UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Chancellor Blvd/ East Mall/ NW Marine Dr Intersection Redesign

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University of British Columbia

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Detailed Design Report

Chancellor Blvd/ East Mall/ NW Marine Dr Intersection Redesign

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EXECUTIVE SUMMARY

Red Fish Blue Fish Consulting (RB Consulting) was retained by UBC SEEDS to undertake the detailed design of the intersection at Chancellor Boulevard and East Mall. Expectations for the redesigned intersection included: improved safety and accessibility for all users, it would act as a gateway to UBC, accommodation of growth, and a focus on sustainability. It is assumed that the reader has access to past reports completed by RB Consulting related to this intersection. Enclosed are the final detailed drawings, along with all key information about the design.

The design consists of a single-lane roundabout with a separated bike lane, rain gardens in the medians for runoff catchment, and a glued laminated timber (glulam) Welcome Archway spanning the West entrance of Marine Drive. The consulting team has completed a detailed economic analysis of the project in order to provide a cost estimate of $1.1 million and an expected contractor schedule of two and a half months.

The angled orientation of the intersection will reduce vehicle speeds, and the probability of collisions by having fewer conflict points than the existing or possible signalized layouts. With a separated bike lane and simplified crosswalks, this intersection will encourage sustainable travel modes and also increase safety for those users. Emissions and noise will be reduced by the new intersection from minimal idle times, enhancing sustainability and the local community.

Furthermore, the footprint of the intersection reduces the overall impervious surface, while the rain gardens are designed to capture all of the remaining runoff from the intersection. Lastly, the Welcome Arch will highlight sustainability with locally-sourced, environmentally-friendly glulam material, and includes additional features that support the local animal habitat.

Prior construction at the intersection the following need to be provided to confirm design assumptions: geotechnical report, survey data, and exact underground utility locations.

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LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

The purpose of this report is to summarize the design components of the proposed single lane roundabout. The main components include a description of the geometry of the roundabout based on traffic analysis, stormwater management, the protected cycling path and gateway features. Each section includes design inputs, considerations and standards used. Lastly, a detailed cost estimate is provided. The following is a summary table indicating each member's contributions to the various tasks as relevant to the development of the report.

Table 1: Member Contributions

Section	Main Contributor	Secondary Contributor	Main Reviewer
Executive Summary	All	-	Sam
Introduction	Nicole	Lindsay	All
Key Components of Design	-	-	-
- Single Lane Roundabout	Curtis	-	Nicole
- Stormwater Management	Nicole	-	Jason
- Protected Cycling Path	Jason	-	Sam
- Structural Planning	Sam/Lindsay	Farin	Farin
Sustainability	Lindsay	-	Farin
Construction Phasing	Farin	Nicole	Curtis
Economic Analysis	Sam	Curtis	Lindsay
Standards & Software	As per sections	-	All
Appendices	As per sections	-	All

2.0 KEY COMPONENTS OF DESIGN

This section provides an in-depth description of the key design components, including a single lane roundabout, stormwater management through rain gardens, a protected cycling path, and structural planning of the glulam welcome archway. Figure 1 below visually outlines these key components.

Figure 1: Overview of Key Design Components

2.1. SINGLE LANE ROUNDABOUT

2.1.1. TRAFFIC VOLUMES

The traffic volume data from 2013 and 2014 was provided by Creative Transportation Solutions Ltd. (CTS). It details the mode of transportation, the approach and time for a very comprehensive breakdown of the existing traffic flow which include vehicle types, pedestrian and cyclist movements at the intersection. One of the drawbacks of the provided data is its lack of seasonal variation: both sets were taken during Fall.

Through technical analysis of these traffic volumes, the design team determined that the current intersection has a level of service B (LOS). The current speed limit for Chancellor Boulevard is 50 km/hr. The Traffic Volume Data and the LOS can be found in the Preliminary Design Report. Through further data analysis, both provided by CTS and collected during site visits, Red Fish

Blue Fish Consulting determined that the traffic presently is not in a saturated flow state. Therefore, when analyzing the preferred solution, the main concern is safety of users and not a question of serviceability with respect to volume.

The second drawback of the provided traffic information is the lack of data points. The client only provided two years, so the growth modelling was limited to a very rudimentary linear increase. It saw a 75% increase of heavy vehicle traffic, and a 25% decrease in vehicle traffic, totally a 1% increase in overall traffic.

2.1.2. GEOMETRY

As per MOTI specifications in order to accommodate the WB-20 vehicle type, the roundabout has an inscribed diameter of 37m. This inscribed diameter consists of two single lanes of 5.4m in width as well as a concrete apron to allow larger trucks to be able to mount and maneuver through the intersection with ease. Along with the sizing of the intersection, the roundabout entrances are angled to slow vehicles down further, promoting safety to all users within the intersection. See General Site Plan and Typical Cross Section – Roundabout in Appendix C for a detailed overview of the roundabout.

2.1.3. SIGNAGE

In order to ensure maximum safety for all of the users at the intersection, Red Fish Blue Fish Consulting examined the average stopping sight distance for a typical driver. From the calculations it was determined that the stop sight distance is to be 11.8m. This can be used to properly place signage and road markings so that users are aware of the manoeuvres they must execute in a safe manner. Calculations for this value can be found in Appendix B - Detailed Calculations.

The single lane roundabout utilizes proper signage standards as according to the Ministry of Transportation and Infrastructure's specifications. The signage and road markings can be seen in the Signage and Paving Plan in Appendix C.

2.1.4. GRADING

Re-grading of the intersection is required to ensure proper safety and drainage of the roundabout. Primarily having an intersection that has approaches which are level to each other promotes safety to all users in the roundabout. Secondly, re-grading will be required to ensure proper drainage of the intersection. Moreover, the changes that will be required for the intersection can be seen in the Surfacing Plan in Appendix C. It is important to note the current grading plan is subject to change because of the lack of current survey information.

The current design as per the preliminary data we have of the intersection will not affect any of the trees that are present currently. However, there is one location on the east side of the intersection that may be of concern of one medium sized tree. Further survey data will be required to know the exact location of that tree and the design may need to be altered to accommodate for it, as one of RB Consulting's core values is the environment.

2.1.5. MATERIALS

Keeping on track with the importance of creating a more sustainable campus, the primary material that will be used for the roadway will be reclaimed asphalt product (RAP) that will be provided by a local supplier. Red Fish Blue Fish examined the opportunity of using recycled asphalt for the intersection; moreover, from our findings it will not increase the project price by an extreme amount. As well it provides a sustainable method to resurfacing the intersection. However, the one draw back to the use of RAP is the potential increase in maintenance costs as future repaving will be more frequent.

2.2. STORMWATER MANAGEMENT

2.2.1. EXISTING CONDITIONS

The existing intersection does not employ any stormwater management practices. The intersection contains several catch basins, which drain the entire area to the stormwater main. This area is part of the North Catchment and the outfall is the Spiral Drain.

UBC is composed of a heterogeneous glacial till deposit, predominantly silt and Quadra sands. The soil at the intersection has been highly compacted from previous development and traffic, leading to nearly impervious compact till with minimal infiltration. It should also be noted that the intersection is near a sensitive cliff which cannot sustain any runoff.

Given these site conditions, it was decided that implementation of stormwater management was necessary. Rain gardens were chosen as the stormwater management system due to the limited space, aesthetic appeal, cost effectiveness and minimal maintenance required.

2.2.2. RAIN GARDEN DESIGN

Rain gardens are an aesthetically pleasing way to protect water quality by blocking point source pollution. The rain gardens are situated in all medians of the intersection, with a total of five locations. The gardens are to be composed of surface vegetation, topsoil, and followed by a layer of ¾" drain rock. A detailed cross section can be seen in the Typical Cross Section - Rain Garden in Appendix C.

The capture target, as per Metro Vancouver Stormwater Source Control Guidelines, is 72% of the 2-year, 24-hour rainfall depth. The drain rock depth was increased above the target to allow for additional capacity and to mitigate flow of the underdrain, which is situated at the top of the drain rock layer to allow for drainage without flooding the topsoil. In addition, an overflow lawn basin at a height of 0.10m above the rain garden invert is incorporated to allow for temporary ponding during high intensity storm events.

Curbs will be discontinuous and notched to allow flow into the basin. Following the curb shall be a transition buffer composed of gravel to keep water and sediment moving. For safety of pedestrians and cyclists the side slopes will be 5%.

2.2.3. SELECTED NATIVE SPECIES

The surface vegetation will increase infiltration rates, reduce erosion, promote biodiversity, and filter runoff. Native plant species were selected as per the Capital Regional District Guidelines. The rain gardens will consist of taper-tipped rush and dagger-leaf rush. These were chosen as per Zone 1 species for areas of periodic or frequent standing water and are able to tolerate the seasonally dry summers without extra watering. Both species are under 2 feet in height and will not impair the sight vision for the users of the intersection.

2.2.4. CONNECTION TO EXISTING INFRASTRUCTURE

In addition to the rain gardens, two catch basins are located on the NW and SE corners of the intersection in areas of potential pooling. See Drainage Plan in Appendix C. These catch basins, the underdrain and overflow lawn basin are to connect to the existing storm main at a sufficient slope to maintain a velocity of 1-3 m/s. As-built information for all existing underground infrastructure is required to produce profile drawings of these connections.

2.2.5. MAINTENANCE REQUIREMENTS

The curbs are to be cleaned regularly to prevent blockage of the notches and therefore potential flooding of the intersection. In addition, the rain gardens also allow for sediment accumulation storage; maintenance will also need to occur to remove excess sediments to prevent blockage of the overflow lawn basin.

2.3. PROTECTED CYCLING PATH

2.3.1. ADDITIONAL SAFETY BENEFITS

A bike lane around the perimeter of the roundabout is separated from both pedestrians and motor vehicles by a raised concrete median. At a width of 1.6m, and a 0.5m protective barrier, the bike lane follows relevant guidelines (see Section 6.0). When considering the cyclist infrastructure, a wide variety of options were considered, summarized by Figure 2.

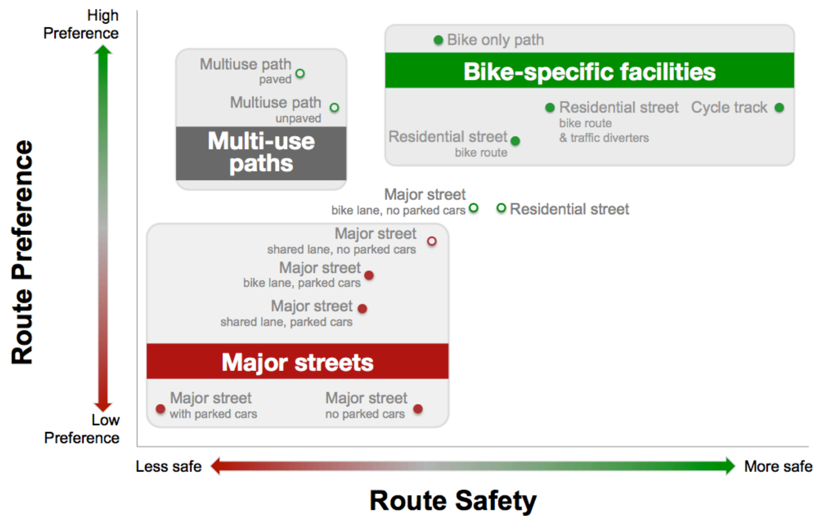

Figure 2: Cyclist Preferences

The decision to protect the cycling path was made based on the 2009 UBC BICE data where out of the 683 incidents observed, only 3% occurred on cyclist only paths, versus 23% on dedicated lanes, and 21% on shared lanes as seen in the table below. While preference is high for many options, perceived and actual safety can be different. For this reason, a cyclist only protected path was chosen.

Table 2: Path Use Statistics

Path Use	Collisions	%
Cyclist Only	23	3.4%
Dedicated Cyclist Lanes	158	23.1%
Shared Cyclist Lanes	147	21.5%
Undesignated	355	52.0%
Total	683	

2.3.2. MAINTENANCE REQUIREMENTS

A potential disadvantage of the protective curb could be an increase in maintenance cost through the restriction of larger street sweepers and an additional pass any street sweeper would need to make. However, the increase in maintenance cost will be fairly minimal as street sweepers are designed to navigate a variety of road widths and can accommodate the new narrow path. A contractor with a mixed fleet of street sweepers should be able to easily accommodate the 1.6m lane width. The only additional cost required is for the street sweeper to cover an additional 150m of road which is insignificant compared to the additional safety provided by the protective curb.

2.4. STRUCTURAL PLANNING

The glue-laminated timber (glulam) archway will be located at the West entrance to the intersection along Marine Drive, as can be seen on Drawing “General Site Plan” in Appendix D. It will have sufficient clearance to accommodate truck traffic (minimum 5.2 m height) and length to clear the road and sidewalks (minimum 19 m). The structure will be mainly constructed of prefabricated glulam timber, with steel connections and reinforced concrete spread footings. If proper maintenance measures are in place, the arch will have an estimated 30-year design life. This arch will act as an entranceway to the university and will include a number of enhancements to meet the sustainability objectives of UBC SEEDS, outlined in section 3.0 .

2.4.1. SUPERSTRUCTURE

The timber superstructure will be constructed from structural glulam, with detailed dimensions found in Appendix D – Welcome Arch Structural Drawings. The connection between the timber column and the horizontal member spanning over the roadway will be an internal knife plate, utilizing both self-tapping screws and standard structural bolts. The connection from the column to the footing will be achieved using structural bolts, and have the steel component embedded into the concrete footing. See structural drawings in Appendix D for the connection detail.

2.4.2. SUBSTRUCTURE

Shallow spread footings will be constructed to transfer axial tension, axial compression, moment support reactions, and lateral loads to the ground. In this case, the loads on the structure are low enough that deep foundation or piles are not warranted. The footings will be constructed well below the ground surface to account for overturning, and connected to the column base through concrete pedestals reinforced with 8-20M dowels. Based on information from surrounding projects, the soil was assumed to be silty sand, but should be tested prior to construction to confirm the bearing pressure. An overview of the footings can be found in the Table 3, (the complete footing detail can be found in Appendix D, and sample foundation calculations in Appendix B).

Table 3: Footing Specifications

Length (mm)	Width (mm)	Depth (mm)
1750	1300	400
Reinforcing (mm)		
15M@200 E/W TOP & BOT		

2.4.3. STRUCTURAL ANALYSIS

The codes, standards, and software used in the structural design of the arch members, connections, and foundations are listed in section 6.0 Standards and Software. Loads that were considered in the structural analysis of the arch were dead load, wind load, rain and snow loads, soil pressures, and earthquake loads Additionally, to account for the risk of vehicle collision, the columns are designed to ensure the structure will withstand the impact of a standard vehicle driving at the speed limit, (see Appendix B Sample Calculations – Structural Archway Loading).

2.4.4. MATERIALS AND MAINTENANCE REQUIREMENTS

The selected contractor will source the Douglas-Fir glulam from British Columbia timber materials. The outside of the timber glulam members will be coated with an approved Oil Bourne PCP Type C sealant to protect against moisture, rain, and other adverse weather effects. All steel components are to be galvanized to prevent corrosion.

As timber is susceptible to deterioration, a qualified engineer must perform periodic inspections to ensure the structural integrity of the arch is maintained. These inspections will cover all aspects of the structure, but will mainly focus on the connection points, which have the greatest chance of failure. Throughout the lifespan of the arch, the reapplication of the protective coating may be required since weathering can weaken its protection capabilities and lead to damage causing structural concern.

2.4.5.ARCH INSTALLATION

To ensure ease and efficiency of arch construction, the components will be installed in the following sequence:

- The footings will be poured during intersection regrading; the column base knife plates will be embedded into the footings, and will be protected during the remaining construction.
- The glulam and steel components will be prefabricated by the contractor offsite prior to construction; during prefabrication, knife plates will be attached to the beam at the column locations using self-tapping screws
- Following paving of the intersection, the three columns will be installed on top of the footings and bolted to the embedded knife plates
- The beam will be mounted onto the three columns by bolting the pre-installed knife plates to the columns. The final installation of the glulam members is expected to be completed over one evening.

3.0 SUSTAINABILITY

To align with the overall goals of UBC SEEDS, sustainability, community, and local culture were highly prioritized in the intersection design. RB consulting deliberately added features to the design that fully embody the aforementioned goals, outlined in the following sections.

3.1.1. METRICS

RB consulting performed extensive analysis to quantify the sustainability improvements of the intersection design, displayed in the figure below. See Appendix B for sample calculations for these sustainability metrics.

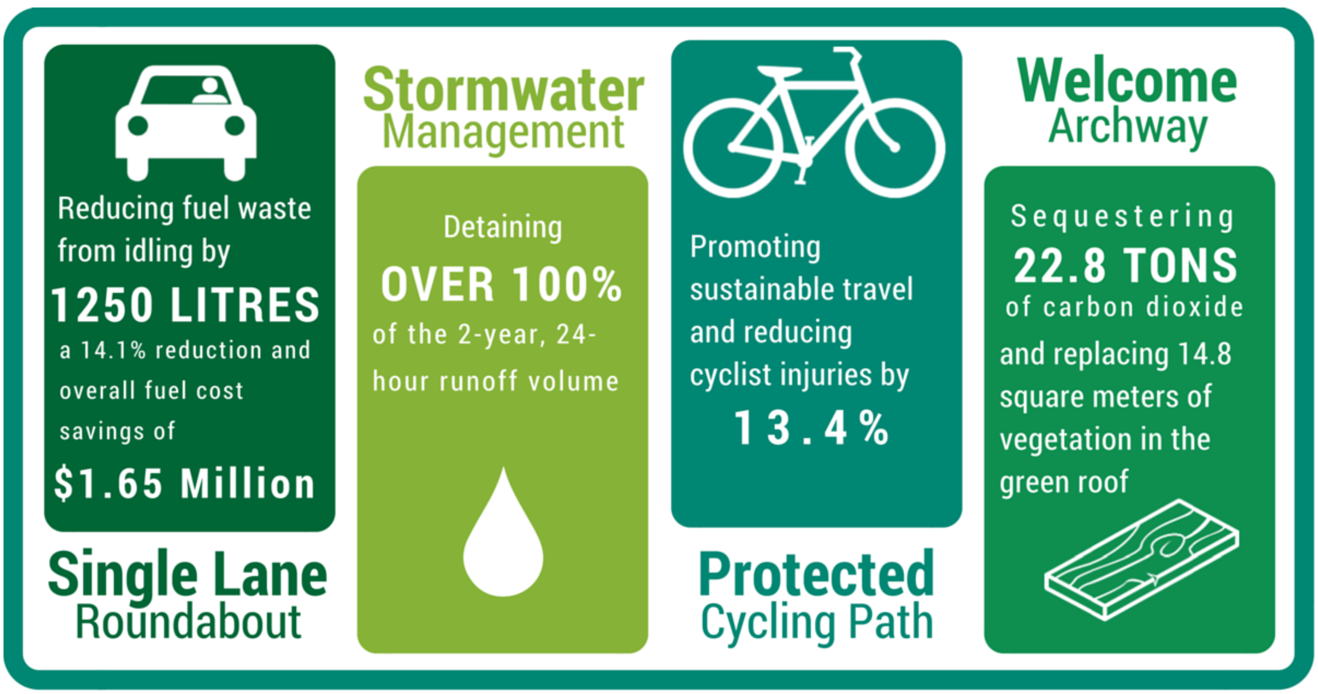

Figure 3: Sustainability Metrics

3.1.2. ARCHWAY ENHANCEMENTS

Atop the timber structure will be a green roof that will replace 14.8 m^2 of the vegetation that the road eliminates. The arch also includes a hanging I bird feeder to support local bird species, aligning with the Vancouver Bird Strategy 2020. Lastly, the arch will feature a “UBC” sign to serve as a gateway into the campus.

The green roof is recommended to be an extensive green roof constructed of Sedum Carpet, 3-4” of engineered growing media, a filter sheet, a drainage and water storage element, a water/nutrient storage mat, a root barrier, and a waterproof membrane. This type of green roof is the simplest to install and only requires maintenance checks once or twice annually. The bird feeders are recommended to be wire mesh as these are low-maintenance, easy to clean, and resistant to squirrel damage. See Figure 4 below for a visual summary of the sustainable enhancements. Table 4 outlines the suggested brands, suppliers, and costs for the sustainable materials (considered in the project’s overall cost estimate).

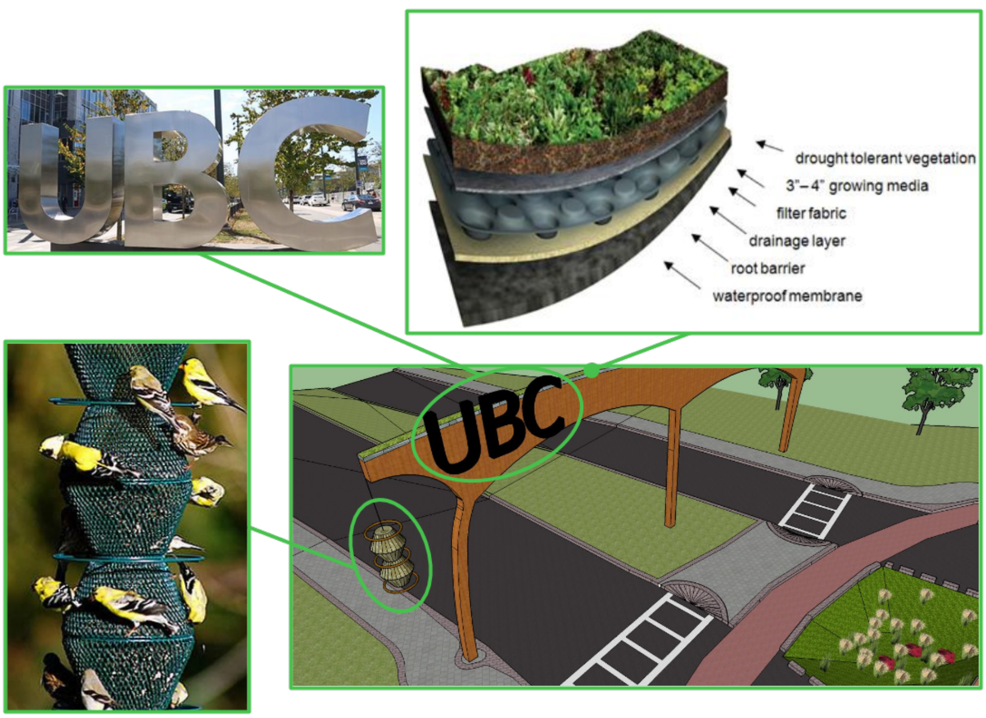

Figure 4: Sustainable Enhancements to Welcome Archway

Product	Suggested Type	Supplier	Cost
Bird Feeder	NO/NO® 5 Tier Forest Green Wild Bird Feeder	www.birdfeeders.com	$29.99 per unit
Green Roof	Sedum Carpet	ZinCo (product supplier) and ARCHITEK (product installer)	$13-$16 per ft^2 (including plants and installation)

Table 4: Sustainable Product Breakdown

4.0 CONSTRUCTION PHASING

Construction of the roundabout, rain gardens, arch and bike lane will occur simultaneously, in two phases to allow for traffic flow at all times. Implementation of traffic control will be required. Each phase will begin with removals and excavations. The intersection will then be re-graded to allow for adequate drainage and profile. At this time, the rain gardens will also be constructed and footings for the arch will be poured. Information on utility profiles is required as re-alignment may be necessary. In addition, a topography survey is necessary for determining exact tie in locations and cut and fill quantities. The curbs and gutter will then be poured and asphalt placed. The raised concrete median for the separated bike lane will be installed and road markings will be implemented. Upon completion of construction, landscaping of the rain gardens and inner circle will occur, as well as installation of signage and the final placement of the glulam arch sections. A depiction of the construction phasing can be seen below and a Gantt Chart of the construction schedule can be seen in Appendix E.

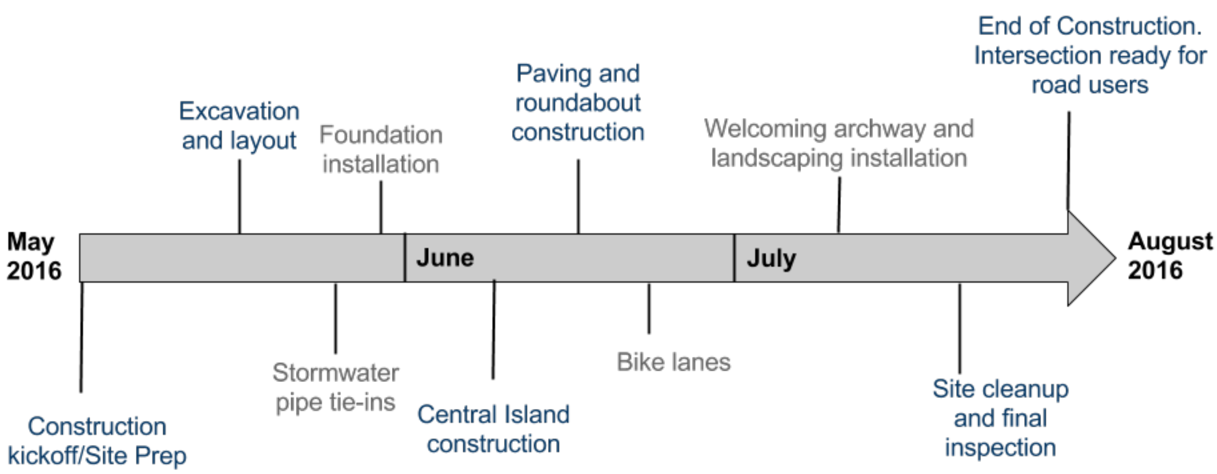

Figure 5: Construction Phasing

5.0 ECONOMIC ANALYSIS

RB Consulting took on a detailed cost estimate of the construction for the intersection and the welcome archway. All expected components of the project were included, as well as contingencies and engineering fees. The overall expected cost including all items of the project is $1.1 million. A high-level cost breakdown is shown in the table below, and detailed breakdown can be found in Appendix F.

Table 5: Cost Breakdown

Item	Estimated Cost
Site Prep	$130,000
Grading	$176,000
Paving & Concrete Works	$262,500
Landscaping	$7500
Welcome Archway	$55,000
Miscellaneous	$87,500
Contractor Profits/Overhead (20%)	$144,000
Engineering Costs (7.5%)	$65,000
Contingency (20%)	$172,500
Total	**$1.1 Million**

6.0 STANDARDS AND SOFTWARE

This table below summarizes the standards and software used in the analysis, design, and drafting of this project.

Table 6: Standards and Software Breakdown

	Standards	Software
Single-Lane Roundabout	• Transportation Association of Canada (TAC) – Geometric Design Guide for Canadian Roads (1999) • BC MOTI Supplement to TAC Geometric Guidelines (2007)	• Synchro Studio 2015 – SimTraffic 6
Protected Cycling Path	• Transportation Association of Canada (TAC) – Geometric Design Guide for Canadian Roads (1999) • Capital Regional District Pedestrian & Cycling Master Plan	• Synchro Studio 2015 – SimTraffic 6
Stormwater Management	• Metro Vancouver Stormwater Source Control Guidelines (2012) • Capital Regional District Rain Gardens Guidelines	• Microsoft Excel 2016
Structural Planning	• National Building Code of Canada (2015) • British Columbia Building Code (2012) • CAN/CSA-A23.3-04 (R2010) - Design of Concrete Structures • CAN/CSA-S16-09 (R2014) - Design of Steel Structures (10th Ed.) • CAN/CSA-O86-09 – Engineered Design in Wood • CWC Wood Design Manual • Soil Mechanics in Engineering Practice (2nd Ed.) – for foundation calculations	• S-Frame Analysis Software – Structural Analysis and Design • Microsoft Excel 2016
Drawings & Drafting	-	• Google SketchUp 2015 • Autodesk AutoCAD 2015 • AutoDesk Inventor 2015

APPENDIX A – REFERENCES

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Wood Design Manual (2010). Ottawa, ON, Canada: Canadian Wood Council.

APPENDIX B - SAMPLE CALCULATIONS

STOP SIGHT DISTANCE

$$d := \frac{V^2}{2\,g \cdot f} \cdot \frac{1000^2}{3600^2} \qquad V := 50 \cdot \frac{km}{hr} \qquad f := .35 \qquad t := 2.5 \cdot s$$

$$SSD := 0.278 \cdot V \cdot t + d \qquad SSD = 11.821\ m$$

Maximum Road Operating Speed (km/h)	Coefficient of Friction (f)
30	0.40
40	0.38
47 - 50	0.35
55 - 60	0.33
63 - 70	0.31
70 - 80	0.30
77 - 90	0.30
85 - 100	0.29
91 - 110	0.28
98 - 120	0.28

IDLE WAIT TIME

Average wait time through existing intersection: 6.4 seconds
Average wait time through one lane roundabout: 5.5 seconds
Average cost of fuel in Vancouver in 2014: 1.316 $/L
Fuel burned per second of idle time: 0.5 mL/s
Number of vehicles through intersection over a work day: 5,000

	Wait per vehicle	Idle peak hour workday time over 15 year design life (hrs)	Wasted Fuel (mL)	Cost of wasted Fuel ($)
Idle time in Existing	6.4	4,952	8,914,286	$11,731,200
Idle TIme in Roundabout	5.5	4,256	7,660,714	$10,081,500
Difference	0.9	696	1,253,571	$1,649,700
% Difference	14.1%	14.1%	14.1%	14.1%

STORMWATER MANAGEMENT

Description	Classification	Units	Source
Soil Composition	Till	-	from GeoMap Vancouver
Soil Type	Silt	-	from GeoTech report
Infiltration Rate	1.6	mm/hr	from Stormwater Plenary - for glacial till

CURRENT DESIGN		
Total Catchment Area	3,140	m2
C	0.90	-
Storm Event	1 in 2	year
Duration	24	hr
Rainfall Depth	54.50	mm
Rainfall Volume	171.13	m3
Runoff Volume	154.02	m3

PROPOSED DESIGN		
Total Catchment Area	3,110	m2
C	0.90	-
Storm Event	1 in 2	year
Duration	24	hr
Rainfall Depth (72%)	39.24	mm
Rainfall Volume	122.04	m3
Runoff Volume	109.83	m3
Area of Medians	310.00	m2
Height of Ponding	0.10	m
Ponding Detention	31.00	m3
Depth of Drain Rock	1.00	m
Volume of Drain Rock	310.00	m3
Void Ratio of Drain Rock	0.40	-
Drain Rock Detention	124.00	m3
Infiltration Detention	11.90	m3
Total Detention Volume	166.90	m3

STRUCTURAL ARCHWAY LOADING

Item	Value	Units	NBCC Clause
Width	750	mm	
Average Beam Height	1250	mm	
Topsoil Depth	101.6	mm	
Average Arch Height	6000	mm	
Column Cross Section	225000	mm^2	
Length	20	m	
Topsoil Unit Weight	14.112	kN/m^3	
Topsoil Dead Load	1.0753344	kN/m	
Wood Unit Weight	4	kN/m^3	
Wood Dead Load	3.75	kN/m	
Rain/Snow Load	IS(SS(CbCwCsCa)+Sr)		4.1.6.2.1
IS	0.8		4.1.6.2.1
Cb	0.75		4.1.6.2.2
Cw	0.75		4.1.6.2.2
Cs	1		4.1.6.2.5
Ca	1		4.1.6.2.8
Ss	1.8		Appendix C, Table C-2
Sr	0.2		Appendix C, Table C-2
Rain/Snow Load	0.97	kPa	
Rain/Snow Load per Meter	0.7275	kPa	
Wind Load	IwqCeCgCp		4.1.7.1.1
Iw	0.8		4.1.7.1.1
q	0.45	kPa	Appendix C, Table C-2
Ce	h/10*0.2 > 0.9		4.1.7.1.5
Ce	0.9		
Cg	2.5		4.1.7.1.6.b
Cp - Front	0.75		4.1.7.1.1
Cp - Back	0.45		4.1.7.1.1
Wind Load	0.972	kPa	
Wind Load per Meter	1.215	kN/m	
Earthquake Load	S(2.0)MvIEW/(RDRO) < V		
	2/3*S(0.2)IEW/(RDRO) > V	if RD >= 1.5	
	S(Ta)MvIEW/(RDRO) = V		
IE	0.8		4.1.8.5.1
Mv	1		4.1.8.11
Weight (W)	79.275	kN	
Ta	0.05(H)*3/4		
Ta	0.225		
Sa(0.2)	0.94		Appendix C, Table C-2
Fa (Class D)	1.1		4.1.8.4.b
S(Ta)=FaSa(0.2)	1.034		
RD	2		4.1.8.4.b
RO	1.5		4.1.8.4.b
Earthquake Load per Meter	0.728625333	kN/m	

FOOTING CALCULATIONS

Input

Allowable bearing at Ultimate	=	1.6	ksf.	
Allowable bearing at Service	=	1.6	ksf.	
Design concrete strength	=	25	MPa	
Total footing depth	=	15	in.	
Footing width	=	4.225	ft.	
Footing length	=	5.74	ft.	
Column width	=	11.81	in.	
Column Length	=	29.5	in.	

Output

Footing ultimate load capacity	=	38.8	kips	=W*L*Fb_Ultimate
Footing service load capacity	=	38.8	kips	=W*L*Fb_Service
Effective depth	=	11.0	in.	=D-4
Effective shear depth	=	11.0	in.	=MAX(eff_d*0.9,0.73*D)
Long col dim / Short col dim	=	2.5		=Lc/Wc
Beam shear capacity	=	13.0	kips/ft.	=0.21*MIN(SQRT(Fc),8)*0.65*dv*25.4*12*25.4*0.0002248
Factored beam shear - across width	=	1.1	kips/ft.	=(+Over_w-dv/12)*Fb_Ultimate
Factored beam shear - across length	=	1.2	kips/ft.	=(+Over_l-dv/12)*Fb_Ultimate
Footing overhang - width direction	=	1.6	ft.	=(+W-(Wc/12))/2
Footing overhang - length direction	=	1.6	ft.	=(+L-(Lc/12))/2
Factored moment - width direction	=	2.1	k-ft/ft.	=Fb_Ultimate*((W-Wc/12)/2)^2/2
Factored moment - length direction	=	2.2	k-ft/ft.	=Fb_Ultimate*((L-Lc/12)/2)^2/2
Reinforcing required for Mfw	=	0.05	in2/ft.	
Reinforcing required for Mfl	=	0.05	in2/ft.	
Reinforcing required - width direction	=	2.07	in2	
Reinforcing required - length direction	=	1.52	in2	

SELF-TAPPING SCREW CALCULATIONS

Number of Screws (n)	12		(in both directions for shear)
Mean Wood Density (ρmean)	490	(kg/m^3)	
Embedment Length (lef)	200	mm	(without tip)
Outer Screw Diameter (d)	10	mm	
Angle to Longitudinal (α)	45		(must be greater than 30)
Φ	0.9		
ρk	411.6		=0.84*ρmean
faxk	11.9531		=0.52*d^-0.5*lef^-0.1*ρk^0.8
effective number of screws (nef)	9.359726		=n^0.9
Fax	183072.7		=Φ*nef*faxk*d*lef/(sin(α)^2+1.2*cos(α)^2)
Restistance F (in direction of shear)	129.4519	kN	=Fax*cos(α)
Required shear (either direction)	56	kN	
Need a total of 24 screws, 12 facing each side of member			

BOLTED PIN CONNECTION CALCULATIONS

	Axial Load (P)	140	kN	
	Shear Load (V)	45	kN	
	Loading Angle to Grain (θ)	17.8189		
	Applied Load	147.054	kN	
Table A.10.1	Wood Mean Relative Density (G)	0.49		
10.4.4.3.3.1	Wood Embedment Strength (fip)	18.277		=50*G*(1-0.01*df)
10.4.4.3.3.1	Wood Embedment Strength (fiq)	8.04188		=22*G*(1-0.01*df)
10.2.1.5	Service Condition Factor (Ksf)	0.67		
4.3.2	Load Duration Factor (Kd)	1		
10.2.1.7	Treatment Factor (Kt)	1		
10.4.4.3.3.1	Embedment Strength for Applied Angle	10.9416	MPa	=fip*fiq/(fip*sin(θ)^2+fiq*cos(θ)^2)*Kd*Ksf*Kt
	Fastener Diameter (df)	25.4	mm	
10.4.4.3.3.3	Fastener Yield Strength (Fy)	310	MPa	
	Number of Fasteners (nf)	16		
	Inner Plate Ultimate Strength (Fu)	450	MPa	

10.4.4.3.3.2	Φsteel	0.67		
10.4.4.3.3.2	Φy	0.8		
10.4.4.3.3.2	Embedment Strength of Steel Plate	1130.63	MPa	=3*Fu*Φsteel/Φy
	Is Inner Plate Steel or Wood?	Steel	(Select either steel or wood)	
	Embedment Strength of Side Member (F1)	10.9416	MPa	
	Embedment Strength of Inner Member (F2)	1130.63	MPa	
	Thickness of Side (Outer) Member (t1)	72	mm	(per side of outer shear plane)
	Thickness of Inner Member(s) (t2)	6	mm	
	Number of Shear Planes (ns)	4		
10.4.4.3.2	Unit Lateral Yielding Resistance (nu)	min of:	kN	
	a	20.0099		
	b			
	c	86.1536		
	d	19.2678		
	e			
	f			
	g	30.5317		
10.4.4.3.1	Factored Yielding Resistance	986.514	kN	=Φy*nu*ns*nf
	Note: Group Tear Out and Row Shear Not Checked (in Compression)			
	Can use a minimum of 3			

BOLTED MOMENT CONNECTION CALCULATIONS

Forces acting on bolt group			
Factored Bending Moment Force (Mf) =	242	kNm	
Factore Shear Force (Vf) =	45	kN	
Factored Compression Force (Pf) =	140	kN	
Shear Force per Bolt (Vfi) =	1.5	kN/bolt	
Compression Force per Bolt (Pfi) =	4.67	kN/bolt	
Input properties (checking 30 bolts with 2 knife plates)			
Bolt diameter (dF) =	25.4	mm	

Member width (w) =	750	mm	
Effective Wood thickness (t_1) =	72	mm	
Knife Plate Thickness (t_2) =	6	mm	
Row Spacing of Bolt Group (SR) =	139.2	mm	
Column Spacing of Bolt Group (SC) =	99.6	mm	
Edge distance (ep) =	49.8	mm	
End distance (aL) =	127	mm	
Number of Bolt Rows (nR) =	6		
Number of Bolt Columns (nC) =	5		
Total Number of Bolts (nf) =	30		
Number of Shear Planes (ns) =	4		
Calculation of applied force and resistance for upper left bolt			
Horizontal Distance from Bolt Group Center (xi) =	-312.5	mm	
Vertical Distance from Bolt Group Center (yi) =	329.2	mm	
Radius Squared from Bolt Group Center (ri) =	206028.89	mm^2	=xi^2+yi^2
Total Polar Moment of Intertia (I_p) =	2992777.1	mm^2	=sum(r1^2,r2^2,r3^2…r30^2)
Horizontal Applied Force on Bolt (Nxj) =	28.1	kN	=Mf*xi/I_p*10^3+Vfi
Vertical Applied Force on Bolt (Nyj) =	-20.6	kN	=Mf*yi/I_p*10^3+Pfi
Resultant Applied Force on Bolt (Nj) =	34.86	kN	=SQRT(Nxj^2+Nyj^2)
Angle of Applied Forece on Bolt (Theta) =	-36.2	degrees	=ATAN(Nyj/Nxj)*180/PI()
Cl. 10.4.4.3 Embedment Strength of Bolt at Angle Theta (fi_theta) =	8.5	MPa	=(fiP*fiQ)/(fiP*(SIN(Theta*PI()/180))^2 +fiQ*(COS(Theta*PI()/180))^2)*(KD*KSF*KT)
Cl. 10.4.4.3 Embedment Strength of Steel Plate (fi_2) =	1130.6	MPa	=3*fu*phi_steel/phi_y
Cl. 10.4.4.3 Resistance of Bolt (Nr) =	49.61	kN	=phi_y*ns*MIN(fi_theta*dF*t_1/1000, 0.5*f_2*dF*t_2/1000, (fi_theta*dF^2*(SQRT(1/6*f_2/(fi_theta+ f_2)*fy/fi_theta)+1/5*t_1/dF))/1000, (fi_theta*dF^2*SQRT(2/3*f_2/(fi_theta+ f_2)*fy/fi_theta))/1000)
Nr > Nj?	YES		
(Calculations repeated for all bolts and Nr > Nj for 30 bolts)			

BEAM CALCULATIONS

	Mfx	87.1	kNm	
	Mfy	32.8	kNm	
	V	56	kN	
	Width (b)	750	mm	
	Height (h)	1500	mm	
	Unsupported Length (L)	9425	mm	
Table 6.3	fb	30.6	MPa	
Table 6.3	fv	2	MPa	
6.4.1	Kd	1		
6.4.3	Kh	1		
6.4.2	Ksb	0.8		
6.4.2	Ksv	0.87		
6.4.4	Kt	1		
6.5.6.5.1	Fb	24.48		=fb*Kd*Kh*Ksb*Kt
6.5.6.5.1	Φ	0.9		
	Lamination Thickness (t)	38.1	mm	
	Lamination Width (B)	228.6	mm	
	Radius of Curvature	9500	mm	
6.5.6.5.2	Kx	0.96783136		=1-2000*(t/R)^2
6.5.6.5.1	Kzbg	0.74616154		=1.03*(B*L)^-.18
6.5.6.4.3	Slenderness Ratio	6.94665387		
6.5.6.4.4	Kl	1		
	Sx	281250000	mm^3	=bh^2/6
	Sy	140625000	mm^3	=hb^2/6
6.5.6.5.1	Mrx	4474.85536	kNm	=min(ΦFbSxKxKzbg,ΦFbSxKxKl)
6.5.6.5.1	Mry	2237.42768	kNm	=min(ΦFbSyKxKzbg,ΦFbSyKxKl)
	Combined Bending	OK		=Mfx/Mrx+Mfy/Mry<=1
6.5.7.2.1	Fv	1.74		=fv*Kd*Kh*Ksv*Kt
	Gross Area (Ag)	1125000	mm^2	
6.5.7.2.2	Kn	1		
6.5.7.3	Shear Load Coefficient (Cv)	6.66		
	Beam Volume (Z)	24.3871875	m^3	
6.5.7.2.1	Vr	3169.35318	kN	=Φ*Fv*0.48*Ag*Kn*Cv*Z^-.18

COLUMN CALCULATIONS

	Mfx	242	kNm	
	Mfy	0	kNm	
	Pf	1000	kN	
	V	45	kN	
	Width (b)	300	mm	
	Height (h)	750	mm	
	Unsupported Length (L)	5200	mm	
Table 6.3	fb	30.6	MPa	
Table 6.3	fv	2	MPa	
Table 6.3	fc	30.2	MPa	
6.4.1	Kd	1		
6.4.3	Kh	1		
6.4.2	Ksb	0.8		
6.4.2	Ksv	0.87		
6.4.2	Ksc	0.75		
6.4.2	Kse	0.9		
6.4.4	Kt	1		
6.5.6.5.1	Fb	24.48		=fb*Kd*Kh*Ksb*Kt
6.5.6.5.1	Φ (b,v)	0.9		
	Lamination Width (B)	38.1	mm	
6.5.6.5.2	Kx	1		
6.5.6.5.1	Kzbg	1		=1.03*(B*L)^-.18
6.5.6.4.3	Slenderness Ratio	8.557647652		
6.5.6.4.4	Kl	1		
	Sx	28125000	mm^3	=bh^2/6
	Sy	11250000	mm^3	=hb^2/6
6.5.6.5.1	Mrx	619.65	kNm	=min(ΦFbSxKxKzbg,ΦFbSxKxKl)
6.5.6.5.1	Mry	247.86	kNm	=min(ΦFbSyKxKzbg,ΦFbSyKxKl)
6.5.8.4.2	Φ (c)	0.8		
6.5.8.4.2	Fc	22.65	=fc*Kd*Kh*Ksc*Kt	
6.5.8.4.2	Kzcg	0.597888406	=0.68*Z^-.13	
Table 6.3	E	12800	MPa	
6.5.8.5	E05	11136	=0.87*E	
6.5.8.1	Ke	1.5		
6.5.8.1	Le	7800	mm	=Ke*L
6.5.8.2	Cc	26	=Le/b	

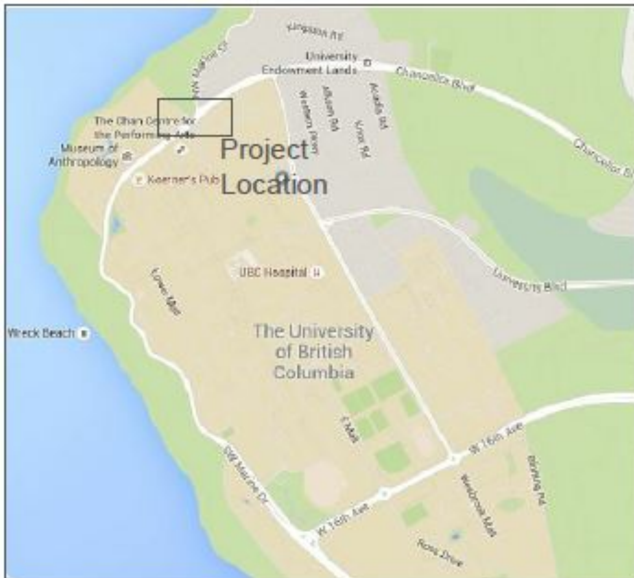
6.5.8.4.2	Kc	0.595759633		
6.5.8.4.2	Pr	1452.218339	kN	
6.5.12	Pe	17147.70765	kN	
	Combined Loading	OK	=(Pf/Pr)^2+Mfx/Mrx*(1/(1-Pf/Pe))<=1	
6.5.7.2.1	Fv	1.74	=fv*Kd*Kh*Ksv*Kt	
	Gross Area (Ag)	225000	mm^2	
6.5.7.2.2	Kn	1		
6.5.7.3	Shear Load Coefficient (Cv)	6.66		
	Beam Volume (Z)	2.691	m^3	
6.5.7.2.1	Vr	942.5519077	kN	=Φ*Fv*0.48*Ag*Kn*Cv*Z^-.18

APPENDIX C – ROUNDABOUT DRAWINGS

Red Fish Blue Fish
Consulting

PROJECT: CHANCELLOR BLVD/ EAST MALL/ NW MARINE DR INTERSECTION REDESIGN

CLIENT: UBC SEEDS PROGRAM

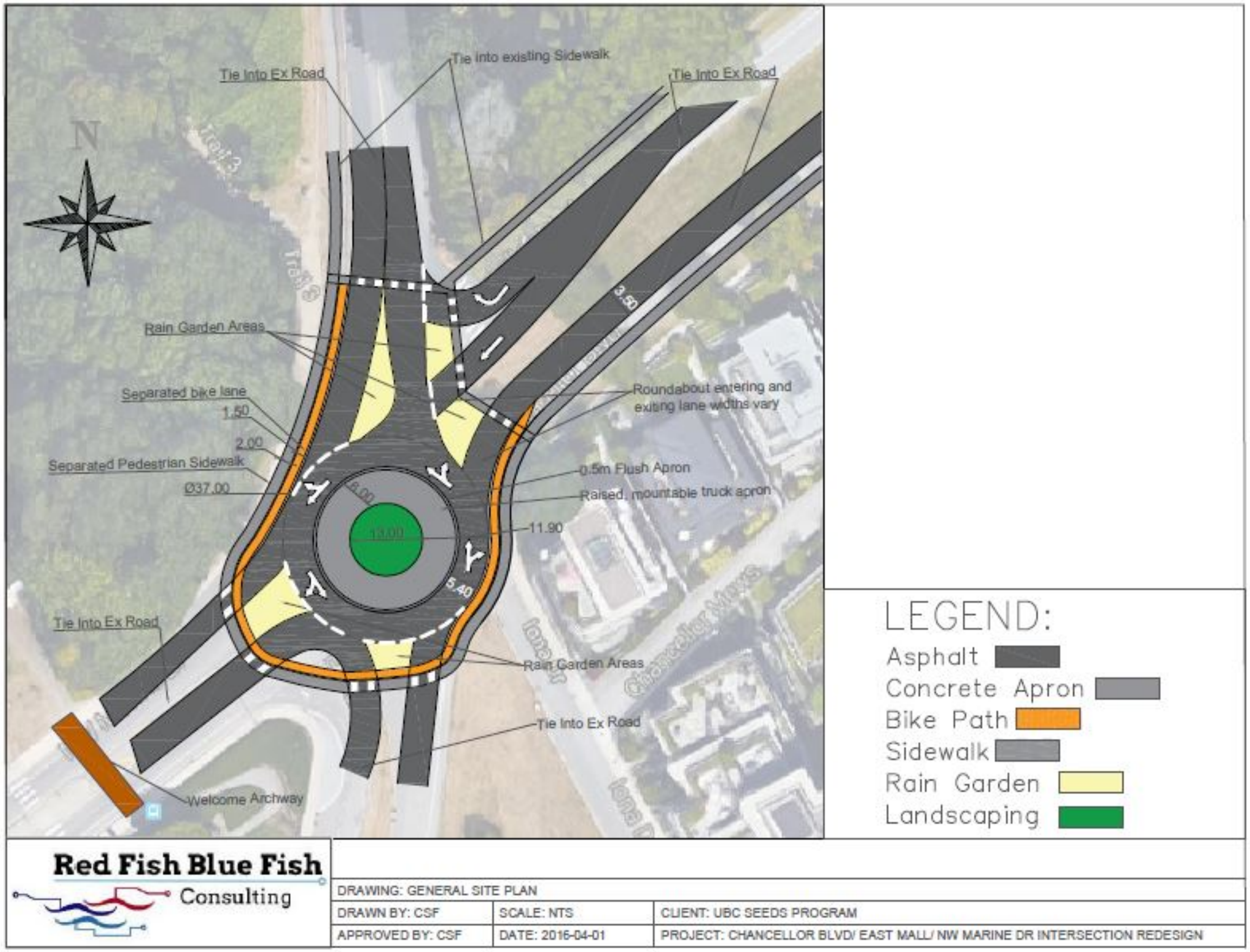


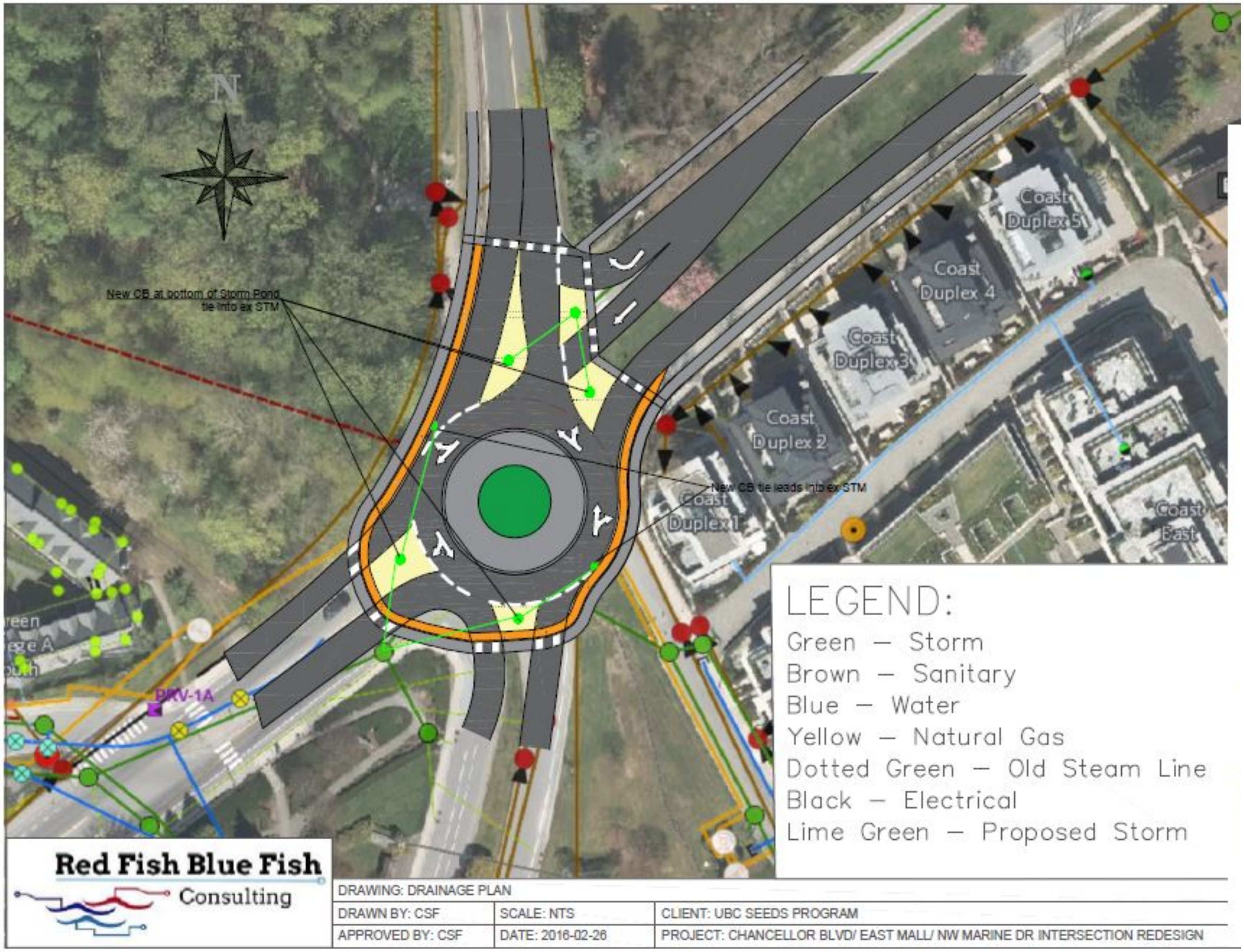
Location Map
NTS

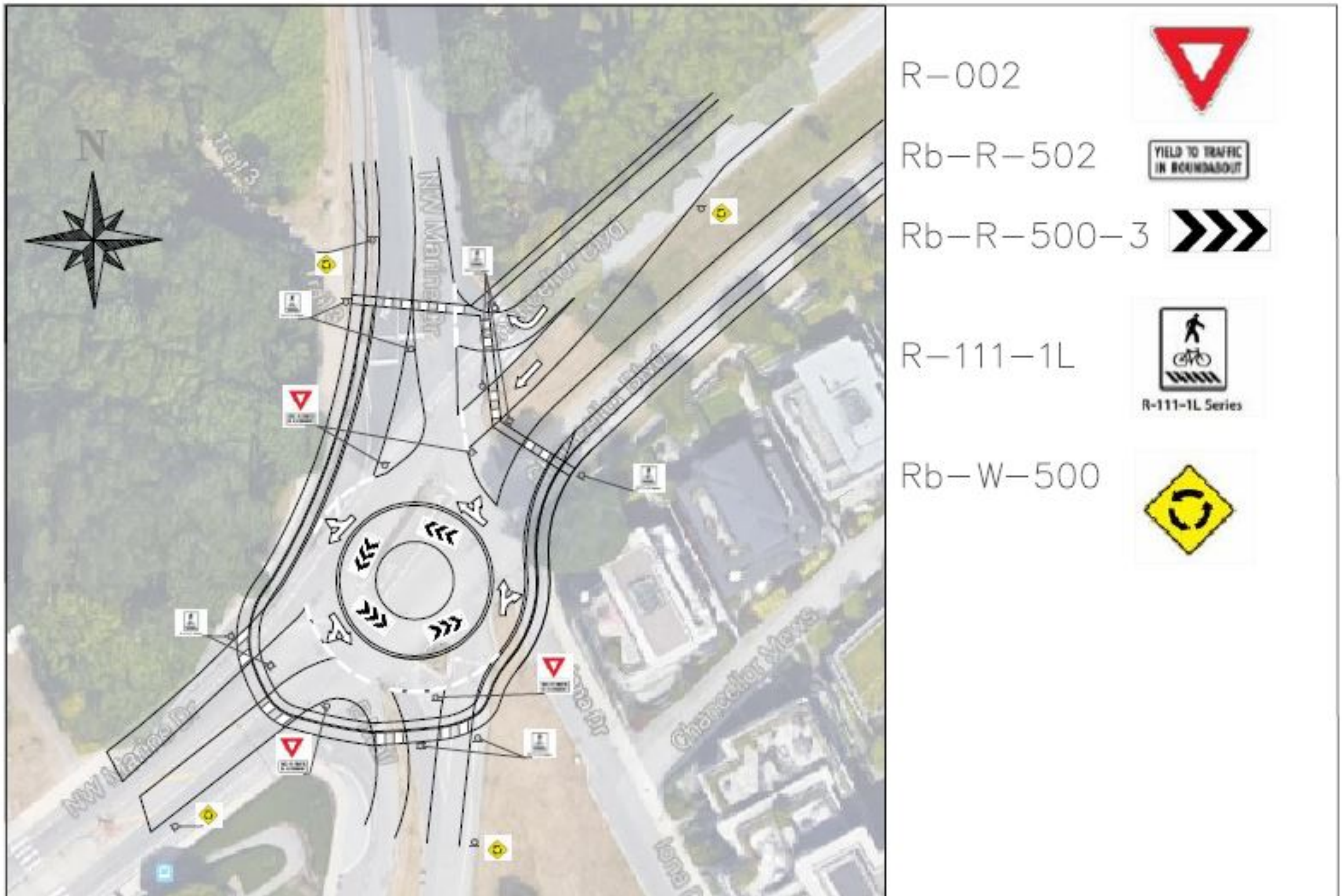
Drawing Index	
Drawing Number	Title
1	Cover Sheet
2	Key Plan
3	General Site Plan
4	Drainage Plan
5	Signing and Paving Plan
6	Surfacing Plan
7	Typical Cross Section — Roundabout
8	Typical Cross Section — Rain Garden

Red Fish Blue Fish
Consulting

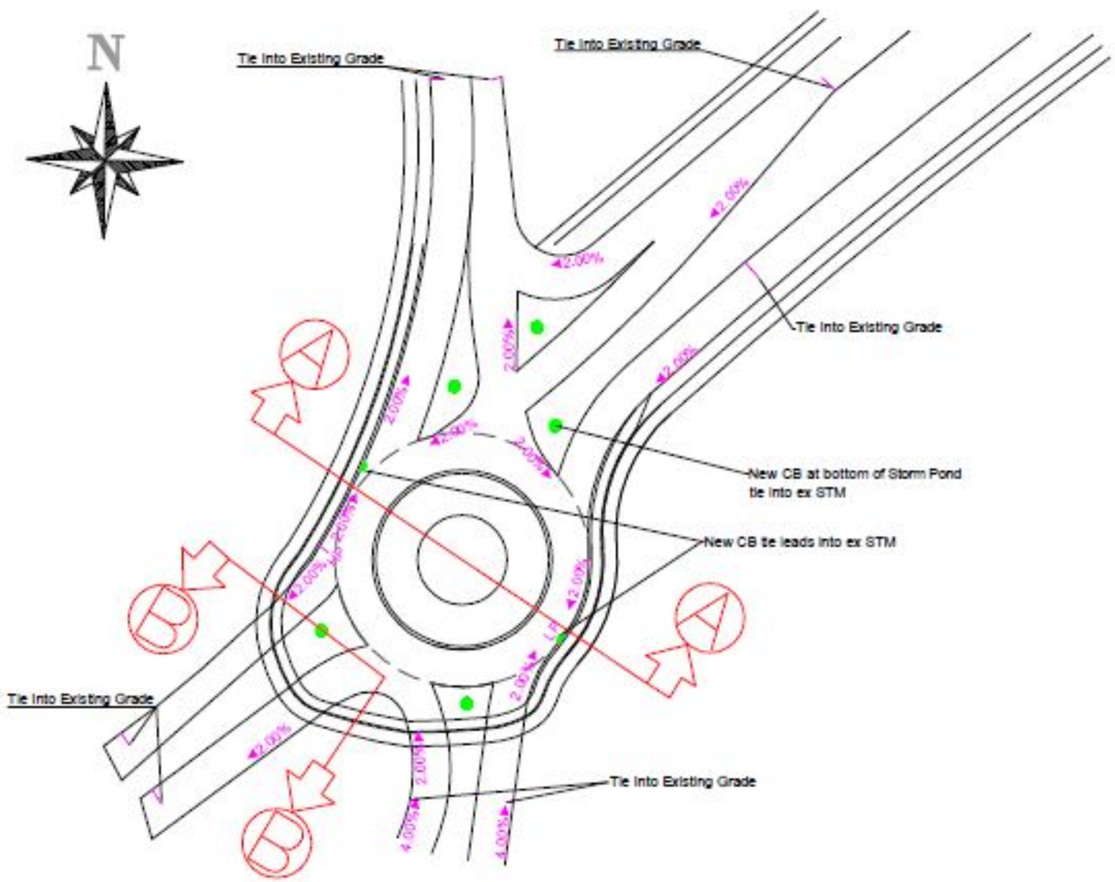
DRAWING: Key Plan		
DRAWN BY: CSF	SCALE: NTS	CLIENT: UBC SEEDS PROGRAM
APPROVED BY: CSF	DATE: 2016-04-01	PROJECT: CHANCELLOR BLVD/ EAST MALL/ NW MARINE DR INTERSECTION REDESIGN


N
Tie Into Ex Road
Tie into existing Sidewalk
Tie Into Ex Road
Rain Garden Areas
Separated bike lane
1.50
2.00
Separated Pedestrian Sidewalk
Ø37.00
3.50
Roundabout entering and exiting lane widths vary
0.5m Flush Apron
Raised, mountable truck apron
11.90
8.00
13.00
5.40
Tie Into Ex Road
Rain Garden Areas
Tie Into Ex Road
Welcome Archway
LEGEND:
Asphalt
Concrete Apron
Bike Path
Sidewalk
Rain Garden
Landscaping
Red Fish Blue Fish Consulting
DRAWING: GENERAL SITE PLAN
DRAWN BY: CSF
SCALE: NTS
CLIENT: UBC SEEDS PROGRAM
APPROVED BY: CSF
DATE: 2016-04-01
PROJECT: CHANCELLOR BLVD/ EAST MALL/ NW MARINE DR INTERSECTION REDESIGN


N
New CB at bottom of Storm Pond
tie into ex STM
New CB tie leads into ex STM
Coast Duplex 5
Coast Duplex 4
Coast Duplex 3
Coast Duplex 2
Coast Duplex 1
Coast East
PRV-1A
LEGEND:
Green — Storm
Brown — Sanitary
Blue — Water
Yellow — Natural Gas
Dotted Green — Old Steam Line
Black — Electrical
Lime Green — Proposed Storm
Red Fish Blue Fish
Consulting
DRAWING: DRAINAGE PLAN
DRAWN BY: CSF
SCALE: NTS
CLIENT: UBC SEEDS PROGRAM
APPROVED BY: CSF
DATE: 2016-02-26
PROJECT: CHANCELLOR BLVD/ EAST MALL/ NW MARINE DR INTERSECTION REDESIGN

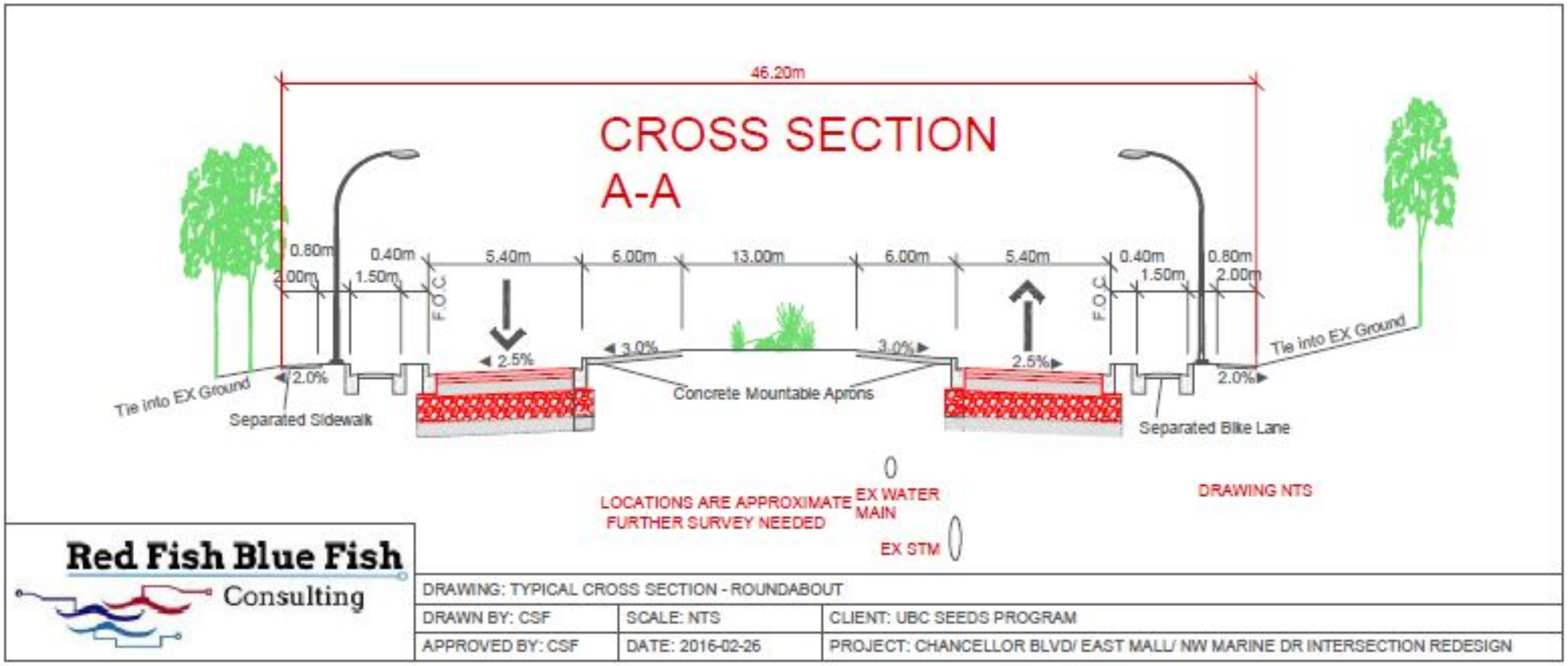


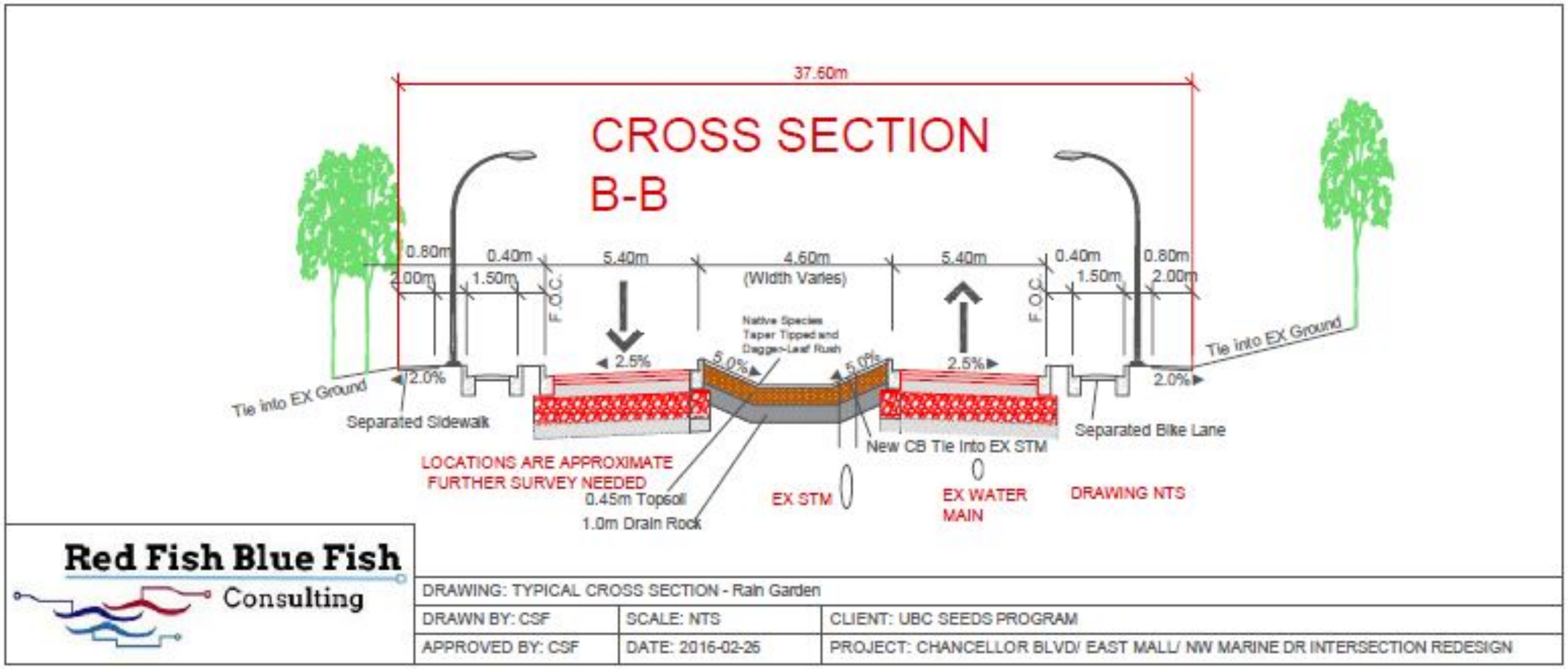
DRAWING: SIGNING AND PAVING PLAN		
DRAWN BY: CSF	SCALE: NTS	CLIENT: UBC SEEDS PROGRAM
APPROVED BY: CSF	DATE: 2016-04-01	PROJECT: CHANCELLOR BLVD/ EAST MALL/ NW MARINE DR INTERSECTION REDESIGN



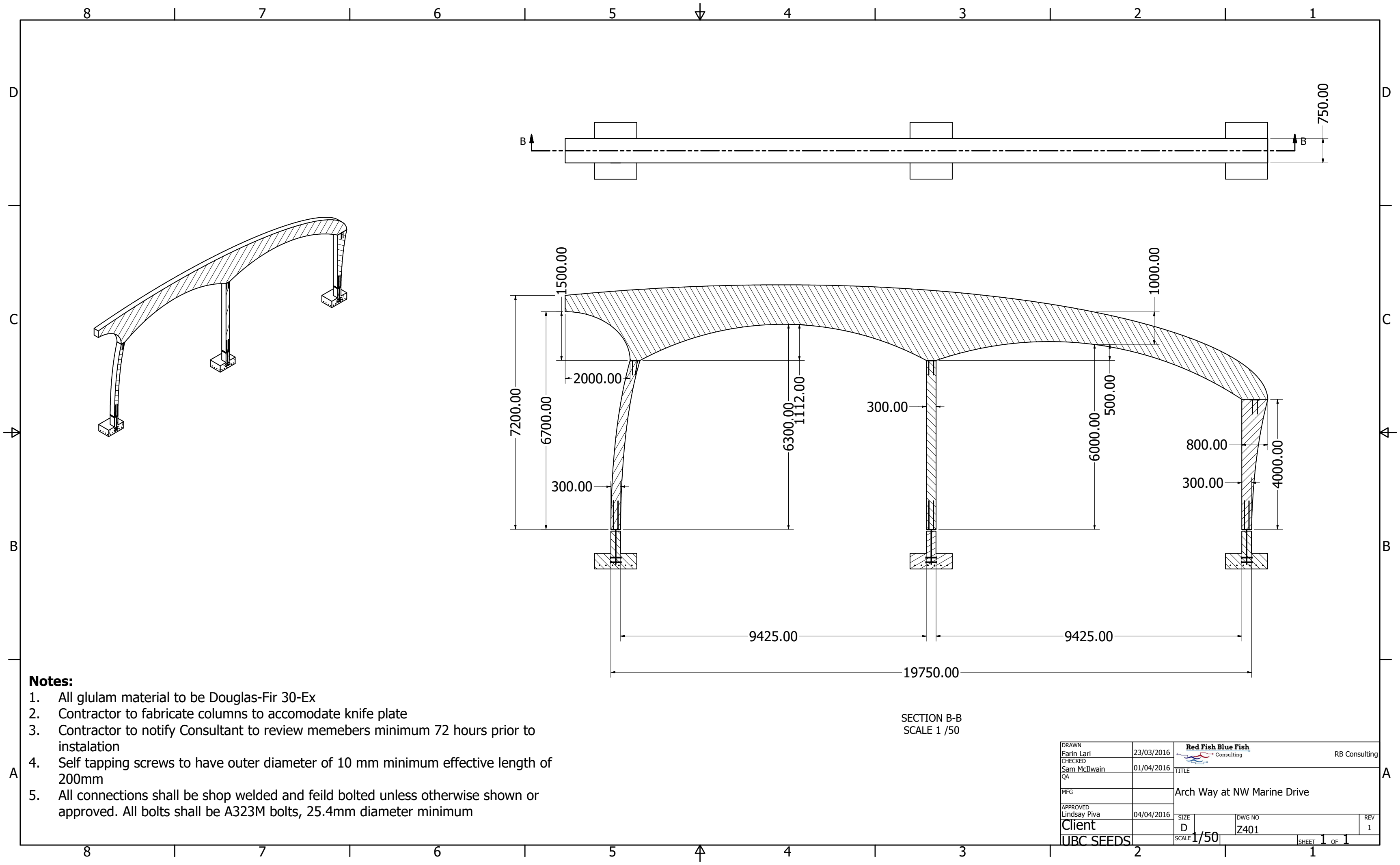
Red Fish Blue Fish Consulting

DRAWING: SURFACING PLAN		
DRAWN BY: CSF	SCALE: NTS	CLIENT: UBC SEEDS PROGRAM
APPROVED BY: CSF	DATE: 2016-02-26	PROJECT: CHANCELLOR BLVD/ EAST MALL/ NW MARINE DR INTERSECTION REDESIGN


46.20m
CROSS SECTION
A-A
0.80m
2.00m
0.40m
1.50m
F.O.C
5.40m
6.00m
13.00m
6.00m
5.40m
F.O.C
0.40m
1.50m
0.80m
2.00m
2.5%
3.0%
3.0%
2.5%
2.0%
2.0%
Tie into EX Ground
Tie into EX Ground
Separated Sidewalk
Concrete Mountable Aprons
Separated Bike Lane
LOCATIONS ARE APPROXIMATE
FURTHER SURVEY NEEDED
EX WATER
MAIN
EX STM
DRAWING NTS
Red Fish Blue Fish
Consulting
DRAWING: TYPICAL CROSS SECTION - ROUNDABOUT
DRAWN BY: CSF
SCALE: NTS
CLIENT: UBC SEEDS PROGRAM
APPROVED BY: CSF
DATE: 2016-02-26
PROJECT: CHANCELLOR BLVD/ EAST MALL/ NW MARINE DR INTERSECTION REDESIGN

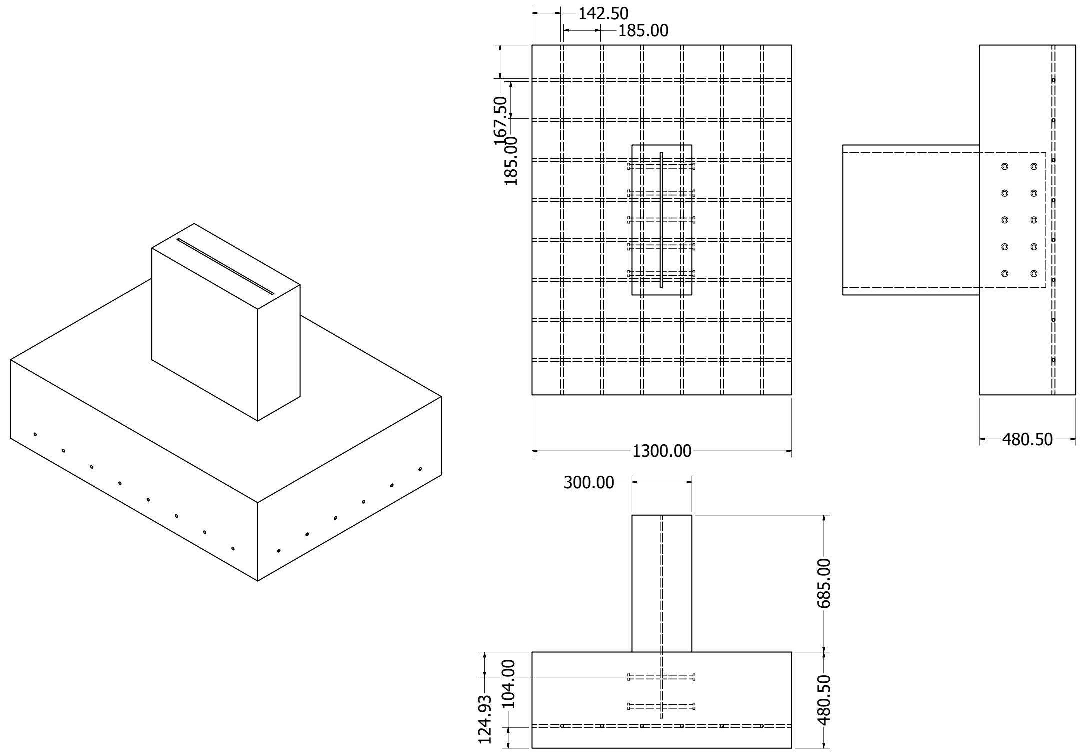

37.60m
CROSS SECTION
B-B
0.80m
2.00m
0.40m
1.50m
F.O.C.
5.40m
4.60m
(Width Varies)
5.40m
F.O.C.
0.40m
1.50m
0.80m
2.00m
Native Species
Taper Tipped and
Dagger-Leaf Rush
2.5%
5.0%
5.0%
2.5%
2.0%
2.0%
Tie into EX Ground
Tie into EX Ground
Separated Sidewalk
Separated Bike Lane
New CB Tie Into EX STM
LOCATIONS ARE APPROXIMATE
FURTHER SURVEY NEEDED
0.45m Topsoil
1.0m Drain Rock
EX STM
EX WATER
MAIN
DRAWING NTS
Red Fish Blue Fish
Consulting
DRAWING: TYPICAL CROSS SECTION - Rain Garden
DRAWN BY: CSF
SCALE: NTS
CLIENT: UBC SEEDS PROGRAM
APPROVED BY: CSF
DATE: 2016-02-26
PROJECT: CHANCELLOR BLVD/ EAST MALL/ NW MARINE DR INTERSECTION REDESIGN

APPENDIX D – WELCOME ARCHWAY STRUCTURAL DRAWINGS



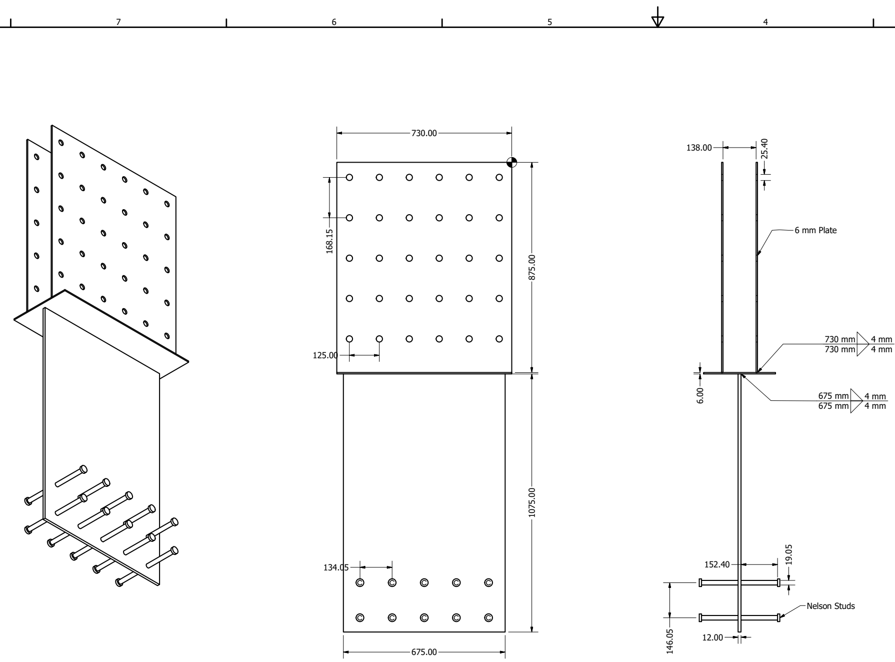
Notes:

1. All glulam material to be Douglas-Fir 30-Ex
2. Contractor to fabricate columns to accomodate knife plate
3. Contractor to notify Consultant to review memebers minimum 72 hours prior to instalation
4. Self tapping screws to have outer diameter of 10 mm minimum effective length of 200mm
5. All connections shall be shop welded and feild bolted unless otherwise shown or approved. All bolts shall be A323M bolts, 25.4mm diameter minimum



Notes:
1. All reinforcing steel to be grade 400Mpa
2. Concrete strength of footings to be 25 MPa
3. Contractor to ensure bearing pressure to be more than 75 kPa
4. Min 4" clear cover to all reinforcing

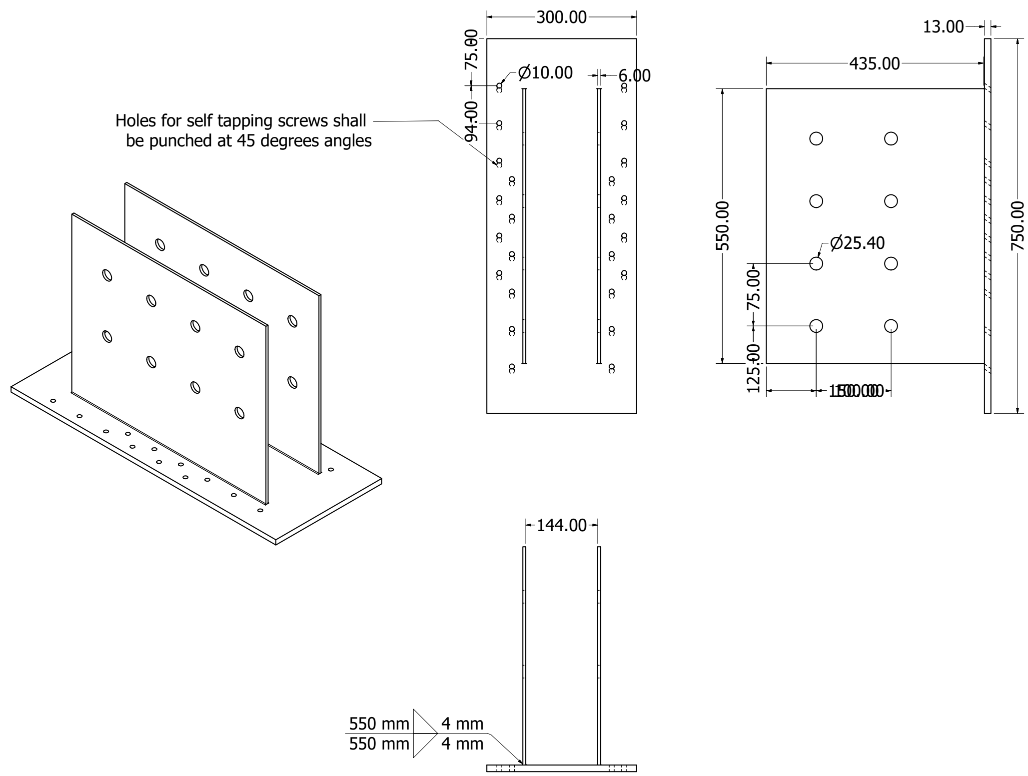
DRAWN Farin Lari	23/03/2016	Red Fish Blue Fish Consulting — RB Consulting
CHECKED Sam McIlwain	01/04/2016	TITLE
QA		Arch Way at NW Marine Drive: Footings
MFG		
APPROVED Lindsay Piva	04/04/2016	SIZE D — DWG NO Z5034 — REV
Client		
UBC SEEDS		SCALE 1/4 — SHEET 1 OF 1



Notes:

1. All connections shall be shop welded and feild bolted unless otherwise shown or approved. All bolts shall be A323M bolts, 25.4mm diameter minimum

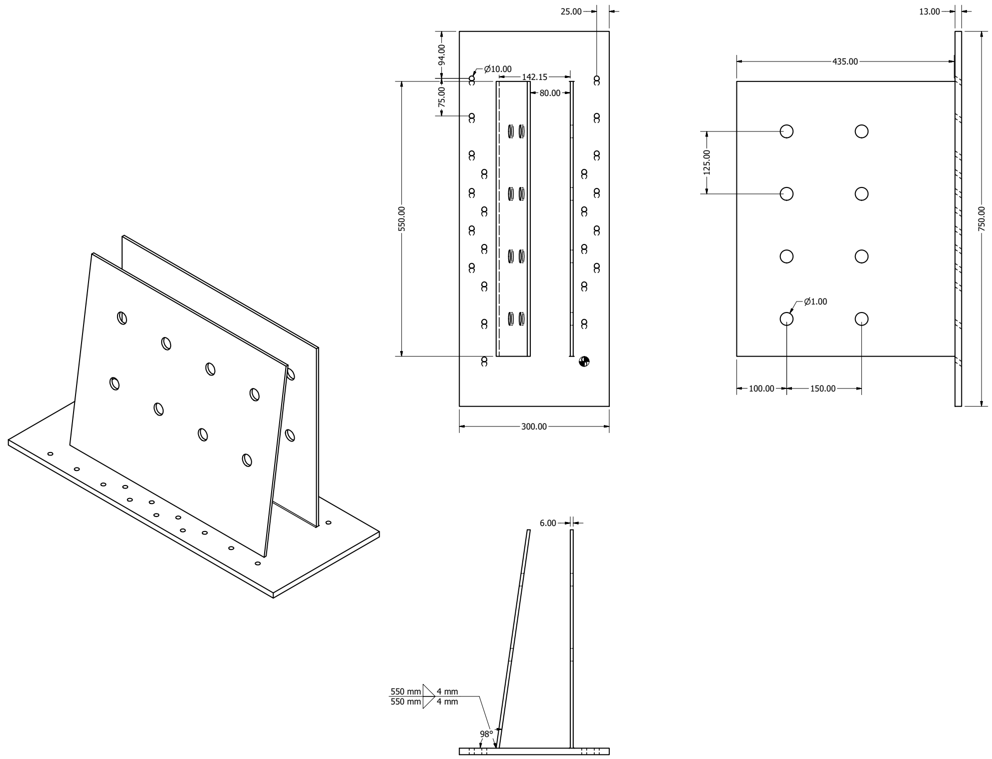
DRAWN Farin Lari	23/03/2016	Red Fish Blue Fish Consulting — RB Consulting
CHECKED Sam McIlwain	01/04/2016	TITLE
QA		Arch Way at NW Marine Drive Connection: Column to Footing
MFG		
APPROVED Lindsay Piva	04/04/2016	SIZE D — DWG NO Z503 — REV
Client UBC SEEDS		SCALE 1/4 — SHEET 1 OF 1



Notes:

1. All connections shall be shop welded and feild bolted unless otherwise shown or approved. All bolts shall be A323M bolts, 25.4mm diameter minimum

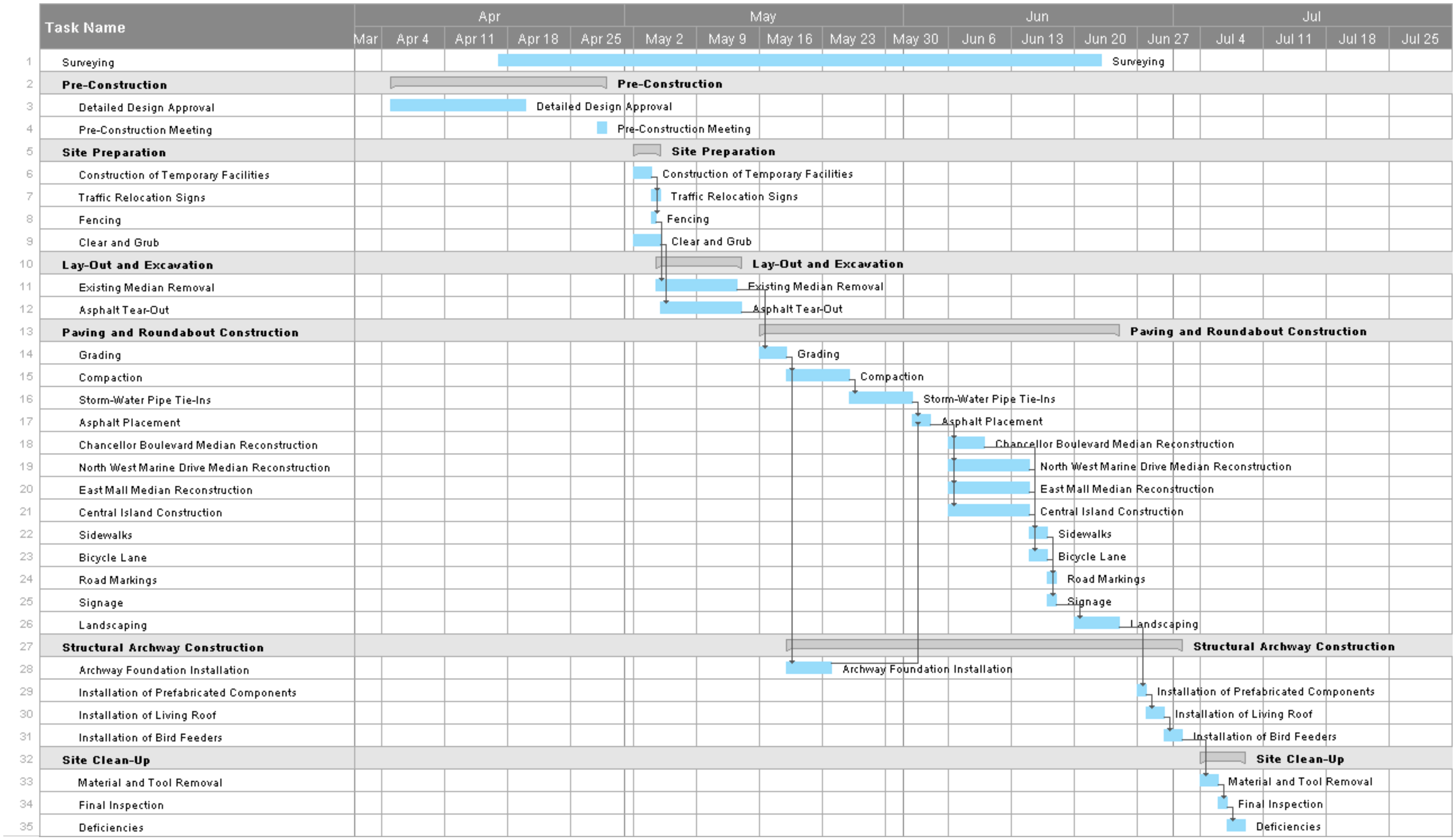
DRAWN Farin Lari	23/03/2016	Red Fish Blue Fish Consulting — RB Consulting
CHECKED Sam McIlwain	01/04/2016	TITLE
QA		Arch Way at NW Marine Drive Connection: Colunm and Beam Knife Plate Drawing
MFG		
APPROVED Lindsay Piva	04/04/2016	SIZE D — DWG NO Z501 — REV
Client UBC SEEDS		SCALE 1/4 — SHEET 1 OF 1



Notes:
1. All connections shall be shop welded and feild bolted unless otherwise shown or approved. All bolts shall be A323M bolts, 25.4mm diameter minimum

DRAWN Farin Lari	23/03/2016	Red Fish Blue Fish Consulting	RB Consulting
CHECKED Sam McIlwain	01/04/2016	TITLE	
QA		Arch Way at NW Marine Drive Connection: Colunm and Beam Knife Plate Drawing	
MFG			
APPROVED Lindsay Piva	04/04/2016	SIZE D	DWG NO Z502 REV
Client UBC SEEDS		SCALE 1/4	SHEET 1 OF 1

APPENDIX E - CONSTRUCTION SCHEDULE



APPENDIX F – COST ESTIMATE

Project Cost Summary					
Item #	**Description of Work**	**Estimated Quantity**	**Unit of Measure**	**Unit Price**	**Line Item Total**
01	**SECTION 1 - GENERAL**				
01.01	General Requirements	1	L.S.	$50,000	$50,000
01.02	Site Mobilization	1	L.S.	$25,000	$25,000
01.03	Safety and Traffic Control	1	L.S.	$40,000	$40,000
01.04	Survey	1	L.S.	$15,000	$15,000
02	**SECTION 2 - GRADING**				
02.01	Soil and Asphalt Removal (6" Average Depth)	6000	sqyr	$12	$72,000
02.02	Landscaping Removal	2000	sqyr	$4	$8,000
02.03	Structural Fill (12" Average Depth)	8000	sqyr	$12	$96,000
03	**SECTION 3- PAVING AND CONCRETE WORKS**				
03.01	Asphalt Replacement	35000	sqft	$5	$175,000
03.02	Sidewalks, including curbs and gutters	1600	lin.ft	$35	$56,000
03.03	Island curbs and truck apron	400	lin.ft	$60	$24,000
03.04	Line Painting	1500	lin.ft	$5	$7,500
04	**SECTION 4 - LANDSCAPING**				
04.01	New Landscaping	2500	sqft	$3	$7,500
05	**SECTION 5 - WELCOME ARCHWAY**				
05.01	Glulam Structure Prefabrication	100	lin.ft	$400	$40,000
05.02	Connection Components	6	each	$1,500	$9,000
05.03	Footings	3	each	$2,000	$6,000
06	**SECTION 6 - MISCELLENOUS**				
06.01	Estimated Stormwater Replacement	150	lin.ft	$250	$37,500
06.02	Relocation of Existing Utilities	1	L.S.	$25,000	$25,000
06.03	Signage and Lighting	1	L.S.	$25,000	$25,000
	SUBTOTAL				$718,500
900.00	Conctractor Profit (10%)				$72,000
900.01	Conctractor Overhead (10%)				$72,000
900.02	Contingency (20% of All Contractor Fees)				$172,500
900.03	Engineering (7.5%)				$65,000
	ESTIMATED CONSTRUCTION TOTAL				$1,100,000