UBC Chancellor Boulevard & East Mall Intersection Redesign

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University of British Columbia

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ANOVA
CONSULTING

Detailed Design Report

UBC Chancellor Boulevard & East Mall Intersection Redesign

TEAM 2

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EXECUTIVE SUMMARY

This report outlines the detailed redesign of the intersection at Chancellor Boulevard and East Mall, at the University of British Columbia. The current intersection does not promote safety, user friendliness, nor does it meet the future anticipated traffic demand of the growing UBC campus. The new intersection design aims at mitigating these issues by placing a roundabout at the intersection. Meanwhile, at the southeast corner of the intersection, a pedestrian lookout platform was designed and detailed within the report. The report begins with discussing the project background information and overarching objectives. It then examines the technical standards governing the design, the software programs used, and the final detailed parameters of the design components. Lastly, the report concludes by presenting the refined cost estimates, construction schedule, work sequence, and additional environmental, stormwater, and First Nations considerations.

The new roundabout shall replace the current two-way stop-controlled intersection, creating a safer and more disciplined travelling environment for its users. The City of Vancouver predicted that by 2030, over 66% of city’s transportation would be through sustainable transport, hence the roundabout has been designed for not only regular drivers, but also the rapidly growing number of pedestrians, cyclists and public transit users.

The pedestrian lookout platform near the intersection will serve as an iconic landmark and provide an inviting gateway into the UBC campus. It has been designed to offer full wheelchair accessibility and optimum safety during any severe storm or seismic events.

In addition, the consultant also investigated the existing stormwater management strategies in this region, and detected potential risks of flooding and cliff erosion on the north perimeter of the campus. In response, it is highly recommended that a subterranean detention tank along with perforated drainage pipes be installed directly east of the intersection.

Project construction is set to begin on May 2nd 2016 and will extend until August 18th 2016. A detailed construction schedule and work required are presented in the report, as well as a phased traffic management plan (sensitive to high traffic events). Overall, the roundabout is expected to cost $980,140, and the pedestrian platform, $362,250.

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GLOSSARY

Please note, all terms included within the glossary and list of abbreviations will be marked at first instance with a ° symbol.

Term	Definition
AutoCAD	Software used for computer-aided design
SAP 2000	Structural software for analysis and design
S-Frame	Structural software for analysis and design features numerous advanced analyses, a variety of hysteretic material models, flexible load combination methods and staged construction, all using fast and accurate sparse solver technology
Synchro Studio	Macroscopic traffic model simulation software
Trimble SketchUp	Modeling program often utilized to develop architectural figures
WB-15 Trucks	Intermediate semitrailer, smaller than a WB0-20 truck
WB-20 Trucks	An interstate semitrailer usually used as the minimum design vehicle, especially in the case of the BC Ministry of Transportation

LIST OF ABBREVIATIONS

Abbreviation	Explanation
BC MOTI	British Columbia Ministry of Transportation and Infrastructure
BMP	Best Management Practices
CHAIR	Construction Hazard Assessment and Implication Review
CSA	Canadians Standards Association
HSS	Hollow Structural Steel
LEED	Leadership in Energy and Environmental Design
MUTCD	Manual on Uniform Traffic Control Devices
NBCC	National Building Code
TAC	Transportation Association of Canada
TMP	Traffic Management Plan
UBC	University of British Columbia

1. INTRODUCTION

The redesign of Chancellor Boulevard and East Mall intersection aims to meet the future traffic demand, increase user safety, and develop an inviting gateway to the UBC campus. The following sections provide a summary of the project overview, objectives, and a brief overview of the design.

1.1. Project Overview

With an overall increase in the campus population and the diversification of transportation modes, UBC is experiencing new challenges with the management of traffic on campus. In particular, the intersection of Chancellor Boulevard and East Mall does not safely nor efficiently serve its users: pedestrians, cyclists and vehicles. Anova Consulting has been tasked with developing a detailed redesign of the intersection to ensure it better meets the demands of its users.

1.2. Project Objectives

This project aims to rectify the current issues by developing an appealing, effective and environmentally conscious redesign of the intersection. This new design will meet the future anticipated demands for traffic, keeping in consideration the expected growth rates of the individual road users in order to maintain a volume-to-capacity ratio of less than 1 over the design life. Furthermore, the design shall decrease the frequency and severity of accidents thereby improving the safety of pedestrians, cyclists, and vehicles.

The project will also include a pedestrian lookout platform that will be fully wheelchair accessible and will create an inviting entry point to the UBC campus. All components have been designed as to minimize the environmental impacts of the project and to reduce the footprint of the intersection by at least 10%. Finally, the entire project shall be administered as to respect and best align with the vision of the local Musquem First Nations community.

1.3. Design Overview

Anova Consulting has created a roundabout design for the project, after completing an evaluation of the project constraints and current issues, and studying various design options in the preliminary stage. The new design will turn the existing two-way stop control into a self-functioning one-lane roundabout, which will be equipped with a standard roundabout center, new signage, pedestrian crossings and flashers, as well as reclaimed green space. The roundabout will be able to effectively cater to the needs of all modes of traffic and improve road safety for pedestrians, cyclists and drivers.

Meanwhile, at the southeast corner of the intersection, a pedestrian lookout platform was proposed. The platform will resemble sloped semi-circular ramps that shall provide full wheelchair accessibility while limiting visual obstruction to the nearby road users to a minimum level. A UBC logo and First Nations artwork will be incorporated into the platform, promoting culture and diversity, and welcoming visitors into the UBC campus.

The two figures below depict the final roundabout and pedestrian lookout platform design.

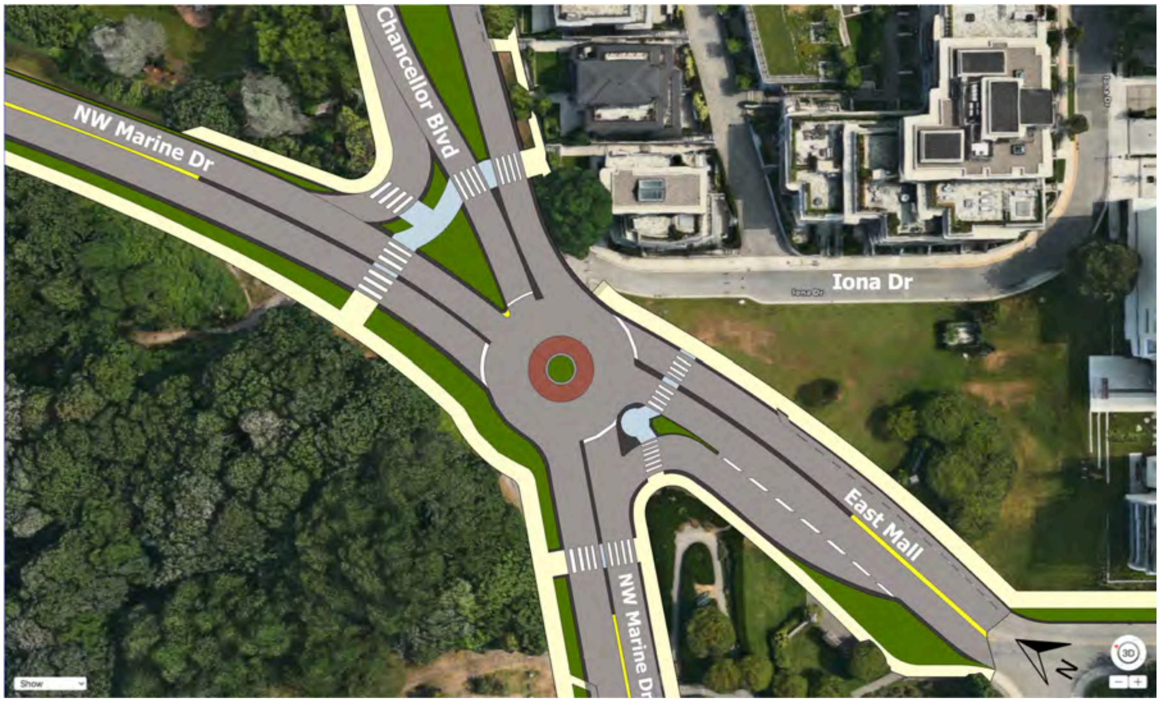

Figure 1 – Overview of Roundabout Design

Figure 2 – Overview of Pedestrian Lookout Platform Design

1.4. Team Member Contributions Breakdown

This section breaks down each team member's contribution to the final design report. If a section is referenced under 2 names that means that those two team members collaborated on that specific section. Kindly note that the number of sections associated to a specific name is not a fully accurate representation of each team member's efforts, as certain components required significantly more research, time and work.

Table 1 – Team Member Contributions Breakdown

Team Member	Sections
Joseph Braun	4.0, 4.1, 4.2, 4.3, 7.0, 7.1, 7.2, 7.3, 8.1, 9.0, 9.1, 9.2
Mengyizhe He	1.1, 1.2, 1.3, 2.2.1, 2.2.3, 2.2.4, 2.2.5, 2.2.6, Platform Model
Reza Jahanbakhsh	2.0, 2.1, 2.1.1, 2.1.3, 2.1.5, 6.0, 6.1, 6.2, 6.3, Roundabout Model
Amit Jain	2.1.2, 2.1.4, 2.1.5, 5.0, 5.1, 5.2
Parinaz Shahmoradi	5.0, 5.1, 5.2, 8.0, 8.2, 10.0
Lin Zhu	2.2.2, 3.0, 3.1, 3.2

2. DESIGN COMPONENTS AND PARAMETERS

To ensure successful delivery of a project, specific goals and objectives must be met through the realization of design components and control of parameters. The key design components are defined by both adaptive and interface specifications. In other words, the adaptable components describe ways that the design can be incorporated within an environment via a set of parameters and the interface components describe the desired characteristics of the implementation for the design component. The following sections provide details on the design of the roundabout and pedestrian lookout platform, namely, the criteria used for judging design functionality and feasibility, standards for defining parameters, and a discussion of the imposed limitations on the design.

2.1. Roundabout

A redesign of the current intersection at Chancellor Blvd. and East Mall is deemed necessary by the basic requirements set forth by the client; meeting future anticipated demands for traffic in the area, improving and ensuring the safety of all users, and reducing the intersection footprint. As justified through the analysis of current usage volumes, historical trends, and the UBC Transportation Report (2009), a roundabout was designed to serve as the best alternative to the current intersection. The design features a single-lane roundabout shared with cyclists, with two approaches from NW Marine Drive, and two approaches from East Mall and Chancellor Boulevard. The design components of the roundabout are interrelated. In other words, compatibility between components of the geometry and the surrounding environment is crucial in order to adhere to the specifications of governing bodies and more importantly meet the overall performance and safety objectives. Since the preliminary design phase, three different roundabout designs were iterated in total. Given that the designs of roundabouts are performance-based, each iteration required the entire design to be evaluated as changes were made. Specifics pertaining to the design of the roundabout are discussed in Sections 2.1.1 – 2.1.5.

2.1.1. Design Criteria

Modern urban roundabouts are characterized by yield controlled entry points and channelized non-tangential approaches (Highway Design Report, 2000). With the purpose of maintaining traffic flow, the circulatory roadway geometry will ensure travel speeds are 50 km/h or lower and deflection angles that provide greater safety for motorists, cyclists, and pedestrians. Hence, as in accordance with the BC MOTI° Guidelines & BC Supplement to TAC° Geometric Design Guide, the following categories and design parameters were used to judge the design of the roundabout:

Table 2 – Summary of Categorized Design Criteria and Parameters

Category	Design Parameters
Safety Improvements	✓ Vehicular, Pedestrian, and Cyclists Conflicts
Operations	✓ Capacity ✓ Accommodation for larger vehicles ✓ Average delay times
Societal and Community Enhancements	✓ Aesthetics ✓ Traffic calming
Costs	✓ Design ✓ Land Acquisition ✓ Construction ✓ Maintenance and Operation
Environmental Benefits	✓ Footprint ✓ Emissions and fuel consumption

Prior to defining the design components and the geometry of the roundabout, three fundamental elements were resolved:

1) The optimal size of the roundabout;
2) The optimal position of the roundabout, as governed by the constraining environment of the intersection (i.e. buildings, trees, etc.);
3) The optimal alignment and arrangement of the approach legs, once again as governed by the constraining environment of the intersection (i.e. buildings, trees, etc.);

As shown in Figure 3 below, the main elements/design components of a roundabout include channelized approaches, an inscribed circle diameter/radius, a central island that separates traffic within the roundabout itself, and most obviously, the entry/exit points.

Highway Design Report, 2000

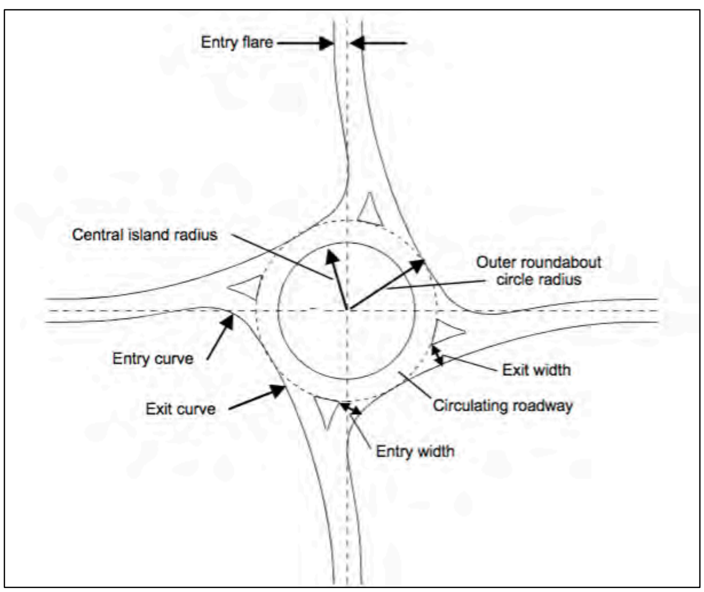

Figure 3 – Main Design Components of a Roundabout

With regards to the management of storm water and potential surface flooding, considerations were given to UBC's Storm Water Management Strategy in the event of a 1-in-200-year storm, as mandated by the BC MOTI. Please see Section 4 for further details.

2.1.2. Standards and Software

The roundabout will be constructed to meet or exceed the guidelines put in place by the TAC° manual. The roundabout will be 15 metres in radius, which will include 7 metres of paved road, a 4-metre apron and a center island with a radius of 4 metres, as shown by Figure 4. The roundabout can accommodate WB-20° type trucks going through the intersection in the east-west direction, namely, on Northwest Marine Drive and Chancellor Blvd. and WB-15° type trucks turning to and from East Mall. The pavement markings will be in accordance to the MUTCD° and the building materials and specifications used at the site will be in accordance to the CSA° and LEED°. The overall design and construction of the facility is evaluated on the Greenroads Rating System to measure and manage sustainability on the project. The roundabout was modeled using Autodesk AutoCAD° and Trimble SketchUp.

2.1.3. Geometric Design

In consultation with the BC MOTI Guidelines and the BC Supplement to TAC Geometric Design Guide, the roundabout was geometrically designed with a sufficient inscribed circle diameter and truck apron width to accommodate a WB-20 design vehicle. By doing so, the roundabout at the intersection will be able to effectively cater to the needs of all modes of traffic using the facility including pedestrians, cyclists and motor vehicles. This accommodation was determined based on several factors, including the classification of the roadways involved, the location of the intersection (e.g. urban or rural, etc.), the vehicle classes (i.e. % of trucks), and volume of vehicles using the intersection. Table 3 and Figure 4 below summarize the specific dimensions of the roundabout. Please note that a detailed dimensioned design can be found in Figure 5 on the following page, and an additional figure annotated with the major design components/elements can be found in Appendix A.

Table 3 – Summary of Roundabout Dimensions

Roundabout Components	Label	Dimensions (m)
Centre Island Radius	a	4
Apron around the Centre Island	b	4
Pavement Width	c	7
Roundabout Radius	d	15

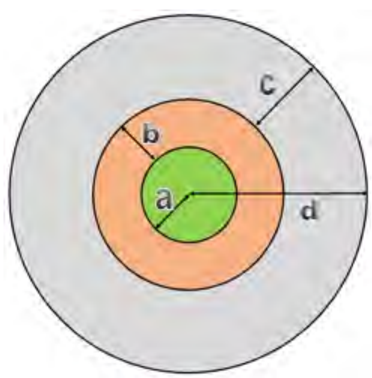

Figure 4 – Roundabout Dimension Labels

Additionally, the channelized approaches will have the following components and associated dimensions:

- 2.0-metre wide sidewalks in all directions
- Pedestrian activated flashers and refuge islands
- 1.5-metre wide bike lanes
- 3.3-metre wide lanes from vehicular traffic

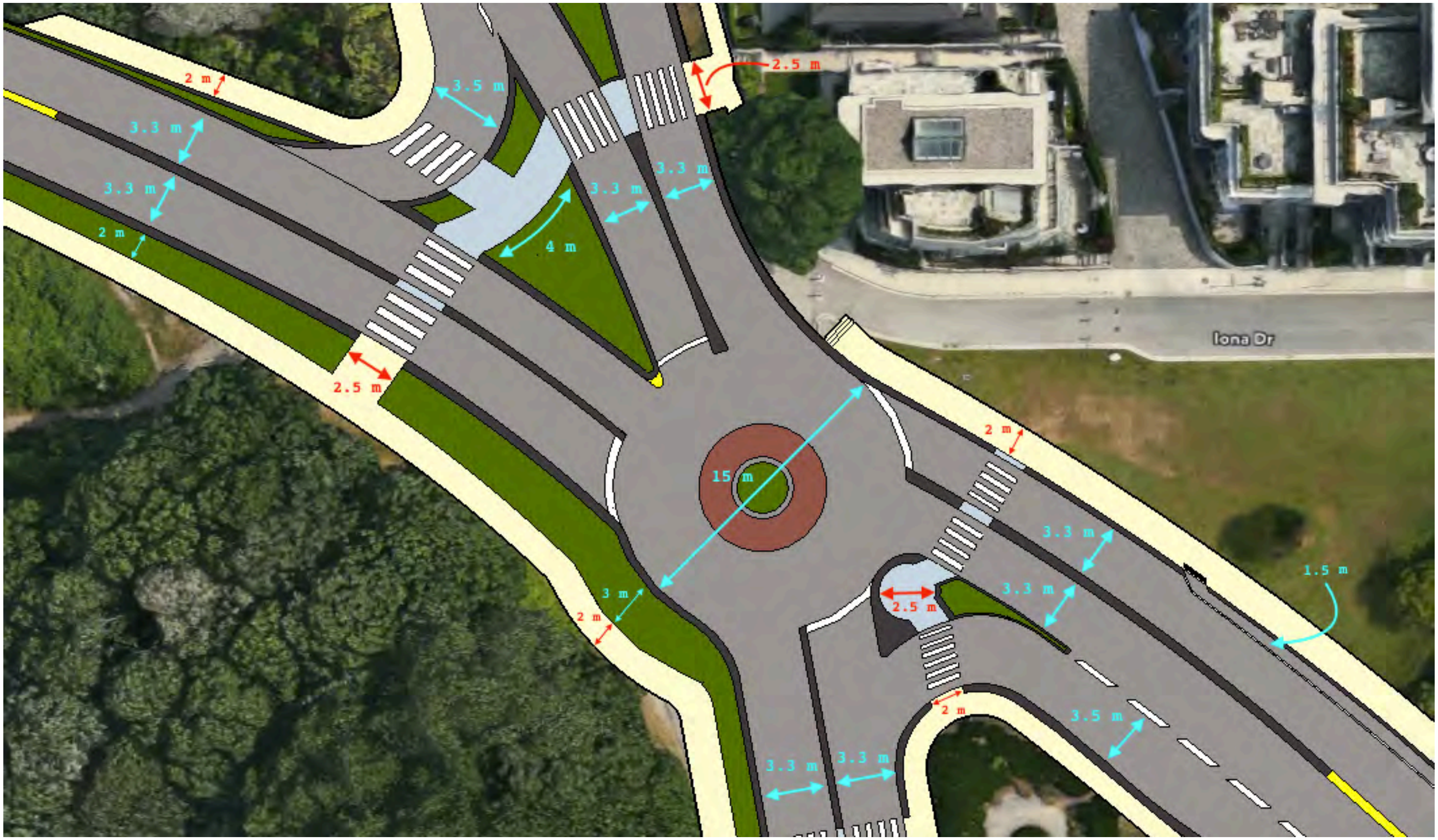

Figure 5 – Roundabout Design with Dimensions

2.1.4. Traffic Movement

The roundabout at the intersection will be able to effectively meet the demands of all modes of traffic using the facility. First, the pedestrians will have a 2-metre wide sidewalk approaching the intersection from all directions, allowing for easy and safe access to the intersection. Pedestrian-activated flashers will be installed at all crossings to provide additional safety when crossing the road. Furthermore, placing refuge islands for pedestrians will shorten the crossing distances. Secondly, 1.5-metre bike lanes will be installed in all directions approaching the intersection. Bike lanes will be truncated before the intersection and bikers will have the option to merge into the slow moving vehicle traffic and ride through the intersection or dismount and use the pedestrian facilities. Although dismounting is not required by the current standards, it will be prescribed at this intersection due to the high pedestrian volumes. Lastly, motorized vehicles using the intersection will have standard 3.3-metre lanes approaching the intersection and will be guided into the roundabout to ensure minimal confusion. The roundabout will also act as a traffic-calming device that will help reduce the speed of vehicles using the facility, making the intersection safer. The facility will also offer fewer conflict points for vehicles and be more aesthetically pleasing when compared against signalized or stop controlled intersections. All the above-mentioned features can be seen within the figures found in Appendix A.

2.1.5. Limitations of the Design

While this design takes into consideration the various design preferences as set forth by BC MOTI Guidelines and BC Supplement to TAC Geometric Design Guide, a few limitations are imposed. Firstly, the geometric design of this intersection is based on general measurements from Google Maps and the AutoCAD files provided by the client. A full detailed survey of the site location is required in order to proceed with more refined calculations/considerations for the geometric design of the roundabout and the intersection as a whole. This would also allow for an analysis of cross-sections, leading to dimensional improvements. In addition, a field test has not been conducted to confirm that the largest design vehicle (WB-20) can traverse the proposed roundabout with ease. This can be achieved by laying out the proposed central island (in an open field/parking lot), truck apron, and inscribed circle diameter (ICD) and having the design vehicle negotiate all possible movements (BC MoT Section 740). Finally, further geotechnical data is required to ensure that the proposed design does not interfere with critical loading conditions on site. In evaluating the recommended design, the roundabout adheres to all provincial and municipal codes of practice, standards, and regulations. Upon finalization, all roundabout documentation shall be sent to the attention of the Ministry’s contacts, for obtaining approvals of the geometric design.

2.2. Pedestrian Lookout Platform

Since the pedestrian lookout platform was introduced in the preliminary phase of the project, the consulting group has rigorously improved and detailed the structure, especially its foundations. The following sections disclose the details about the platform.

2.2.1. Design Criteria

The key objective of the pedestrian lookout platform was to provide a fully accessible and safe platform on which the visitors can enjoy the oceanic scenery and appreciate the sense of place around UBC campus. This ideology was at the forefront of the entire design process.

Design Loading Conditions

The consultant started with the design loading condition of three occupants-per-square-metre. The platform was found to be able to withstand the loads of nearly 50 occupants at once, without compromising user safety and structural stability. Next the design life for the platform was chosen to be 25 years, in order to align with that of the roundabout.

Accessibility

Full accessibility was always a prime objective of the platform, thus, the platform was designed to be as open-concept as possible while maintaining complete wheelchair accessibility and user safety. The minimally sloped ramp design will allow users to comfortably manoeuvre through the space, especially the wheelchair users as this will aid them in operating easily and safely on the main deck.

Aesthetics

Furthermore, aesthetics was heavily weighed in this design, as one of the project objectives was to transform the intersection into an inviting gateway into the UBC campus. The consultant's vision was a step further in that direction, namely, creating an attractive landmark that speaks the same design language and promotes similar architectural expression as the rest of the campus. The design naturally blends into the surrounding existing architecture, but the process did not stop there, beyond appearances is the careful selection of materials used for the platform.

Sustainable Materials

Major materials in the platform will be sourced in accordance to the required common materials outlined in the UBC Vancouver Campus Plan - Part 3 Design Guidelines. The primary materials will be aluminum and natural concrete; some secondary materials in the design will be structural glass that will form a transparent and vibrant façade. The selection of materials will reflect not only the overall architectural palette, but also the idea of sustainability throughout the design. Sustainable materials will help meet the LEED Gold certification as required by the UBC Vancouver Campus Plan (2010). In turn, the design will also be more environmentally friendly throughout its entire lifecycle, from its construction to demolition. Later in the document, Section 3.1 will elaborate on the details regarding sustainable considerations at every step of the design and construction process.

2.2.2. Standards and Software

The pedestrian lookout platform is designed based on the most critical limit state, and then checked with design codes and software programs to ensure the applied loads are within the structure's limit.

The pedestrian lookout platform meets all structural requirements set out by the NBCC° 2010 and CSA codes. Design live loads are based on the worst-case scenario of three occupants-per-square-metre. Please see Appendix B for further details regarding the specific standards considered and software programs used.

2.2.3. Deck

The deck is the essential component in the structure, not only will it form the shape of the platform, it will also provide the space in which the occupants operate. The deck will be primarily comprised of three parts: the main deck, longitudinal beams, and transverse beams. Specifically, the deck, made of steel plates, shall create the floor upon which the users walk; the longitudinal and transverse beams will be made of hollow structural steel, and they will be bolt connected underneath the main deck in the longitudinal orientation and transverse orientation, respectively. This cross member strategy allocates structural rigidity and warping resistance to the relatively flexible steel deck above. A segment of the deck, including its composition is shown below in Figure 6. Additionally, a breakdown of the materials and dimensions of these components are in Table 4.

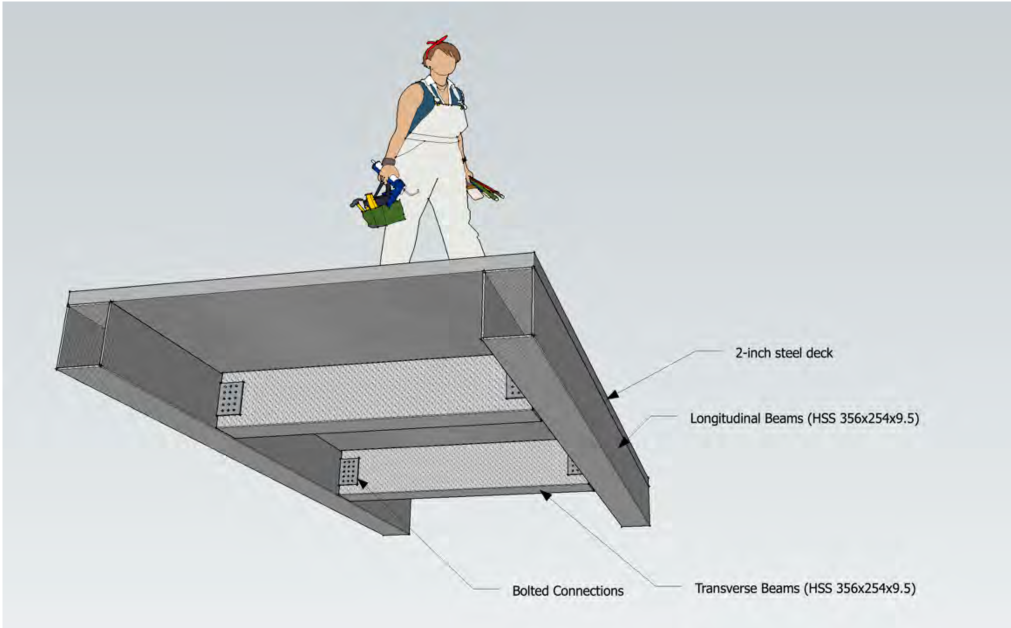

Figure 6 – Pedestrian Lookout Platform Deck

Table 4 – Pedestrian Lookout Platform Deck Components Specifications

Components	Deck	Structural stiffeners
Dimensions (mm)	2300 x 1000 x 50.8 (per panel)	355 x 254 x 9.5 (h x d x t)
Material	Steel panels	HSS 356x254x9.5
Quantity	137.3 m^2	215.0 m

The challenge of designing the deck was finding the appropriate size of the structural beams so that the overall ratio of self-weight to loading capacity could be optimized. Multiple design iterations were performed in Excel to reach the decision of using G40.21 HSS° 356x254x9.5 beams for stiffening the deck.

2.2.4. Handrail and Guards

Another major part of the platform is the brushed aluminum handrail posts on the sides of the ramp, they are located in between two annealed glass side panels, which will provide vibrant transparency, and more importantly, safety. The handrail-and-guard system acts primarily as an aesthetic device, its contribution to the structural integrity is negligible in the design. Specifications of the parts are tabulated below.

Table 5 - Pedestrian Lookout Platform Handrails and Guards Specifications

Components	Handrail posts	Side guards	Connectors
Dimensions (mm)	Ø100	1200 x 1000	N/A
Material	Brushed aluminum tubes	Annealed glass	Steel bolts and plates
Amount	96 items	114.7 m^2	192 items

The handrail posts and glass guards are very commonly used in modern architecture, and are popular due to its aesthetically pleasing features, though there are variations to them. The major design issue in this system was the management of stormwater runoff at the surface of the deck, routing the stormwater quickly to the permeable ground below is crucial in preventing steel corrosion and possible slippage for the users. To do this, the consultant designed the guards to be placed 5 cm above the deck, such an opening will allow surface runoff to be immediately and effectively directed to the ground soil. The underground-perforated drainage pipes discussed in Section 4.2.2 have been sized to be able to handle this increased infiltration. In addition, there were also several ways of connecting the glass panels, standard pin connectors were selected to help elevate the glass panels from the deck, allowing for the drainage gap as previously discussed.

As seen in Figure 7 and 8, two glass panels are tightly connected with two pairs of pin connectors near the top and bottom sections. These connectors can be easily installed, and reduce visual obstruction to the smooth and transparent façade.

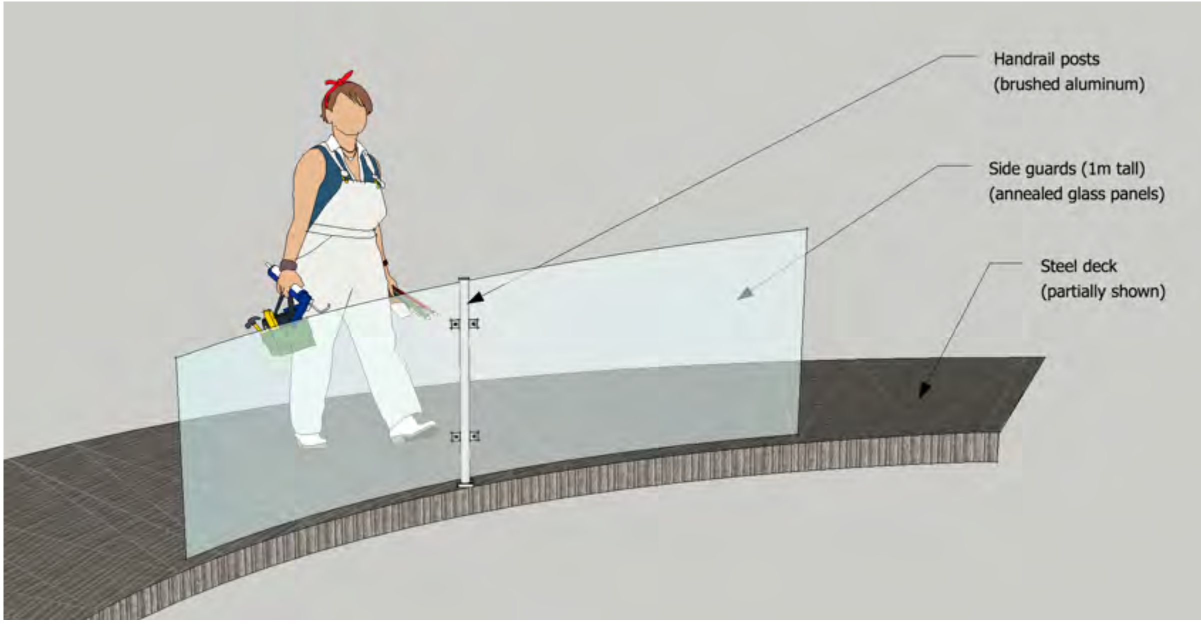

Figure 7 – Pedestrian Lookout Platform Handrail Components

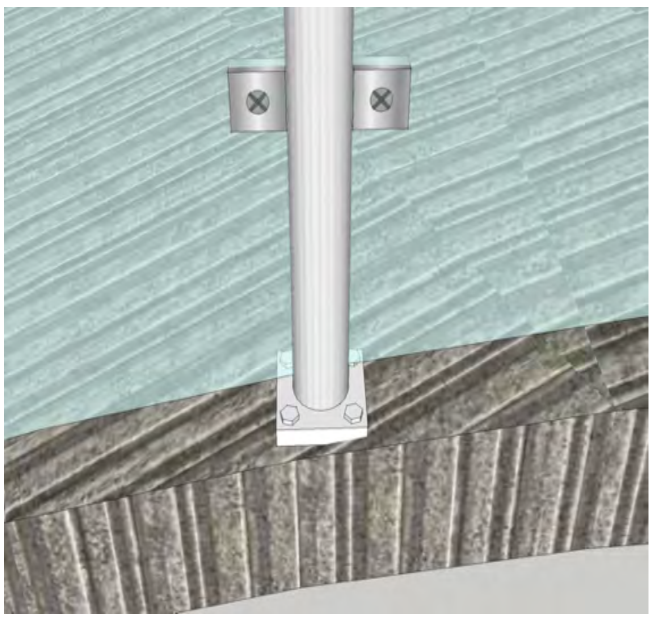

Figure 8 – Pedestrian Lookout Platform Handrail Post Pin Connection Detail

2.2.5. Foundation

The third key component in the design is the foundation, which can be divided into large concrete columns and concrete footings directly beneath. The columns will be 1 metre in diameter, and vary in heights from 2.8 metres to 4 metres above the ground to accommodate the naturally sloped terrain. At the bottom of each column, a square concrete footing will be embedded, to which the column will be bolted down; at the top of each column, a base isolator will be placed and fixed to the deck section to dramatically improve the structural performance during seismic events. Looking deeper into the technical considerations in developing the foundation design, with a thorough analysis in S-Frame°, it was decided that spiral and vertical reinforcement steel bars would be placed inside these cylindrical columns. Table 6 breaks down the exact column sizes, bar sizes and spacing. Detailed S-Frame design report is attached in Appendix B. It is worth mentioning that the base isolators will be incorporated into the system, these act as dampers thereby greatly increasing the seismic soundness and ensuring users' safety in a 1-in-25-year seismic event. The following diagram shows the fundamental components in the foundation system, as well as detailed geometric and dimensional relations between these components.

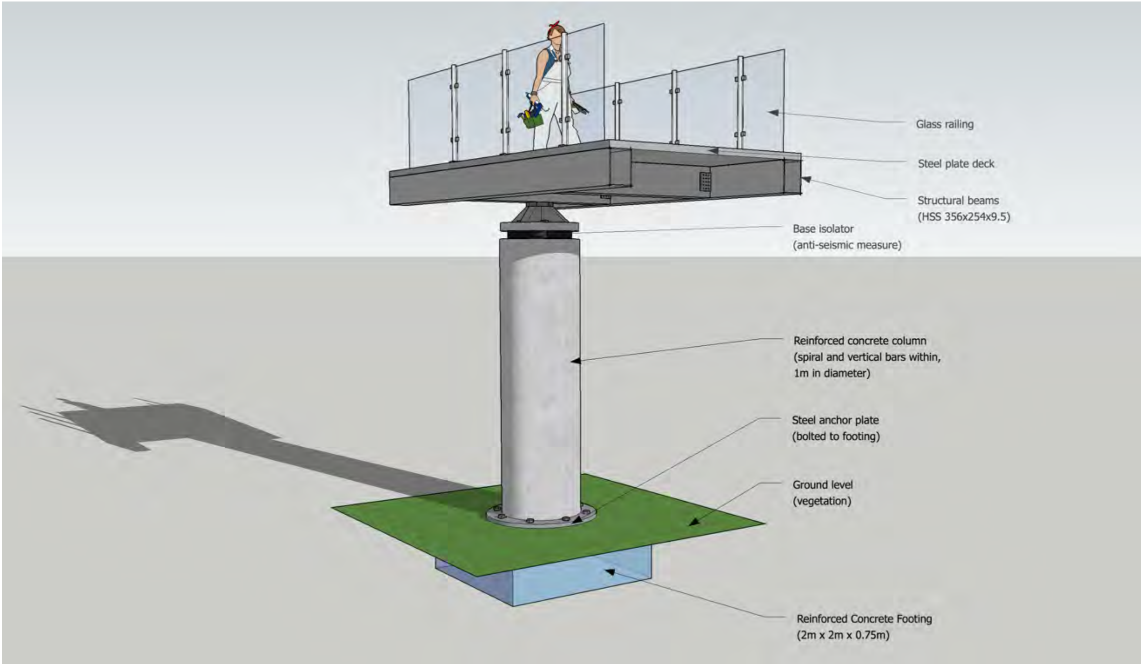

Figure 9 – Pedestrian Lookout Platform Foundational Components

Similar to the previous sections, the dimensions and material quantities required are listed below in Table 6.

Table 6 - Pedestrian Lookout Platform Foundational Components Specifications

Components	Columns	Footings
Dimensions (mm)	Ø1000	2000 x 2000 x 7500
Material	Reinforced concrete	Reinforced concrete
Reinforcement Type and Quantity	21-30M vertical bars + 20M spiral ties 90mm (x4)	20-35M rectangular rebar rings (x4)
Concrete Quantity	7.9 m^3	12 m^3

2.2.6. Limitations of the Design

Many engineering designs inevitably contain some limitations; the consultant strived to moderate them without comprising any of the objectives of the project. Because of the complex curvature of the ramp platform, limited survey data and software, the structural analysis conducted had to be simplified, which prevented the structural soundness from reaching the optimal level of certainty. Moreover, the connections between the deck and the supporting columns were not analyzed considering the limited capabilities of the software available to the consultant. In other words, the design shall be further analyzed with more sophisticated software; lab model testing is highly recommended, before the finalization of the design.

The consultant originally considered designing a roof system for the platform, however, this idea was discarded based on a lower benefit-to-cost ratio in the preliminary feasibility studies. Given that new objectives may develop in the future, or if any upgrades or renovations were to occur, adding in a roofing system may become a viable option.

3. ENVIRONMENTAL IMPACT CONSIDERATIONS

This section of the report examines the environmental impacts on the surrounding buildings and various design guidelines for the existing trees and vegetation on the UBC campus. For this reason, Anova Consulting ensures the protection and care of existing trees and plantation throughout the project. In addition, the team shall seek professional consultation from a certified arborist during construction, to fulfill the requirement by Campus and Community Planning (UBC Vancouver Campus Plan, 2010). The following sections will discuss the necessary tree relocation plan, as well as mandatory LEED considerations. Kindly see Appendix C for tree protection guidelines, coordination process, materials, fencing guidelines for trees and shrubs.

3.1. Sustainability (Vegetation, Trees, and Carbon Emissions)

Sustainability shall be considered in accordance with the UBC LEED Implementation Guide, see Appendix I for a detailed breakdown (UBC Vancouver Campus Plan, 2010). During construction, site work such as underground utilities, drainage and irrigation lines shall be routed outside the Tree Protection Zone, to preserve existing trees, shrubs, and vegetation (UBC Technical Guidelines, 2015). In particular, the consultant would like to highlight that the Summary of UBC Required LEED credits show construction activity pollution prevention as a prerequisite for sustainable sites.

3.2. Necessary Tree Relocation

The pedestrian lookout platform was designed as to limit the amount of trees needing relocation. However, as outlined below, it will be necessary to relocate 5 trees. This shall be done with the utmost care and in accordance with the UBC guidelines found in Appendix C.

Table 7 – Tree Relocation Plan

Detail	Description	Relocation Plan
1,2,3	These trees are located on the south most corner of the intersection between Iona Dr. and East Mall. The trees are estimated to be less than 5 years old and 3m in height, and thus should not pose significant difficulties during relocation.	These trees will be moved to locations A, B, C respectively. These trees are expected to grow to a significant height and width, thus there relocated positions were chosen as to ensure no additional sightlines would be blocked. Note, the trunks of these trees are not yet fully developed, and thus extra care must be exercised during their relocation.
4,5	These trees are located further into campus, still on the median formed between Iona Dr. and East Mall. The trees stand at about 4.5m in height, have a dome shaped top and are estimated to be 10 years old.	These trees will be relocated to locations D and E respectively. They are not expected to further grow in height significantly, and thus will be relocated to regions closer to Allard Hall. The trunks of trees 4 and 5 are well developed, however delicate care should still be administered during the relocation.

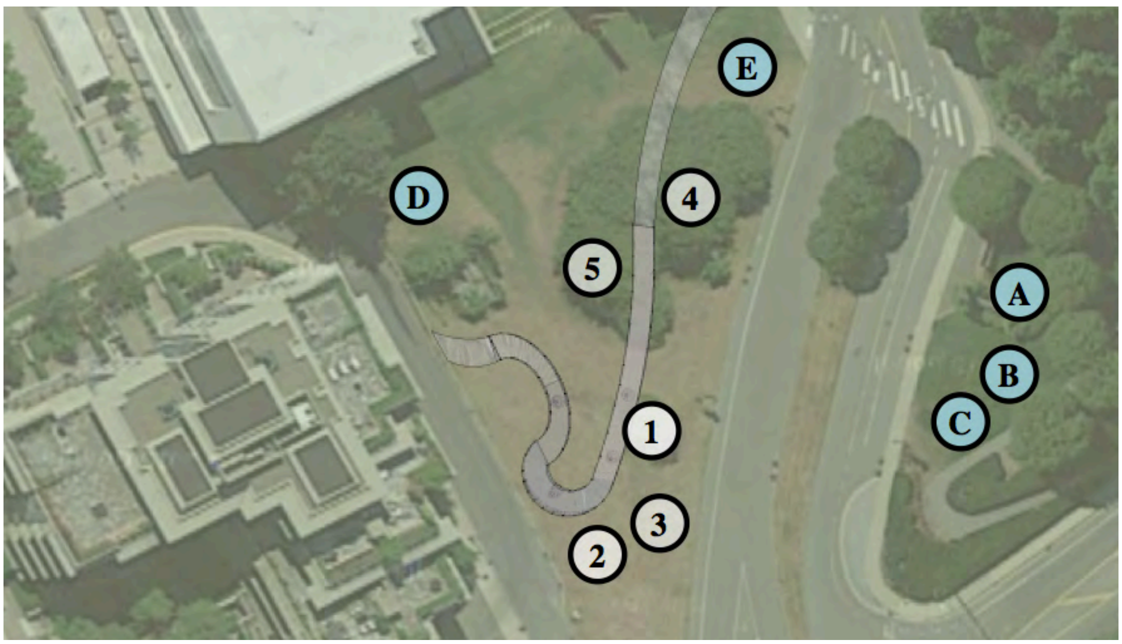

Figure 10 – Tree Relocation Map

4. STORMWATER MANAGEMENT

Stormwater management is a significant component of this project, due to the specific soil conditions at UBC. As a result, the consultant has carried out extensive research and background calculations in order to develop a stormwater management system that will mitigate any adverse effects of the proposed roundabout design. This section describes the stormwater management issues at UBC, the design solutions. Please see Appendix D for constructions BMPs° relating to stormwater management.

4.1. Problem Overview

The specific geological and geographic conditions of the project site at UBC present distinct technical challenges for stormwater management. These challenges are exacerbated by the fact the UBC stormwater drains through jurisdictions of the BC MOTI, Metro Vancouver, and is discharged into the Pacific Ocean that is regulated by the federal Department of Fisheries and Oceans. These facts have resulting in the two following stormwater management implications for this project:

The intersection is located in the north catchment area and is served by spiral drain. This drain discharges into the Pacific Ocean and according to Geoadvice is currently unable to handle both 1-100 and 1-200 year flows (2013). As a BC MOTI intersection, the project site must be equipped to handle a 1-in-200 year storm event, and therefore, the existing storm water management system is grossly undersized.

Infiltrating water flows northeast through the top aquifer towards Pacific Spirit Park, and then discharges from the cliffs at about mid-height. This behaviour creates sand piping and seepage face conditions which result in erosion and poor slope stability at the cliff fronts. As a result, the effects of excessive additional infiltration in this area could be catastrophic

4.2. Design Solution

Anova Consulting viewed the existing conditions at the project site as an opportunity to focus on developing a long-term restorative (as opposed to merely sustainable) stormwater management system. Emphasis was placed on ensuring the system is able to meet the future developed demands of the area. The system is to be comprised of the following two major components:

4.2.1. Detention Tank

In line with UBC's Integrated Stormwater Management Plan (2014) and Geoadvice's Report (2014), the consultant is recommending the construction of a 1700 m^3 subterranean detention tank directly east of the intersection (see Appendix D). The volume of this tank has been recommended as suitable by Geoadvice (2014) to handle the 1-in-200-year storm volumes. The tank shall:

- Be of the following dimensions (Figure 11 not to scale):

Table 8 - Dimensions of Stormwater Detention Tank System

Specification Number	Parameter	Dimension
1	Clearance to roadway	2m
2	Depth of tank	3 m
3	Clearance to bedrock/water table	>0.6 m
4	Width of tank	8 m
5	Inflow orifice diameter	0.8 m
6	Outflow orifice diameter	0.25 m
N/A	Tank length	80 m
N/A	Tank bottom slope	2 %

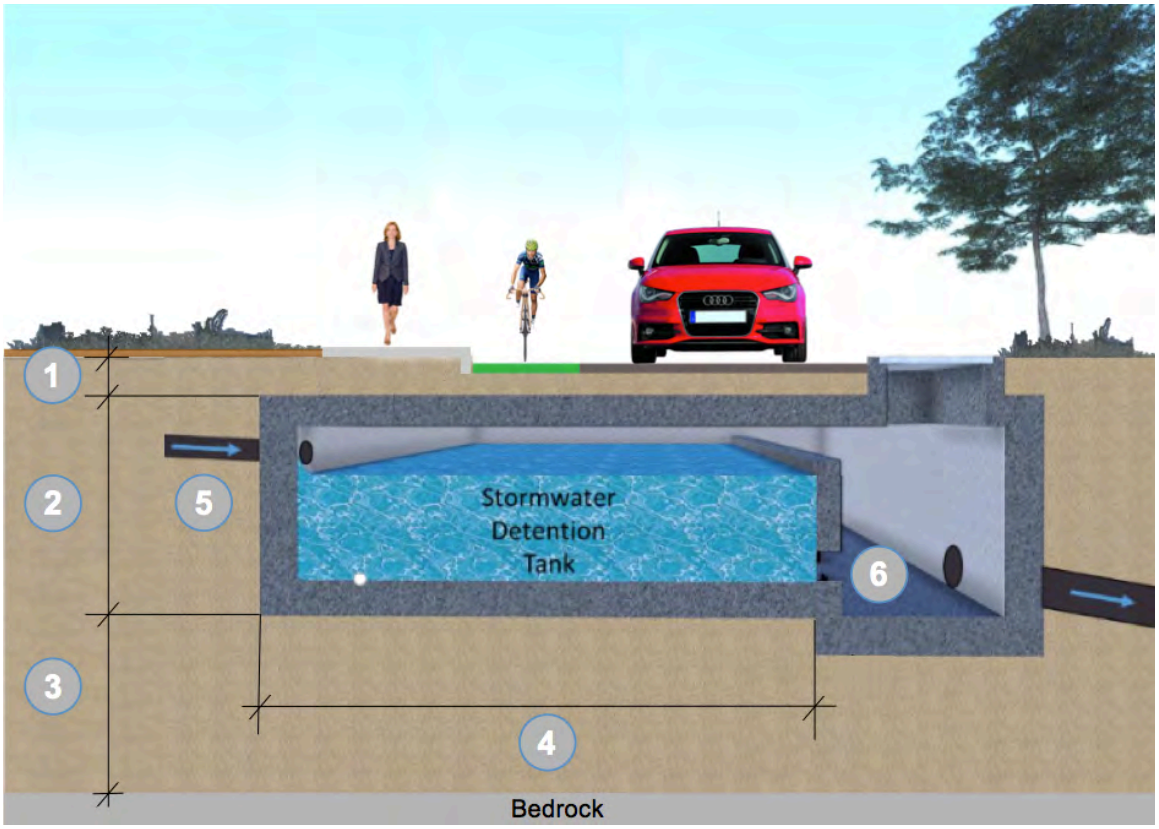

Figure 11 – Cross-sectional View of Stormwater Detention Tank

- Be an online system - will ensure that all captured water receives some degree of suspended solids removal
- Be equipped with a DDC pneumatic valve at the outflow pipe – will allow for load on spiral drain to be reduced during storm events
- Be made of prefabricated reinforced concrete, assembled onsite, sealed with sealers approved for contact with water (i.e. Thoroseal, Antihydro)
- Be positioned such that water table/bedrock be a minimum 0.6 m below bottom surface of tank

- Include an overflow structure - ensure drainage can occur in case of malfunction of the orifice, or failure of outflow valve
- Be graded towards outlet to avoid water stagnation
- Be constructed to allow access inlet/outlet and bottom of tank maintenance and cleaning
- Include orifices that are to be protected by approved mesh screens and must follow the construction details found in Appendix D
- Have a sediment collection sump below the outflow orifice with a minimum depth of 200mm below the invert of the orifice
- Please see Appendix D for calculations and geographical positioning of tanks.

4.2.2. Perforated Drainage Pipes

Perforated pipes will be placed underneath the green spaces to compensate for the additional infiltration. These pipes will collect the infiltrating water at an average depth of 1 metre and transport the water to the detention tank. Such a configuration allows for load equalization before timely removal of the water as to limit the amount of seepage and erosion at the cliff face. In addition, the perforated pipe system shall:

- Be perforated along the top 1/3 of the pipes circumference only, as to ensure the pipe will transport water downstream, without enabling further infiltration
- Be of the following specifications (figure not to scale):

Table 9 – Specifications for Perforated Drainage Pipe System

Specification Number	Parameter	Comment
1	Topsoil hydraulic conductivity	K > 1×10^{-5}m/s
2	Minimum cover to pipe	600 mm (over sealed road) 750 mm (over grassy area)
3	Hydraulic conductivity of gravel surrounding drainage pipe	K>1×10^{-2} m/s
4	Filter Material	Must abide by specifications and gradation as specified by local regulations
5	Clearance to water table/bedrock	>0.6 m

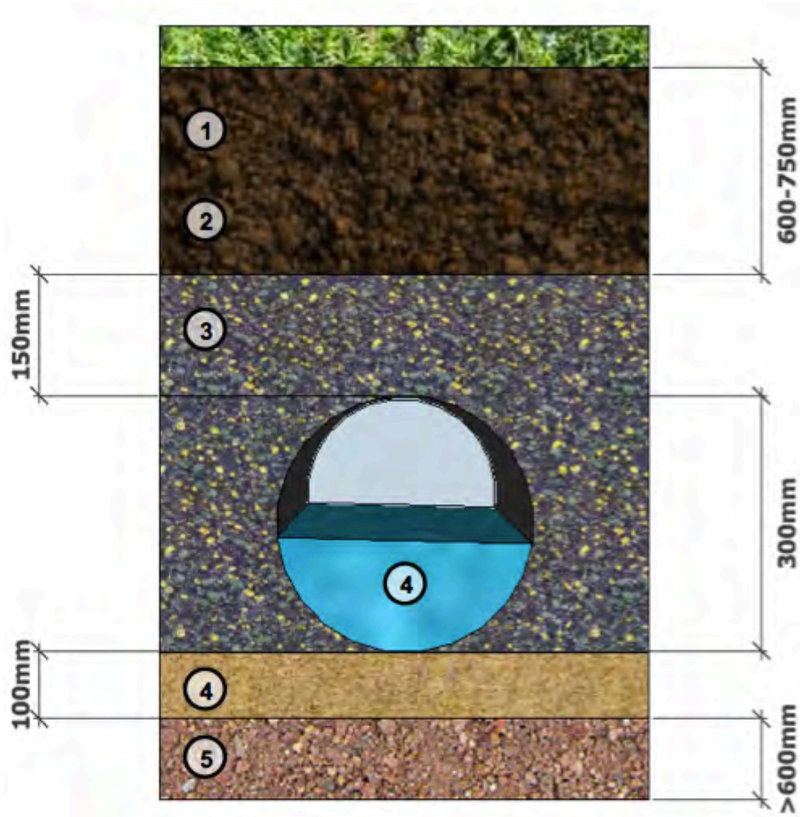

Figure 12 – Cross-sectional View of Perforated Pipe Drain

- Please see Appendix D for:
    - Location of perforated drainage pipes
    - Supporting calculations
    - Construction best management practises

5. CONSTRUCTION WORK AND DETAILED SCHEDULE

The following section provides a detailed schedule as well as a TMP° for the construction phase of the roundabout and the pedestrian lookout platform. The consultant has collaborated with UBC in order to ensure optimal layout of these schedules by taking into account convocation ceremonies, as well as semester end points. As a result, the developed schedule and TMP will interact minimally with campus activities.

5.1. Schedule

The project implementation will start on May 2nd, 2016 and end on August 31st, 2016. The detailed schedule for implementation of the roundabout is based on four construction phases: site preparation, earthwork, construction, and finishing. Table 10 below provides a summary of this sequencing including each phase's duration.

Table 10 – Construction Milestone Dates

Phases	Duration	Start	Finish
Site Preparation	11 days	May 2nd, 2016	May 16th, 2016
Earthwork	~25 days	May 16th, 2016	June 6th, 2016
Construction	~60 days	June 4th, 2016	August 23rd , 2016
Finishing & Final Inspections	14 days	August 12th, 2016	August 31st, 2016

The detailed schedule, as can be found in Appendix E, is provided to accommodate flexibility for the client to make key decisions. The schedule is based on eight-hour days and 22 day months. However, due to 2016 graduation in May, few tasks will be required to be performed on weekends in order to minimize the disruption and meet the deadline. Also, it should be noted that construction will not be carried out during the graduation ceremonies days (i.e. May 25th-27th, and June 1st), and since the site is in a residential area, there will not be any night construction.

Furthermore, the proposed project schedule follows a sequential work path, and the critical tasks are given free flow time in order to reduce the risk of delays due to unpredictable changes and events during the construction phase, as well as to prevent overlapping of the overall schedule. In addition, the implementation of the roundabout intersection will finish before the winter term begins in order to minimize the disruption for UBC commuters during those school days.

5.2. Traffic Management Plan

A TMP has been developed to aid the construction process of the intersection. This TMP is in accordance with the recently updated guidelines set forth by the BC MOTI in the 2015 Interim Traffic Management Manual for Work on Roadways. The Traffic Management Manual provides details about the type of signs, personnel and equipment is required to safely manage the traffic flow thought a corridor.

In total, four phases of the TMP have been developed for the construction period. These phases represent four different work zones where the construction activities will be conducted over the course of the project. It is also worth mentioning that, due to unforeseen circumstances, phases other than the ones shown below in Figures 13-16 might be required. In that case, the general contractor shall contact Anova Consulting as soon as possible to create new phases so that the required work may be completed on schedule.

Due to complexity of the intersection, namely the sightlines not being adequate, four flag personnel are required on the site at the time construction is taking place. Secondly, all four phases, including possible detours will allow for uninterrupted traffic. Furthermore, the TMP created will need to be approved by the BC MOTI and the respective UBC authority. Any alterations made to the plan will require re-approval before it can be implemented.

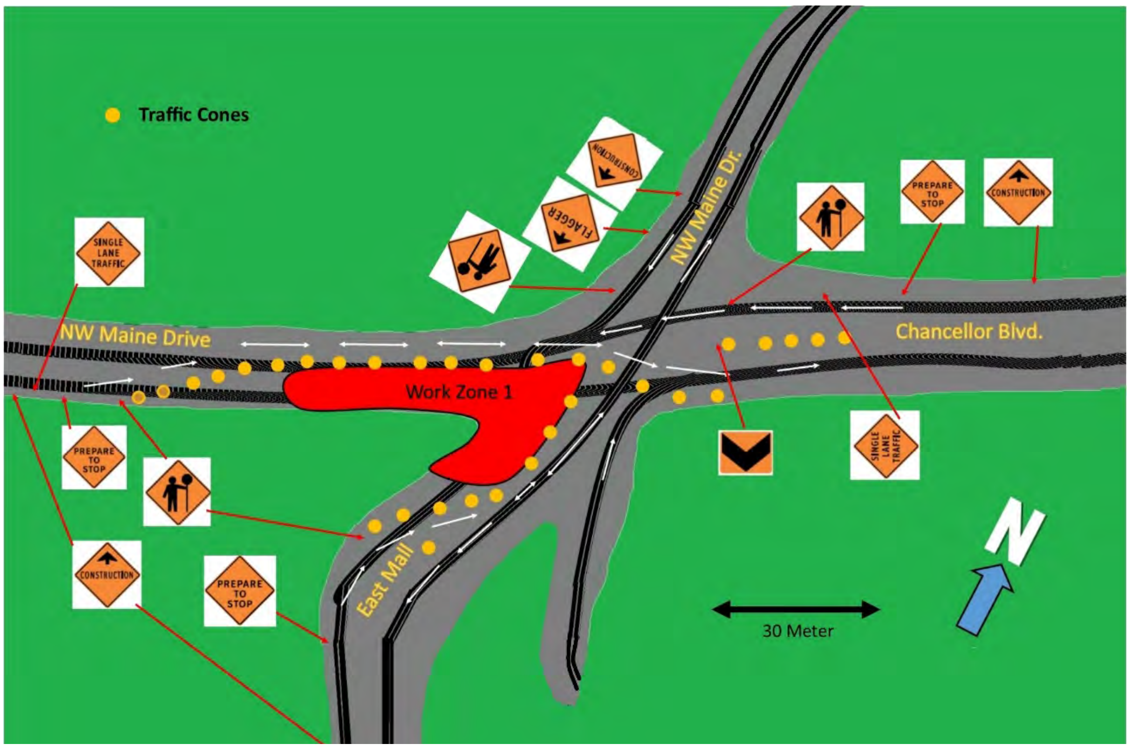

Figure 13 – TMP for Work Being Performed on SW Corner of Intersection

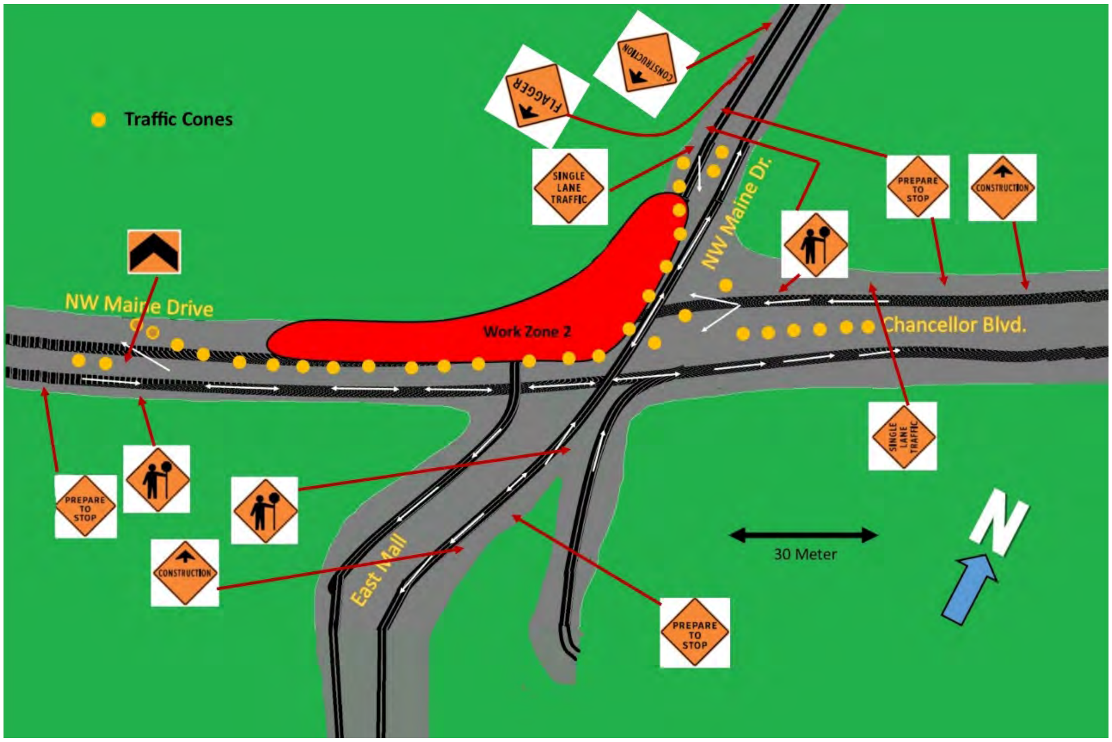

Figure 14 – TMP for Work Being Performed on NW Corner of Intersection

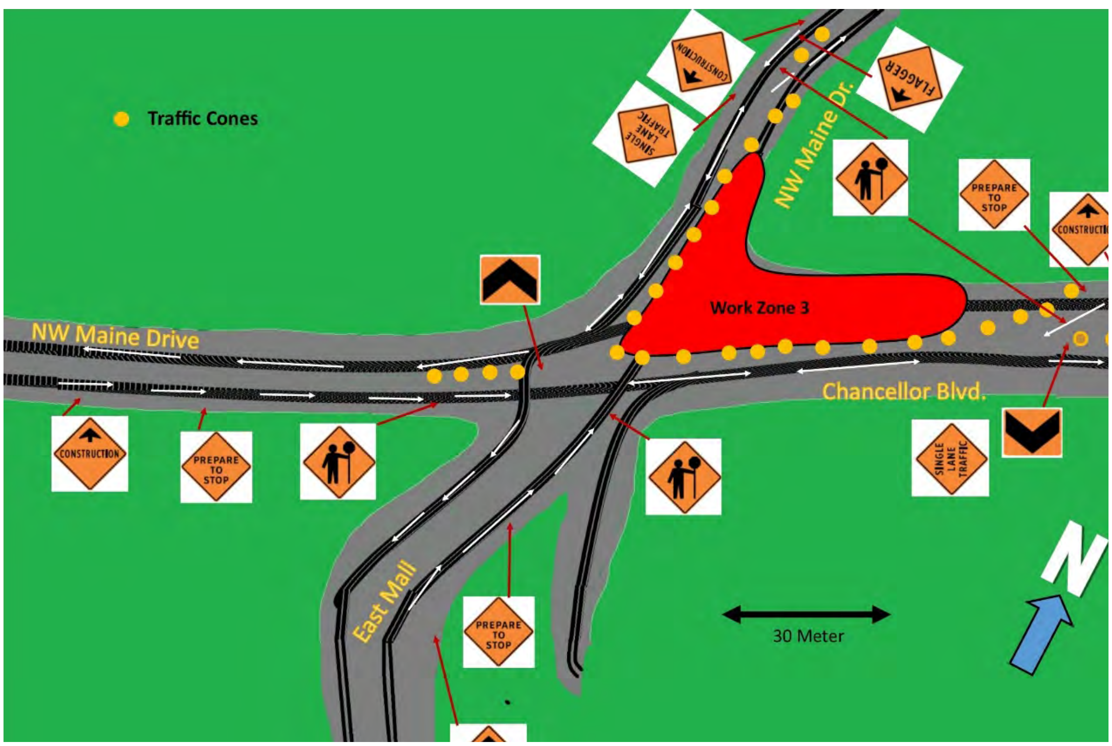

Figure 15 – TMP for Work Being Performed on NE Corner of Intersection

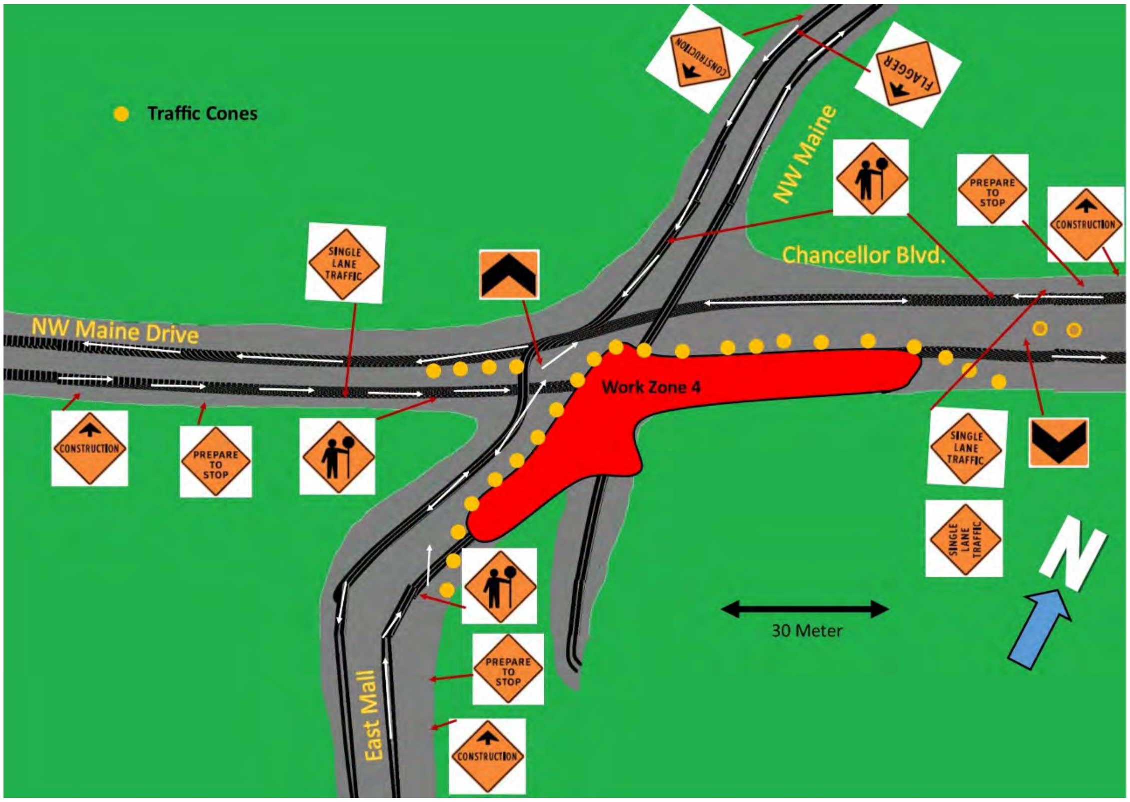

Figure 16 - TMP for Work Being Performed on SE Corner of Intersection

6. DETAILED COST ESTIMATE

The following sections provide details on the estimated initial capital costs and annual operating/maintenance costs for both the roundabout and the pedestrian lookout platform. This detailed cost estimate includes a breakdown of the necessary construction works (quantity take-off calculations, unit costs for materials and equipment, etc.), the planning and design consulting fees, environmental compensations, permits and legal, project management fees, taxes, inflation and escalation, and contingencies. The estimate breakdown, including associated assumptions may be found in Appendix F. Detailed itemized calculations are available upon request.

6.1. Capital Costs

This project, in its entirety, has an estimated total cost of $1,510,044. The determined estimate of probable project costs for the roundabout is $1,147,794, while the pedestrian overlook platform accounts for the remaining $362,250 of the total cost. A breakdown of this estimate is shown in the table below.

Table 11 – Capital Cost Breakdown

Cost Element	Roundabout Costs ($)
Project Management	74,750
Planning	10,005
Engineering Design	111,205
Property Acquisition	0
Environmental	40,250
Construction	1,081,500
Other Costs	135,334
Management Reserve	57,500
Total	1,510,044

It must be noted that this cost projection only serves as a probable estimate and is subject to a +/- 15% accuracy range. In comparison to the Class C estimates provided in the *Preliminary Design Report*, the estimates included here differ by less than 5%. Furthermore, these estimated costs are based on past experiences with projects of similar scale, the use of estimating guidelines as provided by the BC MOTI (refer to *Preliminary Design Report)*. Access to the Ministry's Cost Data Base was not available, nor obtained. Kindly note, the cost estimates exclude the stormwater management system, as this falls outside the scope of the contract.

6.2. Annual Operating Costs

In evaluating the total present worth of the project, ongoing operational and maintenance costs are also considered. Once again, these estimated costs are based on obtained references from projects of similar scale and scope of work (refer to *Preliminary Design Report*).

Table 12 – Annual Operation and Maintenance Cost Breakdown

Annual Maintenance/Operations Costs	
Category	**Roundabout Costs ($)**
Paved Surfaces	475
Roadside	250
Environmental & Drainage	150
Traffic Operations (i.e. Signing, Striping, Signals, Lights, etc.)	350
Landscaping	450
Winter/Rain Storms	165
Emergency Response	75
Miscellaneous Maintenance	350
Total	2,265

6.3. Quality of Cost Estimates

Overall, the proposed cost estimates are detailed, and have taken many measurable considerations into account. Ancillary costs, which include taxes, escalation, and inflation have all been accounted for. However, it must be noted that although the highest caliber of engineering judgement has been exercised, these costs are only calculated estimates. The costs may not serve to be a faithful representation of the projects final costs, but rather an inclusion of the estimates necessary to undertake the detailed design. Knowledge of the current site conditions were inadequate in determining specific quantity calculations, given that site surveys which include dimension calculations were not obtained. Upon obtaining such data, a more detailed estimate may be provided, which will in turn allow for the identification of any site related risks**.** In addition, a sensitivity analysis must be conducted, with the intention of showing the impacts of alternative assumptions on the final costs. For these purposes, a 15% contingency was applied for all estimates. Overall, these estimates will serve as a good starting point for proceeding with further studies and eventually initiating the construction of the project.

7. UTILTIES RELOCATION

The relocation of utilities may lead to increased project costs and delays due to the transparent and efficient coordination which must occur between the street and highway agency (BC MOTI) and the utility facility owners (i.e. Terasen Gas). The consultant has kept this fact prominently in mind, while working alongside a utilities coordinator to intelligently modify the project as to avoid the relocation of many utilities. This section of the report will outline the necessary utility relocations, any nearby utilities of concern as well as the construction BMPs to ensure legal and timely completion of the project. Regulatory and Constructions best management practices may be found in Appendix G.

7.1. Proposed Relocations

The alignment of all roads and the stormwater detention tank was adjusted as to ensure minimal interaction with major utilities. Based on Figure 17 below, it was determined that the proposed design would not infringe on any of the utilities located directly underneath the intersection. This judgement is solidified by the fact that excavations for the roundabout will not exceed 0.2 metres, and the minimum clearance to any major utility is greater than 0.65 metres. Furthermore, the manholes located within the intersection (highlighted in red) will remain in an asphalt zone, thus also avoiding relocation.

However, there are a number of over ground utilities that will need to be relocated in order to allow for general construction and the excavation and installation of the stormwater detention tank. The location of these utilities is depicted in Figure 18 below, while the individual relocation plans may be found in Table 13.

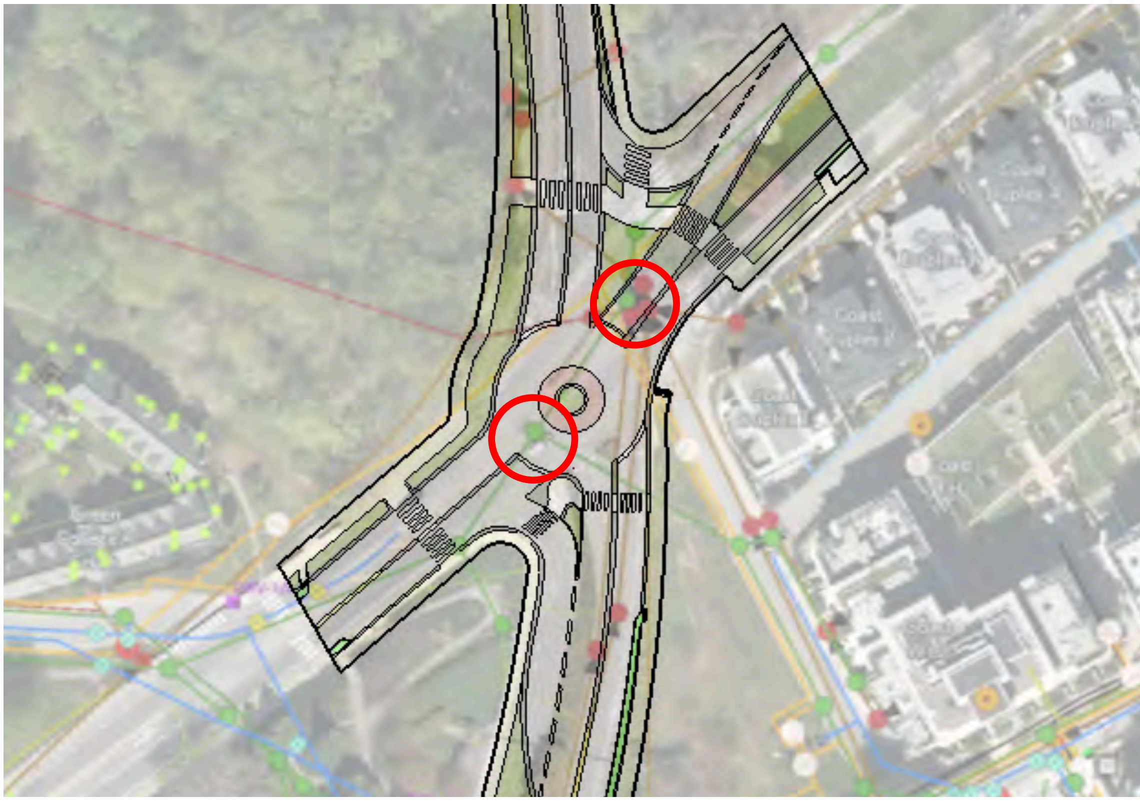

Figure 17 – Schematic Overlay of Roundabout on Underground Utilities

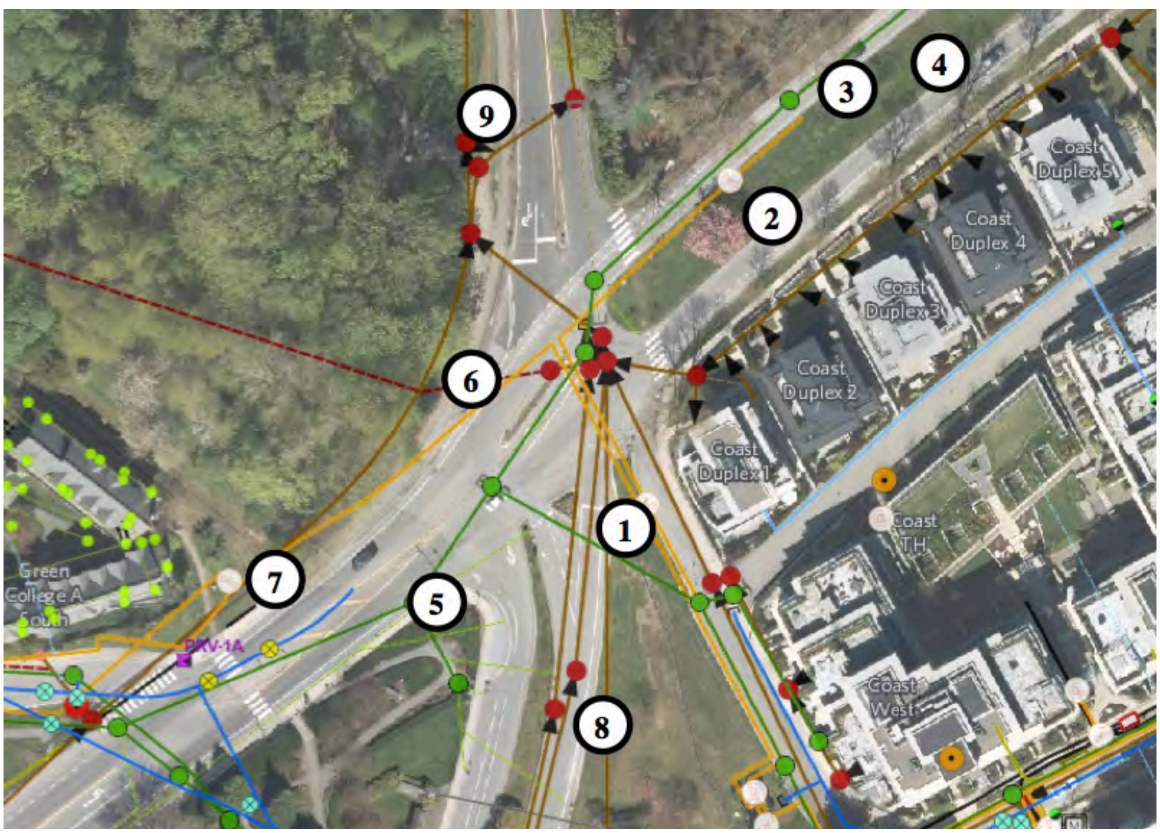

Figure 18 – Utility Relocation Map

Table 13 – Utility Relocation Plan

Detail Number	Description	Relocation Plan
1	Vertical light post, non-standard, combined with street sign, will obstruct construction of the pedestrian lookout platform	The light post will not be relocated after construction. Lighting in the area will be provided by the pedestrian lookout platform. Street name signs will be placed on the adjacent corner of Iona Dr. and Chancellor Boulevard upon removal of original light post.
2,3,4	Vertical light post, non-standard, will obstruct excavation and installation of stormwater detention tank	These light posts will be temporarily removed during construction. They will be inspected, and replaced if necessary. New concrete pedestals will be poured after the installation of the stormwater tank, and light posts re-commissioned in their pre-construction locations. Lighting will be provided in the interim via portable fixtures as to ensure sufficient illumination for crossing pedestrians, and cyclists.
6,7	Curved light post, typical, combined with street name signs, will obstruct excavation and setting of new asphalt, sidewalks and bike lanes	These light posts will be temporarily removed during construction. They will be inspected, and replaced if necessary. New concrete pedestals will be poured after the installation of the stormwater tank, and light posts re-commissioned in their pre-construction locations. Lighting will be provided in the interim via portable fixtures as to ensure sufficient illumination for crossing pedestrians, and cyclists. Street names signs will be placed on mobile floor level pedestals and will be moved as required by the TMP.
8,10	Curved light post, typical, will obstruct excavation and setting of new asphalt, sidewalks and bike lanes	These light posts will be temporarily removed during construction. They will be inspected, and replaced if necessary. New concrete pedestals will be poured after the installation of the stormwater tank, and light posts re-commissioned in their pre-construction locations. Lighting will be provided in the interim via portable fixtures as to ensure sufficient illumination for crossing pedestrians, and cyclists.
9	Vertical light post, non-standard, will obstruct excavation and installation of pedestrian lookout platform	This light posts will be temporarily removed during construction. They will be inspected, and replaced if necessary. Light post will be re-commissioned in its pre-construction locations. Lighting will be provided in the interim via portable fixtures as to ensure sufficient illumination for crossing pedestrians, and cyclists.

7.2. Nearby Utilities of Concern

This section highlights utilities at or nearby the site that will not be relocated, but will influence the construction process. Contractors should be made aware of these utilities as to ensure there are no accidents, nor the creation of potential hazards.

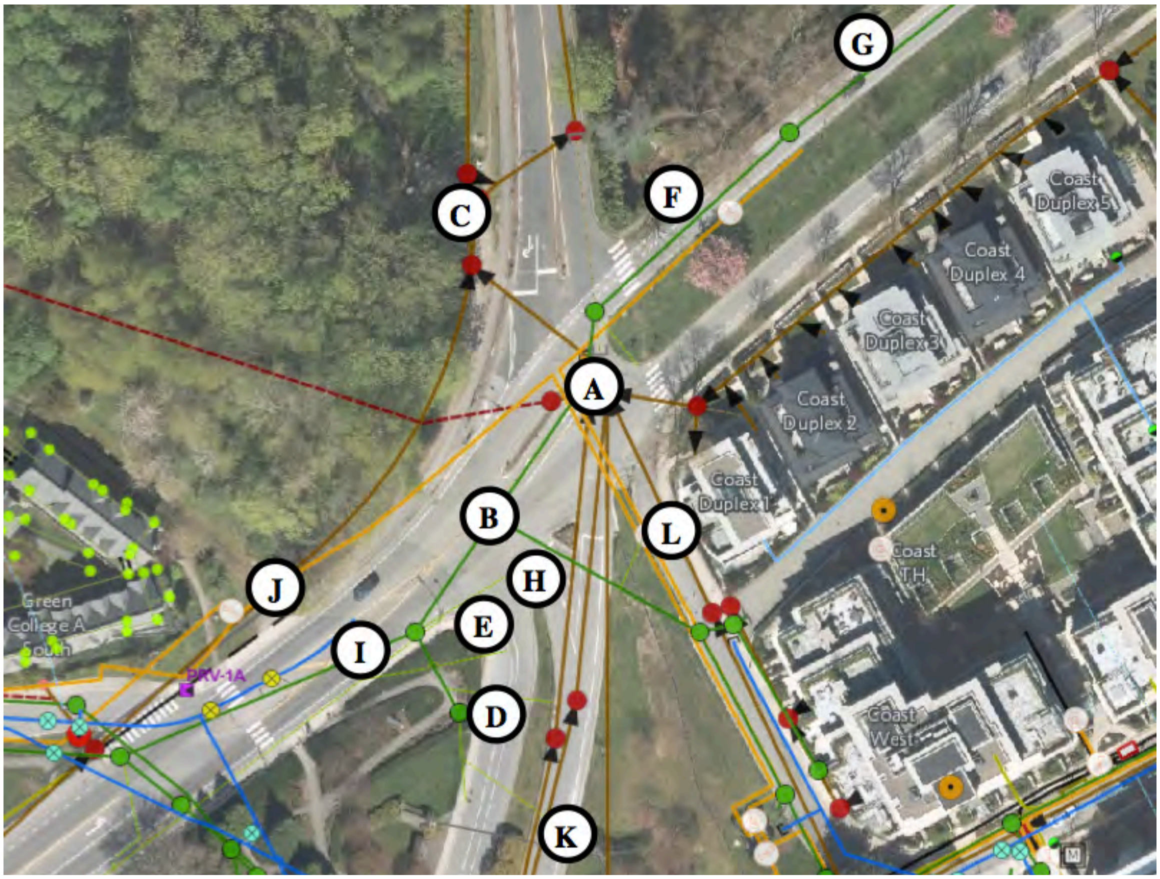

Figure 19 – Nearby Utilities of Concern Map

Table 14 – Nearby Utilities of Concern Plan

Detail Number	Description	Comment
A, B	4 manholes, located at grade on the asphalt, provide access to sanitary and stormwater drains	As can be seen in Figure 19 above, these manholes will remain in asphalt filled area upon completion of the roundabout. The height of the manholes may need to be adjusted depending on the final grade of the roadway to ensure a flush transition. Appropriate filtration screens shall be inserted

		during the construction as to eliminate possibility of contaminant transfer.
C	Access panel, located at grade beside sidewalk along NW Marine Dr	This access panel likely provides access to the sanitary sewage junction located at that location. Construction work should not interfere with it, as it is outside the footprint of the design. Note the access panel shall remain accessible, and unobstructed throughout the duration of construction. The access panel is located sufficiently far away from the road edge, as to eliminate the possibility of interactions during excavation.
D, E, H, I, K	Stormwater drains located throughout the project site	The road alignment has been selected as to ensure there is no need to relocate any of the stormwater drains. It is assumed that the existing drainage locations comply with regulatory requirements, and therefore there is no need to alter locations. A visual inspection of the drains will be conduced to ensure they are in good working order. Please refer to Appendix G for BMPs regarding storm drains.
F	Manhole, located at grade, on sidewalk along Chancellor Blvd.	The location of the sidewalk in this region will not change, and thus this manhole shall not be significantly affected. It is subject to the BMPs discussed in Appendix G.
G	Fire hydrant, located between Chancellor Blvd and the sidewalk	The fire hydrant is located at a significant distance from the project site, and thus should not be impacted by construction activities.
J	Access panel, located at grade on the interior of the sidewalk	This access panel likely provides access to natural gas junction located at that location. Construction work should not interfere with it, as it is outside the footprint of the design. Note, the access panel shall remain accessible, and unobstructed throughout the duration of construction. Contractors should be aware of the concrete casing surrounding this underground vault, as to ensure no breaches occur during excavation.
L	2 manholes located on Iona Dr, at grade	The project does not involve any work on Iona Drive, and thus these manholes should not be impacted by construction. For redundancy and best practices, they are still subject to the BMPs.

8. SUPPLEMENTAL CONSIDERATIONS

The uniqueness of the UBC campus gives rise to a variety of supplemental considerations. The considerations included in this section will aid the consultant in achieving a successful and timely delivery of the project deliverables. This section discusses different First Nations engagement strategies, as well as a risk analysis.

8.1. First Nations Engagement and Involvement

Anova Consulting acknowledges and respects the traditional, ancestral and unceded xʷməθkʷəy’əm (Musquem) land on which the university sits. For this reason a great effort has been made to appropriately and transparently involve the Musquem people wherever possible within the project. The consultant viewed this project, in particular the pedestrian lookout platform as an incredible opportunity to harmonize a structural feat with the beautiful artwork of the First Nations people. The consultant makes note of the following items involving First Nations involvement within this project:

- Any construction fencing put up on the project site will showcase a collaborative design made by UBC and the Musquem First Nations
- The pedestrian lookout platform will bear a circular art piece created by the Musquem people. It will be located directly adjacent to the UBC logo which is positioned underneath the lookout platform
- The glass side panels of the lookout platform will be decorated with a matte white pattern created by the Musquem community. Such a pattern will not only be extremely aesthetically pleasing, but will also provide privacy between the users of the platform and the pedestrians walking at the road level

- In addition, all construction and consultation processes shall follow due practice in regards to First Nations regulations as set out by any relevant UBC policy

Anova Consulting is eager to collaborate with the Musquem First Nations people, and UBC through the implementation of the abovementioned measures.

8.2. Risk Analysis

Through the risk management analysis and CHAIR°, key stakeholders involved in design and implementation of the roundabout will come together in order to identify, assess, and mitigate major risks and potential challenges.

The first CHAIR study was performed during the conceptual design stage of the project in order to detect any fundamental changes that had to be made to the design, schedule, and cost estimate. Now, in order to both quantify and qualify the risks associated with the detailed design and implementation of the intersection, the second and third study of CHAIR will be carried out. In other words, review of the detailed design as well as maintenance and repair issues will be done before the construction.

As a result of risk management analysis, a risk register was created and can be found in Appendix H. The proposed risk management register lists all of the potential risks and their probability of occurrence. After completion of the CHAIR process, a more detailed risk register shall be provided.

9. RECOMMENDATIONS FOR DESIGN IMPROVEMENT

Anova Consulting has exercised the highest degree of engineering knowledge and judgment throughout the design of this project. However, in light of brevity of the preparatory time, the consultant acknowledges that various opportunities for improvement exist. This section seeks to outline a number of investigative and software related improvements, which would increase the certainty of the work carried out.

9.1. Investigation and Resources

- **Surveying data** - Grade information for the intersection location was not readily available, and thus estimates were made regarding the slopes of the existing roads. The maximum overall slope of a roundabout is regulated by law, and hence, should the assumed slope differ from the actual grade, additional cut/fill may be required. This in turn, would affect the cost estimates presented in Section 6. For these reasons, the consultant recommends that professional surveying data be carried out in order to ensure proper road alignments and slope.
- **Detailed geotechnical/hydrogeological information** – Geotechnical, and hydrogeological information for the site was inferred from available published reports, primarily AECOM, 2013 and Geoadvice, 2013. This information was used in the determination of the stormwater detention tank cover, and depth, drainage pipe placement and slope and soil permeability. There are two major implications should a discrepancy exist between the assumed and actual geotechnical/hydrogeological conditions. Firstly, there may be unforeseen implications of the proposed stormwater management system that may adversely affect the sensitive cliff conditions. Secondly, the dimensions, cover and

placement of the stormwater management system may need to be reconfigured. For these reasons, the consultant recommends that a professional geotechnical survey, including multiple boreholes and soil conductivity testing be carried out before finalization of the design.

- **Stormwater management model** – A number of assumptions were made regarding the rainfall intensities corresponding to different storm severities, as well as the specific behaviour of the surface run off. The deviation of these assumed values from actual conditions may yield the stormwater management system as over/under sized. The effects of an undersized system could significantly affect the amount of infiltration and overflow, and cause catastrophic failures at the cliff faces. For these reasons, the consultant recommends a thorough storm water management model be developed for the proposed design, such that the effect of the new layout, and stormwater management system may be properly gauged.
- **Seismic analysis of pedestrian platform –** Although the pedestrian lookout platform has made use of base isolation, its exact behaviour when loaded with an earthquake remains unknown. The unique and asymmetrical layout of the platform exacerbates its eccentricity, and may give rise to structural concerns in the case of a significant earthquake. For these reasons, the consultant recommends a sophisticated computer model of the platform be created, such that the structural effects of such an earthquake may be quantified.

9.2. Software

- **Updated version of Synchro Studio° –** In the preliminary stages of the design, Synchro Studio 6 was utilized in order to determine the optimal intersection configuration. The developers have most recently released version 9, and thus the utilized software is extremely out-dated. As a result, the macro simulation model developed may not take into consideration the latest traffic laws and vehicle information. These shortcomings, may affect the decision to utilize a roundabout as the preferred design option, the project cost, as well as the quantifiable monetary value of its benefits.
- **Micro-simulation software –** The software model developed during the preliminary design was a macroscopic model. The implications of this is that the model is incapable of determining the effect of specific events, such as a collision, time varying traffic flows, and the specific interaction of the different road users. The lack of a microscopic model creates uncertainty regarding the friendliness of the design towards each of the road users. This could effect decisions carried out such as the location of pedestrian/cyclist rest zones, crosswalks, and bike lanes. However, a development of a microscopic model would aid in assuring the comfort of all of the road users, while ensuring the design is optimally safe and feasible. For these reasons, the consultant recommends the development of a micro-simulation model.
- **Stochastic software for accurate growth rates** - The demands on the intersection for the horizon year of 2040 were determined using published data and engineering judgement. These expected trends in conjunction with UBC's

policy were used in prioritizing the different users of the intersection. The deviance of these growth rates from actual values could significantly skew the amount of importance that should have been placed on each of the road users. As a result, the design may be unwelcoming to a certain mode of transportation, or may simply be unable to handle the future demands. For these reasons, the consultant recommends the hiring of a statistical firm to carry out a stochastic analysis, and determine more accurate growth rates for all of the different types of road users.

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APPENDIX A: ROUNDABOUT DESIGN SUPPLEMENTS

This appendix will include an additional figure relating to the roundabout design as well as relevant excerpts from the TAC Geometric Design Guide & Green book Guideline. The figure labels all of the major components of the roundabout. A dimensioned figure may be found within the respective section of the report.

Inscribed Circle Diameter:

Refer to KRG Section 6.1

The BC MoT recommended inscribed circle diameter ranges are as follows:

Table 740.A Recommended Inscribed Circle Diameter (ICD) Ranges

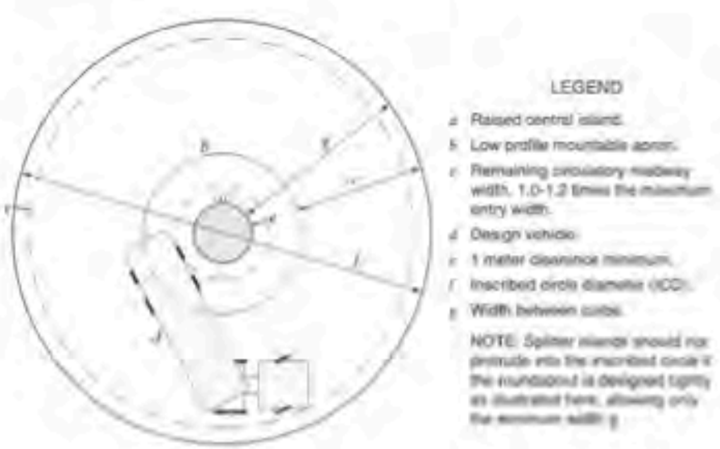
Site Category	Inscribed Circle Diameter Range*
Urban Single Lane	37 – 46 m
Urban Double Lane	46 – 67 m
Rural Single Lane	40 – 61 m
Rural Double Lane	53 – 76 m

* Assumes approximately 90-degree angles between entries and no more than four legs.

Figure 740.A provides turning width requirements for a WB-20 design vehicle for a variety of ICDs. The values provided in Figure 740.A are based on the Surface Transportation Assistance Act (STAA) design vehicle which is similar to the dimensions of the TAC WB-20 design vehicle.

Values in Table 740.A and Figure 740.A were derived by converting imperial measurements to metric.

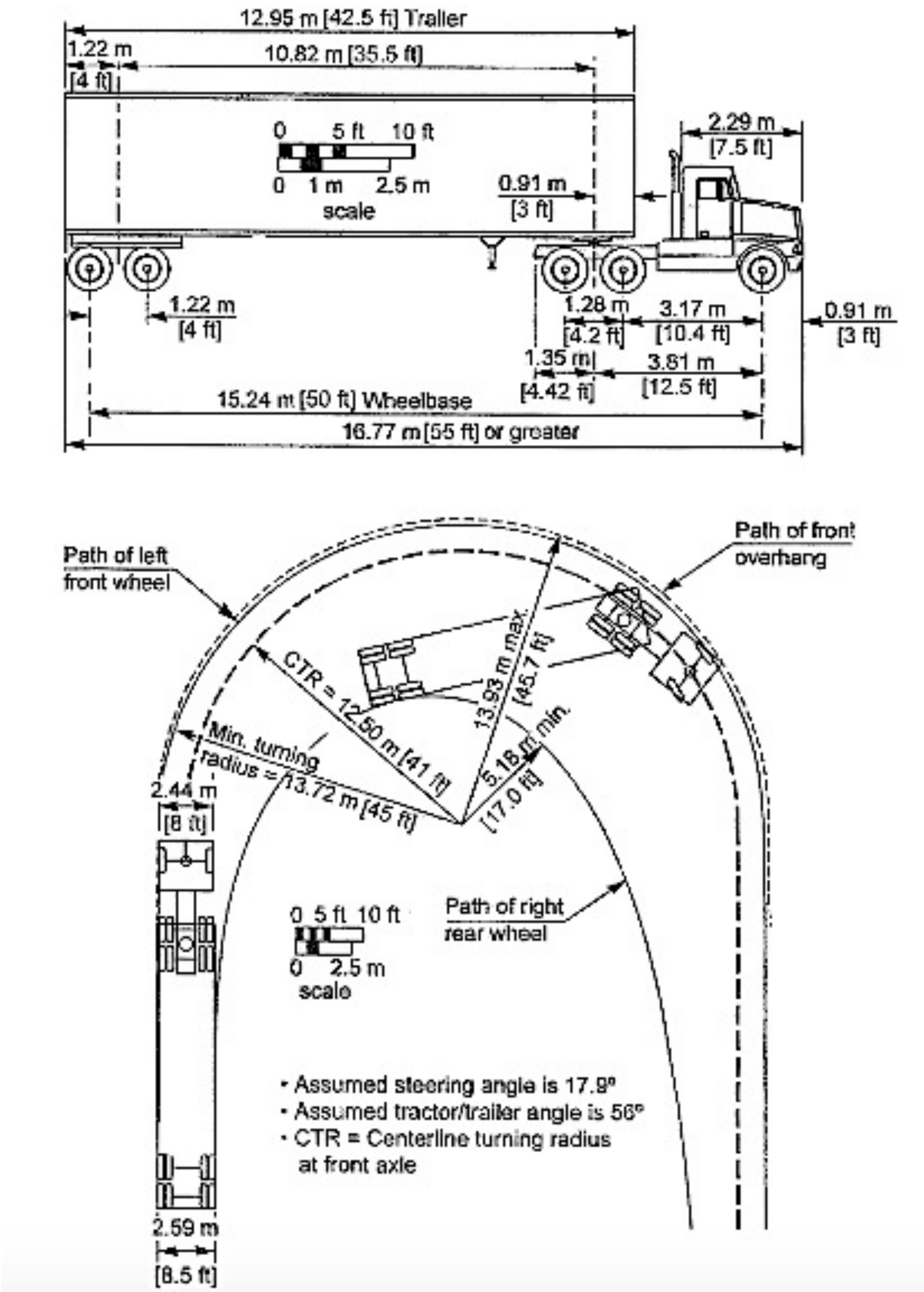
Figure 740.A Required Turning Widths
(from "Roundabout Design Guidelines" Ourston Roundabout Engineering 2001)



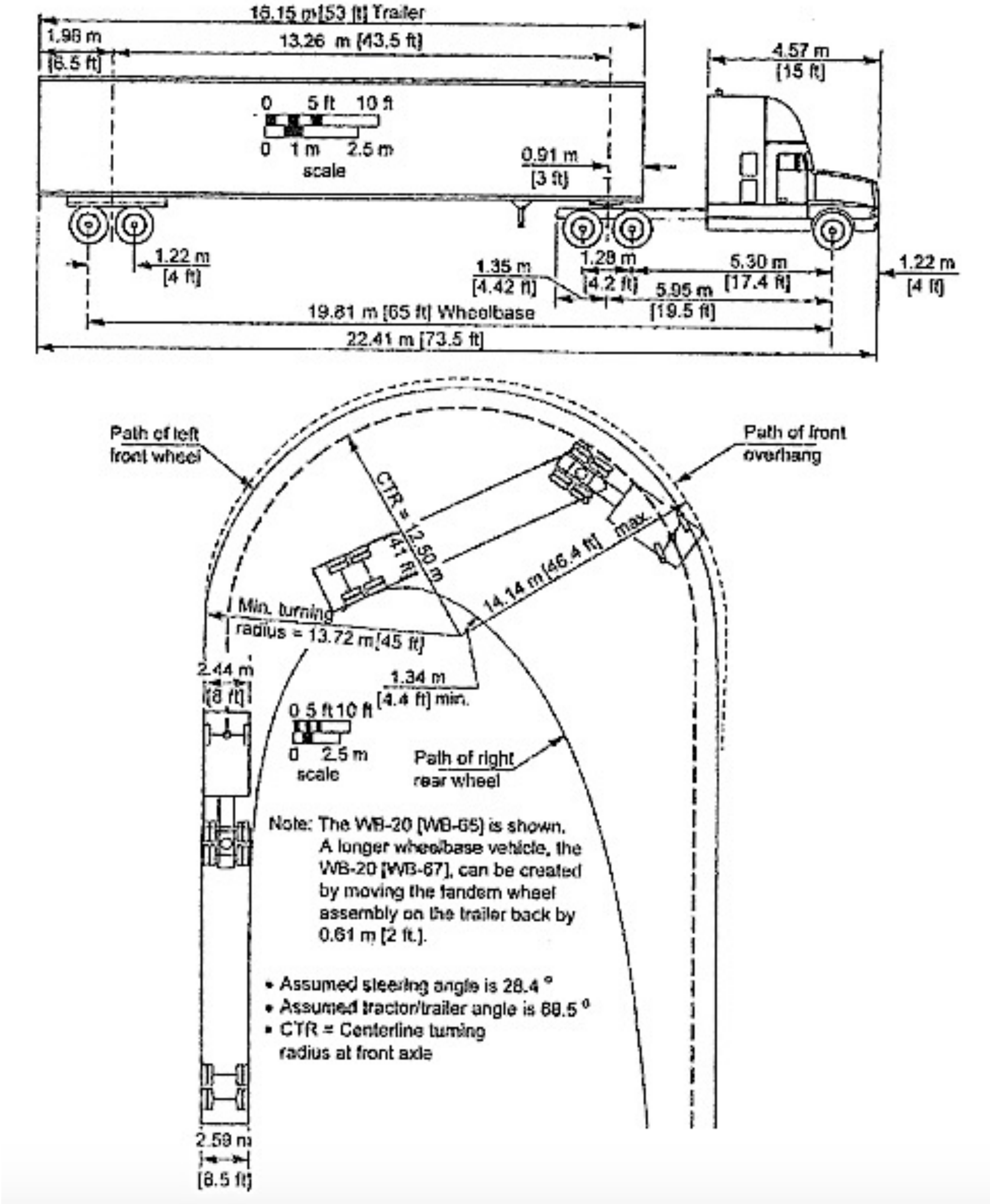
Inscribed Circle Diameter (f) (metres)	Design Vehicle WB-20 (g) (metres)
79.2	7.2
73.2	7.5
67.1	7.8
61.0	8.1
57.9	8.4
54.9	8.7
51.8	9.0
48.8	9.3
45.7	9.8
42.7	10.1
39.6	11.1
36.6	12.2
33.5	13.7
30.5	**
29.0	**

** Design Vehicle requires larger ICD

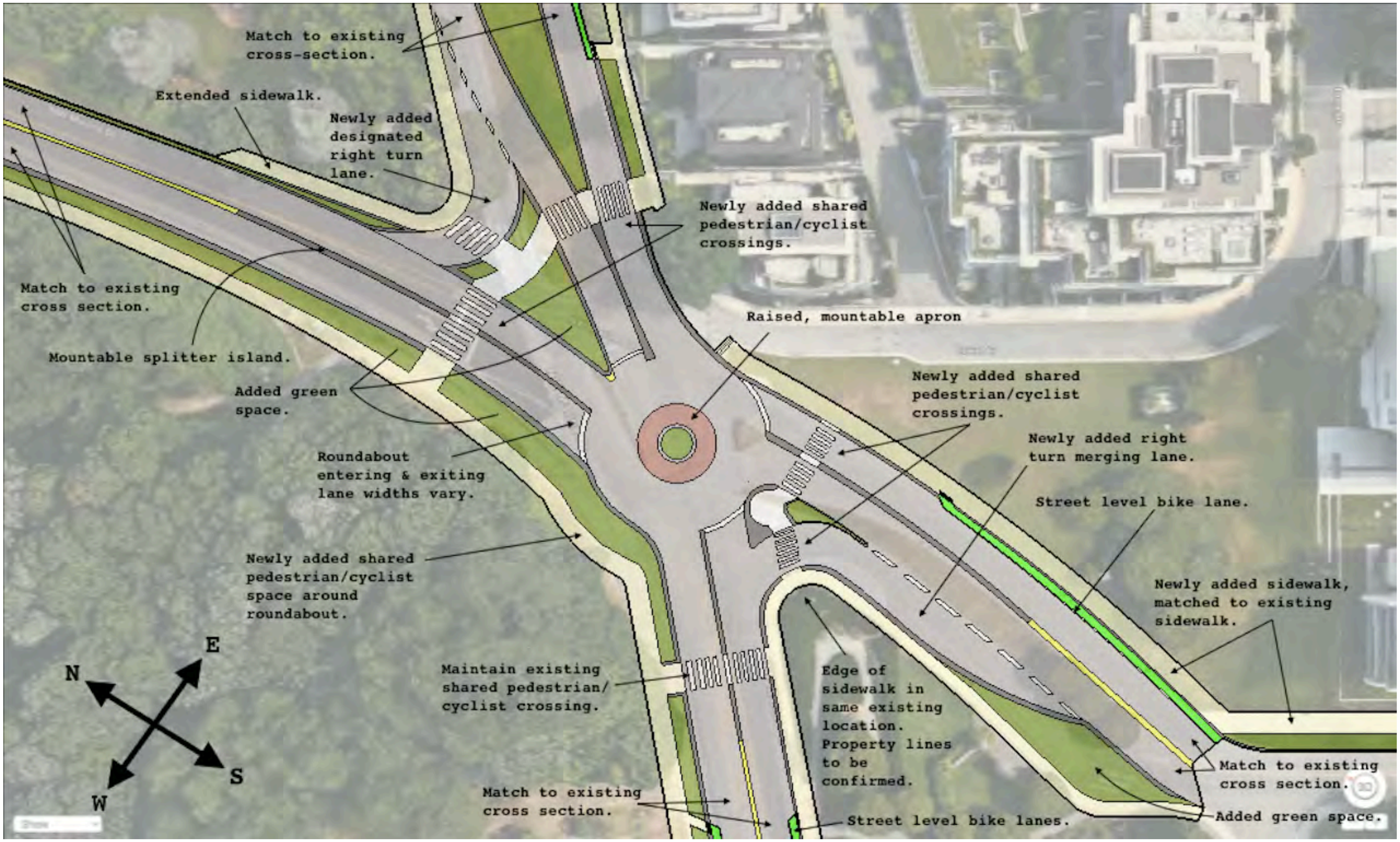
BC MoT Geometric Design Guidelines for Roundabout Core (Section 740.04)



Minimum Turning Path for WB-15 Design Vehicle (GreenBook Guideline)



Minimum Turning Path for WB-20 Design Vehicle (GreenBook Guideline)



Additional Annotated Figure of the Roundabout Design

APPENDIX B: PEDESTRIAN LOOKOUT PLATFORM SUPPLEMENTS

This appendix will include additional information pertaining to the pedestrian lookout platform. Namely, it will discuss standards and software, design codes and standards, computer programs used, as well as additional figures of the platform.

1. Standards and Software

The two types of limit state designs considered during this project are:

- Ultimate Limit State (ULS) – includes the structural stability (the strength) and the robustness of the structure
- Serviceability Limit State (SLS) – includes the deflection and cracking of the structure

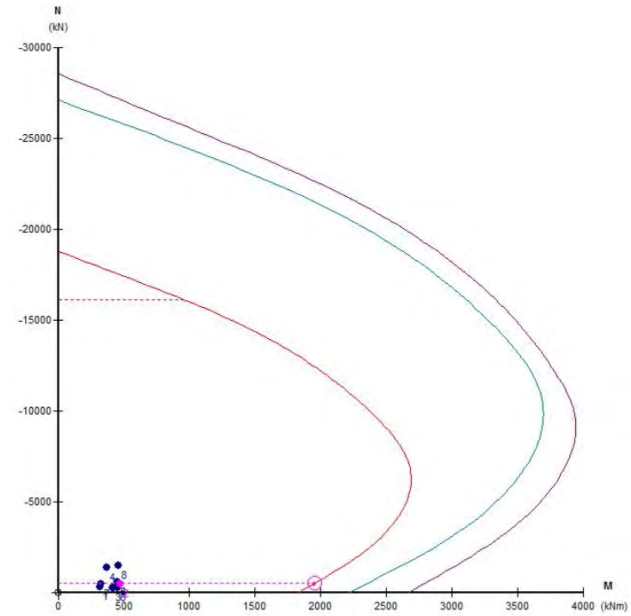
Design Codes and Standards

The structure is designed in accordance with the following codes and standards:

- NBCC 2010 – contains background information and design approach to pedestrian platform and supports such as
  - Limit states design
  - Snow loads
  - Rain loads
  - Seismic effects
  - Live loads due to use and occupancy
  - Extensive material to support the design changes
- Canadian Standards Association (CSA) – provides building code regulations and acts as a guideline for material selection, which are as follows
  - CSA S16-09 – Design of steel structures is used for platform deck.
  - CSA A23.3-04 – Design of concrete structures is used for the platform column supports.

Computer Programme

The structure is analyzed using SAP2000° and S-Frame while the architectural projections are produced on SketchUp°. SAP2000 is used to analyze and design the platform deck and columns, in which the analysis is conducted using the simple "stick-model" approach to assess earthquake effects. The detailed design analysis is created in the S-Frame software package, using S-concrete for the cross-section of the concrete column. Three columns are designed to support the platform deck, and each column is then designed based on the load distribution from the deck. Due to the differences in median, the load distribution for each column is approximated in S-Concrete. The result yields that a diameter of 1000 mm is sufficient to support the deck. As shown in the figure below, the applied load falls within the Moment-Axial Load Interaction Diagram.

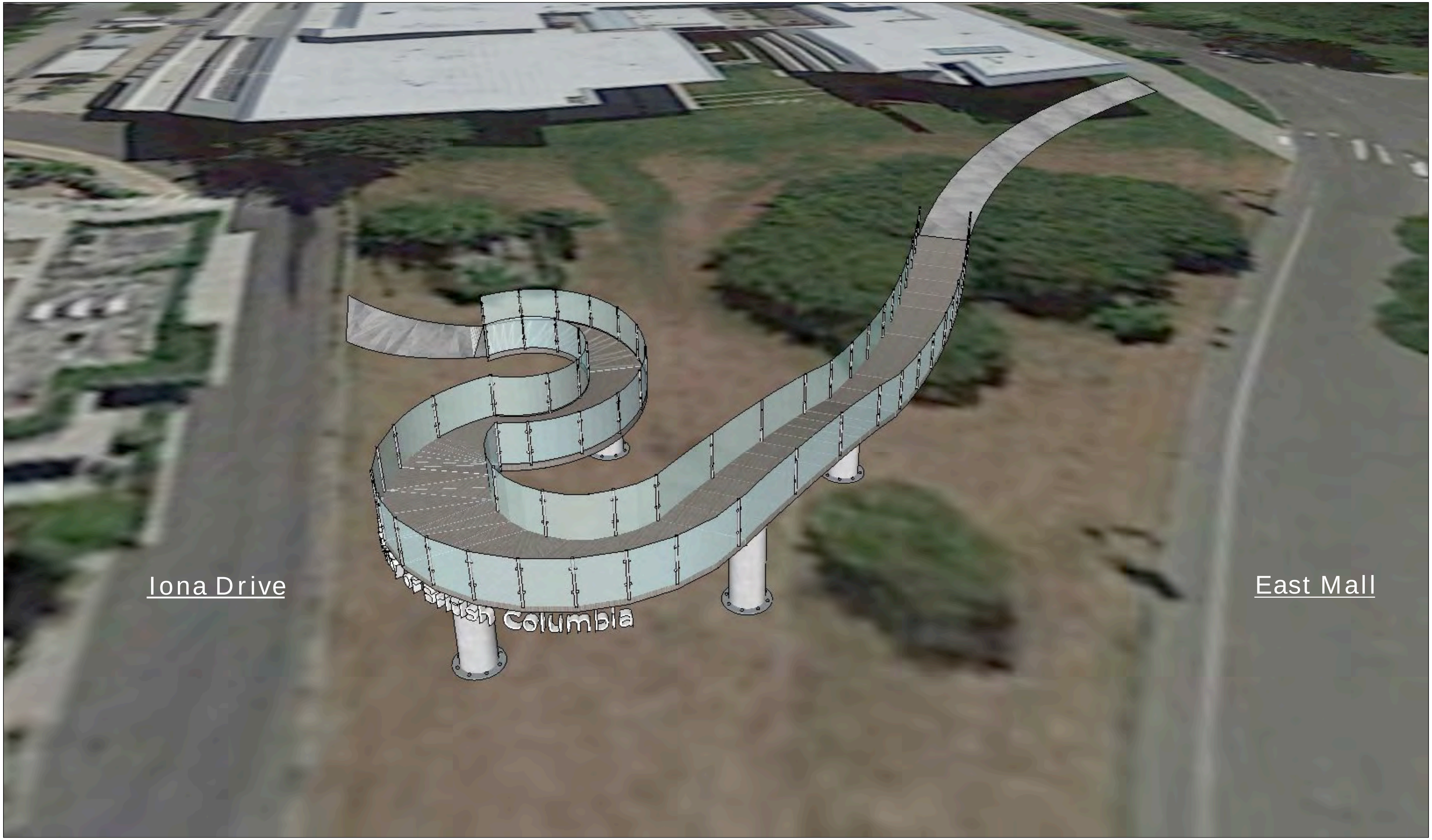


Moment-Axial Load Interaction Diagram

A detailed analysis of the column cross-section may be found within this appendix.

2. Additional Figures of the Pedestrian Lookout Platform

The following section presents the pedestrian lookout platform in its top, side views, dimension labels, and a brief description of each diagram. A cross-section of the platform is then shown, with dimensions and some highlights of material usage. Lastly, the S-Frame report is attached to show the software calculations and design of the concrete columns and reinforcements within.



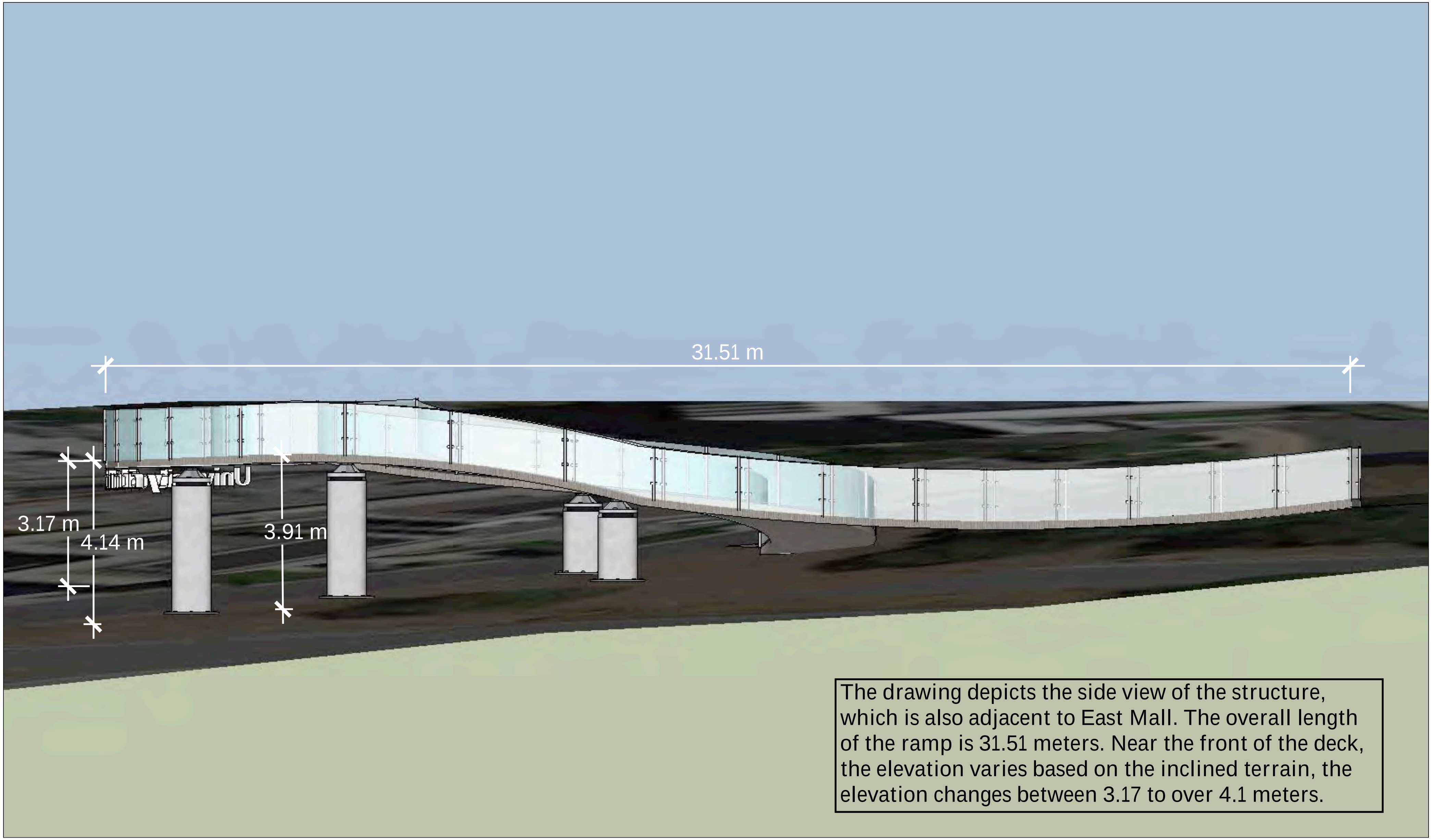
Chancellor Blvd./East Mall Intersection Redesign - Pedestrian Lookout Platform	ANOVA CONSULTING	Shawn He Anova Consulting (Team 2) April 3, 2016

This drawing outlines the building envelope taken by the platform. Note that the platform has a uniform width of 2.30 meters, while the sidewalks to the adjacent streets are wider at over 3.60 meters.

Top View of Pedestrian Lookout Platform	ANOVA CONSULTING Chancellor Blvd./East Mall Intersection Redesign	REVISIONS			A 01
			MM/DD/YY	REMARKS	
		1	12/01/2015	Preliminary Design	
		2	03/25/2016	Detailed Design	
		3		...	
		4	__/__/__	...	
		5	__/__/__	...	

The front view shows the elevation from the deck to the ground, also the heights of the columns, as well as the height of the handrail.

Front View of Pedestrian Lookout Platform	ANOVA CONSULTING Chancellor Blvd./East Mall Intersection Redesign	REVISIONS			02 A
			MM/DD/YY	REMARKS	
		1	12/01/2015	Preliminary Design	
		2	03/25/2016	Detailed Design	
		3		...	
		4	_ _ /_ _ /_ _	...	
		5	_ _ /_ _ /_ _	...	



The drawing depicts the side view of the structure, which is also adjacent to East Mall. The overall length of the ramp is 31.51 meters. Near the front of the deck, the elevation varies based on the inclined terrain, the elevation changes between 3.17 to over 4.1 meters.

Side View of Pedestrian Lookout Platform
(Adjacent to East Mall)

ANOVA CONSULTING

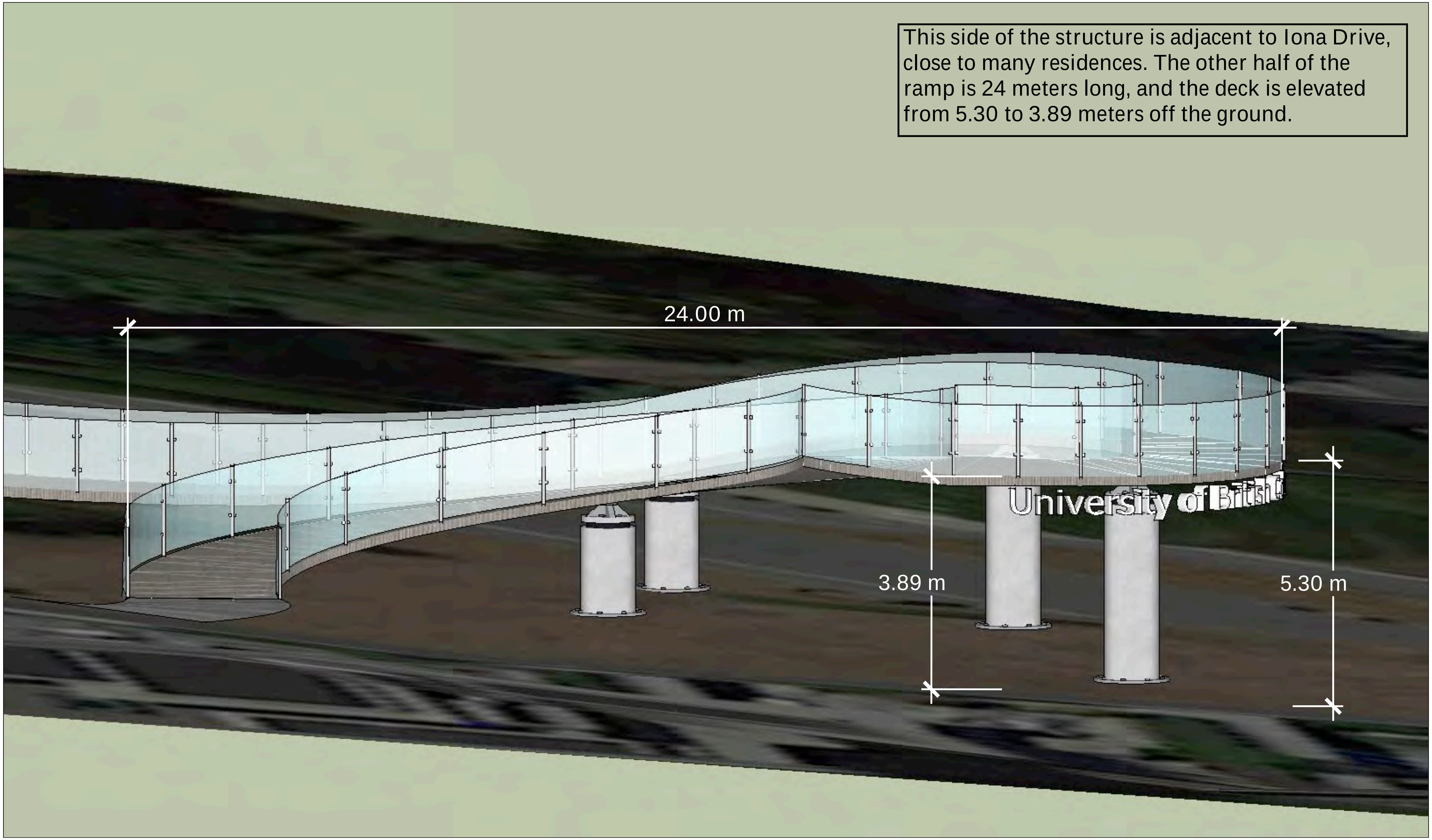
Chancellor Blvd./East Mall Intersection Redesign

REVISIONS

	MM/DD/YY	REMARKS
1	12/01/2015	Preliminary Design
2	03/25/2016	Detailed Design
3		...
4	_ _ /_ _ /_ _	...
5	_ _ /_ _ /_ _	...

03

A



Side View of Pedestrian Lookout Platform
(Adjacent to Iona Drive)

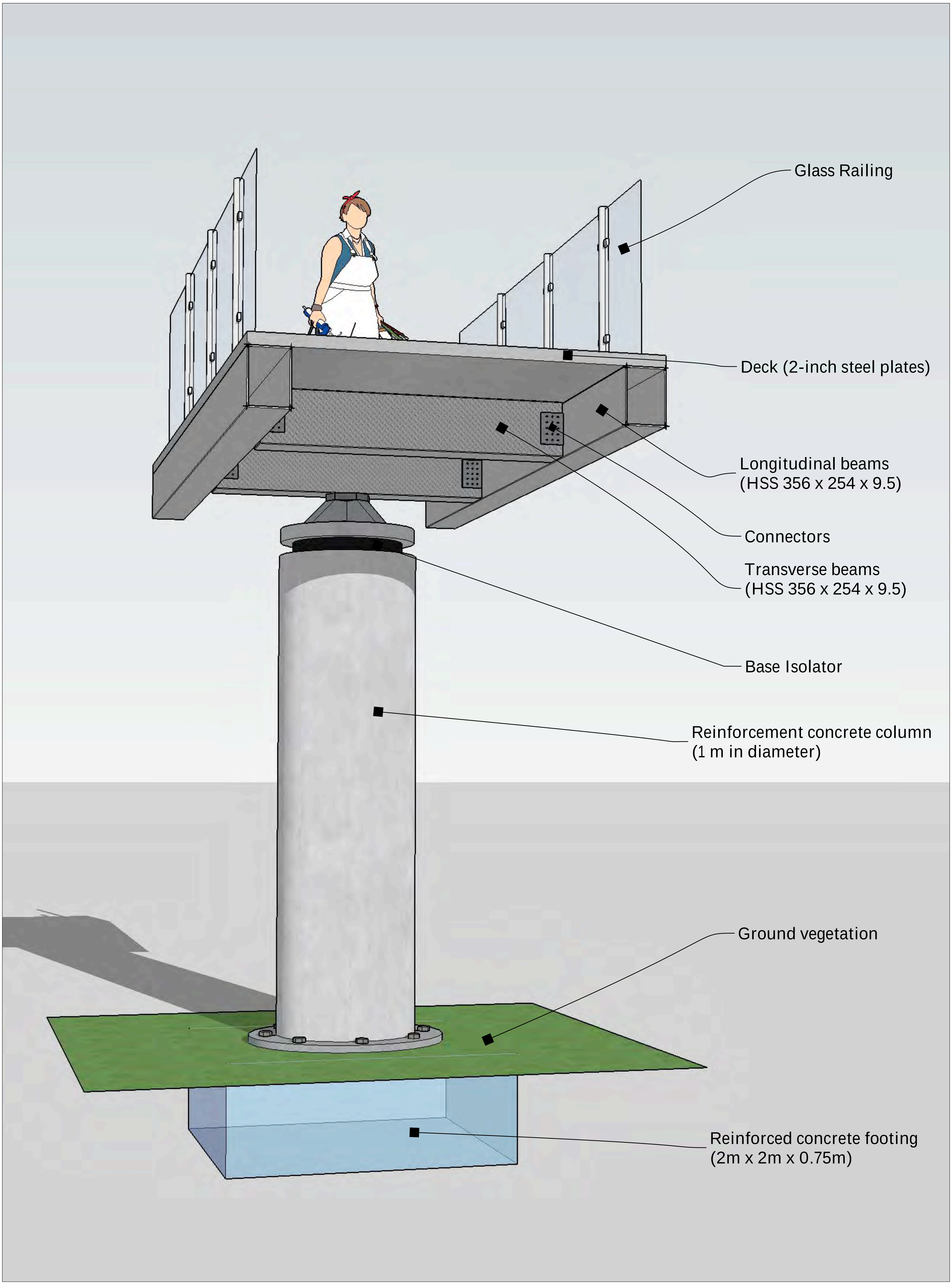
ANOVA CONSULTING

Chancellor Blvd./East Mall Intersection Redesign

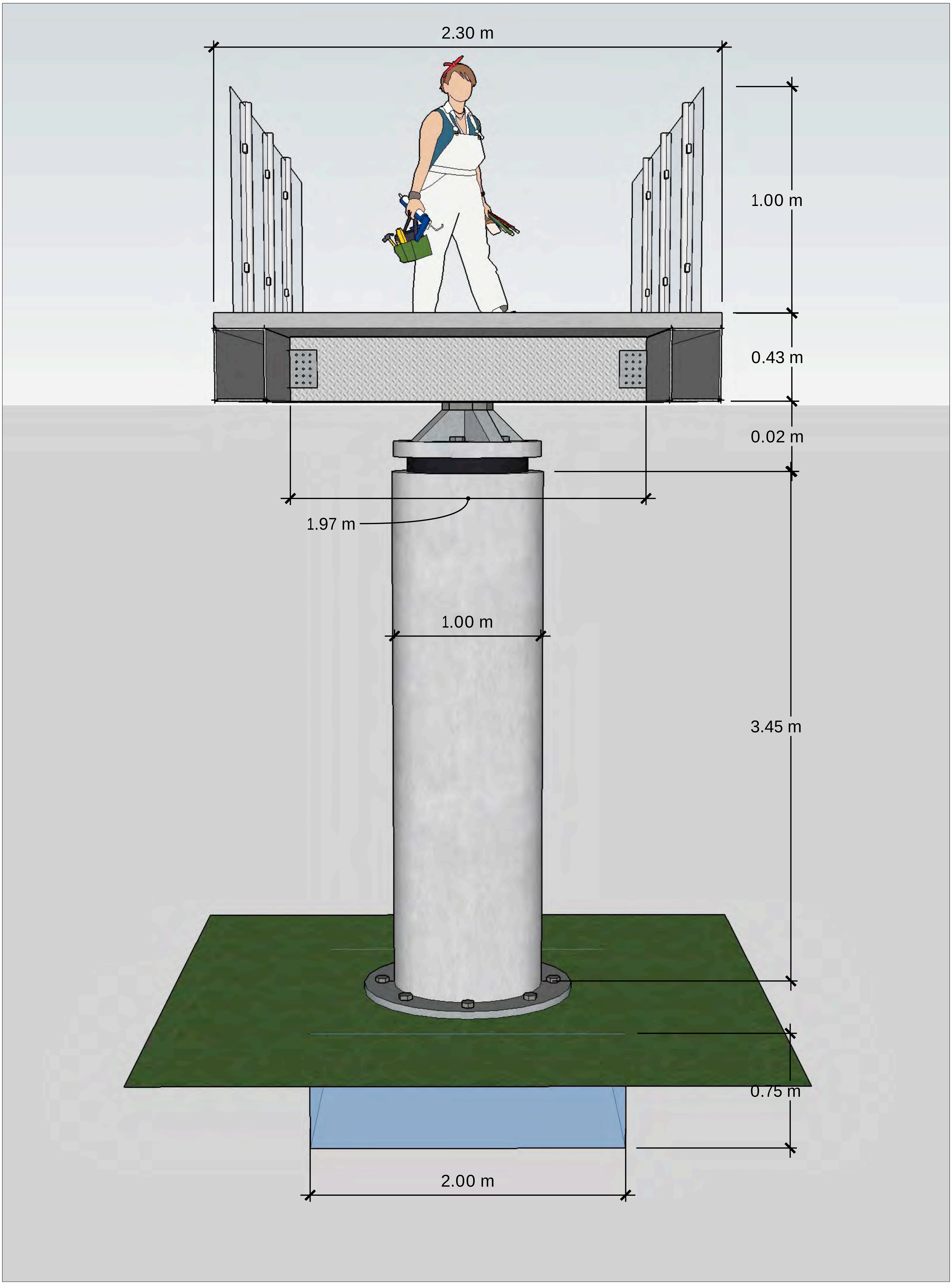
REVISIONS

	MM/DD/YY	REMARKS
1	12/01/2015	Preliminary Design
2	03/25/2016	Detailed Design
3		...
4	_ _ /_ _ /_ _	...
5	_ _ /_ _ /_ _	...

A 04



Chancellor Blvd./East Mall Intersection Redesign - Pedestrian Lookout Platform Design	ANOVA CONSULTING	Author: Shawn He Anova Consulting (Team 2)
		April 3, 2016



Cross-sectional View of
Pedestrian Lookout Platform
(Front View)

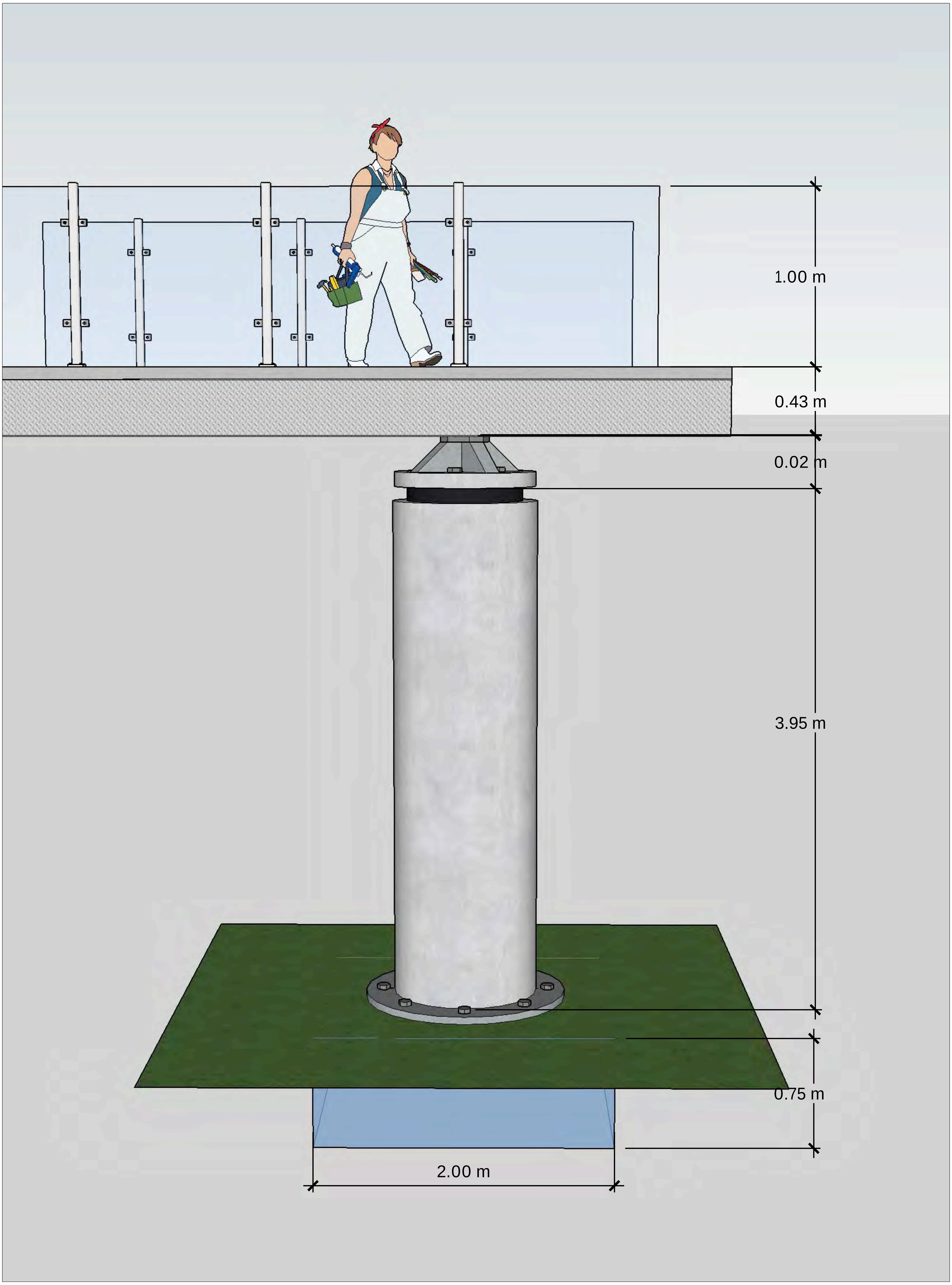
ANOVA CONSULTING

Chancellor Blvd./East Mall Intersection Redesign
- Pedestrian Lookout Platform Design

REVISIONS

	MM/DD/YY	REMARKS
1	03/26/2016	Detailed cross-sectional design
2	_ _ /_ _ /_ _	...
3	_ _ /_ _ /_ _	...
4	_ _ /_ _ /_ _	...
5	_ _ /_ _ /_ _	...

A 01



Cross-sectional View of
Pedestrian Lookout Platform
(Side View)

ANOVA CONSULTING

Chancellor Blvd./East Mall Intersection Redesign
- Pedestrian Lookout Platform Design

REVISIONS

	MM/DD/YY	REMARKS
1	03/26/2016	Detailed cross-sectional design
2	__/__/__	...
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

02

A

Platform Material Usage Calculations

Overall Ramp		
area 1	65.02	m^2
area 2	34.26	m^2
area 3	38.06	m^2
total area	137.34	m^2
uniform width	2.3	m
length 1	28.00	m
length 2	28.30	m
length 3	17.70	m
length 4	6.96	m
length 5	13.12	m
length 6	20.61	m
total length	114.69	m [two sides]

Deck		
steel panel		
amount	137.34	m^2
or	6.976872	m^3
HSS 356x254x9.5		
longitudinal	114.69	m
transverse	100.35	m
amount	215.04	m

Guards and handrail		
glass panel		
height	1	m
length	114.69	m
amount	114.69	m^2
handrail posts		
height	1	m
amount	96	items

Foundation		
precast concrete columns		
height 1	1.80	m
height 2	3.12	m
height 3	3.40	m
height 4	1.75	m
diameter	1.00	m
volume	7.91	m^3
concrete pedestals		
H	0.75	m
W	2.00	m
L	2.00	m
volume	3.00	m^3
quantity	4	footings
total vol.	12	m^3

Platform Simplified Structural Analysis

Inputs	(blue)
Outputs	(green)

Effective legnth and area

Total length	114.7	m	[taken from material estimate calculations]
Total area	137.3	m^2	[taken from material estimate calculations]

Deck steel plate (2 inch thick)		
unit weight	1.954	kN/m^2
area	137.3	m^2
weight	536.7	kN
Longitudinal beams	HSS 356x254x9.5	
unit weight	0.849	kN/m
length	114.7	m
weight	97.4	kN
Transverse beams/stiffners		
length	100.35	m
weight	85.2	kN
Glass railings	100	kN
Total DL	819.3	kN

Total LL		
avg. weight/occupant	75	kg
conversion	0.73575	kN
quantity	58	occupants
LL	42.7	kN

Total factored load		
NBCC: 1.25DL + 1.5LL	1088	kN
Total distributed load	18.98	kN/m

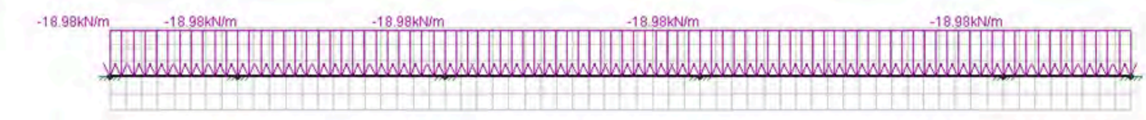
Tributary area + load distribution		
Column 1	14.0	m
Column 2	13.0	m
Column 3	20.6	m
Column 4	16.5	m
total length	64.1	m
Point load 1	237.80	kN
Point load 2	220.82	kN
Point load 3	349.23	kN
Point load 4	280.27	kN
Total load	1088.13	kN

Based on a simplied structural analysis, we yield the following shear force and bending moment diagrams,

Distributed load (18.98 kN/m)

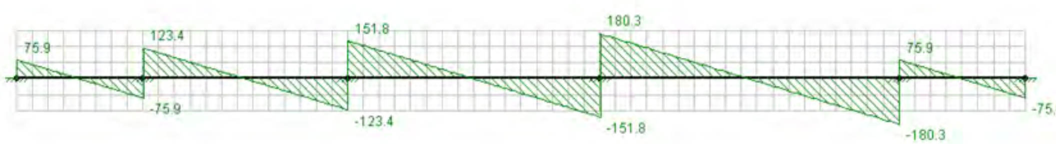

Joint Reactions

	Joint Label	X [kN]	Y [kN]	MZ [kN-m]
1	N1	0	75.92	101.227
2	N2	0	199.29	166.075
3	N3	0	275.21	137.605
4	N4	0	332.15	166.075
5	N5	0	256.23	-469.755
6	N6	0	75.92	-101.227
7	Totals:	0	1214.72	0



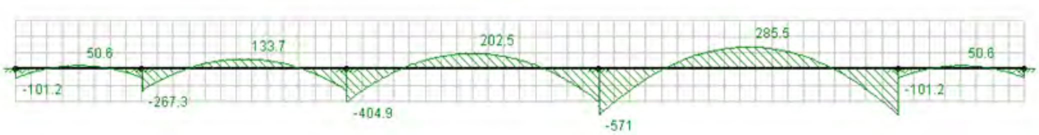
Shear force diagram

Max shear	180.3	kN



Benging moment diagram

Max moment	571	kNm



S-CONCRETE 11.1.06 **(c) S-FRAME Software Inc.**

FOR ACADEMIC USE ONLY. NOT FOR COMMERCIAL USE.

File Name:

Summary

Status	Acceptable
Maximum	1.000
V & T Util	0.046
N vs M Util	0.239

Section Name
Concrete Section

Consultant
UBC

Canadian Building Standards
CSA Standard A23.3-04, "Design of Concrete Structures"
CSA Standard A23.1-04, "Concrete Materials and Methods of Concrete Construction"

Design Aids, Manuals, and Handbooks
"Concrete Design Handbook", Cement Association of Canada, 3rd Edition, 2006
"Prestressed Concrete Structures", Collins and Mitchell, Prentice Hall Inc., 1991 (MCFT)

Section Dimensions
Circular Column
D = 1000 mm

Quantities (approx.)
Concrete = 1850 kg/m
Steel = 194.1 kg/m
Primary = 115.4 kg/m
Secondary = 78.7 kg/m

Material Properties
fc' = 35 MPa
fy (vert) = 400.0 MPa
fy (ties) = 400.0 MPa
Wc = 2400 kg/m3
Ws = 7850 kg/m3
Poisson's Ratio = 0.2
hagg = 20 mm
Es = 200000 MPa
Ec = 28165 MPa
Gc = 11735 MPa
fr = 3.55 MPa

Gross Properties
Zbar = 0 mm
Ybar = 0 mm
Ag = 785398 mm2
Ig (y-y) = 49087xE6 mm4
Ig (z-z) = 49087xE6 mm4
Ashear (Y) = 589049 mm2
Ashear (Z) = 589049 mm2
Jg = 98175xE6 mm4

Effective Properties
Ae = 785398 mm2
Ie (y-y) = 49087xE6 mm4
Ie (z-z) = 49087xE6 mm4
Ase (Y) = 589049 mm2
Ase (Z) = 589049 mm2
Je = 98175xE6 mm4

Vertical Bars
1000 mm Diameter Column
21-30M Vert
As = 14700 mm2
Rho = 1.87 %
Tangential Splice

Spiral
20M Spiral x 90 mm

Miscellaneous
Clear Cover = 40 mm

Factored Input Loads

Load Case/Combo	N (kN)	T (kNm)	Vz (kN)	My (kNm)	Vy (kN)	Mz (kNm)	Comment
1	-324.0	0.0	75.0	100.0	25.0	-300.0	
2	-500.0	0.0	125.0	-450.0	35.0	125.0	
3	-300.0	0.0	100.0	-110.0	27.0	400.0	
4	-1400.0	0.0	88.0	100.0	22.0	350.0	
5	-600.0	0.0	50.0	400.0	100.0	200.0	
6	-300.0	0.0	50.0	400.0	100.0	-200.0	
7	-500.0	0.0	75.0	-125.0	31.0	-300.0	
8	-1500.0	0.0	19.0	-450.0	112.0	-75.0	

Factored Design Loads (with Minimum Moments):

Load Case/Combo	Vz (kN)	My (kNm)	Vy (kN)	Mz (kNm)	Mres (kNm)	Theta

1	79.1	316.2	0.0	0.0	316.2	0º
2	129.8	467.0	0.0	0.0	467.0	0º
3	103.6	414.8	0.0	0.0	414.8	0º
4	90.7	364.0	0.0	0.0	364.0	0º
5	111.8	447.2	0.0	0.0	447.2	0º
6	111.8	447.2	0.0	0.0	447.2	0º
7	81.2	325.0	0.0	0.0	325.0	0º
8	113.6	456.2	0.0	0.0	456.2	0º

N vs M Results

GLC	#2
Status	Acceptable
Utilization	0.239
Maximum	1.000
Theta	0º

Axial Utilization

Nf = -500.0 kN
Nr (max) = -16133.7 kN
Utilization = 0.031

Moment Utilization

Mf = 467.0 kNm
Mr = 1950.9 kNm
Utilization = 0.239

Mn = 2355.8 kNm
Mp = 2791.4 kNm

Shear and Torsion Utilization

GLC	2
Nf	-500.0 kN
Vfz / Vrz	0.046
Vfy / Vry	0.000
Status	Acceptable
Utilization	0.046
Maximum	1.000
Method	Simplified

Shear Z-Direction

bw = 1000 mm
dv = 720 mm
As (Tens) = 9188 mm2
Av = 600 mm2
Lambda = 1.00
Mf (y-y) = 467.0 kNm
Vfz = 129.8 kN
Vsz = 2330.7 kN
Vcz = 498.4 kN
Vrz = 2829.1 kN
Beta = 0.180
Theta = 35.0°

Shear Y-Direction

Vfy = 0 kN
Design Info Not Evaluated

Torsion

Tcr = 286.9 kNm
Tf = 0.0 kNm < 0.25 Tcr
Ignore Torsional Effects

Spiral Pitch for Shear/Torsion

Pitch	90.0 mm
Maximum	1000.0 mm
Status	Acceptable

Maximum Shear Stress

Stress	0.180 MPa
Maximum	5.688 MPa
Status	Acceptable

Spiral Requirements

Rho	1.42 %	
Rho (min)	0.71 %	Acceptable
Diam.	19.5 mm	
Diam. (min)	6.0 mm	Acceptable
Spacers	4 req'd	
Pitch (min)	46 mm	Acceptable
Pitch	90 mm	
Pitch (max)	94.5 mm	Acceptable
D (core)	920 mm	
A (core)	664761 mm2	

Vertical Steel Area		Status	As/Ag	Vertical Bar Splice Type
As	14700 mm2		1.87 %	Tangential Splice

As (min)	7854 mm2	Acceptable	1.00 %	Status	Acceptable
As (max)	31416 mm2	Acceptable	4.00 %		

Vertical Bar Spacing

#Bars	21 Specified
#Bars (max)	26.3 Allowed
Status	Acceptable

Vertical Bar Diameter

db (vert)	29.9 mm
db (min)	16.0 mm
Status	Acceptable

Minimum Number of Vertical Bars

#Bars	21 Specified
#Bars	6 Required
Status	Acceptable

Vertical Reinforcing

fy (min)	300.0 MPa
fy (vert)	400.0 MPa
fy (max)	500.0 MPa
Status	Acceptable

Horizontal Reinforcing

fy (min)	300.0 MPa
fy (horz)	400.0 MPa
fy (max)	500.0 MPa
Status	Acceptable

Concrete Strength

fc' (min)	20.0 MPa
fc'	35.0 MPa
fc' (max)	80.0 MPa
Status	Acceptable

Concrete Density

Wc (min)	1500.0 kg/m3
Wc	2400.0 kg/m3
Wc (max)	2500.0 kg/m3
Status	Acceptable

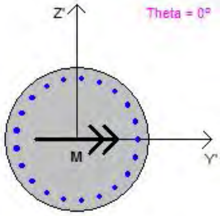
Canadian Reinforcing Bars

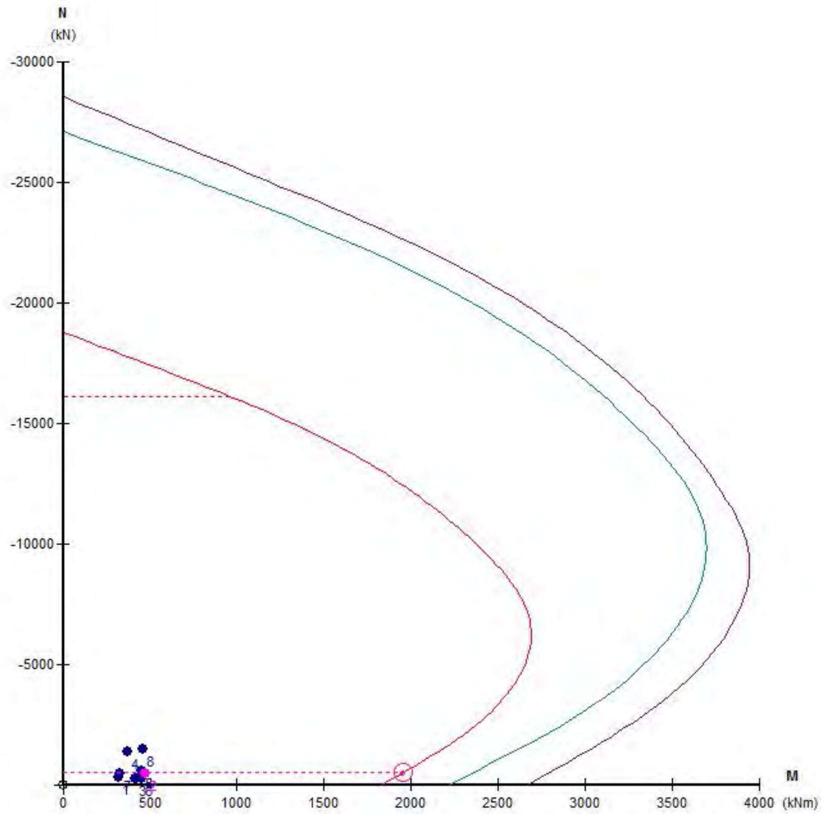
Index	Bar Designation	Diameter (mm)	Area (mm2)
1	10M	11.3	100.0
2	15M	16.0	200.0
3	20M	19.5	300.0
4	25M	25.2	500.0
5	30M	29.9	700.0
6	35M	35.7	1000.0
7	45M	43.7	1500.0
8	55M	56.4	2500.0

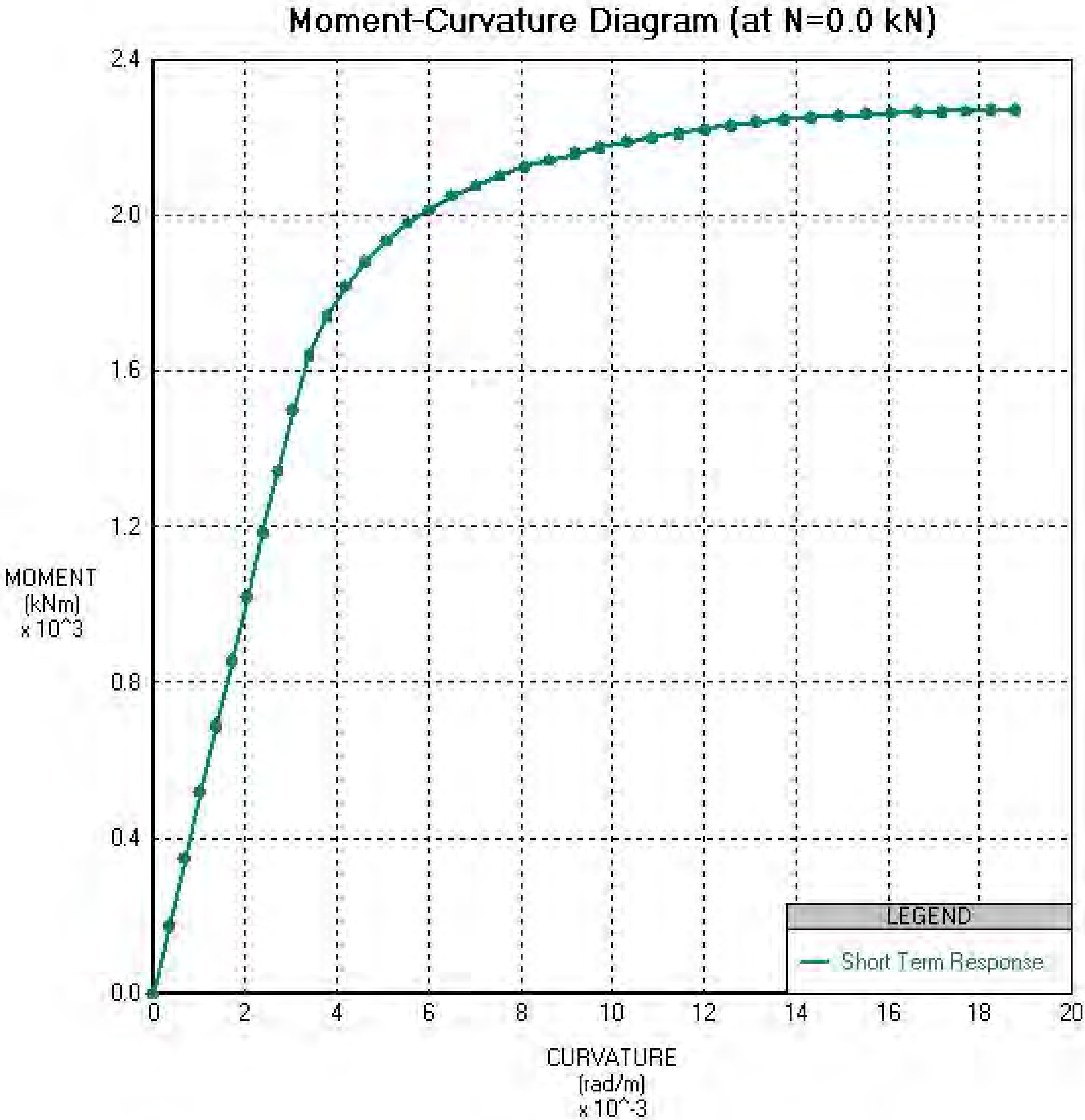
List of Messages

No Messages...

Concrete Section
1000 mm Diameter Column
21-30M Vert
Ag = 785398 mm2
As = 14700 mm
Rho = 1.87 %
fc' = 35 MPa
fy (vert) = 400.0 MPa






Moment-Curvature Diagram (at N=0.0 kN)
MOMENT
(kNm)
x 10^3
2.4
2.0
1.6
1.2
0.8
0.4
0.0
0
2
4
6
8
10
12
14
16
18
20
CURVATURE
(rad/m)
x 10^-3
LEGEND
Short Term Response

APPENDIX C: ENVIRONMENTAL IMPACTS

This appendix will discuss additional environmental impacts pertaining to the project. It discusses guidelines such as those for tree protection and fencing, as well as necessary coordination, and material requirements.

1. Tree Protection Guidelines

Based on the *UBC Vancouver Campus Plan, Part 3 Design Guidelines (2010)*, the design will meet the following criteria but are not limited to the following:

Tree Retention – Existing healthy trees over 10 cm diameter at breast height on a project site shall be retained or otherwise be conserved through relocation on campus.

Arborist Advice – Detailed recommendations will be sought from a certified arborist, especially during construction phase, to meet the Campus and Community Planning guidelines.

Special Trees – Efforts shall be made to protect the following special trees:

- Cherries along Lower Mall, West Mall
- Elms along University Blvd between East Mall and Main Mall
- Ponderosa Pine in front of the Ponderosa Buildings
- Class and commemorative trees (Location of all new trees to be approved by Campus and Community Planning)

Fencing

- Tree protection fencing will be set up around all trees identified for retention during construction. No material storage is permitted within the fence lines. See Section 3.3 for detailed design standards for the fencing.
- Tree protection signage, under Tree Shrub Preservation guidelines (2015), will be displayed at reasonable intervals to discourage hoarding, grade changes and heavy equipment intrusions into Tree Protection Zones, see figure below for UBC standard signage.

Tree Protection Signage

Root Curtain

- Based on the *UBC Technical Guidelines, Section 02014 Tree and Shrub Preservation (2015),* Root Curtain is intended to minimize root damage and is made of heavy wire mesh lined with burlap and supporting posts. Therefore, a temporary Root Curtain shall be required to cover exposed roots along the cut face of excavation made adjacent to Tree Protection Zones.

2. Coordination Process

In order to meet the requirement of *UBC Technical Guidelines, Section 02014 Tree and Shrub Preservation (2015)*, early coordination with UBC Campus Arborist is important in the conceptual and design development phases. Throughout construction phases, the team shall coordinate with UBC Campus Arborist regarding any site changes, or potential damages to the existing trees, and with UBC Building Operations, Head Landscape Technologist for any impacts or potential damages to any existing shrubs or plantings; thereof designated for retention.

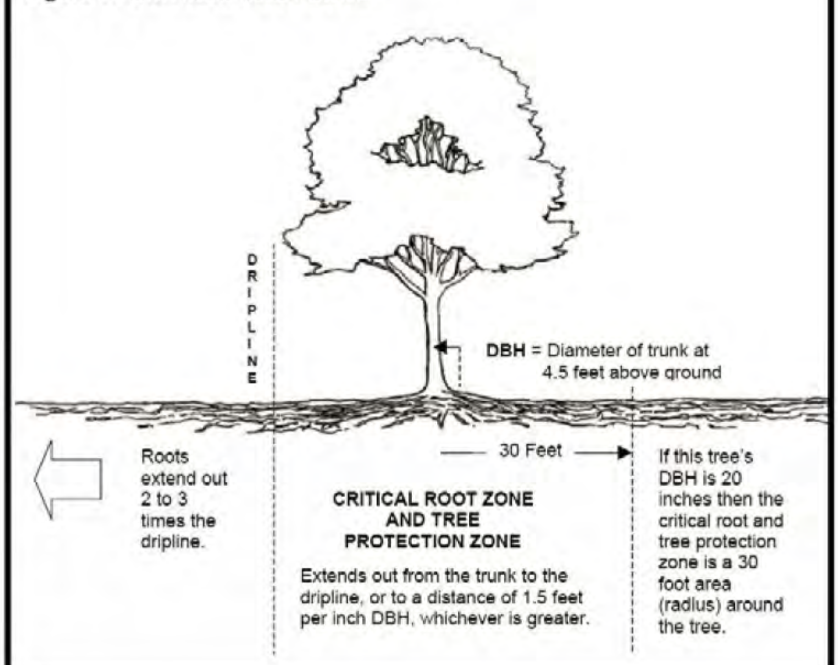
3. Materials and Design Requirement

According to *UBC Vancouver Campus Plan, Part 3 Design Guidelines (2010)* and *UBC Technical Guidelines, Section 02014 Tree and Shrub Preservation (2015)* , tree protection fencing needs to in accordance with the following design standards in relationship to each tree's Critical Root Zone (see figure below):
Configuration – the fencing must have a radius around the subject tree, equivalent to the greater of the two:

- The drip line of the tree canopy
- A radius equal to 1m per 8 cm trunk diameter measured at 300 mm for trees of less than 15 cm trunk diameter.
    - Example: a tree with a 40 cm trunk diameter will require a 5 m radius of protection fence.

Materials – the fencing shall be composed of wood post and frame fencing with snow fencing or mesh around it, and be driven into the ground with a depth of at least 600 mm and shall be placed at least 1 m beyond the dripline of outer canopies.
Height – the fencing height must be 1.8 m high.

Figure 1. CRITICAL ROOT ZONE



Critical Root Zone

APPENDIX D: STORM WATER MANAGEMENT

Additional information regarding storm water management can be found below, along with a figure depicting the proposed location of the storm water detention facilities. Kindly note, all of this information is pending consultation with the UBC stormwater management department, and a stormwater specialist.

Sample Calculations for Stormwater Detention Tank

1. **Volume of tank:**

- Calculated by Geoadvice in 2014

$$Volume = 1700\ m^3$$

- Note, this volume is sufficient to accommodate the additional load from the drainage pipes discussed in 6 and 7 below.

2. **Tank Dimension**

- Based on Hydrostatigraphic Cross Section A-A from AECOM Hydrogeological Stormwater Management Strategy – Phase 1 Desktop Assessment (2013) there are approximately 10 metres of silt/sand below Chancellor Boulevard.
- The width of tank is confined to 8m (width of eastbound lane along Chancellor Boulevard) by the following constraints:
    - There are a number of significant trees in the median, which cannot be removed, nor the soil underneath them disturbed
    - Placing the tank at a depth where it would not interfere with the tree roots, and thus would be able to extend farther than 5 metres would be too costly and may introduce construction difficulties
    - The tank cannot be extended further towards the south, as that would infringe on private property of the residences
    - Based on the proposed footprint by Geoadvice, the length of the tank is 80 metres
    - The depth is then calculated as follows:

$$d = \frac{1700}{80 * 8} = 2.655m \sim 3m$$

- Tank Dimensions are therefore:
  - Length = 80 m
  - Width = 8 m
  - Depth = 3 m
- Note, the actual width of the street is 8.5m, however a 0.5m clearance has been provided to allow for future growth of tree roots
- The clearance between the top of the tank and the roadway must be enough as to provide a sufficient slope for the drainage pipes; minimum slope is to be 1/100.
  - Based on this, the maximum distance between the outermost drainage pipe and the inlet of the detention tank is ~100m, and thus the minimum clearance of the tank below the roadway is 2m.
- **Caution: All of these dimensions are based on pre-existing reports depicted the current soil conditions. Existing conditions may differ from these assumptions, requiring the above dimensions to be altered**

3. Calculation of Inlet and Outlet Orifice Diameters

Stormwater Design Calculations

Description	Calculation	Comments
Sub-catchment area	$A = 4\ ha$	This is an estimate, based on the proposed location of nearby detention tanks as shown in Geoadvice (2014)
Weighted run-off coefficient (post development)	$C_{post} = 0.85 * 1 + 0.15 * 0.45 = 0.92$	This is an estimate, that the total impervious area in the sub-catchment is 85%
Time of Concentration	$t_c = 10\ minutes$	Published values by PUB
Average rainfall intensity for 200 year storm event	$i_{200} = 95mm/hr$	Obtained from BCG's Regional IDF Curves for 2009.
Peak inflow from catchment	$Q = \frac{C_o i_{200} A}{360}$ $Q = \frac{0.92 * 95 * 4}{360}$	

	$= 0.97\, m^3/s$	
Orifice Inlet diameter	$Q_o = C_o A_o \sqrt{2gH_o}$ $0.97 = 0.6 \frac{\pi d_o^2}{4} \sqrt{2 * 9.81 * \left(1 - \frac{d_o}{2}\right)}$ $d_o = 0.77m \sim 0.8m$	Assuming circular orifice flow, and thus discharge coefficient $C_o = 0.6$
Weighted run-off coefficient (pre-development)	$C_{pre} = 0.45 * 1 + 0.55 * 0.15 = 0.55$	We choose to design the outflow based on outflow to closely mimic pre-development conditions. This will ensure that no extraordinary energy is transferred to the receiving system and waters, thereby limiting the possible adverse affects.
Outflow volume based on pre-development flow requirement	$Q_{pre} = \frac{C_{pre} i_{200} A}{360}$ $Q_{pre} = \frac{0.55 * 95 * 4}{360} = 0.58\, m^3/s$	
Outflow volume based on drainage time requirement	$t_{drain} = 4\ hours$ $V_{water} = 1700\, m^3$ $Q_t = \frac{1700}{4 * 60 * 60}$ $Q_t = 0.12\, m^3/s$	
	$Q_t < Q_{pre}$ $Q = 0.12\, m^3/s$	The outflow needed to drain the tank within 4 hours, is within the predevelopment requirement. Note that this predevelopment requirement is in line with UBC and Metro Vancouver ISMP
Orifice outlet diameter	$Q_o = C_o A_o \sqrt{2gH_o}$ $= 0.6 \frac{\pi d_o^2}{4} \sqrt{2 * 9.81 * \left(1 - \frac{d_o}{2}\right)}$ $d_o = 0.25m$	Assuming circular orifice flow, and thus discharge coefficient $C_o = 0.6$

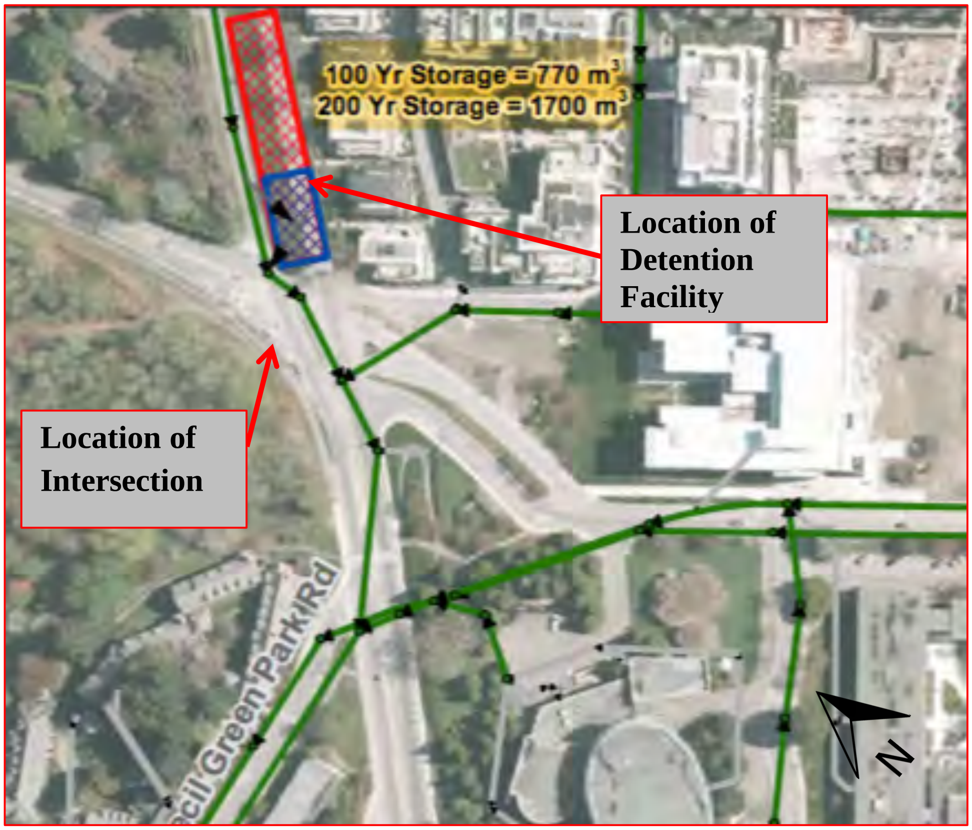
4. Calculation of slope for bottom plate

Dimension Calculations for Detention Tank

Description	Calculation	Comments
Shear stress	$\tau = \gamma * R * I$ $R - Hydraulic\ Radius$ $I = Bottom\ plate\ slope$ $\gamma - specific\ weight\ of\ water$	
Hydraulic Radius	$R = \frac{A}{P_w}$ $R = \frac{3 * 8}{3 + 3 + 8} = 1.71m$	
Specific Weight of Water	$\gamma = 9.819\ kN/m^3$ $T = 10℃$	Note this is an assumption; pilot tests should be conduced to determine the exact density of storm water in the region. However, the specific gravity tends to remain fairly uniform for temperatures between 5-40℃.
Shear Stress	$\tau = 3 - 4\ \ N/m^2$	This is a published value by Grundfos, and is intended to induce sufficient stress to shear settled particles towards the sump during low flow.
Bottom Plate slope	$I = \frac{\tau}{\gamma * R} = \frac{4}{9.819 * 1000 * 1.71}$ $= 2\%$	

5. Geographical location of stormwater detention tank

The location of the stormwater detention tank as selected by Geoadvice is:



Location of Stormwater Detention Tank

6. Sizing perforated pipe drains

- Our goal is to completely capture all of the infiltrating water in the case of a 1 in 200 year storm resulting from the increased green space proposed within this design.
- In addition, an attempt will be made to collect the water infiltrating nearby the pedestrian lookout platform. The reason for this is twofold
  - (1) Impervious area is being increased at this location, and therefore compensation is needed due to this increased load
  - (2) The area closely surrounding the lookout platform,
- For this we need to consider the different intensities, for different intervals, and determine the governing flow

Perforated Pipe Drain Design Calculations

Description	Calculation	Comments
Area of green space	$A = 0.50\ ha$	This is based on the green space in the vicinity of the intersection
Flow through each perforation	$Q_{perf} = C * \frac{A\sqrt{2gH}}{B}$ $C - Circular\ orifice = 0.6$ $B - Blockage\ coefficient = 2$ $A - performation\ diameter\ 0.01m^2$	Assumption are made regarding perfect circular orifice flow, the average level of blockage (based on WSUD Engineering Procedures textbook), and the perforation diameter
Flow through perforation	$Q_{perf} = 0.6 * \frac{0.01\sqrt{2*9.81*0.5}}{2}$ $Q_{perf} = 0.009\, m^3/s$	An assumption is made that in the case of a 1 in 200 year flood, the soil will be fully saturated, and thus the water column will be equal to the depth of the soil above the drainage pipe.
Perforated pipe capacity	$Q = [-2(2gDS_f)^{0.5} log_{10}(k/(3.7D) + 2.51\, v/D\, (2gdS_f)^{0.5})] * A$ $Q = flow$ $D = pipe\ diameter$ $A = area\ of\ pipe$ $S_f = slope\ of\ pipe$ $k = wall\ roughness$	We assume that the flow can be modelled using the Colebrook-White equation
Wall roughness	$k = 0.002$	This is an established value for PVC pipe taken from Swaffield and Bridge (1983)
Diameter	$D = 12" = 12 * 2.54cm \sim 30cm = 0.3m$	This is an assumption, based on common diameters available through manufacturers
Area	$A = \frac{\pi}{4}d^2 = \frac{\pi}{4}0.3^2 = 0.071m^2$	

Viscosity	$v = 0.001003\ kg/m * s$	Assume worst case scenario, so lowest viscosity between $5℃ - 20℃$
Slope of pipe	S_f =0.015	Minimum gradient is typically specified to be 1/100, so we will assume the grade will be 1.5/100
Perforated pipe capacity	$Q = [-2(2 * 9.8 * 0.3 * 0.015)^{0.5} log_{10}(0.02/(3.7 * 0.3) + 2.51 * 0.001003/0.3\ (2 * 9.8 * 0.3 * 0.015)^{0.5})] * 0.071$ $Q_c = 0.103\, m^3/s$	Flow capacity for the pipe using Colebrook-White equation
Comparison between Q_c and Q_{1m}	$Q_c < Q_{1m}$ $Q = Q_c = 0.103\, m^3/s$	Here we see that the amount of flow in the pipe is limited by the pipe capacity, and not by the flow entering the perforations.
Peak 1 in 200 year flow impacting the green space	$Q = \frac{C_o i_{200} A}{360}$ $Q = \frac{1.0 * 95 * 0.50}{360} = 0.134\, m^3/s$	
Amount of total flow which infiltrates the soil	$Q_{inf} = Q$	As a worst-case scenario, we assume that the total amount of flow infiltrates into the soil.
Number of drainage pipes needed	$\# pipes = \frac{0.134}{0.103} = 1.3 \sim 2$	So, we will need at minimum 2 drainage pipes to handle the

7. Location of Perforated Drainage Pipes

The following figure shows the location of the perforated drainage pipes, and the way in which they will be tied into the stormwater detention tank.

Location of Perforated Pipes

8. Construction Best Management Practices

Anova Consulting understands the complexity and sensitivity of the project in regards to stormwater. In an effort to ensure the construction of the project does not adversely affect the nearby aquifers and streams, the consultant will abide by the Best Management Practices (BMPs) as outlined by the BC Ministry of Environment. By doing so, the project will fulfill the following regulatory requirements:

- Water Act Regulation (Section 41 and 42.1)
- Fisheries Act (Section 35 and 35.1)

Additional information regarding these construction BMPs may be found on the website of the BC Ministry of Environment.

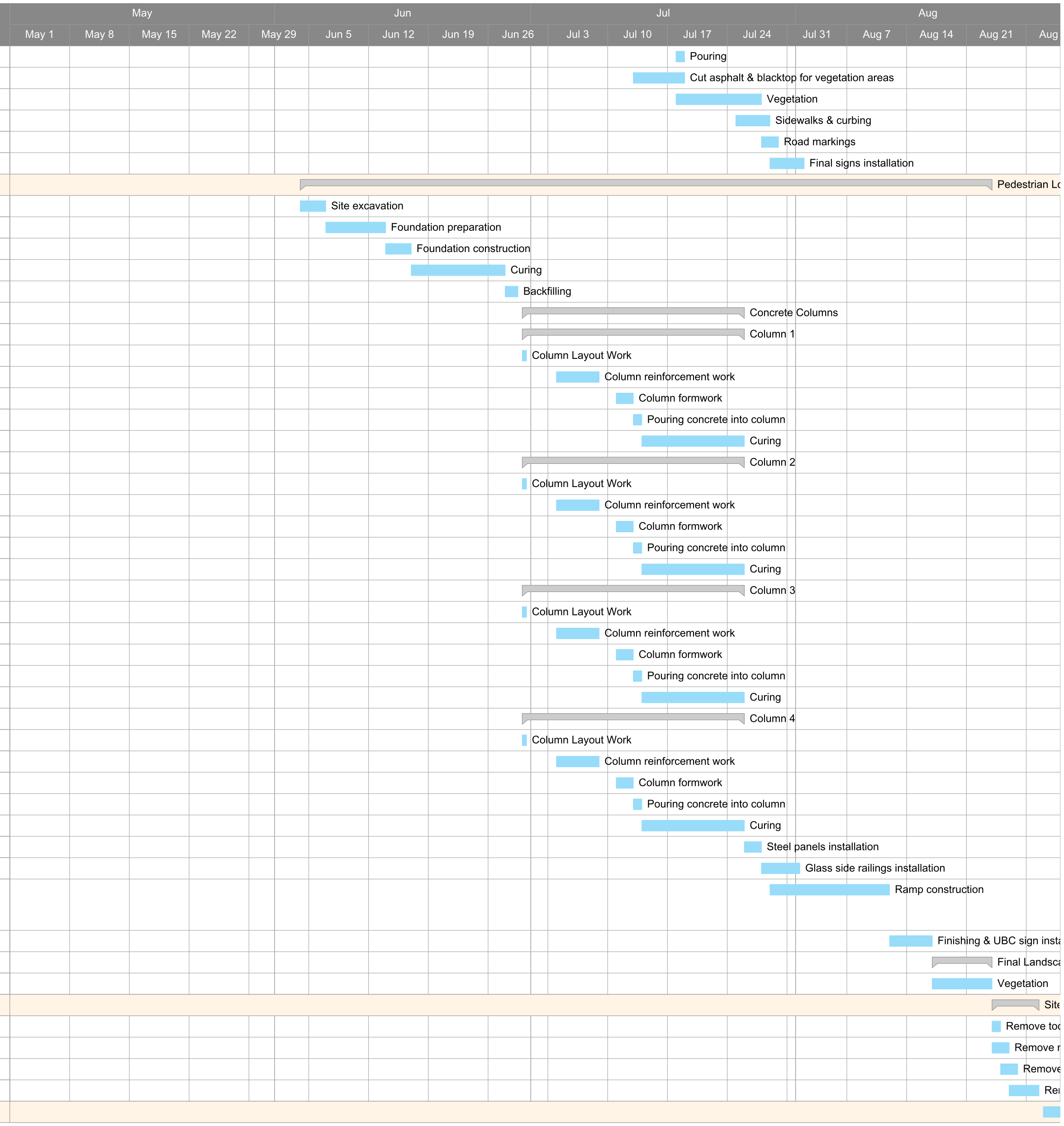
APPENDIX E: DETAILED CONSTRUCTION SCHEDULE

This appendix included a detailed construction schedule. Note the schedule follows a sequential work path, and the critical tasks are given free flow time in order to reduce the risk of delays due to unpredictable changes and events during the construction phase. Kindly note, that the red highlighted work tasks are occurring on weekend as to accommodate convocation ceremonies.

*Note: The boxes filled with red represent the construction work during the weekends.

Task Name	Duration	Start	Finish	Comments
Site Preparation	11d	05/02/16	05/16/16	
Setting up temporary facilities	3d	05/02/16	05/04/16	*On-site washrooms, office space, storage, etc.*
Setting up temporary detour signs	1d	05/05/16	05/05/16	*For more details about their locations, please refer to TMP*
Fencing	1d	05/06/16	05/06/16	
Vegetation removal	3d	05/09/16	05/11/16	
Removal of existing medians & curbs	3d	05/12/16	05/16/16	
Utilities Relocation	6.5d	05/16/16	06/02/16	
Excavation & removal	1.5d	05/16/16	05/17/16	*Removal of light posts*
Notify UBC utilities for inspection	0.5d	05/17/16	05/17/16	
Relocation, lay-in electrical & stormwater facilities	3d	05/18/16	05/20/16	
Construction of detention tank on East of interesection	3d	05/18/16	05/20/16	**3 days + weekend*
Placement of perforated pipes	3d	05/18/16	05/20/16	**3 days + weekend*
UBC utilities inspection	1.5d	05/24/16	06/02/16	
Backfilling	1d	05/21/16	05/21/16	**2 days (to finish paving before graduation ceremonies)*
Temporary paving	1d	05/21/16	05/21/16	**2 days (to finish paving before graduation ceremonies)*
Intersection Construction	42d	06/02/16	08/01/16	
Work Zone 1 (SW Corner)	5d	06/02/16	06/08/16	
Excavation	1d	06/02/16	06/02/16	
Base & sub-base placement	1d	06/03/16	06/03/16	
Final asphalt paving	0.5d	06/04/16	06/04/16	
Blacktop paving	0.5d	06/04/16	06/04/16	
East Mall Median	3d	06/06/16	06/08/16	
Formwork	2d	06/06/16	06/07/16	
Pouring	1d	06/08/16	06/08/16	
Work Zone 2 (NW Corner)	6d	06/09/16	06/16/16	
Excavation	1.5d	06/09/16	06/10/16	
Base & sub-base placement	2d	06/13/16	06/14/16	
Final asphalt paving	1d	06/15/16	06/15/16	
Blacktop paving	1d	06/16/16	06/16/16	
Work Zone 3 (NE Corner)	6d	06/17/16	06/24/16	
Excavation	2d	06/17/16	06/20/16	
Base & sub-base placement	2d	06/21/16	06/22/16	
Final asphalt paving	1d	06/23/16	06/23/16	
Blacktop paving	1d	06/24/16	06/24/16	
Work Zone 4 (SE Corner)	10.5d	06/27/16	07/12/16	
Excavation	2d	06/27/16	06/28/16	
Base & sub-base placement	3d	06/29/16	07/04/16	
Final asphalt paving	1d	07/05/16	07/05/16	
Blacktop paving	1d	07/06/16	07/06/16	
Chancellor Blvd. Median	3.5d	07/07/16	07/12/16	
Formwork	3d	07/07/16	07/11/16	
Pouring	1.5d	07/11/16	07/12/16	
Roundabout Central Island	4d	07/13/16	07/18/16	
Formwork	3d	07/13/16	07/15/16	

Task Name	Duration	Start	Finish	Comments
Pouring	1d	07/18/16	07/18/16	
Cut asphalt & blacktop for vegetation areas	4d	07/13/16	07/18/16	
Vegetation	8d	07/18/16	07/27/16	
Sidewalks & curbing	4d	07/25/16	07/28/16	
Road markings	2d	07/28/16	07/29/16	
Final signs installation	2d	07/29/16	08/01/16	
Pedestrian Lookout Platform	57d	06/04/16	08/23/16	
Site excavation	2d	06/04/16	06/06/16	
Foundation preparation	5d	06/07/16	06/13/16	
Foundation construction	3d	06/14/16	06/16/16	
Curing	7d	06/17/16	06/27/16	
Backfilling	1.5d	06/28/16	06/29/16	
Concrete Columns	17d	06/30/16	07/25/16	
Column 1	17d	06/30/16	07/25/16	
Column Layout Work	0.5d	06/30/16	06/30/16	
Column reinforcement work	5d	07/04/16	07/08/16	
Column formwork	2d	07/11/16	07/12/16	
Pouring concrete into column	1d	07/13/16	07/13/16	
Curing	8d	07/14/16	07/25/16	
Column 2	17d	06/30/16	07/25/16	
Column Layout Work	0.5d	06/30/16	06/30/16	
Column reinforcement work	5d	07/04/16	07/08/16	
Column formwork	2d	07/11/16	07/12/16	
Pouring concrete into column	1d	07/13/16	07/13/16	
Curing	8d	07/14/16	07/25/16	
Column 3	17d	06/30/16	07/25/16	
Column Layout Work	0.5d	06/30/16	06/30/16	
Column reinforcement work	5d	07/04/16	07/08/16	
Column formwork	2d	07/11/16	07/12/16	
Pouring concrete into column	1d	07/13/16	07/13/16	
Curing	8d	07/14/16	07/25/16	
Column 4	17d	06/30/16	07/25/16	
Column Layout Work	0.5d	06/30/16	06/30/16	
Column reinforcement work	5d	07/04/16	07/08/16	
Column formwork	2d	07/11/16	07/12/16	
Pouring concrete into column	1d	07/13/16	07/13/16	
Curing	8d	07/14/16	07/25/16	
Steel panels installation	2d	07/26/16	07/27/16	
Glass side railings installation	2.5d	07/28/16	08/01/16	
Ramp construction	10d	07/29/16	08/11/16	*If required, construction work during weekend
Finishing & UBC sign installation	3d	08/12/16	08/16/16	
Final Landscaping	5d	08/17/16	08/23/16	
Vegetation	5d	08/17/16	08/23/16	
Site Cleanup	3.5d	08/24/16	08/29/16	
Remove tools	1d	08/24/16	08/24/16	
Remove materials	2d	08/24/16	08/25/16	
Remove facilities	2d	08/25/16	08/26/16	
Remove detour signs	1.5d	08/26/16	08/29/16	
Final Inspections	2d	08/30/16	08/31/16	



APPENDIX F: DETAILED COST ESTIMATES

This appendix includes detailed broken down cost estimates for both the roundabout, and the pedestrian lookout platform. As has been discussed in the respective section, this estimates are pending further necessary information from the client before they can be finalized.

COST ELEMENT	BASE ESTIMATE ($)	RISKS & CONTINGENCY		TOTAL ESTIMATE ($)	% of Total Cost	COMMENTS
		%	$			
PROJECT MANAGEMENT	65,000	15%	9,750	74,750	***4.95%***	Assumed as 5.0-5.5% of Total Project Estimate
PLANNING	8,700	15%	1,305	10,005	***0.66%***	Taken as 1% of Construction Base Estimate
ENGINEERING DESIGN						
PRELIMINARY DESIGN	16,700	15%	2,505	19,205		2% of Construction Base Estimate
DETAILED DESIGN SERVICES	80,000	15%	12,000	92,000		Structural Construction 8%, Road Constuction Sub-total and Environmental Compensation 7%, Construction Total and Environmental Compensation 0.6%
DESIGN TOTAL	**96,700**	15%	**14,505**	**111,205**		
ENVIRONMENT					***2.67%***	
ENVIRONMENTAL COMPENSATION	35,000	15%	5,250	40,250		Compensation assumed for possible soil seepage, etc. (with references to similar projects)
ENVIRONMENT TOTAL	**35,000**	15%	**5,250**	**40,250**		
CONSTRUCTION					**71.62%**	
ROAD CONSTRUCTION						
GRADE CONSTRUCTION & EARTHWORKS	125,000	15%	18,750	143,750		As per estimated quantity of required grading and earthworks (available upon request)
PAVEMENT CONSTRUCTION	225,000	15%	33,750	258,750		As per estimated quantity of required paving (available upon request)
UTILITY CONSTRUCTION	60,000	15%	9,000	69,000		As per estimated lighting, pipes, utility relocation, etc. (with references to projects similar in scale)
ROADSIDE CONSTRUCTION	75,000	15%	11,250	86,250		Estimated with references to projects similar in scale and scope
OTHER CONSTRUCTION	35,000	15%	5,250	40,250		Traffic operations, Landscaping, etc.
ROAD CONSTRUCTION SUB-TOTAL	***520,000***	***15%***	***78,000***	***598,000***		
STRUCTURAL CONSTRUCTION	315,000	15%	47,250	362,250		Pedestrian Overlook Platform (estimated with references to cost/sq.ft costs of projects similar in scale and scope of work)
CONSTRUCTION TOTAL	**870,000**	**15%**	**130,500**	**1,000,500**		
CONSTRUCTION SUPERVISION	**70,000**	**15%**	**11,000**	**81,000**		Grading 7%, Other 8%, Structural and Paving 6.5%, and Environmental Compensation 8%
OTHER COSTS					***8.96%***	
GST 5%	54,530	15%	8,180	62,710		
INFLATION + ESCALATION (3.50%)	38,152	15%	5,723	43,875		
TRAFFIC CONTROL	25,000	15%	3,750	28,750		Costs associated with re-routing during construction, signage and signals, etc. (with references to projects similar in scale)
OTHER COSTS TOTAL	**117,682**	**15%**	**17,652**	**135,334**		
MANAGEMENT RESERVE	50,000	15%	7,500	57,500	***3.81%***	(2.5-5% of total estimate)
TOTAL	***1,313,082***	**15%**	***196,962***	***1,510,044***		

Annual Maintenance/Operation Costs	
Category	**Roundabout**
Paved Surfaces	$ 475.00
Roadside	$ 250.00
Environmental & Drainage	$ 150.00
Traffic Operations (i.e. Siging, Striping, Signals, Lights, etc.)	$ 350.00
Landscaping	$ 450.00
Winter/Rain Storms	$ 165.00
Emergency Response	$ 75.00
Miscellaneous Maintenance	$ 350.00
TOTAL	$ 2,265.00

APPENDIX G: UTILTIES RELOCATION CONSTRUCTION BMPS

This appendix will outline the various regulatory requirements relating to utilities relocation and any associated construction BMPs. It is essential that the consultant, as well as any parties involved in the project follow the following BMPS to ensure success of the project:

- All new utilities (both above and below ground) shall be constructed in accordance with the City of Vancouver's *Utility Design and Construction Manual V1.4*
- Abide by the *TAC Guideline for the Coordination of Utility Relocation*
- Existing utilities shall be reviewed for any gross violations of the aforementioned code
- All stormwater drains shall
    - Be fitted with a filter mesh, placed underneath the metal grate and secured by the self weight of the grate
    - Be inspected before and after storm events, at 24 hour intervals during extended storm events, and weekly during the rest of construction as to ensure filter mesh is in working order
    - Be maintained by removing accumulated sediment when it reaches 1/3 of holding capacity and by replacing any damaged or broken meshes
- All manholes shall
    - Be properly marked, noting the associated system for which they grant access to
    - Remain unobstructed, and accessible during the entire duration of the construction
- All vertical protrusions resulting from the removal of surrounding asphalt, outstanding vertical bolts, etc. shall
    - Be clearly marked with reflective tape if in path of pedestrians
    - Be covered with safety cones if deemed necessary
    - Properly marked with reflective signs on roadway, with surrounding bevelled edges of asphalt if necessary to reduce chances of vehicular damage

APPENDIX H: RISK MANAGEMENT ANALYSIS

This appendix acts as an aid to the risk management section found within the report. Primarily, risk register is found here, which describes potential risks, consequences, mitigation strategies, and expected probabilities of encountering.

Risk Register

Risk Category	Risk Item	Description	Consequence	Mitigation	Probability
Site	Traffic Disruption	Risk that the traffic be disrupted	Discomfort for vehicles, pedestrians, and cyclists. As well as causing traffic delays	The community should be informed prior to the start of construction. Also, proper and adequate number of detour signs have to be installed	40%
Financial	Change in cost	Risk that the cost of the project would exceed the estimated costs at the detailed design stage.	Additional costs, un-satisfaction, and delays in project schedule.	Researching into alternative practices to find the right balance of cost, quality, and sustainability.	30%
Construction	Delay in materials delivery	Risk that the materials delivery is delayed due to miscommunications and poor planning.	Delay in project schedule, and change of orders.	Keeping positive relationships with materials suppliers, and planning the deliveries ahead of time.	20%
Safety & Site	Site access	Risk of site access for public and therefore exposing to certain hazards on the site.	Injuries, property damage, reputation, and additional costs.	Setting up proper hazard signs, and proper fencing. Also, communicating the sensitivity of the site location clearly.	20%
Design & Construction	Design changes	Risk that the construction would be delayed due to problems and issues with the proposed design.	Delays in project schedule, and additional costs.	Communicating changes or potential changes as soon as they arise, to the client and relevant stakeholders	15%

Construction	Excavation Collapse	Risk of excavation collapse due to many reasons.	Danger to the workers, delay in construction schedule, reputation, & additional costs.	Sloping, shoring, or shielding methods and training on excavation collapse.	12%
Construction	Workforce Shortage	Risk that the construction would be delayed due to shortage of skilled workers.	Delay in construction schedule & extra costs.	More skilled workers available, and free flow time given to the critical tasks.	10%
Site	Equipment breakdown	Risk that the equipment's would stop working due to poor maintenance and poor ongoing inspection.	Delays in project schedule, safety reduction for workers, and reduction of project quality.	Adequate training and a valid license should be provided for working with the equipment. Also, regular inspections are required.	5%
Construction	Unexpected Soil Conditions	Risk that the construction would be delayed due to unexpected geotechnical conditions (i.e. soil conditions different from what was reported)	Delay in construction schedule, additional costs (e.g. material costs), and new geotechnical test & report required.	Even tough previous geotechnical reports are available for this area; a detailed and accurate geotechnical analysis must be done before the construction. Also, more research done.	5%
Construction	Seismic Events	Risk of an earthquake. Source: Natural reason	Delay in project schedule, extra costs, injuries, and project destruction.	The project should be insured for natural disasters such as an earthquake.	2%
Construction	Platform Failure	Risk of bridge collapse during construction due to a design error.	Danger to workers & road users, delay in construction schedule, reputation, and additional costs.	More detailed structural analysis and a more experienced structural engineer, as well as insurance.	1%

APPENDIX I: UBC LEED CRITERIA REQUIREMENTS

This appendix contains a relevant excerpt from the UBC LEED Implementation Guide. The tables found below, summarize the mandatory LEED credits. Note, that UBC expects all credits classified as mandatory to be achieved. If any of these measures cannot be reasonably achieved, exemption may be granted by requesting a variance from UBC.

APPENDIX 2

UBC LEED IMPLEMENTATION GUIDE

The following table is a summary of the UBC mandatory LEED credits. Note that UBC expects all credits classified as Mandatory to be achieved. Project teams may earn an exemption if it can be demonstrated that credit requirements cannot reasonably be met by requesting a variance.

Summary of UBC Required LEED Credits

CREDIT/PREREQUISITE	UBC CREDIT COMPLIANCE	POINTS REQUIRED	POINTS AVAILABLE
SUSTAINABLE SITES			
SSp1 — Construction Activity Pollution Prevention	**Prerequisite**		
SSc1 — Site Selection	**Mandatory**	1	1
SSc2 — Development Density and Community Connectivity	**Mandatory**	5	5
SSc3 — Brownfield Redevelopment	Optional	0	1
SSc4.1 — Alternative Transportation: Public Transportation Access	**Mandatory**	6	6
SSc4.2 — Alternative Transportation: Bicycles Storage and Change Rooms	**Mandatory**	1	1
SSc4.3 — Alternative Transportation: Hybrid and Alternative Fuel Vehicles	Optional	0	3
SSc4.4 — Alternative Transportation: Parking Capacity	Optional	0	2
SSc5.1 — Site Development: Protect and Restore habitat	**Mandatory**	1	1
SSc5.2 — Site Development: Maximize Open Space	**Mandatory**	1	1
SSc6.1 — Stormwater Design: Quantity Control	**Mandatory**	1	1
SSc6.2 — Stormwater Design: Quality Control	Optional	0	1
SSc7.1 — Heat Island: Non-Roof	**Mandatory**	1	1
SSc7.2 — Heat Island: Roof	Optional	0	1
SSc8 — Light Pollution Reduction	Optional	0	1
WATER EFFICIENCY			
WEp1 — Water Use Reduction	**Prerequisite**		
WEc1 — Water Efficient Landscaping	**Mandatory**	2	4
WEc2 — Innovative Waste Water Technologies	Optional	0	2
WEc3 — Water Use Reduction	**Mandatory**	2	4
ENERGY AND ATMOSPHERE			
EAp1 — Fundamental Building Commissioning	**Prerequisite**		
EAp2 — Minimum Energy Performance	**Prerequisite**		
EAp3 — CFC Reduction in HVAC&R Equipment and Elimination of Halons	**Prerequisite**		
EAc1 — Optimize Energy Performance	**Mandatory**	11	19
EAc2 — Renewable Energy	Optional	0	7
EAc3 — Enhanced Commissioning	**Mandatory**	2	2
EAc4 — Enhanced Refrigerant Management	**Mandatory**	2	2
EAc5 — Measurement and Verification	**Mandatory**	3	3
EAc6 — Green Power	Optional	0	2

CREDIT/PREREQUISITE	UBC CREDIT COMPLIANCE	POINTS REQUIRED	POINTS AVAILABLE
MATERIALS AND RESOURCES			
MRp1 — Storage and Collection of Recyclables		**Prerequisite**	
MRc1.1 — Building Reuse: Maintain Existing Walls, Floors And Roof*	**Mandatory**	1	3
MRc1.2 — Building Reuse: Maintain Interior Non-Structural Elements*	Optional	0	1
MRc2 — Construction Waste Management	**Mandatory**	2	2
MRc3 — Materials Reuse	Optional	0	2
MRc4 — Recycled Content	**Mandatory**	2	2
MRc5 — Regional Materials	**Mandatory**	1	2
MRc6 — Rapidly Renewable Materials	Optional	0	1
MRc7 — Certified Wood	Optional	0	1
INDOOR ENVIRONMENTAL QUALITY			
EQp1 — Minimum IAQ Performance		**Prerequisite**	
EQp2 — Environmental Tobacco Smoke (ETS) Control		**Prerequisite**	
EQc1 — Outdoor Air Delivery Monitoring	Optional	0	1
EQc2 — Increased Ventilation	Optional	0	1
EQc3.1 — Construction Iaq Management Plan: During Construction	**Mandatory**	1	1
EQc3.2 — Construction Iaq Management Plan: Before Occupancy	**Mandatory**	1	1
EQc4.1 — Low-Emitting Materials: Adhesives and Sealants	**Mandatory**	1	1
EQc4.2 — Low-Emitting Materials: Paints and Coatings	**Mandatory**	1	1
EQc4.3 — Low-Emitting Materials: Flooring Systems	**Mandatory**	1	1
EQc4.4 — Low-Emitting Materials: Composite Wood and Agrifibre Products	**Mandatory**	1	1
EQc5 — Indoor Chemical & Pollution Source Control	Optional	0	1
EQc6.1 — Controllability of Systems: Lighting	Optional	0	1
EQc6.2 — Controllability of Systems: Thermal Comfort	Optional	0	1
EQc7.1 — Thermal Comfort: Design	Optional	0	1
EQc7.2 — Thermal Comfort: Verification	Optional	0	1
EQc8.1 — Daylight and Views: Daylight	Optional	0	1
EQc8.2 — Daylight and Views: Views	Optional	0	1
INNOVATION IN DESIGN			
IDc1 — Innovation and Design Process	**Mandatory**	5	5
IDc2 — LEED Accredited Professional	**Mandatory**	1	1
REGIONAL PRIORITY			
RPc1 — Durable Building	Optional	0	1
RPc2 — Regional Priority Credit	**Mandatory**	3	3
	TOTAL	**60**	**110**

Certified: 40–49 points Silver: 50–59 points Gold: 50–79 points Platinum: 80+ points

* Major Renovations Only