UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Redesign of 16th Avenue / SW Marine Drive Intersection

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Executive Summary

This report outlines the redesign of the Southwest Marine Drive and 16th Avenue intersection. The intersection is located in Vancouver, BC, on the southwest corner of Point Grey, sitting next to the eroding Point Grey cliffs. The junction serves as the southern entry point to the University of British Columbia (UBC) campus. Despite significant growth in population, and the development of adjacent residential areas over the past decades, the intersection has remained largely unchanged. The existing design, reminiscent of a highway layout which would have accommodated a now long cancelled ferry terminal, presents challenges and risks for those using active modes of transportation, particularly in terms of comfortable and safe navigation.

The main objective of this project is to redesign the intersection to prioritize public transit and active modes of transportation, ensuring safety and accessibility for pedestrians and cyclists. To create a smooth transition from a highway to a suburban environment, the project aims to calm traffic by reducing travel speeds. It also maintains a buffer distance with the Botanical Garden, incorporates green infrastructure for stormwater retention, and introduces a gateway feature for a distinctive entry to the UBC campus.

Key issues that currently affect the intersection and that this design aims to address can be summarized in a few key points. The design of the current intersection prioritizes the use of single occupancy vehicles travelling along Marine Drive, which creates a safety hazard for pedestrians and cyclists due to the vehicle speeds, and as such reduces the appeal of these modes of transportation. Additionally, the slope to the west of the intersection is particularly exposed to erosion from surface runoff and as such needs to be prevented or minimized. Lastly, the intersection now functions as one of the main entrances to the university campus and remains as the only such entrance to not feature a gateway to adequately inform road users that they are entering the campus.

The proposed design has four key features. First, a roundabout intersection that discourages high speeds by the addition of approach curves alongside lowering the number of lanes. Second, an accessible pedestrian underpass across 16th Avenue enhances active transportation safety. Third, a system involving a soak pit, grass swale, slot drains, and stormwater tank minimizes cliff

erosion. At last, a concrete gateway with Indigenous art acknowledges land property and welcome visitors to the UBC campus.

The schedule developed for this design outlines the main project stages and milestones for the project by providing a comprehensive work breakdown sequence involving construction phases and reoccurring stakeholder consultation. To complete the development during the summer of 2024, construction is expected to last four months, starting May 01 and ending August 16.

A Class A cost estimate based on material, equipment, and labour costs will be created to justify further development of the proposed design. This cost estimate is to be taken within 5 to 10% of the actual cost to account for changes between the final design estimate and the fluctuating prices during construction. The total project cost is estimated to be $2,824,297.

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1. Project Background

The intersection between SW Marine Dr and 16th Avenue serves as the main corridor connecting UBC to the southern half of the Lower Mainland. Currently, the signalized intersection has vehicles speeding through frequently, which leads to it feeling unsafe for pedestrians and cyclists. The intersection is also used by the R4 rapid transit bus, which is the second busiest bus in the Lower Mainland with a total of 7,770,000 riders in 2022 (TransLink, 2023). Finally, the intersection does not provide any indication that a road user has entered the university campus.

1.2. Project Objectives

The main objectives for this project are traffic calming, on-site stormwater collection, accessibility for pedestrians and cyclists, promotion of public transit, and creating a gateway welcoming road users to UBC all without impeding on the space of the nearby Botanical Garden and UBC farm facilities. Additionally, the intersection should accommodate traffic growth based on 2050 population projections alongside TransLink's 2050 goals, and environmental impacts to plant and animal life should be minimized or mitigated as much as possible. Refer to Figure 1 below for a summary of the main project objectives.

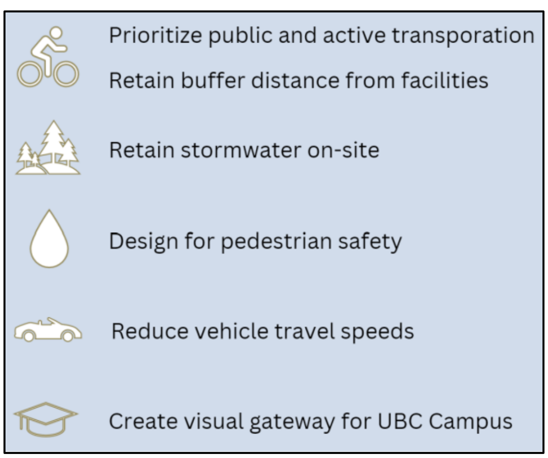


Figure 1. Project Objectives

1.3. Project Financials and Business Needs

The project would be financed by the University of British Columbia, who stated that the project did not have a set budget; as such, budget had a reduced impact in the decision process. In terms of business needs, it is important that the road remains open from September to April for access to the university during the higher traffic loads of the university's fall and winter semesters. Because of this, it is critical that project completion is met by September 2024.

1.4. Site Overview

Currently, the site is a signalized intersection as shown below in Figure 2. It features two through lanes in each direction along SW Marine Drive. With most traffic coming from SW Marine Dr northbound turning onto 16th Ave, it has two dedicated right turn lanes. The intersection features two left turn lanes from 16th Avenue to southbound on SW Marine Drive.

Marine Drive also functions as a disaster route, which would function as a major artery to and from the region in case of natural disasters or other such events. It also marks the southern limit to the UBC Campus and the beginning of the Pacific Spirit Park.

Figure 2. Current 16th Ave and SW Marine Dr Intersection (Google, n.d.)

1.5. Team Member Contributions

All team members contributed heavily to the report, and Table 1 describes the specialized roles and specific contributions of each of the team members. Report sections and roles not mentioned in the table had the work distributed equally between all members.

Table 1. Summary of Team Member Contributions

Team Member	Report Contributions
[redacted]	Underpass calculations, underpass stormwater management design, underpass design and drafting
[redacted]	Cost estimate, stormwater management system, summarised maintenance plan
[redacted]	Traffic simulations, roundabout design, road design
[redacted]	Schedule, construction plan, and project management documentation
[redacted]	Population growth calculations, intersection design
[redacted]	Intersection specifications, entrance design, non-intersection drawings
[redacted]	Executive summary, introduction, key issues, design criteria, SEEDS, Illumination

2. Key Issues and Design Criteria

The goals of the redesign were organized and classified to better understand the process through which they would be achieved. Several key issues affecting the current intersection design along with design criteria were identified and outlined in the following sections. These served as guidelines for the creation of the framework for this redesign so that it would best fit the needs of the client while also adhering to all the regulations and limitations specific to this project.

In this regard, the issues and criteria were analyzed though the triple-bottom-line and administrative lens, to encompass construction planning and regulatory requirements.

2.1. Key Issues

The current intersection was designed with different purposes and goals than those that affect the current demands by road users. This intersection was built with a focus towards maximizing the level of service for single occupancy vehicles, since during its conception it was imagined that a ferry terminal would be constructed on the peninsula, and as such the intersection would have to accommodate that increased traffic. This terminal, however, never came to fruition and the section of highway remained as an overdesigned intersection focused on catering mainly to the users utilizing Pseudo Highway 914:0620, also known as Southwest Marine Drive, to transit to and from the UBC campus.

With the growth of not only UBC, but also the surrounding communities of Westbrook Village and Metro Vancouver, the requirements of road users as well as traffic flows further changed, and it currently stands at a point where an overhaul of the design of the intersection is required. Most of the traffic now flows from South Marine Drive towards 16th Avenue and vice versa, and with a design that did not aim to adequately accommodate cyclists and pedestrians, the existing infrastructure poses significant issues and risks.

The two main safety issues currently affecting the intersection involve speeding, which is a symptom of the unimpeded highway design, and the lack of adequate infrastructure for cyclists and pedestrians using the intersection. Cyclists currently must insert themselves into very high-speed traffic, exposing themselves to risk of serious injury simply to traverse the intersection. Vehicles making the turn into 16th Avenue may not be able to slow to a safe speed during unfavorable conditions, such as snow or heavy rains, posing a severe risk to all road users.

Additionally, to the west of the intersection, the slope's erosion due to surface runoffs is a major point of concern due to the consequences of that phenomenon causing irreversible damage to the surrounding infrastructure. Mitigation strategies are required to be implemented into the design solution. The key points are summarized below in Table 2.

Table 2. Key Issues

Safety Issues	Environmental Issues
• Speeding vehicles posing a risk to themselves and other road users • Cyclists exposing themselves to vehicles when traversing the intersection with no purpose-built safety features	• Surface rainwater runoff eroding the slope west of the intersection

2.2. Design Objectives

To ensure that the design properly addressed the concerns raised by the client in the project proposal, the key issues were established early on and constantly referred to in the iterative design process through to final design. Table 3 below outlines those issues, along with the solutions incorporated in the design to address them through several different approaches acting in tandem with each other.

Table 3. Design Objectives

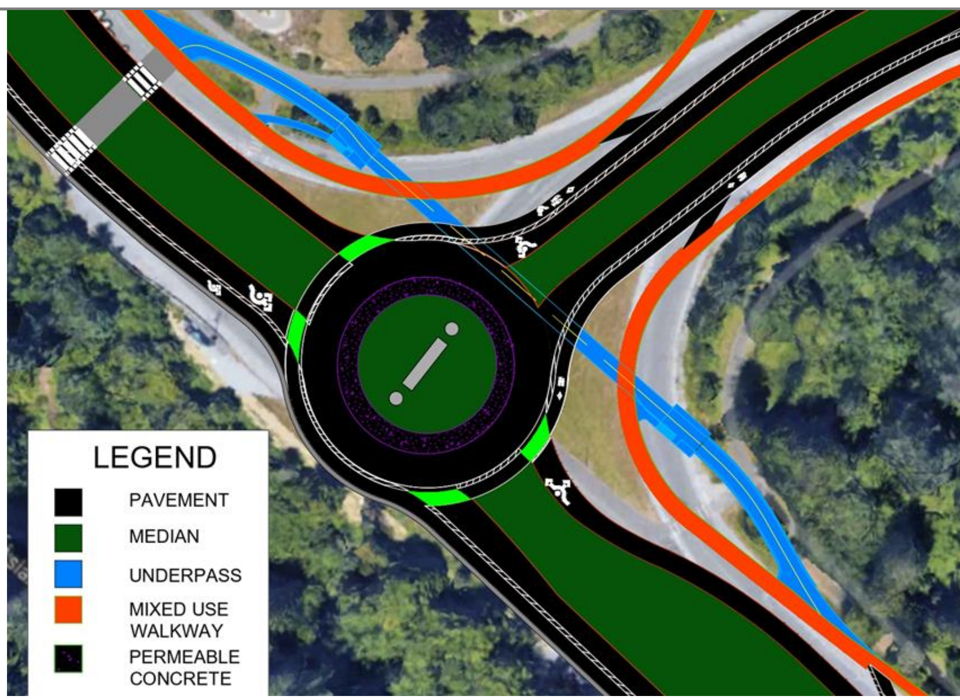
Key Issues	Design Solutions
High vehicle speeds	Fewer lanes, increased horizontal deflection, and removal of slip lanes
Erosion of nearby cliff face in heavy rain	Use of slot drains, grassed swales, and soak pits
No visual indication of entering UBC	A large UBC entrance sign with local flora
Large number of single occupancy vehicles	Separated cyclist lanes, wider pedestrian sidewalks, and an underpass

3. Detailed Design

3.1. Detailed Design Overview

This section of the report focuses on the detailed design, key features, and analysis undertaken. Table 4 contains a diagram of our detailed design. The four key components of the primary design are: the intersection, underpass, stormwater management system, and entrance. For the complete list of drawings, refer to Appendix J. Each design component will be covered in more detail in the following sections.

Table 4. Diagram of the Design with Features, Relevant Sections, and Drawings



Our proposed design consists of:

1. A one lane roundabout providing level of service C during projected 2050 peak traffic
2. A design speed of 30 km/h and increased deflection on approach to slow vehicles
3. Pedestrian and bicyclist infrastructure kept safe from vehicle traffic using a raised bicycle and pedestrian pathway, a two-way mixed-use underpass, and a rectangular rapid flashing beacon (RRFB) crosswalk
4. Separated bicycle lanes through the roundabout for cyclist ease of use while retaining alternative routes that give cyclists the option to bypass entering the roundabout
5. A stormwater management system that directs rainwater and runoff to a buried tank beneath the roundabout using grassed swales surrounding the central island, a soak pit near the western slope, and slot drains along roads
6. A large UBC entrance sign in the central island surrounded by local flora and two traditional wooden totem poles to welcome all road users to the university
7. A small overall footprint to retain as many existing natural features as possible

3.2. Detailed Design Deliverables

Design deliverables refer to the unique tangible construction milestones offered by a project design. The detailed design proposed by Team 9 has five main deliverables as seen below in Figure 3. The full construction schedule for the components is contained in Section 4.5.

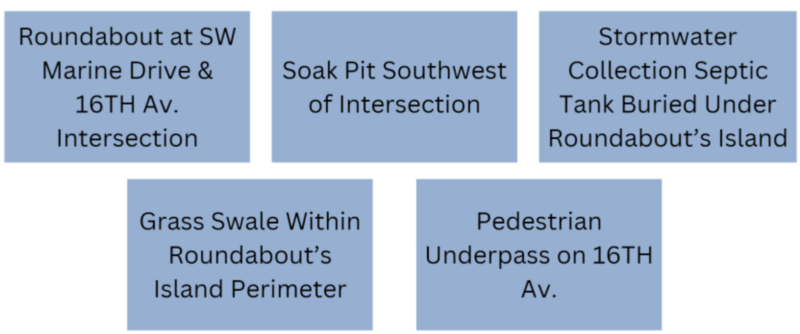


Figure 3. Detailed Design Deliverables

3.3. Intersection Design

3.3.1. Design

3.3.1.1. *Roundabout*

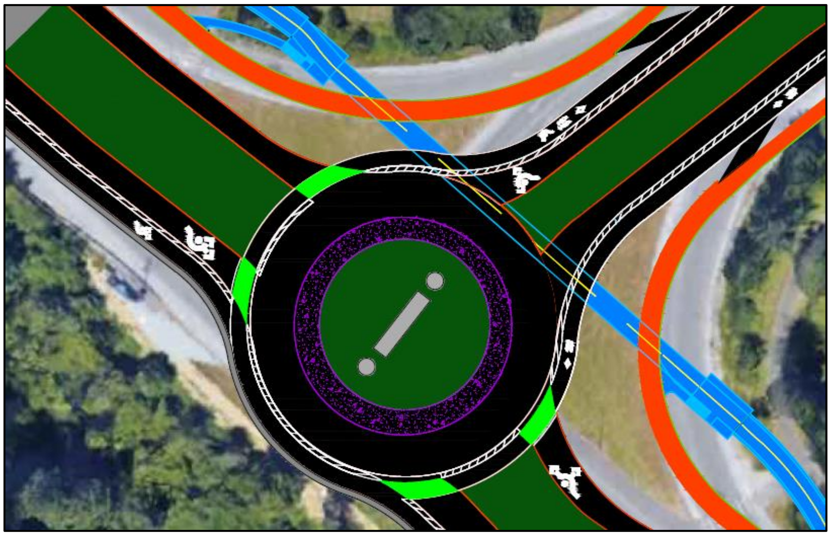


Figure 4. Roundabout Plan View

As shown in Figure 4, the proposed intersection design is a one-lane roundabout. A complete visual of all road markings and signage can be found in Appendix J.

Table 5 contains a summary of the key geometric properties of the roundabout. The radii and widths were uniform across all approaches and exits. Across all geometric design decisions, controlling factors were most often capacity requirements, speed reduction targets, and design vehicle maneuverability requirements. For a more comprehensive list of geometric design elements, the BC MoTI geometric design information sheet can be found in Appendix F.

Table 5. Key Geometric Properties of the Roundabout

Geometric Property	Value	Geometric Property (cont.)	Value (cont.)
Inscribed Circle Diameter	55m	Exit Width	7m
Circulatory Road Width	8m	Exit Radius	35m
Entry Radius	30m	Truck Apron Width	4.2m
Entry Width	6m		

Circulatory Road Width and Inscribed Circle Diameter: The circulatory road width and inscribed circle diameter (ICD) were controlled by the need to accommodate the turning radius of the TAC WB-20 (tractor semi-trailer) design vehicle, the standard design vehicle for ministry roads (BC Ministry of Transportation and Infrastructure, 2019a). By designing for the WB-20, the TAC I-BUS (standard intercity bus) will also be accommodated. In doing so, the frequent TransLink R4 buses that pass through the intersection will be able to maneuver safely.

Entry Radius and Entry Width: To limit speeds, small entry radii and widths were chosen. The entry radius and width play key roles in controlling capacity and safety of the intersection. A larger entry width lowers entry deflection imposed on vehicles, resulting in increased entry speeds (US Department of Transportation, 2000). However, as the roundabout must accommodate large vehicles, minimum entry radius and width must be met. With an entry radius and width of 30m and 6m, respectively, deflection is significant enough to slow drivers without comprising the ability of the roundabout to meet 2050 volumes or delaying large vehicles.

Exit Radius and Exit Width: The exit radius and width were set greater than the entry radius and entry width to decrease the risk of congestion of collisions at the exits. Exit radii and widths are typically set large enough to accommodate the design vehicle and reduce the risk of collisions caused by crossing exit paths on multi-lane roundabouts (US DoT, 2000). As the proposed roundabout is one-lane, the risk of two or more vehicles colliding due to crossing exit paths is low so the exit radius and width could be reduced without major risk. As a result, exit radius and width were minimized to 35m and 7m, respectively, to accommodate the WB-20, limit exit speeds, and increase the safety of pedestrians on the northwestern crosswalk.

Truck Apron Width: The truck apron is a raised section of pavement that gives large vehicles extra space to turn. A minimum width of 2m is required by BC MoTI (2019a). As the proposed circulatory road width is large, the truck apron did not need to be larger than the minimum to accommodate the WB-20. However, since the truck apron of the proposed design is used to manage stormwater, the width of the apron is also controlled by stormwater considerations. As a result, the truck apron is 4.2m to increase rainfall capture and infiltration volume.

3.3.1.2. *Alignments*

To minimize the time and money of excavation and paving, the alignments of 16th Avenue and SW Marine Drive have only been minorly changed from their current centrelines. Lane widths of proposed roads remain similarly unchanged from the current design.

Figure 5 shows the proposed design overlaid with the current intersection. The proposed redesign reduces all approaches and exits near the roundabout to one lane and removes all slip lanes.

Traffic volumes are not large enough to justify two lanes on each exit and approach or any slip lanes. Moreover, the crosswalks over the slip lanes are not pedestrian or cyclist friendly as vehicles tend to pass through at high speeds. Since speeding is a significant issue at the current intersection, the lane reductions of the redesign will work to lower entry and exit speeds. In place of the old traffic lanes, bike lanes have been added on each approach and exit to promote active transportation and provide cyclists with safe travel paths.

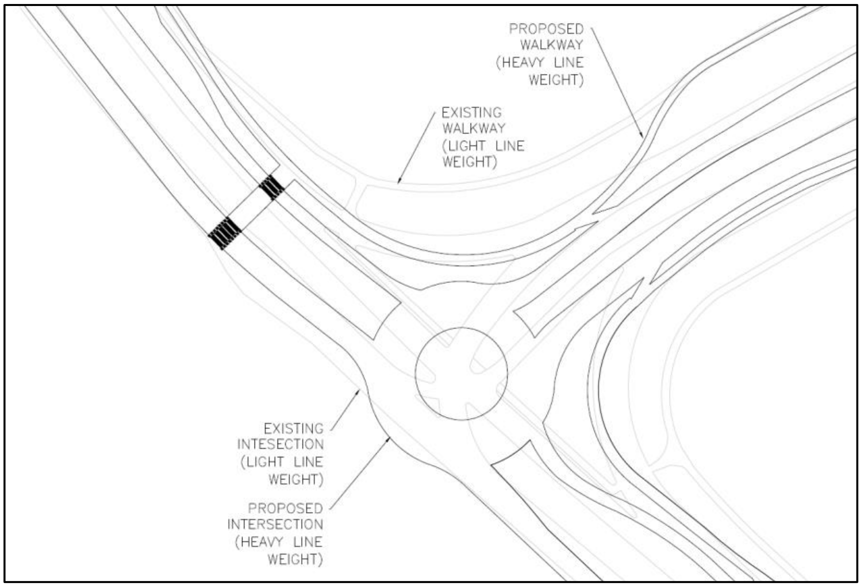


Figure 5. Plan View of Current and Proposed Intersections

Figure 6 shows the alignment of the northwestern exit and approach of SW Marine Dr. A crosswalk spans the two lanes and the median, allowing cyclists and pedestrians to safely cross the road. On either side of the crosswalk and in the median, pedestrian-controlled rectangular rapid flashing beacons (RRFBs) warn drivers of crossings. In order to meet roundabout offset requirements, the alignment of the northwestern approach was shifted northward to ensure that drivers would have adequate time to react to unexpected events in the intersection.

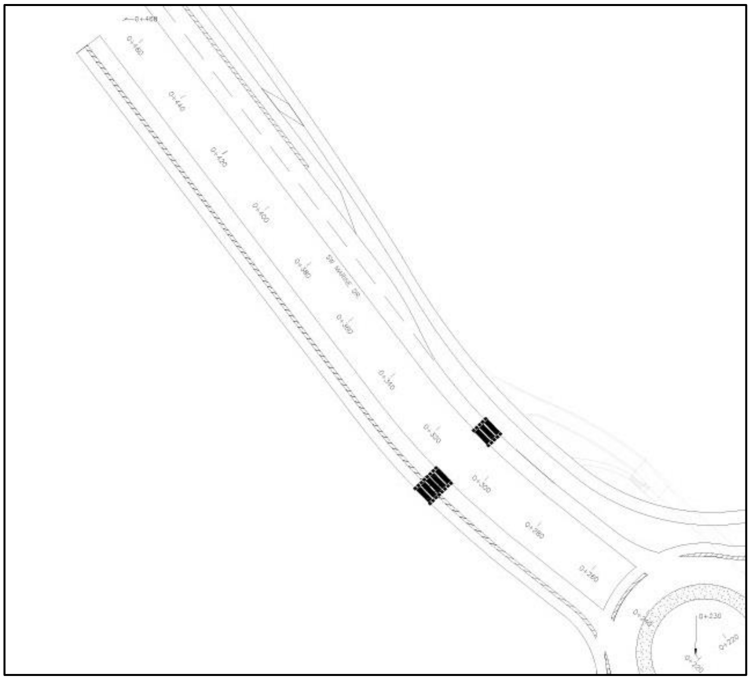


Figure 6. North SW Marine Dr Alignment

The alignments of the southern SW Marine Dr approach and exit are shown below in Figure 7. Although alignment of the southern exit is typical, the centreline of the southern approach has been shifted by approximately 7m. As vehicles tend to drive enter at high speeds on this approach, the design incorporates an increase in deflection to slow entry speeds. Refer to Section 3.3.1.7 for a detailed description of this measure.

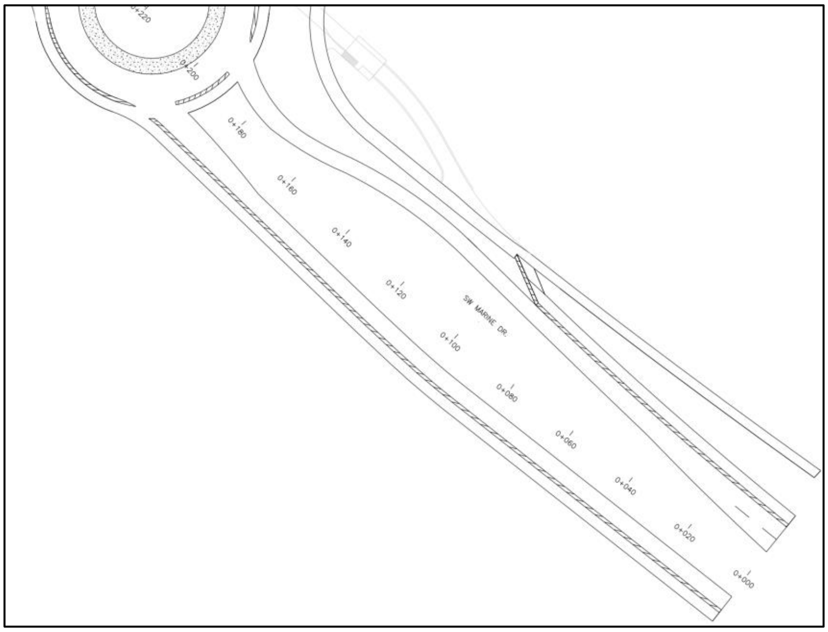


Figure 7. South SW Marine Dr Alignment

Figure 8 below shows the alignment of 16th Avenue to the northeast of the roundabout. Of note, a mixed-use underpass allows for pedestrians and cyclists to safely cross 16th Ave without interrupting traffic flow. Refer to Section 3.4 for information on the design of the underpass.

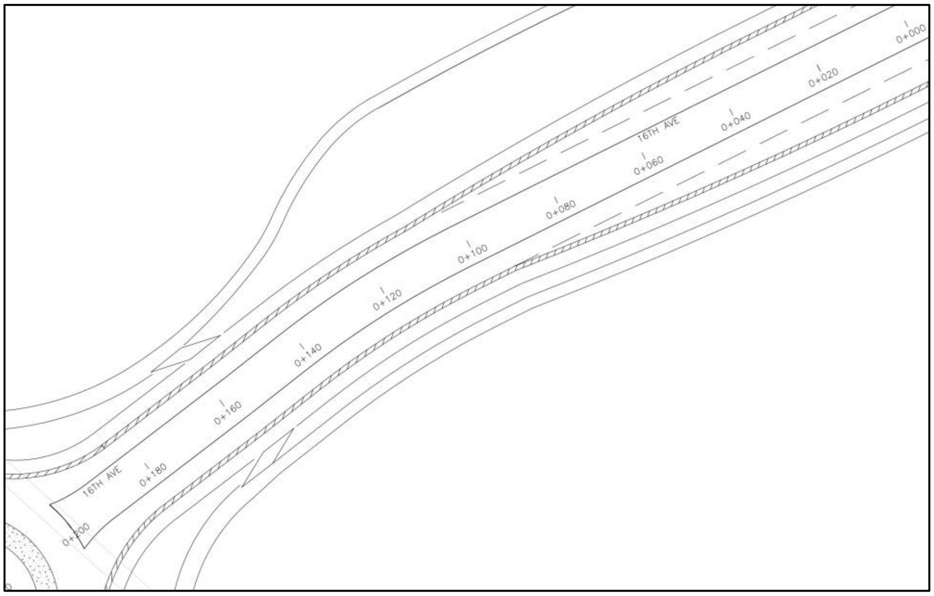


Figure 8. 16th Ave Alignment

3.3.1.3. *Profiles*

Figure 9 shows the profile of the roundabout along SW Marine Dr. Although the roundabout is at-grade, the 2% superelevation of the circulatory roadway and truck apron is atypical as it is positive rather than negative. As grassed swales around the central island provide drainage to the roundabout, the positive superelevation is used to help surface water flow toward the swales. Due to its superelevation, the proposed design slightly aids left turns and through maneuvers while hindering right turns. As the roundabout design speed is low, the minor 2% superelevation will not cause difficulty in navigating the intersection or increase the number of accidents.

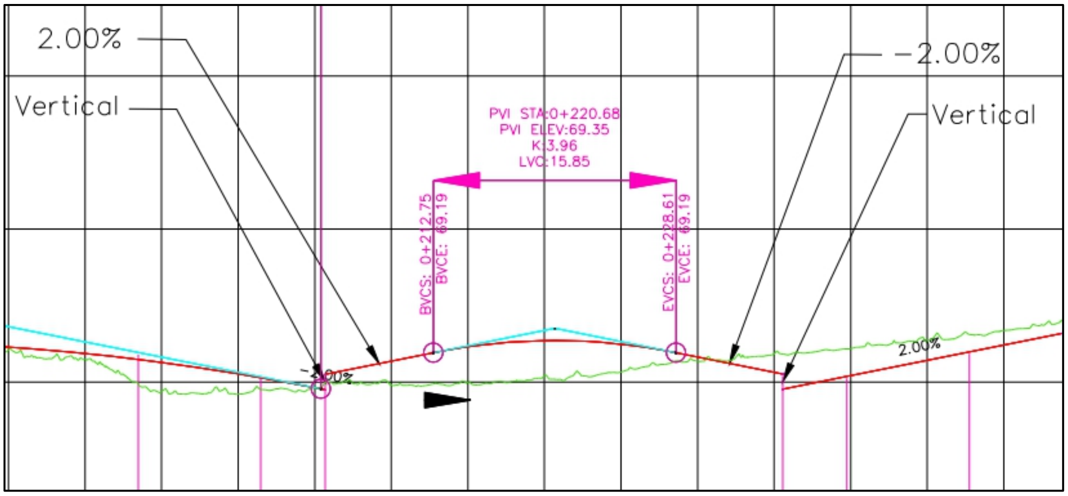


Figure 9. Roundabout Profile View

Figure 10 and Figure 11 show the finish grade profiles of 16th Avenue and SW Marine Drive, respectively, with the existing ground profiles. The existing ground profiles were taken from LIDAR data provided by the City of Vancouver (City of Vancouver, 2022). To minimize construction costs, proposed road profiles follow closely with the current road profiles. As shown in both figures, the roundabout is at-grade.

SW Marine Drive rises from the south to the north with the southern approach having a moderate maximum grade of 1.06%. The maximum grade of northern approach of SW Marine Drive is slightly higher at 2.21% but remains within recommended limits.

16th Avenue slopes downwards steeply towards the intersection with a grade of 4.56%. Although higher than the BC MoTI recommended grade maximum of 4%, due to the existing ground elevation, reducing the grade would require significant excavation, planning, and paving along a large portion of 16th Avenue (BC MoTI, 2019a). Furthermore, while high grades typically cause sight lines issues, the smaller footprint of the proposed design as compared to the existing intersection means that sight lines are clearer. The risk of load shifting within semi-trailers is slightly higher due to the 4.56% grade, however, the sag curve as the road nears the roundabout will reduce the dangers of cargo movement. Ultimately, although non-ideal, the 4.56% grade of 16th Ave will not cause major issues.

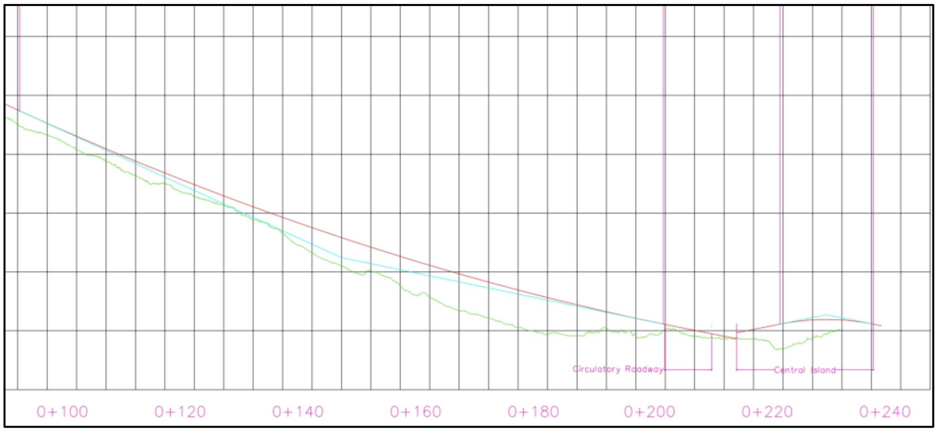


Figure 10. 16th Ave Profile View

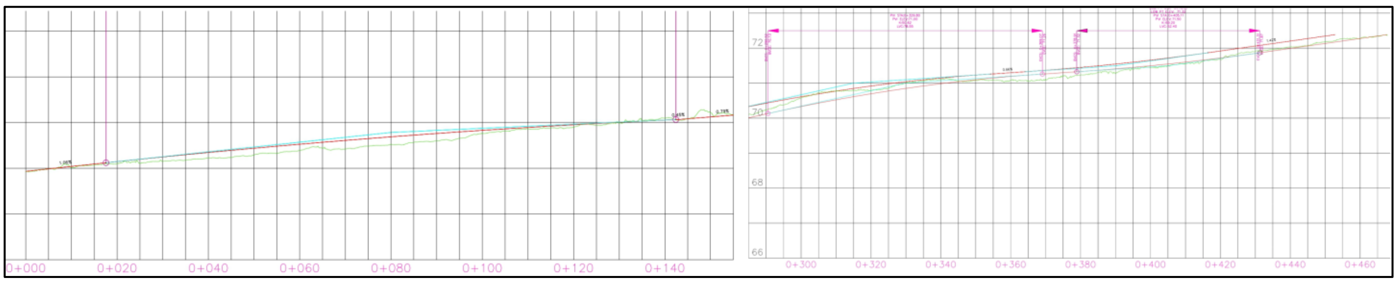


Figure 11. SW Marine Dr Profile Views

3.3.1.4. *Cross Sections*

Figure 12 and Figure 13 show a cross-section along both 16th Avenue and SW Marine Drive, respectively. Table 6 contains a summary of key cross-section dimensions. The proposed roads contain a 2% cross slope to allow rainfall to drain into slot drains placed alongside the roads. The roads will be constructed using practices and materials that follow the BC MoTI design manual (BC MoTI, 2019a). Further information on road construction can be found in the specification package of Appendix I.

Table 6. Intersection Road & Median Dimensions

	16th Avenue	**SW Marine Drive**
Width of Median	9m	15m
Height of Median	0.25m	0.25m
Width of Approaches	3.5m	4.25m (NB), 4.5m (SB)
Width of Exits	4m	4.25m (NB), 4.5m (SB)

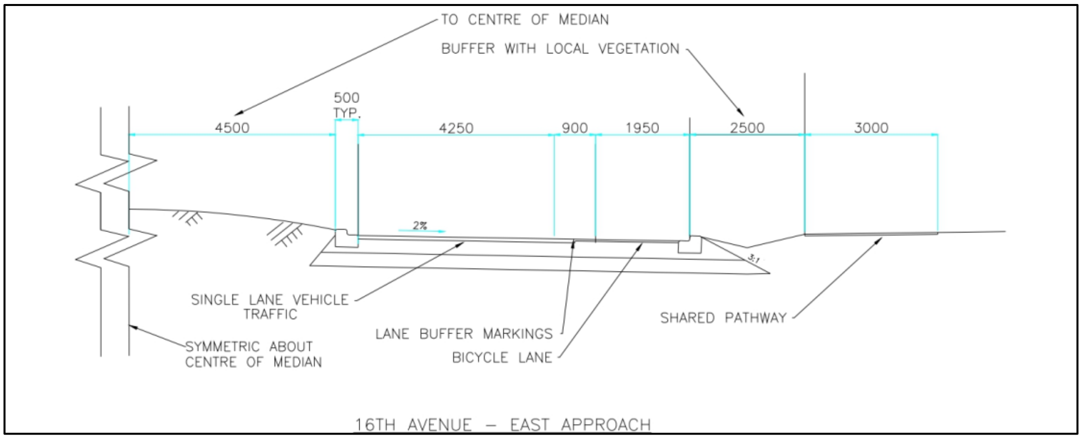


Figure 12. 16th Ave Cross-Section View

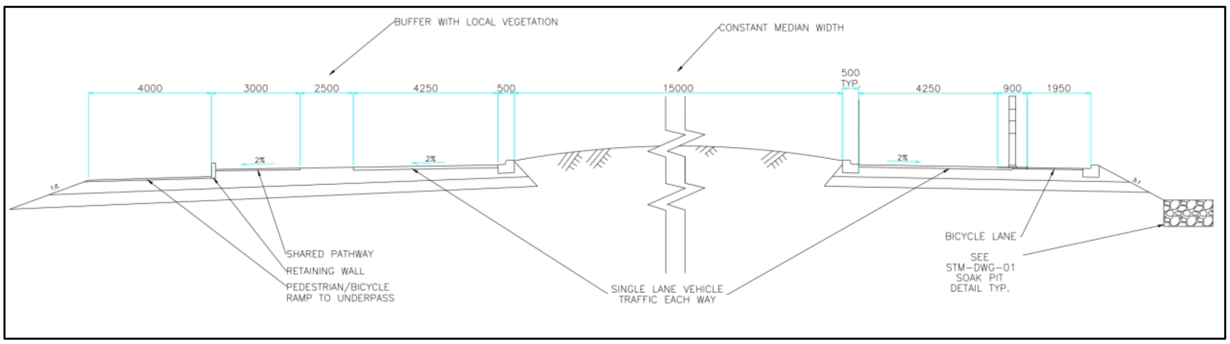


Figure 13. SW Marine Dr Cross-Section View

3.3.1.5. *Active Transportation Considerations*

To prioritize transit and active transport in the intersection, the design was developed to create a safe and accessible environment that encourages people to walk and cycle while limiting single occupant vehicle travel. Community engagement was conducted early in the planning process to ensure pedestrians and cyclist preferences were considered. Methods to achieve prioritization of these transportation modes include bike and pedestrian infrastructure, a pedestrian/cyclist crosswalk, traffic calming measures, and general intersection design.

As measured through morning traffic counts, cyclists are the greatest portion of active users in this intersection (Appendix C). With most of these cyclists travelling north through SW Marine Dr the main concern was the conflict of traffic posed by 16th Ave. For convenience and safety, an underpass was incorporated into the design which allows for unhindered cyclist travel in the north direction. Furthermore, cyclists avoid conflict with vehicles in every direction but one: the transition from 16th Avenue to SW Marine Dr (South). To address this, cyclists can travel around the roundabout in a buffered lane or use the signalized pedestrian crosswalk.

Another feature that prioritized active transport users were dedicated active transport lanes. To provide a greater sense of safety, lane widths with buffer zones were widened above minimum levels (see Table 7). Where not already available, trees and greenery were placed between the cyclists and pedestrians to provide a safety barrier and a natural esthetic. Where conflict with vehicles could not be avoided signage and pavement marking was used. For example, cyclists will have green coloured pavement markings to highlight conflict zones with vehicles and enhance rider visibility (16th Ave to SW Marine Dr transition) and directional arrows that are used to identify the safest route (BC MoTI, 2019b). Similarly, pedestrians will have white pavement markings in conflict zones.

Table 7. Minimum Lane Widths (BC Active Transportation Design Guide, BC MoTI, 2019b)

User	Lane Width (m)	Buffer Width (m)	Buffer Location
Cyclist	1.8	0.6	Motorist-Cyclist
Pedestrian	1.5	Variable	Cyclist-Pedestrian

The pedestrian (or cyclist) initiated crosswalk is another key feature for active user prioritization. Rectangular rapid flashing beacons are known to slow vehicle speeds and increase the likelihood that motorists will yield for those at a crosswalk (VanWagner et al., 2011). Furthermore, lighting enhances user visibility and the pedestrian initialized crossing will be phased to prioritize these users over motorists. Pedestrians will also have the safety and convenience of using the underpass in both directions when travelling through the intersection along SW Marine Dr.

3.3.1.6. *Signage and Road Markings*

All signage and pavement markings will be provided as per Section 740.06 of the BC TAC Geometry Design Guide, and sections G1, G2, and G3 of the BC Active Transportation Design Guide. Placement of signage and pavement markings can be found on pages 14-17 of the INT section in the attached drawings package.

3.3.1.7. *Speed Reduction Measures*

As a major issue of the current intersection is speeding vehicles, the following measures were taken to lower speeds:

1. **Minimization of roundabout size**

Research has shown that roundabouts can be used as effective speed controls with speed reduction closely correlated with size (Antov et al., 2009; Ritchie & Lenters, 2005). As larger roundabouts result in faster speeds, the roundabout at 16th and SW Marine was designed small as possible. A limiting factor in reducing the size of the roundabout was maintaining operational performance. Although high speeds are undesirable, low speeds result in lower capacities and can cause significant congestion. Additional consideration also had to be given to the current bus traffic as the roundabout had to be large enough to accommodate the turning radius of TransLink's articulated R4 buses.

Ultimately, the size of the roundabout was chosen to balance the aforementioned factors. The entry width, entry radius, and circulatory road widths were all carefully minimized to limit entry and circulatory speeds. The final design is one that is well tailored to the traffic needs of 2050, is large enough for buses and semi-trailers, and has a design speed of just 30 km/hr.

2. Reduction in number of lanes

To reduce entry speeds, the number of lanes on all approaches were reduced. Traffic simulations showed that even the peak hour traffic volumes of 2050 did not justify the number of lanes provided. As research has shown that the number and width of lanes is correlated with traffic speeds, lane reductions will lower speeds (Liu et al., 2016).

3. Increase in deflection on southern approach

As the speed limit along a large portion of SW Marine Dr is 80 km/hr, vehicles tend to enter the intersection from the south at high speeds. As a result, further treatment was added to reduce entry speeds and increase safety. Research has shown the use of curves with successively smaller radii to shift the road by 7m to be an effective measure in reducing speeds (Krammes et al, 1995). Drivers will slow as they must turn through the curves to reach the roundabout. The proposed design uses three curves to shift the centreline with special consideration given to bus and semi-trailer maneuverability.

3.3.1.8. *Design Manuals*

The primary design manual utilized in the design of the roundabout was the BC MoTI *Supplement to TAC Geometric Design Guide* (BC MoTI, 2019a). Dimensioning, signage, road markings, and sight distance requirements all follow BC MoTI standards. Per the recommendations of the *Supplement to the TAC,* illumination at the roundabout was designed following the design values outlined in IESNA RP-8 (Recommended Practice: Lighting Roadway and Parking Facilities, 2022*)*. For guidance and recommendations on fastest path analyses, capacity factors, road alignments, and general design principles, the US Department of Transportation's *Roundabouts: An Informational Guide* was referenced (US DoT, 2000). Bike lanes, active transportation pathways, and underpass considerations followed the *British Columbia Active Transportation Design Manual* (BC MoTI, 2019b).

3.3.1.9. *Design Life*

The design of the roundabout and all proposed roads were created for a design life of approximately 25 years. A typical roundabout has a design life lasts 20 years (US DoT, 2000); the life of the proposed design was extended by 5 years past the usual life to align with both the UBC Campus Vision 2050 (UBC Campus and Community Planning, 2023) and TransLink Transport 2050 (TransLink, 2022) strategic planning documents.

Although factors including site soil conditions, degradation of asphalt, freeze-thaw cycling, traffic loading, and weather all place limits on the lifespan of the roundabout and roads, the primary consideration in planning for the design life is traffic performance. In other words, the proposed intersection is only designed to adequately accommodate traffic volumes from the present to 2050. Beyond that point, as traffic volumes increase or decrease, the intersection will likely perform sub-optimally. Additionally, maintenance of the roundabout and roads and associated operating costs are only accounted for over the 25-year design life.

3.3.2. Analysis

3.3.2.1. *2050 Traffic Volumes*

Volume estimates were preformed to ensure that the intersection would be suitable for traffic demands into the year 2050. Estimates were based off historical vehicle trips to UBC and future transit advancements, not notably being Skytrain's arrival to campus.

Historic vehicle traffic volumes have been rising an average of around 1.0% per year and there has been a trend of fewer high occupancy vehicle trips to UBC (see Appendix E). Carrying this growth into the future, there will roughly be an increase of 27% in vehicle traffic by 2050. Other data from TransLink suggests that a UBC extension could carry 130,000 people per day

(TransLink, 2022). When applying this number of transit passengers to ridership by 2030, there will result in an 11%

decrease in vehicle traffic to campus. Translink's planned rapid transit system along the 41st/SW Marine corridor is expected to see an additional 10% reduction in trips by vehicle. Due to the uncertainty of the type of rapid transit and project completion dates, only an additional 7% reduction was used for vehicle traffic growth between 2030 and 2050. All data considered would see a final 9% increase in traffic volume by 2050. Detailed calculations can be found in Appendix E.

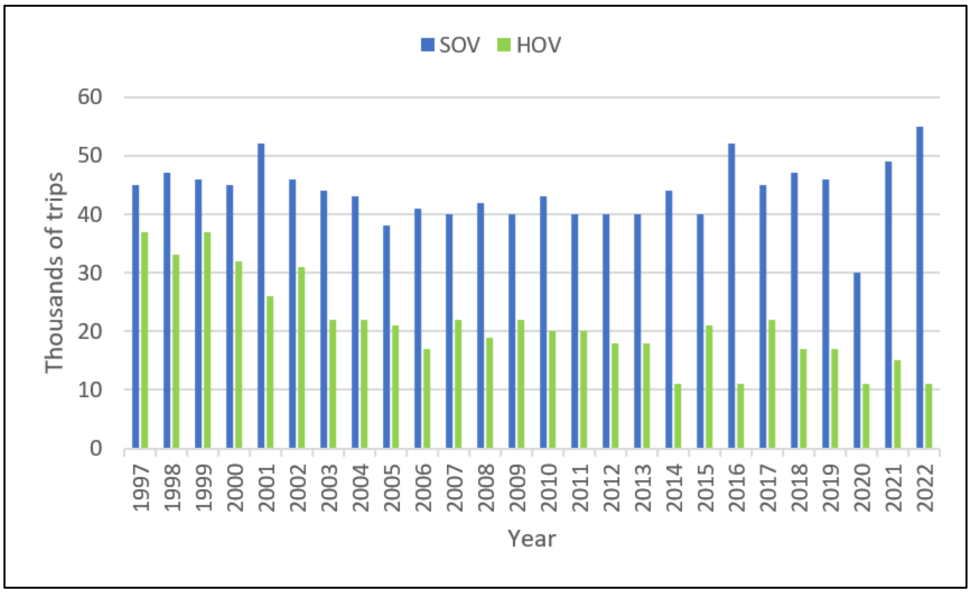


Figure 14. UBC SOV and HOV Trips 1997-2022 (UBC Transportation Status Report, 2022)

3.3.2.2. *Traffic Performance Analysis*

The ability of the roundabout to accommodate both present and future traffic volumes was an important design consideration. To ensure that the intersection met acceptable roundabout measures of effectiveness, traffic simulations of peak hour 2050 traffic volumes were run in the computer simulation programs SIDRA and Synchro. Although the intersection was simulated as accurately as possible, several assumptions had to be made regarding traffic volumes. The following assumptions were used to model the intersection in SIDRA and Synchro:

- Peak hour volumes occur during weekday AM rush from 8:00AM to 9:00AM
- Peak weekday AM volumes are averaged across all weekdays

- Percentages of future turning traffic will be the same as percentages of turning traffic observed during the AM traffic count (based on Appendix C)
- 2050 traffic volumes will increase by 9%, following the predictions of Section 3.3.2.1
- SIDRA settings were set per Chapter 740 Appendix B of the *Supplement to TAC* (BC MoTI, 2019a)

With 24-hour 2019 and 2021 autumnal traffic volume data, AM peak hour traffic counts, and a 9% increase in 2050 traffic volumes, the 2050 peak hour traffic volumes were estimated. Table 8 contains the estimated 2050 traffic volumes that were inputted into SIDRA and Synchro. Using the model, three measures of effectiveness were tested using the model: the level of service (LOS), average vehicle delay, and average queue length of each approach.

Table 8. Predicted Number of Vehicles Performing Each Maneuver in 2050 Peak Hour Conditions

		Entry Approach		
		North SW Marine Dr	South SW Marine Dr	16th Ave
Maneuver Performed	Right Turn	N/A	926	87
	Left Turn	74	N/A	318
	Through	453	617	N/A
Totals		**527**	**1,543**	**405**

The primary internal measure of effectiveness for the roundabout was the LOS. As 62% of total traffic entered through the southern approach in 2050 peak hour conditions, the LOS of the southern road was most critical. The objective in choosing a suitable LOS was to ensure that the roundabout did not have too high a LOS and sit near empty in peak hour conditions, promoting high speeds through the roundabout, nor have too low a LOS and fail in its purpose of conveying vehicles, causing congestion. Ultimately, we decided that a LOS C on the southern approach would be ideal, with LOS D considered acceptable.

As shown in Table 9, the LOS for the approaches varied from A to D. The high-volume southern approach had the lowest LOS, as expected. Although LOS C on the southern approach was considered optimal, consideration of the non-traffic related design elements such as road widths, required stopping sight distances, and active transportation pathways, among others, placed constraints on the design of the roundabout. As a result, the optimal LOS C could not be reached. Through successive design iterations, the proposed design was created to satisfy both the non-traffic related criteria and to maintain a LOS D on the southern approach. Overall, taking traffic volumes into account, the intersection has an average LOS C.

Table 9. SIDRA Lane Level of Service Results

Approach	Level of Service
North SW Marine Dr	A
South SW Marine Dr	D
16^{th} Ave	C

The second internal measure of effectiveness tested was average delay per vehicle. As shown in Table 10, as expected with its high volumes, the highest delays occur on the southern approach. Although the average delays of south SW Marine Drive are significant, they are not unreasonable for a roundabout in peak hour conditions. The long delay also serves to slow down the fast-approaching vehicles that arrive through Pacific Spirit Park.

Table 10. Average Intersection Delay per Vehicle of Each Approach and Maneuver

Approach	Right Turn Delay (s)	Left Turn Delay (s)	Through Delay (s)
North SW Marine Dr	N/A	11.4	4.8
South SW Marine Dr	45.2	N/A	44.7
16^{th} Ave	10.2	16.6	N/A

Average queue length, the third measure of effectiveness, was simulated to ensure that any congestion on the approaches would not back up and affect upstream intersections. Table 11 shows the average queue length during the peak hour as well as the average queue storage ratio, the ratio of the average queue length to the available queue storage length. Notably, although the queue length of the southern approach is significantly larger than the other approaches, there is sufficient storage to store all vehicles in the queue without affecting other intersections. As slowing vehicles is of primary importance, the long queue on the high-volume southern approach was considered acceptable.

Table 11. Average Queue Lengths and Queue Storage Ratios of Each Approach

Approach	Average Queue Length (m)	Average Queue Storage Ratio (%)
North SW Marine Dr	12	2
South SW Marine Dr	296	59
16^{th} Ave	20	4

3.3.2.3. *Sight Distances*

Sight distances were designed according to Section 9.9.2 of the TAC Geometric Design Guide for Canadian Roads (Transportation Association of Canada, 2017). The design stopping sight distance for cars approaching a crosswalk is 69 meters.

The design minimizes the presence of objects obstructing the line of sight of all road users. The line of sight of users in the roundabout is not obstructed by the earth mound in the roundabout or the entrance sign. Additionally, underpass allows for road users to traverse the intersection without forcing vehicles to stop or creating any above ground obstacles to impede the view of cars making an entrance into 16th Avenue. The retaining walls of the underpass' ramps also does not block the sight triangle of vehicles on the road, or pedestrians and cyclists entering or exiting the underpass. Finally, proper maintenance of vegetation as mentioned in this report.

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This design exceeds the design requirement for sight distances established by code also by drastically reducing speeds of vehicles entering the intersection. The multitude of measures taken to improve and extend the sight triangle of all road users in the intersection, exemplifies the commitment of the design towards safety and wellbeing.

3.3.2.4. *Fastest Path and Design Speed*

The design speed of the roundabout was determined by finding the fastest path allowed by the roundabout geometry. The fastest path is the most direct path traced by a vehicle as it moves through the roundabout as quickly as possible. Following roundabout vehicle path analysis procedures from the US Department of Transportation (US DoT, 2000), several possible fastest paths through the proposed roundabout were drawn by assuming the following:

- The vehicle will maintain a minimum distance of 1.5m from any concrete curbs or roadway centrelines and a minimum distance of 1.0m from any painted edge lines
- There are no vehicles in the intersection

Figure 15 shows the fastest paths and associated radii in dark red of the northbound through, southbound through, and northbound right turn maneuvers. The speed along the paths can be calculated using speed-curvature relationship. As vehicle speeds tend to increase with radii, the fastest path through a roundabout is the path with the largest radius on its sharpest turn.

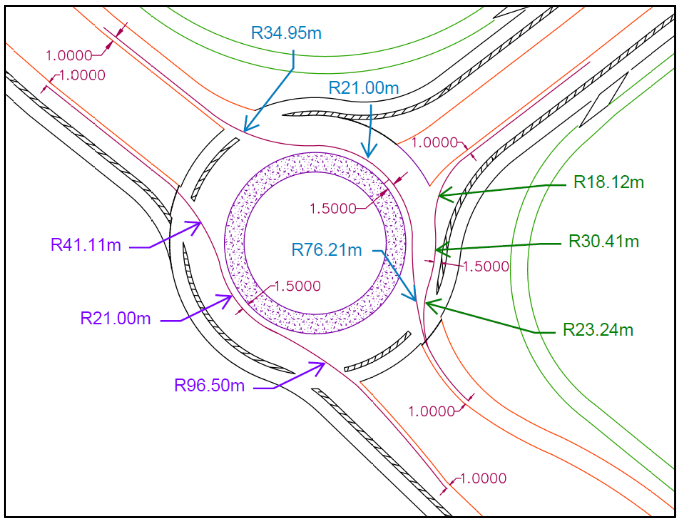

Figure 15 . Three Possible Fastest Paths and Radii

For the proposed design, the fastest path is both the northbound and southbound through maneuvers, as the radii of the sharpest turns on both paths are 21m, higher than the sharpest turn radius of 18.12m along the right turn maneuver. With the 21m radius, Figure 16 from the US DoT shows the corresponding speed, considering the atypical positive superelevation in the roundabout of the proposed design (US DoT, 2000). As shown, the 21m radius corresponds to a roundabout design speed of approximately 29 – 30 km/h.

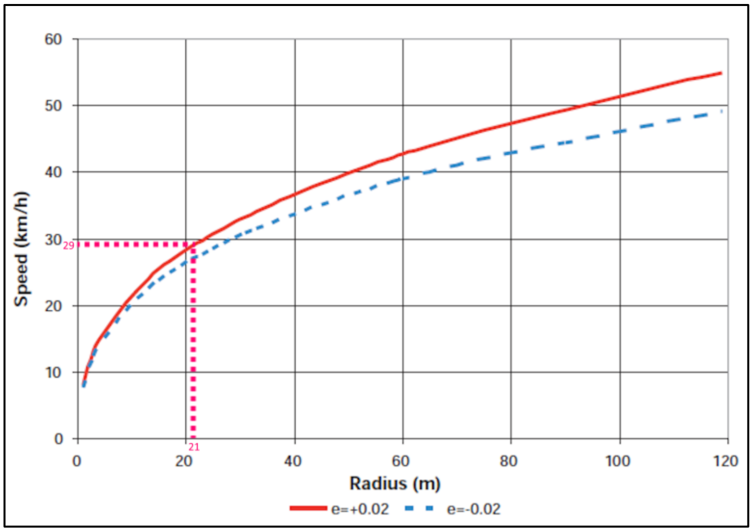

Figure 16. Controlling Radius and Roundabout Design Speed Relationship (US DoT, 2000)

As one of the primary design criteria for the intersection redesign was the reduction in vehicle speeds, a low design speed of ~30 km/h is desirable. Additionally, guidance on the geometric design of roundabouts has shown that a maximum design speed of 35 km/h is recommended to minimize vehicle collisions (US DoT, 2000). Overall, vehicle path analysis has shown that the roundabout will be effective in reducing speeds without causing an increase in accidents.

3.4. Underpass Design

3.4.1. Design

The underpass is positioned immediately north of the roundabout intersecting W 16th Avenue, as shown. It is designed as a two-lane structure with an interior width and height of 4 and 3 meters, respectively. The top of the underpass sits 0.5 meters below the highest point of W 16 Avenue and has a length of approximately 60 meters (excluding ramps). It is meant for both cyclists and pedestrians to use.

At both entrances, there is a ramp specifically designed for cyclists to enter and exit the underpass, as shown in Figure 17. Additionally, there are staircases and accessible ramps at both entrances to provide pedestrian access. Inside the underpass there are two lanes, abiding the right-hand traffic rule.

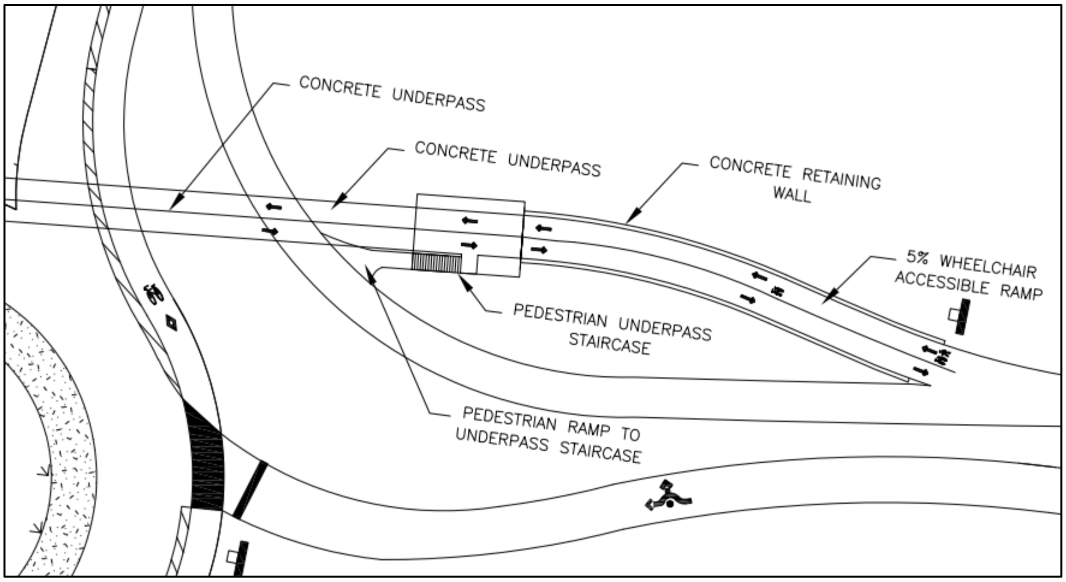

Figure 17. Underpass Site Plan

3.4.1.1. *Base*

The foundation of the underpass will consist of a cast-in-place concrete slab positioned atop compacted granular gravel. This concrete base, measuring 250 mm thick, will incorporate rebar closer to the bottom section. Each side of the concrete slab will include a chamfered notch, designed to aid in waterproofing by collaborating with the bentonite seal. The concrete foundation detail is shown in Appendix J – Drawing UND-DWG-03.

3.4.1.2. *C-Channel*

The underpass structure will utilize prefabricated C-channel concrete sections, each extending 10 meters in length. A total of 6 of these prefabricated concrete sections will be required for the underpass construction. Both the wall and roof components of the channel will measure 250 mm in thickness and will incorporate 10M rebars oriented in both directions, situated close to the interior of the underpass. For further detail, refer to the concrete C-channel detail outlined in Appendix J – Drawing UND-DWG-03.

3.4.1.3. *Drainage and Waterproofing*

To manage surface water, 100 mm wide metal griddled trench drains will be positioned on each side of the underpass, spanning the length of the underpass. These two trench drains will link the primary drainage system through six downspouts located at 10 meters, 30 meters, and 50 meters away from the south entrance. Also, because the water table is positioned 52 meters below ground level, uplift calculations were not needed for the underpass structure.

After the installation of the C-channel sections, the gaps between these sections will require grouting to eliminate any voids. The underpass exterior will be coated with a liquid waterproofing membrane designed for below-ground use. Subsequently, a dimple drainage board will be applied over this waterproofing layer to facilitate water drainage. At the base exterior of the underpass, drainage systems will be installed to collect surplus water and channel it towards a catchment tank for gradual dispersal.

3.4.1.4. *Ramp*

A 5% accessible ramp is built on both sides of the underpass entrance. The ramp is shouldered by 250 mm cast-in-place reinforced concrete retaining walls. Granular A material and drain tile is installed behind the retaining wall to facilitate water drainage and prevent water buildup behind the wall. The accessible ramp detail is shown in Appendix J – Drawing UND-DWG-02.

3.4.2. Design Analysis

Based on the findings from the morning peak hour traffic volume count on a typical weekday (refer to Appendix C), two significant conclusions emerged. Firstly, approximately 60% of the traffic originating from the south side of the intersection opts for a right turn onto W 16th Ave, this includes 100% of all R4 rapid transit bus traffic. Secondly, most cyclists approaching the intersection do not follow the same right turn pattern. These observations highlight evident conflicts between straight-moving cyclists and right-turning vehicles, depicted in Figure 18. Consequently, ensuring cyclist safety becomes imperative in the intersection's redesign. An underpass spanning W 16th Avenue is proposed to enhance safety for both cyclists and pedestrians crossing the intersection.

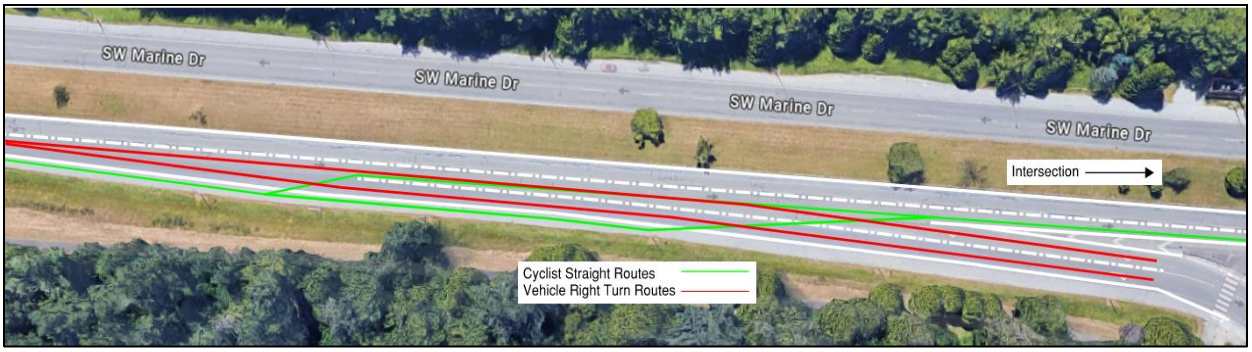

Figure 18. Points of Conflict between Cyclists and Vehicles at the Intersection

3.4.3. Underpass Analysis

The concrete component of the underpass design is based on CSA A23.3 and shall follow the Reinforced Cast-in-place Concrete specifications. The earthwork component of the underpass shall follow the Site Earthworks and Engineering Fill specifications. Both specifications are shown in Appendix I. Underpass design calculations are summarized in Appendix B.

3.5. Stormwater Management Design

3.5.1. Design

3.5.1.1. *Current Site Stormwater Information*

Currently, the site does not have any water management tools apart from the natural infiltration and evapotranspiration of the greenery in the surrounding area. 9.6% of this water experiences infiltration, 49% experiences evapotranspiration, leaving 39.4% of the rainfall to run over the edge of the cliff (Piteau Associates, 2002); the goal of the stormwater management design is to decrease this number to 0%. The site also has a pipe running underneath that serves as the stormwater drainage for the site of campus known as 16th Avenue Catchment. This catchment zone has an area of 32ha and drains to the southwest of the intersection beneath the botanical garden ("UBC", 2010). This catchment area could be of concern, as water flowing from it could potentially flow onto the site of the intersection of concern; however, it was determined that the existing stormwater management tools in the catchment area would be sufficient to deal with a storm. Because of this, the design of this intersection is only taking into consideration rain falling directly onto the intersection and the immediately adjacent area. The final concern is the site groundwater, which sits 6.5m below the ground level (Piteau Associates, 2002). The design drawings for all the below stormwater elements can be seen in Appendix J, and the relevant specifications regarding construction and maintenance can be found in appendix I.

3.5.1.2. *Grassed Swale Design*

The grassed swale is wrapped around the inside of the roundabout and is designed as both a storage option as well as a method of moving water from where it falls to the storage tank. The grassed swale was chosen to have a trapezoidal shape with a depth of 0.8715 m, side slopes of 2H:1V, a top width of 4.2 m and a bottom width of 0.714 m. These dimensions give a total volume of 315m^3. In case of overflow, a pipe of diameter 150 mm will be built in along the top of the grassed swale that takes stormwater from the swale into the underground tank described in Section 4.5.6. To meet the geometric design requirements for roundabouts (Government of British Columbia, 2019), the grass swale will be filled with a granular fill with a permeable pavement layer over the top. This will decrease the storage capacity by 70% but it is necessary to prevent vehicles from falling into the grassed swale. This 70% drop in storage capacity means that the true storage capacity used in the design is 94.5m^3

3.5.1.3. *Soak Pit Design*

The soak pit is placed along the western edge of the intersection as a last resort preventing stormwater from flowing over the cliff face. It is to have a depth of 1 m, a width of 1 m, and a length of 90 m, with highly permeable gravel acting as a fill. A 150mm diameter pipe running through it will act as an overflow prevention method, and as a method of moving excess water to the soak pit after a rainfall event has finished and the soak pit has capacity for water to continue infiltration. At the top of the soak pit is to be thin filter layer to prevent excess sediment from flowing into the stormwater management system.

3.5.1.4. *Slot Drains Design*

Slot drains will be included in the design of the road and can be seen in the road design drawings. They will be 1.25 cm wide and will be used to collect the water that runs off the road. This sizing was chosen based on a rainfall rate of 127 mm/hr, to prevent back-ups from happening because of the one-hundred-year rainfall event.

3.5.1.5. *Underground Tank Design*

The underground tank is to be constructed beneath the location of the entrance sign in the middle of the intersection. The top of the tank will be at a depth of 3 m below ground level, has a length of 10 m, and a radius of 1.4 m for a total storage volume of 61.5 m^3. The tank has pipes feeding into it from the grassed swale, soak pit and the drainage system from the underpass in case any of them overflow and will have a pipe going from the tank to the existing pipe network in case the capacity of the tank is met.

3.5.1.6. *Piping Design*

The pipes used to move water around were designed so that they could hit the upper limit of desired flow velocity in the case of the 15-minute 100-year peak flow conditions. The peak volumetric flow was calculated by finding all the rain falling over the catchment area and putting it through the pipe all at once. By combining this data with the desired flow velocity of 1-3 m/s, the pipe diameter to deal with a 100-year rainfall event was determined to be 150 mm in diameter. The material for the pipes was chosen to be PVC because it had the best cost analysis for our system when comparing construction costs and long-term maintenance.

3.5.1.7. *Pump Design*

A pump is to be placed at the bottom of the storage tank and will be used to pump water from the storage tank to the soak pit during times when the tank has water in it, but the soak pit is not at capacity. This is a way to empty out the storage tanks without relying on the existing pipe network and without worrying about over saturation of the soil. Additionally, a pump will be connected to the pipe that connects the storage tank to the existing pipe network to ensure the stormwater has enough head to prevent back flow into the storage tank from other catchment zones on campus. The pump is to be a 4.5-inch diameter variable speed pump, with rotation speeds from 2900 RPM to 3450 RPM. This pump rotation speed was chosen based off the head needed to move the water.

3.5.2. Design Criteria

The stormwater management system is designed to withstand a one-hundred-year storm, per the City of Vancouver design criteria (City of Vancouver, 2018). From rainfall data (Government of Canada, 2017), a logarithmic model was used to determine that the 15-minute rainfall intensity for a 100-year rainfall event would come out to 127.35 mm/hr; this rainfall event was used to determine the drainage capabilities needed for the intersection, as well as flow rates out of storage facilities. Additionally, any of the system components that are calculated for their storage capacity were calculated using the 24-hour 100-year storm rainfall amounts, which came out to

4.7mm/hr (112.8mm/day). From this, calculations were completed for the storage capacity of grassed swales, soak pits and storage tank, and the flow rated needed in the slot drains of the road, and the required diameters for all pipes.

3.5.3. Analysis

All designs made regarding the stormwater management system were done in accordance with the BC stormwater Planning Guidebook. Detailed calculations for capacities are shown in Appendix B.

3.6. Entrance Design

3.6.1. Aesthetic Considerations

Local First Nations artists will be hired to create a detailed design for the entrance. The current proposal consists of a large concrete sign flanked by two wooden totems themed around the connection between UBC and First Nations groups. The chosen artist will have primary control over the entrance including sizes and types of elements. A rendering of the design is provided below. The totem designs were not modelled for this project, but sample designs are provided. Completely changing the entrance according to the artist's wishes will be accommodated with the agreement of UBC Campus and Community Planning.

Figure 19. 3D Rendering of Entrance Design and Sample Totem Designs

3.6.2. Geotechnical Considerations

General geotechnical calculations were done to assess the soil's reaction to the gateway. The landscaped roundabout mound will be constructed using engineered fill with a specified unit weight and soil properties. The fill will be selected and compacted in agreement with ASTM D 698 to account for the loads of the entrance structure. An allowable bearing pressure was calculated to size the concrete footings. Settlement, sliding, and overturning were not considered due to the lack of consequence if failure were to occur. These calculations are not likely to govern the design of small structures. All calculations are contained in Appendix B.

3.6.3. Structural Considerations

Calculations on the footings for the proposed entrance dimensions were conducted to support the Class A cost estimate. The footings were sized to reach the required bearing, moment, and shear strengths according to CSA A3.3 - 2014. The materials were assumed to be wood for the totems and concrete for the primary sign to estimate the weights of the structures. Concrete foundation calculations and drawings are contained in Appendix B and J, respectively.

3.7. Design Maintenance Plan

To ensure the continued use of the design, the following design maintenance plan was decided upon. Table 12 below gives a summary of the different aspects of the maintenance plan.

Table 12. Maintenance Plan Summary

Design Component	**Reference**	**Custom Specification in Appendix I**
Pavement (General)	4th Edition: Asphalt Pavement Maintenance Guide (MOTI, 2016)	Section 2.2 Intersection Maintenance
Pavement (Winter Weather)	BC Winter Highway Safety and Maintenance (BC Government, 2022)	Section 2.2.3 Winter Pavement Maintenance
Vegetation Control	BC Winter Highway Safety and Maintenance Roadside Vegetation Control Maintenance Specifications (MOTI, 2003)	Section 7 Vegetation Control
Underpass	Highway Maintenance Specifications for Highway Concessions (Infrastructure BC, 2004)	Section 6 Underpass Maintenance
Stormwater	Guidebook for British Columbia Stormwater Planning (BC Ministry of Environment, 2002) and Inspection and Maintenance of Stormwater Best Management Practices (Sustainable Technologies, 2018)	Section 4.1.2 Waterworks Maintenance

3.8. SEEDS Sustainability

Environmental stewardship was an essential pillar of the design process, and as such the intersection features several design aspects in line with several sustainability goals which are of great importance to several stakeholders.

SEEDS' Big 5 Research Priorities, namely the "Maintain & Enhance Urban Biodiversity" goal, as well as goals 3, 9, 11, 13, and 17 of the United Nations Sustainable Development Goals (United Nations, n.d.) played a big role in determining the tools with which our design would address the design criteria and objectives.

The selection of a roundabout design not only served the purpose of lowering speeds without the need for traffic signals, but it also minimized the impermeable surface area and provided space for a green garden in the center of the intersection.

Implementing grass swales, permeable pavement, and slot drains provide not only a resilient method of dealing with surface runoff, but also maximized the green area as well as natural methods of dealing with the runoff that do not strain the stormwater system, and blends in seamlessly with the surrounding environment.

Routing cyclist and pedestrian crossings of 16th Avenue underground instead of above ground by the means of an overpass also had significant influence from the environmental perspective. By shifting the crossing underground, the impact on visibility and the natural feel of the intersection's environment is preserved, while also maximizing the green area and minimizing the environmental impact as well as maintenance costs.

4. Schedule & Key Milestones

This section of the report focuses on the final project schedule and key milestones for the detailed design outlined in Section 4.5. The three main objectives of this section are identifying the optimal construction path through a work breakdown sequence, outlining the anticipated timeline for the development and implementation of the project, and identifying the key milestones for the project's success. Please refer to Appendix H for a full overview of the project schedule and Table 13 for the key milestones.

4.1. Work Breakdown Sequence

Before developing a final schedule, it is important to create a work breakdown sequence that accomplishes all the project's deliverables, minimizes waste of resources, takes into consideration the site context, adheres to UBC's Campus and Community Planning project criteria, and follows British Columbia's Transportation and Infrastructure requirements for provincial roads. By developing a work breakdown sequence, our team will ensure that the construction of the intersection will maximize efforts, minimizes losses, and stays within the regulatory requirements.

As mentioned in Section 3.2, the final design has five main deliverables. Although the project's schedule is not based entirely upon these deliverables, they play a pivotal role as they represent the tangible milestones that need to be achieved for a successful project handover. Some of the impacts that the main deliverables have over the project are task dependencies, resource allocation, critical path identification, client and stakeholder expectations, and risk management. Please refer to Figure 3 for a review of the detailed design deliverables.

Considering site context is crucial when developing a construction schedule because it directly impacts the feasibility, efficiency, and success of the project. The unique characteristics of a site can significantly influence construction methodologies, material availability, and the overall construction timeline. Ignoring site context may lead to unforeseen challenges, delays, and increased costs during the construction process. For the detailed site context analysis relevant to this project, please reference Section 1.4.

In terms of the project criteria relevant to the schedule, outlined by UBC Campus and Community Planning request for proposal, the project must be completed during summer when traffic decreases. Therefore, construction must start on May 01, 2024, and must be completed before September 01, 2024. Additionally, a continuous traffic flow must be maintained during the construction of the intersection as Marine Drive is a disaster route. Finally, it has been mentioned that no changes to existing underground utilities must be made during this intersection redevelopment.

BC Transportation & Infrastructure "2020 Traffic Manual for Work on Roadways" delineates hard constraints that must be always followed during the construction of the intersection and thus affect construction sequencing. Therefore, a series of traffic management plans (TMPs) that stipulate code adherence have been developed through the different construction phases to check feasibility. The TMPs outline the location of traffic control persons (TCPs), channelizing devices, traffic buffer distances, screening, signaling, and more. Refer to Section 5 for further information on the TMPs.

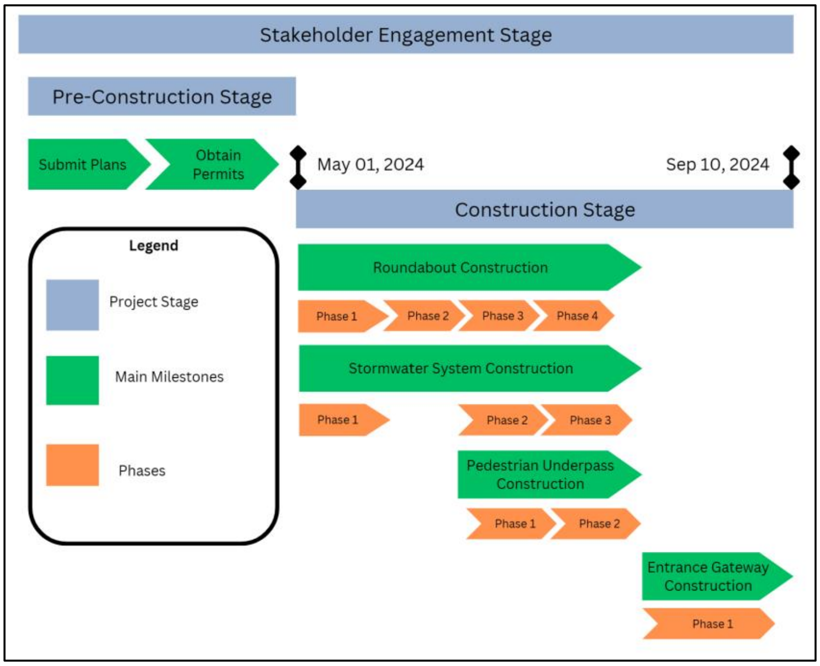

Figure 20. Work Breakdown Sequence

By taking all the aforementioned factors into account, our team has developed a comprehensive work breakdown sequence as seen above in Figure 2020. This sequence categorizes the project into stages; each having their respective milestones and phases. Our team understands the importance of having continuous stakeholder engagement and will therefore have periodic meetings with relevant parties throughout the entire project. The pre-construction stage focuses on submitting the project plans and securing the required permits. On the other hand, the construction stage coordinates the construction of the main project deliverables while minimizing waste and adhering to all design requirements and local regulations.

4.2. Stakeholder Engagement Schedule

The stakeholder engagement schedule is a vital element within the broader framework of project management for any civil project. Although previous stakeholder engagement plans have already been developed and undertaken, it is indispensable to keep stakeholders engaged in a timely manner to address concerns, incorporate valuable feedback, and maintain alignment between project goals and expectations. This schedule aims to provide a structured approach to involving stakeholders at key junctures and ensuring meaningful participation in decision-making process and serves as a tool to enhance transparency and foster collaboration.

The overall stakeholder engagement schedule is composed of nine monthly recurring meetings, starting on January 1, 2024 (currently ongoing). This schedule allows for a timely collection of feedback before and during the construction phase. Refer to Figure 22 in Appendix H for the stakeholder engagement schedule.

4.3. Pre-Construction Schedule

The pre-construction schedule focuses on getting all the requirements ready before construction starts. This includes meeting with UBC Utilities Staff and UBC Campus and Community Planning, preparing all drawings for construction, developing TMPs, submitting all required plans, obtaining permits, capping off or disconnecting existing utilities, and establishing and storage and working area for construction. As seen in Figure 22 of appendix H, the pre-construction stage will start January 8, 2024, and allocates plenty of time for permit review and approval. An important note to make is that the pre-construction stage is a predecessor to the construction stage, therefore it is vital to achieve all the requirements in this stage before May 01, 2024, as seen in Figure 22 in Appendix H.

4.4. Construction Schedule

The construction schedule focuses on coordinating the construction of the main project deliverables while minimizing waste and adhering to all design requirements and local regulations. To achieve this, the work breakdown sequence outlined above has been used to create a digestible schedule for the construction of each deliverable. Please refer to Figure 23 in Appendix H for a general overview of the construction schedule and a full overview of the project's schedule. In summary, construction has been divided into four main components: roundabout, stormwater retention system, pedestrian underpass, and entrance gateway. Each component of the intersection construction was then sub-divided into stages which will be used in Section 5 for construction and traffic management planning. Construction will start May 01, 2024, and the project turnover is scheduled for September 10, 2024.

4.5. Key Milestones Completion Dates

Construction Stage	Milestone	Completion Date
Stage 1	Complete Stormwater Rentention System Construction Phase 1	22-May-24
	Complete Roundabout Construction Phase 1	23-May-24
Stage 2	Complete Roundabout Construction Phase 2	13-Jun-24
Stage 3	Complete Pedestrian Underpass Phase 1	05-Jul-24
	Complete Roundabout Construction Phase 3	22-Jul-24
	Complete Stormwater Rentention System Construction Phase 2	22-Jul-24
Stage 4	Complete Pedestrian Underpass Phase 2	14-Aug-24
	Complete Stormwater Rentention System Construction Phase 3	27-Aug-24
	Complete Roundabout Construction Phase 4	30-Aug-24
	Complete Gateway Constsuction Phase 1	10-Sep-24

Table 13. Key Milestones

As a summary of the previous sections, the key milestones alongside their completion date have been highlighted in Table 13 above. Please visit Appendix G for the full project charter. Note that the construction stage for each milestone has been included as a segway for the following section, which will cover in detail the construction sequence, traffic management plants, and activities to be undertaken for each construction phase.

5. Construction and Traffic Management Plans

This section of the report outlines the construction requirements, plans, and traffic management plans drafted for the project delivery. Additionally, anticipated construction issues related to site context have been identified to address them promptly. For a more detailed description of the tasks and dates involved in each construction phase please visit Appendix H.

5.1. Construction Requirements

To adhere to the Traffic Management Manual for Work on Roads (TMM) stipulated by the BC MoTI, our team has included a series of construction requirements that will improve safety during the project delivery. Whenever advance warning areas (construction and traffic change signals) are required, the criteria outline in Section 6.2.2 of the TMM must be followed. This involves proper color, placement, and visibility of signage. Additionally, protective barricade systems should allow for a buffer distance and follow the requirements highlighted in Section 6.2.4 and 4.5.8 of the TMM respectively. Finally, whenever traffic control persons (TCP) are utilized, Section 5 of the TMM must be followed. This involves TCP apparel, equipment, communication, positioning, and signaling requirements. However, an important note to make is that in the case of our project, TCPs will only be required during peak hours.

5.2. Construction Stages

The following sections will outline the general workflow for construction through the different stages. Note that for each construction stage drawing, an overlay has been provided for visual context. Additionally, hatched sections and lines indicate the proposed new curb geometry and work areas respectively.

5.2.1. Construction Stage 1

The first construction stage will have two main objectives. The first objective is completing the roundabout construction phase 1, which involves two tasks. The first task involves setting up three temporary roads that will facilitate traffic flow in later construction stages. The second task is replacing the southbound NW Marine Drive right traffic curb with a cyclist lane and upgrading the southwest corner of the intersection. The second objective is completing the stormwater retention system construction phase 1. For this, the southwest corner of the intersection will be excavated, and the soak pit will be installed. As a part of the TMPs, construction and traffic flow changes signals will be placed alongside protective barricade systems. It is important to note that during this stage, only the southbound Marine Drive traffic will be affected as the two lanes merge into one and thus no traffic control persons will be required. Please refer to Figure 18 below for the Construction Stage 1 Drawing.

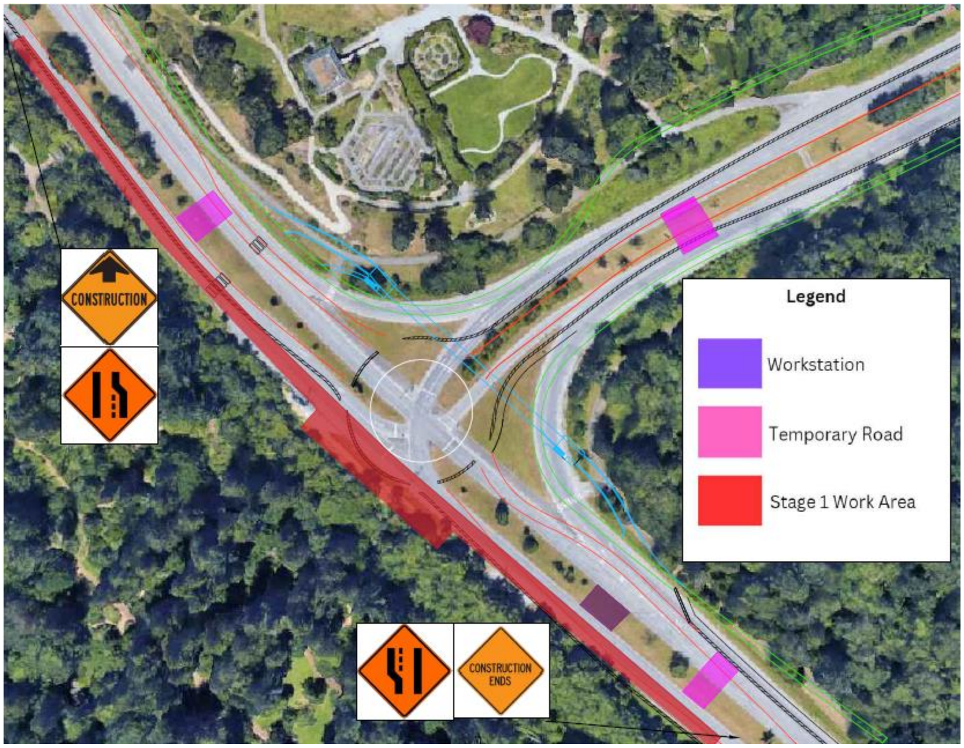

Figure 18. Construction Stage 1 Drawing

5.2.2. Construction Stage 2

The second construction stage has one main objective, completing the roundabout construction phase 2. This objective mainly involves upgrading the northbound NW Marine Drive left curb and the central section of the intersection. As a part of the TMPs, construction and traffic flow changes signals will be placed alongside protective barricade systems. Given that the traffic on NW Marine Drive turning left into W16th Avenue and vice versa will be interrupted during this stage, a traffic control person will be placed at each temporary road alongside NW Marine Drive. This will improve safety and traffic flow during peak hours for pedestrians, cyclists, and drivers. Please refer to Figure 19 below for the Construction Stage 2 Drawing.

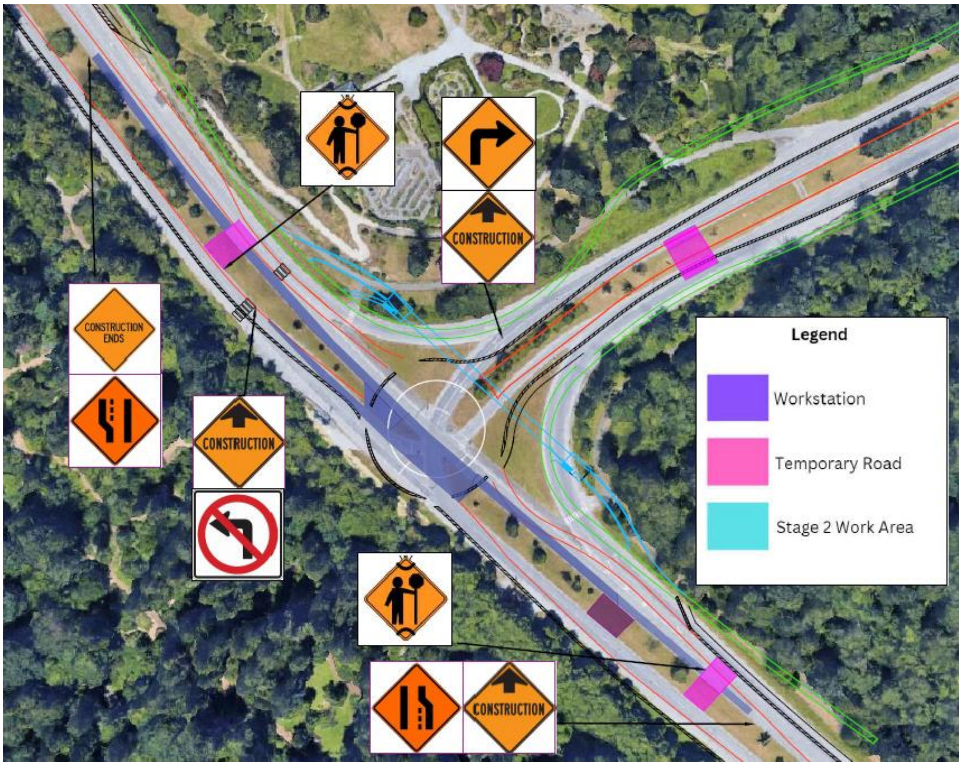

Figure 19. Construction Stage 2 Drawing

5.2.3. Construction Stage 3

The third construction stage has three main objectives. The first objective is completing the pedestrian underpass construction phase 1. This task involves excavating the middle section of the underpass, casting concrete slab, and placing the precast "C" covers over the slab. The second objective is completing the roundabout construction phase 3, which involves upgrading the northbound SW Marine Drive right lane and northeast section of the intersection. Additionally, the two lanes adjacent to the median along W16th Avenue will be removed. The third objective is completing the stormwater retention system construction phase 3, which involves excavating the inner section of the roundabout and installing the grass swale. As a part of the TMPs, construction and traffic flow changes signals will be placed alongside protective barricade systems. An additional traffic control person will be placed on the temporary road alongside W16th Avenue given that the northbound NW Marine Drive traffic will be interrupted. Please refer to below for the Construction Stage 3 Drawing.

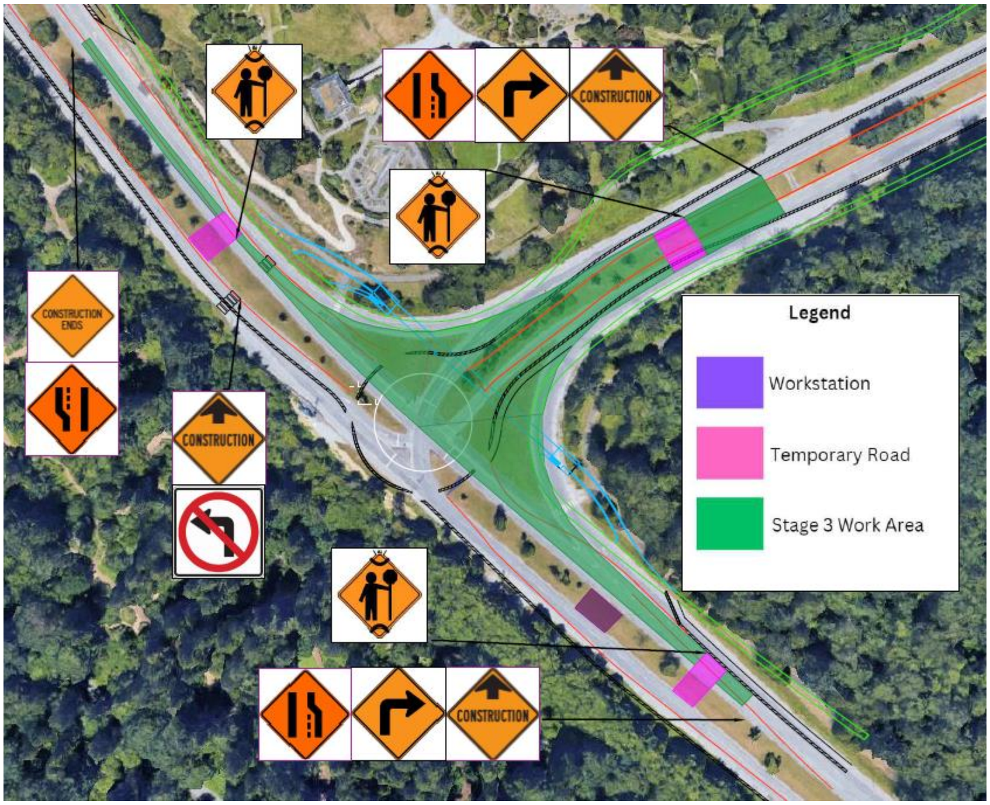

Figure 20. Construction Stage 3 Drawing

5.2.4. Construction Stage 4

The fourth and final construction stage has four objectives. The first objective is completing the pedestrian underpass construction phase 2 by following the same steps as in phase 1 but for the lateral sides. Additionally, pedestrian staircases and lighting will be installed in the underpass during this stage. The second objective is completing the stormwater retention system construction phase 3. This involves excavating the inner section of the roundabout, installing the septic tank, and placing service connections to the previously mentioned stormwater systems. The third objective of this stage is completing the roundabout construction phase 4. For this, the right curb along northbound NW Marine Drive will be replaced with a cyclist lane and the remaining curb of W16th Avenue will be removed. Additionally, the existing pedestrian walkways will be upgraded to meet with the new ones. The fourth objective of this stage is completing the gateway construction phase 1. As a part of the TMPs, construction and traffic flow changes signals will be placed alongside protective barricade systems. However, no traffic control persons will be required as traffic will not be interrupted in any direction. Please refer to Figure 21 below for the Construction Stage 4 Drawing.

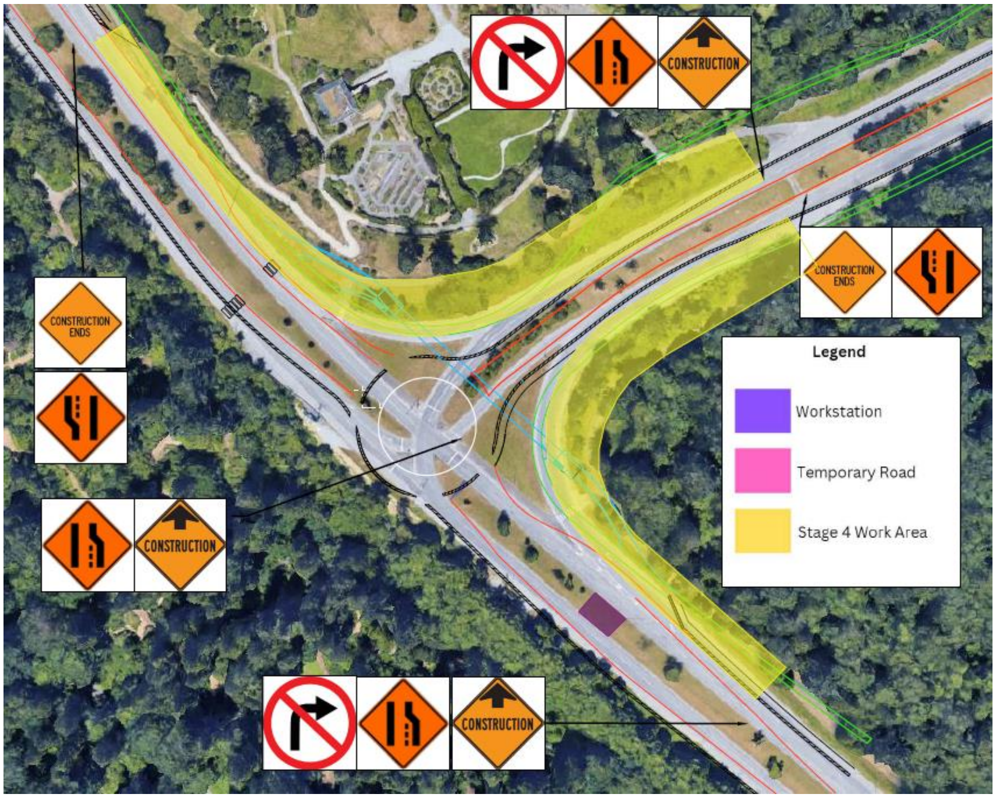

Figure 21. Construction Stage 4 Drawing

5.3. Anticipated Construction Issues

An anticipated issue during construction activities is the impact on pedestrian and cyclist safety. Construction sites often occupy sidewalks and bike lanes, forcing pedestrians and cyclists to navigate around obstacles or share road space with vehicles, increasing the risk of accidents. Temporary closures or diversions can create confusion for pedestrians and cyclists, leading to potential conflicts with vehicular traffic. Additionally, construction vehicles entering and exiting work zones can impede the flow of traffic, causing congestion and delays. Proper signage, designated alternate routes, and clear communication are essential to mitigate these risks and ensure the safety of all road users during construction projects. Therefore, our team has focused on adequately placing protective systems and traffic control persons that will serve in their purpose.

6. Class A Cost Estimate

A Class A cost estimate was prepared for the detailed design proposed in this project. Being Class A, this cost estimate is expected to be taken with a margin of error of ±5-10% of the total value proposed and was calculated by considering all potential costs the project could accumulate. The cost estimate was broken down into subsections, which can be seen in Table 14.

Table 14. Class A Cost Estimate Values

MATERIAL COSTS	$657,637
LABOUR / EQUIPMENT COSTS	$406,058
ENGINEERING / PERMITTING COSTS	$750,000
TRAFFIC MANAGEMENT	$75,000
MOBILIZATION (5%)	$63,821
MAINTENANCE	$334,487
CONTRACTOR	$159,443
CONTINGENCIES (20%)	$377,739
TOTAL ESTIMATE:	$2,824,297

Complete material quantity takeoff and labour / construction cost estimate sheets are provided in Appendix D.

6.1. Material Costs

The material costs were taken from analyzing the detailed design drawings and determining the quantities of each material or object used in construction. These were then multiplied by the unit price for each object to determine the total cost of $657,637. This price, in addition to labour and construction costs, were adjusted for their time value and the material costs were adjusted by a tax rate of 13%. The material cost quantity takeoff can be found in Appendix D.1.

6.2. Labour and Construction Costs

Labour costs reference the amount of work hours needed for the project to be completed during construction; the total labour cost was found by multiplying the hours worked (R.S. Mean Company Inc, 2009) by each job on the project by the pay rate of said job. This was then combined with the construction costs, as the two are heavily connected; the construction costs are the costs of renting and using and equipment needed in the project. These sections combined for a total cost of $406,057.

6.3. Engineering and Permitting Costs

Engineering and permitting costs incorporate the work hours committed by the engineering teams behind the project; this work includes geotechnical analysis of the site, transportation analysis of the intersection and traffic demands, structural analysis of the proposed solutions, and all other aspects relating to the project. In addition to these engineering fees, this also incorporates the fees needed for gathering the required permits, such as construction permits, tree removal permit, or traffic management permits. These costs were determined to be $750,000.

6.4. Traffic Management

The cost of the traffic management plan, as described in Section 5, has been assigned a cost of $75 000; this is based off standard pricing practices, and covers the pricing of asphalt for temporary roads, temporary signage, traffic flaggers, and other aspects of the plan.

6.5. Mobilization

The mobilisation free, taken as 6 percent of the material, labour, and equipment costs, is a fee applied to the site setup ahead of any construction. This includes the setup of a working office, on site material storage, and measures to ensure the public's safety such as temporary environmental or pedestrian protection walls, for a total cost of $63,821.

6.6. Maintenance

Based off the maintenance plan shown in Section 3.7, this fee was applied. The amount of $13,000 per year was determined; from this, the present value of $334,469 for maintenance was determined using an estimated interest rate of 3% and a design lifetime of 50 years.

Appendix A – References

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Appendix B – Calculations

Appendix B.1. Underpass Reinforced Concrete Strength Calculations

Steel Yield Strength	400	Mpa
Concrete Compresive Strength	35	Mpa
Assuming 1m long section	1000	mm
Inisde Height	2500	mm
Inside Width	3000	mm
Slab Depth	250	mm
Wall Width	250	mm
Soil Depth Above Top of Slab	300	mm
Concrete Density	23500	N/m^3
Soil Density	19130	N/m^3
Live Load	25000	N/m^2
Distributed Dead Load	11614	N/m
Distributed Live Load	25000	N/m
Load Combination	52017	N/m
Mf+	34350	Nm
Mf-	36300	Nm
Vf	94170	N
Load per wall, Pf	91	kN
Horizontal Stress at top of slab	3197.2125	N/m
Horizontal Stress at bottom of wall	32504.9938	N/m

TUL Check		
Steel %	0.003	
Min Steel Area	750.0	mm^2
Rebar Size	15.0	mm
Steel Area Chosen	800.0	mm^2
Depth	202.5	mm
a1	0.8	
b1c	14.1	mm
Mr-	50039.6	Nm
Is Mr->Mf-?	Yes	

BLL Check		
Steel %	0.002	
Min Steel Area	500.0	mm^2
Rebar Size	15.0	mm
Steel Area Chosen	600.0	mm^2
Depth	202.5	mm
a1	0.8	
b1c	10.5	mm
Mr+	37867.3	Nm
Is Mr+ > Mf+?	Yes	
Dv	182.3	mm
beta	0.2	
Vr	136343.2	N
is Vr>Vf?	Yes	

Wall Compression Check		
Steel %	0.02	
Ag	250000	mm^2
As	5000	mm^2
Ac	245000	mm^2
a1	0.7975	
Pro	4916.0525	KN
Is Pro>Pf?	Yes	

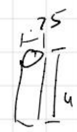
Appendix B.2. Entrance Foundation Design Calculations

Gateway Design

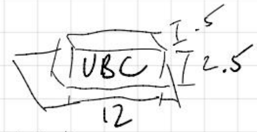
Assumptions: fill (for central mound) – $\gamma = 18\ kN/m^3$
↳ above WT
↳ $\phi = 30°$
↳ sand, $c = 0$

Wood "totem" dimensions – circular
– 4m × .5m diam
– 10 kN/m³ (conservative

totems (wood)



Stone sign dimensions – 2m × .5m × 2.5m
– 22 kN/m³



Concrete foundations – 25MPa, 23.5 kN/m³

Bearing Capacity – Hansen's BC formula

For totem: assume square 1.5×1.5m @ 0.75m depth
↳ for env. prot.

$\sigma'_p = \gamma D = 18(0.75) = 13.5$

$N_q = 18.4$

$s_q = 1 + \frac{B}{L}\tan\phi = 1 + \tan(30) = 1.58$

$d_q = 1 + 2\tan\phi(1-\sin\phi)^2 \frac{D}{B} \Rightarrow$ for $D \le B$
$= 1 + 2\tan(30)(1-\sin 30)^2(\frac{.75}{.8})$

$d_q = 1.27$

$\gamma = 18\ kN/m^3$

$B = 0.8m$

$N_\gamma = 15.1$

$s_\gamma = 1 - .4\frac{B}{L} = 1 - .4(\frac{.8}{.8}) = .6$

For square footings:

$q_{ult} = \sigma_p N_q s_q d_q + .4\gamma B N_\gamma s_\gamma = 13.5(18.4)(1.58)(1.27) + .4(18)(.8)(15.1)(.6)$

$q_{ult} = 550.6\ kPa$

using a bearing resistance factor of $0.5 \Rightarrow$ CFEM

$q_{allow} = 275.3\ kPa \Rightarrow$ for preliminary design, use 300kPa for sign as well

Totem

$DL = 10\,kN/m^3 \left(4 \times \frac{\pi(.75)^2}{4}\right)$
$DL = 17.7\ kN$

$P_f = 1.4DL = 24.7kN$

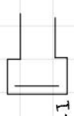
For $1500_{mm} \times 1500_{mm} \times 200_{mm}$

Check allowable bering

$B = \frac{17.7}{1.5^2} + 23.5(.2)$

$B = 12.6 < B_r = 300kPa$ ✓

Check shear for 10M



$d = 200 - 75 - \frac{10}{2} = 120_{mm}$
$d_v = .9d = 108$
$0.05 < d_v$, so no critical plane of shear

Check moment

$M_f = \frac{P_f}{A_{ftg}}\left(c_1 - \frac{.05}{2}^2\right) = \frac{24.7}{1.5^2}\left(1.5 - \frac{.05}{2}^2\right)$

$M_f = 16.5\,kNm$

for min. reinforcement:
$A_s = .002A_g = .002(1.5 \times .2)$
$A_s = 600\ mm^2 \Rightarrow 6-10_m$ bars $= 600_{mm}^2$

$\beta_1 c = \frac{\phi_s f_y A_s}{\alpha_1 \phi_c f'_c b} = \frac{.85(400)(600)}{.81(.65)(25)(600)}$

$\beta_1 c = 25.8\ mm << d$, so reinforcement yields ✓

$M_r = \phi_s f_y A_s\left(d - \frac{\beta_1 c}{2}\right) = .85(400)(600)\left(120 - \frac{25.8}{2}\right)$

$M_r = 21.8\,kNm > M_f$ ✓

Sign

$DL = 22(12 \times .5 \times 2.5)$
$DL = 330\ kN$

$P_f = 1.4DL = 462\ kN$

For $12000 \times 500_{mm} \times 200_{mm}$

$B = \frac{330}{12 \times .5} + 23.5(.2)$

$B = 59.7 \leq B_r = 300kPa$ ✓

- no shear as foundation dim. same as "col" dim

- no moment as foundation dim. same as "col" dim

- use min reinforcement for safety
$A_s = .002A_g = .002(2.5 \times .2) = 1000\ mm^2$
↳ 5-15M bars along long edge
$A_s = .002(.5 \times .2) = 200_{mm}^2$
↳ 2-10M bars along short edge

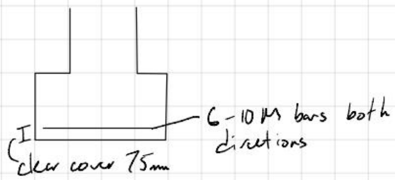
Check bearing stress

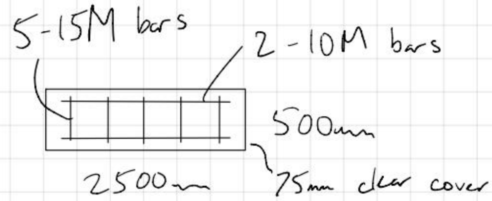
$F_b = .85\phi_c f'_c \left(\pi \frac{D^2}{4}\right) = .85(.65)(30)\left(\frac{\pi 1.5^2}{4}\right)$

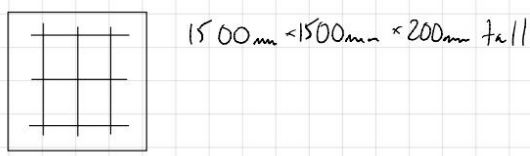
$F_b = 29.3 \text{ kN} > P_f = 24.7\text{kN}$

- no bearing on concrete as foundation dim. same as "col" dim

Design Summary (NTS)







Appendix B.3. Stormwater Management Hand Design Calculations

Road diameter = 55m

$$Ra\inf a\,llArea = A = * (55/2)2 = 2376m^2$$

$$24 - hour100yearstorm = 112.8mm/day$$

For the grass center area:

$$A = \pi * (34/2)^2 = 907.9m^2$$

$$Q = CIA = (.3)(112.8mm/day)(907.9m^2) = 30.7m^3/day$$

Road:

$$Q = CIA = (.9)(112.8mm/day)(2376m^2 - 907.9m^2) = 149m^3/day$$

Total storage demand for 24-hour 100-year storm

$$V = 30.7m^3 + 149m^3 = 179.7m^3$$

Storage from soak pit:

$$V = lwh_c = (90m)(1m)(1m)(.3) = 27m^3$$

Note: The .3 is applied to account for volume reductions from the granular fill

Storage from Grassed Swale:

$$V = \pi \int_0^{.875} [(OR)^2 - (IR)^2]dy$$

$$V = \pi \int_0^{.875} [(2y + R_3)^2 - (R_2 - 2y)^2]dy$$

$$V = \pi \int_0^{.875} [4y^2 + 2yR_3 + R_3^2 - R_3^2 + 2yR_2 - 4y^2]dy$$

$$V = \int_0^{.875} (R_3^2 - R_2^2 + 2yR_3 + 2yR_2)dy$$

$$V = (R_3^2 d - R_2^2 d + R_3 d + R_2 d)$$

$$V = 314.9m^3$$

After applying the granular fill reduction factor

$$V = 94.5m^3$$

Pipe calcs:

Max 15-minute 100-year flow = 32mm/15min

Assume ALL stormwater flows into one pipe for the entire catchment

$$Q = (.3)(127mm/hr)(907.9m^2) + (.9)(127mm/hr)(2376m^2 - 907.9m^2) = .056m^3/s$$

Using a design speed of 3m/s

$$Cross\ \sec tional\ area = (.056m^3/s)/(3m/s) = .0187m^3$$

$$Radius = \sqrt{\frac{.0187m^2}{\pi}} = .077m$$

therefore, use 150 mm pipes

Appendix C – Traffic Count Data

October 12, 2023 From 7:41 AM to 8:41 AM					
From	**Towards**	**Vehicles per Hour**	**Buses per Hour**	**Pedestrians per Hour**	**Cyclists per Hour**
South Marine Drive	North Marine Drive	439	0	1	16
South Marine Drive	W 16th Avenue	632	19	1	8
North Marine Drive	South Marine Drive	116	0	4	11
North Marine Drive	W 16th Avenue	19	0	2	0
W 16th Avenue	North Marine Drive	61	0	4	4
W 16th Avenue	South Marine Drive	208	16	0	4

Appendix D – Cost Estimate Takeoff Sheets

Appendix D.1 Material Takeoff Sheet

Item	Item Name	Unit	Quantity	Unit Cost	Total Cost
1.0	**Intersection Design**			**Subtotal:**	**$198995**
1.1	**Pavement Materials for Construction**				
1.1.1	Bituminous Concrete	M3	297.2	106.58	31669.96
1.1.2	19mm Crushed Granular Surfacing	M3	1179.5	45.00	53079.72
1.1.3	Granular Sub-base	M3	1352.7	50.00	67635.92
1.1.4	Permeable Paved Surface	M3	25.6	30.00	767.02
1.2	**Pavement Materials for Removal**				
1.2.1	Total Volume of Road Material Removed	M3	2255.3	20.00	45106.61
1.2.2	Total Volume of Sidewalk Material Removed	M3	36.8	20.00	735.78
2.0	**Stormwater Management Systems**			**Subtotal:**	**$72715.96**
2.1	**Soak Pits**				
2.1.1	Fill Material	M3	160.0	7.35	1176.00
2.1.2	Porous Wall Material (Brick)	M3	14.9	67.30	1003.86
2.1.3	150mm PVC Piping	LM	90.0	20.00	1800.00
2.1.4	Permeable Rock Surface Layer	M3	32.0	65.00	2080.00
2.2	**Grassed Swale**				
2.2.1	Fill Material	M3	709.0	7.35	5211.15
2.2.2	150mm Diameter PVC piping	LM	94.2	13.00	1884.96
2.2.3	Permeable Cover Layer	M3	132.0	30.00	3960.00
2.3	**Slot Drains**				
2.3.1	150mm Diameter PVC Piping	LM	100.0	20.00	2000.00
2.4	**Storage Tank**				
2.4.1	10m x 3m diameter storage tank	EA	1.0	50000.00	50000.00
2.4.2	Variable Speed 4.5 In Diameter Pump	EA	2.0	1800.00	3600.00
3.0	**Underpass**			**Subtotal:**	**$83782**
3.1	**Structural Concrete**				
3.1.1	Pre-cast Concrete Walls / Roof	M3	195.0	300.00	57915.00
3.1.2	Cast-in-place Concrete Floor	M3	52.5	300.00	15592.50
3.2	**Reinforcing Structural Steel**				
3.2.1	Slab TUL: 1.25m 15M Reinforcing Steel	EA	180.0	5.13	922.50
3.2.2	Slab BLL: 3.3m 15M Reinforcing Steel	EA	240.0	13.53	3247.20
3.3	**Miscellaneous**				
3.3.1	100mm Diameter PVC Piping	LM	30.0	30.00	900.00
3.3.2	Bottom Granular Fill	M3	63.0	7.35	463.05
3.3.3	Drainage System	EA	1.0	4000.00	4000.00

4.0	**Entrance Sign**			**Subtotal:**	**$76446**
4.1	**Footings**				
4.1.1	Concrete	M3	5.0	300.00	1500.00
4.1.2	1350mm Long 10M Reinforcing Steel Bars	EA	12.0	8.00	96.00
4.2	**Sign**				
4.2.1	Cast-in-place Concrete Sign	M3	50.0	297.00	14850.00
4.2.3	Design + Material of Totem Poles	EA	2.0	30000.00	60000.00
5.0	**Miscellaneous**			**Subtotal:**	**$126709**
5.1	Electrical	LS	1.0	10000.00	10000.00
5.2	Removal of Excavated Earth	M3	1321.2	20.11	26568.41
5.3	Underground 50mm Diameter PVC Pipe (Outside previously stated)	LM	204.2	20.00	4084.96
5.4	Utility Relocation	LS	1.0	1441.00	1441.00
5.5	20’ Lighting Poles	EA	10.0	4300.00	43000.00
5.6	Signage	EA	7.0	170.00	1190.00
5.7	Painted on crosswalks	EA	4.0	40.00	160.00
5.9	Grubbing	M2	1871.0	21.52	40264.78
		Total	**CAD**		**$558,649**

Appendix D.2 Labour and Equipment Takeoff Sheet

Item	Item Name	Unit	Quantity	Unit Cost	Total Cost
1.0	**Intersection Design**			**Subtotal:**	**83759.11**
1.1	Removal of Existing Road Components	LH	99.2	135	13389.44
1.1.1	Laying Pavement for New Road	LH	571.0	110	62809.67
1.1.2	Installation of Slot Drains	LH	108.0	70	7560.00
2.0	**Stormwater Management Systems**			**Subtotal:**	**71762.88**
2.1	**Soak Pits**				
2.1.1	Installation of Pipe	LH	9.4	140	1317.65
2.1.2	Filling with Granular Fill	LH	41.9	140	5859.62
2.1.3	Laying of Permeable Surface	LH	8.4	140	1171.92
2.2	**Grassed Swale**				
2.2.1	Installation of Pipe	LH	11.1	140	1552.32
2.2.2	Filling with Granular Fill	LH	185.5	140	25965.43
2.2.3	Laying of Permeable Pavement	LH	66.0	100	6600.00
2.3	**Storage Tank**				
2.3.1	Installation of tank	LH	20.0	1300	26000.00
2.3.2	Installation of pipes	LH	24.0	130	3123.79
2.3.43	Refilling soil above tank	LH	1.3	130	172.159
3.0	**Underpass**			**Subtotal:**	**50639.23**
3.1	Pouring of granular fill below underpass	LH	16.5	90	1483.22

3.2	Pouring of cast-in-place Concrete	LH	13.7	90	1236.01
3.3	Installation of drainage system	LH	40.0	130	5200.00
3.4	Installation of precast concrete walls and roof	LH	288.0	40	11520.00
3.5	Installation of ramp concrete pieces	LH	250.0	120	30000.00
3.6	Filling with soil	LH	10.0	120	1200.00
4.0	**Entrance Sign**			**Subtotal:**	**16204.84**
4.1	**Footings**				
4.1.1	Installation of steel for footings	LH	81.8	130	10635.30
4.1.2	Cast-in-place for footings	LH	2.0	80	160.00
4.2	**Sign**				
4.2.1	Cast-in-place Concrete Sign	LH	13.1	120	1569.54
4.2.2	Installation of Letters on sign	LH	8.0	120	960.00
4.2.3	Installation of Wooden Totem Poles	LH	24.0	120	2880.00
5.0	**Miscellaneous**			**Subtotal:**	**167412.8**
5.1	Installation of Electrical	LH	80.0	90	7200.00
5.2	Renting Tow Trucks	RH	517.9	120	62152.20
5.3	Tow Truck Driver	LH	517.9	50	25896.75
5.4	Rental of Excavator	RH	65.2	100	6518.07
5.5	Excavator Operator	LH	65.2	45	2933.13
5.6	Renting Concrete Truck	RH	62.1	85	5278.26
5.7	Concrete Truck Operator	LH	62.1	45	2794.37
5.8	Truck Crane Rental	RH	288.0	110	31680.00
5.9	Crane Operator	LH	288.0	50	14400.00
5.10	Street Light Installation	LH	40.0	80	3200.00
5.11	Relocation of Utilities	LH	67.0	80	5360.00
		Total	**CAD**		**$389,779**

Appendix E – 2050 Population Estimate

Appendix E.1 Vehicle Volume Projection

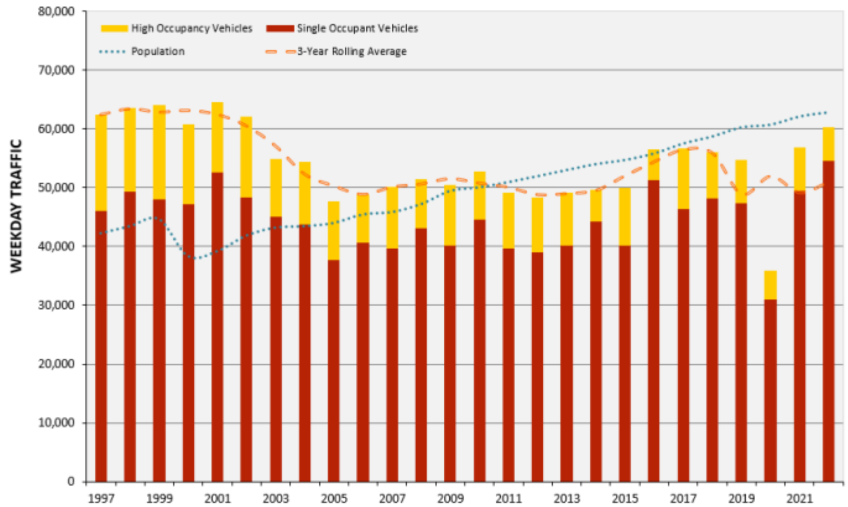


Figure B: Average Weekday Automobile Traffic to / from UBC, 1997 – 2022

Year	Trips/week (1000's)	% difference	
1997	62	0.016	
1998	63	0.016	
1999	64	-0.047	
2000	61	0.049	
2001	64	-0.031	
2002	62	-0.113	
2003	55	-0.018	
2004	54	-0.13	
2005	47	0.043	
2006	49	0.02	
2007	50	0.02	
2008	51	-0.039	
2009	49	0.061	
2010	52	-0.058	
2011	49	-0.02	
2012	48	0.021	
2013	49	0.02	
2014	50	0	
2015	50	0.1	
2016	55	0	
2017	55	0	
2018	55	-0.018	
2019	54	-0.352	
2020	35	0.629	
2021	57	0.07	
2022	61		
2030's		-0.11	Arrival of Skytrain (Broadway)
2050		-0.07	Arrival of RT (41st/Marine)
Calculation		**Sample Calculation**	**Factor**
Average yearly increase		SUM(%difference)/(2022-1998)	0.009958
Projected increase (2023 to 2050)		(2050-2023)*1.0%	0.268875
Reductions from Rapid Tranport		(-0.07 -0.11)	0.158875
Total Projected Increase 2050		(0.269) + (-0.07-0.11)	0.088875
			9% projected increase

Appendix F – BC MoTI Design Geometric Information Sheet

ROUNDABOUT
GEOMETRIC DESIGN INFORMATION SHEET

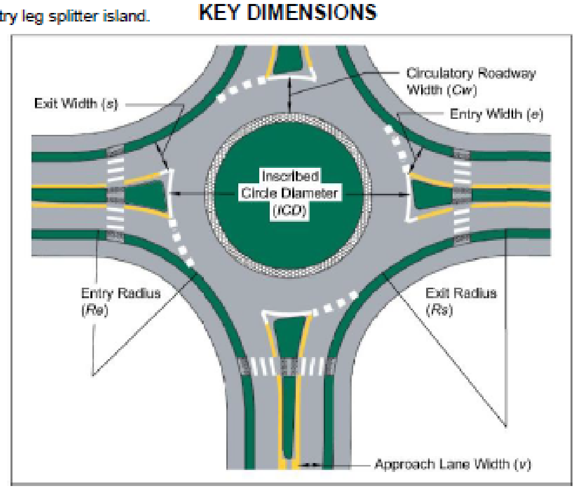
Project:	*SW Marine Drive / 16th Avenue Intersection Redesign*
Type of work:	*Intersection Redesign*
Location:	*16th Avenue and SW Marine Drive*
Length:	*468m - SW Marine Drive, 230m - 16th Avenue*

GEOMETRIC DESIGN ELEMENTS **See last page for a diagram of Key Dimensions**	**BC MoTI GUIDELINES CRITERIA**	**Southwest Marine Dr. N/B Appr. South Leg** **Proposed Criteria**	**Southwest Marine Dr. S/B Appr. North Leg** **Proposed Criteria**	**16th Ave. E/B Appr. West Leg** **Proposed Criteria**
Functional Classification of Approach Road:	----	Major Road	Major Road	Minor Road
Design Classification of Approach Road:	----	Urban arterial divided	Urban arterial divided	Urban arterial divided
Posted Speed of Approach Road:	----	60km/h	60km/h	50km/h
Angle of Intersecting Roads[1]:	**desirable 75° to 105°**	83°	99°	178°
Approach Grade:	**desirable max. 4%**	1.06%	-2.21%	-4.56%
Inscribed Circle Diameter (*ICD*):		55m	55m	55m
Circulatory Roadway Width (C_w)[2]:	**e to 1.2e**	8m	8m	8m
Apron Width:	**2.0 m min.**	4.2m	4.2m	4.2m
No. of lanes (by leg: entry/exit)[3]:	----	1/1	1/1	1/1
Approach Lane Width (*v*):	----	4.25m	4.5m	4m
Entry Width (e)[4]:	----	6m	6m	6m
Entry Radius (R_e):	----	30m	30m	30m
Exit Width (*s*):	----	7m	7m	7m
Exit Radius (R_s):	----	35m	35m	35m
Bypass Lane (Yes or No)	----	No	No	No
Current Traffic Volume: SADT[5]:	----	12,533	8,209	12,246
Design Hour Approach Volumes[5] (*enter design year*) (AM/PM):	----	1543 (2050 Weekday AM)	528 (2050 Weekday AM)	404 (2050 Weekday AM)
Truck Volume %:	----	7%	0%	9%
Level of Service:	----	D	A	B
Design Vehicle:	----	WB-20	WB-20	WB-20

1 This is the interior angle measured between the approach leg tangent and the adjacent right side exit leg tangent.
2 *Cw* should be equal to or up to 20% larger than the widest Entry Width (*e*). *Cw* to be measured in front of entry leg splitter island.
3 Example: "2/1" means there are 2 entry lanes and 1 exit lane for this leg.
4 *e* = perpendicular distance from left lane edge/yield line point to edge of pavement (excluding gutter pan).
5 Use winter volumes if appropriate (ex. ski resort area).

NOTE:
Justification for deviation from guidelines and proposed mitigation must be documented and referenced by footnote number on subsequent pages attached to this sheet.

KEY DIMENSIONS



Appendix G - Project Charter

<table>
<tr><td colspan="6">Project Charter of Redesign of SW Marine Drive & 16Th Av. Intersection</td></tr>
<tr><td>Project Title</td><td colspan="3">Redesign of SW Marine Drive & 16Th Av. Intersection</td><td>Project Manager</td><td>Cesar Padilla Lopez</td></tr>
<tr><td>Project Start Date</td><td>01-May-24</td><td>Project End Date</td><td>10-Sep-24</td><td>Project Sponsor</td><td>UBC Campus & Community Planning</td></tr>
<tr><td colspan="6">Business Needs</td></tr>
<tr><td colspan="6">1. Reducing healthcare costs due to current hazardous intersection conditions for pedestrians and cyclists.
2. Accommodate future traffic volumes to an appropriate future year scenario.
3. Create a safe and attractive intersection that serves as a gateway to the campus.</td></tr>
<tr><td colspan="3">Project Scope</td><td colspan="3">Deliverables</td></tr>
<tr><td colspan="3">1. Prioritize public transit and active modes over single occupant vehicles.
2. Design to safely accommodate, support and attract people walking, biking, and rolling.
3. Retain buffer distance with nearby Botanical Garden property.
4. Incorporate green infrastructure to retain stormwater on-site.
5. Create a visual “gateway” feature that spans the roadway for people arriving to the UBC campus.</td><td colspan="3">1. Roundabout at SW Marine Drive & 16Th Av. Intersection.
2. Soak Pit Southwest of Roundabout.
3. Stormwater Collection Septic Tank Buried Under Roundabout's Island.
4. Grass Swale Within Roundabout's Island Perimeter.
5. Pedestrian Underpass on 16TH Av.</td></tr>
<tr><td colspan="6">Financials</td></tr>
<tr><td colspan="6">This project will be financed by UBC Campus and Community Planning through a Design-Build contract with Rocky Mountain Engineering Consultants. No budget constraints have been outlined for the consulting engineering firm but the project's cost must be according to similar projects taking into consideration project's size, location, inflation, and time.</td></tr>
<tr><td colspan="6">Milestone Schedule</td></tr>
<tr><td colspan="2">Milestone</td><td colspan="2">Target Completion Date</td><td colspan="2">Actual Completion Date</td></tr>
<tr><td colspan="2">Meet With UBC Utilities Staff and UBC Campus and Community Planning</td><td colspan="2">08-Jan-24</td><td colspan="2">08-Jan-24</td></tr>
<tr><td colspan="2">Obtain Construction, Excavation, and Utilities Shut Down Permits</td><td colspan="2">16-Apr-24</td><td colspan="2"></td></tr>
<tr><td colspan="2">Complete Roundabout Construction Phase 1</td><td colspan="2">23-May-24</td><td colspan="2"></td></tr>
<tr><td colspan="2">Complete Roundabout Construction Phase 2</td><td colspan="2">13-Jun-24</td><td colspan="2"></td></tr>
<tr><td colspan="2">Complete Roundabout Construction Phase 3</td><td colspan="2">22-Jul-24</td><td colspan="2"></td></tr>
<tr><td colspan="2">Complete Roundabout Construction Phase 4</td><td colspan="2">30-Aug-24</td><td colspan="2"></td></tr>
<tr><td colspan="2">Complete Stormwater System Construction Phase 1</td><td colspan="2">22-May-24</td><td colspan="2"></td></tr>
<tr><td colspan="2">Complete Stormwater System Construction Phase 2</td><td colspan="2">22-Jul-24</td><td colspan="2"></td></tr>
<tr><td colspan="2">Complete Stormwater System Construction Phase 3</td><td colspan="2">27-Aug-24</td><td colspan="2"></td></tr>
<tr><td colspan="2">Complete Pedestrian Underpass Construction Phase 1</td><td colspan="2">05-Jul-24</td><td colspan="2"></td></tr>
<tr><td colspan="2">Complete Pedestrian Underpass Construction Phase 2</td><td colspan="2">14-Aug-24</td><td colspan="2"></td></tr>
<tr><td colspan="2">Complete Gateway Construction Phase 1</td><td colspan="2">10-Sep-24</td><td colspan="2"></td></tr>
</table>

Appendix H – Project Schedule

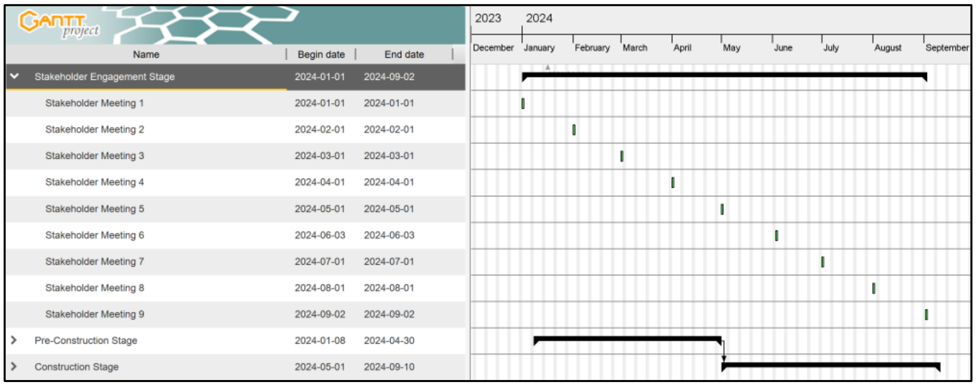


Figure 22. Stakeholder Engagement Schedule

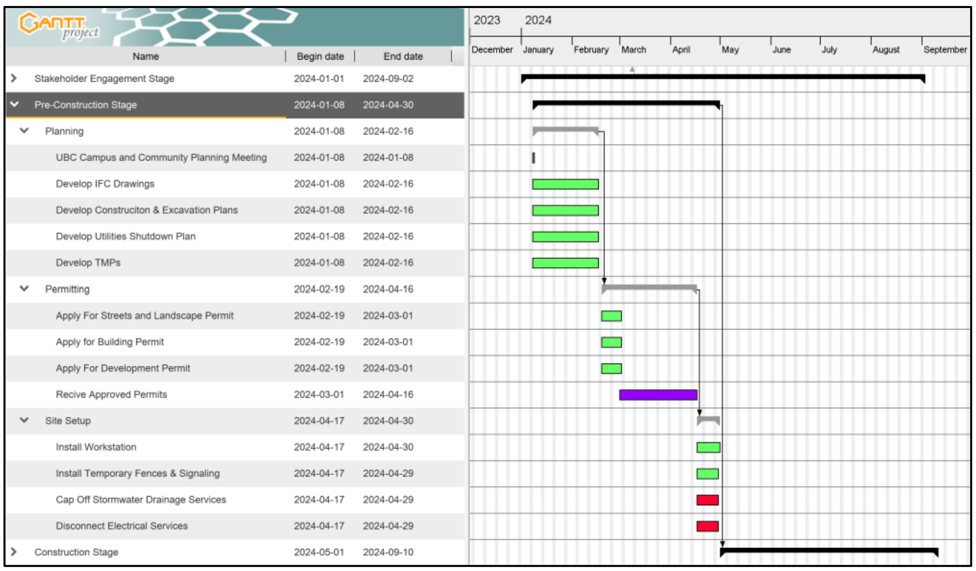


Figure 23. Pre-Construction Schedule

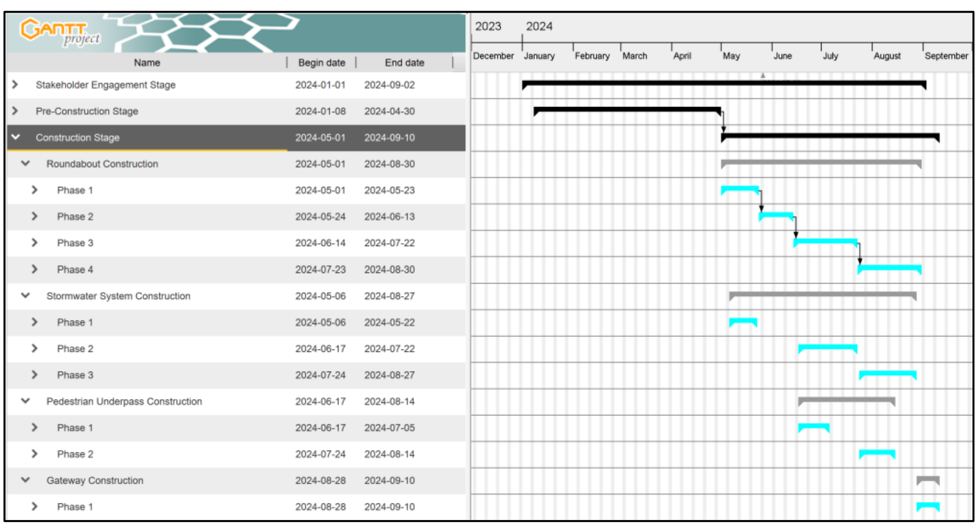
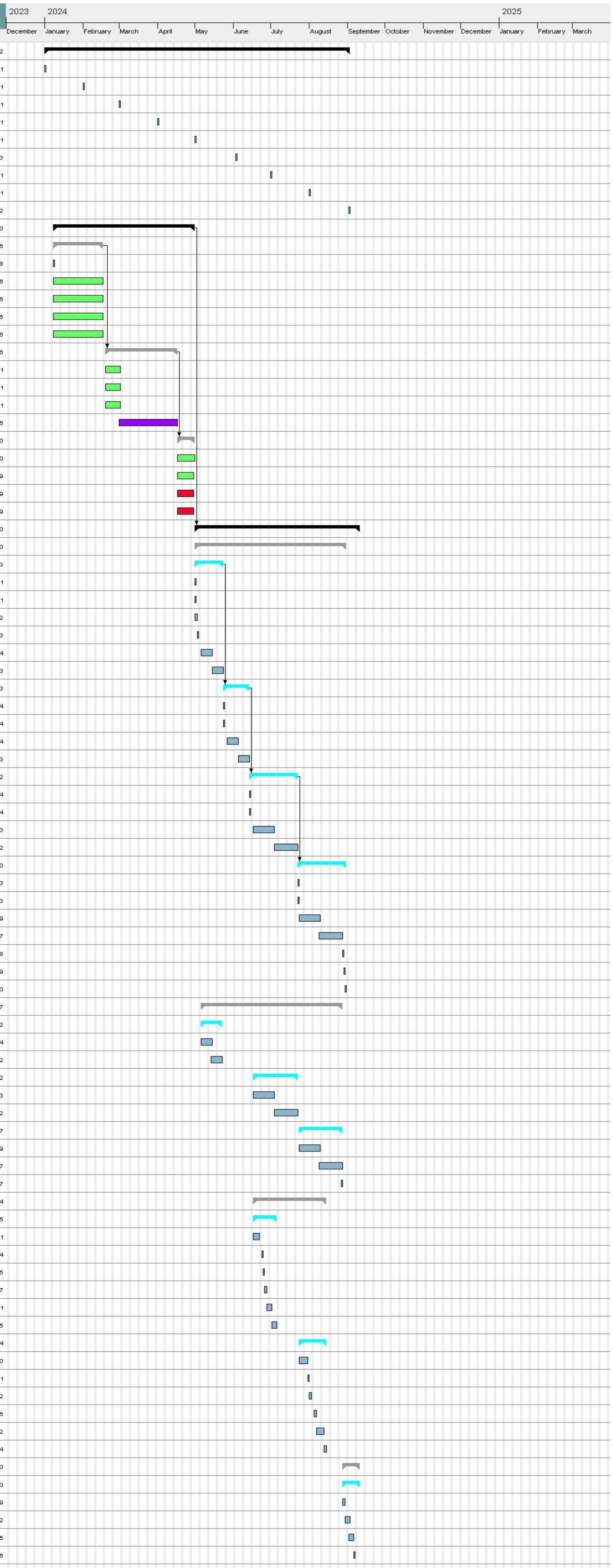


Figure 24. Construction Schedule

Complete Project Schedule

Name	Begin date	End date
Stakeholder Engagement Stage	2024-01-01	2024-09-02
Stakeholder Meeting 1	2024-01-01	2024-01-01
Stakeholder Meeting 2	2024-02-01	2024-02-01
Stakeholder Meeting 3	2024-03-01	2024-03-01
Stakeholder Meeting 4	2024-04-01	2024-04-01
Stakeholder Meeting 5	2024-05-01	2024-05-01
Stakeholder Meeting 6	2024-06-03	2024-06-03
Stakeholder Meeting 7	2024-07-01	2024-07-01
Stakeholder Meeting 8	2024-08-01	2024-08-01
Stakeholder Meeting 9	2024-09-02	2024-09-02
Pre-Construction Stage	2024-01-08	2024-04-30
Planning	2024-01-08	2024-02-16
UBC Campus and Community Planning Meeting	2024-01-08	2024-01-08
Develop IFC Drawings	2024-01-08	2024-02-16
Develop Construciton & Excavation Plans	2024-01-08	2024-02-16
Develop Utilities Shutdown Plan	2024-01-08	2024-02-16
Develop TMPs	2024-01-08	2024-02-16
Permitting	2024-02-19	2024-04-16
Apply For Streets and Landscape Permit	2024-02-19	2024-03-01
Apply for Building Permit	2024-02-19	2024-03-01
Apply For Development Permit	2024-02-19	2024-03-01
Recive Approved Permits	2024-03-01	2024-04-16
Site Setup	2024-04-17	2024-04-30
Install Workstation	2024-04-17	2024-04-30
Install Temporary Fences & Signaling	2024-04-17	2024-04-29
Cap Off Stormwater Drainage Services	2024-04-17	2024-04-29
Disconnect Electrical Services	2024-04-17	2024-04-29
Construction Stage	2024-05-01	2024-09-10
Roundabout Construction	2024-05-01	2024-08-30
Phase 1	2024-05-01	2024-05-23
Place Protective Barricades	2024-05-01	2024-05-01
Place Construction Signage	2024-05-01	2024-05-01
Cut Down Medians	2024-05-01	2024-05-02
Place Temporary Roads	2024-05-03	2024-05-03
Remove Old Curb/Asphalt	2024-05-06	2024-05-14
Install New Curb/Asphalt	2024-05-15	2024-05-23
Phase 2	2024-05-24	2024-06-13
Relocate Protective Barricades	2024-05-24	2024-05-24
Relocate Construction Signage	2024-05-24	2024-05-24
Remove Old Curb/Asphalt	2024-05-27	2024-06-04
Install New Curb/Asphalt	2024-06-05	2024-06-13
Phase 3	2024-06-14	2024-07-22
Relocate Protective Barricades	2024-06-14	2024-06-14
Relocate Construction Signage	2024-06-14	2024-06-14
Remove Old Curb/Asphalt	2024-06-17	2024-07-03
Install New Curb/Asphalt	2024-07-04	2024-07-22
Phase 4	2024-07-23	2024-08-30
Relocate Protective Barricades	2024-07-23	2024-07-23
Relocate Construction Signage	2024-07-23	2024-07-23
Remove Old Curb/Asphalt	2024-07-24	2024-08-09
Install New Curb/Asphalt	2024-08-09	2024-08-27
Remove Temporary Roads	2024-08-28	2024-08-28
Re-install Medians	2024-08-29	2024-08-29
Install New Traffic Signage	2024-08-30	2024-08-30
Stormwater System Construction	2024-05-06	2024-08-27
Phase 1	2024-05-06	2024-05-22
Soak Pit Excavation	2024-05-06	2024-05-14
Soak Pit Installation	2024-05-14	2024-05-22
Phase 2	2024-06-17	2024-07-22
Grass Swale Excavation	2024-06-17	2024-07-03
Grass Swale Installation	2024-07-04	2024-07-22
Phase 3	2024-07-24	2024-08-27
Septic Tank Excavation	2024-07-24	2024-08-09
Spetic Tank Installation	2024-08-09	2024-08-27
Stormwater Sewer System Installation	2024-08-27	2024-08-27
Pedestrian Underpass Construction	2024-06-17	2024-08-14
Phase 1	2024-06-17	2024-07-05
Excavation	2024-06-17	2024-06-21
Stormwater Sewer System Installation	2024-06-24	2024-06-24
Pre-Cast Installation	2024-06-25	2024-06-25
Cocnrete Formwork	2024-06-26	2024-06-27
Reinforcement Installation	2024-06-28	2024-07-01
Concrete Pouring & Curing	2024-07-02	2024-07-05
Phase 2	2024-07-24	2024-08-14
Excavation	2024-07-24	2024-07-30
Pre-Cast Installation	2024-07-31	2024-07-31
Cocnrete Formwork	2024-08-01	2024-08-02
Reinforcement Installation	2024-08-05	2024-08-06
Concrete Pouring & Curing	2024-08-07	2024-08-12
Illumination Installation	2024-08-13	2024-08-14
Gateway Construction	2024-08-28	2024-09-10
Phase 1	2024-08-28	2024-09-10
Cocnrete Formwork	2024-08-28	2024-08-29
Reinforcement Installation	2024-08-30	2024-09-02
Cocnrete Pouring & Curing	2024-09-02	2024-09-05
Gateway Installation	2024-09-06	2024-09-06
Landscaping & Illumination	2024-09-09	2024-09-10



Appendix I – Construction Specification Package

1. GENERAL REQUIREMENTS

1.1. All construction procedures, activities, and materials are to be in accordance with:

1.1.1. The latest edition of the UBC Development & Building Regulations

1.1.2. The latest edition of the Master Municipal Construction Document (mmcd) and Standard Detail Drawings

1.1.3. The latest edition of Ministry of Transportation and Infrastructure BC Traffic Control Manual for Work on Roadways

1.1.4. The latest edition of the Workers' Compensation Act Occupational Health and Safety Regulations

1.2. Mapping datum is NAD 83 Zone 10

1.3. Elevation datum is Canadian Geodetic Vertical Datum (cgvd2013)

1.4. Mapping for drawings is based on LiDAR, City of Vancouver survey on 2022-09-07

1.5. All elevations are in meters and refer to the geodetic datum

1.6. All dimensions are shown in metres unless otherwise specified

1.7. The contractor must ensure all required permits and licences are acquired

1.8. The contractor shall confirm with Team 9 that they are working from civil drawings stamped "Issued for Construction" by Team 9

1.9. The contractor shall give a minimum of 24 hours notice for construction inspections

1.10. All construction is to be completed to the satisfaction of the engineer

1.11. Any change to the design must be approved in writing by Team 9

1.12. All drawing discrepancies are to be reported to the engineer prior to installation

1.13. The contractor must have an up-to-date health and safety plan acceptable to the engineering before commencing work

2. ROADS AND SITE IMPROVEMENTS

2.1. CONSTRUCTION

Read this document in conjunction with the BC Ministry of Transportation 2020 Standard Specifications for Highway Construction Volume 1.

2.1.1. TRAFFIC MANAGEMENT FOR WORK ZONES

The contractor must provide a traffic management plan, and construction schedule must provide safe passage through the work area for all road users. All proposed traffic control procedures must be accepted by the ministry representative prior to the start of that phase. The plan must be submitted at least 14 days prior to the start of work obstructing traffic.

Temporary roadway condition must be kept well-graded throughout the use of that road. The layout of portable traffic signals must be submitted to the ministry representative along with anticipated volumes. All traffic signs must meet the current ministry specifications for standard highway sign materials, fabrication and supply.

2.1.2. BASE PREPARATION AND PROCESSING

This section refers to the shaping and compacting of a granular base to the designed grade and cross section.

The base course material must be watered, graded and compacted to produce a road surface that conforms to the given drawings to +-10mm. Any failed area must be excavated. The area will be backfilled using material specified by the ministry representative and compacted to the same density as the other material.

The final density of the base course shall be compacted to a minimum 100% of the standard proctor density as obtained by ASTM D698.

2.1.3. USE OF RECLAIMED ASPHALT PAVEMENT

Reclaimed asphalt pavement (RAP) is permitted as long as it does not exceed a maximum percentage as specified by the BC Ministry of Transportation. Any RAP used must be tested and sampled according to ASTM D75 to determine the moisture content, asphalt content, gradation, percent fracture, and specific gravity of course and fine material.

2.1.4. PRODUCTION OF ASPHALT MIX

All aggregate supplied must be tested according to ASTM C136 and follow the gradation provided in SS 507-A. Degradation of crushed aggregate should have a factor not less than 40 in accordance with ASTM D6928.

At least seven days before mixing, the contractor must supply the ministry representative with a sample of the aggregate, asphalt mix and type of asphalt to be used on the project.

2.1.5. GRADED AGGREGATE SEAL COAT (EPS)

Surface seals must be used to provide a surface impervious to moisture and resistant to skidding. The contractor must provide asphalt emulsion, and aggregate to be used in construction. The contractor must also supply a graded aggregate seal coat design prepared by a qualified person. Quality control test results as specified in SS 508-E will be obtained by the contractor from the supplier.

2.2. MAINTENANCE

Read this document in conjunction with the BC Ministry of Transportation Schedule “21” Maintenance specifications.

2.2.1. SURFACE MAINTENANCE

Asphalt pavement must be maintained to provide a smooth, stable and sealed surface for highways as well as bicycle and pedestrian paths. Refer to section 502 of the Standard Specifications for Highway Construction for the density of hand patching, asphalt content, aggregate sizes and smoothness of machine patches.

Safe, clean surfaces must be kept to allow for drainage. All drainage holes must be cleaned annually unless accumulations are reported in which the area must be cleaned within 7 days.

2.2.2. DRAINAGE MAINTENANCE

Drainage must remain unobstructed throughout the intersection. In times of high water flow, debris must be removed within 4 hours when reported.

2.2.3. WINTER MAINTENANCE

Precipitation must be monitored, anticipated and managed, especially in the case of snow in order to allow for a safe traffic flow. Refer to PM3.01.2-1 to view the amount of acceptable snow accumulation. Snow should be moved such that snowmelt does not drain across traffic lanes. Anti-icing, de-icing or pre-wetting materials as approved by the province must be applied to the road surface to increase traction.

2.2.4. TRAFFIC MAINTENANCE

Signs must be maintained such that they are clean, legible, erect and properly placed within 7 days of a report stating otherwise. The contractor is not responsible for maintenance of electronic components. All work must comply with the manual of standard traffic signs and pavement markings, specifications for standard highway sign materials, fabrication and supply, sign blank dimensions unless approved by the province.

2.2.5. STRUCTURES MAINTENANCE

The contractor must remove accumulations, surface contaminants and chemicals from any structure's surface. A damaged, rusted, or missing drainpipes must be repaired or replaced within 14 days.

Load-bearing concrete structures must be maintained. All materials must be repaired immediately, any structurally damaged concrete surfaces as determined by the province. Any other damaged or deteriorated concrete structures must be repaired within 6 months.

All retaining walls must be kept safe and stable. Any structural damage must be repaired immediately as determined by the province. Other damage or deterioration must be repaired or replaced within 6 months. The contractor must supply and use material of the same type, quality and size as the existing structure.

2.2.6. MAJOR EVENT RESPONSE

In the event of damage to the highway, the contractor must ensure the safety of all users, repair damaged infrastructure and re-establish traffic flow. The province will assess any damage, specify the required repair and determine when the infrastructure is deemed restored. Temporary detour routes must be built or removed with the cooperation of the province according to the manufacturer's specifications and recommendations.

3. REINFORCED CAST-IN-PLACE CONCRETE

The Work shall consist of:

- Supplying of materials and the mixing and placing of reinforced cast-in-place concrete as shown and described on the Drawings and in this Specification, including placing, vibrating, finishing, and curing.
- Supplying, fabricating, constructing, maintaining and removing temporary works, including falsework and formwork.
- Heating and cooling concrete, if necessary.

- Developing concrete mix design(s) that meets the performance requirements, including trial batches.
- The quality control (QC) testing of all materials; and
- Supplying and installing water seals and joint fillers (when applicable).

Concrete supplied under this Specification will be specified in accordance with CSA A23.1:

- All concrete plants, equipment, and truck mixers comply with the requirements of CSA A23.1 and this Specification.
- All materials to be used in the concrete comply with the requirements of CSA A23.1 and this Specification.
- All the concrete mix design(s) satisfy the requirements of CSA A23.1 and this Specification.
- Production and delivery of concrete will meet the requirements of CSA A23.1 and this Specification.

3.1. REFERENCES AND RELATED SPECIFICATIONS

All reference standards and related specifications shall be current issue or the latest revision at the date of tender advertisement.

References:

- ASTM D 75, Standard Practice for Sampling Aggregates
- ASTM C 494, Standard Specification for Chemical Admixtures for Concrete
- CSA A3001, Cementitious materials for use in concrete
- CSA A3004 – Test methods and standard practices for cementitious materials for use in concrete and masonry
- CSA A3005 – Test equipment and materials for cementitious materials for use in concrete and masonry
- CSA A23.1 – Concrete materials and methods of concrete construction
- CSA A23.2 – Test methods and standard practices for concrete
- CSA A23.3 – Design of concrete structures
- A23.4 – Precast concrete – Materials and construction
- CSA S269.1 – Falsework and formwork

- CSA S6 – Canadian Highway Bridge Design Code

3.2. MATERIALS

3.2.1. FINE AGGREGATE

Fine aggregate shall meet the grading requirements of Section 4.2.3 of CSA A23.1, be graded uniformly and not more than 3% shall pass a 75 um sieve.

3.2.2. COARSE AGGREGATE

The maximum nominal size of coarse aggregate shall be 20 mm and meet the grading requirements of CSA A23.2-2A, Table 2. Coarse aggregate shall be uniformly graded and not more than 1% shall pass a 75 um sieve.

3.2.3. CEMENTITIOUS MATERIALS

Cementitious materials shall conform to the requirements of CSA A3001 and shall be free from lumps. Normal Portland cement, Type GU or GUb, or sulphate resistant, Type HS or HSb, shall be supplied unless otherwise specified on the Drawings.

3.2.4. WATER

Water to be used for mixing and curing concrete or grout and saturating the substrate shall be potable, shall conform to the requirements of Section 4.2.2 of CSA A23.1 and shall be free of oil, alkali, acidic, organic materials or deleterious substances.

3.1.1. FORMWORK

Forms for exposed surfaces shall be made of good quality plywood in "like-new" condition and uniform in thickness, with or without a form liner.

3.3. CONSTRUCTION METHOD

3.3.1. MIXING CONCRETE

All concrete shall be mixed thoroughly until it is uniform in appearance, with all ingredients uniformly distributed. In no case shall the mixing time per batch be less than one minute for mixers of one cubic metre capacity or less. The “batch” is considered as the quantity of concrete inside the mixer. This figure shall be increased by 15 seconds for each additional half cubic metre capacity or part thereof. The mixing period shall be measured from the time all materials are in the mixer drum.

3.3.2. TIME OF HAULING

The maximum time allowed for all types of concrete to be delivered to the site of the Work, including the time required to discharge, shall not exceed 90 minutes after batching. Batching of all types of concrete is considered to occur when any of the mix ingredients are introduced into the mixer, regardless of whether the mixer is revolving. For concrete that includes silica fume, this requirement is reduced to 60 minutes.

3.3.3. FALSEWORK AND FORMWORK

The design, fabrication, erection, and use of concrete formwork shall conform to the requirements of CAN/CSA- S269.3-M and CSA S269.1. All forms shall be oiled or otherwise treated to facilitate stripping. For narrow walls and columns, where the bottom of the form is inaccessible, or wherever necessary, removable panels shall be provided in the bottom form panel to enable cleaning out of extraneous material immediately before placing the concrete. Falsework shall conform to CSA S269.1, Falsework for Construction Purposes. All falseworks shall be designed and constructed to provide the necessary rigidity and to support the loads without appreciable settlement or deformation.

3.3.4. PUMPING OF CONCRETE

When the Contractor chooses to pump the concrete, the operation of the pump shall produce a continuous flow of concrete without air pockets. The equipment shall be arranged such that vibration is not transmitted to the freshly placed concrete that may damage the concrete. When pumping is completed, the concrete remaining in the pipeline, if it is to be used, shall be ejected in such a manner that there will be no contamination of the concrete or separation of the ingredients.

3.4. COLD WEATHER PRECAUTIONS

3.4.1. GENERAL

When the ambient temperature falls below 5°C or when there is a probability of it falling below 5°C within 24 hours of placing the concrete, the Contractor shall make provisions for heating the water, aggregates and freshly deposited concrete.

3.4.2. AGGREGATES

Aggregates shall be heated to a temperature of not more than 65°C. For concrete containing silica fume, the aggregate shall not be heated to more than 40°C. The heating apparatus and the housing for the aggregates shall be sufficient to heat the aggregates uniformly without the possibility of the occurrence of hot spots which may burn the material.

3.4.3. WATER

The water shall be heated to a temperature of not more than 65°C. For concrete containing silica fumes, the water shall not be heated to more than 40°C.

3.4.4. CONCRETE

The temperature of the mixed concrete shall not be less than 15°C and not more than 25°C at the time of placing in the forms. Temperature requirements for concrete containing silica fume shall be between 10°C and 18°C at the time of placing in the forms. Sufficient stand-by heating equipment must be available to allow for any sudden drop in outside temperatures and any breakdowns that may occur with the equipment.

3.4.5. CURING REQUIREMENTS

Water curing of concrete shall be terminated at least 12 hours before the end of the protection period during periods of freezing weather.

The curing compound shall be water-based membrane forming and of a type approved by the Engineer. It shall conform to the requirements of ASTM C-309 and be applied as directed by the Manufacturer. The rate of each application shall not be less than the rate specified by the Manufacturer of the compound. If rain falls on the newly coated concrete before the film has dried sufficiently to resist damage, or if the film is damaged in any other manner during the curing period, a new coat of solution shall be applied to the affected portions equal in curing value to that specified above.

All superstructure concrete with a specified exposure class of C-XL or C-1 shall be wet cured for a minimum period of 7 days at a minimum temperature of 15°C and for the time necessary to attain 50% of the specified compressive strength.

3.5. QUALITY CONTROL

Sampling of concrete shall be carried out in accordance with CSA A3004. When a concrete pump is used to place concrete, sampling shall be at the end of the discharge hose. Making and curing concrete test cylinders shall be carried out in accordance with CSA A3004, except that the time for cylinders to reach the testing laboratory shall be between 20 and 48 hours. The test cylinders shall be cast by the Contractor in standard CSA approved molds.

3.6. OPEN TO TRAFFIC

The structure shall not be opened to traffic until the concrete has attained a minimum compression strength of 100% of the design strength. The Contractor shall be responsible for all costs associated with any additional testing that may be required to satisfy the strength requirement.

4. UTILITIES

4.1. WATERWORKS

4.1.1. CONSTRUCTION AND FINISHING

The granular fill in the soak pit and grassed swale are to be filled with clean round stone or crush rock, with a maximum diameter of 75mm and a minimum diameter of 38mm. The pipes in the grassed swale and soak pit require a minimum diameter of 150mm. During construction, the sites of the grassed swale and the soak pits need to be protected from sedimentation by being covered up with a removable layer.

The pervious paved layer covering soak pits and grassed swales requires a surface covering of 3mm clean crush aggregate. The permeable layer requires being covered during construction to prevent sedimentation.

4.1.2. MAINTENANCE

Grassed swales and soak pits shall have the surrounding grass kept at a maximum height of 150mm and a preferred minimum height of 50mm. The grassed swale and soak pit are to be weeded as needed. Sediment is to be removed from the soak pit and grassed swale as needed, and pipes are to be cleaned out in the case they are clogged. The stormwater management system is to be analysed twice a year, and any sedimentation is to be noted and reported to prevent back ups. The pervious pavement layer covering the grassed swales and soak pits is to be cleaned with a mechanical suction brush twice a year to remove sediments. If pipes are found clogged through sediments, they are to be cleaned out using a hydro-vac jet nozzle. The filter cloth of the soak pit shall be replaced every 2 years. The soak pit and grassed swale should have routine inspections done yearly, maintenance verified at least every 5 years, and performance verification done at least every 15 years.

5. EARTHWORKS

5.1. SITE EARTHWORKS

All site earthworks recommendations should be complemented by reference to CSA Z240.10.1. Any deleterious or contaminated filling should be stripped and disposed of in accordance with the recommendation provided in our environmental report. The exposed subgrade should be proof rolled, any existing uncontrolled filling and rubble be removed and replaced with engineered fill as specified below. Engineered fill is to be used to backfill batters and to raise the site level where required.

Where clays are exposed at subgrade level, they will undergo substantial loss in strength when wet and may even become untrafficable. Therefore, it is important to provide good and effective drainage during construction. The principal aim of the drainage is to promote run-off towards designated sumps by cross-falls and to reduce ponding.

Following stripping and completion of the proposed excavations, it is recommended that the soil subgrade be proof rolled and inspected by an experienced geotechnical engineer. The proof rolling should involve at least four passes of a vibratory smooth drum roller (e.g. minimum 8 tonne deadweight) for the detection of unstable or “soft” areas.

Subgrade heaving may occur during proof rolling in areas where the clays may have become “saturated”. Heaving areas should be locally removed to a “stiff” base and replaced with engineered fill as defined below. Depending on the extent and depth of the heaving areas, it may be necessary to provide a bridging layer. If the in-situ clays exhibit shrinkage cracking, then the surface should be watered and rolled until the shrinkage cracks are no longer evident. Engineered fill should also be used where it is proposed to raise the levels.

5.2. ENGINEERED FILL

Engineered fill should comprise well-graded granular material (sands, ripped or crushed sandstone), free of deleterious substances and having a maximum particle size of "25 mm". Excavated sands from the site may be reused as fill provided that any unsuitable material (organic clays) and any building rubble or deleterious material is excluded. The engineered fill, and any excavation backfill where subgrade support is required, should be compacted in layers of not greater than "200 mm" loose thickness, to a density ratio of 95% of standard maximum dry density (SMDD).

Density tests should be regularly carried out on the fill in accordance with ASTM D6938 standard to confirm the above specifications are achieved. The frequency of density testing should be at least one test per layer per "5m^2".

6. UNDERPASS MAINTENANCE

6.1. SCHEDULE

A comprehensive maintenance schedule includes the following components:

INSPECTIONS: conducted at regular intervals to assess the condition of the structure and identify any signs of deterioration or damage.

PREVENTIVE MAINTENANCE: proactive measures taken to mitigate potential sources of deterioration.

CORRECTIVE MAINTENANCE: prompt repair or rehabilitation of identified defects or damage to prevent further deterioration and restore structural integrity.

6.2. INSPECTION

A thorough inspection checklist is prepared to ensure proper maintenance:

SURFACE CONDITION OF CONCRETE: inspect the surface of the concrete for signs of deterioration such as cracking, spalling, scaling, or discoloration.

PRESENCE OF CRACKS, SPALLING, OR DELAMINATION: document the location, size, and severity of any cracks observed in the concrete. Cracks can be indicative of underlying structural issues or deterioration processes such as corrosion of reinforcing steel. Similarly, identify areas where spalling has occurred.

CORROSION OF REINFORCING STEEL: inspect areas where the reinforcing steel is exposed or visible for signs of corrosion. Corrosion of reinforcing steel can compromise the structural integrity of the underpass and necessitate prompt intervention.

DRAINAGE SYSTEMS: evaluate the effectiveness of drainage systems in preventing the accumulation of water within the underpass structure. Check for clogged drains, or inadequate slope gradients that may contribute to moisture ingress and deterioration.

STRUCTURAL STABILITY AND ALIGNMENT: assess the overall structural stability and alignment of the underpass. Look for signs of settlement, distortion, or misalignment that may indicate underlying structural issues or movement of the soil beneath the structure.

ENVIRONMENTAL FACTORS: consider environmental factors that may impact the condition of the underpass, such as vegetation growth, debris accumulation, or exposure to de-icing salts. Remove vegetation and debris that could impede drainage.

6.3. REPAIR

Based on the findings of the inspection, appropriate repair and rehabilitation techniques should be selected to address identified defects and maintain the structural integrity of the underpass. Repair techniques include:

CONCRETE PATCHING AND REPAIR: fill cracks and spalled areas with appropriate repair materials to restore the integrity of the concrete surface.

CRACK SEALING AND INJECTION: seal cracks in the concrete to prevent moisture ingress and inhibit further propagation of cracks. Injection of epoxy or polyurethane grouts may be used to fill and structurally reinforce cracks.

CORROSION PROTECTION MEASURES: apply coatings or cathodic protection systems to mitigate corrosion of reinforcing steel.

7. VEGETATION CONTROL

As per the Roadside Vegetation Control Maintenance Specifications Chapter 4-350 (British Columbia Ministry of Transportation and Infrastructure, 2003), the following vegetation maintenance is to be done.

Vision Protection: Any tree limbs that grow into the right of way of users or block line of sights are to be removed as necessary.

Grass Maintenance: Any vegetation beyond the shoulder edge that impedes drainage, obscures visibility or constitutes noxious weeds are to be removed as necessary. Additionally, the grass surrounding the soak pit and grassed swale should be maintained between the heights of 50mm and 150mm.

Appendix J – Drawings

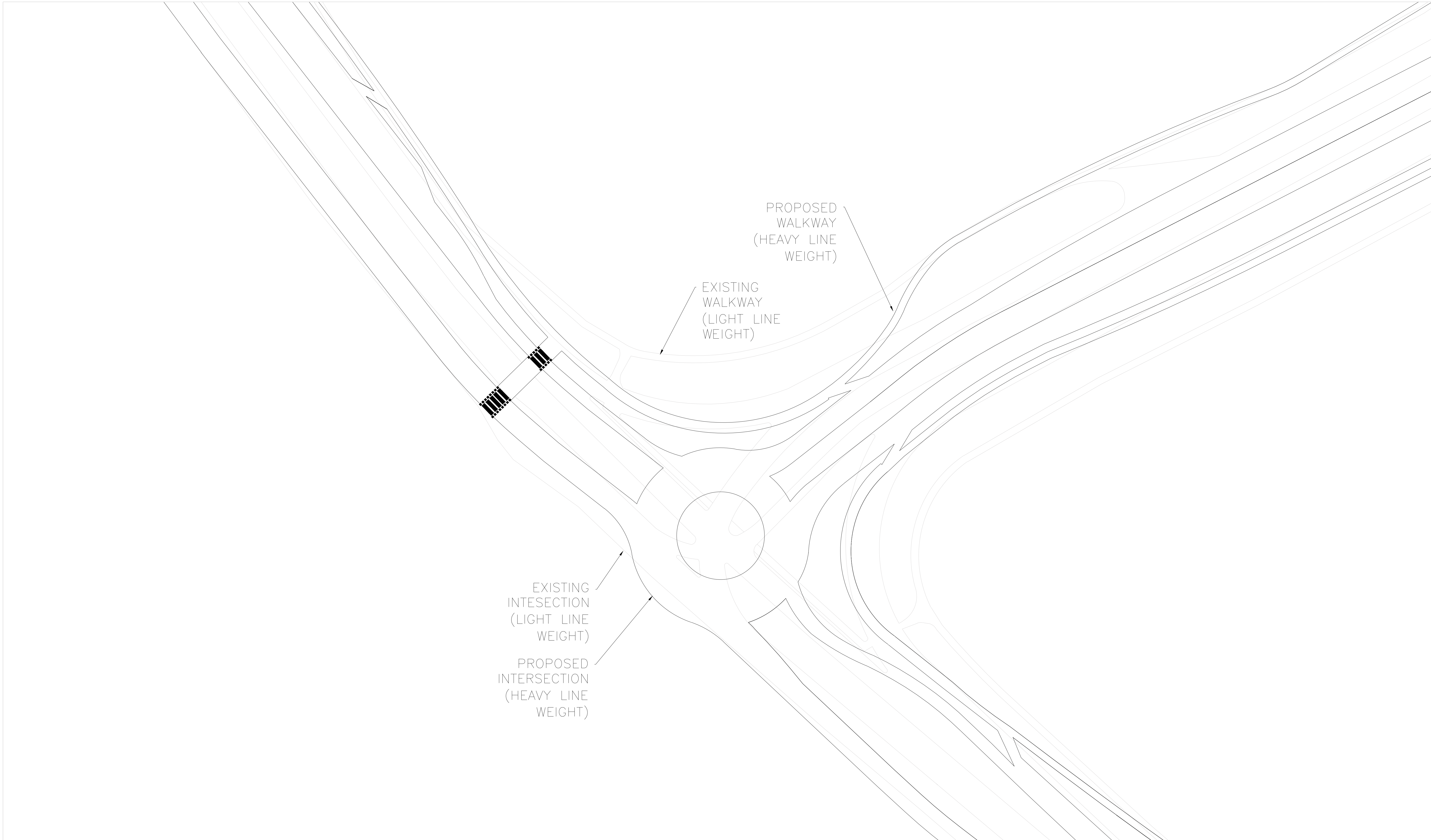
REDESIGN OF 16TH AVENUE / SW MARINE DRIVE INTERSECTION

UNIVERSITY OF BRITISH COLUMBIA

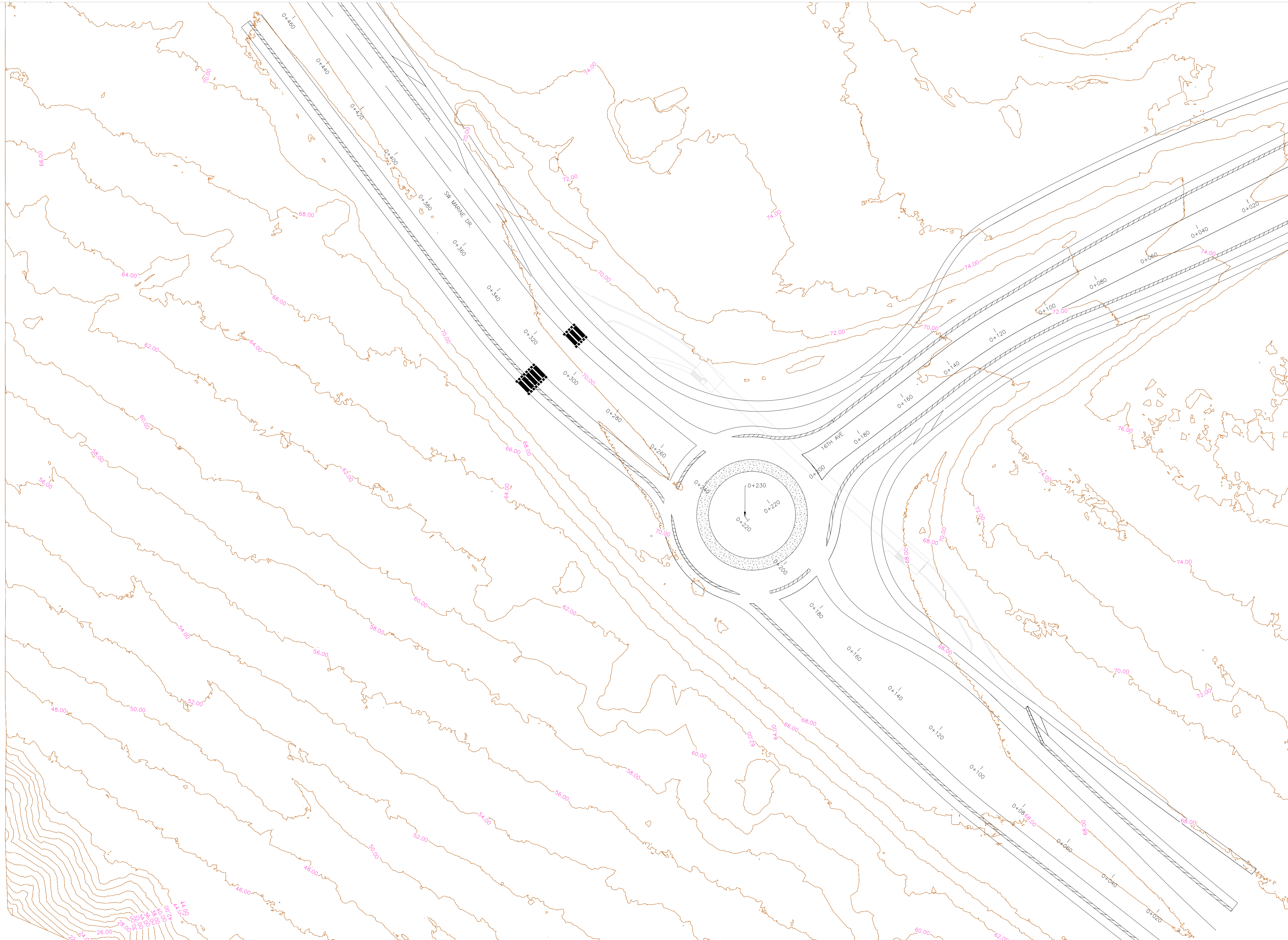
VANCOUVER, BC

ISSUED FOR CONSTRUCTION

Drawing Index	
General	SW Marine (North Approach) and 16th Avenue – INT-DWG-13
Existing and Proposed Road and Pathways – INT-DWG-01	Vehicles Signs / Markings – North – INT-DWG-14
Intersection Contour Map – INT-DWG-02	Vehicles Signs / Markings – South – INT-DWG-15
General Site Plan – INT-DWG-11	Active Transport Signs / Markings – North – INT-DWG-16
Intersection	Active Transport Signs / Markings – South – INT-DWG-17
16th Avenue Alignment – INT-DWG-03	**Underpass**
SW Marine Dr Alignment – North of Intersection – INT-DWG-04	Mixed-Use Underpass South End – UND-DWG-01
SW Marine Dr Alignment – South of Intersection – INT-DWG-05	Mixed-Use Underpass Entrance Ramp – UND-DWG-02
SW Marine Dr Profile 0+000 to 0+140 – INT-DWG-06	Mixed-Use Underpass Typical Section – UND-DWG-03
SW Marine Dr Profile 0+160 to 0+280 – INT-DWG-07	**Entrance**
SW Marine Dr Profile 0+300 to 0+480 – INT-DWG-08	Entrance Sections and Details – ENT-DWG-01
16th Avenue Profile 0+000 to 0+080 – INT-DWG-09	**Stormwater Management**
16th Avenue Profile 0+100 to 0+240 – INT-DWG-10	Stormwater Management Details – STM-DWG-01
Roundabout and SW Marine (South Approach) – INT-DWG-12	



ROCKY MOUNTAIN ENGINEERING CONSULTANTS LTD.	NOTE:	UBC ENDOWMENT LANDS REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION UBC CAMPUS AND COMMUNITY PLANNING	EXISTING AND PROPOSED ROAD AND PATHWAYS (AT GRADE) PLAN	DES. C.C.	SCALE 1:300	
				DR. P.N.	INT–DWG–01	
				DATE 10/4/24		A



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NOTE:

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REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION
UBC CAMPUS AND COMMUNITY PLANNING

INTERSECTION CONTOUR MAP

PLAN

DES.	C.C.	SCALE	1:200
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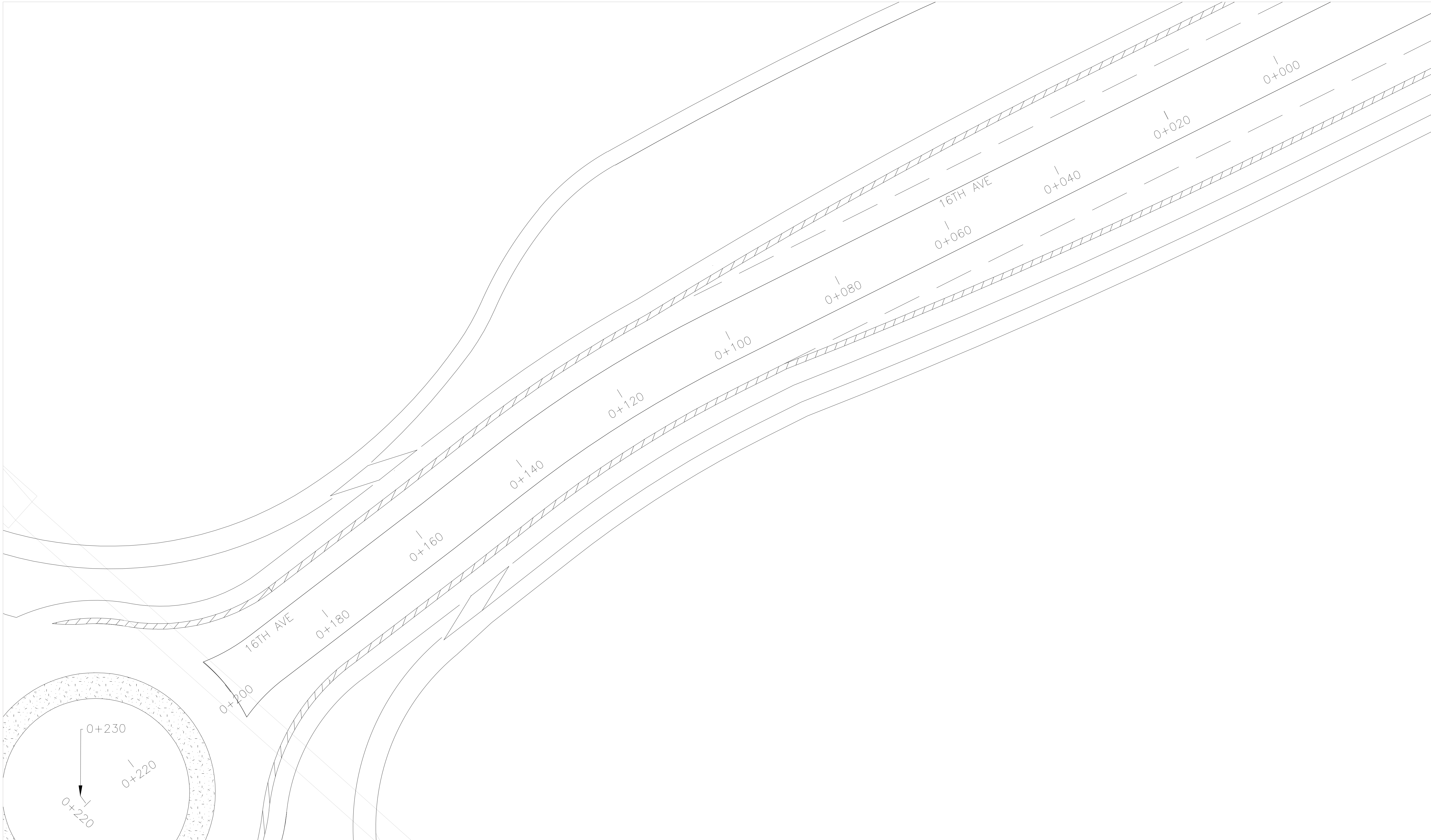
DATE	10/4/24		A



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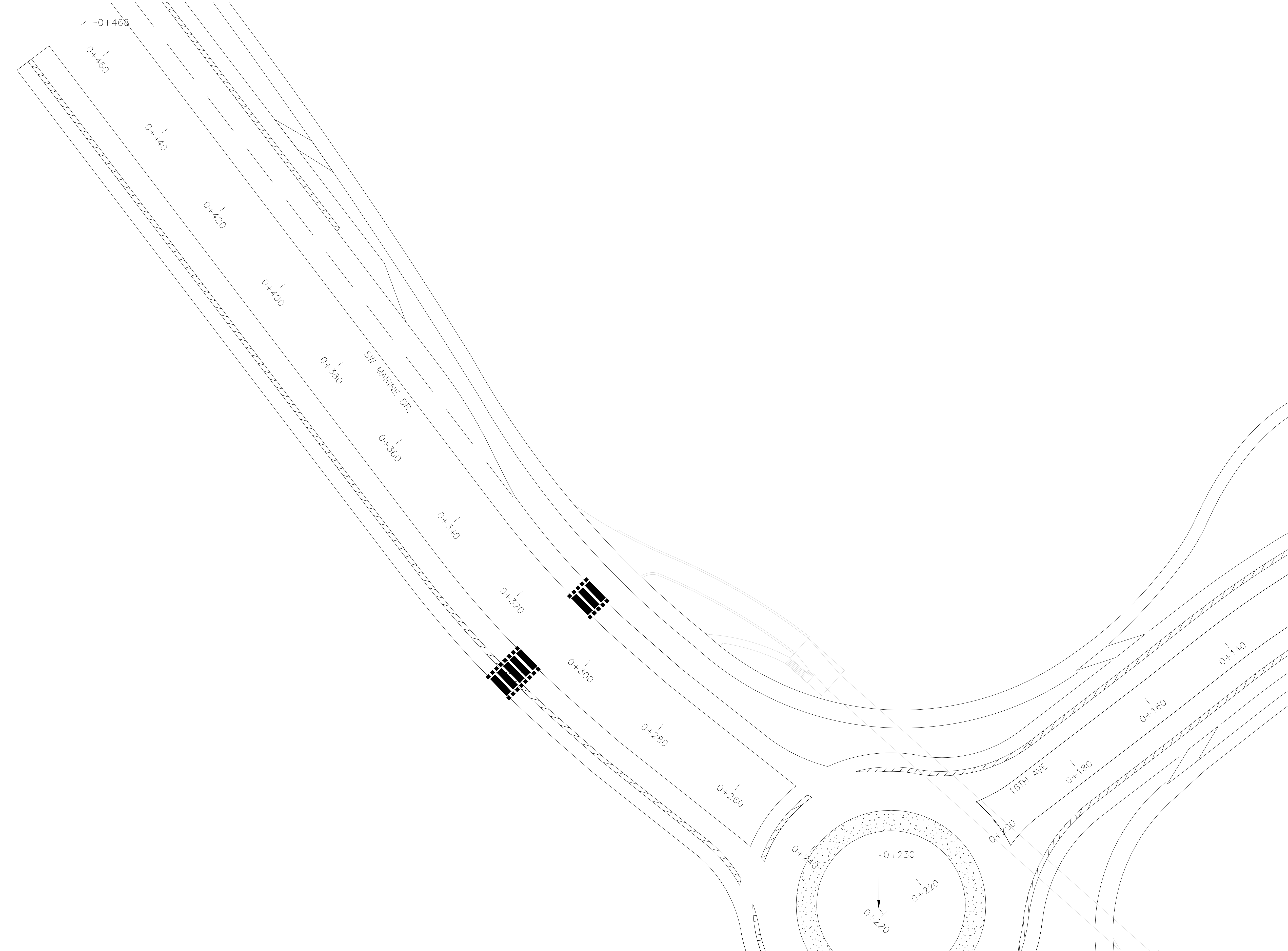
REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION
UBC CAMPUS AND COMMUNITY PLANNING

16th AVENUE ALIGNMENT

PLAN

DES. C.C.	SCALE 1:200
DR. P.N.	INT-DWG-03
DATE 10/4/24	A



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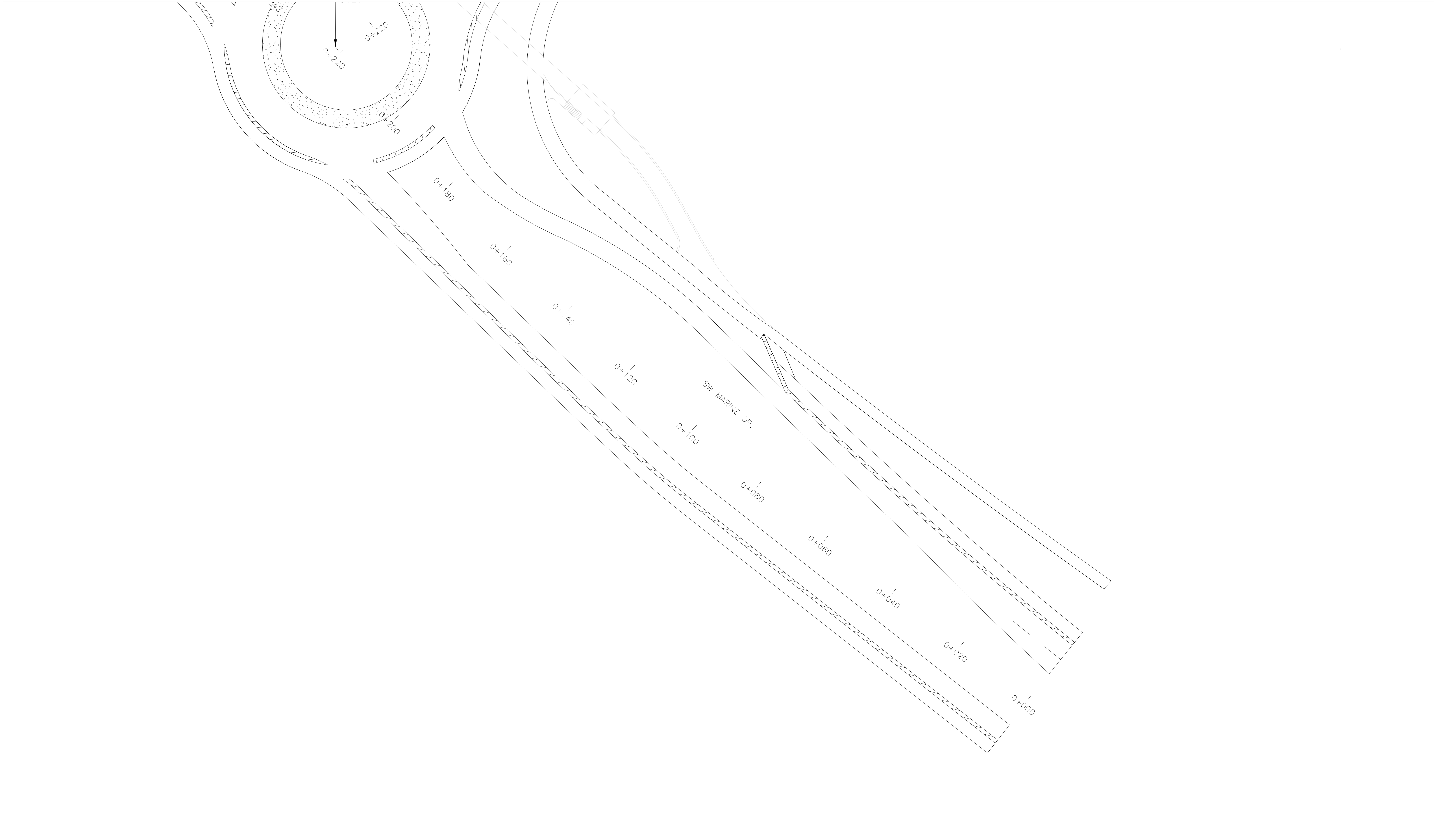
SW MARINE DR ALIGNMENT – NORTH OF INTERSECTION

PLAN

DES. C.C.	SCALE 1:200
DR. P.N.	INT–DWG–04
DATE 10/4/24	A



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REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION
UBC CAMPUS AND COMMUNITY PLANNING

SW MARINE DR ALIGNMENT – SOUTH OF INTERSECTION

PLAN

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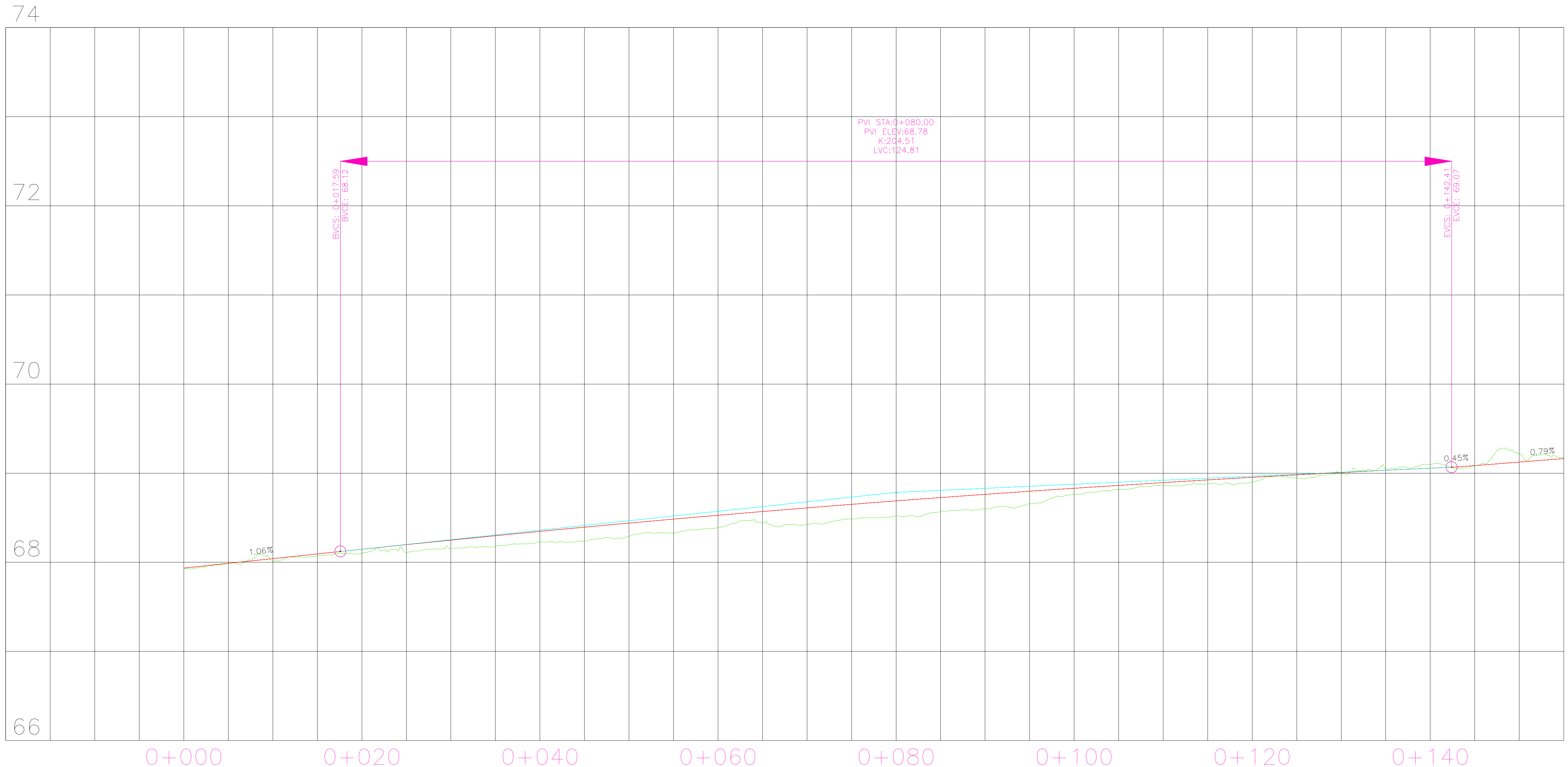

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NOTE:

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REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION
UBC CAMPUS AND COMMUNITY PLANNING

SW MARINE DR EXSITING AND PROPOSED PROFILE 0+000 TO 0+140

PLAN

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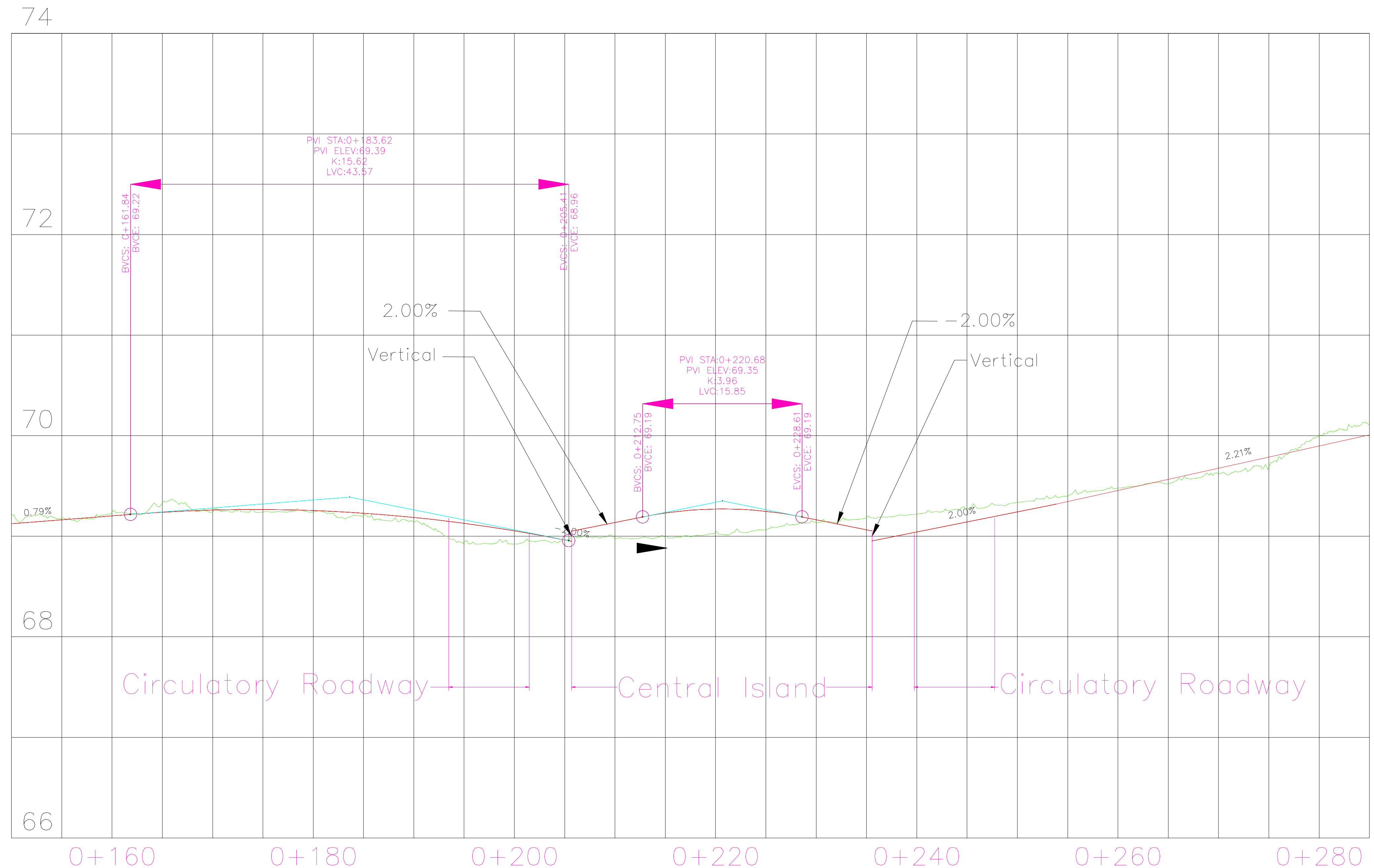
DATE	10/4/24		A



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NOTE:

UBC ENDOWMENT LANDS
REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION
UBC CAMPUS AND COMMUNITY PLANNING

SW MARINE DR EXSITING AND PROPOSED PROFILE 0+160 TO 0+280

PLAN

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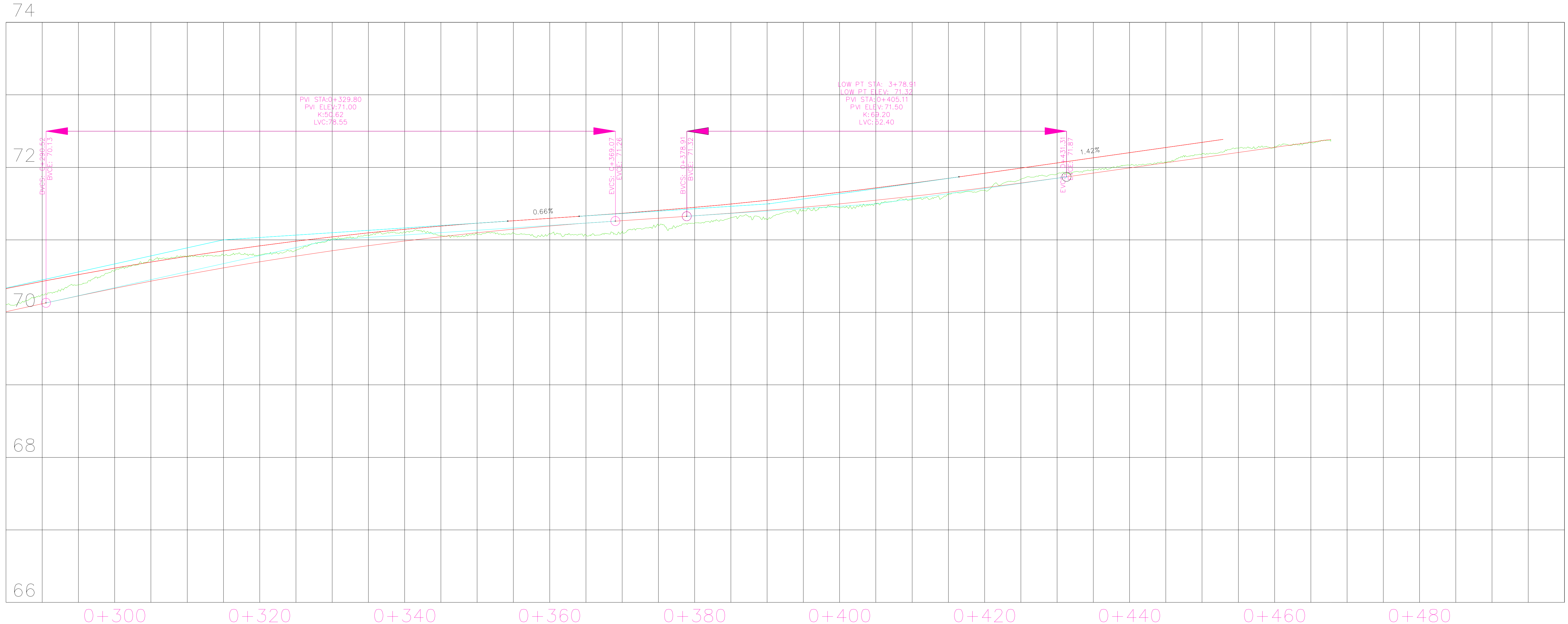
DATE	10/4/24		A



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REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION
UBC CAMPUS AND COMMUNITY PLANNING

SW MARINE DR EXSITING AND PROPOSED PROFILE 0+300 TO 0+480

PLAN

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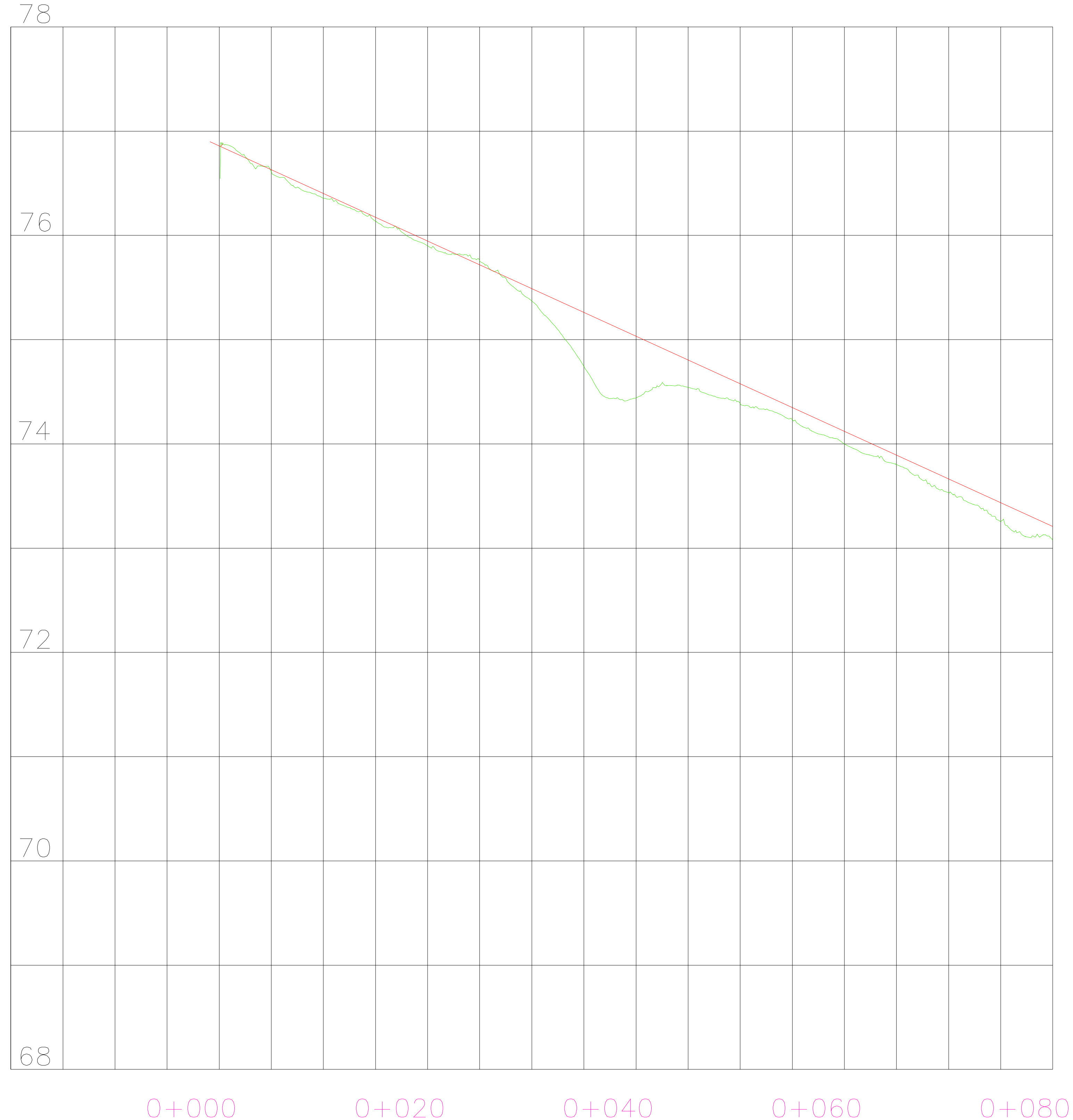
DATE 10/4/24		A



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REDESIGN OF 16TH AVE /
SOUTHWEST MARINE DR INTERSECTION
UBC CAMPUS AND
COMMUNITY PLANNING

16TH AVENUE EXSITING AND PROPOSED
PROFILE 0+000 TO 0+080

PLAN

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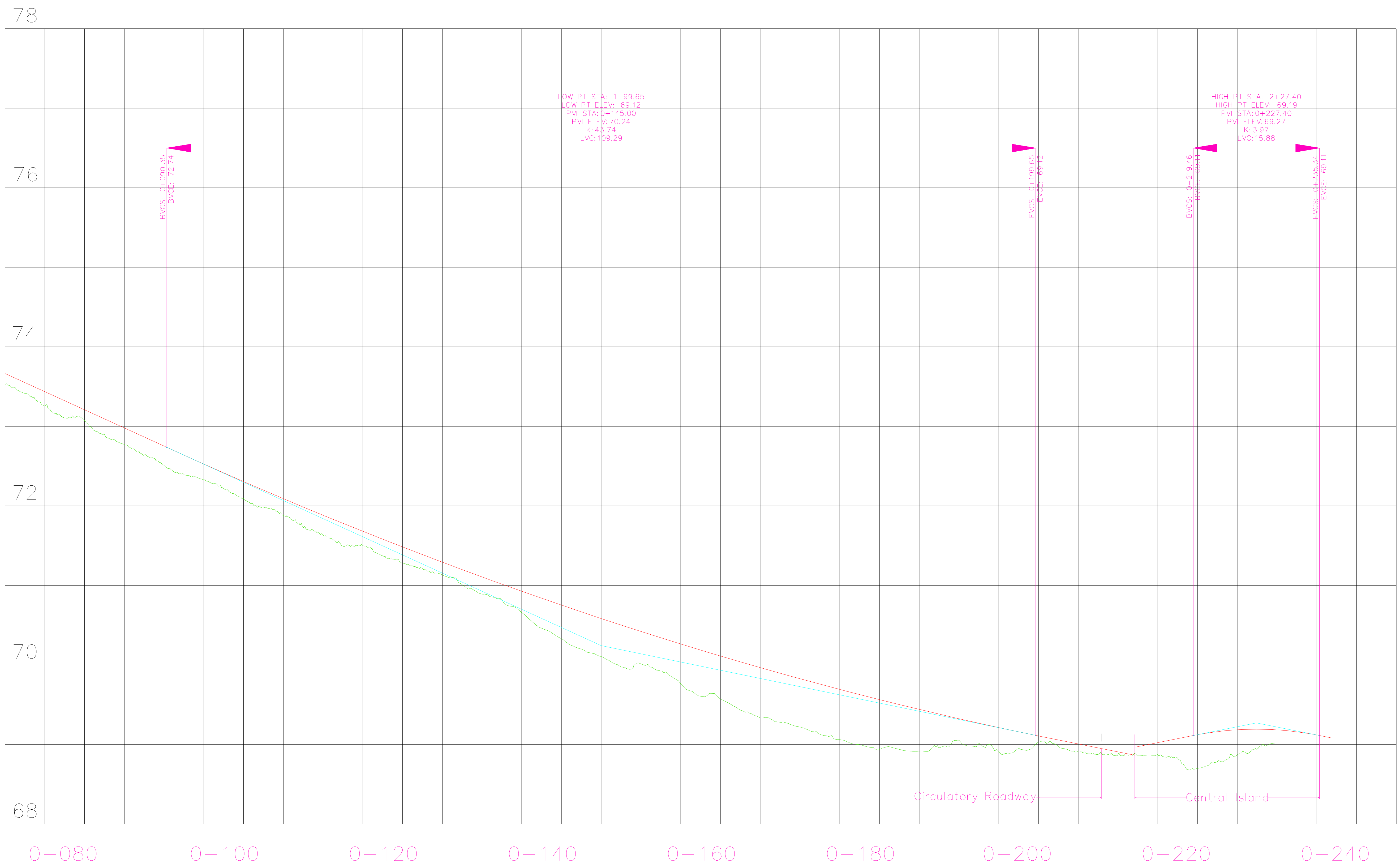
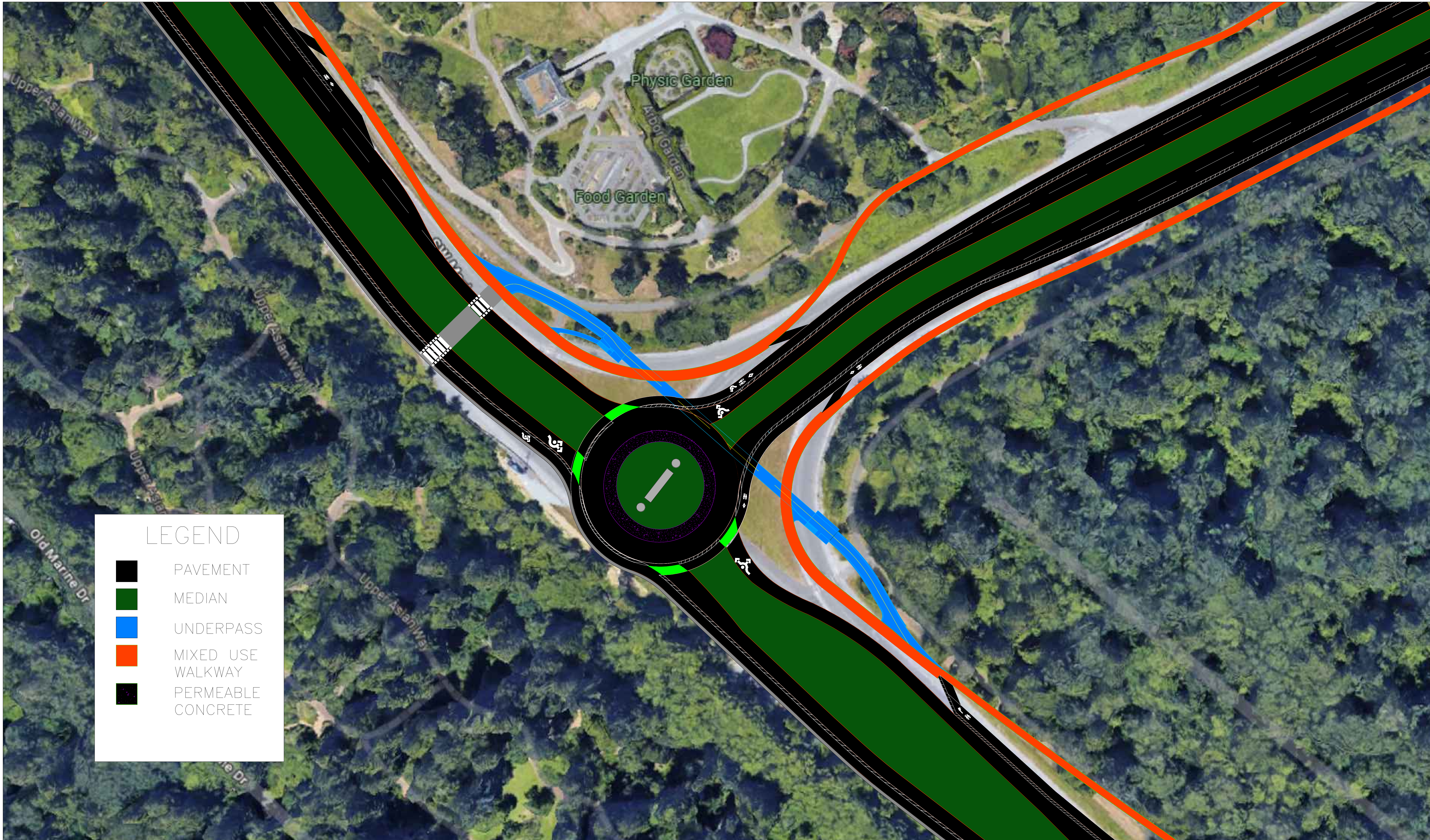
DATE	10/4/24		A



ROCKY MOUNTAIN ENGINEERING CONSULTANTS LTD.	NOTE:	UBC ENDOWMENT LANDS REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION UBC CAMPUS AND COMMUNITY PLANNING	16TH AVENUE EXSITING AND PROPOSED PROFILE 0+080 TO 0+240 PLAN	DES. C.C. DR. P.N. DATE 10/4/24	SCALE N/A INT-DWG-10 A



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NOTE:

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REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION
UBC CAMPUS AND COMMUNITY PLANNING

GENERAL SITE PLAN

PLAN–OVERLAY

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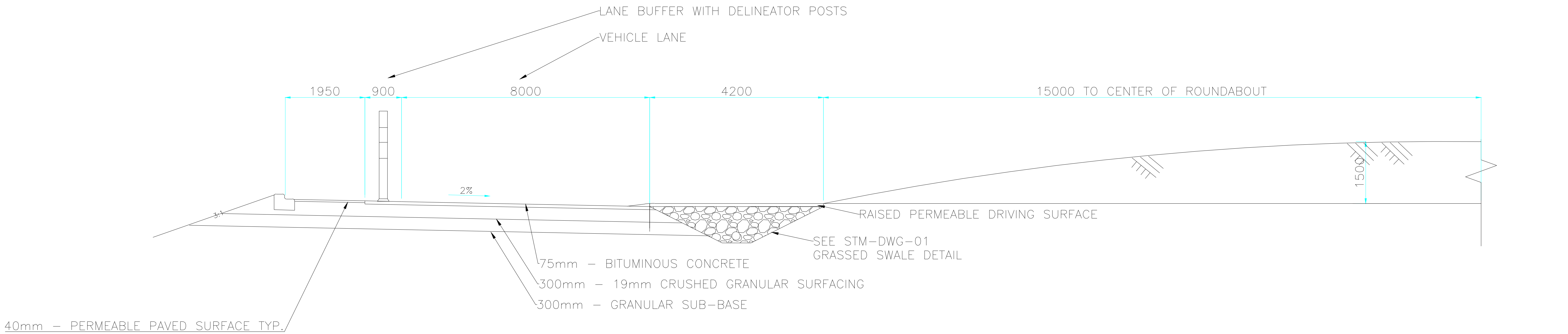
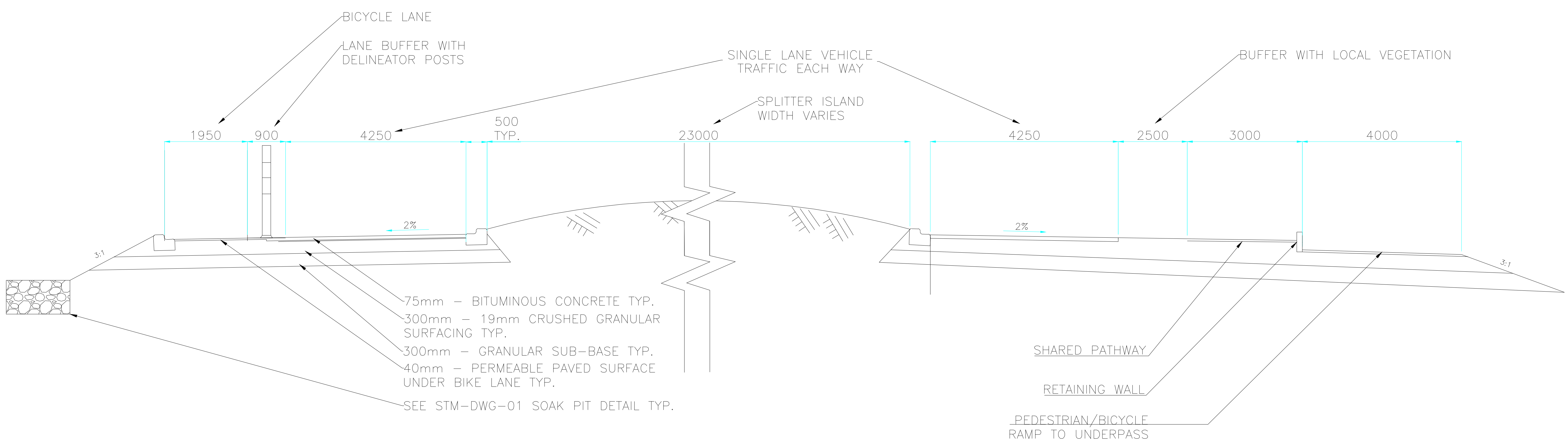
DATE	10/4/24		A



TYPICAL HALF ROUNDABOUT SECTION
SCALE 1:100



SOUTHWEST MARINE DR - SOUTH APPROACH
SCALE 1:100

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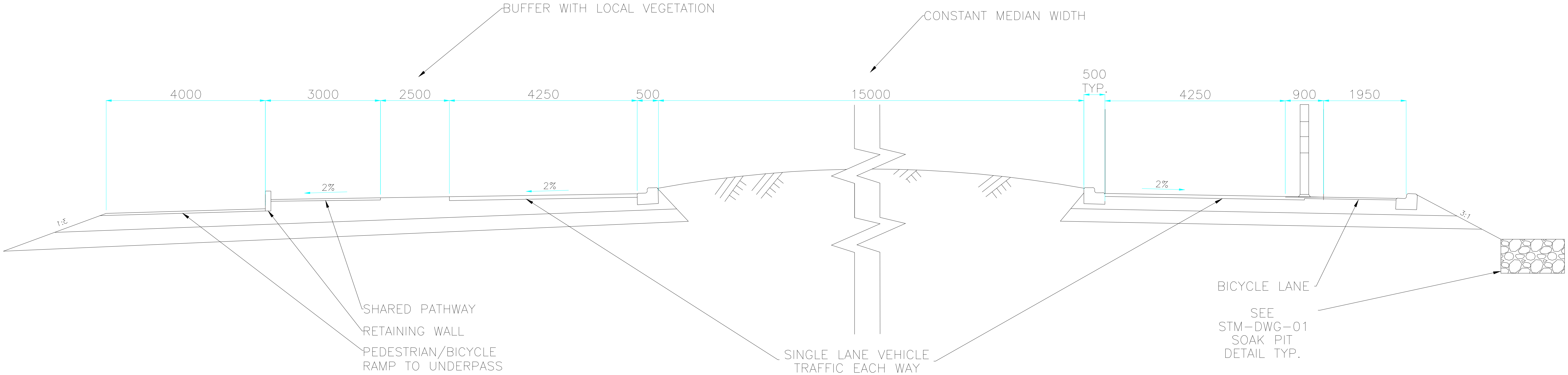
NOTE:

UBC ENDOWMENT LANDS
REDESIGN OF 16TH AVE /
SOUTHWEST MARINE DR INTERSECTION
UBC CAMPUS AND
COMMUNITY PLANNING

ROAD CROSS SECTIONS -
ROUNDABOUT AND SW MARINE
(SOUTH APPROACH)
ELEVATION

DES. C.C.	SCALE N/A
DR. A.S.	INT-DWG-12
DATE 12/5/23	A



SOUTHWEST MARINE DR – NORTH APPROACH
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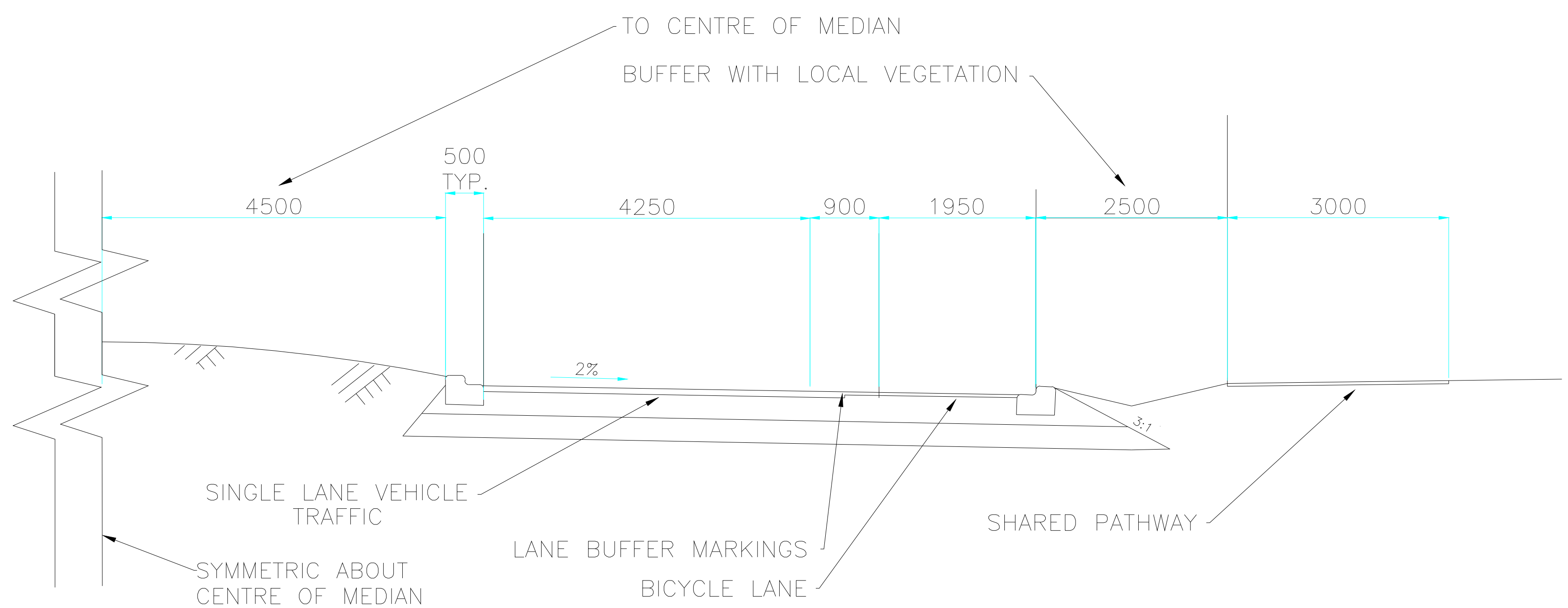

16TH AVENUE – EAST APPROACH
SCALE 1:100

ROCKY MOUNTAIN ENGINEERING CONSULTANTS LTD.	NOTE:	UBC ENDOWMENT LANDS REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION UBC CAMPUS AND COMMUNITY PLANNING	ROAD CROSS SECTIONS – SW MARINE (NORTH APPROACH) AND 16TH AVENUE ELEVATION	DES. C.C. DR. P.N. DATE 10/4/24 SCALE N/A INT–DWG–13 A

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NOTE:

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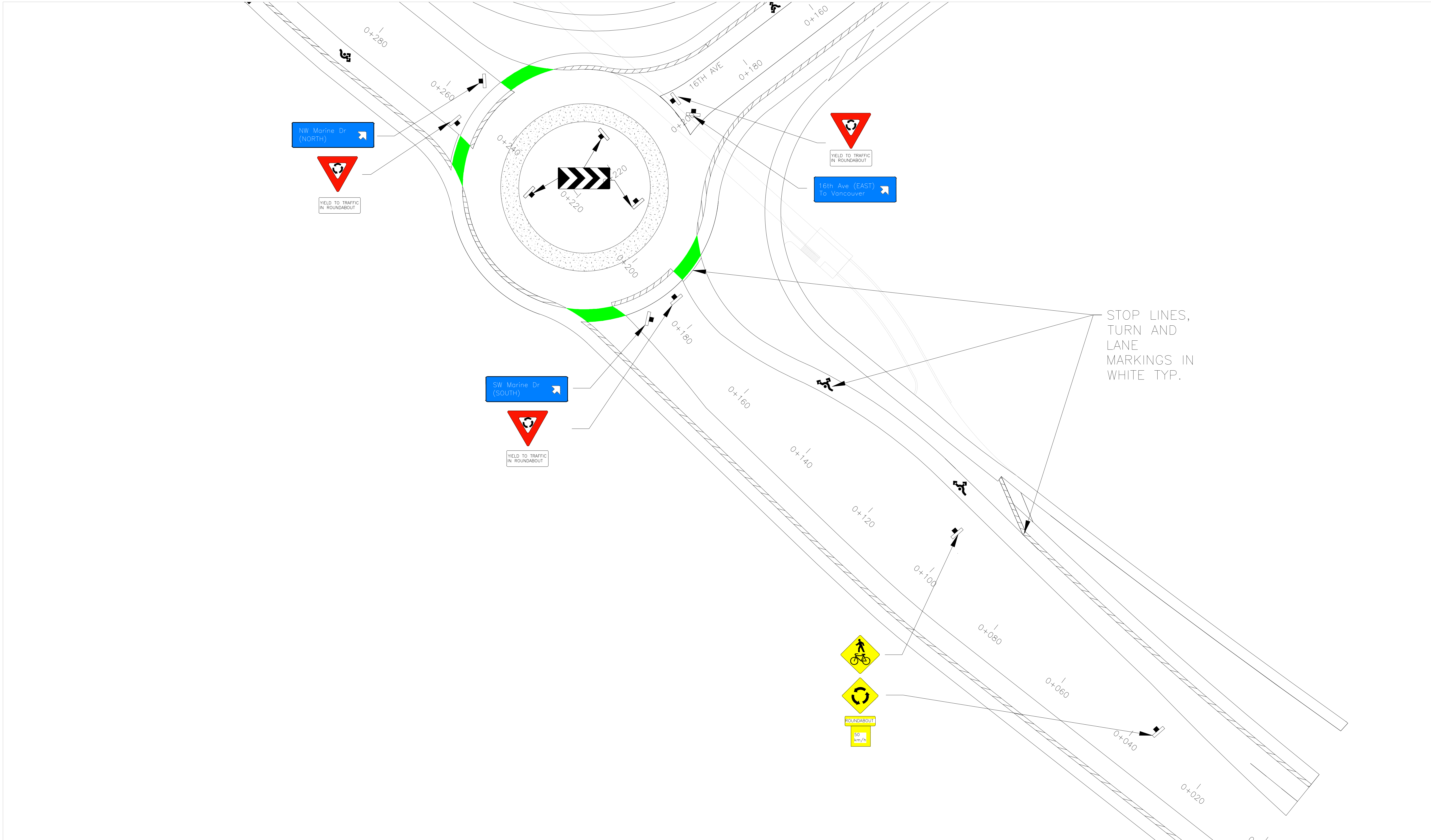
REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION
UBC CAMPUS AND COMMUNITY PLANNING

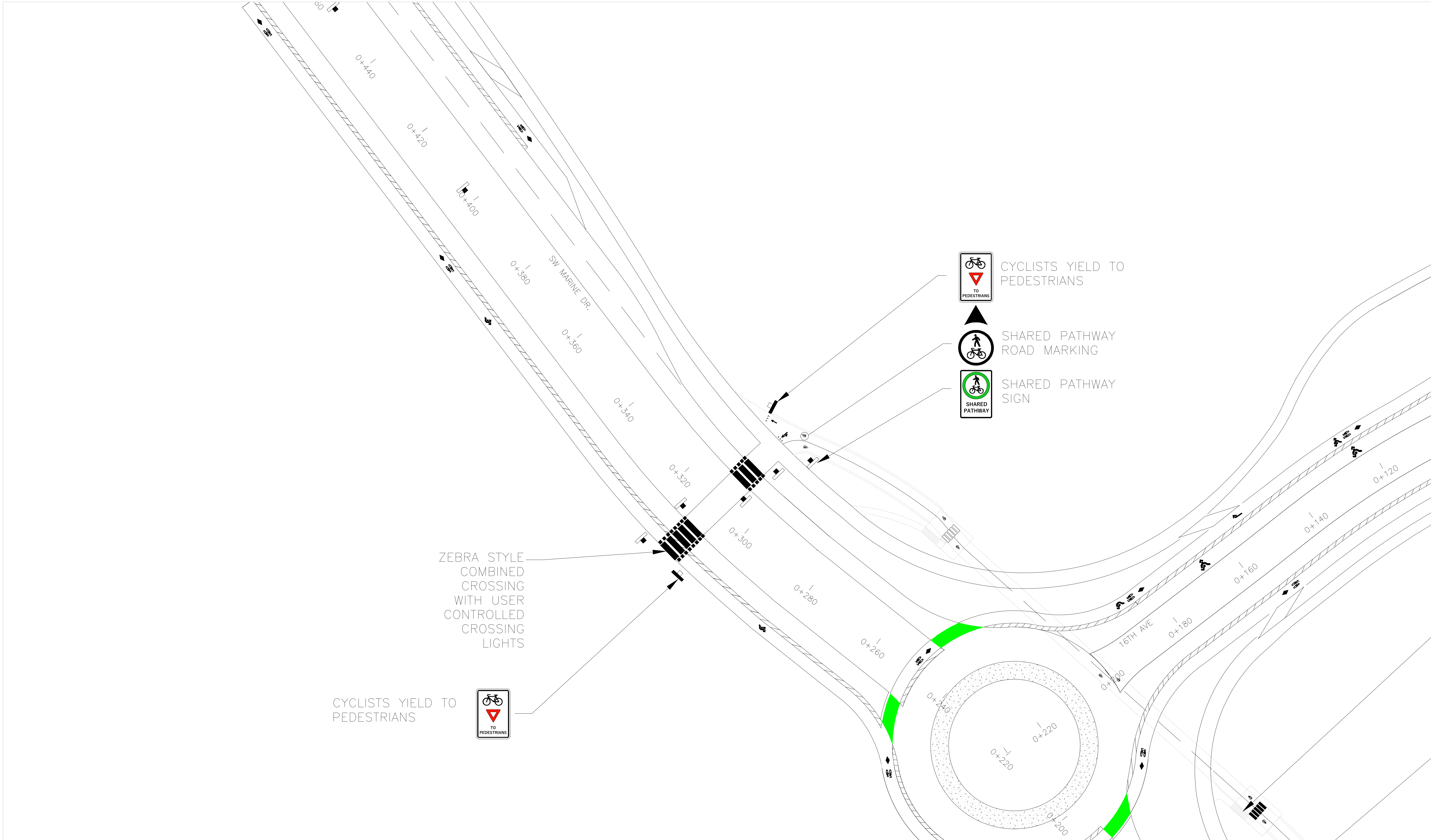
VEHICLE SIGNS/MARKINGS–NORTH

PLAN

DES. C.C.	SCALE 1:200
DR. P.N.	INT–DWG–14
DATE 10/4/24	A



ROCKY MOUNTAIN ENGINEERING CONSULTANTS LTD.	NOTE:	UBC ENDOWMENT LANDS REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION UBC CAMPUS AND COMMUNITY PLANNING	VEHICLE SIGNS/MARKINGS–SOUTH PLAN	DES. C.C. DR. P.N. DATE 10/4/24
				SCALE 1:200 INT–DWG–15 A



ROCKY MOUNTAIN
ENGINEERING CONSULTANTS LTD.

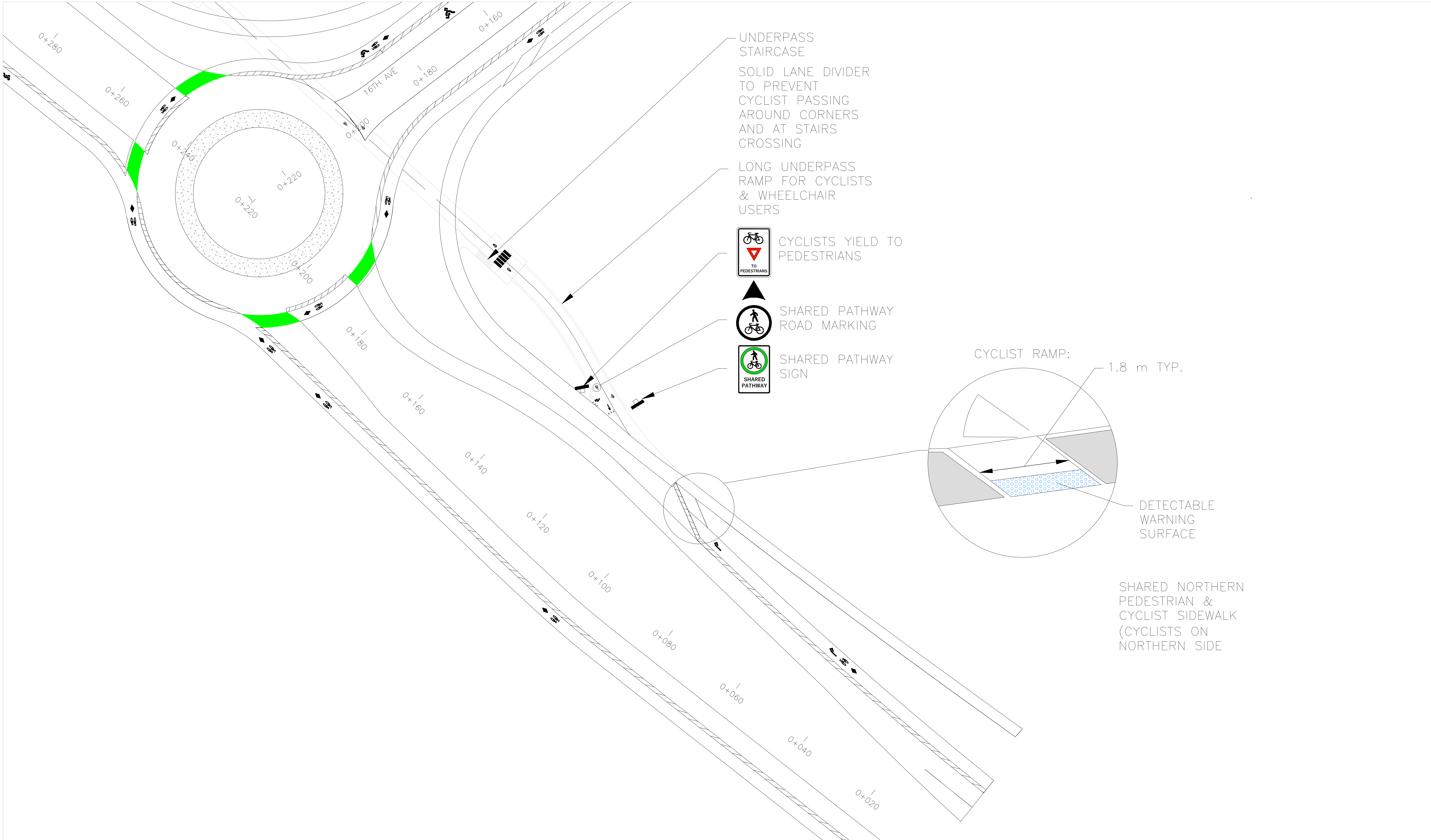
NOTE:

UBC ENDOWMENT LANDS
REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION
UBC CAMPUS AND COMMUNITY PLANNING

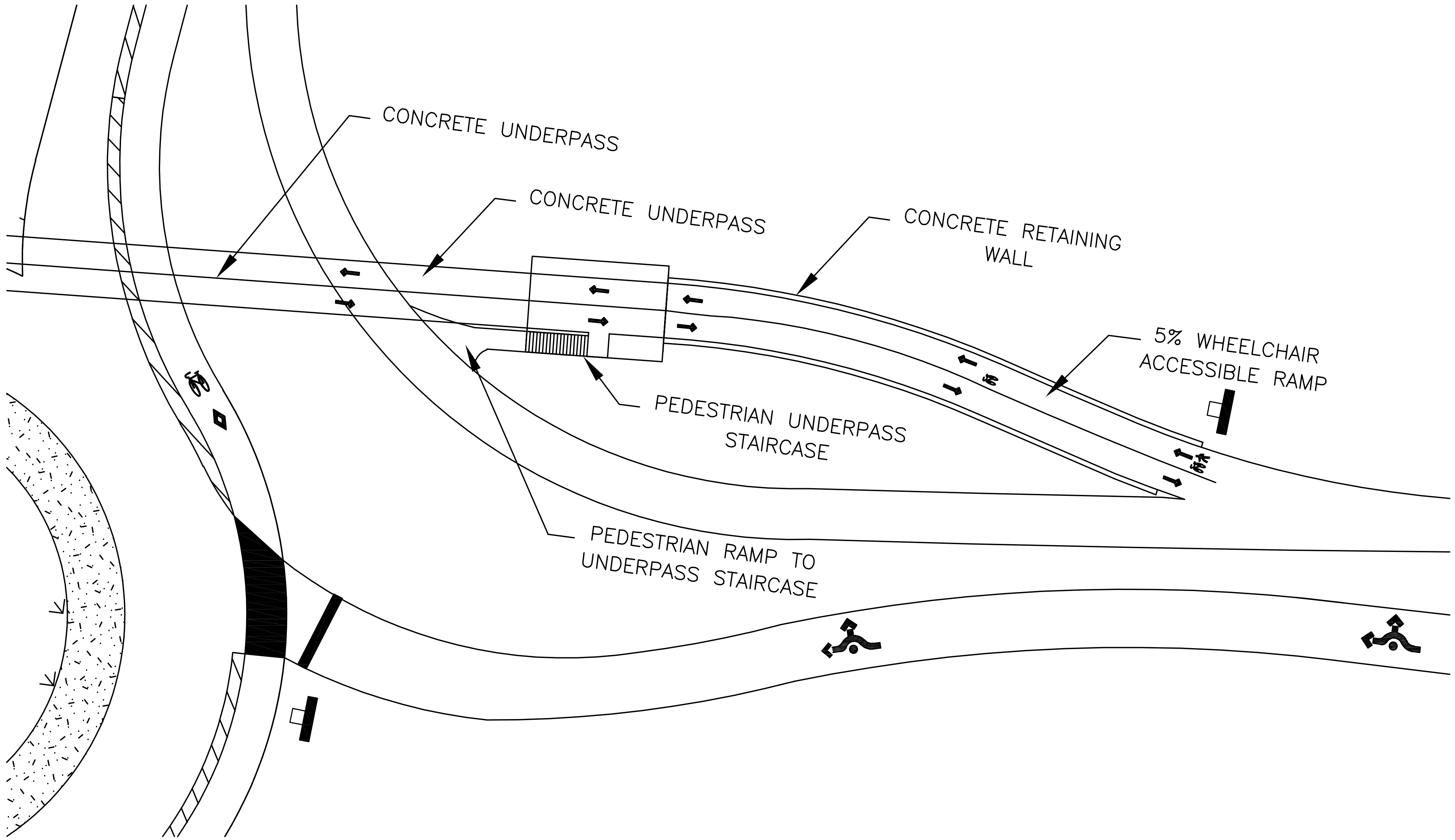
ACTIVE TRANSPORT SIGNS/MARKINGS–NORTH

PLAN

DES. C.C.	SCALE 1:200	
DR. P.N.	INT–DWG–16	
DATE 10/4/24		A



ROCKY MOUNTAIN ENGINEERING CONSULTANTS LTD.	NOTE:	UBC ENDOWMENT LANDS REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION UBC CAMPUS AND COMMUNITY PLANNING	ACTIVE TRANSPORT SIGNS/MARKINGS–SOUTH PLAN	DES. C.C. DR. P.N. DATE 10/4/24	SCALE 1:200 INT–DWG–17 A

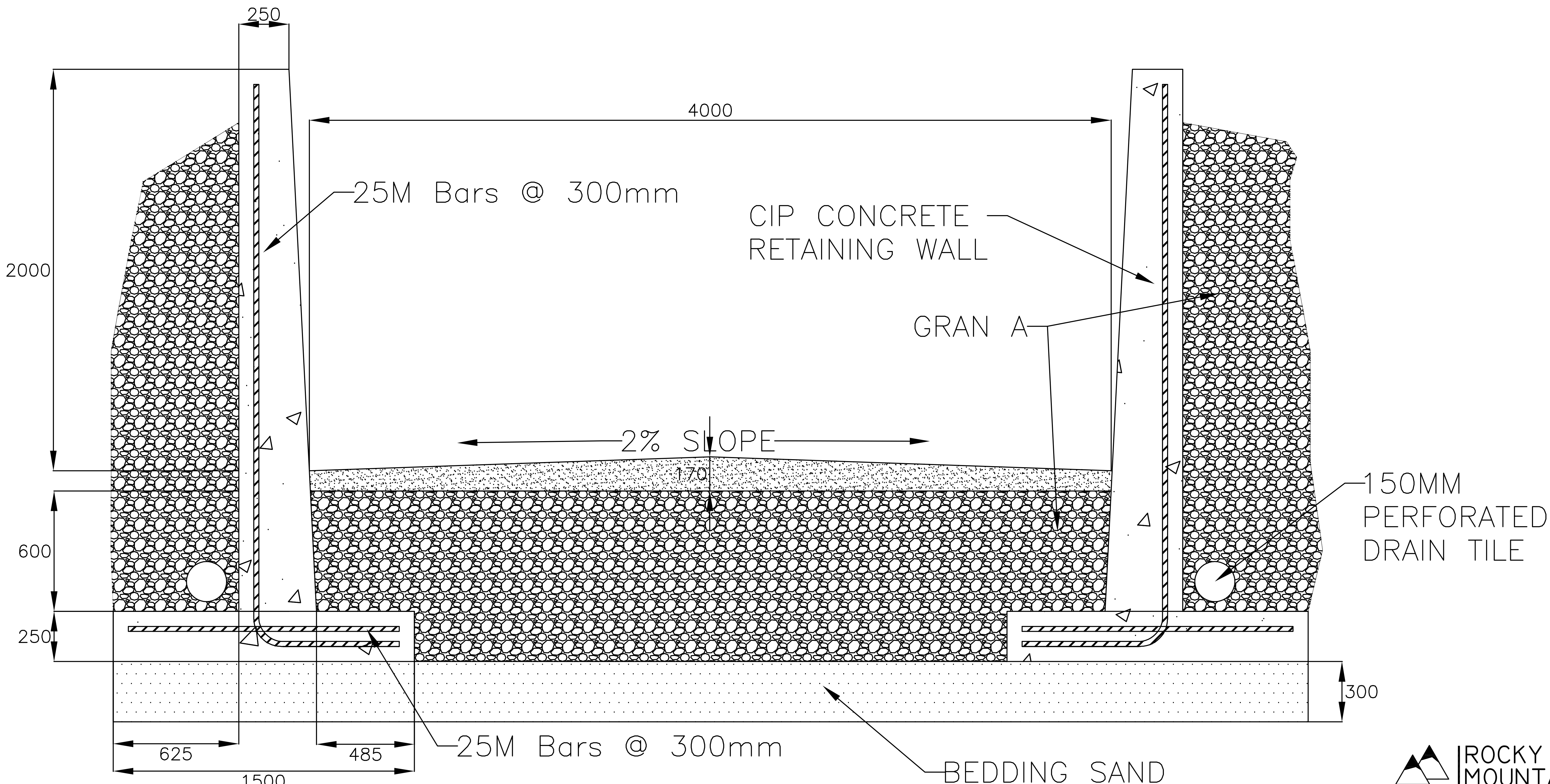


ROCKY MOUNTAIN
ENGINEERING CONSULTANTS LTD.

NOTE:

ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED

UBC ENDOWMENT LANDS REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION UBC CAMPUS AND COMMUNITY PLANNING	MIXED–USE UNDERPASS SOUTH END PLAN	DES. W.B. DR. B.Z. DATE 04/09/24	SCALE 1:100 UND–DWG–01 C

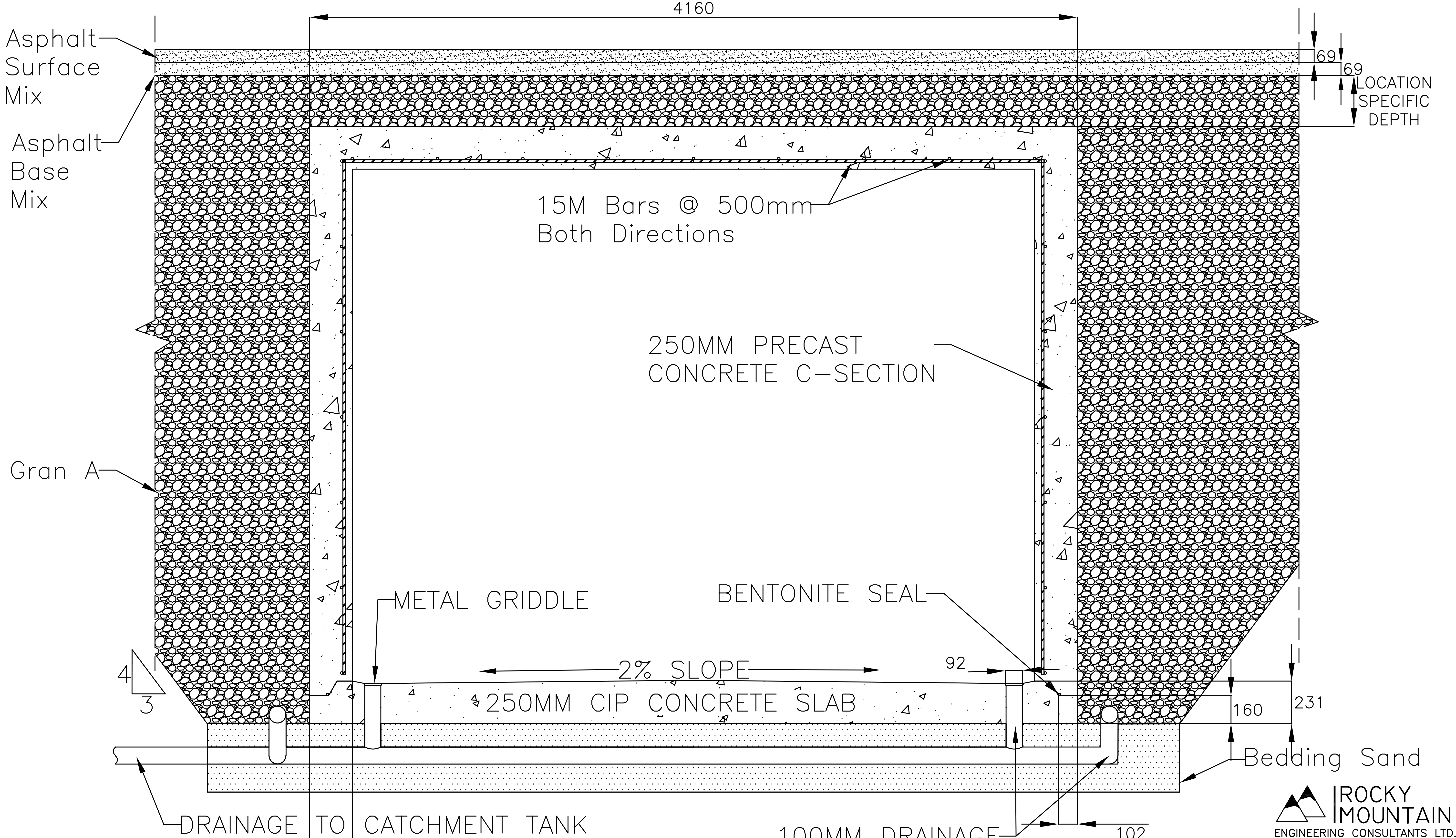


ROCKY MOUNTAIN
ENGINEERING CONSULTANTS LTD.

NOTE:

ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED
LEAVE NATIVE SOIL AROUND THE EXCAVATED AREA

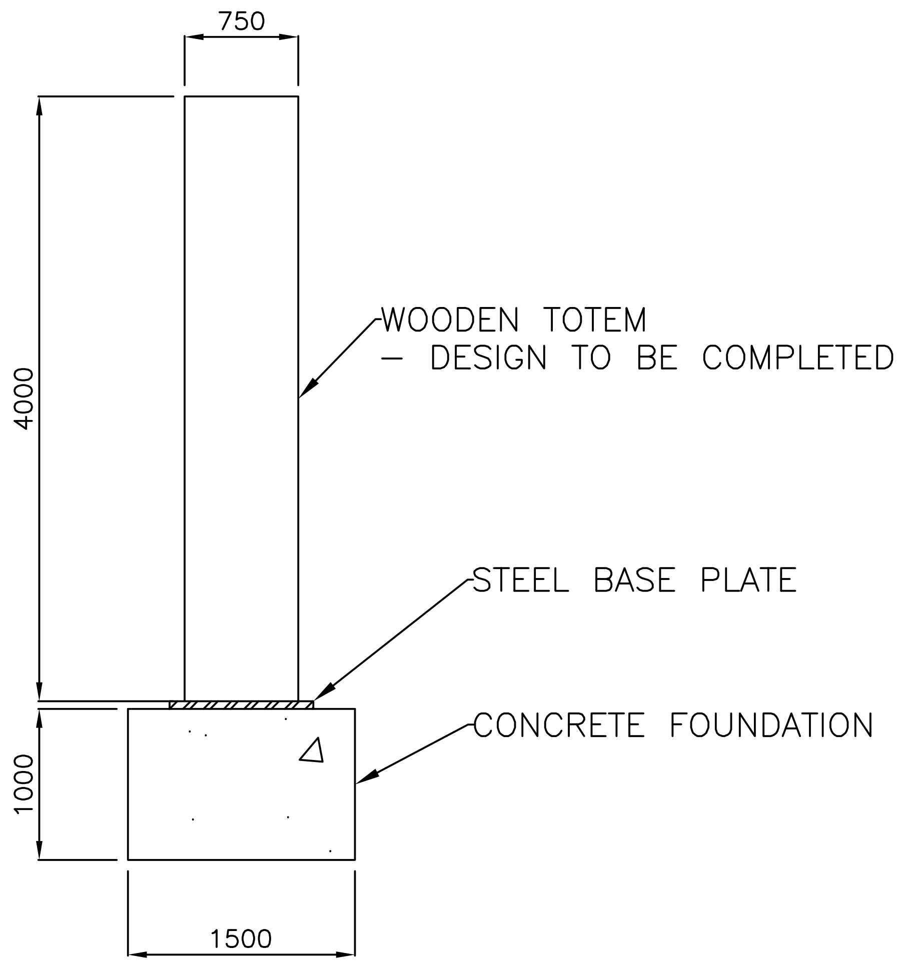
UBC ENDOWMENT LANDS REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION UBC CAMPUS AND COMMUNITY PLANNING	MIXED–USE UNDERPASS ENTRANCE RAMP SECTION	DES. W.B. DR. B.Z. DATE 04/09/24	SCALE 1:20 UND–DWG–02 C



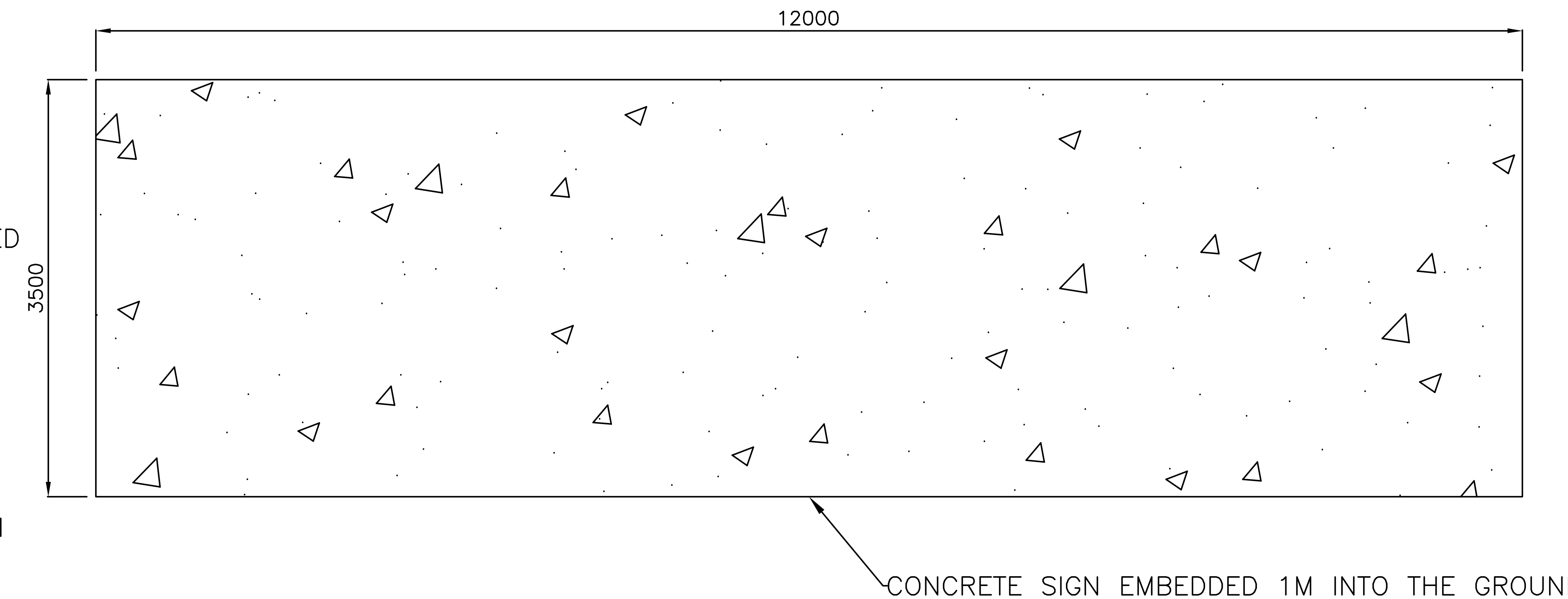
NOTE:

ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED

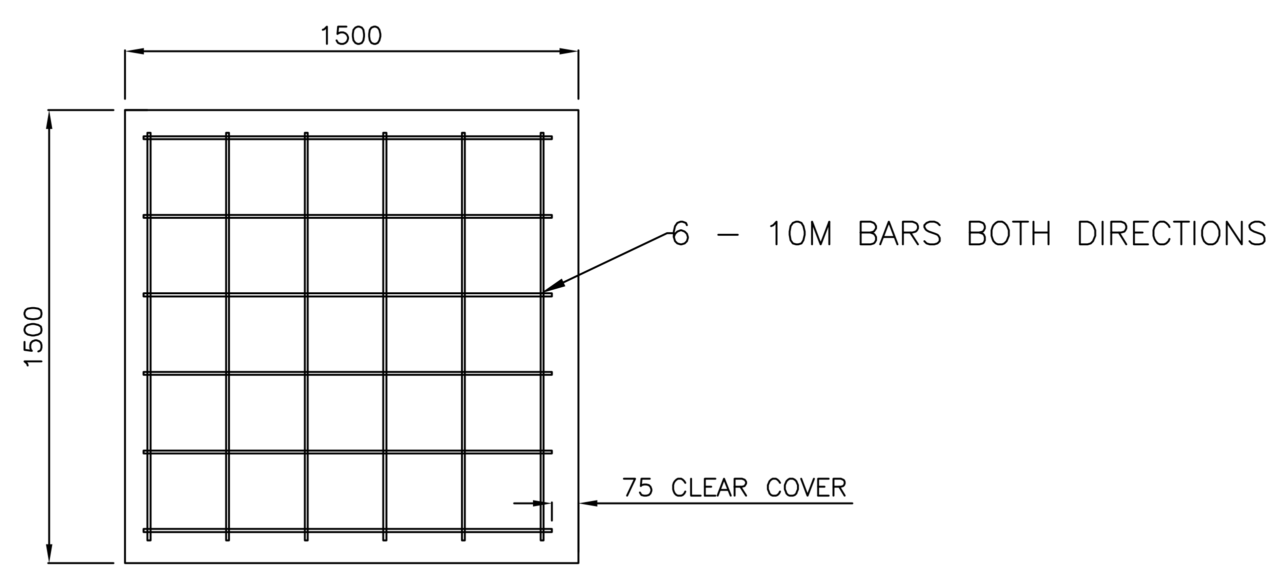
UBC ENDOWMENT LANDS REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION UBC CAMPUS AND COMMUNITY PLANNING	MIXED-USE UNDERPASS TYPICAL SECTION SECTION	DES. W.B.	SCALE 1:20
		DR. B.Z.	UND-DWG-03
		DATE 04/09/24	C



ENTRANCE TOTEMS – ELEVATION
SCALE 1:200



ENTRANCE SIGN – ELEVATION
SCALE 1:200



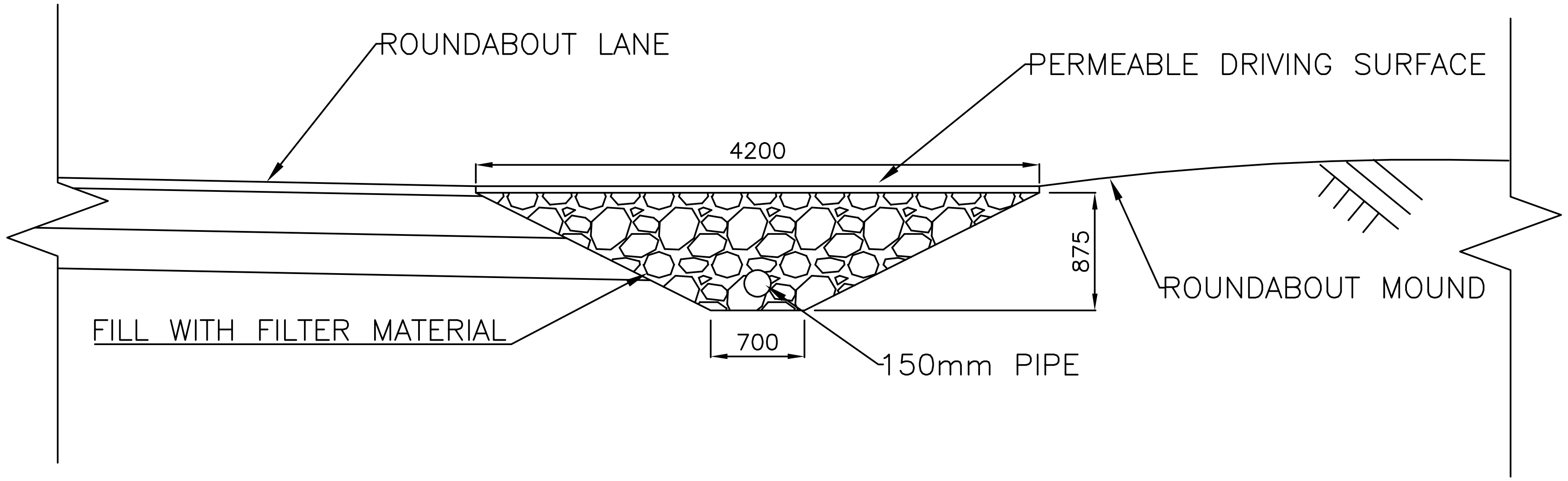
ENTRANCE TOTEM FOUNDATIONS – PLAN
SCALE 1:400

ROCKY MOUNTAIN
ENGINEERING CONSULTANTS LTD.

NOTE:

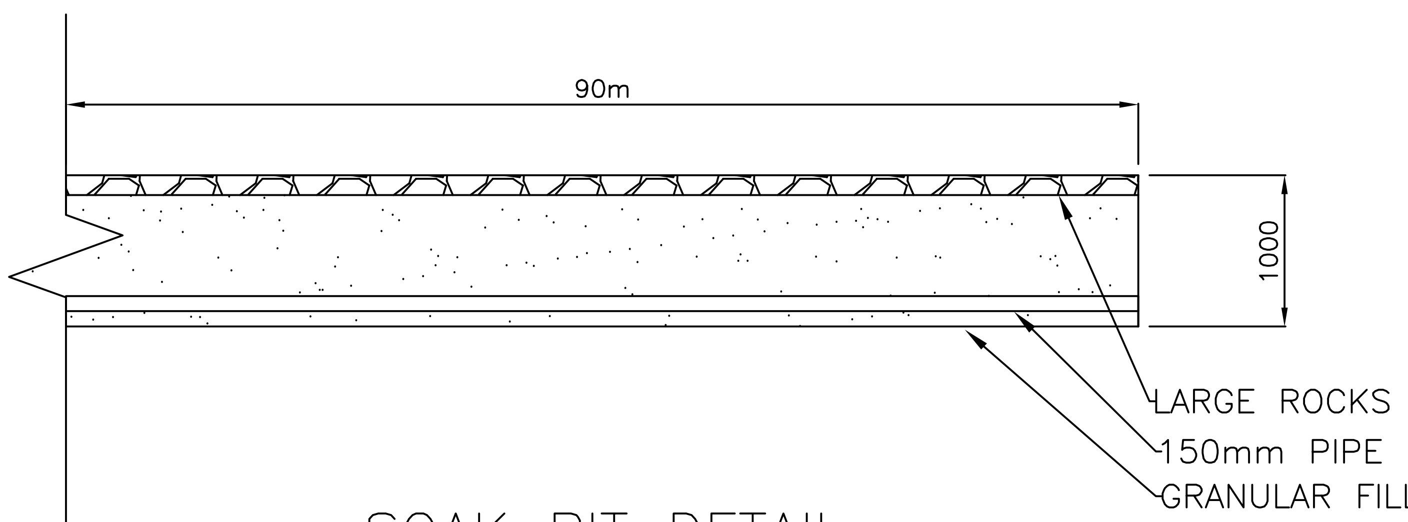
ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED

UBC ENDOWMENT LANDS REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION UBC CAMPUS AND COMMUNITY PLANNING	ENTRANCE SECTIONS AND DETAILS ELEVATION	DES. A.S. DR. A.S. DATE 4/7/24	SCALE NTS ENT–DWG–01 C



GRASSED SWALE DETAIL

SCALE 1:50



SOAK PIT DETAIL

SCALE 1:50

NOTE:

ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED

ROCKY MOUNTAIN
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UBC ENDOWMENT LANDS REDESIGN OF 16TH AVE / SOUTHWEST MARINE DR INTERSECTION UBC CAMPUS AND COMMUNITY PLANNING	STORMWATER MANAGEMENT DETAILS ELEVATION	DES. R.B.	SCALE 1:50
		DR. A.S.	STM-DWG-01
		DATE 04/07/24	C