Corridor Redesign of Chancellor Boulevard - Team 16

Xi Chao, Wenzhan Chen, Yanshan Jin, Zheyu Lu, Zixuan Xue, Ruifang Yang

University of British Columbia

CIVL 445

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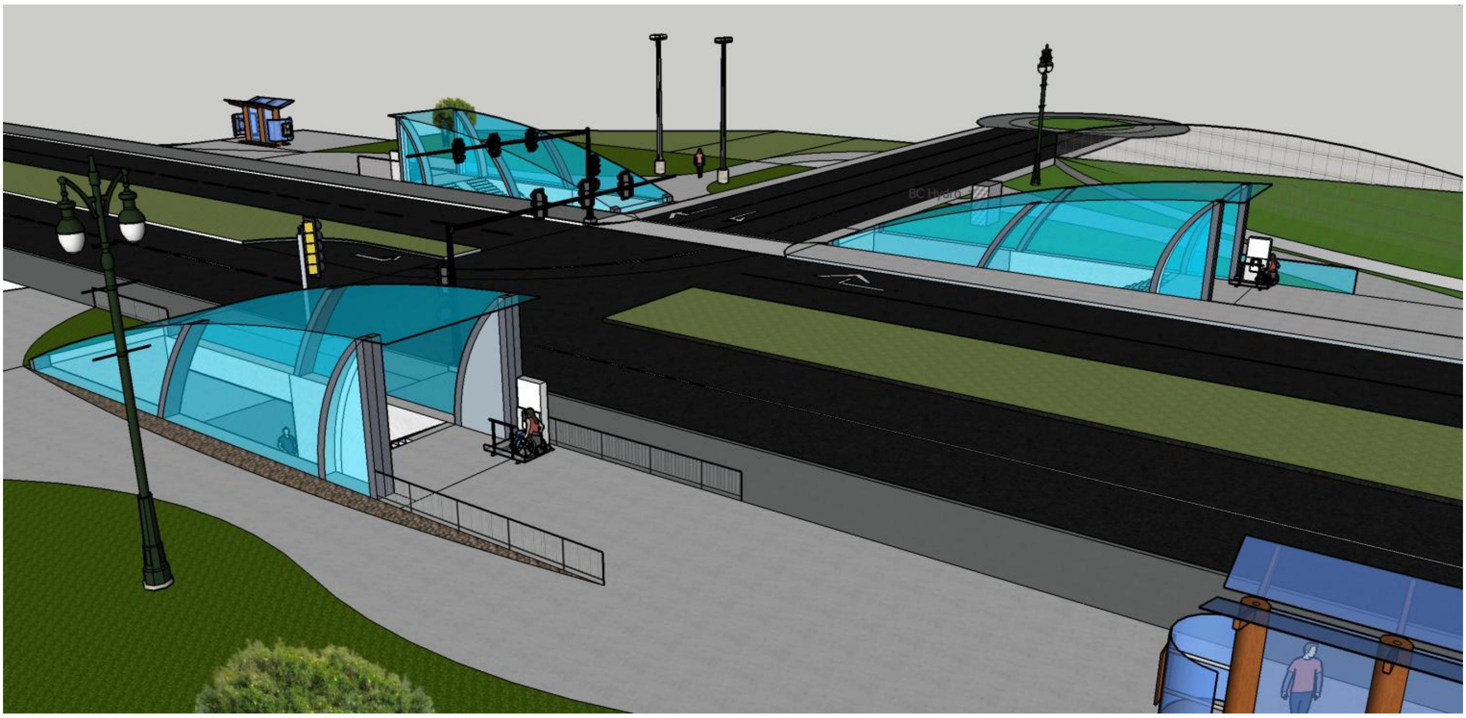

Corridor Redesign of Chancellor Boulevard

Final Design Report

Client: UBC SEEDS (Social Ecological Economic Development Studies) Sustainability Program

Prepared by: Alpine Breeze Engineering Consulting Ltd. (Team 16)

Xi Chao
Wenzhan Chen
Yanshan Jin
Zheyu Lu
Zixuan Xue
Ruifang Yang

April 9, 2018

Letter of Transmittal

April 9, 2018

UBC SEEDS (Social Ecological Economic Development Studies) Sustainability Program
Campus and Community Planning
University of British Columbia
2210 West Mall
Vancouver, BC Canada V6T 1Z4

Dear Sir/Madam,

As one of the key deliverables, please find attached for our submission of final design report for the project entitled Corridor Redesign of Chancellor Boulevard.

This report provides a detailed description of the final design with structural calculations and engineering drawings being attached as supplementary materials. Our roadway design mostly focuses on adjusting current lane configurations and developing a shared pathway for pedestrians and cyclists along both sides of Chancellor Boulevard.

A road-crossing underpass will be constructed at the intersection of Hamber Road with Chancellor Boulevard for best efficiency and safety considerations. Construction works are scheduled to start on May 1st, 2018, with a proposed duration of 93 days in total. The class B cost estimate is calculated as 5.4 million for this entire project.

We hope you will find this report helpful. Please feel free to contact us if you have any question or concern regarding this final design.

Sincerely yours,

Alpine Breeze Engineering Consulting Ltd.
6250 Applied Science Lane
Vancouver, BC Canada V6T 1Z4

Executive Summary

According to the request from UBC SEEDS, Alpine Breeze Engineering Consulting Ltd. has redesigned Chancellor Boulevard in order to facilitate traffic flow and improve safety of all road users, while accommodating increasing demands due to population growth. Our design focuses on the specified project corridor, which starts from Acadia Road and runs eastwards to Drummond Road. This report introduces the finalized design option in details and provides comprehensive rationales together with drawings for clear demonstration of design components and structures.

Our final planning consists of both changes on road geometry and construction of an additional road-crossing underpass for pedestrians and cyclists. The existing layout of 2 lanes per direction has been kept with lane widths adjusted to 3.5 meters. Bicycle lanes along roadsides are integrated together with pavements to form a shared walkway for both pedestrians and cyclists. Volume sensors will be used to activate the control of traffic signal at intersection of Hamber Road with Chancellor Boulevard. Some other improvements are adjustments on gradient in order to accelerate drainage, installation of flexible posts at turnings, increased number of traffic signs and special paintings on road for speed control, installation of cats eyes for better night vision, as well as planting of vegetation on median. Drawings illustrating details are attached in Appendix E.

The additional underpass was designed to locate at the intersection of Hamber Road and Chancellor Boulevard to provide a safe and efficient option for road crossing, while at the same time minimizing the disturbance on traffic flow. Detailed design drawings are included in Appendix E with overviews for entrances, lifts, retaining structures, storage tanks and drainage pumps, lighting, and vandal-proof equipment.

Construction is scheduled to commence on May 1st, 2018 and be completed on September 9th. The whole project construction could be divided into 5 zones, with an overall duration of 17 weeks. The schedule is planned with the consideration that disturbance to traffic should be minimized by avoiding full closure to the road. A detailed construction schedule could be found attached in Appendix A. Information regarding to construction will be released online for public as well as to local communities, and transportation relevant departments several weeks in advance. There will also be interacting events include information sessions and open houses to obtain feedbacks from stakeholders and clients.

Based on our finalized design, the detailed cost estimate is calculated to be 5.4 million, with road surface construction taking up to 3.6 million, and underpass construction sharing the rest 1.2 million with other costs such as permitting and maintenance. Detailed cost breakdown is enclosed in Appendix B for further reference.

We are very pleased to provide SEEDS with an improved road and traffic system with better efficiency and experience with increased safety for all road users, as well as protecting the natural surrounding environment and ecosystem along Chancellor Boulevard.

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1.0 INTRODUCTION

Alpine Breeze Engineering Consulting Ltd. has performed a redesign of Chancellor Boulevard as requested by UBC SEEDS (Social Ecological Economic Development Studies) Sustainability Program. The project corridor spans from east of Acadia Road to west of Drummond Drive, with a total length of approximately 1.8 km. This design aims to improve overall road serviceability and construct a road-crossing underpass for pedestrians and cyclists at a suitable location. The purpose of this report is to summarize the final detailed design based on previous preferred preliminary designs.

1.1 Project Overview

Chancellor Boulevard is one of the five arterial roads that connects UBC Point Grey campus directly to the city of Vancouver. Managed by University Endowment Lands, it is an east-west roadway passing through the Pacific Spirit Regional Park and terminating at the intersection with Drummond Drive. This corridor provides a total of four driving lanes in both travel directions, which are separated by a 5-meter-wide median in the middle. Each driving lane is about 3.7 m in width. Meanwhile, there are no reserved bicycle lanes within the whole length of project corridor, and Chancellor Boulevard provides only one direction of pedestrian sidewalk in this region.

Figure 1 Overview of Existing Project Corridor (Image source: Google Maps)

1.2 Project Objectives

The project corridor serves a great amount of vehicles both traveling into and out of the main campus, especially during peak hours on weekdays. Currently, only the intersection of Hamber Road with Chancellor Boulevard is signalized with one set of pedestrian-controlled traffic signals. This location is the only choice for road users other than vehicle drivers to safely cross Chancellor Boulevard. Since Chancellor Boulevard also provides the only access to University Hill Elementary School on Hamber Road, an overlap of traffic volume significantly increases possibilities of traffic conflicts and raises safety concerns for pedestrians and cyclists. Therefore this intersection is considered as our main design focus for implementing improvements on traffic conditions. The proposed pedestrian underpass will be located here as well to provide maximum service efficiency for this infrastructure.

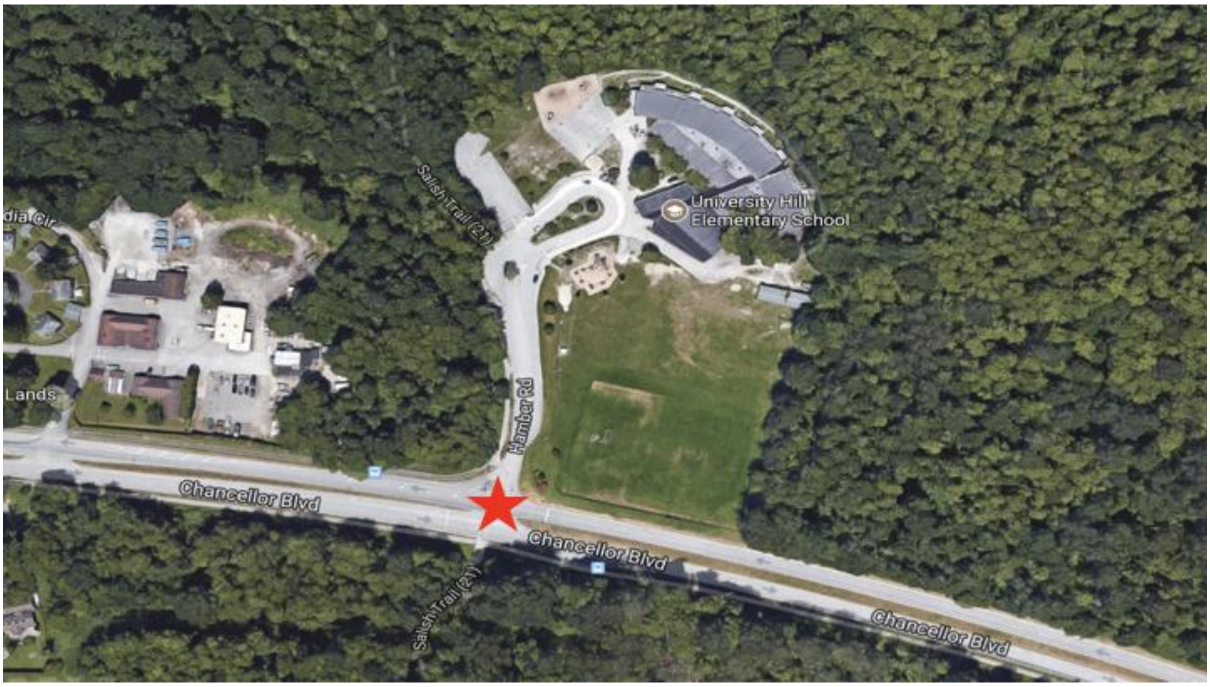

Figure 2 Marked Location of the Intersection of Chancellor Boulevard with Hamber Road (Image source: Google Maps)

The most important objective of our design is to maximize travel safety for every road user in all travel modes, including walking, cycling, driving, and taking public transportations. Vehicle speed is proposed to be reduced, with road priorities being assigned to pedestrians, cyclists, buses, and emergency vehicles. After road improvements, the corridor will be able to accommodate an increased travel demand in the future according to population growth. By improving the drainage system, the impact of storm events will be minimized, which also positively influences users' experiences. The proposed project aims to be completed within a comparatively acceptable cost budget.

Considering sustainability as another major aspect of the design, one of the targets is to minimize the potential influence on the environment and disturbance to wild creatures caused by construction. This also aligns with UBC's target of promoting sustainable travel and reducing single occupant vehicles (UBC Transportation Plan Vancouver Campus, 2014). Design features will also fit with existing culture and economic background of the project corridor.

Several key issues are also identified from existing road conditions and site visits during the design stage, which closely relates to safety of road users. One of the key issues is that cyclists have to either share the road with vehicles or occupy part of pedestrian sidewalks. Moreover, the speed limit is 60 km/hr on the corridor including a turning at east side close to Drummond Drive which is not safe enough when cyclists and cars are sharing the same road. There is also a heavy accumulation of left turning vehicles from Chancellor Boulevard onto Hamber Road on east bound during morning peak hours, which significantly reduces intersection efficiency and raises potential risk of conflicts between road users.

1.3 Team Contributions to Final Design

Table 1 below summarizes contributions by each team member towards the completion of final detailed design. Contributions are organized by teamwork assignment, which later develops into report components. Each component has a main contributor and a secondary contributor, and has been reviewed by a specified reviewer. Names of all team members are represented by initial letters.

Table 1 Summary of Team Member Contributions to Final Design

Design Components	**Main Contributor**	**Secondary Contributor**
Structural design and analysis	RJ	KC
Roadway drawing	LL	KC
Stormwater management	GY	XC
Specifications and Maintenance Plan	XC	LL
Engineering Drawings	KC	RJ
Construction Plan and Schedule	LL	AX
Cost Estimate	AX	GY

Specifically, **Table 2** summarizes contributions of each team member to this final design report.

Table 2 Summary of Team Member Contributions to Final Design Report

Report Components	**Main Contributor**	**Secondary Contributor**	**Reviewer**
Letter of Transmittal	RJ	-	AX
Executive Summary	GY	XC	RJ
Introduction	XC	LL	GY
Design Criteria	RJ	GY	GY
Technical Considerations	RJ	KC	GY
Key Design Components	GY	AX	RJ
Final Cost Estimate	AX	KC	RJ
Schedule	LL	AX	GY
Maintenance Plan	XC	KC	LL
Engineering Drawings	KC	LL	RJ

2.0 DESIGN CRITERIA

In the process of developing our design from conceptual stage to its final stage, a list of design criteria have been adopted to assess the overall design performance, which comprehensively covers several aspects ranging from city standards to social and economical considerations. This section summarizes those design criteria for both the overall road section along project corridor and the pedestrian/cyclist underpass, respectively.

2.1 Roadway Design

Referring to the UBC Transportation Plan (2014), UBC Vancouver Campus Plan (2014), and project design specifications, the key criteria of roadway redesign for Chancellor Boulevard could be concluded with strong focuses on user safety, sustainability, and cost efficiency.

Table 3 Key Roadway Design Criteria and Guidelines

Regulatory guidelines and city standards	Master Municipal Construction Document (MMCD)	
	City of Vancouver Street Restoration Manual	
General criteria	Sustainability	♦ Maximize performance ratio ♦ Minimize disturbance to environment ♦ Resilient and innovative design
	Future demands	♦ Maximum 2000 vehicles per direction during peak hours
	Safety	♦ Reduction of traffic speed to 50 km/hr ♦ Road priority to buses and emergency vehicles
	Stormwater drainage capacity	♦ 1 in 20 years capacity
	Cost	♦ Minimize construction and maintenance cost ♦ Maximize cost efficiency
	Stakeholders	♦ Positive feedback from most relevant stakeholders

2.2 Underpass Design

In general, design criteria for pedestrian/cyclist underpass follows the same baseline as that for road section. However, the regulatory requirements and city standards are different due to the variance in the nature of these two structures.

Table 4 Key Underpass Design Criteria and Guidelines

Regulatory guidelines and city standards	Master Municipal Construction Document (MMCD)	
	City of Vancouver Street Restoration Manual	
	CSA A23.3 04 Design of Concrete Structures	
	British Columbia Building Code (2012)	
General criteria	Sustainability	♦ Maximize performance ratio ♦ Minimize disturbance to environment ♦ Resilient and innovative design
	Future demands	♦ Maximum 480 pedestrians and 120 cyclists during peak hours
	Safety	♦ Service life of 50 years ♦ 24 hour lighting with 17.5 lux ♦ Fencing near the entrances at the intersection
	Accessibility	♦Ease of access for pedestrians /cyclists /disabilities to the underpass
	Drainage	♦ Minimize stormwater into the underpass Cleaning requirements ♦1 in 20 years stormwater capacity
	Cost	♦ Minimize construction and maintenance cost ♦ Maximize cost efficiency
	Appearance	♦ Proper appearance regarding to the surrounding environment

3.0 TECHNICAL CONSIDERATIONS

The two main components of this project consist of road renovation and underpass construction, which both have positive impacts on facilitating traffic on the project corridor. One of the most important considerations is to arrange a reasonable schedule that minimizes traffic disturbances during the construction phase. This will be achieved by constructing underpass in two sections so that half of the corridor can be used to accommodate traffic in both directions during construction. The remaining roadway construction will also be divided into several zones to minimize disruption on traffic flow. In addition, the construction method should be selected such that influences on the surrounding environment is reduced to the minimum possible value due to the location of project corridor within Pacific Spirit Regional Park. Waste disposal needs to be arranged properly for sustainability considerations. After evaluating capacity of the existing drainage system during intensive rainfall events, it is obvious that the whole system needs to be redesigned and updated to accommodate for the expected 1 in 20 years rainfall event.

Moreover, structural durability and reliability is another essential consideration for the underpass. Since the maximum change in elevation of the underpass is 3.5 meters deep from ground surface, it is important to denote locations of existing underground facilities including wires, pipelines and others. Rerouting of these facilities might be needed depending on the situation. Uncertainties regarding to foundation conditions and encountering of similar unexpected situations should be taken into account for project management and schedule arrangements.

4.0 KEY DESIGN COMPONENTS

This section provides a detailed insight into the key components of our proposed final design for the project corridor along Chancellor Boulevard. Those components fall into two main categories: the roadway design and the underpass design, with the underpass being considered as the focus of this report. Together with some changes in lane configurations and improvements in traffic signal controls, the target of this design is to enhance overall travel efficiency and road safety by introducing better traffic conditions along Chancellor Boulevard.

4.1 Roadway Design

Proposed roadway design is developed based on existing geometries. Additional features and changes are made in order to meet criteria mentioned above. In accordance with UBC's goal and Vancouver Greenest City 2020 Action Plan, the proposed corridor design will improve pedestrian and cyclist safety and promote green transit such as public transit and cycling. Traffic phases and geometry at the intersection with Hamber Road is redesigned to optimize traffic flows, as well as to accommodate the use of proposed road-crossing underpass. Landscape and green areas around entrances of underpass are one of the proposed features to provide a more comfortable environment for pedestrians and cyclists. An overview of the proposed geometry of Chancellor Corridor is shown in the figure below.

4.1.1 Geometry Design

In order to minimize impact to existing trees and green areas at both side of Chancellor Boulevard, our proposed design tend to retain existing width of road cross section. Space occupied by the existing bicycle path will be utilized to construct the proposed pedestrian and cyclist shared pathway when necessary. Road medians will remain unchanged in the middle of the road as before. Width of this median will vary due to available constructive space in line with the goal of minimizing impact to green areas at both sides of the road. The major reason of keeping this median is for safety considerations that dividing traffics traveling in opposite directions separately. Since no lightings will be installed for the entire scope along Chancellor Boulevard, vehicles tend to turn on high beam at night. Bushes and trees will be planted on the median to minimize impacts of high beam from opposite direction and also add an aesthetic green feature to the region.

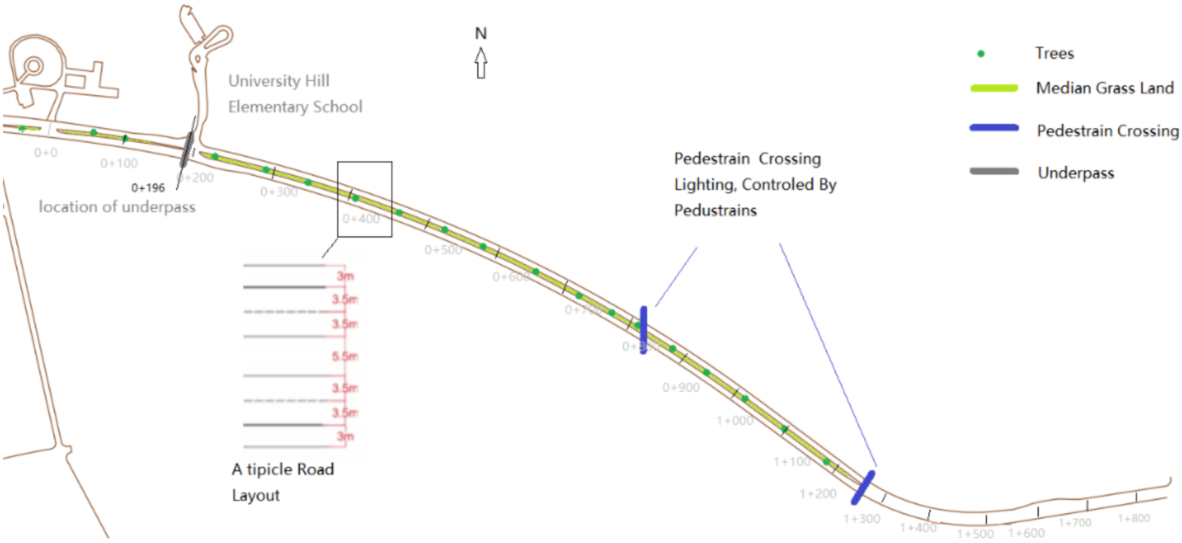

Figure 3 Geometry Overview of Chancellor Boulevard

Table 5 below summaries key dimensions of roadways design.

Table 5 Table of Proposed Road Widths

Item Description	**Dimension (m)**
Driving Lane	3.5
Median	0 – 5.5
Left-Turn Lane	3.5

The width of lane is designed according to Geometry Design Guide of Canadian Roads as a standard width of lane. It is also one of the considerations that the width of lane is kept not as wide to help cars slow down and follow the speed limit of 50 km/hr on the project corridor.

Some modifications are made to the intersection at Hamber Road and Chancellor Boulevard to improve traffic traveling in and out of University Hill Elementary School. The roadway design also accommodates with the proposed underpass design which will be discussed later in this section. One of the major changes at this intersection is the removal of a triangular concrete island at the northwest corner of the intersection. **Figures 4 and 5** below provide an insight into existing and proposed configurations, respectively. After the removal of this existing concrete island, more space is created to construct the entrance to underpass at the northwest corner. This decision is made in accordance with one of our design goals of minimizing impact on existing landscape as well. After this removal, merging to one lane along westbound is designed to happen at Acadia Cir which is located to the west of Hamber Road. Therefore, the two lanes at Acadia Road are designed for straight driving and right turn lane respectively as existing road configuration. Drawings in Appendix E provide more details regarding to the proposed roadway design.

Figure 4 Existing Road and Lane Configuration (Image source: Google Maps)

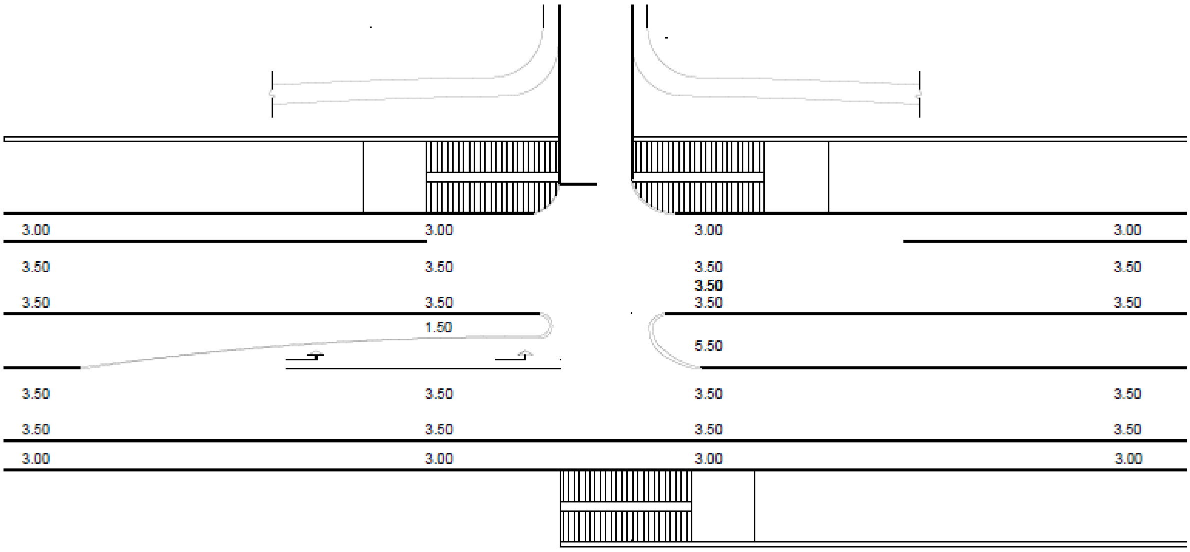

Figure 5 Proposed Road and Lane Configuration Design for Chancellor Boulevard

4.1.2 Pedestrian and Cyclist Pathway Design

One of the main design features of this project is the proposed pedestrian and cycling shared pathway. A 3-meter-wide shared pathway will be constructed along both sides of Chancellor Boulevard. Similar to roadway regulations, bicycle traffic are also divided into two directions. Signages will be installed along the pathway to remind cyclist biking in the indicated direction. In considerations of budget saving, the pathways are proposed to be paved by asphalt. It is recommended that pedestrians and cyclists each share half of the pathway together. Due to safety considerations, special painting will be applied to this pathway to distinguish a 1.5-meter-wide space for cyclists and the other 1.5-meter-wide space for pedestrians. In order to further separate the shared pathway from traffic on road, the pathway will also be raised up by 150mm using concrete curbs. Those curbs are selected to be MF 137-A-1 type according to City of Vancouver Street Restoration Manual and detailed information can be found in Appendix E.

4.1.3 Pavement Design

All roadways and shared pathways on Chancellor Boulevard within the redesign scope are proposed to be paved by asphalt. Concrete pavement will only be applied to sidewalks and trails around entrances to underpass in landscape areas. As Chancellor Boulevard is considered as an arterial road and according to City of Vancouver Street Restoration Manual and Master Municipal Construction Documents, the total thickness of asphalt pavement have to be 150 mm. This 150 mm asphalt will be paved in three lifts where each lift is 50 mm thick with tack coat applied in between each lift. Gravel base and sub-base will be installed to provide firm foundation to asphalt pavement on top of it. Gravel base will be graded according to the designed slope for drainage purposes. Thickness of gravel sub-base may vary depending on changes in road grade. A similar structure is proposed for the shared asphalt pathway for pedestrians and cyclists. **Table 6** below summaries thickness of asphalt, gravel base and sub-based layers for both roadway and shared pathway:

Table 6 Material Summary of Roadway and Pathway Structures

Item Description	**Roadway**	**Shared Pathway**
Asphalt Surface Lift	**50mm** Superpave 12.5mm Surface Course	**65mm** Asphaltic Concrete Paving -Upper Course #2
Asphalt Base Lift	**100mm** Superpave 25mm Base Course in 2 lifts	N/A
Granular Base	**150mm** Granular Base	**100mm** Granular Base
Granular Sub-base	**450mm** Granular Sub-base -Thickness varies	**300mm** Granular Sub-base

Types of asphalt specified in the table above are selected according to City of Vancouver Street Restoration Manual, City of Surrey Supplementary Master Municipal Construction Documents, and Master Municipal Construction Document.

4.1.4 Landscape Design

Besides the proposed landscape on medians, all other landscape design is made for areas around entrances to the underpass. At both north and south sides of the underpass, a landscape area is proposed to accommodate pedestrians, cyclists, and children from the elementary school, as well as tourists visiting Pacific Spirit Regional Park. Some features of these landscape areas include concrete trails, aesthetic pleasing planting, and post lights where necessary for safety consideration. **Figures 7 and 8** below illustrate a brief overview of the landscape area. Meanwhile, population of pedestrians, tourists and cyclists entering this project corridor is expected to increase with the development of the proposed underpass. Therefore, the designed landscape area is proposed to lower crowd density around entrances and provide a pleasing and relaxing environment.

Figure 6 Brief Overview of Landscape Area (South Entrance)

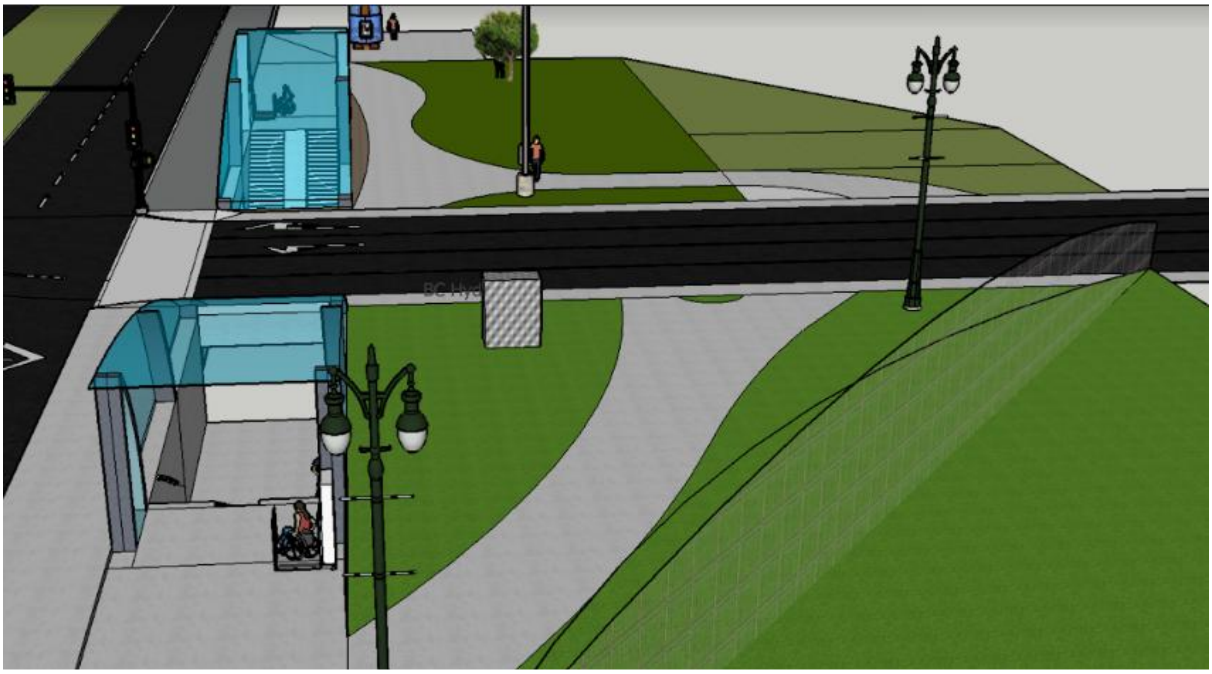

Figure 7 Brief Overview of Landscape Area (North Entrances)

4.1.5 Traffic Design

According to our site observations, about 40% of the cars traveling along eastbound during morning peak hours will make a left turn onto Hamber Road. However, morning major traffic volume usually occurs in westbound, and the pedestrian crossing is also quite busy, left turning vehicles struggle a lot to find a chance to make their turn. This delay on the left turning lane could accumulate in a short time and even cause influences on vehicles traveling along the straight lanes. In order to improve traffic efficiency of the whole intersection, a traffic sensor will be installed approximately 20 meters behind stop line at the collector lane for left turning vehicles. Since there is no need for pedestrian controlled signals, number of vehicles waiting for left turns will be used to activate a special left turning signal phase at this intersection. This design ensures that all vehicles could safely pass through the intersection with minimum delays and possibility of conflicts. In order to protect traffic flows on westbound, a green light protection phase will be used after the left turning phase.

Synchro is used to model and optimize the proposed traffic cycle length. Based on our road geometry design and prediction of vehicle volumes in the future, a cycle length of 60 seconds will be appropriate, comparing with the existing length of 25 seconds for pedestrian crossing and another half a minute of cool down time for traffic. Detailed report could be found attached in Appendix D.

In order to further improve our design and provide more convenient travel conditions for pedestrians and cyclists, a flashing beacon pedestrian crossing system and reminding signs will be installed at where Pioneer Trail intersects with Chancellor Boulevard. This design could also help vehicle drivers reduce their speed and follow the proposed speed limit along the whole project corridor.

4.2 Pedestrian and Cyclist Underpass

4.2.1 Location Selection

Due to the location of University Hill Elementary School, the intersection of Hamber Road with Chancellor Boulevard is the busiest section along the whole project corridor. It has the greatest possibilities for traffic conflicts and maximum demands for pedestrian and cyclist road crossing. This intersection could maximize overall efficiency and road safety, therefore it has been selected as the location for our pedestrian/cyclist underpass.

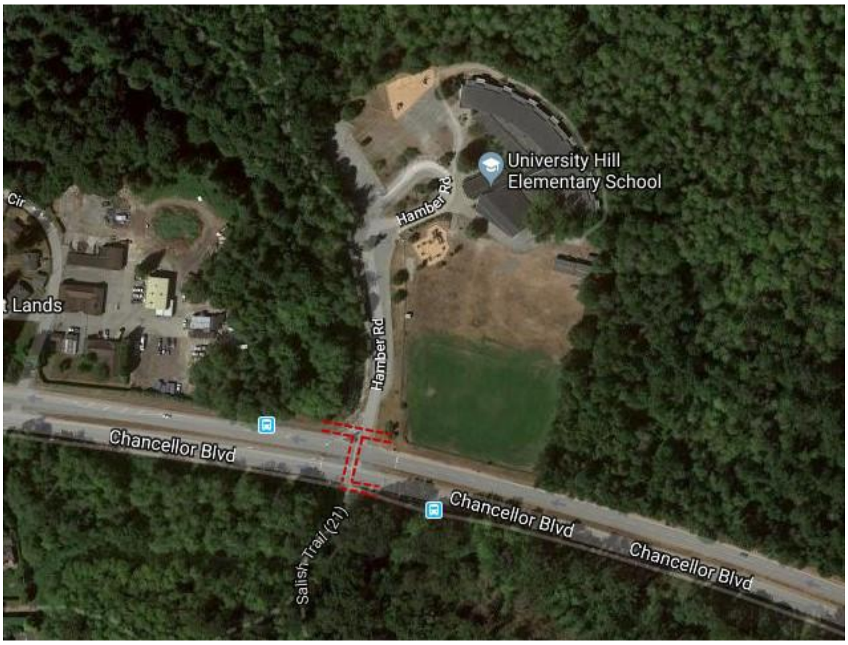

Figure 8 Proposed Location and Layout of Underpass at the Intersection
(Image source: Google Maps)

4.2.2 Structural Components

Considering structural functioning, safety, and construction feasibility, the underpass will be placed right in the middle of the intersection. Since the design life will reach a maximum of 50 years, main structure of the underpass will be made of reinforced concrete, which is strong enough, durable, and comparatively easy to maintain. Compressive strength of concrete will be 45 MPa, which could provide maximum strength per unit volume as a type of normal concrete.

As shown in **Figure 9** below, a two-way reinforced concrete slab will serve as part of the road, as well as the ceiling of pedestrian/cyclist underpass. A 150 mm thick asphalt layer will be covering the top surface of the slab for protection against abrasion and corrosion caused by water from the environment. The slab will support a dead load caused by its self weight and live loads contributed by moving vehicles and other road users. Considering a minimum allowable depth of 120 mm (CSA A23.3 04) and resistance to factored shear and moment, the thickness is decided to be 250 mm. 10 M Steel reinforcement will be installed close to the bottom of this slab in both directions. A spacing of 80 mm from center to center is designed for both resistance and protection against shrinkage and thermal effect.

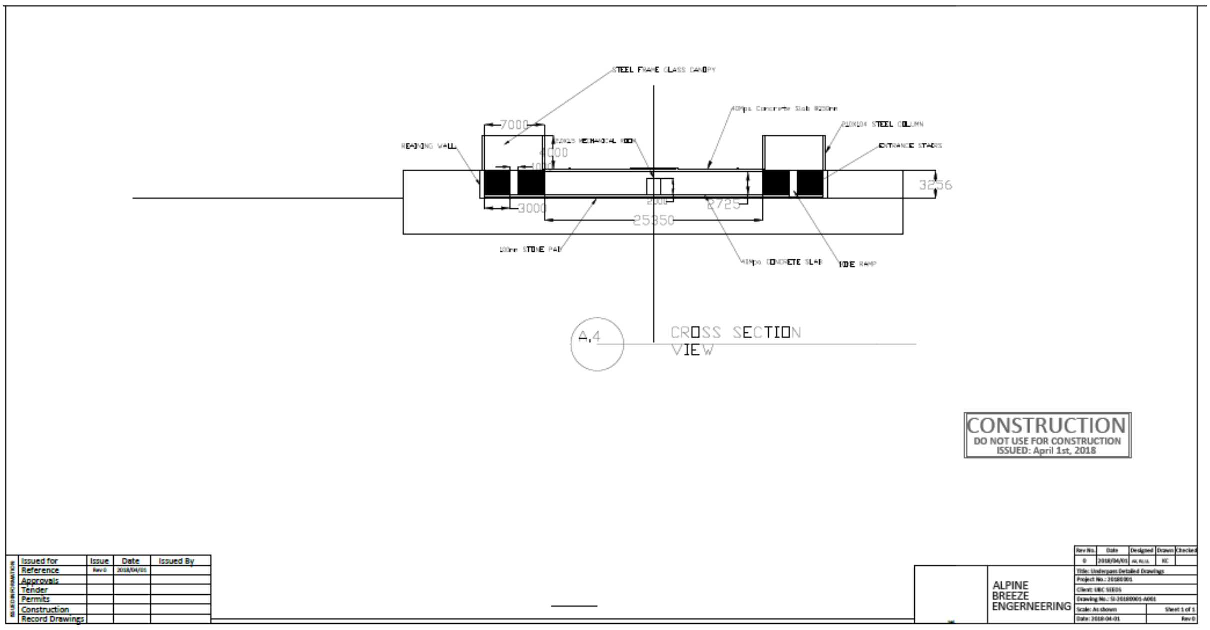

Figure 9 Cross Section Design for Pedestrian and Cyclist Underpass

The transition from slab to existing asphalt road surface is designed to be natural and smooth by installing connection rebars during construction. Rubber expansion joints are adopted to prevent moving and transfer of shear and other loads to the supporting retaining walls (CSA A23.3 04).

Retaining walls will support the concrete slab and transfer loads from upper structure to the foundation through footing strips. The design basically follows the CSA guideline for basement walls, with a recommended thickness of 200 mm and 10M rebars in both horizontal and vertical directions. Other than vertical loads carried from the concrete slab, the walls are also designed to take lateral earth pressure and bearing forces due to eccentric loading conditions. Rebar spacing is 250 mm in horizontal direction, which is a bit denser than the 300 mm spacing for vertical direction. The matrix of rebars should be placed close to the center of the wall for protection against worst exposure case to the environment.

The whole pedestrian and cyclist underpass is 7 meters in width and 27 meters in length, which ensures enough space for travellers from both directions. Its height reaches approximately 2.8 meters along the centerline of the longer direction. A -2% slope extends from this centerline towards walls on both sides, which provides indoor drainage for the underpass. Drainage channels along both sides will be collecting and directing water to drainage pipelines. Detailed drainage designs for the underpass could be found later in this section. The minimum thickness of concrete pavement at both sides of the cross-section is 150 mm. A layer of gravels is installed beneath this pavement to absorb and transfer vibration to the soil foundation.

Reinforced concrete footing with proper steel connection to the retaining walls will be used as the supporting structure to transfer loads into soil foundation. The footing strips are 1m in width along both sides of the underpass, with the base being 250mm in height. Gravels are used to fill the space and provide side drainage outside of the retaining walls. The inner edge of the footing will be supporting the concrete pavement inside the underpass. **Figure 10** below provides a detailed drawing of design for footing structures.

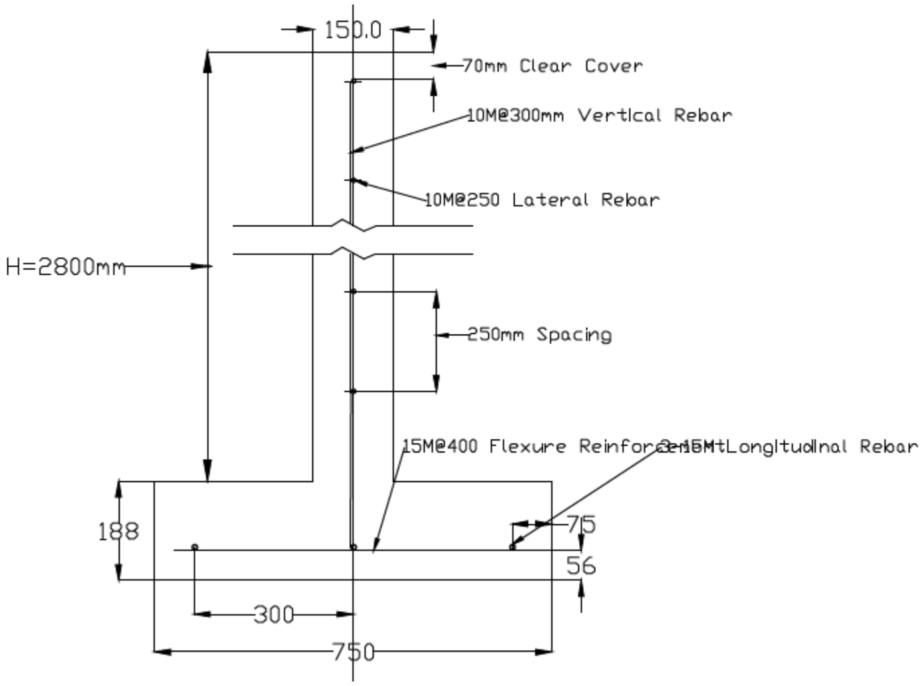

Figure 10 Detailed Design Drawing for Footing Strips

For concrete stairs connecting all three entrances to the underpass, a straight-run flight layout with rectangular threads will be adopted in our design, with a riser height of 118 mm and depth of 531 mm (British Columbia Building Code, 2012). A ramp with 22% slope and 1 m in width along the centerline of the stairs will allow cyclists to carry their bicycles down to the underpass. Total width of stairs together with the slope will be 7 m, with 3 m distributed on each side of the slope. A foldable wheelchair platform will be installed at each entrance for use of disabilities. When not in use, this platform can be folded aside to reserve space for pedestrians and cyclists.

Figure 11 Example of Foldable Platform for Wheelchair Users (Image source: Google)

4.2.3 Underpass Entrance

Entrances to underpass are designed to meet the design criteria such that it is convenient for all type of users and promotes energy saving by maximizing natural lighting. The entrance is mostly designed by three components: glass roof and wall, galvanized steel columns and concrete stairs. Glass wall and roof provides an excellent source of natural lighting. The curved roof feature as shown in **Figure 13** below is designed to facilitate self-drainage.

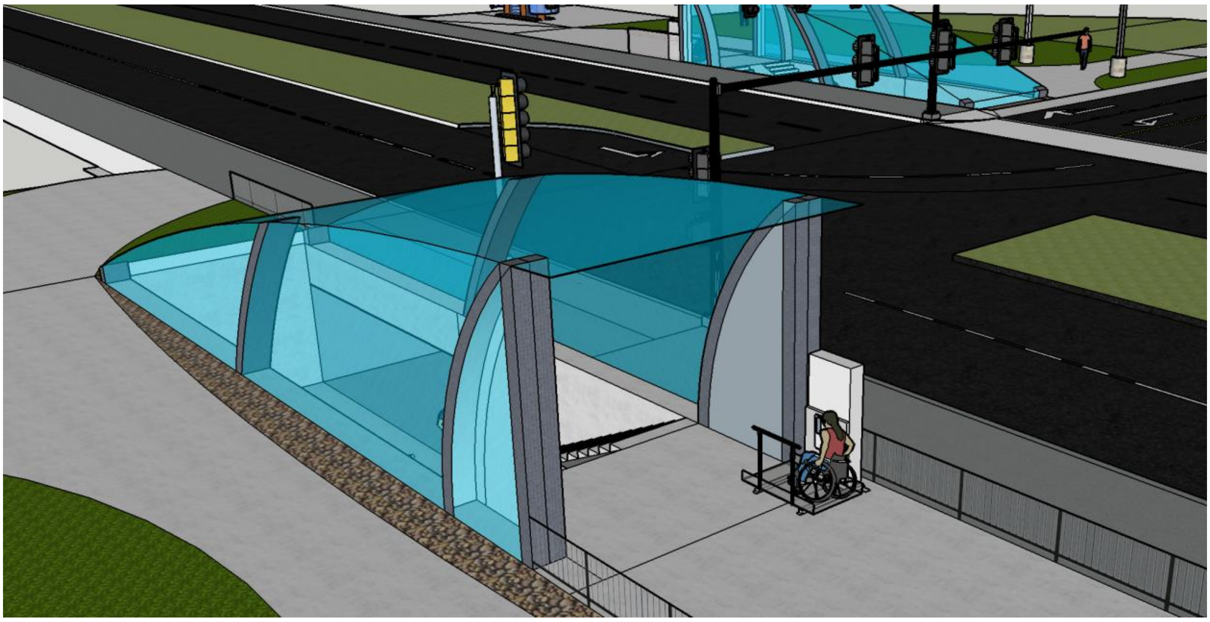

Figure 12 Curved Roof Feature at the Entrances to Underpass

Clear crushes are to be placed around the entrances to collect stormwater flowing off from the roof of underpass. The concrete slab at the entrance will be raised by 0.2 m from ground level with a small ramp. This feature is to ensure no rain water will flow into the underpass during normal storm event, and the small ramp is provided to maintain accessibility for disabilities. In addition, storm drain channel made of stainless steel grate will be installed in the front of the ramp and at the end of the stairs to underpass for rainwater collection. All features are designed to meet a 1 in 20 year rain event capacity. Detailed calculation for stormwater management can be found in Appendix C.

4.3 Drainage and Utilities

During storm events, water might be brought into the underpass by users or through potential seepage. As the lowest point is at approximately 3.5 m below ground, with the assumption that it is lower than the sewer pipelines, a storage tank and pump are necessary for transferring ponding out.

Storage tank is designed to locate near the mechanical room, which is in the middle of the underpass at the east side, with pump installed at the bottom of it, connecting the tank to sewer and combined pipeline with a service connection pipe. Therefore, the drainage system can be accessed through the mechanical room for repair and maintenance.

The drainage channel has a symmetric gradient of 2%, with highest elevation at entrances and lowest at the middle, where the collection points locate, and extra pipes are used connecting the collection points on both sides to storage tank to minimizing surface water in the underpass.

Pump is set in a way that it rests during normal times, but will be activated once the water level reaches a specific height, which will be calculated later, to transport water out. The amount of water in the underpass is calculated by multiplying the estimated number of users during peak hours with the amount of water they carried, with a factor of safety taken into consideration.

According to our previous discussion, there will be 480 pedestrians and 120 cyclists using the underpass per hour for peak rate. We assume the amount of water on pedestrians and cyclists are 30 cm^3 and 50 cm^3, respectively, then the total amount of water will be calculated as:

$$Q = (480 \times 30 + 120 \times 50)\ \text{mm}^3 = 20.4\ L$$

Overlapping time between the precipitation event and users' activity considered to be 2 hours, and the factor of safety is assumed to be 1.75, which ensures the capability of the structure even under severe situations. Therefore, the threshold volume is determined as:

$$Q = 20.4\ L/h\text{r} \times 2\ h\text{r} \times 1.75 = 71.4\ \text{L}$$

The activation water level is set at 35 cm, and the bottom area for the cylindrical tank is calculated to be 20400 mm^2, which gives the radius of 25.5 cm.

The designed size for the storage tank is then designed to be a cylindrical with height of 65 cm, which should be higher than the threshold water depth, with inner radius of 25.5 cm.

Diameter of pipe connecting the drainage channel inside the underpass and the storage tank is assumed to be 125 mm, which is capable of delivering the flow calculated above.

The pump size is not determined at this stage, as there's no requirement from the client about the speed of dewatering. However, due to the small amount of water and low head required, a regular small pump should be capable.

4.4 Other Facilities

4.4.1 Lighting

According to city requirement, 24-hr of lighting should be provided as the length of the underpass exceeds 20m. Electricity is supplied through power lines connected to mechanical room. In order to save energy, LED lighting is selected with the illuminating level of 17.5 lux.

8-watts of LED light bulb will give 450 lumens, with 17.5 lux at consideration, indicating the service area of 25.7 m. For our 7 m width underpass, with 2 light bulbs per row, each one will need to serve 7.3 m in length and 3.5 in width.

As the underpass has the total length of approximately 25 m, 6 8-watts LED bulbs will be necessary, consisting of 3 rows and 2 per row, with separating length of 7.3 m.

4.4.2 Vandal Proof

Vandal proof system will be installed including 4 cameras, with two at the north entrance, one in the front of mechanical room and one at the south entrance, for facility and equipment protection.

Electricity power will also be supplied through mechanical room, which connects to surrounding power lines.

4.4.3 Underground Facilities

The major considerations regarding to underground facilities include two parts: the disruptions brought by construction and checking for capability of existing pipelines for large storms.

For constructions, one existing manhole near Hamber Road will be relocated due to underpass construction, and correspondingly, two pipelines will be re-routed as the figure below shown:

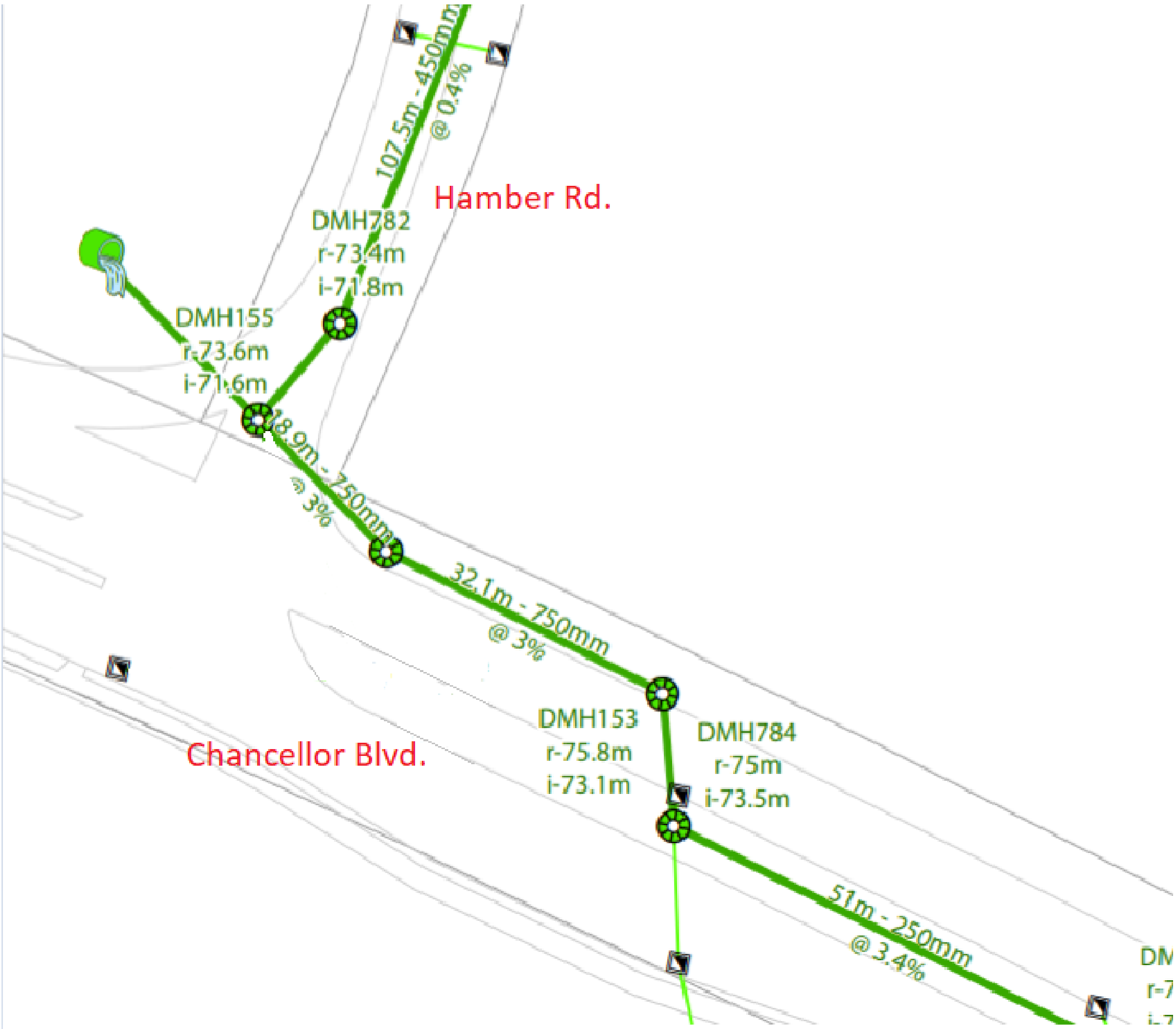

Figure 13 Existing Drainage Pipeline Utility Drawing at the Intersection of Chancellor Boulevard with Hamber Road

For storm water collection, we went through the “Sewer and Combined” pipeline layout, finding out that the pipes are all of large diameters, which should be capable for the 20-

year return period storm event. Therefore, no upgrade in pipe size will be made, and layout at places along the corridor other than the intersection shown above will stay the same.

5.0 FINAL COST ESTIMATE

A class B cost estimation is conducted based on the detailed design drawings, city standards, and relevant specifications. Historical project-based unit rates are applied to conduct this cost estimate, and the total cost should be within 5% to 10% of actual contract price.

As shown in the table below, the roadway construction is 3.62 millions which occupies the bigger proportion of the overall cost; whereas the cost of constructing underpass is calculated to be 1.24 millions. The reason for the roadway construction cost being greater than that of the underpass is because of its large quantity in regard to its total area. The project management cost is calculated as 10% of the total construction cost according to the MoTi guidelines, and it turns out to be $486,000. Therefore, the total cost of the Chancellor Corridor project is 5.4 millions including project management fee.

In addition to the project management design, there will be a permitting fee for reconstructing roadway and building underpass. This permitting fee is estimated to be $7,900 for a total of six permits includes development permit, excavation permit, utility permit, traffic management permit, building permit, and street and landscape permits.

Table 7 Summary of Class B Cost Estimate

1	Project Design	$	58,000
2	Permitting	$	7,900

Roadway Construction			
3	Excavation, Earthwork and Asphalt paving	$	2,953,725
4	Concrete works	$	427,200
5	Pavement Marking and Signage	$	80,000
6	Fences	$	7,500
7	Electrical Works	$	150,000
	Total Roadway Construction	$	3,618,425

Underpass Construction			
8	Excavation and earthwork	$	237,800
9	Concrete Works	$	539,500
10	Electrical Works	$	121,800
11	Stormwater Management	$	8,000
12	Underpass Entrances	$	334,100
	Total Underpass Construction	$	1,241,200

Total Construction Cost	**$4,859,625**
Project Management Cost (10%)	**$486,000**
Total Construction Cost with PM, Design and Permitting (2018 Dollars)	**$5,411,525**
Annual Operating and Maintenance Fee (0.7%)	**$34,000**

This cost estimate has implemented the unit rate estimating method. The cost of labor, materials, and equipment are included in the unit rate for each item. According to the final design schedule, this cost estimate includes a total of 5 mobilizations to site for roadway and underpass construction. Any additional demobilization and remobilization fee will be conducted by specific contractors building bidding and construction period.

Therefore, the total estimated cost of the proposed design comes up to be $5,411,525 including cost of construction, project management, project design and permitting. The annual operating and maintenance fee is estimated to be $34,000 according to the MoTi guidelines as 0.7% of the net construction cost. No inflation rate is applied on the estimated prices, so that all prices are in 2018-dollar value. A schedule of quantity and cost breakdown is enclosed in Appendix B for further information.

6.0 SCHEDULE

The proposed schedule is planned based on a consideration of minimizing disruption on local traffics. Therefore, the overall construction is divided into a total number of five zones, with each zone to be under construction during different times. A detailed construction schedule is generated using Microsoft Project. Construction of this project is anticipated to start on May 1st, 2018, with a total duration of 93 days until early September. Reason for choosing this start date is that a comparatively low volume of traffic can be expected in and out of University Hill Elementary School during summer months. In addition, the nice weather during summer provides a preferred weather condition for most construction activities such as material transportation, excavation, and placement of concrete and asphalt.

6.1 Construction Zones

Construction of the project at Chancellor Boulevard has been divided into 5 different zones to minimize impact on local traffic, as shown in **Figure 16** below.

Zone 1: North-West of underpass

Zone 2: South-West of underpass

Zone 3: North-East of underpass

Zone 4: South-East of underpass

Zone 5: Underpass

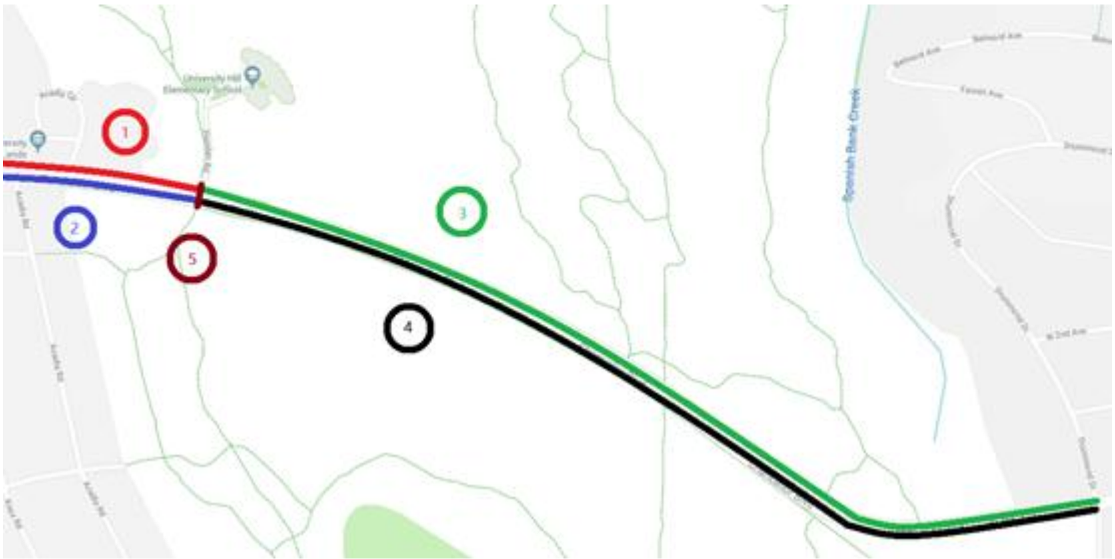

Figure 14 Construction Zone Planning

6.2 Construction Planning

A high-level summarized construction schedule is illustrated below in **Figure 17**. Construction of the underpass is planned as the very first task, with all the zones designed to avoid traffic shot down of the entire Chancellor Boulevard. Closure of road traffic will only happen to half of the road cross section, with both lanes in one direction providing full services while the other half is under construction. After excavation, a temporary shoring system will be constructed to ensure stability of underground structures during construction. Zone 1 and zone 3 will start construction on May 1st, followed by zone 2 and zone 4. The two lanes of eastbound will first be used for traffic for both directions while westbound is under construction. Similarly, westbound will be used to provide full services while eastbound is under construction. This construction plan minimizes possible traffic disruption during the construction period and minimizes impacts on local neighbourhoods.

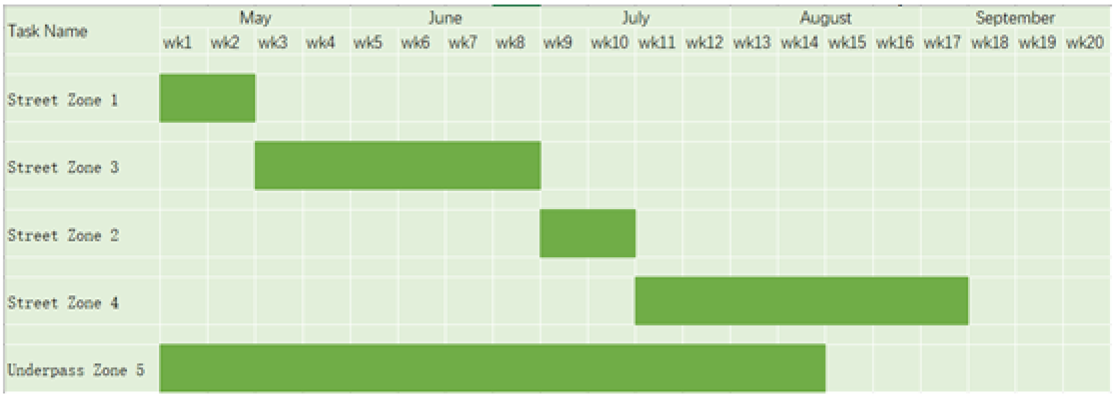

Figure 15 Summarized Construction Schedule

A detailed project Gantt Chart is attached in Appendix A with the critical path being highlighted with a red line.

6.3 Anticipated Construction Issues

Some problems could be occurring during the construction period that need to be taken into consideration at early stage. They can lead to significant delays on construction schedule, as well as affecting final quality after finish of construction. A list of those anticipated issues are listed as follows:

- Non- universality of information
- Weak performance of construction management
- Inefficient communications
- Unexpected site conditions
- Poor connections between construction zones and times
- Inadequate risk management

7.0 MAINTENANCE PLAN

A project maintenance plan is designed to maintain the project service level during the designated service life. Listed below are some critical components that are included in the project maintenance plan:

- Routine maintenance

  Routine maintenance is proposed to maintain the average service level of road and underpass in a relatively high frequency. It may include cleaning for the road surface and underpass, tree trimming, grass cutting, and snow cleaning or de-icing during winter. It should also be under routine maintenance to mitigate traffic chaos if the traffic lights and flashing beacon pedestrian crossing system are out of order.

- Periodical maintenance

  This category usually involves large scale and programmable maintenance during the whole life-span of road and underpass. Based on a reasonable time interval, the road signs, flexible posts, and other project components with damage will be replaced, and the road surface layer will be re-paved with newly painted road labels or lane borders for clearer indication. The lighting system in underpass will be checked, and light bulbs will be replaced based on a certain period. This period is decided according to site investigation results and specifications provided by light manufacturers.

- Special maintenance

  Special maintenances are designed to respond to hazards and damages due to unexpected incidents. When the road or underpass structures are failed to resist natural hazards such as floods, earthquakes, and tsunamis, engineers and constructors will take responsibilities to mitigate possible impacts and plan for renovations of the structure. If necessary, the road embankment and road shoulders will be stabilized in special maintenance.

- Emergency plan

  Any emergencies will be addressed immediately and call for proper responses, therefore a comprehensive emergency plan with detailed descriptions will be needed. Risks such as potential hazards will be identified together with proposed responding measures. According to different probabilities and levels of consequences of hazards, engineers will be able to quickly assess and react as needed. Final risk control and corresponding plans will aim to transfer, reduce, or avoid risks, as well as minimize potential consequences.

- Improvements

  As the external environment is always changing over the time, it is reasonable to expect changes on traffic demands, policies, and site conditions. When new concerns and problems are to be addressed, the design should also be updated to include improvements on current project. For example, if the traffic volume is increasing dramatically in the future, engineers could consider shrinking the width of the median in the middle of the road to support more traffic capacity.

  Improvements are not only necessary for this project, but also for the maintenance plan. This plan should be updated iteratively as more issues and concerns could occur as time passes by.

Any processes in dealing with maintenance will be transparent in order to avoid ethical issues and other unexpected situations. All relevant tasks must be performed by qualified personnel and with proper onsite supervision. Records should be properly and safely conserved in case for future reference.

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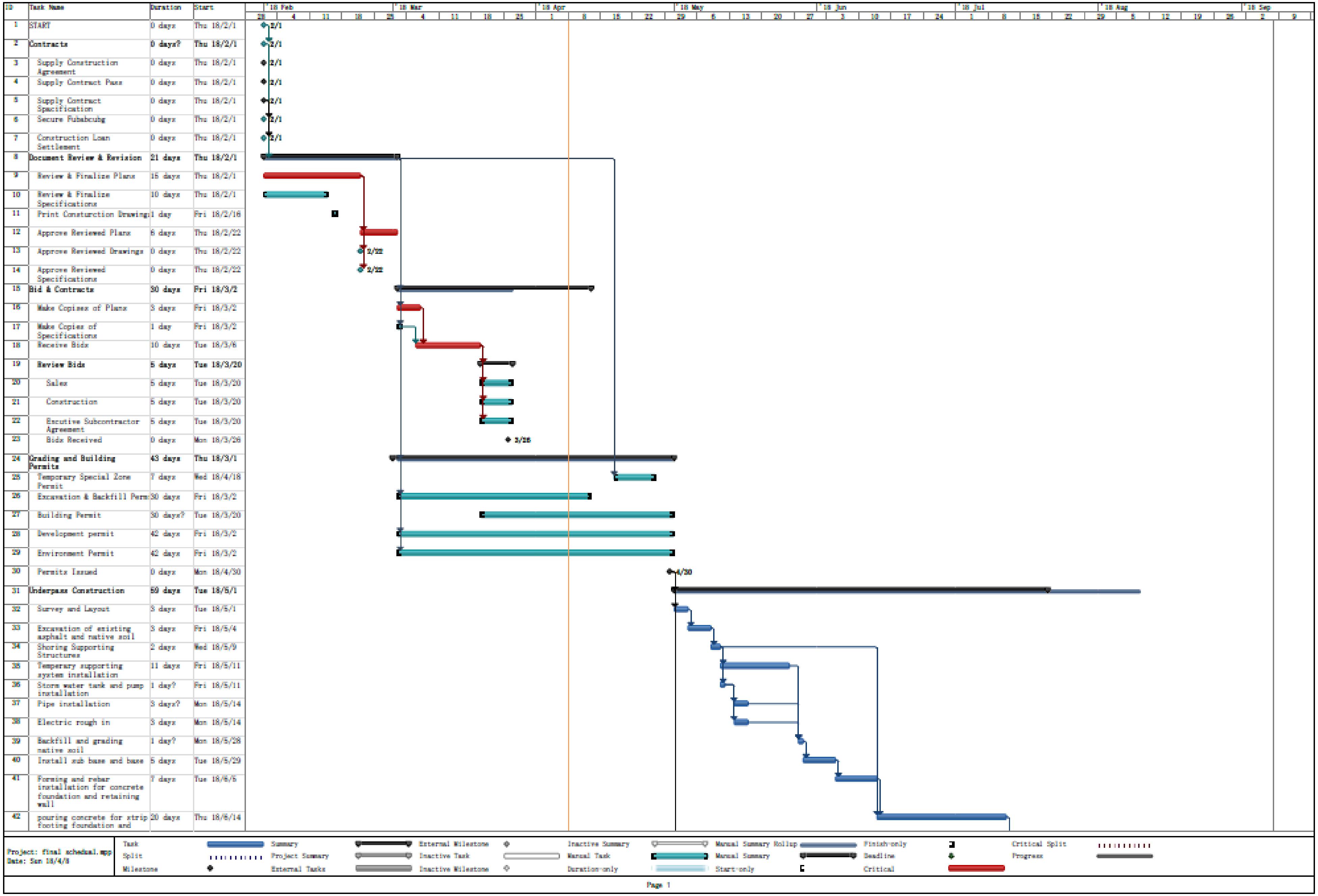
APPENDIX A SCHEDULES



ID	Task Name	Duration	Start
1	START	0 days	Thu 18/2/1
2	**Contracts**	**0 days?**	**Thu 18/2/1**
3	Supply Construction Agreement	0 days	Thu 18/2/1
4	Supply Contract Pass	0 days	Thu 18/2/1
5	Supply Contract Specification	0 days	Thu 18/2/1
6	Secure Pubabcubg	0 days	Thu 18/2/1
7	Construction Loan Settlement	0 days	Thu 18/2/1
8	**Document Review & Revision**	**21 days**	**Thu 18/2/1**
9	Review & Finalize Plans	15 days	Thu 18/2/1
10	Review & Finalize Specifications	10 days	Thu 18/2/1
11	Print Consturction Drawings	1 day	Fri 18/2/16
12	Approve Reviewed Plans	6 days	Thu 18/2/22
13	Approve Reviewed Drawings	0 days	Thu 18/2/22
14	Approve Reviewed Specifications	0 days	Thu 18/2/22
15	**Bid & Contracts**	**30 days**	**Fri 18/3/2**
16	Make Copiess of Plans	3 days	Fri 18/3/2
17	Make Copies of Specifications	1 day	Fri 18/3/2
18	Receive Bids	10 days	Tue 18/3/6
19	**Review Bids**	**5 days**	**Tue 18/3/20**
20	Sales	5 days	Tue 18/3/20
21	Construction	5 days	Tue 18/3/20
22	Excutive Subcontractor Agreement	5 days	Tue 18/3/20
23	Bids Received	0 days	Mon 18/3/26
24	**Grading and Building Permits**	**43 days**	**Thu 18/3/1**
25	Temporary Special Zone Permit	7 days	Wed 18/4/18
26	Excavation & Backfill Perm	30 days	Fri 18/3/2
27	Building Permit	30 days?	Tue 18/3/20
28	Development permit	42 days	Fri 18/3/2
29	Environment Permit	42 days	Fri 18/3/2
30	Permits Issued	0 days	Mon 18/4/30
31	**Underpass Construction**	**59 days**	**Tue 18/5/1**
32	Survey and Layout	3 days	Tue 18/5/1
33	Excavation of existing asphalt and native soil	3 days	Fri 18/5/4
34	Shoring Supporting Structures	2 days	Wed 18/5/9
35	Temperary supporting system installation	11 days	Fri 18/5/11
36	Storm water tank and pump installation	1 day?	Fri 18/5/11
37	Pipe installation	3 days?	Mon 18/5/14
38	Electric rough in	3 days	Mon 18/5/14
39	Backfill and grading native soil	1 day?	Mon 18/5/28
40	Install sub base and base	5 days	Tue 18/5/29
41	Forming and rebar installation for concrete foundation and retaining wall	7 days	Tue 18/6/5
42	pouring concrete for strip footing foundation and	20 days	Thu 18/6/14

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Date: Sun 18/4/8

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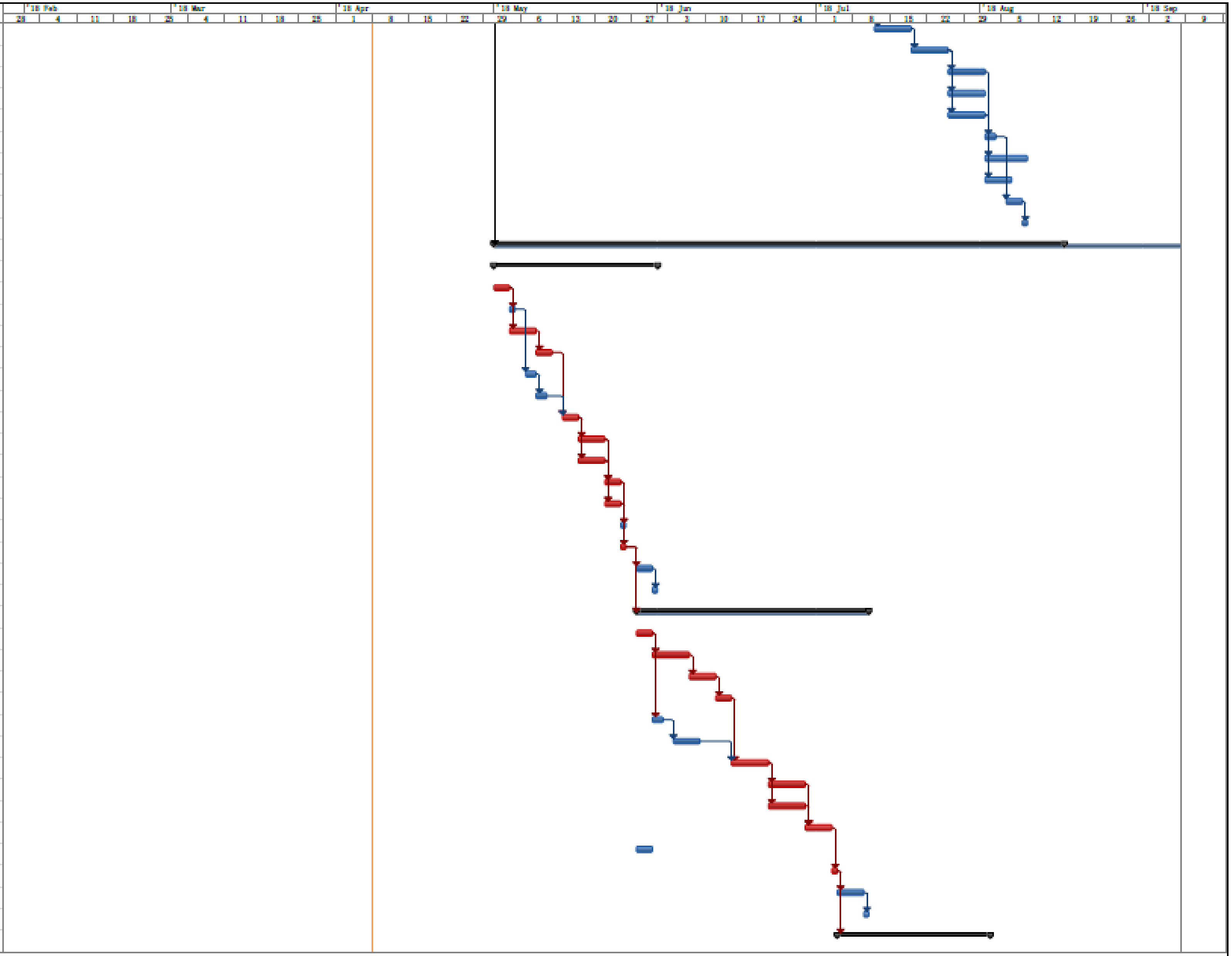
ID	Task Name	Duration	Start
43	Shotcrete for retaining wall	5 days	Thu 18/7/12
44	Install upper concrete structure	5 days	Thu 18/7/19
45	Pouring concrete for stair	5 days	Thu 18/7/26
46	Drainage system installation	5 days	Thu 18/7/26
47	Steel column installation	5 days	Thu 18/7/26
48	Glazing	2 days	Thu 18/8/2
49	Interior finishing	6 days	Thu 18/8/2
50	lighting & Security Cameras installation	3 days	Thu 18/8/2
51	Entrence and landscape	3 days	Mon 18/8/6
52	Testing(North)	1 day	Thu 18/8/9
53	**Road Construction**	**78 days**	**Tue 18/5/1**
54	**Road Construction zone 1**	**23 days**	**Tue 18/5/1**
55	Survey and Layout	3 days	Tue 18/5/1
56	Excavation of existing asphalt and native soil	1 day	Fri 18/5/4
57	New Road Granular Sub-Base Fill	3 days	Fri 18/5/4
58	New Road Granular Base Fill	3 days	Wed 18/5/9
59	Cycle Path Granular Sub-Base Fill	2 days	Mon 18/5/7
60	Cycle Path Granular Base Fill	2 days	Wed 18/5/9
61	Concrete Forming	3 days	Mon 18/5/14
62	Road Concret and Asphaltic Paving	3 days	Thu 18/5/17
63	Cycle Path Concret and Asphaltic Paving	3 days	Thu 18/5/17
64	Road Surface Coating	3 days	Tue 18/5/22
65	Cycle Path Surface Coating	3 days	Tue 18/5/22
66	Final layer paving for asphalt	1 day	Fri 18/5/25
67	Testing	1 day	Fri 18/5/25
68	Painting and Zoning	3 days	Mon 18/5/28
69	Fencing	1 day	Thu 18/5/31
70	**Road construction zone 3**	**32 days**	**Mon 18/5/28**
71	Survey and Signage Installing	3 days	Mon 18/5/28
72	Existing Surface Removia	5 days	Thu 18/5/31
73	New Road SUB-Base Fill	3 days	Thu 18/6/7
74	New Road Base Fill	3 days	Tue 18/6/12
75	Cycle Path Sub-Base Fill	2 days	Thu 18/5/31
76	Cycle Path Base Fill	5 days	Mon 18/6/4
77	Forming	5 days	Fri 18/6/15
78	Cycle Path Concret and Asphaltic Paving	5 days	Fri 18/6/22
79	Road Concret and Asphaltic Paving	5 days	Fri 18/6/22
80	Road Surface Coating	3 days	Fri 18/6/29
81	Cycle Path Surface Coating	3 days	Mon 18/5/28
82	Testing	1 day	Wed 18/7/4
83	Painting and Zoning	3 days	Thu 18/7/5
84	Fencing	1 day	Tue 18/7/10
85	**Road Construction zone 2**	**21 days**	**Thu 18/7/5**



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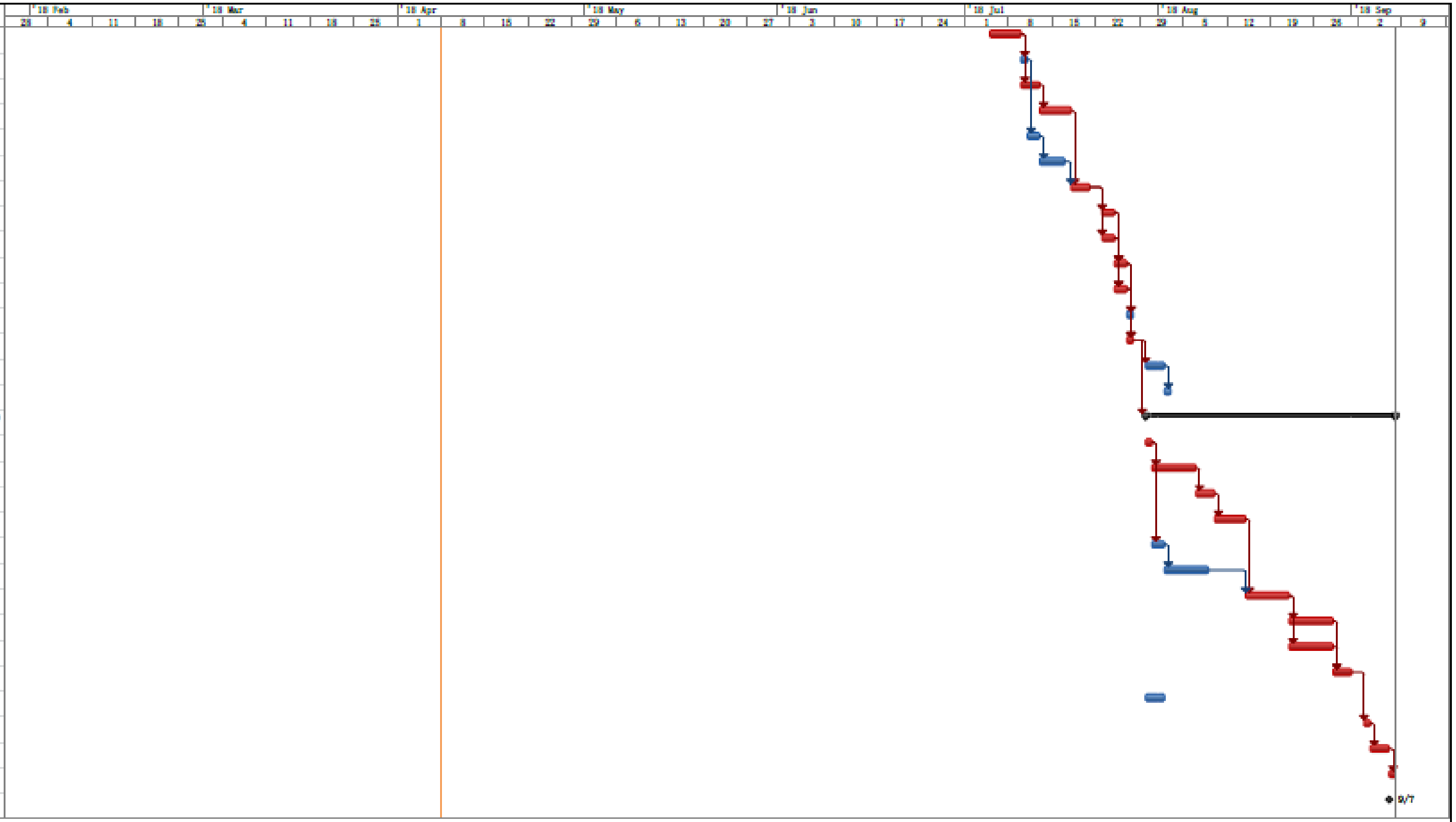
Task	▬	Summary	▬	External Milestone	◆	Inactive Summary	▭	Manual Summary Rollup	▬	Finish-only	]	Critical Split	¦¦¦¦¦¦¦¦¦¦
Split	¦¦¦¦¦¦¦¦¦¦	Project Summary	▬	Inactive Task	▭	Manual Task	▬	Manual Summary	▬	Deadline	⬇	Progress	▬
Milestone	◆	External Tasks	▬	Inactive Milestone	◇	Duration-only	▬	Start-only	[	Critical	▬		

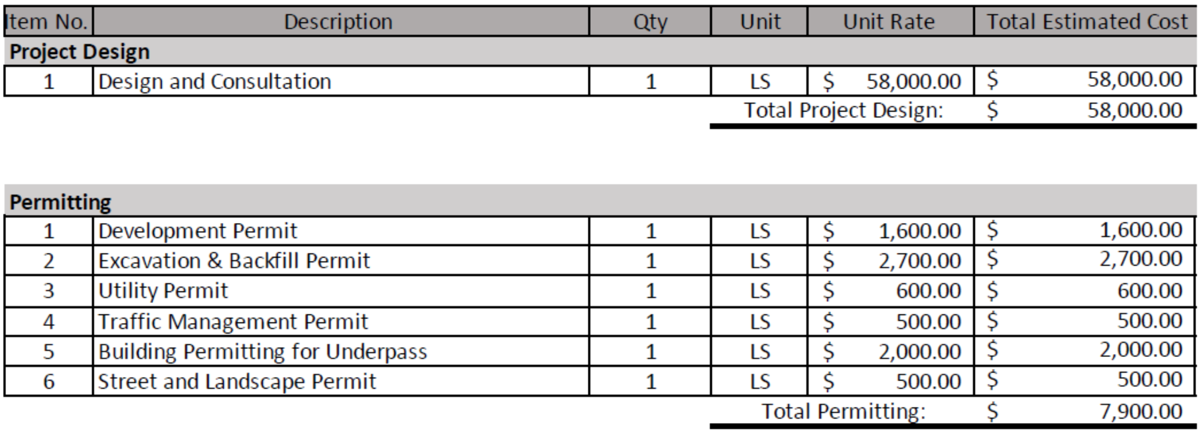
ID	Task Name	Duration	Start
86	Survey and Layout	3 days	Thu 18/7/5
87	Excavation of existing asphalt and native soil	1 day	Tue 18/7/10
88	New Road Granular Sub-Base Fill	3 days	Tue 18/7/10
89	New Road Granular Base Fill	3 days	Fri 18/7/13
90	Cycle Path Granular Sub-Base Fill	2 days	Wed 18/7/11
91	Cycle Path Granular Base Fill	2 days	Fri 18/7/13
92	Concrete Forming	3 days	Wed 18/7/18
93	Road Concret and Asphaltic Paving	2 days	Mon 18/7/23
94	Cycle Path Concret and Asphaltic Paving	2 days	Mon 18/7/23
95	Road Surface Coating	2 days	Wed 18/7/25
96	Cycle Path Surface Coating	2 days	Wed 18/7/25
97	Final layer paving for asphalt	1 day	Fri 18/7/27
98	Testing	1 day	Fri 18/7/27
99	Painting and Zoning	3 days	Mon 18/7/30
100	Fencing	1 day	Thu 18/8/2
101	**Road construction zone 4**	**30 days**	**Mon 18/7/30**
102	Survey and Signage Installing	1 day	Mon 18/7/30
103	Existing Surface Removia	5 days	Tue 18/7/31
104	New Road SUB-Base Fill	3 days	Tue 18/8/7
105	New Road Base Fill	3 days	Fri 18/8/10
106	Cycle Path Sub-Base Fill	2 days	Tue 18/7/31
107	Cycle Path Base Fill	5 days	Thu 18/8/2
108	Forming	5 days	Wed 18/8/15
109	Cycle Path Concret and Asphaltic Paving	5 days	Wed 18/8/22
110	Road Concret and Asphaltic Paving	5 days	Wed 18/8/22
111	Road Surface Coating	3 days	Wed 18/8/29
112	Cycle Path Surface Coating	3 days	Mon 18/7/30
113	Testing	1 day	Mon 18/9/3
114	Painting and Zoning	3 days	Tue 18/9/4
115	Fencing	1 day	Fri 18/9/7
116	Whole project complete	0 days	Fri 18/9/7



Project: final schedual.mpp
Date: Sun 18/4/8

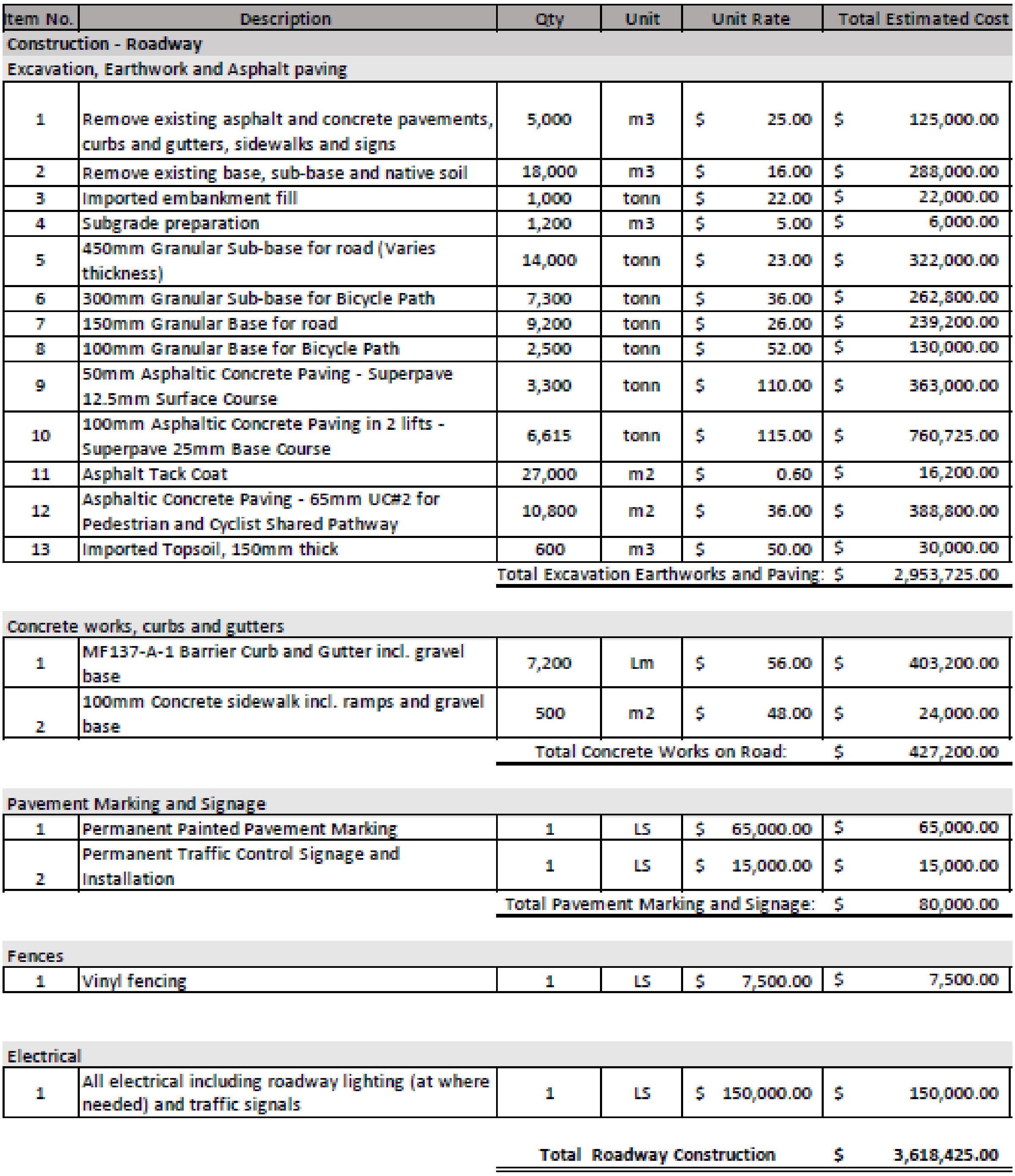
Task	▬	Summary	▬	External Milestone	◆	Inactive Summary	▭	Manual Summary Rollup	▬	Finish-only	]	Critical Split	┆┆┆┆┆┆┆┆┆┆
Split	┆┆┆┆┆┆┆┆┆┆┆	Project Summary	▬	Inactive Task	▭	Manual Task	▬	Manual Summary	▬	Deadline	⬇	Progress	▬
Milestone	◆	External Tasks	▬	Inactive Milestone	◇	Duration-only	▬	Start-only	[	Critical	▬		

APPENDIX B COST ESTIMATES

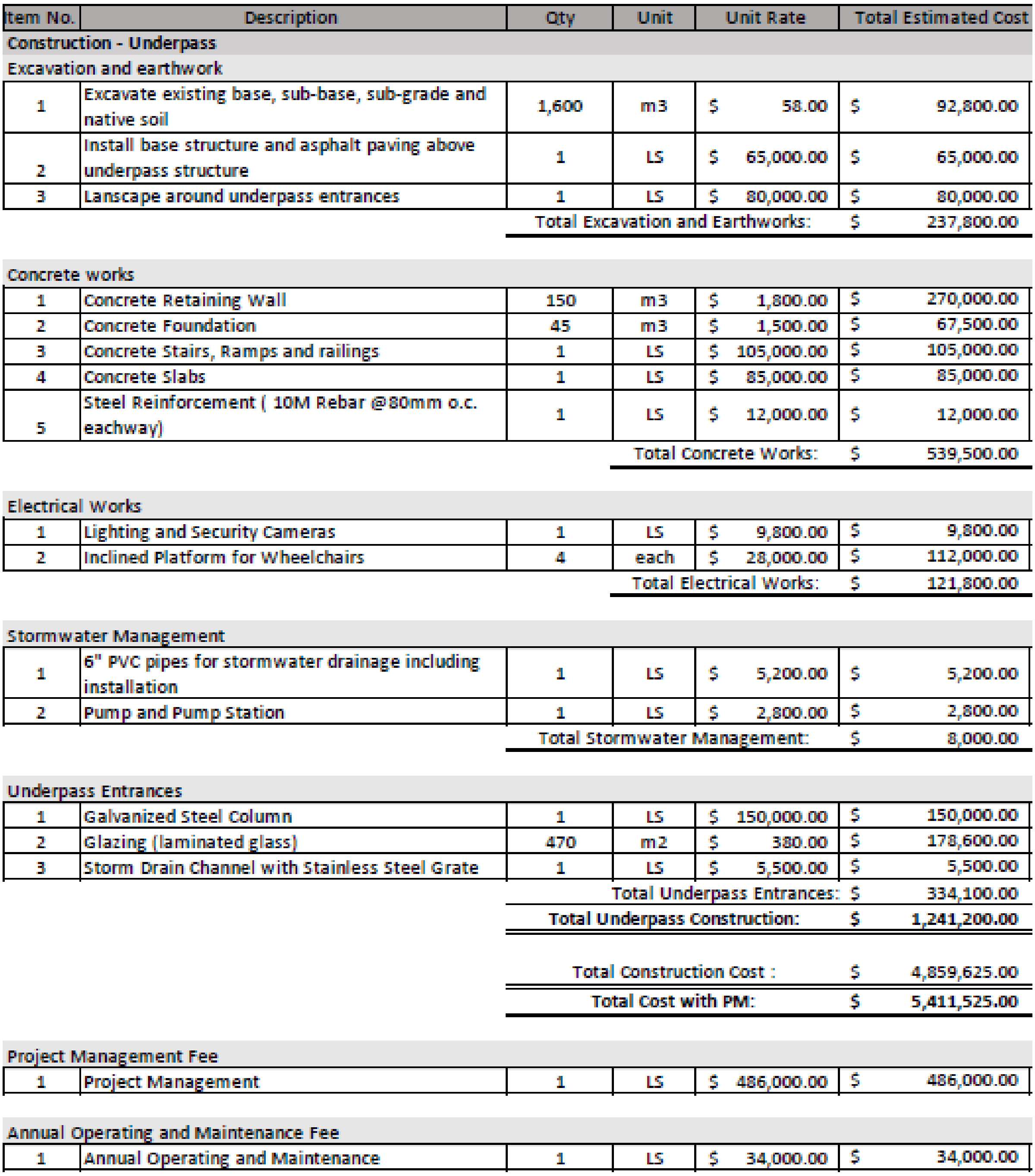


Item No.	Description	Qty	Unit	Unit Rate	Total Estimated Cost
Project Design					
1	Design and Consultation	1	LS	$ 58,000.00	$ 58,000.00
			Total Project Design:		$ 58,000.00

Item No.	Description	Qty	Unit	Unit Rate	Total Estimated Cost
Permitting					
1	Development Permit	1	LS	$ 1,600.00	$ 1,600.00
2	Excavation & Backfill Permit	1	LS	$ 2,700.00	$ 2,700.00
3	Utility Permit	1	LS	$ 600.00	$ 600.00
4	Traffic Management Permit	1	LS	$ 500.00	$ 500.00
5	Building Permitting for Underpass	1	LS	$ 2,000.00	$ 2,000.00
6	Street and Landscape Permit	1	LS	$ 500.00	$ 500.00
			Total Permitting:		$ 7,900.00



Item No.	Description	Qty	Unit	Unit Rate	Total Estimated Cost
Construction - Roadway					
Excavation, Earthwork and Asphalt paving					
1	Remove existing asphalt and concrete pavements, curbs and gutters, sidewalks and signs	5,000	m3	$ 25.00	$ 125,000.00
2	Remove existing base, sub-base and native soil	18,000	m3	$ 16.00	$ 288,000.00
3	Imported embankment fill	1,000	tonn	$ 22.00	$ 22,000.00
4	Subgrade preparation	1,200	m3	$ 5.00	$ 6,000.00
5	450mm Granular Sub-base for road (Varies thickness)	14,000	tonn	$ 23.00	$ 322,000.00
6	300mm Granular Sub-base for Bicycle Path	7,300	tonn	$ 36.00	$ 262,800.00
7	150mm Granular Base for road	9,200	tonn	$ 26.00	$ 239,200.00
8	100mm Granular Base for Bicycle Path	2,500	tonn	$ 52.00	$ 130,000.00
9	50mm Asphaltic Concrete Paving - Superpave 12.5mm Surface Course	3,300	tonn	$ 110.00	$ 363,000.00
10	100mm Asphaltic Concrete Paving in 2 lifts - Superpave 25mm Base Course	6,615	tonn	$ 115.00	$ 760,725.00
11	Asphalt Tack Coat	27,000	m2	$ 0.60	$ 16,200.00
12	Asphaltic Concrete Paving - 65mm UC#2 for Pedestrian and Cyclist Shared Pathway	10,800	m2	$ 36.00	$ 388,800.00
13	Imported Topsoil, 150mm thick	600	m3	$ 50.00	$ 30,000.00
		Total Excavation Earthworks and Paving:			$ 2,953,725.00
Concrete works, curbs and gutters					
1	MF137-A-1 Barrier Curb and Gutter incl. gravel base	7,200	Lm	$ 56.00	$ 403,200.00
2	100mm Concrete sidewalk incl. ramps and gravel base	500	m2	$ 48.00	$ 24,000.00
		Total Concrete Works on Road:			$ 427,200.00
Pavement Marking and Signage					
1	Permanent Painted Pavement Marking	1	LS	$ 65,000.00	$ 65,000.00
2	Permanent Traffic Control Signage and Installation	1	LS	$ 15,000.00	$ 15,000.00
		Total Pavement Marking and Signage:			$ 80,000.00
Fences					
1	Vinyl fencing	1	LS	$ 7,500.00	$ 7,500.00
Electrical					
1	All electrical including roadway lighting (at where needed) and traffic signals	1	LS	$ 150,000.00	$ 150,000.00
		Total Roadway Construction			**$ 3,618,425.00**



Item No.	Description	Qty	Unit	Unit Rate	Total Estimated Cost
Construction - Underpass					
Excavation and earthwork					
1	Excavate existing base, sub-base, sub-grade and native soil	1,600	m3	$ 58.00	$ 92,800.00
2	Install base structure and asphalt paving above underpass structure	1	LS	$ 65,000.00	$ 65,000.00
3	Lanscape around underpass entrances	1	LS	$ 80,000.00	$ 80,000.00
		Total Excavation and Earthworks:			$ 237,800.00
Concrete works					
1	Concrete Retaining Wall	150	m3	$ 1,800.00	$ 270,000.00
2	Concrete Foundation	45	m3	$ 1,500.00	$ 67,500.00
3	Concrete Stairs, Ramps and railings	1	LS	$ 105,000.00	$ 105,000.00
4	Concrete Slabs	1	LS	$ 85,000.00	$ 85,000.00
5	Steel Reinforcement (10M Rebar @80mm o.c. eachway)	1	LS	$ 12,000.00	$ 12,000.00
		Total Concrete Works:			$ 539,500.00
Electrical Works					
1	Lighting and Security Cameras	1	LS	$ 9,800.00	$ 9,800.00
2	Inclined Platform for Wheelchairs	4	each	$ 28,000.00	$ 112,000.00
		Total Electrical Works:			$ 121,800.00
Stormwater Management					
1	6" PVC pipes for stormwater drainage including installation	1	LS	$ 5,200.00	$ 5,200.00
2	Pump and Pump Station	1	LS	$ 2,800.00	$ 2,800.00
		Total Stormwater Management:			$ 8,000.00
Underpass Entrances					
1	Galvanized Steel Column	1	LS	$ 150,000.00	$ 150,000.00
2	Glazing (laminated glass)	470	m2	$ 380.00	$ 178,600.00
3	Storm Drain Channel with Stainless Steel Grate	1	LS	$ 5,500.00	$ 5,500.00
		Total Underpass Entrances:			$ 334,100.00
		Total Underpass Construction:			**$ 1,241,200.00**
		Total Construction Cost :			$ 4,859,625.00
		Total Cost with PM:			**$ 5,411,525.00**
Project Management Fee					
1	Project Management	1	LS	$ 486,000.00	$ 486,000.00
Annual Operating and Maintenance Fee					
1	Annual Operating and Maintenance	1	LS	$ 34,000.00	$ 34,000.00

APPENDIX C SAMPLE CALCULATIONS

Part 1 Concrete Cover Slab

(1) Load Calculations

Use gravity acceleration $g = 9.81 \frac{\mathrm{N}}{\mathrm{kg}}$

Design load factors 1.25 for dead load, 1.5 for live load

Maximum load for a single vehicle is based on weight limits of a double truck with eight axles, with the truck head weighing 5500 kg and truck body weighing 62500 kg, respectively.

Single vehicle weight $G_v = 5500\ \mathrm{kg} + 62500\ \mathrm{kg} = 68000\ \mathrm{kg}$

Single vehicle load $W = G \times g = 68000\ \mathrm{kg} \times 9.81 \frac{\mathrm{N}}{\mathrm{kg}} = 667080\ \mathrm{N} = 667.08\ \mathrm{kN}$

For each side of the wheels, point live load $F = \frac{1}{2}W = \frac{1}{2} \times 667.08\ \mathrm{kN} = 333.54\ \mathrm{kN}$

Maximum possible numbers of vehicle carried by slab N = 6

Applying design load factors, total live load $\mathrm{LL} = 1.5\ \mathrm{WN} = 1.5 \times (667.08\ \mathrm{kN} \times 6) = 6003.72\ \mathrm{kN}$

Assume concrete density $\rho = 2400 \frac{\mathrm{kg}}{\mathrm{m}^3}$, section width D = 7 m, section unsupported length L_u = 27 m

Start with slab thickness t = 300 mm for design calculations

Total slab weight per unit length $G_s = \rho \times t \times D = 2400 \frac{\mathrm{kg}}{\mathrm{m}^3} \times 0.3\ \mathrm{m} \times 7\ \mathrm{m} = 5040 \frac{\mathrm{kg}}{\mathrm{m}}$

Total slab load per unit length $w = G_s\, g = 5040 \frac{\mathrm{kg}}{\mathrm{m}} \times 9.8 \frac{\mathrm{N}}{\mathrm{kg}} = 49392 \frac{\mathrm{N}}{\mathrm{m}} \approx 50 \frac{\mathrm{kN}}{\mathrm{m}}$

Applying design load factors, total dead load $\mathrm{DL} = 1.25 \times 50 \frac{\mathrm{kN}}{\mathrm{m}} = 62.5 \frac{\mathrm{kN}}{\mathrm{m}}$

Combining DL = 62.5 $\frac{\mathrm{kN}}{\mathrm{m}}$ and LL = 6003.72 kN with different load distribution patterns on SAP2000, the overall maximum design input parameters over underpass span are summarized as follows:

	Dead	Live	Rounded up total
Maximum shear at support(kN)	848.48	3591.11	4500
Maximum moment at support(kNm)	5726	23080	29000

(2) Calculation for longitudinal flexural reinforcement (based on a b = 1000 mm unit section)

Summarized design parameters:

f_c'	F_y	α_1	β_1	ϕ_c	ϕ_s
45 MPa	400 MPa	0.8	0.9	0.65	0.85

Minimum required reinforcement $A_{s,min} = 0.002A_g = 0.002 \times 1000\text{ mm} \times 300\text{ mm} = 600\text{ mm}^2$

Effective depth $d = 300\text{ mm} - (75\text{ mm} + 10\text{ mm}) = 215\text{ mm}$

$$As = 0.00153f_c'b\left[d - \sqrt{d^2 - \frac{3.85M_r}{f_c'b}}\right]$$

$$= 0.00153 \times 45\text{ MPa} \times 1000\text{ mm} \times \left[215\text{ mm} - \sqrt{(215\text{ mm})^2 - \frac{3.85 \times 29000\text{ kNm}}{45\text{ MPa} \times 1\text{ m}}}\right] = 402.75\text{ mm}^2$$

Since A_s is smaller than $A_{s,min}$, try reducing slab thickness to t = 250 mm

Minimum required reinforcement $A_{s,min} = 0.002A_g = 0.002 \times 1000\text{ mm} \times 250\text{ mm} = 500\text{ mm}^2$

Effective depth $d = 250\text{ mm} - (75\text{ mm} + 10\text{ mm}) = 165\text{ mm}$

$$A_s = 0.00153f_c'b\left[d - \sqrt{d^2 - \frac{3.85M_r}{f_c'b}}\right]$$

$$= 0.00153 \times 45\text{ MPa} \times 1000\text{ mm} \times \left[165\text{ mm} - \sqrt{(165\text{ mm})^2 - \frac{3.85 \times 29000\text{ kNm}}{45\text{ MPa} \times 1\text{ m}}}\right] = 530\text{ mm}^2$$

Select 10M rebars with rebar diameter d_b = 10 mm and cross-sectional area A_b = 100 mm^2

Assume maximum size of aggregates MSA = 20 mm

Minimum required rebar number $N_{min} = \frac{A_s}{A_b} = \frac{530\text{ mm}^2}{100\text{ mm}^2} = 5.3 \approx 6$

Min rebar spacing $s_{min} = \max(1.4d_b, 1.4\text{MSA}, 30\text{ mm}) = \max(14\,mm, 28\,mm, 30\,mm) = 30\,mm$

Max rebar spacing $s_{max} = \min(3t, 500\text{ mm}) = \min(750\,mm, 500\,mm) = 500\,mm$

Select spacing s = 80mm, $N = 1000\frac{\text{mm}}{\text{s}} = \frac{1000\text{ mm}}{80\text{ mm}} = 12.5$

Total reinforcement area $A_s = 1000\frac{\text{mm}}{\text{s}}A_b = \frac{1000\text{ mm}}{80\text{ mm}} \times 100\text{ mm}^2 = 1250\text{ mm}^2$

Check steel yielding $\rho_s = \frac{A_s}{b \times d} = \frac{1250\ \mathrm{mm}^2}{1000\ \mathrm{mm} \times 250\ \mathrm{mm}} = 0.005$ is smaller than ρ_b for f_c' = 45 MPa, steel will yield before concrete fails

Assume cover = 75 mm for highest exterior exposure

Actual effective depth $\mathrm{d} = \mathrm{t} - \mathrm{cover} - \frac{d_b}{2} = 250\ \mathrm{mm} - 75\ \mathrm{mm} - 5\ \mathrm{mm} = 170\ \mathrm{mm}$

Depth of neutral axis from top of slab $\mathrm{c} = \frac{700}{700+400}\mathrm{d} = \frac{700}{1100} \times 170\ \mathrm{mm} = 108.2\ \mathrm{mm}$

Depth of compression block from top of slab $\mathrm{a} = \beta_1 \mathrm{c} = 0.9 \times 108.2\ \mathrm{mm} = 97.4\ \mathrm{mm}$

Actual moment resistance:

$$\mathrm{Mr} = \varphi_s f_y A_s \left(\mathrm{d} - \frac{\mathrm{a}}{2}\right) = 0.85 \times 400\ \mathrm{MPa} \times 1250\ \mathrm{mm}^2 \times \left(170\ \mathrm{mm} - \frac{97.4\ \mathrm{mm}}{2}\right) = 5156\ \mathrm{kNm}$$

Check for crack control parameter

$f_s = 0.6\, f_y = 0.6 \times 400\ \mathrm{MPa} = 240\ \mathrm{MPa}$

Since only one layer of rebar at slab bottom, $d_c = d_s = \mathrm{cover} + \frac{d_b}{2} = 75\ \mathrm{mm} + 5\ \mathrm{mm} = 80\ \mathrm{mm}$

$A_e = 2 \times d_s \times b = 2 \times 80\ \mathrm{mm} \times 1000\ \mathrm{mm} = 160000\ \mathrm{mm}^2$

$A = \frac{A_e}{N} = \frac{160000\ \mathrm{mm}^2}{12.5} = 12800\ \mathrm{mm}^2$

Check $Z = f_s \sqrt[3]{d_c \times A} = 240\ \mathrm{MPa} \times \sqrt[3]{80\ \mathrm{mm} \times 12800\ \mathrm{mm}^2} = 24190.5 \frac{\mathrm{N}}{\mathrm{mm}} < 25000 \frac{\mathrm{N}}{\mathrm{mm}}$ OK

Therefore, use 10M@80 mm

Check shrinkage and temperature rebar layout

Minimum required reinforcement $A_{s,min} = 0.002A_g = 0.002 \times 1000\ \mathrm{mm} \times 250\ \mathrm{mm} = 500\ \mathrm{mm}^2$

Max rebar spacing $s_{max} = \min(5t, 500\ \mathrm{mm}) = \min(1250\ mm, 500\ mm) = 500\ mm$

Therefore, same rebar layout could be used as for flexural rebar design, 10M@80 mm

(2) Calculations for retaining wall

Bearing calculation based on tributary areas and the total load carried by concrete slab. Use the north end supporting wall as example.

Total length L = 7 m, tributary width b = 3.5 m

Total dead load $\mathrm{DL} = \rho \times t \times g = 2400 \frac{\mathrm{kg}}{\mathrm{m}^3} \times 0.3\ \mathrm{m} \times 9.8 \frac{N}{kg} = 7056 \frac{N}{m^2} = 7.056 \frac{kN}{m^2}$

Total live load per unit area $\mathrm{LL} = \frac{\mathrm{WN}}{\mathrm{L} \times \mathrm{L_u}} = \frac{667.08\ \mathrm{kN} \times 6}{7\ \mathrm{m} \times 27\ \mathrm{m}} = 21.18 \frac{kN}{m^2}$

Factored distributed load $w_f = 1.25DL + 1.5LL = 1.25 \times 7.056 \frac{kN}{m^2} + 1.5 \times 21.18 \frac{kN}{m^2} = 40.59 \frac{kN}{m^2}$

Total factored distributed load $w = w_f \times b = 40.59 \frac{kN}{m^2} \times 3.5\ m = 142.05 \frac{kN}{m}$

According to code recommendations, assume wall thickness t = 200 mm

Wall height h = 2.8 m, design factors K = 0.8, α_1 = 0.8

Total vertical gross sectional area $A_g = l_b \times t = 1000\ mm \times 200\ mm = 200000\ mm^2$

Bearing resistance per unit length

$$P_r = \frac{2}{3}\alpha_1 \varphi_c f_c' A_g \left[1 - \left(\frac{Kh}{32t}\right)\right] = \frac{2}{3} \times 0.8 \times 0.65 \times 45\ MPa \times 200000\ mm^2 \times \left[1 - \left(\frac{0.8 \times 2.8}{32 \times 200}\right)^2\right]$$

$$= 2737.8\ kN/m$$

Resistance to lateral earth pressure

t = 200 mm, $P_f = 142.05 \frac{kN}{m}$

Maximum moment $M_f = 13.58 \frac{kNm}{m}$ at the point approximately 1.9 m from top of the wall

Effective depth $d = t - cover - \frac{d_b}{2} = 200\ mm - 20\ mm - \frac{10\ mm}{2} = 175\ mm$

Assume 10M bars, rebar diameter $d_b = 100\ mm^2$, rebar cross sectional area $A_b = 100\ mm^2$

Total vertical reinforcement per 1 m unit length

$$A_s = 0.00153 fc'b \left(d - \sqrt{d^2 - \frac{3.85\ Mr}{fc'b}}\right)$$

$$= 0.00153 \times 45\ MPa \times 1000mm \times \left(175\ mm - \sqrt{(175\ mm)^2 - \frac{3.85 \times 13.58 \frac{kN}{m}}{45MPa \times 1\ m}}\right) = 230.76\ mm^2$$

Spacing $s \le A_b \frac{1000\ mm}{A_s} = 100\ mm^2 \times \frac{1000\ mm}{230.76\ mm^2} = 433.35mm$

Max rebar spacing $s_{max} = \min(3t, 500\ mm) = \min(600\ mm, 500\ mm) = 500\ mm$

Therefore, use 10M@300 mm

Total reinforcement area $A_s = \frac{1000\ mm}{s} A_b = \frac{1000\ mm}{300\ mm} \times 100\ mm^2 = 333.33\ mm^2$

Minimum required reinforcement $A_{v,min} = 0.0015A_g = 0.0015 \times 200000\ mm^2 = 300\ mm^2$

Check steel yielding $\rho = \frac{A_s}{bd} = \frac{\frac{1000}{300}100}{1000 \times 175} = 0.0019$ is smaller than ρ_b for f_c' = 45 MPa, steel will yield before concrete fails

Maximum horizontal shear force at bottom of wall $V_f = 21.384\,\frac{\mathrm{kN}}{\mathrm{m}}$

$d_v = \max(0.9d, 0.72t) = \max\,(157.5\text{ mm}, 144\text{ mm}) = 157.5\text{ mm}$

$b_w = 1000\text{ mm}$

$$\beta = \frac{230}{1000 + d_v} = 0.1987$$

Assume λ = 1 for normal concrete

Actual shear resistance per 1 m unit length

$$V_c = \varphi_c \lambda \beta \sqrt{f_c{}'} b_w d_v = 0.65\ \times 1\ \times 0.1987\ \times \sqrt{45\text{ MPa}}\ \times 1000\text{ mm} \times 157.5\text{ mm} = 136.46\text{ kN}$$

Total horizontal gross sectional area $A_g = l_b\ \times t = 1000\text{ mm}\ \times 200\text{ mm} = 200000\text{ mm}^2$

Minimum required reinforcement $A_{h,min} = 0.002\ \times 200000\text{ mm}^2 = 400\text{ mm}^2$

Therefore, use 10 M @ 250 mm

Part 2 Footing

(1) Determine the footing width (L)

$L >= P_s/(b*q_{all}) = (24kn/m + 71kn/m)/(1*100KPA) = 1.0$ m

Use L = 1.0 m for the footing width

(2) Determine the factored soil pressure

$A = L*b = 1.0m * 1.0m = 1.0m^2$

Calculate the factored soil bearing pressure as

$q_f = P_f/A = (1.25*24kn/m+1.5*71kn/m)/1.0m^2 = 137kpa$

(3) Determine the required footing thickness(h), trial h 250mm

Because 15M reinforcement used and d_b = 15mm, cover = 75mm

d = 250mm-75mm-7.5mm/2 = 165mm

$V_f = q_f * b * [(l-t)/2 – d] = 137kpa*1.0m*[(1.0m-0.2m)/2 – 0.165] = 33KN/m$

Calculate the effective shear depth d_v

d_v = max.(0.9*d, 0.75*h) =max.(0.9*165, 0.75*250) = 180mm

β= 0.21 since h=250mm < 350mm

$V_c = \phi_c*\gamma*\beta*(f_c)^{0.5}*b_w*d_v = 0.65*0.21*(45MPA)^{0.5}*1000mm*180mm= 165KN/m$

$V_f < V_c$, No shear reinforcement required for shear.

(4) Determine the required flexural reinforcement based on the flexural design requirement:

$M_f = q_f * b * (l-t)/2 *(l-t)/4*b= 137*(1.0m-0.2m)/2 *(1.0m-0.2m)/4*1.0m= 11KNm/ m$

$M_r >= M_f = 11$ KN/m

$A_s = 0.0015*f_c'*b*[d-(d^2-3.85*M_r/ f_c'*b)^{0.5}] = 0.0015*45MPA*1000mm*[165mm-((165mm)^2-3.85*11*10^6 Nmm/m)/(45MPa*1000mm)^{0.5}] = 195mm^2/m$

(5) Confirm that the minimum reinforcement required is satisfied

$A_g = h*b = 250mm *1000mm = 250{,}000mm^2$

Then, $A_{smin}= 0.002\ A_g = 0.002 * 250{,}000mm^2 = 500mm^2/m$

Because $A_s = 195\ mm^2/m < A_{smin}= 500mm^2/m$

The minimum reinforcement is satisfied since we chose minimum reinforcement.

$A_s = A_{smin} = 500mm^2/m$

(6) The maximum reinforcement requirement is satisfied since we chose minimum reinforcement.

(7) Determine the required bar spacing for flexural reinforcement for 15M bars,

$A_b = 200mm^2$ (see table A1)

Therefore: $S <= A_b*(1000/A_s) = 200mm^2 (1000mm/500mm^2/m) = 400mm$

According to A23.3 CL.7.4.1.2 and CL.13.10.4

S_{max} = min (3*h, 500mm) = 500mm (governs)

$S = 400mm < S_{max} = 500mm$

Use 15M bar at 40mm spacing (15M@400)

(8) Design the minimum reinforcement in the longitudinal direction:

$A_g = h*l = 250mm * 1000mm = 250,000mm^2$

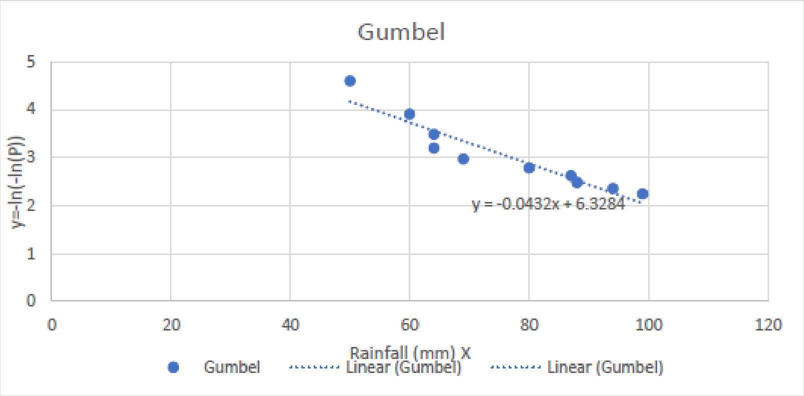
$A_{smin} = 0.002*A_g = 0.002*250,000mm^2 = 500mm^2$

Use 3-15M bars ($A_b = 200mm^2$)

$As = 3*200mm^2 = 600mm^2 > A_{smin} = 500mm^2$ and $S_{max} = 500mm$ (governs)

Precipitation Calculations

N	99		recording interval	12.66667		Tr	20	P	0.366667
						Q	0.633333	y	-0.0033
Date	Rainfall(mm)	n	Q	P	y			x=H	146.5671
12/05/1870	50	1	0.01	0.99	4.600149				
03/04/1850	60	2	0.02	0.98	3.901939				
28/06/1957	64	3	0.03	0.97	3.491367				
31/01/1843	64	4	0.04	0.96	3.198534				
21/05/1894	69	5	0.05	0.95	2.970195				
02/11/1861	80	6	0.06	0.94	2.782633				
15/10/1954	87	7	0.07	0.93	2.623194				
14/09/1843	88	8	0.08	0.92	2.484328				
15/08/1905	94	9	0.09	0.91	2.361161				
27/06/1957	99	10	0.1	0.9	2.250367				



road width	3.7	m	Total Area	6660	m^2
road length	1800	m	Water Volume	976.1366	m^3
Total CB	40		Assumed T	4.5	hr
Water /CB	24.4034142		Area of CB	0.221904	
flow	24.43841	m/hr		6.788447236	m/s

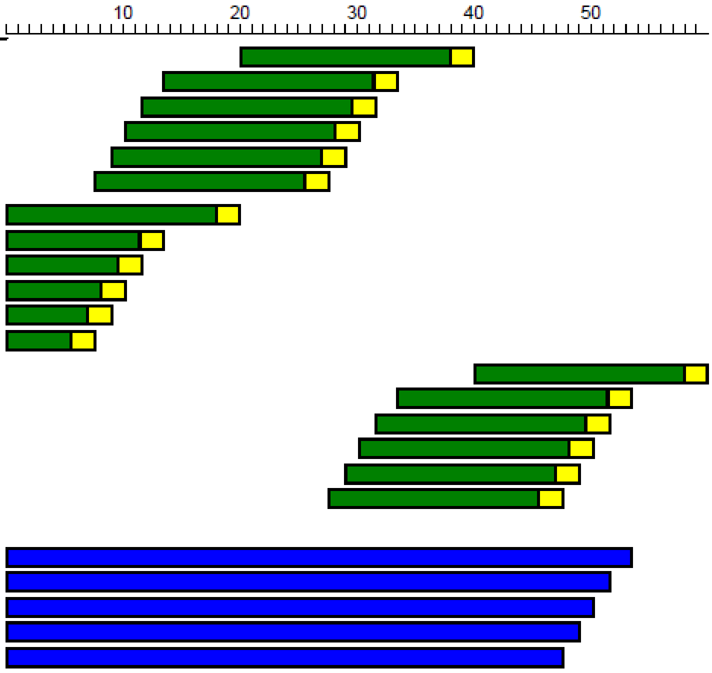
APPENDIX D SYNCHRO STATUS REPORT

Actuated Signal, Actual Green Times and Starts
3: Int

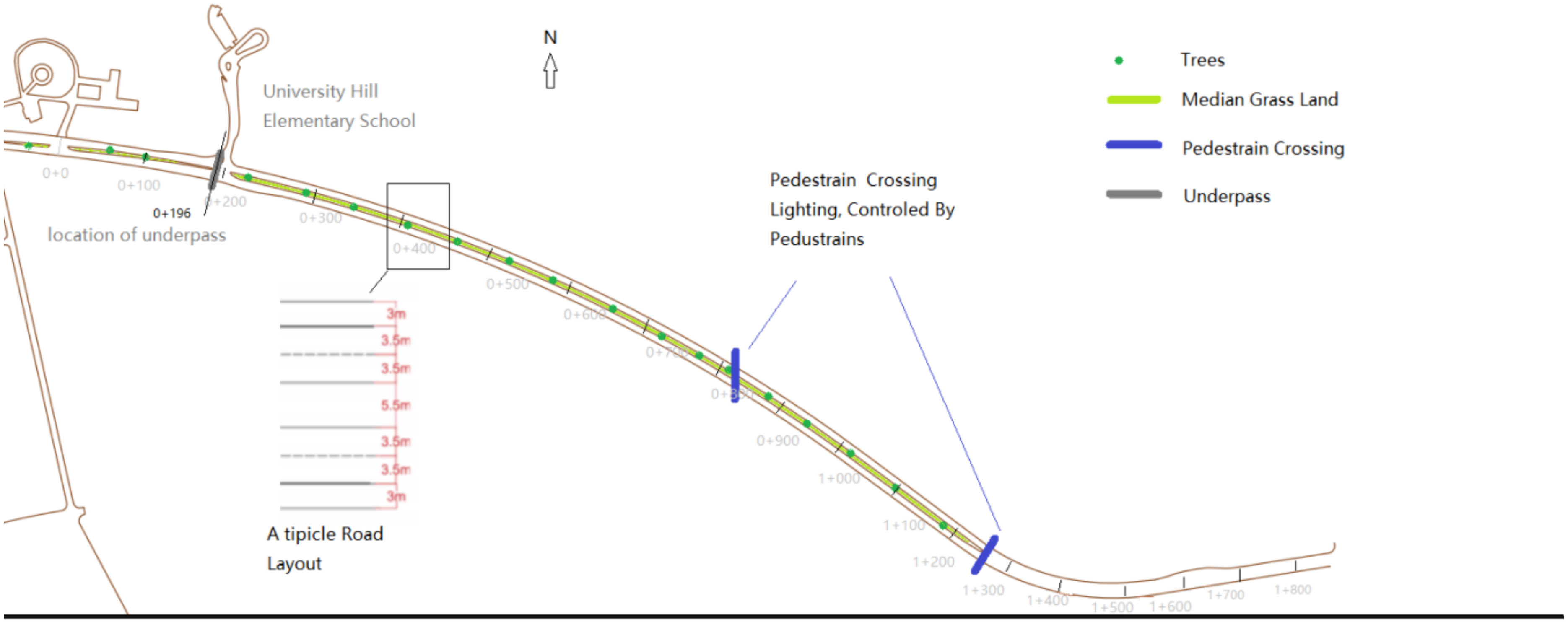
2018-04-06

Phase	%ile	Green	Start	Termination
4 EBL	Max	18.0	20.0	Max
	90th	18.0	13.4	Max Out
	70th	18.0	11.5	Max Out
	50th	18.0	10.2	Max Out
	30th	18.0	9.0	Max Out
	10th	18.0	7.5	Max Out
6 SBL	Max	18.0	0.0	Max
	90th	11.4	0.0	Gap Out
	70th	9.5	0.0	Gap Out
	50th	8.2	0.0	Gap Out
	30th	7.0	0.0	Gap Out
	10th	5.5	0.0	Gap Out
8 EBWB	Max	18.0	40.0	Max
	90th	18.0	33.4	Max Out
	70th	18.0	31.5	Max Out
	50th	18.0	30.2	Max Out
	30th	18.0	29.0	Max Out
	10th	18.0	27.5	Max Out

%ile	Cycle	Red-Rest
90	53.4	0.0
70	51.5	0.0
50	50.2	0.0
30	49.0	0.0
10	47.5	0.0



APPENDIX E ENGINEERING DRAWINGS



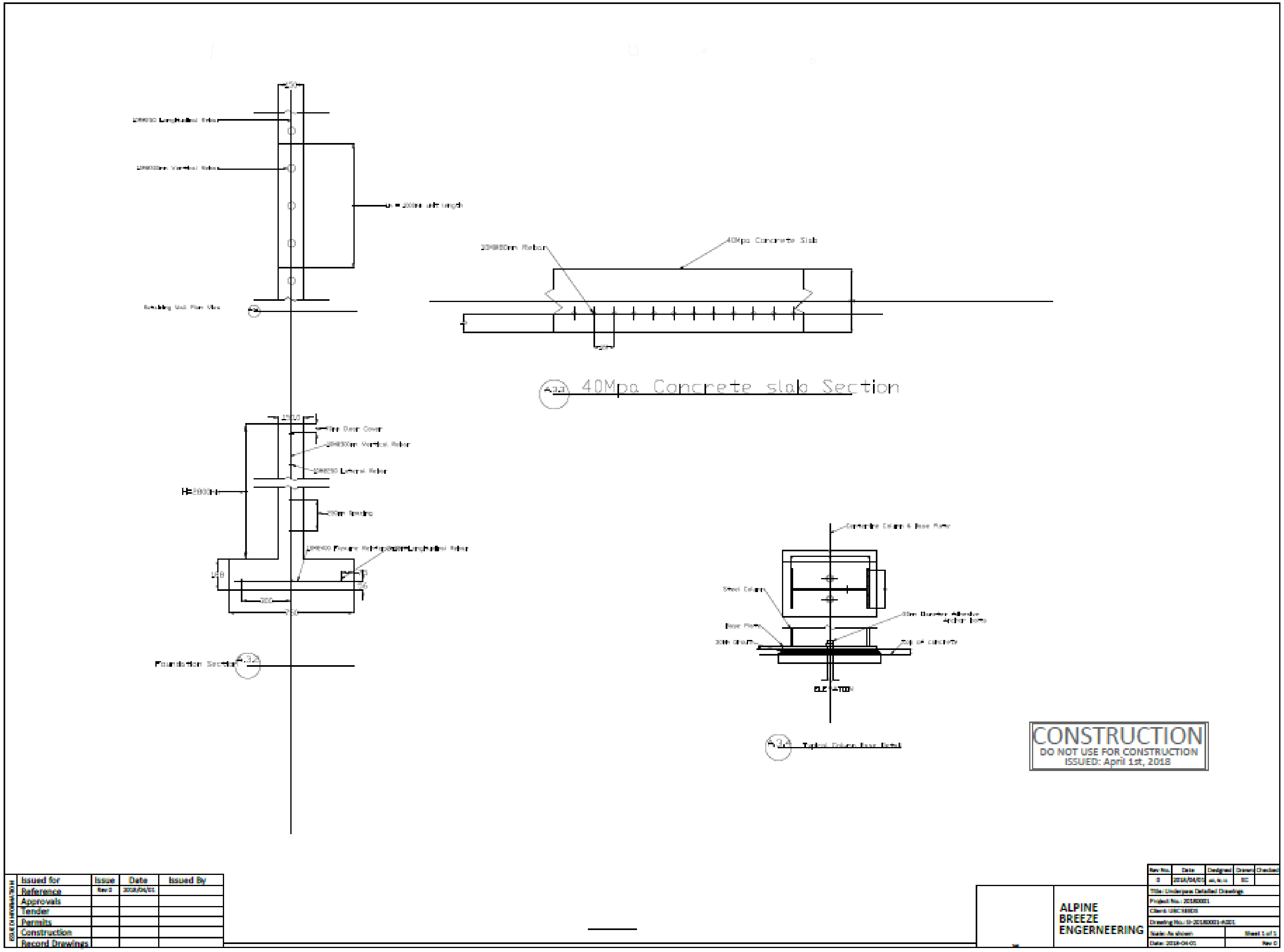
Issued for	Date	Issued By		
Reference				
Approvals				
Tender				
Permits				
Construction				
General Revision				

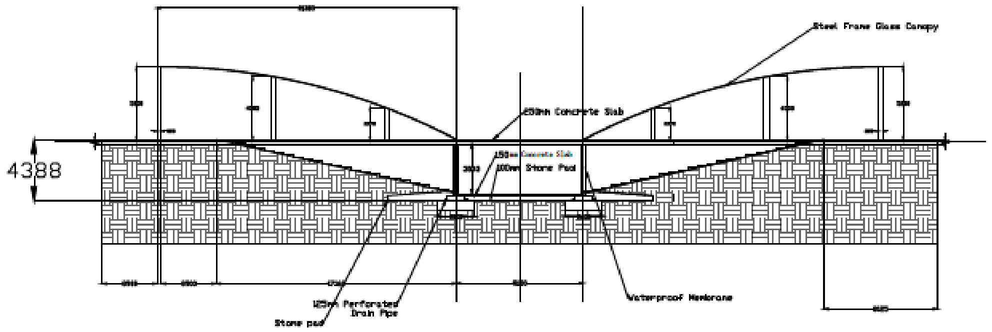
Rev.No.	Date	Designed	Drawn	Checked	Description of Revision	Rev.No.	Date	Designed	Drawn	Checked	Description of Revision

SEAL

68464 Rafdaf Road
Vancouver, B.C.
778-542-8544

OVER VIEW OF CHANCELLOR
BLV


250
Longitudinal Rebar
Vertical Rebar
Retaining Wall Plan View
40Mpa Concrete Slab
20M@80mm Rebar
40Mpa Concrete slab Section
1500
Clear Cover
Vertical Rebar
Lateral Rebar
H=2800mm
200mm Spacing
Longitudinal Rebar
200
750
Foundation Section
Centerline Column & Base Plate
Steel Column
Base Plate
Anchor bolts
Top of concrete
ELEVATION
Typical Column Base Detail
CONSTRUCTION
DO NOT USE FOR CONSTRUCTION
ISSUED: April 1st, 2018
Issued for
Issue
Date
Issued By
Reference
Approvals
Tender
Permits
Construction
Record Drawings
ALPINE
BREEZE
ENGERNEERING
Rev No.
Date
Designed
Drawn
Checked
Title: Underpass Detailed Drawings
Scale: As shown
Sheet 1 of 1
Rev 0



A.2 CROSS SECTION VIEW

CONSTRUCTION
DO NOT USE FOR CONSTRUCTION
ISSUED: April 1st, 2018

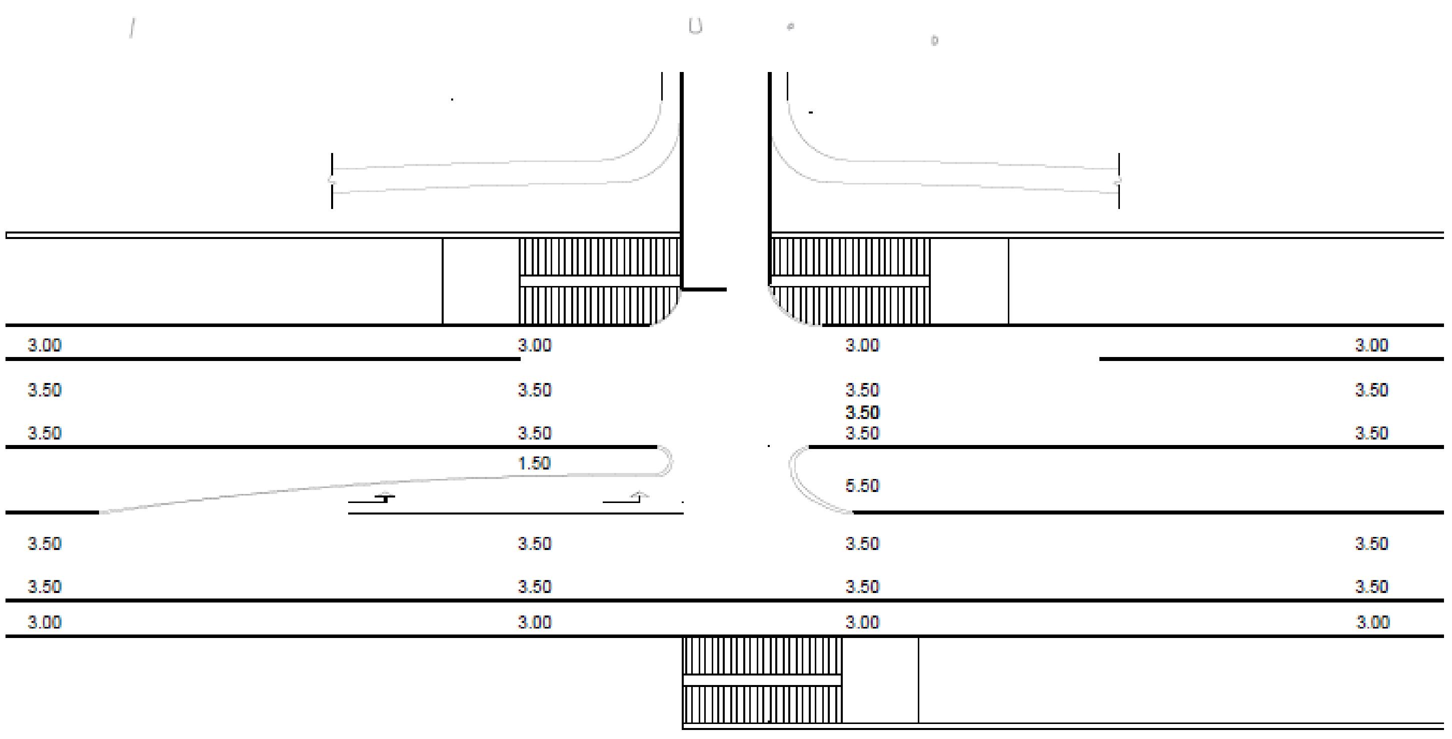
ISSUED INFORMATION

Issued for	Issue	Date	Issued By
Reference	Rev 0	2018/04/01	
Approvals			
Tender			
Permits			
Construction			
Record Drawings			

ALPINE
BREEZE
ENGERNEERING

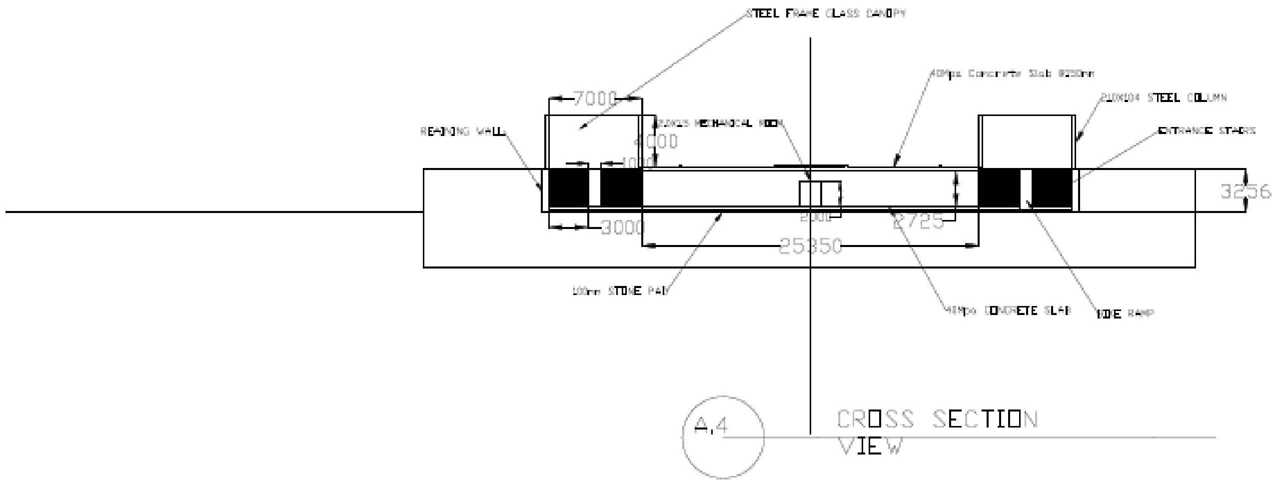
Rev No.	Date	Designed	Drawn	Checked
0	2018/04/01	[illegible]	KC	

Title: Underpass Detailed Drawings
Project No.: 20180001
Client: UBC SEEDS
Drawing No.: SI-20180001-A001
Scale: As shown | Sheet 1 of 1
Date: 2018-04-01 | Rev 0



A.1 INTERSECTION PLAN VIEW

CONSTRUCTION
DO NOT USE FOR CONSTRUCTION
ISSUED: April 1st, 2018



CONSTRUCTION
DO NOT USE FOR CONSTRUCTION
ISSUED: April 1st, 2018

ISSUE INFORMATION

Issued for	Issue	Date	Issued By
Reference	Rev 0	2018/04/01	
Approvals			
Tender			
Permits			
Construction			
Record Drawings			

ALPINE
BREEZE
ENGERNEERING

Rev No.	Date	Designed	Drawn	Checked
0	2018/04/01	AC, ALL	KC	

Title: Underpass Detailed Drawings	
Project No.: 20180001	
Client: UBC SEEDS	
Drawing No.: SI-20180001-A001	
Scale: As shown	Sheet 1 of 1
Date: 2018-04-01	Rev 0