UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

# Corridor Redesign of Chancellor Boulevard - Team 18

**George Hill, Max Leung, Mackenzie Lubberding, Tamara McPherson, Andy Stewart**

**University of British Columbia**

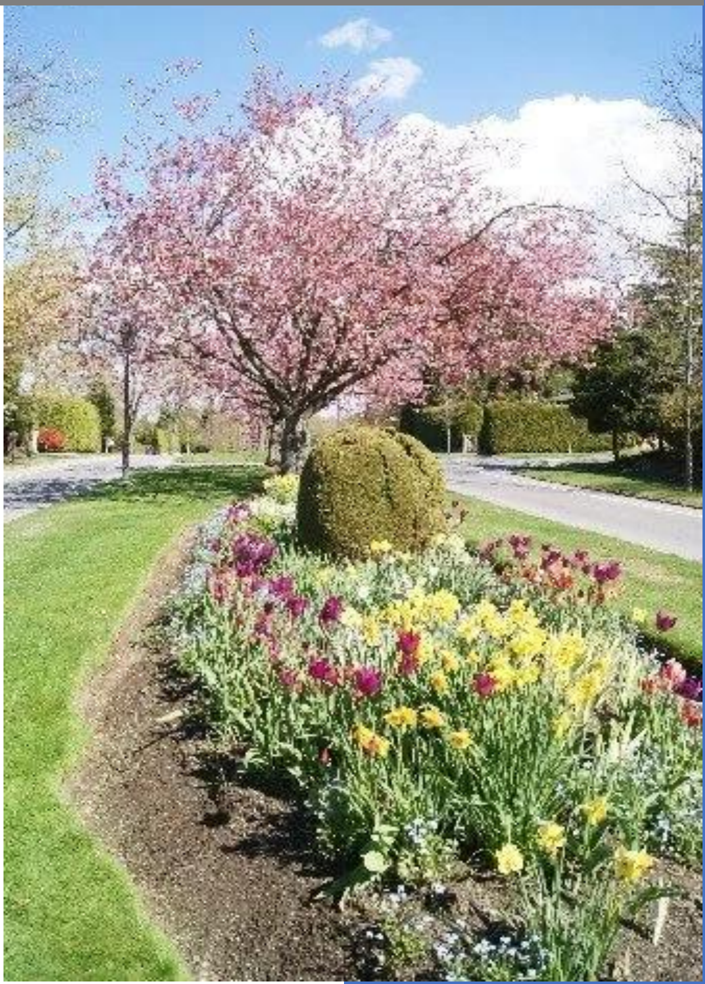
**CIVL 445**

**Themes: Transportation, Community, Land**

**April 9, 2018**

# Corridor Redesign of Chancellor Boulevard

*Final Design Report*



THREE-WAY ENGINEERING LTD.

Mackenzie Lubberding, Tamara McPherson,
Andy Stewart, Max Leung, George Hill

PRODUCED BY: E18

4/8/2018

**Date:** April 8th, 2018

University of British Columbia Campus and Community Planning

UBC SEEDS (Social Ecological Economic Development Studies) Sustainability Program

**Attention:** Krista Falkner, David Gill

**Subject:** Corridor Redesign of Chancellor Boulevard

Dear Ms. Falkner and Mr. Gill,

We are very excited to submit 3-Way Engineering Ltd.'s Final Design for the Corridor Redesign of the Chancellor Boulevard at UBC. With extensive experience in transportation engineering that has seen us complete numerous high-profile transportation projects in the Metro Vancouver and the Pacific Northwest of the United States. Our firm's experience will be seen in the quality and original thought behind the following design.

This corridor redesign presented unique challenges in its demand for new, innovative methods being required to calm traffic and increase the pedestrian use and safety along the corridor. The opportunity to design a cohesive design between the University of British Columbia's sustainability ideals and the needs of the British Columbia's Ministry of Transportation and Infrastructure presents an exciting opportunity for our company.

Our team has worked to ensure that the attached design is effective and efficient, both in cost and function. We look forward to the opportunity to discuss the design with you further.

Sincerely,

Three-Way Engineering Ltd.

THREE-WAY
ENGINEERING LTD.

# Table of Contents

## LIST OF FIGURES



## LIST OF TABLES

# EXECUTIVE SUMMARY

The transportation infrastructure that currently exists in the Chancellor Boulevard Corridor is either in a state of disrepair or it is not meeting the safety and functional needs of its users. The problem with upgrading this corridor is that as it is owned by the BC Ministry of Transportation and Infrastructure; UBC SEEDS must have a design that is able to prioritize safety, pedestrians and alternate transportation in the most cost effective manner possible in order to receive cost sharing. According to our modelling and research, a mix of modifications and upgrades to the corridor will significantly increase the safety, usage and efficiency of the corridor in a cost effective way.

To address the problems outlined above, Three-Way Engineering proposes the following:

1. Reduction of Traffic Speeds: Through the reduction in the number of lanes for motorized vehicles, there will no longer be vehicles travelling at higher speeds as they attempt to pass others. A posted speed limit of 50km/h is also planned to reduce overall speeds.
2. Increased Safety/Priority of Pedestrians, Cyclists and Buses: The conversion of the north set of lanes through the corridor into a pedestrian and cyclist pathway will separate the vehicle traffic and cyclists, making the corridor significantly safer and more desirable for the cyclists travelling to the University. By constructing bus stop pull-outs we are able to give buses the space they require without disrupting flow.
3. Increased Efficiency (Less stop-and-go): The removal of the signals at Hamber Road and the construction of a large raised traffic circle means that traffic will flow without stoppage, and at "rush hour" periods there will be less overall congestion due to signals.
4. Future Demand: Every aspect of the modifications and upgrades in the corridor have been designed with the future expected usage of the corridor in mind. The final product will be able to handle the next 10 years of traffic with minor needs for typical roadway repairs.

In order to successfully complete this project with minimal disruptions to traffic and produce a final product that will have the ability to meet current and future demands, a budget of approximately $6,600,000 is required.

# 1.0 INTRODUCTION

The project that Three-Way Engineering (TWE) has been tasked with is the redesign of the existing Chancellor Boulevard. This is an extension of West 4th Avenue and serves as one of five access roads to the University of British Columbia (UBC) campus. The corridor is subject to a variety of transportation modes including, cars, trucks, construction vehicles, and bikes, as well as pedestrians using the beautiful Pacific Spirit Park which surrounds the road. It has been suggested that this project will need to have the potential to increase safety, better manage future traffic demands, as well as increase recreation opportunities around the area. The design which has been produced by TWE addresses all of these criteria while providing new opportunities for recreational activities in and through the corridor.

## 1.1 PROJECT BACKGROUND

UBC has identified this corridor as an outdated, inefficient and unsafe. The corridor is currently owned and operated by the BC Ministry of Transportation and Infrastructure, and consists of two lanes travelling in each direction. The main issue with this is that the roadway does not currently encourage transportation by bike or by foot. The boulevard is bordered by Pacific Spirit Park on the north side, which consists of many different trails that are used by both locals of the area, as well as tourists. With the current design of the roadway, most users are averaging a speed well over the posted limit, creating an unsafe variance in travel speeds as well as a hazard to cyclists on the roadway. The only pathway currently designated for pedestrians is located on the north and south sides of the corridor, and has very poor ground conditions for cyclists as it is not properly paved. Most cyclists who use the corridor travel in the shoulder which is very unsafe due to the high travel speeds of the roadway's users.

Included in the design for this project will be a pedestrian and cyclist underpass, located at a point along the corridor. There is currently no easy and safe way for pedestrians and cyclists to cross the road, as there is only one set of lights located at Hamber Road. Below is an aerial view of the existing corridor, showing both the Acadia and Hamber intersections. The project boundaries for this redesign are from just west of Drummond Drive to just west of Acadia Road.


**Figure 1: Chancellor Boulevard Existing Conditions**

## 1.2 PROJECT OBJECTIVES

The main objective of this redesign project is to accommodate for future travel demands that will prioritize cyclists and pedestrians, as well as busses. A significant increase in safety for the users of the corridor will also be of utmost importance to the design of this project. Although the budget is not a huge constraint to this project, TWE intends to minimize the cost of construction.

Another important aspect of the project is contributing to UBC's sustainability initiatives and sustainable design standards in every way possible. TWE will be getting involved with other UBC faculties, including Arts and Forestry. Having these faculties help with a few of the non-technical aspects of the design will support community engagement and add creativity to the design.

The boulevard is located within the University Endowment Lands boundaries, which means that various consultations must be made before the beginning of construction to ensure the satisfaction of all stakeholders. TWE will be engaging early in the design process with everyone involved and impacted by the redesign, including the First Nations.

## 1.3 SUMMARY TABLE AND CONTRIBUTIONS

The following table indicates each team member's contributions to the development of this report.

**Table 1: Project Team Contributions**

| Project Aspect | Contributing Member(s) |
|---|---|
| **Overall Design** | All |
| **Underpass** | George Hill |
| **Utilities** | Tamara McPherson |
| **Traffic Circle / Traffic Modelling** | Max Leung |
| **Retaining Structures** | Andy Stewart |
| **Pedestrian Pathway** | Max Leung/Mackenzie Lubberding |
| **Pedestrian Crossings** | Mackenzie Lubberding |
| **Bicycle Intersection** | Andy Stewart/Mackenzie Lubberding |
| **Corridor Model (3D)** | George Hill |
| **Scheduling** | Mackenzie Lubberding |
| **Cost Estimate** | Max Leung (et. al.) |
| **Report Section** | **Contributing Member(s) – Written By** |
| **Executive Summary** | Andy Stewart |
| **Introduction** | Andy Stewart |
| **Key Issues** | Mackenzie Lubberding |
| **Methodology** | Mackenzie Lubberding |
| **Final Design: Design Overview** | Mackenzie Lubberding |
| **Final Design: Multi-Use Pathway** | Mackenzie Lubberding |
| **Final Design: Traffic Circle** | Max Leung |
| **Final Design: Underpass** | Mackenzie Lubberding |
| **Final Design: Retaining Structures** | Andy Stewart |
| **Final Design: Bicycle Intersection** | Andy Stewart/Mackenzie Lubberding |
| **Final Design: Underground Utilities** | Tamara McPherson |
| **Lighting and Signalization** | Max Leung |
| **Road and Pathway Painting** | Max Leung |
| **Roadway Signage** | Max Leung |
| **Tie-In to Existing Infrastructure** | George Hill |
| **Design Analysis: Synchro Modelling** | Max Leung |
| **Design Analysis: Retaining Structures** | Andy Stewart |
| **Scheduling** | Mackenzie Lubberding |
| **Cost Estimate** | Max Leung (Tamara McPherson provided data) |
| **Report Summary** | Mackenzie Lubberding |
| **Appendix A** | George Hill |
| **Appendix B** | Andy Stewart |
| **Appendix C** | Max Leung |
| **Appendix D** | Tamara McPherson |
| **Appendix E** | Tamara McPherson |
| **Appendix F** | Tamara McPherson |
| **Appendix G** | Mackenzie Lubberding |
| **Appendix H** | Max Leung |
| **Appendix I**<br>**DWGS 001 – 00Y** | 001 – 003 George Hill<br>004 – 006 Andy Stewart<br>007 – 00X Max Leung<br>00X – 00Y Tamara McPherson |

Final Formatting has been completed by Andy Stewart.

## 2.0 KEY ISSUES

The biggest challenge in the redesign of this roadway is to minimally affect the surrounding environment. Pacific Spirit Park is very well used and TWE wants to assure that all trails will be able to be used both during and after the completion of construction. It is very important that none of the existing natural environment becomes altered, as this would affect recreationalists in the area and would also have an impact on the wildlife.

Having a minimal disruption to stakeholder traffic is extremely important to TWE. The entire construction schedule will be designed to prevent a major disruption in traffic along the boulevard. It will be proposed for the construction to be completed during the spring and summer months, when UBC students are not in classes and there is less congestion in the area. Having to use a detour route the whole time the corridor is under construction would be very frustrating for road users, and therefore TWE plans to have the road closed to public for only one and a half months.

# 3.0 METHODOLOGY

## 3.1 MAJOR CONSTRAINTS

Chancellor Boulevard leads through the beautiful Pacific Spirit Park, which is used as a recreational area for many people. This results in a huge project constraint, as it is critical that the existing natural environment remains untouched and is not harmed during construction. The project was designed with this in mind and it will be made sure that the construction crews are made aware of the importance of this.

Another constraint for this project is the fact that this corridor serves as a major entrance to the UBC campus and sees high volumes of traffic on a daily basis. This creates the need to complete construction as quickly as possible, so that major traffic reroutes are not needed for long periods of time.

## 3.2 DESIGN CRITERIA

There are a few key design criteria that were kept in mind throughout the design process, as the success of the project is based off of these goals being achieved. These design criteria are as follows:

- Corridor should be designed to accommodate all future traffic demands
- Drainage improvements should be considered and included in the design
- Design should give priority to buses, cyclists and pedestrians
- Safety should be maximized, and costs should be minimized

The design is required to address engineering issues related to all disciplines including transportation, structural, geotechnical, materials as well as environmental considerations. Another important criterion was the contribution to promoting sustainable transportation options at UBC.

## 3.3 STANDARDS AND SOFTWARE

A number of standards, by-laws, guidelines, best practices and software packages assist engineers with the design and implementation of projects. The following list outlines the major standards and software packages which were utilized by TWE during the design of this project.

- AutoCAD
- RoadEng Civil
- Synchro Studio
- Microsoft Excel (utilities analysis)

- Minnesota Bikeway Design Manual
- Seattle Pavement Markings
- Towards a Canadian Standard for the Geometric Design of Speed Humps (Phillip A. Weber, P. Eng.)
- Soil Mechanics and Foundations – 3E (Budhu)

### 3.4 DESIGN STEPS

TWE began by analyzing the current state of the roadway and identifying major flaws and areas that are needed to be improved. Preliminary traffic counts were performed to gain an idea on what sort of traffic volumes will be using the corridor during peak hours. This data was then put into Synchro to model the traffic flows and calculate demands.

Three design options were originally created. Each of the three options shared certain commonalities as well as various differences. The three design options were analyzed based on their cost, environmental impact, safety and overall ability to accommodate all travel demands. After carefully considering each option a final design option was chosen. Further detail and design was put into the chosen option and CAD drawings were created for each key design component. This report presents the completed final design.

## 4.0 FINAL DESIGN

### 4.1 DESIGN OVERVIEW

The following section gives a high level overview of the corridor redesign. Following the overview of the aspects of design, the next section will outline the key components of the final design, followed by a look at the engineering analysis which has gone into the design of various components.

#### 4.1.1 MULTI-USE PATHWAY

The multi-use pathway exists on the north side of the corridor and includes both cyclist and pedestrian paths. The main goal kept in mind when designing this pathway was the increase in safety for its users. The current corridor is a dangerous road for cyclists, as most people drive well over the posted speed limit, and there is no designated bicycle lane. With the pathway being completely separated from vehicle lanes, users should feel a lot more comfortable and safe and this should promote a higher usage of the area.

### 4.1.2 VEHICLE ROADWAY

One of the key objectives of this re-design project was to increase the safety throughout the corridor, which will come with a reduction in vehicle speed. For that reason, the vehicle lanes will be reduced from two lanes in each direction to one lane and will both be located on the south side of the corridor. This will greatly reduce the average travel speed throughout the corridor because users will no longer be able to pass one another. Vehicle drivers will be much more aware of their travel speed when driving on a two-way road, and will also be forced to be more cautious.

### 4.1.3 UNDERPASS

The underpass was designed with three key goals: Safety, Usage, and Community Value. Users should feel safe using the underpass and therefore the underpass meets Crime Prevention through Environmental Design Guidelines (CPTED). Usage is important because otherwise pedestrians and bikes will decide to jaywalk. Increased usage is a benefit as well for increasing the natural surveillance of the area in line with CPTED guidelines. Community Value is important because the community needs to feel as though the infrastructure integrates with the community and encompasses community values. Encouraging non-vehicular transportation modes and allow for local artwork and living gardens are both ways that the underpass contributes to the Community and provides Community Value.

### 4.1.4 INTERSECTIONS

This section gives a brief overview of the key components at each intersection throughout the corridor.

#### 4.1.4.1HAMBER ROAD

The intersection at Hamber Road features a few key components. These components can be seen in Figure 2.

- Roundabout for vehicular traffic
- Underpass for bike and pedestrian traffic
- New bus pads
- New multi-use pathway access to the school

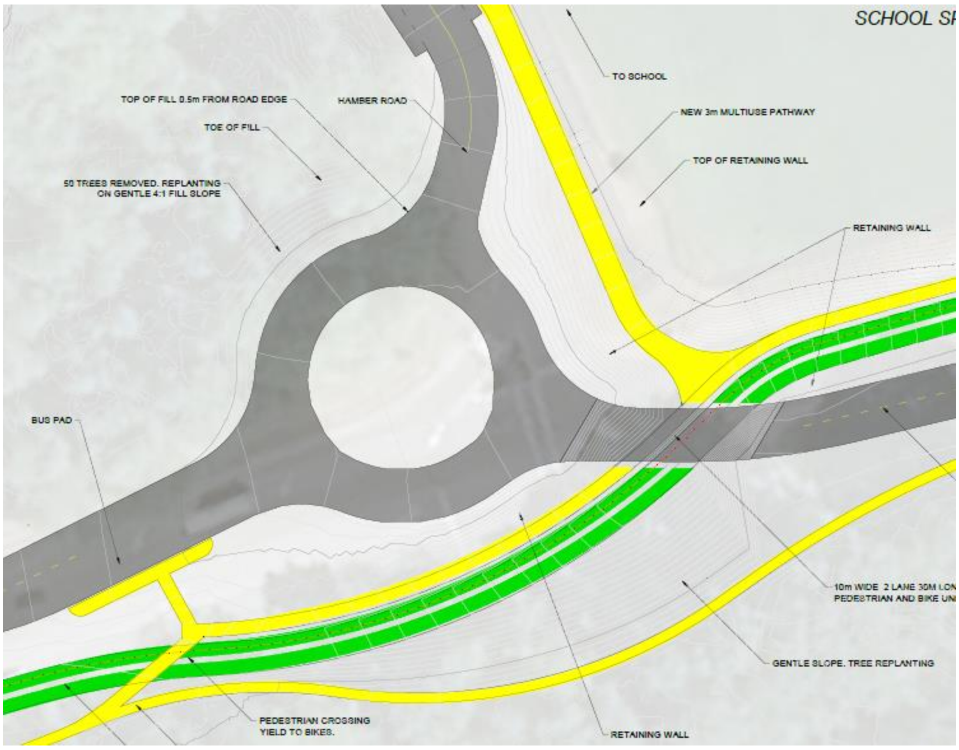



**Figure 2: Hamber Road Intersection**

The roundabout was chosen to encourage traffic flow through the intersection even with high volumes occurring in the morning and evening rushes tied to the elementary school. The roundabout additionally serves as a speed control device. Currently vehicles have no motivation to reduce to the 50 km/h speed limit when travelling westbound on the corridor as traffic is very typically free-flow with the intersection at Hamber maintaining a flashing green light for the majority of its daily operation. The roundabout adds a horizontal alignment change that forces drivers to slow down and if the driver is to exceed the speed limit after they exit the roundabout, they will need to purposely accelerate to that speed. This is in contrast to the current conditions where a driver can maintain a high speed into the residential area.

New bus pads are provided with the new design such that they will tie into the new pedestrian pathways. The new multi-use pathway lies immediately beside the school field and increases safety by reducing the interactions of pedestrians and vehicles on Hamber Road. It additionally benefits school users as it reduces the distance from the intersection to the school.

#### 4.1.4.2 DRUMMOND DRIVE

Drummond Drive is located on the east end of the project boundaries and acts as the border between Chancellor Boulevard and West 4$^{th}$ Avenue. This is where the project will tie in to the existing road network, with no improvements designed for this intersection.

#### 4.1.4.3ACADIA ROAD

Acadia Road marks the west end boundary for the scope of this project, but TWE has proposed that the new design be extended all the way through to East Mall. At this intersection, both cyclists and pedestrians will be travelling across Acadia Road on the south side of Chancellor. Drivers will be required to come to a complete stop, as stop signs will be installed on both the north and south sides of the multi-use pathway. These stop signs will have flashing lights that will notify drivers in advance that they are coming up to a pedestrian and cyclist crossing.

#### 4.1.4.4 TRAIL CROSSINGS

There are three trail crossings within the project boundaries: Salish trail crossing and both Spanish trail crossings. There are currently no existing crosswalks and it can be seen that a lot of illegal crossing takes place at these trail crossings. TWE has decided to install pedestrian crosswalks at each of these trail crossings that will be flasher controlled as to only disrupt traffic flow when there is a pedestrian crossing. These crosswalks will also be raised above road level, with the intention of slowing vehicular traffic down coming into the pedestrian crossings. A detailed description will be presented in section 4.7.

## 4.2 MULTI-USE PATHWAY

As previously mentioned, the multi-use pathway will be located on the north side of the corridor. It will begin just west of Drummond Drive, and extend through all the way to East Mall. There will be two bike lanes of 2m width and one pedestrian pathway of 2m width. The current roadway is 8m wide, so this efficiently uses the space and will leave room for a small separation between lanes. The existing gravel pathway on the south side of the corridor will remain in place but will be re-surfaced with new asphalt. Once the underpass at Hamber Road is reached, the multi-use pathway will cross the corridor using the underpass and will continue along the south side of the corridor. This serves as a benefit to all users who are traveling to UBC, as it allows for a safe and easy access of the campus. The design is shown in the figure presented below. The cyclist lanes are drawn in green and the pedestrian paths are drawn in yellow.

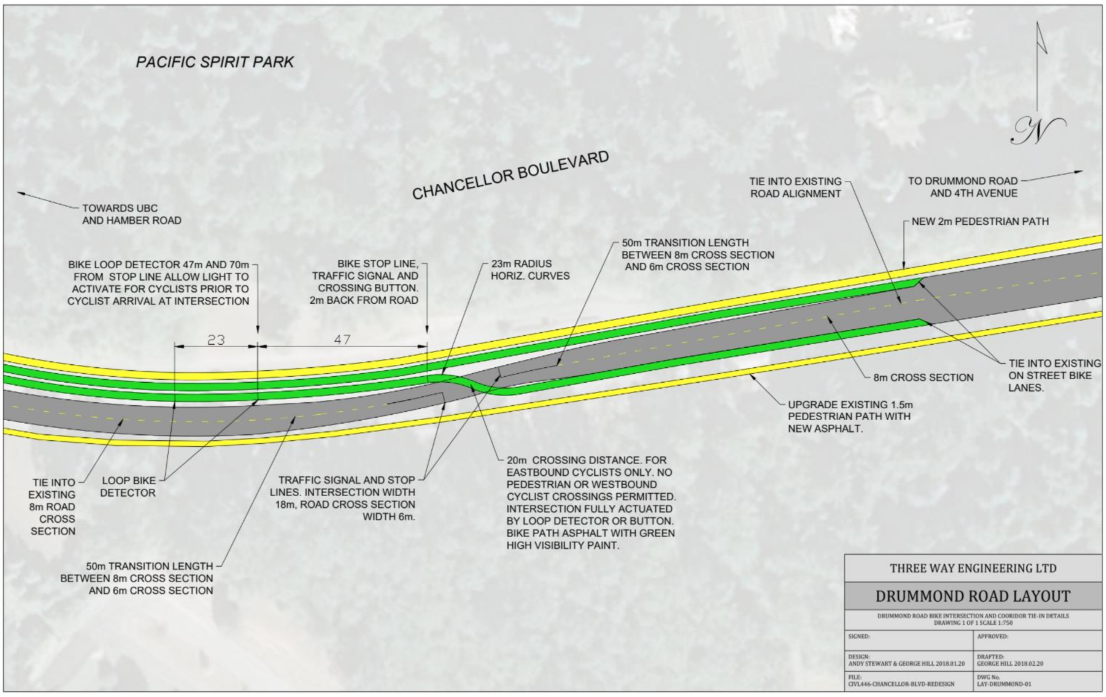



**Figure 3: Bicycle Intersection Plan View**

The painting of this multi-use pathway will follow the Transportation Design Guidelines of Vancouver.

## 4.3 TRAFFIC CIRCLE

The roundabout at Chancellor Boulevard and Hamber Road has been designed to allow free flowing while preventing the possibility of collision between vehicles. As noted, pedestrians and cyclists will not access the roundabout at grade as they will utilize the underpass that has been specifically designed for their usage. Thus, there are no crosswalks or any infrastructure to assist cyclists and pedestrians. Through Three-Way Engineering's technical traffic analysis using Synchro 6 software, a one lane minimum roundabout shall suffice. However, it was understood from the analysis that during peak school travel times in the morning and afternoon, a significant number of vehicles access Hamber Rd from Chancellor Blvd to University Hill Elementary School. Therefore, the entrance at the westbound approach has been split to two lanes (3.2 meters in width) to allow the left to access the roundabout to the westbound exit and the right lane to momentarily enter the roundabout before exiting onto Hamber Rd. The entrance at the Hamber Rd approach will merge onto the roundabout and after travelling approximately 15 meters, drivers can select inner lane to continue around the roundabout or take the outer lane to exit onto Chancellor Blvd towards the westbound direction. Similarly, the entrance at eastbound Chancellor Blvd will merge on to the roundabout and select the inner lane to exit onto Hamber Rd or make a U-turn back onto Chancellor Blvd towards the westbound direction. Alternatively, vehicles can take the outer lane to exit onto Chancellor heading in the eastbound direction on Chancellor Blvd. As depicted in Appendix C, the proposed roundabout design is a mixture of a single lane and double lanes roundabout that intends to allow seamless connection and avoid collisions at entrances and exits.

### 4.3.1 ROUNDABOUT GEOMETRIC ELEMENTS

The roundabout at Hamber Rd and Chancellor Blvd has an inscribed circle diameter (ICD) of 44 meters with a raised central island that is 26 meters in diameter. The outer edge of the circulatory roadway and central island is constructed with the combined curb and gutter in accordance with the BC Ministry of Transportation and Infrastructure Standard Specifications for Highway Construction. The central island has a maximum height of 0.5 meters at the center and a slope of 2% towards the apron. Landscaping such as grass and flowers are placed at the central island to provide aesthetic benefits. The low profile apron surrounding the raised central island is 1 meter in width, which meets the minimum 1 meter clearance identified in the BC Supplement to Transportation Association of Canada (TAC) Geometric Design Guide. The slope of the apron is approximately 2% away from the central island. Mountable curb and gutter is utilized for the apron and the curb height is 50 millimeters. The apron is constructed with stamped concrete cobblestone patterns to improve visibility during both day and night conditions. The circulatory roadway width is 9 meters with certain areas of the roundabout split into two lanes that are 4.5 meters in width. The total width of the roadway and apron is 10 meters, which satisfies the minimum necessary width of 10 meters for the WB-20 design vehicle according to TAC standards. While the roundabout has been designed to accommodate the largest frequent design vehicle side by side with a passenger car, it is not expected that there will be many trucks will access the corridor as it will be mainly utilized by buses and passenger vehicles. Conforming to the Geometric Design Guide for Canadian Roads, the roundabout entry width is within the range of 4 meters to 8 meters. The raised splitter islands at the entrances and exits are designed to separate the entering and exiting vehicles and prevent vehicles from travelling the roundabout in a clockwise direction. The roundabout has been designed so that the entry angles of all entrances range from 20 to 60 degrees. The purpose of the splitter islands at the entrances and exits are to deflect traffic and help reduce vehicle speeds at the approaches. The splitter island curbing is also designed to snowplow activity in the event of snowfall. The structure of the splitter islands and central island is constructed with concrete. Figure 4 depicts the geometric elements of the roundabout according to BC Supplement to TAC Geometric Design Guidelines. The dimensions for the roundabout design can be found in Figure 5.

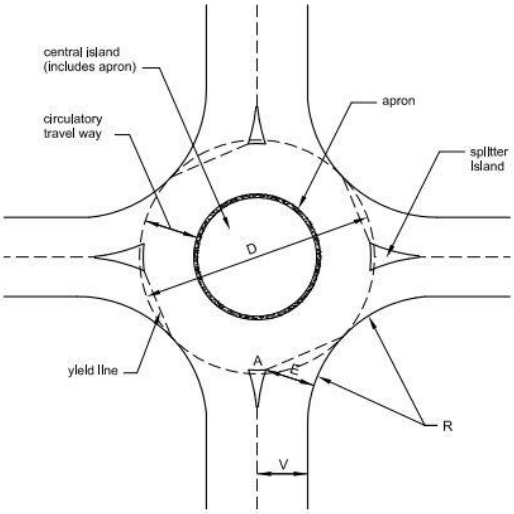



Figure 4: Geometric Elements of a Typical Roundabout (BC Supplement to TAC Geometric Design Guidelines)

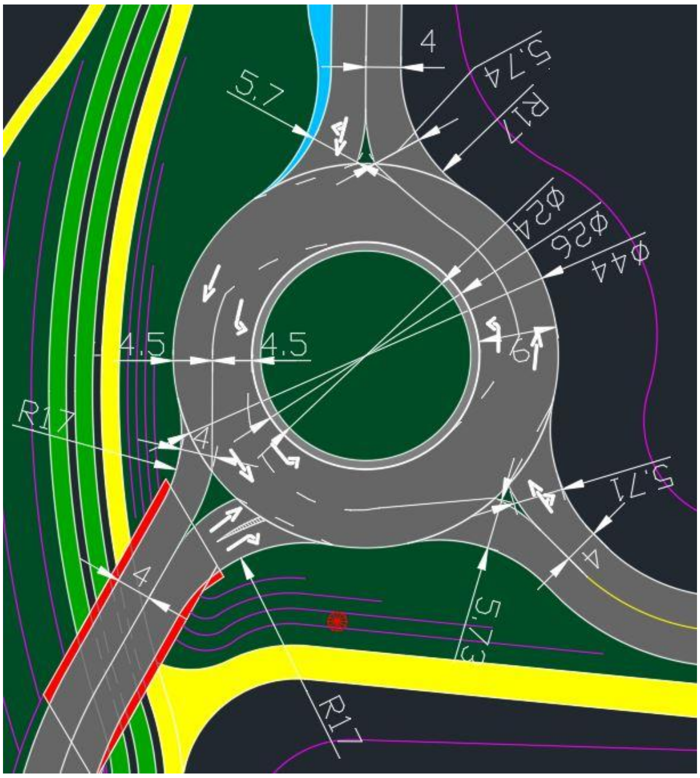



Figure 5: Dimensions for the Proposed Roundabout Design

### 4.3.2 ROUNDBOUT SIGNAGE AND ROAD MARKINGS

To warn drivers that they are approaching a roundabout, W-17 roundabout signs are installed at all approaching legs approximately 60 meters from the yield lines. According to the Geometric Design Guide for Canadian Roads, the designed roundabout is categorized as large roundabout in an urban setting; therefore, the recommended entry speed is 40km/hr. Thus, Three-Way Engineering has lowered the speed limit at the roundabout to 40 km/hr. W-22 posted speed limit signs with a speed of 40 km/hr are placed directly below the roundabout signs. Incoming traffic at the entrances must yield to traffic inside the roundabout. R-2 Yield signs are placed on the left at the splitter islands and on the right of the entry. They are placed approximately 0.5 meters to 1 meter from the edge of the road. At the approach end of the splitter islands, R-14 R Keep Right signs are installed to alert drivers to keep right in advance of the splitter islands. R6-4 counterclockwise direction signs are installed at the central island in the line of vision of incoming vehicles for all roundabout entrances. Lane configuration signs are installed in the roundabout and at the westbound Chancellor Blvd approach. The design of the lane configuration sign along with the locations or which they are installed can be found in c

All the pavement markings within the roundabout and at the approaches are designed according to the BC MOTI Manual of Standard Traffic Signs & Pavement markings. The solid white lines within the roundabout, which are 100 mm in width, denote that lane changes are prohibited. The broken white lines (100 mm width) are guiding lines that allow lane changes. The straight, right, left, and straight and right arrows in the roundabout and at the approaches are designed according to standards. The approach entrance yield lines are designed to help prevent the collisions as incoming vehicles shall be behind the line and only access the roundabout when deemed safe. The roundabout design with signage and pavement markings can be found in Appendix C.

### 4.1.2 SAFETY CONSIDERATIONS

When designing the roundabout, the following safety aspects were considered: angle between legs, gradient and visibility of entering and exiting vehicles. For the high-flow entry points apparent at the westbound Chancellor Boulevard approach, a larger angle was designed from the nearest exit. The gradient was kept at 2% or less to ensure that the grade will not influence vehicle traffic at the roundabout. To improve visibility for all vehicles accessing the roundabout, there will be no vegetation or infrastructure extending above the minimum line of vision from the vehicle at the splitter islands. The signage and vegetation and the center of the roundabout will also maintain a maximum height of 1 meter to avoid visually impairing drivers.

## 4.4 UNDERPASS

The pedestrian underpass is located just east of the traffic roundabout at Hamber road. The main goal of this underpass is to increase safety for cyclists and pedestrians, as well as to improve the flow of traffic around the area at all hours of the day. The feature itself acts as an underpass as pedestrians and cyclists will cross under the road, but there will actually be a timber bridge structure installed on ground level to allow vehicles to drive over the underpass. TWE chose to design a timber bridge as oppose to a steel structure as it fits the existing surrounding environment better. The bridge structure will be pre-fabricated before it is brought to site and installed.

The timber bridge spans a length of 30m and is 10m in width. It consists of 8, 24F-E D.FIR-L 315x1330x30000 GLT girders that are supported by concrete strip footings. The girders are held together by 4, 50x50L steel diaphrams. On top of the girders sits a No.2 D-FIR.L 86x1000x10000 GLT deck. Underneath the deck and above the steel diaphrams are 37x100 typ. gauge beams that are installed parallel to the road surface. A small layer of concrete primer, wire mesh and waterproof membrane lays on top of the timber deck to prevent damage from wet conditions. The road surface itself is the final layer of this design and is fabricated from 40-90mm plant- mix asphalt. There is a drainage pipe installed on each side of the bridge structure which will serve as direct drainage to a catch basin below.

The timber bridge structure is shown in Figure 6. The underpass itself consists of 2 cyclist lanes and 1 pedestrian lane, all of which are 2m wide with a 1m gap between each. The lanes will flow smoothly from the north side of the corridor under the timber bridge and continue on the south side of the corridor. The complete dimensions can be seen in Figure 7, and all structural calculations for this design can be found in Appendix A.

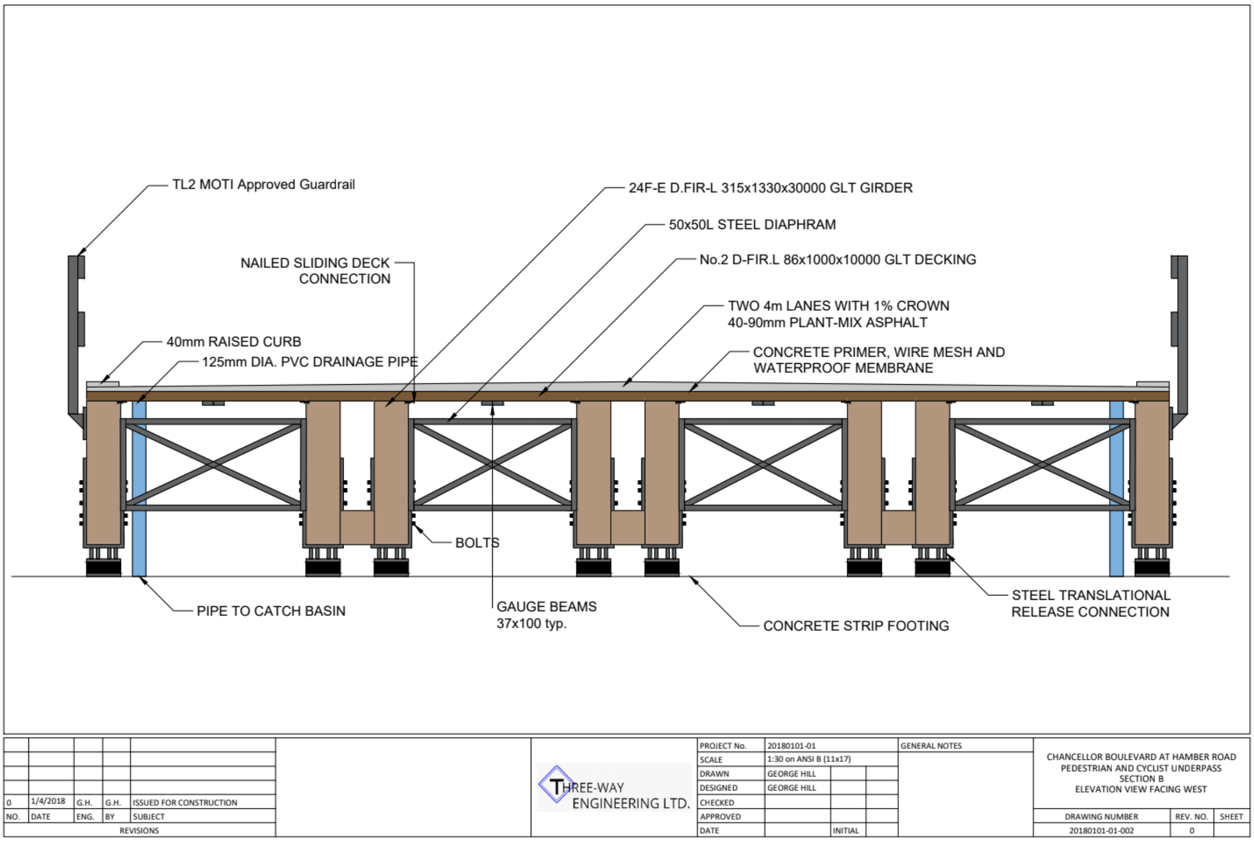
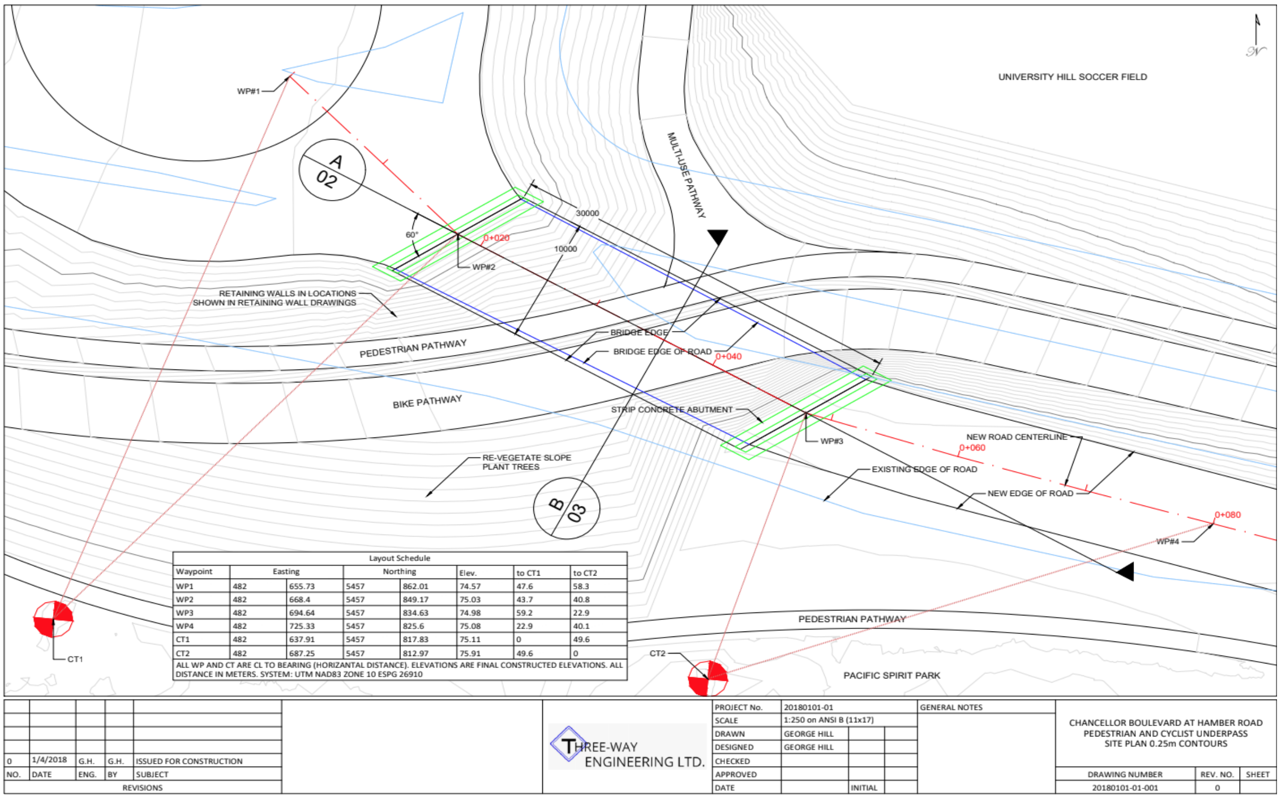



**Figure 6: Bridge Cross-Section**




Layout Schedule

| Waypoint | Easting | | Northing | | Elev. | to CT1 | to CT2 |
|---|---|---|---|---|---|---|---|
| WP1 | 482 | 655.73 | 5457 | 862.01 | 74.57 | 47.6 | 58.3 |
| WP2 | 482 | 668.4 | 5457 | 849.17 | 75.03 | 43.7 | 40.8 |
| WP3 | 482 | 694.64 | 5457 | 834.63 | 74.98 | 59.2 | 22.9 |
| WP4 | 482 | 725.33 | 5457 | 825.6 | 75.08 | 22.9 | 40.1 |
| CT1 | 482 | 637.91 | 5457 | 817.83 | 75.11 | 0 | 49.6 |
| CT2 | 482 | 687.25 | 5457 | 812.97 | 75.91 | 49.6 | 0 |

ALL WP AND CT ARE CL TO BEARING (HORIZANTAL DISTANCE). ELEVATIONS ARE FINAL CONSTRUCTED ELEVATIONS. ALL DISTANCE IN METERS. SYSTEM: UTM NAD83 ZONE 10 ESPG 26910

**Figure 7: Bridge Dimensions**

### 4.1.3 GEOTECHNICAL CONSIDERATIONS

The current design around Hamber Road will require cuts for the underpass and fills for the roundabout. These cuts and fills are balanced such that all material cut excluding stripping will be used as fill materials. Cross Sections in Appendix C show the cut and fill area for the roundabout, the bike and pedestrian paths and the underpass. Fills will be required to be constructed in compacted lifts as per the engineering drawings to be produced at the detailed design stage. Materials used for the road fill will be required to meet a specific gradation range and will additionally be as per the detailed designs. Ballast Walls for the underpass will be designed such that they will withstand the design pressures.

## 4.5 RETAINING STRUCTURES

Due to the proximity of the lowered pathway around the new roundabout being installed at Hamber, there are a few locations where the combination of steep soil slopes as well as surcharges at the top of the slope require there to be retaining structures in place. The image below outlines the area where the three variations of Mechanically Stabilized Earth (MSE) Retaining Walls will be installed.

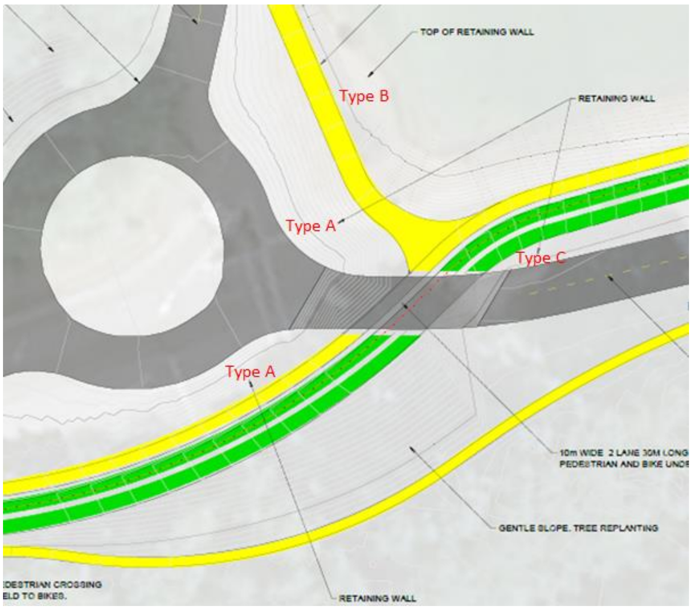



**Figure 8: Retaining Wall Locations**

The MSE retaining walls will utilize a geotextile membrane with a wide-width tensile strength of 60kPa. This geotextile will resist the lateral loading on the retaining wall through increased lateral friction resistance. A detailed calculation of the three variations of retaining wall designs can be found in Appendix B. The simplest retaining structure will be installed adjacent to the University Hill Elementary School's soccer field, on the north-east side of the underpass pathway. The detailed design of this wall can be found in the image below.

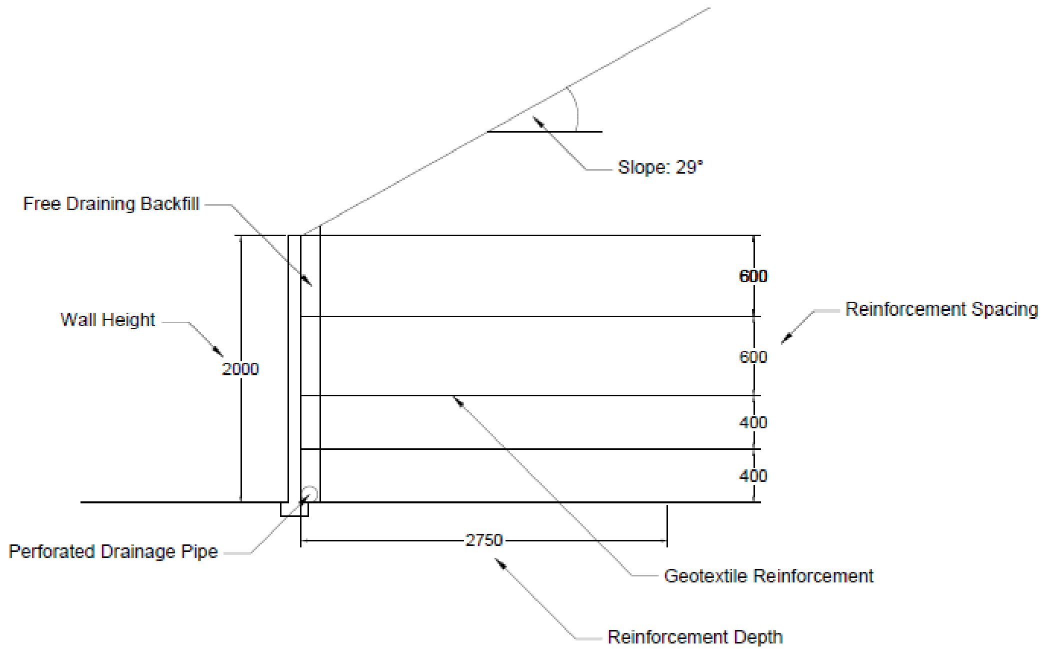



**Figure 9: MSE Retaining Wall - Type B**

The retaining wall drawings found in Appendix I, are designed for the most severe reinforcement scenario in its length, and the wall height will remain constant as the pathway and lower ground elevation rises to meet its height along the length of the pathway. It should be noted that geotextiles suffer a reduction of strength due to ultraviolet light exposure. As construction is taking place outside, special care must be taken not to expose the material to sunlight more than is absolutely necessary in order to maintain its high tensile strength.

A second design component to the retaining walls is the installation of a perforated drainage pipe and the bottom of the wall, lying beneath free draining backfill. This piping will convey water from behind the wall, away from where it can cause instability and into the stormwater network.

Aesthetically, the retaining walls will have a living wall system installed on the outer face. This will allow for sustainable agriculture practices to take place in addition to providing test locations for studies by UBC on the implementation of plant life in underpasses to increase overall public perception of underpasses at twighlight and nightime hours.

## 4.6 BICYCLE INTERSECTION

Located just west of the pioneer trail crossing is the bike crossing, which takes cyclists from the south side of the road to the north side, or vice versa. The goal of this feature is to have cyclists travelling on the same side of the road, to maximize use of the pedestrian underpass located just east of Hamber. Incorporated into the design of this bike crossing is a loop detection system, which allows cyclists to cross the corridor without having to come to a stop. Once a cyclist is detected by the system, the lights will change as to stop vehicle traffic and allow for the cyclist to safely cross the road.

There was a series of calculations performed to reach a proper phasing and timing cycle for this system. Firstly, the intergreen period for cars was found using the following formula:

$$I = t_r + \frac{V}{2fg} + \frac{W_c + L}{V}$$

Where,

tr: perception- reaction time (s)
V: vehicle speed (m/s)
f: pavement friction
g: 9.81 m/s2
Wc: width of intersection (m)
L: length of vehicle (m)

The intergreen period was calculated as 5.3s, which was rounded up to 6s. This was then split into 4s of amber and 2s of all-red.

The minimum bicycle clearance time was calculated as the length of the bike crossing plus the length of a bike with a buggy, all divided by the average speed of a cyclist. The length of a bike with a buggy was taken as 3m, and the average cyclist speed used was 7.6 m/s. This resulted in a bicycle clearance time of 2.83s, which was rounded up to 3s as this is the minimum clearance as per the Seattle guidelines. The bike crossing is shown below in Figure 8.

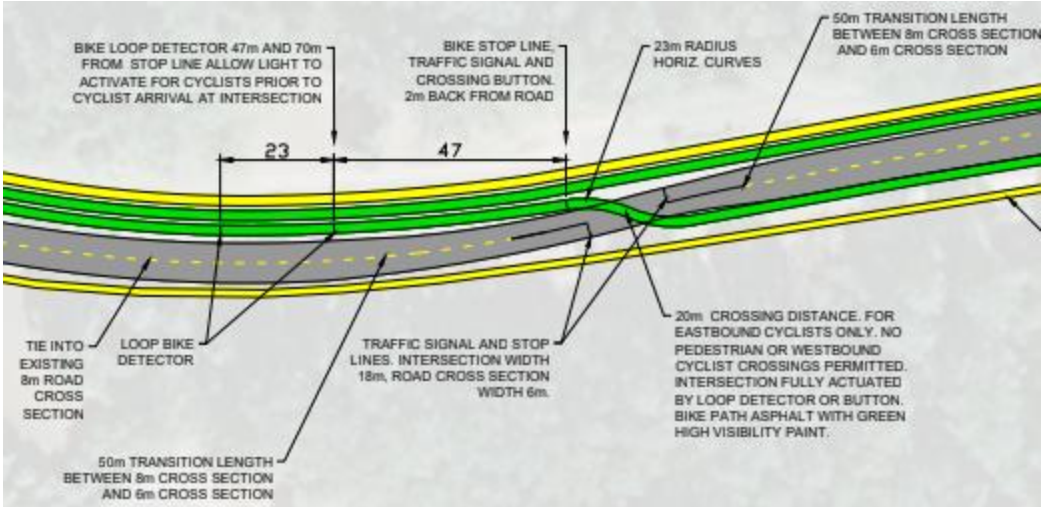



**Figure 10: Bike Intersection**

Stopping sight distance (SSD) for cyclists was calculated using the same formula that was used for vehicles, except the average cyclist speed was used as oppose to vehicle speed. The result of this was 16.5m, and the distance travelled during the yellow phase was added to achieve a distance of 47m.

## 4.7 PEDESTRIAN CROSSWALKS

The final design incorporates three pedestrian crosswalks into the corridor, each of which is located at a trail crossing. When studying the current state of the corridor, it was noticed that there are a few areas along the corridor where pedestrians are constantly crossing the road illegally. These spots where located at each of the trail crossings: pioneer trail, and both of the Spanish trail crossings. The goal of the flashers is to increase safety for pedestrians, while causing a minimal disruption to traffic as they will only be activated when a pedestrian is present.

Calculations were performed for these crossings to find the stopping sight distance (SSD) for vehicles, as well as the pedestrian clearance time. The SSD was found using the following formula:

$$SSD = vt_r + v^2/2f_xg$$

Where,

$t_r$: reaction time taken as 1s
v: design speed taken as 50 km/hr

$f_x$: coefficient of friction taken as 0.5
g: 9.81 $m/s^2$

The SSD was calculated to be 33.36m, which is the distance needed for a car to come to a complete stop once they realize that they need to stop. The pedestrian clearance time is simply calculated as the distance the pedestrian has to travel, divided by the velocity of the pedestrian. The total travelling distance is 26.25ft and the average velocity of a pedestrian was taken as 4 ft/s, which results in a pedestrian clearance time of approximately 7 seconds. With an included factor of safety in the design, the pedestrian flashers will run for a minimum of 10 seconds.

Table 2: Recommended Speed Humps for Bus Routes

**Table 7.8**
**Recommended Speed Humps for Bus Routes**

| Desired Speed (km/h) | Hump-Crossing Speed (km/h) | Speed Hump Dimensions (m, mm) (ft, in.) |
|---|---|---|
| 30 | 25 | 6.1 x 100 (20 x 4) |
| 40 | 35 | 8.8 x 100 (29 x 4) |
| 50 | 45 | See Below |

Another feature of these crosswalks is that they will actually be raised above road surface. The reference used for the design of the raised crosswalks was a thesis paper from Carleton University. As seen in Table2, they were designed as a trapezoidal speed hump with a desired speed of 30 km/hr. Due to the Chancellor corridor being a bus route, the bus route dimensions were used for the design. This is intended to slow down traffic within the corridor even when pedestrians are not present, as it causes an awareness of travel speed. A cross section of the crosswalks is shown below in Figure 11.

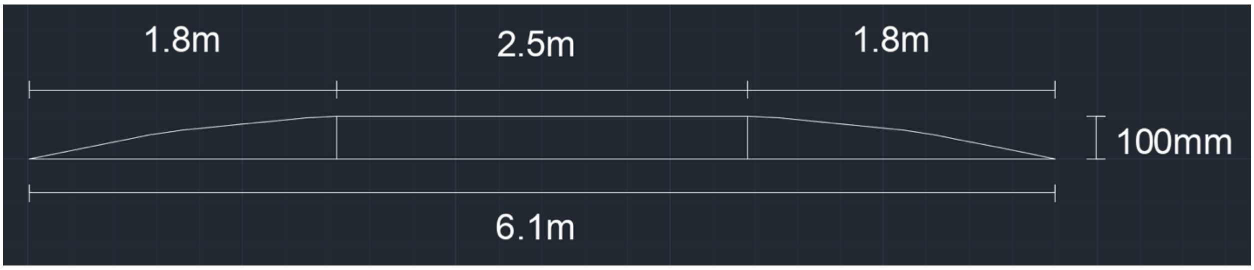



**Figure 11: Raised Crosswalk Cross-Section**

## 4.7 UNDERGROUND UTILITIES

In conjunction of the Chancellor Boulevard Corridor redesign, TWE has developed a master drainage plan and have sized a minor storm sewer network for the proposed design that will adequately convey up to the 1:5-year return period storm under free flow conditions. The objective of this task is to minimize inconvenience and maximize the safety by eliminating frequent surface runoff on the roadway and pedestrian/cyclist pathway. The deliverables include the following:

1. A figure showing the storm sewers, manholes, catch basins and service connections required to convey the 5-year design storm;
2. A table showing the design flow calculations for each pipe, selected pipe size, and resulting capacity
3. A table showing the proposed inverts, ground elevation, depth from road, and street/pipe slopes
4. Overland surface flow measures for the 1:100-year return period storm event

From corridor drainage perspective and capacity evaluation, the stormwater drainage system for the catchment area in subject was analyzed using the methodology described in Section 5.2.3: Methodology of Analysis from the Surrey Design Criteria. All storm drains that have a calculated peak flow in excess of the flow at pipe capacity will be classified as overcapacity and require an increased pipe size, increased slope, or both. Starting every pipe diameter at the existing pipe size, the pipes that had a flow capacity over 100% were upsized until the design criteria was met. The design loadings table of each storm network can be found in Appendix F.

Seeing how the proposed corridor redesign utilizes the existing roadway where possible, most of the existing storm network could be reused. Only 2 pipe upgrades were required for the proposed corridor parking lot, from manholes ESMH5 to ESMH7, increasing from 300mm to 375mm in diameter. Additionally, a new storm network system was designed to successfully drain runoff for the underpass/roundabout at Hamber Rd and the existing storm utilities are to be demolished. The existing storm utility networks to the west of the proposed roundabout and east of Spanish trail could be reused.

The plan view drawings of the entire corridor can be found in Appendix D, as well as a profile of the storm network system at the roundabout from PSMH2 to PSMH5.

### 4.7.1 STORMWATER FLOW GENERATION

The Rational Method was used to calculate flows in the sub-catchments because the total catchment area was less than 20 hectares (Ha). Rainfall data from the Surrey Kwantlen Park's rainfall gauges was used for the flow generation and the following data interpolated from the IDF curve was used in design calculations for the 1:5 and 1:100 year storm events.

**Table 3: IDF Curve Data**

| | R-mean (mm/hr) | A Coefficient | B Coefficient |
|---|---|---|---|
| 5 Yr | 24.0 | 17.286 | 29.158 |
| 100 Yr | 43.7 | -0.520 | -0.564 |

Rational formula below was used to calculate peak discharge from the drainage basin runoff and the formulas used in design can be found in Appendix F.

The tributary drainage areas from each storm main were established using the 1-metre contours from the City of Vancouver's online GIS database (VanMaps). The runoff coefficients for UEL's zoning were determined from equivalent City of Surrey zoning using a worst-case scenario runoff coefficient of 0.3 for parks and 0.8 for Hamber Elementary School. Table 4: Runoff Coefficients shows the runoff coefficients used for 1:5 and 1:100 year storm events and their equivalent impervious ratio. Table 3: Weighted Runoff Coefficient can be seen following where it shows how the corridor runoff coefficient was calculated, as it varies in surface type.

**Table 4: Runoff Coefficients**

| Zoning ID | City of Surrey's Equivalent Zoning | % Imperviousness | Runoff Coeff. (5yr Event) | Runoff Coeff. (100 yr Event) |
|---|---|---|---|---|
| RES2 | Single Residential | 50 | 0.45 | 0.54 |
| POSNA | Parks, Playgrounds, Cemeteries, Agricultural Land | 20 | 0.25 | 0.30 |
| CRUM1 | Commercial | 90 | 0.80 | 0.95 |
| INST | Institutional; School; Church | 90 | 0.80 | 0.95 |
| RES4 | Multiple Residential (15) RM-15 | 65 | 0.60 | 0.72 |
| RES5 | Multiple Residential (30) RM-30 | 65 | 0.60 | 0.72 |

Table 5: Weighted Runoff Coefficient

| Corridor Section (Typical) | Asphalt/Cement | Grass |
|---|---|---|
| Catchment Area (m^2) | 2187 | 1073 |
| Total Catchment Area (m^2) | 3260 | |
| Runoff Coefficient (5yr) | 0.9 | 0.3 |
| Weighted Runoff Coefficient (5yr) | 0.703 | |

The Time of Concentration (Tc) is defined as the required time for stormwater runoff to travel the longest distance (meaning longest travel time) towards the point of interest and is used in determining the design rainfall intensity. The equation used to calculate Tc can be found in Appendix F.

As per requested in the Surrey Design Criteria, the following maximum/minimum Time of Concentration's were used for the developed basin in Deep Cove.

Table 6: Time of Concentration Constraints

| Developed Area (m^2) | Minimum Tc (mins) | Maximum Tc (mins) |
|---|---|---|
| **Less than 2,000** | 10 | 15 |
| **2,000 to 4,000** | 15 | 20 |
| **More than 4,000** | 15 | 30 |

### 4.7.2 STORM SEWER DESIGN

#### 4.7.2.1 PIPE SIZING

As noted in the City of Surrey Design Criteria, the following minimum sewer sizes were met.

Table 7: Minimum Pipe Sizes

| Pipe Description | Min Pipe Size (mm) |
|---|---|
| **Catch basin leads** | 200mm |
| **All Storm sewers in zones and land-uses** | 250mm |
| **Where ditches discharge directly into storm sewer** | 375mm |

Using the recommended pipe supplier of BestPipesBestPrice, storm sewer pipes were designed from the following pipe size product selection.

Table 8: Pipe Product Sizes

| Pipe Diameters | $ / lineal metre |
|---|---|
| 200mm | $125 |
| 250mm | $140 |
| 300mm | $160 |
| 375mm | $165 |
| 450mm | $180 |
| 600mm | $240 |

#### 4.7.2.2 PIPE & MANHOLE LOCATIONS

Where possible, storm sewers were located under the right or left hand side of the roadways to accommodate future construction of sanitary sewers, water mains, and outside utilities in the corridor.

Manhole locations in the proposed storm sewer design have met the following requirements outlined in the City of Surrey Design Criteria:

- A maximum 150metres apart
- At the top end of all terminal sewers
- At every alignment change or change in grade
- All sewer confluences and junctions (except those with interceptor sewers)

#### 4.7.2.3 PIPE DEPTHS & GRADING

On the following page is a table including the following information for each manhole in the proposed storm sewer system: Depth constraints outlined in the City of Surrey Design Criteria, manhole road elevations, invert elevations, pipe depth, and general comments on the design.

Table 9: Manhole Road Elevations, Inverts, and Depths

| Depth | |
|---|---|
| Constraint Description | Cover (m) |
| Min Ideal | 1.5 |
| Max: Ideal | 3.0 |
| Min: Not in Roadways/Driveways | 1.0 |
| Max: no service connections | 4.5 |

| MH# | Road Elev. (m atm) | Invert Elev. (m atm) | Depth (m) | Comments |
|---|---|---|---|---|
| ESMH1 | 80.00 | 78.50 | 1.50 | min ideal |

| | | | | |
|---|---|---|---|---|
| ESMH2 | 77.25 | 75.75 | 1.50 | min ideal |
| ESMH3 | 75.00 | 73.50 | 1.50 | min ideal |
| ESMH4 | 73.75 | 72.25 | 1.50 | min ideal |
| ESMH5 | 73.25 | 71.75 | 1.50 | min ideal |
| ESMH6 | 73.25 | 70.25 | 3.00 | max ideal |
| ESMH7 | 73.75 | 69.25 | 4.50 | no service connections |
| ESMH8 | 74.10 | 72.60 | 1.50 | min ideal |
| ESMH9 | 75.20 | 73.70 | 1.50 | min ideal |
| ESMH10 | 77.00 | 75.50 | 1.50 | min ideal |
| ESMH11 | 78.50 | 77.00 | 1.50 | min ideal |
| ESMH12 | 74.40 | 72.90 | 1.50 | min ideal |
| ESMH13 | 75.00 | 73.50 | 1.50 | min ideal |
| PSMH1 | 75.80 | 74.30 | 1.50 | min ideal |
| PSMH2 | 71.00 | 70.00 | 1.00 | not in roadway (under sidewalk) |
| PSMH3 | 71.90 | 69.84 | 2.06 | ideal |
| PSMH4 | 73.60 | 69.64 | 3.96 | no service connections |
| PSMH5 | 73.20 | 69.35 | 3.85 | no service connections |
| PSMH6 | 74.80 | 71.80 | 3.00 | max ideal |

The next table contains the pipe grading constraints used for the propsed system for various sewer sizes, following the pipe lenghts, road grades, and pipe grades for each piep in the proposed system.

**Table 10: Pipe Lengths, Road Grades & Pipe Grades**

| Grade | | | |
|---|---|---|---|
| Sewer Size | Min | Constraint | Comments |
| CB leads (200&250) | 1.00% | min slope | |
| 300mm | 0.22% | min slope | Consultant to confirm (if less than 0.4%) |
| 375mm | 0.15% | min slope | Consultant to confirm (if less than 0.4%) |
| 450mm | 0.12% | min slope | Consultant to confirm (if less than 0.4%) |
| 525mm and larger | 0.10% | min slope | Consultant to confirm (if less than 0.4%) |
| Most US sewer | 0.40% | min slope | Unless approved by Engineer |
| Any Size | <15% | min slope | Include anchoring system |

`

| Pipe | Length (m) | Road Elev. From | Road Elev. To | Road Grade (%) | Invert From | Invert To | Pipe Grade (%) | Comments |
|---|---|---|---|---|---|---|---|---|
| ESMH1-ESMH2 | 84.2 | 80 | 77.25 | 3.3% | 78.5 | 75.75 | 3.3% | `Good |
| ESMH2-ESMH3 | 90.9 | 77.25 | 75 | 2.5% | 75.75 | 73.5 | 2.5% | Good |
| ESMH3-ESMH4 | 90.9 | 75 | 73.75 | 1.4% | 73.5 | 72.25 | 1.4% | Good |
| ESMH4-ESMH5 | 90.0 | 73.75 | 73.25 | 0.6% | 72.25 | 71.75 | 0.6% | 600mm – Good |
| ESMH5-ESMH6 | 46.9 | 73.25 | 73.25 | 0.0% | 71.75 | 70.25 | 3.2% | Good |
| ESMH6-ESMH7 | 9.6 | 73.25 | 73.75 | -5.2% | 70.25 | 69.25 | 10.4% | Good |
| Outfall 2 | | | | | | | | |
| ESMH11-ESMH10 | 87.0 | 78.50 | 77.00 | 1.7% | 77.00 | 75.50 | 1.7% | Good |
| ESMH10-ESMH9 | 87.30 | 77.00 | 75.20 | 2.1% | 75.50 | 73.70 | 2.1% | Good |
| ESMH9-ESMH8 | 86.9 | 75.20 | 74.10 | 1.3% | 73.70 | 72.60 | 1.3% | Good |
| ESMH8-ESMH7 | 31.4 | 74.10 | 73.75 | 1.1% | 72.60 | 69.25 | 10.6% | Good |
| Outfall 2 | | | | | | | | |
| PSMH1-PSMH2 | 89.9 | 75.80 | 71.00 | 5.3% | 74.30 | 70.00 | 4.8% | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **PSMH2-PSMH3** | 28.6 | 71.00 | 71.90 | -3.1% | 70.00 | 69.84 | 0.6% | 450mm – Good - Profile Included |
| **PSMH3-PSMH4** | 31.8 | 71.90 | 73.60 | -5.3% | 69.83 | 69.64 | 0.6% | 600mm – Good - Profile Included |
| **PSMH4-PSMH5** | 48.30 | 73.60 | 73.20 | 0.8% | 69.64 | 69.35 | 0.6% | 600mm – Good - Profile Included |
| **PSMH5-Outfall 3** | 21.00 | 73.20 | - | - | 69.35 | 69.2 | 0.7% | |
| **Outfall 3** | | | | | | | | |
| **ESMH12-PSM6** | 54.9 | 74.40 | 74.80 | -0.7% | 72.90 | 71.80 | 2.0% | Good |
| **ESMH6-PSMH5** | 37.9 | 74.80 | 73.20 | 4.2% | 71.80 | 69.35 | 6.5% | Good |
| **Outfall 3** | | | | | | | | |
| **ESM13-PSM6** | 39.4 | 75.00 | 74.80 | 0.5% | 73.50 | 71.80 | 4.3% | Good |
| **Tie-In to PSMH6** | | | | | | | | |

#### 4.7.2.4 PIPE VELOCITIES

Due to the topography in the area, the required minimum pipe velocity of 1.0m/s was easily achieved for all storm sewers in the proposed system. Although, a few pipe velocities at capacity are greater than 3.0m/s: ESMH6-ESMH7, ESMH8-ESMH8, PSMH6-PSMH5, ESMH13-PSMH6. For these pipes an appropriate analysis was done to prevent sewer displacement and pipe durability concerns. Energy dissipation measures are to be done to prevent scour and control the flow velocity. The following is a table of each pipe flow and velocity at peak flow and at capacity.

**Table 11: Pipe Flow and Velocities at Peak Flow and Capacity**

| Manhole | | Flow | | Sewer Design | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Q(5)** | **Q(100)** | **Pipe Slope** | **Pipe Dia.** | **Manning's "n"** | **Q Cap.** | **V Cap.** | **Pipe Length** |
| **From** | **To** | (L/s) | (L/s) | % | (mm) | | (L/s) | (m/s) | (m) |
| **ESMH1** | **ESMH2** | 23.84 | 38.10 | 3.3% | **200** | 0.013 | 59.26 | 1.89 | 84.2 |
| **ESMH2** | **ESMH3** | 40.04 | 64.00 | 2.5% | **200** | 0.013 | 51.59 | 1.64 | 90.9 |
| **ESMH3** | **ESMH4** | 58.25 | 93.10 | 1.4% | **250** | 0.013 | 69.73 | 1.42 | 90.9 |
| **ESMH4** | **ESMH5** | 75.32 | 120.38 | 0.6% | **375** | 0.013 | 130.68 | 1.18 | 90.0 |
| **ESMH5** | **ESMH6** | 80.50 | 126.70 | 3.2% | **375** | 0.013 | 313.48 | 2.84 | 46.9 |
| **ESMH6** | **ESMH7 (OF2)** | 137.10 | 224.35 | 10.4% | **750** | 0.013 | 3583.40 | 8.11 | 9.6 |
| | | | | | | | | | |
| **ESMH11** | **ESMH10** | 20.13 | 31.69 | 1.7% | **250** | 0.013 | 78.08 | 1.59 | 87.00 |
| **ESMH10** | **ESMH9** | 41.40 | 66.17 | 2.1% | **250** | 0.013 | 85.38 | 1.74 | 87.30 |
| **ESMH9** | **ESMH8** | 57.51 | 91.93 | 1.3% | **250** | 0.013 | 66.90 | 1.36 | 86.90 |
| **ESMH8** | **ESMH7 (OT2)** | 79.47 | 127.02 | 10.6% | **250** | 0.013 | 193.69 | 3.95 | 31.40 |
| | | | | | | | | | |
| **PSMH1** | **PSMH2** | 19.37 | 30.49 | 4.8% | **250** | 0.013 | 129.98 | 2.65 | 89.90 |
| **PSMH2** | **PSMH3** | 70.22 | 111.76 | 0.56% | **450** | 0.013 | 213.25 | 1.34 | 28.60 |
| **PSMH3** | **PSMH4** | 70.22 | 297.24 | 0.60% | **600** | 0.013 | 474.61 | 1.68 | 31.80 |
| **PSMH4** | **PSMH5** | 223.14 | 360.58 | 0.60% | **600** | 0.013 | 475.77 | 1.68 | 48.30 |
| **PSMH5** | **Outfall 3** | 223.14 | 360.58 | 0.7% | **600** | 0.013 | 518.93 | 1.84 | 21.00 |
| | | | | | | | | | |
| **ESM12** | **PSM6** | 20.52 | 32.80 | 2.0% | **250** | 0.013 | 84.17 | 1.71 | 54.90 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **PSM6** | **PSM5** | 79.18 | 124.62 | 6.5% | **375** | 0.013 | 445.31 | 4.03 | 37.90 |
| | | | | | | | | | |
| **ESM13** | **PSM6** | 39.05 | 61.46 | 4.3% | **375** | 0.013 | 364.02 | 3.30 | 39.40 |

### 4.7.3 CATCH BASINS

Where possible, catch basins were provided at regular intervals along roadways, at the upstream end of the radius at intersections and at all low points on the roadways. Catch basins were spaced based on the hydraulic requirements to capture the 5-year peak flow with a maximum drainage area of 500 square metres for road slopes less than 3% and 350 square metres for road slopes greater. In general, most the road slopes were less than 3% and the following equation was used.

$$\# \, Catch \, Basins = Total \, Road \, Catchment \, Area \, (m^2)/500m^2$$

In order to ensure no flooding of the pedestrian/cyclist underpass, a few additional catch basins were added at the lowest contour of the underpass as well as just before the ramps, allowing redundancy of the system. A few additional catch basins and catch basin relocations were required in the corridor to unsure sufficient drainage of both the road pedestrian/cyclist pathways and all changes can be found in the plan view drawings located in Appendix D.

### 4.7.4 DITCH

The existing ditch system located on the north and south sides of the corridor is currently used to convey storm runoff from Pacific Spirit Park to the existing outfalls. The ditch is also used as a corridor drainage capacity solution for when storm mains are full at the 1:100-year storm event and surface runoff can be drained to the ditch rather than ponding on the roadway. Most of the ditch located on the north side of the corridor was re-used excluding the required offset of 12.0m north at the parking lot located west of Pioneer Trail. The ditch on the south side of the corridor required an offset of 4.3m south to accommodate the pedestrian pathway. An additional ditch catch basin was added on the north side, east of the underpass, to catch all surface runoff and ensure soil near the structural components of the underpass and roundabout stay dry.

### 4.7.5 STORM OUTFALLS

Outfalls 1 and 2 located at Spanish Trail and west of Pioneer Trail, respectively, were re-used for the proposed corridor redesign. Outfall 3, located at Hamber Rd. was extended roughly 45m north of its existing outlet to accommodate the location of the roundabout and also achieve sufficient grading of the gravity drainage system.

### 4.7.6 SANITARY SEWERS

The only sanitary sewer in the project scope is currently running south to north across Chancellor Boulevard, running along Hamber Rd. to service the Hamber Elementary School and ties-in to a combined sewer downstream that "outfalls" on Marine Drive. Due to the proposed underpass location and traffic circle, a relocation of the 380mm sanitary main was required because its existing alignment currently runs through the underpass ramp. The proposed 380mm sanitary sewer alignment is to run along the roadway west of the traffic circle, follow the proposed roadway of Hamber Rd. and tie-in to the existing sanitary system just downstream. The abandoned sanitary sewers running across Chancellor Bld. and Hamber Dr. are to be removed to accommodate the underpass construction and abandoned sanitary sewers upstream of Chancellor Bld. in Pacific Spirit Park are to be capped and filled. No impact was done on the loading of the sanitary sewers so a detailed analysis was not required by TWE. All changes to the sanitary sewer system were design in accordance to the City of Surrey Guidelines, similar to the proposed storm network and the detailed drawings can be found in Appendix E.

### 4.7.7 WATER MAINS

It is standard that water mains are to be located underneath the sidewalk to prevent traffic disruption when completing an upgrade or service connection installation. The proposed design utilizes the existing paved road on the south side of the corridor, east of the underpass, and the north side of the corridor, west of the underpass. Therefore, majority of the water mains in the project scope were to City of Surrey Design Criteria standard. The proposed underpass conflicts with the water main servicing Hamber Elementary School but a simple relocation solution to run along the proposed roadway in the area. No impact was done on the loading of the water main network and a detailed analysis was not required by TWE. A detailed drawing of the proposed changed can be found in the drawings in Appendix E.

## 5.0 ADDITIONAL DESIGN ASPECTS

### 5.1 LIGHTING AND SIGNALIZATION

As per BC Hydro's initiative to transition BC's entire street lighting system to LED type lighting, all the lighting to be implemented in the project will use LED fixtures. This type of lighting will provide significant advantages over traditional lighting including but not limited to increased efficiency and reduced light pollution. The planned lighting and signal systems for the different sections of the corridor are broken down into their respective roles below:

Pedestrian Path Lighting: Lighting along the pedestrian pathway in the main section of the corridor will be forgone in an effort to maintain the natural environment curated by Pacific Spirit Park through the reduction of light pollution.

Pedestrian Crossing Lighting: At each of the three pedestrian crossings at pathway access points to Pacific Spirit Park there will be pedestrian operated flashers as well as lighting for improved safety at all crossing points. This will combine with the use of Rectangular Rapid Flashing Beacons (RRFB) at the pedestrian crossings which will be lit to stop traffic only when required by pedestrians waiting to cross.

**Figure 12: Example pedestrian crossing utilizing RRFB signals**

Cyclist Crossing Lighting: The cyclist intersection to be placed just West of Drummond Drive will use LED lighting as mentioned above. This will also be the location furthest East in the corridor that continuous lighting will be found as lighting will only be used at pedestrian crossings between the bike intersection and the traffic circle at Hamber Road. The signal system at the bike crossing will use traffic lights specific to bike traffic need as determined by the loop detection system to be installed in the bike path on both the East and West approaches to the intersection.

Figure 13: Example Bike Intersection Signaling (Not Pictured: Red Traffic Signal)

Street Lighting: Continuous LED street lighting will be utilized from the east most portion of the project until the bike intersection and then resumed just East of the multi-use underpass until the western end of the project boundary (including the traffic circle).

Underpass Lighting: The underpass will be using bright white LED lighting to simulate day-time brightness throughout the day in order to reduce shadowing and throughout the night to discourage loitering in dimly lit areas. The lighting used throughout the tunnel will be continued for a number of meters past the mouth of the tunnel to provide a safe perimeter of lighting around the underpass.

## 5.2 ROAD AND PATHWAY PAINTING

All the pavement markings along the corridor are designed according to the BC MOTI Manual of Standard Traffic Signs & Pavement markings. The solid white lines that are 100 mm in width, denotes that lane changes are prohibited. Crosswalk markings are located at the pedestrian crossing, which 3 meters in length and 0.6 meters in width according to MOTI standards. The broken white lines (100 mm width) designate that lane changes are allowed. The solid yellow lines (100 mm width) are directional dividing lines. The bus pullouts will have bus restricted lane markings that are aligned with MOTI standards. The specific road markings for the roundabout are presented in the detail in the roundabout section.

## 5.4 ROADWAY SIGNAGE

In addition to the road signage near and at the roundabout, additional signs are needed along the corridor. All the road signage is in accordance with BC MOTI Manual of Standard Traffic Signs & Pavement Markings. W-22 speed limit signs are located at the entrances of the corridor and will be installed approximately 300 meters apart along Chancellor Boulevard. The speed limit of the corridor has been set at 50 km/hr. Approximately 50 meters from the pedestrian crosswalk in each direction, SP-2 Pedestrian Crosswalk Ahead signs are installed for both pedestrian crosswalks at the trails. Prior to the bike crossing near Drummond Rd, WC-7 Bike Crossing Ahead signs will be installed to notify drivers. At the ends of the corridor, G-125 Bike Lane Ends and G-124 Bike Lane Begins signs are installed to inform cyclists using the corridor. At the entrances of the bus pull out areas, a combination of the R-103 Except Buses (below) and R-9 Do Not Enter sign (above) is installed.

## 5.5 TIE-IN TO EXISTING INFRASTRUCTURE

A very key part of the design is that it must properly tie in with the already existing parts of the roadway on either end. This was something that was kept in mind and considered throughout the entire design process. On the east end of the corridor near Drummond Drive, there is a bike lane that already exists on both sides of the roadway. The re-designed bike lanes will be directly tied into the existing ones, with a bike crossing being located just west of Drummond Drive. Also already existing is a pedestrian walking path on both sides of the corridor, the issue being that they are very rough gravel paths. They will be properly paved and the tie in will occur just west of Drummond drive. This can be seen in Figure 12 below.

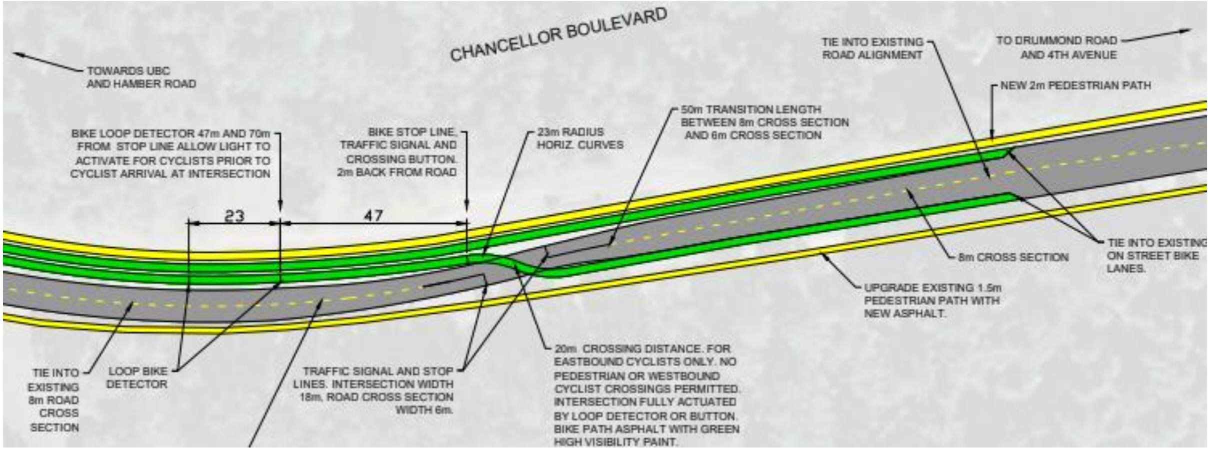



**Figure 14: Drummond Drive Tie-In**

For the west tie in, it is important that the upgrades for this project be completed after the East Mall to Acadia Road section is completed. These works are herein described as Phase 1 with this project as Phase 2. Previous capstone years completed designs for Marine Dr. and East Mall intersections and the Chancellor Blvd and Wesbrook Mall intersections, however for the vision of this project, only the Marine Drive and East Mall work with the project. The modified Marine Drive and East Mall intersection as designed by Liang et al. al. in 2016 is shown below in Figure XXX. The Chancellor Boulevard and Wesbrook Mall intersection will required a re-design with the vision of this project in mind. One potential solution is shown below in Figure XXX.

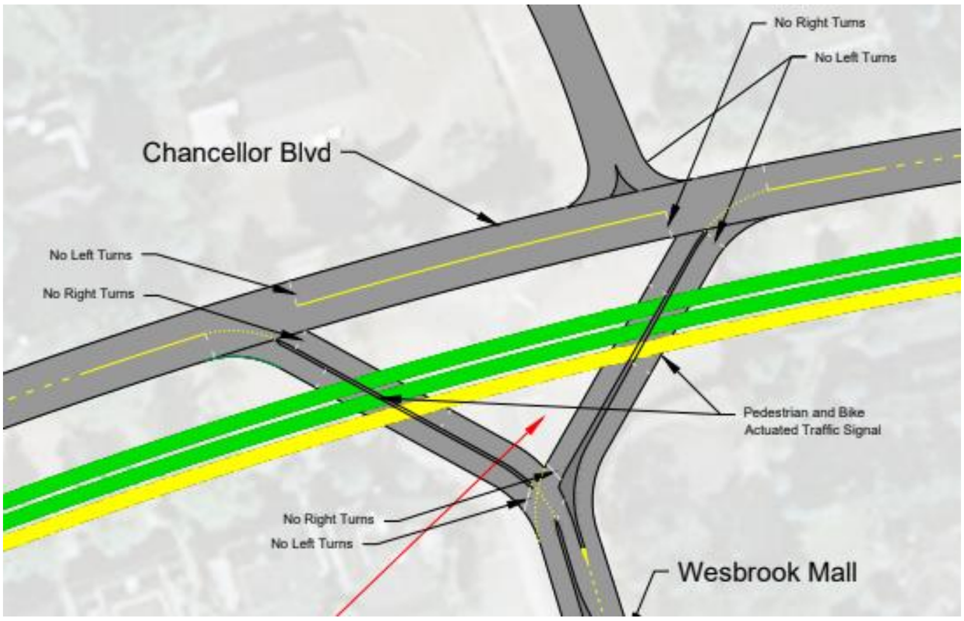



**Figure 15: Wesbrook Mall Conceptual Tie-In**

The above west-tie in works With Phase 1 complete, the bike lanes and pedestrian pathway crossing to the south side of Chancellor Boulevard will seamlessly connect to the new Phase 1 bike and pedestrian pathways, also, on the south side of Chancellor Boulevard.

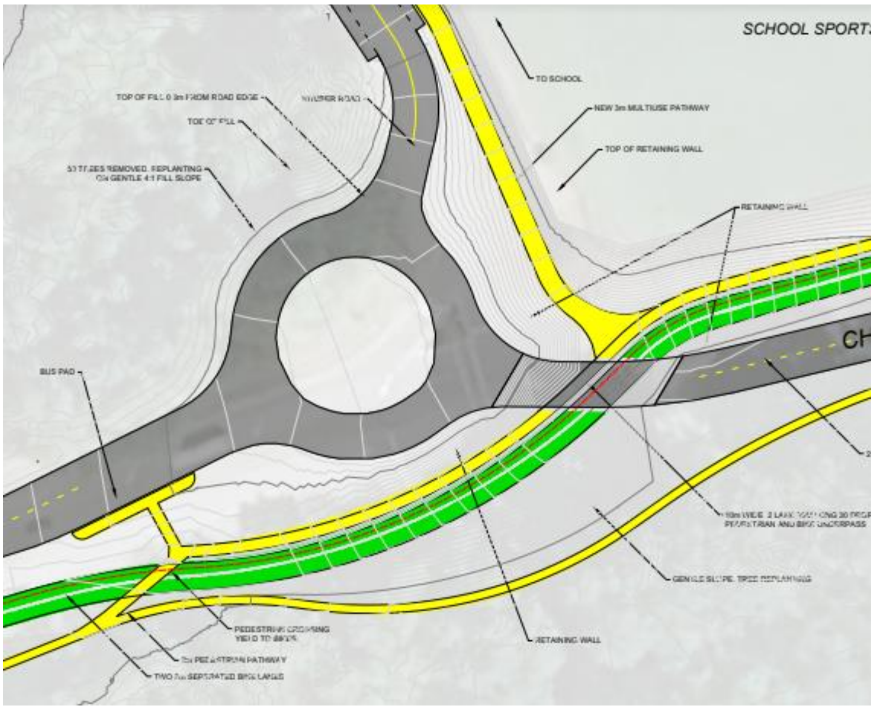



**Figure 16: Hamber Intersection**

The existing roadway on the west side of Hamber Road is narrowed due to a wide median and as part of Phase 1 will need to have the cross-section increased to accommodate two way traffic. The vehicular lanes of this project will connect to these lanes of Phase 1. It is recognized that Phase 1, was not within the project boundaries as initially set out by the client, however, without Phase 1 the main benefits of this project Phase 2, cannot be realized.

For the tie in at Hamber Road, both bike lanes will cross the road using the underpass, as well as the pedestrian pathway that is located on the north side of the corridor. This pedestrian path will tie into the already existing sidewalk on the south side of the corridor. Since the existing roadway on the west side of Hamber Road is narrowed due to a much wider median, the bike lanes will be both be moved to the south side of the road adjacent to the sidewalk. Although this is not within the project boundaries, it is proposed that this will continue until East Mall. An AutoCAD sketch of these designs is presented in Figure XX.

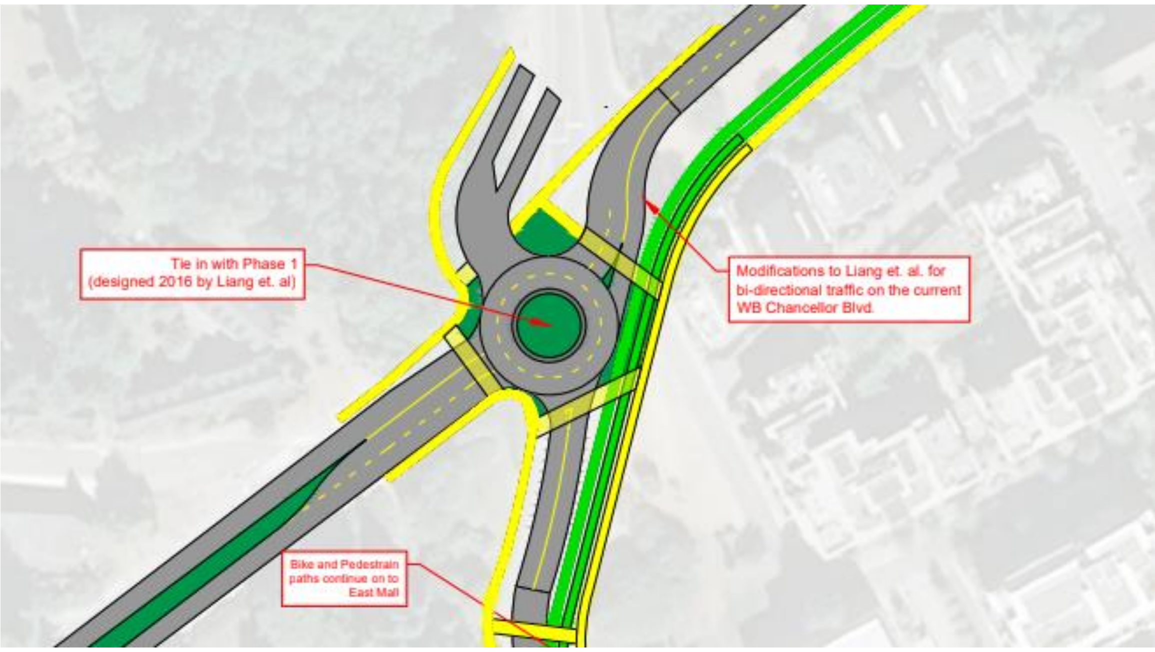



**Figure 17: East Mall Conceptual Tie-In**

# 6.0 DESIGN ANALYSIS

## 6.1 SYNCHRO MODELLING

Three-Way Engineering utilized the software application, Synchro 6, to analyze the traffic conditions based on present day traffic volume conditions for the proposed corridor design.

### 6.1.1 INPUT PARAMETERS

The Synchro Model has been created to reflect the purposed design. The entire corridor is one lane in each direction with a channelized left turn at Westbrook Mall and Chancellor Boulevard in the westbound direction. For the proposed design, only the intersection at Drummond Dr. and Chancellor Blvd has traffic lights with a pre-timed signal. Pedestrian activated signals are located are Pioneer Trail and Spanish Trail. Hamber Rd and Chancellor Blvd have been configured as a roundabout. Acadia Rd, Allison St, Western Pkwy and Westbrook Mall are all configured to allow through traffic on Chancellor Blvd but stop signs are located at the intersections for vehicles turning onto Chancellor Blvd. The Synchro model simulates pedestrians and cyclists' movements as the south side of Chancellor Blvd west of Hamber Rd will interfere with vehicles turning on Chancellor Blvd. The signal timings have been optimized using the optimization setting on the Synchro 6 software. The following are the key input parameters for the Synchro Model:

- Motor vehicles, pedestrians and cyclists' volumes are based on traffic volume counts conducted on November 7th, 2017 at 7:38 AM at Acadia Rd, November 8th, 2017 at 3:00PM at Hamber Rd and November 3rd at 10:15AM at Spanish Trail, Pioneer Trail and Drummond Dr.
- The peak hour factor inputted was calculated based by TWE staff
- Volume balancing was conducted for the corridor based on the traffic counts conducted by TWE staff

### 6.1.2 ASSUMPTIONS

The following assumptions are applied to the Synchro model:

Lane Window

- Lane widths are assumed to be 3.6 meters
- Right turning speed is 15 km/hr while left turning speed is 25 km/hr
- Grade % along this corridor is minimal; therefore, it is assumed to be 0%

Volume Window

- Heavy Vehicle Percentage is assumed to be 2%
- Assumed to have no bus blockages as the bus stoppages will be located at the bus bays
- There are no parked vehicles adjacent to the corridor
- An assumed growth factor of 1.4% annually has been applied to the model

### 6.1.3 RESULTS AND ANALYSIS

Based on the Synchro model results, all the unsignalized interesections (Westbrook Mall, Western Pkwy, Allison St, Acadia Rd, Hamber Rd, Pioneer Trail and Spanish Trail) have intersection level of service ratings of "A", which denotes that there are no volume to capacity issues. The utilization rate of the aforementioned intersections ranges between 25% to 45%. This is particularly important for the roundabout at Hamber Rd, which experiences the most motor vehicle traffic along the corridor. The level of service at Hamber Rd proves that the roundabout allows free-flow traffic and positively influences motor vehicle progression. For the pre-timed signal at Drummond Dr and Chancellor Blvd, a configuration of 65 seconds cycle length produces a level of service rating of a "B" and a volume to capacity ratio of 0.67. As such, there are no volume to capcity or level of service issues for the proposed design with only one lane in each direction on Chancellor Blvd. It must be noted that the Synchro software only analyzes the particular section for the proposed design and does not account for the efffects of the entire transportation network within the district or region.

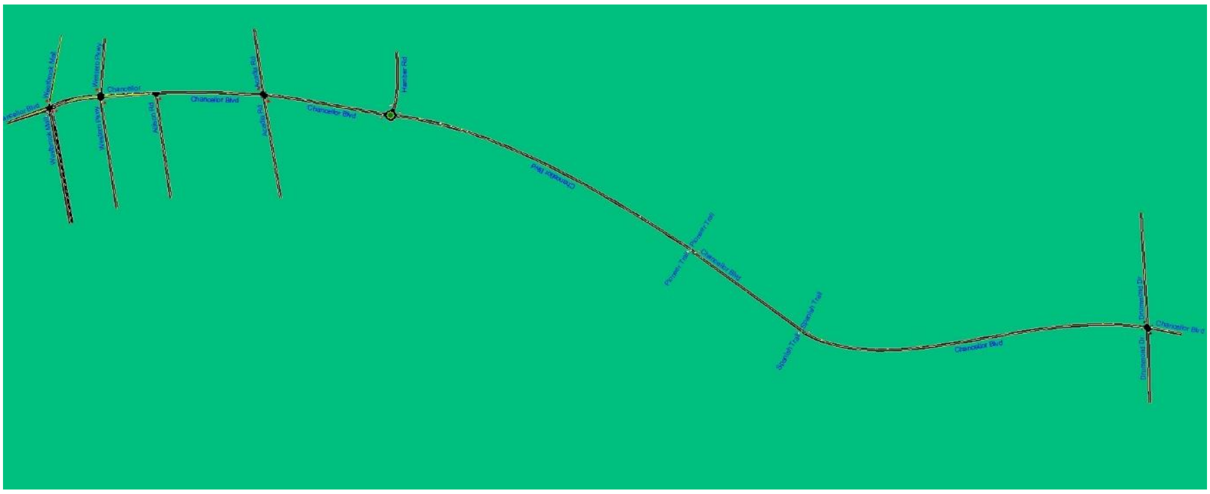


**Figure 18: Synchro Model**

## 6.2 RETAINING STRUCTURES

In order to calculate the required length and spacing of the geotextile reinforcement which gives the retaining wall its resistance to failure, a design process was established and followed for each loading scenario in the project's retaining wall designs. The process by which the design dimensions were determined is outlined below following the process found in Budhu, 2011. The implementation of the process showing the calculated values for each wall scenario can be found in Appendix B.

<u>Design Steps:</u>

Step 1: Calculate allowable Tension force in Geotextile (given ultimate tensile strength).

$$T_{allow} = T_{ULT}\left(\frac{1}{FS_{ID}FS_{CR}FS_{CD}FS_{BD}}\right)$$

Where the factors of safety are found in Table 15.2 (Budhu, 2011)

Table 12: Budhu 2011 - Table 15.2

**TABLE 15.2 Typical Ranges of Factor of Safety**

| Factor of safety | Range |
|---|---|
| $(FS)_{ID}$ | 1.1 to 2.0 |
| $(FS)_{CR}$ | 2.0 to 4.0 |
| $(FS)_{CD}$ | 1.0 to 1.5 |
| $(FS)_{BD}$ | 1.0 to 1.3 |

Step 2: Calculate vertical spacing of Geotextile.

$$S_z = \frac{T_{allow}}{K_a(\sigma_z' + q_s)FS_{sp}}$$

Where the factor of safety for spacing is 1.5

Step 3: Calculate required Geotextile depth at base of wall.

$$L_b = \frac{P_{ax}FS_T}{\gamma' H_o \tan \emptyset'}$$

Where the factor of safety for Tension is 1.5

Step 4: Calculation of Total Reinforcement Length at varying depths following step 3 spacing.

$$L_e = \frac{K_a S_z S_y FS}{2w \tan \emptyset_i}$$

$$L_R = (H_0 - z)\tan(45^{\circ} - \frac{\emptyset_c'}{2})$$

Where the factor of safety is 1.5, and $S_y$ = w = 1 for a unit width analysis.

Step 5: Check external stability for bearing capacity under ESA and TSA.

$$FS_b > 3$$

# 7.0 SCHEDULING

## 7.1 CONSTRUCTION SCHEDULE

The final estimated construction schedule has been completed assuming a start date of May 1st, 2018, with the projected end date being one week into December of 2018. The schedule has been completed using conservative timelines and may be able to be tightened based on volume of construction workers on site throughout the summer months and the rate of work. The schedule includes all major elements that are critical to an on-time delivery of this project. The construction activities with the most allotted time are the paving of both the cyclist and pedestrian pathways, along with the re-surfacing of the vehicle lanes. A lot of the activities in the schedule are overlapped to create a more efficient use of time.

Not included in this schedule is the process of consulting with stakeholders and the timeline for project permit approvals. It is assumed that the Owner has undertaken the required steps to begin construction on May 1st. The majority of construction is to be performed in the spring and summer months, as this is when the traffic around UBC campus will be at a minimum. At the submittal of our preliminary design, the construction was planned to be completed before the students return to campus in September. Following the completion of our detailed design work, and the subsequent updates on the construction schedule, it has been determined that this is not a feasible goal. The construction of the project will run through into December, a total construction period of 7 months. Appropriate measures will be taken throughout construction to ensure a minimal impact on vehicular and pedestrian traffic around the area.

There are a few construction issues that are anticipated to arise, with the biggest one being surprises in geotechnical data. With very little geotechnical information known, it is anticipated that there will be a few areas where the soil layers are different from what was expected. This may affect the length of time it takes to perform excavations and could possibly lead to a delay in schedule. It is also anticipated for there to be weather delays throughout the construction process, seeing as how construction continues through the fall months. This was accounted for and built into the construction schedule so that it remains as conservative as possible.

The complete construction schedule can be found in Appendix G.

# 8.0 COST ESTIMATE

A Class D cost estimate for the Redesign of Chancellor Boulevard project is developed, which has been categorized by design & planning costs and construction costs. Within design and planning costs, the category is broken down to design and planning fees, project management costs, and environmental costs. The components associated with construction costs are the utilities, underpass, roadway, roundabout and electrical aspects. The overall project including the design & planning costs and construction costs totaled to $6,598,690 with a 30% contingency included. This estimate excludes bonding, insurance and taxes associated with the project. The components with the highest contribution in amount are the roadway features and the roundabout. Although the roadway features consume a large majority of the costs, it includes the resurfacing current road surface in a multi-use pathway for cyclists and pedestrians, and creating a new sidewalk along the south side of the corridor. The roundabout costs are mostly associated with the new circular road construction, acquiring property to accommodate the roundabout and the development of the retaining wall. By utilizing a lamented wood underpass, significant costs can be saved as opposed to using purely steel or concrete. Electrical costs are also quite significant because it includes the two pedestrian signals at the trails, the bicycle signal near Drummond Rd and all the lighting adjacent to the corridor. The overall cost estimate is displayed in Table 13 below. Each of the individual construction cost components have more detailed cost estimates, which are presented in Appendix H.

**Table 13: Project Cost Estimate (Summary)**

| Overall Cost Estimate | | | | | |
|---|---|---|---|---|---|
| **Project Title:** Chancellor Boulevard Redesign | | | | | |
| **Project No:**18001-00 | | | | | |
| **Project Location: Chancellor Boulevard** | | | | **Currency Dollar:** | CAD |
| **Estimate Date:** April 5th, 2018 | | | | **Est. Class:** | D |
| | | | | | |
| **Item** | **Description** | **Base Estimate** | **Contingency** | **Total Price** | **Comments** |
| | | | | | |
| | ***Design and Planning Costs*** | | | | |
| 1.01 | Design and Planning Fees | $160,000.00 | 30% | $208,000.00 | na |
| 1.02 | Project Management | $180,000.00 | 30% | $234,000.00 | na |
| 1.03 | Environmental Costs | $100,000.00 | 30% | $130,000.00 | na |
| | | | | $572,000.00 | |
| | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | ***Construction Costs*** | | | | |
| 2.01 | Utilities | $191,912.50 | 30% | $249,486.25 | na |
| 2.02 | Underpass | $371,100.00 | 30% | $482,430.00 | na |
| 2.03 | Roadway | $1,802,052.99 | 30% | $2,342,668.89 | na |
| 2.04 | Roundabout | $1,389,304.81 | 30% | $1,806,096.26 | na |
| 2.05 | Electrical | $881,545.00 | 30% | $1,146,008.50 | na |
| | | | | $6,026,689.90 | |
| | | | | | |
| | ***Total*** | | | $6,598,689.90 | |

## 9.0 REPORT SUMMARY

Three-Way Engineering's proposed design transforms the current two lanes in each direction configuration into a one lane travel route in each direction that aims to improve safety by reducing motor vehicle travel speeds while meeting traffic demands. The Chancellor Boulevard corridor is also targeted to be pedestrian and bicycle friendly with the implementation of a multi-use pathway and an underpass crossing. Three-Way Engineering has reviewed and analyzed the various engineering aspects of the proposed design and provided a construction schedule along with a cost-estimate for the project. The estimated completion time of the project is seven months with a total cost of XXX.

# REFERENCES


B. (2000, September). Manual of Standard Traffic Signs & Pavement Markings. Retrieved January, 2018, from https://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/engineering-standards-and-guidelines/traffic-engineering-and-safety/traffic-engineering/traffic-signs-and-pavement-markings/manual_signs_pavement_marking.pdf

B. (2007). BC Supplement to TAC Geometric Design Guide 2007 Edition. Retrieved January, 2018.

C. (2014). Seattle Pavement Markings. Retrieved Febuary, 2018.

Minnesota Bikeway Design Manual. (March, 2007). Retrieved January, 2018.

T. (2011). Geometric Design Guide for Canadian Roads. Retrieved February, 2018.

T. (2011, December 13). Roundabout Guidelines. Retrieved January, 2018, from http://www.calgary.ca/Transportation/TP/Documents/Safety/Roundabout-Guidelines.pdf?noredirect=1

Weber, P. A. (1998). Http://ljournal.ru/wp-content/uploads/2017/03/a-2017-023.pdf. Towards a Canadian Standard for the Geometric Design of Speed Humps. doi:10.18411/a-2017-023

Budhu, M., (2011). Soil Mechanics and Foundations 3E. Retrieved March 3, 2018.

# APPENDIX A – TIMBER BRIDGE STRUCTURAL CALCULATIONS

Live Loading

Uneven Wheel loading
↓
× 60%

Axle loading

50 125 125 (centroid) 175 150

← 5.8 → ← 9.2 → ← 4.4 →

← 3.6 → ← 1.2 → ← 6.6 → ← 6.6 →

18m length

3.0m clearance envelope

Wheels on 1.8m centers

Wheel loading.

30 75 75 105 90

This is equivalent to distributed load of 21 kN/m

Deck Width $W_c$ = 10.0m → Table 3.5 → n = 2 Design Lanes

50 km/h ≈ 14 m/s → 4 sec vehicle spacing = 56m

However, vehicles will likely stop/near a stop on the bridge due to roundabout.

6 km/h ≈ 1.67 m/s → 3 sec = 5 m spacing

Assume vehicle extends 3.5m infront and behind of front and back axles

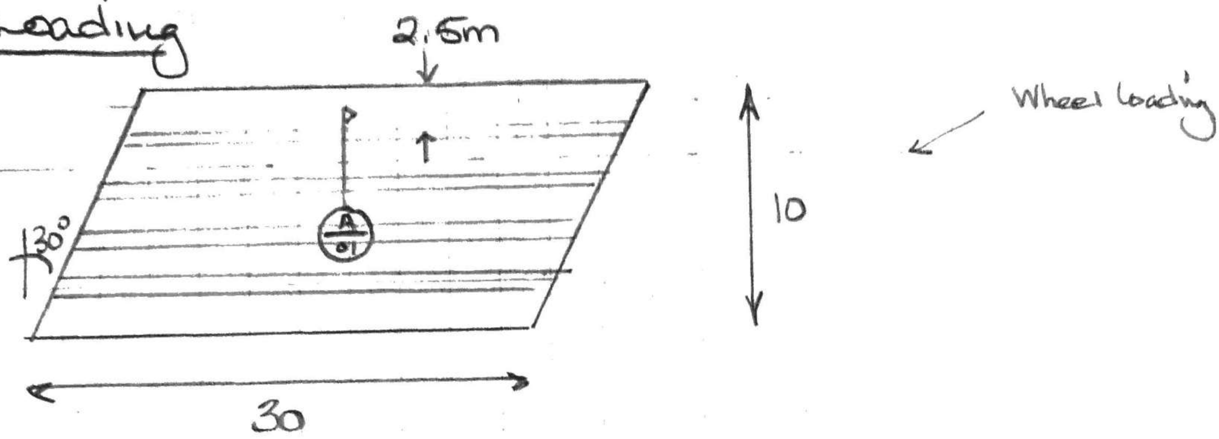
↳ ∴ 30 − 18 − 5 − 3.5 − 3.5m = 0 → only 1 vehicle on bridge at one time

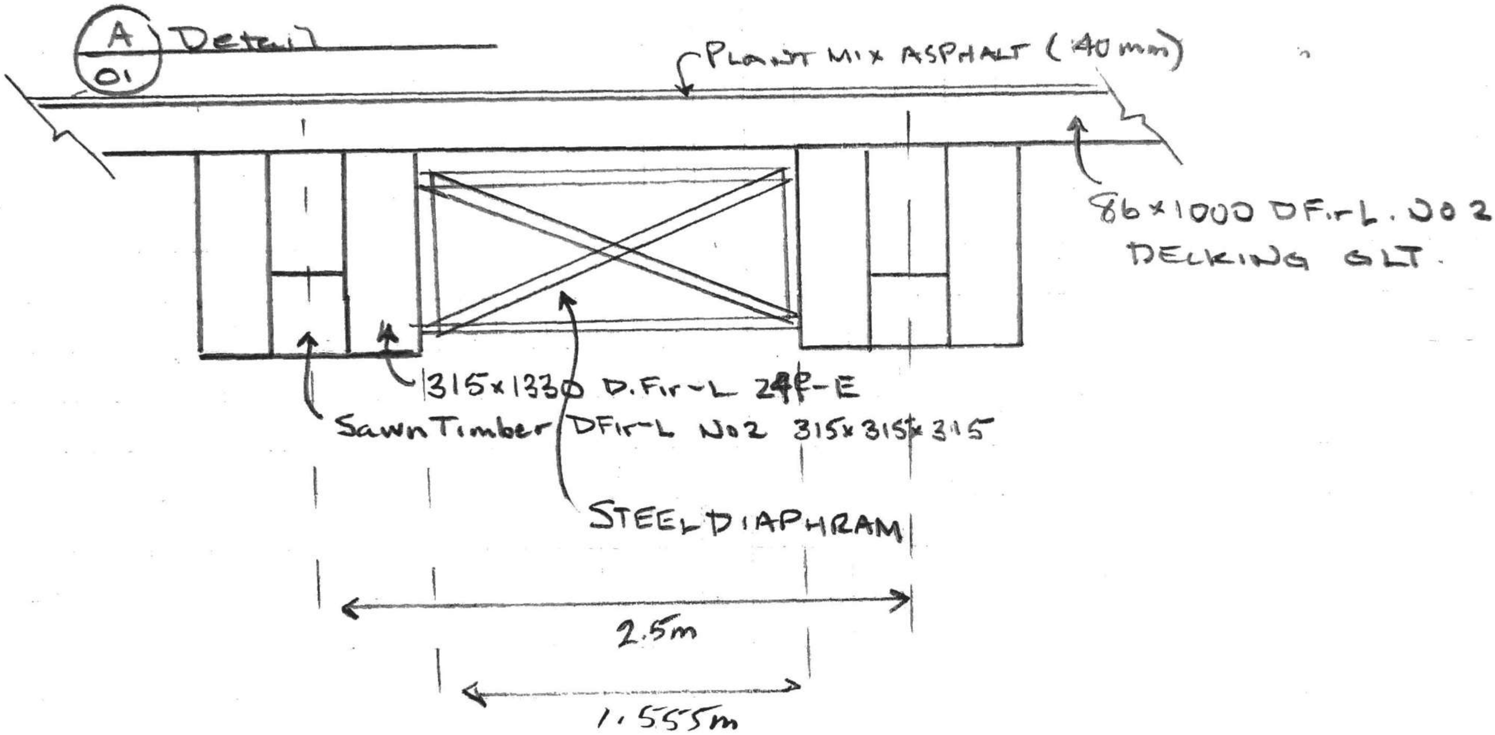
SAP Analysis of Moving Load (one wheel lane)

$M_{max}$ = 1893.6 kNm → 1900 kNm

$V_{max}$ = 280.1 kN → 280 kN

# Dead Loading




Density Wood DFir-L = 4.8 kN/m³

Girders

(315 × 1330) × 2 × 30m = 25.137 m³

= 120.65 kN

= 4.02 kN/m

Decking

(86 × 2500) × 4.8 = 1.03 kN/m

Asphalt Density = 12.7 kN/m³

(2500 × 40) × 12.7 = 1.27 kN/m

Steel Connections & Diaphrams ~ ⟶ 1.5 kN/m

Dead Load Unfactored = 7.82 kN/m

Dead Load Moment & Shear

$M_D = qL^2/8 = 7.82 \times 30^2/8 = 880$ kNm

$V_D = qL/2 = 117.3$ kN

Snow = $I_s [ S_g (C_b C_w C_s C_a) + S_r ]$

Site in Vancouver
elev of our site ~ 70m

$S_g = 1.8$ $S_r = 0.2$

$C_b = 0.8$ → ground snow

$C_w = 0.75$ → exposed to wind

$C_s = 1.0$ → flat (0°)

$C_a = 1.0$ → Load case I

$I_s = 1.0$ → Normal

$SL = 1.28$ kN/m²

↳ Elevation Adjust → $SL = 1.44$ kN/m²

Low Profile - Low Wind Loads → Neglect.

$SL = 3.6$ kN/m (2.5m TA)

$M_s = 405$ kNm

$V_s = 54$ kN

## Case II : 1.25 D + 1.50 L + 0.5 S

| | D | L | S |
|---|---|---|---|
| $M_f$ = | 880 | 1900 | 405 |
| $V_f$ = | 117 | 280 | 54 |

$M_f$ = 4152.5 → over two 315 × 1330 beams

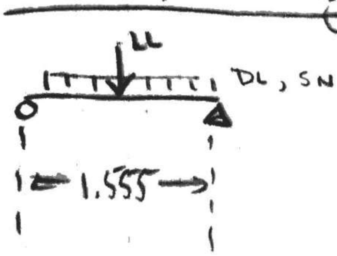
$V_f$ = 593.2

Over One 315 × 1330 beam:

$M_f$ = 2076.25

$V_f$ = 296.63

## Deck Loading




LL = 105 kN

DL = 12.7 × 1,000 × 0.04 = 0.508 (Asphalt)

+ 4.8 × 1.000 × 0.086 = 0.4128 (Deck)

= 0.92.08 kN/m

SL = 1.44 kN/m² × 1 m = 1.44 kN/m

$$M_f = \frac{105 \times 1.555^2}{2} \times 1.50 + \frac{0.9208 \times 1.555^2}{8} \times 1.25 + \frac{1.44 \times 1.555^2}{8} \times 0.5$$

**$M_f$ = 190 kNm**

$$V_f = 105 \times 1.5 + \frac{0.9208 \times 1.555}{2} \times 1.25 + \frac{1.44 \times 1.555}{2} \times 0.5$$

**$V_f$ = 160 kN**

## Camber

$M_D = 440\ kNm \quad q_D = 3.91\ kN/m$

$$\Delta_D = \frac{5(3.91)30^4}{384 E_s I}$$

$E_s = E(K_{SE} \times K_T) = 12800(0.8 \times 1.0) = 10,240,000\ \frac{kN}{m^2}$

$$I = \frac{0.315 \times 1.33^4}{12} = 0.082$$

$\Delta_D = 0.049\ m = 49\ mm$

$$Camber = \frac{1}{600} 30,000 + 2 \times 49\ mm$$

$= 148\ mm \sim 150\ mm$

## Barrier Exposure Level

Two way divided $k_h = 1.0$   straight $k_c = 1.0$

flat $k_g = 1.0$

< 5m height = $k_s = 0.7$

$$B_e = \frac{AADT}{1000} \Sigma k = \frac{3000}{1000} \times 0.7 = 2.1$$

Design Speed = 50 kph

% truck = 2%

∴ TL-2 barrier acceptable

Table 12.5   56-14

# APPENDIX B – RETAINING WALL DESIGN CALCULATIONS

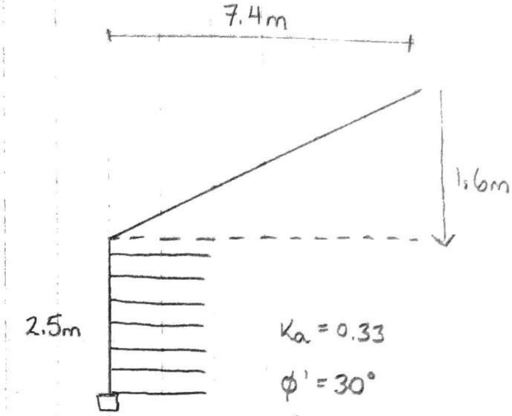
(A)

TRAFFIC CIRCLE

$L = 30m$

## STEP 1

$$T_{ALL} = \frac{(60KPa)}{(1.6)(2)(1.3)(1.3)} = \underline{\underline{11.1KN/m}}$$




## STEP 2

$\sigma_z' = \frac{1}{2}\gamma H_0^2$

$q_s$ = ROAD L.L + ASPHALT & SOIL D.L.

$q_s$: HIGHWAY L.L. = 20KPa [USDOT]

ASPHALT : $\gamma = 23KN/m^3$ [USDOT] (145 lbs/cu.f)

$\forall = A \times t = 6.873m^2 \times 0.09m = 0.619m^3$

$t = 0.09m$ [USDOT]

$A$ = 1m OUTER ANNULUS SLICE → $A = (R^2 - r^2)\pi \times \frac{\theta}{360°}$

SOIL = $\left(\frac{7.4m \times 1.6m}{2}\right)\left(\frac{1}{7.4m \times 1m}\right)\gamma = 15.2KPa$

$R = 16m$

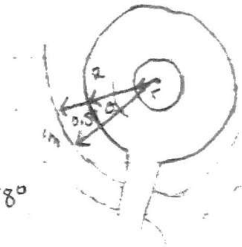
$r = 6m$

$q_s = 20 + (0.619m^3 \times 23KN/m^3) + 15.2$

$= 49.5KPa$

$\theta = \sin^{-1}\left(\frac{0.5m}{16m}\right) = 3.58°$

$A = 6.873m^3$




$(\sigma_x)_{max} = K_a\sigma_z' + K_a q_s$

$= K_a \frac{1}{2}\gamma H_0^2 + K_a q_s$

$= (\frac{1}{3})(\frac{1}{2})(19)(2.5)^2 + (\frac{1}{3})(49.5) = 36.3KPa$

$S_z = \frac{T_{ALL}}{(\sigma_x)_{max}(FS)_{SP}} = \frac{11.1KN}{(36.3KPa)(1.3)} = 0.235m$

@ $\frac{H_0}{2}$ $S_z = \frac{11.1KN}{(21.45KPa)(1.3)} = 0.398mm$

* FOR EASE OF CONSTRUCTION:

D = 0m − 1.25m : $S_z$ = 0.3m

D = 1.25m − 2m : $S_z$ = 0.2m

## STEP 3

$P_{AX} = \frac{1}{2}K_a\gamma H_0^2 + K_a q_s H_0$

$= (\frac{1}{2})(\frac{1}{3})(19)(2.5)^2 + (\frac{1}{3})(49.5)(2.5) = 61 KN/m$

$L_b = \frac{P_{AX}(FS)}{\gamma H_0 \tan\phi_b'} = \frac{(61)(1.5)}{(19)(2.5)(\tan 30°)} = 3.34m \approx \underline{\underline{3.5m}}$

## STEP 4

| $Z$(m) | $S_Z$ (m) | $L_R$(m) | $L_e$(m) | $L_T$(m) |
|---|---|---|---|---|
| 0.3m | 0.3m | 1.27 | 0.21 | 1.5 |
| 0.6m | 0.3m | 1.10 | 0.21 | 1.35 |
| 0.9m | 0.3m | 0.93 | 0.21 | 1.2 |
| 1.2m | 0.3m | 0.75 | 0.21 | 1.0 |
| 1.4m | 0.2m | 0.64 | 0.14 | 0.8 |
| 1.6m | 0.2m | 0.52 | 0.14 | 0.7 |
| 1.8m | 0.2m | 0.41 | 0.14 | 0.55 |
| 2.0m | 0.2m | 0.29 | 0.14 | 0.45 |
| 2.2m | 0.2m | 0.18 | 0.14 | 0.35 |
| 2.4m | 0.2m | 0.06 | 0.14 | 0.20 |
| [BOTTOM] 2.5m | 0.1m | 0 | 0.07 | 0.07 |

* ALL $L_T < L_b = 3.5m$ ∴ USE 3.5m IN CONSTRUCTION

## STEP 5 [EXTERNAL STABILITY] – BEARING

TSA:

$$q_{ULT} = 200 KPa$$
$$(\sigma_z)_{max} = \gamma H_o = 47.5 KPa$$
$$(FS)_B = \frac{q_{ULT}}{(\sigma_z)_{max}} = \frac{200}{47.5} = 4.2 > 3 \checkmark$$

ESA:

$$q_{ULT} = 0.5 \gamma B N_\gamma i_\gamma$$
$$(\sigma_z)_{max} = 47.5 KPa$$

$$i_\gamma = \left(1 - \frac{H}{V_n}\right)^{n+1} \qquad N_\gamma = 0.1054 e^{\wedge(9.6 \phi'_p)}$$

$$H = P_{ax} = 61 KN \qquad \phi'_p = 30°$$
$$V_n = \gamma H_o L_b = (19)(2.5)(3.5) = 166.25 KN \qquad n = 2$$

$$i_\gamma = \left(1 - \frac{61}{166.25}\right)^3 \qquad N_\gamma = 0.1054 e^{\wedge(9.6(30°)\pi \div 180)}$$

$$i_\gamma = 0.254 \qquad N_\gamma = 16.1$$

$$q_{ULT} = 0.5(19)(3.5)(16.1)(0.254) = 136 KPa$$

$$(FS)_B = \frac{q_{ULT}}{(\sigma_z)_{max}} = \frac{136}{47.5} = 2.86 < 3 \rightarrow L_b = 4m \rightarrow (FS)_B = 4.03 > 3$$

∴ $L_b = 4m$

*BACKFILLED

(B)

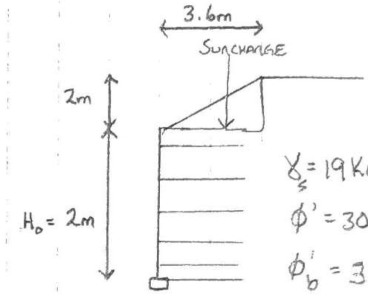
SOCCER FIELD

STEP 1 ALLOWABLE T

$L = 125m$

$$T_{ALL} = \frac{(60KPa)}{(1.6)(2)(1.3)(1.3)} = 11.1 KN/m$$

STEP 2 SPACING




$K_a = 0.33$

$\sigma_z' = ? = \frac{1}{2}\gamma_s H_o^2$

$q_s = ? = \left(\frac{b \times h}{2}\right)\left(\frac{1}{b \times 1m}\right)\gamma$

$\sigma_x = K_a\sigma_z' + K_a q_s$

$= K_a \gamma' z + K_a\left(\frac{2 \times 3.6}{2 \times 3.6m}\right)(\gamma)$

$= (0.33)(19)(z) + (0.33)(19 KN/m^2)$

$(\sigma_x)_{max} = 6.33(H_o) + 6.33 KPa$

$= 19 KPa$

$$S_z = \frac{T_{ALL}}{(\sigma_x)_{max}(FS)_{sp}} = \frac{11.1 KN/m}{(19KPa)(1.3)} = 0.449m = 450mm$$

$$@\frac{H_o}{2} \quad S_z = \frac{11.1 KN/m}{(12.66)(1.3)} = 0.675mm$$

* FOR EASE OF CONSTRUCTION & SAFETY USE:

> BOTTOM HALF: $S_z = 400mm$
> TOP HALF: $S_z = 600mm$

STEP 3

$P_{ax} = \frac{1}{2} K_a \gamma H_o^2 + K_a q_s H_o$

$= \frac{1}{2}\left(\frac{1}{3}\right)(19 KN/m^3)(2)^2 + \left(\frac{1}{3}\right)(19KPa)(2m) = 25.33 KN/m$

$$L_b = \frac{P_{ax}(FS)}{\gamma' H_o \tan\phi_b'} = \frac{(25.33KN/m)(1.5)}{(19KN/m^3)(2)\tan(20°)} = 2.747m \approx 2.75m$$

STEP 4

| Z (m) | Sz (m) | LR (m) | Le (m) | LT (m) |
|---|---|---|---|---|
| 0.6m | 0.60 | 0.92 | 0.41 | 1.4 |
| 1.2m | 0.60 | 0.69 | 0.41 | 1.1 |
| 1.6m | 0.40 | 0.46 | 0.28 | 0.8 |
| 2.0m | 0.40 | 0.- | 0.28 | 0.3 |

* ALL LENGTHS < $L_b$ = 2.75m ∴ USE 2.75m IN CONSTRUCTION

STEP 5 [EXTERNAL STABILITY] - BEARING [TRANSLATION SATISFIED BY $L_b$]

FROM GEOTECHNICAL DATA (BH 1)*:

TSA:

$q_{ULT}^* = 200\,KPa$

$(\sigma_z)_{max} = \gamma H_o = (19)(2) = 38\,KPa$

$(FS)_B = \frac{q_{ULT}}{(\sigma_z)_{max}} = \frac{200}{38} = 5.3 > 3$ ✓ OKAY

ESA:

$q_u = 0.5\gamma B N_\gamma i_\gamma$

$(\sigma_z)_{max} = 38\,KPa$

$i_\gamma = \left(1 - \frac{H}{V_n}\right)^{n+1}$ $N_\gamma = 0.1054\,e^{\wedge}(9.6\phi_p')$

$H = P_{ax} = 25.33\,KN$ $\phi_p' = 30°$

$V_n = \gamma H_o L_b = (19)(2)(2.75) = 104.5\,KN$ $\eta = 2$

$i_\gamma = \left(1 - \frac{25.33\,KN}{104.5\,KN}\right)^{2+1}$ $N_\gamma = 0.1054\,e^{\wedge(9.6(30°)\frac{\pi}{180})}$

$i_\gamma = 0.435$ $N_\gamma = 16.1$

$q_u = 0.5(19\,KN/m^3)(2.75m)(16.1)(0.435) = 183\,KPa$

$(FS)_B = \frac{q_u}{(\sigma_z)_{max}} = \frac{183}{38} = 4.8 > 3$ ✓ OKAY

Ⓒ

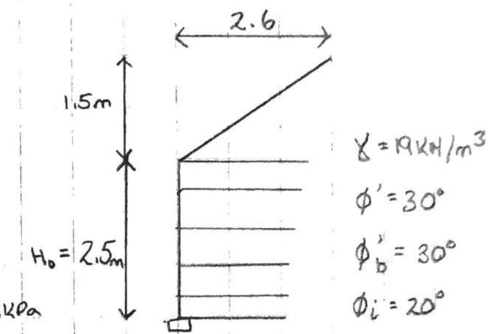
UNDERPASS

$L = 60m$

## STEP 1

$$T_{ALL} = \frac{(60KPa)}{(1.6)(2)(1.3)(1.3)} = 11.1 KN/m$$

## STEP 2




$\sigma'_z = \frac{1}{2} \gamma H_o^2$

$q_s$ = ROAD L.L + ASPHALT + SOIL

$q_s$: HIGHWAY = 20KPa

ASPHALT = $(4m^2)(0.09m)(23KN/m^3) = 8.28KPa$

SOIL = $\left(\frac{2.6 \times 1.5}{2}\right)\left(\frac{1}{2.6 \times 1}\right)\gamma = 14.25 KPa$

$q_s = 20 + 8.28 + 14.25 = 42.5 KPa$

$(\sigma'_x)_{max} = K_a \sigma'_z + K_a q_s$

$= K_a \frac{1}{2} \gamma H_o^2 + K_a q_s$

$= (\frac{1}{3})(\frac{1}{2})(19)(2.5)^2 + (\frac{1}{3})(42.6) = 34KPa$

$$S_z = \frac{T_{ALL}}{(\sigma_x)_{max}(FS)_{sp}} = \frac{11.1 KN}{(34KPa)(1.3)} = 0.251m \approx 0.25m$$

$$@\frac{H_o}{2} \quad S_z = \frac{11.1KN}{(19.15)(1.3)} = 0.446m \approx 0.4m$$

FOR EASE OF CONST. & SAFETY

## STEP 3

$P_{ax} = \frac{1}{2} K_a \gamma H_o^2 + K_a q_s H_o$

$= (\frac{1}{2})(\frac{1}{3})(19)(2.5)^2 + (\frac{1}{3})(42.5)(2.5) = 55.21 KN/m$

$$L_b = \frac{P_{ax}(FS)}{\gamma H_o \tan \phi'_i} = \frac{(55.21)(1.5)}{(19)(2.5)\tan 30} = 3.0m$$

STEP 4

| Z(m) | Sz(m) | LR(m) | Le(m) | LT(m) |
|---|---|---|---|---|
| 0.4 | 0.4 | 1.22 | 0.18 | 1.40 |
| 0.8 | 0.4 | 1.0 | 0.18 | 1.20 |
| 1.2 | 0.4 | 0.76 | 0.18 | 0.95 |
| 1.45 | 0.25 | 0.61 | 0.11 | 0.75 |
| 1.70 | 0.25 | 0.47 | 0.11 | 0.58 |
| 1.95 | 0.25 | 0.32 | 0.11 | 0.45 |
| 2.20 | 0.25 | 0.18 | 0.11 | 0.30 |
| [BOTTOM] 2.50 | 0.30 | 0 | 0.13 | 0.13 |

* ALL $L_T < L_b = 3m$ ∴ USE 3.0m IN INSTALLATION

STEP 5 [EXTERNAL STABILITY] - BEARING

TSA: $q_{ULT} = 200KPa$, $(\sigma_z)_{MAX} = \gamma H_0 = 47.5KPa$ } $(FS)_B = \frac{q_{ULT}}{(\sigma_z)_{max}} = 4.2 > 3$ ✓

ESA: $q_u = 0.5\,\gamma B N_\gamma i_\gamma$

$(\sigma_z)_{max} = 47.5KPa$

$i_\gamma = \left(1 - \frac{H}{V_n}\right)^{n+1}$ $\qquad N_\gamma = 0.1054\, e^{\wedge}(9.6\phi_p')$

$H = P_{az} = 55.21\,KN$ $\qquad \phi_p' = 30°$

$V_n = \gamma H_0 L_b = (19)(2.5)(3) = 143KN$ $\qquad \eta = 2$

$i_\gamma = \left(1 - \frac{55.21}{143}\right)^3$ $\qquad N_\gamma = 0.1054\, e^{\wedge}(9.6(30°)\frac{\pi}{180})$

$i_\gamma = 0.231$ $\qquad N_\gamma = 16.1$

$q_u = 0.5(19)(3)(16.1)(0.231) = 106\,KPa$

$(FS)_B = \frac{q_u}{(\sigma_z)_{max}} = \frac{106KPa}{47.5KPa} = 2.23 < 3 \rightarrow L_b = 4m \rightarrow 4m \rightarrow (FS)_B = 4.03 > 3$

∴ $L_b = 4m$

## APPENDIX C – ROUNDABOUT FIGURES

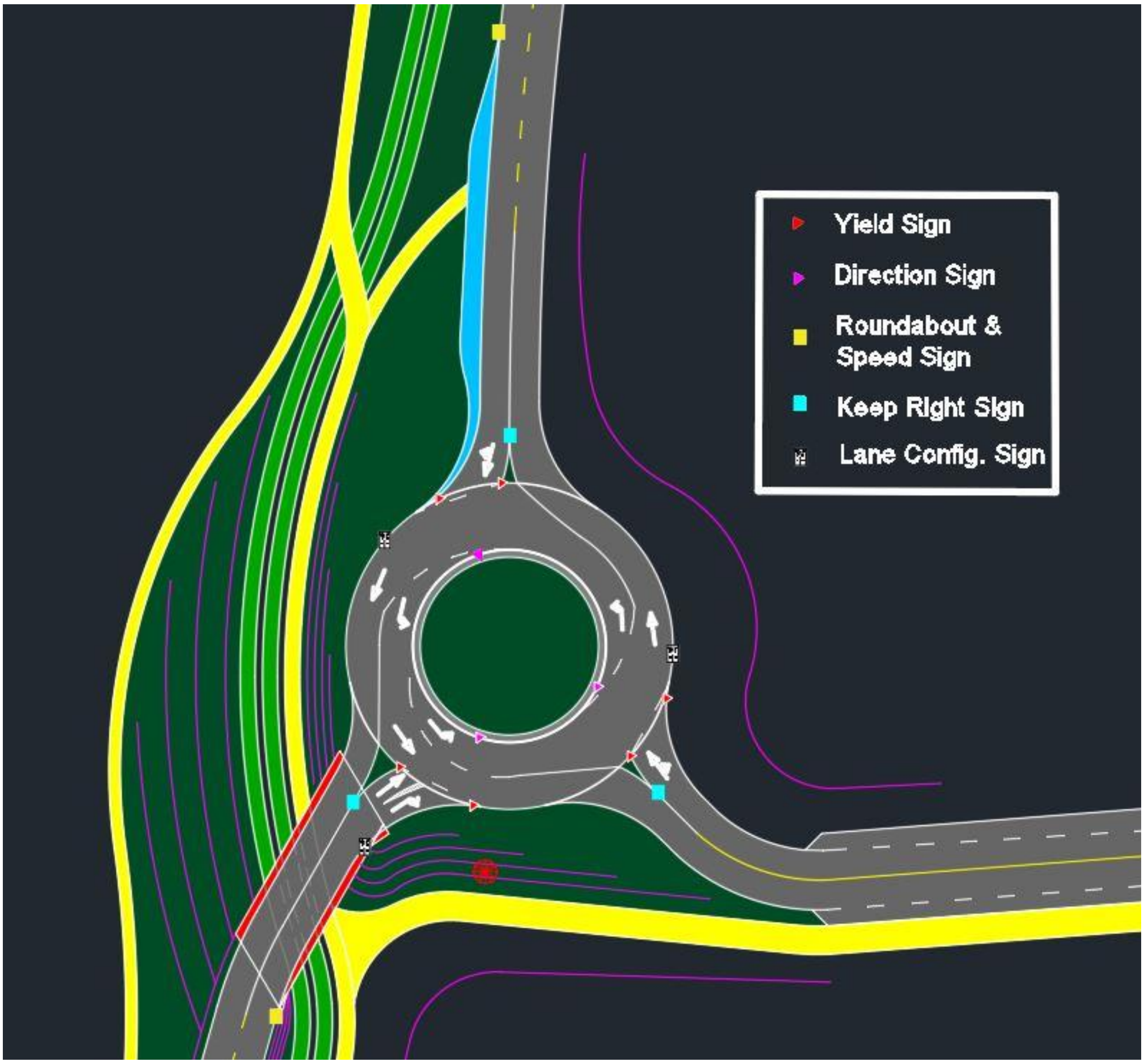



**Figure 19: Roundabout Design with Signage & Pavement Markings**

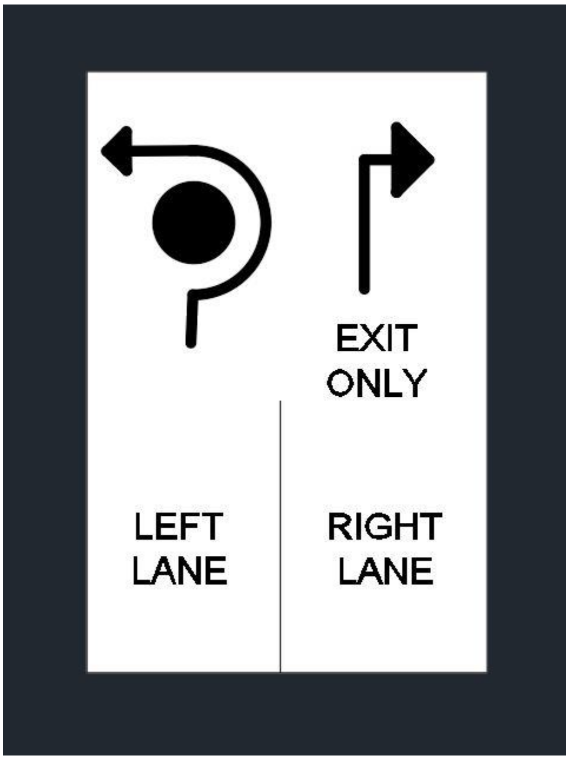



**Figure 20: Roundabout Lane Configuration**

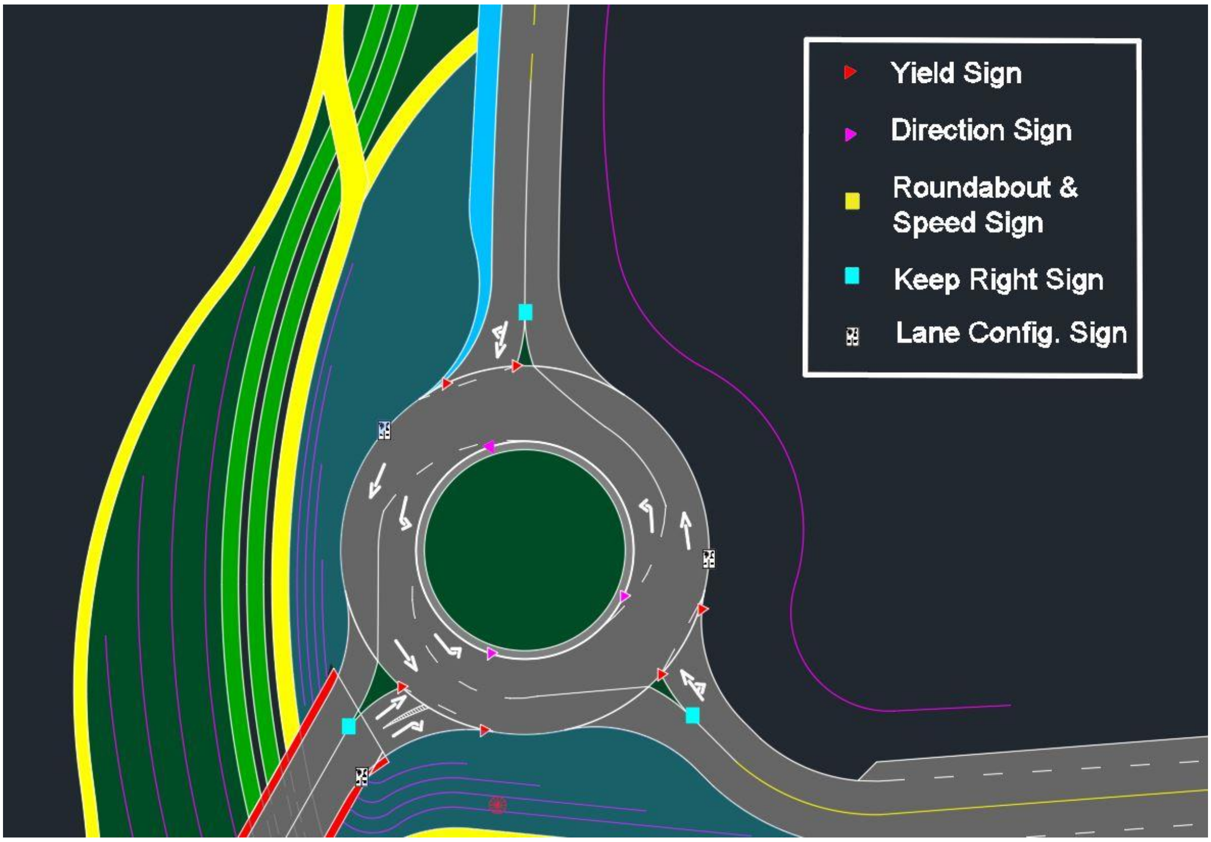
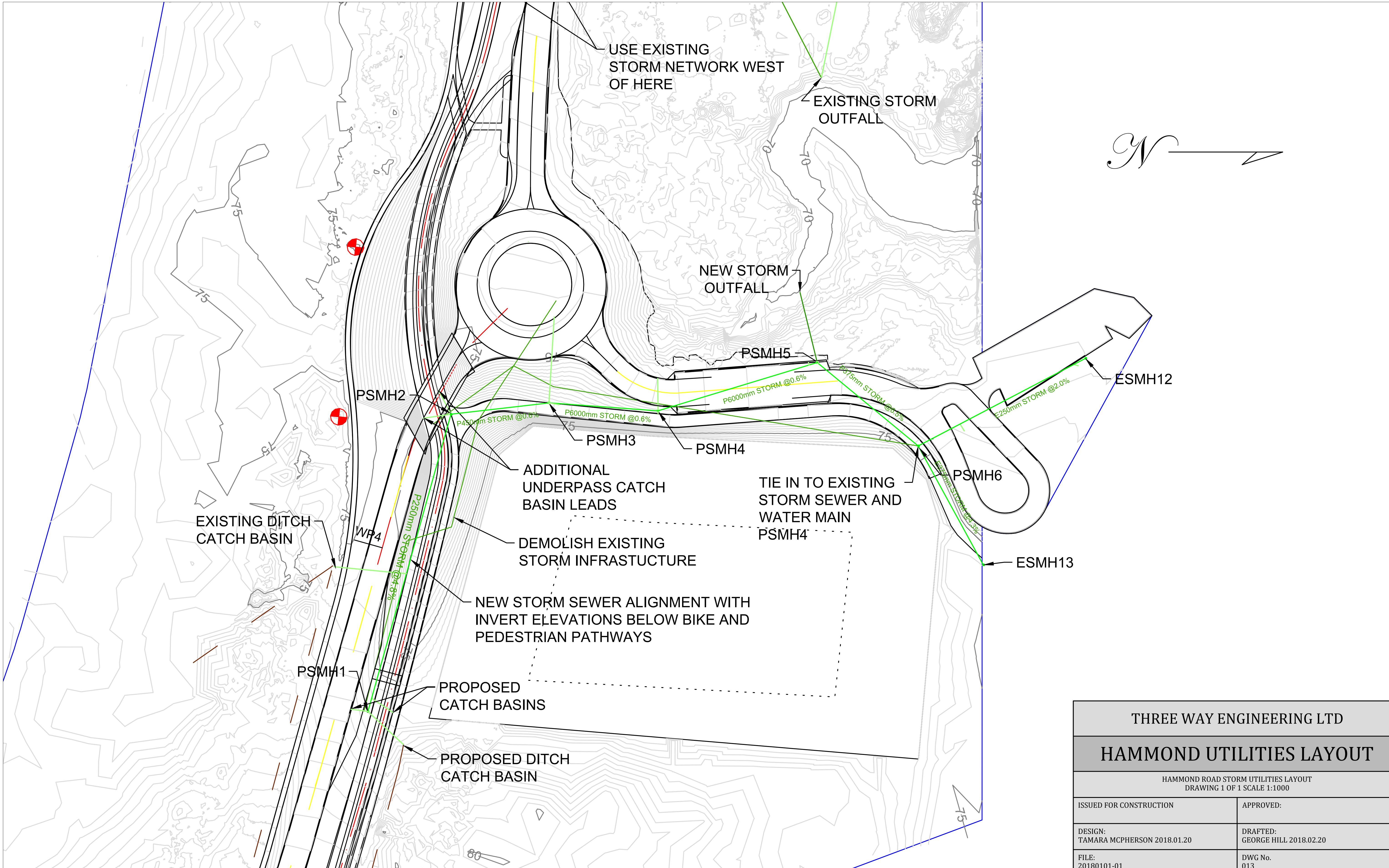
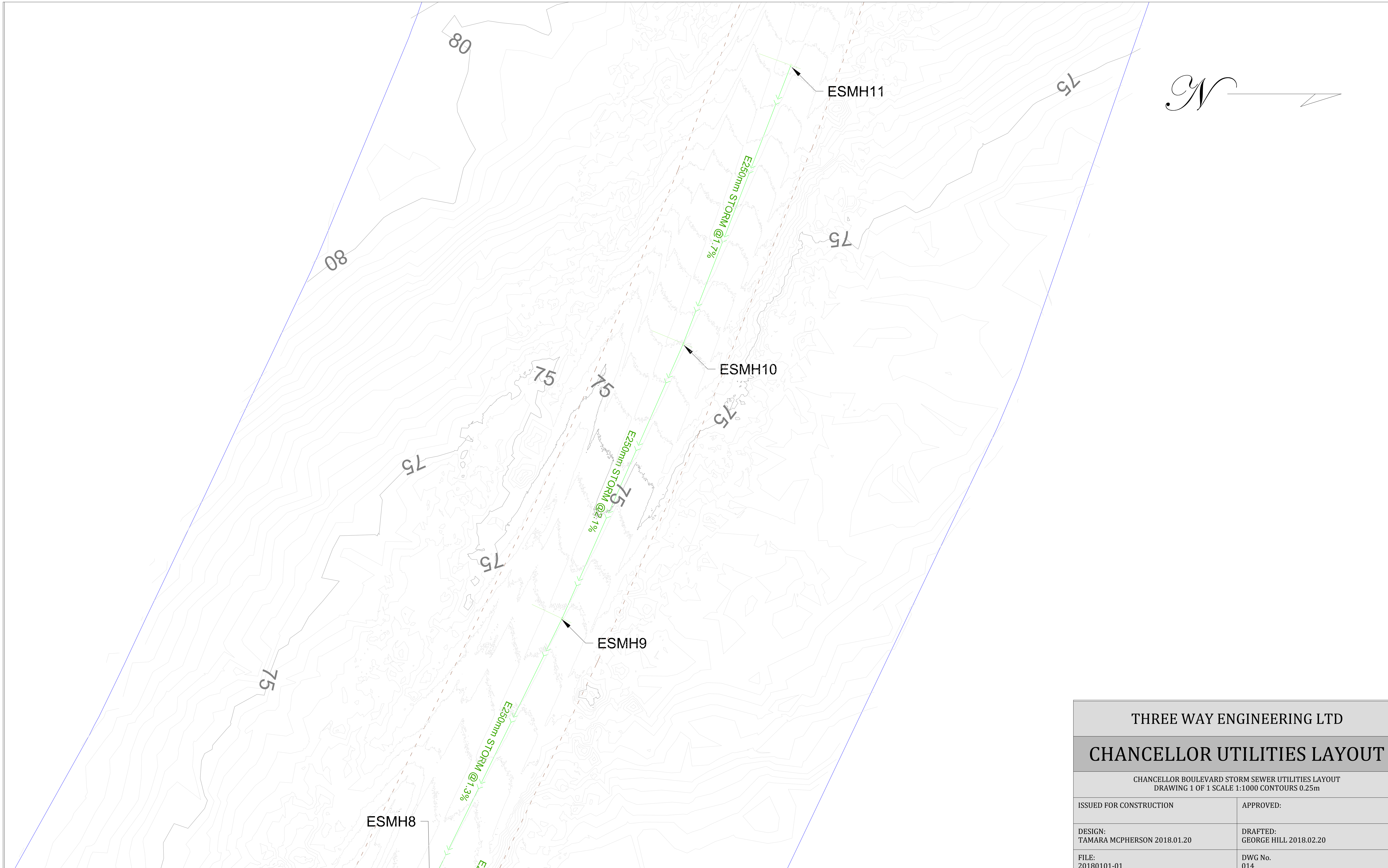



**Figure 21: Zoom-In View of Roundabout Design with Signage & Pavement Markings**

# APPENDIX D – STORM NETWORK DRAWINGS




| | |
|---|---|
| THREE WAY ENGINEERING LTD | |
| HAMMOND UTILITIES LAYOUT | |
| HAMMOND ROAD STORM UTILITIES LAYOUT<br>DRAWING 1 OF 1 SCALE 1:1000 | |
| ISSUED FOR CONSTRUCTION | APPROVED: |
| DESIGN:<br>TAMARA MCPHERSON 2018.01.20 | DRAFTED:<br>GEORGE HILL 2018.02.20 |
| FILE:<br>20180101-01 | DWG No.<br>013 |

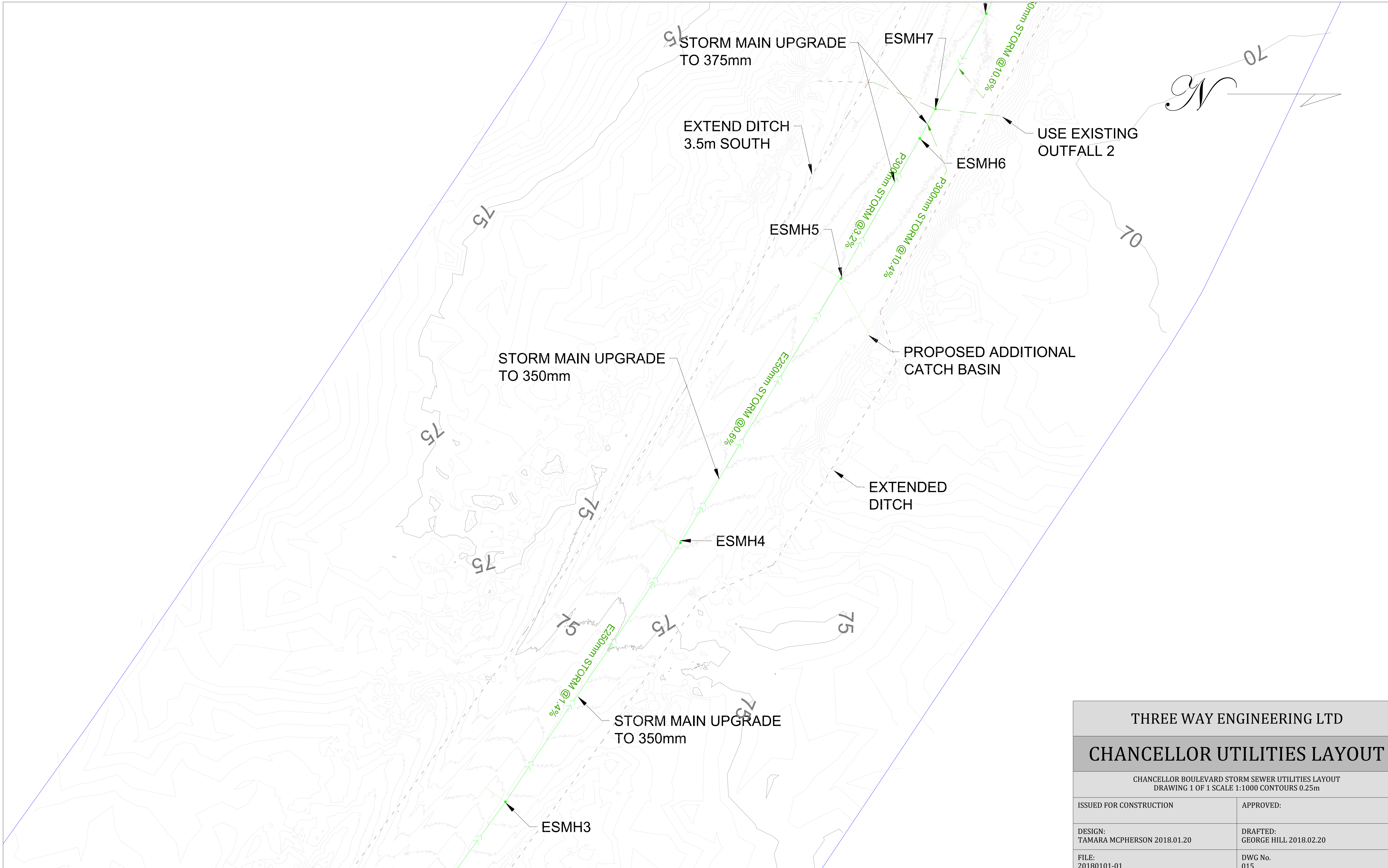



## THREE WAY ENGINEERING LTD

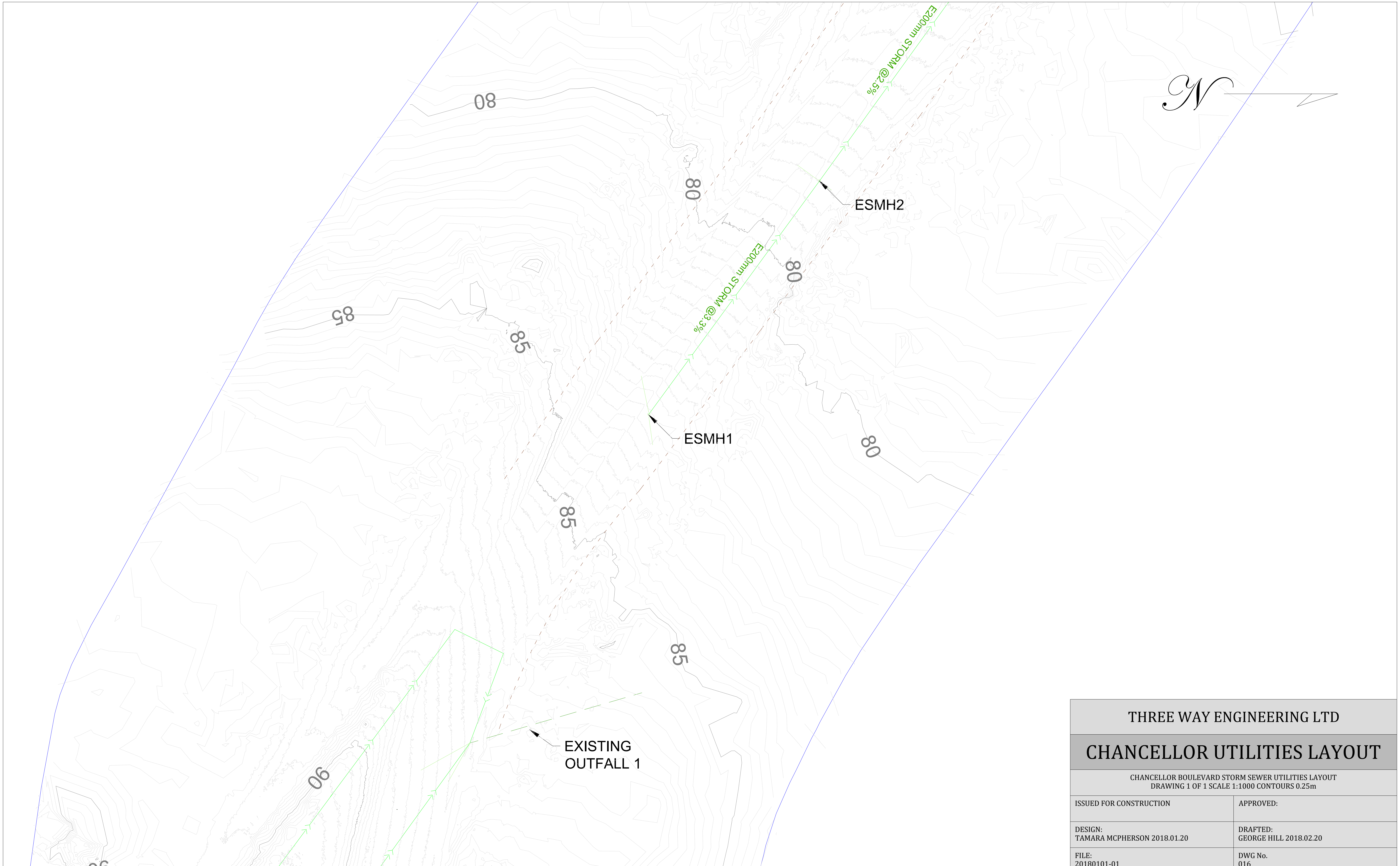
# CHANCELLOR UTILITIES LAYOUT

CHANCELLOR BOULEVARD STORM SEWER UTILITIES LAYOUT
DRAWING 1 OF 1 SCALE 1:1000 CONTOURS 0.25m

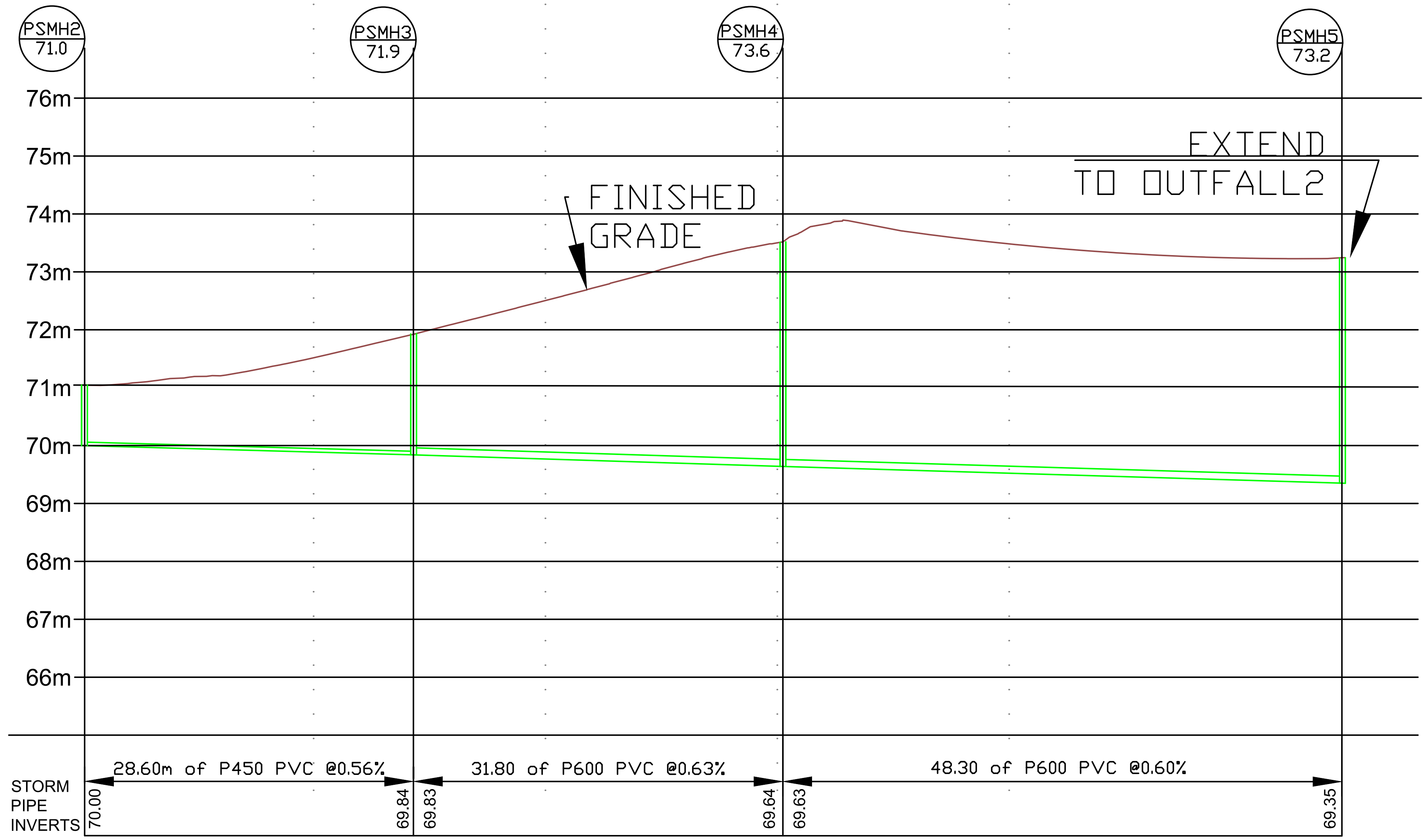
| | |
|---|---|
| ISSUED FOR CONSTRUCTION | APPROVED: |
| DESIGN:<br>TAMARA MCPHERSON 2018.01.20 | DRAFTED:<br>GEORGE HILL 2018.02.20 |
| FILE:<br>20180101-01 | DWG No.<br>014 |




| THREE WAY ENGINEERING LTD | |
|---|---|
| **CHANCELLOR UTILITIES LAYOUT** | |
| CHANCELLOR BOULEVARD STORM SEWER UTILITIES LAYOUT<br>DRAWING 1 OF 1 SCALE 1:1000 CONTOURS 0.25m | |
| ISSUED FOR CONSTRUCTION | APPROVED: |
| DESIGN:<br>TAMARA MCPHERSON 2018.01.20 | DRAFTED:<br>GEORGE HILL 2018.02.20 |
| FILE:<br>20180101-01 | DWG No.<br>015 |




| THREE WAY ENGINEERING LTD | |
| --- | --- |
| CHANCELLOR UTILITIES LAYOUT | |
| CHANCELLOR BOULEVARD STORM SEWER UTILITIES LAYOUT<br>DRAWING 1 OF 1 SCALE 1:1000 CONTOURS 0.25m | |
| ISSUED FOR CONSTRUCTION | APPROVED: |
| DESIGN:<br>TAMARA MCPHERSON 2018.01.20 | DRAFTED:<br>GEORGE HILL 2018.02.20 |
| FILE:<br>20180101-01 | DWG No.<br>016 |




THREE WAY ENGINEERING LTD

# CHANCELLOR UTILITIES PROFILE

CHANCELLOR BOULEVARD STORM SEWER UTILITIES PROFILE
DRAWING 1 OF 1 SCALE 1:500 V.SCALE 1:100 CONTOURS 0.25m

| | |
|---|---|
| ISSUED FOR CONSTRUCTION | APPROVED: |
| DESIGN:<br>TAMARA MCPHERSON 2018.01.20 | DRAFTED:<br>GEORGE HILL 2018.02.20 |
| FILE:<br>20180101-01 | DWG No.<br>017 |

## APPENDIX E – SANITARY AND WATER MAIN DRAWINGS


THREE WAY ENGINEERING LTD

# HAMMOND UTILITIES LAYOUT

HAMMOND ROAD SANITARY AND WATER UTILITIES LAYOUT
DRAWING 1 OF 1 SCALE 1:1000

| | |
|---|---|
| ISSUED FOR CONSTRUCTION | APPROVED: |
| DESIGN: TAMARA MCPHERSON 2018.01.20 | DRAFTED: GEORGE HILL 2018.02.20 |
| FILE: 20180101-01 | DWG No. 012 |

## APPENDIX F – STORM NETWORK LOADING CALCULATIONS AND FORMULAS

**Rational Formula**

$$\boldsymbol{Q = RAIN}$$

*Where:*

$Q = Flow\ in\ cubic\ metres\ per\ second\ \left(\frac{m^3}{s}\right)$

*R = Runoff coefficient*

*A = Drainage area in hectares (Ha)*

*I = Rainfall intensity in mm/hr*

*N = Conversion factor 0.00278*

**Time of Concentration**

$$\boldsymbol{T_c = Overland\ Flow\ Time\ (T_o) + Travel\ Time\ (T_t)}$$

*Where:*

$$T_o = \frac{3.26 * (1.1 - R) * \sqrt{L}}{SS^{\frac{1}{3}}} \qquad [Airport\ Method]$$

$$T_t = \frac{L}{V_{Cap}/60}$$

$$V_{Cap} = \frac{Q_{Cap}}{1000 * \pi * (D/2000)^2}$$

$$Q_{Cap} = \frac{\pi * (D/2000)^2}{n} * (D/4000)^{\frac{2}{3}} * \sqrt{PS} * 1000$$

*Where:*

$R = Runoff\ Coefficient$

$L = Pipe\ Lenght\ (m)$

$SS = Street\ Slope\ (\%)$

$PS = Pipe\ Slope\ (\%)$

$D = Pipe\ Diameter\ (mm)$

$V_{Cap} = Pipe\ Velocity\ at\ Capacity\ (\frac{m}{s})$

$Q_{Cap} = Pipe\ Volumetric\ Flow\ at\ Capacity\ (\frac{m^3}{3})$

$$n = mannings\ coefficient = 0.013\ for\ PVC\ pipes)$$

## Table 5.3.14: Rational Method Calculation Sheet

| | | |
|---|---|---|
| Consultant: Threeway Engineering Ltd. | Storm Sewer Design Criteria | Sheet of |
| Project No.: **1600-00** | Rainfall Intensity (5-year storm) | File Name: **1600-00** |
| Project Description: **Storm Water Management Plan** | Rainfall Intensity (100-year storm) | Completed by: Tamara |
| | Q = RAIN | Date:4th April, 2018 |
| Location: University Endownment Lands, BC, Canada | Q = C*I*A | Checked by: TWE Engineer |
| | MANNINGS "n" = **0.013** | Date:6th April, 2018 |

| Branch | Branches Added | Manhole | | Drainage Area Description | Area (A) | Lenght (L) | Slope (%) | Runoff Coefficient | C *A | Total C *A | Time of concentration Airport method | Time of concentration Travel time | Total Time | Intensity | | Flow | | Sewer Design | | | | | | Ratio | | Q(100) Slope | Min Tc | Max Tc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | I(5) | I(100) | Q(5) | Q(100) | Pipe Slope | Pipe Dia. | Mannings "n" | Q Cap. | V Cap. | Pipe Length | Q(5)/ Q Cap. | Q(100)/ Q Cap. | | | |
| | | From | To | | (m2) | (m) | % | C | (ha) | (ha) | (min) | (min) | (min) | (mm/hr) | (mm/hr) | (L/s) | (L/s) | % | (mm) | | (L/s) | (m/s) | (m) | % | % | % | | |
| A | | ESMH1 | ESMH2 | Asphalt/Grass | 3991 | 84.2 | 3.3% | 0.703 | 0.280 | 0.280 | 37.20 | 0.744 | 20.00 | 30.61 | 48.92 | 23.84 | 38.10 | 3.3% | **200** | 0.013 | 59.26 | 1.89 | 84.2 | 40.22% | 64.29% | 0.03 | 15 | 20 |
| | | ESMH2 | ESMH3 | Asphalt/Grass | 2713 | 90.9 | 2.5% | 0.703 | 0.191 | 0.471 | 42.40 | 0.923 | 20.00 | 30.61 | 48.92 | 40.04 | 64.00 | 2.5% | **200** | 0.013 | 51.59 | 1.64 | 90.9 | 77.60% | 124.04% | 0.02 | 15 | 20 |
| | | ESMH3 | ESMH4 | Asphalt/Grass | 3049 | 90.9 | 1.4% | 0.703 | 0.214 | 0.685 | 51.57 | 1.066 | 20.00 | 30.61 | 48.92 | 58.25 | 93.10 | 1.4% | **250** | 0.013 | 69.73 | 1.42 | 90.9 | 83.53% | 133.51% | 0.01 | 15 | 20 |
| | | ESMH4 | ESMH5 | Asphalt/Grass | 2858 | 90.0 | 0.6% | 0.703 | 0.201 | 0.886 | 69.41 | 1.268 | 20.00 | 30.61 | 48.92 | 75.32 | 120.38 | 0.6% | **375** | 0.013 | 130.68 | 1.18 | 90.0 | 57.63% | 92.12% | 0.01 | 15 | 20 |
| | | ESMH5 | ESMH6 | Asphalt/Grass | 4032 | 46.9 | 0.0% | 0.703 | 0.283 | 1.169 | 191.19 | 0.275 | 30.00 | 24.79 | 39.01 | 80.50 | 126.70 | 3.2% | **375** | 0.013 | 313.48 | 2.84 | 46.9 | 25.68% | 40.42% | 0.00 | 15 | 30 |
| | | ESMH6 | ESMH7 (OF2) | Asphalt (no catch) | 0 | 9.6 | -5.2% | 0.703 | 0.000 | 1.169 | 10.76 | 0.020 | 10.78 | 42.22 | 69.08 | 137.10 | 224.35 | 10.4% | **750** | 0.013 | 3583.40 | 8.11 | 9.6 | 3.83% | 6.26% | -0.05 | 10 | 15 |
| B | | ESMH11 | ESMH10 | Asphalt/Grass | 4162 | 87.00 | 1.7% | 0.703 | 0.292 | 0.292 | 46.79 | 0.912 | 30.00 | 24.79 | 39.01 | 20.13 | 31.69 | 1.7% | **250** | 0.013 | 78.08 | 1.59 | 87.00 | 25.78% | 40.58% | 0.02 | 15 | 30 |
| | | ESMH10 | ESMH9 | Asphalt/Grass | 2770 | 87.30 | 2.1% | 0.703 | 0.195 | 0.487 | 44.16 | 0.837 | 20.00 | 30.61 | 48.92 | 41.40 | 66.17 | 2.1% | **250** | 0.013 | 85.38 | 1.74 | 87.30 | 48.49% | 77.50% | 0.02 | 15 | 20 |
| | | ESMH9 | ESMH8 | Asphalt/Grass | 2698 | 86.90 | 1.3% | 0.703 | 0.190 | 0.677 | 51.83 | 1.063 | 20.00 | 30.61 | 48.92 | 57.51 | 91.93 | 1.3% | **250** | 0.013 | 66.90 | 1.36 | 86.90 | 85.97% | 137.40% | 0.01 | 15 | 20 |
| | | ESMH8 | ESMH7 (OT2) | Asphalt/Grass | 3676 | 31.40 | 1.1% | 0.703 | 0.258 | 0.935 | 32.51 | 0.133 | 20.00 | 30.61 | 48.92 | 79.47 | 127.02 | 10.6% | **250** | 0.013 | 193.69 | 3.95 | 31.40 | 41.03% | 65.58% | 0.01 | 15 | 20 |
| C | | PSMH1 | PSMH2 | Asphalt/Grass | 4005 | 89.90 | 5.3% | 0.703 | 0.281 | 0.281 | 32.64 | 0.566 | 30.00 | 24.79 | 39.01 | 19.37 | 30.49 | 4.8% | **250** | 0.013 | 129.98 | 2.65 | 89.90 | 14.90% | 23.46% | 0.05 | 15 | 30 |
| | | PSMH2 | PSMH3 | Asphalt/Grass | 8439 | 28.60 | -3.1% | 0.703 | 0.593 | 0.874 | 21.95 | 0.356 | 22.31 | 28.92 | 46.02 | 70.22 | 111.76 | 0.56% | **450** | 0.013 | 213.25 | 1.34 | 28.60 | 32.93% | 52.41% | -0.03 | 15 | 30 |
| | D | PSMH3 | PSMH4 | Asphalt/Grass | 2083 | 31.80 | -5.3% | 0.703 | 0.146 | 2.171 | 19.41 | 0.316 | 19.72 | 30.83 | 49.30 | 70.22 | 297.24 | 0.60% | **600** | 0.013 | 474.61 | 1.68 | 31.80 | 14.79% | 62.63% | -0.05 | 15 | 20 |
| | | PSMH4 | PSMH5 | Asphalt/Grass | 1275 | 48.30 | 0.8% | 0.703 | 0.090 | 2.260 | 44.51 | 0.478 | 15.00 | 35.54 | 57.44 | 223.14 | 360.58 | 0.60% | **600** | 0.013 | 475.77 | 1.68 | 48.30 | 46.90% | 75.79% | 0.01 | 10 | 15 |
| | | PSMH5 | Outfall 3 | Pacific Spirit Park (no catch) | 0 | 21.00 | 0.7% | 0.703 | 0.000 | 2.260 | 30.83 | 0.191 | 15.00 | 35.54 | 57.44 | 223.14 | 360.58 | 0.7% | **600** | 0.013 | 518.93 | 1.84 | 21.00 | 43.00% | 69.49% | 0.01 | 10 | 15 |
| D | | ESM12 | PSM6 | Asphalt/Grass | 3436 | 54.90 | -0.7% | 0.703 | 0.241 | 0.241 | 49.53 | 0.534 | 20.00 | 30.61 | 48.92 | 20.52 | 32.80 | 2.0% | **250** | 0.013 | 84.17 | 1.71 | 54.90 | 24.38% | 38.97% | -0.01 | 15 | 20 |
| | D1 | PSM6 | PSM5 | Hamber Elementary Field | 11382 | 37.90 | 4.2% | 0.300 | 0.341 | 1.150 | 46.12 | 0.157 | 30.00 | 24.79 | 39.01 | 79.18 | 124.62 | 6.5% | **375** | 0.013 | 445.31 | 4.03 | 37.90 | 17.78% | 27.98% | 0.04 | 15 | 30 |
| D1 | | ESM13 | PSM6 | Hamber Elementary School | 7089 | 39.40 | 0.5% | 0.800 | 0.567 | 0.567 | 35.72 | 0.199 | 30.00 | 24.79 | 39.01 | 39.05 | 61.46 | 4.3% | **375** | 0.013 | 364.02 | 3.30 | 39.40 | 10.73% | 16.88% | 0.01 | 15 | 30 |

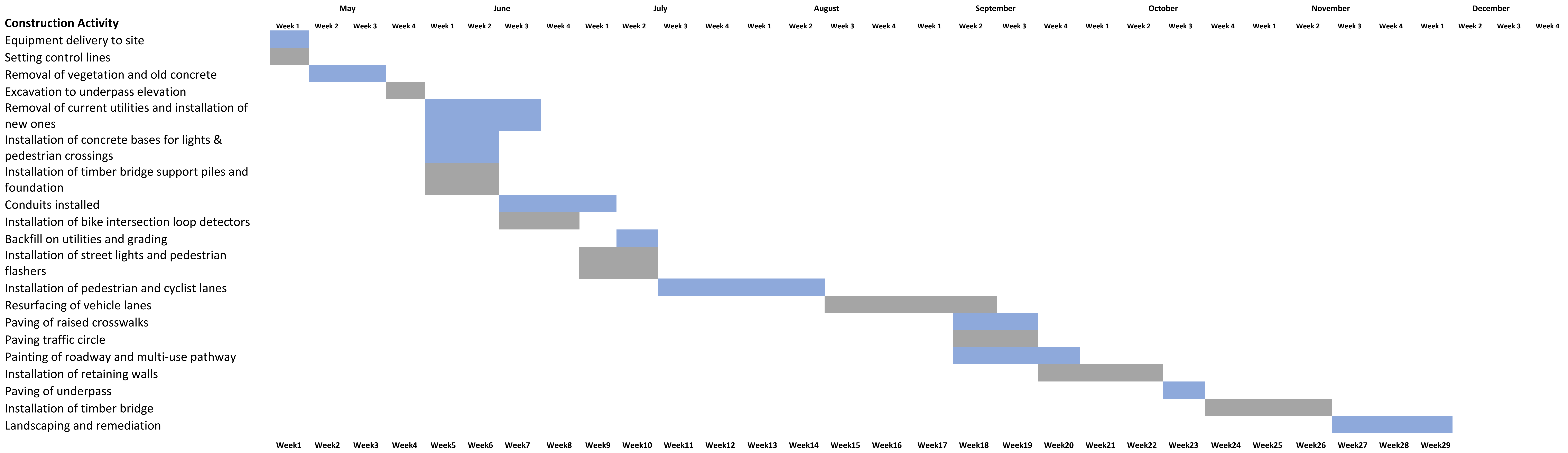
| Kwantlen Park Rainfall IDF Data | | |
|---|---|---|
| | 5 year | 100 year |
| | | |
| A | 17.286 | 26.499 |
| B | (0.520) | (0.558) |

| |
|---|
| Reused Existing Main |
| Upsized Existing Main |
| Proposed Main (re-design) |

| Mixed Zoning Calcs | | |
|---|---|---|
| **Corridor** | Ashphalt | Grass |
| Area (m^2) | 2187 | 1073 |
| Total Area (m^2) | 3260 | |
| Runoff Coefficent (5yr) | 0.9 | 0.3 |
| Weight Runoff Coefficent (5yr) | 0.703 | |

100-yr Overland Flow to Ditch System

# APPENDIX G – PROJECT SCHEDULE



## Storm Network Cost Estimate

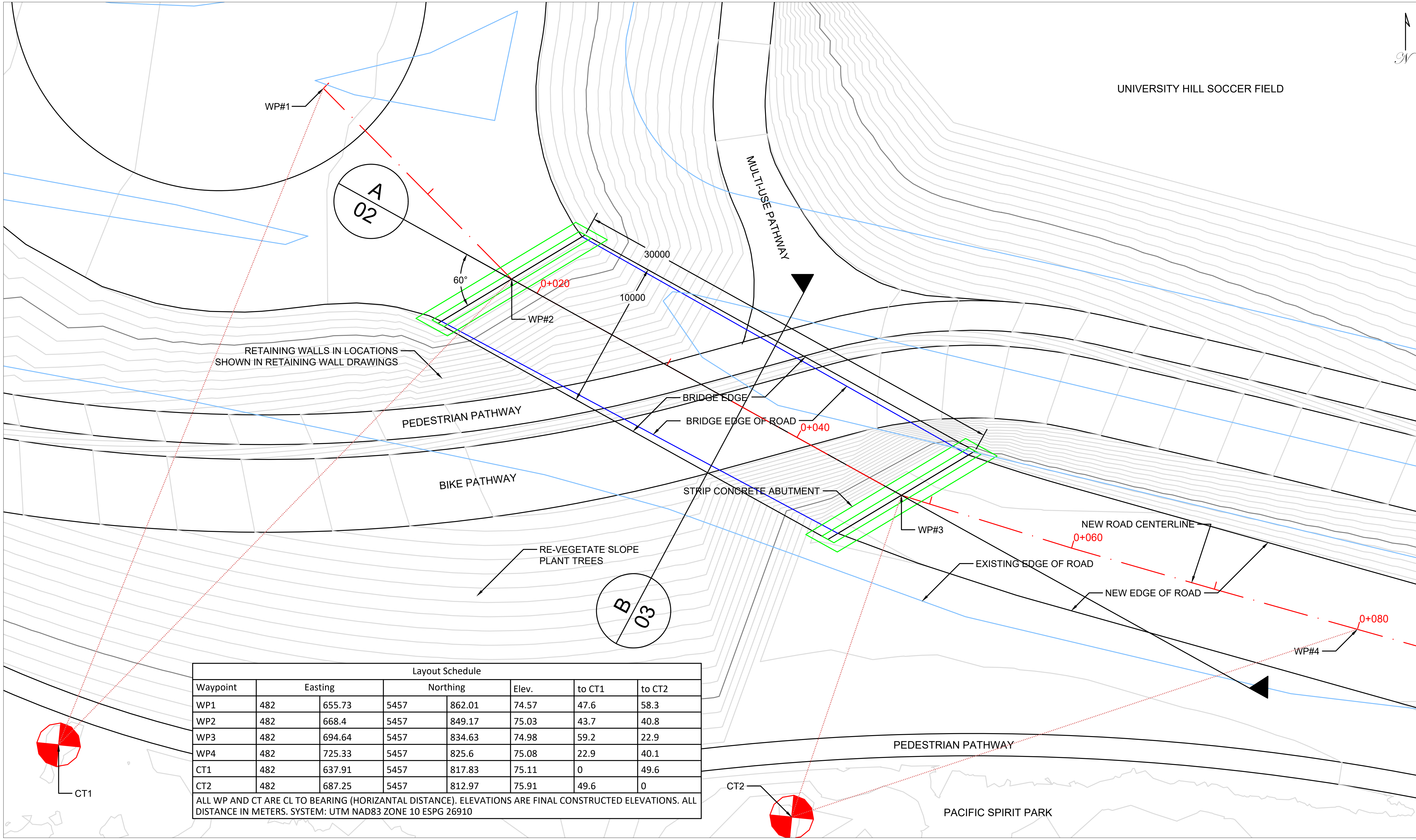
| | | | | | | |
|---|---|---|---|---|---|---|
| **Project Title:** Chancellor Boulevard Redesign | | | | | | |
| **Project No:**18001-00 | | | | | | |
| **Project Location: Chancellor Boulevard** | | | | | **Currency Dollar:** | CAD |
| **Estimate Date:** April 5th, 2018 | | | | | **Est. Class:** | D |
| **Item** | **Description** | **Est. Qty** | **Unit** | **Unit Rate** | **Total Price** | **Comments** |
| | ***Pipes*** | | | | | |
| 1.00 | 250mm dia PVC Stormpipe | 144.8 | lm | $140.00 | $20,272.00 | na |
| 1.01 | 300mm dia PVC Stormpipe | 0.0 | lm | $160.00 | $0.00 | na |
| 1.02 | 375mm dia PVC Stormpipe | 136.9 | lm | $165.00 | $22,588.50 | na |
| 1.03 | 450mm dia PVC Stormpipe | 28.6 | lm | $180.00 | $5,148.00 | na |
| 1.04 | 600mm dia PVC Stormpipe | 101.1 | lm | $240.00 | $24,264.00 | na |
| | ***Manholes*** | | | | | |
| 1.05 | 1050mm dia. Manhole | 9 | ea | $3,000.00 | $27,000.00 | na |
| | ***Catch Basins*** | | | | | |
| 1.06 | Standard Catch Basin Additional | 5 | ea | $1,750.00 | $8,750.00 | na |
| 1.07 | Standard Catch Basin Relocation | 6 | ea | $500.00 | $3,000.00 | na |
| 1.08 | Ditch Catch Basin | 1 | ea | $2,500.00 | $2,500.00 | na |
| | ***Total*** | | | | $110,522.50 | |

## Sanitary Sewer Cost Estimate

| | | | | | | |
|---|---|---|---|---|---|---|
| **Project Title:** Chancellor Boulevard Redesign | | | | | | |
| **Project No:**18001-00 | | | | | | |
| **Project Location: Chancellor Boulevard** | | | | | **Currency Dollar:** | CAD |
| **Estimate Date:** April 5th, 2018 | | | | | **Est. Class:** | D |
| **Item** | **Description** | **Est. Qty** | **Unit** | **Unit Rate** | **Total Price** | **Comments** |
| | ***Pipes*** | | | | | |
| 1.09 | 380mm dia PVC Stormpipe | 307.0 | lm | $170.00 | $52,190.00 | na |
| | ***Manholes*** | | | | | |
| 1.10 | 1050mm dia. Manhole | 5 | ea | $3,000.00 | $15,000.00 | na |
| | ***Total*** | | | | $67,190.00 | |

| Water Main Cost Estimate | | | | | | |
|---|---|---|---|---|---|---|
| **Project Title:** Chancellor Boulevard Redesign | | | | | | |
| **Project No:**18001-00 | | | | | | |
| **Project Location: Chancellor Boulevard** | | | | | **Currency Dollar:** | CAD |
| **Estimate Date:** April 5th, 2018 | | | | | **Est. Class:** | D |
| | | | | | | |
| **Item** | **Description** | **Est. Qty** | **Unit** | **Unit Rate** | **Total Price** | **Comments** |
| | | | | | | |
| | ***Pipes*** | | | | | |
| 1.09 | 150mm dia CAST IRON Watermain | 140.0 | lm | $100.00 | $14,000.00 | na |
| | | | | | | |
| | ***PRV*** | | | | | |
| 1.10 | Relocation | 2 | ea | $100.00 | $200.00 | na |
| | ***Total*** | | | | $14,200.00 | |

# APPENDIX I – DETAILED DESIGN DRAWINGS




Layout Schedule

| Waypoint | Easting | | Northing | | Elev. | to CT1 | to CT2 |
|---|---|---|---|---|---|---|---|
| WP1 | 482 | 655.73 | 5457 | 862.01 | 74.57 | 47.6 | 58.3 |
| WP2 | 482 | 668.4 | 5457 | 849.17 | 75.03 | 43.7 | 40.8 |
| WP3 | 482 | 694.64 | 5457 | 834.63 | 74.98 | 59.2 | 22.9 |
| WP4 | 482 | 725.33 | 5457 | 825.6 | 75.08 | 22.9 | 40.1 |
| CT1 | 482 | 637.91 | 5457 | 817.83 | 75.11 | 0 | 49.6 |
| CT2 | 482 | 687.25 | 5457 | 812.97 | 75.91 | 49.6 | 0 |

ALL WP AND CT ARE CL TO BEARING (HORIZONTAL DISTANCE). ELEVATIONS ARE FINAL CONSTRUCTED ELEVATIONS. ALL DISTANCE IN METERS. SYSTEM: UTM NAD83 ZONE 10 ESPG 26910

| NO. | DATE | ENG. | BY | SUBJECT |
|---|---|---|---|---|
| 0 | 1/4/2018 | G.H. | G.H. | ISSUED FOR CONSTRUCTION |

REVISIONS

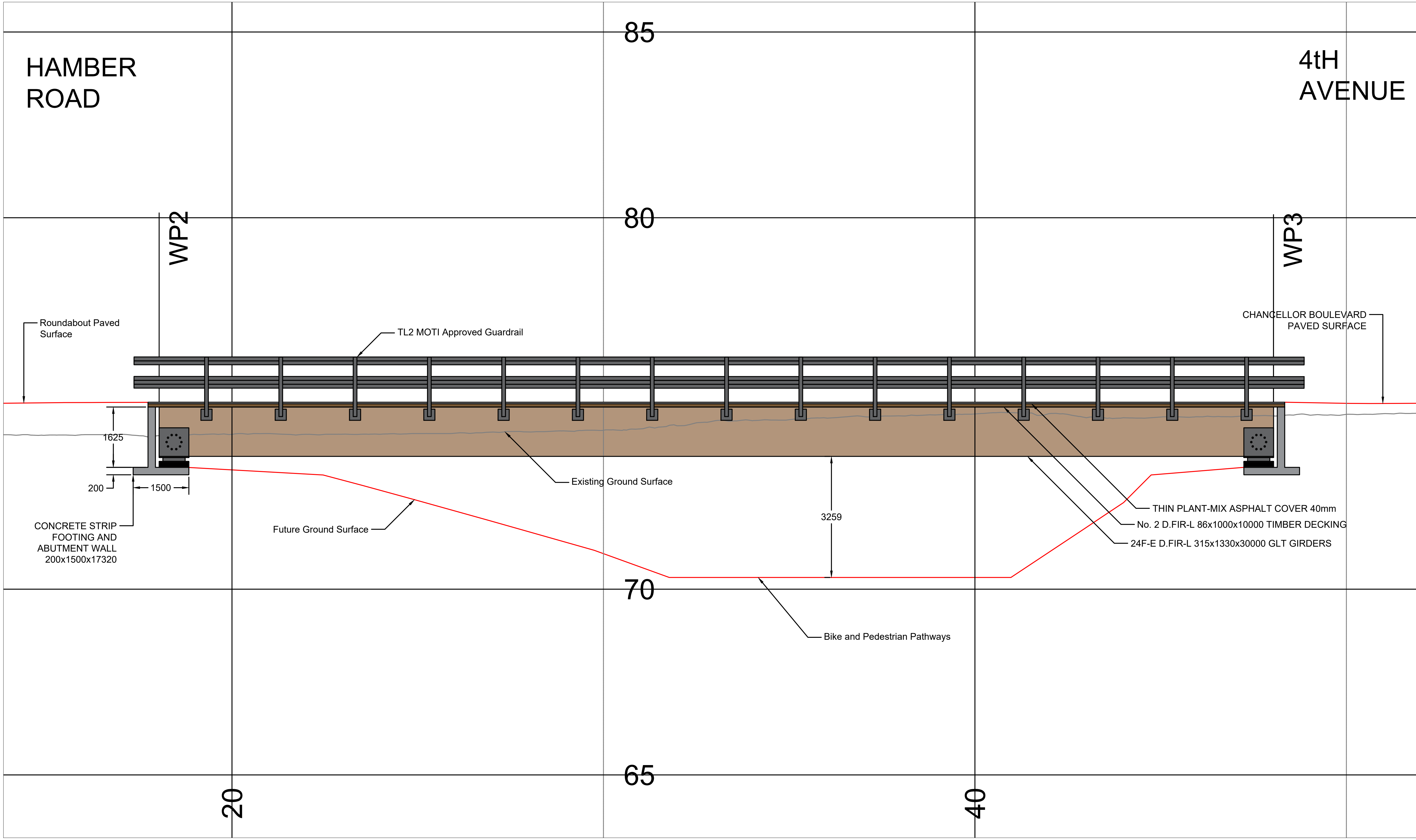
THREE-WAY ENGINEERING LTD.

| | |
|---|---|
| PROJECT No. | 20180101-01 |
| SCALE | 1:250 on ANSI B (11x17) |
| DRAWN | GEORGE HILL |
| DESIGNED | GEORGE HILL |
| CHECKED | |
| APPROVED | |
| DATE | INITIAL |

GENERAL NOTES

CHANCELLOR BOULEVARD AT HAMBER ROAD
PEDESTRIAN AND CYCLIST UNDERPASS
SITE PLAN 0.25m CONTOURS

| DRAWING NUMBER | REV. NO. | SHEET |
|---|---|---|
| 20180101-01-001 | 0 | |




| NO. | DATE | ENG. | BY | SUBJECT |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| 0 | 1/4/2018 | G.H. | G.H. | ISSUED FOR CONSTRUCTION |

REVISIONS

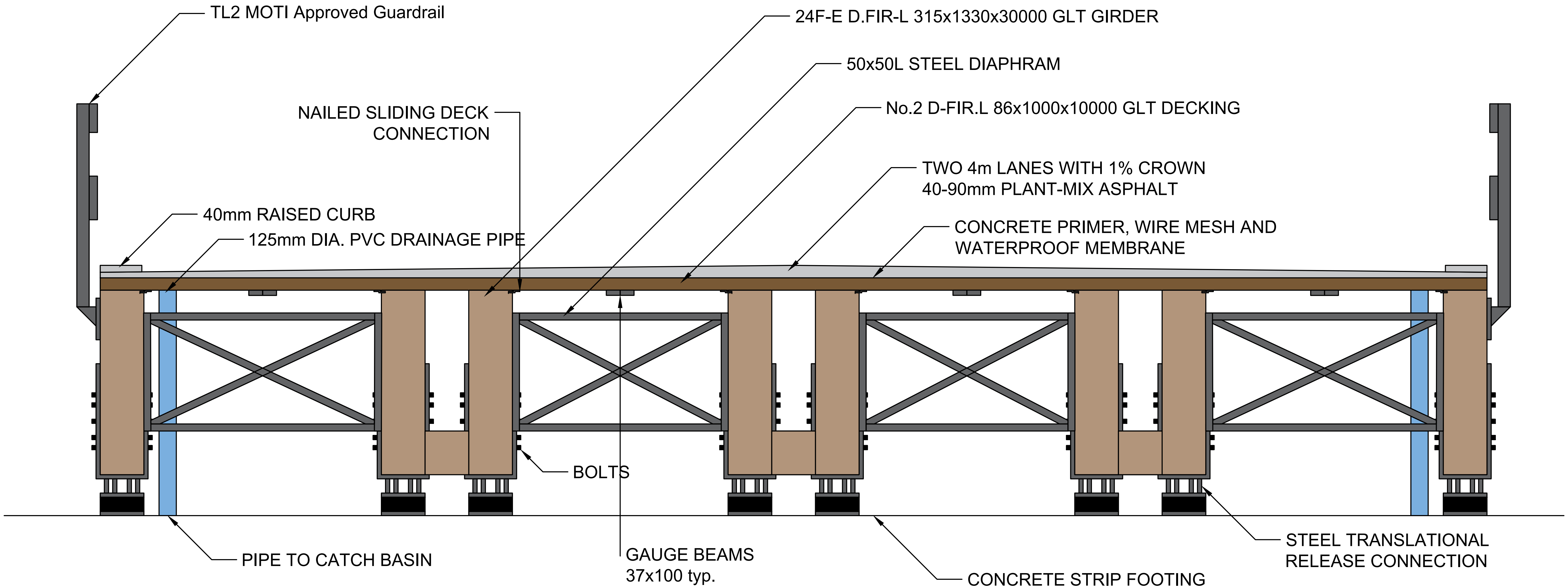
THREE-WAY ENGINEERING LTD.

| | | | |
|---|---|---|---|
| PROJECT No. | 20180101-01 | | |
| SCALE | 1:100 on ANSI B (11x17) | | |
| DRAWN | GEORGE HILL | | |
| DESIGNED | GEORGE HILL | | |
| CHECKED | | | |
| APPROVED | | | |
| DATE | | INITIAL | |

GENERAL NOTES

CHANCELLOR BOULEVARD AT HAMBER ROAD
PEDESTRIAN AND CYCLIST UNDERPASS
SECTION A
PROFILE VIEW FACING NORTH

| DRAWING NUMBER | REV. NO. | SHEET |
|---|---|---|
| 20180101-01-002 | 0 | |




| NO. | DATE | ENG. | BY | SUBJECT |
|---|---|---|---|---|
| 0 | 1/4/2018 | G.H. | G.H. | ISSUED FOR CONSTRUCTION |

REVISIONS

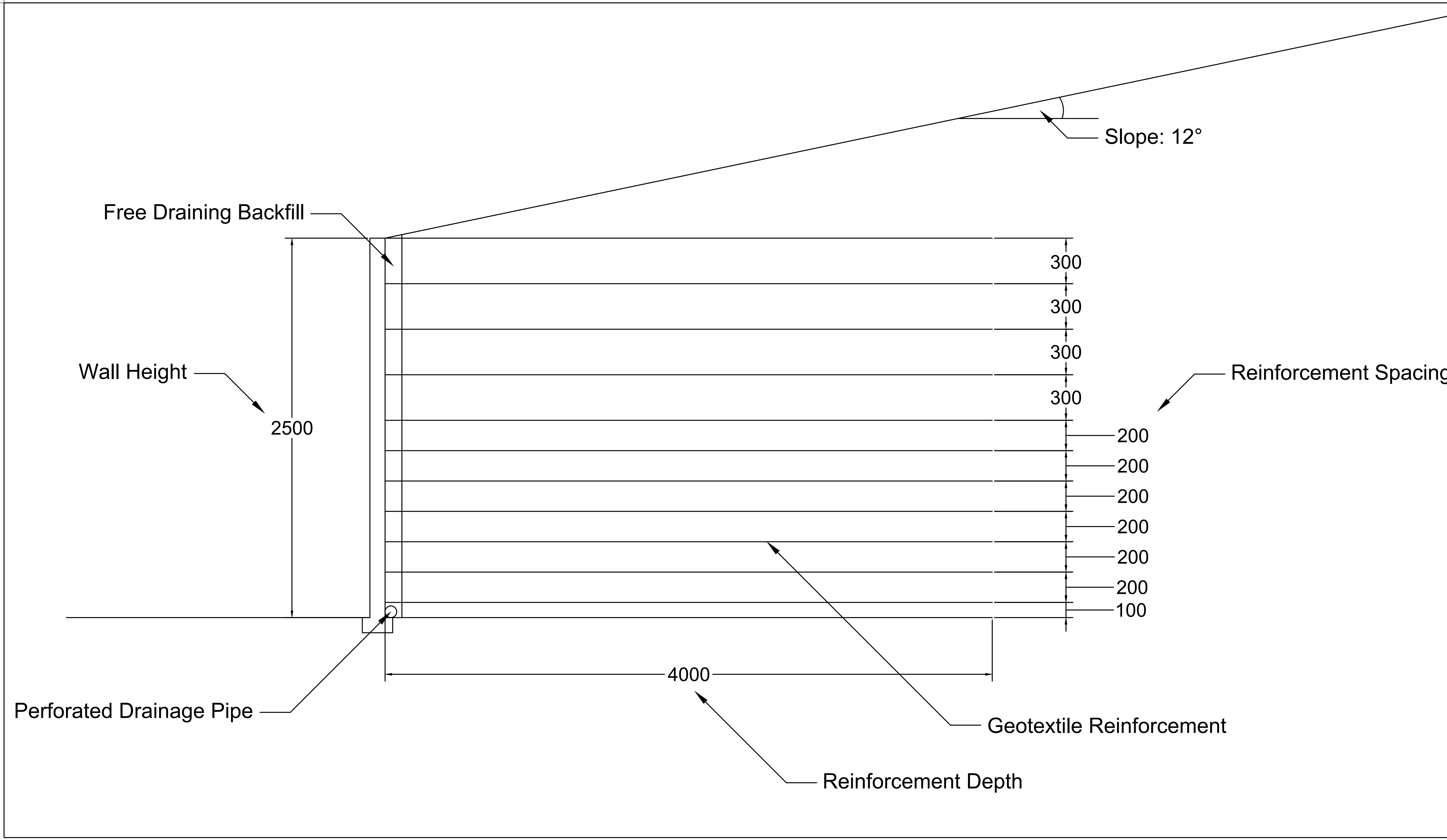
THREE-WAY ENGINEERING LTD.

| | | | |
|---|---|---|---|
| PROJECT No. | 20180101-01 | | |
| SCALE | 1:30 on ANSI B (11x17) | | |
| DRAWN | GEORGE HILL | | |
| DESIGNED | GEORGE HILL | | |
| CHECKED | | | |
| APPROVED | | | |
| DATE | | INITIAL | |

GENERAL NOTES

CHANCELLOR BOULEVARD AT HAMBER ROAD
PEDESTRIAN AND CYCLIST UNDERPASS
SECTION B
ELEVATION VIEW FACING WEST

| DRAWING NUMBER | REV. NO. | SHEET |
|---|---|---|
| 20180101-01-002 | 0 | |




| NO. | DATE | ENG. | BY | SUBJECT |
|---|---|---|---|---|
| 0 | 1/4/2018 | A.S. | A.S. | ISSUED FOR CONSTRUCTION |

REVISIONS

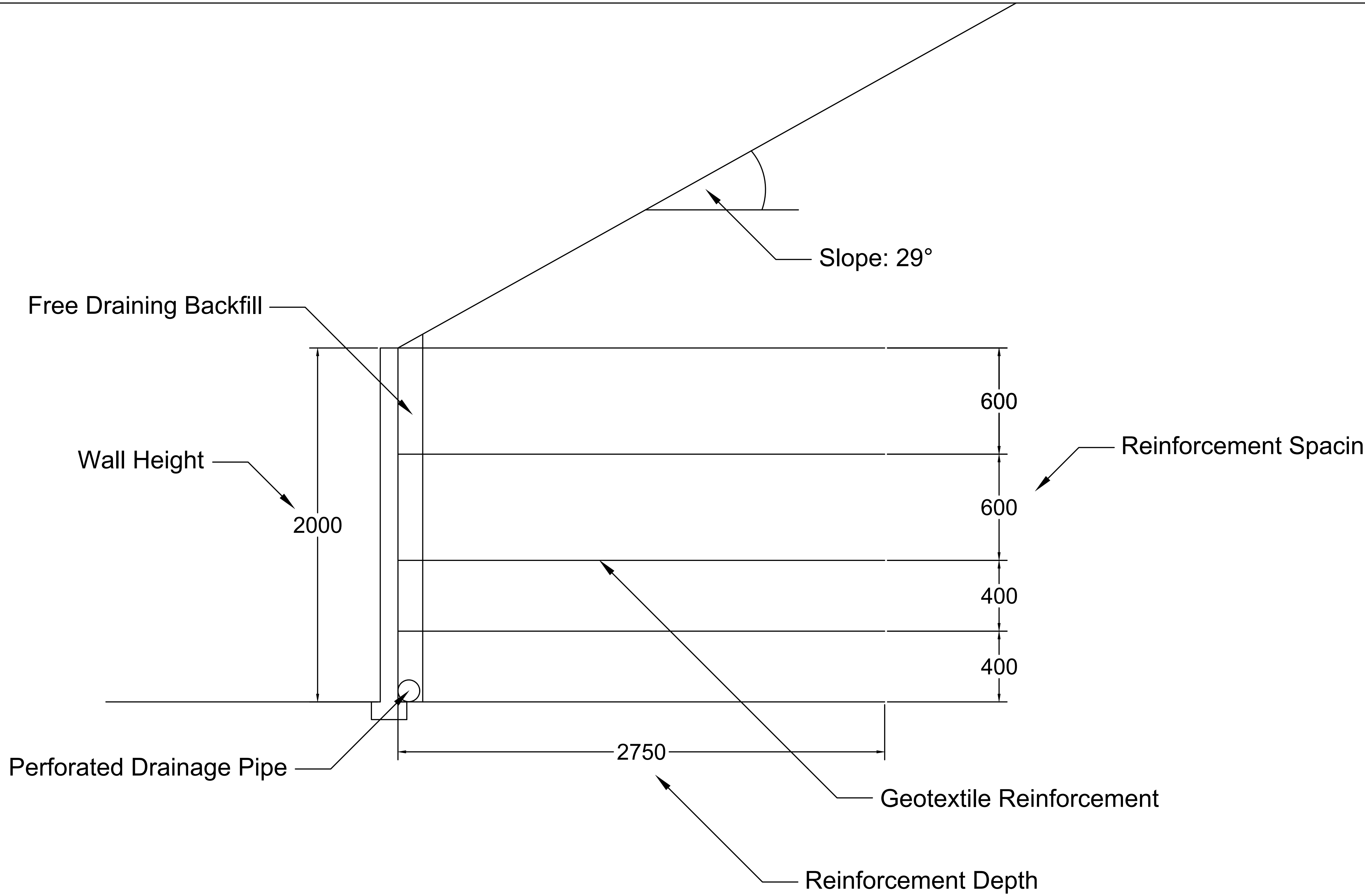
THREE-WAY ENGINEERING LTD.

| | | | |
|---|---|---|---|
| PROJECT No. | 20180101-01 | | |
| SCALE | 1:25 (ON 11"x17") | | |
| DRAWN | ANDY STEWART | | |
| DESIGNED | ANDY STEWART | | |
| CHECKED | | | |
| APPROVED | | | |
| DATE | 2018/04/8 | INITIAL | A.S. |

GENERAL NOTES

CHANCELLOR BOULEVARD AT HAMBER ROAD
PEDESTRIAN AND CYCLIST UNDERPASS
MSE RETAINING STRUCTURE TYPE A

| DRAWING NUMBER | REV. NO. | SHEET |
|---|---|---|
| 20180101-01-004 | 0 | |




| NO. | DATE | ENG. | BY | SUBJECT |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| 0 | 1/4/2018 | A.S. | A.S. | ISSUED FOR CONSTRUCTION |

REVISIONS

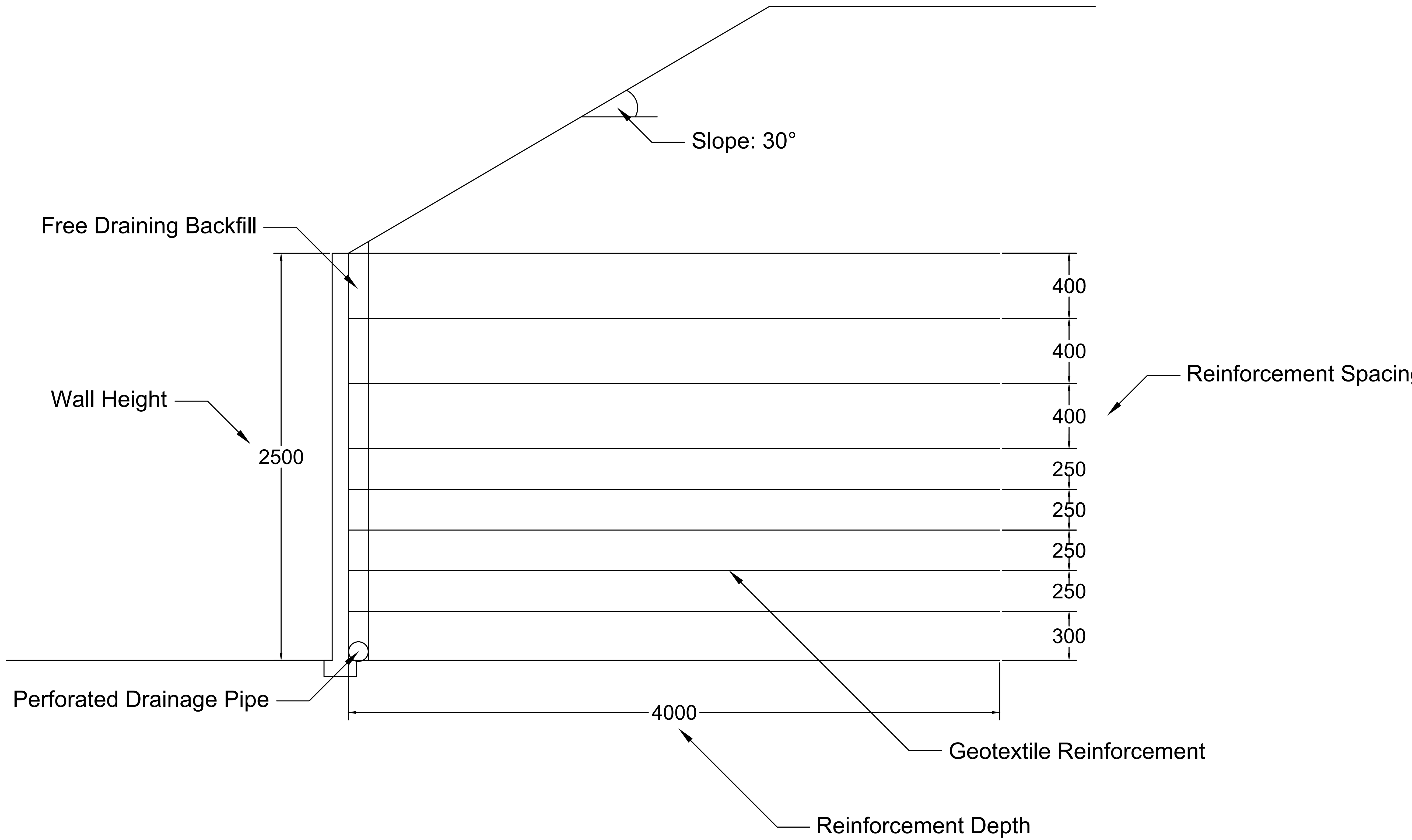
THREE-WAY ENGINEERING LTD.

| | | | |
|---|---|---|---|
| PROJECT No. | 20180101-01 | | |
| SCALE | 1:25 (ON 11"x17") | | |
| DRAWN | ANDY STEWART | | |
| DESIGNED | ANDY STEWART | | |
| CHECKED | | | |
| APPROVED | | | |
| DATE | 2018/04/8 | INITIAL | A.S. |

GENERAL NOTES

CHANCELLOR BOULEVARD AT HAMBER ROAD
PEDESTRIAN AND CYCLIST UNDERPASS
MSE RETAINING STRUCTURE TYPE B

| DRAWING NUMBER | REV. NO. | SHEET |
|---|---|---|
| 20180101-01-005 | 0 | |




| NO. | DATE | ENG. | BY | SUBJECT |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| 0 | 1/4/2018 | A.S. | A.S. | ISSUED FOR CONSTRUCTION |

REVISIONS

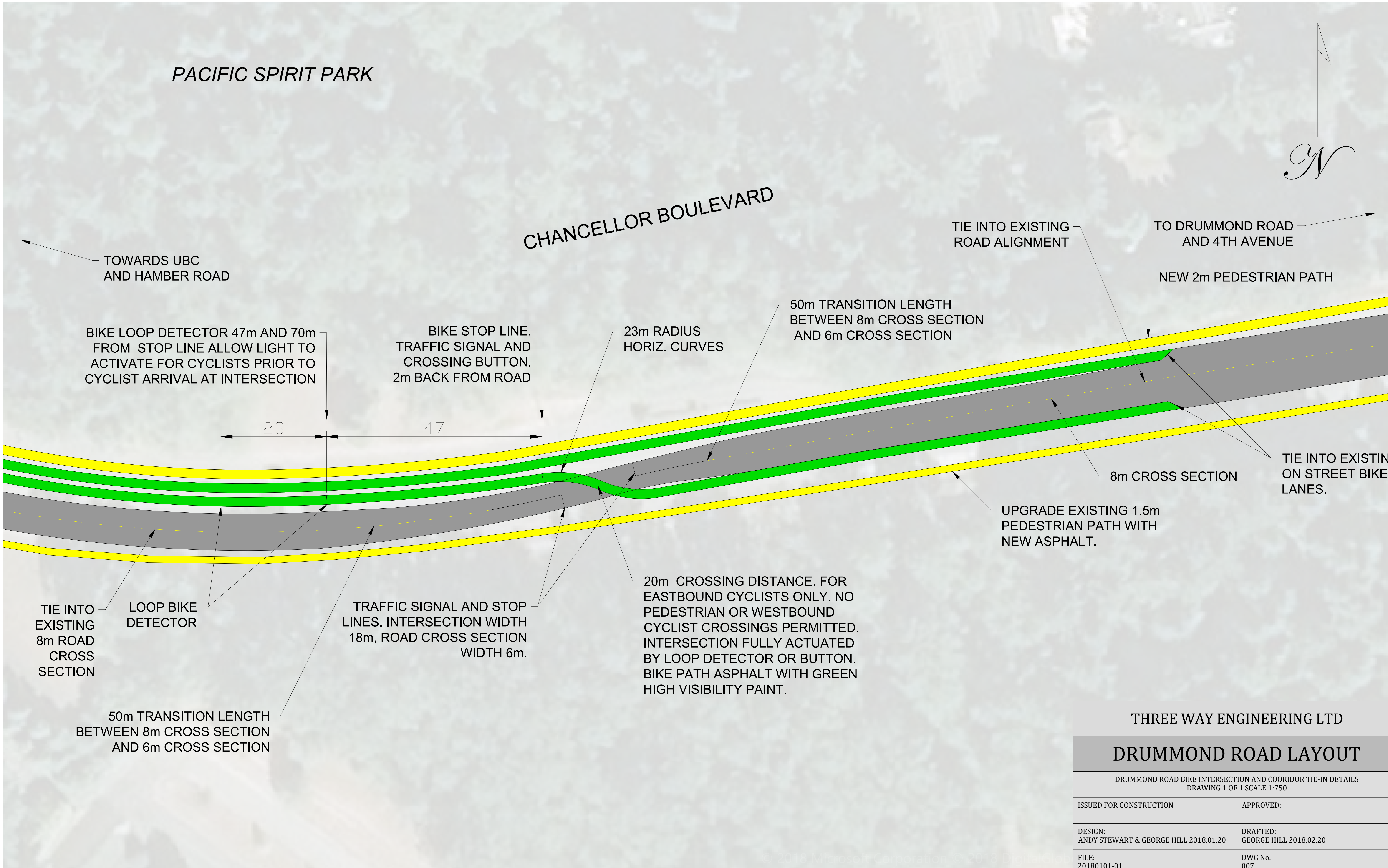
THREE-WAY ENGINEERING LTD.

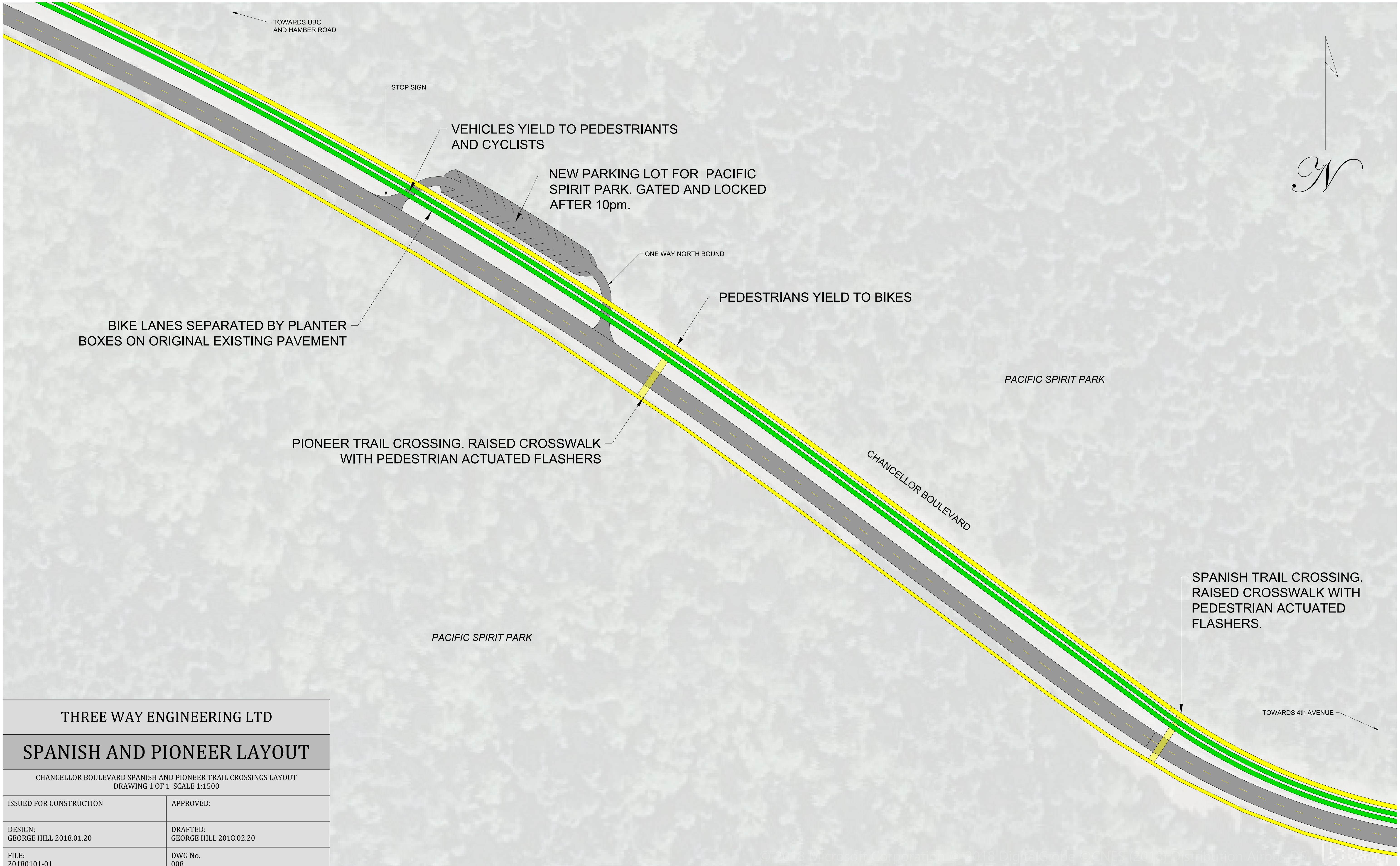
| | | | |
|---|---|---|---|
| PROJECT No. | 20180101-01 | | |
| SCALE | 1:25 (ON 11"x17") | | |
| DRAWN | ANDY STEWART | | |
| DESIGNED | ANDY STEWART | | |
| CHECKED | | | |
| APPROVED | | | |
| DATE | 2018/04/8 | INITIAL | A.S. |

GENERAL NOTES

CHANCELLOR BOULEVARD AT HAMBER ROAD
PEDESTRIAN AND CYCLIST UNDERPASS
MSE RETAINING STRUCTURE TYPE C

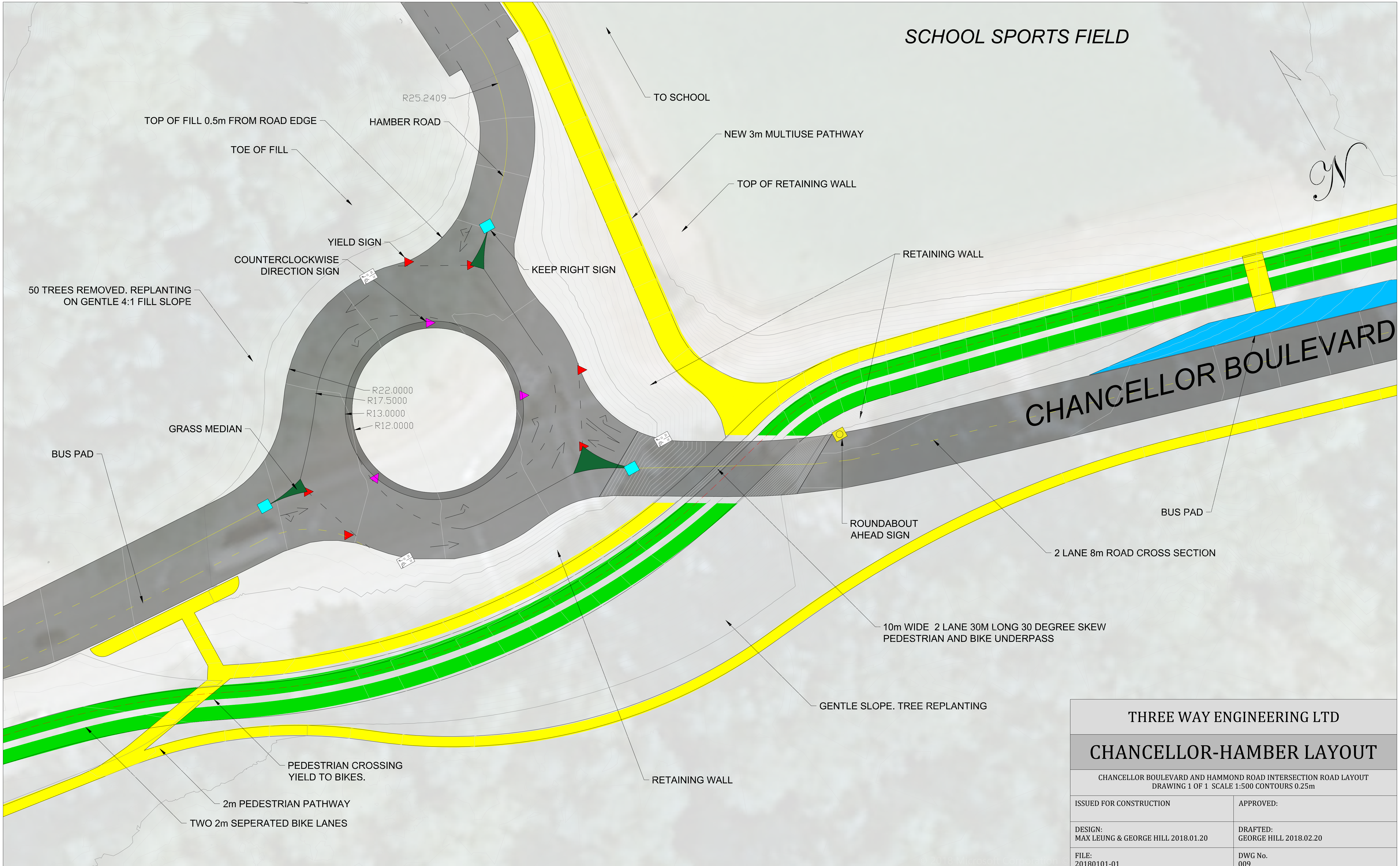
| DRAWING NUMBER | REV. NO. | SHEET |
|---|---|---|
| 20180101-01-006 | 0 | |

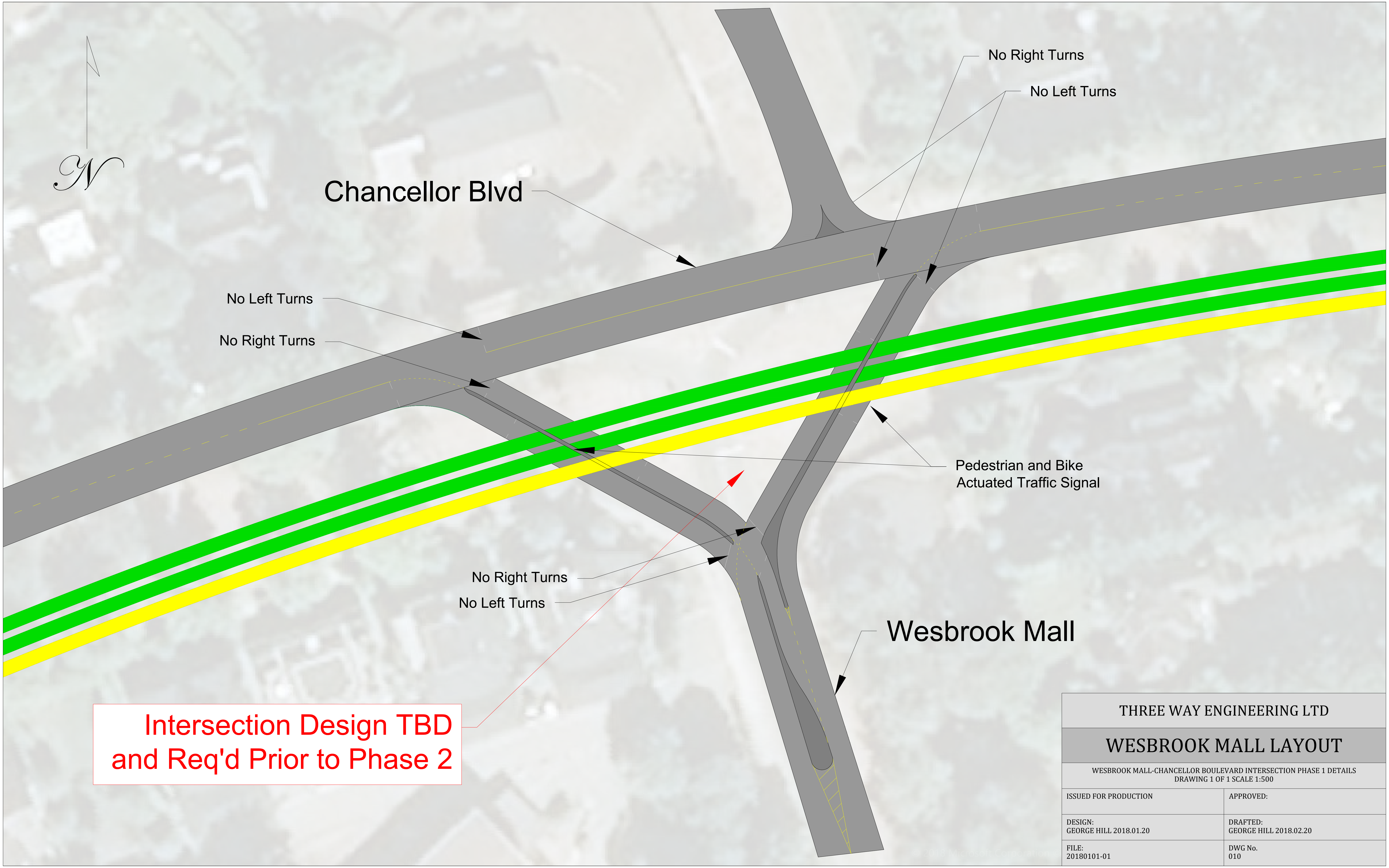

PACIFIC SPIRIT PARK
CHANCELLOR BOULEVARD
N
TOWARDS UBC AND HAMBER ROAD
TO DRUMMOND ROAD AND 4TH AVENUE
TIE INTO EXISTING ROAD ALIGNMENT
NEW 2m PEDESTRIAN PATH
BIKE LOOP DETECTOR 47m AND 70m FROM STOP LINE ALLOW LIGHT TO ACTIVATE FOR CYCLISTS PRIOR TO CYCLIST ARRIVAL AT INTERSECTION
BIKE STOP LINE, TRAFFIC SIGNAL AND CROSSING BUTTON. 2m BACK FROM ROAD
23m RADIUS HORIZ. CURVES
50m TRANSITION LENGTH BETWEEN 8m CROSS SECTION AND 6m CROSS SECTION
23
47
8m CROSS SECTION
TIE INTO EXISTING ON STREET BIKE LANES.
UPGRADE EXISTING 1.5m PEDESTRIAN PATH WITH NEW ASPHALT.
TIE INTO EXISTING 8m ROAD CROSS SECTION
LOOP BIKE DETECTOR
TRAFFIC SIGNAL AND STOP LINES. INTERSECTION WIDTH 18m, ROAD CROSS SECTION WIDTH 6m.
20m CROSSING DISTANCE. FOR EASTBOUND CYCLISTS ONLY. NO PEDESTRIAN OR WESTBOUND CYCLIST CROSSINGS PERMITTED. INTERSECTION FULLY ACTUATED BY LOOP DETECTOR OR BUTTON. BIKE PATH ASPHALT WITH GREEN HIGH VISIBILITY PAINT.
50m TRANSITION LENGTH BETWEEN 8m CROSS SECTION AND 6m CROSS SECTION
THREE WAY ENGINEERING LTD
DRUMMOND ROAD LAYOUT
DRUMMOND ROAD BIKE INTERSECTION AND COORIDOR TIE-IN DETAILS
DRAWING 1 OF 1 SCALE 1:750
ISSUED FOR CONSTRUCTION
APPROVED:
DESIGN: ANDY STEWART & GEORGE HILL 2018.01.20
DRAFTED: GEORGE HILL 2018.02.20
FILE: 20180101-01
DWG No. 007

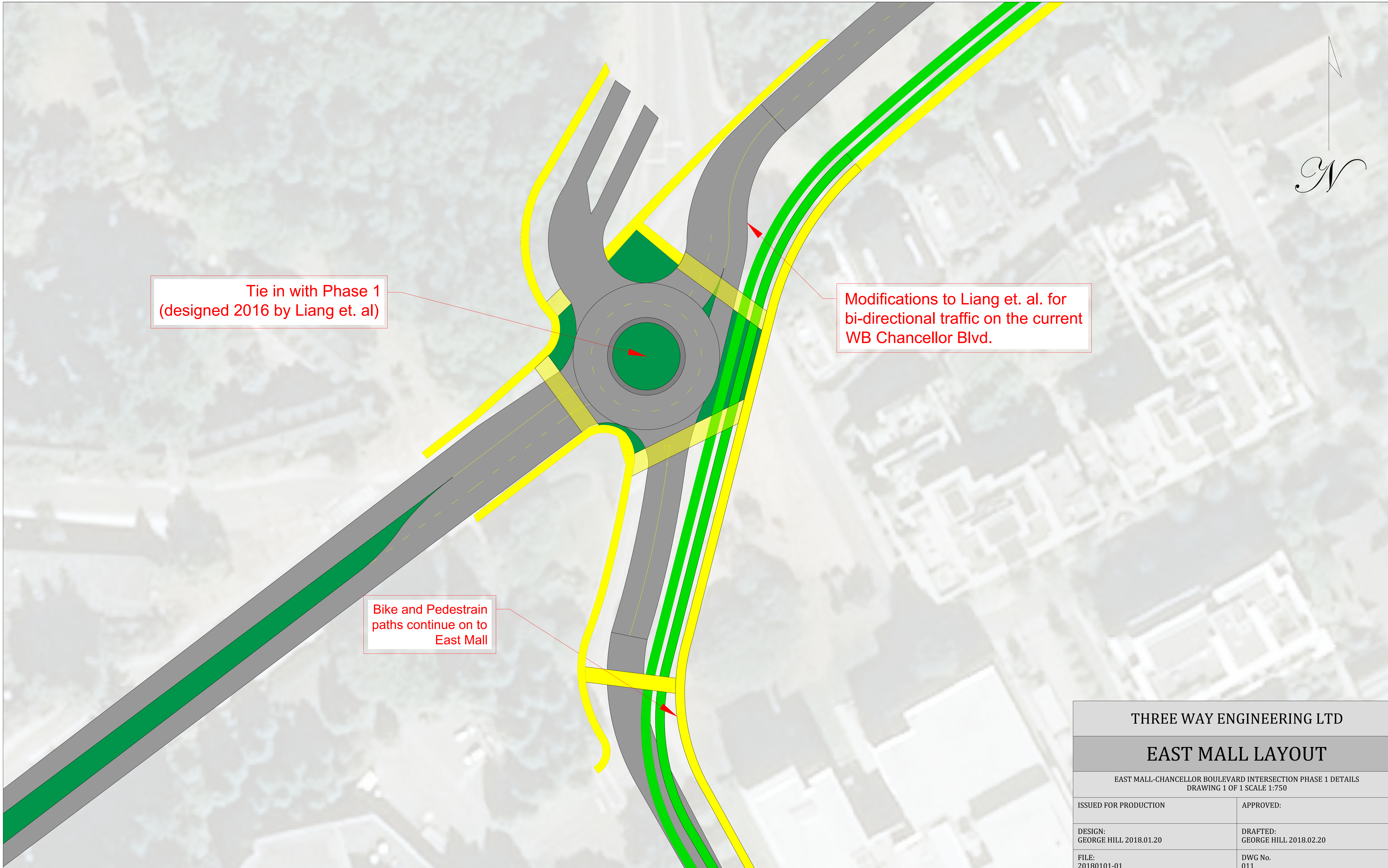





| | |
|---|---|
| THREE WAY ENGINEERING LTD | |
| SPANISH AND PIONEER LAYOUT | |
| CHANCELLOR BOULEVARD SPANISH AND PIONEER TRAIL CROSSINGS LAYOUT<br>DRAWING 1 OF 1 SCALE 1:1500 | |
| ISSUED FOR CONSTRUCTION | APPROVED: |
| DESIGN:<br>GEORGE HILL 2018.01.20 | DRAFTED:<br>GEORGE HILL 2018.02.20 |
| FILE:<br>20180101-01 | DWG No.<br>008 |


SCHOOL SPORTS FIELD
TO SCHOOL
NEW 3m MULTIUSE PATHWAY
TOP OF RETAINING WALL
RETAINING WALL
R25.2409
TOP OF FILL 0.5m FROM ROAD EDGE
HAMBER ROAD
TOE OF FILL
YIELD SIGN
COUNTERCLOCKWISE
DIRECTION SIGN
KEEP RIGHT SIGN
50 TREES REMOVED. REPLANTING
ON GENTLE 4:1 FILL SLOPE
R22.0000
R17.5000
R13.0000
R12.0000
GRASS MEDIAN
BUS PAD
CHANCELLOR BOULEVARD
ROUNDABOUT
AHEAD SIGN
BUS PAD
2 LANE 8m ROAD CROSS SECTION
10m WIDE 2 LANE 30M LONG 30 DEGREE SKEW
PEDESTRIAN AND BIKE UNDERPASS
GENTLE SLOPE. TREE REPLANTING
PEDESTRIAN CROSSING
YIELD TO BIKES.
RETAINING WALL
2m PEDESTRIAN PATHWAY
TWO 2m SEPERATED BIKE LANES
THREE WAY ENGINEERING LTD
CHANCELLOR-HAMBER LAYOUT
CHANCELLOR BOULEVARD AND HAMMOND ROAD INTERSECTION ROAD LAYOUT
DRAWING 1 OF 1 SCALE 1:500 CONTOURS 0.25m
ISSUED FOR CONSTRUCTION
APPROVED:
DESIGN:
MAX LEUNG & GEORGE HILL 2018.01.20
DRAFTED:
GEORGE HILL 2018.02.20
FILE:
20180101-01
DWG No.
009


N
Chancellor Blvd
No Right Turns
No Left Turns
No Left Turns
No Right Turns
Pedestrian and Bike
Actuated Traffic Signal
No Right Turns
No Left Turns
Wesbrook Mall
Intersection Design TBD
and Req'd Prior to Phase 2
THREE WAY ENGINEERING LTD
WESBROOK MALL LAYOUT
WESBROOK MALL-CHANCELLOR BOULEVARD INTERSECTION PHASE 1 DETAILS
DRAWING 1 OF 1 SCALE 1:500
ISSUED FOR PRODUCTION
APPROVED:
DESIGN:
GEORGE HILL 2018.01.20
DRAFTED:
GEORGE HILL 2018.02.20
FILE:
20180101-01
DWG No.
010




| | |
|---|---|
| THREE WAY ENGINEERING LTD | |
| EAST MALL LAYOUT | |
| EAST MALL-CHANCELLOR BOULEVARD INTERSECTION PHASE 1 DETAILS<br>DRAWING 1 OF 1 SCALE 1:750 | |
| ISSUED FOR PRODUCTION | APPROVED: |
| DESIGN:<br>GEORGE HILL 2018.01.20 | DRAFTED:<br>GEORGE HILL 2018.02.20 |
| FILE:<br>20180101-01 | DWG No.<br>011 |