulting in daily rainfalls of value up to 224.6 mm. From the close contour map five distinct basins have been identified for Hdh. Kulhudhuffushi with a view to prepare plans for the improvement of SWMS in the island. For the convenience in planning the project, these basins were identified in Zones A to D according to the priority. Figure (1.1)

There are existing natural ponds in the Hdh. Kulhudhuffushi Island to act as storm water detention ponds. Rehabilitation of these ponds will be necessary for domestic, environmental and aesthetic purposes and to maintain ecological balance of the island. Additionally these ponds can also be used as emergency storage areas for excess water from main asphalt road and the housing area.

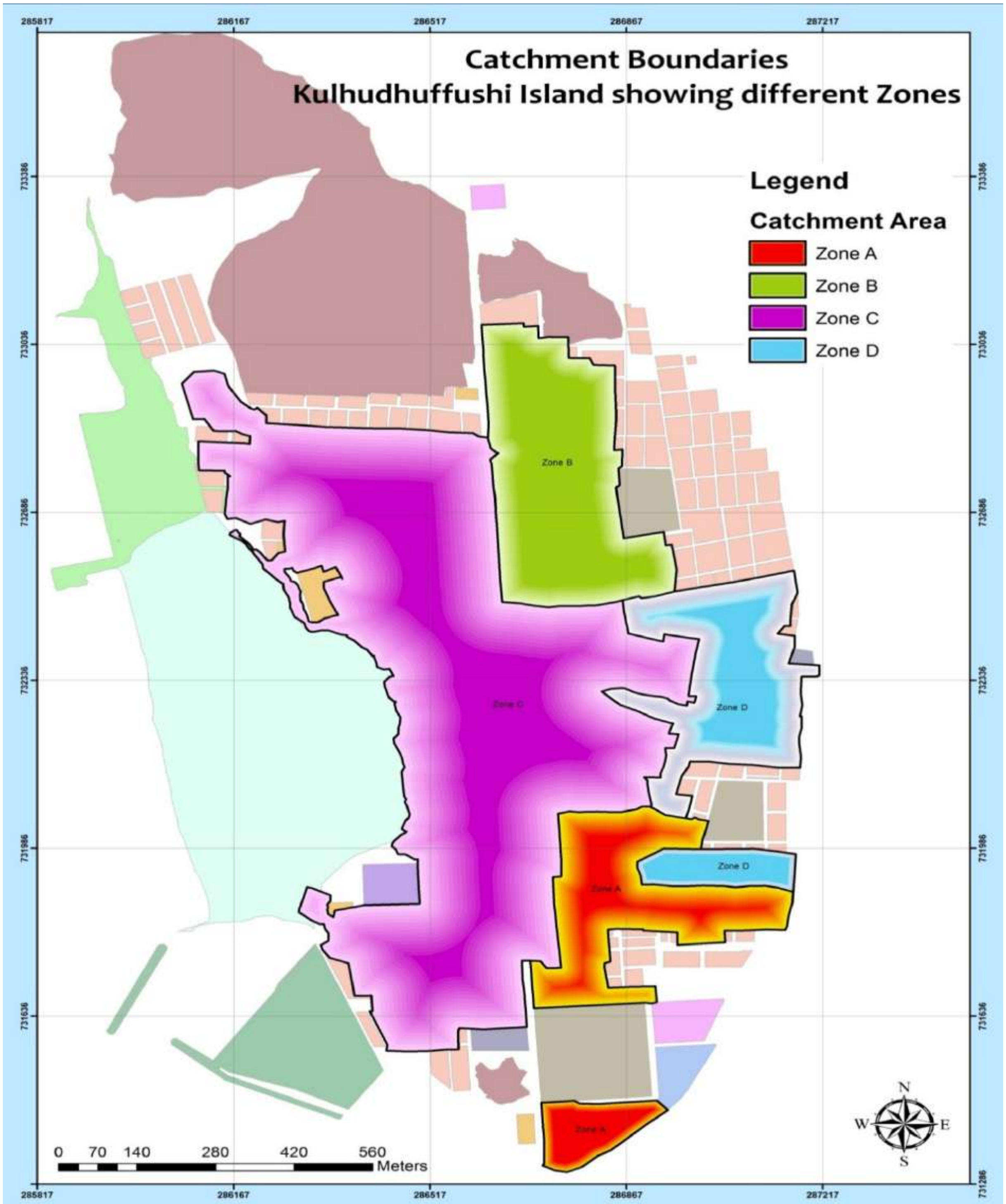


Figure 1.1– Catchment Boundaries Hdh. Kulhudhuffushi Island

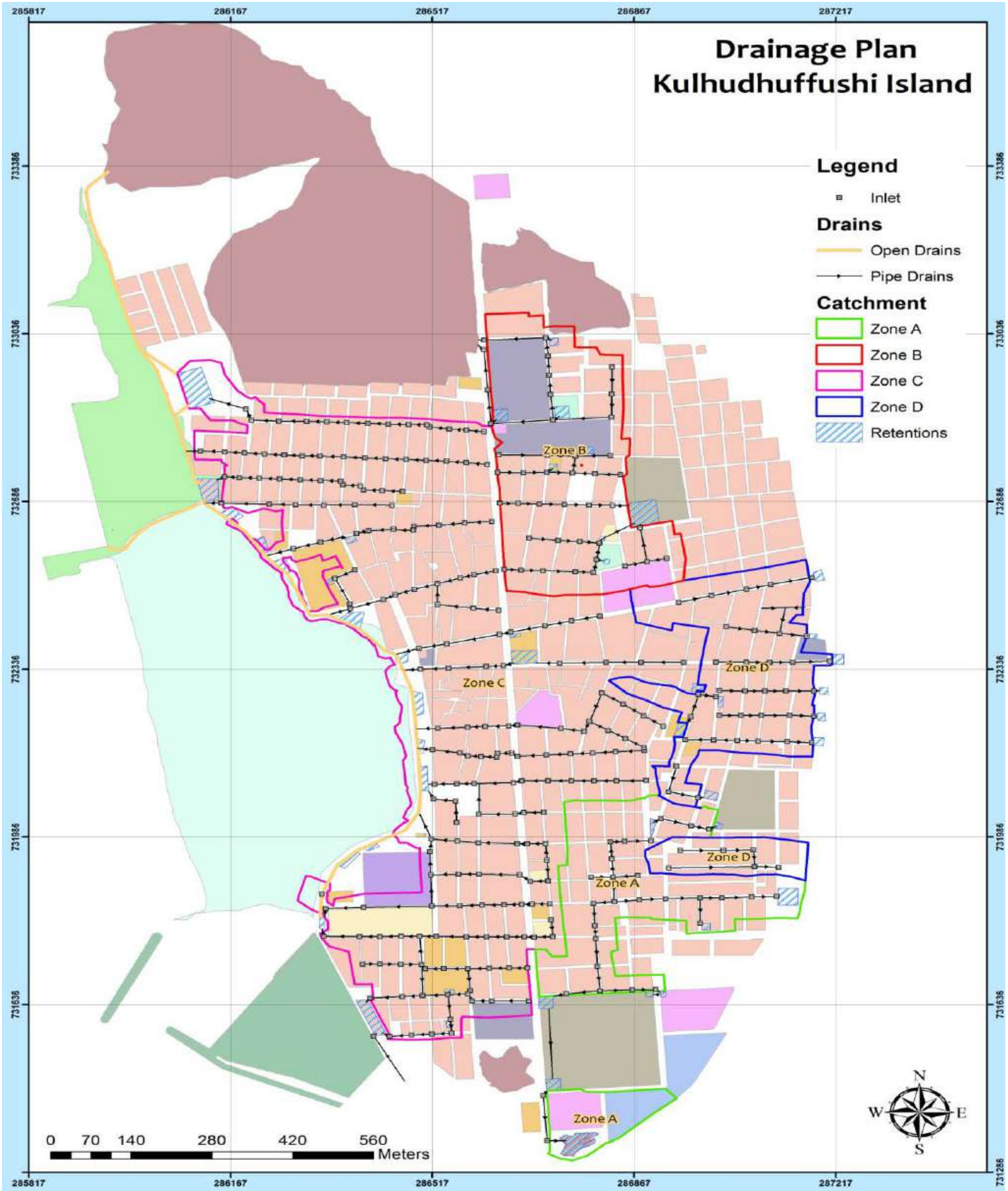


Figure 1.2– Drainage plan Hdh. Kulhudhuffushi Island

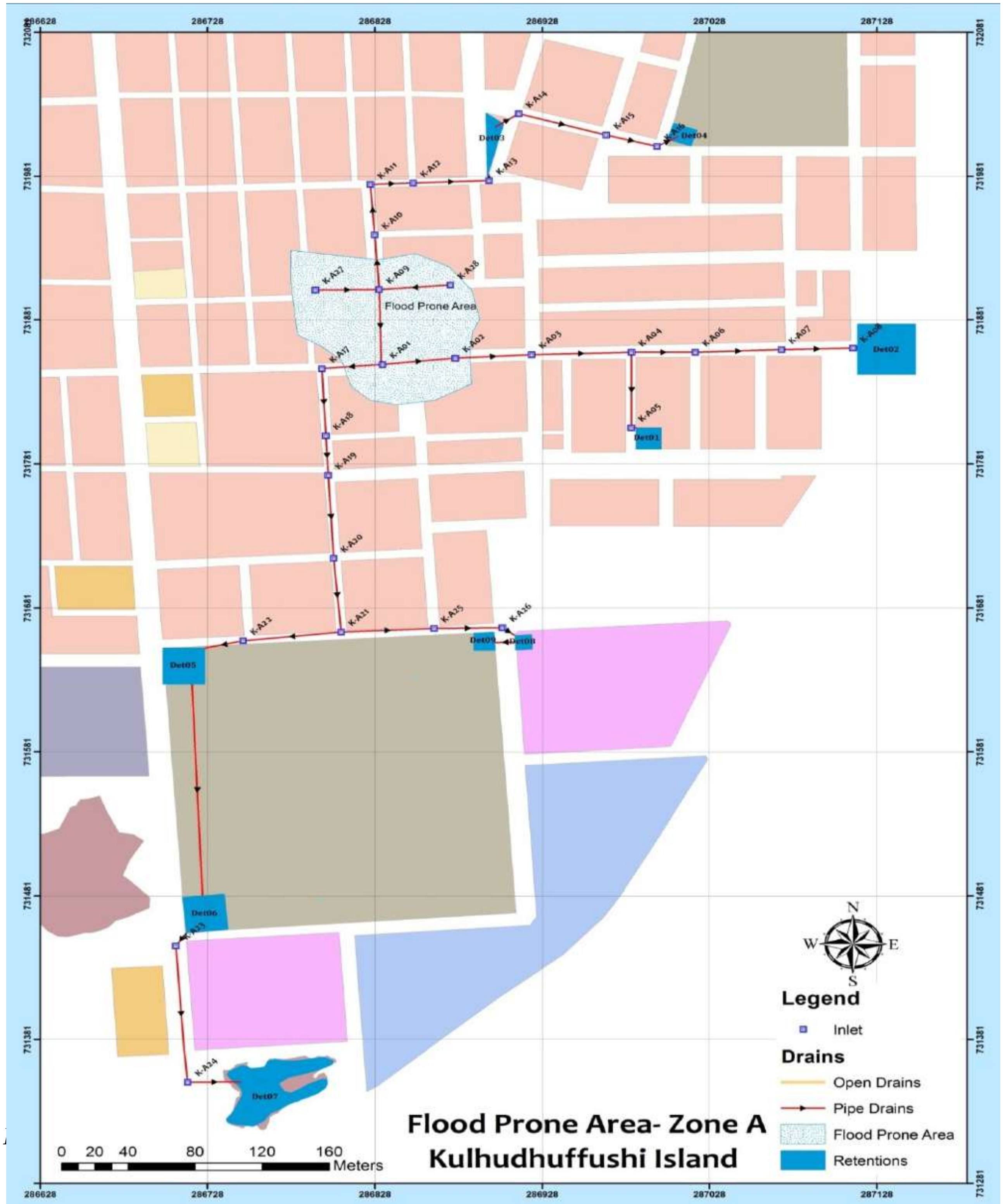


Figure 1.3– Flood prone area Zone A Hdh. Kulhudhuffushi Island

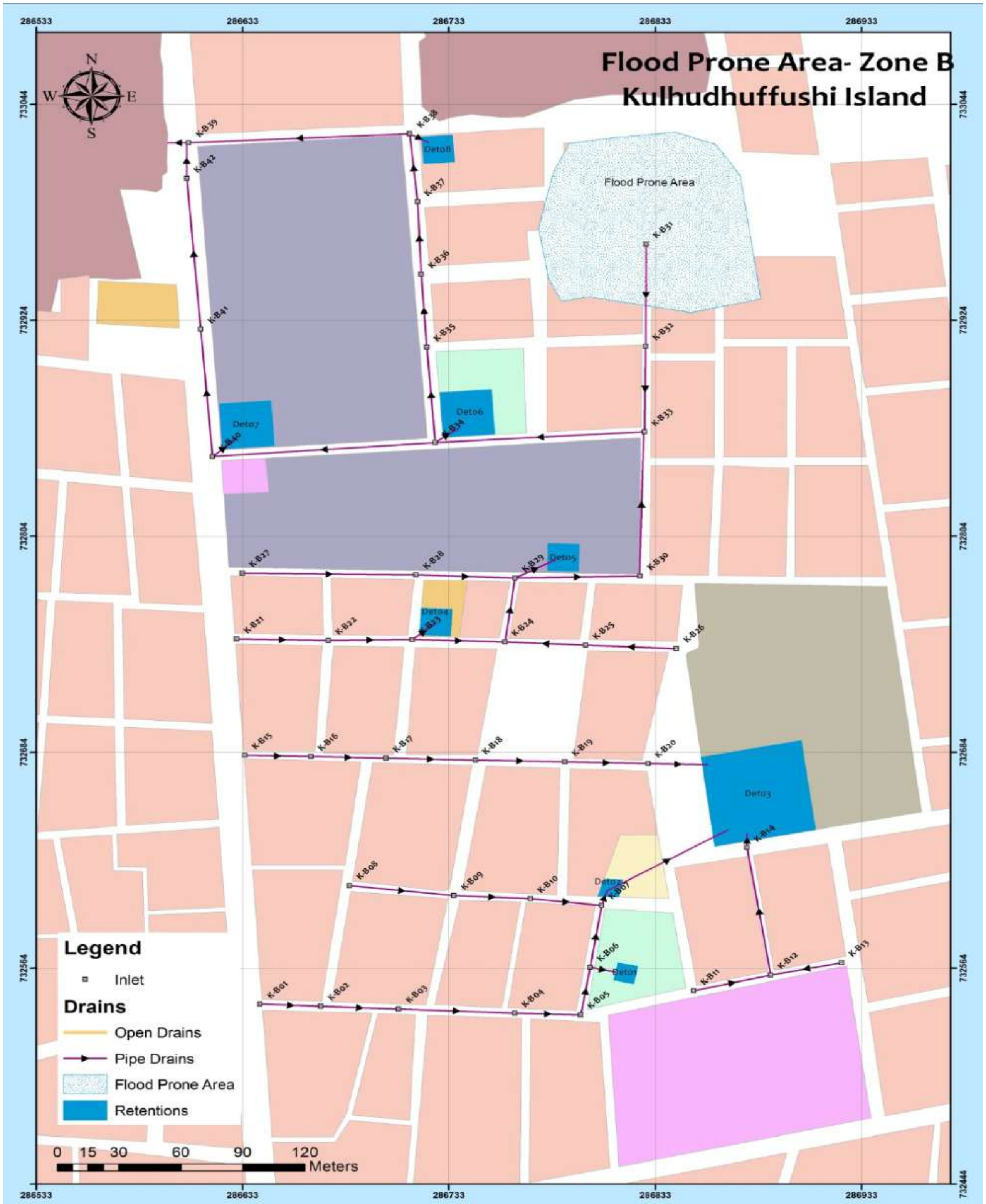


Figure 1.4– Flood prone area Zone B Hdh. Kulhudhuffushi Island

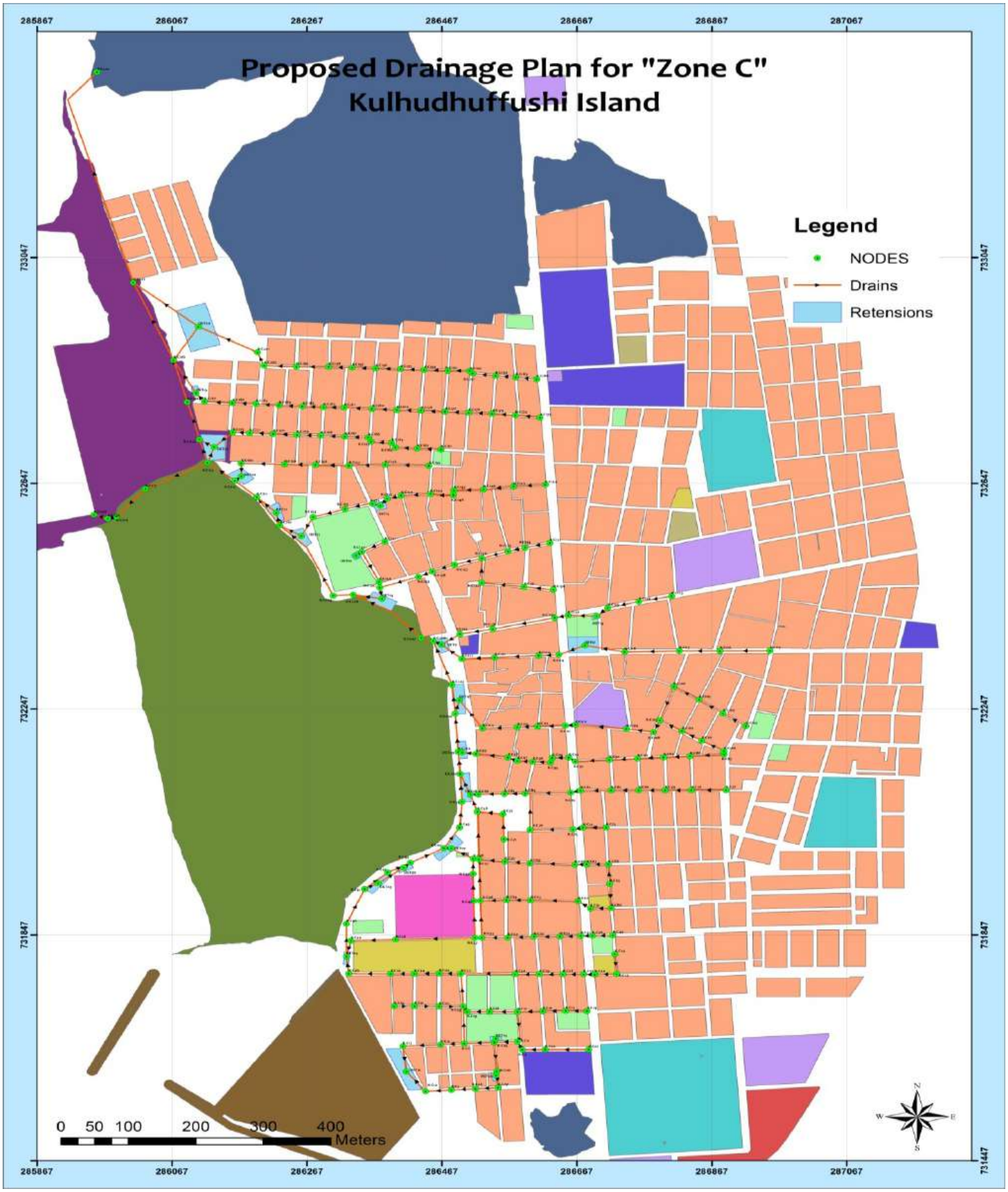


Figure 1.5– Flood prone area Zone C Hdh. Kulhudhuffushi Island

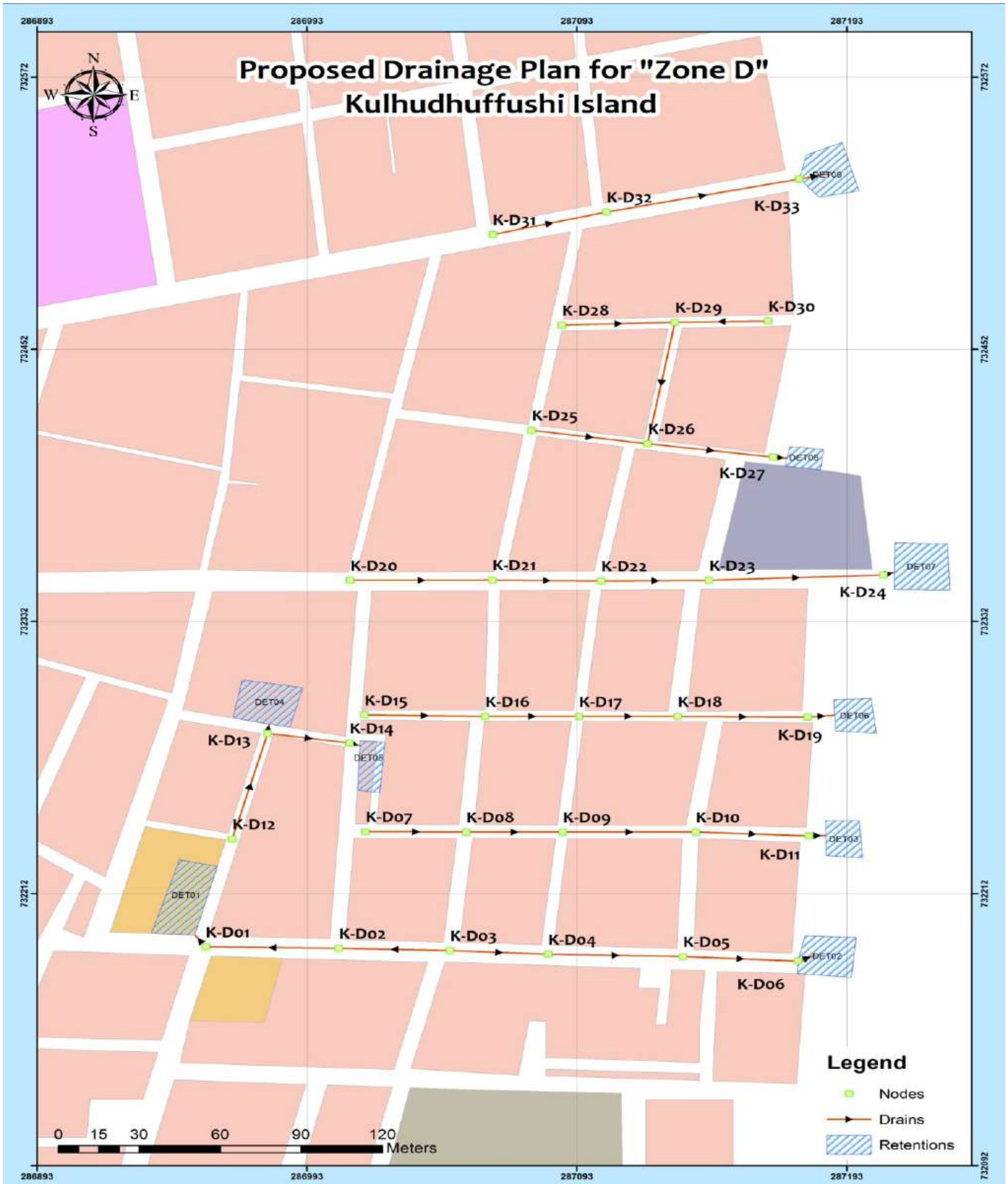


Figure 1.6– Flood prone area Zone D Hdh. Kulhudhuffushi Island

2 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 were identified. Based on the priorities indicated by the island council, Zone A and B were selected for full investigation. Detail designs and estimates have been prepared for these two pilot projects in order to commence construction work in January 2014. In the event of funds being available work on Zone C and Zone D also could be taken up.

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.

3 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 Hdh. Kulhudhuffushi Island. Rainfall data collected from Metrological Department of Male at Kaadedhdoo, Hanimaadhoo 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:-	Kaadedhdoo	–	from 1994 to 2012 – [19 yrs.]
	Hanimaadhoo	–	from 1991 to 2012 – [22 yrs.]
• 3 Hourly rainfall Data :-	Kaadedhdoo	–	from 2000 to 2008 – [9 yrs.]
	Hulhule	–	from 2008 to 2012 – [5 yrs.]
	Hanimaadhoo	–	3 hourly data not available

3.2 Rainfall Intensity Analysis

The catchment areas of individual sub-basins in the Hdh. Kulhudhuffushi under consideration for effective drainage are comparatively small. Therefore Time of Concentration, (TC) as defined in surface hydrology is very short. The details of the basin show that the largest catchment area is limited to 200 ha. The TC is of the order of 30 to 60 minutes. Therefore in designing SWMS for these small urban catchments, the need for accurate rainfall intensity figures even for short durations, such as 5,10,15,30 minutes etc. is very important. Apart from that, 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 3.1 to 3.5.

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

Table3.1 - Rainfall Depth Duration Frequency Data (mm) at Hulhule

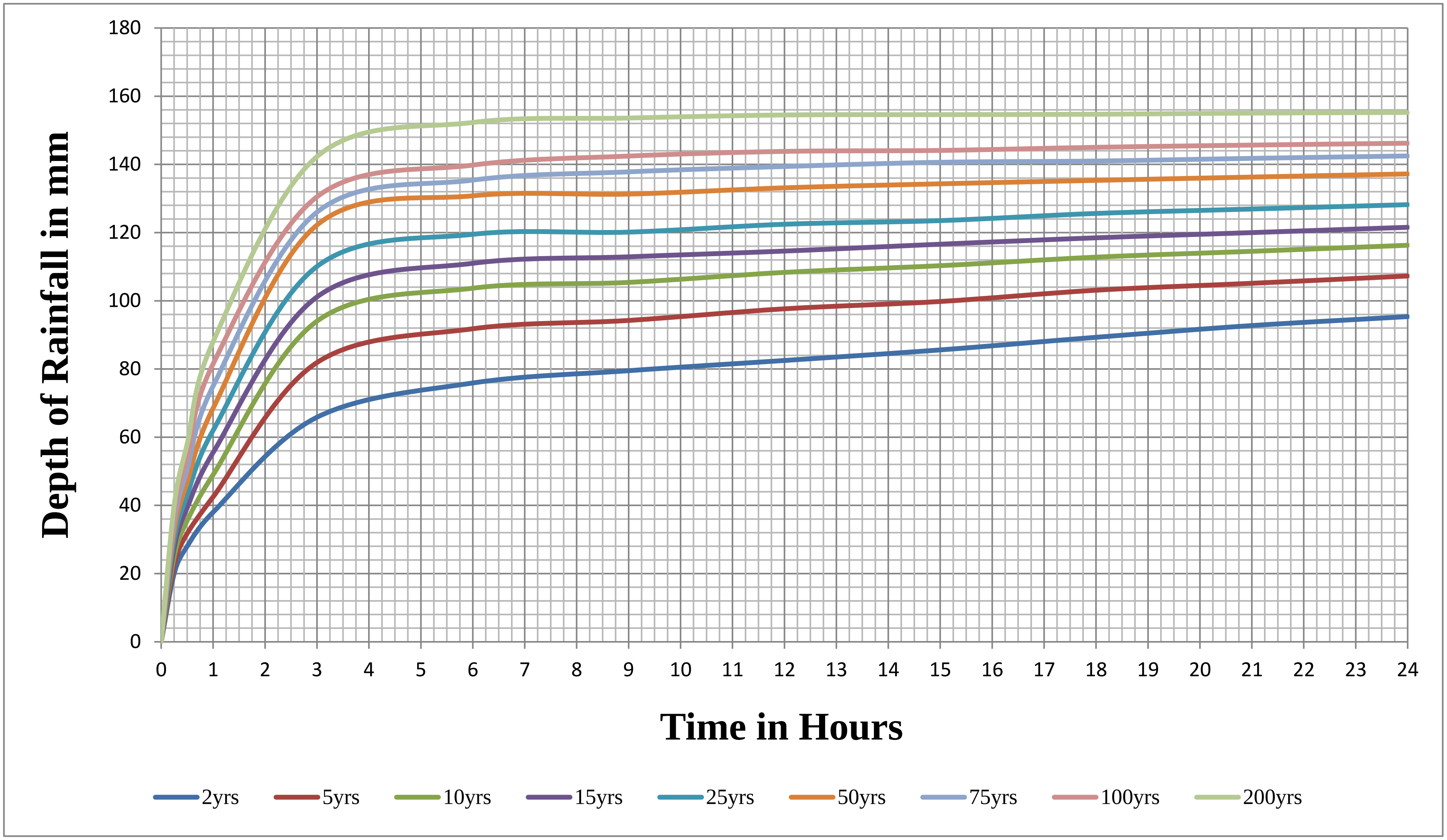


Figure 3.1 - Depth Duration Frequency Curves fort Hulhule

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

Table3.2 - Rainfall Intensity Duration Frequency Data (mm/hour) at Hulhule

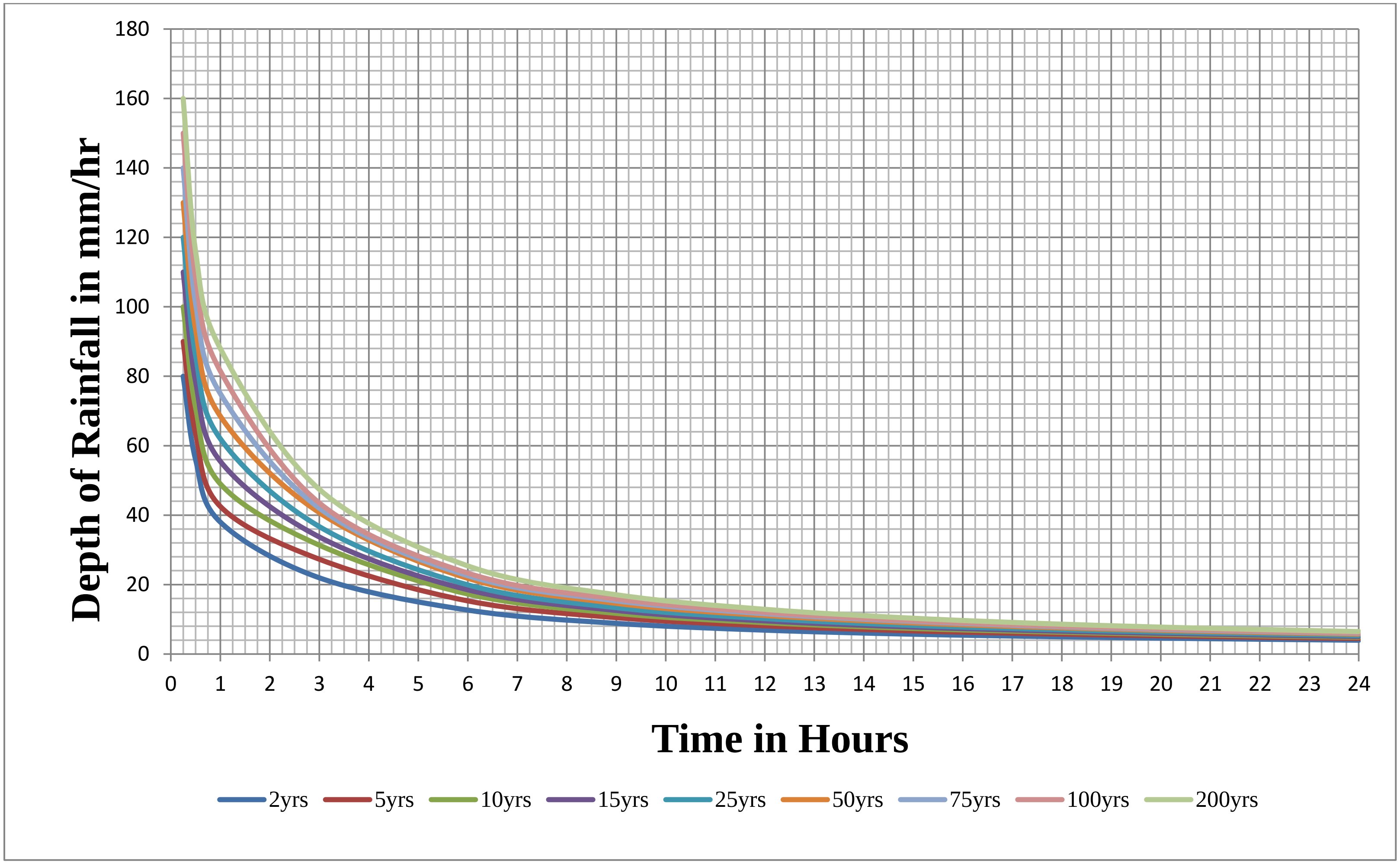


Figure 3.2Intensity Duration Frequency Curves for Hulhule

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		$5 \leq T \geq 1440$

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

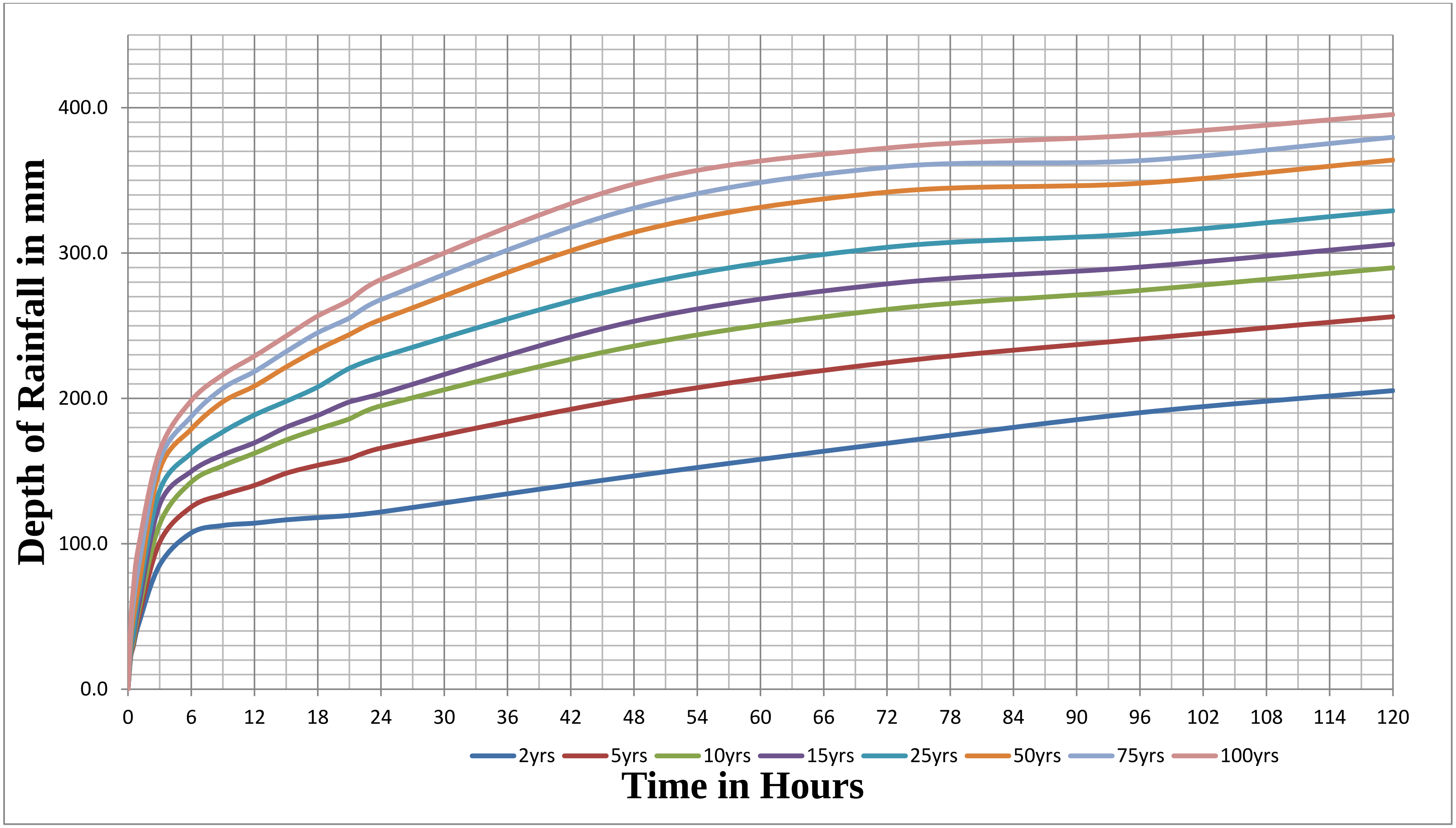


Figure 3.3- Depth Duration Frequency Curves for Kaadedhdoo

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 – Rainfall Intensity Duration Frequency (mm/h) at Kaadedhdoo

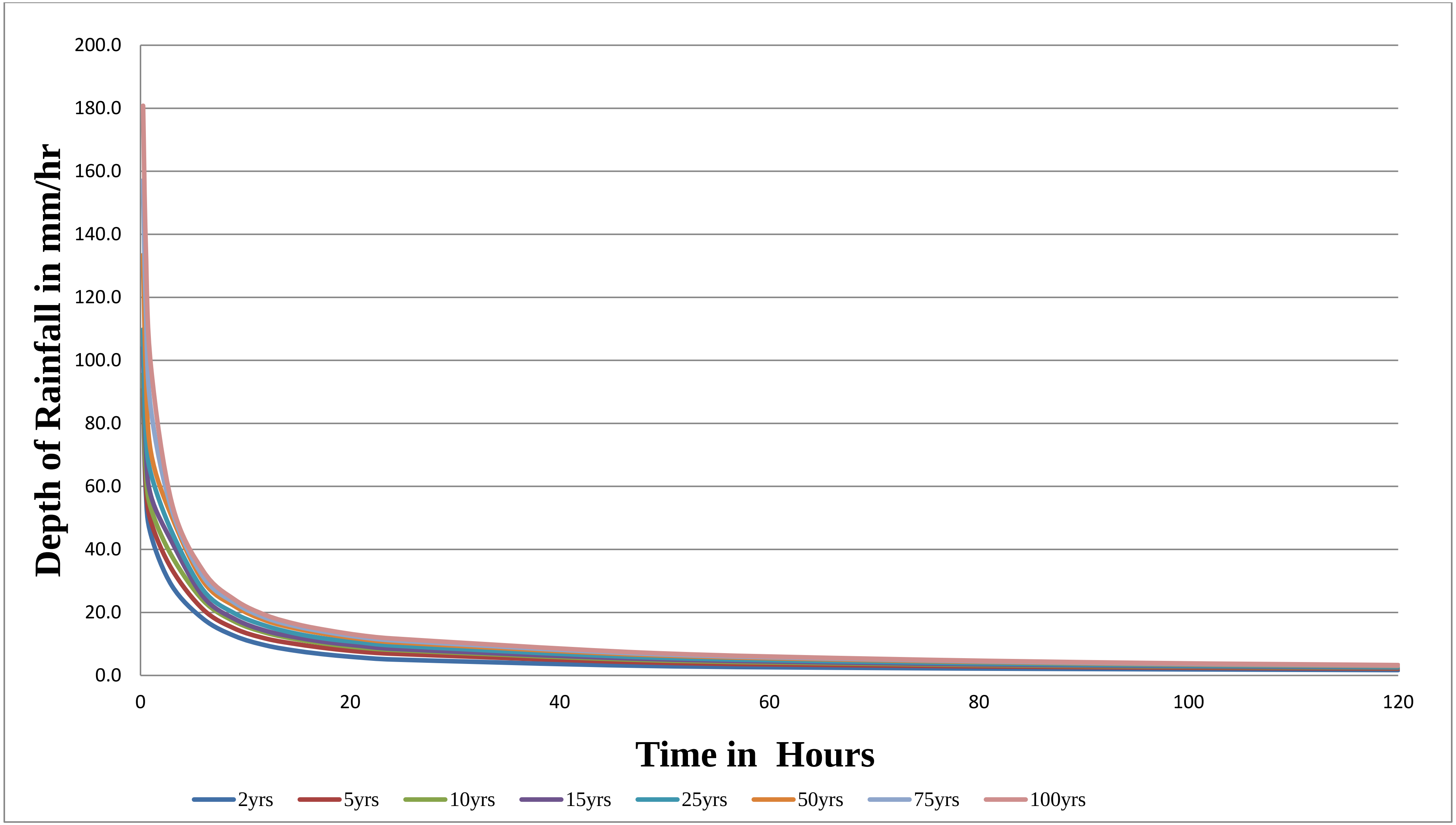


Figure 3.4 - Intensity Duration Frequency Curves for Kaadedhdoo

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

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 catchments 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 3.5.

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

	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

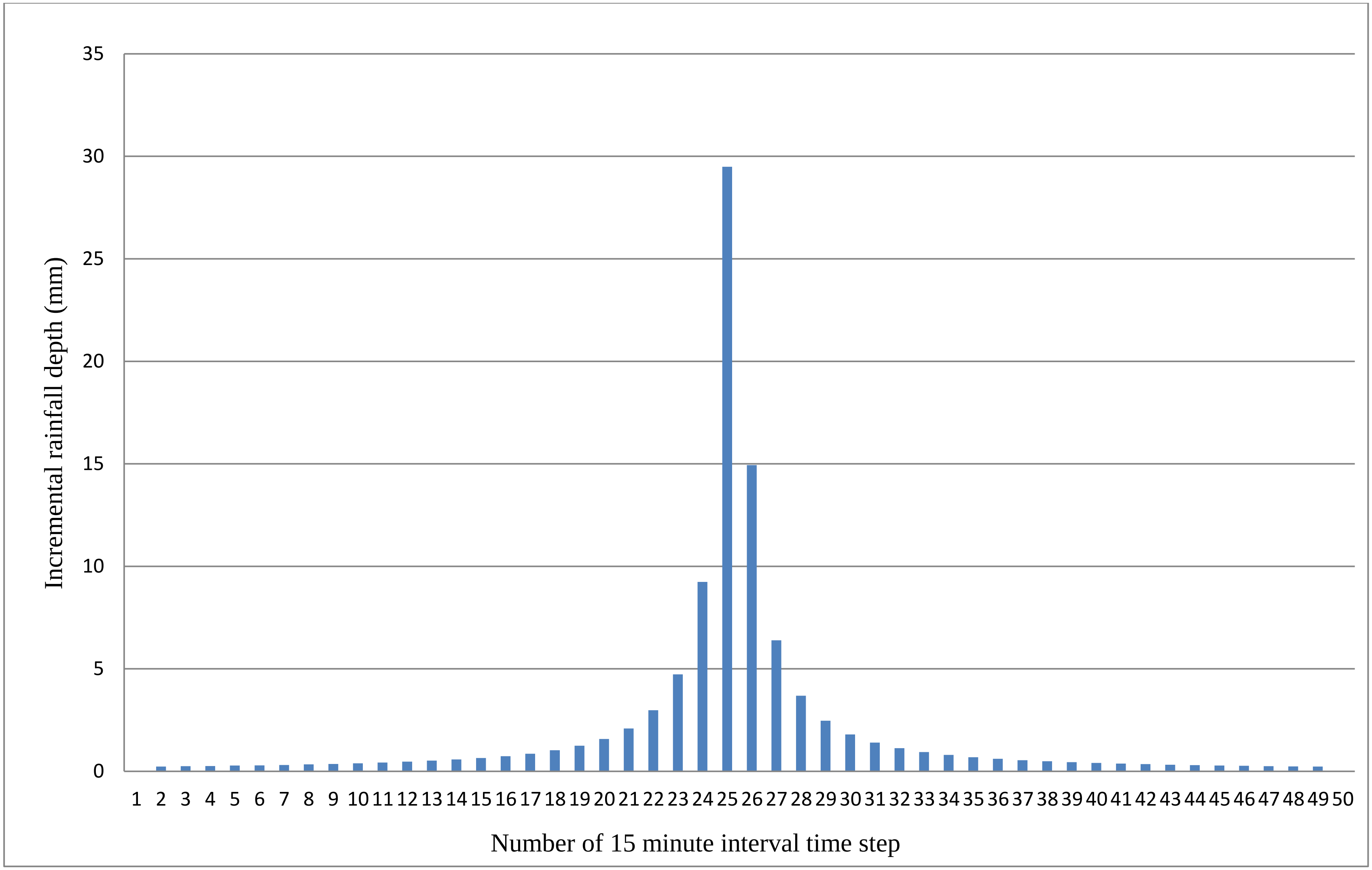


Figure 3.5 – Graphical interpretation of the design storm for 5 yr. ARI

4 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 outlet. The exit level of all the storm water paths 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.

4.1 Hdh. Kulhudhuffushi Coastline

Hdh. Kulhudhuffushi Island is on the east side of the Atoll. Therefore the eastern shoreline is directly exposed to the northeast monsoon. The beach is relatively steep and narrow compared to the west. Western coast is facing the inside of the atoll and exposed to a relatively mild sea conditions due to the shallow reef. Part of the west coastline has been reshaped due a large scale land reclamation done in the year 2011. Two harbours on the west and southwest act as retaining structures for the reclaimed land.

Wave and wind data in the island is necessary to ascertain the wave and wind set up which can be very high and can cause inundation in low lying areas and may lead to disruption of storm water drainage.

According to the Admiralty tide tables, Tidal constituents are available at Ihavandhoo (Table 4.1) which is only about 40km North from Hdh. Kulhudhuffushi. Therefore the tide that can be generated for Ihavandhoo is applicable for Hdh. Kulhudhuffushi.

Tidal constituent	Phase (deg.)	Amplitude (m)
M2	338	0.24
S2	37	0.11
K1	63	0.18
O1	51	0.09

Table4.1: Tidal Constituents at Ihavandhoo

According to the generated tide (Figure 4.1) with mean sea level at 0.68 m above the Chart Datum, tidal range is about 1.1 m.

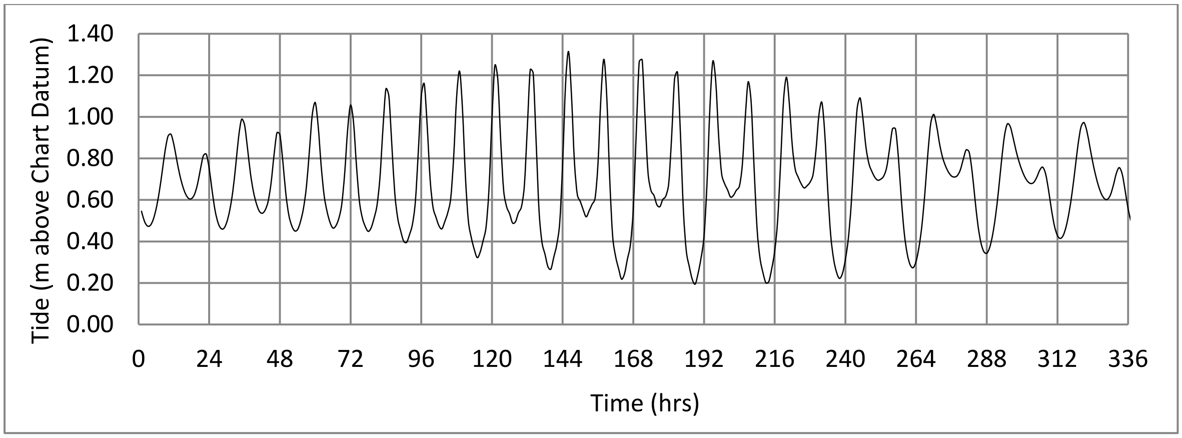


Figure 4.1-Typical tidal levels at Hdh. Kulhudhuffushi

Sea Level at Hdh. Kulhudhuffushi Island

There is no historical sea level data at Hdh. Kulhudhuffushi to establish the design sea levels around the island. Closest sea level gauging station is at Hanimaadhoo (Latitude: 06-46N, Longitude: 073-10E) which is about 15km North of Hdh. Kulhudhuffushi.

According to the 1 hour tide data available at the Joint Archive for Sea Level at the University of Hawaii Sea Level Centre /National Oceanographic Data Centre, at Hanimaadhoo, the maximum water level recorded during the period January2002 to October 2013 is 1.695m above the staff zero. It was recorded at 16.00 Hours on 22/12/2007. However, as in the case of Gann, 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 2002 to 2013, is 1.010m above the staff zero. That means the maximum sea level record 1.695m is 0.685m 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 11 years.

In conclusion the maximum sea level that is recorded during the past 11 years is 0.685m above the average sea level.

5 Methodology and Design consideration

After the first meeting for the familiarization of the project in the latter part of October, a discussion was held at MWSC office with Engineering Manager and other Engineers. First site visit was held with the following officials from 30th September to 3rd October at Hdh. Kulhudhuffushi Island

1. Mr. Abdulla Waheed - 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. Ghnanapala - Civil Engineer , ECL

Findings

- Based on the discussions with Island Council and some of the residents, it was found that storm water drainage was not so much of an issue in most parts of the Island, except in Zones A to D. (**Refer Figure 1.3 & 1.4**)
- Pipes from road side gutters are connected to a soak pit laid at the center of the road that are covered with asphalt and inaccessible for maintenance purpose. This method needs to be improved with the introduction of Manhole Covers to be in flush with the road surface. These pipes are only adequate to take road surface runoff.
- 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 rises up to ground level and the depth of puddles are more than 600mm in the most severely affected areas(**Refer Figure 1.3 & 1.4**)
- Natural ground of the island has a gradient from East to West which will provide an easy water flow from all the roads to the planned peripheral drainage between Natural Island and newly reclaimed area. However, the higher finished level of newly constructed road (Ameenee Magu) will be obstruction for this natural flow of water which will result storm water issues in the eastern side of the island. It was observed that the north and south side of the island are prone to flooding. Regularization of this situation is very

important to develop the area in future urban planning and maintaining ecological balance of the Island.(**Refer Figure 6.1**)

- There are plots of land such as playgrounds, premises of schools, mosques etc. that can be utilized for the construction of underground storm water storage tanks at various locations in the island.(**Refer Figure 6.1**)
- Upstream sections of the storage areas are heavily silted and needs to be desilted so as to enhance the storage capacity.
- 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.

2nd site visit has been carried out in the company of Council Members from 29th October 2013 to 01 of November 2013 in Hdh. Kulhudhuffushi Islands to collect more details at site for Modeling Process and to also to 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, economic 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.

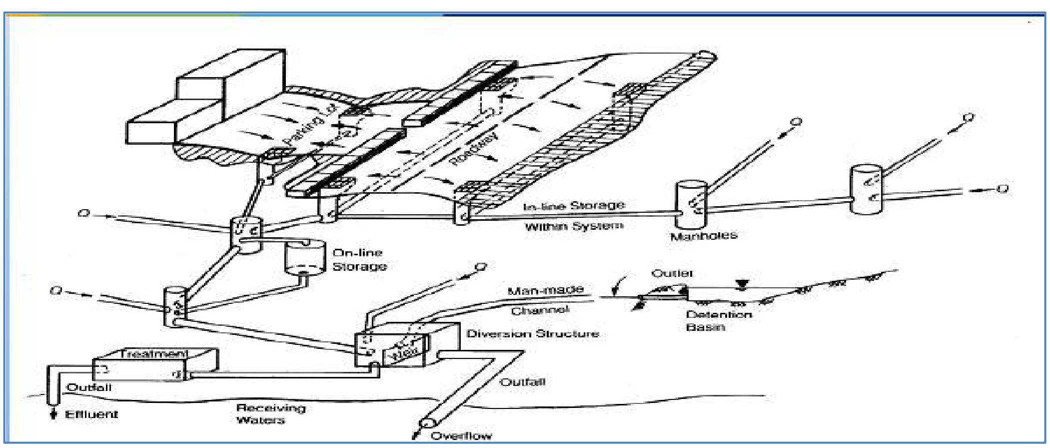
The following factors have been adopted to consider 2030 scenario.

- 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.



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

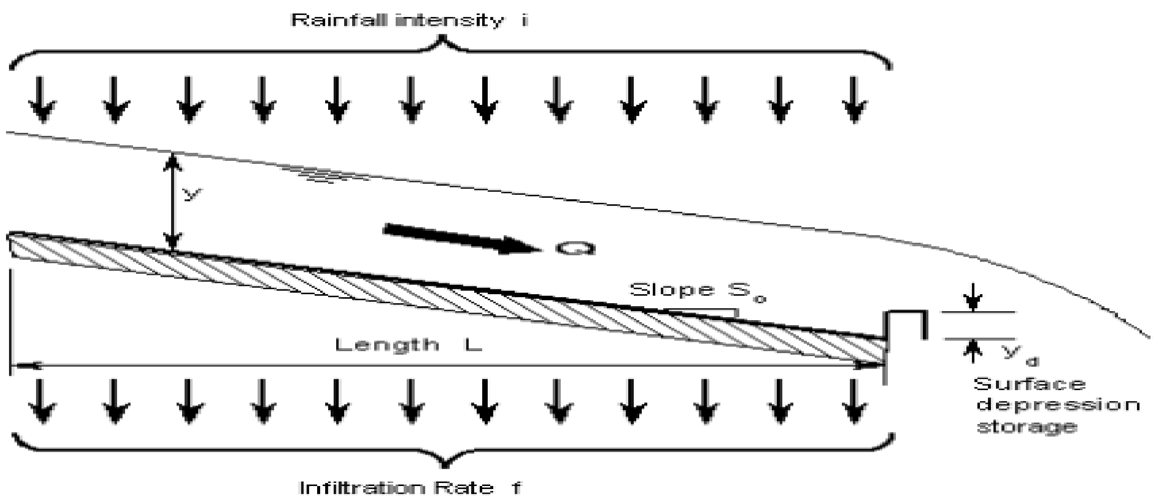
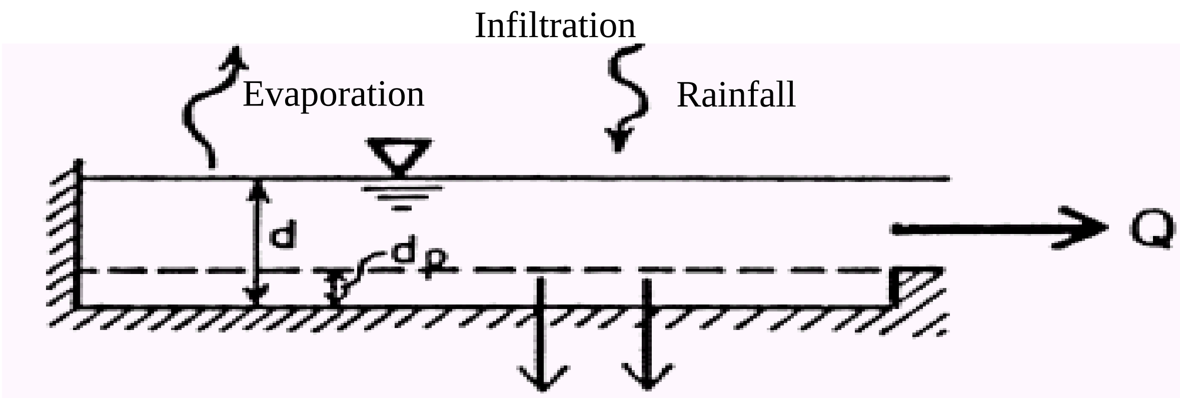


Figure 5.2 – Idealization of the Section of a sub-catchment within SWMM

The following conceptualization is used within 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.



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.

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

Figure 5.3 - Rainfall-Runoff model structure with in SWMM

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.

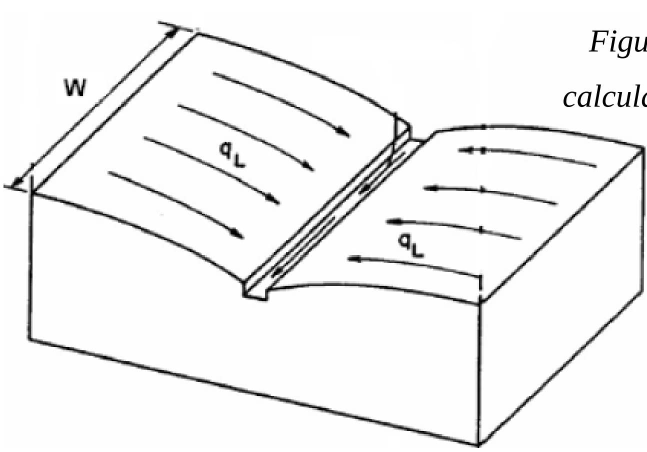


Figure 5.4 - Idealization of a sub catchment to calculate the characteristic width of the catchment

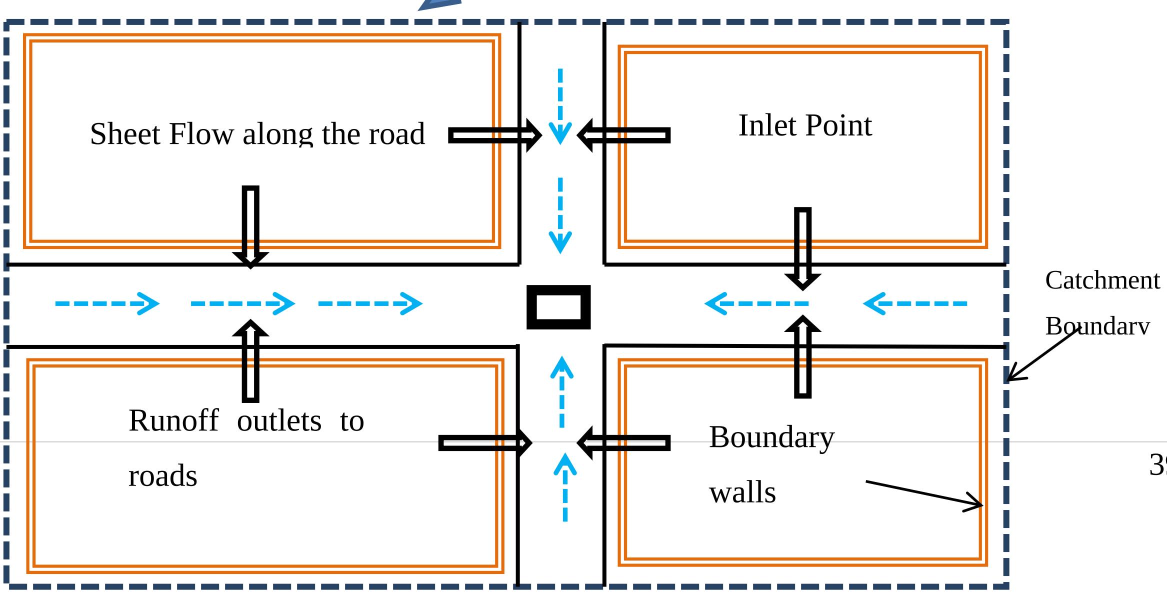
However, based on the site visits, the physical drainage process of the two Islands deviate from this assumption and the model idealization of the actual drainage process within one typical sub-catchment are presented in Figure 5.5.

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 with in 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 with in the house hold 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 in to number of gratings based on the catchment inflows to inlet points.

The terrain of these two islands 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 set-up



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)

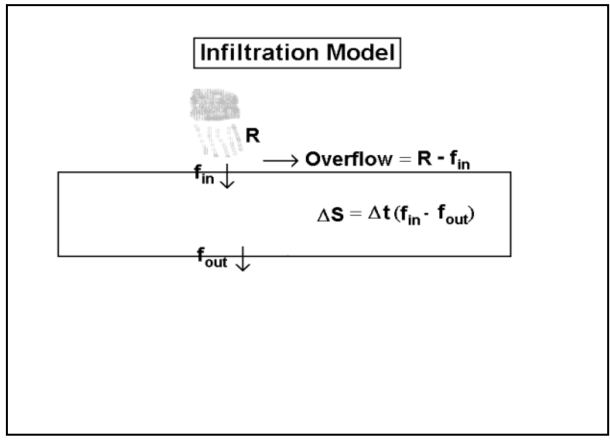
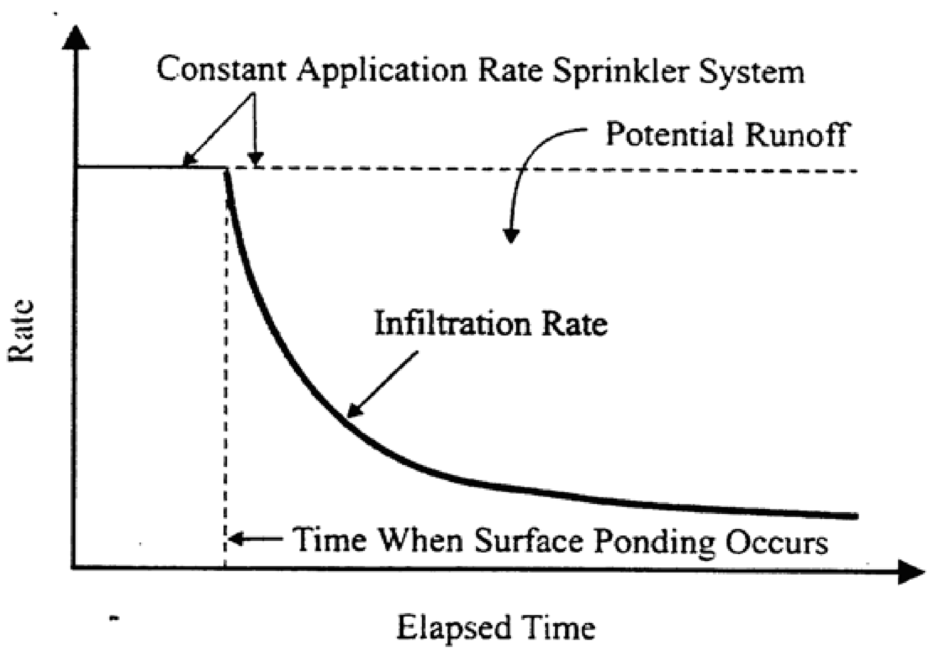


Figure 6.4 – Horton's Infiltration



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, *Fc*		
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

Soil Type	(in/hr)	(mm/hr)
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 within 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 with in 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 ROW plant.
- ❖ Low elevated levels of the roads already considered for possible minimum filling after carrying out value engineering and possible height is 150 mm to 300mm.
- ❖ 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 & 9.2.
- 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 Storm Water Management Plan

The entire proposed drainage network Figure 6.1 for the Hdh. Kulhudhuffushi Island was modeled within the SWMM model setup as per the criteria stipulated in Section 05.

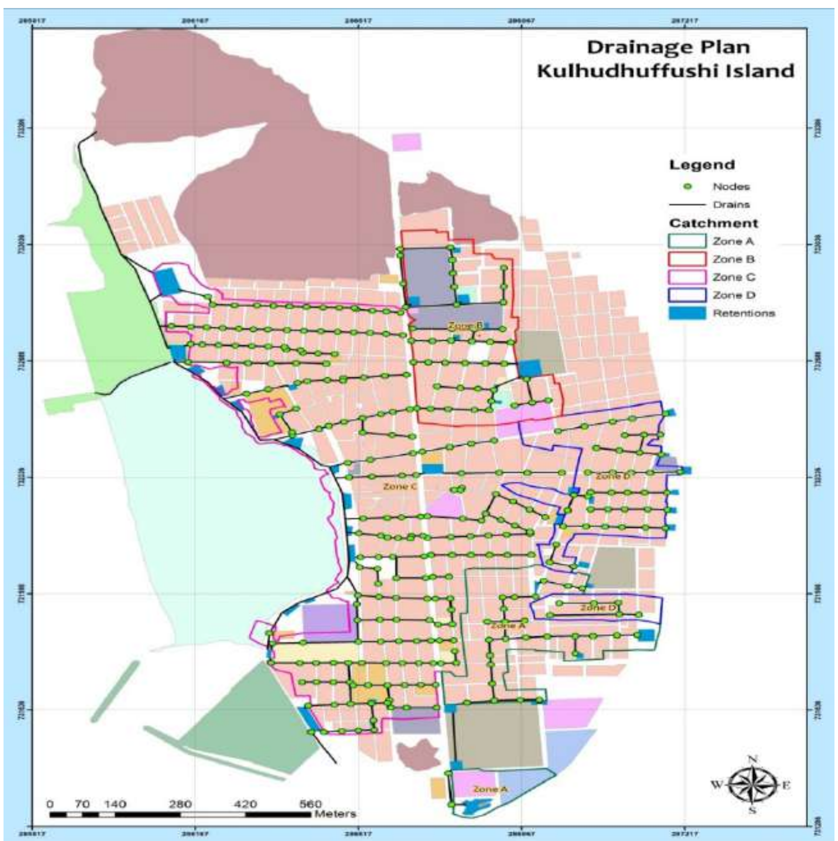


Figure 6.1 SWMM model set up for Hdh. Kulhudhuffushi Island

The road levels below 1.0m MSL are assumed to be raised up to 1.0m, MSL in some of the areas. All the storm water runoff with in the drainage network was directed to storage boxes as much as possible and thereby the outflow to the existing ponds has been made minimal so that the people could get the maximum utilization of water while being flood free.

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

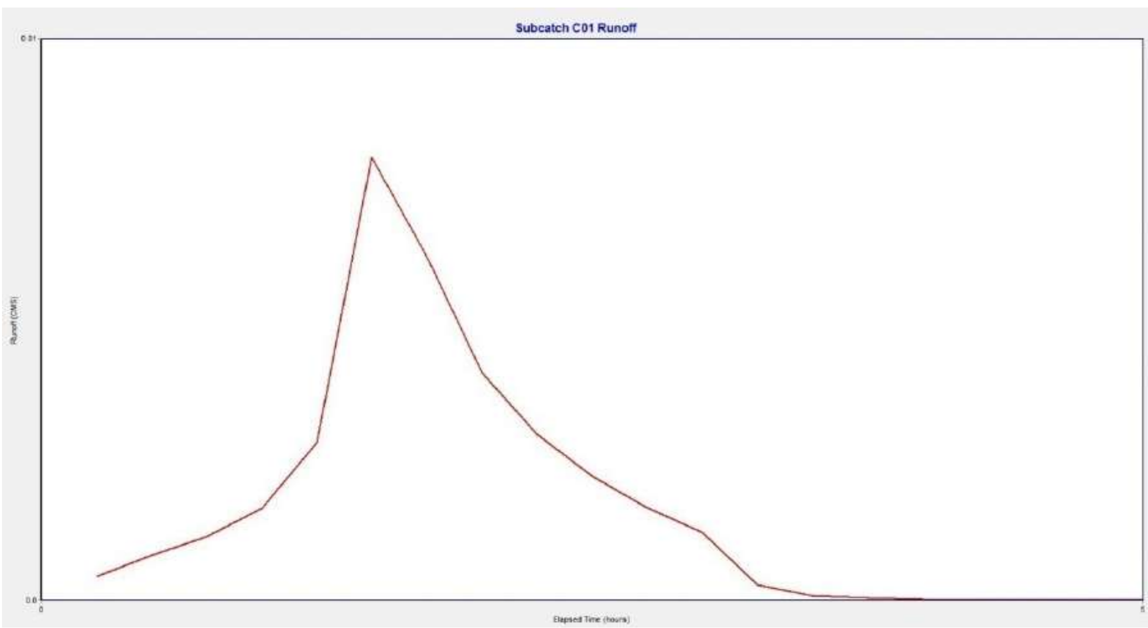


Figure 6.2 out flow hydrograph of a tropical sub catchment

The maximum flow profile along the existing flooding location of Zone B is shown in figure 6.5 and that also gives acceptable flood free maximum levels after the new proposal is implemented.

- 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.
- Proposed pipe line network and ground tank for zone C is shown in Figure 6.5.
- Proposed pipe line network and ground tank for zone D is shown in Figure 6.6.
- 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 is 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
- Volume of ground storage tank for zone A is shown in Table 6.9
- Volume of ground storage tank for zone B is shown in Table 6.10
- Volume of ground storage tank for zone C is shown in Table 6.11
- Volume of ground storage tank for zone D is shown in Table 6.12
- Typical section of water elevation profile is shown in Figure 6.7
- Invert level of the storage tank is shown in Table 6.13

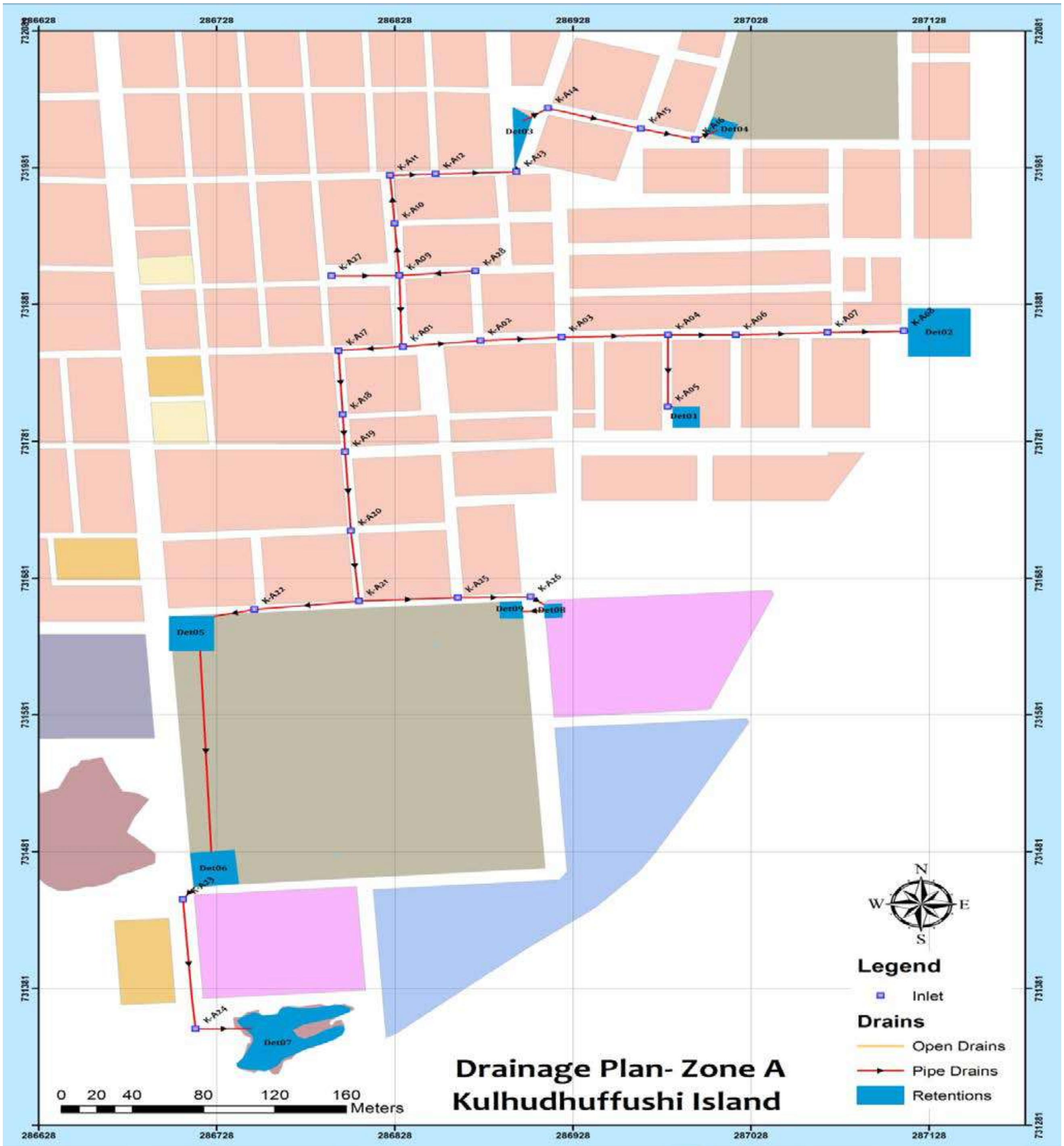


Figure 6.3 out Drainage plan Zone A – Hdh. Kulhudhuffushi Island

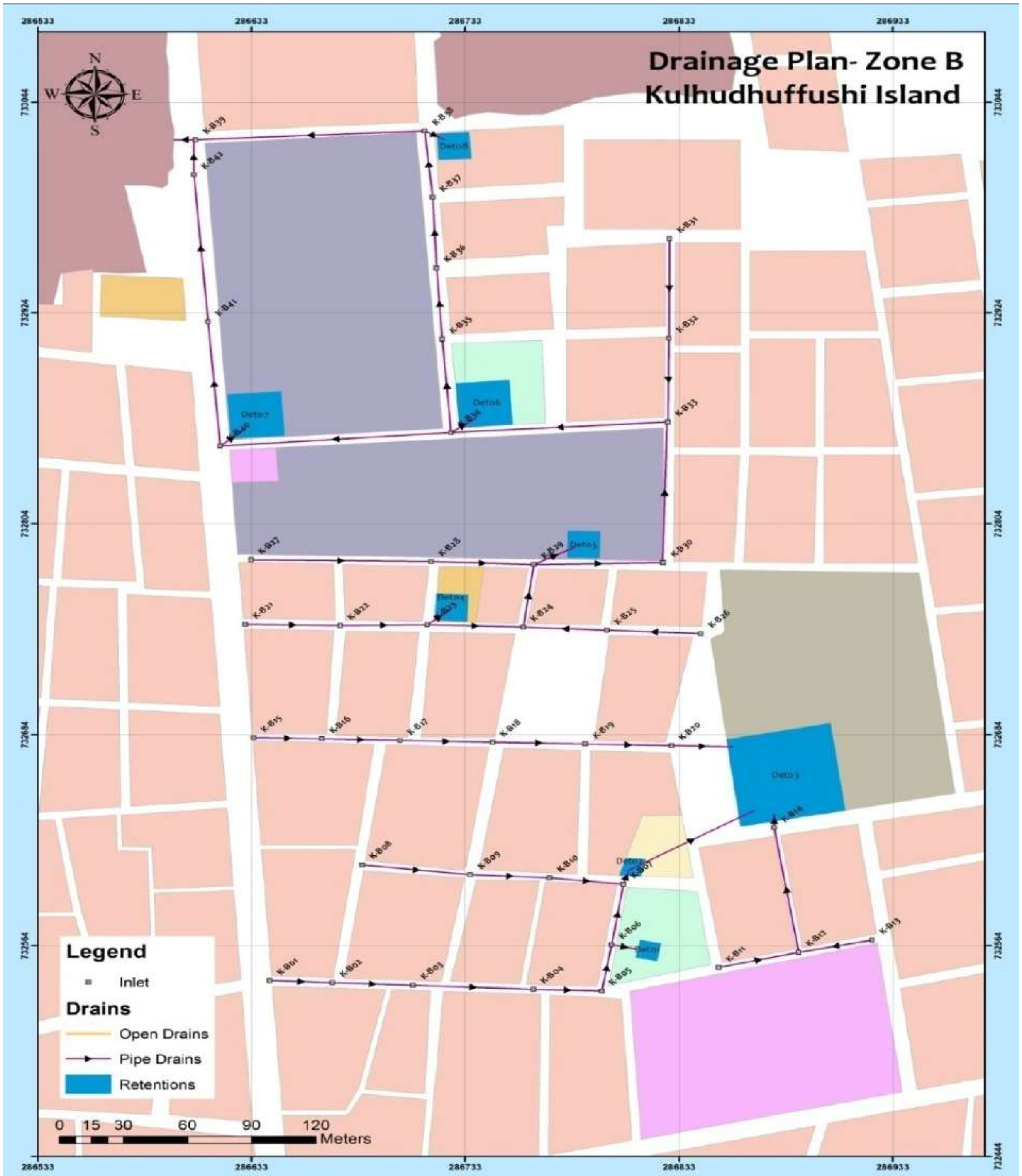


Figure 6.4 out Drainage plan Zone B Hdh. Kulhudhuffushi Island

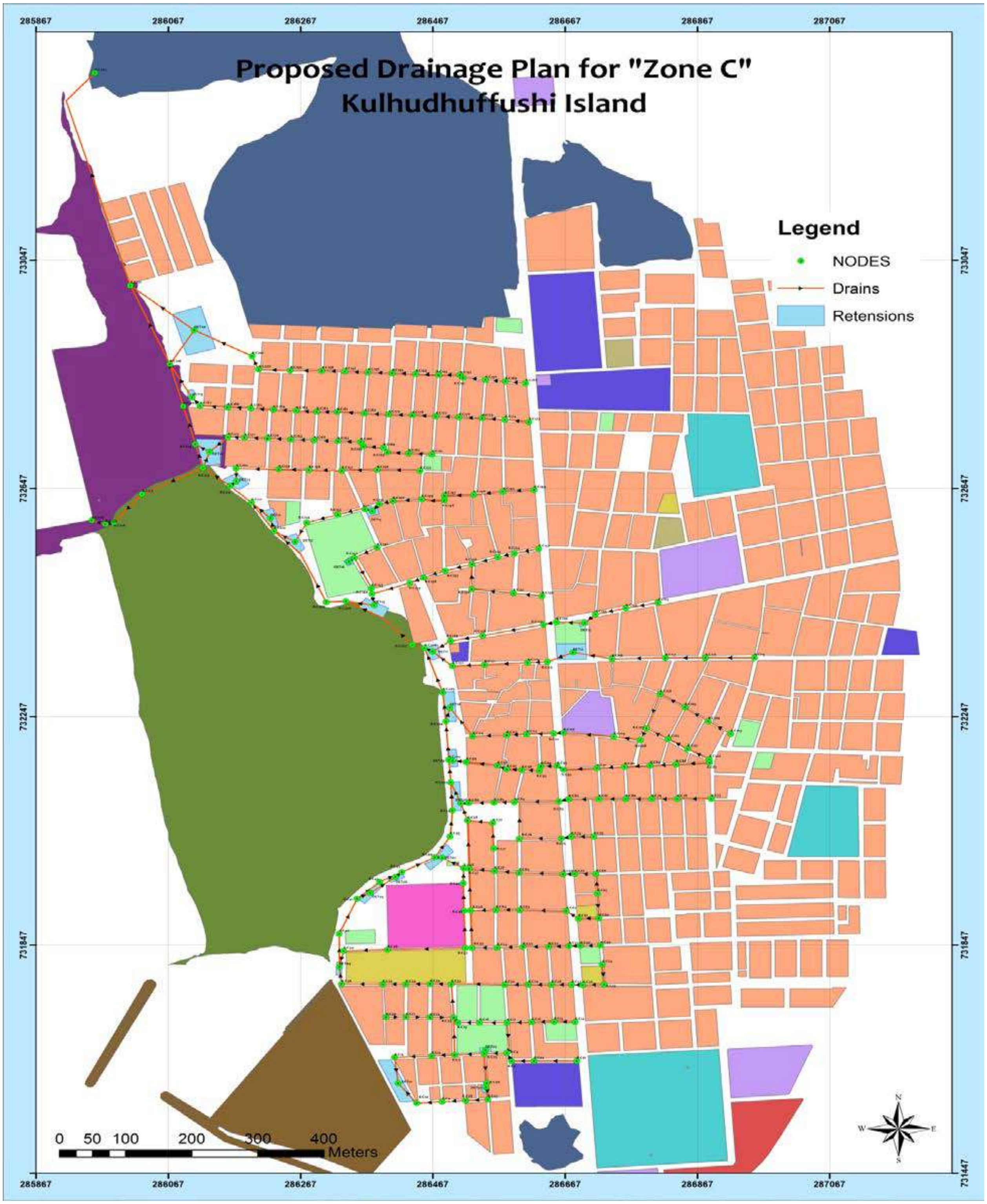


Figure 6.5 out Drainage plan Zone C Hdh. Kulhudhuffushi Island

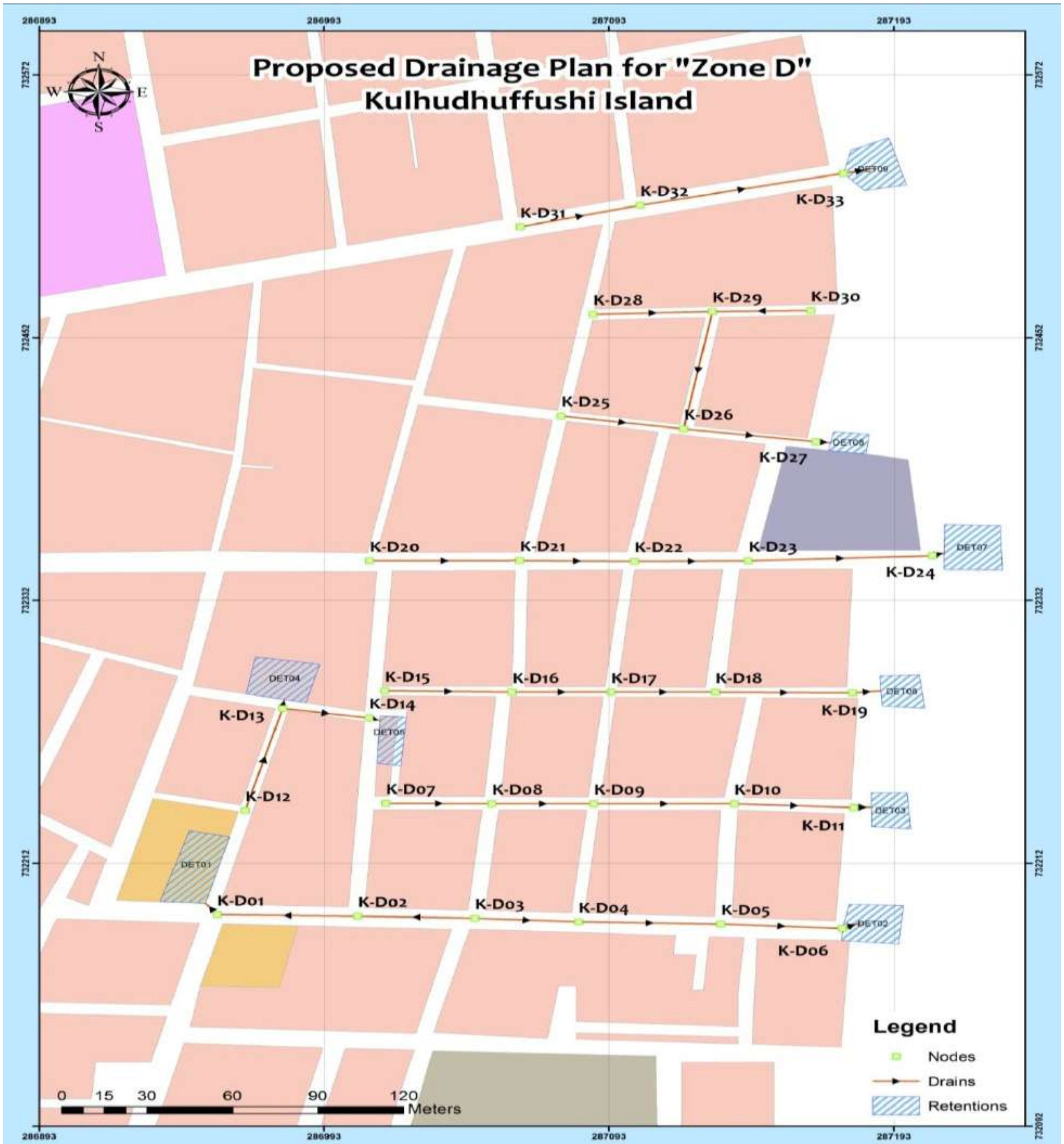


Figure 6.6 out Drainage plan Zone D Hdh. Kulhudhuffushi Island

Table 6.1 Zone A Summary of pipes

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
K-A01	0.55	0.9	0.15
K-A02	0.5	1.025	0.325
K-A03	0.455	1.055	0.4
K-A04	0.395	1.06	0.465
K-A05	0.345	1	0.455
K-A06	0.358	0.968	0.41
K-A07	0.307	0.9	0.393
K-A08	0.264	1.011	0.547
K-A09	0.55	0.9	0.25
K-A10	0.513	0.9	0.287
K-A11	0.478	0.9	0.322
K-A12	0.453	0.9	0.347
K-A13	0.407	1.009	0.402
K-A14	0.377	0.979	0.402
K-A15	0.323	1.085	0.562
K-A16	0.292	1.074	0.582
K-A17	0.55	0.9	0.25
K-A18	0.504	0.9	0.196
K-A19	0.477	0.9	0.223
K-A20	0.42	0.9	0.28
K-A21	0.369	1.013	0.444
K-A22	0.311	0.94	0.429
K-A23	0.477	1.1	0.423
K-A24	0.383	1.1	0.517
K-A25	0.314	1.2	0.686
K-A26	0.273	1.22	0.747
K-A27	0.56	1.01	0.25
K-A28	0.56	1.01	0.25

Table 6.2 Summary of Nodes Zone A

Upstream	Downstream	Pipe Length	Pipe Diameter	No. of pipes	Pipe Slope (%)
K-B01	K-B02	29.4	0.2	1	0.1
K-B02	K-B03	38	0.2	2	0.1
K-B03	K-B04	56	0.2	2	0.1
K-B04	K-B05	32	0.2	2	0.1
K-B05	K-B06	27	0.2	2	0.1
K-B06	Det01	15	0.2	1	0.1
K-B06	K-B07	35	0.2	2	0.1
K-B07	Det02	10	0.2	2	0.1
K-B08	K-B09	51	0.2	1	0.1
K-B09	K-B10	37	0.2	1	0.1
K-B10	K-B07	35	0.2	1	0.1
K-B11	K-B12	38	0.2	1	0.1
K-B13	K-B12	35	0.2	1	0.1
K-B12	K-B14	72	0.2	1	0.1
Det02	Det03	68	0.2	2	0.1
K-B14	Det03	15	0.2	1	0.1
K-B15	K-B16	31	0.2	1	0.1
K-B16	K-B17	36	0.2	1	0.1
K-B17	K-B18	44	0.2	1	0.1
K-B18	K-B19	44	0.2	2	0.1
K-B19	K-B20	40	0.2	2	0.1
K-B20	Det03	30	0.2	2	0.1
K-B21	K-B22	44	0.2	1	0.1
K-B22	K-B23	41	0.2	1	0.1
K-B23	Det04	15	0.2	1	0.1
K-B26	K-B25	44	0.2	2	0.1
K-B25	K-B24	39	0.2	2	0.1
K-B24	K-B23	45	0.2	1	0.1
K-B24	K-B29	36	0.2	1	0.1
K-B29	K-B30	60	0.2	1	0.1
K-B29	Det05	15	0.2	1	0.1
K-B27	K-B28	84	0.2	1	0.1
K-B28	K-B29	48	0.2	1	0.1
K-B30	K-B33	80	0.2	1	0.1
K-B31	K-B32	57	0.2	1	0.1
K-B32	K-B33	48	0.2	2	0.1
K-B33	K-B34	101	0.2	2	0.1
K-B34	Det06	15	0.2	1	0.1
K-B34	K-B40	108	0.2	1	0.1
K-B40	Det07	15	0.2	1	0.1
K-B35	K-B36	41	0.2	2	0.1
K-B36	K-B37	40	0.2	2	0.1
K-B37	K-B38	38	0.2	2	0.1
K-B38	Det08	15	0.2	2	0.1
K-B38	K-B39	107	0.2	2	0.1
K-B39	Det09	50	0.2	2	0.1
Det07	K-B41	60	0.2	1	0.1
K-B41	K-B42	83	0.2	1	0.1
K-B42	Det09	50	0.2	1	0.1
Det06	K-B35	55	0.2	1	0.1
Det09	Out let	100	0.2	1	0.1

Table 6.3 Zone B Summary of pipes

Node Name	Invert Level	Ground	Existing
K-B01	0.9	1.25	0.15
K-B02	0.871	1.161	0.09
K-B03	0.8333	1.233	0.2
K-B04	0.777	1.277	0.3
K-B05	0.7451	1.245	0.3
K-B06	0.7183	1.078	0.16
K-B07	0.6834	1.513	0.63
K-B08	0.841	1.191	0.15
K-B09	0.7902	1.21	0.22
K-B10	0.753	1.153	0.2
K-B11	0.78	1.23	0.25
K-B12	0.7224	1.152	0.23
K-B13	0.8	1.3	0.3
K-B14	0.6401	1.07	0.23
K-B15	0.827	1.327	0.3
K-B16	0.7951	1.205	0.21
K-B17	0.7587	1.169	0.21
K-B18	0.7153	1.145	0.23
K-B19	0.6719	1.092	0.22
K-B20	0.6316	1.092	0.26
K-B21	0.76	1.11	0.15
K-B22	0.7156	1.176	0.26
K-B23	0.675	1.165	0.29
K-B24	0.656	1.146	0.29
K-B25	0.695	1.055	0.16
K-B26	0.739	1.089	0.15
K-B27	0.906	1.256	0.15
K-B28	0.822	1.202	0.18
K-B29	0.62	0.99	0.17
K-B30	0.56	1.12	0.36
K-B31	0.55	0.9	0.15
K-B32	0.51	0.9	0.19
K-B33	0.462	0.902	0.24
K-B34	0.361	0.961	0.4
K-B35	0.55	0.9	0.15
K-B36	0.493	0.903	0.21
K-B37	0.453	0.903	0.25
K-B38	0.415	0.905	0.29
K-B39	0.308	0.898	0.39
K-B40	0.253	0.973	0.52
K-B41	0.443	0.913	0.27
K-B42	0.359	0.909	0.35

Table 6.4 Summary of Nodes Zone B

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%
K-C1	K-C2	64.80	0.2	1	0.1
K-C2	K-C3	33.90	0.2	2	0.1
K-C3	K-C4	15.90	0.2	1	0.1
K-C4	K-C5	34.60	0.2	2	0.1
K-C5	K-C6	51.40	0.2	2	0.1
K-C6	K-C7	29.00	0.2	2	0.1
K-C7	K-C8	33.70	0.2	2	0.1
K-C8	K-C9	35.50	0.2	2	0.1
K-C9	K-C10	38.50	0.2	2	0.1
K-C10	DET1	45.30	0.2	2	0.1
K-C6	DET2	7.32	0.2	1	0.1
DET1	outfall 1	50.00	0.2	1	0.1
K-C5	DET3	7.00	0.2	1	0.1
K-C5	K-C11	44.60	0.2	1	0.1
K-C11	K-C12	34.90	0.2	1	0.1
K-C12	K-C13	56.00	0.2	1	0.1
K-C13	DET1	45.00	0.2	1	0.1
K-C14	K-C15	31.60	0.2	1	0.1
K-C15	K-C16	34.20	0.2	1	0.1
K-C16	K-C17	37.00	0.2	1	0.1
K-C17	K-C4	45.90	0.2	1	0.1
K-C17	K-C18	41.70	0.2	1	0.1
K-C18	K-C19	32.50	0.2	1	0.1
K-C11	K-C23	65.30	0.2	2	0.1
K-C19	K-C23	11.10	0.2	1	0.1
K-C20	K-C21	30.30	0.2	1	0.1
K-C21	K-C22	36.40	0.2	1	0.1
K-C22	K-C23	36.00	0.2	1	0.1
K-C23	K-C32	58.40	0.2	2	0.1
K-C24	K-C25	35.30	0.2	1	0.1
K-C25	K-C26	32.40	0.2	1	0.1
K-C26	K-C27	16.70	0.2	1	0.1
K-C27	K-C28	30.70	0.2	1	0.1
K-C28	K-C29	35.20	0.2	1	0.1
K-C29	K-C30	35.50	0.2	1	0.1
K-C30	K-C31	51.30	0.2	1	0.1

Table 6.5 Zone C Summary of pipes

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%
K-C31	K-C32	29.40	0.2	1	0.1
K-C32	K-C33	32.00	0.2	2	0.1
K-C33	K-C34	36.80	0.2	2	0.1
K-C34	K-C35	35.10	0.2	2	0.1
K-C35	K-C36	62.00	0.2	2	0.1
K-C36	DET4	15.00	0.2	2	0.1
K-C37	K-C38	117.94	0.2	1	0.1
K-C38	K-C39	66.29	0.2	1	0.1
K-C39	DET4	30.71	0.2	1	0.1
K-C40	K-C41	67.23	**	**	**
K-C41	K-C42	45.38	**	**	**
K-C41	DET5	22.47	0.2	1	0.1
DET5	DET6	47.17	0.2	1	0.1
K-C42	K-C43	37.81	**	**	**
DET6	K-C43	12.93	0.2	2	0.1
K-C43	K-C44	56.27	**	**	**
K-C44	DET7	11.06	0.2	2	0.1
K-C44	K-C45	43.19	**	**	**
K-C37	K-C46	65.00	0.2	1	0.1
K-C46	K-C47	48.00	0.2	1	0.1
K-C47	K-C48	27.00	0.2	1	0.1
K-C48	DET7	59.00	0.2	1	0.1
K-C49	K-C50	30.50	0.2	1	0.1
K-C50	K-C51	17.30	0.2	1	0.1
K-C51	K-C52	30.70	0.2	1	0.1
K-C52	K-C53	38.70	0.2	1	0.1
K-C53	K-C54	38.80	0.2	1	0.1
K-C54	K-C55	38.50	0.2	1	0.1
K-C55	K-C56	65.30	0.2	2	0.1
K-C56	K-C57	73.50	0.2	2	0.1
K-C57	K-C58	84.50	0.2	2	0.1
K-C58	DET8	32.00	0.2	3	0.1
K-C45	K-C59	45.80	**	**	**
K-C60	K-C61	30.81	0.2	1	0.1

Table 6.5 Zone C Summary of pipes   Cont.…

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%
K-C61	K-C62	22.52	0.2	1	0.1
K-C62	K-C63	70.42	0.2	1	0.1
K-C63	K-C64	35.77	0.2	1	0.1
K-C64	K-C56	38.65	0.2	1	0.1
K-C60	K-C65	43.22	0.2	1	0.1
K-C65	K-C66	34.51	0.2	1	0.1
K-C66	K-C67	32.39	0.2	1	0.1
K-C67	K-C68	17.24	0.2	1	0.1
K-C68	K-C69	66.72	0.2	1	0.1
K-C69	K-C70	37.01	0.2	1	0.1
K-C70	K-C57	38.86	0.2	1	0.1
K-C71	K-C72	44.67	0.2	1	0.1
K-C72	K-C58	38.46	0.2	1	0.1
K-C73	K-C74	34.29	0.2	1	0.1
K-C74	K-C75	15.14	0.2	1	0.1
K-C75	K-C76	63.61	0.2	1	0.1
K-C76	K-C84	64.38	0.2	1	0.1
K-C77	K-C78	51.33	0.2	1	0.1
K-C78	K-C79	38.89	0.2	1	0.1
K-C79	K-C80	39.29	0.2	1	0.1
K-C80	K-C81	40.48	0.2	1	0.1
K-C81	K-C82	45.40	0.2	1	0.1
K-C82	K-C83	15.02	0.2	2	0.1
K-C83	K-C84	67.72	0.2	2	0.1
K-C84	K-C85	30.71	0.2	2	0.1
K-C85	K-C86	38.38	0.2	2	0.1
K-C86	DET8	11.95	0.2	2	0.1
K-C87	K-C88	37.80	0.2	1	0.1
K-C88	K-C89	39.30	0.2	1	0.1
K-C89	K-C90	38.70	0.2	1	0.1
K-C90	K-C91	42.00	0.2	1	0.1

Table 6.5 Zone C Summary of pipes   Cont.…

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%
K-C91	K-C92	50.50	0.2	1	0.1
K-C92	K-C93	11.70	0.2	1	0.1
K-C93	K-C94	24.60	0.2	2	0.1
K-C94	K-C95	8.54	0.2	2	0.1
K-C95	K-C96	26.40	0.2	2	0.1
K-C96	K-C97	22.90	0.2	2	0.1
K-C97	K-C98	15.20	0.2	2	0.1
K-C98	K-C99	47.70	0.2	2	0.1
K-C99	DET9	20.80	0.2	2	0.1
K-C100	K-C101	37.80	0.2	1	0.1
K-C101	K-C102	34.10	0.2	1	0.1
K-C102	K-C107	37.60	0.2	1	0.1
K-C103	K-C104	40.60	0.2	1	0.1
K-C104	K-C105	43.00	0.2	1	0.1
K-C105	K-C106	43.90	0.2	1	0.1
K-C106	K-C107	63.40	0.2	1	0.1
K-C107	K-C108	22.60	0.2	2	0.1
K-C108	K-C109	40.60	0.2	2	0.1
K-C109	K-C110	75.90	0.2	2	0.1
K-C110	K-C111	15.00	0.2	2	0.1
K-C111	K-C112	41.20	0.2	2	0.1
K-C112	K-C113	32.80	0.2	2	0.1
K-C113	K-C114	48.80	0.2	2	0.1
K-C114	DET10	60.70	0.2	2	0.1
K-C115	K-C116	74.35	0.2	2	0.1
K-C116	K-C117	60.32	0.2	2	0.1
K-C117	K-C118	80.63	0.2	2	0.1
K-C118	DET12	60.04	0.2	2	0.1
DET12	K-C119	42.21	0.2	2	0.1
K-C119	K-C120	29.82	0.2	2	0.1
K-C120	K-C121	65.15	0.2	2	0.1

Table 6.5 Zone C Summary of pipes Cont.…

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%
K-C121	K-C122	48.79	0.2	2	0.1
K-C122	DET11	39.35	0.2	2	0.1
K-C123	K-C124	49.55	0.2	2	0.1
K-C124	K-C125	47.25	0.2	2	0.1
K-C125	DET13	22.05	0.2	2	0.1
DET13	K-C126	42.60	0.2	2	0.1
K-C126	K-C127	20.38	0.2	2	0.1
K-C127	K-C128	93.67	0.2	2	0.1
K-C128	K-C129	49.49	0.2	2	0.1
K-C129	DET11	32.84	0.2	2	0.1
K-C130	K-C131	43.70	0.2	1	0.1
K-C131	K-C132	63.10	0.2	1	0.1
K-C132	K-C136	43.60	0.2	1	0.1
K-C133	K-C134	37.70	0.2	1	0.1
K-C134	K-C135	26.00	0.2	1	0.1
K-C135	K-C136	40.90	0.2	1	0.1
K-C136	K-C137	42.00	0.2	2	0.1
K-C137	K-C138	35.20	0.2	2	0.1
K-C138	K-C139	22.90	0.2	2	0.1
K-C139	K-C140	60.10	0.2	2	0.1
K-C140	DET14	20.20	0.2	3	0.1
K-C141	K-C142	38.70	0.2	1	0.1
K-C142	DET16	10.50	0.2	1	0.1
K-C142	K-C143	58.90	0.2	1	0.1
K-C143	K-C140	9.97	0.2	1	0.1
K-C144	K-C145	47.10	0.2	2	0.1
K-C145	K-C146	44.80	0.2	2	0.1
K-C146	K-C147	44.10	0.2	2	0.1
K-C147	K-C148	8.28	0.2	2	0.1
K-C148	K-C149	34.30	0.2	2	0.1
K-C149	K-C150	43.50	0.2	2	0.1
K-C150	K-C151	21.50	0.2	3	0.1

Table 6.5 Zone C Summary of pipes Cont.…

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%
K-C151	DET15	16.20	0.2	2	0.1
DET15	K-C152	16.50	0.2	2	0.1
K-C152	K-C153	37.60	0.2	2	0.1
K-C153	K-C154	49.30	0.2	2	0.1
K-C154	DET17	51.50	0.2	3	0.1
K-C155	K-C156	64.84	0.2	1	0.1
K-C156	K-C157	53.78	0.2	1	0.1
K-C157	K-C158	49.54	0.2	1	0.1
K-C158	K-C159	45.73	0.2	1	0.1
K-C159	K-C160	64.46	0.2	1	0.1
K-C160	DET18	22.50	0.2	1	0.1
K-C161	K-C162	35.51	0.2	1	0.1
K-C162	K-C163	32.16	0.2	1	0.1
K-C163	K-C164	10.00	0.2	1	0.1
K-C164	K-C165	30.51	0.2	1	0.1
K-C165	K-C166	8.45	0.2	2	0.1
K-C166	K-C167	34.46	0.2	2	0.1
K-C167	K-C168	35.74	0.2	2	0.1
K-C168	K-C169	35.36	0.2	2	0.1
K-C169	K-C170	35.48	0.2	2	0.1
K-C170	K-C171	34.70	0.2	2	0.1
K-C171	K-C172	25.21	0.2	2	0.1
K-C172	DET18	37.72	0.2	2	0.1
K-C173	K-C174	36.59	0.2	1	0.1
K-C174	K-C175	34.57	0.2	1	0.1
K-C175	K-C176	35.12	0.2	1	0.1
K-C176	K-C177	34.97	0.2	1	0.1
K-C177	K-C178	35.61	0.2	1	0.1
K-C178	K-C179	35.90	0.2	1	0.1
K-C179	K-C180	36.88	0.2	1	0.1
K-C180	K-C181	41.18	0.2	2	0.1

Table 6.5 Zone C Summary of pipes Cont.…

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%
K-C181	K-C182	30.80	0.2	2	0.1
K-C182	K-C183	31.16	0.2	2	0.1
K-C183	K-C184	34.66	0.2	2	0.1
K-C184	K-C185	34.26	0.2	2	0.1
K-C185	K-C186	34.97	0.2	2	0.1
K-C186	K-C187	41.66	0.2	2	0.1
K-C187	DET19	18.95	0.2	3	0.1
K-C188	K-C189	31.09	0.2	2	0.1
K-C189	K-C190	29.97	0.2	2	0.1
K-C190	K-C191	34.20	0.2	2	0.1
K-C191	K-C192	6.59	0.2	2	0.1
K-C192	K-C193	32.07	0.2	2	0.1
K-C193	K-C194	35.27	0.2	2	0.1
K-C194	K-C195	35.27	0.2	2	0.1
K-C195	K-C196	36.64	0.2	2	0.1
K-C196	K-C197	34.85	0.2	2	0.1
K-C197	K-C198	34.74	0.2	2	0.1
K-C198	K-C199	47.94	0.2	2	0.1
K-C199	K-C200	47.58	0.2	2	0.1
K-C200	K-C201	24.62	0.2	2	0.1
K-C201	DET20	98.63	0.2	3	0.1
K-C59	K-C202	49.30	**	**	**
DET8	K-C202	5.00	0.2	2	0.1
K-C202	K-C203	39.30	**	**	**
DET9	K-C203	5.00	0.2	2	0.1
K-C203	K-C204	67.00	**	**	**
K-C204	K-C205	52.00	**	**	**
DET10	K-C205	10.00	0.2	2	0.1
K-C205	K-C206	82.00	**	1	**
DET11	K-C206	5.00	0.2	2	0.1

Table 6.5 Zone C Summary of pipes Cont...

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%
K-C181	K-C182	30.80	0.2	2	0.1
K-C182	K-C183	31.16	0.2	2	0.1
K-C183	K-C184	34.66	0.2	2	0.1
K-C184	K-C185	34.26	0.2	2	0.1
K-C185	K-C186	34.97	0.2	2	0.1
K-C186	K-C187	41.66	0.2	2	0.1
K-C187	DET19	18.95	0.2	3	0.1
K-C188	K-C189	31.09	0.2	2	0.1
K-C189	K-C190	29.97	0.2	2	0.1
K-C190	K-C191	34.20	0.2	2	0.1
K-C191	K-C192	6.59	0.2	2	0.1
K-C192	K-C193	32.07	0.2	2	0.1
K-C193	K-C194	35.27	0.2	2	0.1
K-C194	K-C195	35.27	0.2	2	0.1
K-C195	K-C196	36.64	0.2	2	0.1
K-C196	K-C197	34.85	0.2	2	0.1
K-C197	K-C198	34.74	0.2	2	0.1
K-C198	K-C199	47.94	0.2	2	0.1
K-C199	K-C200	47.58	0.2	2	0.1
K-C200	K-C201	24.62	0.2	2	0.1
K-C201	DET20	98.63	0.2	3	0.1
K-C59	K-C202	49.30	**	**	**
DET8	K-C202	5.00	0.2	2	0.1
K-C202	K-C203	39.30	**	**	**
DET9	K-C203	5.00	0.2	2	0.1
K-C203	K-C204	67.00	**	**	**
K-C204	K-C205	52.00	**	**	**
DET10	K-C205	10.00	0.2	2	0.1
K-C205	K-C206	82.00	**	1	**
DET11	K-C206	5.00	0.2	2	0.1

Table 6.5 Zone C Summary of pipes Cont.…

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%
K-C206	K-C207	18.00	**	**	**
K-C207	K-C208	128.00	**	**	**
DET14	K-C208	10.00	0.2	2	0.1
K-C208	K-C209	30.00	**	**	**
K-C209	K-C210	150.00	**	**	**
DET17	K-C210	10.00	0.2	2	0.1
K-C210	K-C211	60.00	**	**	**
K-C210	DET21	10.00	0.2	2	0.1
DET21	K-C211	15.00	0.2	2	0.1
K-C211	K-C212	43.00	**	**	**
K-C212	DET22	50.00	0.2	2	0.1
K-C212	K-C213	51.00	**	**	**
K-C213	K-C214	43.00	**	**	**
DET18	K-C214	10.00	0.2	2	0.1
K-C214	K-C215	69.00	**	1	**
DET19	K-C215	10.00	0.2	1	0.1
K-C215	K-C216	76.00	**	**	**
K-C213	K-C217	103.00	0.3	1	0.1
K-C217	K-C218	65.00	0.3	1	0.1
K-C218	K-C219	13.00	0.3	1	0.1
K-C219	K-C220	22.00	0.3	1	0.1
K-C222	DET23	20.00	0.3	2	0.1
K-C220	2	10.00	0.2	2	0.1
DET20	K-C221	124.00	0.2	2	0.1
K-C221	K-C222	400.00	**	**	**
K-C216	K-C221	150.00	**	**	**
K-C39	K-C40	50.00	0.2	1	0.1

Table 6.5 Zone C Summary of pipes

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
K-C1	0.55	0.900	0.150
K-C2	0.4852	0.900	0.215
K-C3	0.4513	0.900	0.249
K-C4	0.4354	0.910	0.275
K-C5	0.4008	0.910	0.309
K-C6	0.3494	1.000	0.451
K-C7	0.3204	0.900	0.380
K-C8	0.2867	0.900	0.413
K-C9	0.2512	0.900	0.449
K-C10	0.2127	1.110	0.697
K-C11	0.3562	0.900	0.344
K-C12	0.3213	0.900	0.379
K-C13	0.2653	0.900	0.435
K-C14	0.6	0.950	0.150
K-C15	0.5684	0.940	0.172
K-C16	0.5342	1.000	0.266
K-C17	0.4972	1.000	0.303
K-C18	0.4555	1.000	0.345
K-C19	0.423	0.900	0.277
K-C20	0.61	1.220	0.410
K-C21	0.5797	1.159	0.380
K-C22	0.5433	1.087	0.343
K-C23	0.412	0.900	0.288
K-C24	0.577	0.927	0.150
K-C25	0.5417	1.000	0.258
K-C26	0.5093	1.000	0.291
K-C27	0.4926	1.000	0.307
K-C28	0.4619	1.000	0.338
K-C29	0.4267	1.000	0.373
K-C30	0.3912	1.100	0.509
K-C31	0.3399	1.100	0.560
K-C32	0.3105	1.100	0.590
K-C33	0.2785	0.960	0.482
K-C34	0.2417	0.900	0.458
K-C35	0.2066	0.900	0.493
K-C36	0.1446	0.900	0.555

Table 6.6 Summary of Nodes Zone C Cont.…

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
K-C37	0.677253	1.027	0.150
K-C38	0.55930874	1.009	0.250
K-C39	0.493023352	1.439	0.746
K-C40	0.4	1.300	0.700
K-C41	0.4	1.150	0.550
K-C42	0.4	1.300	0.700
K-C43	0.4	1.000	0.400
K-C44	0.4	1.000	0.400
K-C45	0.4	0.900	0.300
K-C46	0.6123	1.300	0.488
K-C47	0.5643	1.100	0.336
K-C48	0.5373	1.100	0.363
K-C49	0.65	1.000	0.150
K-C50	0.6195	1.000	0.181
K-C51	0.6022	1.000	0.198
K-C52	0.5715	1.000	0.229
K-C53	0.5328	1.100	0.367
K-C54	0.494	1.135	0.441
K-C55	0.4555	1.100	0.445
K-C56	0.3902	1.400	0.810
K-C57	0.3167	1.200	0.683
K-C58	0.2322	1.189	0.757
K-C59	0.4	0.900	0.300
K-C60	0.56621	0.916	0.150
K-C61	0.535402168	1.000	0.265
K-C62	0.512884954	1.015	0.303
K-C63	0.442462748	1.200	0.558
K-C64	0.406690333	1.218	0.611
K-C65	0.56621	0.896	0.130
K-C66	0.64041	0.990	0.150
K-C67	0.608024299	1.000	0.192
K-C68	0.590784323	1.012	0.221
K-C69	0.524060787	1.200	0.476
K-C70	0.487052301	1.200	0.513

Table 6.6 Summary of Nodes Zone C Cont.…

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
K-C71	0.926954	1.277	0.150
K-C72	0.882282275	1.298	0.216
K-C73	0.65	1.000	0.150
K-C74	0.615709655	1.033	0.218
K-C75	0.600574139	1.092	0.291
K-C76	0.536965456	1.300	0.563
K-C77	0.55	0.900	0.150
K-C78	0.498671243	0.900	0.201
K-C79	0.459777763	0.900	0.240
K-C80	0.420485233	1.000	0.380
K-C81	0.380005933	1.090	0.510
K-C82	0.334604011	1.200	0.665
K-C83	0.319581887	1.200	0.680
K-C84	0.251866382	1.372	0.920
K-C85	0.221154486	1.300	0.879
K-C86	0.182779372	1.294	0.911
K-C87	0.49135	0.841	0.150
K-C88	0.45355	1.000	0.346
K-C89	0.41425	1.076	0.462
K-C90	0.37555	1.196	0.621
K-C91	0.33355	1.323	0.789
K-C92	0.28305	1.200	0.717
K-C93	0.27135	1.207	0.736
K-C94	0.647	1.387	0.540
K-C95	0.638209305	1.344	0.506
K-C96	0.611809305	1.300	0.488
K-C97	0.588909305	1.300	0.511
K-C98	0.573709305	1.304	0.530
K-C99	0.526009305	1.400	0.674
K-C100	0.49135	0.841	0.150
K-C101	0.45355	0.980	0.327

Table 6.6 Summary of Nodes Zone C Cont…

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
K-C102	0.41945	1.114	0.494
K-C103	0.55	0.900	0.150
K-C104	0.5094	1.100	0.391
K-C105	0.4664	1.392	0.725
K-C106	0.4225	1.400	0.778
K-C107	0.3591	1.442	0.883
K-C108	0.3365	1.575	1.038
K-C109	0.2959	1.478	0.983
K-C110	0.22	1.432	1.012
K-C111	0.205	1.369	0.964
K-C112	0.564	1.604	0.840
K-C113	0.531	1.501	0.770
K-C114	0.482	1.282	0.600
K-C115	0.95	1.300	0.150
K-C116	0.875652235	1.359	0.283
K-C117	0.815328306	1.300	0.285
K-C118	0.734694942	1.300	0.365
K-C119	0.692483405	1.300	0.408
K-C120	0.662658937	1.412	0.550
K-C121	0.597510471	1.201	0.403
K-C122	0.548716246	1.037	0.289
K-C123	0.95	1.300	0.150
K-C124	0.900445757	1.300	0.200
K-C125	0.853196364	1.288	0.235
K-C126	0.810591945	1.216	0.205
K-C127	0.790215108	1.200	0.210
K-C128	0.696547882	1.100	0.203
K-C129	0.64705651	1.001	0.154
K-C130	0.85	1.200	0.150
K-C131	0.8063	1.233	0.227
K-C132	0.7432	1.300	0.357

Table 6.6 Summary of Nodes Zone C Cont…

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
K-C133	0.85	1.200	0.150
K-C134	0.8123	1.200	0.188
K-C135	0.7863	1.200	0.214
K-C136	0.7454	1.219	0.274
K-C137	0.7034	1.300	0.397
K-C138	0.6682	1.218	0.350
K-C139	0.6453	1.135	0.290
K-C140	0.5852	0.900	0.115
K-C141	0.690606	1.041	0.150
K-C142	0.651906	0.869	0.017
K-C143	0.5924	0.902	0.110
K-C144	0.85	1.200	0.150
K-C145	0.8029	1.200	0.197
K-C146	0.7581	1.259	0.301
K-C147	0.714	1.200	0.286
K-C148	0.705720607	1.200	0.294
K-C149	0.671420607	1.114	0.243
K-C150	0.627920607	1.100	0.272
K-C151	0.606420607	1.076	0.270
K-C152	0.606420607	1.071	0.265
K-C153	0.568820607	0.893	0.124
K-C154	0.519520607	0.900	0.180
K-C155	0.85	1.200	0.150
K-C156	0.785157049	0.900	-0.085
K-C157	0.731373931	0.981	0.049
K-C158	0.681837445	0.900	0.018
K-C159	0.636109982	0.900	0.064
K-C160	0.571652927	1.100	0.328
K-C161	0.738765	1.089	0.150
K-C162	0.703255564	0.900	-0.003
K-C163	0.671093186	0.900	0.029
K-C164	0.661094381	0.900	0.039

Table 6.6 Summary of Nodes Zone C Cont…

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
K-C165	0.630579425	0.900	0.069
K-C166	0.622127979	0.900	0.078
K-C167	0.587669321	0.900	0.112
K-C168	0.551927045	0.900	0.148
K-C169	0.516563493	0.900	0.183
K-C170	0.481085634	0.900	0.219
K-C171	0.446382962	0.902	0.256
K-C172	0.421176488	1.052	0.431
K-C173	0.756538	1.107	0.150
K-C174	0.719950671	1.187	0.267
K-C175	0.685383575	1.055	0.170
K-C176	0.650263872	1.000	0.150
K-C177	0.615295196	1.000	0.185
K-C178	0.579684024	0.909	0.129
K-C179	0.54378393	0.976	0.233
K-C180	0.506904738	1.000	0.293
K-C181	0.465728325	1.000	0.334
K-C182	0.434924173	0.906	0.271
K-C183	0.403768704	0.900	0.296
K-C184	0.369107247	0.900	0.331
K-C185	0.334843839	0.900	0.365
K-C186	0.299872538	0.900	0.400
K-C187	0.258211778	0.972	0.514
K-C188	0.65	1.000	0.150
K-C189	0.618911529	0.965	0.146
K-C190	0.588939984	0.900	0.111
K-C191	0.554742455	0.961	0.207
K-C192	0.548156876	0.929	0.181
K-C193	0.516087739	0.900	0.184
K-C194	0.480813994	0.900	0.219
K-C195	0.445544528	0.900	0.254

Table 6.6 Summary of Nodes Zone C Cont…

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
K-C196	0.408904103	0.900	0.291
K-C197	0.374053383	0.900	0.326
K-C198	0.339312751	0.900	0.361
K-C199	0.291369072	0.900	0.409
K-C200	0.243792723	0.900	0.456
K-C201	0.219172176	0.900	0.481
K-C202	0.4	0.900	0.300
K-C203	0.4	0.900	0.300
K-C204	0.4	0.900	0.300
K-C205	0.4	0.900	0.300
K-C206	0.4	0.900	0.300
K-C207	0.4	0.900	0.300
K-C208	0.4	0.900	0.300
K-C209	0.35	0.900	0.350
K-C210	0.35	0.900	0.350
K-C211	0.35	0.900	0.350
K-C212	0.35	0.900	0.350
K-C213	0.35	0.900	0.350
K-C214	0.35	0.900	0.350
K-C215	0.35	0.900	0.350
K-C216	0.35	0.900	0.350
K-C217	0.6	0.900	0.100
K-C218	0.5	0.900	0.200
K-C219	0.5	0.900	0.200
K-C220	0.5	0.900	0.200
K-C221	0.35	0.900	0.350
K-C222	0.3	0.900	0.400

Table 6.6 Summary of Nodes Zone C

Upstream Node	Downstream Node	Pipe Length (m)	Pipe Diameter (m)	No. of pipes	Pipe Slope (%)
K-D03	K-D02	41.2	0.2	1	0.0010
K-D02	K-D01	49.3	0.2	1	0.0010
K-D03	K-D04	36.4	0.2	1	0.0030
K-D04	K-D05	50	0.2	1	0.0030
K-D05	K-D06	42.7	0.2	1	0.0010
K-D07	K-D08	37.3	0.2	1	0.0010
K-D08	K-D09	35.8	0.2	1	0.0030
K-D09	K-D10	49.3	0.2	1	0.0010
K-D10	K-D11	41.9	0.2	2	0.0010
K-D01	DET1	6.63	0.2	1	0.0010
K-D06	DET2	6.93	0.2	1	0.0010
K-D11	DET3	6.23	0.2	2	0.0010
K-D12	K-D13	48.4	0.2	1	0.0010
K-D13	DET4	4.16	0.2	1	0.0010
K-D13	K-D14	30.7	0.2	1	0.0010
K-D14	DET5	3.97	0.2	1	0.0010
K-D15	K-D16	44.7	0.2	1	0.0010
K-D16	K-D17	34.8	0.2	1	0.0010
K-D17	K-D18	36.7	0.2	1	0.0010
K-D18	K-D19	48.1	0.2	1	0.0010
K-D19	DET6	9.99	0.2	1	0.0010
K-D20	K-D21	52.7	0.2	1	0.0010
K-D21	K-D22	40.3	0.2	1	0.0020
K-D22	K-D23	40	0.2	1	0.0020
K-D23	K-D24	64.6	0.2	2	0.0020

K-D24	DET7	4.22	0.2	2	0.0010
K-D25	K-D26	43.4	0.2	1	0.0040
K-D26	K-D27	46.9	0.2	2	0.0030
K-D27	DET8	5.07	0.2	2	0.0010
K-D28	K-D29	41.9	0.2	1	0.0010
K-D30	K-D29	34.5	0.2	1	0.0010
K-D29	K-D26	54.5	0.2	1	0.0010
K-D31	K-D32	43.2	0.2	1	0.0010
K-D32	K-D33	72.9	0.2	1	0.0020
K-D33	DET9	11.4	0.2	1	0.0010
DET2	OUTLET	50	0.2	1	0.0010

Table 6.7 Zone D Summary of pipes

Node Name	Invert Level (m.MSL)	Ground Level (m.MSL)	Existing Covering (m)
K-D01	0.71	1.020	0.11
K-D02	0.759	1.170	0.211
K-D03	0.8	1.200	0.2
K-D04	0.692	1.100	0.208
K-D05	0.542	0.900	0.158
K-D06	0.499	1.170	0.471
K-D07	0.863	1.213	0.15
K-D08	0.826	1.220	0.194
K-D09	0.718	1.034	0.116
K-D10	0.669	0.970	0.101
K-D11	0.627	1.260	0.433
K-D12	0.81	1.160	0.15
K-D13	0.762	1.290	0.328
K-D14	0.732	1.300	0.368
K-D15	0.724	1.270	0.346
K-D16	0.68	1.250	0.37
K-D17	0.646	1.210	0.364
K-D18	0.609	1.040	0.231
K-D19	0.561	1.034	0.273
K-D20	1	1.350	0.15
K-D21	0.947	1.400	0.253
K-D22	0.867	1.350	0.283
K-D23	0.787	1.100	0.113
K-D24	0.657	1.100	0.243
K-D25	1.06	1.410	0.15
K-D26	0.888	1.240	0.152
K-D27	0.747	1.100	0.153
K-D28	1.014	1.364	0.15
K-D29	0.972	1.340	0.168
K-D30	0.75	1.100	0.15
K-D31	0.814	1.164	0.15
K-D32	0.771	1.180	0.209
K-D33	0.625	1.000	0.175

Table 6.8 Summary of Nodes Zone D

Name of the Storage Area	Volume (m^3)
Det_01	200
Det_02	850
Det_03	225
Det_04	900
Det_05	625
Det_06	625

Table 6.9 Volume of ground storage tank - ZONE A – Hdh. Kulhudhuffushi Island

Name of the Storage Area	Volume (m^3)
Det01	100
Det02	100
Det03	1900
Det04	225
Det05	350
Det06	500
Det07	400
Det08	180

Table 6.10 Volume of ground storage tank - ZONE B – Hdh. Kulhudhuffushi Island

Name of the Storage Area	Volume (m3)
DET1	975
DET2	70
DET3	100
DET4	675
DET5	210
DET6	210
DET7	210
DET8	700
DET9	210
DET10	350
DET11	280
DET12	90
DET13	300
DET14	420
DET15	170
DET16	70
DET17	630
DET18	585
DET19	390
DET20	1250
DET21	280
DET22	260
DET23	Natural pond

Table 6.11 Volume of ground storage tank - ZONE C – Hdh. Kulhudhuffushi Island

Name of the Storage Area	Volume (m^3)
DET01	225
DET02	350
DET03	350
DET04	350
DET05	150
DET06	350
DET07	400
DET08	400

Table 6.12Volume of ground storage tank - ZONE D – Hdh. Kulhudhuffushi Island

Name	Invert Level (m.MSL)
Det01	0.1183
Det02	0.17
Det03	0.15
Det04	0.162
Det05	0.153
Det06	0.15
Det07	0.143
Det08	0.15
Det09	0.15

Summary of Detentions

Table 6.13 Invert level of the ground storage tank – Hdh. Kulhudhuffushi Island

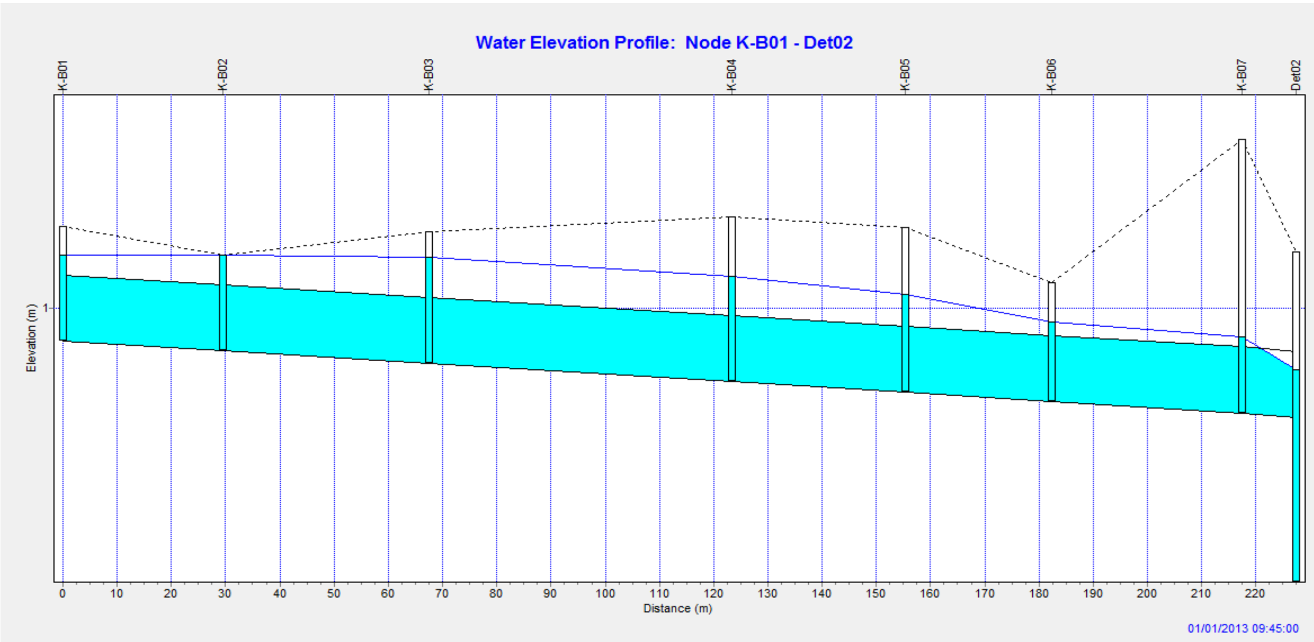


Figure 6.7 Typical section of water elevation profile

6.1 Model Results Analysis

Result Analysis for Zone A

The location of Zone "A" and the catchment delineation is depicted in Figures 6.8 and 6.9 respectively. Simulation result for sub catchments in Zone A is shown in table 6.14.Maximum water surface profile is shown in Figure 6.10.

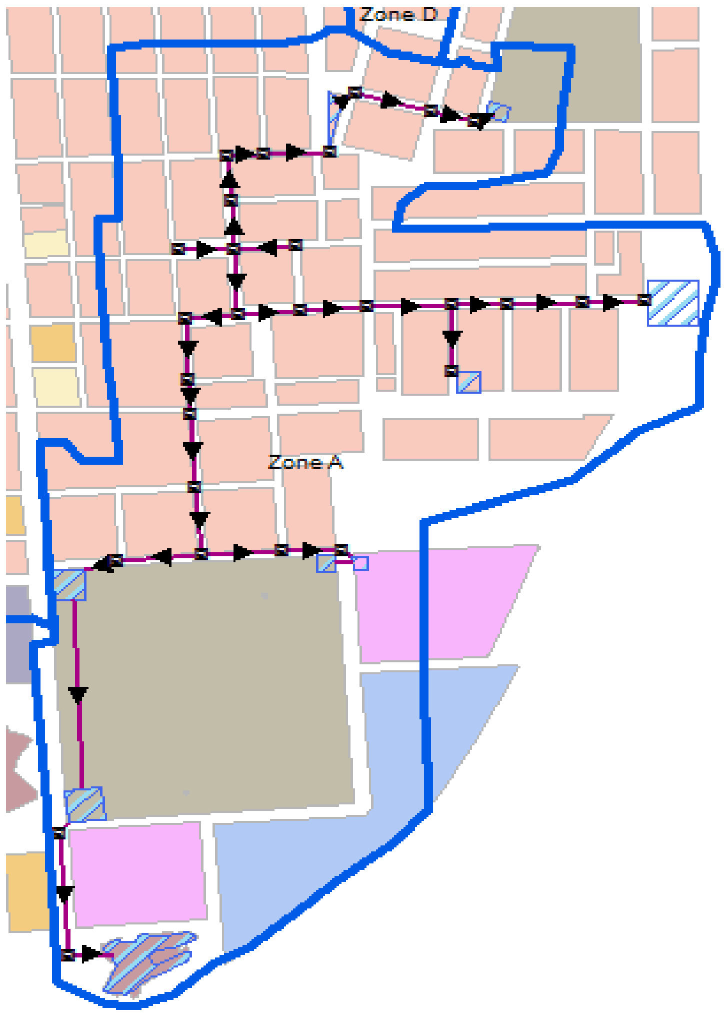


Figure 6.8 -: Location of Zone "A" with in the Hdh. Kulhudhuffushi drainage network

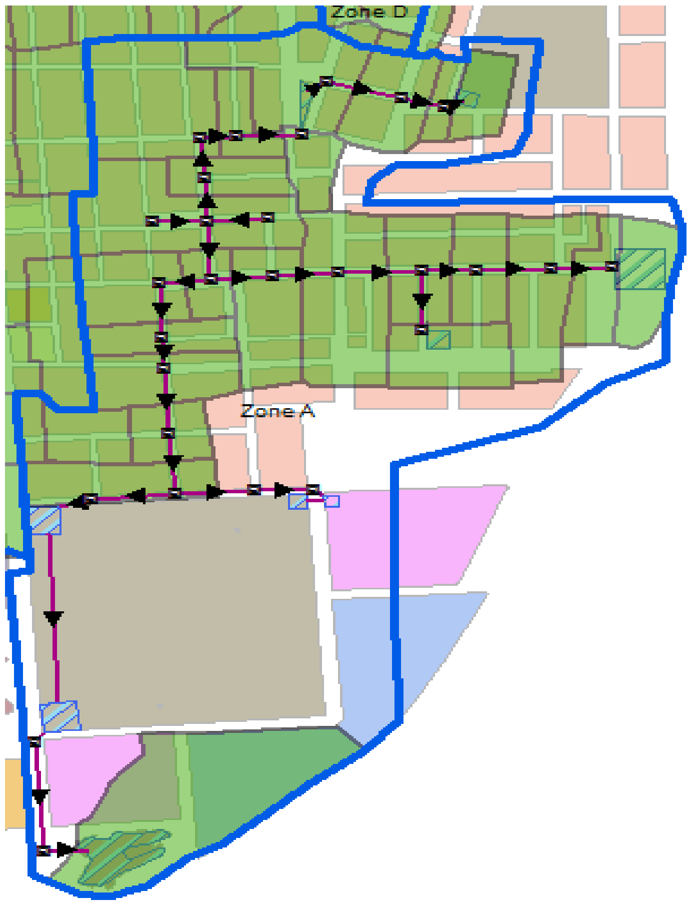


Figure 6.9 -: Sub-catchment delineation in Zone A

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		
Cat_01	0.21	115.32	242.172	82.67	173.607	32.89	69.069	0.01	0.285
Cat_02	0.3	115.32	345.96	78	234	37.6	112.8	0.02	0.326
Cat_03	0.57	115.32	657.324	77.45	441.465	38.02	216.714	0.03	0.33
Cat_04	0.31	115.32	357.492	78.22	242.482	37.36	115.816	0.02	0.324
Cat_06	0.37	115.32	426.684	79.49	294.113	36.06	133.422	0.02	0.313
Cat_07	0.46	115.32	530.472	76.17	350.382	39.34	180.964	0.02	0.341
Cat_08	0.25	115.32	288.3	76.79	191.975	38.85	97.125	0.02	0.337
Cat_09	0.34	115.32	392.088	78.87	268.158	36.69	124.746	0.02	0.318
Cat_10	0.25	115.32	288.3	77.54	193.85	38	95	0.01	0.329
Cat_11	0.28	115.32	322.896	77.53	217.084	38.08	106.624	0.02	0.33
Cat_12	0.55	115.32	634.26	70.43	387.365	45.04	247.72	0.03	0.391
Cat_14	0.1	115.32	115.32	78.44	78.44	37.49	37.49	0.01	0.325
Cat_15	0.25	115.32	288.3	76.79	191.975	38.85	97.125	0.02	0.337
Cat_05	0.32	115.32	369.024	78.44	251.008	37.13	118.816	0.02	0.322
Cat_13	0.25	115.32	288.3	76.79	191.975	38.85	97.125	0.02	0.337
Cat_16	0.54	115.32	622.728	82.38	444.852	33.1	178.74	0.02	0.287
Cat_17	0.43	115.32	495.876	80.6	346.58	34.91	150.113	0.02	0.303
Cat_18	0.13	115.32	149.916	73.19	95.147	42.68	55.484	0.01	0.37
Cat_19	0.27	115.32	311.364	77.29	208.683	38.33	103.491	0.02	0.332
Cat_20	0.45	115.32	518.94	80.95	364.275	34.56	155.52	0.02	0.3

Cat_21	0.24	115.32	276.768	76.53	183.672	39.12	93.888	0.02	0.339
Cat_22	0.4	115.32	461.28	80.06	320.24	35.47	141.88	0.02	0.308
Cat_23	0.28	115.32	322.896	77.53	217.084	38.08	106.624	0.02	0.33
Cat_24	0.28	115.32	322.896	77.53	217.084	38.08	106.624	0.02	0.33
Cat_30	1.66	115.32	1914.31	71.6	1188.56	33.59	557.594	0.05	0.291
Cat_31	0.34	115.32	392.088	82.75	281.35	32.8	111.52	0.02	0.284
Cat_32	0.13	115.32	149.916	76.89	99.957	38.96	50.648	0.01	0.338
Cat_33	0.52	115.32	599.664	77.42	402.584	37.98	197.496	0.02	0.329
Cat_34	0.17	115.32	196.044	81.22	138.074	34.4	58.48	0.01	0.298

Table 6.14 -: Simulation results for sub-catchments in Zone A

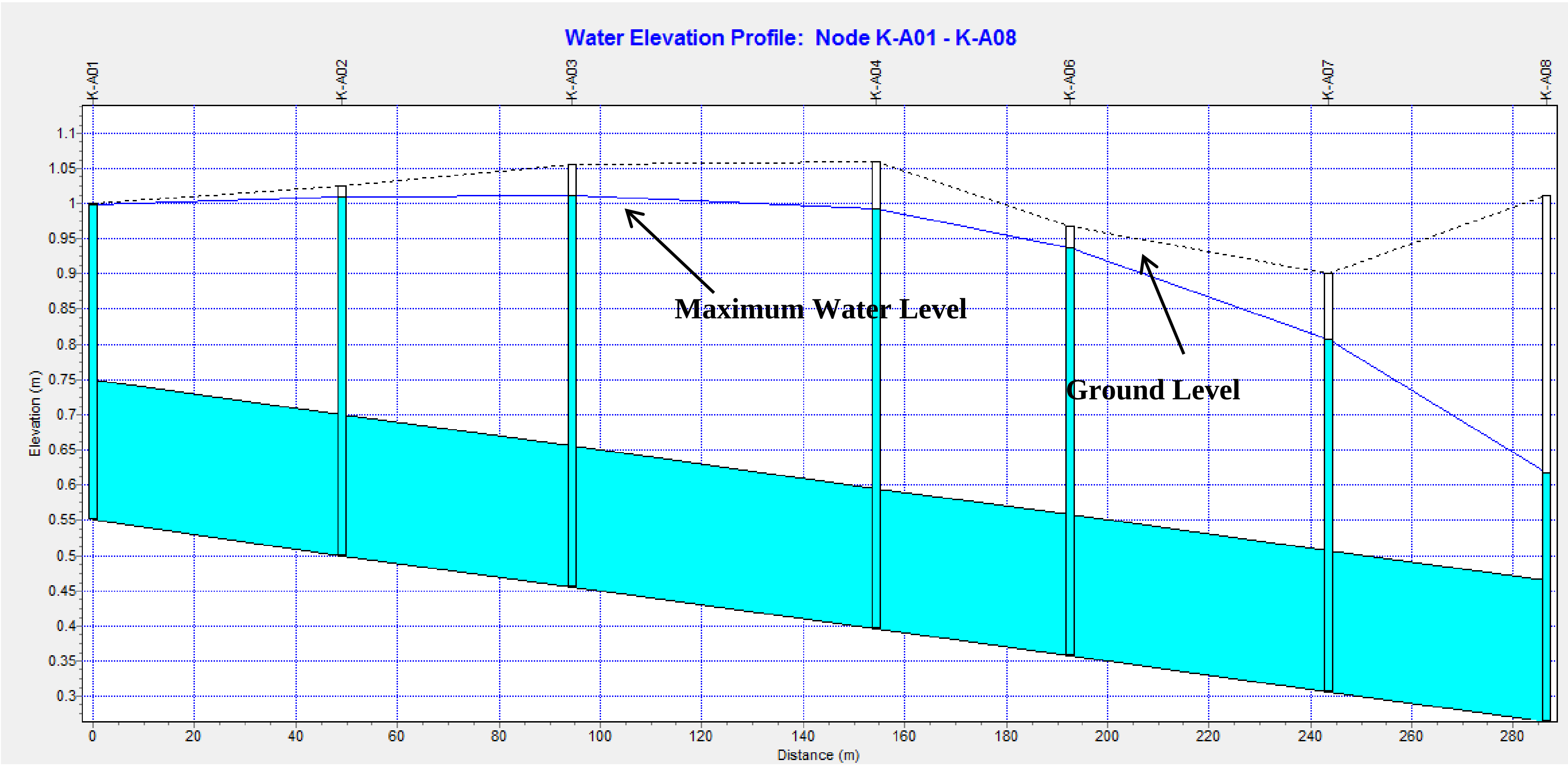


Figure 6.10 -: Maximum Water Level from Node K-A01 to K-A08 of Zone A

Results analysis for Zone "B"

The location and catchment delineation for Zone "B" are depicted in Figure 6.11 and 6.12.Simulation result for sub catchments in Zone B is shown in table 6.15.Maximum water surface profile is shown in Figure 6.13.

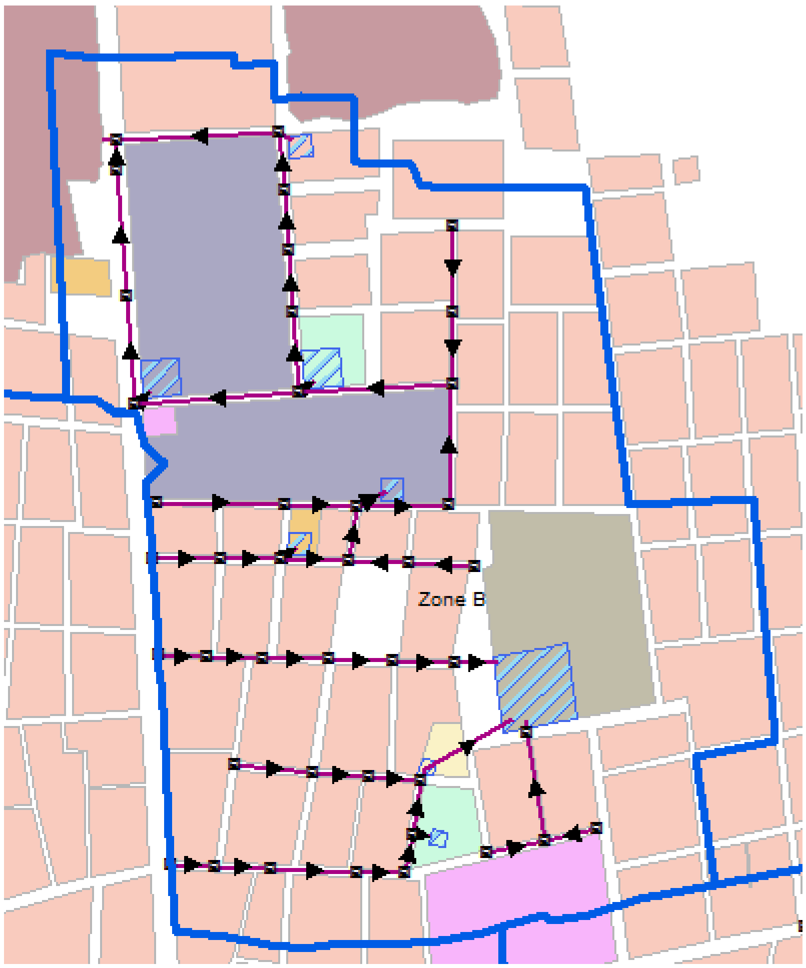


Figure 6.11-: Location of Zone "B" within the Hdh. Kulhudhuffushi drainage network of

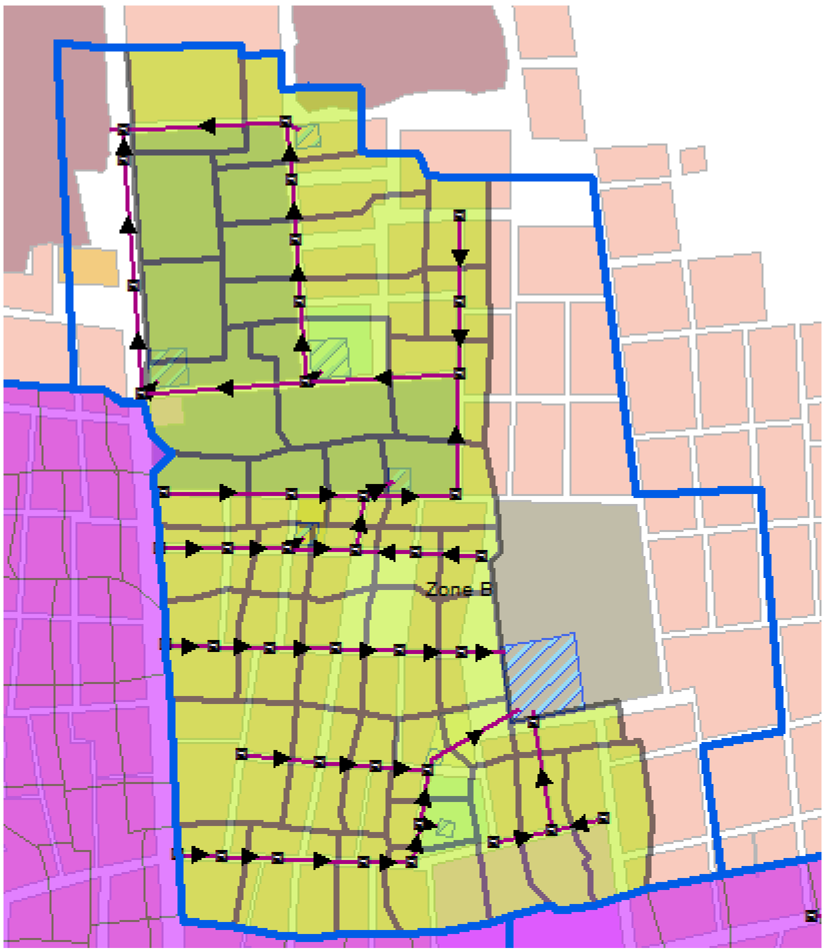


Figure 6.12 -: Sub-catchment delineation in Zone B

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**		
C01	0.28	115.32	322.896	73.88	206.864	41.47	116.116	0.02	0.36
C02	0.45	115.32	518.94	71.96	323.82	43.37	195.165	0.02	0.376
C03	0.23	115.32	265.236	72.44	166.612	42.91	98.693	0.01	0.372
C04	0.36	115.32	415.152	75.86	273.096	39.48	142.128	0.02	0.342
C05	0.18	115.32	207.576	70.82	127.476	44.55	80.19	0.01	0.386
C06	0.31	115.32	357.492	74.66	231.446	40.69	126.139	0.02	0.353
C07	0.36	115.32	415.152	70.01	252.036	45.33	163.188	0.02	0.393
C08	0.49	115.32	565.068	72.74	356.426	42.58	208.642	0.02	0.369
C09	0.63	115.32	726.516	75.18	473.634	40.14	252.882	0.03	0.348
C10	0.32	115.32	369.024	74.91	239.712	40.44	129.408	0.02	0.351
C11	0.22	115.32	253.704	72.14	158.708	43.22	95.084	0.01	0.375
C12	0.24	115.32	276.768	72.74	174.576	42.61	102.264	0.02	0.37
C13	0.18	115.32	207.576	70.82	127.476	44.55	80.19	0.01	0.386
C14	0.33	115.32	380.556	75.15	247.995	40.19	132.627	0.02	0.349
C15	0.29	115.32	334.428	74.14	215.006	41.21	119.509	0.02	0.357
C16	0.32	115.32	369.024	74.91	239.712	40.44	129.408	0.02	0.351
C17	0.41	115.32	472.812	71.13	291.633	44.21	181.261	0.02	0.383
C18	0.3	115.32	345.96	74.4	223.2	40.94	122.82	0.02	0.355
C19	0.27	115.32	311.364	73.6	198.72	41.75	112.725	0.02	0.362
C20	0.17	115.32	196.044	70.46	119.782	44.9	76.33	0.01	0.389
C21	0.2	115.32	230.64	71.49	142.98	43.87	87.74	0.01	0.38
C22	0.17	115.32	196.044	70.46	119.782	44.9	76.33	0.01	0.389
C23	0.16	115.32	184.512	70.1	112.16	45.27	72.432	0.01	0.393

C24	0.45	115.32	518.94	71.96	323.82	43.37	195.165	0.02	0.376
C25	0.22	115.32	253.704	72.14	158.708	43.22	95.084	0.01	0.375
C26	0.25	115.32	288.3	73.04	182.6	42.32	105.8	0.02	0.367
C27	0.3	115.32	345.96	74.4	223.2	40.94	122.82	0.02	0.355
C28	0.24	115.32	276.768	72.74	174.576	42.61	102.264	0.02	0.37
C29	0.2	115.32	230.64	71.49	142.98	43.87	87.74	0.01	0.38
C30	0.43	115.32	495.876	71.55	307.665	43.78	188.254	0.02	0.38
C31	0.64	115.32	738.048	75.34	482.176	39.98	255.872	0.03	0.347
C32	0.41	115.32	472.812	75.57	309.837	39.77	163.057	0.02	0.345
C33	0.59	115.32	680.388	74.53	439.727	40.79	240.661	0.02	0.354
C34	0.48	115.32	553.536	76.97	369.456	38.36	184.128	0.02	0.333
C35	0.45	115.32	518.94	76.39	343.755	38.94	175.23	0.02	0.338
C36	0.58	115.32	668.856	74.36	431.288	40.96	237.568	0.02	0.355
C37	0.35	115.32	403.62	72.6	254.1	42.66	149.31	0.02	0.37
C38	0.38	115.32	438.216	73.14	277.932	42.11	160.018	0.02	0.365
C39	0.53	115.32	611.196	75.29	399.037	39.91	211.523	0.03	0.346

Table6.15 -: Simulation results for sub-catchments in Zone B

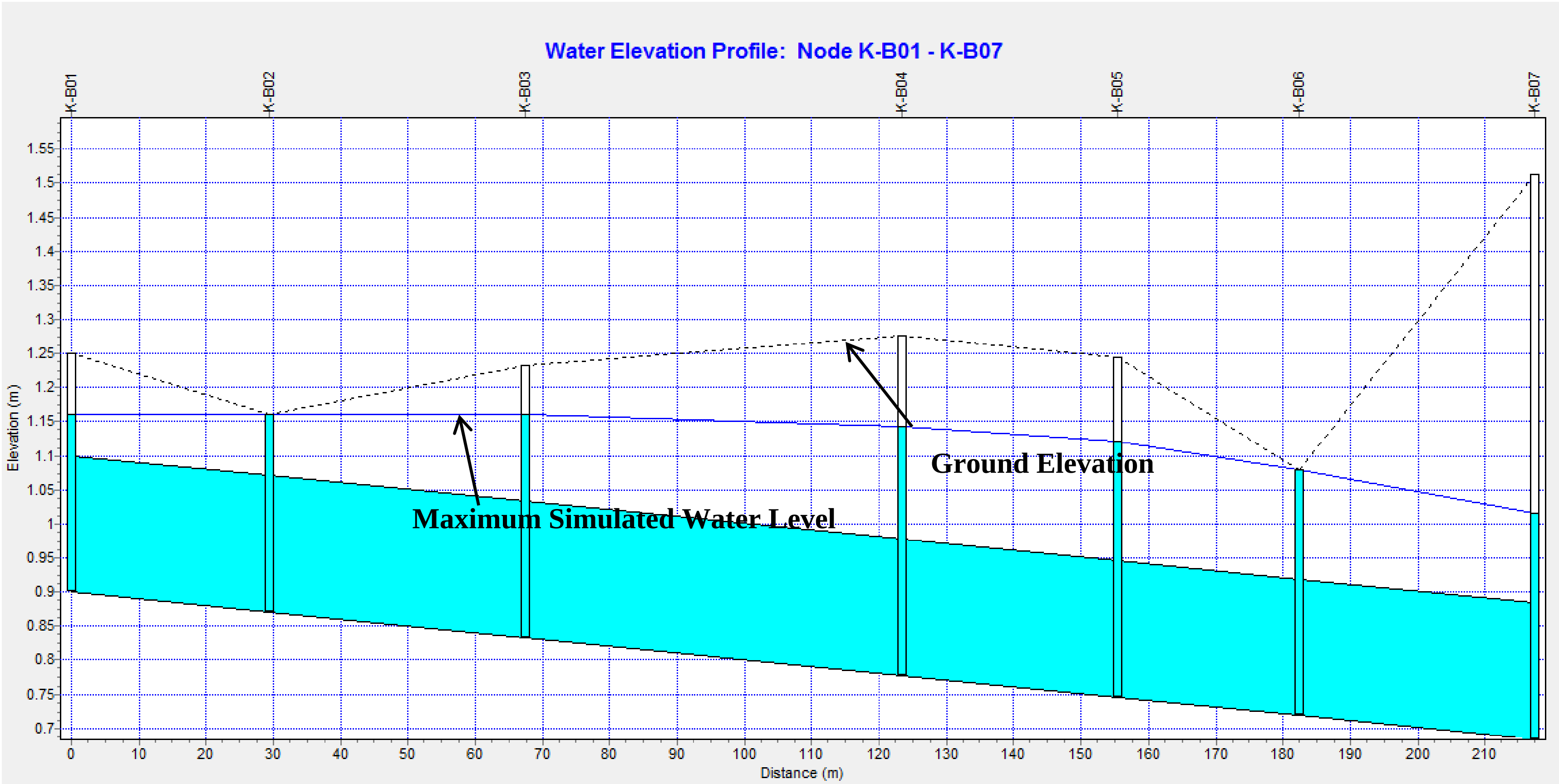


Figure 6.13 -: Maximum Water Level from Node K-B-01 to K-B-07 of Zone B

Result analysis for Zone C

The location and catchment delineation for Zone C are depicted in Figure 6.14 and Figure 6.15.Simulation result for sub catchments in Zone C is shown in table 6.16. Maximum water surface profile is shown in Figure 6.16.

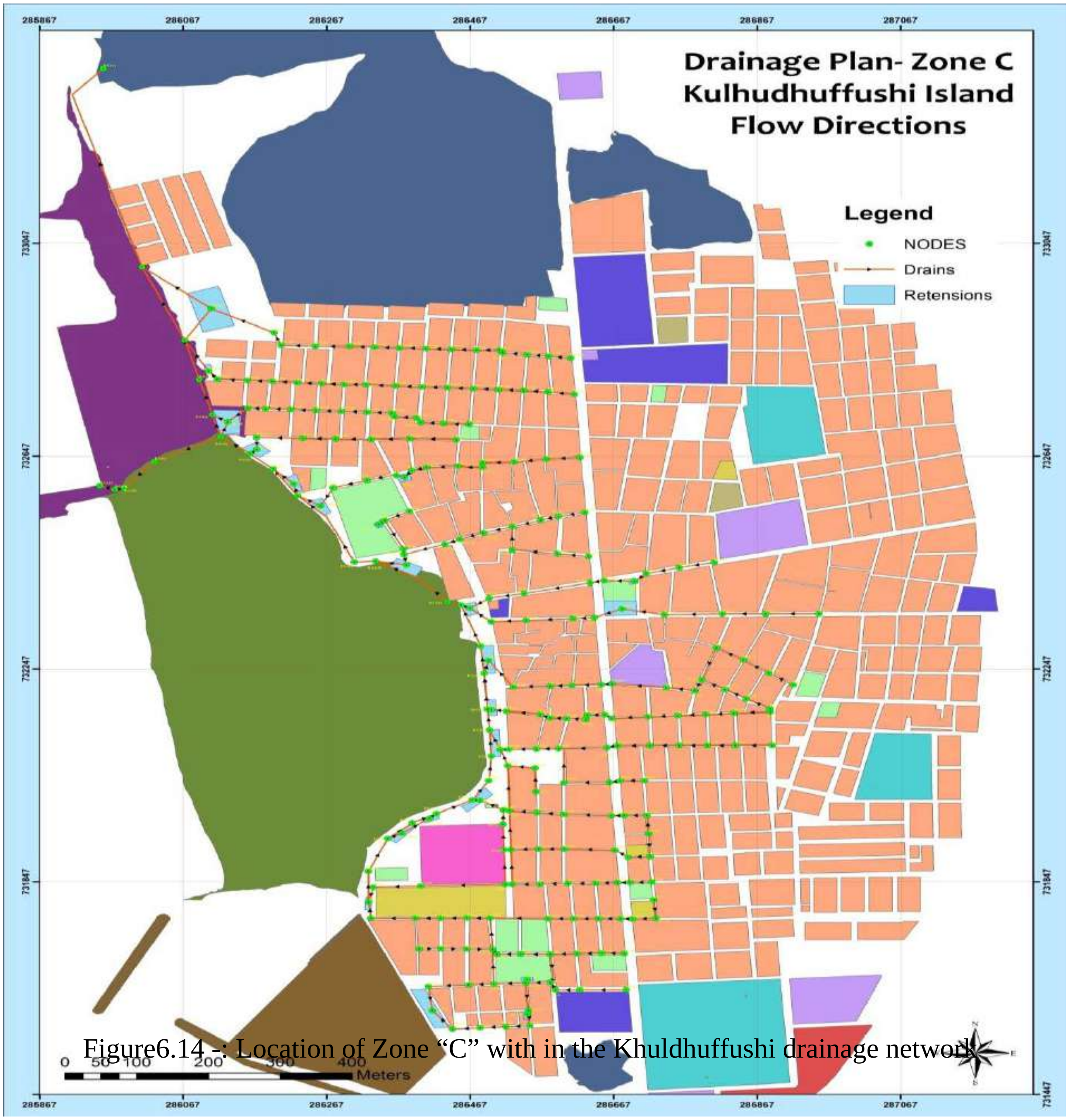


Figure6.14 -: Location of Zone "C" with in the Khuldhuffushi drainage network

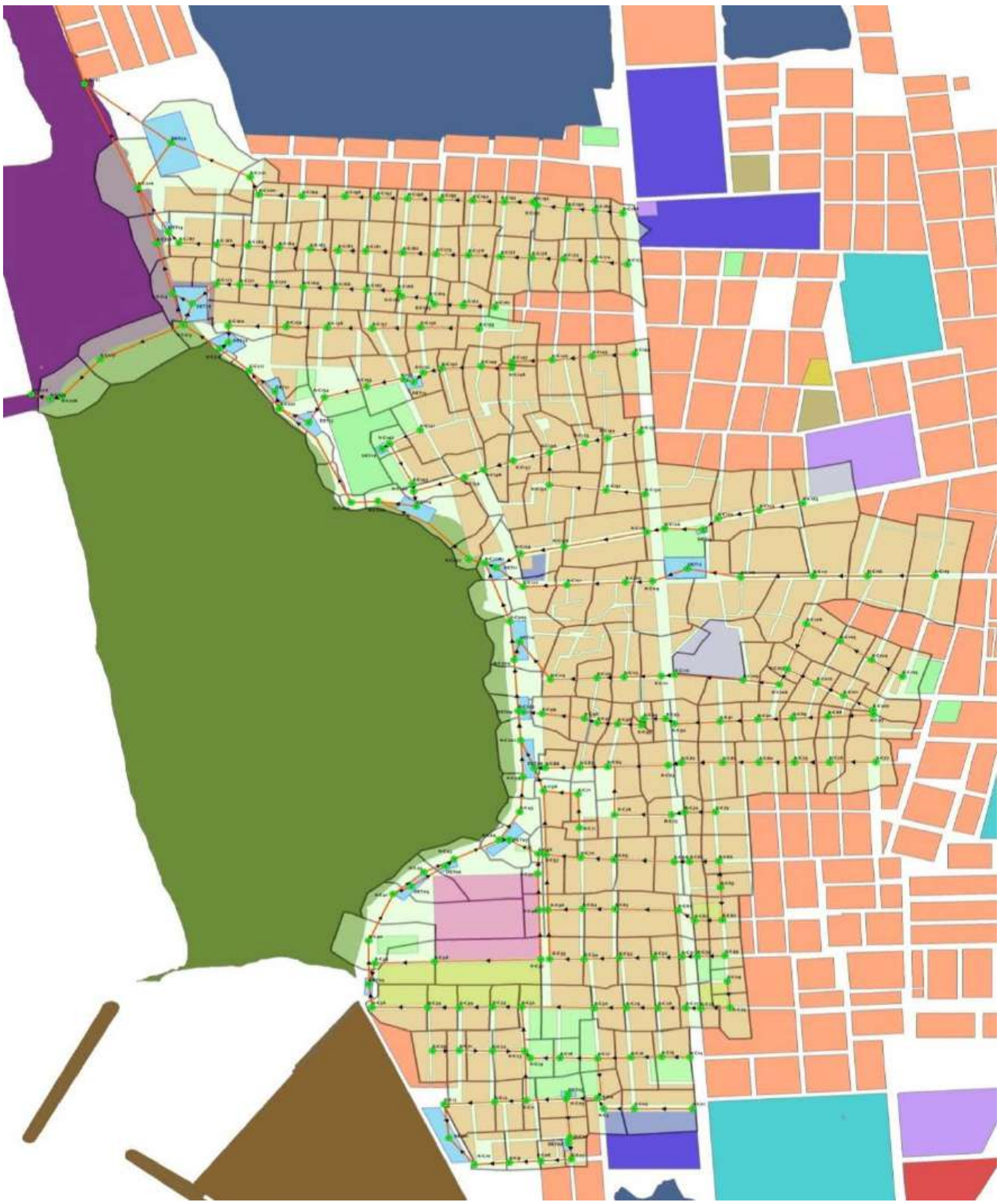


Figure 6.15 -: Sub-catchment delineation in Zone C

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		
SC1	0.47	115.32	538.0	96.79	451.6	18.55	86.5	0.01	0.16
SC2	0.20	115.32	226.2	92.9	182.2	22.46	44.0	0.01	0.20
SC3	0.15	115.32	172.2	91.69	136.9	23.68	35.4	0.01	0.21
SC4	0.29	115.32	335.9	94.71	275.9	20.64	60.1	0.01	0.18
SC5	0.15	115.32	175.9	91.78	140.0	23.58	36.0	0.01	0.21
SC6	0.09	115.32	107.3	89.74	83.5	25.64	23.9	0.01	0.22
SC7	0.11	115.32	123.0	90.28	96.3	25.1	26.8	0.01	0.22
SC8	0.19	115.32	221.6	92.81	178.3	22.55	43.3	0.01	0.20
SC9	0.21	115.32	238.6	93.15	192.8	22.21	46.0	0.01	0.19
SC10	0.11	115.32	126.7	87.5	96.1	27.88	30.6	0.01	0.24
SC11	0.21	115.32	239.2	90.34	187.4	25.02	51.9	0.01	0.22
SC12	0.35	115.32	401.0	92.93	323.2	22.42	78.0	0.01	0.19
SC13	0.31	115.32	362.4	95.05	298.7	20.3	63.8	0.01	0.18
SC14	0.34	115.32	388.7	95.37	321.4	19.98	67.3	0.01	0.17
SC15	0.24	115.32	276.7	93.82	225.1	21.53	51.7	0.01	0.19
SC16	0.14	115.32	162.8	91.45	129.1	23.92	33.8	0.01	0.21
SC17	0.16	115.32	188.0	92.08	150.1	23.29	38.0	0.01	0.20
SC18	0.24	115.32	277.8	93.84	226.0	21.51	51.8	0.01	0.19
SC19	0.15	115.32	169.8	91.63	134.9	23.74	35.0	0.01	0.21
SC20	0.20	115.32	233.8	93.05	188.7	22.3	45.2	0.01	0.19
SC21	0.24	115.32	273.1	93.76	222.1	21.59	51.1	0.01	0.19
SC22	0.13	115.32	147.1	91.02	116.1	24.36	31.1	0.01	0.21
SC23	0.21	115.32	238.0	93.13	192.2	22.22	45.9	0.01	0.19

SC24	0.10	115.32	117.6	90.1	91.9	25.28	25.8	0.01	0.22
SC25	0.13	115.32	153.5	91.19	121.4	24.18	32.2	0.01	0.21
SC26	0.15	115.32	178.2	91.84	141.9	23.53	36.4	0.01	0.20
SC27	0.21	115.32	246.6	93.3	199.5	22.06	47.2	0.01	0.19
SC28	0.20	115.32	232.2	93.02	187.3	22.34	45.0	0.01	0.19
SC29	0.36	115.32	420.7	95.72	349.2	19.62	71.6	0.01	0.17
SC30	0.17	115.32	199.9	92.35	160.1	23.01	39.9	0.01	0.20
SC31	0.19	115.32	218.7	92.75	175.9	22.61	42.9	0.01	0.20
SC32	0.21	115.32	247.6	93.31	200.3	22.04	47.3	0.01	0.19
SC33	0.21	115.32	236.7	93.11	191.1	22.25	45.7	0.01	0.19
SC34	0.34	115.32	392.3	95.41	324.5	19.94	67.8	0.01	0.17
SC35	0.71	115.32	823.4	98.48	703.2	16.85	120.3	0.02	0.15
SC36	0.32	115.32	370.5	95.15	305.7	20.19	64.9	0.01	0.18
SC37	0.50	115.32	579.4	97.1	487.9	18.24	91.6	0.01	0.16
SC38	0.83	115.32	956.5	99.01	821.2	16.32	135.4	0.02	0.14
SC39	0.30	115.32	351.2	94.91	289.1	20.44	62.3	0.01	0.18
SC40	0.57	115.32	654.5	97.6	553.9	17.74	100.7	0.02	0.15
SC41	0.22	115.32	259.4	93.53	210.4	21.83	49.1	0.01	0.19
SC42	0.27	115.32	309.0	94.33	252.7	21.02	56.3	0.01	0.18
SC43	0.13	115.32	149.9	91.1	118.4	24.28	31.6	0.01	0.21
SC44	0.19	115.32	219.1	92.76	176.2	22.6	42.9	0.01	0.20
SC45	0.06	115.32	69.2	88.2	52.9	27.2	16.3	0.00	0.24
SC46	0.15	115.32	167.5	91.57	133.0	23.8	34.6	0.01	0.21
SC47	0.08	115.32	97.1	89.37	75.2	26.05	21.9	0.00	0.23
SC48	0.12	115.32	139.9	90.81	110.2	24.57	29.8	0.01	0.21
SC49	0.20	115.32	233.5	93.05	188.4	22.31	45.2	0.01	0.19
SC50	0.24	115.32	278.2	93.85	226.4	21.51	51.9	0.01	0.19

SC51	0.25	115.32	284.2	93.94	231.5	21.41	52.8	0.01	0.19
SC52	0.31	115.32	355.1	94.96	292.4	20.39	62.8	0.01	0.18
SC53	0.25	115.32	293.5	94.09	239.4	21.26	54.1	0.01	0.18
SC54	0.15	115.32	177.1	91.81	141.0	23.55	36.2	0.01	0.20
SC55	0.11	115.32	124.4	90.32	97.4	25.05	27.0	0.01	0.22
SC56	0.11	115.32	128.3	90.45	100.6	24.93	27.7	0.01	0.22
SC57	0.19	115.32	222.3	92.82	178.9	22.53	43.4	0.01	0.20
SC58	0.10	115.32	112.9	89.94	88.1	25.44	24.9	0.01	0.22
SC59	0.10	115.32	120.2	90.19	94.0	25.19	26.3	0.01	0.22
SC60	0.38	115.32	437.3	95.89	363.6	19.45	73.7	0.01	0.17
SC61	0.22	115.32	254.7	93.44	206.4	21.91	48.4	0.01	0.19
SC62	0.16	115.32	180.0	91.88	143.4	23.48	36.7	0.01	0.20
SC63	0.28	115.32	320.5	94.49	262.6	20.86	58.0	0.01	0.18
SC64	0.19	115.32	221.1	92.8	177.9	22.56	43.3	0.01	0.20
SC65	0.23	115.32	270.1	93.71	219.5	21.64	50.7	0.01	0.19
SC66	0.30	115.32	351.1	94.91	288.9	20.44	62.2	0.01	0.18
SC67	0.38	115.32	435.3	95.87	361.9	19.47	73.5	0.01	0.17
SC68	0.25	115.32	285.2	93.96	232.4	21.39	52.9	0.01	0.19
SC69	0.10	115.32	110.7	89.86	86.2	25.52	24.5	0.01	0.22
SC70	0.21	115.32	239.2	93.16	193.3	22.2	46.1	0.01	0.19
SC71	0.29	115.32	336.2	94.71	276.1	20.64	60.2	0.01	0.18
SC72	0.09	115.32	102.6	89.57	79.7	25.81	23.0	0.01	0.22
SC73	0.15	115.32	167.7	91.57	133.1	23.79	34.6	0.01	0.21
SC74	0.41	115.32	470.7	96.21	392.7	19.13	78.1	0.01	0.17
SC75	0.20	115.32	225.2	92.88	181.4	22.47	43.9	0.01	0.20
SC76	0.24	115.32	278.3	93.85	226.5	21.51	51.9	0.01	0.19
SC77	0.39	115.32	448.2	96	373.1	19.34	75.2	0.01	0.17

SC78	0.31	115.32	357.6	94.99	294.6	20.36	63.1	0.01	0.18
SC79	0.20	115.32	235.5	93.09	190.1	22.27	45.5	0.01	0.19
SC80	0.29	115.32	336.3	94.71	276.2	20.64	60.2	0.01	0.18
SC81	0.36	115.32	416.2	95.67	345.3	19.67	71.0	0.01	0.17
SC82	0.11	115.32	130.9	90.53	102.8	24.84	28.2	0.01	0.22
SC83	0.15	115.32	176.8	91.81	140.8	23.56	36.1	0.01	0.20
SC84	0.20	115.32	236.1	93.1	190.6	22.26	45.6	0.01	0.19
SC85	0.14	115.32	164.1	91.48	130.2	23.89	34.0	0.01	0.21
SC86	0.20	115.32	225.5	92.89	181.7	22.47	43.9	0.01	0.20
SC87	0.23	115.32	264.4	93.61	214.7	21.74	49.9	0.01	0.19
SC88	0.25	115.32	283.0	93.92	230.5	21.43	52.6	0.01	0.19
SC89	0.16	115.32	189.0	92.1	151.0	23.26	38.1	0.01	0.20
SC90	0.11	115.32	128.4	90.45	100.7	24.92	27.7	0.01	0.22
SC91	0.06	115.32	71.6	88.31	54.8	27.09	16.8	0.00	0.24
SC92	0.06	115.32	68.0	88.14	52.0	27.26	16.1	0.00	0.24
SC93	0.16	115.32	179.7	91.88	143.2	23.49	36.6	0.01	0.20
SC94	0.12	115.32	139.0	90.78	109.5	24.59	29.6	0.01	0.21
SC95	0.12	115.32	140.3	90.82	110.5	24.56	29.9	0.01	0.21
SC96	0.19	115.32	220.0	92.78	177.0	22.58	43.1	0.01	0.20
SC97	0.20	115.32	228.3	92.95	184.0	22.41	44.4	0.01	0.19
SC98	0.15	115.32	168.8	91.61	134.1	23.76	34.8	0.01	0.21
SC99	0.20	115.32	226.6	92.91	182.5	22.45	44.1	0.01	0.20
SC100	0.27	115.32	306.7	94.29	250.7	21.06	56.0	0.01	0.18
SC101	0.21	115.32	237.0	93.12	191.4	22.24	45.7	0.01	0.19
SC102	0.21	115.32	243.7	93.24	197.0	22.11	46.7	0.01	0.19
SC103	0.33	115.32	377.4	95.23	311.7	20.11	65.8	0.01	0.17
SC104	0.16	115.32	186.7	92.05	149.1	23.32	37.8	0.01	0.20

SC105	0.14	115.32	158.2	91.32	125.3	24.04	33.0	0.01	0.21
SC106	0.34	115.32	389.4	95.37	322.1	19.97	67.4	0.01	0.17
SC107	0.62	115.32	715.2	97.94	607.4	17.39	107.9	0.02	0.15
SC108	0.35	115.32	404.9	95.55	335.5	19.79	69.5	0.01	0.17
SC109	0.20	115.32	230.9	93	186.2	22.36	44.8	0.01	0.19
SC110	0.46	115.32	533.4	96.75	447.5	18.59	86.0	0.01	0.16
SC111	0.81	115.32	930.8	98.92	798.4	16.41	132.4	0.02	0.14
SC112	0.76	115.32	876.6	98.7	750.3	16.62	126.3	0.02	0.14
SC113	0.89	115.32	1031.0	99.26	887.5	16.06	143.6	0.02	0.14
SC114	0.64	115.32	740.8	98.08	630.1	17.25	110.8	0.02	0.15
SC115	0.54	115.32	618.4	97.37	522.1	17.97	96.4	0.02	0.16
SC116	0.37	115.32	423.9	95.75	352.0	19.59	72.0	0.01	0.17
SC117	0.32	115.32	370.1	95.15	305.4	20.2	64.8	0.01	0.18
SC118	0.22	115.32	257.4	93.49	208.7	21.86	48.8	0.01	0.19
SC119	0.49	115.32	565.3	97	475.5	18.34	89.9	0.01	0.16
SC120	0.38	115.32	443.8	95.96	369.3	19.39	74.6	0.01	0.17
SC121	0.39	115.32	447.0	95.99	372.1	19.35	75.0	0.01	0.17
SC122	0.50	115.32	577.2	97.08	485.9	18.25	91.3	0.01	0.16
SC123	0.62	115.32	710.4	97.92	603.2	17.41	107.2	0.02	0.15
SC124	0.34	115.32	390.8	95.39	323.3	19.95	67.6	0.01	0.17
SC125	0.46	115.32	529.8	96.72	444.4	18.62	85.6	0.01	0.16
SC126	0.29	115.32	338.0	94.73	277.6	20.61	60.4	0.01	0.18
SC127	0.51	115.32	590.2	97.17	497.3	18.16	92.9	0.01	0.16
SC128	0.14	115.32	156.5	91.28	123.9	24.09	32.7	0.01	0.21
SC129	0.34	115.32	397.6	95.47	329.1	19.88	68.5	0.01	0.17
SC130	0.17	115.32	200.7	92.36	160.7	23	40.0	0.01	0.20
SC131	0.33	115.32	377.3	95.23	311.6	20.11	65.8	0.01	0.17

SC132	0.21	115.32	247.4	93.31	200.2	22.05	47.3	0.01	0.19
SC133	0.39	115.32	453.6	96.05	377.8	19.29	75.9	0.01	0.17
SC134	0.16	115.32	188.9	92.1	150.9	23.27	38.1	0.01	0.20
SC135	0.59	115.32	683.2	97.77	579.3	17.57	104.1	0.02	0.15
SC136	0.13	115.32	152.9	91.18	120.9	24.19	32.1	0.01	0.21
SC137	0.25	115.32	291.6	94.06	237.9	21.29	53.8	0.01	0.19
SC138	0.24	115.32	281.3	93.9	229.1	21.46	52.4	0.01	0.19
SC139	0.28	115.32	322.8	94.53	264.6	20.82	58.3	0.01	0.18
SC140	0.33	115.32	381.2	95.28	315.0	20.07	66.4	0.01	0.17
SC141	0.10	115.32	118.8	90.14	92.9	25.24	26.0	0.01	0.22
SC142	0.33	115.32	377.3	95.23	311.5	20.11	65.8	0.01	0.17
SC143	0.47	115.32	542.9	96.83	455.8	18.51	87.1	0.01	0.16
SC144	0.21	115.32	244.8	93.26	197.9	22.09	46.9	0.01	0.19
SC145	0.21	115.32	240.2	93.18	194.1	22.18	46.2	0.01	0.19
SC146	0.39	115.32	450.2	96.02	374.8	19.32	75.4	0.01	0.17
SC147	0.40	115.32	455.7	96.07	379.7	19.27	76.2	0.01	0.17
SC148	0.19	115.32	224.6	92.87	180.8	22.49	43.8	0.01	0.20
SC149	0.33	115.32	380.7	95.27	314.5	20.07	66.3	0.01	0.17
SC150	0.26	115.32	302.6	94.23	247.3	21.12	55.4	0.01	0.18
SC151	0.26	115.32	297.3	94.15	242.7	21.2	54.6	0.01	0.18
SC152	0.41	115.32	475.2	96.26	396.7	19.09	78.7	0.01	0.17
SC153	0.14	115.32	156.9	91.29	124.2	24.08	32.8	0.01	0.21
SC154	0.32	115.32	369.0	95.13	304.4	20.21	64.7	0.01	0.18
SC155	0.09	115.32	101.4	89.53	78.7	25.86	22.7	0.01	0.22
SC156	0.19	115.32	220.2	92.78	177.1	22.58	43.1	0.01	0.20
SC157	0.10	115.32	119.4	90.16	93.3	25.22	26.1	0.01	0.22
SC158	0.17	115.32	199.4	92.34	159.7	23.03	39.8	0.01	0.20

SC159	0.17	115.32	193.8	92.21	154.9	23.15	38.9	0.01	0.20
SC160	0.18	115.32	207.2	92.51	166.2	22.85	41.1	0.01	0.20
SC161	0.18	115.32	203.6	92.43	163.2	22.93	40.5	0.01	0.20
SC162	0.17	115.32	197.6	92.3	158.1	23.07	39.5	0.01	0.20
SC163	0.15	115.32	174.2	91.74	138.6	23.63	35.7	0.01	0.21
SC164	0.24	115.32	277.9	93.84	226.2	21.51	51.8	0.01	0.19
SC165	0.20	115.32	230.8	92.99	186.1	22.36	44.7	0.01	0.19
SC166	0.26	115.32	299.5	94.18	244.6	21.17	55.0	0.01	0.18
SC167	0.23	115.32	264.3	93.61	214.6	21.74	49.8	0.01	0.19
SC168	0.21	115.32	240.9	93.19	194.7	22.17	46.3	0.01	0.19
SC169	0.32	115.32	364.2	95.07	300.2	20.27	64.0	0.01	0.18
SC170	0.30	115.32	348.8	94.88	287.0	20.47	61.9	0.01	0.18
SC171	0.24	115.32	277.2	93.83	225.6	21.52	51.7	0.01	0.19
SC172	0.29	115.32	328.8	94.61	269.7	20.74	59.1	0.01	0.18
SC173	0.26	115.32	299.8	94.19	244.9	21.16	55.0	0.01	0.18
SC174	0.20	115.32	234.6	93.07	189.4	22.29	45.4	0.01	0.19
SC175	0.25	115.32	289.4	94.03	236.0	21.33	53.5	0.01	0.19
SC176	0.18	115.32	208.7	92.54	167.5	22.82	41.3	0.01	0.20
SC177	0.22	115.32	249.9	93.36	202.3	22	47.7	0.01	0.19
SC178	0.22	115.32	258.9	93.52	210.0	21.84	49.0	0.01	0.19
SC179	0.29	115.32	333.2	94.67	273.5	20.68	59.7	0.01	0.18
SC180	0.15	115.32	172.5	91.7	137.1	23.67	35.4	0.01	0.21
SC181	0.10	115.32	111.4	89.89	86.8	25.49	24.6	0.01	0.22
SC182	0.19	115.32	214.6	92.67	172.4	22.69	42.2	0.01	0.20
SC183	0.20	115.32	231.9	93.02	187.1	22.34	44.9	0.01	0.19
SC184	0.25	115.32	293.8	94.09	239.7	21.26	54.2	0.01	0.18
SC185	0.16	115.32	179.7	91.88	143.1	23.49	36.6	0.01	0.20

SC186	0.18	115.32	206.1	92.48	165.3	22.88	40.9	0.01	0.20
SC187	0.17	115.32	199.6	92.34	159.8	23.02	39.8	0.01	0.20
SC188	0.13	115.32	145.0	90.95	114.3	24.42	30.7	0.01	0.21
SC189	0.21	115.32	239.4	93.16	193.4	22.2	46.1	0.01	0.19
SC190	0.22	115.32	252.5	93.4	204.5	21.95	48.1	0.01	0.19
SC191	0.20	115.32	233.2	93.04	188.2	22.32	45.1	0.01	0.19
SC192	0.16	115.32	189.4	92.11	151.3	23.26	38.2	0.01	0.20
SC193	0.41	115.32	472.8	96.23	394.5	19.11	78.4	0.01	0.17
SC194	0.13	115.32	144.2	90.93	113.7	24.44	30.6	0.01	0.21
SC195	0.23	115.32	265.2	93.63	215.3	21.73	50.0	0.01	0.19
SC196	0.52	115.32	599.7	97.24	505.6	18.1	94.1	0.02	0.16
SC197	0.20	115.32	230.6	92.99	186.0	22.37	44.7	0.01	0.19
SC198	0.42	115.32	487.8	96.37	407.6	18.97	80.2	0.01	0.17
SC199	0.56	115.32	645.8	97.54	546.2	17.79	99.6	0.02	0.15
SC200	0.10	115.32	115.3	90.02	90.0	25.36	25.4	0.01	0.22
SC201	0.39	115.32	445.1	95.97	370.4	19.37	74.8	0.01	0.17
SC202	0.50	115.32	580.1	97.1	488.4	18.23	91.7	0.01	0.16
SC203	0.14	115.32	156.8	91.29	124.2	24.08	32.7	0.01	0.21
SC204	0.27	115.32	316.0	94.43	258.7	20.92	57.3	0.01	0.18
SC205	0.26	115.32	296.4	94.14	241.9	21.22	54.5	0.01	0.18
SC206	0.93	115.32	1072.5	99.39	924.3	15.93	148.1	0.02	0.14
SC207	0.70	115.32	807.2	98.4	688.8	16.93	118.5	0.02	0.15
SC208	0.42	115.32	484.3	96.34	404.6	19	79.8	0.01	0.17

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

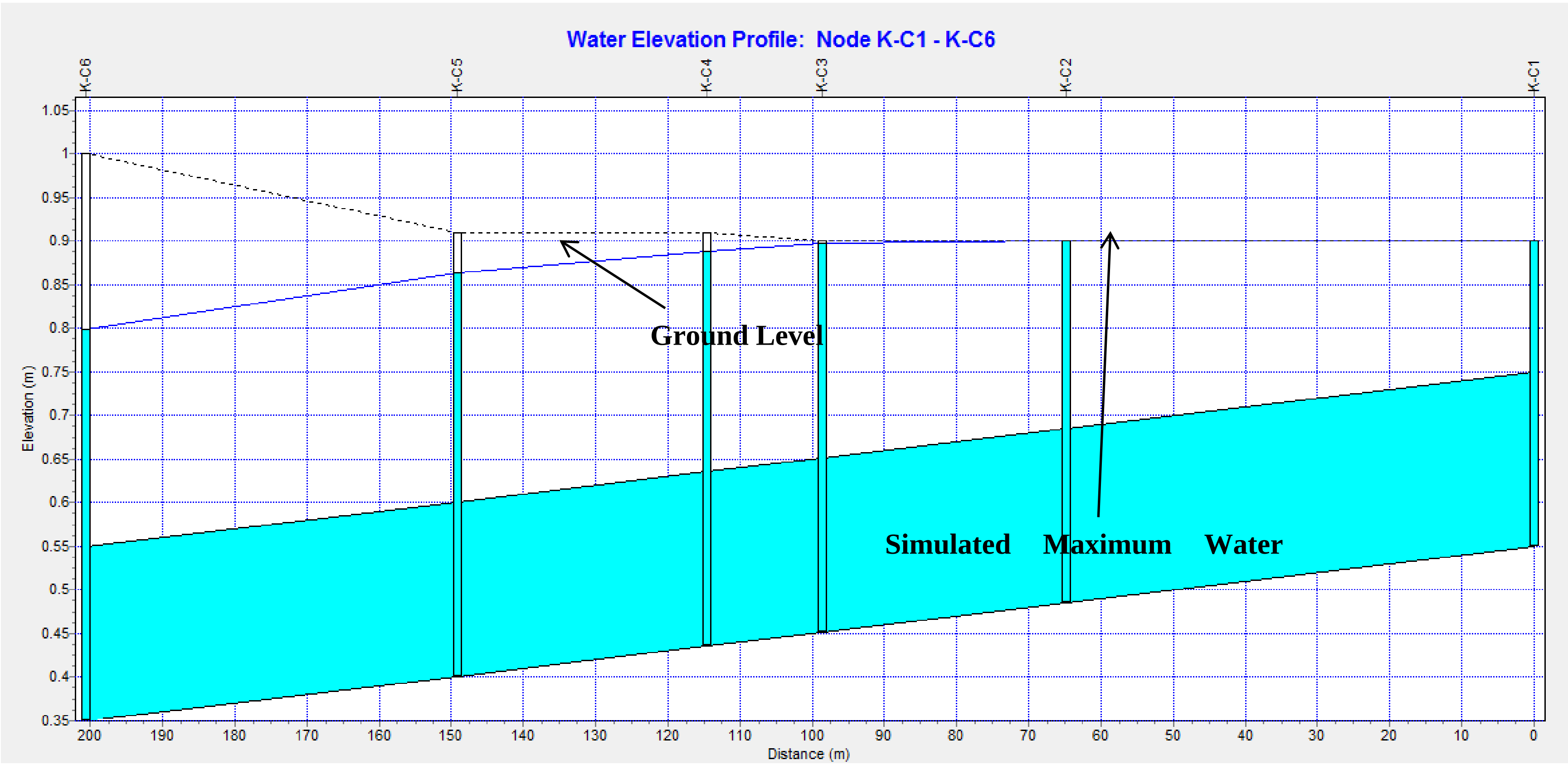


Figure6.16 -: Maximum Water Level from Node K-C1 to K-C6 of Zone C

Result analysis for Zone D

The location and Catchment delineation for Zone "D" are depicted in Figure 6.17 and 6.18.

Simulation results for sub Catchment in shown in table 6.17 and maximum water surface profile shown in Figure 6.19.

Figure6.17:- Location of Zone "D" with in the Hdh. Kulhudhuffushi drainage network

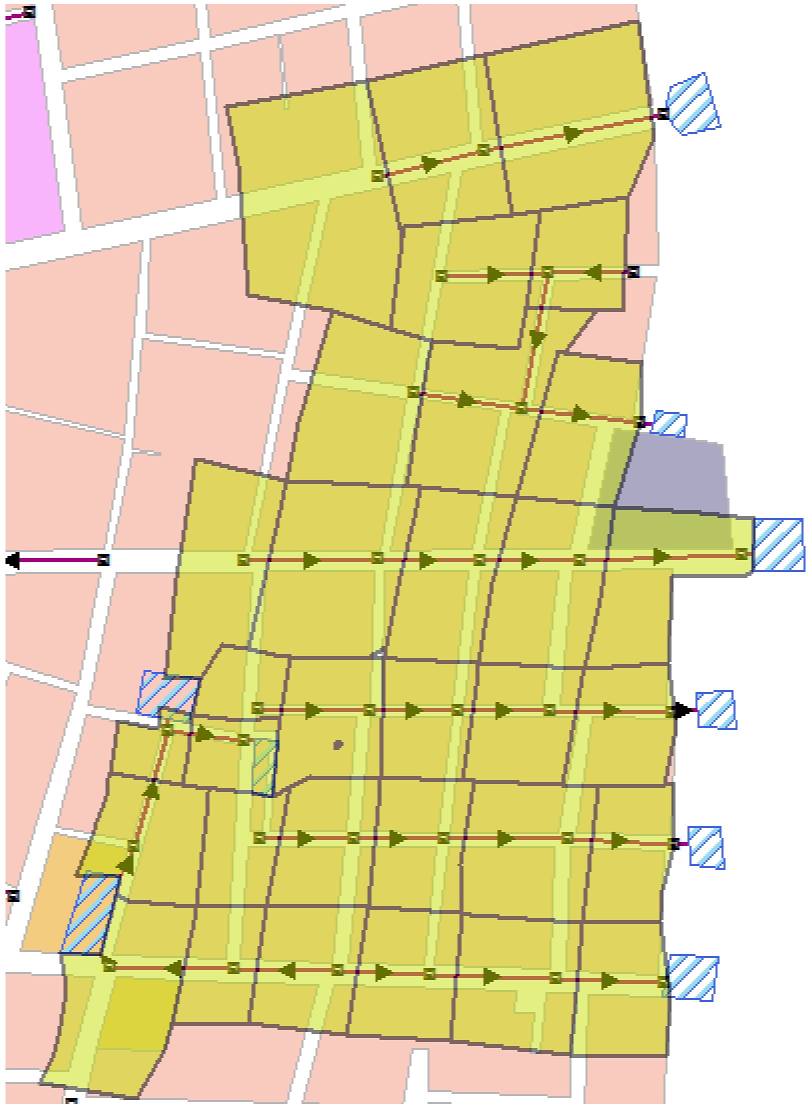


Figure 6.18:- Sub-catchment delineation in Zone D

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**		
SC1	0.31	115.32	356.96	89.9	278.27	25.79	79.83	0.01	0.22
SC2	0.13	115.32	153.94	86.4	115.34	29.62	39.54	0.01	0.26
SC3	0.19	115.32	223.38	87.81	170.09	28.02	54.28	0.01	0.24
SC4	0.20	115.32	230.47	87.94	175.75	27.88	55.72	0.01	0.24
SC5	0.25	115.32	285.10	88.86	219.68	26.89	66.48	0.01	0.23
SC6	0.19	115.32	218.62	87.72	166.30	28.12	53.31	0.01	0.24
SC7	0.14	115.32	156.67	86.46	117.46	29.55	40.15	0.01	0.26
SC8	0.19	115.32	223.83	87.82	170.45	28.01	54.37	0.01	0.24
SC9	0.19	115.32	216.17	87.68	164.35	28.17	52.80	0.01	0.24
SC10	0.27	115.32	307.55	89.2	237.89	26.52	70.73	0.01	0.23
SC11	0.17	115.32	193.24	87.23	146.17	28.67	48.04	0.01	0.25
SC12	0.20	115.32	233.35	88	178.07	27.83	56.31	0.01	0.24
SC13	0.07	115.32	80.57	84.51	59.05	32.03	22.38	0.01	0.28
SC14	0.10	115.32	118.06	85.54	87.57	30.66	31.39	0.01	0.27
SC15	0.09	115.32	102.22	85.11	75.44	31.19	27.65	0.01	0.27
SC16	0.20	115.32	226.20	87.87	172.36	27.97	54.86	0.01	0.24
SC17	0.16	115.32	189.76	87.18	143.45	28.74	47.29	0.01	0.25
SC18	0.19	115.32	219.93	87.75	167.35	28.09	53.57	0.01	0.24
SC19	0.19	115.32	214.78	87.65	163.25	28.2	52.52	0.01	0.25
SC20	0.27	115.32	309.47	89.23	239.46	26.49	71.09	0.01	0.23
SC21	0.37	115.32	423.00	90.71	332.73	24.93	91.44	0.01	0.22
SC22	0.25	115.32	294.03	89	226.93	26.74	68.18	0.01	0.23
SC23	0.28	115.32	319.82	89.38	247.88	26.33	73.02	0.01	0.23
SC24	0.25	115.32	289.77	88.93	223.46	26.81	67.37	0.01	0.23
SC25	0.29	115.32	329.50	89.52	255.78	26.18	74.80	0.01	0.23

SC26	0.32	115.32	366.08	90.01	285.74	25.66	81.46	0.01	0.22
SC27	0.22	115.32	259.25	88.45	198.84	27.34	61.46	0.01	0.24
SC28	0.25	115.32	293.10	88.98	226.15	26.75	67.99	0.01	0.23
SC29	0.15	115.32	176.10	86.89	132.69	29.07	44.39	0.01	0.25
SC31	0.51	115.32	590.63	92.37	473.09	23.2	118.82	0.02	0.20
SC32	0.29	115.32	331.09	89.54	257.07	26.16	75.11	0.01	0.23
SC33	0.39	115.32	454.74	91.07	359.11	24.56	96.85	0.01	0.21

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

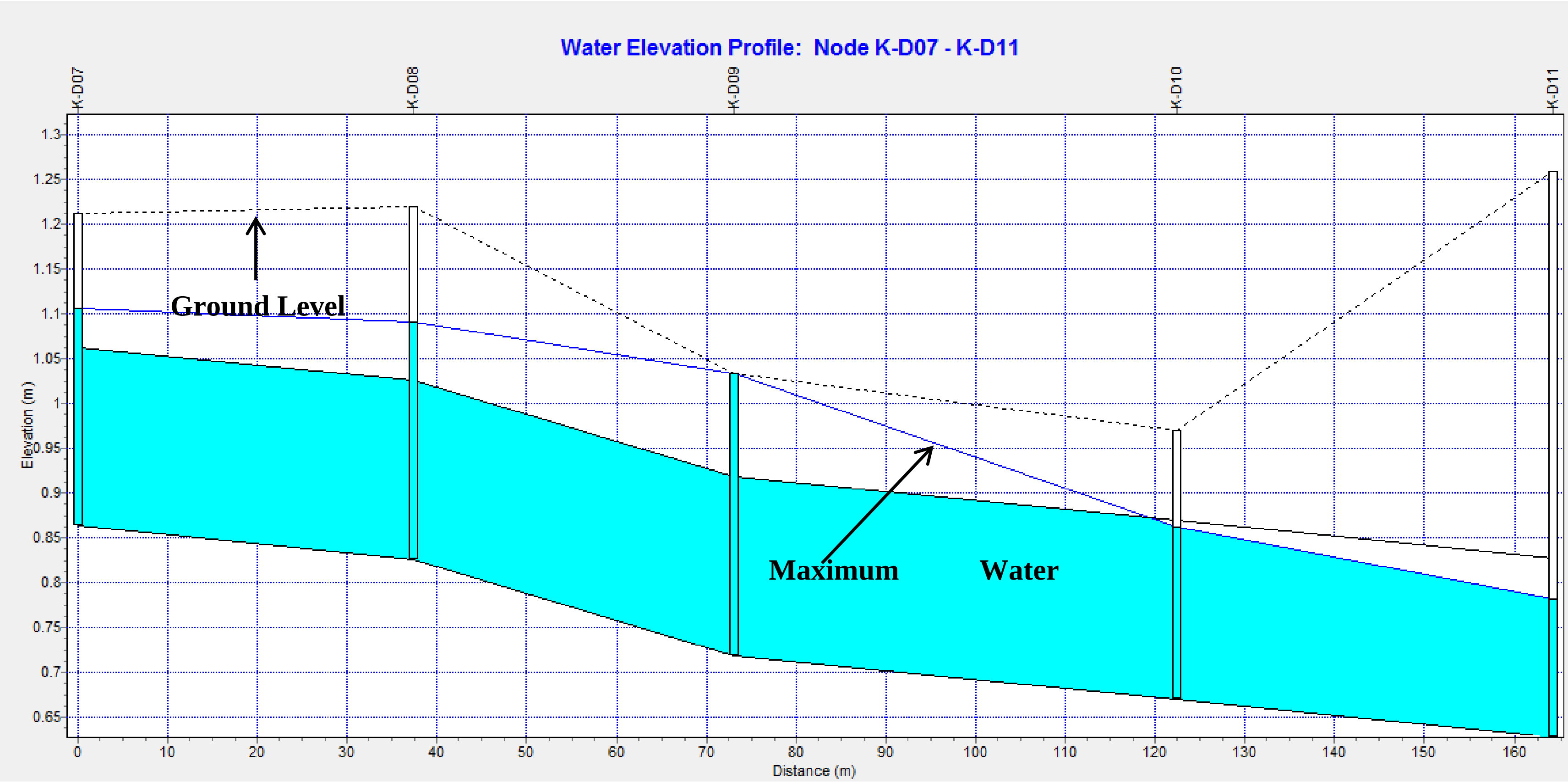


Figure 6.19:- Water Elevation Profile

Overall Evaluation of the model results for Hdh. Kulhudhuffushi 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 Hdh. Kulhudhuffushi Island is shown in Table 6.18.

An interpretation in terms of a schematic diagram for the combined model results for the drainage proposal for Hdh. Kulhudhuffushi Island is given in Figure 6.20.

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	10.65	115.32	12281.6	77.14	8215.4	36.8	3919.20	0	3919.2
Zone B	13.37	115.32	15418.3	73.6	9840.3	41.7	5575.29	0	5575.29
Zone C	55.30	115.32	63773.4	94.9	52480.8	20.5	11336.75	553	10783.75
Zone D	7.27	115.32	8387.4	88.92	6467.3	26.9	1956.47	0	1956.47

Table 6.18:-Summary of the Zonal model results for Hdh. Kulhudhuffushi Island

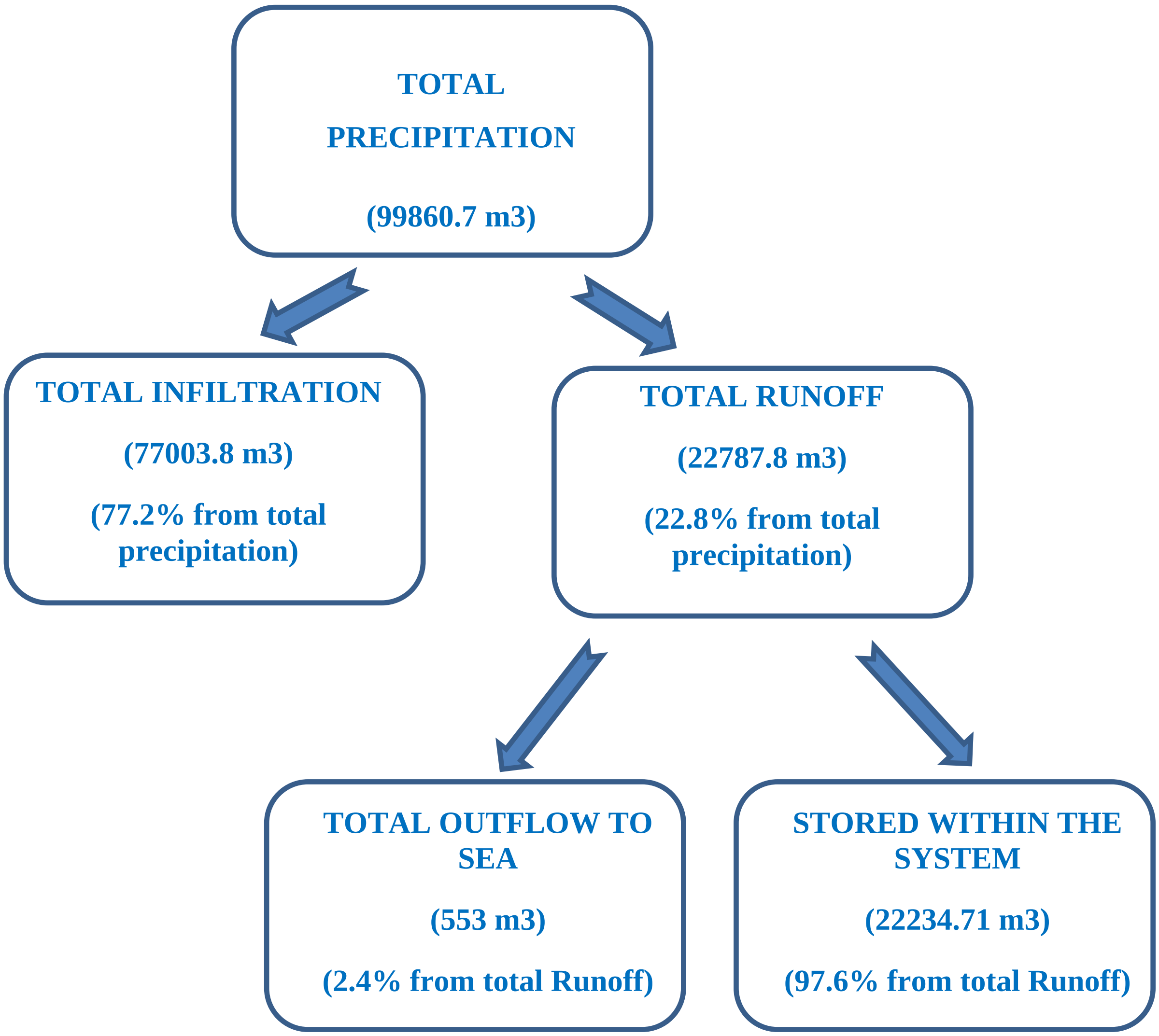


Figure 6.20:- Interpretation of the combined model results for the Hdh. Kulhudhuffushi Island

Conclusively about 97% of runoff volume is stored within the system for the benefit of the people while addressing the flood issue

7 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 mosque, 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.

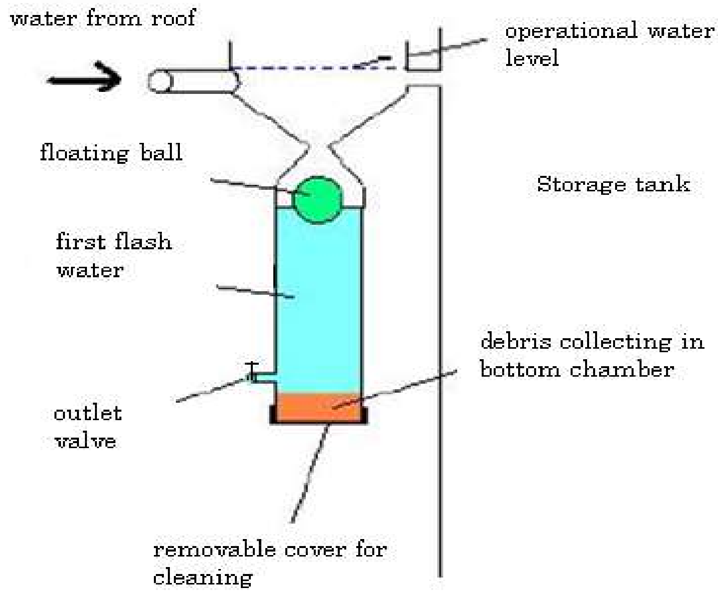
Proposed method to be adopted in getting the system cleaned to prevent contamination of water

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 $50m^2$ 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 does 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 $50m^2$ 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) = 30m

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 annul 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

Rules and regulations on Storm Water Management

Water is a scares 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 program.

- 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.
- It should also be mandatory for private buildings with more than 100sq.m floor area. Necessary provision can be made in national building code.
- 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 rain water at schools.
- School education and public education/awareness need to be intensified.
- Ground water recharge through rain water harvesting and rain water use for agricultural uses should be encouraged.
- Government should accord priority to this program and provide incentives to the community for popularizing the system.
- Rain water harvesting cell/unit need to be created within the ministry of water to coordinate and monitor the program and provide technical guidance to community.
- 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 Liters 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.

<u>Calculation</u>

Volume to be retained in housing units = 10.53% of total rain

= 0.1053 x 0.099 x 0.46 x10000

= 48 m3

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

Volume to be retained in one housing unit = 6 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. 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 µPVC 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 controlled within the individual premise. But exact percentage has to be decided by the Local Authority depend on the above factors.

With all these development activities, the Island of Hdh. Kulhudhuffushi would provide a springboard for a lot of potential projects. Therefore the Ministry of Environments and Energy can confidently provide a facelift to the Hdh. Kulhudhuffushi 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 O&M 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.

8 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 including peripheral drain and there design levels is shown in Figure 8.1 and Figure 8.2.

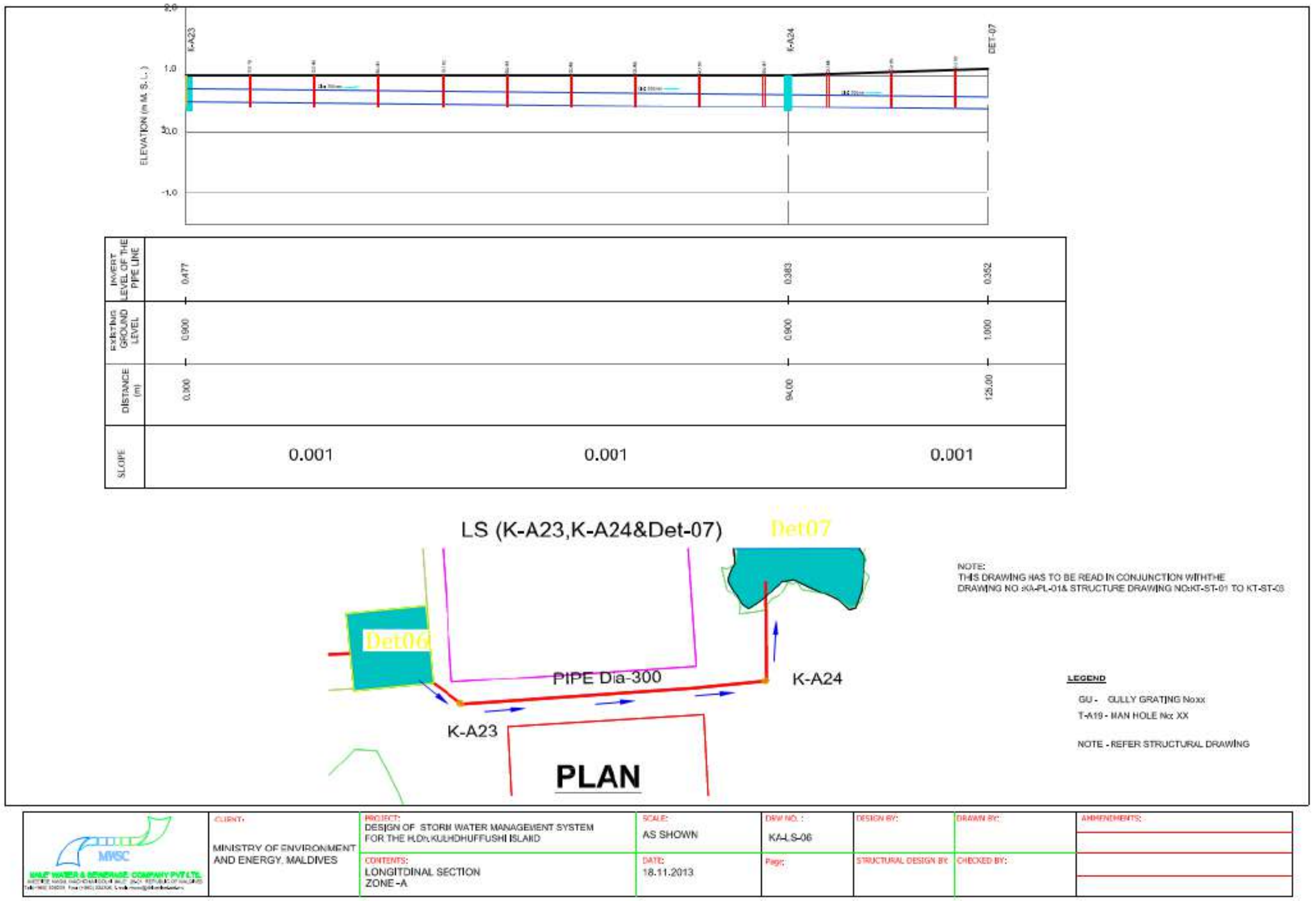


Figure 8.1 Sample drawings

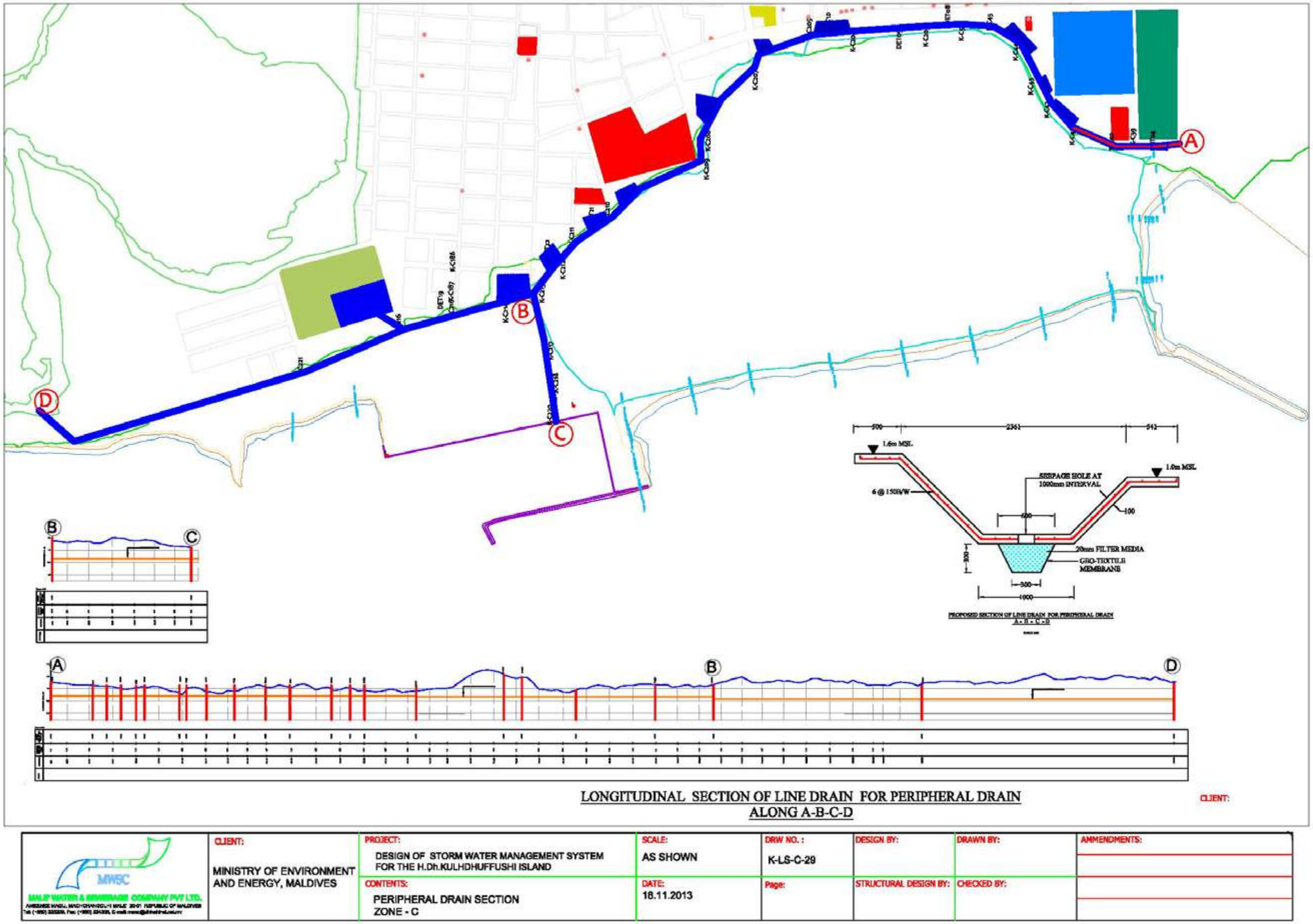


Figure 8.2 Sample drawings

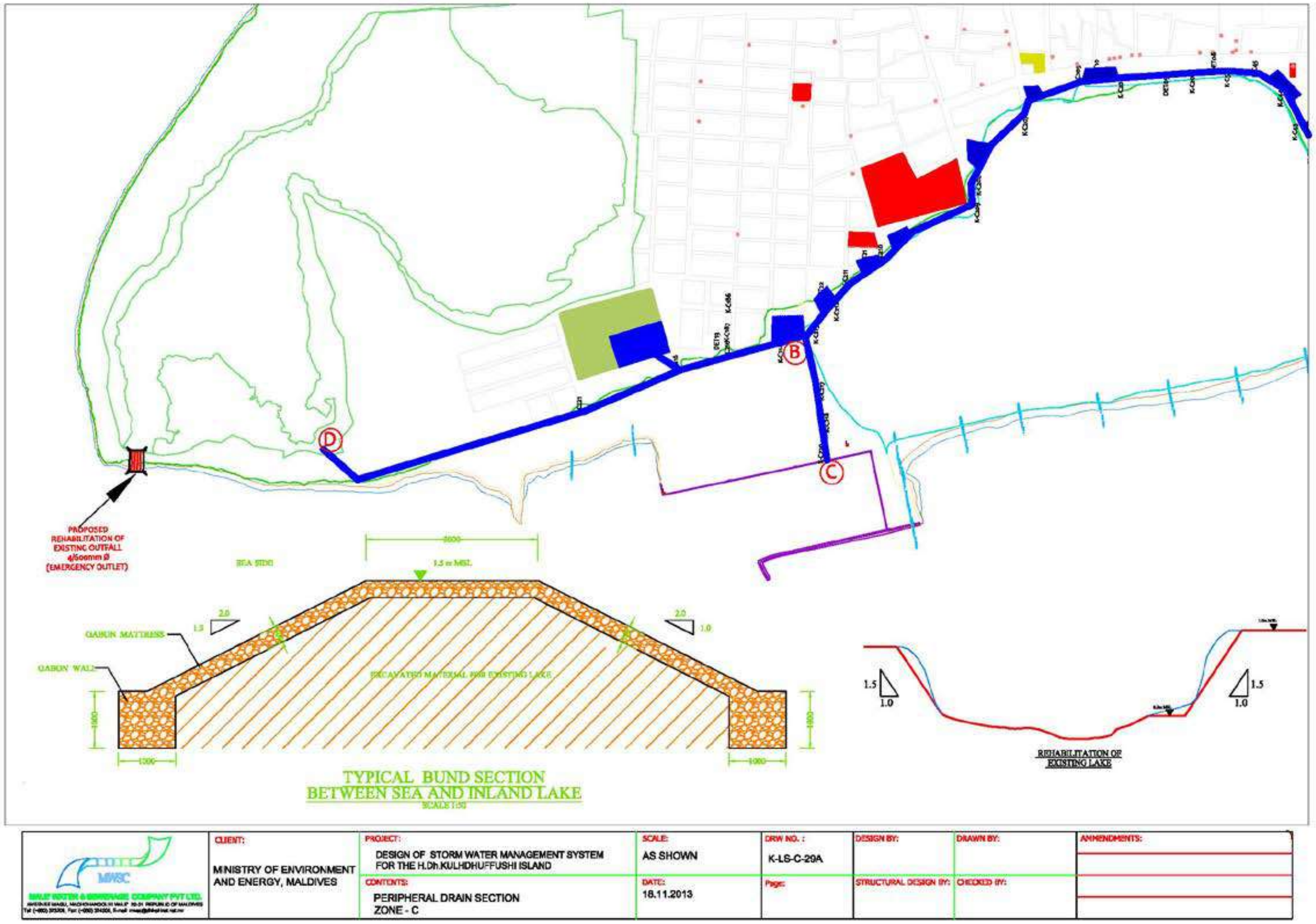


Figure 8.3 Sample drawings

9 Rehabilitation of ponds

There are three existing ponds having lager water spread areas and these are significant in detaining storm water during rainy period. These ponds have to be cleaned to enhance the capacity and can be maintained for the domestic, aesthetic and environmental purposes and existing pipe outlet from main asphalt road can be connected to these ponds. See photos page No135 and 137.

10 Flap Gate

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

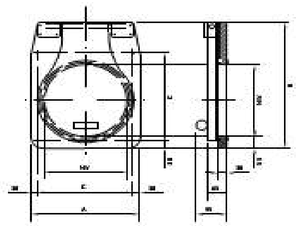
Figure 9.1 Proposed Flap Gate

10.1.1 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

11 Environmental Impacts

Existing Environment

There is a need for enhancement of the environment within the island of 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

a) Reduce rainwater flooding / inundation.
b) Improved aesthetic environment.
c) Reduce traffic delays.
d) Reduce inconvenience to people.
e) Improved rainfall recharging system.
f) Reduce saltwater intrusion into the Island.
g) Enhancing the capacity of the existing ponds will lead to an ecological balance within the Island.

Mitigation 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 mitigation 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.

12 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 jetters 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.

- Carrying out regular Preventive Maintenance.
- 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:-

- Immediate repair of any deterioration threatening structural integrity.
- Catch basins should be cleaned as frequently as possible.
- Stenciling of catch basins and inlets Handling and Disposal.
- 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.

Open Channel

- Consider modification of storm channel characteristics to improve channel hydraulics, to increase conveyance, and to enhance channel/creek aesthetic and habitat value in ponds.
- Conduct channel modification/improvement in accordance with existing laws.

Maintenance of Storm water Storage tank

General Information

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 or after 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 to 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 into the storm water system.
   b. Flush the system to remove any sediment or construction debris immediately.

Inspections

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

1. Frequency
   - 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 build up.
   - Adjacent Area: soil runoff, gravel, trash removal.
   - Second year plus; establish an annual inspection frequency based on the information collected during the first year. At a minimum an inspection should be performed semi-annually.
   - Seasonal change; regional areas affected by seasonal change may require additional inspections at the change of seasons in addition to semi-annually.

2. Inspect:
   - Inspection points.
   - Inflow and outflow points including the inlet/manhole and pipes.
   - Discharge area.

3. Identify and Report maintenance required:
   - Sediment accumulation.
   - System backing up.
   - Flow rate change.

Maintenance Procedures

- Conform to all local, Environmental regulations.
- Determine if maintenance is required. If a pre-treatment device is installed, follow manufacturer recommendations.
- Use a vacuum pump truck to evacuate debris from the inflow and outflow points.
- Flush the system with clean water forcing debris from the system. Take care to avoid extreme direct water pressure when flushing the system.
- 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 impurities. 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 feasible machine recommended for the maintenance

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 Options

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)	3/8	5/8	1/4

		Jet Hose			
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

13 Cost Estimate (Blank BOQ of full Island using, Under Ground Tank)

STORM WATER MANAGEMENT SYSTEM FOR KULDHUFUSSI ISLAND, MALDIVES BILL OF QUANTITIES					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES				
	GRAND SUMMARY				
A	General Items				
B	Zone A works				
C	Zone B works				
D	Zone C works				
E	Zone D works				
	GRAND TOTAL			USD	
	TAXES				

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES GENERAL ITEMS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	GENERAL ITEMS				
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	Item	1.0		
R	Environment Impact Assessment report	Item	1.0		
	Total general items carried to summary			USD	

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE A WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES - **SUMMARY - ZONE A WORKS**				
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	

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE A WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	EARTHWORKS				
	Earth filling				
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	2,568.0		
	Road reinstatement				
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 H DH. KULHUDHUFFUSHI ISLAND, MALDIVES **BILL OF QUANTITIES** **ZONE A WORKS**					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	PIPEWORK - PIPES Pipes 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.				
A	nominal diameter 200 mm	m	2,774.0		
	Total pipe works - pipes carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE A WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	PIPEWORK - MANHOLES AND PIPEWORK ANCILLARIES Manholes PE inspection manholes, including excavation, concrete bedding, jointing, dewatering, earthworks support , back filling , paving and concrete curb; all in accordance with drawings and specifications.				
A	600 mm diameter	nr	26.0		
	Gutter inlet 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.				
B	400 x 400 mm	nr	278.0		
	Grade 25 concrete pipe encasing including formwork, concrete and reinforcement; all in accordance with drawings and specifications.				
C	200 mm diameter pipes	m	2,774.0		
	Valves HDPE flap valve including jointing; all in accordance with drawings and specifications.	nr			
E	200 mm diameter		1.0		
F	Rehabilitation of existing silt trap; all in accordance with drawings and specifications.	nr	1.0		
	Construction of outfall ; all in accordance with drawings and specifications				
A	Outfall	nr	1.0		
	Silt trap				
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 H DH. KULHUDHUFFUSHI ISLAND, MALDIVES
BILL OF QUANTITIES
ZONE A WORKS

Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	STORAGE TANK				
	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)				
A	Storage area A-1 (Volume 200 m3)	Item			
B	Storage area A-2 (Volume 850 m3)	Item			
C	Storage area A-3 (Volume 225 m3)	Item			
D	Storage area A-4 (Volume 900 m3)	Item			
E	Storage area A-5 (Volume 625 m3)	Item			
F	Storage area A-6 (Volume 625 m3)	Item			
	Total storage tank carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE B WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI 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	

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE B WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (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	2,300.0		
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	2,816.0		
	<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 H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE B WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	PIPEWORK - MANHOLES AND PIPEWORK ANCILLARIES				
	Manholes PE inspection manholes, including excavation, concrete bedding, jointing, dewatering, earthworks support , back filling , paving and concrete curb; all in accordance with drawings and specifications.				
A	600 mm diameter	nr	43.0		
	Gutter inlet 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.				
B	400 x 400 mm	nr	325.0		
	Grade 25 concrete pipe encasing including formwork, concrete and reinforcement; all in accordance with drawings and specifications.				
C	200 mm diameter pipes	m	2,769.0		
	Valves HDPE flap valve including jointing; all in accordance with drawings and specifications.				
D	200 mm diameter	nr	1.0		
E	Construction of outfall ; all in accordance with drawings and specifications	nr	1.0		
D	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 H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE B WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	STORAGE TANK				
	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)				
A	Storage area B-1 (Volume 100 m3)	Item			
B	Storage area B-2 (Volume 100 m3)	Item			
C	Storage area B-3 (Volume 1900 m3)	Item			
D	Storage area B-4 (Volume 225 m3)	Item			
E	Storage area B-5 (Volume 350 m3)	Item			
F	Storage area B-6 (Volume 500 m3)	Item			
G	Storage area B-7 (Volume 400 m3)	Item			
H	Storage area B-8 (Volume 180 m3)	Item			
	Total storage tank carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE C WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES				
	SUMMARY - ZONE C WORKS				
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	

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE C WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (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	3,500.0		
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	3,818.0		
	<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	13,430.0		
	Total pipe works - pipes carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE C WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	PIPEWORK - MANHOLES AND PIPEWORK ANCILLARIES				
	Manholes				
	PE inspection manholes, including excavation, concrete bedding, jointing, dewatering, earthworks support , back filling , paving and concrete curb; all in accordance with drawings and specifications.				
A	600 mm diameter	nr	245.0		
	Gutter inlet				
	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.				
B	400 x 400 mm	nr	1,343.0		
	Grade 25 concrete pipe encasing including formwork, concrete and reinforcement; all in accordance with drawings and specifications.				
C	200 mm diameter pipes	m	6,107.0		
	Valves				
	HDPE flap valve including jointing; all in accordance with drawings and specifications.				
D	200 mm diameter	nr	1.0		
E	Construction of outfall ; all in accordance with drawings and specifications	nr	1.0		
F	Silt trap: including excavation, backfilling, concrete, formwork, reinforcements covering and gratings; all in accordance with drawings and specifications.	nr	1.0		
	Peripheral drain				
A	Peripheral drain including excavation, backfilling, concrete, formwork, reinforcement, filter media, geotextile and seepage holes; all in accordance with drawings and specifications.	m	1,400.0		
	Total pipe works - manholes and pipe work ancillaries carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE C WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	STORAGE TANK 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)				
A	Storage area DET-1 (Volume 1050 m3)	Item		≈	
B	Storage area DET-2 (Volume 70 m3)	Item			
C	Storage area DET-3 (Volume 88 m3)	Item			
D	Storage area DET-4 (Volume 630 m3)	Item			
E	Storage area DET-5 (Volume 210 m3)	Item			
F	Storage area DET-6 (Volume 210 m3)	Item			
G	Storage area DET-7 (Volume 210 m3)	Item			
H	Storage area DET-8 (Volume 700 m3)	Item			
J	Storage area DET-9 (Volume 210 m3)	Item			
K	Storage area DET-10 (Volume 350 m3)	Item			
L	Storage area DET-11 (Volume 280 m3)	Item			
M	Storage area DET-12 (Volume 70 m3)	Item			
N	Storage area DET-13 (Volume 210 m3)	Item			
P	Storage area DET-14 (Volume 420 m3)	Item			
Q	Storage area DET-15 (Volume 140 m3)	Item			
R	Storage area DET-16 (Volume 70 m3)	Item			
S	Storage area DET-17 (Volume 630 m3)	Item			
A	Storage area DET-18 (Volume 630 m3)	Item			
B	Storage area DET-19 (Volume 420 m3)	Item			
C	Storage area DET-20 (Volume 1750 m3)	Item			
D	Storage area DET-21 (Volume 280 m3)	Item			
E	Storage area DET-22 (Volume 280 m3)	Item			
	Total storage tank carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE D WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	<u>STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI 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 H DH. KULHUDHUFFUSHI ISLAND, MALDIVES
BILL OF QUANTITIES
ZONE D WORKS

Item No	Item Description	Unit	Qty	Rate (USD)	Amount (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	2,000.0		
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	1,103.0		
	<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 H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE D WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	PIPEWORK - PIPES Pipes 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.				
A	nominal diameter 200 mm	m	1,440.0		
	Total pipe works - pipes carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI ISLAND, MALDIVES BILL OF QUANTITIES ZONE D WORKS					
Item No	Item Description	Unit	Qty	Rate (USD)	Amount (USD)
	PIPEWORK - MANHOLES AND PIPEWORK ANCILLARIES				
	Manholes				
	PE inspection manholes, including excavation, concrete bedding, jointing, dewatering, earthworks support , back filling , paving and concrete curb; all in accordance with drawings and specifications.				
A	600 mm diameter	nr	33.0		
	Gutter inlet				
	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. -				
B	400 x 400 mm	nr	144.0		
	Grade 25 concrete pipe encasing including formwork, concrete and reinforcement; all in accordance with drawings and specifications.				
C	200 mm diameter pipes	m	1,130.0		
	Total pipe works - manholes and pipe work ancillaries carried to summary				

STORM WATER MANAGEMENT SYSTEM FOR H DH. KULHUDHUFFUSHI 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 -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)</u>				
A	Storage area DET-1 (Volume 225 m3)	Item	1.0		
B	Storage area DET-2 (Volume 225 m3)	Item	1.0		
C	Storage area DET-3 (Volume 350 m3)	Item	1.0		
D	Storage area DET-4 (Volume 350 m3)	Item	1.0		
E	Storage area DET-5 (Volume 150 m3)	Item	1.0		
F	Storage area DET-6 (Volume 350 m3)	Item	1.0		
G	Storage area DET-7 (Volume 400 m3)	Item	1.0		
H	Storage area DET-8 (Volume 400 m3)	Item	1.0		
	Total storage tank carried to summary				

14 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 if 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.
- Desilting of the existing downstream pond has to carry out to enhance the capacity of the pond and to maintain ecological balance of the Island. See photo page no: 141.
- 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.
- Rules and regulations on Storm Water Management

  Water is a scares 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 program.

- 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.

15 Photos

Location select for the ground tank along the peripheral drain

Existing road along the peripheral drain selected for the ground tank

Open area recommended for the ground

Existing natural overflow outlet from inland lake – view from sea side

Existing natural outflow from inland lake – view from inland side

Lowest point flooding is taking place

Open area selected for water storage

Open area from school premises selected for the ground water storage

Existing tank to be preserved to storm water daring rainy period

Open area available for ground tank along the peripheral drain between newly reclaimed land and existed lands

Open area available for ground tank

Water level in the well during rainy period

Open area recommended along the peripheral drain

Open area recommended along the peripheral drain

Recommended to desilt upstream area of the tank

Recommended to desilt upstream area of the tank

Recommended to desilt upstream area of the tank

View of the existing tank

Traditional rainfall harvesting Method

Proposed Location for storage tank

Localize Flooding area

SECTION 2

INTRODUCTION

Price BOQ for the Island of Hdh. Khulhudhufushi 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)

<u>**OPTION 1**</u>

BILL OF QUANTITIES

Item No	Description	Unit	Qty	Rate	Amount
	Bill No. 1 **General & Preliminaries**				
1.1	General & Preliminaries Cost consisting the following: • 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	***Earth Works***				
2.1.1	Filling and compaction of sand , in 150 mm layers for road works ; all in accordance with drawings and specifications.	m^3	1,500	295	442,500
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	2,568	295	757,560
2.2	***Pipe Works, Manholes & Gutters***				
2.2.1	Diameter 200 mm Pipe • 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	2,774.0	1,200	3,328,800
2.2.1	600mm Diameter Manholes • PE inspection manholes, including excavation, concrete bedding, jointing, dewatering,	nos	26	25,000	650,000

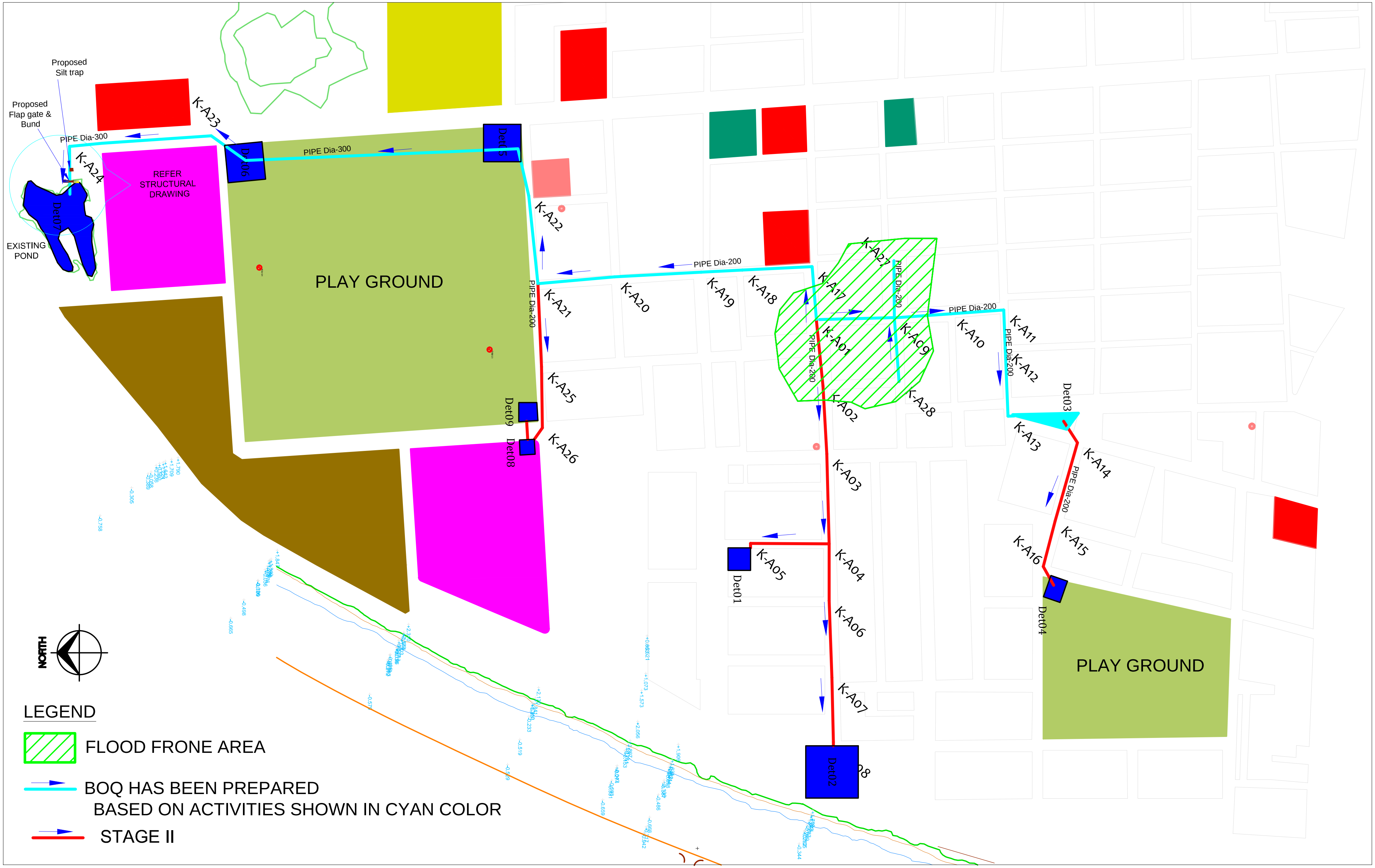
	earthworks support , back filling , paving and concrete curb; all in accordance with drawings and specifications.				
2.2.3	Gutter Inlet 400mm x 400mm • PE infiltration gutter inlet , including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb ; all in accordance with drawings and specifications.	nos	278	5,420	1,506,760
2.3	*FLIP GATE INSTALLATION*				
2.3.1	Installation of Flap Gate and bringing the needed modification to Sea-outfall	item	150,000	150,000	150,000
2.4	*STORAGE TANK* • 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-1 (Volume 200 m3)	m^3	200	5,550	1,110,00
2.4.2	Storage area A-2 (Volume 850 m3)	m^3	850	5,550	4,717,500
2.4.3	Storage area A-3 (Volume 225 m3)	m^3	225	5,550	1,248,750
2.4.4	Storage area A-4 (Volume 900 m3)	m^3	900	5,550	4,995,000
2.4.5	Storage area A-5 (Volume 625 m3)	m^3	625	5,550	3,468,750
2.4.6	Storage area A-6 (Volume 625 m3)	m^3	625	5,550	3,468,750
	Bill No. 3 **ZONE B**				
3.1	*Earth Works*				
3.1.1	Filling and compaction of sand , in 150 mm layers for road works ; all in accordance with drawings and specifications.	m^3	1,150	295	339,250
3.1.2	Filling and compaction of sand , in 150 mm layers	m^3	1,408	295	415,360

	for storage tanks , minimum total thickne 300 mm ; all in accordance with drawings and specifications.				
3.2	***Pipe Works, Manholes & Gutters***				
3.2.1	Diameter 200 mm Pipe • 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	1,628	1,200	1,953,600
3.2.1	600mm Diameter Manholes • 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	22	25,000	550,000
3.2.3	Gutter Inlet 400mm x 400mm • 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	163	5,420	854,120
3.3	***FLIP GATE INSTALLATION***				
3.3.1	Installation of Flap Gate and bringing the needed modification to Sea-outfall	item	150,000	150,000	150,000
3.4	***STORAGE TANK*** • 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)				
3.4.1	Storage area B-1 (Volume 100 m3)	m^3	100	5,550	555,000
3.4.2	Storage area B-2 (Volume 100 m3)	m^3	100	5,550	555,000
3.4.3	Storage area B-4 (Volume 225 m3)	m^3	225	5,550	1,248,750

3.4.4	Storage area B-5 (Volume 350 m3)	m^3	350	5,550	1,942,500
3.4.5	Storage area B-6 (Volume 500 m3)	m^3	500	5,550	2,775,000
3.4.6	Storage area B-7 (Volume 400 m3)	m^3	400	5,550	2,220,000
3.4.7	Storage area B-8 (Volume 180 m3)	m^3	180	5,550	999,000
	TOTAL				**40,041,950**

OPTION 2

(USING UNDERGROUND TANKS)



MWSC MALE' WATER & SEWERAGE COMPANY PVT LTD. AMEENEE MAGU, MACHCHANGOLHI MALE' 20-01 REPUBLIC OF MALDIVES Tel: (+960) 323209, Fax: (+960) 324306, E-mail: mwsc@dhivehinet.net.mv	CLIENT: MINISTRY OF ENVIRONMENT AND ENERGY, MALDIVES	PROJECT: DESIGN OF STORM WATER MANAGEMENT SYSTEM FOR THE H.Dh.KULHDHUFFUSHI ISLAND	SCALE: AS SHOWN	DRW NO. : KA-LP-A-01	DESIGN BY:	DRAWN BY:	AMMENDMENTS:
		CONTENTS: LAYOUT PLAN ZONE -A	DATE: 14.12.2013	Page:	STRUCTURAL DESIGN BY:	CHECKED BY:	

<u>**OPTION 2**</u>

BILL OF QUANTITIES

Item No	Description	Unit	Qty	Rate	Amount
	Bill No. 1 **General & Preliminaries**				
1.1	General & Preliminaries Cost consisting the following: • 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	*Earth Works*				
2.1.1	Filling and compaction of sand , in 150 mm layers for road works ; all in accordance with drawings and specifications.	m^3	300	295	88,500
2.2	*Pipe Works, Manholes & Gutters*				
2.2.1	Diameter 200 mm Pipe • 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	1,393	1,200	1,671,600
2.2.1	600mm Diameter Manholes • 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	17	25,000	425,000
2.2.3	Gutter Inlet	nos	140	5,420	758,800

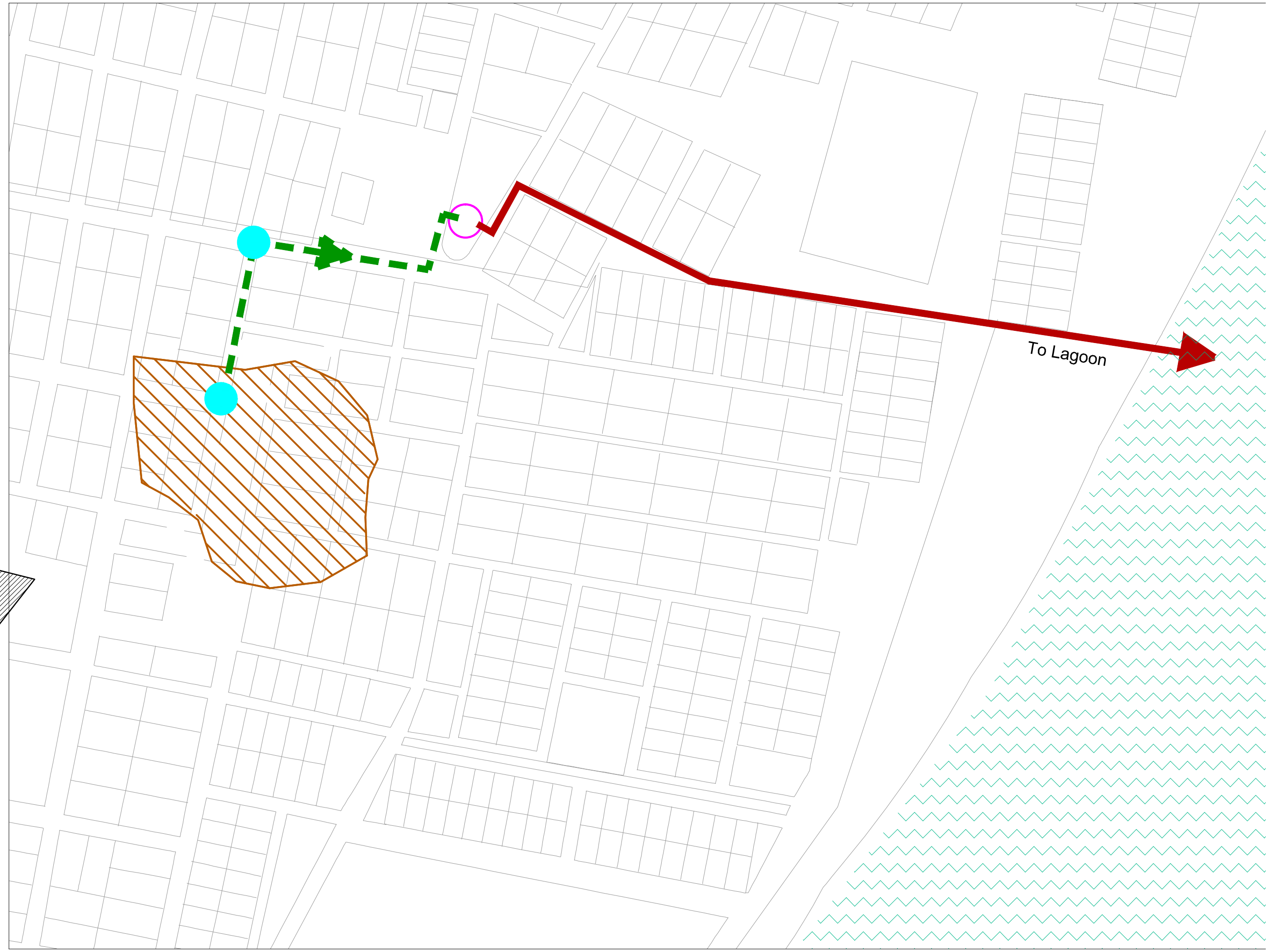
	400mm x 400mm • PE infiltration gutter inlet , including excavation, concrete bedding, jointing, dewatering, earthworks support, back filling, paving and concrete curb ; all in accordance with drawings and specifications.				
2.3	***FLIP GATE INSTALLATION***				
2.3.1	Installation of Flap Gate and bringing the needed modification to Sea-outfall	item	150,000	150,000	150,000
2.4	***STORAGE TANK*** • 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 225 m3)	m^3	225	5,550	1,248,750
	TOTAL				**4,842,650**

OPTION 3

(ALTERNATIVE 1)

(USING PUMP STATION TO PUMP TO SEA)

STORM WATER DRAINAGE SYSTEM - OPTION-IV (Alternative 1)
H DH. KULHUDHUFFUSHI



Gravity line interconnected with gutters

Pressure Main

Flood prone area

Pumping Chamber (refer details)

Collecting Chamber

MWSC MALE' WATER & SEWERAGE COMPANY PVT LTD.	PROJECT: Design of Storm water Management System for H.Dh.Kulhudhuffushi Island	SCALE: NTS	DRW NO. : KSW/C-04A	DESIGN BY: ---	DRAWN BY: HAPPY	AMMENDMENTS:
	CONTENTS: Conceptual Layout - Option IV (Alternative 1)	DATE: 25 - 12 - 2013		STRUCTURAL DESIGN BY: --	CHECKED BY: MIA	

OPTION 3 (ALTERNATIVE 1)

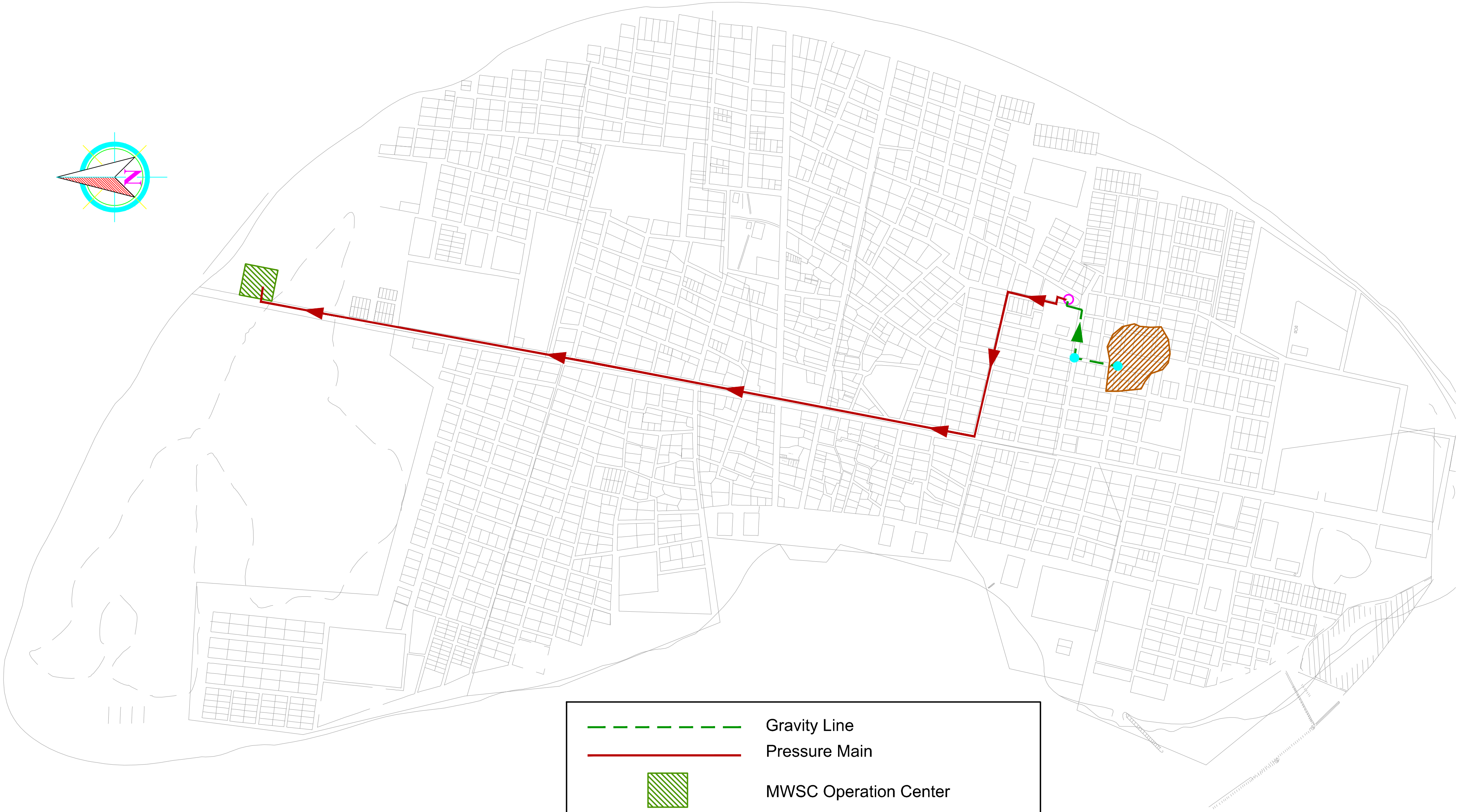
BILL OF QUANTITIES

Item No	Description	Unit	Qty	Rate	Amount
	Bill No. 1 **General & Preliminaries**				
1.1	General & Preliminaries Cost consisting the following: • 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	*PIPE LAYING*				
2.1.1	Laying of 160mm Ø PE Forcemain pipe line (material and labour)	m	371	1,250	463,750
2.1.2	Laying of 200mm Ø Upvc gravity pipe line (material and labour)	m	193	1,200	231,600
2.2	*LIFTING STATION & COLLECTION CHAMBERS*				
2.2.1	Pump stations	nos	1	700,000	500,000
2.2.2	Collection chambers	nos	2	25,000	50,000
2.2.3	Pumps	nos	1	150,000	150,000
	TOTAL				**1,895,350**

OPTION 3

(ALTERNATIVE 2)

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



STORM WATER DRAINAGE SYSTEM - OPTION-IV
(Alternative 2) - H DH. KULHUDHUFFUSHI

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	CONTENTS: Conceptual Layout - Option IV (Alternative 2)	DATE: 25 - 12 - 2013		STRUCTURAL DESIGN BY: --	CHECKED BY: MIA	

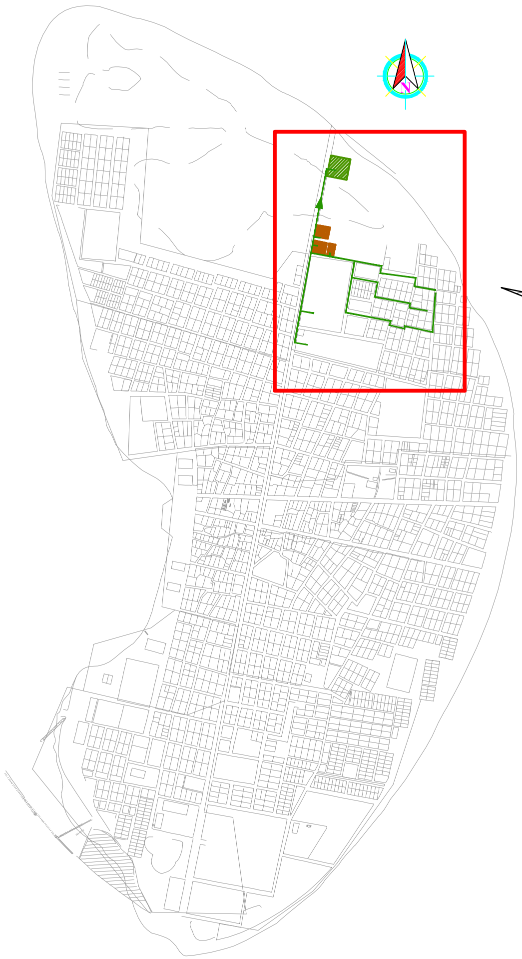
<u>**OPTION 3 (ALTERNATIVE 2)**</u>

BILL OF QUANTITIES

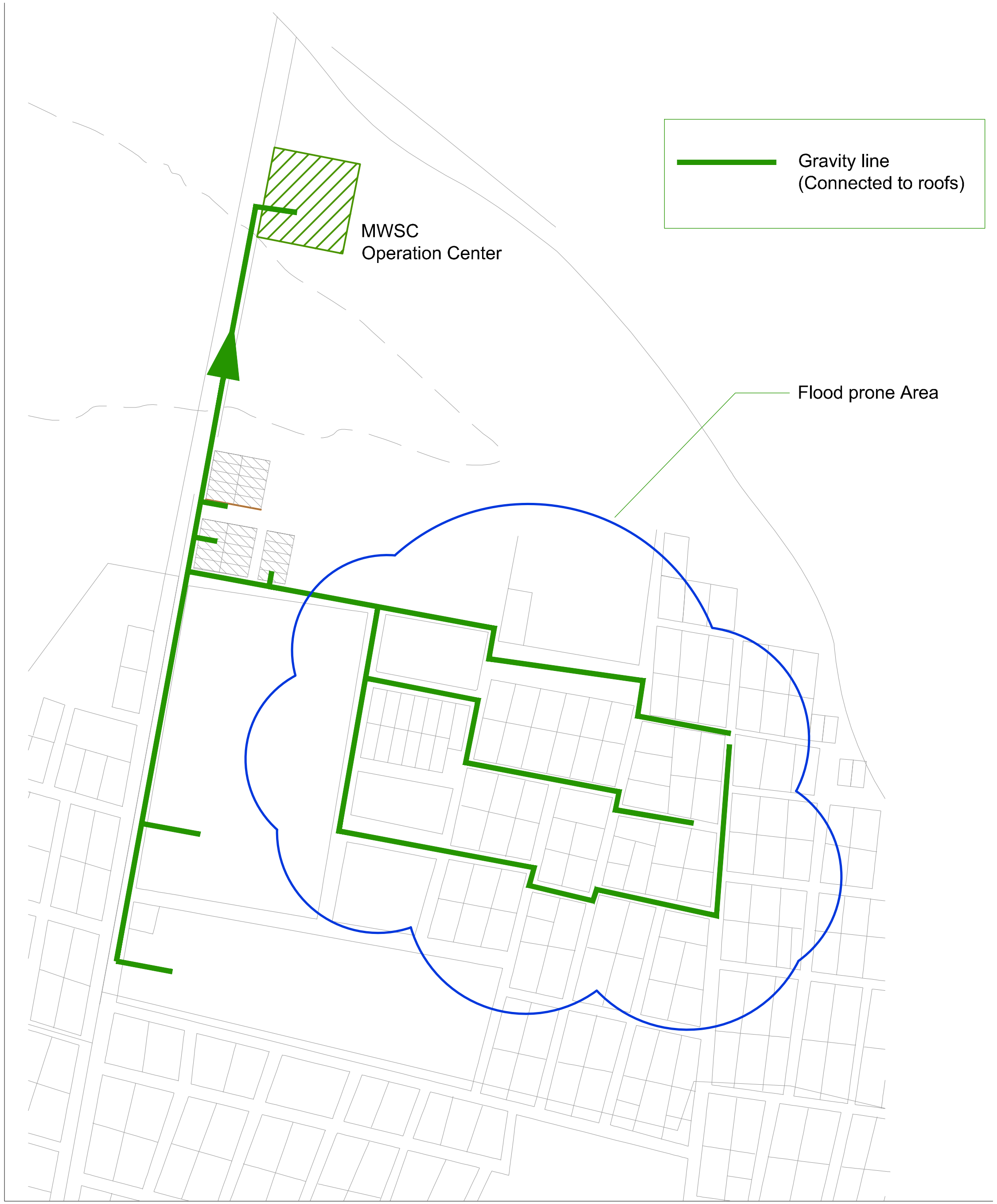
Item No	Description	Unit	Qty	Rate	Amount
	Bill No. 1 **General & Preliminaries**				
1.1	General & Preliminaries Cost consisting the following: • Provision and Maintenance of Equipments such as Excavators, Leveling Equipment, ..etc needed in the project. • Material Transportation • Material Storage • Contractors Accommodation and administrative works	item	1	500,000	500,000
	Bill No. 2				
2.1	*PIPE LAYING*				
2.1.1	Laying of 160mm Ø PE Forcemain pipe line	m	1615	1,250	2,018,750
2.1.2	Laying of 200mm Ø Upvc gravity pipe line	m	193	1,200	231,600
2.2	*LIFTING STATION & COLLECTION CHAMBERS*				
2.2.1	Pump stations	nos	1	500,000	500,000
2.2.2	Collection chambers	nos	2	25,000	50,000
2.2.3	Pumps	nos	1	200,000	200,000
	TOTAL				**3,500,350**

OPTION 4

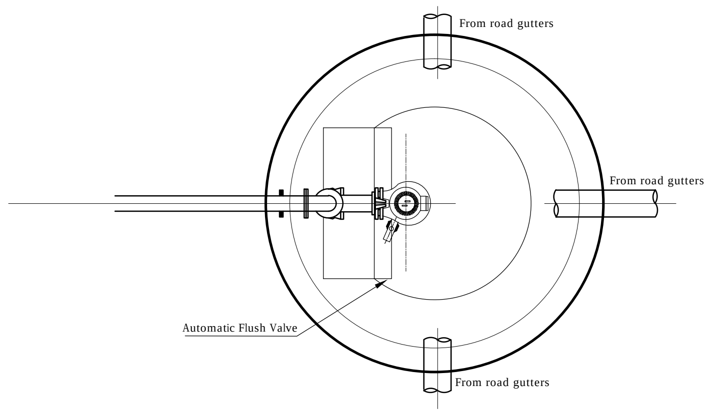
(RAINWATER HARVESTING)



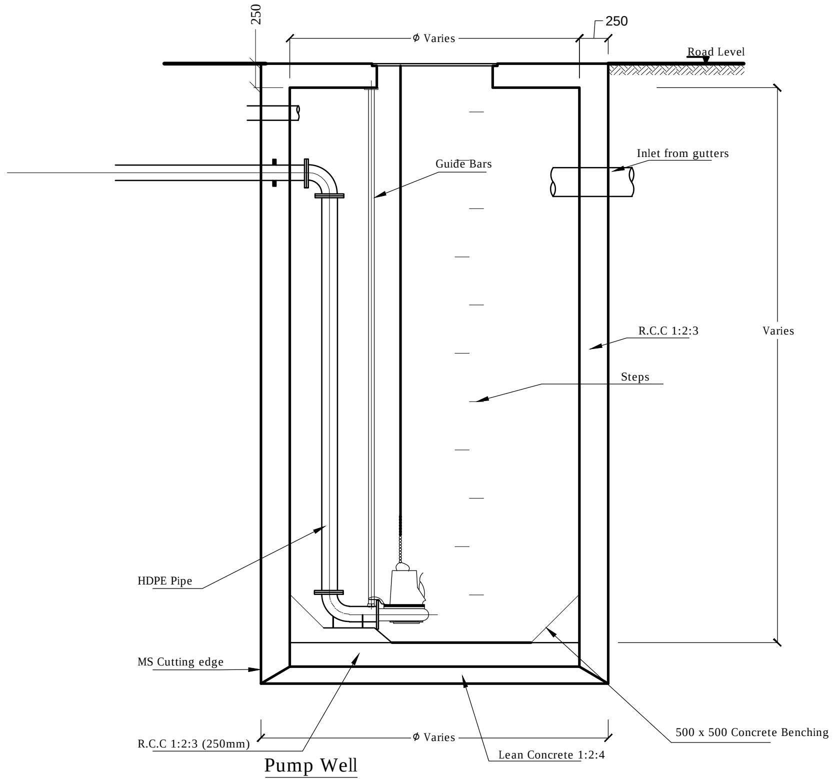
STORM WATER DRAINAGE SYSTEM - OPTION-III
H DH. KULHUDHUFFUSHI



MALE' WATER & SEWERAGE COMPANY PVT LTD.	PROJECT: Design of Storm water Management System for H.Dh.Kulhudhuffushi Island	SCALE: NTS	DRW NO. : KSW/C-03	DESIGN BY: ---	DRAWN BY: HAPPY	AMMENDMENTS:
	CONTENTS: Conceptual Layout - Option III	DATE: 25 - 12 - 2013		STRUCTURAL DESIGN BY: --	CHECKED BY: MIA	



SECTIONAL PLAN VIEW



SECTIONAL ELEVATION (SUMP)

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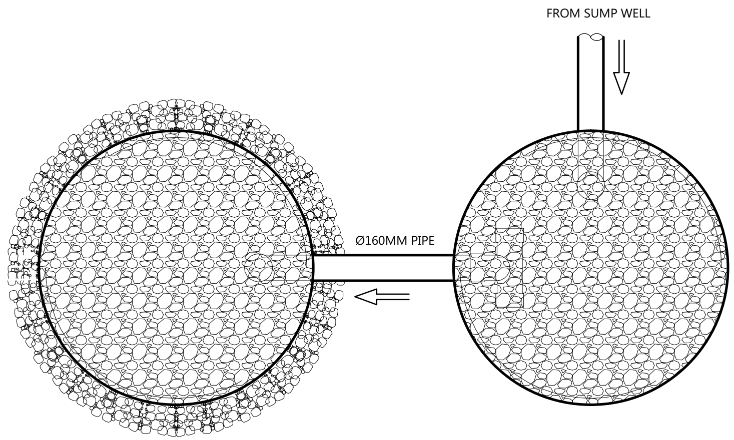
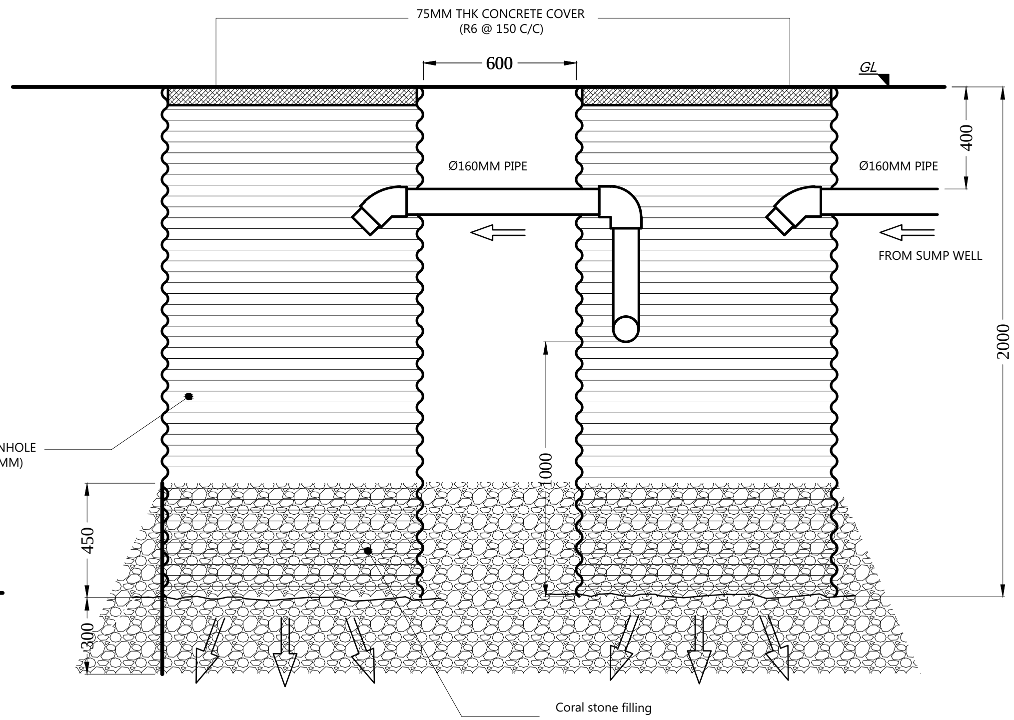
	CONTENTS: Typical Pump Station	DATE: 25 - 12 - 2013		STRUCTURAL DESIGN BY: --	CHECKED BY: MIA	





SECTIONAL ELEVATION

SCALE 1:25

SETTLING CHAMBER

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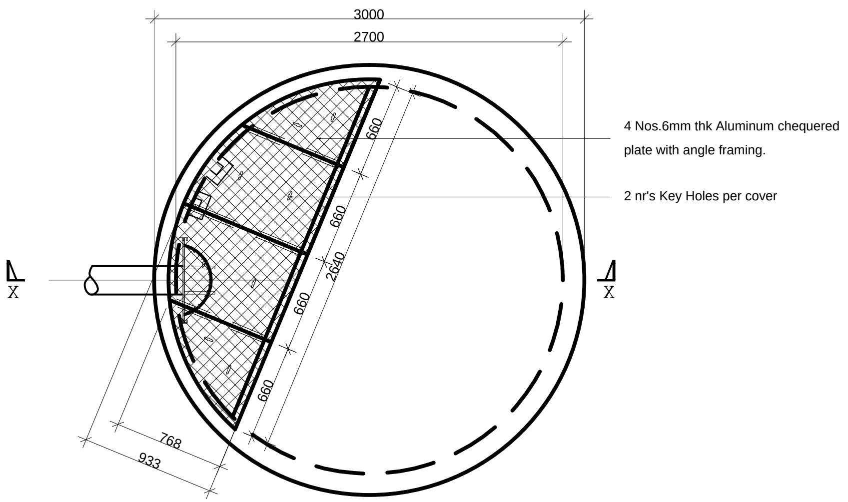
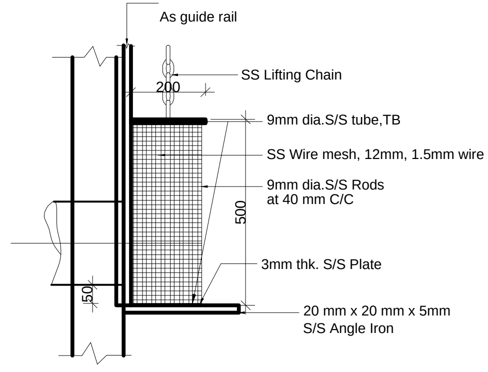
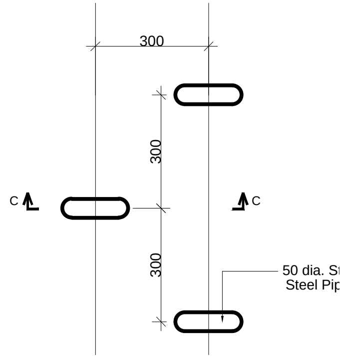
	CONTENTS: Typical Settling Chamber	DATE: 25 - 12 - 2013		STRUCTURAL DESIGN BY: --	CHECKED BY: MIA	



PLAN - LIFT STATION
NTS

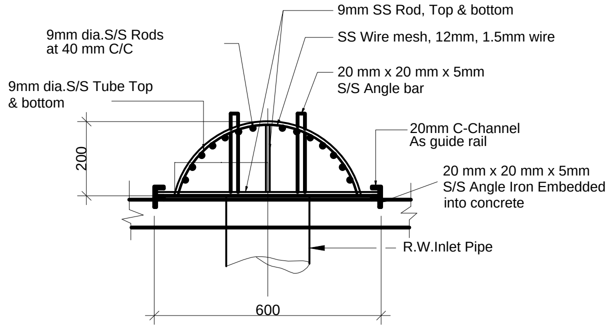


Section



Elevation

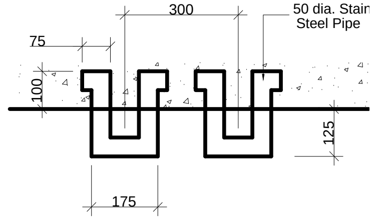
20mm C-Channel



Plan View

Detail of Basket Screen

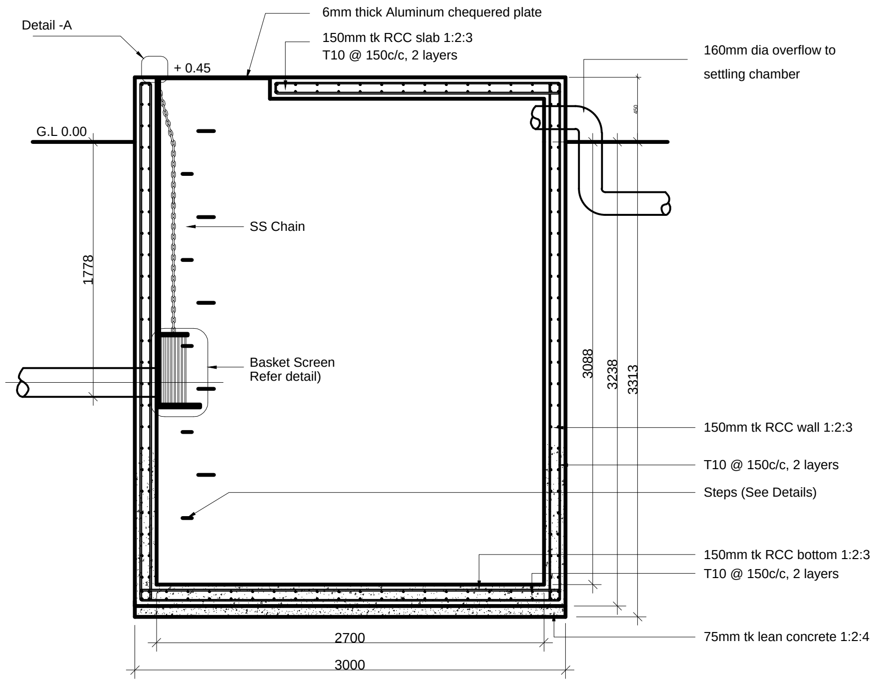
Scale - 1:20



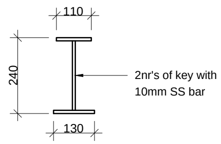
Section C-C

Detail of Steps

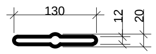
Scale - 1:20



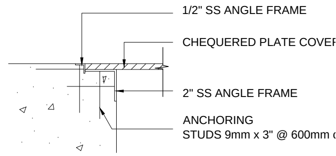
SECTION X-X
NTS



KEY DETAIL
NTS

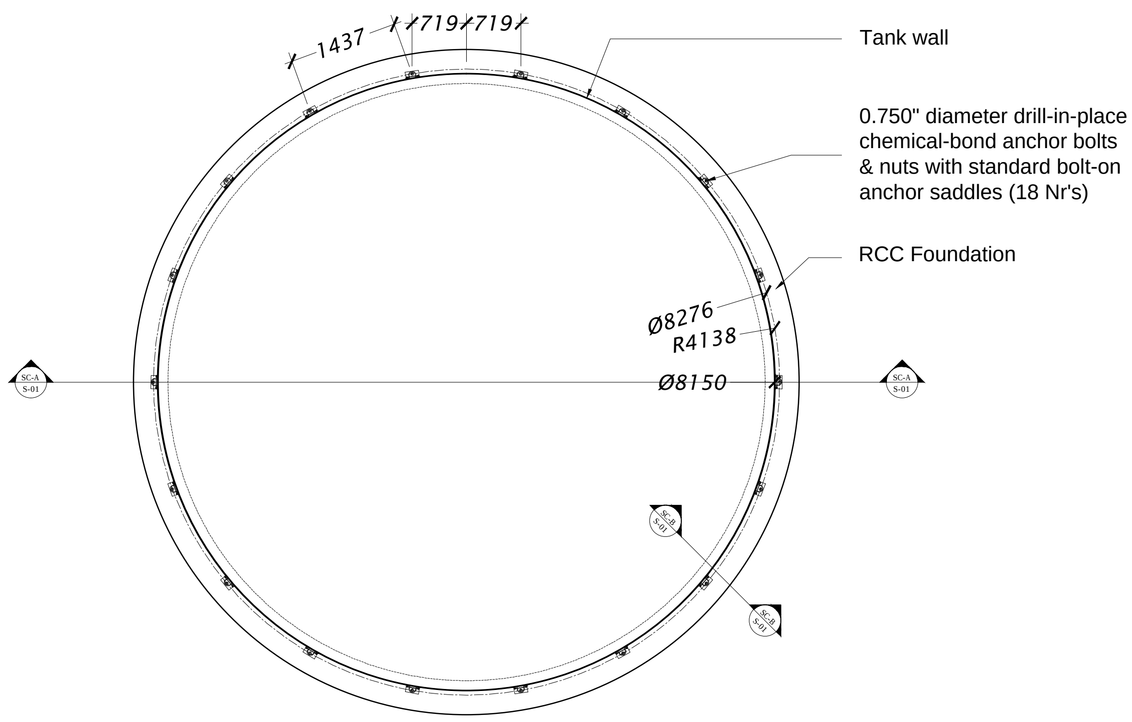


KEY HOLE DETAIL
NTS

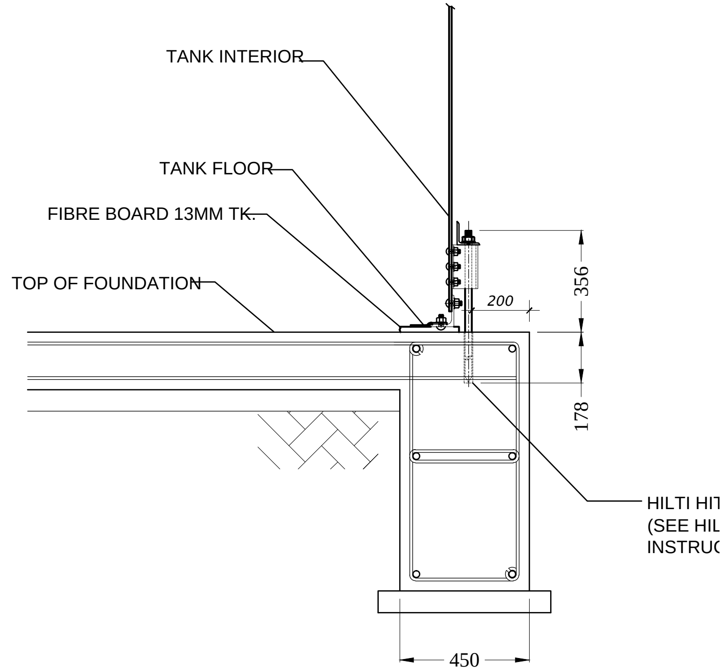


DETAIl-A
NTS

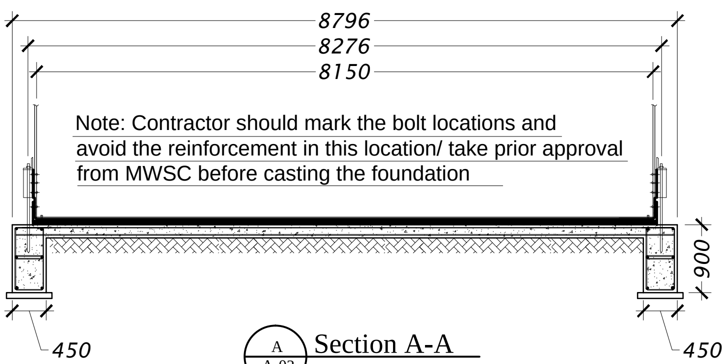
MALE' WATER & SEWERAGE COMPANY PVT LTD. AMEENEE MAGU, MACHCHANGOLHI MALE' 20-01 REPUBLIC OF MALDIVES Tel: (+960) 323209, Fax: (+960) 324306, E-mail: mwsc@dhivehinet.net.mv	PROJECT: Design of Storm water Management System for H.Dh.Kulhudhuffushi and G DH.Thinadhoo Island	SCALE: As Given	DRW NO. : KTSW/TD-03	DESIGN BY: ---	DRAWN BY: HAPPY	AMMENDMENTS:
	CONTENTS: Typical Lift Station	DATE: 25 - 12 - 2013		STRUCTURAL DESIGN BY: --	CHECKED BY: MIA	



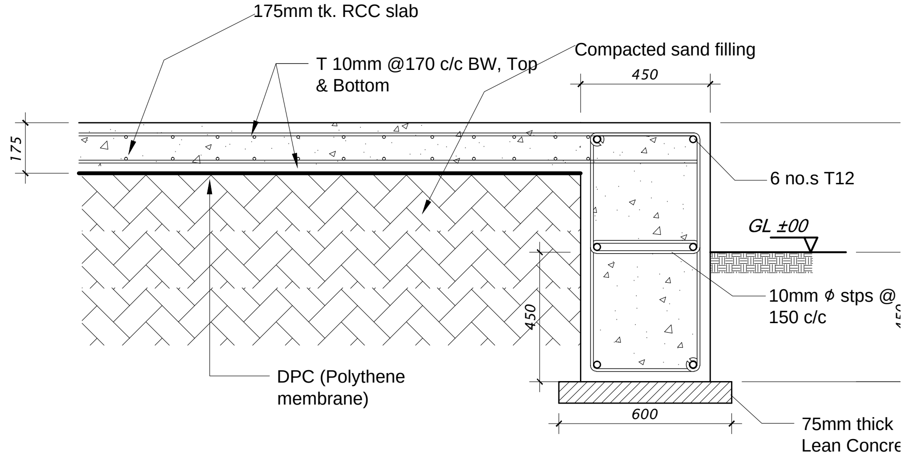
A A-01 Plan
SCALE 1:100



S S-01 Section B-B/ Tank erection
SCALE 1:20



A A-02 Section A-A
SCALE 1:100



S S-02 Section B-B/Foundation
SCALE 1:20

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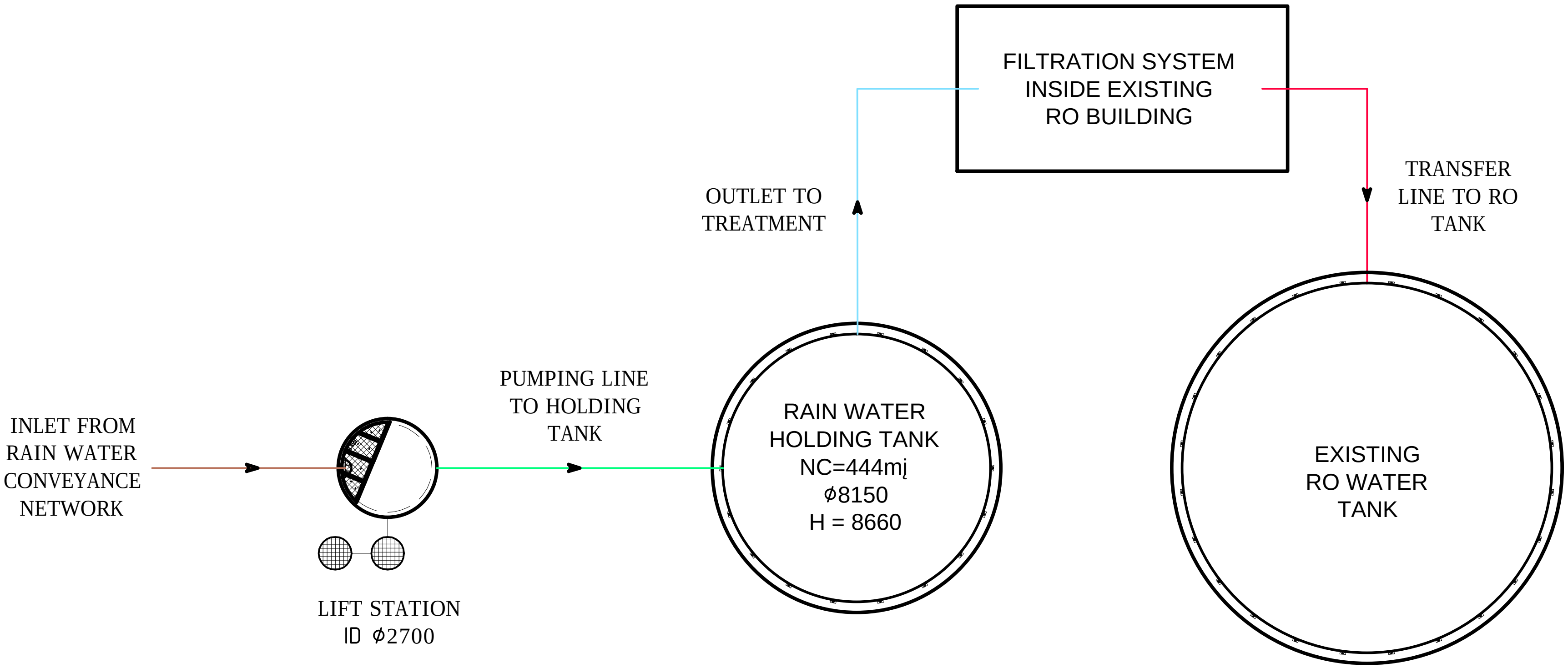
	CONTENTS: Typical Storage Tank	DATE: 25 - 12 - 2013		STRUCTURAL DESIGN BY: --	CHECKED BY: MIA	



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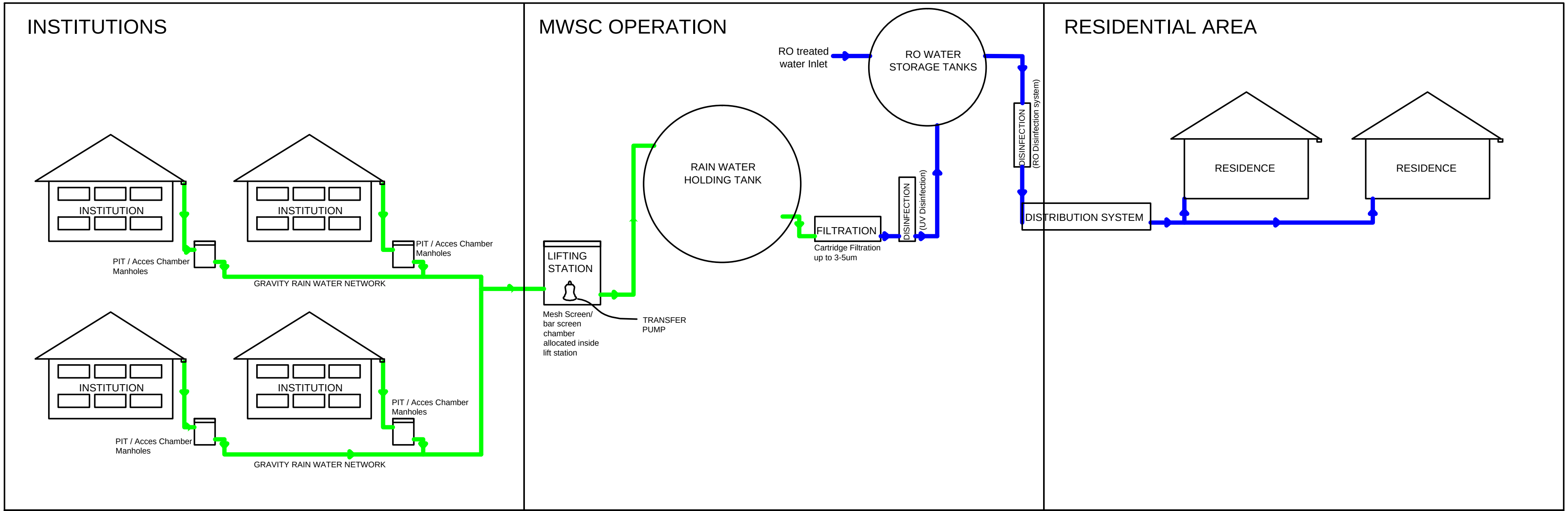
	CONTENTS: Typical Flow Diagram	DATE: 25 - 12 - 2013		STRUCTURAL DESIGN BY: --	CHECKED BY: MIA	

STAGE-1 (RAIN WATER COLLECTION) | STAGE-2 (RAIN WATER PROCESSING) | STAGE-3 (DISTRIBUTION)



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

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

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

<u>**OPTION 4**</u>

BILL OF QUANTITIES

Item No	Description	Unit	Qty	Rate	Amount
	Bill No. 1 **General & Preliminaries**				
1.1	General & Preliminaries Cost consisting the following: • 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	***PIPE LAYING***				
2.1.2	Laying of 200mm Ø Upvc gravity pipe line (material and labour)	m	1850	1,200	2,220,000
2.2	***ROOF CONNECTIONS***				
2.2.1	Roof Connections	nos	60	20,000	1,200,000
2.3	***LIFTING STATION & COLLECTION CHAMBERS***				
2.3.1	Lift stations	nos	1	500,000	500,000
2.3.2	Collection chambers	nos	32	25,000	800,000
2.3.3	Pumps	nos	1	200,000	200,000
2.3	***RAINWATER STORAGE TANK***				
	Foundation & Erection	nos	1	500,000	500,000
	400 m3 Water Tank	nos	1	1,200,000	1,200,000

3.0	***FILTRATION SYSTEM***				
3.1	Filtration system (Filtration System which consist of UV System,Filter, pumps..etc needed) **<u>Note</u>** It is assumed that the Filteration System is placed in an existing RO Building and hence cost of a separate Building is not provided.	item	1	720,000	720,000
	TOTAL				**7,840,000**