UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Spiral Drain Enhancement Project – Final Design Report

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University of British Columbia

CIVL 446

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EXECUTIVE SUMMARY

In January of 1935 a large storm event washed out a substantial swath of the Point Grey cliffs at the North end of UBC's campus. With the university growing steadily, and a concern for nearby buildings and infrastructure, the UBC spiral drain was developed as a means to move storm water down to the beach below. It is a unique structure, one of only two remaining in North America, which now handles storm water from all of UBC's North Catchment. While the spiral drain continues to function well, and could last for another 50 years or more, it has had its capacity exceeded on a couple of occasions. Some mitigation work has been done in the area surrounding the drain to improve its capacity to that of about a 1-in-70 year storm. However, UBC is interested in improving this to a 1-in-200 year event and is also beginning to wonder about what ought to replace the spiral drain when it reaches the end of it useful life altogether.

This project was presented to UBC Civil Engineering students as part of a capstone design project as the "UBC Spiral Drain Replacement." This report presents the final design produced by Team 23 in response to UBC 's concerns with respect to the spiral drain. It suggests that the most appropriate and optimal solution to this design problem is the development of a Dry-Pond in the vicinity of the spiral drain capable of handling excess storm water up to that of a 1-in-200 year event. The Dry-Pond design provides opportunity for redevelopment of the area, avoids disruption of the nearby fragile cliff environment and, perhaps most importantly, works in conjunction with the existing spiral drain. As it became clear to the design team that the optimal path forward was to incorporate the existing spiral drain into the new design, the project was re-labeled the "Spiral Drain Enhancement Project." The proposed Dry-Pond addresses UBC's concerns for the next few decades, and yet is designed to be incorporated into the eventual replacement of the spiral drain by providing excess storm water storage.

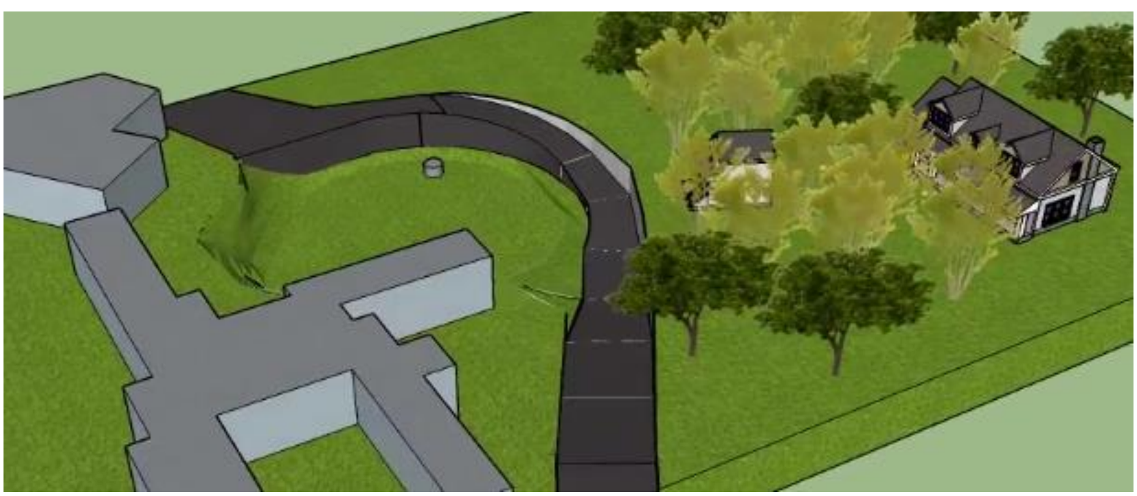


Figure 1: A 3D Rendering of the Dry-Pond Design

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The purpose of this report is to describe the final design for the UBC spiral drain enhancement project developed by Team 23 for the CIVL 446 capstone course at UBC. The project was undertaken at the request of the UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program, and overseen by Mr. Doug Doyle, P.Eng, the Associate Director of Municipal Engineering for UBC's Campus and Community Planning Department. This final design report builds on a preliminary design completed during the previous semester course CIVL 445, involving the same team of six students. A list of the authors is provided on the following page including a brief overview of their contributions to this report and the final design development. The report begins by providing the reader with some background information on the project in section 2.0, including a description of the project and the site surrounding the spiral drain. The design criteria are also outlined, including the design life and loadings. The next section, 3.0, explains the design team's process over the last two semesters including a presentation of early conceptual designs and the design selection procedure. Codes and standards used in the design are mentioned here as are any software programs or other tools employed.

In section 4.0 the report provides an overview of the final design, a dry-pond, including the site perimeter and some key features. Necessary adjustments to some underground utilities are explained, as is the drainage strategy for the final design. Hydraulic modeling is then presented in section 5.0 which addresses the need for improvements to some of the infrastructure upstream of the spiral drain in order to alleviate locations of potential flooding. Detailed components of the dry-pond itself are then described in section 6.0, including an amphitheatre, sidewalk berms, retaining walls and a redesigned Cecil Green Park Road. Section 7.0 addresses the project schedule including milestones and activities. A Gantt chart of activities along with a high-level Work Breakdown Structure are included. The section ends with an explanation of some potential issues during the construction phase. Following schedule, a final cost estimate is presented in section 8.0. This includes an updated estimate of the project's first costs as well as annual maintenance costs.

Appendices are attached to this document and serve to support and enhance its contents. They include 2D CAD drawings, a link to the team's 3D model, some sample calculations, a more detailed Work Breakdown Structure and finally a detailed engineer's estimate for the project.

Table 1: Contributions of each Team Member towards Completion of Report

Name	Contributions
Eliot Huang	Eliot developed the 2D CAD drawing of the site plan. This involved detailed analysis of the existing utility lines and determining what needed to be moved and where it needed to go. He then described this process in the written report.
Kai Lin	Kai built the Project Estimate, including first costs and long term maintenance costs and compiled the associated appendix. He also developed drawings of the road and wrote about it in the report.
Ben Stevens	Ben wrote the Executive Summary, the Introduction and the section of the report describing the project and its context and introducing the final design. He also formatted, compiled and published the report.
Daniel Tan	Daniel developed the Project Schedule, including the WBS, the Gantt chart and the lists of Tasks and Milestones. He also wrote the section on Project Schedule and developed the 3D Sketch Up model.
Andy Wu	Andy compiled the calculations appendix showing the volume of the dry pond. He also developed the 2D CAD drawings of the sidewalk berm, retaining wall, amphitheatre stage, and seating. He then described these features in his section of the report.
Richard Wu	Richard ran the SWMM 5 model analysis and developed a redesign of the trunk lines entering the spiral drain. He wrote about this in the report.

2.0 PROJECT BACKGROUND

Prior to any discussion of the design process, it is important to first understand the project objectives and constraints. This section describes the UBC spiral drain and explains the need for it to be either replaced or enhanced. The project site is also discussed, since the location of the existing spiral drain presents some unique challenges that ought to be well understood.

2.1 Project Description

The UBC spiral drain is a fascinating and impressive component of UBC's storm water management system. It was built in the 1930s to move storm water from throughout the north half of the campus down the Point Grey cliffs and into the ocean. Unfortunately its capacity has been exceeded on at least two occasions over the years resulting in major wash out events occurring on the Point Grey cliffs (see Figure 2 below). To prevent this from happening again, UBC is looking to replace or enhance the spiral drain to increase capacity from a 1-in-70-year event to a 1-in-200-year storm.

Figure 2: UBC Campus in 1972 with Point Grey Cliffs Washed out by a Storm Event

2.2 Site Description

The spiral drain is located at the far north end of the UBC campus between the back of the Museum of Anthropology and Cecil Green College. It collects water from throughout the north catchment of UBC by way of four large trunk lines. Water then spirals down the vertical shaft of the drain before discharging into the ocean via an outlet buried under tower beach. Figure 3 below shows the location of the spiral drain in relation to its surroundings as well as the location of its outfall into Burrard Inlet.

Figure 3: The Location of the Spiral Drain in relation to its Outfall into the Ocean

The drain is only 20 or 30 meters from steep cliffs that have washed out before, and have since been carefully reinforced through bio-engineered erosion mitigation. It is critical that any design to replace or improve the spiral drain avoid causing damage to this fragile area. It is also important to recognize that while the most damaging flooding might occur near the spiral drain, there are other areas of campus that flood when the spiral drain's capacity is exceeded and water backs up. Furthermore, any design that requires large scale construction, or permanently alters the landscape surrounding the spiral drain will have an impact on the users of the buildings in the area. Stakeholders located very close to the spiral drain include the Museum of Anthropology, Cecil Green College and UBC's Department of Anthropology.

3.0 DESIGN PROCESS

While the purpose of this report is ultimately to describe the final design for the project, it is important to provide some background by describing the design process to date. This section begins with a description of early stage designs, before explaining the decision-making process that led to the selection of a chosen design. The codes and standards that needed to be well understood and to which the design necessarily adheres are then presented and explained, followed by a description of the software and tools employed in the design process.

3.1 Early Conceptual Designs

The design process began with a great deal of brainstorming and idea generation. After some time, the design team settled on three conceptual designs that were to be explored further. The first of these, Conceptual Design A, was a large detention tank located in the area depicted in Figure 4 below. The idea was that the spiral drain could continue to handle the entire flood volume, but that a detention tank would provide it with respite in the event that its capacity was exceeded.

Figure 4: Plan View of Conceptual Design A - A Detention Tank

Conceptual design B was a mid-height bypass as shown in Figure 5 below. The concept here is for storm water to build up in the spiral drain until it reaches roughly the half-way point. The hydraulic pressure would then open valve into horizontal bypass line that would spill out over the lower third of the cliffs

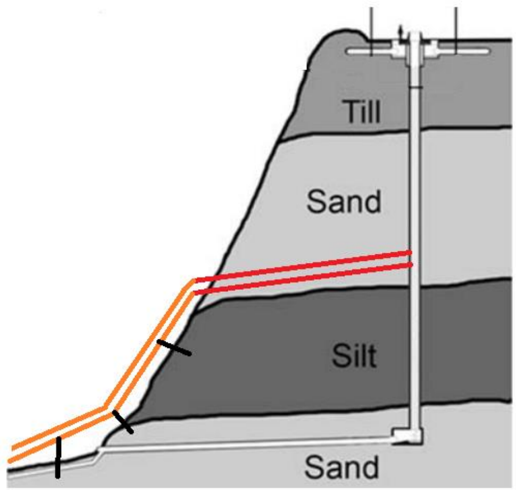


Figure 5: Elevation View of Conceptual Design B - A Mid-Height Bypass

The design team's third and final conceptual design was an above grade pipeline running down the length of the point grey cliffs. The size of the pipe was designed only to carry flood water the exceeded the capacity of the entire spiral drain in the event that it began to overspill.

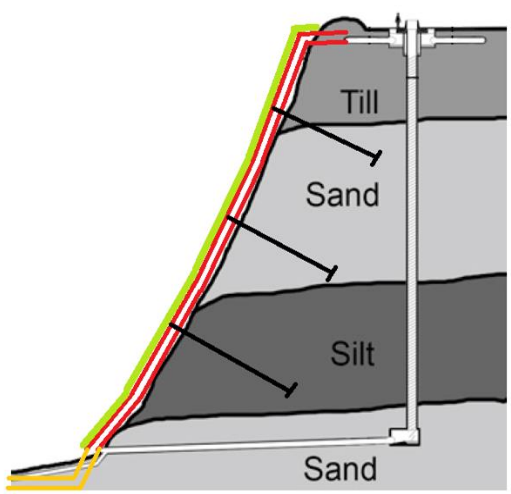


Figure 6: Elevation View of Conceptual Design C - An Above Grade Pipeline

3.2 Design Selection Process

With three unique concepts in place, the design team proceeded to weigh the costs, risks and benefits of each with the intention of choosing a preferable solution. An almost exhaustive list of criteria were developed and then ranked by their respective importance. The most critical of these are listed in Table 2 below along with an assigned weighting on a scale of 1 to 10. It should be noted that the first criteria listed received a weight of 10 since the design team decided that meeting the 200 year flood demand ought to be non-negotiable. All three designs were considered to meet this criteria in full, and were therefore assigned a score of 10. The capability of the three designs to meet the other important criteria was also assessed as shown the in the matrix below. This allowed for a quantitative comparison and made it clear that Conceptual Design A, the Detention Tank, was the preferred option.

Table 2: Decision Matrix used to assist in the Selection of a Conceptual Design

Criteria	Weight	A. Detention Tank	B. Bypass Pipe	C. Above Grade Pipeline
Meets 200 year demand	10	10	10	10
Low Construction costs	6	3	6	6
Low maintenance costs	4	7	6	6
Long service life	7	9	4	7
Minimal construction disruption	3	3	7	6
Multi-purpose potential	5	9	1	1
Minimal Environmental impact (esp. to the cliffs)	8	8	6	4
	Totals:	**327**	**262**	**264**

In October 2016 the project design team met with instructors from the CIVL 446 course and representatives from the UBC SEEDS sustainability program for a presentation of the three conceptual designs. The matrix above was discussed, and the decision to choose a detention tank explained. The client was pleased with this idea and encouraged the team to continue down this path of design. It was pointed out that an ambient pressure above grade detention tank is commonly referred to as a “Dry-Pond” in industry. Since this meeting, the design team has adopted the term Dry-Pond and has enhanced and improved upon the original detention tank idea.

3.3 Codes and Standards

Throughout the design process, the project team worked carefully to ensure that codes and standards that would affect the design were consulted and well understood. Relevant documents included:

- BC Municipal Construction Documents
- Greater Vancouver Regional District Sewer Use Bylaw No. 164
- UBC’s Environmental Protection Policy #6
- UBC’s Sustainability Development #5
- The Fisheries Act
- Best Management Practices Guide for Storm water, Greater Vancouver Sewerage and Drainage
- CSA 23.3
- The Canadian Highway Bridge Design Code

While the above list includes the most important documents from the perspective of the design team, it is expected that construction firms bidding the project undertake their own due diligence in adhering to all necessary codes and standards.

3.4 Software and Tools

With the necessary codes and standards in mind, the project team made use of the following software and tools in the development of the design:

- EPANet’s SWMM 5 for hydraulic modeling
- AutoCAD for 2D plan and elevation drawings, including the site plan and detailed construction drawings
- SketchUp for 3D modeling
- Excel spreadsheets for development of the estimate, design calculation and graphing
- Google earth and Google maps for site overlays and conceptual designs
- Micorsoft Projects for development of the schedule

4.0 OVERVIEW OF FINAL DESIGN

With an understanding of how the design came together, the final design can be presented with a greater appreciation what lead the design team to this stage. This section presents the final Dry-Pond design including a description of the site perimeter and features of the final design. It goes on to explain some necessary adjustments to the underground utilities in the area and ends with a description of how the dry-pond is designed the fill and then drain in the event of a large strom.

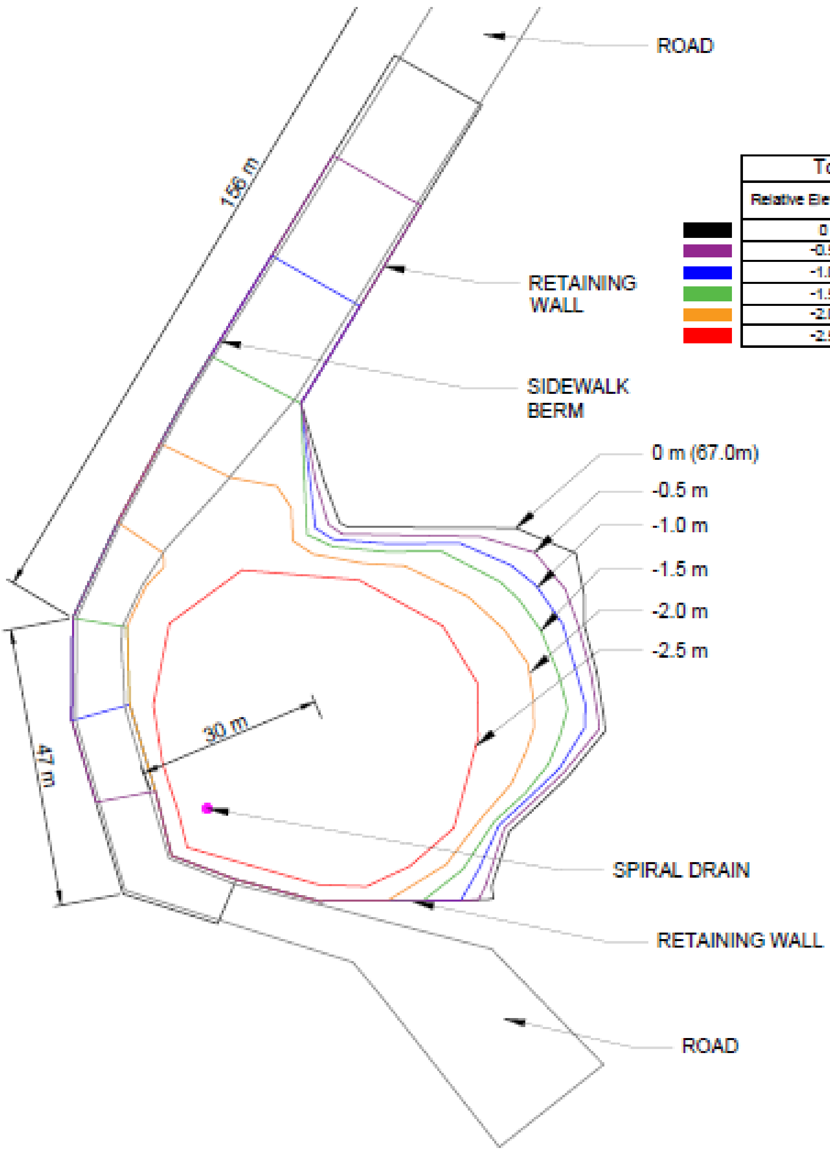
4.1 Site Perimeter

The perimeter of the Dry-Pond design is depicted in Figure 7 below and indicates the limits of necessary excavation for this project. The location of the site is centered at the spiral drain because of the convenience of the elevation. The spiral drain is the lowest elevation point in the UBC North Catchment system. If the drainage system is properly sized, the spiral drain should be the starting point of a flood. In the past, the area received minor landscaping to contain a smaller flood. The site perimeter was then delineated to utilize existing terrain and minimize excavations. The perimeter adjacent to the cliff is outside of the 35 degree building setback distance recommended by the provided geotechnical assessment report.

Figure 7: 3D Google Maps View showing the Location of the Dry Pond

4.2 Features of Final Design

Figure 8 below shows the final dimensions and depth of the Dry-Pond design. As is clear from the image, there is a great deal of usable space in the middle of the excavated area for some unique features for be included in the redevelopment of this area. In fact, the Dry-Pond design encourages the use of added green space in good weather. Removed trees and bushes will be replanted. Trails will be installed to create a usable space enriched by picnic tables and a field. The trails are designed to have a 1 to 12 slope to be accessible by persons with disabilities. A series of Victorian street lamps will be installed to illuminate evening traverse.



Total Detention Volume: 11,000 m^3		
Relative Elevation (m)	Area (m^2)	Volume (m^3)
0	790	0
-0.5	719	360
-1.0	744	744
-1.5	879	1319
-2.0	1317	2634
-2.5	2376	5940

Figure 8: Plan View of Dry Pond Showing Dimensions and Depths

4.3 Underground Utilities

The construction of the dry pond conflicts with a number of existing underground utilities. The conflicts are with a natural gas pipe and the storm water drainage trunks near the spiral drain. Natural gas pipes on UBC campus have a minimum cover requirement of 600mm, as per UBC Technical guidelines. To satisfy the requirement, the gas pipe indicated in the figure below will be lowered by 300mm.

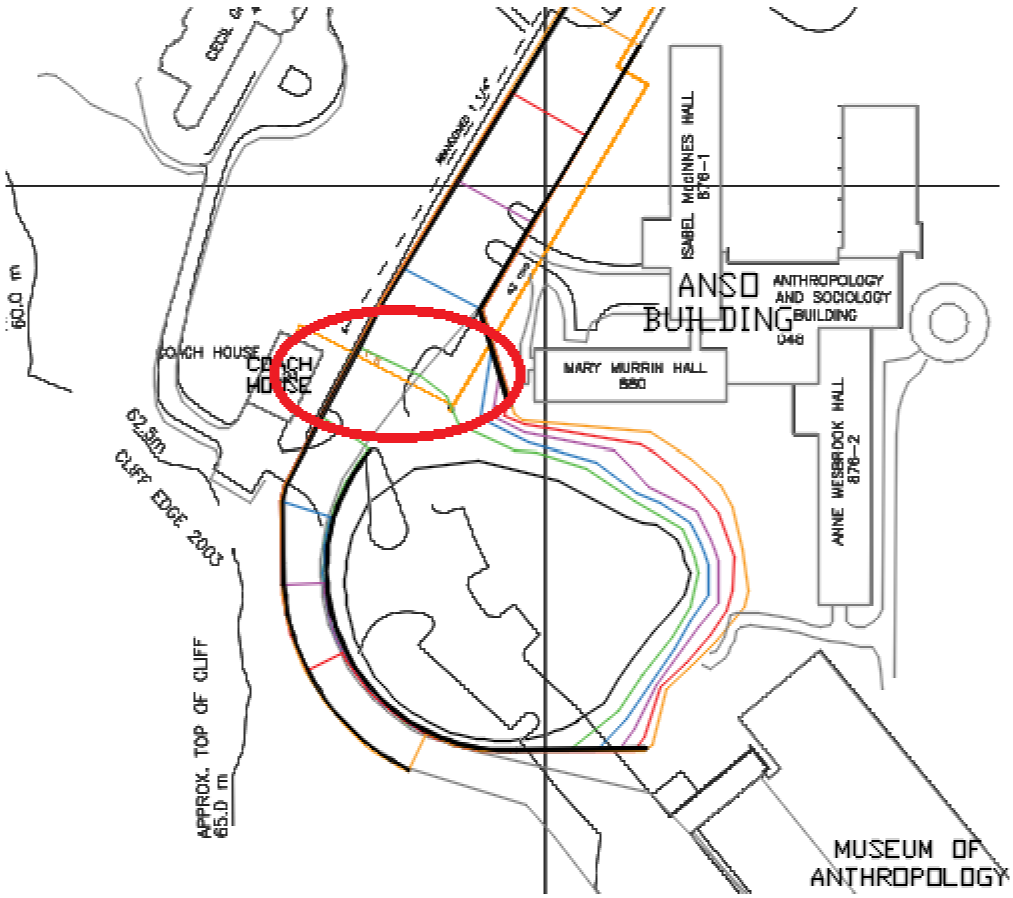


Figure 9: Section of Gas Pipe Circled in Red to be Lowered

The remaining conflicts are the storm water drainage trunks connecting to the spiral drain. The elevation of the grade next to the spiral drain will be lowered by 1.25 m, resulting in a trunk cover of 0.9m. UBC Technical Guidelines require 1.0 m minimum storm pipe cover unless special approval is obtained. Typical precast pipe protection slabs will need to be procured. The protection slabs overcompensates for the missing cover depth, but will streamline the process to obtain special approval. The protection slab is to be applied on the highlighted pipe sections in Figure 10 on the following page.

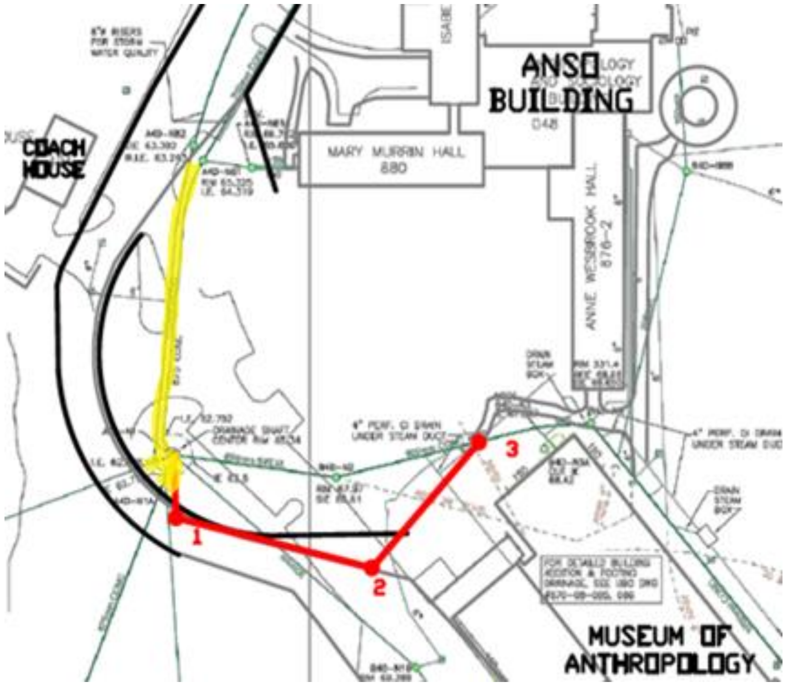


Figure 10: Pipe Protection Requirements (yellow) and New Manholes (red)

The drainage trunk arriving between the MOA and ANSO building rests above the grade of the finished dry pond. Therefore, the trunk cannot benefit from pipe protection slabs and must be redirected. The new drainage trunk will follow the path of the new road as illustrated in red in Figure 10 above. Beyond the changes described in this section, all remaining underground utilities are unaffected.

4.4 Drainage

The center trough of the dry pond is drained by minor 100 mm pipes. Following a flood event, retained water will enter the minor pipes via four drains that are scattered near the trough. The pipes then join the major storm water drainage trunks entering the spiral drain. These minor pipes require pipe protection slabs as well.

5.0 HYDRAULIC MODELING

The previous section provided an overview of the Dry-Pond itself, and described some necessary adjustments the elevation and location of utilities in the vicinity of the spiral drain. However, it was important to recognize that in a 1-in-200 year event there are capacity concerns elsewhere in the storm water system that will result in flooding if not improved. This section describes the trunk lines upstream of the spiral drain, and presents hydraulic modeling used to determine some necessary adjustments.

5.1 Existing Trunk Lines

All storm water collected in North Catchment of UBC enters the spiral drain via one of four trunk lines. To ensure that flooding only occurs in the proposed Dry Pond, and that its capacity is fully utilized, the trunk lines leading into the spiral drain will need to have their utility maximized. This means that the four trunk lines will need to have sufficient inline storage to convey storm water during a 1-in-200 year event to the dry pond and not back-up and flood at manholes upstream of the Dry-Pond. The existing trunk lines, including manholes of interest and an approximate outline of the proposed dry pond are shown below in Figure 11.

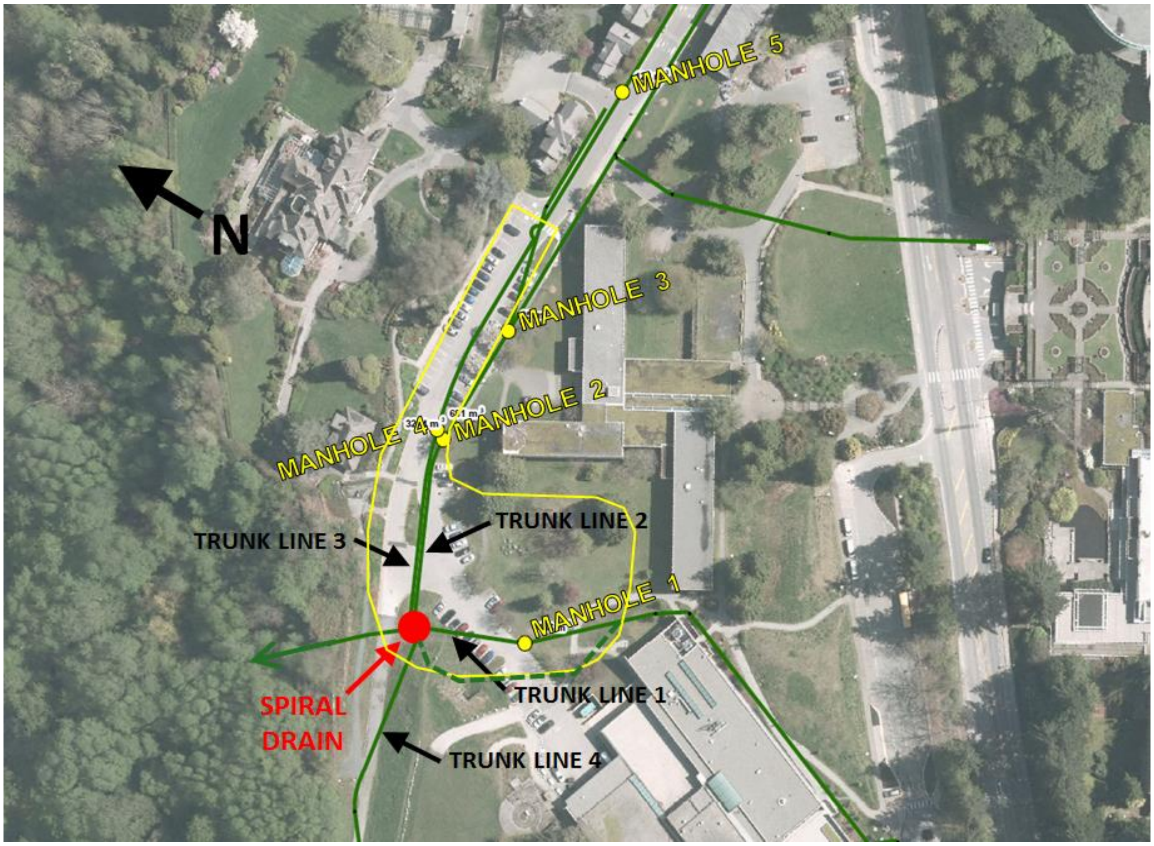


Figure 11: Plan View of Trunk Lines Entering Spiral Drain

The construction of the dry pond will require the re-route of trunk line 1 such that it hugs the western edge of the dry pond (as shown by the green dashed line in Figure 11); manhole 1 will move as well. This is required because excavation will be deeper than the pipe depth underground on some sections along its length. Trunk lines 2 and 3 will receive a reduction in cover within the dry pond and trunk line 4's position will remain unchanged. Additionally, the ground elevations of Manholes 2 and 4 will be lowered to match the new ground elevations at their respective locations in the dry pond.

5.2 SWMM Modeling

To ensure that the trunk lines have sufficient inline storage, a Storm Water Management Model (SWMM) of the UBC storm water system was run and analyzed for deficiencies in the proposed Dry-Pond area. The system simulated a 200-year 24-hour SCS Type 1A storm event. 24-hour rainfall distribution is shown below in Figure 12.

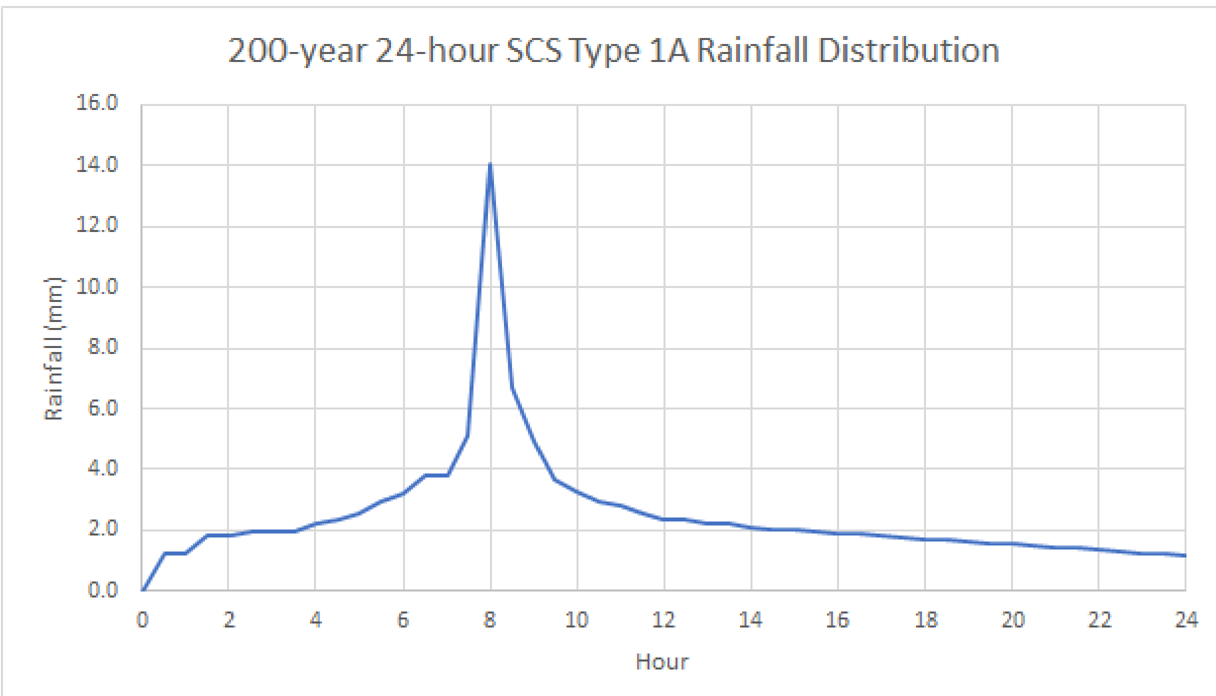


Figure 12: Expected Rainfall during a 200-year Storm Event

An initial run of the model with the existing storm water system yielded the results in Table 3. The flooding at these 5 manholes indicate that there is insufficient inline storage in trunk lines 1 through 3 to fully convey a 1-in-200 year storm event.

Table 3: Manhole Flooding at Dry Pond Site in Existing Storm-water System

Manhole	Total Flooding (m^3)	Flood Duration (hours)
1	150	0.34
2	3017	1.34
3	22	0.35
4	651	0.99
5	182	0.71

5.3 Trunk Line Upgrades

Upgrades to sections of trunk lines 1 through 3 will be required to ensure sufficient inline storage during a 200-year storm event. Table 4 summarizes the trunk line section upgrades that will eliminate flooding at the manholes upstream of the dry pond. These upgraded sections will allow the dry pond's capacity to be taken full advantage of in a 200-year storm event, as all flooding will occur within the dry pond.

Table 4: Summary of Trunk Line Section Upgrades

Trunk Line	Section		Existing Maximum Depth (m)	Upgraded Maximum Depth (m)
	Origin	Terminus		
1	Manhole 1	Spiral Drain	0.65	0.725
2	Manhole 3	Manhole 2	0.75	0.9
3	Manhole 5	Manhole 4	0.6	0.75

6.0 DETAILS OF FINAL DESIGN

As mentioned in section 4.0, the design of a Dry-Pond is advantageous in that it allows for the redevelopment of a significant area of land. Opportunities exist for unique uses of this space, and the design team decided that an amphitheatre, to be used for outdoor lectures and concerts, would provide a strong enhancement to the area. In addition to amphitheatre, this section describes some less exciting but still necessary details of the final design. These include sidewalk berms, retaining walls and the redesigned Cecil Green Park Road.

6.1 Amphitheatre

The amphitheatre stage will serve as the platform for performer/speakers to the audience in the amphitheatre. It will be in a fan shape, with 120° arc of 5m radius. Its area will be approximately 26m^2. It will be built using cast-in-place concrete and contain one layer of reinforcement placed both ways for temperature shrinkage/crack control purposes. The concrete mix will be designed to withstand exposure to weather events. Details of the stage are provided in drawing 002 in appendix A.

There will be 4 rows of seating for the amphitheatre. The shape of the rows is an arc, with the arcs ranging in lengths of approximately 10m-15m. It can comfortably seat around 100 people. Each seat has been designed to include enough space and height offset for functionality. Each seat is buried part way into the ground for stability. A stairway will be constructed down the middle of the stage for access. An accessibility ramp/path will be provided in nearby areas. The seating and stairs will be constructed using cast-in-place concrete. It will contain a small amount of reinforcement for temperature shrinkage/crack control purposes. Each seat has a cross section area of 1.0m (W) x 0.8m (H). Approximately 75% of this area will be occupied by concrete, and 25% will be occupied by two Styrofoam blocks. The concrete seating won't be exposed to any high loading, the Styrofoam will serve as a cost-saving measure and to provide support to the reinforcing cage. Adequate gap between the Styrofoam blocks will be provided during pour to ensure concrete flows to the bottom of the formwork. The seating will be poured in segments to avoid cracking later on. A detailed drawing of the amphitheatre seating can be found in Appendix A.

6.2 Sidewalk Berms

Sidewalk berms will be placed along the road next to lower lying Cecil Green House properties. They will act as an insulator against seepage during a flood event. They will be constructed using a combination of vegetation, topsoil, waterproof membrane, geocells, foundation soil, and compacted cores. An illustration of this concept can be found in appendix A. Approximately 100 linear meters of this berm need to be constructed. Some flexibility in material and construction methods will be allowed to suit field conditions as needed, provided they are approved by a geotechnical engineer.

6.3 Retaining Walls

Modular, pre-engineered retaining walls will be installed at sharp drop locations as indicated on the Site Plan (see Appendix A, drawing 001). The decision to choose modular retaining walls is primarily for construction ease and speed. Since these walls can be prefabricated elsewhere and assembled on site, construction speed can be significantly increased. Prefabrication also removes the risk and uncertainty of traditional on site construction. These modular retaining walls will be installed as per manufacturer's recommendations. Adequate drainage will be provided near the bottom of the walls to prevent water from accumulating and forming hydrostatic loads. The design team recommends using StoneStrong System retaining walls, or equivalent. These are modular, gravity wall systems with hollowed insides for soil fills. They can be easily procured from local precast concrete plants and installed on site.

6.4 New Cecil Green Park Road

Using the spiral drain as a reference point, the plan view drawing as shown in the appendix displays the path and dimension of the rerouted road. The road which allows access to the back entrance of the MOA will be rerouted west of the spiral drain. On the west side of the road, the existing berm will be extended. The turning radius of the rerouted road will be 39m and the steepest point will have around 2.5% grade. One lane of the two-way road has a width of 11 feet. The two-way road and two shoulders together are 30 feet wide. The surface course which is on the top layer of the road will be asphalt concrete, that is a construction aggregate with a bituminous binder. The base course which is in the middle layer of the road will be clean uniformly graded coarse aggregate. Typical base course thickness ranges from 100 to 150 millimetres. The blanket course which is on bed bottom will be non-woven geotextile. At detailed cross section of the redesigned road can be found in Appendix A.

7.0 PROJECT SCHEDULE

The spiral drain enhancement project requires careful planning and thus, the following project schedule will help guide corresponding parties to successful completion. The schedule for this project is separated into two main phases; design and construction. In the Master Gantt Chart, the design phase is shown in green and construction is shown in blue. Currently, the design phase commences on Sept. 1st, 2016 and is scheduled to be completed by March 31st, 2017 (152 days). This allows two weeks at the beginning of April for Tendering and Bidding. The construction phase commences on May 1st, 2017 and is scheduled to be completed by Feb. 16th, 2018 (210 days). In comparison to the construction schedule within the preliminary report, the duration has been cut down by 30 days. Previously, 80 days were allocated for construction of features (potential amphitheater, fountain, pedestrian overpass). After further discussion and design, the project eam decided to go ahead with a concrete stage and seating area. As a result, the whole project spans over a period of about 382 working days.

7.1 Milestones

Table 5 below lists the major milestones of the project along with their corresponding dates.

Table 5: Major Project Milestone Dates associated with Design and Construction

Milestone Title	Date
EA Application	Sept. 12th, 2016
Stakeholder Engagement	Jan. 16th, 2017
Finalized Design	Mar. 31st, 2017
Permits Obtained	Apr. 28th, 2017
Construction Commencement	May 1st, 2017
Project Completion	Feb. 16th, 2018

7.2 Activities and Gantt chart

Further to the above milestones, Table 6 below and the Gantt chart on the following page (Figure 13) reflect the duration of activities during the execution of the project. The Gantt chart in particular provides a visual understanding of the way the work will proceed, and which times will be most critical to project success.

Table 6: High Level Project Tasks and their Associated Durations

Task Title	Start Date	End Date	Duration
Design	Sept. 1st, 2016	Mar. 31st, 2017	152 Days
Tendering & Bidding	Apr. 3rd, 2017	Apr. 28th, 2017	20 Days
Site Deconstruction	May 1st, 2017	May 12th, 2017	10 Days
Site Excavation	May 15th, 2017	May 26th, 2017	10 Days
Relocate Existing Utilities	May 29th, 2017	July 21st, 2017	40 Days
Road Construction	July 24th, 2017	Aug. 4th, 2017	10 Days
Compaction	Aug. 7th, 2017	Sept. 8th, 2017	25 Days
Retaining Walls	Sept. 11th, 2017	Sept. 29th, 2017	15 Days
Stage & Seating Construction	Oct. 2nd, 2017	Dec. 8th, 2017	50 Days
Landscaping	Dec. 11th, 2017	Feb. 2nd, 2018	40 Days
Commissioning	Feb. 5th, 2018	Feb. 9th, 2018	5 Days
Site Cleaning	Feb. 12th, 2018	Feb. 16th, 2018	5 Days
		Total:	**382 Days**

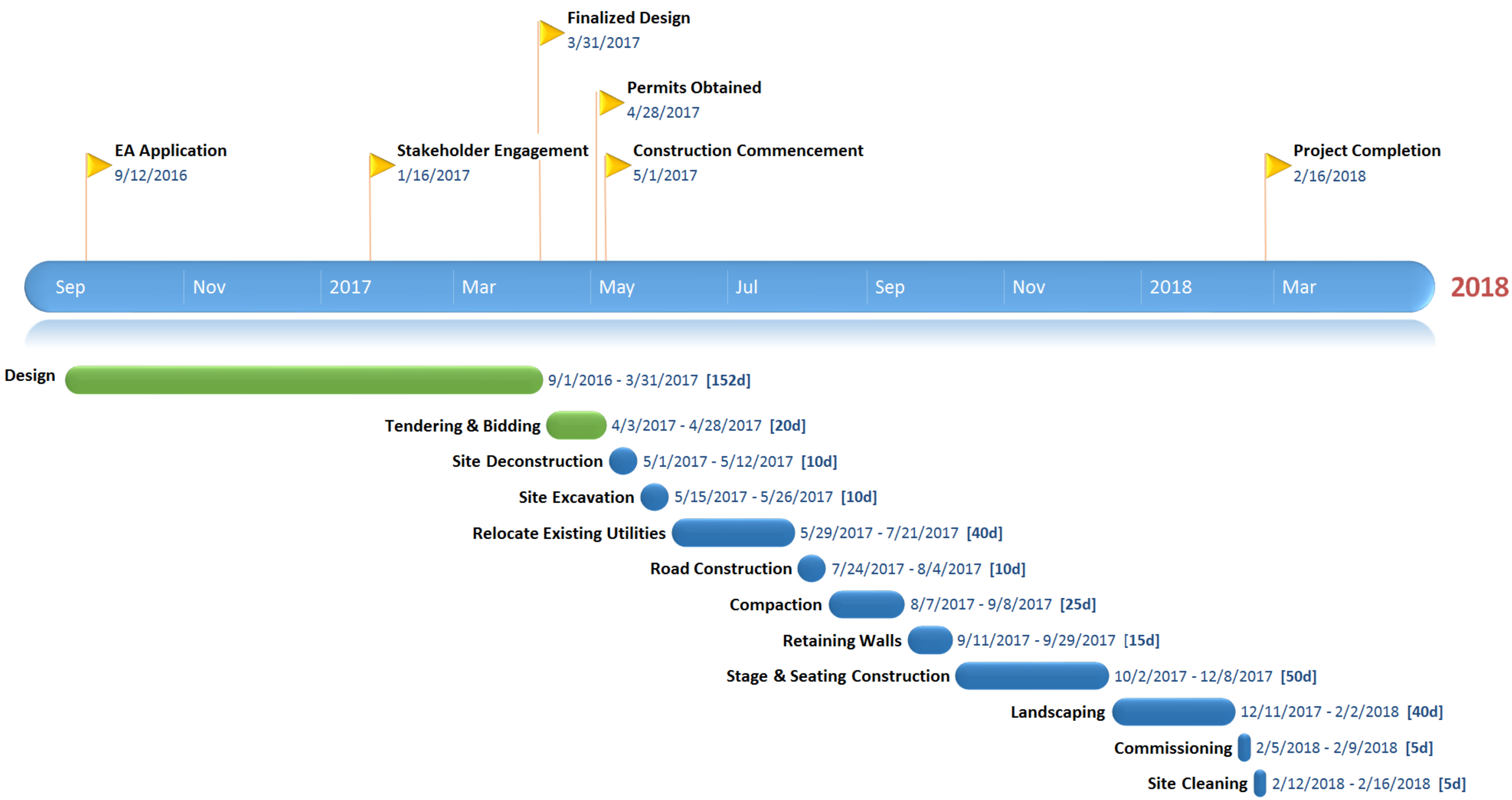


Figure 13: A Gantt Chart Showing the Overall Project Schedule

7.3 Work Breakdown Structure

The following list in Table 7 illustrates the hierarchy structure of the WBS. The design phase is broken down to two further stages: initiation and design. Similarly, the construction phase is broken down to three further stages: execution, control and closeout. Figure 14 on the following page provides a visual representation of the project's WBS. Meanwhile, a much more detailed description of activities under each WBS code is provided in Appendix D.

Table 7: A Project Work Breakdown Structure showing 3 Levels of the Hierarchy

Level 1	**Level 2**	**Level 3**
Dry Pond Project	1.1 Initiation	1.1.1 Client Engagement 1.1.2 Obtaining Documents 1.1.3 Review Documents 1.1.4 Conceptual Design 1.1.5 Preliminary Design
	1.2 Design	1.2.1 Detailed Design 1.2.2 Stakeholder Engagement 1.2.3 Finalized Design 1.2.4 Permits Obtained
	1.3 Execution	1.3.1 Site Deconstruction 1.3.2 Site Excavation 1.3.3 Relocate Existing Utilities 1.3.4 Road Construction 1.3.5 Compaction 1.3.6 Retaining Walls 1.3.7 Features Construction 1.3.8 Landscaping
	1.4 Control	1.4.1 Commissioning
	1.5 Closeout	1.5.1 Site Cleaning

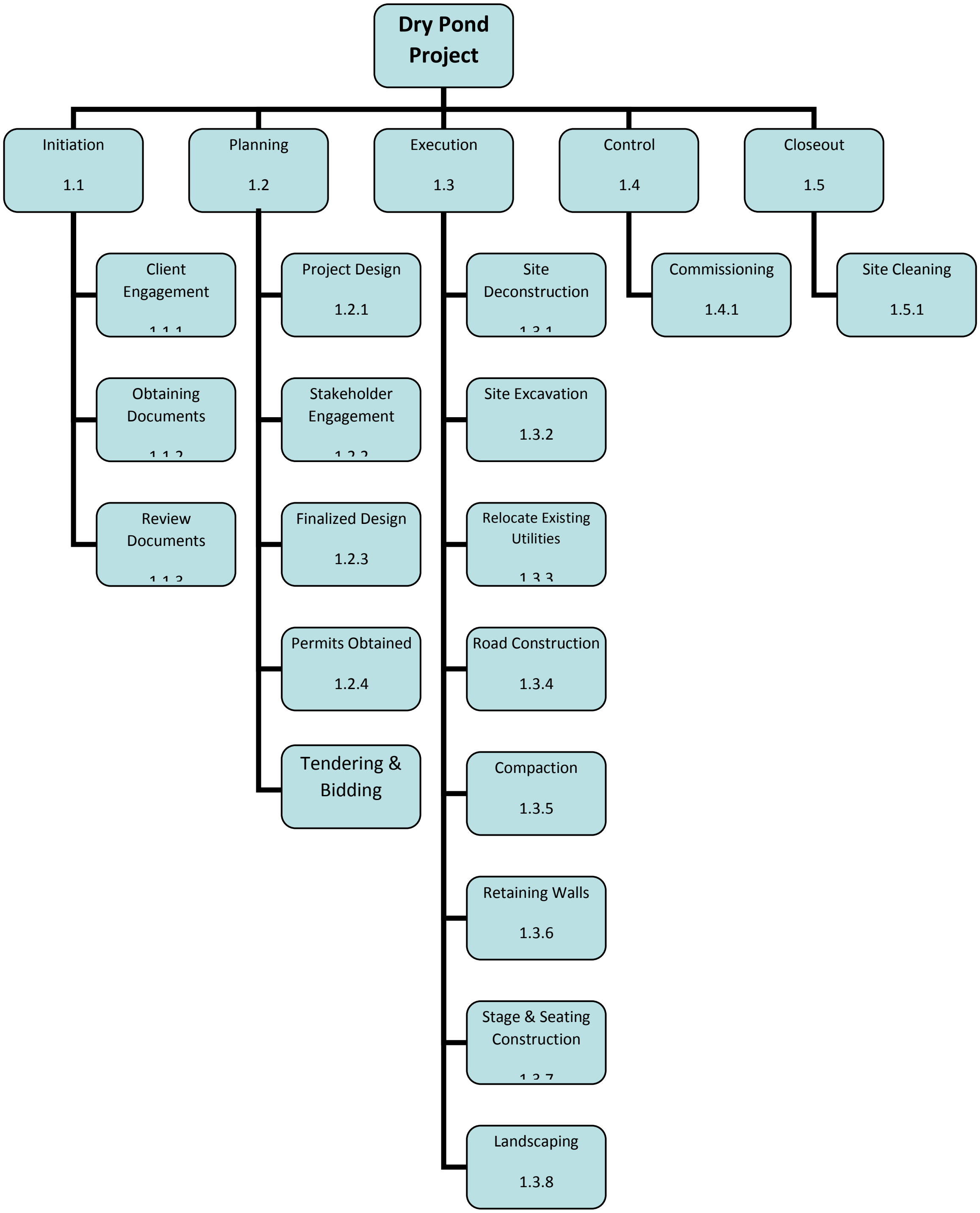


Figure 14: An Organizational Chart of the Project Work Breakdown Structure

7.4 Anticipated Issues during Construction

The construction of the proposed Dry-Pond in the project area will certainly come with challenges. It is important to recognize this early on in order to allow for mitigation strategies and appropriate planning to be put in place prior to ground being broken. This following list provides some of the critical issues that may arise during the construction process:

- Risk of shoring collapse during excavation
- Safety concerns related to underground utilities
- Concerns related to tying in to existing infrastructure that is very old and is only understood through simple drawings
- Concerns related to the redirection of traffic from the museum of Anthropology, Cecil Green College, and the nearby faculty
- Risk of buildings shifting due to excavation (especially the Faculty of Anthropology building)
- Issues related to parking disruption during construction
- Concerns that there will be resource delays or worker shortages that will drag construction beyond the proposed schedule.

8.0 FINAL COST ESTIMATE

A major advantage of breaking down a project using a WBS, as described in section 7.0, is that it becomes much easier to accurately estimate the cost of the work. This section of the report presents the expected first costs and maintenance costs of the Dry-Pond project, and discusses the quality of the estimate. A detailed engineer's cost estimate for the entire project is provided for reference in Appendix E.

8.1 First Costs and Maintenance Costs

A summary of the first costs and maintenance costs associated with the final design are presented in the table below. These amounts are derived by analyzing material, labour, and equipment requirements. When estimating the cost for this project, there is uncertainty as to the precise content of all items in the estimate, how work will be performed, what work conditions will be like when the project is executed and so on. These uncertainties are risks to the project. Therefore, we include the contingency to cover the costs due to these uncertainties.

Table 8: A Summary of the Final Project Cost Estimate

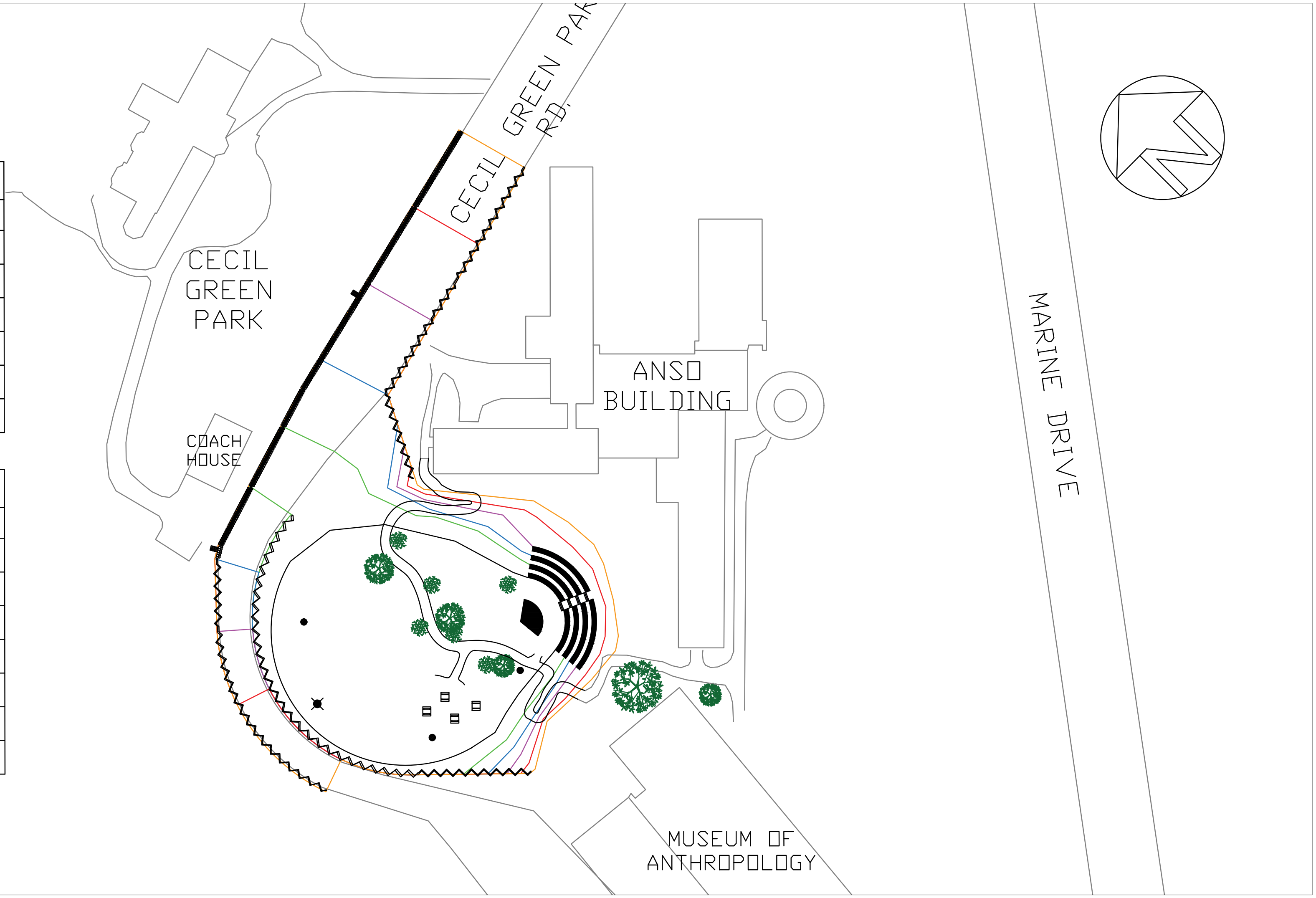
First Costs	
• Permitting	$ 3475
• Project Management	$ 598,000
• Construction	$ 6,737,976
Subtotal	$ 7,339,451
Contingency (8%)	$ 587,156
Total – First Costs	**$ 7,927,607**
Total – Maintenance (Annual)	**$ 8,841**

8.2 Quality of Final Estimate

The cost estimate included in this report is the approximation of the cost of the Spiral Drain project. The variables are estimated based on study, past experience and research to calculate the total project cost. There are also several elements that affect the accuracy of the cost estimate. For example, wrong assumptions made during the estimation process may lead to a wrong cost. Also, it is important to take into account some human calculation errors. A safety factor of 1.1 to 1.2 is recommended. Before the start of construction, there are a few approaches that can be done to improve the accuracy of the cost estimate. After the project is approved, subcontractors will be contacted and communicated with to ensure the accuracy of the budgets. Moreover, the cost estimate can be improved by confirming the unit cost of each material with the local materials' suppliers prior to commencement of construction.

APPENDIX A - 2D CAD DRAWINGS

Note: CAD Drawings in Appendix A have been reduced to fit on 8.5 x 11 pages. For full size drawings, please contact the authors.



CONTOUR		
	RELATIVE ELEVATION (m)	ELEVATION ASL (m)
	0	67.0
	-0.5	66.5
	-1.0	66.0
	-1.5	65.5
	-2.0	65.0
	-2.5	64.5

LEGEND	
	SPIRAL DRAIN
	PICNIC TABLE
	TREE
	RETAINING WALL
	TRAIL
	DRAIN
	AMPHITHEATRE
	SIDEWALK BERM

23 North
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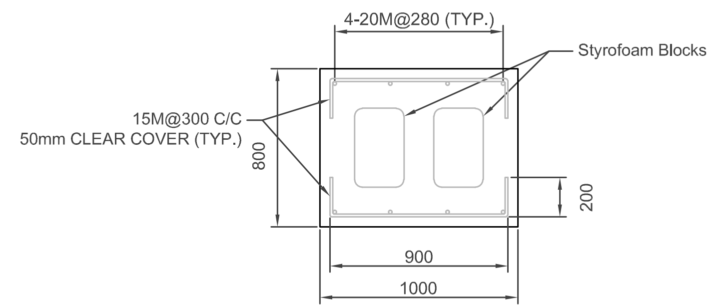
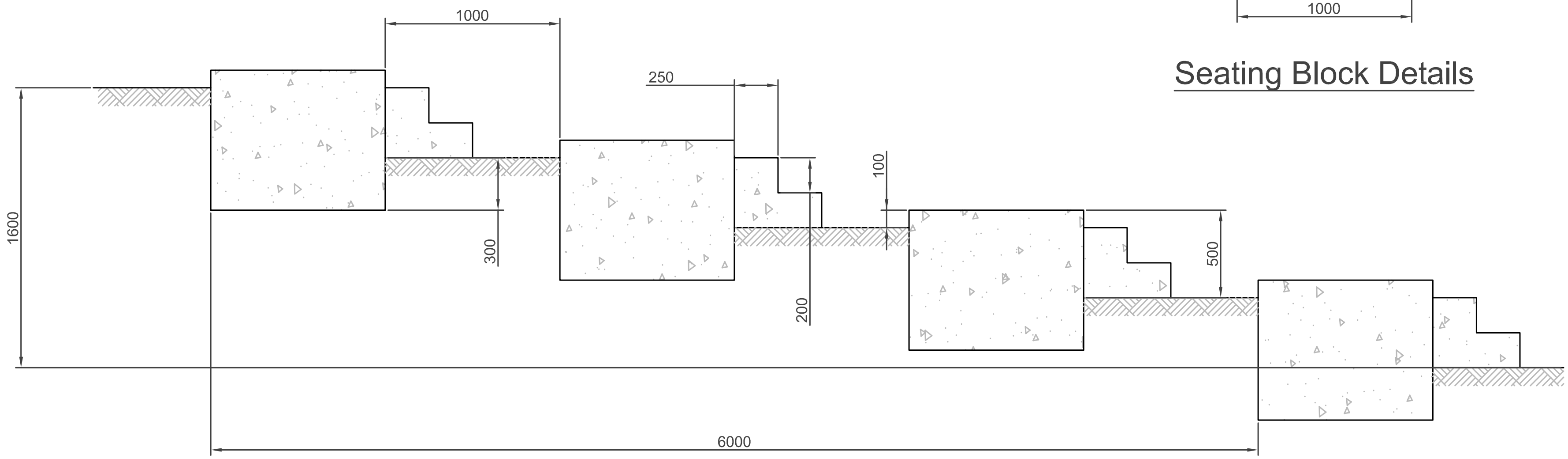
DWG: SITE PLAN			Project: UBC SPIRAL DRAIN ENHANCEMENT
Date: 2017-02-28	Scale: NTS	Drawn by: AW	1 of 1

Notes:
1. All units in mm.
2. Concrete Properties:
Slump: 100+/-20 mm
Air: 5-8%
28 Day Str: 35 MPa
MSA: 20mm
3. Reinforcing bars fabricated to CSA G30.18-09.
4. Use 50mm clear cover.
5. For plan view of seating blocks please refer to Site Plan.



Seating Block Details



Section View

23 North
ENGINEERING CONSULTANTS LTD

DWG: Concrete Seating

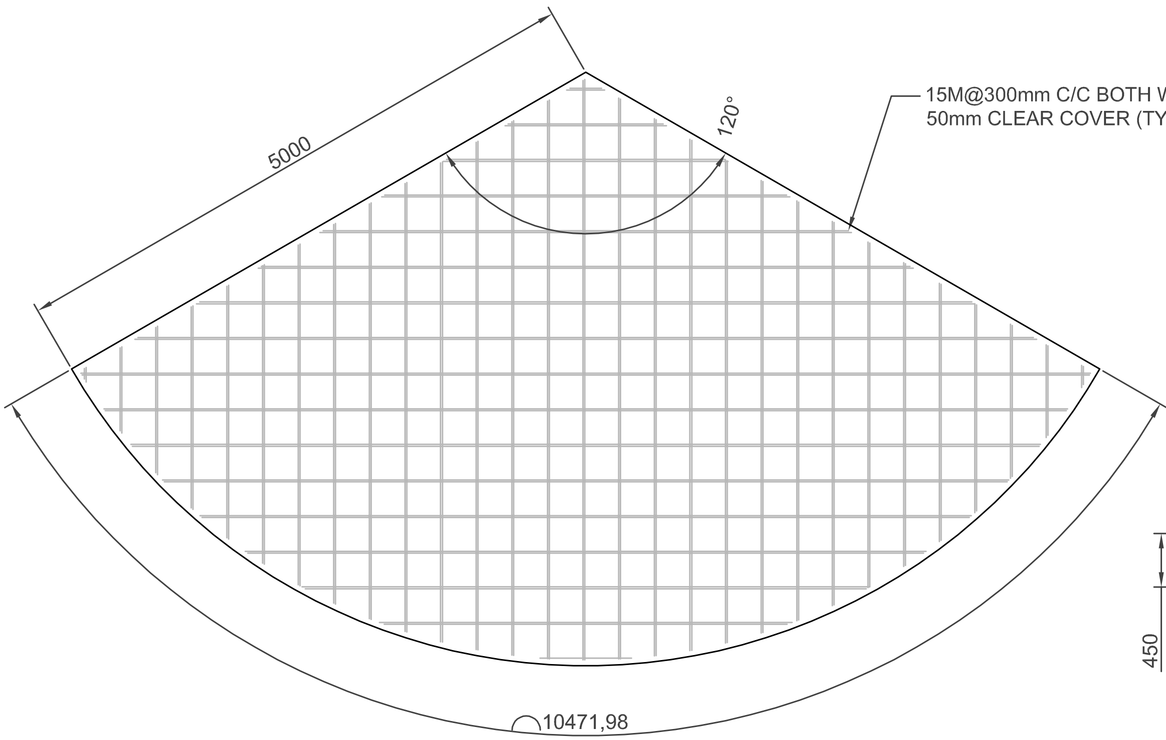
Date: 2017-02-28

Scale: 1:30

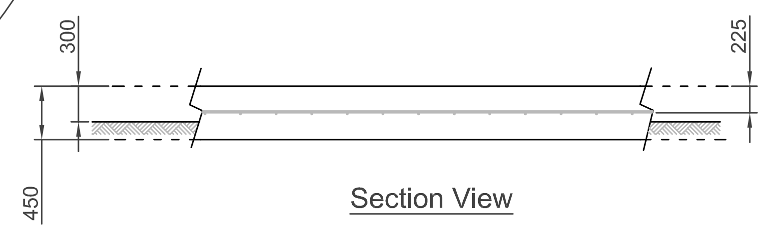
Drawn by: AW

Project: UBC Spiral Drain Enhancement

1 of 1



Plan View



Section View

Notes:
1. All units in mm.
2. Concrete Properties:
   Slump: 100+/-20 mm
   Air: 5-8%
   28 Day Str: 35 MPa
   MSA: 20mm
3. Reinforcing bars fabricated to CSA G30.18-09.
4. Place reinforcing at mid layer of slab as shown.
4. Construct Stage at 150mm below ground as shown.

23 North
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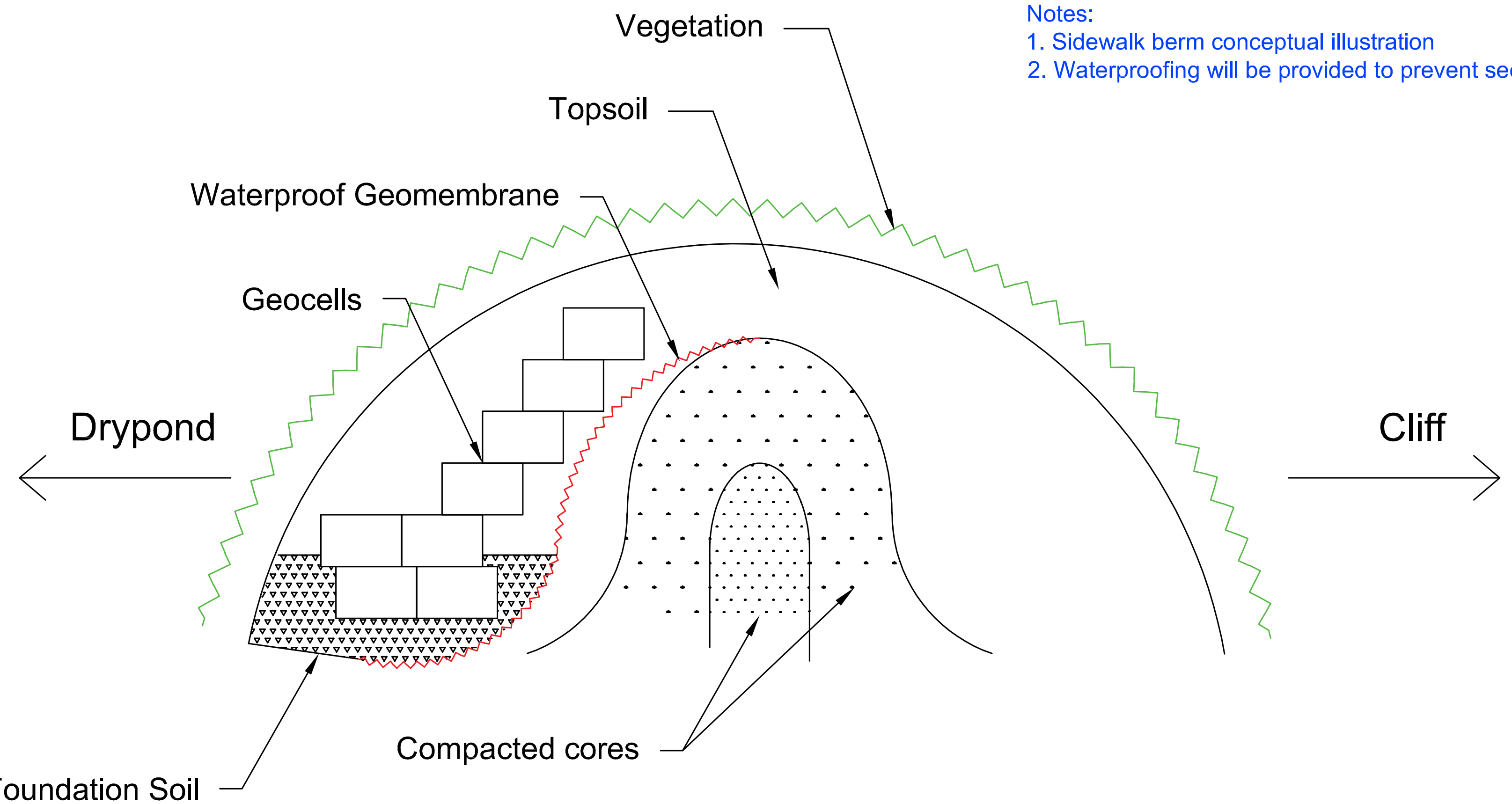
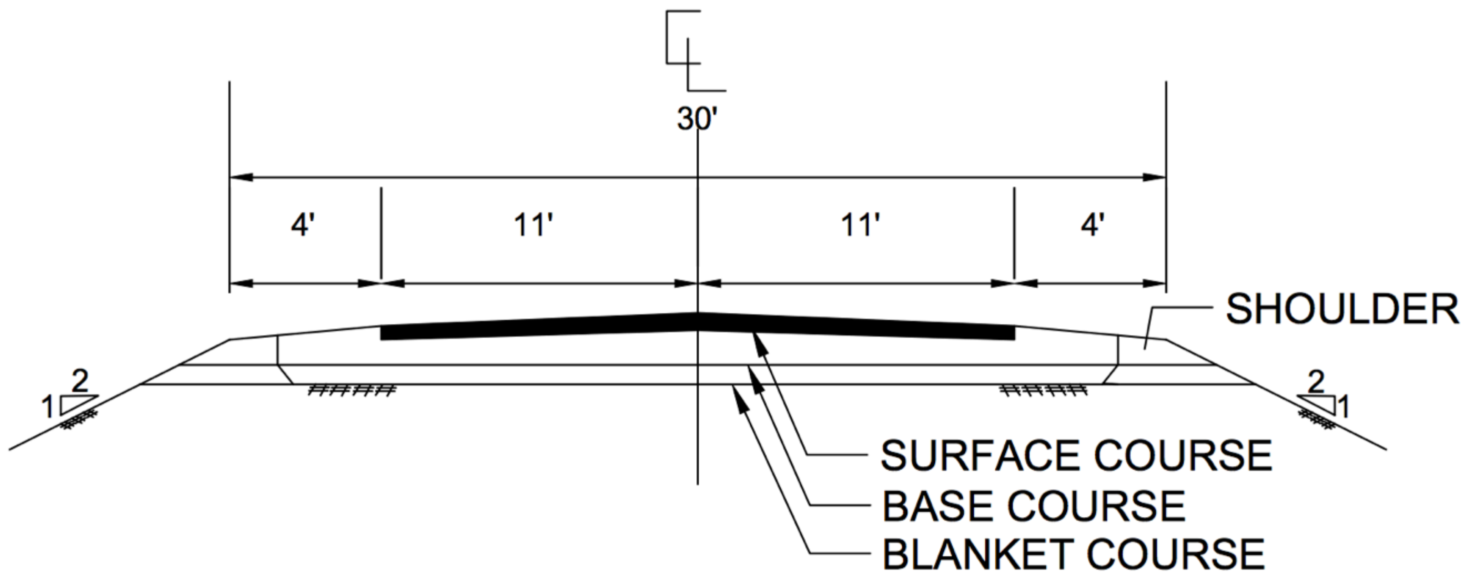
DWG: Concrete Stage			Project: UBC Spiral Drain Enhancement
Date: 2017-02-28	Scale: 1:50	Drawn by: AW	1 of 1



Notes:
1. Sidewalk berm conceptual illustration
2. Waterproofing will be provided to prevent seepage across the berms

23 North ENGINEERING CONSULTANTS LTD	DWG: Sidewalk Berm Concept			Project: UBC Spiral Drain Enhancement
	Date: 2017-02-28	Scale: NTS	Drawn by: AW	1 of 1



23 North
ENGINEERING CONSULTANTS LTD

DWG: Road Section			Project: UBC Spiral Drain Enhancement
Date: 2017-04-01	Scale: 1:30	Drawn by: KL	1 of 1

APPENDIX B - 3D MODEL

A complete 3D SketchUp Model can be downloaded using the following link:

https://drive.google.com/open?id=0B7Ube52nCv-TV2ZMdTZVa3hfMVU

An MP4 fly-through of the SketchUp Model can be viewed as well as downloaded using this second link:

https://drive.google.com/open?id=0B7Ube52nCv-TLUwxdFJpcVZ2XzQ

APPENDIX C - CALCULATIONS

Dry Pond Detention Capacity Calculations:

Block	Area (m^2)	Eff. Area (m^2)	Height (m)	Volume (m^3)
2.5	6825	790	0	0
2	6035	719	0.5	359.5
1.5	5316	744	1	744
1	4572	879	1.5	1318.5
0.5	3693	1317	2	2634
0	2376	2376	2.5	5940
			Sum	**10996**

APPENDIX D – DETAILED WORK BREAKDOWN STRUCTURE

Level	WBS Code	Element Name	Description
1.1	1.1.1	Client Engagement	**Client:** Doug Doyle, P. Eng, Assoc. Direction, Municipal Engineering Campus and Community Planning **Program:** Social Ecological Economic Development Studies (SEEDS) Sustainability Program
	1.1.2	Obtaining Documents	Obtain relevant contour, topographic, electrical, gas, storm, water, etc. drawings
	1.1.3	Review Documents	General review of documents mentioned above
1.2	1.2.1	Project Design	Project design includes conceptual, preliminary and detailed design: Conceptual - Present different concepts to client and decide on one to progress with using a decision matrix. Preliminary - Provide a report outlining the dry pond project with a decision matrix, implementation schedule, cost estimation and relevant drawings/calculations. Detailed - Provide a detailed report with precise calculations on the dimensions of all aspects of the project with a more refined schedule and cost estimation

Level	WBS Code	Element Name	Description
	1.2.2	Stakeholder Engagement	Relevant stakeholders: • Client • Design team • Construction team • General public • Museum of Anthropology • Musqueam Territory Representative • Cecil Green Park Representative • Metro Vancouver Anthropology and Sociology Building Representative
	1.2.3	Finalized Design	Milestone
	1.2.4	Permits Obtained	Building and development permits approved
	1.2.5	Tendering & Bidding	Respond to the open Request for Proposal (RFP) through the tendering process and submit estimated
1.3	1.3.1	Site Deconstruction	Remove existing plants, trees, shrubs, berms and topsoil
	1.3.2	Site Excavation	Excavate existing road and hills to create dry pond
	1.3.3	Relocate Existing Utilities	Existing gas, electrical, water and storm utilities will be disconnected and reconnected at an acceptable elevation below our dry pond base. A new drainage path/system will be implemented at this time to address future drainage issues. To achieve this, isolation with shut-off valves are ensured

Level	WBS Code	Element Name	Description
	1.3.4	Road Construction	A new road will be constructed on the outer perimeter (on the far side near the ocean) for vehicle access to surrounding buildings. Process includes embankments using cuts and fills, as well as paving
	1.3.5	Compaction	Includes soil compaction, dirt levelling, spray and geomembrane installation
	1.3.6	Retaining Walls	Installation of prefabricated concrete retaining walls along critical slopes
	1.3.7	Stage & Seating Construction	Construction of proposed stage and seating area. Installation of formwork, vapor barriers and pour of concrete
	1.3.8	Landscaping	Installation of sidewalks, railings, stairways, lifts, lights, vegetation, plants, flowers, shrubs, gravel paths, etc.
1.4	1.4.1	Commissioning	To test newly implemented drainage plan, retaining walls, stability of structures and for leakage by temporary filling the dry pond with a 1-200 year flood volume
1.5	1.5.1	Site Cleaning	Site clean-up, touch-ups and final walk-through

APPENDIX E – DETAILED COST ESTIMATE

Description	Material				Labour				Equipment				Total Amount
	Unit	Quantity	Rate	Amount	Unit	Quantity	Rate	Amount	Unit	Quantity	Rate	Amount	
FIRST COSTS													
Permitting													
For initial evaluation		1	225	225									225
Construction value		13	250	3250									3250
Project-management													
Tendering and bidding					month	1	100000	100000					100000
Project manager					month	19	12000	228000					228000
Consultant					people	6	45000	270000					270000
Construction													
Project coordinator					month	10	7000	70000					70000
Superintendent					month	10	7500	75000					75000
Safety officer					month	10	6000	60000					60000
Temporary facilities and utilities					lump sum	2	5500	11000	lump sum	1	9500	9500	20500
Traffic control and flagging					day	105	150	15750					15750
Site survey and layout					people	2	50000	100000					100000
Demolish existing site					week	1.43	21000	30000	week	1.43	70000	100000	130000
Excavation					m3	9120	68	620160	m3	9120	88	802560	1422720
Relocate existing utilities					day	40	10103	404120	day	40	13280	531200	935320
New road	m	262	312.5	81729	day	10	1185	11852					93581
Enbankment	megaton	2.22	150	333	m3	838	11	9222	m3	838	8	6707	16263
Formwork	m2	1100	21	23100	m2	1100	15	16500					39600
Rebar and concrete placement	m3	330	310	102300	m3	330	122	40260	m3	330	6	1980	144540
Install retaining walls	m3	41.8	310	12972	m3	41.8	135	5649	m3	41.8	9	377	18998
Install sidewalk	m	262	78.1	20432	m	10	296	2963					23395
Install stairways	lump sum	2	4000	8000	lump sum	2	3000	6000					14000
Elevator lift													20000
Landscaping and surface restoration					m2	6050	420	2543653					2543653
Storm drain manhole		2	3240	6480									6480
Catch basin box		3	2725	8175									8175
Connection to existing system						1	980000	980000					980000
First costs													$ 7,339,451
Contingency 8%													$ 587,156
Total first costs													$ 7,926,607
MAINTENANCE COSTS													
Storm filters		5	200	1000									1000
Pipe inspection					hour	37.5	80	3000	m	87.2	14	1220	4220
Pond sediment removal					time	1	3621	3621					3621
Annual maintenance costs													$ 8,841