An-Najah National University
Faculty of Engineering and Information Technology

جامعة النجاح الوطنية
كلية الهندسة و تكنولوجيا المعلومات

Graduation Project Report II

Design of a Stormwater Collection Network for Part of Al-Amriya Town

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DEDICATION

We dedicate this project to The Almighty Allah, our creator, strong pillar and source of knowledge, understanding, wisdom, inspiration and strength.

We also dedicate this project to our supervisor, Dr. Mohammad N. Almasri, who encouraged us during our journey and made sure that we give all we've got to finish what we started.

To our parents who incorporeally supported us, we dedicate this project.

Thank you all.

Our love for you can never be quantified.

God bless you.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful. All praises to Allah for the strengths and His blessing in completing this project. Special appreciation goes to our supervisor, Dr. Mohammad Almasri for his supervision and patience with us during the research. His wise suggestions and constructive comments along the experiment we went through during this semester led to the success of this research. Special thanks to PWA for their generosity in offering useful material that was of high importance for our project. Last but not least, our utmost gratitude goes to our parents who were encouraging us, praying for us and helping us with everything they could. Thank you all very much.

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ABSTRACT

It is an undisputed fact that water is the pillar of life. Water on the surface of oceans evaporates, ascends to the upper layers of the atmosphere until it condenses to form clouds, which keep moving, and finally falls back as rain, snow or hail in what is known as the water cycle.

The combination of pure rainwater and anything carried by the rain in urban areas is called stormwater.

Combined sewers are predominant in Palestine. These sewers sometimes cease to take more sewage in and because of that floods occur creating many losses in lives or properties. For instance, in Anabta, an event happened in 2013 where two ladies died after a flood happened in a heavy rainy day that went for too long.

Hence the importance of having a drainage network to prevent these floods from occurring. Therefore the purpose from this project is to design a stormwater collection network for part of Nablus (al-amriya) depending on rainfall readings, which is implicitly represented in an IDF curve, to avoid any more losses. The approach in this project was based on the use of Bentley StormCAD, ESRI ArcGIS and MS Excel to develop a reality-simulating model.

The model consists mainly of three elements. The catchment, where 27 catchments were drawn, taking into account the elevations, so that the water is drained to the lowest point in the catchment, at which the catch basin was placed. The rational coefficient, time of concentration and the area were calculated for each catchment, and the catch basins were connected together by conduits.

The output of the model was that we came to a design that appears in conduits and their diameters, and catch basins and their dimensions.

In addition, we enhanced our results with two profiles, some conclusions and recommendations.

CHAPTER ONE : INTRODUCTION

1.1Background

In the first project, we discussed the topic of floods, their history, the factors that help them form, and ways to prevent them, drawing lessons and lessons from the Derna flood, and delving into the details of the distribution of water bodies in the West Bank and the history of floods there. In order for our work to be fruitful, in this project we designed a rainwater drainage network in the Amriya area, which We chose it for several reasons, including the availability of the necessary data, the suitability of the area's topography, and because it is an area close to the university and our team can visit it easily. Rain precipitates to earth with different intensities . As rain reaches the ground, it flows as runoff, and if the quantity is great where weak storm control exists, the situation deteriorates and counting of casualties begins whether they are deaths, injuries or property losses. Stormwater networks serves as a lifesaver for such situation. In this project we use Bentley StormCAD alongside ESRI ArcMap to establish a stormwater network for Al-amriya to avoid the aforementioned tragedies.

1.2Objectives

In this project, we aim to design a stormwater collection network for a part of the town of Al-amriya in Nablus , Palestine.

1.3 Methodology

1.3.1 Problem identification

Enormous amounts of runoff in some areas had some destructive impacts at some point in the past. The blockage of the culverts makes the possibility of floods higher. Cross slopes for streets are not that good and ponding happens a lot , Al Amriya area is relatively high and exposed to this problem.

1.3.2 Selection of study area

There are two factors that led us to choose the study area. Firstly, the area is high and has high slopes . Secondly, the study area has available data.

1.3.3 Data collection

We used the shapefiles available on Geomolg[1] to work on the project. These shapefiles include buildings, contour maps and physical plan for roads.

1.3.4 Delineate catchments and determine catch basin locations

We delineated the catchments on ArcMap and then did that again on StormCAD . We were careful that the catch basin is placed at the lowest point of the catchment.

1.3.5 StormCAD modeling

After the previous procedure, we used ArcMap to create an intersection between the physical map for roads and the catchments. Each catch basin was connected with a conduit considering the maximum spacing being less than 50 m. All required data for the run process in StormCAD was inserted.

The catchment data includes the catchment area, runoff coefficient and time of concentration.

The catch basin data includes ground elevation, rim elevation, structure type, head loss method and coefficient, clogging factor, sump depth, cross road slope and inlet type and location.

The conduit data includes section type, material, manning coefficient and section size.

Outlet data includes rim and ground elevations.

When the first run was executed, notifications and errors appeared and after solving these problems, results were displayed.

1.3.6 Conclusion and recommendations

After we had run the model, we depended on the results and offered some conclusions and recommendations.

CHAOTER TWO : STUDY AREA DESCRIPTION

2.1 Location

Al-Amriya is located at the southwestern edge of the city of Nablus. It is bordered to the east by the Mohandiseen Housing, to the west by the village of Surra, to the north by the village of Al-Junaid, and to the south by the village of Tell. It is considered a residential area, the buildings there are independent houses, and there are small agricultural areas.

Figure 1 Al-amriya

The watershed for the town has a substantial amount of rainfall with an average of 660 m .

A 52km^2 urban part in the southwest of Nablus was chosen to be our study area.

2.2 Importance

The study area is actually interesting, given its exposure to large amounts of rainfall, its high location, and the lack of water drainage network.

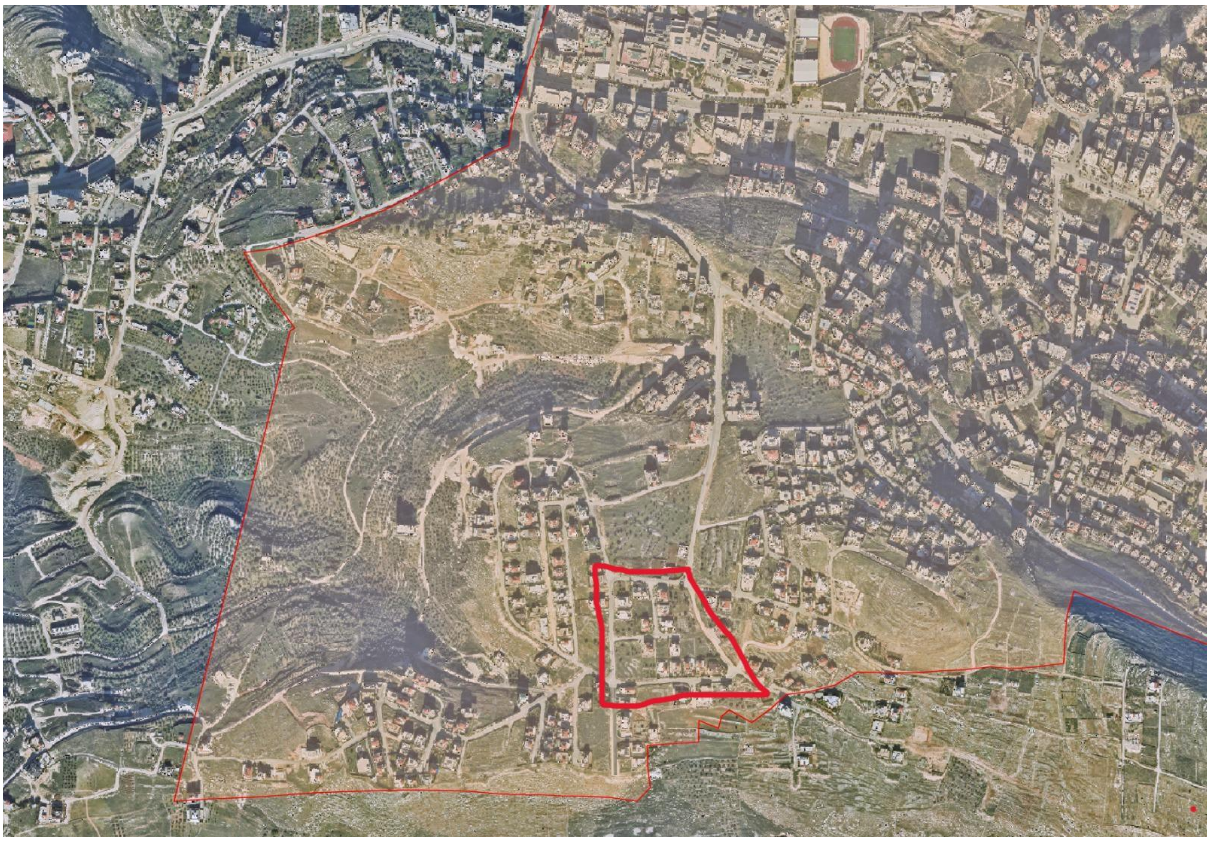

Figure 2 Study area in alamriya

2.3Topography

alamriya is about 700 m above mean sea level . The land is mountainous with hills surrounding it from all sides.

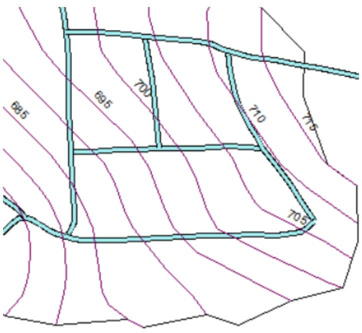

Figure 3 Contour map for the study area

CHAPTER THREE : HYDRAULIC BACKGROUND

3.1 Runoff

To estimate the amount of flow coming out of a catchment, we used the Rational Method, that can be formulated in the following equation:

$Q = .0028 \times C \times I$

Where,

Q: Maximum runoff (m^3/s)

C: Runoff coefficient

i: Intensity of rainfall for a certain frequency, and duration equals at least the time of concentration (mm/hr)

A: Drainage area (hectares)

The Rational Method is based on the principle that the rate of runoff depends on:

The average intensity of the storm

The size of the drainage area

The type of the surface of the drainage area

The rationale for the method lies in the concept that a steady, uniform rainfall with an average intensity (i) over an impervious area (A) will cause runoff to reacah its maximum rate (Q) when all parts of the watershed are contributing to the outflow at the point of design simultaneously .

3.2 Catch basins

We used physical plan for roads to place the catch basins on the right side of the road, taking under consideration the maximum distance between two consecutive catch basins to be less than 50 m. There is 27 catch basins in our project.

3.3 Catchments

3.3.1 Introduction

After we have placed the catch basins on the study area according to the contours, there were 27 catchments in the project. Each catchment was drawn considering that each point drains to a lower point until all the flow reaches the lowest point in the catchment, which is referred to as the outlet.

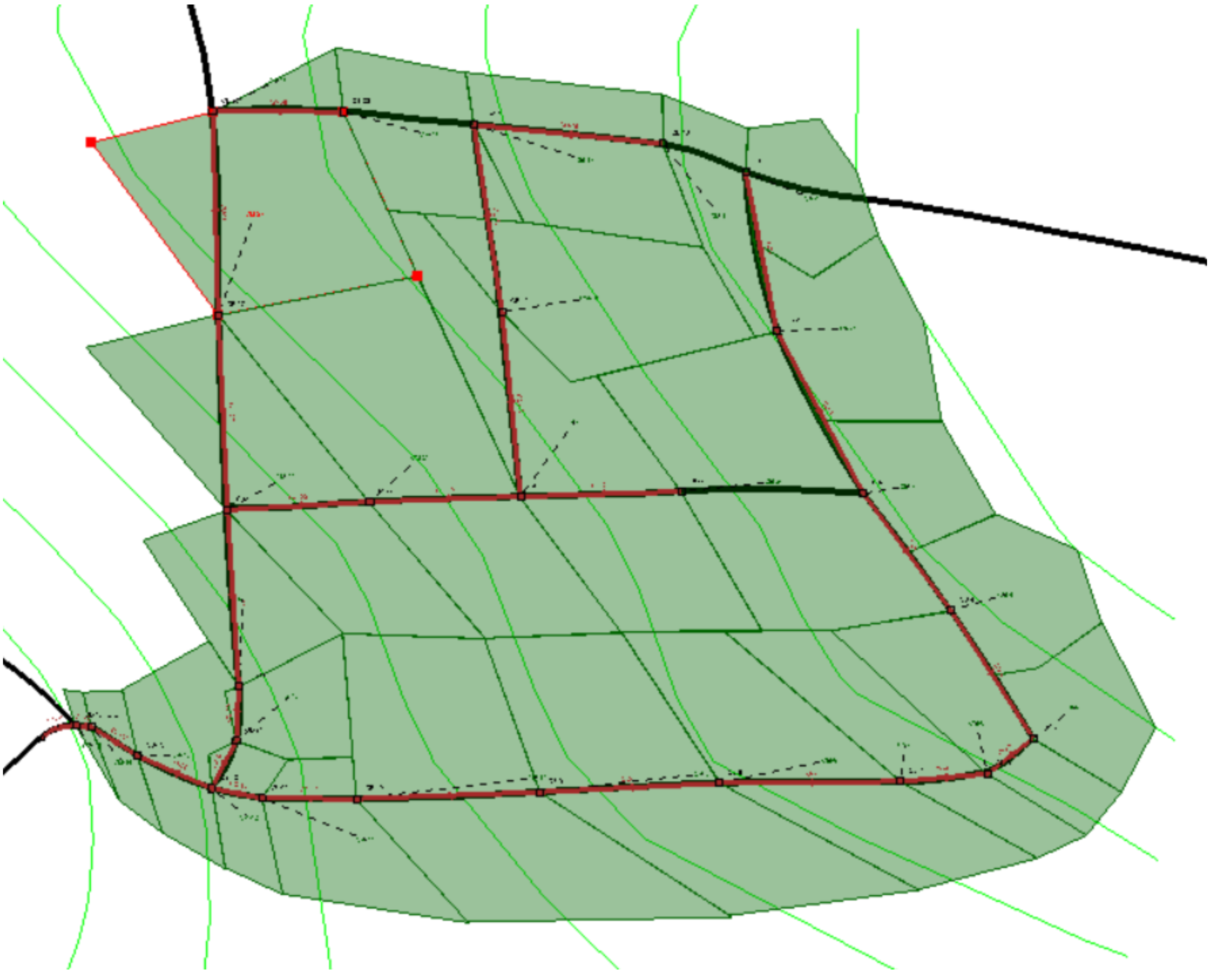

Figure 4 Catchments of the study area

3.3.2 Runoff coefficient

In ArcMap, an intersection between the physical plan and the catchments leads to calculating C values. As a result of the intersection, three categories were obtained and they are shown in the subsequent table:

Table 1 Runoff coefficients for different land uses

Land use	C
Approved roads	0.8
Residence	0.5

Cultivated	0.2

The runoff coefficient (C) depends on:

Soil type

Shape of drainage area

Previous moisture conditions

Slope of watershed

Amount of impervious

Land use

The weighted average for C can be calculated using the following equation:

$$C = \frac{\sum(A * C)}{\sum A}$$

3.3.3 Intensity

Rainfall intensity is defined as the ratio of the total amount of rain falling during a given period to the duration of the period. It is expressed in depth units per unit time, usually as mm per hour (mm/h).

Table 2 IDF curve for Nablus

Duration (min)	2 Year (mm/h)	5 Year (mm/h)	10 Year (mm/h)	20 Year (mm/h)	100 Year (mm/h)
10	38.6	46.9	51.5	54.4	61.1
20	27.2	36.6	42.5	47.1	59.3
30	21.9	29.5	34.7	38.6	48.9
40	18.4	24.2	28.2	31.3	38.4
50	16.1	21.1	24.6	27.2	34.3
60	14.7	18.9	21.9	24.2	30.2
120	10.2	12.8	14.6	15.9	19.6
180	8.4	10.3	11.7	12.7	15.4
240	7.3	9.1	10.3	11.3	13.8

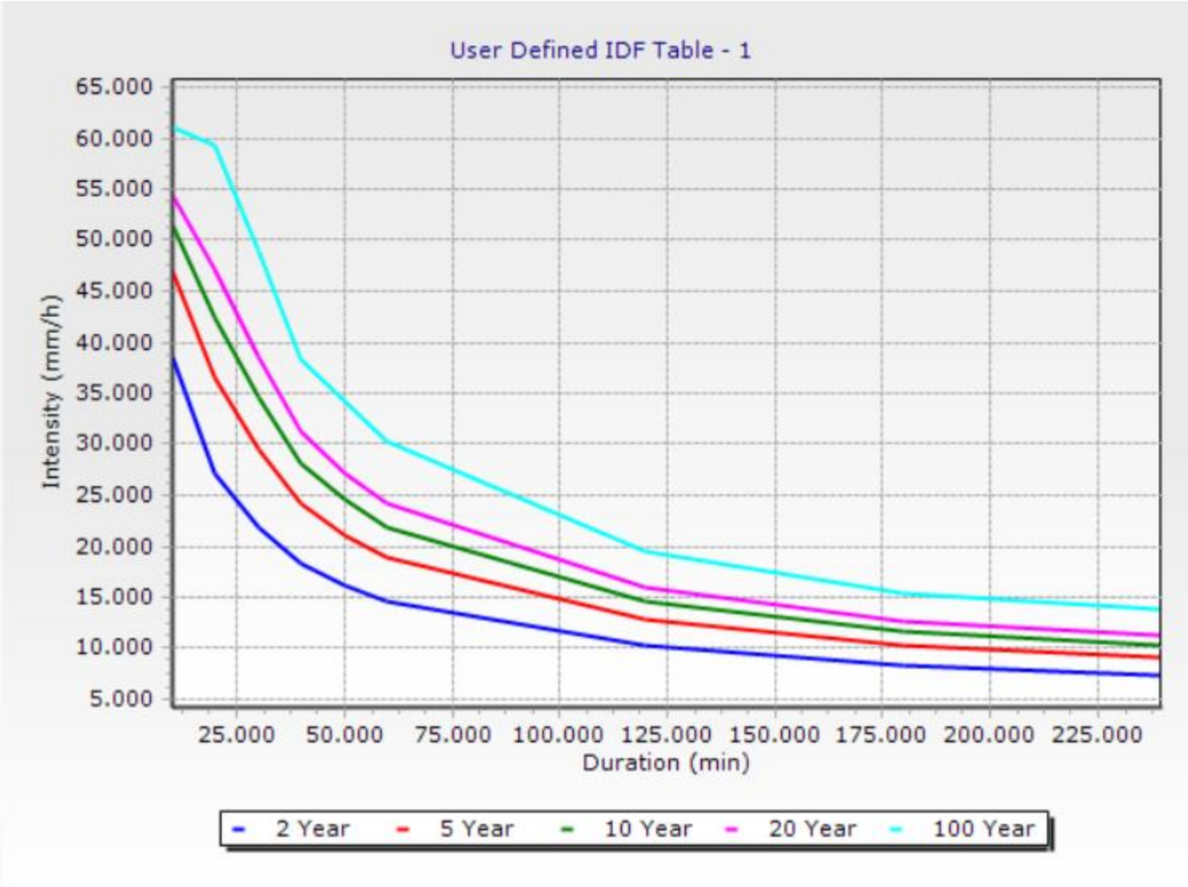

Figure 5 IDF curve for Nablus

3.3.4 Time of concentration

The time of concentration is calculated for each catchment, using the Federal Aviation Administration (1970) equation:

$$Tc = \frac{1.8 * (1.1 - C) * L^{0.5}}{S^{.333}}$$

Where,

Tc: Time of concentration (minutes)

L: Overland flow path length (ft)

S: Slope of overland flow path (decimal)

C: Runoff coefficient

A sample for the time of concentration will be calculated in addition to the figure below, while the results for the rest of computations are summarized in Appendix C.

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H2 | =1.8*(1.1-E2)*I2^0.5/G2^0.333

	A	B	C	D	E	F	G	H	I
1	label	length(m)	elevation 1	elevation 2	c	area(ha)	slope	Tc(min)	length(ft)
2	CM-1	40.2	715	712	0.3	0.11	7.462687	8.468255	131.8898
3	CM-2	40.4	715	710.1	0.3	0.17	12.12871	7.221633	132.5459
4	CM-3	29.2	713	709	0.3	0.1	13.69863	5.895667	95.80053
5	CM-4	38.35	715	708.5	0.3	0.14	16.94915	6.294068	125.8202
6	CM-5	38.7	712.5	706.5	0.8	0.11	15.50388	2.442447	126.9685
7	CM-6	46	709	704.5	0.6	0.15	9.782609	5.173596	150.9186
8	CM-7	45.5	705.5	703	0.6	0.16	5.494505	6.235116	149.2782
9	CM-8	49.75	703	699	0.6	0.29	8.040201	5.743514	163.2218
10	CM-9	46.8	699.5	693	0.6	0.37	13.88889	4.643545	153.5433
11	CM-10	56.6	694	686.5	0.3	0.41	13.25088	8.299572	185.6955
12	CM-11	66.2	687	683	0.3	0.13	6.042296	11.65853	217.1916
13	CM-12	22.3	684	680.5	0.3	0.06	15.69507	4.924003	73.16273
14	CM-13	33.7	683.5	677.5	0.3	0.12	17.80415	5.804253	110.5643
15	CM-14	13.2	678	676	0.3	0.03	15.15152	3.8331	43.30709

Figure 6 Sample calculation for Tc

Catchment 1 :

$$Tc = \frac{1.8 \times (1.1 - 0.3) \times 131.88^{0.5}}{7.46^{0.333}} = 8.46min$$

CHAPTER FOUR : STORMCAD

4.1 Background

Bentley is of supreme position in developing engineering-related software solutions. WaterCAD is used for the analysis and design of water distribution networks, SewerCAD is used for the analysis and design of wastewater collection networks and StormCAD is used for the analysis and design of stormwater collection networks. The previously mentioned software solutions are a few examples of what this company provides engineers with.

4.2 Advantages

The reasons behind choosing to use Bentley StormCad in our project could be summarized as follows:

Availability of learning material, such as tutorials and videos

Possibility of integrating the software with Geographic Information Systems (GIS)

Possibility of integrating the software with Autodesk AutoCAD

Provision of features we need, such as profiles

Displaying the results in a comprehensible form

4.3 Design Constraints

In automated design, many constraints are entered to the software where one might affect the other and the computer cannot satisfy both simultaneously. Concerning the constraints, there are no fixed values for them, and instead these values are determined by engineering sense and experience in the field.

The following figure shows the design constraints concerning the slope.

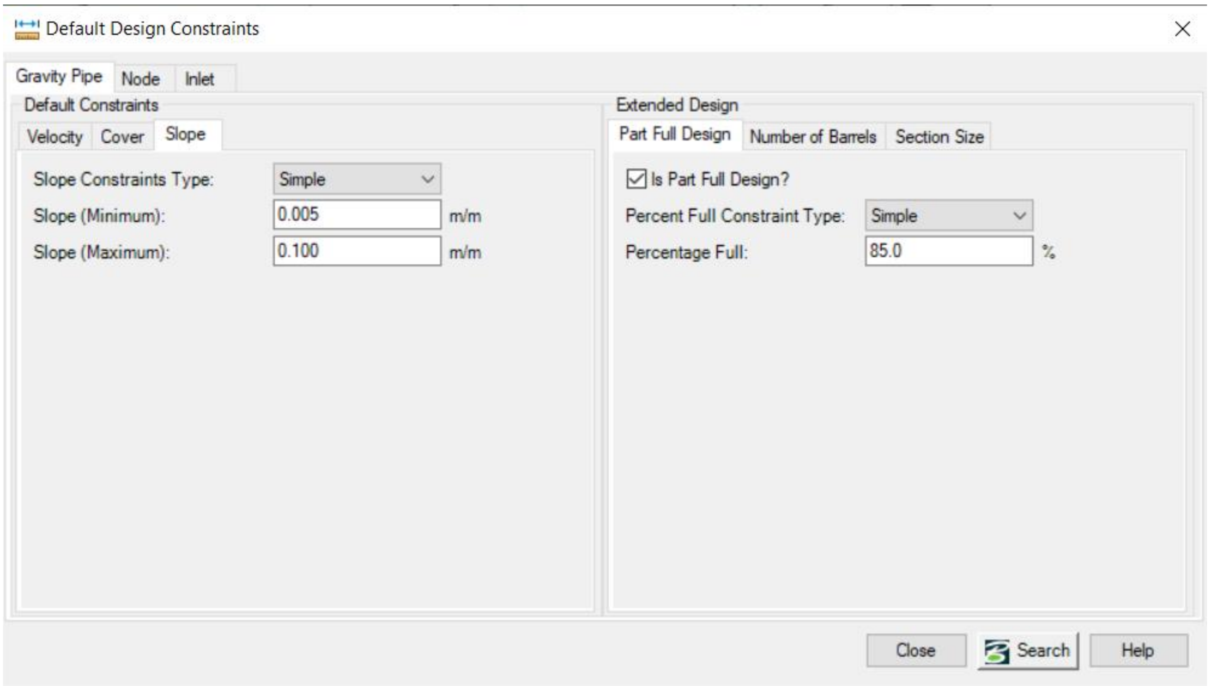

Figure 7 Slope constraint

In piping systems where it is possible for solids to exist, or where water could settle and create corrosion zones in low spots, a minimum value of 3 ft/s (0.9 m/s) is normally used. "It is true that concrete pipes can carry clear water with extremely high velocities without eroding" (ACPA, 1996). However, many other factors lead to a maximum value for velocity of 15 ft/s (4.6 m/s), which is often used to minimize the possibility of erosion by solids and water hammer caused by quickly closing a valve.

The following figure shows the design constraints concerning the velocity.

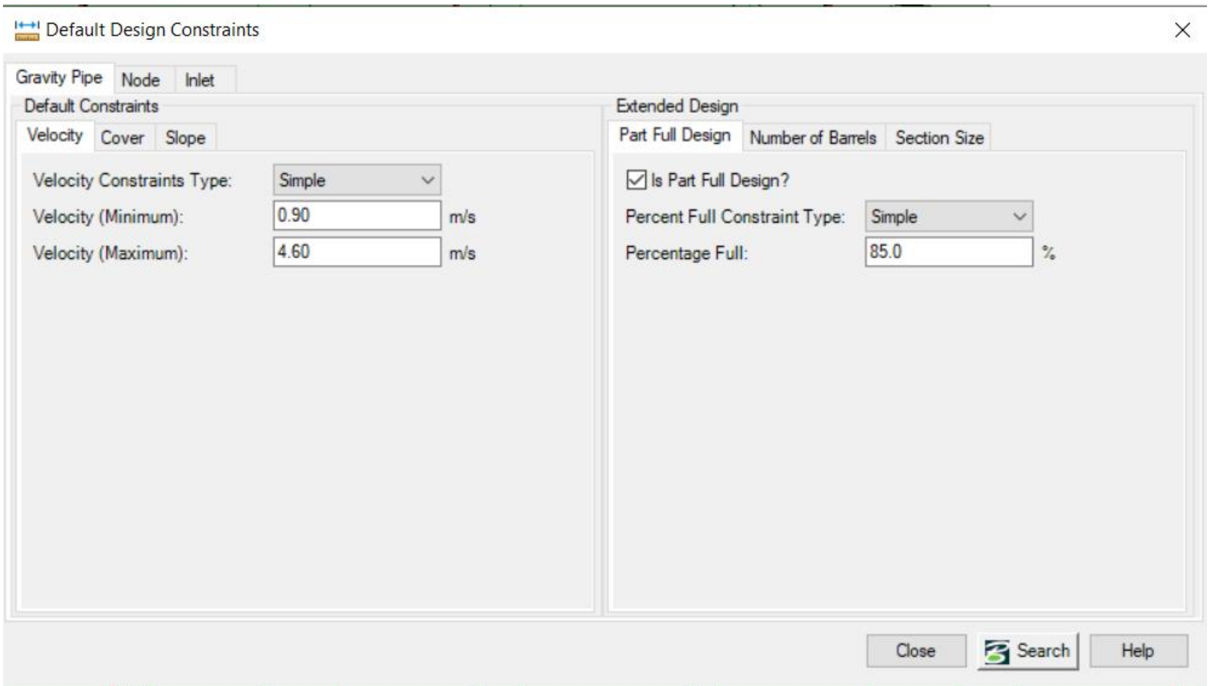

Figure 8 Velocity constraint

The following figure shows the design constraints concerning the cover.

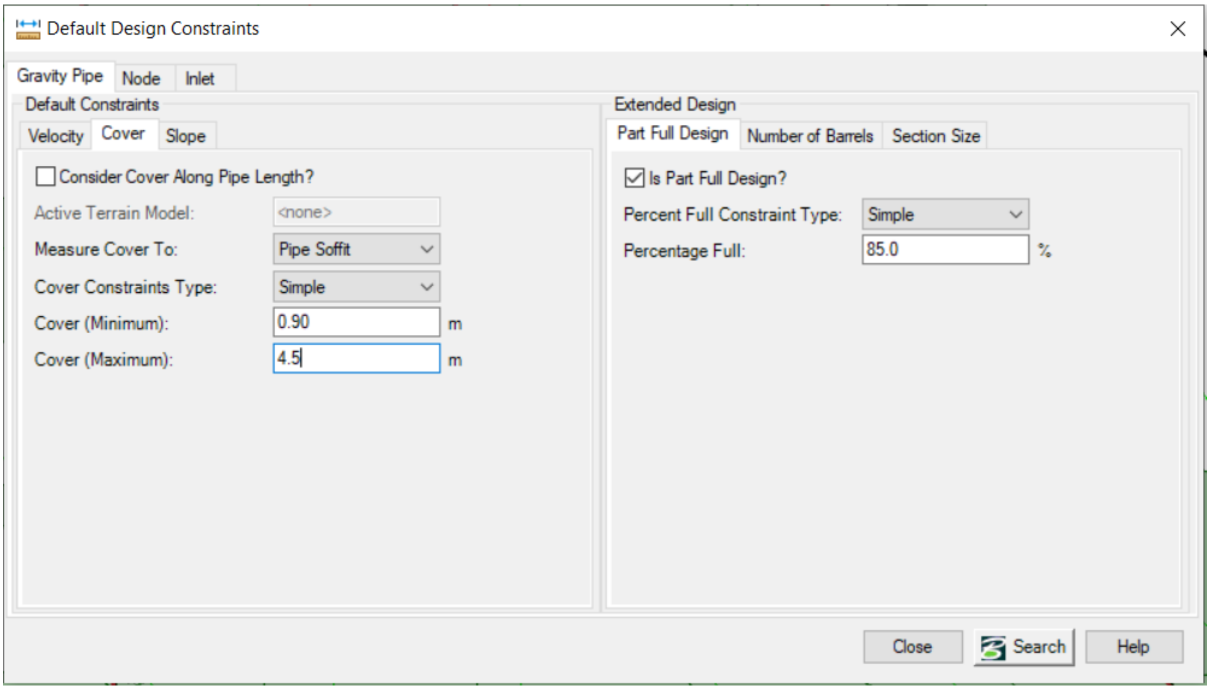

Figure 9 Cover constrains

The following figure shows the dimensions for the catch basins (inlets).

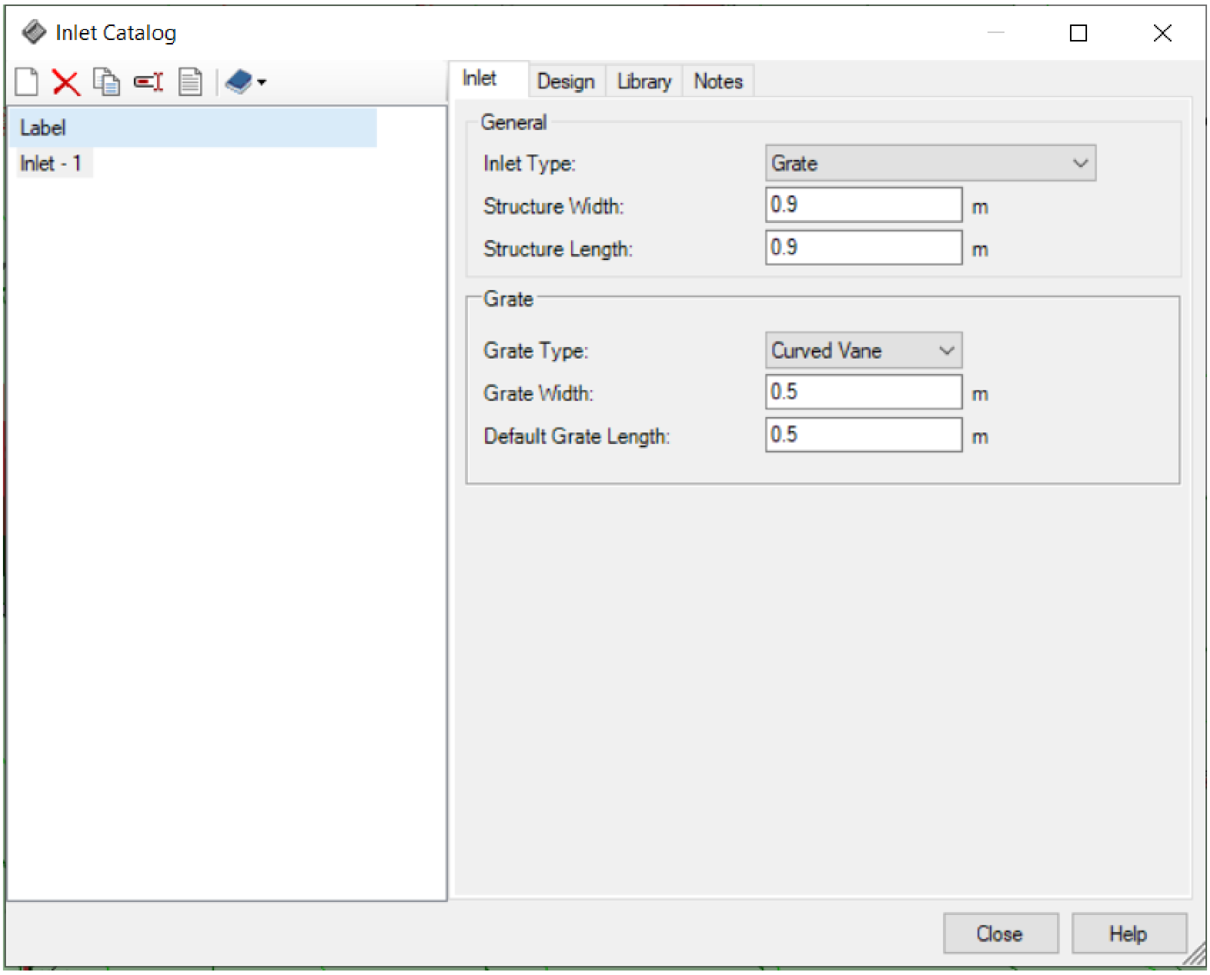

Figure 10 Inlet catalog

As for the conduits, we used 24 in diameter for all .

4.4 Run

The model that was designed using the software, emulates the real-life situation. Based on the run process we obtained the results that will be shown in the next chapter.

CHAPTER FIVE : RESULTS

5.1 Catch basins

For the study area, there were 27 catch basins placed on the right side of the streets while taking into consideration that these catch basins must not be placed in private properties and shall only be located in public ones.

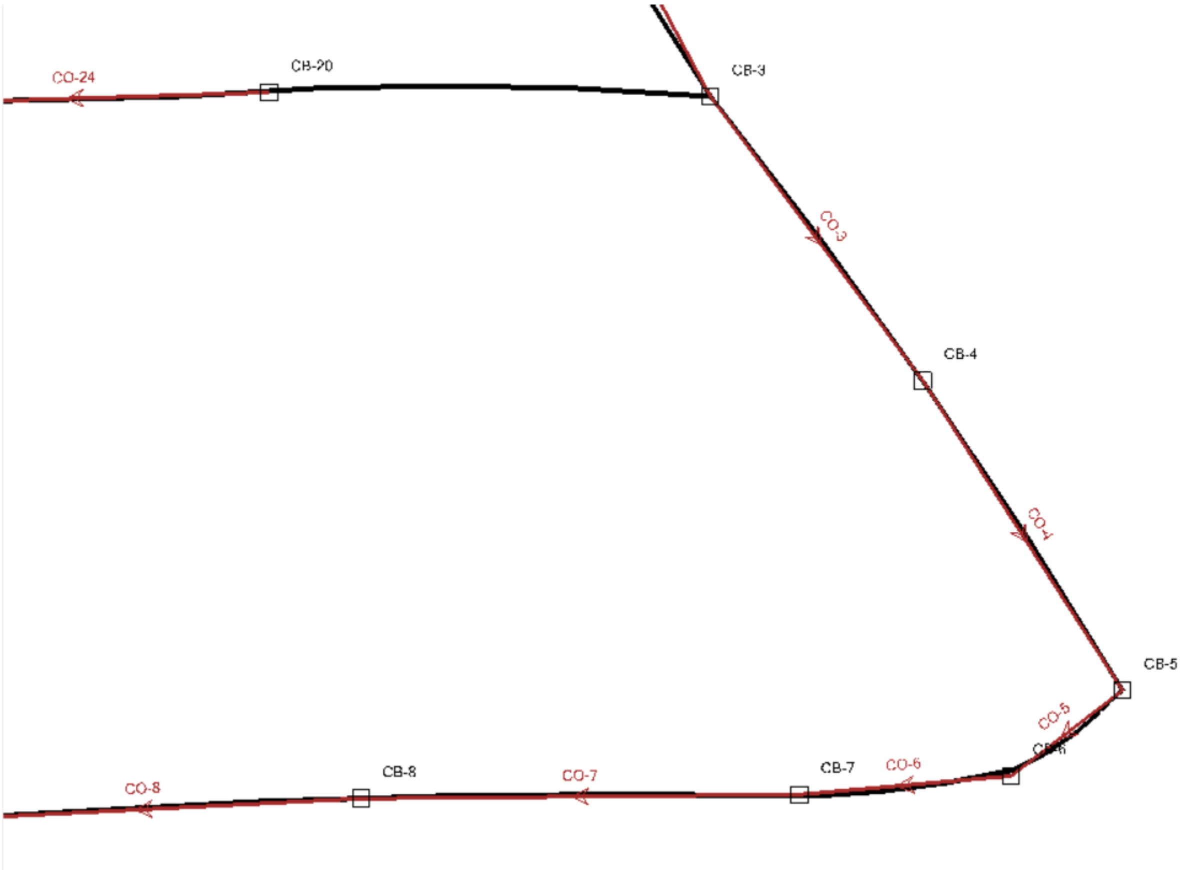

Figure 11 Placement of catch basins

The following figure shows the constituents of the catch basins structure.

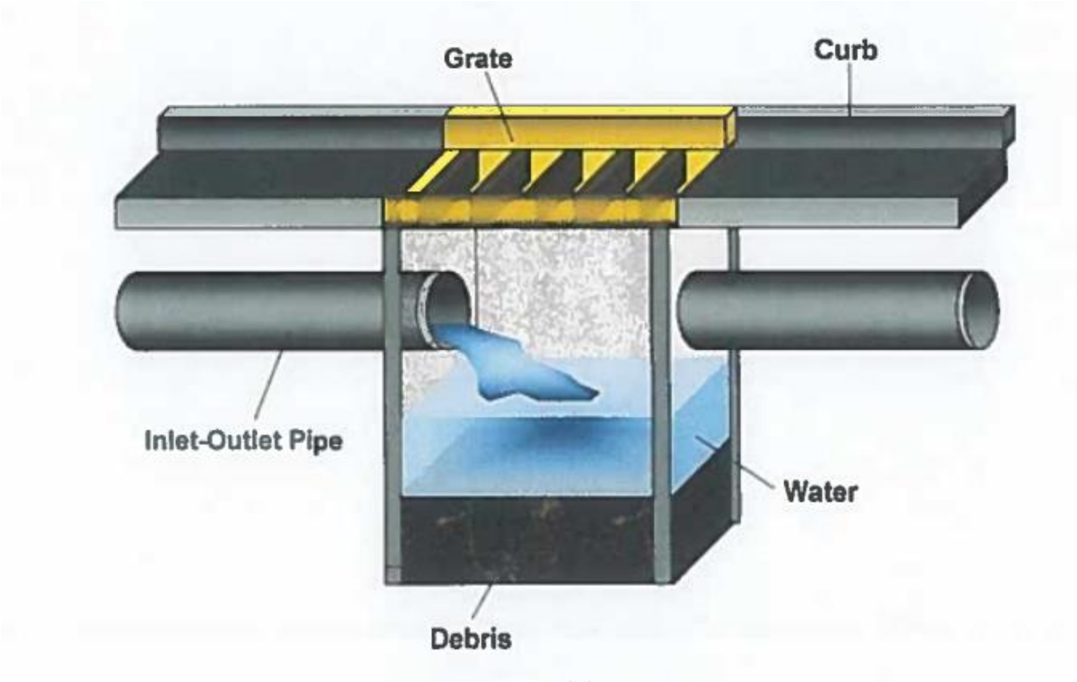

Figure 12 Catch basin structure

The following figure shows the flex table for the catch basins.

ID	Label	Elevation (Ground) (m)	Set Rim to Ground Elevation?	Elevation (Rim) (m)	Elevation (Invert) (m)	Length (m)	Width (m)	Inlet Type	Flow (Maximum in) (m^3/s)	Inflow-Capture Curve	Capture Efficiency (Calculated) (%)	Flow (Captured) (m^3/s)	Hydraulic Grade Line (In) (m)	Spread / Top Width (m)
27	CB-5	706.63	☑	706.63	704.63	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.01	704.72	1.3
28	CB-6	704.60	☑	704.60	702.60	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.01	702.71	1.3
30	CB-7	702.72	☑	702.72	700.72	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.01	700.85	1.3
32	CB-8	699.18	☑	699.18	697.18	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.02	697.33	1.8
34	CB-9	692.95	☑	692.95	690.95	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.03	691.12	2.1
36	CB-10	686.90	☑	686.90	684.90	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.02	685.09	1.5
38	CB-11	682.90	☑	682.90	680.90	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.00	681.09	0.8
40	CB-12	680.60	☑	680.60	678.60	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.00	678.88	0.7
42	CB-13	677.49	☑	677.49	675.49	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.01	675.77	0.8
44	CB-14	675.98	☑	675.98	673.98	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.00	674.26	0.5
46	CB-15	675.25	☑	675.25	673.25	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.00	673.54	0.3
100	CB-26	697.30	☑	697.30	695.30	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.00	695.35	0.6
102	CB-27	693.47	☑	693.47	691.47	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.03	691.58	1.9
104	CB-22	687.47	☑	687.47	685.47	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.02	685.70	1.8
106	CB-23	683.58	☑	683.58	681.58	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.00	681.81	0.7
109	CB-24	682.33	☑	682.33	680.33	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.00	680.56	0.6
112	CB-4	709.13	☑	709.13	707.13	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.01	707.21	0.9
114	CB-3	709.31	☑	709.31	707.10	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.00	707.26	0.8
116	CB-2	710.21	☑	710.21	708.21	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.01	708.28	1.0
118	CB-1	711.75	☑	711.75	709.75	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.00	709.79	0.8
120	CB-16	709.44	☑	709.44	707.44	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.00	707.48	0.8
122	CB-17	704.19	☑	704.19	702.90	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.01	702.97	1.0
124	CB-25	700.73	☑	700.73	698.73	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.01	698.78	0.9
127	CB-20	703.27	☑	703.27	701.27	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.02	701.35	1.4
129	CB-19	697.78	☑	697.78	695.78	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.01	695.92	1.3
131	CB-21	692.28	☑	692.28	690.28	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.03	690.45	2.0
134	CB-18	701.65	☑	701.65	699.65	0.90	0.90	Catalog Inlet		<Collection:	100.0	0.01	699.74	1.1

Figure 13 Flex table for the catch basins

A unified design for all catch basins were followed where, for example the width is 0.90 m, the length is 0.90 m

5.2 Outfall

One outfall was used in this project, and it was located at the lowest point of the entire study area. The total flow is 16986.39 m^3/day. The following figure shows the flex table for the outfall.

Label	Elevation (Ground) (m)	Set Rim to Ground Elevation?	Elevation (Invert) (m)	Boundary Condition Type	Boundary Element	Elevation (User Defined Tailwater) (m)	Hydraulic Grade (m)	Flow (Total Out) (m³/day)
O-1	673.38	☑	671.38	Free Outfall			671.50	16,986.39

Figure 14 Flex table for the outfall

5.3 Conduits

A total of 27 conduits with diameters of 24 in

	Label	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (Scaled) (m)	Slope (Calculated) (m/m)	Section Type	Diameter (in)	Manning's n	Flow (m³/day)	Velocity (m/s)	Depth (Out) (m)	Flow / Capacity (Design) (%)
: CO-1	CO-1	CB-1	709.75	CB-2	708.21	44.5	0.035	Circle	24.0	0.013	383.93	0.97	0.07	0.4
: CO-2	CO-2	CB-2	708.21	CB-3	707.10	50.7	0.022	Circle	24.0	0.013	961.45	1.09	0.16	1.2
: CO-3	CO-3	CB-3	707.10	CB-4	707.13	40.2	-0.001	Circle	24.0	0.013	1,283.10	0.05	0.08	8.5
: CO-4	CO-4	CB-4	707.13	CB-5	704.63	41.8	0.060	Circle	24.0	0.013	1,285.82	1.70	0.09	1.0
: CO-5	CO-5	CB-5	704.63	CB-6	702.60	15.9	0.127	Circle	24.0	0.013	1,994.06	2.52	0.11	1.0
: CO-6	CO-6	CB-6	702.60	CB-7	700.72	24.1	0.078	Circle	24.0	0.013	2,723.59	2.33	0.13	1.8
: CO-7	CO-7	CB-7	700.72	CB-8	697.18	49.7	0.071	Circle	24.0	0.013	3,493.79	2.44	0.15	2.4
: CO-8	CO-8	CB-8	697.18	CB-9	690.95	49.4	0.126	Circle	24.0	0.013	4,872.58	3.29	0.17	2.5
: CO-9	CO-9	CB-9	690.95	CB-10	684.90	50.3	0.120	Circle	24.0	0.013	6,628.26	3.56	0.19	3.5
: CO-10	CO-10	CB-10	684.90	CB-11	680.90	26.1	0.153	Circle	24.0	0.013	7,577.12	4.03	0.19	3.5
: CO-11	CO-11	CB-11	680.90	CB-12	678.60	14.1	0.163	Circle	24.0	0.013	7,870.37	4.17	0.28	3.5
: CO-12	CO-12	CB-12	678.60	CB-13	675.49	22.2	0.140	Circle	24.0	0.013	16,668.59	4.93	0.28	8.1
: CO-13	CO-13	CB-13	675.49	CB-14	673.98	14.9	0.101	Circle	24.0	0.013	16,927.72	4.41	0.28	9.6
: CO-14	CO-14	CB-14	673.98	CB-15	673.25	4.4	0.167	Circle	24.0	0.013	16,978.64	5.27	0.29	7.5
: CO-15	CO-15	CB-15	673.25	O-1	671.38	9.9	0.188	Circle	24.0	0.013	16,997.38	5.50	0.12	7.1
: CO-16	CO-16	CB-16	707.44	CB-17	702.90	52.2	0.087	Circle	24.0	0.013	371.31	1.32	0.07	0.2
: CO-17	CO-17	CB-17	702.90	CB-18	699.65	52.0	0.062	Circle	24.0	0.013	1,009.69	1.60	0.09	0.7
: CO-18	CO-18	CB-18	699.65	CB-19	695.78	51.0	0.076	Circle	24.0	0.013	1,769.31	2.03	0.14	1.2
: CO-19	CO-19	CB-19	695.78	CB-21	690.28	41.5	0.133	Circle	24.0	0.013	4,173.47	3.20	0.17	2.1
: CO-20	CO-20	CB-21	690.28	CB-22	685.47	39.2	0.123	Circle	24.0	0.013	6,477.03	3.55	0.23	3.3
: CO-21	CO-21	CB-22	685.47	CB-23	681.58	48.6	0.080	Circle	24.0	0.013	11,015.01	3.58	0.23	7.0
: CO-22	CO-22	CB-23	681.58	CB-24	680.33	15.0	0.083	Circle	24.0	0.013	11,228.59	3.65	0.23	7.0
: CO-23	CO-23	CB-24	680.33	CB-12	678.60	14.8	0.117	Circle	24.0	0.013	11,377.64	4.14	0.28	6.0
: CO-24	CO-24	CB-20	701.27	CB-19	695.78	44.2	0.124	Circle	24.0	0.013	1,378.96	2.24	0.14	0.7
: CO-25	CO-25	CB-25	698.73	CB-26	695.30	36.0	0.095	Circle	24.0	0.013	489.85	1.49	0.05	0.3
: CO-26	CO-26	CB-26	695.30	CB-27	691.47	55.9	0.068	Circle	24.0	0.013	657.93	1.45	0.11	0.5
: CO-27	CO-27	CB-27	691.47	CB-22	685.47	53.7	0.112	Circle	24.0	0.013	2,752.37	2.65	0.23	1.5

Figure 15 Flex table for conduits

CHAPTER SIX : PROFILES

Profiles represent a relationship between the station on the x-axis and the elevation on the y- axis. Not only do they show water movement inside the conduits, but they also justify the reason behind slopes that are low and those that are high.

Figures 27 and 28 show different profiles taken in the network, with the red line representing the Total Energy Line (TEL), the blue line represents the Hydraulic Grade Line (HGL) and the green line represents the ground elevation.

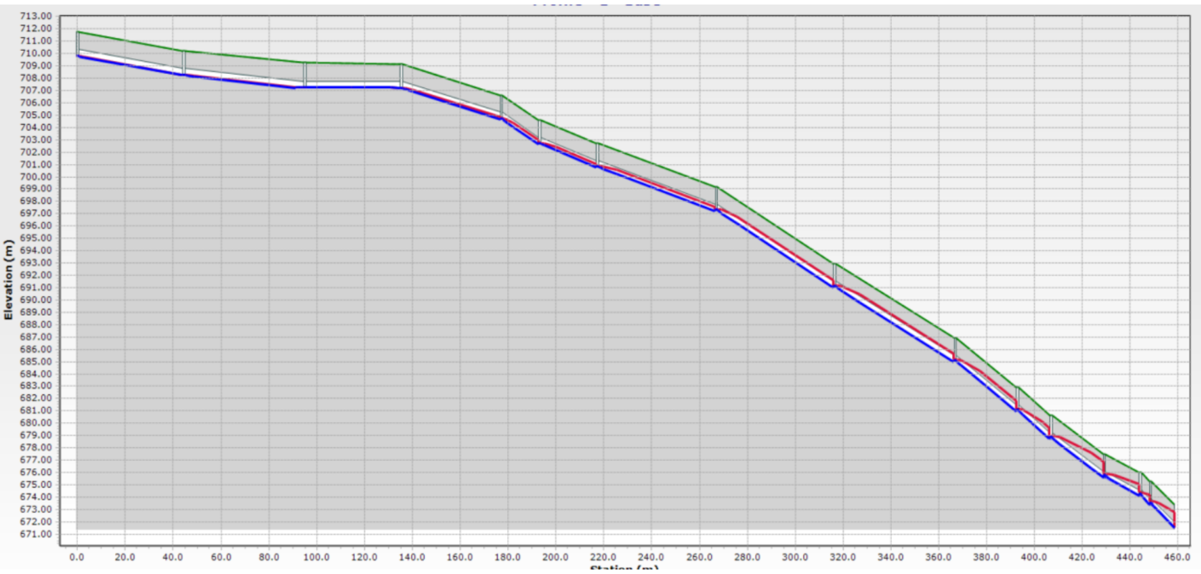

Figure 16 Profile 1

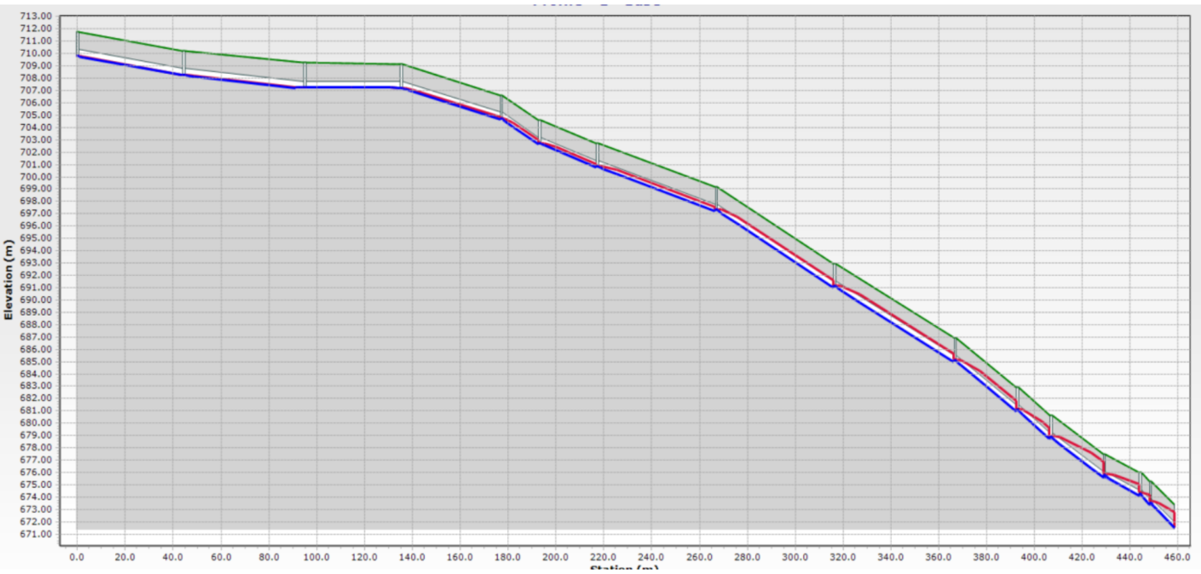

Figure 17 Profile 2

CHAPTER SEVEN : CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

It is clear that the StormCAD is a professional program, but it depends on the inputs which have lots of assumptions. For instant, the time of concentration and runoff coefficient have a sensitive effect on the whole drainage system simulation.

One outfall was used in our design with a flow rate of 16986.39 m^3/day. The outfall occupies the lowest point in the study area.

The network consists of 27 catch basins and 27 catchments,the conduit diameters is 24",the conduits are made of concrete with a Manning's coefficient of 0.013

The identification of problem areas, such as excessive runoff and inadequate drainage systems, is essential for implementing effective stormwater solutions and reducing the impact of flooding incidents .

7.2 Recommendations

The first recommendation would be to construct a stormwater collection network in Al-amriya to avoid catastrophes like that of 2013 in anabta , which could recur due to high amount of runoff.

Asphalt of roads is now worn. No suitable cross slope exists, and not to mention roads are filled by cracks. All of that would cause ponding. The suggestion here is to rehabilitate the roads.

It's recommended that the DWS specify staff for the documentation of rainfall events in terms of road condition assessment (by taking photos), recording the intensities for these events.

Conducting periodic assessments and simulations of the stormwater collection network to identify potential vulnerabilities, optimize performance, and address any emerging challenges proactively .

CHAPTER EIGHT : REFERENCES

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