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Attention: Mr Gerry McGeough

Conceptual Design of Fairview Square
University of British Columbia
Vancouver BC

This is the technical report on our conceptual design of Fairview Square at UBC. This study was authorized by Dr Susan Nesbit and Dr Greg Johnston on January 1 2009.

Our report includes our water balance model for the area and our recommendations for the development of a water sustainable site. Herein are five creative design ideas for water management that met difficult design criteria. For the conceptual design of Fairview Square we took into account functionality as well as the importance of educating the public to the importance of conserving water.

We appreciate the opportunity to research the area and recommend a sustainable conceptual design. We look forward to assisting you with the final design.

Sincerely,

Stanley Chan

Andrew Klade

Matthew Lam

Spencer Lonergan

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Kate Robinson

2nd Year Civil Engineering

Fairview Square Conceptual Design

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EXECUTIVE SUMMARY

The redevelopment of Fairview Square will evolve to become a public and central node to the surrounding faculties along the southern end of Main Mall. The square will be both a public and infrastructural asset to the campus showcasing a marriage of ecological, architectural and engineering design solutions. The product of these solutions addresses the defined project goals of reducing stormwater runoff from impervious areas, providing collected stormwater for irrigation and creating a visual awareness of sustainable strategies in practice.

This project is an opportunity to create a model for sustainable innovation, integration and implementation that fulfills the policies and directives defined by the 1997 Sustainable Development Policy #5, 1997 Official Community Plan, 2000 Comprehensive Community Plan, the 2008 Vancouver Campus Plan, and operationally the Integrated Stormwater Management Review. These policies and plans guided and defined our stormwater management approach. These plans include protecting UBC's environmental systems, following ecological principles, paralleling natural systems and minimizing impact on the environment.

We used a systematic approach leading to the establishment of a design strategy of catchment, containment and conveyance, which was coined as the 3 C's. The catchment components—curbside ponds and roof drains—deal with interception of stormwater, the containment features—in-ground storage gravel pits or detention ponds—provide the means to manage the varying volumes of precipitation expected and conveyance measures—water trenches—provide the conduit to transport the collected water to containment or dispersal areas of the stormwater system. Through implementation of these control measures a marked decline in stormwater is noted, which is measured by comparing the before and after effect on the water balance model. The stormwater control measures provided are selected based on their ability to maximize the capture of precipitation, and storage and release of collected water. Features designed are primarily based on functionality, educating the public on sustainability and being aesthetically pleasing.

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1.0 INTRODUCTION

With sustainability at the heart of UBC's development operations, the proposed Fairview Square will be a shining beacon of environmental awareness for Vancouver, and all of Canada. Built originally as an access road at the intersection of Main Mall and Stores Road, the area will undergo significant changes in the near future. Buildings such as Earth and Ocean Sciences Main and Frank Forward will be expanded and The Barn will be removed. With the introduction of a completely sustainable street as a visual exhibition to the public, UBC hopes to uphold the title of Vancouver being "the best place on earth".

This report addresses the goals and challenges of creating a conceptual design of Fairview Square from a Civil Engineering perspective. Our recommendation for the water drainage system for Fairview Square and the surrounding buildings is based on an analysis of: our water balance model, the approximated areas, mitigations strategies for stormwater run-off and the estimated results if our design was to be implemented. While being functional, we want the conceptual design to incorporate environmental innovations.

This report was commissioned by Dr. Susan Nesbit and Dr. Greg Johnson in an effort to analyze potential designs and configurations of Fairview Square. As Civil Engineering students we focused on a water balance model and the most effective way to capture, contain and convey rainwater. Our research includes a dynamic spreadsheet to analyze water capacity, literary sources published water conservation, as well as online resources published by those involved in hydrological sustainability. This report provides valuable insight into many innovative Civil Engineering design solutions essential for an undertaking of this magnitude.

2.0 SUMMARY OF BACKGROUND INFORMATION

The University of British Columbia was established on the Point Grey bluffs in 1914. Since endowment by the Province of British Columbia, UBC has grown and developed the majority of its land. Every year the Point Grey bluffs are subjected to heavy erosion. Due to snow melt and heavy rainfall, in 1935 there was a significant embankment washout which carved a drainage gully on the north end of campus. The University has established several plans and policies that address adequate stormwater management, which include the 1997 Sustainable Development Policy #5, 1997 Official Community Plan, 2000 Comprehensive Community Plan and the 2008 Vancouver Campus Plan. Additionally, the Integrated Stormwater Management Review reports that rainfall accumulated and is allowed to seep into the upper aquifer is of concern as this outflow is along a higher cliff elevation and is a contributor to cliff face erosion.

These policies and plans guided and defined our stormwater management approach. These plans include protecting UBC's environmental systems, following ecological principles and paralleling natural systems, and minimizing impact on the natural environment. Importantly, the Comprehensive Community Plan calls for reduced groundwater infiltration to manage cliff instability and erosion. It is this fundamental issue that requires response to the existing ecological system within the University Campus. The University's Integrated Stormwater Management Review has affirmed that the existing spiral drain, installed in 1936, and dry detention berms are only capable of dealing with a 1 in 70 year storm; whereas, capacity is needed for a 1 in 200 year storm event. It is the onus of the University to address this deficiency and explore alternative stormwater management strategies for the north watershed and the entire campus to support its sustainable growth. The analysis and recommendations contained in this report can be utilized to invoke further design and implementation strategies for not just the stormwater system but expanded to include buildings and other public realms.

3.0 3 C'S APPROACH TO STORMWATER RUNOFF MANAGEMENT

A simplistic, strategic approach was undertaken to address stormwater management. Three primary functional realms are identified and shall be implemented to provide a mitigating approach to reducing and regulating the amount of precipitation entering the campus stormwater system. Guided by Dunnet and Clayden, a strategy is founded based on three functional categories that deal with catchment, containment and conveyance, while upholding the defined project goals.

The catchment features are paramount to the success of a stormwater management system because they rely on the volume of surface run-off that is captured. The catchment strategy will optimize the level of catchment in our defined project area. Catchment areas shall be incorporated to capture precipitation not only from roadways, but from other impervious areas such as sidewalks, paved surfaces, and roof surfaces within existing and new pervious grass or gravel areas.

The containment element is a key intermediary feature of the stormwater system that will be required to accommodate the additional precipitation that is captured. The containment systems must be able to control the collected water through infiltration and detention. The scale of the containment features are appropriately selected based on their functional requirements, as well as their proximity to the catchment areas. In accordance with the project goals, containment features will also be selected to create sustainable awareness while being least intrusive to the existing ambiance of Main Mall.

The conveyance system will be the conduit for moving stormwater. This system allows water to be moved from feature to feature, such as roof drains to a containment tank or from storage tanks to an irrigated planting bed. They can be visible at the surface or hidden below ground, depending on the functionality and project goal requirements. We opted to select a conveyance system that is visible without being intrusive in the public environment.

4.0 MAIN GOALS

Before we began investigating possible conceptual designs for Fairview Square our group came up with project goals that would outline our purpose. We decided the following three goals incorporated the client's requests in the best way:

I. Erosion of the cliffs: A major concern at UBC is erosion of the cliffs on the Northwest end of campus due to surface water runoff. In our design we attempted to reduce the volume of water overtopping the cliffs to minimize erosion.

II. Water management: Being able to store water throughout the year using a containment tank for use in the dry summer months would be beneficial to both UBC and the Greater Vancouver Regional District (GVRD). Having a large portion of runoff water be redirected into a tank for later use would significantly reduce the amount of water entering storm drains, and also lessen the extent to which UBC uses the GVRD water supply for irrigation purposes.

III. Awareness: In order to promote sustainability around campus we wanted to make all of our features as visible as possible. Along with visual appeal, we tried to incorporate a social meeting place that wasn't intrusive but aesthetically pleasing and convenient.

With these project goals in mind we brainstormed possible solutions for each by weighing the pros and cons. Having these goals made it much simpler to prioritize our ideas and maintain our focus.

5.0 AREA CALCULATIONS

In order to complete the Water Balance Model for Fairview Square (both existing and proposed designs) it was necessary to determine specific areas, outlined in Appendix A, within the project vicinity. In order to do this we used a method of scaling each length off of a map provided. We took a tape measure and found the span of a few key elements, including the width of the Kaiser building and the width of the boulevard. Then using the maps provided we could establish dimensions of all features contained within the Fairview Square project area (see Appendix C: Figure 18).

After we determined the length of all key features we inserted these dimensions into an excel spreadsheet (see Appendix A). From this, we computed all of the areas shown in Appendix C: Figure 18, including roof areas, to use in further calculations. Estimating values for runoff coefficients in each area, we decided there would be four categories; each with a different coefficient, as shown in Table 1 below:

Table 1: Areas with respective runoff coefficients

Type of area	Runoff coefficient
Greenspace	0.2
Sidewalks	0.8
Roads	0.9
Permeable Roads	0.5

For each area, we had to estimate what portion of the region would be in each of these four categories. This proved to be quite difficult for sidewalks and greenspace, so we estimated the percentage of the area that was sidewalk and greenspace instead of measuring the tangible sections. We used the diagrams provided to estimate the roof areas for both existing and proposed designs, which would then become the rainwater catchment zones where water could be conveyed to a storage tank for later use.

5.1 ASSUMPTIONS MADE

During the course of our conceptual design necessary assumptions were made. In creating the water balance model, as mentioned before, we had to estimate the areas consisting of greenspace, sidewalks, roads and (semi)permeable surfaces. Since these values are not exact they create an uncertainty in our calculations. Another source of uncertainty is the runoff coefficients. As mentioned to our class in a lecture, the coefficients can vary within each category. For example, in a greenspace environment, depending on the type of plants present there could be significant increase or decrease in the amount of runoff and infiltration occurring. We took an average value for the parts of Fairview Square that included greenspace.

In order to meet the irrigation needs for a single year we had to estimate the volume of water that needed to be stored in the system. This incorporates another variable into our calculations, because the Plant Operations watering schedule was not available for our use, and as such we were not able to accurately estimate the amount of water used per year for irrigation purposes. We assumed that grass needs 25mm of water per week to survive during the summer months. In the fall and spring months we reduced this amount to 15mm per week. During the winter, we assumed that no irrigation was necessary.

6.0 WATER BALANCE MODEL

Our water balance model is a dynamic algorithm that takes user input for rainfall, specific areas, runoff coefficients, and irrigation requirements and creates a graphical representation of water stored, infiltrated water, and water supply vs. demand. This dynamic model shows that our conceptual design greatly reduced the water storage volume requirements by taking into consideration summer rainfall, water collection and watering needs, and lets us see where peak rainfalls have significant effects on runoff, seepage and water storage. This model allows us to see the difference that making changes to our dynamic constraints has on our preferred outcomes. For example, by reducing greenspace area or the required weekly depth of water that greenspace needs to survive, we see the managing all of Fairview Square's irrigation demand with pure captured rainwater is a reasonable goal.

We used our water balance model to calculate stormwater runoff with the existing Fairview Square project area and with our proposed conceptual design. Listed in Appendix B are the water balance model calculations for light, normal and heavy rainfall years. In these calculations are graphs of water infiltration, amount of water down the storm drains, amount of water in storage tanks and water needed versus water available per week of the year. To reach these conclusions, Excel macroinstructions were utilized within the Excel spreadsheet which calculated and graphed the parameters listed above.

7.0 CONCEPTUAL DESIGN IDEAS

7.1 CURBSIDE PONDS

Along Main Mall, the majority of the impermeable surfaces are roads and sidewalks. These impermeable surfaces create large volumes of surface runoff which is solely directed into the current stormwater drainage system. To contain this water volume and reduce the strain placed on the storm drains, we propose implementing curbside ponds (see Appendix C: Figures 7 and 8). These curbside ponds will provide an alternative area for this surface runoff to be directed, and an aesthetic attraction to educate the public about sustainable water management.

Through a perforated pipe and gravel drainage system placed underneath these ponds, this water which otherwise drains into the stormwater system will be directed into our submerged gravel pit located under the Main Mall Boulevard. This infiltration and direction of water will increase the capacity of surface runoff to be addressed by the curbside ponds. The overall results of the curbside ponds are; decreased surface runoff, an attractive and educational experience for the public, containment and direction of stormwater, and a reduced rate of water infiltration.

7.2 ROOF DRAINS

The rooftop areas of the three proposed buildings along Main Mall are the main catchment areas of the rainwater which will be discharged into the containment tanks. The three proposed buildings along Main Mall include the Earth Systems Science Building, and the two proposed buildings that will replace the existing Engineering Annex and The Barn Café and have an area of 56,000ft^2 (Appendix A). Considering an average precipitation year (1992) the annual rainfall was recorded to be 1,100mm, which suggests that the rooftops can be expected to capture approximately 6000m^3 of rainwater. (Appendix A).

In response to the increasing awareness of rainwater catchment, we propose to add an aesthetically appealing wall-side waterfall to direct the rainwater down from the rooftop. The wall side waterfall will serve the purpose of the existing roof drains which are visually unappealing, as shown in

Appendix C: Figure 2. A conceptual sketch of the wall-side waterfall is presented in Appendix C: Figure 10, however the relative width of the waterfall will be determined based on the expected flow rate from the rooftop.

We chose to locate the wall-side waterfall in front of the proposed Earth Systems Science Building facing Main Mall because it has the largest water catchment area among the three rooftop catchments. The rooftop of the proposed Earth Systems Science Building has an estimated area of over 27000ft^2 (Appendix A). During an average precipitation year, we can expect up to 47mm of rainfall per day (Appendix B). This means that up to 4,000ft^3 of rainwater will flow down the wall-side waterfall during heavy rainfall. As the wall-side waterfall will be visible to Main Mall, it effectively serves the purpose of promoting and reflecting the community's awareness of rainwater catchment.

For the other two proposed buildings in the Fairview Square at either end of Main Mall, with a relatively lower catchment area, we will direct the rainwater down the roof drains into a small gravel pit on the side of the building adopting the design in Appendix C: Figure 9. The rainwater will then flow from the gravel pits through water trenches below the ground surface, and discharge into curbside ponds.

7.3 WATER TANKS

Incorporating water tanks into our conceptual design is a way of addressing both irrigation and surface runoff concerns. The water tanks below the Biological Sciences Building (100m^3) were considered for our design but lack the required capacity (5000m^3). Instead we met this demand by creating a storage tank underneath the Main Mall Boulevard, in the form of a gravel pit (see Appendix C: Figure 17).

To achieve our desired irrigation levels, the dimensions for the impervious portion of the gravel pit were chosen to be 200m x 10m x 5m. Assigning gravel a void ratio of 0.5, this size of pit will provide 5000m^3 of water which can be utilized during months of low rainfall. To avoid overflow of our system, relief piping will be placed in a gravel layer above the impervious portion of our pit. This piping will protect against flooding in the gravel pit system and will direct the infiltrated water towards features in Fairview Square, mainly the proposed Amphitheatre.

The gravel pit walls will have a layered system. The bottom portion of the pit will be an impervious clay layer such as bentonite that will effectively prevent the water from seeping through into the surrounding soil. Next, a small layer of semi-pervious soil will be implemented so that if the pit becomes too full in times of heavy rainfall the excess water will be able to seep through this layer into the surrounding environment to prevent overflow of the gravel pit. Should the capture of water be so large that the level of water becomes higher than the semi-permeable layer, there will be an area where excess water is directed down existing water management features.

The purpose behind implementing a large subterranean gravel pit was to minimize the intrusive factor of our conceptual design on the aesthetic appeal of Main Mall. With all of our other ideas which are intended to improve awareness about sustainability we feel that the gravel pit should be underground and not visible to the public. A large storage tank situated above ground would seriously disrupt the open feel of the existing boulevard and would not be beneficial to our design.

7.4 WATER TRENCHES

During periods of heavy rainfall, large volumes of water are carried down from the rooftops. To slow down the water flow, roof water will be directed into the water trenches along a chosen path before discharging into the containment tanks (see Appendix C: Figure 4).

A conceptual 2D sketch of the proposed rainwater features is presented in Appendix C: Figure 9, showing the path of the rainwater from the rooftop down to the curbside ponds. As shown in the sketch, the water trench meanders in front of the building and crosses the sidewalk reaching the curbside ponds. The entrance of the Earth Systems Science Building will be connected to the sidewalk with an arch bridge which allows people to walk over the water trenches with water flowing between the flowerbeds.

7.5 AMPHITHEATRE

The amphitheatre, situated between the proposed Earth Systems Science Building and the location of the existing Barn Cafe, will become the defining element of Fairview Square and provide an intersection for the south portion of Main Mall. By removing roads and paved surfaces in front of the Frank Forward building grass surfaces would provide an inviting area that would be utilized as a social space. This area would gain aesthetic appeal and result in a space that is filled with activity and serve to educate the public. This made the incorporation of the amphitheatre an ideal element in this prominent location of Fairview Square.

This outdoor area will become a focal point of Fairview Square with an approximate area of 60,000ft^2. The amphitheatre will be located close to the Main Mall pedestrian walkway and will be gently sloped (roughly 18” elevation change) and broadly terraced (30’’ widths) (see Appendix C: Figure 16). The amphitheatre seating is complimented with stepped water containment ponds/waterfall (weirs), which not only serve as an architectural feature but also as a stormwater system (see Appendix C: Figure 17). These containment ponds will empty out into a drainage channel and pick up other catchment areas at a channeling confluence downstream as it heads out of Fairview Square. The amphitheatre will be flanked by a wide pervious concourse that can accommodate pedestrian traffic.

8.0 ESTIMATED RESULTS

After examining our proposed concept plan with the dynamic water balance model, we observed that our goals of dramatically reducing and slowing the rate of stormwater runoff are met and are represented graphically in Appendix B: Graphs 5, 8 and 11. We also see an increase in seepage water, specifically in the summer when a portion of the water that would normally be going down the storm drain in the winter is being distributed by irrigation methods in the summer over greenspace with a high seepage coefficient (see Appendix B: Graphs 6, 9 and 12).

To give a comprehensive view of how our plan will respond to different levels of rainfall, we have used the dynamic water balance model to analyze three different rainfall years. We did this by taking our normal yearly rainfall data, and multiplying the weekly values by 1.5 for a heavy year, and dividing the weekly values by 2 for a light year. Taking this data and results for each type of year, we then plotted a number of graphs: Water Down the Storm Drain, Water Seeping Into the Ground, Water Collected versus Water needed (for irrigation), and Final Water Supply (Volume of water in our storage tank at any point in the given year). See Appendix B (Graphs).

Using the normal year's rainfall data, we observe a reduction of 400m^3 of water down the storm drain. During the heaviest rainfall week, there is over a 25% decrease in stormwater drainage. With irrigation in the summer, there can be no rainfall during a given week but still have runoff and therefore stormwater drainage. This is the trade off we were looking for; a dramatic decrease in stormwater drainage when volumes are high and capacity is pushed, and an increase in stormwater drainage when the drainage capacity is low.

Our goal of decreasing stormwater runoff in heavy rainfall periods and increasing the volume of water that is allowed to seep into the ground when precipitation is low is met by storing water in the winter, and by timed release in the summer. An advantage of this technique is that the total volume of water that would be used to irrigate greenspace can be obtained from captured rainwater, rather than the GVRD. These results are significant because they maximize the available greenspace, and therefore increasing the overall aesthetics of Fairview Square.

9.0 CONCLUSION

Fairview Square and the creation of a sustainable boulevard promises to herald a new era in innovative technology and building design in Vancouver. A number of issues arose in the design process that will be met with equally unique solutions. Based on site area calculations we created a dynamic water balance model. Our main goal for Fairview Square was to create a catchment and water storage area that was equally functional and aesthetically pleasing. When managing stormwater runoff, we created a “3 C’s” approach which focused on catchment, containment, and conveyance.

Our conceptual design is based upon the use of curbside ponds and roof drains as well as large water tanks, water trenches, and an amphitheatre. The main purpose of the curbside ponds is to capture, contain and then filter water into the gravel pit in a visually stimulating manner. Roof drains as well as the curbside ponds capture water but are more visually interactive in the path that the water takes. These drains will take the water that normally would be released into the GVRD stormwater system and stores it in water tanks. The main function of the water tanks is to contain water runoff so it can be used for irrigation. Irrigation trenches convey water during periods of heavy rainfall from the rooftops to the water tanks. This serves to slow down the flow rate of the water as well as provide the aesthetic appeal of a meandering stream. The large amphitheatre is the largest and most interactive part of our conceptual design. Serving to capture, contain, and convey water, the amphitheatre covers an area of approximately 60,000ft^2. The amphitheatre has a large catchment area, stepped water containment ponds and a large central gathering area.

If our designs were to be implemented there would be a significant change in the ability to sustainably manage stormwater runoff in the existing Fairview Square area. Estimated results show that there is 25% less water in the system and plenty of water will be available for irrigation in the dry months. Water capture, containment and conveyance is paramount in the sustainability of Fairview Square. The Fairview Square project hopes to build upon the existing values of sustainability at UBC in an effort to uphold Vancouver’s standard of being the best place on earth.

11. APPENDIX A: AREA CALCUATIONS

Side	Measurement (mm)	True Distance (ft)
1	25	112
2	30	134.4
3	7	31.36
4	58	259.84
5	32	143.36
6	82	367.36
7	65	291.2
8	77	344.96
9	12	53.76
10	18	80.64
11	6	26.88
12	19	85.12
13	17	76.16
14	17	76.16
15	19	85.12
16	27	120.96
17	27	120.96
18	40	179.2
19	16	71.68
20	47	210.56
21	11	49.28
22	17	76.16
23	6	26.88
24	19	85.12
25	42	188.16
26	65	291.2
27	65	291.2

Section	Area (ft^2)
A1	4214.784
A2	37116.2624
A3	228300.8
A4	4335.2064
A5	7245.4144
A6	6101.4016
A7	9212.3136
A8	12584.1408
A9	33718.272
	342828.595

A10	441.5488
Total Area:	342387.0464

Proposed

Roof	Area (ft^2)
1	10537
2	27135
3	5500
4	13648
	56820

Existing

Roof	Area (ft^2)
1	19918
2	4164
3	7148
4	10410
	41640

Existing Road/Sidewalk Area (ft^2)		
Road	24166.6667	
Boulevard	41566.6667	-sidewalks?
Big Sidewalk	14016.6667	
Small Sidewalk	7733.33333	

Scale 3mm=25'

A1 is 100% impermeable

A3 + A2 Taken up by small sidewalks

10% ((A3+A2) - roof area - road - big sidewalk)

= 18559

Remainder A4 - A9

25%((A4+A5+A6+A7+A8+A9-A10) - roof area)

= 14776.8 (proposed)

= 15586.3 (existing)

Area	Type	ROC	Total Area (ft²)			
A1	Road	0.9	4214.78			
	Sidewalks	0.8	0			
	Permeable Road	0.5	0			
	Greenspace	0.2	0			
A2&A3	Road	0.9	24166.6667			
	Sidewalks	0.8	32575.6667			
	Permeable Road	0.5	0			
	Greenspace	0.2	188270.396	(proposed)	188270.4	(existing)
A4-A9	Road	0.9	5910.72		6234.52	
	Sidewalks	0.8	8866.08		9351.78	
	Permeable Road	0.5	32508.96		34289.86	
	Greenspace	0.2	11821.44		12469.04	

ft^2	existing	proposed
Total Road:	34292.16667	34292.16667
Total Sidewalk:	41441.74667	41441.74667
Total Permeable Road:	34289.86	32508.96
Total Greenspace:	200091.8357	200739.4357

12. APPENDIX B: WATER BALANCE MODEL

12.1. NORMAL RAINFALL YEAR DATA

Formulas

CalcRoofWaterCollected(RainFall, RoofArea)
CalcVolWaterDownStorm(GreenArea, ROCofGreenArea, IrrigatedArea, ROCofIrrigatedArea, NonGreenArea, ROCofNonGreenArea, DWI, RainFall)
CalcVolWaterDrainedThroughSoil(GreenArea, SECofGreenArea, IrrigatedArea, SECofIrrigatedArea, NonGreenArea, SECofNonGreenArea, DWI, RainFall)
CalcVolWaterNeeded(IrrigatedArea, DWI, RainFall)
CalcVolTotalWaterInTank(VolWaterFromPrevWeek, WaterCollected, WaterNeeded)
CalcVolExcessWater(WaterCollected, WaterNeeded)

Areas of Proposed Roofs and Their Respective Run-off Coefficients

Name	Area	Type of Roof	Run-off Coefficient
Roof1	10537	Flat	1
Roof2	27135	Flat	1
Roof3	5500	Flat	1
Roof4	13648	Flat	1
RoofTotal	56820	TotalRoofArea (sqf)	

Land Areas and Their Respective Run-off Coefficients

Name	Area (ft²)	Type of Surface	Run-off Coefficient	Seepage Coefficient
Road Area	34292	Road	0.9	0.1
Sidewalk Area	41442	Sidewalk	0.8	0.2
Permeable Area	32508	Permeable Road	0.5	0.5
Green Area	200739	Green Space	0.2	0.8
NonGreenArea	108242	Variable	0.74	0.26
GreenArea	**200092**	**Green Space**	**0.2**	0.8
IrrigatedArea	**200092**	**Irrigated Area**	**0.2**	0.8

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GreenArea (ft²)	ROCofGreenArea	SECofGreenArea	IrrigatedArea (ft²)	ROCofGreenArea	SECofGreenArea	NonGreenArea (ft²)
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
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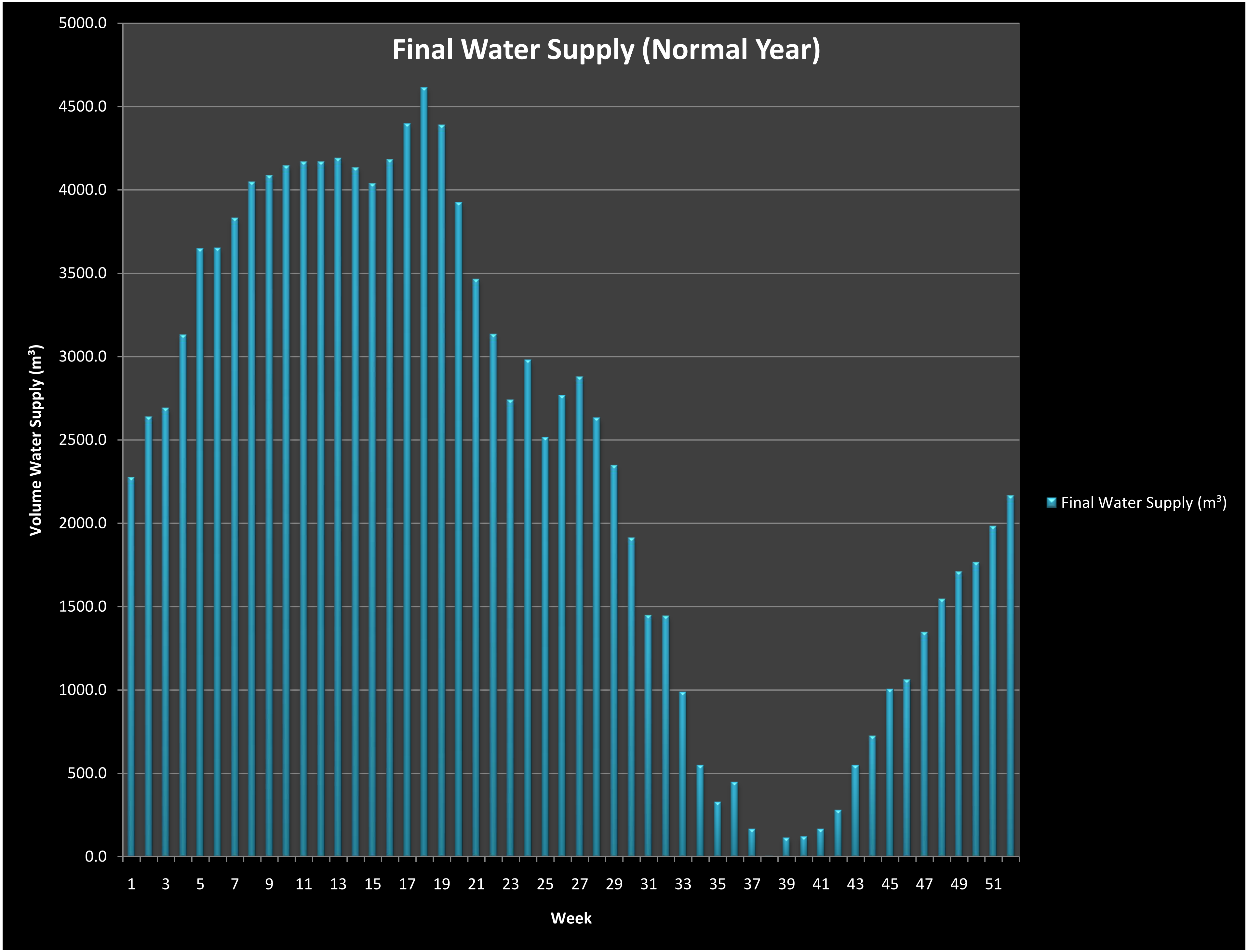
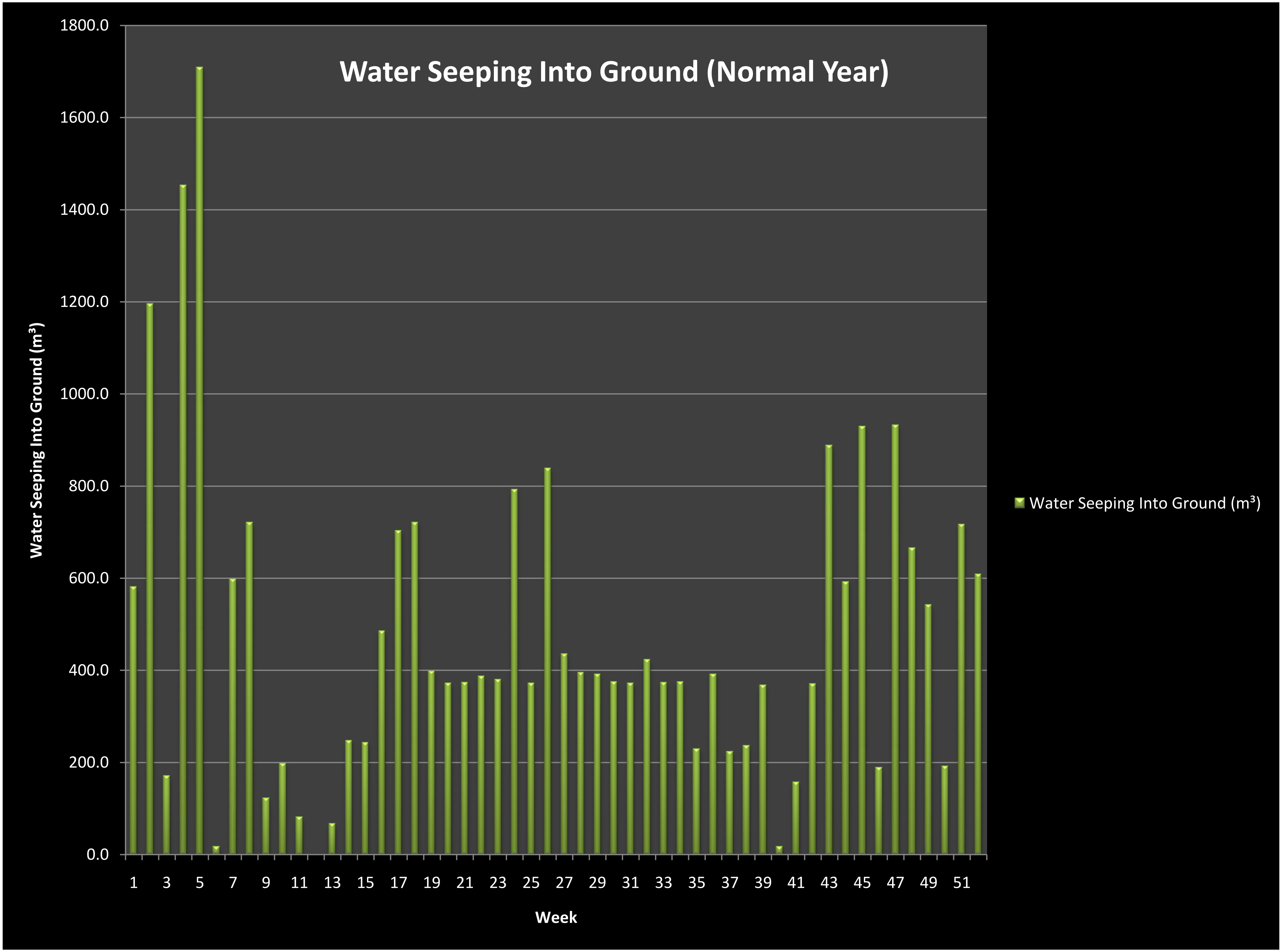
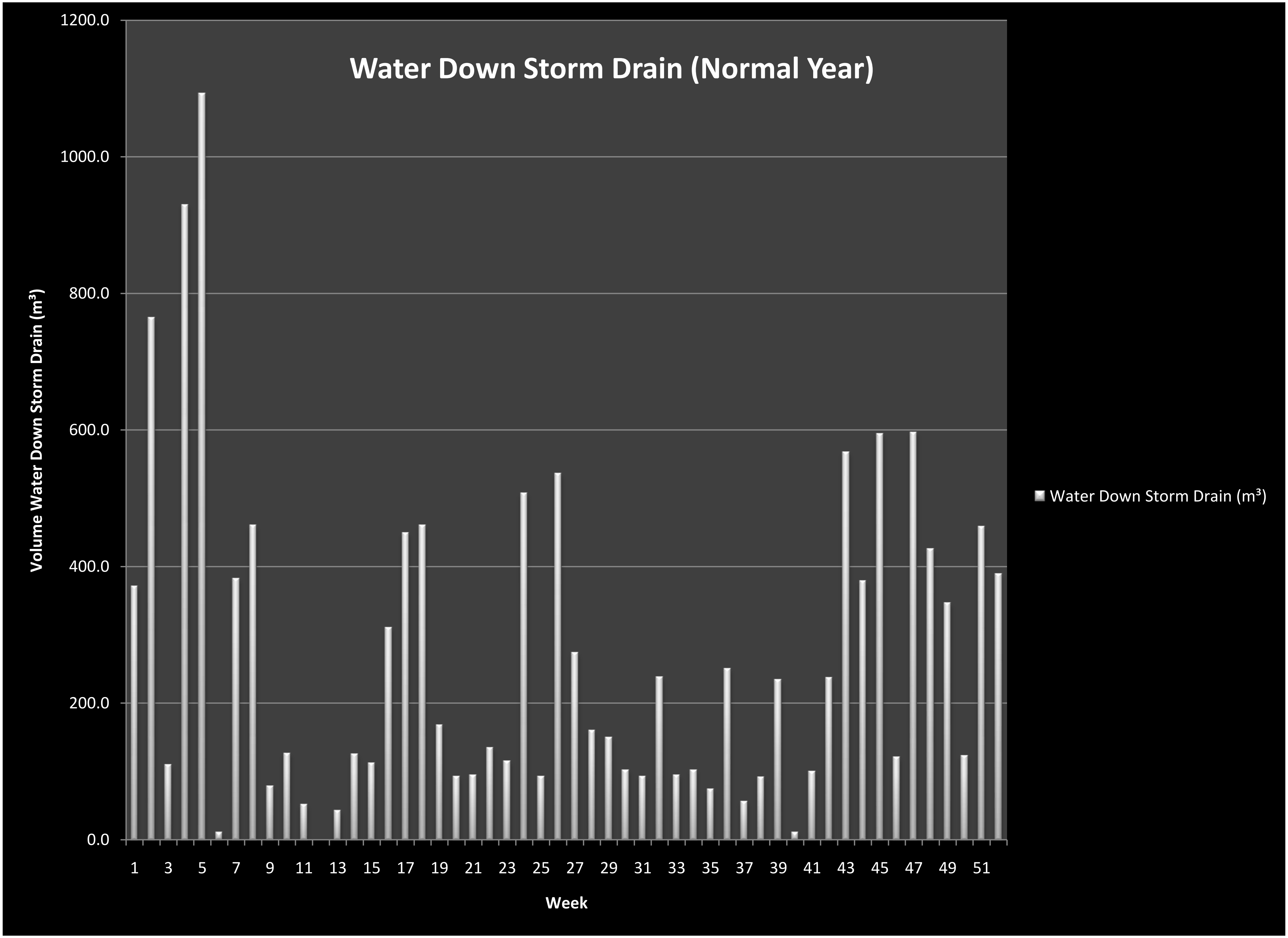
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242
200092	0.2	0.8	200092	0.2	0.8	108242

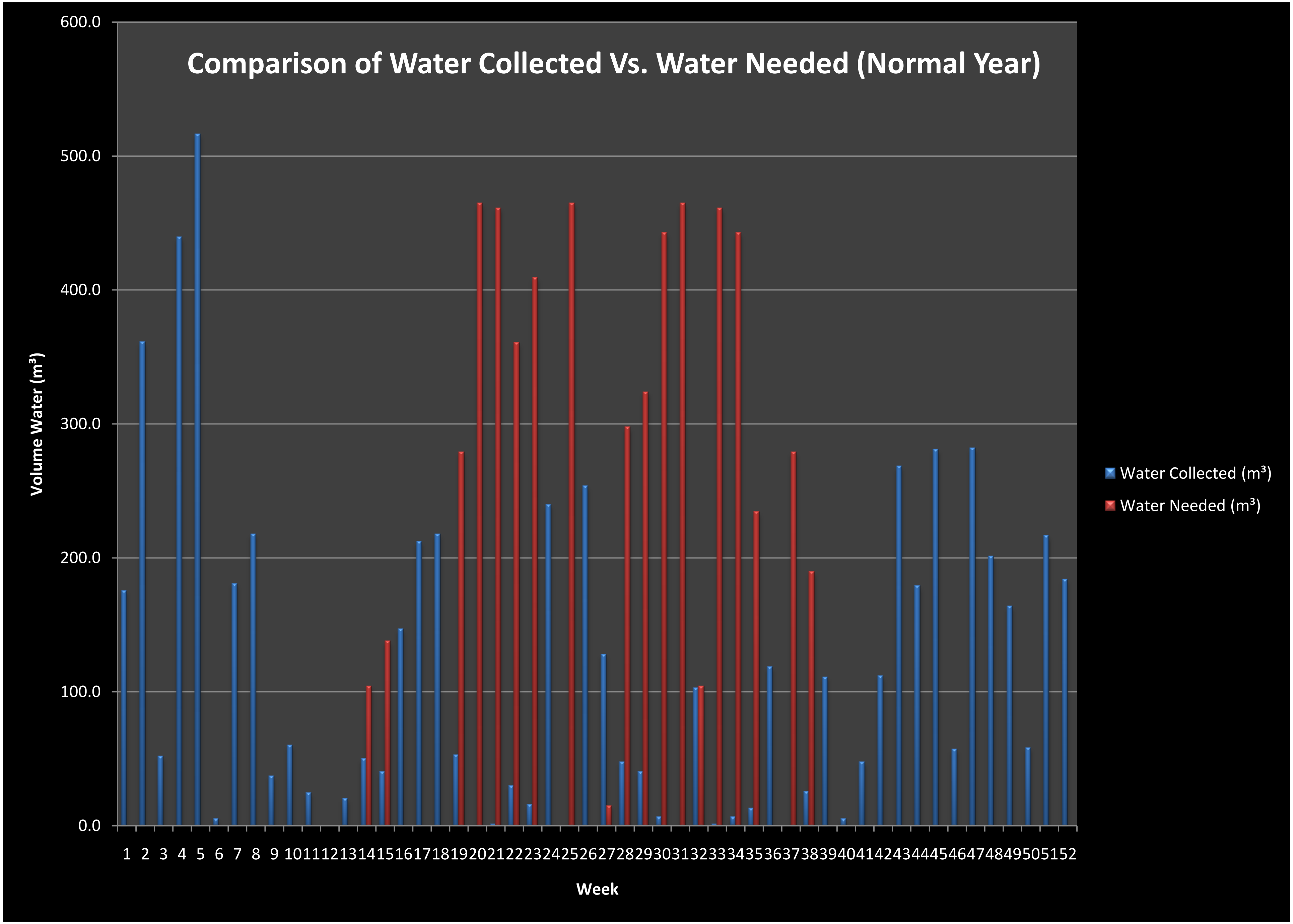
ROCofNonGreenArea	SECofNonGreenArea		Week	Rainfall (0.1 mm)	Rainfall (mm)	Roof Area (ft^2)	Depth Of Water Required For Irgtn. (DWI) in mm	Water Supply (m^3)
0.74	0.26	Jan	1	332	33.2	56820	0	2100.0
0.74	0.26		2	684	68.4	56820	0	2275.2
0.74	0.26		3	98	9.8	56820	0	2636.3
0.74	0.26		4	832	83.2	56820	0	2688.0
0.74	0.26	Feb	5	978	97.8	56820	0	3127.2
0.74	0.26		6	10	1	56820	0	3643.5
0.74	0.26		7	342	34.2	56820	0	3648.7
0.74	0.26		8	412	41.2	56820	0	3829.3
0.74	0.26	March	9	70	7	56820	0	4046.7
0.74	0.26		10	113	11.3	56820	0	4083.7
0.74	0.26		11	46	4.6	56820	0	4143.3
0.74	0.26		12	0	0	56820	0	4167.6
0.74	0.26		13	38	3.8	56820	0	4167.6
0.74	0.26	April	14	94	9.4	56820	15	4187.7
0.74	0.26		15	76	7.6	56820	15	4133.2
0.74	0.26		16	278	27.8	56820	15	4035.8
0.74	0.26		17	402	40.2	56820	15	4182.5
0.74	0.26	May	18	412	41.2	56820	25	4394.7
0.74	0.26		19	100	10	56820	25	4612.2
0.74	0.26		20	0	0	56820	25	4386.1
0.74	0.26		21	2	0.2	56820	25	3921.4
0.74	0.26	June	22	56	5.6	56820	25	3461.5
0.74	0.26		23	30	3	56820	25	3130.4
0.74	0.26		24	454	45.4	56820	25	2737.3
0.74	0.26		25	0	0	56820	25	2977.0
0.74	0.26	July	26	480	48	56820	25	2512.3
0.74	0.26		27	242	24.2	56820	25	2765.6
0.74	0.26		28	90	9	56820	25	2878.5
0.74	0.26		29	76	7.6	56820	25	2628.6
0.74	0.26		30	12	1.2	56820	25	2345.3
0.74	0.26	Aug	31	0	0	56820	25	1909.2
0.74	0.26		32	194	19.4	56820	25	1444.5
0.74	0.26		33	2	0.2	56820	25	1442.8
0.74	0.26		34	12	1.2	56820	25	982.8
0.74	0.26	Sept	35	24	2.4	56820	15	546.8
0.74	0.26		36	224	22.4	56820	15	325.2
0.74	0.26		37	0	0	56820	15	443.5
0.74	0.26		38	48	4.8	56820	15	164.6
0.74	0.26	Oct	39	210	21	56820	0	0.4
0.74	0.26		40	10	1	56820	0	111.2
0.74	0.26		41	90	9	56820	0	116.5
0.74	0.26		42	212	21.2	56820	0	164.0
0.74	0.26	Nov	43	508	50.8	56820	0	275.9
0.74	0.26		44	339	33.9	56820	0	544.1
0.74	0.26		45	532	53.2	56820	0	723.0
0.74	0.26		46	108	10.8	56820	0	1003.8
0.74	0.26	Dec	47	534	53.4	56820	0	1060.8
0.74	0.26		48	381	38.1	56820	0	1342.7
0.74	0.26		49	310	31	56820	0	1543.8
0.74	0.26		50	110	11	56820	0	1707.5
0.74	0.26		51	410	41	56820	0	1765.5
0.74	0.26		52	348	34.8	56820	0	1981.9

Water Collected (m^3)	Water Needed (m^3)	Final Water Supply (m^3)	Water Down Storm Drain (m^3)	Water Seeping Into Ground (m^3)
175.2	0.0	2275.2	371.0	580.0
361.1	0.0	2636.3	764.4	1194.9
51.7	0.0	2688.0	109.5	171.2
439.2	0.0	3127.2	929.7	1453.5
516.2	0.0	3643.5	1092.9	1708.5
5.3	0.0	3648.7	11.2	17.5
180.5	0.0	3829.3	382.2	597.5
217.5	0.0	4046.7	460.4	719.7
37.0	0.0	4083.7	78.2	122.3
59.6	0.0	4143.3	126.3	197.4
24.3	0.0	4167.6	51.4	80.4
0.0	0.0	4167.6	0.0	0.0
20.1	0.0	4187.7	42.5	66.4
49.6	104.1	4133.2	125.9	247.5
40.1	137.6	4035.8	112.4	242.8
146.7	0.0	4182.5	310.7	485.6
212.2	0.0	4394.7	449.2	702.3
217.5	0.0	4612.2	460.4	719.7
52.8	278.8	4386.1	167.5	397.8
0.0	464.7	3921.4	92.9	371.8
1.1	461.0	3461.5	94.4	372.3
29.6	360.6	3130.4	134.7	386.3
15.8	408.9	2737.3	115.3	379.6
239.6	0.0	2977.0	507.3	793.1
0.0	464.7	2512.3	92.9	371.8
253.4	0.0	2765.6	536.4	838.5
127.7	14.9	2878.5	273.4	434.7
47.5	297.4	2628.6	160.1	395.2
40.1	323.4	2345.3	149.6	391.5
6.3	442.4	1909.2	101.9	374.9
0.0	464.7	1444.5	92.9	371.8
102.4	104.1	1442.8	237.6	422.2
1.1	461.0	982.8	94.4	372.3
6.3	442.4	546.8	101.9	374.9
12.7	234.2	325.2	73.7	229.3
118.2	0.0	443.5	250.3	391.3
0.0	278.8	164.6	55.8	223.1
25.3	189.6	0.4	91.6	235.5
110.9	0.0	111.2	234.7	366.9
5.3	0.0	116.5	11.2	17.5
47.5	0.0	164.0	100.6	157.2
111.9	0.0	275.9	236.9	370.4
268.2	0.0	544.1	567.7	887.4
178.9	0.0	723.0	378.8	592.2
280.8	0.0	1003.8	594.5	929.4
57.0	0.0	1060.8	120.7	188.7
281.9	0.0	1342.7	596.7	932.9
201.1	0.0	1543.8	425.8	665.6
163.6	0.0	1707.5	346.4	541.6
58.1	0.0	1765.5	122.9	192.2
216.4	0.0	1981.9	458.2	716.2
183.7	0.0	2165.6	388.9	607.9

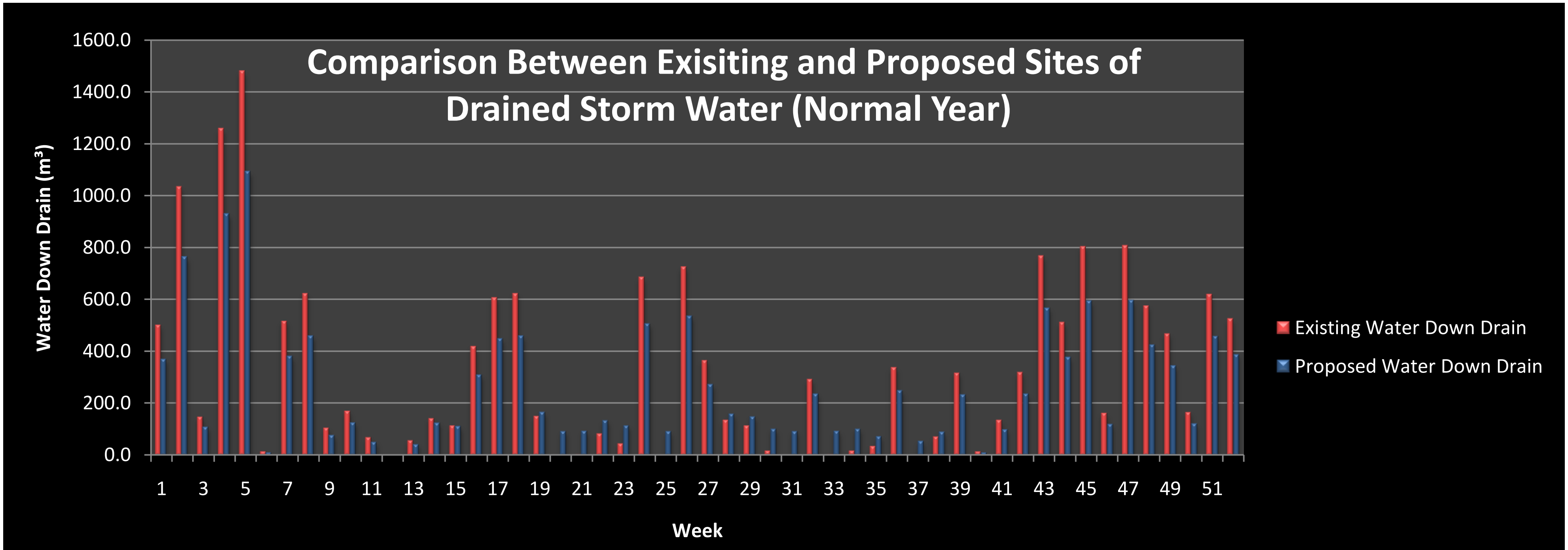

Final Water Supply (Normal Year)
Volume Water Supply (m³)
5000.0
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
Week
Final Water Supply (m³)

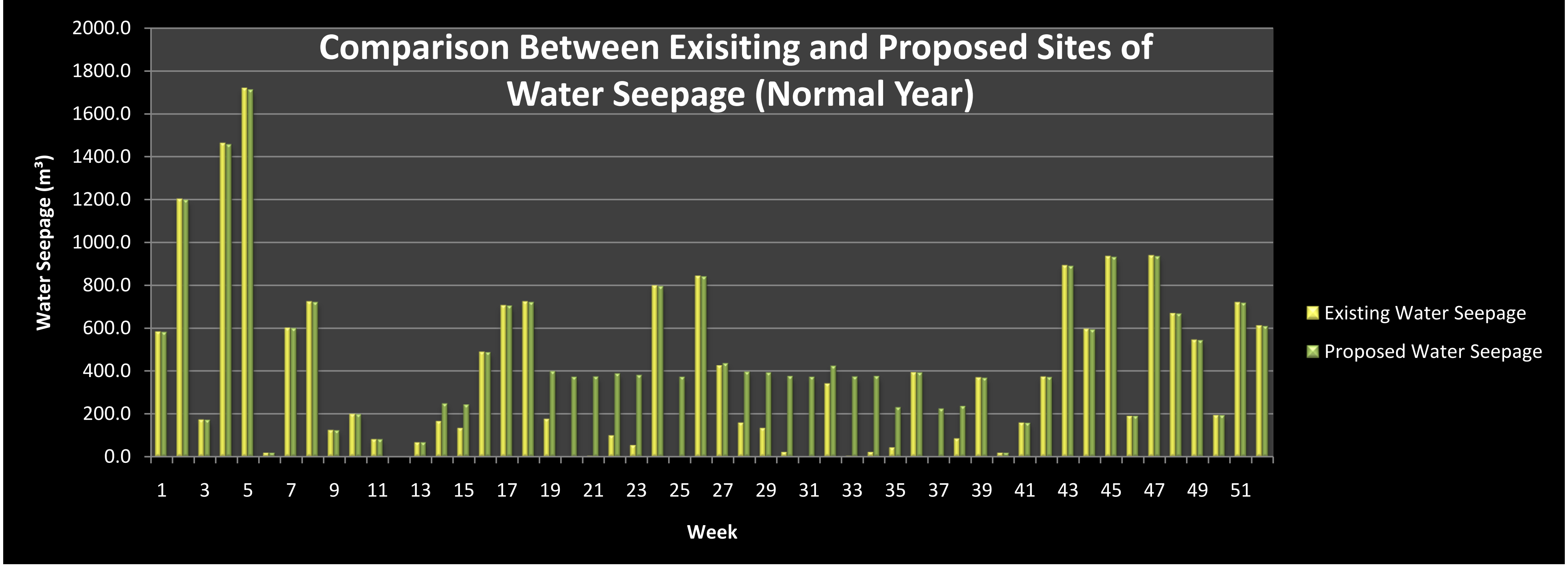

Water Seeping Into Ground (Normal Year)
Water Seeping Into Ground (m³)
Week
Water Seeping Into Ground (m³)
0.0
200.0
400.0
600.0
800.0
1000.0
1200.0
1400.0
1600.0
1800.0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51


Water Down Storm Drain (Normal Year)
Volume Water Down Storm Drain (m³)
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
49
51
Week
Water Down Storm Drain (m³)

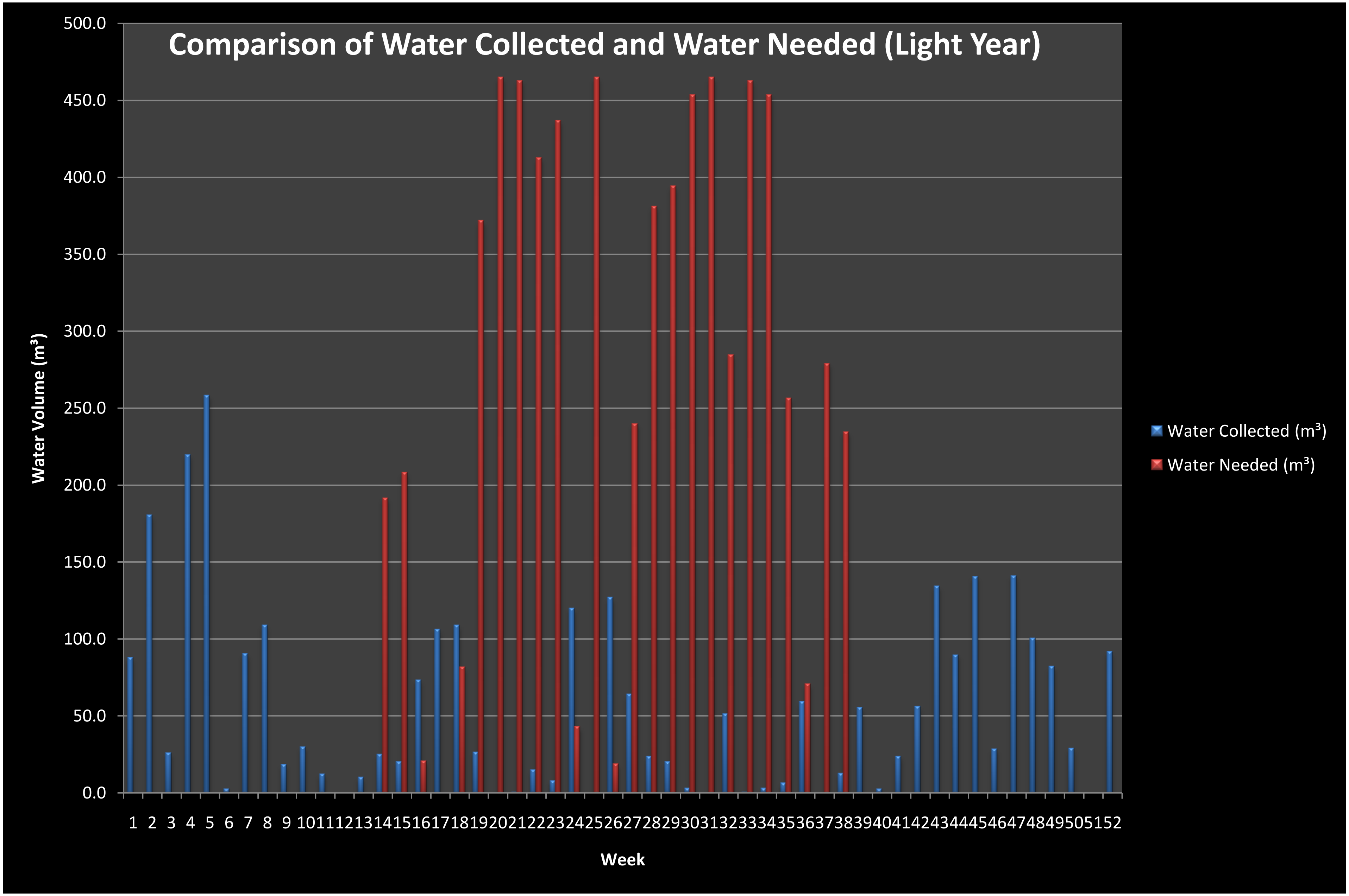


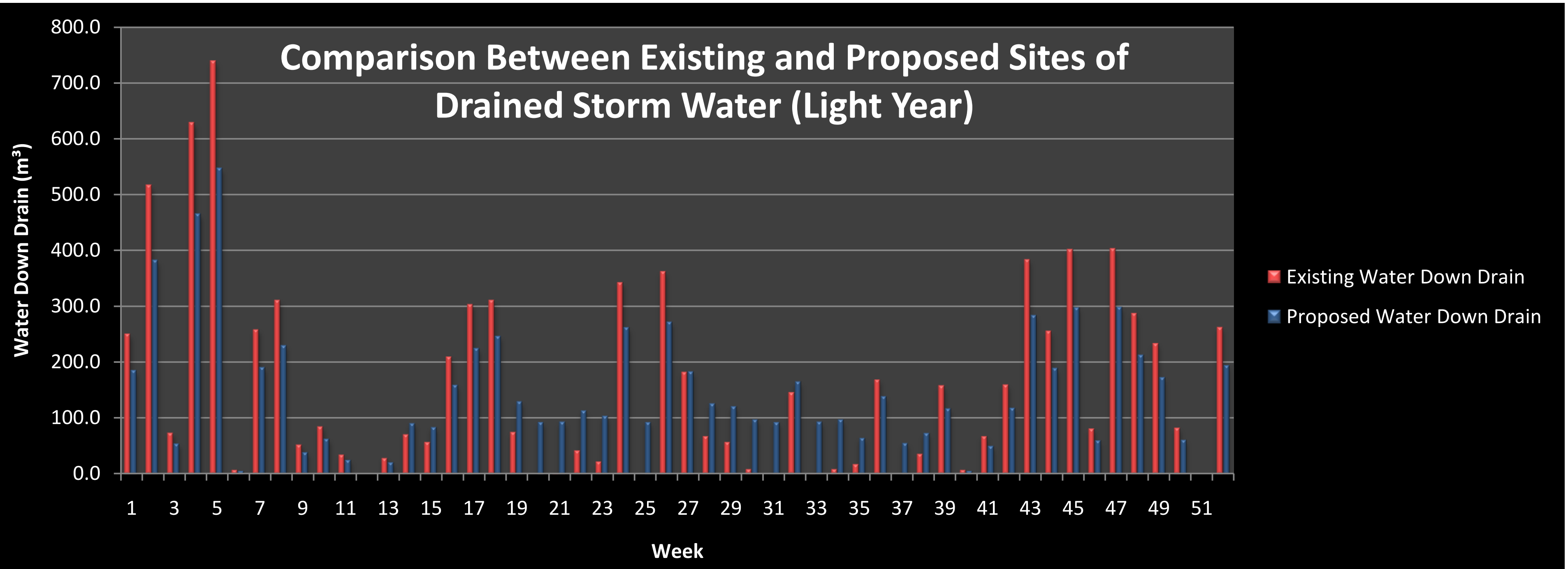
Comparison of Water Collected Vs. Water Needed (Normal Year)
600.0
500.0
400.0
300.0
200.0
100.0
0.0
Volume Water (m³)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52
Week
Water Collected (m³)
Water Needed (m³)

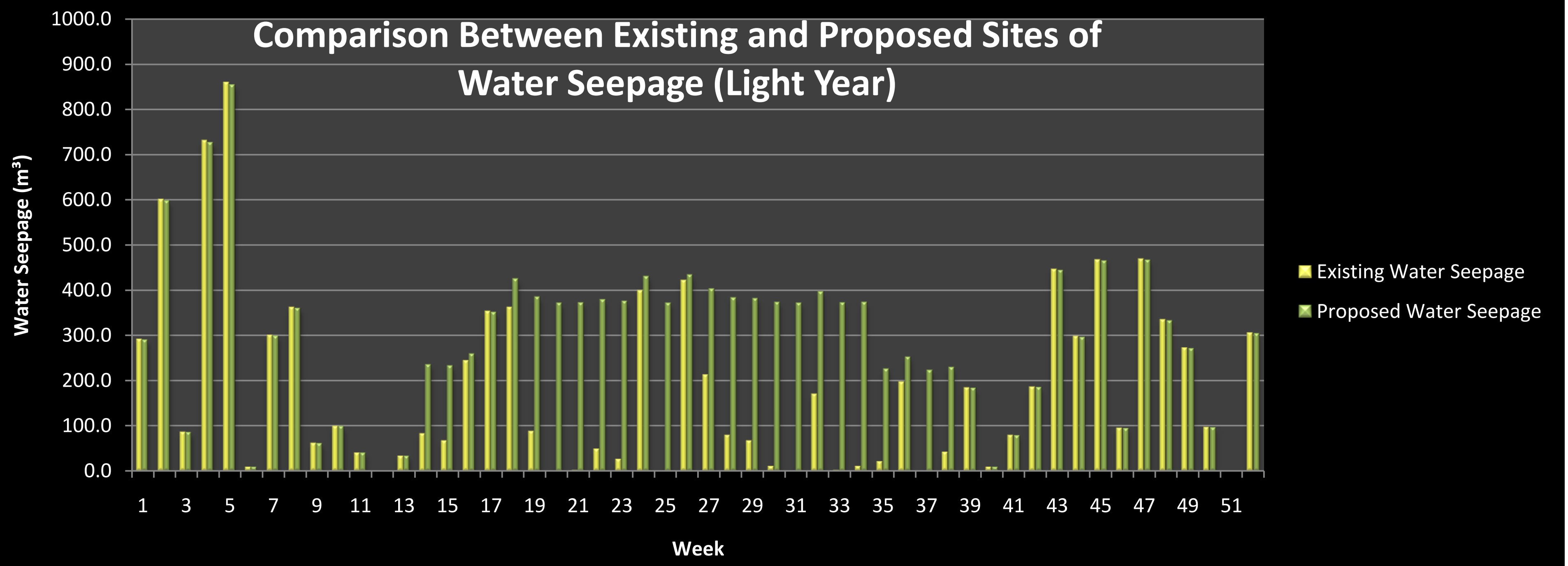

Comparison Between Exisiting and Proposed Sites of Drained Storm Water (Normal Year)
Water Down Drain (m³)
Week
Existing Water Down Drain
Proposed Water Down Drain


Comparison Between Exisiting and Proposed Sites of Water Seepage (Normal Year)
Water Seepage (m³)
Week
Existing Water Seepage
Proposed Water Seepage

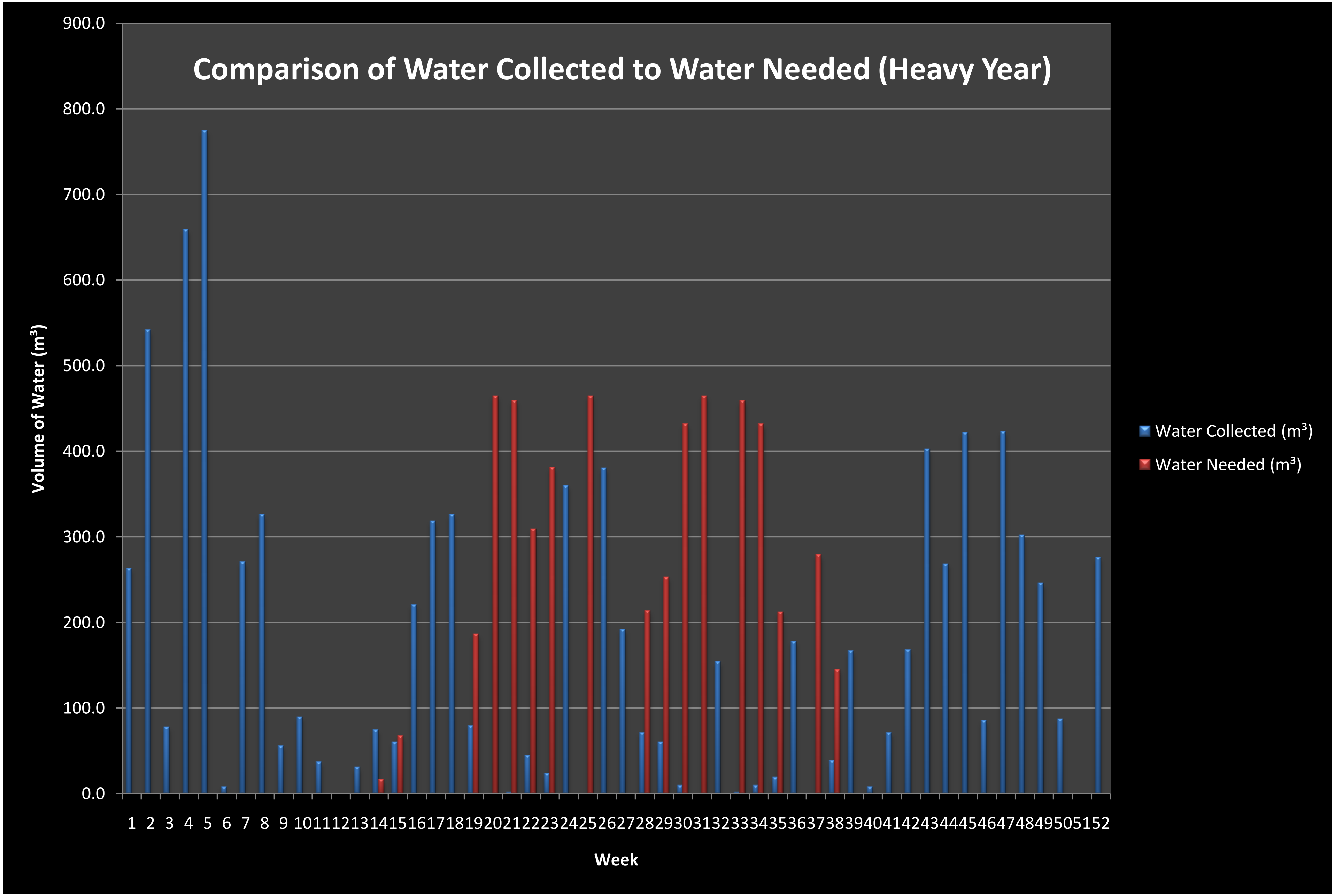
12.2. LIGHT RAINFALL YEAR DATA

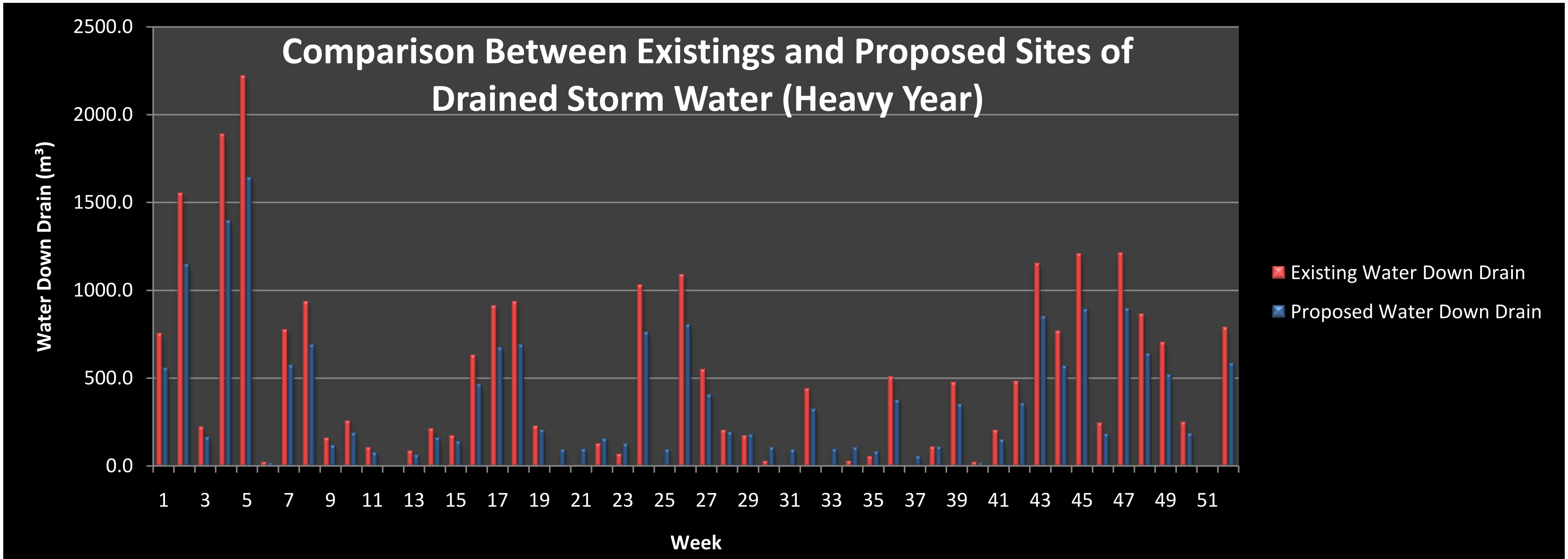


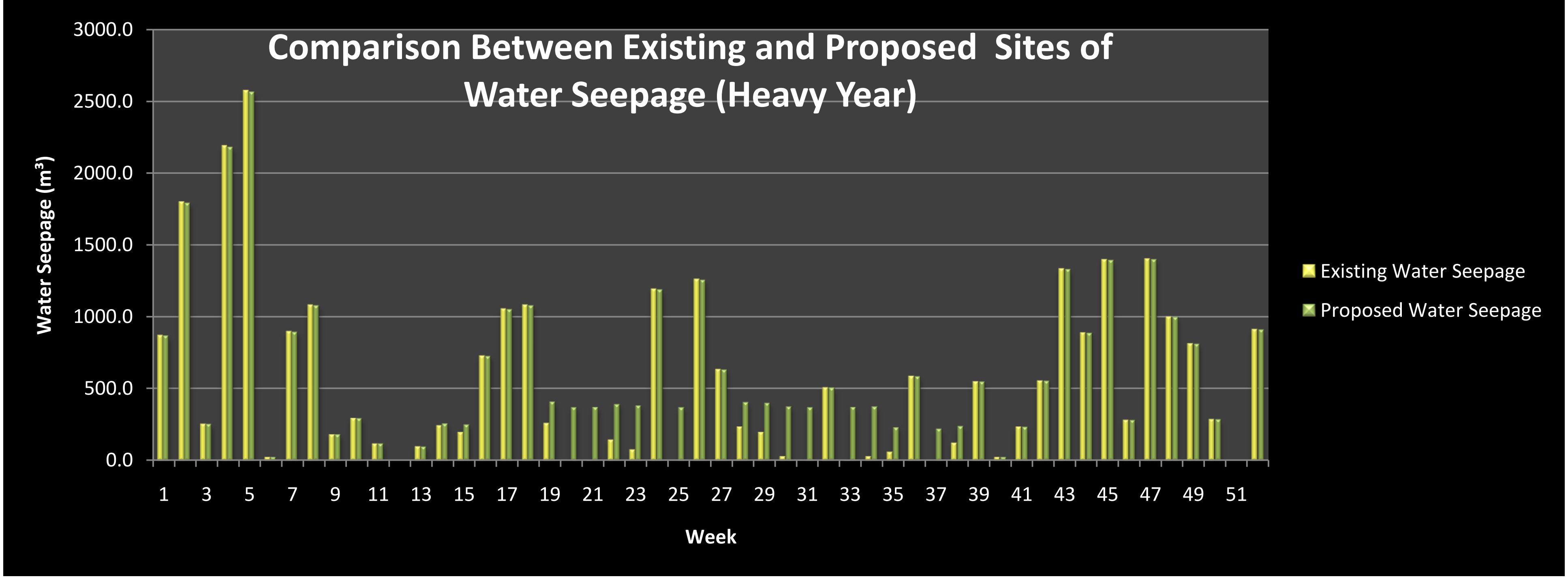

Comparison Between Existing and Proposed Sites of Drained Storm Water (Light Year)
Water Down Drain (m³)
Week
Existing Water Down Drain
Proposed Water Down Drain


Comparison Between Existing and Proposed Sites of Water Seepage (Light Year)
Water Seepage (m³)
Week
Existing Water Seepage
Proposed Water Seepage

12.3. HEAVY RAINFALL YEAR DATA




Comparison Between Existings and Proposed Sites of Drained Storm Water (Heavy Year)
Water Down Drain (m³)
Week
Existing Water Down Drain
Proposed Water Down Drain
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51


Comparison Between Existing and Proposed Sites of Water Seepage (Heavy Year)
Water Seepage (m³)
Week
Existing Water Seepage
Proposed Water Seepage
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51

13. APPENDIX C: FIGURES

13.1. CATCHMENT SYSTEMS

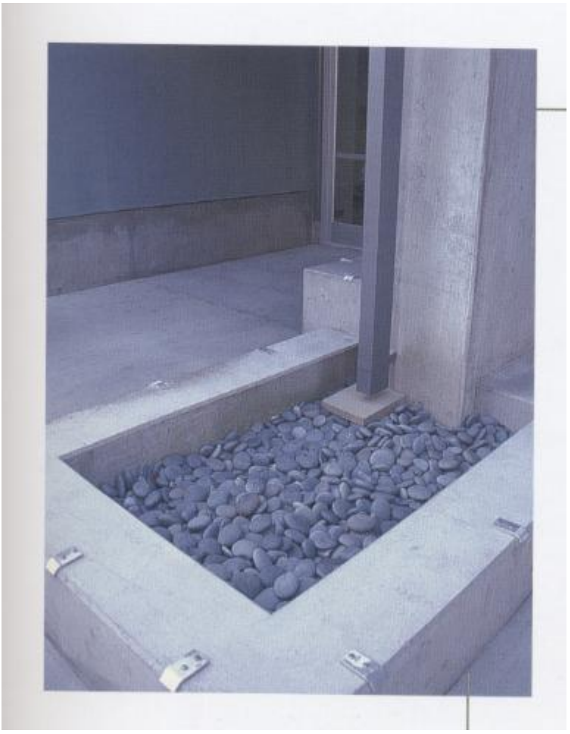


Figure 1: Disconnect roof drain to rock pit

Figure 2: Drainage of rock pit through sidewalk channel

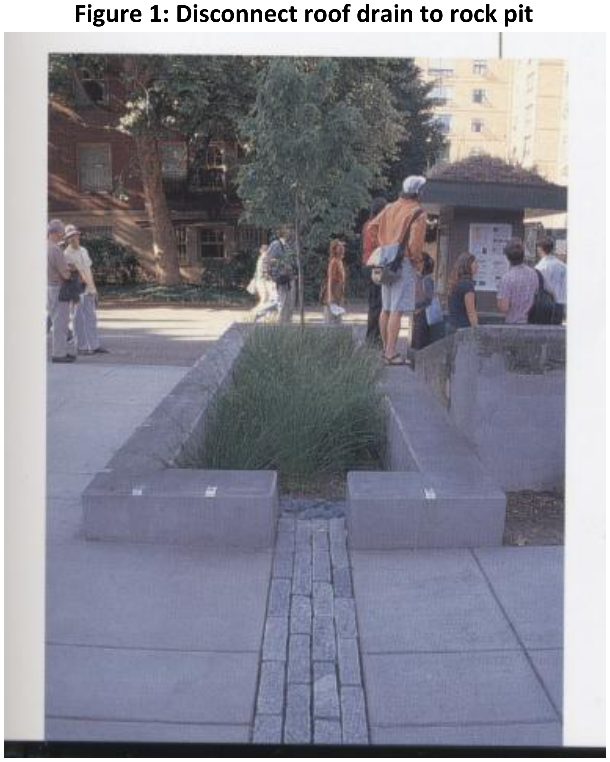


Figure 3: Outflow of sidewalk channel to planter

Figure 4: Carry roof drainage to dispersion area

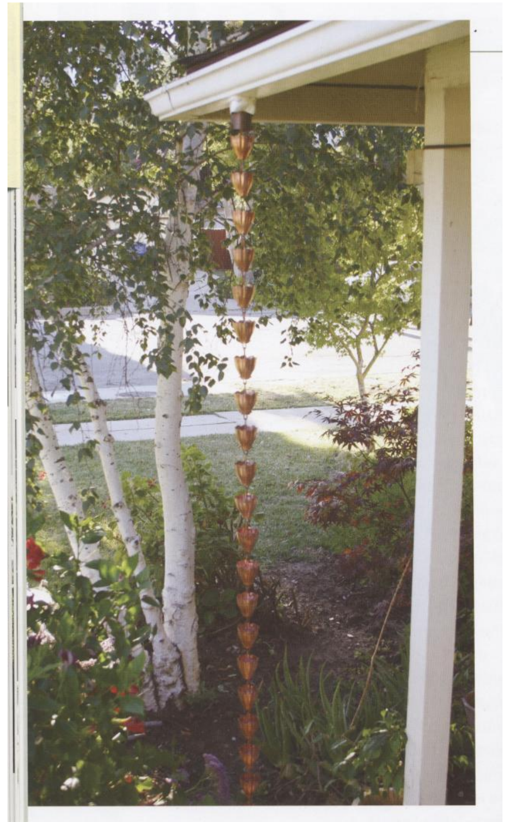


Figure 5: Roof drainage via drainage channels

Figure 6: Alternative rain drainage conduit

Figure 8: Curbside pond catching sidewalk runoff

Figure 7: Curbside ponds

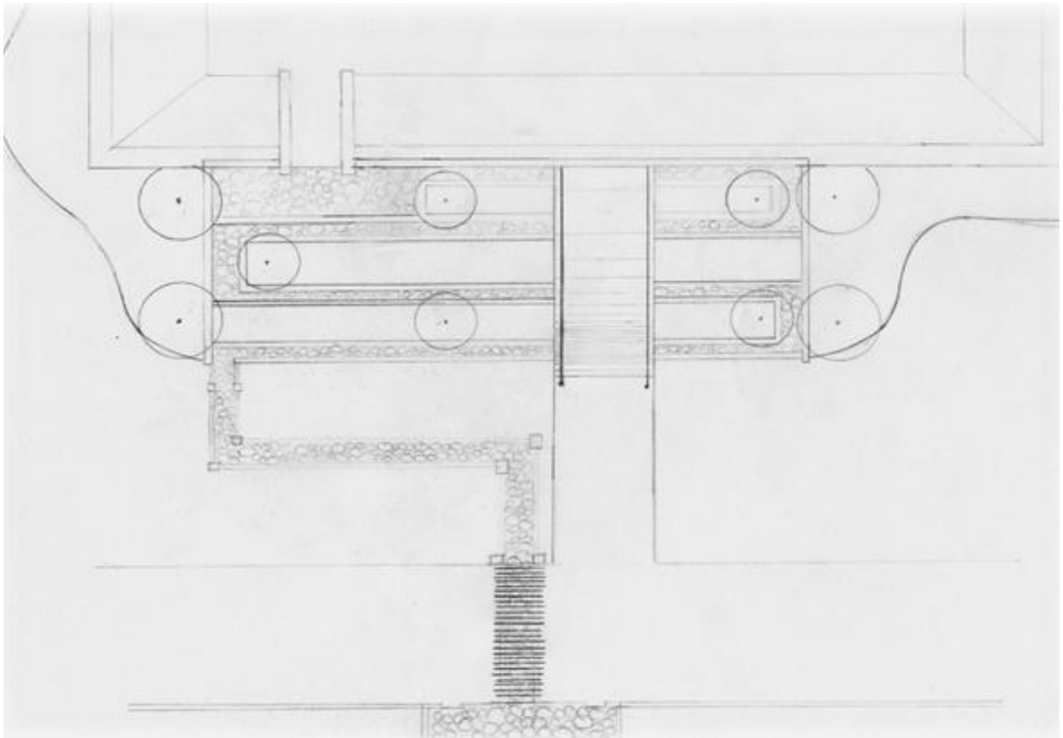


Figure 9: Meandering roof capture and conveyance system

Figure 10: Rendering of integrated roof drainage using building face waterfall

13.2. CONVEYANCE SYSTEMS

Figure 11: Open drainage channels

Figure 12: Integrated watercourse with elevation changes

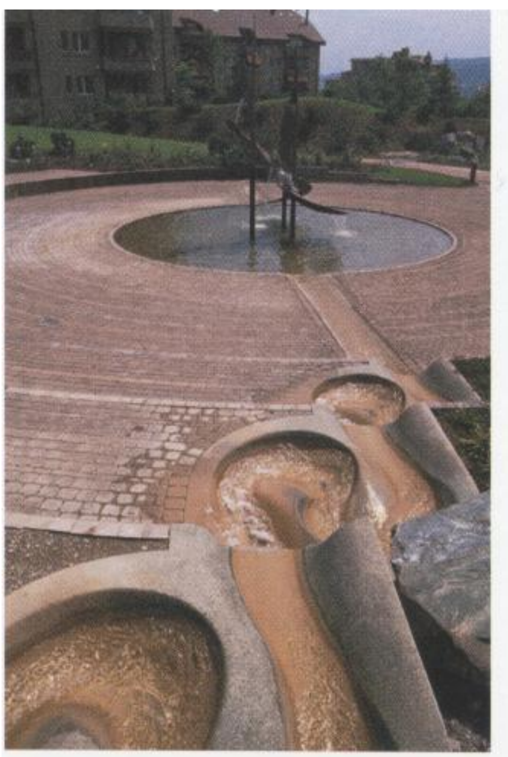


Figure 13: Playful waterfall conveying to water feature

Figure 14: Subtle use of water trenches

Figure 15: Terrace for water and human interaction

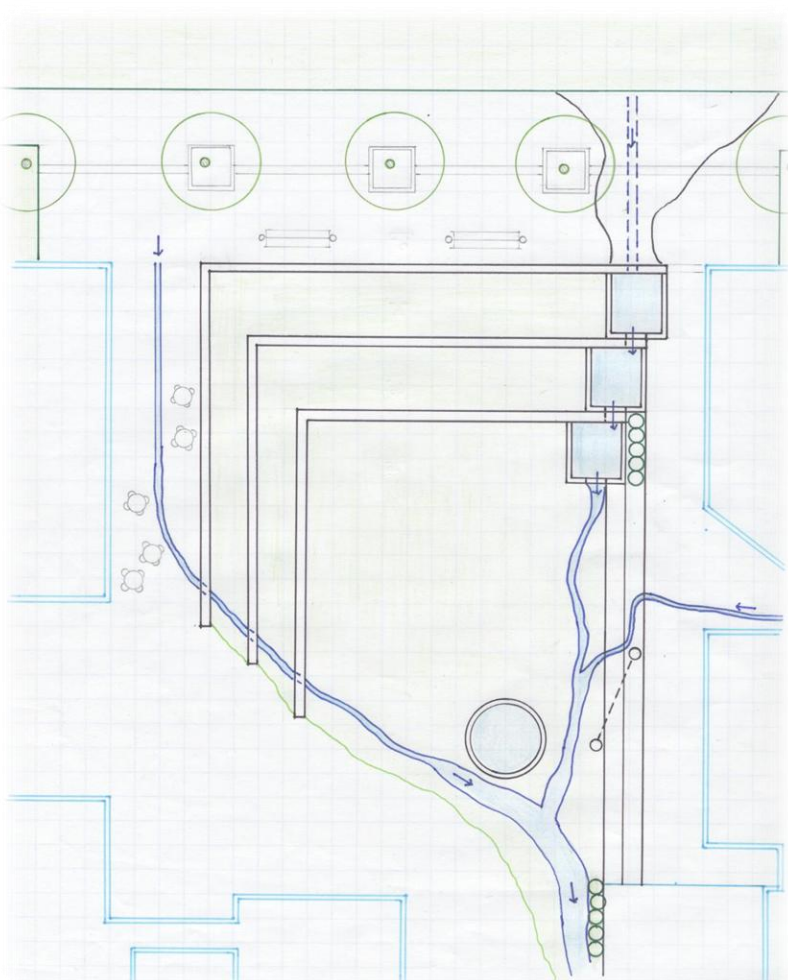


Figure 16: Overhead conceptual design of the Ampthitheatre

Figure 17: Conceptual rendering of Amphitheatre space

13.3. CONTAINMENT SYSTEMS

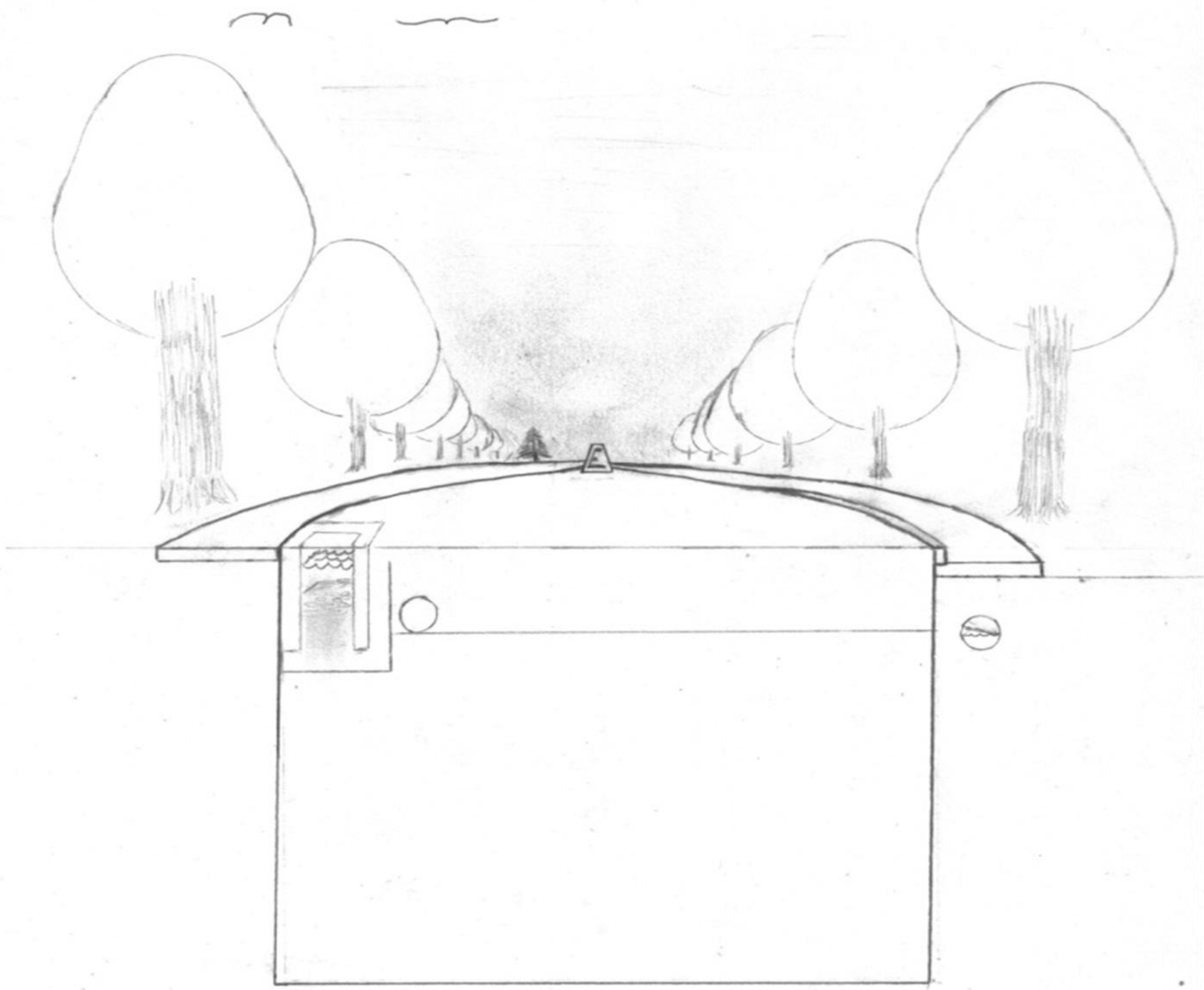


Figure 17: Gravel pit storage under the Main Mall Boulevard

13.4. AREA CALCULATIONS

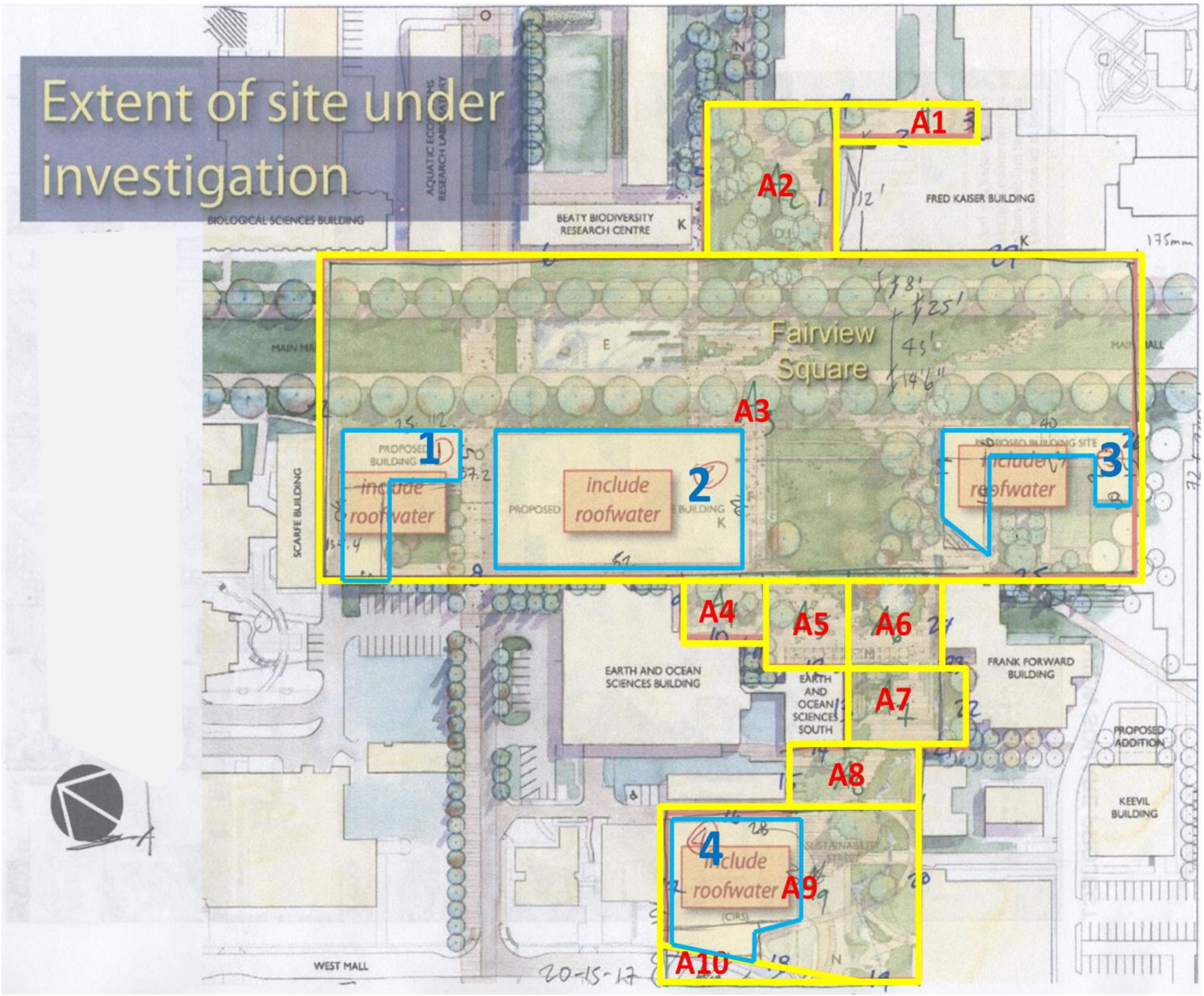


Figure 18: Map used to scale off Fairview Square areas

14. APPENDIX D: REFERENCES

1. CIVL 202 VISTA Webpage:
    a. Fairview Square Lecture Notes/Presentation Slides
    b. UBC Vancouver Integrated Stormwater Management Review
    c. Natural Approaches to Stormwater Management. State of Washington. 2003.
    d. Stormwater Solutions Handbook. City of Portland, OR.
    e. UBC Sustainability Street
2. Dunnet, Nigel et al.: Rain Gardens: managing water sustainably in the garden and designed landscape. Timber Press. Portland. 2007.
3. Dreiseitl, Herbert et al.: Waterscapes. Birkhauser. Berlin. 2001