

Planning and Design of Storm water Management System for the H Dh. Kulhudhuffushi and G Dh. Thinadhoo Island Inception Report



Project:

Consultancy Services for Detail Designs to
Address storm water Management in H Dh.
Kulhudhuffushi and G Dh. Thinadhoo Island

November, 2013

Submitted by:

Male' Water and Sewerage Company Pvt
Ltd.

Engineering Consultants (Pvt) Limited

Client:

Ministry of Environment and Energy

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1.0 Introduction

1.1 H dh. Kulhudhuffushi

The H Dh. Kulhudhuffushi Island has an approximate area of above 236 ha and large concentration of people (8974) resides in this island.

Localized flooding problem in the area is due to several factors such as;

- ❖ Topography
- ❖ Land use
- ❖ Improper slope of the roads
- ❖ Non existence of drainage system
- ❖ Variation of existing ground
- ❖ Variation of sea levels
- ❖ Absence of sea outlets around the island
- ❖ Deterioration of original natural drainage path
- ❖ High intensity rainfall
- ❖ Level survey plan shows that most of the areas are below 1.0 m MSL.

The area identified to provide drainage facilities under the project is administered by the Island council. Contour map has been prepared by the consultant by using available levels maps, to distinct flooding locations in order to prepare proper water management system for the island. An accurate estimate of land form classification according to the elevation above mean sea level will be under taken during the study. Figure No 1.1 & 1.2 shows localized flooding locations and contour maps of the basins.

LAND USE MAP SHOWING FLOODING LOCATIONS

Map Legend :



















-  PRIMARY BENCH MARK
PSM 01; 285982.2478E, 732828.1350N
PSM 02; 285893.2591E, 732888.0377N
-  PSM 03; 288851.5215E, 731491.8261N
PSM 04; 288795.7595E, 731478.1530N
- ROAD LEVEL AND RECLAIMED AREA LEVELS
BEACH PROFILE LEVELS
SHOPS
-  RESIDENTIAL ZONE / BLOCKS
-  INSTITUTIONAL & COMMUNITY ZONE
-  SPORTS AND RECREATION ZONE
-  UTILITY AND MUNICIPAL ZONE
-  GOVERNMENT OFFICE
-  SCHOOLS
-  HOSPITALS
-  TELECOM INSTITUTIONS
-  REGIONAL PORT
-  HARBOUR AND LOADING AREA
-  RECLAIMED AREA NEW
-  RECLAIMED AREA OLD
-  HIGH TIDE LINE
-  BEACH TIDE
-  VEGETATION LINE
-  Localized Flooding area
-  Road are Getting Flooded Intermittently



Figure No 1.1: Land use map showing flooding locations

Terrain of Kulhudhuffushi

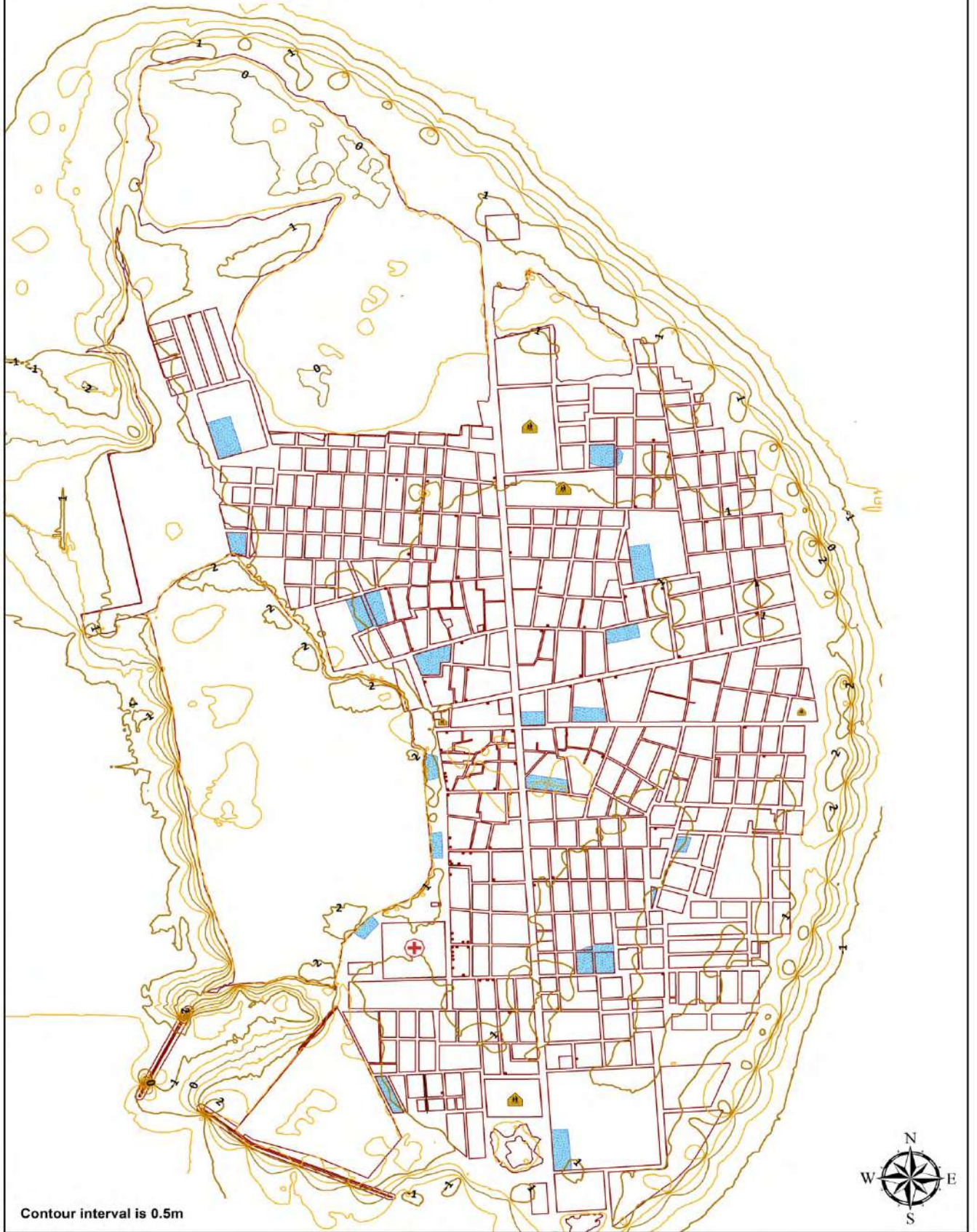


Figure No 1.2: Proposed plan for ground tank area

1.2 G Dh. Thinadhoo

The G Dh Thinadhoo Island has an approximate area of about 115.5 ha and highly urbanized settlement with over 8000 inhabitants.

Localized flooding problem in the area is due to several factors such as;

- ❖ Topography
- ❖ Improper slope of the roads
- ❖ Low elevated areas within the housing scheme
- ❖ Unavailability of flap gate to prevent salt water intrusion into the inland areas
- ❖ Inadequacy of existing and newly constructed outfall to sea

Figure 1.3 & 1.4 shows localized flooding locations and contour maps of the basins

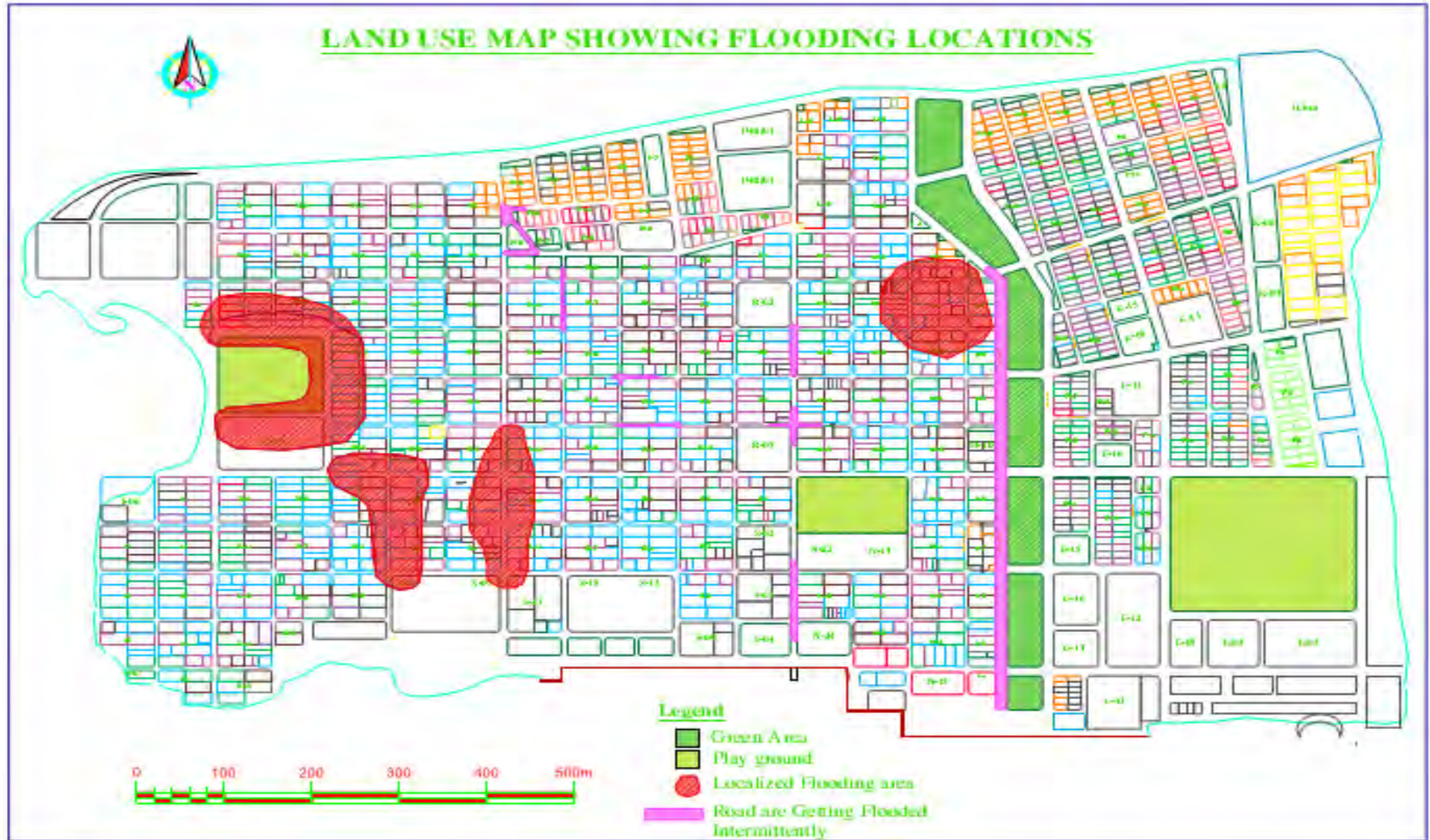


Figure No 1.3: Land use map showing flooding locations

Topography of Thinadhoo Island

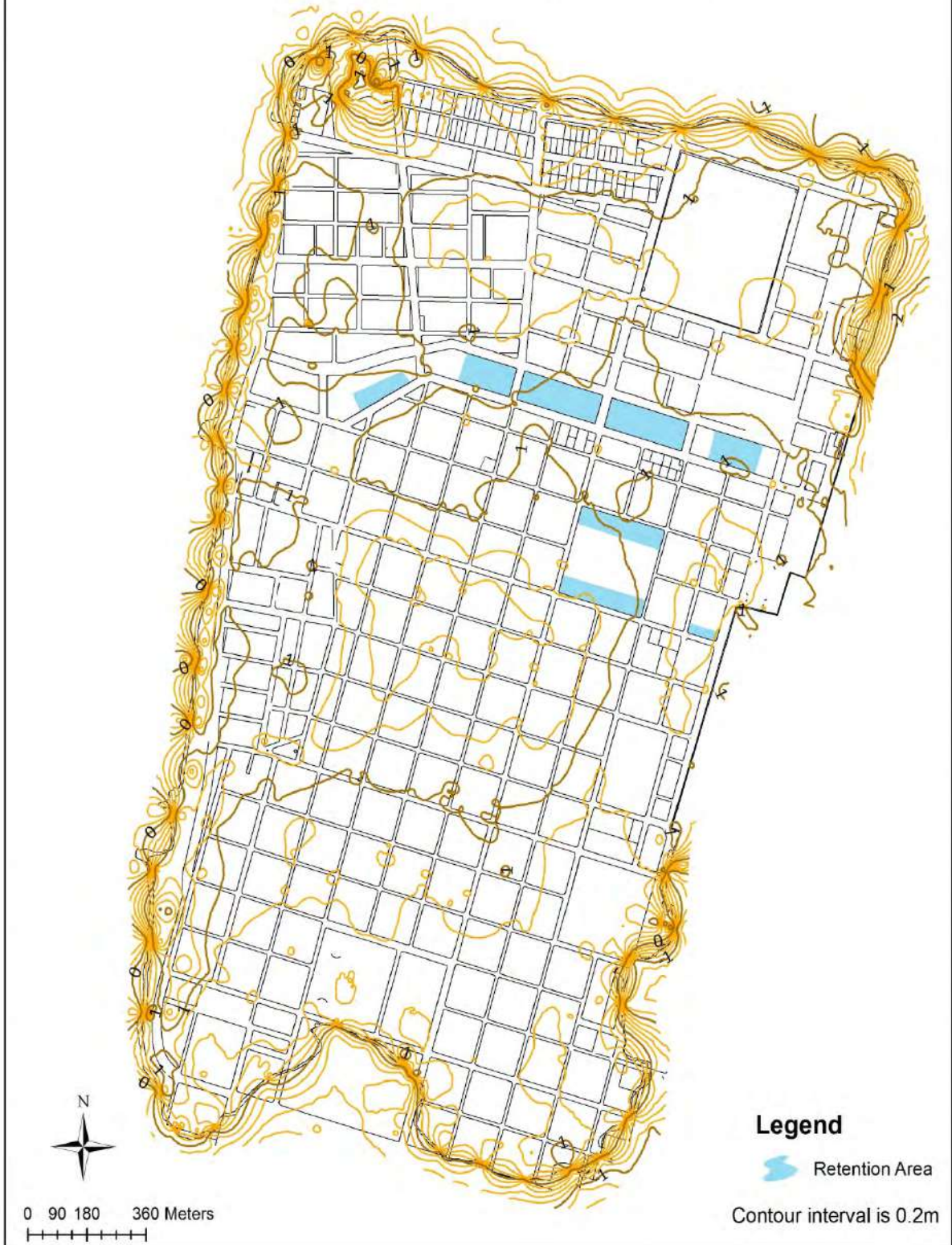


Figure No 1.4: Proposed plan for ground tank area

2.0 Strategy

In order to utilize the funding already available for the project and also to derive timely benefit for the affected community, sensitive problem areas were identified as pilot basins for detailed investigations. Designs and estimations will be completed for these two islands in order to commence the construction work simultaneously.

3.0 Scope of the consultancy assignment

The consultant should write up a detailed design report and prepare detailed design drawings for the storm water management problem for the two Islands **Hdh. Khuldhufushi & Gdh. Thinadhoo**. The following actions will be essentially undertaken during the entirety of the project.

- Review and assess all the available data related to civil works and drainage undertaken in the past and current development practices
- Review pertinent reports and available data
- Carry out field visits or surveys as required
- Assist consultations with council, local communities and stakeholders to gather information on flooding related experiences and specific problems that need to be addressed in design and implementation
- Assist in creating awareness of the benefits of implementing green infrastructure or green streets approaches in addressing problems of flooding
- Detailed preparation of design for specific flood prone areas in two islands and engineering options for low impact development of rainfall management
- Detailed preparation of design options, specific and replicable, for the management of storm water
- Detailed plan for managing runoff at the source
- The report and design should show integration with the roads in the island and should suggest on road design changes that may be required for the storm water
- Writing of specifications and assisting in the preparation of bills of quantities, tender documents and evaluation process
- Writing of operations and maintenance manuals

During this consultancy services, it was decided to obtain the assistance of following specialist consultants.

1. Services of senior drainage specialist
2. services of meteorologist
3. Services of gate specialist
4. Services of coastal expert

The contents of the technical report envisaged under this consultancy services can be enhanced to a full comprehensive detailed design technical report. If the socio economics aspects are included to analyze the cost benefit and the economic justification of the project, this might be useful to seek any funding to implement the project proposals.

4.0 Climate

4.1 Rainfall

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

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

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

4.2 Rainfall Intensity Analysis

The catchment areas of individual sub-basins in the HDh.Kulhudhffushi and GDh.Thinadhoo under consideration for effective drainage are comparatively small. Therefore time of concentration, (T_c) as defined in surface hydrology is very short. The details of the basin show that the largest catchment area is limited to 200 ha. The time of concentration (T_c) is of the order of 30 to 60 minutes. Therefore in designing storm water management system for these small urban catchments, the rainfall intensity for short duration, such as 5,10,15,30 minutes is very important. In addition, 24 hour rainfall data of the automatic rain gauges maintained at the above weather stations were analyzed for several years.

4.2.1 Development of intensity depth duration frequency curves for Hulhule weather station

3 hourly rainfall values available for the above station were analyzed for durations of 3 hrs, 6 hrs, 9 hrs, 12 hrs, 15 hrs, 18 hrs, 21 hrs and 24 hrs. Also checked the maximum values from daily basis and for consecutive days. It was found that critical values are located within the rainfall values collected in 3 hrs intervals.

3 hourly rainfall data analysis were carried out to find out the monthly maximum rainfall values, from 3 hrs to 24 hrs for monthly basis from January to December from 2008 to 2012 are shown in the **Tables 4.1 to 4.5**. The annual maximum observed are shown in **Table 4.6 (a) and** rainfall values with statistics are shown in **4.6 (b)**.

It is to be noted that the maximum rainfall in the considered period for 3 hrs and 6 hrs are observed in November 2011.

Based on the above analysis, monthly maximum has been calculated and same analysis has been repeated for the balance five years. Depth duration frequency (DDF) curves developed by using Gumble (EV1) method is shown in **Table 4.7 and Figure 4.1**. DDF values for less than 3hrs time interval has been calculated after interpolating DDF curves developed for time interval greater than 3hrs. Depth duration frequency curves have been used to develop intensity depth duration frequency curves (IDF) as shown in **Table 4.8 and Figure 4.2**.

It is to be noted that when the data which has been collected before year 2008 for shorter duration is available, it can be used to improve IDF curves which have been already developed on the above station. Due to lack of daily rainfall data at Hulhule metrological station, DDF and IDF curves cannot be extended from 24 hrs to 120hrs duration.

The annual maximum 24 hour rainfall and rainfall intensities for short durations are shown in **Tables 4.1 to 4.5**, it can be seen that the maximum 24 hour rainfall during the last 21 years was 100.5mm. The frequency analysis of these rainfall data was done to obtain the rainfall depths for different frequencies. Due to readily available set of data, rainfall intensities up to 100 year return period with durations 3, 6, 12 hourly and 24 hourly could be calculated at each locations using frequency analysis.

Table 4.1: Monthly Observed Maximum Rainfall Depths at Hulhule in year 2008 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Maximum
3 hrs	10.8	17.9	46.7	25.9	47.5	33.8	23.4	38.4	7.1	42.9	27.0	32.7	47.5
6 hrs	16.7	21.0	56.5	25.9	51.9	48.5	28.6	61.9	8.0	44.6	28.2	40.0	61.9
9 hrs	20.5	21.0	56.5	25.9	53.1	53.3	28.6	62.3	8.0	45.6	28.2	40.9	62.3
12 hrs	22.1	21.0	56.5	25.9	53.1	68.0	29.9	62.6	9.7	45.6	37.3	41.9	68.0
15 hrs	22.5	23.3	66.8	25.9	53.1	68.7	30.2	62.6	9.7	46.4	38.3	49.7	68.7
18 hrs	23.2	23.3	81.3	25.9	53.1	68.7	30.2	62.6	9.7	46.4	44.0	54.6	81.3
21 hrs	27.0	27.7	91.1	25.9	58.6	69.0	30.2	64.4	9.7	46.4	44.8	66.3	91.1
24 hrs	28.4	38.9	92.8	25.9	59.8	73.2	30.2	64.8	11.1	46.4	44.8	72.2	92.8

Table 4.2: Monthly Observed Maximum Rainfall Depths at Hulhule in year 2009 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Maximum
3 hrs	22.9	5.3	21.5	32.3	19.1	33.3	64.0	29.5	29.7	28.1	33.8	20.6	64.0
6 hrs	34.5	7.3	21.5	32.8	20.7	33.5	66.5	57.0	29.8	29.1	38.6	33.8	66.5
9 hrs	45.1	8.8	21.5	32.8	23.5	36.3	97.5	57.9	35.8	29.4	45.1	33.8	97.5
12 hrs	50.3	8.8	21.5	32.8	26.8	41.9	99.6	57.9	35.8	29.4	48.9	33.8	99.6
15 hrs	53.1	8.8	21.5	34.8	26.8	46.8	99.6	58.5	50.0	29.4	63.7	41.7	99.6
18 hrs	54.1	8.8	21.5	38.2	29.8	46.8	99.6	62.9	50.1	29.4	80.0	42.7	99.6
21 hrs	54.7	8.8	21.5	38.2	30.8	49.7	100.5	74.6	56.1	29.4	84.7	42.7	100.5
24 hrs	54.7	8.9	21.5	38.2	30.8	67.9	100.5	78.0	56.1	29.4	85.7	43.6	100.5

Table 4.3: Monthly Observed Maximum Rainfall Depths at Hulhule in year 2010 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Maximum
3 hrs	4.5	51.3	12.0	44.2	36.6	23.4	26.9	24.7	21.6	28.4	30.2	73.6	73.6
6 hrs	5.0	60.6	12.4	44.9	38.1	41.1	33.0	34.6	34.3	36.7	60.1	75.9	75.9
9 hrs	5.0	60.6	12.9	45.5	38.1	44.6	35.1	43.4	35.4	40.0	60.4	83.9	83.9
12 hrs	5.0	60.6	17.4	45.5	38.8	48.7	37.6	59.7	43.6	49.2	61.2	83.9	83.9
15 hrs	5.6	60.6	17.4	45.5	40.1	50.2	48.7	73.5	43.6	71.8	61.8	83.9	83.9
18 hrs	5.6	60.6	17.4	45.5	43.3	52.2	65.1	75.2	57.6	74.8	61.8	83.9	83.9
21 hrs	5.6	60.6	17.4	45.5	45.3	54.8	67.2	75.8	58.0	75.3	61.8	83.9	83.9
24 hrs	5.6	60.6	17.4	45.5	49.6	58.1	69.7	76.1	58.2	78.3	61.8	83.9	83.9

Table 4.4: Monthly Observed Maximum Rainfall Depths at Hulhule in year 2011 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Maximum
3 hrs	36.7	3.9	6.1	24.5	24.0	14.6	27.4	37.7	24.5	34.0	92.0	21.4	92.0
6 hrs	71.4	6.0	6.9	26.3	28.4	16.6	37.2	39.3	24.5	43.2	93.4	24.0	93.4
9 hrs	73.6	6.0	7.4	26.7	29.7	17.4	37.9	39.7	24.5	46.1	93.4	24.0	93.4
12 hrs	73.6	6.0	12.9	27.0	30.5	17.9	37.9	41.3	24.5	67.9	93.4	24.0	93.4
15 hrs	73.6	6.0	12.9	27.2	30.7	17.9	42.4	41.3	33.5	70.3	93.4	24.0	93.4
18 hrs	75.0	6.0	13.4	42.6	32.3	31.2	43.1	41.3	39.7	71.0	95.7	24.0	95.7
21 hrs	75.0	6.0	13.4	48.8	33.7	32.0	45.6	41.3	40.5	71.0	97.1	24.0	97.1
24 hrs	77.5	6.0	16.1	49.1	40.3	32.5	46.4	41.3	41.0	85.9	97.3	24.1	97.3

Table 4.5: Monthly Observed Maximum Rainfall Depths at Hulhule in year 2012 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Maximum
3 hrs	14.3	32.6	7.6	46.5	51.8	13.6	9.2	55.7	39.0	35.6	26.3	34.2	55.7
6 hrs	15.9	53.2	9.2	62.1	59.6	23.7	13.8	68.1	54.7	36.3	26.3	50.8	68.1
9 hrs	25.8	71.6	9.2	63.2	61.7	24.3	14.4	68.5	57.7	42.5	26.3	62.1	71.6
12 hrs	26.1	88.4	9.2	63.2	61.7	24.3	14.6	68.5	58.2	43.1	26.3	66.0	88.4
15 hrs	29.5	88.4	9.2	67.7	61.7	24.3	15.6	68.5	59.7	43.1	26.3	66.5	88.4
18 hrs	30.6	88.4	9.2	68.8	61.7	24.3	20.1	68.5	62.5	43.4	26.3	69.0	88.4
21 hrs	30.6	88.4	9.2	68.8	61.7	24.3	21.8	68.5	64.1	43.4	26.3	74.6	88.4
24 hrs	30.6	88.4	10.9	68.8	61.7	24.3	22.0	68.5	64.6	47.0	42.2	81.4	88.4

Table 4.6 (a) : Annual Observed Maximum Rainfall Depths at Hulhule (mm)

Duration	Year				
	2008	2009	2010	2011	2012
3 hrs	47.5	64.0	73.6	92.0	55.7
6 hrs	61.9	66.5	75.9	93.4	68.1
9 hrs	62.3	97.5	83.9	93.4	71.6
12 hrs	68.0	99.6	83.9	93.4	88.4
15 hrs	68.7	99.6	83.9	93.4	88.4
18 hrs	81.3	99.6	83.9	95.7	88.4
21 hrs	91.1	100.5	83.9	97.1	88.4
24 hrs	92.8	100.5	83.9	97.3	88.4

Table 4.6 (b): Annual Observed Maximum Rainfall Depths at Hulhule With Statistics (mm)

Year	Duration							
	3 hrs	6 hrs	9 hrs	12 hrs	15 hrs	18 hrs	21 hrs	24 hrs
2008	47.5	61.9	62.3	68.0	68.7	81.3	91.1	92.8
2009	64.0	66.5	97.5	99.6	99.6	99.6	100.5	100.5
2010	73.6	75.9	83.9	83.9	83.9	83.9	83.9	83.9
2011	92.0	93.4	93.4	93.4	93.4	95.7	97.1	97.3
2012	55.7	68.1	71.6	88.4	88.4	88.4	88.4	88.4
Maximum	92.0	93.4	97.5	99.6	99.6	99.6	100.5	100.5
Minimum	47.5	61.9	62.3	68.0	68.7	81.3	83.9	83.9
Average	66.6	73.2	81.7	86.7	86.8	89.8	92.2	92.6
Standard Deviation	15.4	11.1	13.2	10.7	10.4	6.9	6.0	6.0

Table 4.7: Rainfall Depth Duration Frequency Data (mm)

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

Table 4.8: Rainfall Intensity Duration Frequency Data (mm/hour)

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

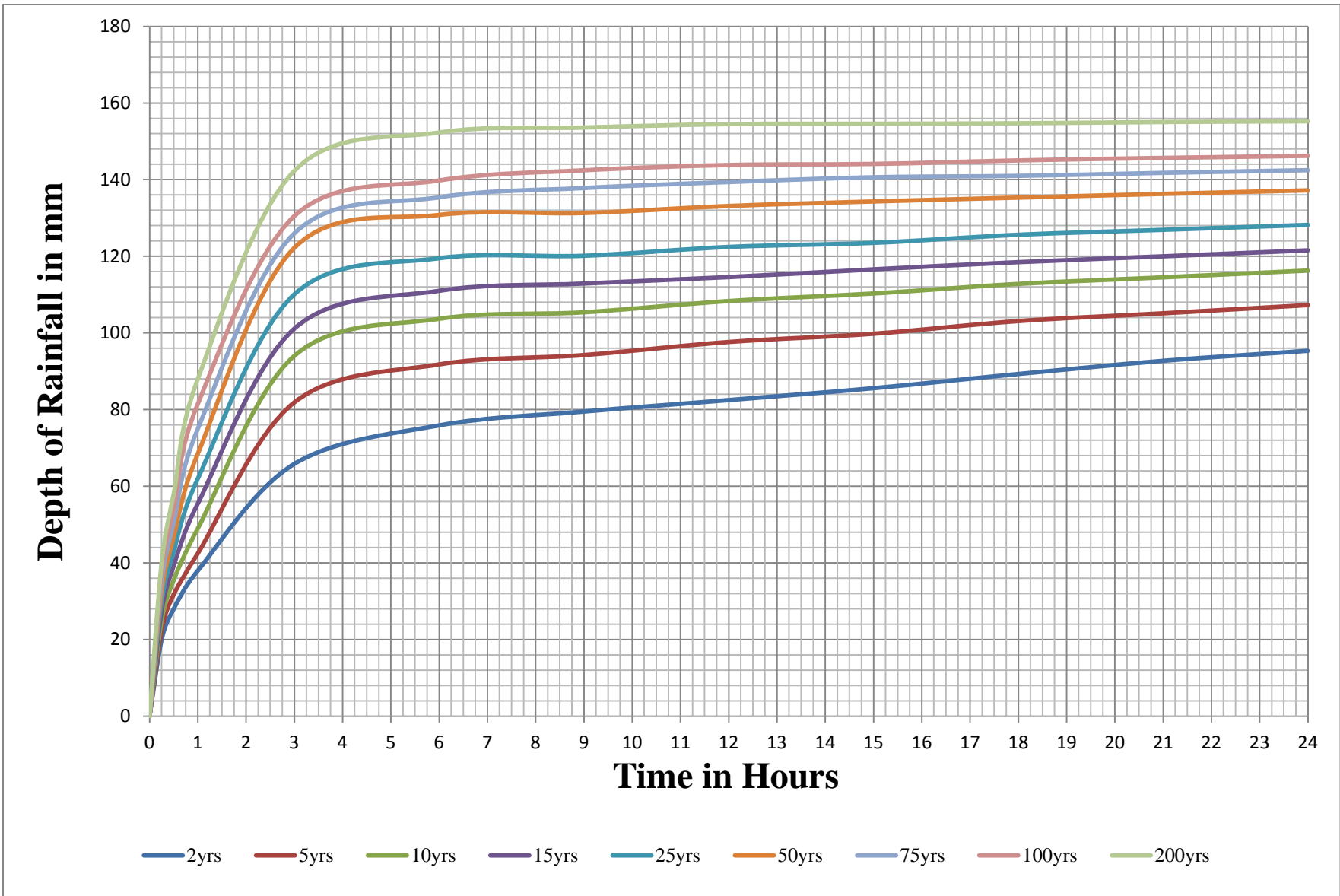


Figure 4.1 : Depth Duration Frequency Curves at Hulhule

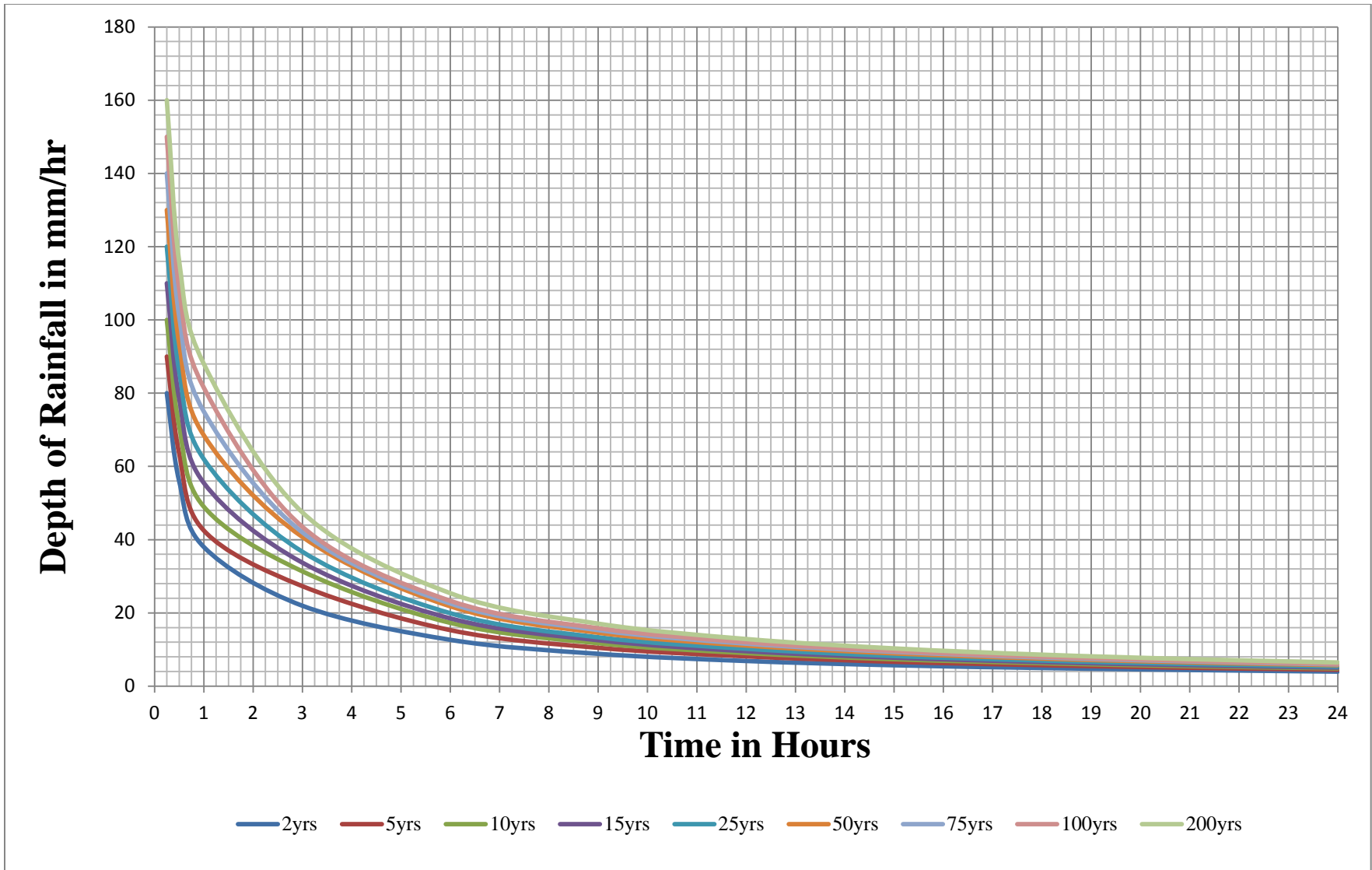


Figure 4.2 : Intensity Duration Curves at Hulhule

4.2.2 Development of intensity depth duration frequency curves for Kaadedhoo weather station

3 hourly rainfall values available for the above station were analyzed for durations of 3 hrs, 6 hrs, 9 hrs, 12 hrs, 15 hrs, 18 hrs, 21 hrs and 24 hrs. Also checked the maximum values from daily basis and for consecutive days. It was found that critical values are located within the rainfall values collected in 3 hrs intervals.

3 hourly rainfall data analysis were carried out to find out the monthly maximum values from 3 hrs to 24 hrs for monthly basis from January to December from 2000 to 2008 are shown in the **Tables 4.9 to 4.17**. It is to be noted that the maximum rainfall in the considered period for 3 hrs and 6 hrs durations are observed in July 2002. It was observed that the values observed in 2002 are outliers. Therefore statistics analysis has been carried out after removing values corresponding to year 2002. The observed annual maximum rainfall data are shown in **Table 4.18** and rainfall values with statistics are shown in **Table 4.19**.

Based on the above analysis monthly maximum has been calculated and analysis has been repeated for the balance nine years. Annual maximum rainfall depth duration is shown in **Table 4.20**. Depth duration frequency (DDF) curves developed by using Gumble (EV1) method is shown in **Table 4.21 and Figure 4.3**. DDF values for less than 3 hrs has been calculated after interpolating DDF curves developed for time intervals greater than 3 hrs.

Depth duration frequency curves have been used to develop intensity depth duration frequency curves (IDF) is shown in **Table 4.22 and Figure 4.4**.

It is to be noted that when the data which has been collected before year 2000 and after year 2008 for shorter duration is available, it can be used to improve IDF curves which have been already developed on the above station

The annual maximum 24 hour rainfall and rainfall intensities for short durations are shown in **Tables 4.9 to 4.17**, it can be seen that the maximum 24 hour rainfall during the last 21 years was 224.4mm. The frequency analysis of these rainfall data was done to obtain the rainfall depths for different frequencies. Due to a readily available set of data, rainfall intensities up to 100 years with durations 3, 6, 12,15,18,21 and 24 hrs could be calculated at each locations using frequency analysis.

Variation of Monthly Rainfall at Kaadedhdho is shown in **Table 4.23 and Figure 4.5**. This is shown in the annual variation of rainfall pattern in the island. Annual Rainfall at Kaadedhdho and Variation of Annual Rainfall Anomaly at Kaadedhdho is shown in **Table 4.24 and Figure 4.6**. This representation is useful to design proper water Management system in the islands. Seasonal Variation of Average Rainfall in relations to the monsoons at Kaadedhdho is shown in **Table 4.25**. Effective volume of rainfall derived from this table.

Normally 25 years of data is required for a reasonable analysis of this nature, but only five years of data were received and analysis has been completed for the same. Therefore by collecting rainfall data for shorter intervals can be used to improve the IDF curves which already developed for the Kaadedhoo weather station. It may be noted that short duration intensities are useful in assessing peak flows for small catchment, whilst for larger drainage areas storms of durations of one day and above would be more relevant.

Table 4.9 : Monthly Observed maximum rainfall depths at Kadeedhdhoo in year 2000 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
3 hrs	20	8.4	37.5	64.3	40	90.3	37.6	25.1	50.5	36	26.8	45.8	90.3
6 hrs	35.8	8.4	37.5	64.3	52	90.3	37.6	25.1	59.3	36	41.2	46.6	90.3
9 hrs	42.8	8.4	37.5	64.3	52.1	90.3	39.8	25.1	65.6	41.8	42.2	46.6	90.3
12 hrs	42.8	8.4	37.5	64.3	52.1	90.3	39.8	32.5	74.4	45.9	61.2	46.6	90.3
15 hrs	42.8	8.4	37.5	74.3	52.1	97.2	46.1	34.2	77.9	45.9	61.4	46.8	97.2
18 hrs	42.8	8.4	37.5	74.3	52.1	97.2	47.8	34.2	99.3	45.9	61.4	46.8	99.3
21 hrs	42.8	8.4	37.5	74.3	52.1	97.2	48.3	34.2	99.5	48.2	61.4	46.8	99.5
24 hrs	42.8	8.4	37.5	74.3	52.1	97.2	50	34.2	114.4	52.3	66.6	46.8	114.4

Table 4.10 : Monthly Observed maximum rainfall depths at Kadeedhdhoo in ear 2001 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
3 hrs	12.5	0	2.2	30	22.6	6.8	48.4	64.9	42	44.1	52.8	99	99
6 hrs	12.5	0	2.2	48.1	36.2	6.8	48.4	65.9	42.2	59.2	55	112.8	112.8
9 hrs	12.5	0	2.2	48.1	36.4	6.8	49	65.9	74	60.2	55	116.1	116.1
12 hrs	12.5	0	2.2	48.1	36.4	7.1	49	65.9	75.4	60.6	55	116.5	116.5
15 hrs	12.5	0	2.2	52.4	36.4	7.1	49.3	65.9	101.7	60.6	60.4	117.2	117.2
18 hrs	12.5	0	2.2	61.9	36.4	7.1	49.3	65.9	101.7	69	65.6	117.2	117.2
21 hrs	12.5	0	2.2	61.9	36.4	7.1	64.9	65.9	101.7	73	65.6	117.2	117.2
24 hrs	12.5	0	2.2	61.9	36.4	7.1	64.9	65.9	101.7	77.3	65.9	117.3	117.3

Table 4.11 : Monthly Observed maximum rainfall depths at Kadeedhdhoo in year 2002 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
3 hrs	17	74	34	70	64.4	19.1	164.3	23.2	38.4	61	28.5	90.4	164.3
6 hrs	30.3	74	34	71.2	74.4	34.8	190.8	25.4	59.6	74	43.5	98.7	190.8
9 hrs	30.3	74	38.2	74.1	79	34.9	195.9	25.4	78.4	88.3	52.5	98.7	195.9
12 hrs	33.8	74	38.7	74.2	79.1	36.2	198.7	25.4	100.8	113.3	71.5	98.7	198.7
15 hrs	33.8	74.5	39.3	74.2	79.5	36.2	208.2	29.3	106.8	114.6	73.5	107	208.2
18 hrs	33.8	74.5	39.3	74.2	79.5	37.2	216.5	30.4	107.6	114.7	73.7	108.6	216.5
21 hrs	33.8	74.5	39.6	74.2	79.5	45	221.6	30.9	107.6	114.7	82.3	108.8	221.6
24 hrs	35.1	74.5	40.1	88.5	79.5	45.1	224.4	30.9	107.6	114.7	84.3	108.8	224.4

Table 4.12 : Monthly Observed maximum rainfall depths at Kadeedhdhoo in year 2003 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
3 hrs	27.5	0	12.7	41.3	32	38.5	60	49.7	10.1	21.2	58	49.7	60
6 hrs	28	0	12.7	47.8	32	45.4	104.3	60.6	14.6	24.1	61.7	60.6	104.3
9 hrs	28	0	14.7	49.6	41.1	45.5	108.5	64.1	17.7	24.3	62.2	64.1	108.5
12 hrs	28	0	14.7	56.1	43.6	45.5	108.5	84.6	17.7	29	62.5	84.6	108.5
15 hrs	28	0	14.7	57.9	43.6	68.1	108.5	84.7	17.7	41	62.5	84.7	108.5
18 hrs	31.2	0	14.7	58.7	49.9	75	108.5	84.7	20.6	41.2	62.7	84.7	108.5
21 hrs	31.5	0	14.7	58.7	49.9	75	108.5	84.7	20.6	41.2	64.3	84.7	108.5
24 hrs	32.1	0	14.7	58.7	49.9	75	108.5	84.7	20.6	53.5	64.8	84.7	108.5

Table 4.13 : Monthly Observed maximum rainfall depths at Kadeedhdhoo in year 2004 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
3 hrs	69.0	8	5.2	26.5	28.6	21.2	84.6	69.1	29.5	57.4	102.6	74	102.6
6 hrs	69.0	10.9	5.2	53	35.5	21.2	91.4	69.7	36.8	58.7	102.9	74	102.9
9 hrs	69.0	11	5.2	54.4	36.2	21.8	91.4	71	36.8	58.7	102.9	74	102.9
12 hrs	74.4	11	5.2	54.4	36.2	24.6	91.4	72.2	40.1	58.7	103.4	74	103.4
15 hrs	74.4	11	5.2	54.4	36.5	24.8	95.8	72.9	40.1	59.9	103.7	74	103.7
18 hrs	81.5	11	5.2	55.8	37.1	24.8	99.7	78.1	41.3	97.9	104.3	74	104.3
21 hrs	81.5	11	5.2	61.6	37.1	24.8	100.9	78.1	68.2	97.9	104.3	74	104.3
24 hrs	81.5	11	5.2	63	37.4	24.8	101.1	78.1	74	97.9	104.3	74	104.3

Table 4.14: Monthly Observed maximum rainfall depths at Kadeedhdhoo in year 2005 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
3 hrs	58.8	37	17.8	0	44.7	77	62.2	52	25	33	9.4	28.3	77
6 hrs	59.7	67.5	18.2	0	62.2	77.1	62.2	52	25	47.9	9.4	28.3	77.1
9 hrs	59.7	67.6	18.2	0	69.7	77.1	62.2	52	25	50.9	10	28.3	77.1
12 hrs	59.7	67.6	18.2	0	69.7	80.6	86.8	53.2	25	52.3	12.2	41.4	86.8
15 hrs	59.7	67.6	18.2	0	71.7	80.7	87	53.2	25	53.7	12.2	41.4	87
18 hrs	59.7	67.6	18.2	0	71.7	80.7	88.4	53.2	25	53.8	12.2	41.5	88.4
21 hrs	59.7	67.6	18.2	0	71.7	80.7	88.4	53.2	32.3	56.5	12.2	41.5	88.4
24 hrs	59.7	80.1	18.2	0	71.7	80.7	97.6	53.2	35.6	57.4	12.2	41.8	97.6

Table 4.15: Monthly Observed maximum rainfall depths at Kadeedhdhoo in year 2006 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
3 hrs	71	44.5	12.2	29.7	9.3	28	37.1	20.2	24.3	46	93	65.5	93
6 hrs	78.7	60	12.2	29.7	9.4	54.6	37.1	20.2	27.1	58.9	108.5	69	108.5
9 hrs	78.8	99	12.2	29.7	10.9	55.2	37.1	23.4	27.1	58.9	134.7	81.9	134.7
12 hrs	81.2	104.5	12.9	29.7	11.5	59.3	37.1	24.6	32.4	58.9	134.9	85.4	134.9
15 hrs	81.2	104.5	13.6	34.8	13.5	59.9	37.1	31.6	40.3	59.4	134.9	85.4	134.9
18 hrs	81.2	104.5	13.6	34.8	16.3	60	37.1	36.9	46.5	59.4	139.3	85.4	139.3
21 hrs	101.7	104.5	15.7	34.8	16.3	60	37.1	43.6	46.5	59.4	139.5	86.3	139.5
24 hrs	103.1	104.5	15.7	34.8	16.3	60.3	37.1	44.8	46.5	59.4	139.7	86.3	139.7

Table 4.16 : Monthly Observed maximum rainfall depths at Kadeedhdhoo in year 2007(mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
3 hrs	112	0.5	5.9	28.5	49	52	25.4	20	73.2	48.7	34.5	76.3	112
6 hrs	131.7	0.5	5.9	35.1	51	57.5	26.2	20.5	78	85.4	43.5	108.7	131.7
9 hrs	132.9	0.5	5.9	35.2	62.7	59.6	26.2	37.1	83.2	93.3	43.5	148.7	148.7
12 hrs	141.6	0.5	6.2	38.7	74.2	102.1	26.2	37.1	93.4	96.1	43.5	164.8	164.8
15 hrs	161.3	0.5	6.3	39.4	74.5	107.6	26.2	37.1	94.5	96.1	43.5	182.4	182.4
18 hrs	162.5	0.5	6.7	40.2	77.9	107.8	40.1	39.7	94.8	96.1	43.5	191.5	191.5
21 hrs	163.3	0.5	6.7	56.3	89.4	107.8	40.9	39.7	94.8	114.1	43.5	197.4	197.4
24 hrs	163.3	0.5	6.7	56.4	95.2	107.8	40.9	39.7	94.8	122	43.5	215	215

Table 4.17 : Monthly Observed maximum rainfall depths at Kadeedhdhoo in year 2008 (mm)

Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
3 hrs	66.8	11.7	14.1	22.7	40.2	42.3	36.8	21	13.4	52.3	36.8	55.6	66.8
6 hrs	70.2	13.6	14.7	33.7	54.2	52.3	37.7	21.6	16.4	62.9	42.1	70.2	70.2
9 hrs	71.1	13.6	14.7	39.2	63.4	52.3	48.8	34.4	23.2	71.1	52.7	76.2	76.2
12 hrs	72.4	15	16.7	42	64.7	52.3	54.3	34.4	23.2	74.3	57.5	104.7	104.7
15 hrs	74.7	16.9	18.6	47.5	72.8	52.3	70.1	34.4	23.2	75.9	59.6	110.3	110.3
18 hrs	83.9	16.9	19.2	50.3	73.3	52.3	70.1	34.4	23.2	76.4	59.9	115.1	115.1
21 hrs	88.3	16.9	19.3	58	73.6	52.3	70.1	34.4	23.2	76.4	64.3	115.5	115.5
24 hrs	94.2	16.9	32	63.5	73.6	52.3	70.1	39.2	23.4	76.9	64.7	115.8	115.8

Table 4.18 : Annual Observed Maximum Rainfall Depths at Kadeedhdhoo (mm)

Year	Duration hours							
	3 hrs	6 hrs	9 hrs	12 hrs	15 hrs	18 hrs	21 hrs	24 hrs
2000	90.3	90.3	90.3	90.3	97.2	99.3	99.5	114.4
2001	99.0	112.8	116.1	116.5	117.2	117.2	117.2	117.3
2002	164.3	190.8	195.9	198.7	208.2	216.5	221.6	224.4
2003	60.0	104.3	108.5	108.5	108.5	108.5	108.5	108.5
2004	102.6	102.9	102.9	103.4	103.7	104.3	104.3	104.3
2005	77.0	77.1	77.1	86.8	87.0	88.4	88.4	97.6
2006	93.0	108.5	134.7	134.9	134.9	139.3	139.5	139.7
2007	112.0	131.7	148.7	164.8	182.4	191.5	197.4	215.0
2008	66.8	70.2	76.2	104.7	110.3	115.1	115.5	115.8
Maximum	164.3	190.8	195.9	198.7	208.2	216.5	221.6	224.4
Minimum	60	70.2	76.2	86.8	87	88.4	88.4	97.6
Average	96.1	109.8	116.7	123.2	127.7	131.1	132.4	137.4
Stand Deviation	30.7	35.6	38.4	37.0	41.0	44.0	46.3	48.1

Table 4.19: Annual Observed Maximum Rainfall Depths at Kadeedhdhoo with Statistics (mm)

Year	Duration hours							
	3 hrs	6 hrs	9 hrs	12 hrs	15 hrs	18 hrs	21 hrs	24 hrs
2000	90.3	90.3	90.3	90.3	97.2	99.3	99.5	114.4
2001	99	112.8	116.1	116.5	117.2	117.2	117.2	117.3
2002								
2003	60	104.3	108.5	108.5	108.5	108.5	108.5	108.5
2004	102.6	102.9	102.9	103.4	103.7	104.3	104.3	104.3
2005	77	77.1	77.1	86.8	87	88.4	88.4	97.6
2006	93	108.5	134.7	134.9	134.9	139.3	139.5	139.7
2007	112	131.7	148.7	164.8	182.4	191.5	197.4	215
2008	66.8	70.2	76.2	104.7	110.3	115.1	115.5	115.8
Maximum	112	131.7	148.7	164.8	182.4	191.5	197.4	215
Minimum	60	70.2	76.2	86.8	87	88.4	88.4	97.6
Average	87.6	99.7	106.8	113.7	117.7	120.5	121.3	126.6
Stand Deviation	16.932	18.621	24.314	23.858	27.795	30.251	31.983	35.362

Table 4.20: Depth Frequency Table at Kaadeedhdhoo (mm)

No	Year	Duration				
		24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
1	1994	132.7	145.2	170.7	189.8	249.4
2	1995	131.6	245.0	261.5	286.0	290.4
3	1996	67.6	75.7	101.5	111.0	141.5
4	1997	83.7	127.4	160.2	203.2	217.6
5	1998	153.4	159.0	179.2	201.1	209.6
6	1999	60.0	103.4	106.7	144.7	145.1
7	2000	103.3	134.2	176.6	203.1	217.1
8	2001	113.6	133.5	160.1	186.3	195.1
9	2002	219.8	227.9	235.5	240.6	244.2
10	2003	104.3	108.5	119.1	151.3	165.6
11	2004	103.7	118.3	176.8	195.9	219.0
12	2005	88.4	104.9	133.7	145.8	176.8
13	2006	113.3	155.0	197.1	211.9	220.1
14	2007	199.1	263.5	310.2	312.7	339.1
15	2008	111.0	142.8	149.0	197.4	215.8
16	2009	98.4	140.7	161.0	163.0	173.1
17	2010	94.1	135.0	135.6	161.5	161.8
18	2011	186.3	211.9	218.6	224.2	227.3
19	2012	130.4	194.6	203.9	216.0	224.8
Maximum		219.8	263.5	310.2	312.7	339.1
Minimum		60.0	75.7	101.5	111.0	141.5
Average		120.8	154.0	176.7	197.1	212.3
Stand Deviation		41.598	49.982	51.502	47.043	47.285

Table 4.21: Depth Duration Frequency Table

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 4.22 : Intensity Duration Frequency Table

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

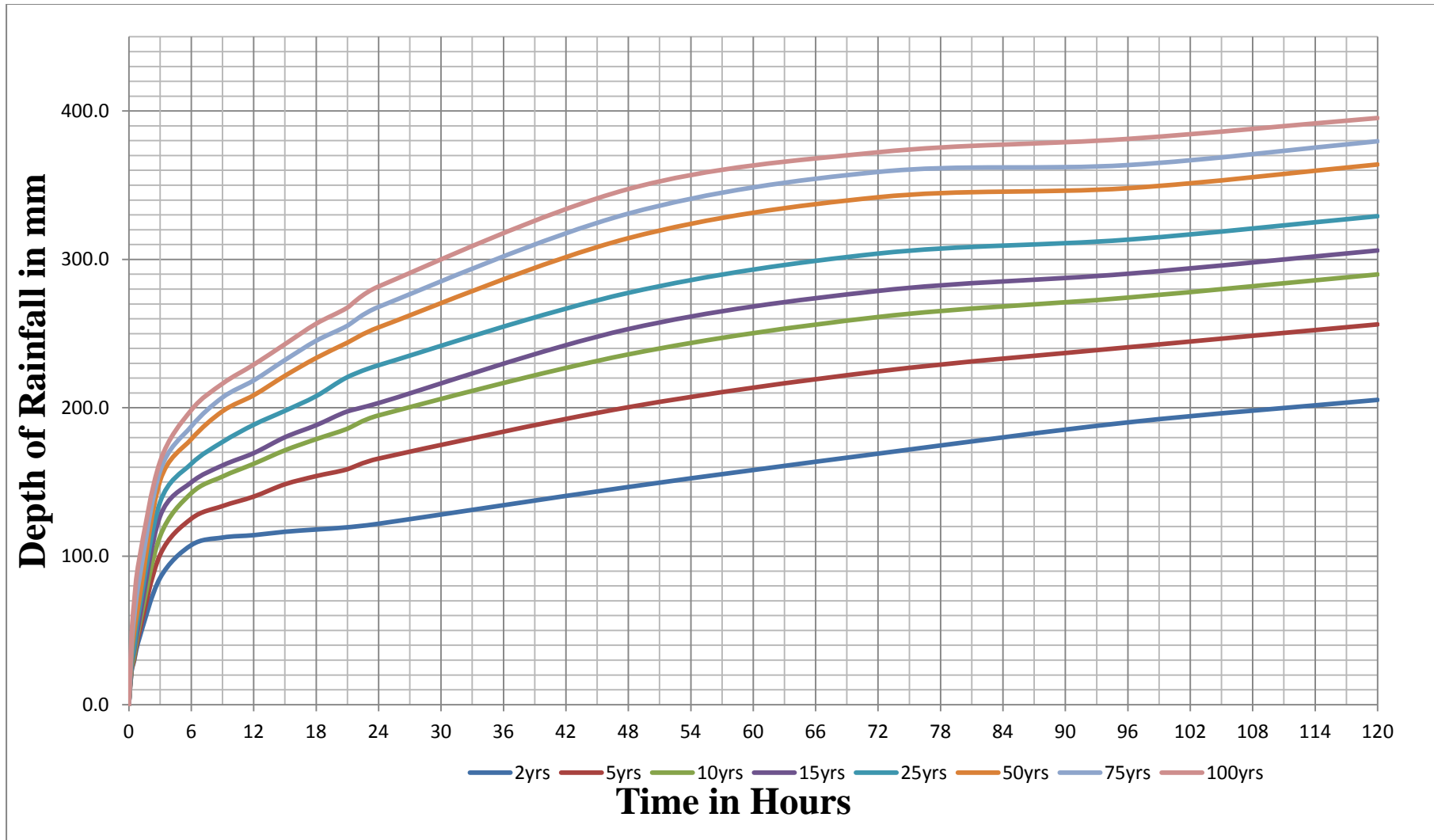


Figure 4.3 : Depth Duration Frequency Curves at Kaadedhdoo

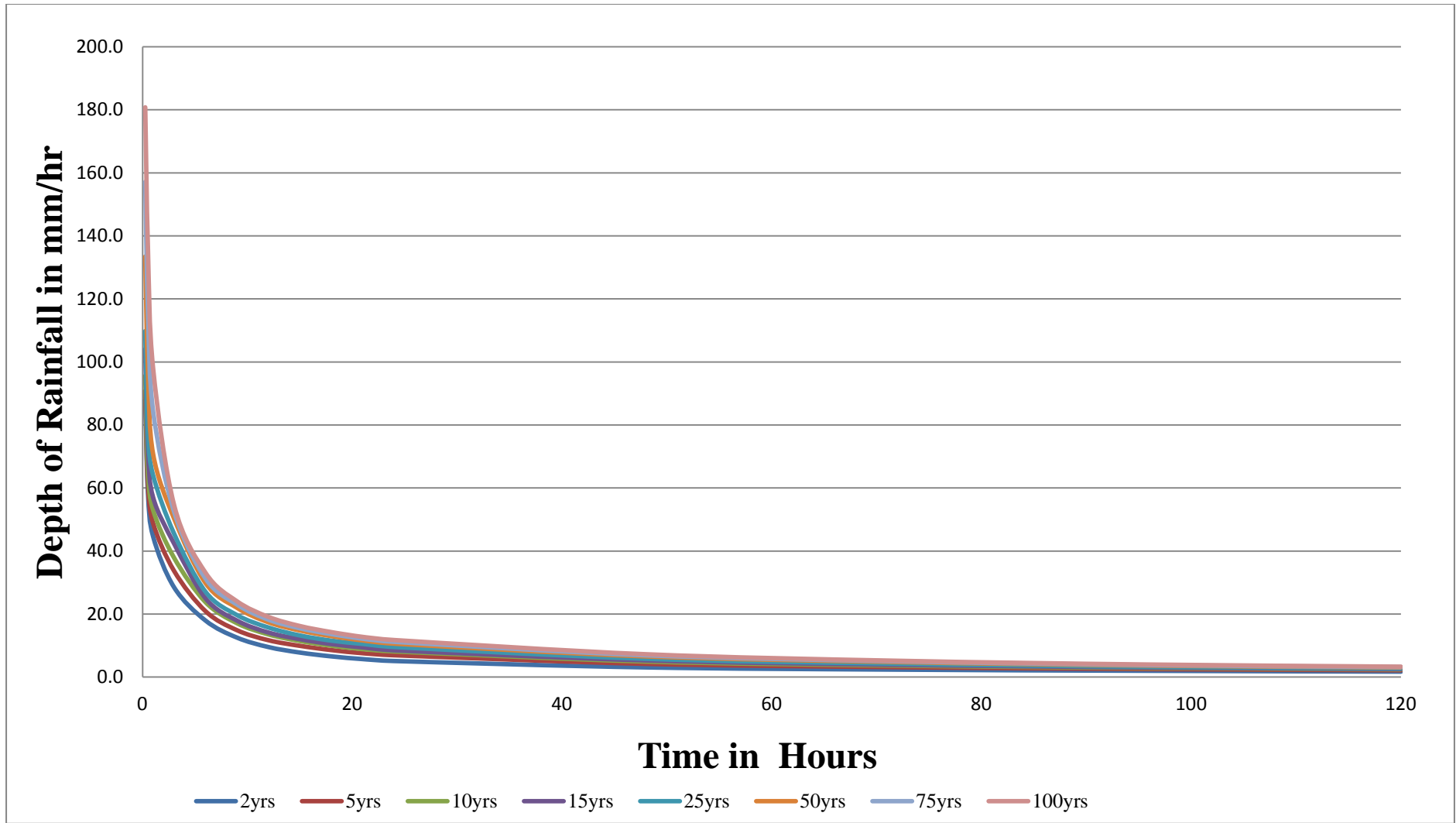


Figure 4.4 : Intensity Duration Curves at Kaadedhdoo

Table 4.23: Variation of Monthly Rainfall at Kaadedhdho (mm)

No	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	1994	287.3	22.5	7.5	262.7	418.9	303.2	104.6	114.6	369.6	208.4	480.0	479.8	3059.1
2	1995	168.7	230.4	76.4	314.8	331.8	325.3	40.8	313.1	188.7	406.7	153.4	89.4	2639.5
3	1996	77.3	78.4	50.8	55.5	276.8	126.7	262.6	303.6	225.7	297.8	295.8	86.6	2137.6
4	1997	59.7	41.5	239.0	68.9	370.7	59.6	157.6	235.5	341.1	211.9	56.1	290.5	2132.1
5	1998	281.9	52.6	132.5	106.3	418.0	135.9	171.1	133.6	65.5	251.6	135.4	150.5	2034.9
6	1999	312.4	54.7	93.5	189.3	151.2	123.9	69.2	103.6	138.7	149.4	214.0	214.7	1814.6
7	2000	101.4	18.3	65.6	144.2	121.6	375.9	167.7	172.8	426.1	166.7	351.5	161.9	2273.7
8	2001	29.9	0.0	6.6	218.7	91.4	34.7	191.2	246.8	295.1	273.6	296.1	245.9	1930.0
9	2002	105.6	199.9	133.1	223.2	215.2	267.3	389.2	113.1	286.5	361.1	217.8	469.5	2981.5
10	2003	103.6	0.0	52.5	184.3	204.7	222.7	220.7	130.3	110.3	125.2	185.7	403.6	1943.6
11	2004	259.2	24.0	5.2	171.3	100.9	97.1	180.8	222.9	217.7	301.4	469.2	265.9	2315.6
12	2005	181.3	124.6	18.8	85.5	210.0	289.0	226.7	161.6	105.9	434.2	30.5	85.8	1953.9
13	2006	245.5	248.9	51.3	145.8	89.1	117.7	134.6	99.3	113.9	196.2	624.9	423.6	2490.8
14	2007	340.2	0.7	10.2	147.8	189.2	239.8	164.6	97.2	268.8	380.9	155.3	558.5	2553.2
15	2008	243.6	21.2	60.7	189.3	234.8	152.7	190.4	173.7	73.0	278.9	272.7	260.1	2151.1
16	2009	242.7	50.0	60.5	124.3	307.3	32.5	83.2	318.1	180.8	188.0	155.2	280.6	2023.2
17	2010	150.3	35.9	80.5	179.7	129.6	74.1	257.7	264.6	293.2	70.7	114.3	24.0	1674.6
18	2011	21.7	5.1	54.0	120.1	219.2	36.8	40.2	140.2	78.5	275.1	303.5	268.8	1563.2
19	2012	7.7	165.4	41.8	51.6	181.5	73.0	150.3	121.4	313.9	336.5	250.2	122.2	1815.5
Maximum		340.2	248.9	239.0	314.8	418.9	375.9	389.2	318.1	426.1	434.2	624.9	558.5	3059.1
Minimum		7.7	0.0	5.2	51.6	89.1	32.5	40.2	97.2	65.5	70.7	30.5	24.0	1563.2
Average		169.5	72.3	65.3	157.0	224.3	162.5	168.6	182.4	215.4	258.6	250.6	256.9	2183.6
Standard Deviation		103.2	78.7	54.9	67.9	102.1	106.1	82.2	74.9	106.8	96.2	147.0	148.3	398.1

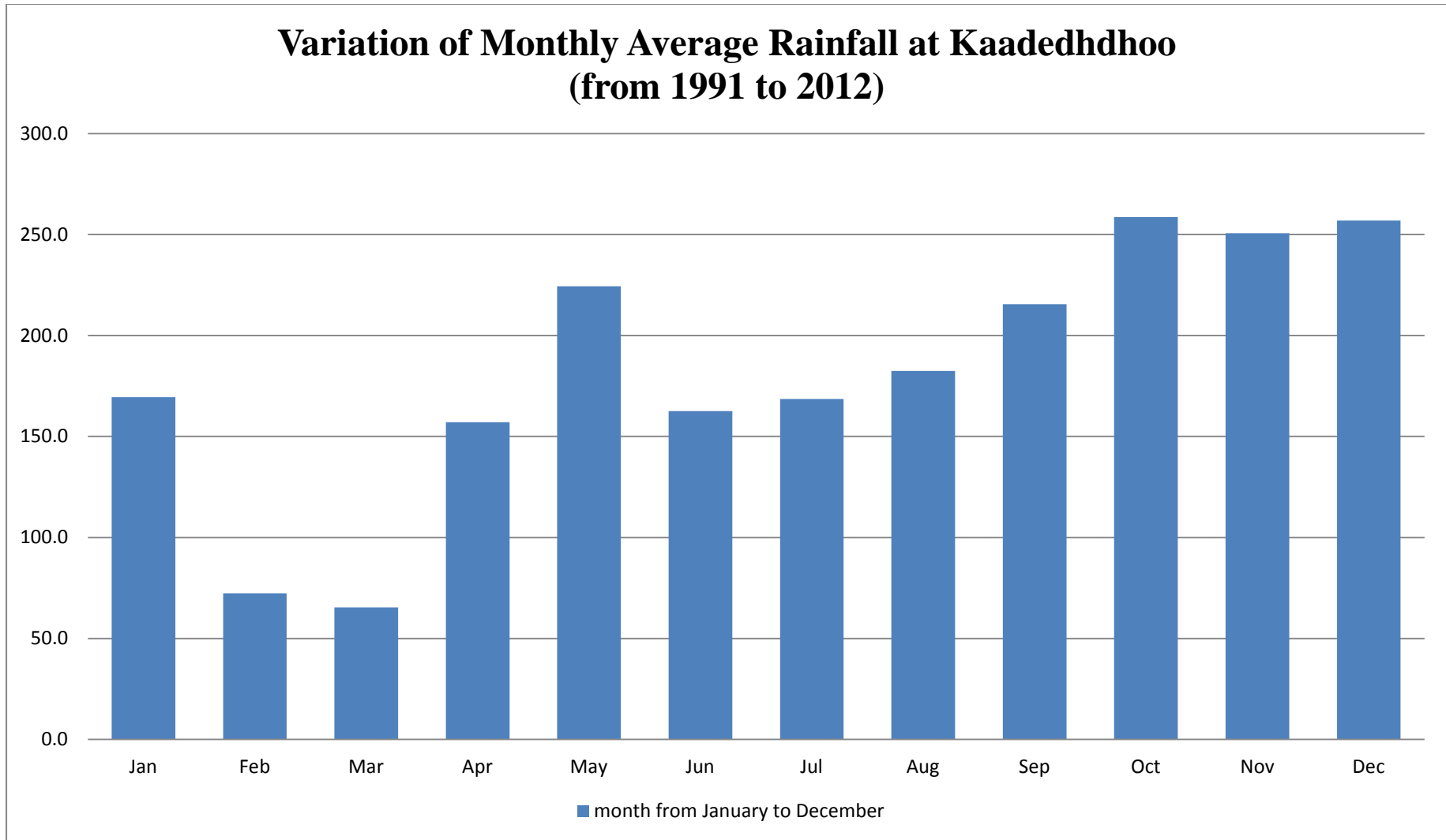


Figure 4.5 : Monthly Average Rainfall Variation at Kaadedhdho

Table 4.24 : Annual Rainfall at Kaadedhdhoo (mm)

No	Year	Rainfall in mm
1	1994	3059.1
2	1995	2639.5
3	1996	2137.6
4	1997	2132.1
5	1998	2034.9
6	1999	1814.6
7	2000	2273.7
8	2001	1930.0
9	2002	2981.5
10	2003	1943.6
11	2004	2315.6
12	2005	1953.9
13	2006	2490.8
14	2007	2553.2
15	2008	2151.1
16	2009	2023.2
17	2010	1674.6
18	2011	1563.2
19	2012	1815.5
Maximum		3059.1
Minimum		1563.2
Average		2183.6
Standard Deviation		398.1

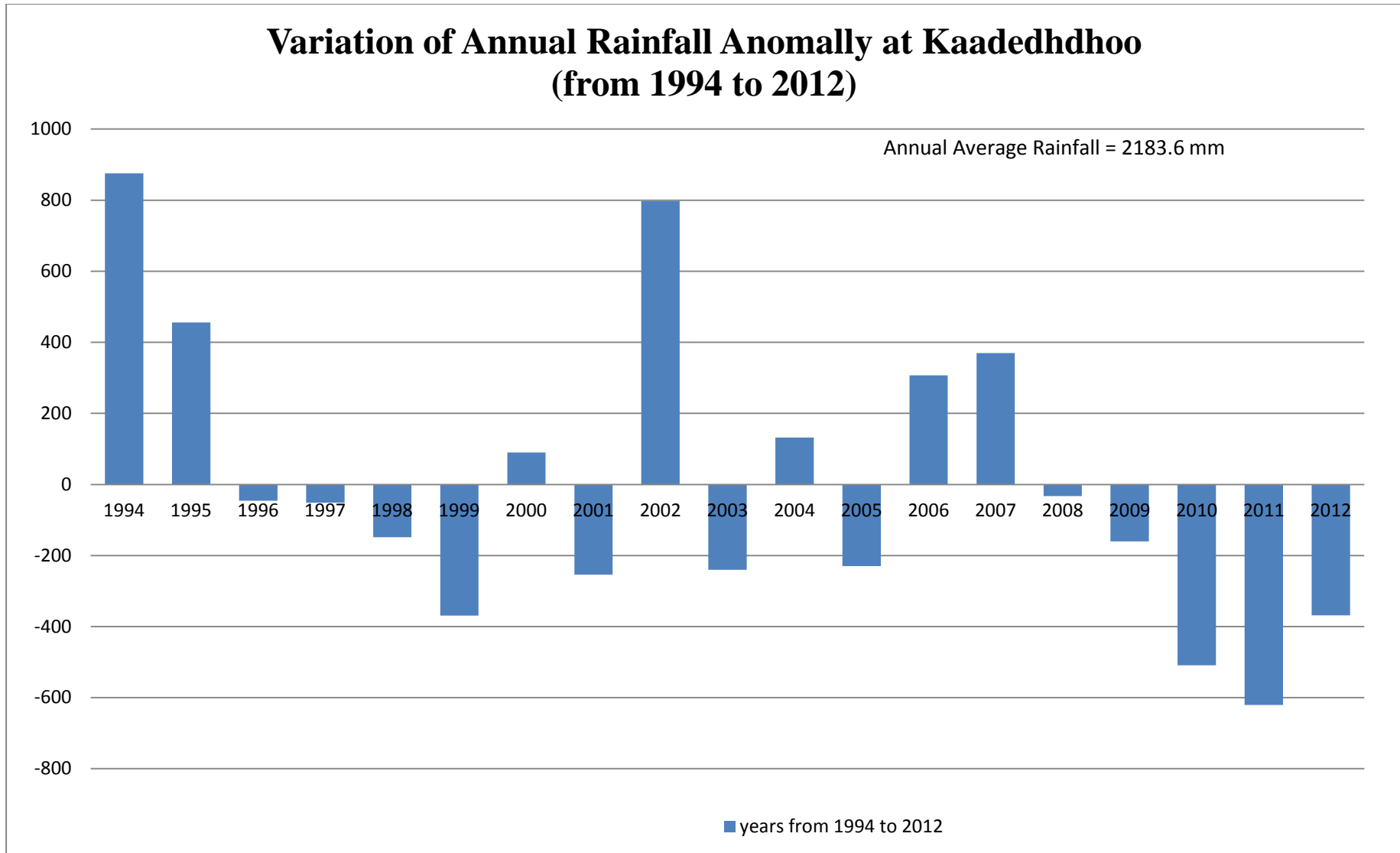


Figure 4.6 : Variation of Annual Rainfall Anomaly at Kaadedhdhoo

Table 4.25: Seasonal Variation of Average Rainfall at Kaadedhdhoo

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

5.0 Variation of sea water levels

The variation of sea water level during high tide and low tide is important as the excess storm water from all the basins eventually discharges to the sea. The exit level of all the canals will be designed in such a way that water level at the exit is kept at the low tide level. The flap gates also will be provided to close during the high tides and to open during the low tides. (See Figure – 5.1 and Table 5.1)

Flap Gates



24" Heavy Duty Flap Gate

Applications

- Flood Control
- Municipal Projects
- Farm Levees
- Sewer Outfalls
- Industrial Waste Lines
- Water and Sewage Treatment Plants
- Tidal Drainage
- Irrigation Systems
- Pump Discharge Control

Description

Hydro Gate flap gates are made of cast iron or ductile iron, depending on the type of service. A small differential pressure on the back of the gate causes it to open automatically to allow discharge through levees, sewer lines or drainage conduits. When water on the face side of the gate rises above water on the back side, the gate closes automatically to prevent backflow.

Flap gates are equipped with flat-back seats for attaching to wall thimbles, new concrete headwalls, existing walls or pipe flanges. The seat or frame of the flap gate is attached to a wall or pipe flange and forms the opening through which water passes. Since the gate opens or closes automatically, a mechanical lifting device is not necessary.

Automatic drainage gates must be kept clean if they are to function correctly. The hinged flap acts as a natural skimmer to cause timber, logs or trash to catch between the flap and the seat at low flow. Periodic inspection and cleaning should be scheduled when the water flowing through the flap gate carries floating material.

To make the gate more self-cleaning, it should be mounted 12 to 18 in. above the apron in front of the gate. This allows room at the bottom for floating material to work its way out and makes the gate flap somewhat self-cleaning.

Seat (Frames)

A seat (or frame) is a one-piece casting. The seating face is cast and machined at an angle off vertical so that the hinged cover has a horizontal force component to completely seat the gate by gravity.

Corrosion-resistant seating faces are pneumatically impacted into dovetail grooves for heavy-duty gates. All seating faces (above 4" diameter) are machined flat and to a 63 micro-inch finish.

When rubber seats are specified, the gurdrop cross-section rubber seal is locked into a deep dovetail groove in the seat.

Flaps (Covers)

Flaps are iron castings of reinforced flat plate design. Reinforcing ribs (both horizontal and vertical) are cast integrally along with bosses for the hinges.

Corrosion-resistant seating faces are attached as described in the previous section for frames.

Figure 5.1 : Flap Gate

Nodes

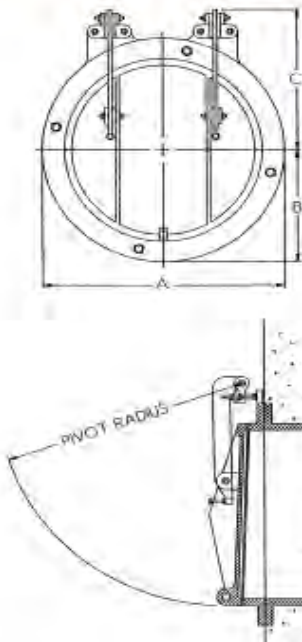
Outfalls:

- ▣ Downstream boundary condition of the model.
- ▣ Properties:
 - ▣ invert elevation
 - ▣ boundary condition type and stage description
 - ▣ presence of a flap gate to prevent backflow through the outfall.



Figure 5.2 : Flap Gate

Dimensional Data



Model 50C Round Opening for Heads to 50 Ft

Opening Size Dia. (In.)	Dimensions (In.)			Pivot Radius (In.)	Opening Size Dia. (In.)	Dimensions (In.)			Pivot Radius (In.)
	A	B	C			A	B	C	
4	9.00	4.50	5.25	7.31	30	38.75	19.38	23.25	38.50
6	11.00	5.50	6.25	11.75	36	46.00	23.00	27.50	45.50
8	13.50	6.75	7.50	14.00	42	53.00	26.50	32.50	53.50
10	16.00	8.00	9.75	15.25	48	59.50	29.75	37.75	61.75
12	19.00	9.50	10.25	16.75	54	66.25	33.25	39.75	67.25
14	21.25	10.63	12.50	19.75	60	73.00	36.50	46.00	76.00
15	22.25	11.13	12.50	20.31	66	80.00	40.00	50.00	83.00
16	23.50	11.75	13.00	21.25	72	86.50	43.25	54.25	90.00
18	24.75	12.50	15.75	25.00	78	93.50	46.75	58.25	97.00
20	27.50	13.75	18.25	26.25	84	100.00	50.00	62.25	104.25
21	28.00	14.00	16.50	27.38	90	106.50	53.25	65.50	111.25
24	32.00	16.00	19.25	31.25	96	113.25	56.63	65.50	117.25
27	34.75	17.38	21.25	36.00	108	125.00	62.50	75.13	129.75

Table 5.1: Dimensional Data

5.1 Khulhudhuffishi coastline:

Khulhudhuffishi 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 reclamation.

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

According to the Admiralty tide tables, Tidal constituents are available at Ihavadhoo (**Table 5.2**) which is only about 40km North from Khulhudhuffishi. Therefore the tide that can be generated for Ihavadhoo is applicable for Khulhudhuffishi.

Table 5.2: Tidal Constituents at Ihavadhoo

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

According to the generated tide (**Figure 5.2**) with mean sea level at 0.68 m above the Chart Datum, tidal range is about 1.1 m.

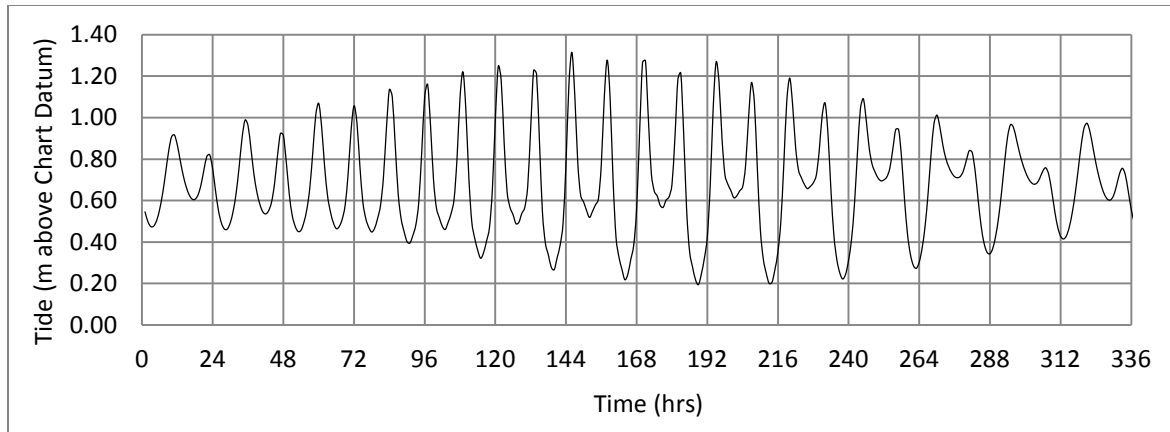


Figure 5.3 : Typical tidal levels at Khulhudhuffishi Island

5.2 Thinadhoo Coastline:

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

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

According to the Admiralty tide tables, Tidal constituents are available at Addhoo atoll (Table 5.3) which is only about 130km South from Thinadhoo. Therefore the tide that can be generated for Addhoo atoll is applicable for Thinadhoo.

Table 5.3: Tidal Constituents at Addhoo atoll

Tidal constituent	Phase (deg.)	Amplitude (m)
M2	37	0.30
S2	76	0.18
K1	75	0.09
O1	86	0.05

According to the generated tide (**Figure 5.3**) with mean sea level at 0.66 m above the Chart Datum, tidal range is about 1.5m.

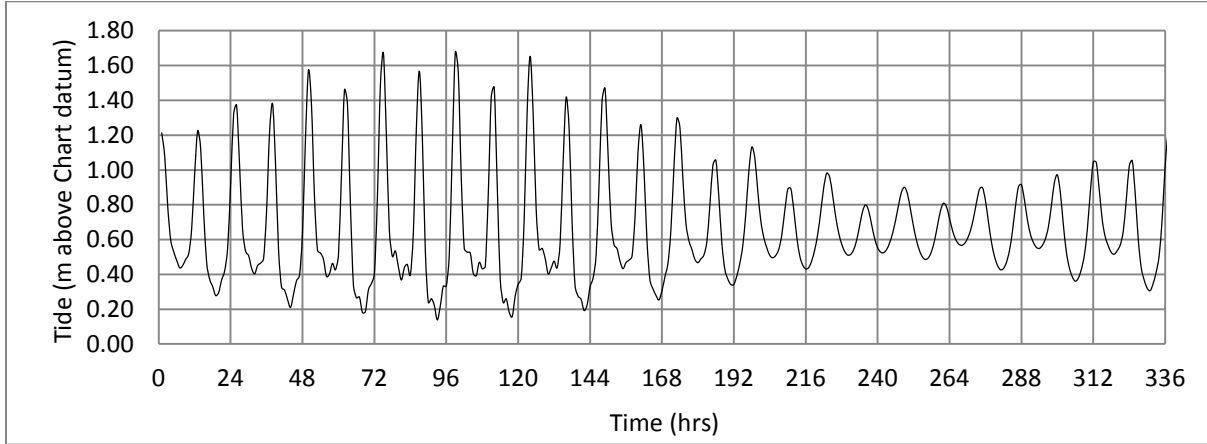


Figure 5.4 : Typical tidal levels at Thinadhoo Island

6.0 Methodology and design consideration

After the first meeting for the familiarization of the project in the later part of October, a discussion was held at MWSC office with engineering manager and his engineers. First site visits has been carried out with following officials from 30th September to 3rd October at H Dh. Kulhudhuffushi Island

1. Mr. Abdulla Waheed - Ministry of Environment and Energy
2. Mr. Mohamed Imrean Aina - Manager, Planning & Design
3. Mr. Mohomaed Adam - Engineer , Planning
4. Mr. P.P. Ghananapala - Civil Engineer , ECL

Findings are as follows;

- Based on the discussions with island council and some of the residents, it was found that storm water issues was not that much severe in most parts of the island, although some parts had issues.(**Refer Figure 1.1**)
- Type of drainage system in the newly asphalted road may not be suitable for the current condition (Pipes from road side gutters are connected to a soak pit laid at the center of the road which was covered with asphalt and inaccessible for maintenance purpose). 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 raises up to ground level and the depth of puddles were more than 600mm in the most severely affected areas(**Refer Figure 1.1**)
- 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. (**Refer Figure 6.1**)
- There are available empty lands for construction of underground storages at various locations in the island (**Refer Figure 1.2**)
- A large area of marsh land is now desiccated due to the longer dry period and will be over flowed during rainy season according to the information provided by island people.
- Existing wells and water harvesting methods also inspected.

Second site visit has carried out with the following officials from 6th October to 9th October at **G Dh Thinadhoo Island**.

- 1 Ms. Najfa shaheem Razee – Project Manager , Ministry of Environment and Energy
- 2 Mr.Mohomad Dmrean Adna - Manager, Planning & Design
- 3 Mr. Mohomaed Adam - Engineer , Planning
- 4 Mr. P.P.Ghananapala - Civil Engineer, ECL

Findings are as follows;

- Based on the discussion with island council, it was found that storm water flooding is severe in some parts of the island.
- There are outlets without flap gates to control safe water intrusion. Back water will take place during high tide.
- At the lowest areas of the island, flooding occurs during rainy season and puddles remain for 2 to 3 weeks. In these areas, ground water level raises up to ground level and the depth of puddles were more than 500mm in the most severed areas. (**Refer Figure 1.3**)
- Natural slope of the island has a gradient from natural beach side from West to East which will provide an easy runoff along the road towards newly constructed key wall side. (**Refer Figure 6.2**)
- There are enough open space available to construct underground storage tank ground at various location in the island (**Refer Figure 6.2**)
- Existing wells and water harvesting methods also inspected.

After having inspections and discussions with the relevant officials, it was decided to establish the following methodologies and criteria:

1. In the absence of distinct names to identify different sub basins, SWMM model was used to identify effective sub basins (**Refer Figure 6.3**)
2. Design return period for hydraulic calculation will be considered as 5 years
3. Consideration of design Horizon as 2030

By considering future infrastructure developments in Islands, design horizon taken as 2030. Land use map from year 2012 received from previous study have been updated to year 2030 to represent the existing conditions. The main parameter from the land use maps which the SWMM and Rational methods use is the runoff coefficient. It was decided to apply the runoff coefficients dependent on following land use types. 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 water management aspect and not to worsening the flooding situation in the future.
 - The level of urbanization is assessed through the degree of imperiousness on sub basin level and increases the percentages.
 - The drainage capacity is represented through the present flood inundation pattern based on joining criteria.
4. As there is no intention of providing pumps, the drainage will be by gravity alone. But sump will be provide at the sea outlet to use, if need arises for pumping
 5. Low elevated levels and roads will be considered for possible minimum filling after carrying out value engineering
 6. There are several locations acting as ponding areas during rainy period. Some of these can be improved to increase detention capacity. Study will be carried out to study the functioning of these ponding areas to verify whether which locations are vulnerable to storm water during rainy period.
 7. 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.
 8. Longitudinal and cross section of the roads will be prepared as per the design requirements.
 9. For drains having no bed gradient (zero) due to topographical conditions will be designed for minimum velocity after model analysis. (**Refer Figure 6.3**)
 10. For concrete drain, the manning function factor of 0.015 and earthen drain 0.025 will be assumed.
 11. Rational method and SWMM model will be used to calculate the final output of discharge having considered the items included in water management system (**Refer Figure 6.4**)
 12. A rainfall depth duration curves have been already developed by analyzing the observed rainfall record at Hulhule and Kaadedhdhoo weather stations. These curves will be used to design a design rainfall event for each blocks and compare it with the observed rainfall event at the above weather stations
 13. Construction of underground tank is very essential in this project due to environmental reasons and possibility of constructing maximum no of tanks will be considered. (**Refer Figure 6.5**)
 14. For cross sections, rectangular shape for drains in city areas and traphizoidal section for canals in open areas and closed conduit with gully grating will be considered.
 15. Underground tank will be constructed appropriately from model output (SWMM)
 16. Guide lines for rainfall harvesting and ground water recharge methodology will be established for public and private buildings after finalization of design parameters subjected to model calibration and verification.

Storm Water Flow Pattern of Kulhudhuffushi

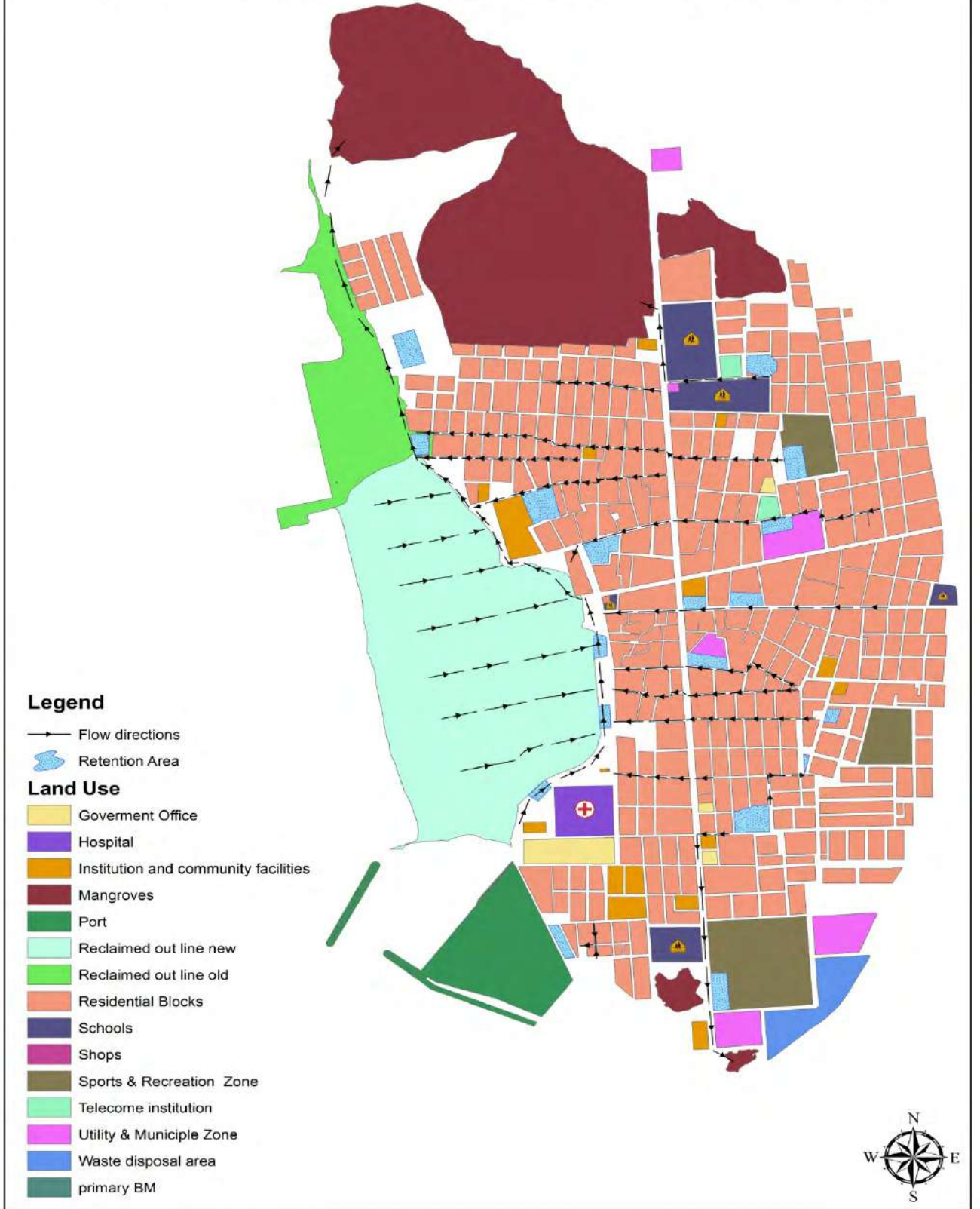


Figure No 6.1: Storm Water pattern of Kulhudhuffushi

Storm Water Flow Pattern of Thinadhoo Island



Figure No 6.2: Storm Water pattern of Thinadhoo

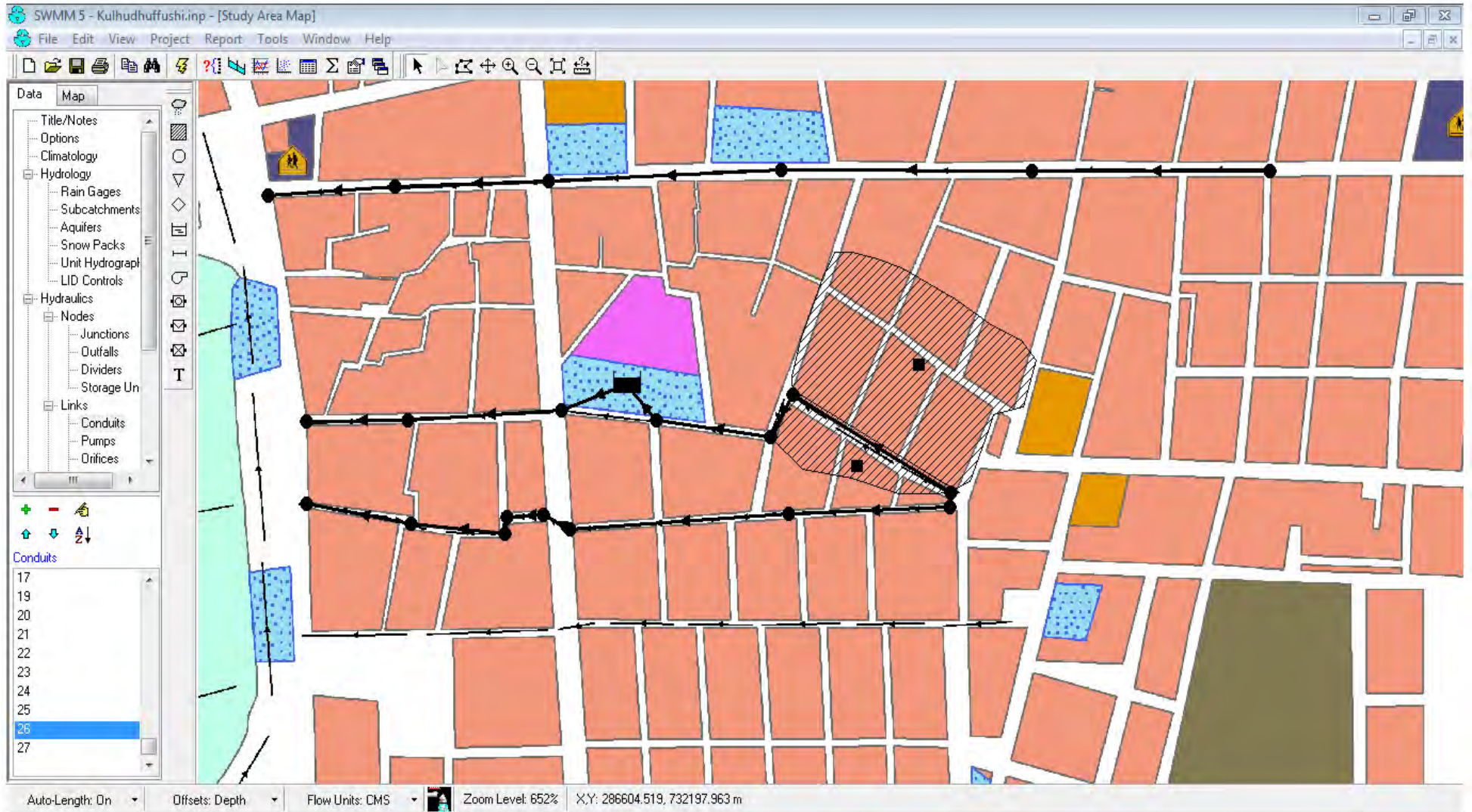


Figure No: 6.3: Sample Model for SWMM (1)

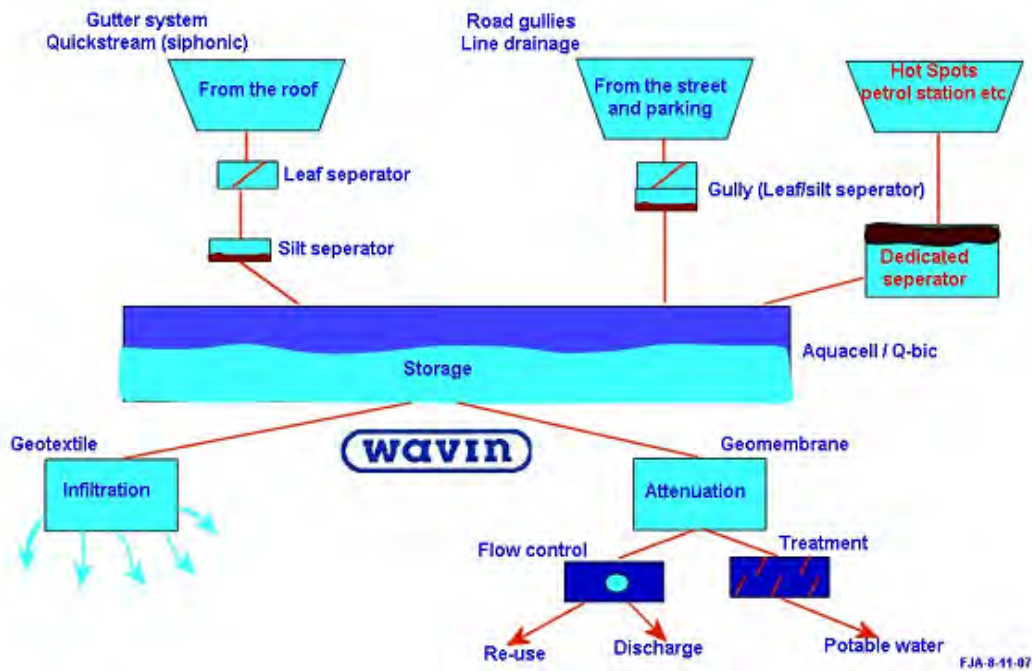


Figure 6.4: Overview of the proposed function to be included in part of the water management system



1300 m³ of water storage to catch and infiltrate the water from the parking.

As a result: The groundwater is recharged and the existing city storm water pipe does not get overloaded.

Figure No. 6.5: Proposed underground tank for the storm water storage

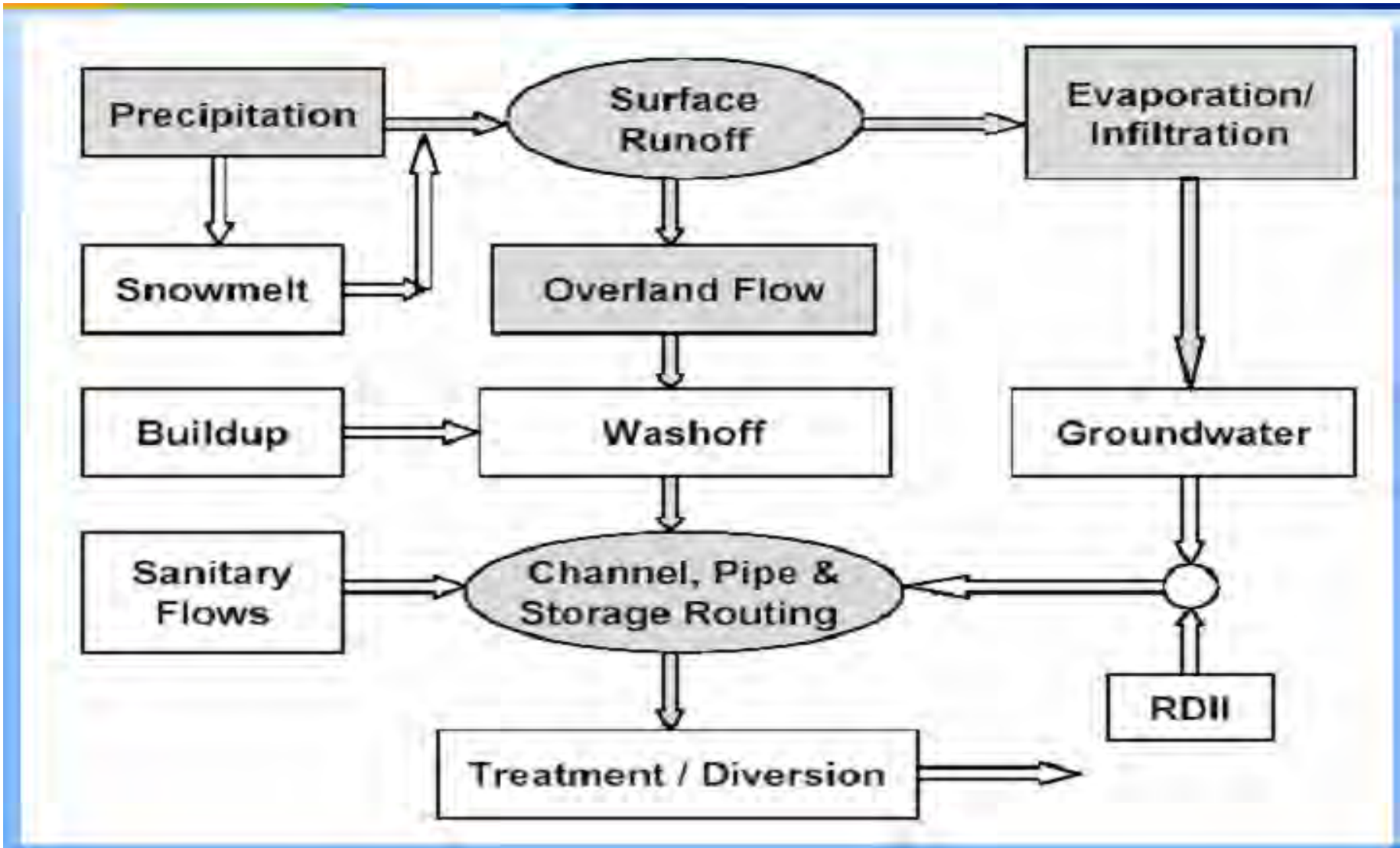


Figure No.6.6: SWMMS Process Models to suite the Storm Water Management

7.0 Current situation of the island

7.1 H Dh. Kulhudhuffushi



Proposed open area for ground tank



Proposed open area for ground tank



Houses are getting flooded about 0.30m



Part of the playground proposed for ground tank



Flooding area depth of flooding is around 0.50m



Area recommended for ground tank



Preschool ground Proposed for ground tank



End of the road can be used for ground tank



Flooding area – depth of flooding is around 0.30m



Existing lagoon to be preserved to store excess water during rainy period



Out let of the lagoon excess water over topping during rainy period



Well showing existing water table



Existing pond to be rehabilitated to store water during rainy period



Newly constructed asphalt road with gully grating



Area recommended for ground tank



Existing path of the open drain between newly reclaimed area and existed land



Area can be used as open shallow tank along with peripheral drain between newly reclaimed area and existed land

7.2 G Dh. Thinadhoo Island



Water collected at junction. Closed by playground.



Water collected along the road – close to sea.



Earthen drain along the road – constructed by council



Open areas proposed for underground tank



Open areas proposed to underground storage



Link road to be filled to match the slope towards as main drainage path along the main road



Low elevated areas along the link road to be filled to match natural slope



House entrance has been raised to protect from road floods



Open areas proposed for underground storage



Existing drainage inlet – upstream of the sea



Earthen drain constructed by council



Flap gate has to be design to prevent salt water intrusion into inland area



Part of the area proposed for underground storage



Part of the playground proposed to store storm water



Part of the children park proposed to store storm water



Newly constructed shallow drain – acceptable solution to control downstream boundary condition



Flap gate to be constructed to prevent salt water intrusion in to inland area



Part of the land proposed for ground tank



Open area can proposed for ground tank



Part of the playground area proposed for ground tank



Existing out fall to be regularize by constructing pipe culvert cum flap gate



Existing outfall to be regularize by constructing pipe culvert cum flap gate



Existing earthen drain has to be design with rubble pitching protection



Flooding area without proper outfall



Existing out fall to be rehabilitated after constructing culvert cum flap gate



Observation from existing well to determine height of the ground tank



Existing out fall has to be rehabilitated by constructing flap gate cum culvert



Recommended height of the ground tank may be considered as 1.0m

8.0 Work Plan

Work plan has been prepared for the completion of project in two islands for the preparation of conceptual design and detail design report

