UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

# Stadium Neighbourhood Underground Parkades and Water Storage


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**CIVL 446**

**Themes: Water, Climate, Land**

**April 8, 2019**

# Executive Summary

The Stadium Neighbourhood is a planned residential development that incorporates a new university sports stadium located in the southwest of UBC campus. Thunderfish Consulting Ltd. was asked to design a stormwater management system and underground parkade for the new development. UBC Properties Trust requires that the stormwater system prevents overland flooding and maintains, or reduces, the flow demand on the outfall pipe located to the SW of the catchment area. The flow demand is based on the existing, pre-development rate, which is currently sufficient to prevent erosion at the outfall.

The selected design proposes to divide the site into three zones:

- Zone 1 is the new stadium: the stadium collects its own rain water on its blue roof and stores the run-off in a concrete tank structurally built-in to the top-level of the stadium. The water is re-used as non-potable flushing water within the stadium.
- Zone 2 is the athletic field which collects water, detains it underground, and releases it slowly through bioswales where the filtered run-off is further detained in a dry pond.
- Zone 3 covers the residential buildings and roadways: water is collected in each building in green roofs, ground-infiltrated through permeable paving, or collected off of impermeable surfaces and directed into underground storage tanks. All stored water is then released through a controlled release port to the outfall.

In addition to being designed with sustainable development principles, the system releases water into the downstream stormwater system at approximately 35 L/s, an increase of 4 L/s from the estimated pre-development rate of 31 L/s. The proposed design is expected to be constructible within 8 months at a final cost estimate of $12.5 million dollars.

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# 1 Introduction

The Stadium Neighbourhood ("SN") is a proposed development in the traditional unceded territory of the Musqueam and Tsleil-Waututh First Nation, currently occupied by the University of British Columbia, on a primarily green-field site near the intersection of East Mall and 16th Avenue. The purpose of the neighbourhood is to provide mid- and high-rise housing for UBC faculty, staff, and students. The neighbourhood includes the development of a new Thunderbird Stadium, from which the neighbourhood gets its name. The proposed site is outlined in Figure 1, which also highlights the 16th St Corridor catchment area in relation to UBC campus. Thunderfish Consulting was asked to explore design alternatives and conduct a detailed design for both the SN stormwater management system ("storm system") and a parkade for the new stadium ("stadium parkade").


*Figure 1 Map highlighting proposed site for Stadium Neighbourhood*

Source: Google Maps

SN is located on the relatively small, West 16th Avenue catchment area which drains through a series of creeks and ditches surrounding the UBC Botanical Garden to an outfall in the cliffs of Pacific Spirit Park. The primary purpose of the SN integrated stormwater management system is to protect the cliffs in Pacific Spirit Park from erosion by sustaining, or ideally reducing, the existing rate and volume of stormwater exiting the outfall. Additionally, the storm system must prevent flooding (pooling of water) and overland flow.

The purpose of the parkade is to supplement the capacity of the existing Thunderbird Parkade, located at Thunderbird Avenue at Wesbrook Mall, which provides parking capacity for stadium events. However, the new parkade will primarily be for community daily parking use and not for event parking.

This report discusses the detailed design of the SN and outlines construction plans and specifications, as well as a cost estimate and construction schedule.emi

# 2 Overview of Design

Thunderfish Consulting used a multi-faceted approach that incorporated key components from various alternative designs. These include: storage tanks, blue & green roofs, bioswales, raingardens, pervious pavers, and a dry pond. Thunderfish identified these design components as effective methods to meet the project requirements of flood mitigation and net-zero runoff from SN to the W 16$^{th}$ Avenue catchment outfall. These design elements, that were chosen in combination, help to build resiliency into the storm system and improve adaptation to changes in the hydrological cycles due to climate change. The selected design is divided into three zones as seen in Figure 2, next page:

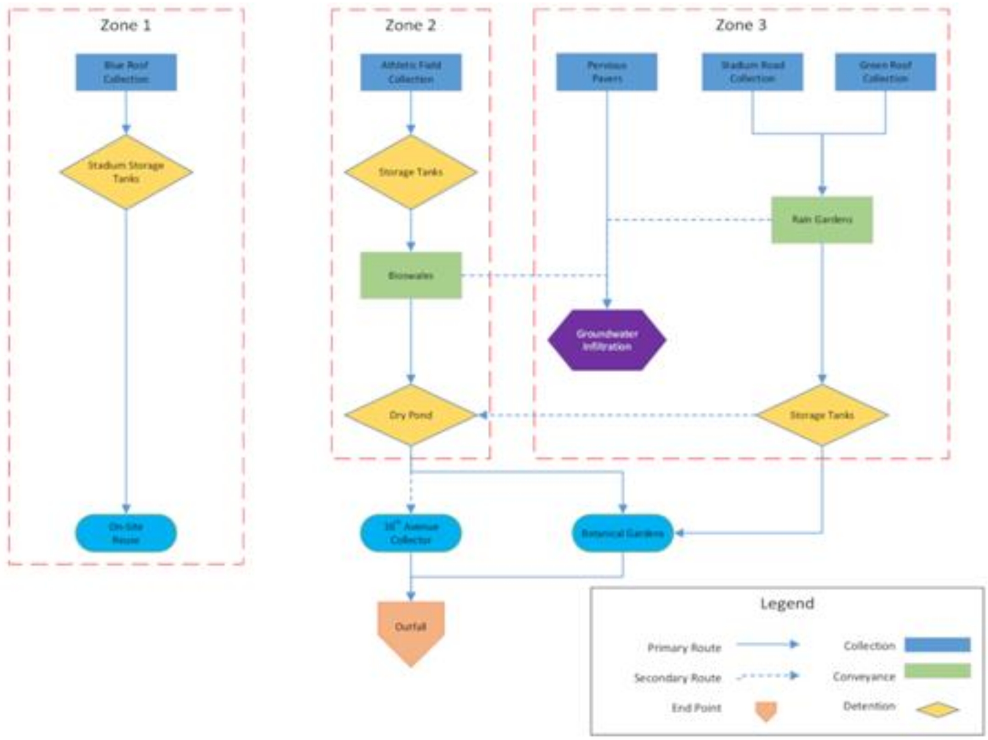



*Figure 2 Flow Chart of the Stadium Neighbourhood Stormwater Management System*

Figure 2 shows the delineation of the three zones for design purposes. In doing so, Thunderfish is capable of isolating calculations to determine flows, storage volumes, and infiltration in an expedient and concise manner. Also, though requiring further investigation, by defining Zone 2 and 3 as such, Thunderfish may choose to separate the discharges accordingly. One strategy is to have all zones flow to the dry pond in Zone 2, which discharges out to the adjacent 16$^{th}$ Street stormwater infrastructure. Alternatively, by isolating Zone 2 and 3 as separate systems, Zone 2 can discharge to 16$^{th}$ Street, and Zone 3 can be constructed to discharge to Stadium Road and its stormwater infrastructure. This may relieve stress on the outfall by increasing time of concentration and possibly discharging to a separate, alternative, outfall upstream of the one specified for this project.

Primarily, the driving factor of the selected design is to incorporate as many low impact developments (LID) as possible and to decrease hard surface areas. The premise of incorporating LID is for each system to mimic natural processes in the hydrological cycle such as evaporation, transpiration, and infiltration. This method is known as biomimicry. By incorporating green infrastructure, it is anticipated that there will be less strain or need to upgrade existing infrastructure, which will reduce cost overall as the natural environmental processes will be self-sustainable. LID locations can be seen numbered in Figure 3, below.

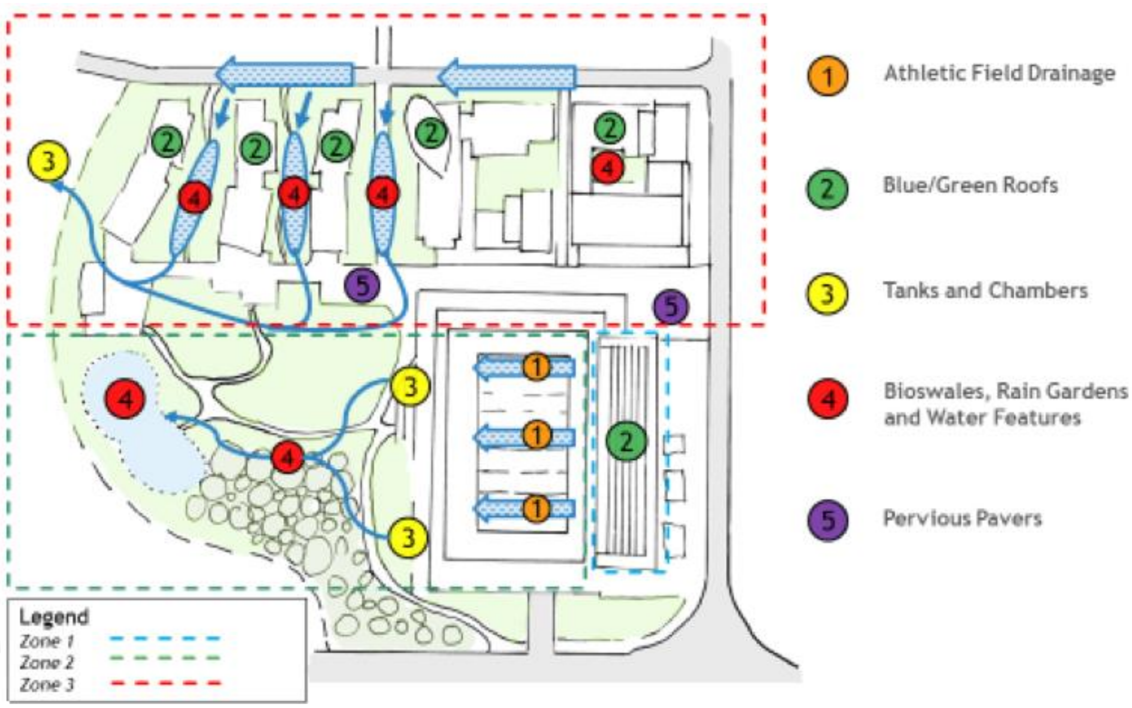



*Figure 3 Design for Stormwater Management at Stadium Neighbourhood*

Advantages and disadvantages of the proposed selected design are specified in Table 2:

*Table 1 Advantages and Disadvantages of the Preferred Design Strategy*

| Advantages | Disadvantages |
|---|---|
| Infiltration reduces demand on system | Inevitable disturbance to natural habitat |
| Stadium manages its own stormwater | Tank storage and pervious pavers require (bi)annual maintenance |
| Tank storage allows for expandability | Uncertainties regarding future environmental response to inclusion of partly natural systems |
| Tank storage can interface with UBC Botanical Gardens for future re-use | |
| Bioswales promote redundancy by draining to holding tanks | |
| Stormwater diversion from Stadium Road reduces demand on outfall | |
| Raingardens, permeable pavers, and green roofs enhance environment | |

# 3 Description of Key Design Components

Thunderfish Consulting is responsible for the technical design of the stormwater management system at the Stadium Neighbourhood (SN) project of which, a significant design priority is managing on-site stormwater and designing for climate change resilience. In order to do so, an integrated stormwater management system is employed to allow for collection, conveyance, detention, and if necessary, site emergency discharge.

To design the storm system, anticipated flows are required for the site. These anticipated volumes can be calculated through modelling, by observing historical rainfall data and applying statistics on the likelihood of occurrence of storm severity. A common practice for designing stormwater infrastructure sizing is the use of Intensity-Duration-Frequency (IDF) curves, which are an aggregate of historical rainfall data and probability of storm occurrence, to determine return periods for a specific location of interest. The IDF curve is used in conjunction with site area and ground characteristics to estimate a stormwater flow rate, or runoff rate. This anticipated runoff rate is used to determine the required capacity of the stormwater infrastructure. Technical design requirements are addressed in Section 8 Design Specifications and Requirements.

## 3.1 Design Elements

The preliminary stormwater management plan for SN can be broken down into four sequential design elements: collection, conveyance, detention, and discharge. Stormwater will first be collected in various features in SN, conveyed through infrastructure to the detention facilities, and discharged at the outfall. Each element of design is broken up into various components that are designed to be sustainable and resilient. The aesthetics around community areas such as plazas and pathways, are emphasized in the designs since SN will be a high pedestrian traffic area during athletic events. Design elements for the parking structure will be discussed further.

## 3.2 Collection Systems

The collection sites in the SN storm system include the following systems:

- Green roofs
- Pervious pavers and green space infiltration
- Athletic field collection

The design philosophy is to allow all surfaces to be a functional collection system that processes stormwater in some way. The intention is to eliminate hard surfaces that merely redistribute water to other locations but do nothing to slow or filter stormwater. This is a priority for SN because it allows for a more integrated and sustainable design through the addition of natural infrastructure, such as green space and pervious pavers.

The largest collector on site is the green space located in Zone 2, as seen in Figure 4 (page 9), covering approximately 2 hectares. This space is relied on for natural infiltration which is permissible given its distance of approximately 600m from the cliff outfall location.

### 3.2.1 Pervious Pavers

Traditional pavements, such as concrete or asphalt, is impervious, meaning water cannot infiltrate through the hard surface and must drain to a sewer system. Permeable paving utilizes precast concrete, brick, stone, or cobbles and are placed with gaps to allow water to flow between them (Figure 4). A partial infiltration pervious paver system will be located at the promenade where all rainfall is intended to infiltrate into the underlying soil and drainage system. The promenade will act as the main pedestrian-cyclist friendly walkway connecting East Mall to the west area of the neighbourhood as well as to adjacent buildings. The pervious pavers system is ideal for SN along the promenade as it is a low traffic area with little to no vehicle use. The main goal with permeable paving is the reduction of stormwater runoff volume by infiltration. The reduction of runoff volume will reduce the amount of water to the outfall and, subsequently, erosion of the UBC cliffs.

*Figure 4 Example of Partial Installation of Pervious Pavers*

Source: Mississippi Watershed Management Organization

The soils at UBC are comprised of silty sand with traces of gravel and cobbles and silt with traces of fine sand and gravel clasts (GeoPacific Consultants Ltd., 2006). A report compiled by Piteau Associates determined the mean hydraulic conductivity to be approximately 1,728 mm/hr with a standard deviation of 576 mm/hr (Piteau Associates, 2002). Due to design constraints, a 4.86 mm/hr hydraulic conductivity will be used instead which will allow for a one metre deep rock reservoir and a drain time of three days (Kerr Wood Leidal Associates; Lanarc Consultants; Goya Ngan, 2012). Water not infiltrated into the underlying soil will flow into the drainage system to the detention pond. More information regarding the dry pond can be found in Section 2.6.

Due to the design of permeable pavers, gaps in-between concrete units tend to fill with debris, referred to as surface plugging (Elgin Sweeper Company, n.a.). Erosion and sediment control measures should be taken into account to limit the amount of sediment entering the site during construction. Maintenance of permeable pavers requires regular cleaning to ensure water will continue to percolate through to the underlying layers. With regular maintenance pervious pavers are expected to last approximately 20 years.

Permeable paving must conform to UBC Vancouver Campus Plan Part 3 Section 2.5.1: Surface Infrastructure – Paving and UBC Technical Guidelines 2018 Edition.

### 3.2.2 Green Roofs

Green roofs at SN will contribute to just over 7800 square meters (or 0.78 hectares) of pervious area, while spanning a total of six rooftops. The SN stormwater management system uses extensive green roofs (Figure XX) to filter and reduce stormwater runoff on low- and mid-rise residential buildings. Extensive green roof (EGR) systems are typically designed to be no more than 6 inches in depth and require little to no irrigation. EGR systems are selected for use at SN due to their high performance, effectiveness, and relative low cost. The EGR systems have been designed to mimic a natural environment, while reducing operating and maintenance costs. They are also designed to meet specified engineering performance objectives (Miller, 2016).

*Figure 5 Example of Green Roof*

EGR considers a number of subsystems, including drainage, plant support and nourishment, membrane protection, waterproofing, and insulation. A properly designed drainage system captures precipitation and reduces runoff volumes leaving the roof surface; EGRs also designed to provide protection against erosion, wind, surface ponding, and soil nutrient loss. Plant nourishment and support subsystems provide EGRs with an engineered water holding capacity, a means to prevent erosion within the system, and a sufficient medium for plant growth. The waterproofing systems act as a barrier between the vegetative system and the building's underlying structural system. The insulation system is included as part of an EGR to contribute to the buildings overall energy saving capabilities.

At SN, the use of EGR systems contributes to the overall reduction of impervious surface on the site. Green roof systems are fast becoming a desirable alternative to traditional roof systems due to their ability to contribute to stormwater filtration, runoff reduction, and transpiration, while also contributing to whole building energy savings.

Detailed design drawings can be found in Appendix A, and include both a typical EGR section and component detail. EGR specifications can be found in Appendix D. A typical EGR system can last between 30 and 50 years. The service-life maintenance plan can be found in Appendix E.

#### 3.2.3 Athletic Field Collection

The artificial turf athletic field comprises ~10% of the surface area of the proposed Stadium Neighbourhood with an area of ~12000 $m^2$, indicating a significant source of surface water runoff and discharge. The drainage system will divert water collected from the field surface to bioswales leading to the dry pond downstream. The internal drainage installed on the field will conform to common field requirements that ensure proper field management for player safety and maintenance operations.

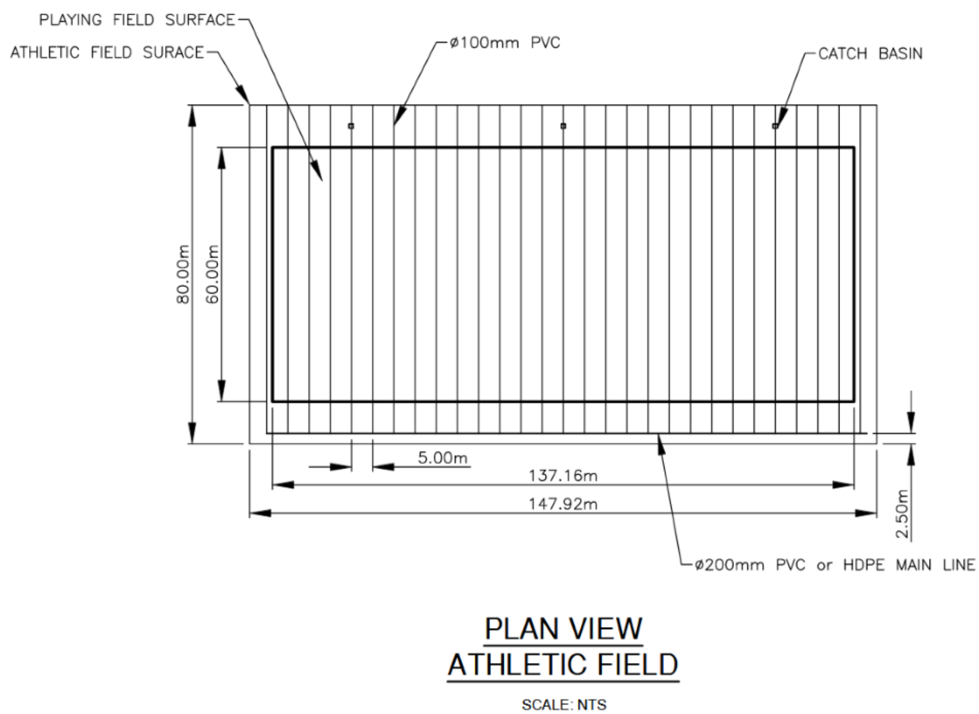



*Figure 6 Athletic Field Drainage System*

The drainage system is designed for a flat-surface field with a 0.5-1.5% slope can be seen in Figure 6, above. Once initial excavation is completed, the subsurface is to be compacted to adequate proctor density, lined with an impermeable liner, and filled with a base layer of gravel within the drainage trenches. PVC perforated pipes, typically 100mm in diameter, will be installed at min. 5 m - max 10 m spacing intervals with a minimum depth of 600 mm and a maximum 6% slope. The perforated pipes will direct the stormwater runoff to a main pipe (PVC or HDPE) drain (200 mm diameter) at the southwest side of the field, which will distribute the percolated stormwater to an outfall oriented at the southeast-most corner to be connected with the bioswale. Catch basins will be installed on the northeast side of the field in 0.5 m depressions for stormwater runoff not captured by the field drainage system and concrete liner with be installed around the perimeter to ensure water drains to the outlet.

The design utilizes the fast/immediate percolation of artificial turf and granular subsurface to create effective drainage of the field, while ensuring all runoff is contained and diverted to the bioswale. Rather than allowing the water to infiltrate the native soil underneath the field, the drainage system will accommodate the net-zero design objective for the downstream outfall by collecting all stormwater runoff on the field. Field irrigation will also be captured by the drainage system to be diverted to the bioswale, and the irrigation system will be installed concurrently with the field drainage system.

For future reference, the athletic field drainage design may be changed to the owner's specification to incorporate a crowned field where the drainage layout is changed to a herring-bone design as seen in Figure 7.

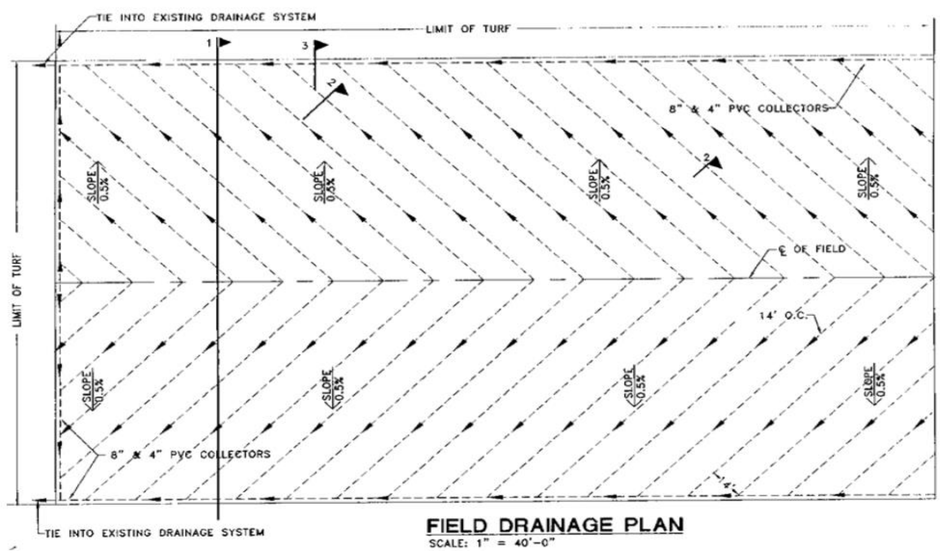



*Figure 7 Herringbone Style Drainage System*

Source: Synthetic Turf Council, 2011

Other concerns for the drainage design are as follows:

- Ponding: generally, the design must accommodate 1-in-10 year storms, but in the event that larger storm surges occur, the field drainage system needs to be able to shed water quickly from the field to prevent ponding.
- Percolation: subsurface materials will be designed according to common practice standards but will also need to be engineered to ensure water infiltrates quickly from the field surface in proportion to the hydro-climate of UBC.
- Properly sized perforated pipes: the installed perforated pipes along the field must be designed to accommodate large storm events while also sized appropriately to not cause structural issues under specified surface loading.
- Clogging: material may filter through the subgrade and clog the perforated pipes, causing blockages that inhibit drainage to the mainline; engineered sand subgrade or fine mesh wrapped around the perforated pipes may be used to ensure proper filtration of silty materials.
- Efficient design for excavation: as the field is initially assumed to be flat-surface, the excavation for the drainage will reach an effective depth that is deeper than a crowned-surface drainage design; proper coordination with the underground parkade design will be necessary.
- Lateral orientation of drainage pipes (herringbone, straight, etc.): a cost-benefit analysis may be performed to determine the most cost-efficient design in relation to the client's needs.
- Over compaction of subsurface: the native soil underneath the drainage system will need to be compacted to a specified proctor density to ensure structural integrity of the field, i.e. uniform level with no surface defects, while maintaining soil consolidation that will not crush the pipes due to loading from vehicles that may need to travel over the surface.

## 3.3 Conveyance

Once collected in the above systems, the stormwater is transported through a series of conveyancing systems including:

- An upgraded storm sewer system
- Bioswales
- Rain gardens

As the objective of the project is to reduce the effect of stormwater runoff to pre-development levels, it must be managed according to the water that would have infiltrated or been stored naturally, but now, due to construction of buildings and hard surfaces, the stormwater runs off surfaces such as rooftops, parking lots, and sidewalks, i.e. impervious surfaces. Thunderfish Consulting has designed the above conveyance facilities to manage 1-in-10 year storm events and mitigate the destructive potential of extreme and rare storm events, such as 1-in-100 year events, by slowing the flow of water and filtering it prior to reaching the detention facilities.

### 3.3.1 Storm Sewer System

Traditionally, surface water runoff is collected and conveyed through an underground pipe system to a receiving water body. However, this method can be harmful as high runoff volume can lead to erosion and poor water quality can introduce pollutants to downstream receiving waters. Thunderfish Consulting has identified the use of more sustainable practices such as source controls as a design priority over the traditional storm sewer system. However, the storm sewer system is still required to connect the low impact development (LID) features by conveying runoff from the features to the dry pond where open water conveyance via rain gardens is not available. The storm sewer system will also provide conveyance from the dry pond outlet to a connection with the existing storm sewer main on West 16$^{th}$ Avenue.

The current storm sewer system serving the Stadium Road Neighbourhood site was constructed in the 1950's and is expected to be nearing the end of its service life. Further, the development of SN will require the pipe system to be upgraded to properly service the site and meet current standards outlined by UBC and/or Metro Vancouver. The client has indicated a preference to the use of alternates to PVC material, including cast-in-place concrete, vitrified clay, or high density polyethylene (HDPE). Thunderfish Consulting has identified HDPE as the preferred design material for this project as the material is chemically inert, maintains structural strength, and has a long service life.

Potential construction challenges for the storm sewer system include locating the existing storm sewer on West 16th to tie-into, improper pipe installation and connection to LID structures, and poor material quality.

### 3.3.2 Bioswales

Traditional bioswales (Figure 8) behave like open ditches lined with grass to convey water to a discharge point. Types of bioswales include grassed channels, wet swales, and dry swales. Bioswales are intended to reduce runoff volumes and remove pollutants such as heavy metals and oil. Modern bioswales should incorporate native plants to promote further reduced runoff volume and pollutant removal. Water entering the channel can either directly infiltrate into the ground or can be drained into a perforated pipe underground. The designed sizing of bioswales is less approximately two hectares each as these areas are intended to hold minor storm events with low infiltration rates for the lining.

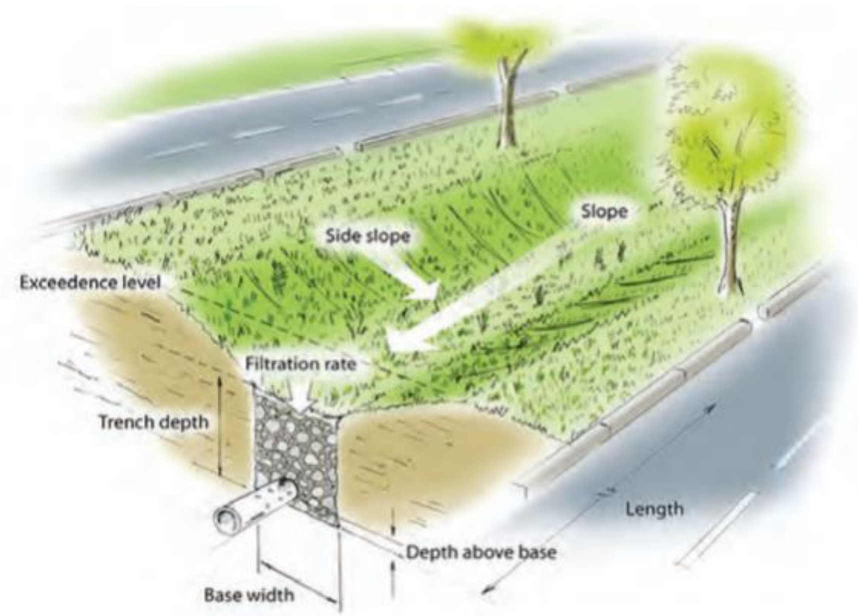



*Figure 8 Traditional bioswale cross section*

Source: sustain.ok.ubc.ca, IRMP Maintenance Manual

Incorporating bioswales into SN is beneficial in that it is aesthetically pleasing and is able to naturally blend into the surrounding environment. Bioswales are an inexpensive method to convey water to the man-made dry pond while simultaneously filtering pollutants from the surface runoff.

### 3.3.3 Rain Gardens

A rain garden ("RG") is a landscape feature that is designed to capture rainwater runoff from nearby impervious surfaces such as roadways, rooftops, and parking lots as seen in Figure 9, below. They are engineered to convey stormwater runoff while also providing temporary storage that facilitates the infiltration of stormwater into the subsurface soil layers.

*Figure 9 Example of a rain garden showcased at UBC*

Source: planning.ubc.ca, Turning Rainfall into a Resource

Our designed rain garden will receive stormwater runoff from both an inflow pipe and surface flow and will temporarily retain water within the sunken garden feature. The slope of the rain garden is designed to be 5% and the ratio of garden size vs. Impervious draining area capacity is 1:5, meaning that for every 50 $m^2$ of rain garden, 250$m^2$ of impervious area can be drained by the garden. This optimal capacity is dependent on regular maintenance of the rain garden by removing garbage and clearing grits so as to remove any obstructions. The rain garden is able to accommodate a maximum ponding of 3.2 inches. The topsoil layer is organic mulch and is deigned to be 500mm deep and has a permeability of 6mm/hr. This layer of topsoil is designed to achieve varying rates of infiltration as a way to reduce runoff and provide groundwater recharge. It also has the ability to remove various types of pollutants from stormwater with coordination in selecting plant species that enhance filtration. Specifications for this mulch is provided in Appendix D. The subsoil substructure is designed to be 700mm deep and will function to further increase the area for infiltration. Lastly, native plants such as shrubs, flowers, trees, and grasses were selected for all three rain gardens; specifications for these plants are available in Appendix D.

Challenges associated with the design and construction of RG systems include:

- Size: RGs are most effective at smaller scales.
- Siting: Multiple RGs distributed throughout a system are more effective than single systems.
- Slopes/Grading: RGs are most effective on shallow slopes that promote infiltration and decrease erosion.
- Maintenance: RGs' dual purpose as a landscape feature and a stormwater filtration system requires proper education and training by the operator to ensure effectiveness and to promote long-term efficiency.

Detailed design of RGs at Stadium Neighbourhood requires a total RG area of 502 $m^2$. As such, three individual RGs with a minimum tributary width of 5 ft and measuring 100 m 122 m and 80m in length. A detailed section drawing is available in Appendix A.

## 3.4 Detention

A detention structure is designed to receive and hold stormwater from a storm event. Unlike retention systems which do not discharge stormwater, the water is released from detention structures via gravity flow, gradient, or capacity. More specifically, release rate is limited by the downstream system capacity. If the soil surrounding the detention structure is saturated and at capacity, water will be held in the detention system. However, as water slowly drains from the surrounding soil, water from the detention structure naturally flows into the surrounding areas.

### 3.4.1 Dry Pond

A dry pond is a large, multipurpose recessed area, built at the low point of a site, with an outlet that controls outflow. The addition of a dry pond to the SN design adds resiliency in the stormwater detention process for extreme storm events while primarily acting as a green space when not detaining water the majority of the time. The dry pond provides stormwater detention for rainfall events that exceed the source controls upstream, namely storms with a return period between 1-in-10 years and 1-in-100 years. As such, the dry pond is designed for a hydraulic capacity of ~650 $m^3$ as calculated in Appendix F. The dry pond is located in the southwest corner of the site situated in the brown-field of the old stadium, utilizing the low-point of the stadium neighbourhood to collect stormwater. Designing on-site stormwater storage for extreme events reduces destructive flows at the downstream cliff outfall to mitigate cliff erosion.

The dry pond is designed to detain and slowly release stormwater at a controlled flow rate to discharge to the W 16$^{th}$ Ave storm. This is accomplished through hydraulic design of the structure and sizing of the outlet to ensure a controlled, gravity-driven flow rate out of the dry pond through the outlet.

The dry pond is located at the low-point of the site to collect on-site stormwater, either through the integrated stormwater system or overland flows, using bioswales as the fore bay to filter out pollutants. The pond drains at the standard minimum drainage grade of 0.5% toward the outlet to ensure complete drainage after major storm events. The inlets and outlets are designed as pre-cast concrete headwalls, complete with upstream trash racks to prevent debris from entering the system. Upstream of the structure, a bioswale leads to the inlet culvert which runs through the inlet headwall. Downstream of the structure, the headwall and culvert discharge to UBC's West 16th Avenue ditch system that drains to the cliff outfall. An emergency spillway outlet is designed at the top of the bank to provide emergency drainage in the event that the 100-year capacity is exceeded. A dry pond of similar concept is shown in Figure 10, below.

*Figure 10 Example of a Dry Pond*

*Source: Low Impact Development in Coastal South Carolina: A Planning and Design Guide*

A berm is constructed where topographically necessary to act as the banks of the dry pond and supply freeboard for storage. The berm can be constructed from native fill excavated during construction, providing savings in construction and material costs. The banks of the berm are designed at a 3-to-1 horizontal to vertical slope to ensure slope stability and are lined with grasses and native plants to mitigate bank soil erosion. The design allows for infiltration at the base of the dry pond, though this is anticipated to be insignificant due to the slow-draining geological characteristics of the site.

Anticipated construction challenges include ensuring the drainage gradients in the dry pond are met as well as the potential use of poor quality native soil for berm construction. However, the topography of the current site includes a large sunken stadium area. The construction of the dry pond will require partially filling of this area which can be done with cut material generated from on-site excavation.

Operations and maintenance for the dry pond will include annual sediment and debris removal, regular landscaping on the grassed area, annual berm stability inspections, and pipe condition inspections.

The dry pond is an important part of the Stadium Neighbourhood system because it provides stormwater storage for extreme events and work to recover the ecosystem that had been damaged when constructing the existing stadium. Implementing water management processes such as a dry pond, storm water activity can be mitigated by preventing runoff from causing soil erosion downstream.

## 3.5 Site Discharge

The site is located within the W 16$^{th}$ Avenue catchment where the primary surface runoff discharges at an outfall located within Pacific Spirit Park near the UBC Botanical Gardens (Kerr Wood Leidal, 2010). A secondary discharge point drains into Museum Creek (Kerr Wood Leidal, 2010). These outfalls are sensitive to past storm events causing flooding and erosion and, therefore, require special attention to construction of new developments upstream and climate change (UBC Campus + Community Planning, 2017). A site visit to the outfall was conducted on November 1, 2018 by Thunderfish to gain further understanding of cliff erosion sensitivity. With the development of SN there will be a reduction of permeable land and an increase of impermeable land that impact downstream flow rates at the outfall. Climate change and the development of hard surfaces will increase runoff volumes and the amount of short, high intensity rainfall events to the outfall. The objective of SN is to either maintain, mitigate, or have net-zero discharge at the outfall by replicating the hydrologic cycle via LIDs.

Runoff volume of pre-development and post-development were calculated using the Rational Method and the Unit Area Release Rate Method. The Rational Method is commonly used to determine peak flow rate using runoff coefficients, rainfall intensity, and site area less than 30 ha. The Unit Area Release Rate (UARR) differs from the Rational Method in that it considers the uniform distribution of the storm sewer system based on a 1-in-5 year storm event per hectare (City of Calgary, 2011). It is determined the peak flow at pre-development is roughly 31 L/s based off a 2-year, 24-hour rainfall event. In the implementation of LIDs, the peak flow at post-development is roughly 35 L/s based off the same rainfall event. Peak flow will be increased by 4 L/s at the outfall.

## 3.6 Stadium Parkade

A single-storey, underground parking structure was design for the new Thunderbird Stadium. The purpose of the parkade is to provide community-use parking for the regular users of the stadium facility, in addition to the inhabitants of the Stadium Neighbourhood: the new parkade is not intended for stadium “event parking” as this is accommodated with the already-existing Thunderbird Parkade. The stadium parkade is sized to accommodate only this community parking with a total of 141 spots, including four disability parking spaces.

Supporting documentation of the parkade design, including load assumptions, analysis results, and concrete calculations can be found in Appendix G. Detailed design drawings can be found in Appendix A. The below is a discussion on the decisions made in producing the resulting design.

### 3.6.1 Road Access

To discourage event parking use, Thunderfish Consulting altered the entrance of the parkade from the proposed dual entrance/exit on 16th Avenue to a single lane access off of southbound East Mall. This arrangement can be seen below in Figure 11. By allowing access to the parkade from SB East Mall only, traffic coming into UBC via 16 Avenue will not be able to access the parkade entrance without first driving to SW Marine Drive and looping around on Stadium Road.

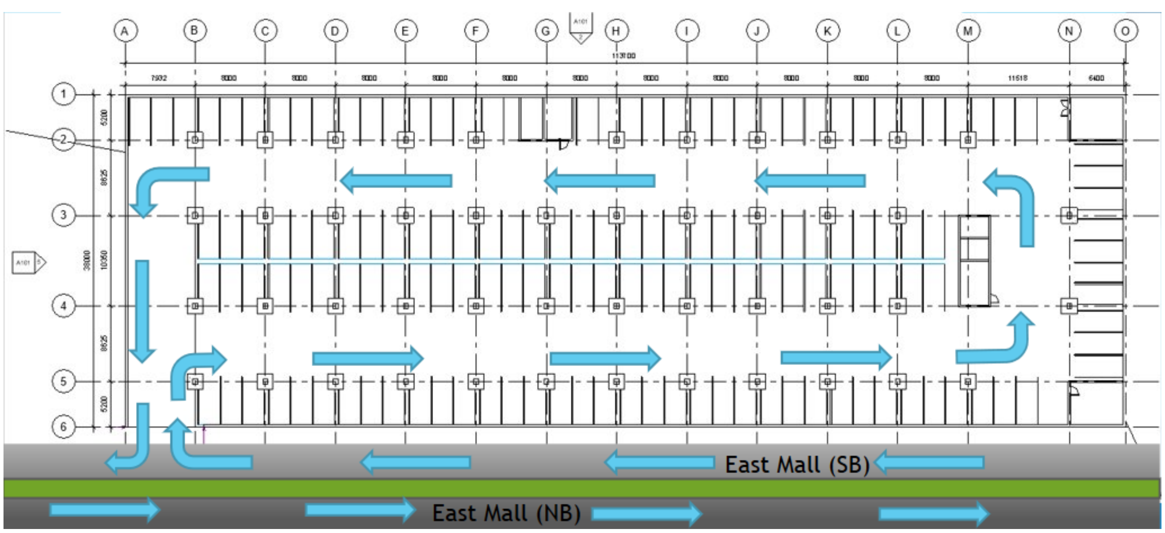



*Figure 11 Parkade Traffic Flow*

### 3.6.2 Contribution to Storm Water Management

The new stadium parkade was originally conceived of as a component of the larger Stadium Neighbourhood SWMP where it was thought that the parkade itself could contribute as a water detention facility, with storage existing either in the parkade area or in a sub-grade vault below the car deck. A review of the topography of the Stadium Neighbourhood site and the proposed location of the new stadium revealed that the stadium and parkade would be located on the highest point on the site. This site would be unsuitable for water detention because all water would be naturally flowing away from it as opposed to toward it: storm water detention facilities are typically located at the bottom of a storm system for the purpose of buffering the release of water into the environment. Thunderfish Consulting decided to not utilize the parkade structure for stormwater detention because its location would necessitate pumping water against gravity solely for the purpose of detention.

Thunderfish Consulting is instead proposing that the roof of the future stadium be a rainwater collector and that the top floor of the new stadium itself be host to a longitudinal tank, that spans the length of the stadium, to store rainwater at elevation. The pressure head available because of this elevated storage allows the stored water to be utilized in a gravity-fed system throughout the stadium for its daily water use. A particularly suitable application would be for toilet flushing as this does not require a potable water source. While the design of such a system is beyond the scope of this report, Thunderfish Consulting has performed an analysis of the potential water storage and proposed volume of a tank which would be suitable for this use in Table 3, next page:

*Table 2 Required volume for tank storage on top floor of stadium*

| SVF (100 year event) | Stadium Roof Area | Runoff Coefficient (C1) | Storage Volume Req'd |
|---|---|---|---|
| (m3/(Area * C1) | (m2) | | m3 = (SVF*Area*C1) |
| 0.1 | 4632 | 0.91 | 421 |

Thunderfish Consulting recommends a longitudinal storage vessel on the top of the stadium measuring 1m x 5m x 100m as can be seen in the conceptual figure below:

### 3.6.3 Structural Design and Layout

The structural analysis and design of the parkade was performed in S-Frame with its Integrated Concrete Design module. However, because the stadium parkade will be structurally supporting a full stadium, estimates were performed to determine the load of the new stadium. In doing so, the following assumptions were made:

- The new stadium would structurally utilize mass timber as part of BC's Wood First (2009) sustainability legislation; this would make the building significantly lighter than if it were entirely of concrete
- The stadium would occupy a footprint of approximately 38 m x 115 m and would be approximately four to five storeys tall
- A total of four stair cores, two that also include elevators, would be included in the stadium that would extend down to the parkade
- The parkade would provide vehicle access at grade from East Mall but would only provide pedestrian access through the main floor of the stadium; this is to enhance community use of the stadium building

- The height of the parkade would allow for the entrance of "coach" style buses to enter (maximum of 4 m) to allow for the delivery and pick-up of visiting sports teams.

### 3.6.4 Foundation System

The stadium and parkade have been designed to sit upon a raft slab foundation. The reasons for this are as follows:

- The parkade design is supported by 51 columns at a semi-regular spacing. Consideration was given to utilizing pad footings but it was decided that the cost for specially excavating and forming each footing would be excessively fussy and time consuming.
- In lieu of forming pad footings, consideration was also given to pile foundations; however the number of piles required would be equal, again, to the number of columns and the depth of piles required for adequate bearing would make pile foundations excessively expensive.
- The geotechnical report from GeoPacific Consultants (2006) suggest that the strata located at a depth of approximately 4m would be well suited for bearing. To reduce the costs of labour forming large pad footings under each column, it was decided to pour a raft foundation over the whole area. The completed foundation would also serve as the car deck slab.

The raft slab foundation has been reinforced to be able to support moment loads from the internal columns resulting from lateral movement.

### 3.6.5 Building Information Model (BIM)

A decision was made to develop a building information model ("BIM") for the parkade structure; this model was built in Autodesk Revit 2019. Whereas in a typical CAD drawing the only information that would be retained about the building would be 2-dimensional geometry data, BIM allows for the storage of both 3-dimension geometry data and non-geometrical information about building components, such as the materials they are made of. This information can be used for various analysis purposes, such as generating material take-offs, in addition to producing 2-dimensional construction drawings, automatically.

The drawings attached in Appendix A, were generated directly from the parkade BIM.

# 4 Design Criteria, Standards, and Software

## 4.1 Design Criteria

An integrated stormwater management plan (ISMP) is a sustainable approach to stormwater management that aligns with UBC's goals of leadership in sustainability. The Thunderfish rationale for the design of the ISMP aligns closely with the UBC SEEDS Sustainability Program's 15 thematic areas (UBC Sustainability, 2018). We focus primarily on the areas of climate, energy, water, land, materials, biodiversity, health, and wellbeing. In addition to the SEEDS thematic areas, Thunderfish Consulting Ltd. chose to incorporate six of Campus and Community Planning's guiding principles in the development of SN (UBC Campus and Community Planning, 2018), these include:

- Build long term value
- Be a good neighbour
- Use the site to shape the place
- Enhance the ecology
- Design for flexibility and resilience
- Engage the community in a meaningful way

These guiding principles and thematic areas actively make up the triple bottom line, which comprises economic, environmental, and socio-cultural considerations. The triple bottom line is the main driving force in providing greater perspective and consideration of all aspects of the project design to be incorporated into the SN ISMP.

For the purpose of this project, the design has no budgetary constraints, and, therefore, no economic requirements exist for the project. However, Thunderfish Consulting takes into consideration providing an economically feasible design in conjunction with environmental sustainability principles so that the project has real world significance considering UBC's goals in implementing net zero infrastructure.

## 4.2 Design Standards

Technical design of the integrated stormwater management system at SN will abide by the following technical guidelines, standards, and best management practices (BMP):

- UBC Technical Guidelines 2018 Edition (Divisions 32 and 33)
- UBC Integrated Stormwater Management Plan (ISMP) 2017
- UBC ISMP Best Management Practices for Stormwater
- Metro Vancouver Stormwater Source Control Design Guidelines (2012)
- Greater Vancouver Regional District Best Management Practices for Stormwater
- Toronto Green Roof Construction Standard Supplementary Guidelines
- UBC Transportation Plan (Parking)
- UBC Structural Technical Guidelines
- Vancouver Building Bylaw 10908
- Vancouver Parking Bylaw 6059
- BC Building Code (2018)
- NBCC 2015

## 4.3 Software Packages

Computer modelling software is an integral tool in the development of an efficient design for stormwater management at SN. Table 3 outlines a list of the software used by Thunderfish Consulting Ltd. during detailed design phase.

*Table 3: List of Software Packages*

| Software | Application |
| --- | --- |
| AutoCAD Civil 3D | Technical drawings, site layout, site analysis, site grading, quantity take-offs, material estimates |
| Google Earth Pro | Site reconnaissance, mapping |
| ArcGIS/QGIS | Site reconnaissance, storm main layout, topographical data analysis |
| Microsoft Office Suite | Report production, spreadsheet analysis, presentation materials, system flow chart, construction scheduling |
| S-Frame | Parkade structural analysis and concrete design |
| Autodesk Revit | Parkade BIM authoring and drawing generation |

# 5 Technical Considerations

**Due to the fact that the location of SRN is in a densely populated area with sensitive downstream conditions, many technical considerations were taken into account during the design stages of this stormwater management plan.**

## 5.1 Stormwater Through the Site and Physical Space

One of the main goals of this SWMP was to reduce the volume at the outfall, which in turn erodes the cliffside. To achieve this, Thunderfish Consulting Ltd. decided to implement various stormwater management strategies in order to reduce runoff and therefore volume at the outfall. The main technical consideration was that the post development run-off had to be less than the pre-development run-off. As such, many low impact development (LID) strategies such as rain gardens, green roofs, pervious paver, and bioswales were implemented. We designed these LIDs in between pervious areas to purposefully breakup runoff and increase infiltration. Moreover, we wanted the natural infrastructure to contain native plants and vegetation, and we were able to do that through careful consideration and selection. Thunderfish Consulting Ltd. has prioritized environmental sustainability through the preservation of most trees on site, and a limited use of expensive and environmentally damaging material such as concrete. Additionally, innovation was a key component of our design, as we wanted the space to be multi-functional by allowing both community members, residents, visitors, and users. As such, we've designed unique elements such as a highly permeable turf surface for the athletic field, and a detention pond that is both effective and esthetically pleasing.

## 5.2 Parkade & Community

In the parkade, many technical considerations were undertaken throughout the design process. Firstly, the team decided to make the parkade underground, as that would be the least destructive to the plants in the area and it would also help capture more stormwater runoff. The entrance of the parkade is located in an area where it minimizes traffic congestion and potential hot spots for collisions. Serious emphasis was put on creating as many parking spots as possible, and further sustainability considerations were taken through the addition of a blue roof system. Lastly, the needs of the community and the clients put all technical considerations in to context. Major stakeholders such as UBC Botanical Gardens and the community were consulted in the design process, and all advice given by the client during meetings and correspondence were taken into our design.

# 6 Stakeholder Analysis

Thunderfish Consulting has conducted a detailed stakeholder analysis and has identified the key stakeholders to be the following:

- UBC Properties Trust
- UBC Campus and Community Planning
- UBC SEEDS
- UBC Botanical Gardens
- UBC Community

For the purposes of the capstone project, we recognize the UBC Department of Civil Engineering as a minor stakeholder in the project. UBC Properties Trust and UBC Seeds are the clients in the project and are key stakeholders because they control essentials such as budget, deadlines, and support. UBC Botanical Gardens is a key stakeholder since they have property adjacent to SN, as well as immediately downstream of the site. Lastly, the UBC Community is a significant stakeholder because they are the ones who will interact with and live at SN for years to come. Once the four major stakeholders were identified, Thunderfish Consulting compiled information about their needs and interests through engagement such as community open houses and sit-down meetings. Emphasis was put on designing various elements with their interests and needs in mind. By satisfying these major stakeholders' needs, the lifespan of the project is increased as it decreases the probability of future work or redesign in the future.

## 6.1 UBC Properties Trust

Founded in 1988, UBC Properties Trust (UBC PT) is a private property management company owned by the University of British Columbia. Its purpose is to manage UBC's real estate assets such as family housing, residential buildings, and commercial developments for the financial benefit of UBC. The main interest of UBC PT for this project is functionality over cost. Elements of high functionality have been included in the final design. An example of this is the pervious pavers which populate all the walkways within SN. These pavers are highly effective in reducing stormwater runoff by creating space for infiltration to occur. However, the system of pervious pavers has a preliminary cost estimate of over $2 million. Thunderfish Consulting has decided to continue with the design while searching for value engineering opportunities, because of the high functionality of the pavers and their aesthetic appeal adding to the overall feeling of community. Also, the addition of green roofs is not essential for the system in order to reduce stormwater runoff to target rates, but the design includes them because they have high functionality by absorbing over half of its expected rainfall in addition to creating an aesthetically pleasing space.

## 6.2 UBC SEEDS

The SEEDS sustainability program is a program within UBC that aims to advance campus sustainability initiatives and strategies. SEEDS is comprised of faculty, staff, and students and engages approximately 1,000 people every year. UBC SEEDS is the client for this preliminary stormwater management design at SN, and they are a key stakeholder. SEEDS and UBC have expressed the desire to take a natural systems approach to stormwater management. As a result, this criterion is integrated and emphasized in the design rationale. The traditional, more common approach to stormwater management is to increase the capacity of the subgrade infrastructure at roads or to build large retention or detention facilities. Rather than using unsustainable man-made materials, the stormwater management plan for SN will take a more natural approach by utilizing green elements such as bioswales and rain gardens that contain native plants for filtration and absorption.

## 6.3 UBC BOTANICAL GARDENS

Due to the topographical location in proximity to the Stadium Neighborhood, the UBC Botanical Gardens is significantly affected by runoff from the W 16$^{th}$ Ave catchment area. The proposed design will implement feedback from the UBC Botanical Gardens to ensure the design meets standards to mitigate and adapt to major concerns and constraints regarding stormwater.

In coordination with the Director of UBC Botanical Garden, Patrick Lewis, Thunderfish Consulting will communicate throughout the design of the Stadium Neighbourhood Stormwater Management Plan. In previous discussions, Mr. Lewis has emphasized the influence of upstream developments on the downstream creek conditions that run through the botanical garden. As the hydrological cycle of UBC is unique, storm events vary in rainfall intensity and duration. During more severe weather events, flooding of the creek beds has proved to be problematic, even resulting in pedestrian bridges being washed out, requiring costly repairs and maintenance. High intensity rainfall has also resulted in extreme discharge rates from the outfall, increasing likelihood of erosion of the surrounding cliff, which, as stated before, is a key consideration for Thunderfish project as a criterion to be resolved in designing the stormwater management for Stadium Neighbourhood.


*Figure 12 Current UBC Botanical Garden Map (Ponds Circled)*

Source: UBC Botanical Garden Collections

UBC Botanical Garden has four major ponds, as seen in Figure 13, which are supplemented by municipal water to prevent them from drying up in summer climate. However, even during the rainy season, the water features at the gardens are still supplemented by municipal water with considerable amounts of water wastage due to unsustainable designs of the ponds and man-made streams. In conjunction with the stormwater design for the Stadium Neighbourhood, UBC Botanical Gardens suggest that stormwater runoff be retained on the proposed site. This water then may be used to supplement the garden's water features as well as possible irrigation use in lieu of municipal water, provided the Botanical Gardens can develop the required infrastructure.

## 6.4 UBC Community and UBC Campus & Community Planning

To engage the community in a meaningful way is one of Thunderfish's guiding principles for the SN project. Early on in the project, our team identified a number of key opportunities that allowed our team to engage the local UBC Community through a number of engagement activities lead by UBC Campus and Community Planning. This resulted in Thunderfish team members attending an open house, where we spoke with both community members and key project proponents. Attending the open house event allowed our team to develop a greater understanding of the project's primary goals and objectives, such as the preservation of green space and the promotion of the site's local ecology. It also allowed our team to engage the community and identify some of the concerns that surround the project, such as the preservation of the existing trees on site.

Thunderfish team members chose to attend a public talk lead by Charles Montgomery, a local Vancouverite and the author of Happy Cities. The talk focused on the SN project and its legacy to the UBC Community and emphasized the opportunities that exist within the SN project for establishing a holistic design approach that considers the blending of human comfort and environmental stewardship. A key takeaway of Montgomery's talk is the idea that designers need to consider human well-being in their design. One way to do this is to facilitate an increase in the number of potential interactions between people by providing communal green space. An idea raised by the audience, a key proponent for considerations in our design, is to create and enable opportunities for community members to contribute to the SN project by leaving portions of the design unfinished and to be completed by the community. This helps to create a sense of place and belonging within the neighbourhood and enables community members to leave their mark on the project.

# 7 Cost Estimate

The cost estimate provides an estimation of consulting fees, construction costs, capital costs, and maintenance costs for the project, but does not include purchase of land. This document builds upon the final design cost estimate, and is to be reviewed and approved by the client prior to the start of the project construction. Total cost has been adjusted to current 2018 market conditions and is subject to change. It is projected that the cost is $ 12,541,276.28 as outlined in the cost estimate, included in Appendix B.

# 8 Construction Schedule

The construction schedule, which includes a draft plan of construction work, is included in Appendix C.

## 8.1 Anticipated Construction Issues

### 8.1.1 Site Conditions

While currently not developed, the location of the new Stadium Neighbourhood is not on an untouched site. Construction in the region had previously been conducted during the construction of the current Thunderbird Stadium. As such, we are anticipating that the geotechnical conditions are not consistent across the site. It is possible that the area may have been used as a dumping ground for overburden excavated from projects in decades past: material unsuitable for building may need to be excavated and replaced.

Additionally, the geotechnical report revealed that there is a high likelihood of water lenses in the soil substrate. Additional coordination measures will need to be taken during excavation of the parkade to ensure that the site does not flood.

### 8.1.2 Coordination

Thunderfish Consulting's scope of work is distributed throughout the construction schedule starting with the excavation and construction of the stadium parkade and continuing on throughout the project contributing to areas on and around the new buildings, the roadways, and the landscape. As such, coordination amongst trades that are typically disconnected (e.g. roofers who will be working on the green roof, carpenters who will be building formwork for the parkade, and landscapers who will be building bioswales and raingardens) will be critical to the success of the project.

### 8.1.3 Cut and Fill

Currently existing on the site is a large mound of fill material of unknown origin. The location of the mound is approximately on the site of the new stadium. This causes a potential benefit of having pre-loaded the soil in that region: the additional pressure from the mound may have caused the soil beneath to become over-consolidated and potentially capable of sustaining higher foundation pressures. However, this material will need to be either utilized on the site, relocated, or disposed of.

Opportunity to use the material on site exists because of the need to fill in the existing Thunderbird Stadium however, it is unknown what the balance of material will be. A site survey at the beginning of the project will allow for estimates of cut and full balancing.

### 8.1.4 Erosion During Construction

While the site is currently considered in a pre-development state, during the actual construction, there will be a significant risk of errant flow and soil erosion. This has been identified and erosion control measures have been identified in the project schedule as needing to be completed prior to any excavation or clearing.

# 9 Drawings, Specifications, and Maintenance Plan

Project drawings, specifications, and service-life maintenance plan are included in Appendix A, D, and E, respectively.

# 10 References


City of Camas (2009). *Storm Sewer Systems Operation and Maintenance Manual*. Camas, Washington.

City of Calgary. (2011). *Stormwater Management & Design Manual.* Water Resources. City of Calgary.

GeoPacific Consultants Ltd. (2006). *Re: Geotechnial Investigation Report of Proposed Mixed Commercial/Residential Development Lot 10 - UBC South Campus, Westbrook Drive at 16th Avenue, Vancouver, B.C.* Vancouver, B.C.

Kerr Wood Leidal. (2010, April n.a.). *Risk Management Services.* Retrieved from UBC Risk Management Services: http://riskmanagement.sites.olt.ubc.ca/files/2016/06/UBC-Drainage-Map-2010.pdf

Kerr Wood Leidal Associates; Lanarc Consultants; Goya Ngan. (2012). *Stormwater Source Control Design Guidelines 2012.* Vancouver: Metro Vancouver.

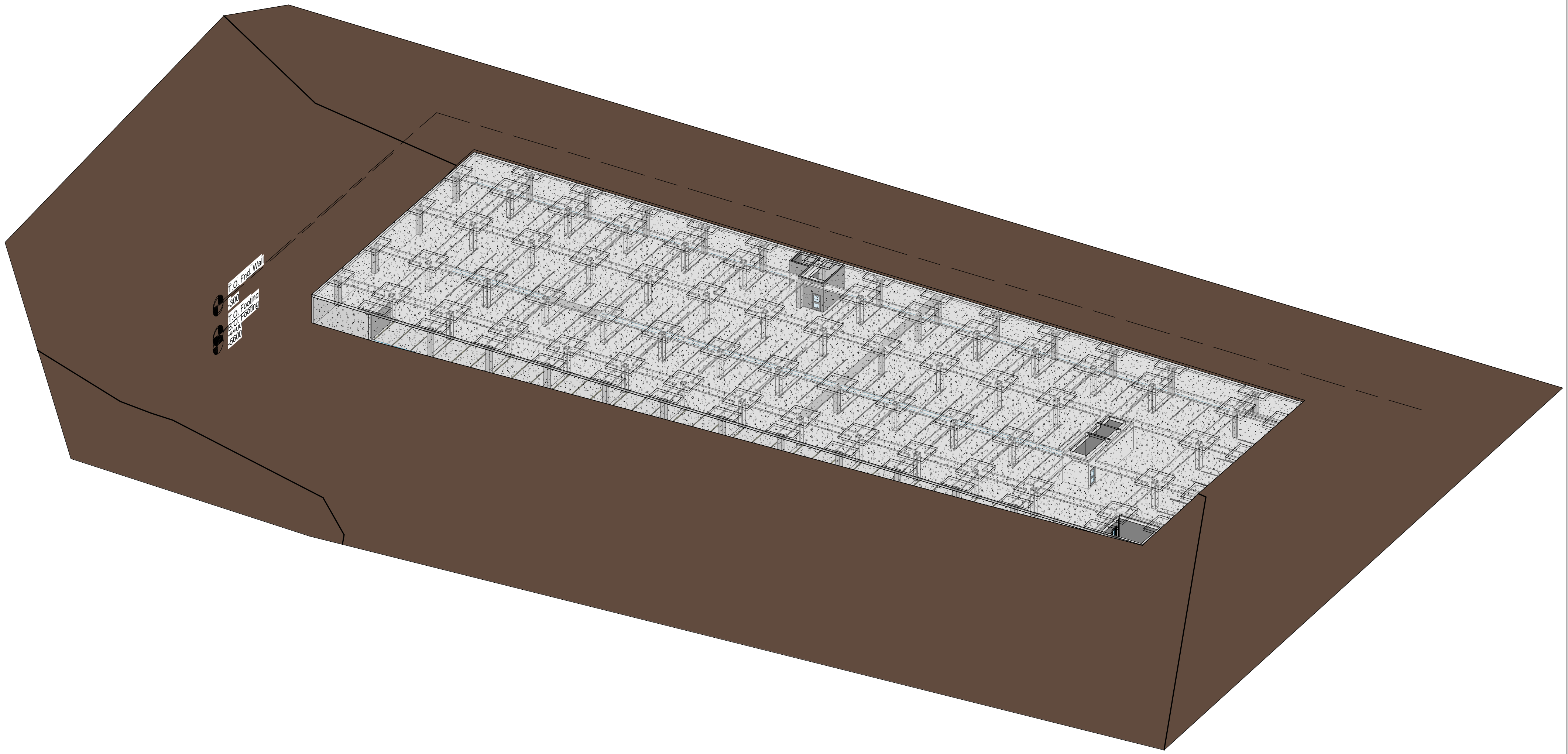
Piteau Associates. (2002). *Hydrogeological and Geotechnical Assessment of Northwest Area UBC Campus, Vancouver.* Vancouver, B.C.

UBC Campus + Community Planning. (2017). *Integrated Stormwater Management Plan.* UBC Campus + Community Planning.

The University of British Columbia (2017). UBC Technical Guidelines, Storm Drainage. Vancouver, B.C.

# Appendix A: Detailed Design Drawings

# Stadium Neighrbourhood: Stadium Parkade



Thunderfish Consulting Ltd.

| No. | Description | Date |
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| 1 | Issued for Construction | 2019-04-08 |

Stadium Neighbourhood Parkade

Cover Sheet

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| Project number | 0001 |
| Date | 2019-04-08 |
| Drawn by | Connor Ferster |
| Checked by | Connor Ferster |

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# GENERAL NOTES

GENERAL REQUIREMENTS:

1. STRUCTURAL DRAWINGS SHALL BE USED IN CONJUNCTION WITH THE SPECIFICATIONS AND OTHER PROJECT DRAWINGS BY OTHER DISCIPLINES. ALL WORK SHALL CONFORM TO THE REQUIREMENTS OF THE CODES LISTED BELOW.

2. CONTRACTOR SHALL VERIFY ALL DIMENSIONS AND ELEVATIONS RELATIONG TO EXISTING CONDITIONS BY MAKING FIELD SURVEYS AND MEASUREMENTS PRIOR TO COMMENCING FABRICATION OR CONSTRUCTION.

3. THE GENERAL CONTRACTOR SHALL ENSURE THAT ALL CONSTRUCTION METHODS USED WILL NOT CAUSE DAMAGE TO ADJACENT BUILDINGS, UTILITIES, OR OTHER PROPERTY. THIS REQUIREMENT IS PARTICULARLY IMPORTANT DURING FOUNDATION INSTALLATION.

4. DETAILS LABELE 'TYPICAL' SHALL APPLY TO ALL SITUATIONS THAT ARE THE SAME OR SIMILAR TO THOSE SPECIFICALLY DETAILED. SEE DETAIL TITLES FOR APPLICABLITY OF A PARTICULAR DETAIL. TYPICAL DETAILS SHALL APPLY WHETHER OR NOT THEY ARE SPECIFICALLY KEYED AT EACH LOCATION. THE ENGINEER SHALL HAVE FINAL AUTHORITY TO DETERMINE APPLICABILITY OF TYPICAL DETAILS.

5. WHERE CONFLICTS EXIST BETWEEN STRUCTURAL DOCUMENTS, THE STRICTEST REQUIREMENTS, AS INDICATED BY THE STRUCTURAL ENGINEERS, SHALL GOVERN.

6. NO STRUCTURAL MEMBERS SHALL BE CUT, NOTCHED, MODIFIED, OR OTHERWISE REDUCED IN STRENGTH UNLESS APPROVED BY THE STRUCTURAL ENGINEER.

PRIMARY CODES AND SPECIFICATIONS

1. GENERAL BUILDING CODE:
   A. BC BUILDING CODE 2018
   B. VANCOUVER BUILDING BYLAW

2. CONCRETE CODES:
   A. CSA A23.1, CONCRETE MATERIALS AND METHODS OF CONCRETE CONSTRUCTION
   B. CSA A23.3, DESIGN OF CONCRETE STRUCTURES

3. FORMWORK AND FALSEWORK CODES:
   A. CSA S269.3, CONCRETE FORMWORK
   B. CSA S269.1, FALSEWORK AND FORMWORK

DESIGN LOADS:

IMPORTANCE FACTOR: 1.0 (NORMAL)

1. PARKADE ROOF SUPERIMPOSED DEAD LOAD @ 2..0 KPA

2. LIVE LOADS:
   A. PARKADE ROOF LIVE LOAD @ 4.8 KPA - ASSEMBLY OCCUPANCY
   B. PARKADE FLOOR LIVE LOAD @ 4.8 KPA - ASSEMBLY OCCUPANCY

4. WIND LOADS:
   A. LOADS BASED ON BCBC-18 FOR VANCOUVER CITY HALL

   50 YEAR WIND PRESSURE, $q_{50}$ ........................................0.45 KPA
   EXPOSURE FACTOR, Ce ........................................1.32
   INTERNAL PRESSURE GUST FACTORS, $C_{gI}C_{pI}$........................................-0.45 TO 0.30
   ASSUMED ROOF SLOPE........................................4.8 DEGREES

5. SEISMIC LOADS:
   A. GROUND ACCELERATIONS FROM ENVIRONMENT CANADA:

| $S_a(0.2)$ | $S_a(0.1)$ | $S_a(0.2)$ | $S_a(0.3)$ | $S_a(0.5)$ | $S_a(1.0)$ | $S_a(2.0)$ | $S_a(5.0)$ |
|---|---|---|---|---|---|---|---|
| 0.467 | 0.712 | 0.879 | 0.886 | 0.786 | 0.441 | 0.266 | 0.083 |

   B. ASSUMED BUILDING PERIOD ($T_a$) @ 1.0 (BASED ON ASSUMED STADIUM HEIGHT OF 40M)
   C. SITE CLASS C
   D. $R_d$, $R_o$ @ (4.0, 1.2)
   E. $ST_a$ @ 0.441
   F. V @ 11.884 MN

CONCRETE

1. ALL CONCRETE SHALL CONFORM TO CSA A23.1, HAVING A MINIMUM COMPRESSIVE STRENGTH AS SHOWN BELOW
2. SUBMIT CONCRETE MIX DESIGN TO ENGINEER PRIOR TO PRODUCTION; NO WATER SHALL BE ADDED TO THE CONCRETE AT THE SITE.
3. THE OWNER WILL EMPLOYA A TESTING COMPANY TO CONDUCT SLUMP AND AIR ENTRAINMENT TESTS FOR EVERY BATCH THAT ARRIVES ON SITE. ADDITIONALLY, COMPRESSIVE STRENGTH TEST CYLINDERS WILL BE MADE ONCE PER DAY THAT CONCRETE IS BEING POURED ON SITE.
4. BULL FLOAT CONCRETE SURFACES AND PROVIDE A LIGHT TROWEL FINISH TO PRODUCE A SMOOTH, NON-SLIP SURFACE FREE FROM RIDGES, VOIDS, AND MACHINE MARKS. EXTERIOR CONCRETE WALKING SURFACES SHALL HAVE A LIGHT BROOM FINISH TO CREATE A NON-SLIP SURFACE. PROVIDE ROUGH SURFACE AT COLD JOINTS.
5. KEEP CONTINUOUSLY MOIST ALL EXPOSED NON-FORMED SURFACES FOR A MINIMUM OF SEVEN CONSECUTIVE DAYS AFTER PLACEMENT OF CONCRETE UNLESS NOTED OTHERWISE.
6. VIBRATE ALL CONCRETE. ENSURE ALL CONCRETE IS DENSE, FREE OF HONEY COMBING, AND THAT NO SEGREGATION OCCURS.

CONCRETE PROPERTIES

| APPLICATION | COMPRESSIVE STRENGTH (MPa) @ 28 DAYS | EXPOSURE CLASS |
|---|---|---|
| SLAB-ON-GRADE (INTERIOR) | 35 MPa | N |
| SLAB-ON-GRADE (EXTERIOR) | 35 MPa | C-2 |
| RETAINING/FOUNDATION WALLS | 30 MPa | F-2 |
| COLUMNS | 35 MPa | F-2 |

EROSION AND SEDIMENT CONTROL

1. EROSION AND SEDIMENT CONTROL MEASURES WILL BE IMPLEMENTED PRIOR TO, AND MAINTAINED DURING CONSTRUCTION PHASES, TO PREVENT ENTRY OF SEDIMENT INTO WATER. ALL DAMAGED EROSION AND SEDIMENT CONTROL MEASURES SHOULD BE REPARIED AND REPLACED WITHIN 48 HOURS OF INSPECTION.
2. THE AMOUNT OF SITE AREA DISTURBED WILL BE MINIMIZED TO THE EXTENT THAT IT IS POSSIBLE TO DO SO.
3. ALL ACTIVITIES, INCLUDING MAINTENANCE PROCEDURES, WILL BE CONTROLLED TO PREVENT THE UNNECESSARY DISTRUBANCE OF SENSITIVE PRE-LANDSCAPED AREAS.

STORM SEWERS

1. ALL PUBLIC STORM SEWER AND DRAINAGE SYSTEM CONSTRUCTION IS SUBJECT TO INSPECTION APPROVAL BY THE CITY OF VANCOUVER'S DEPARTMENT OF PUBLIC WORKS.
2. WATER QUALITY DEVICES WILL BE INSTALLED AND FUNCITONING PRIOR TO COMMENSING WITH INSTALLATION OF PAVEMENT FOR ALL AREAS DRAINIGN INTO THE WATER QUALITY SYSTEM. VEGETATION IN VEGETATIVE FACILITIES SHALL BE ESTABLISHED AND MECHANICAL DEVICES AND FILTER MEDIA SHALL BE INSTALLED.
3. ROOF DOWNSPOUT RUNOFF MUST BE RETAINED ON EACH SPECIFIC SITE LOCATION. DOWNSPOUTS SHALL NOT DRAIN TO THE STREET OR ANY ADJACENT PROPERTIES UNLESS UNLESS SPECIFIC APPROVED HAS BEEN OPTAINED.
4. ALL NEW CATCH BASINS WILL BE PROTECTED WITH A BARRIER OF SANDBAGS OR OTHER PERMEABLE FILTRATION BARRIER TO PREVENT ANY SEDIMENT THAT MAY HAVE GATHERED BEYOND THE EROSION CONTROL SYSTEM FROM ENTERING THE STORM SYSTEM.

SITE CLEARING

1. TREES AND OTHER EXISTING LARGE VEGETATION SHALL BE PRESERVED IN ITS CURRENT LOCATION AND SHALL NOT BE CUT, HARVESTED, OR DESTROYED WITHOUT OBTAINING PRIOR PERMISSION FROM EITHER THE SITE ENGINEER OR THE OWNER'S REPRESENTATIVE.
2. SITE GRADING WILL DISTURB AS LITTLE OF THE EXISTING AREA AS POSSIBLE.

Thunderfish Consulting Ltd.

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| 1 | Issued for Construction | 2019-04-08 |

Stadium Neighbourhood Parkade

General Notes

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| Project number | 0001 |
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| Checked by | Connor Ferster |

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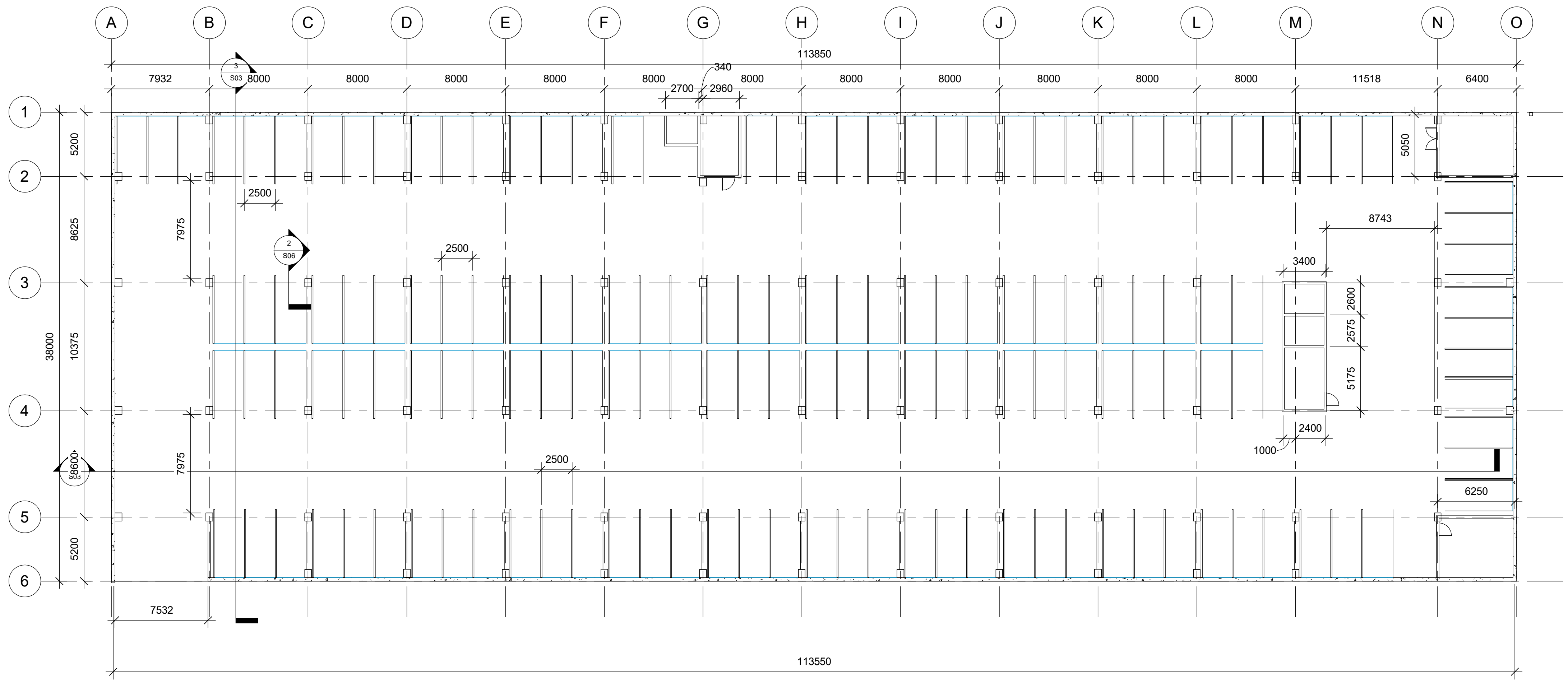


1 Parking Plan
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Thunderfish Consulting Ltd.

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# Stadium Neighbourhood Parkade

## Parking plan

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| Checked by | Connor Ferster |

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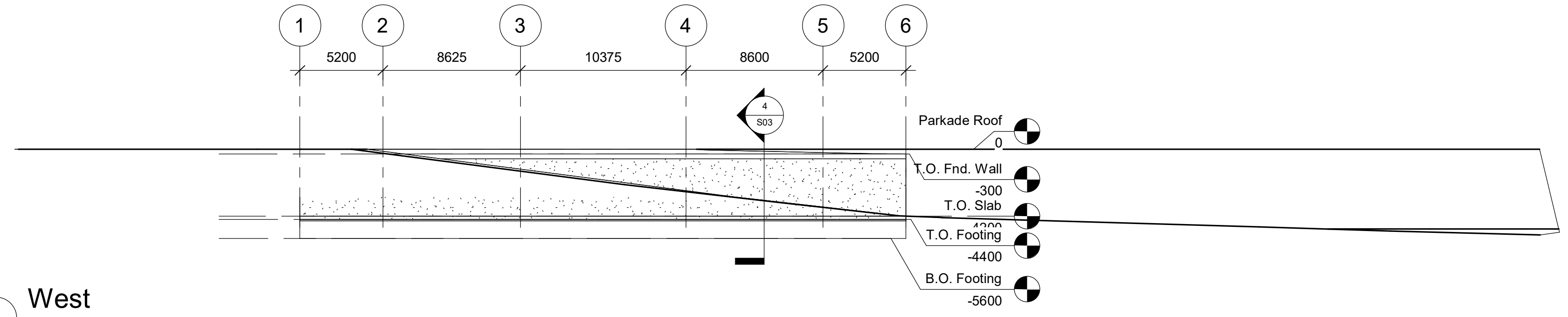


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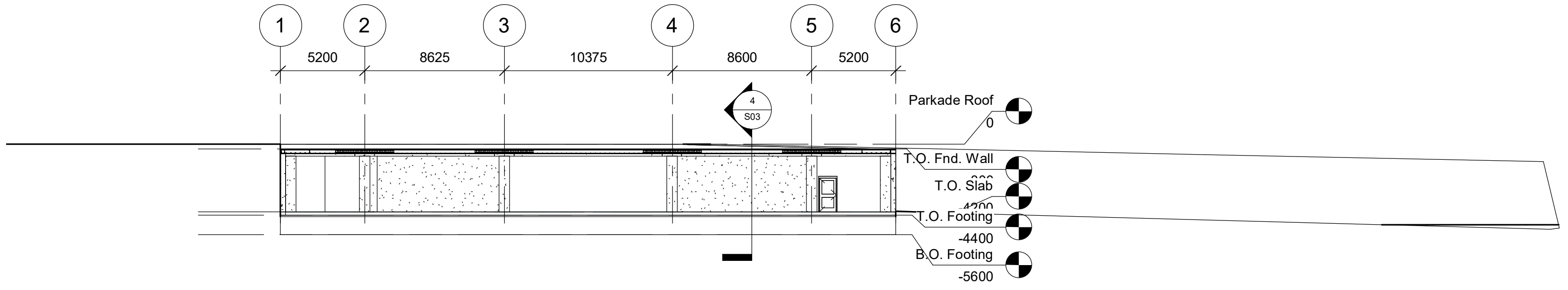


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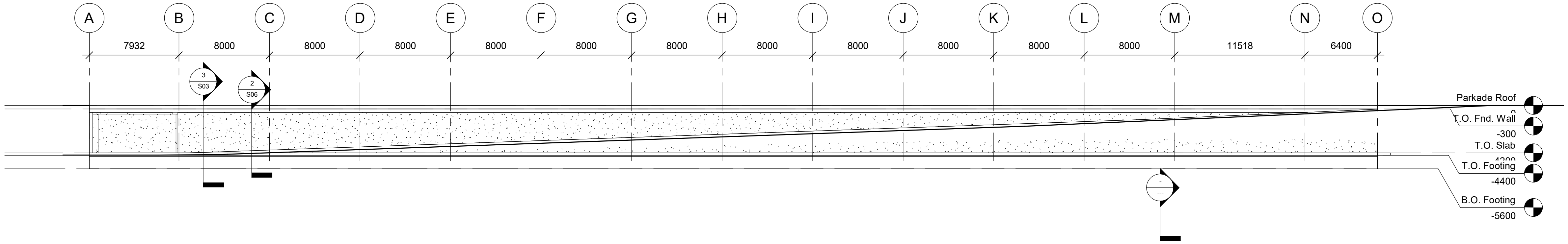


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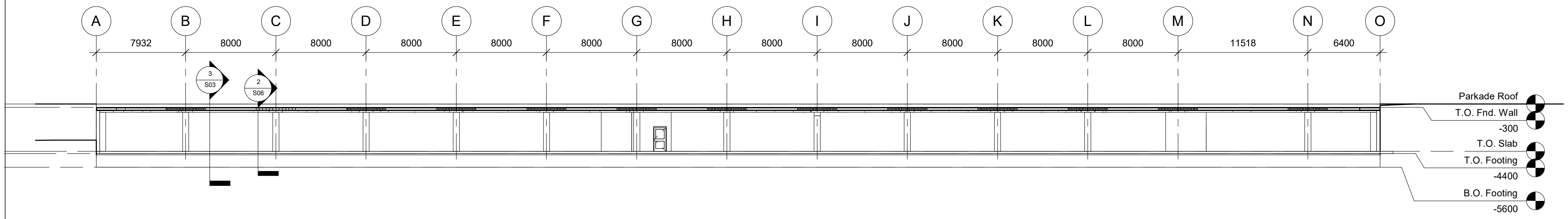


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# Stadium Neighbourhood Parkade

## Elevs & Sects

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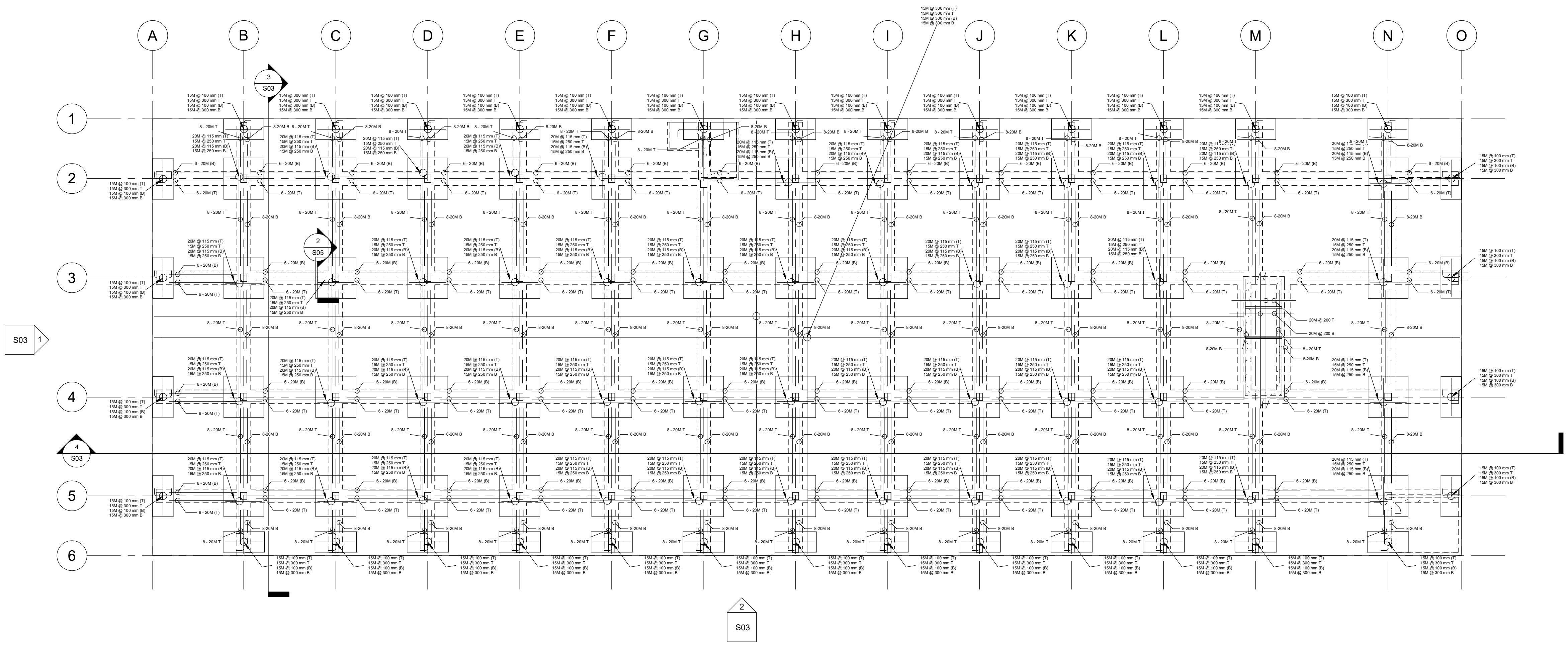


1 Parkade Roof
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Thunderfish Consulting Ltd.

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# Stadium Neighbourhood Parkade

## Level 1 slab

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| Scale | 1 : 200 |

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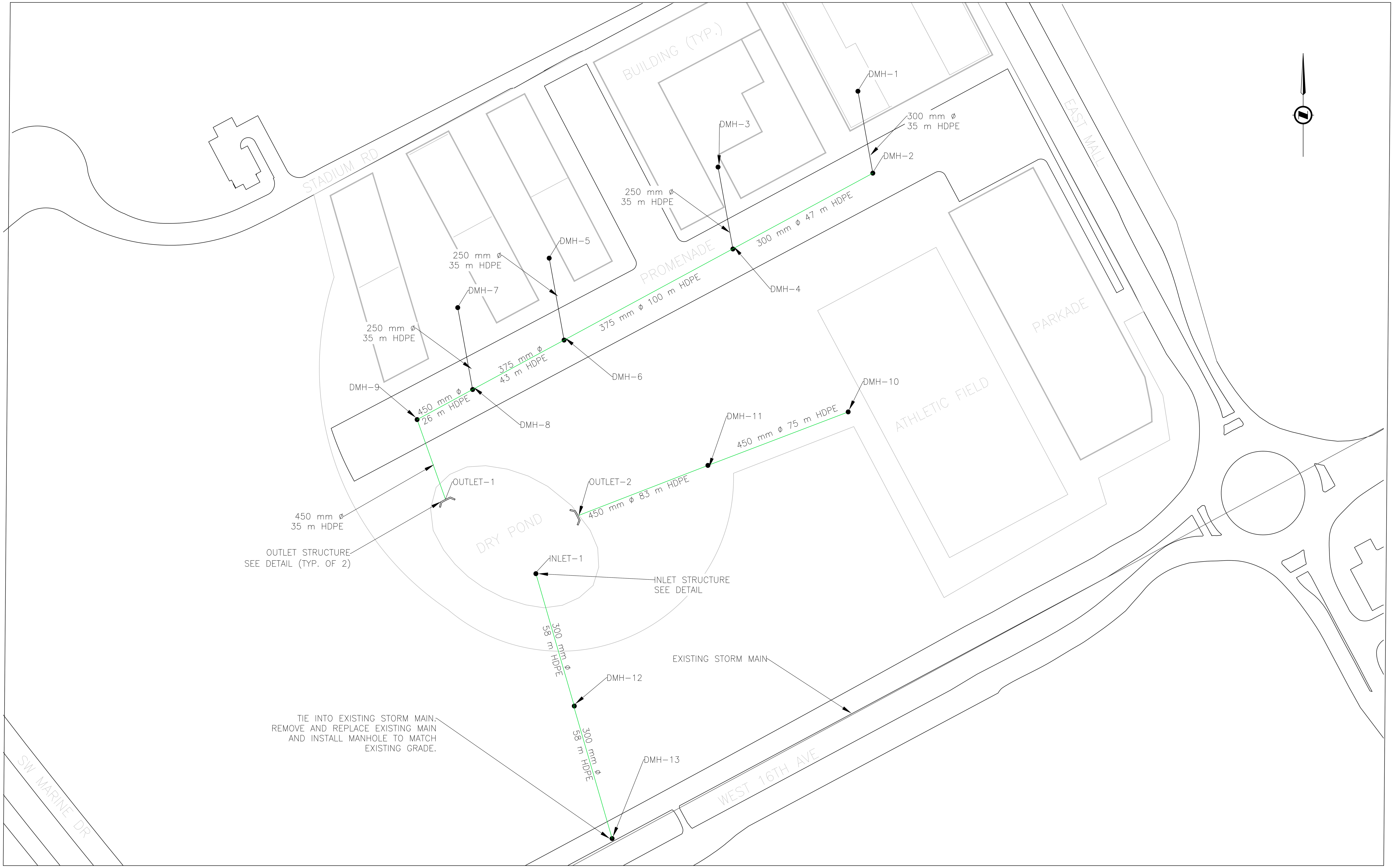



1 STORM SEWER PLAN

SCALE: 1:750

ISSUED FOR CONSTRUCTION

| REV NO | REVISIONS | DATE | DRAWN | APPR'D |
|---|---|---|---|---|
| 1 | ISSUED FOR CONSTRUCTION | 3/30/2019 | JR | APW |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Thunderfish Consulting Ltd.

STORM SEWER PLAN

Windows OLE Object

▸ DESIGN

DESIGN NO.

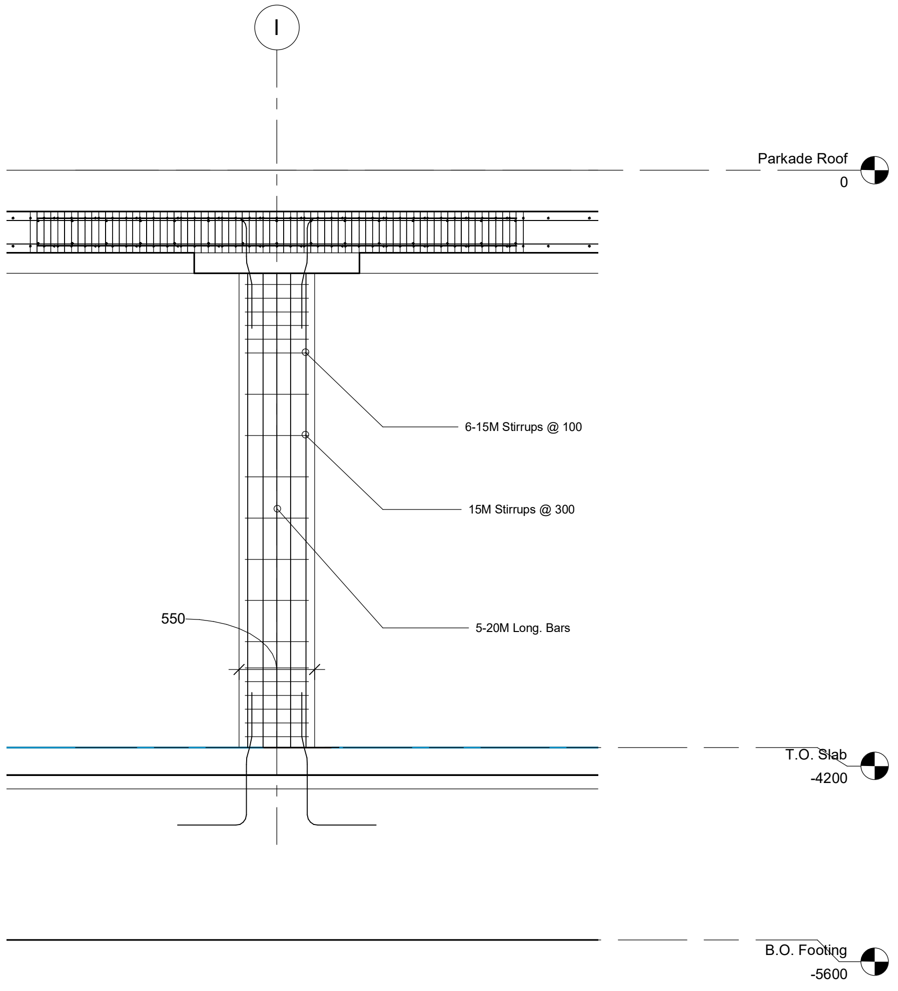
| | | | |
|---|---|---|---|
| SCALE | NA | DATE | 2015-11-01 |
| DRAWN BY | JR | DESIGN BY | JR |
| CHECKED BY | APW | APPROVED BY | APW |

DWG. NO. C-100

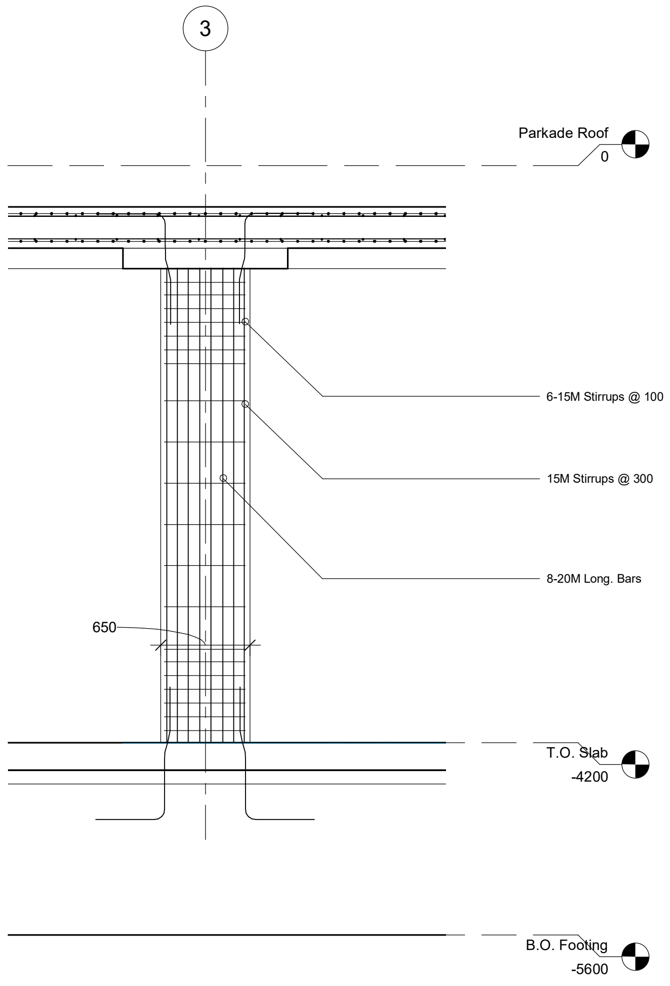
1 OF 8

REV. REV

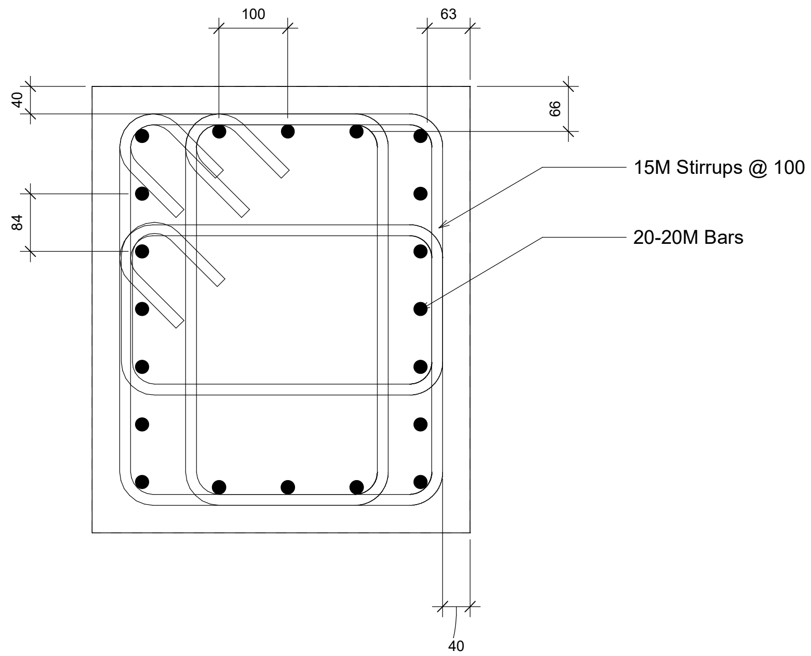
PLOT DATE: April 3, 2019 - /Users/jimjam/Downloads/C-100-STORMSEWERPLAN.dwg




1 Column Detail, 550mm side
1 : 25




2 Column Detail, 650mm side
1 : 25




3 Column Section
1 : 5

Thunderfish Consulting Ltd.

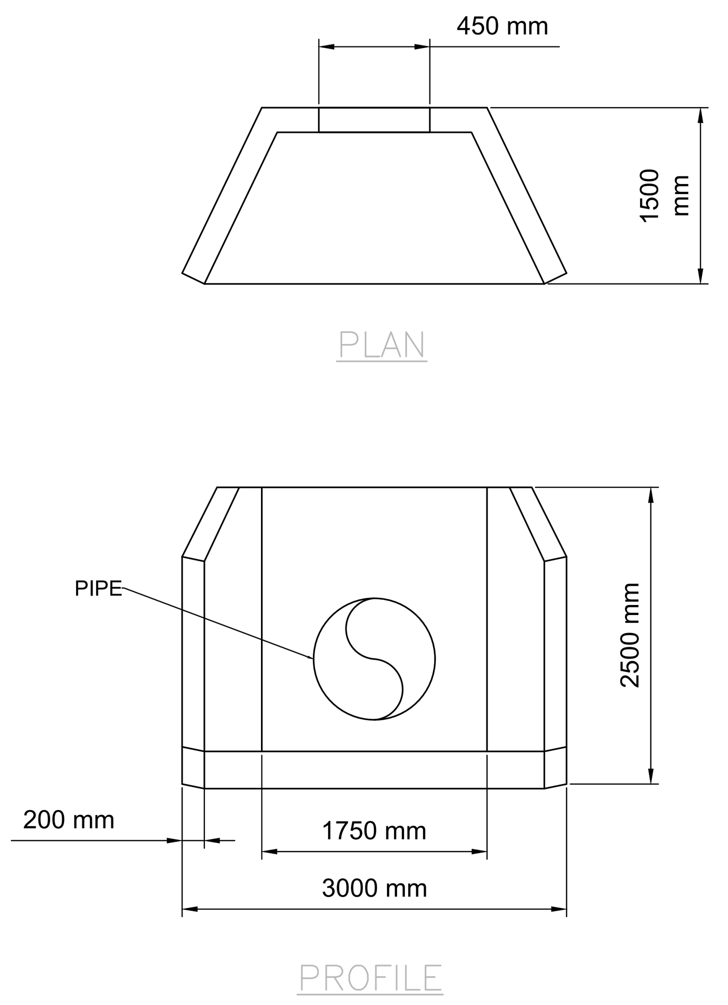
| No. | Description | Date |
|---|---|---|
| 1 | Issued for Construction | 2019-04-08 |

# Stadium Neighbourhood Parkade

## Column details

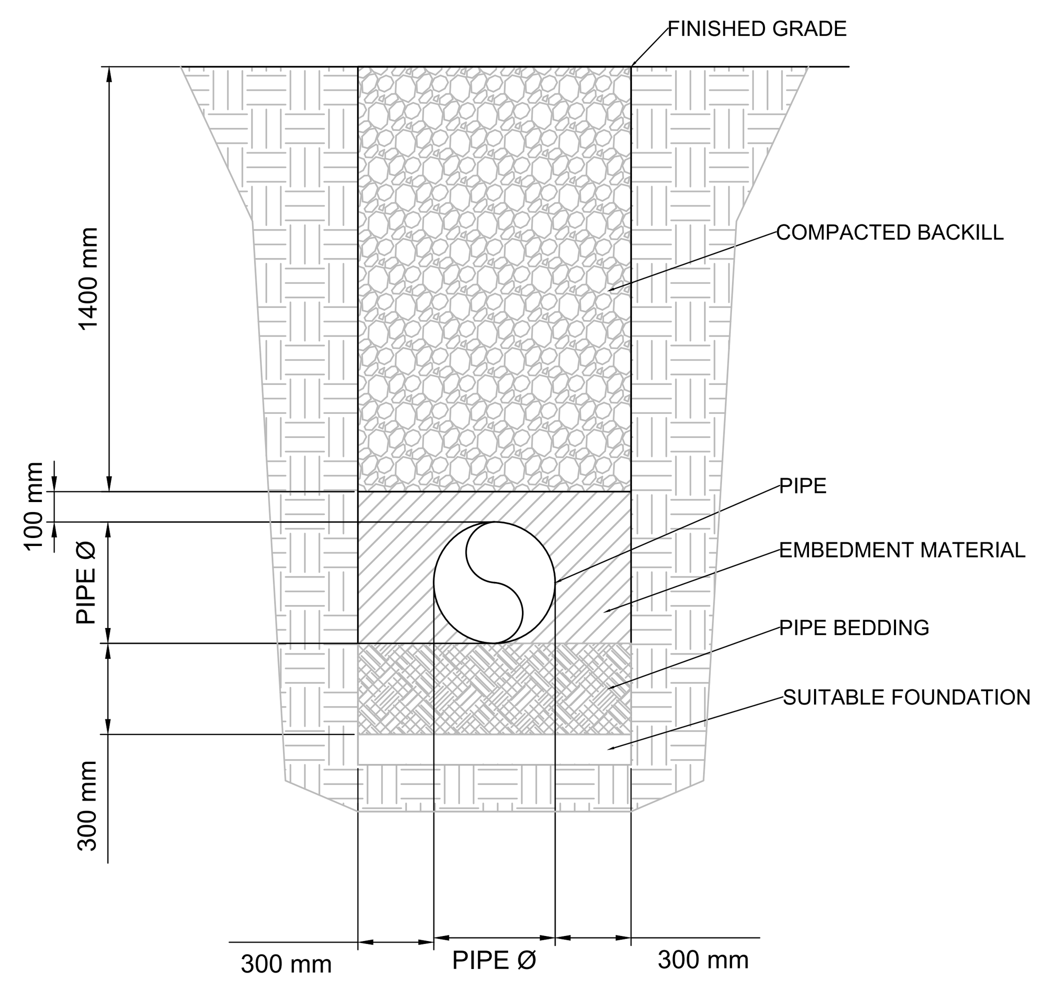
| | |
|---|---|
| Project number | 0001 |
| Date | 2019-04-08 |
| Drawn by | Connor Ferster |
| Checked by | Connor Ferster |
| | S05 |
| Scale | As indicated |

2019-04-08 2:00:40 PM




NOTES:
1. PRE-CAST HEADWALL C/W TRASH RACK FROM LANGLEY CONCRETE CO OR APPROVED EQUIVALENT.
2. ALL DIMENSIONS IN MILLIMETERS.

2 / _ TYPICAL HEADWALL OUTLET DETAIL
SCALE: NOT TO SCALE




NOTES:
1. ALL DIMENSIONS IN mm UNLESS OTHERWISE NOTED.
2. MINIMUM PIPE COVER TO BE 1500 mm FROM TOP OF PIPE TO FINISHED GRADE.
3. WHERE THE TRENCH BOTTOM IS UNSTABLE, CONTRACTOR SHALL EXCAVATE TO DEPTH REQUIRED BY THE ENGINEER AND REPLACE WITH SUITABLE SOIL AS SPECIFIED BY THE ENGINEER.
4. CLEAN NATIVE FILL AS COMPACTED BACKFILL MATERIAL TO BE APPROVED BY THE ENGINEER.
5. EMBEDMENT MATERIAL TO BE COMPACTED TO A MINIMUM OF 95% STANDARD PROCTOR DENSITY.

1 / _ TYPICAL PIPE TRENCH DETAIL
SCALE: NOT TO SCALE

▶ DESIGN — DESIGN NO.

| REV NO | REVISIONS | DATE | DRAWN | APPR'D |
|---|---|---|---|---|
| 1 | ISSUED FOR CONSTRUCTION | 3/30/2019 | JR | APW |

Thunderfish Consulting Ltd.

# STORM SEWER DETAILS

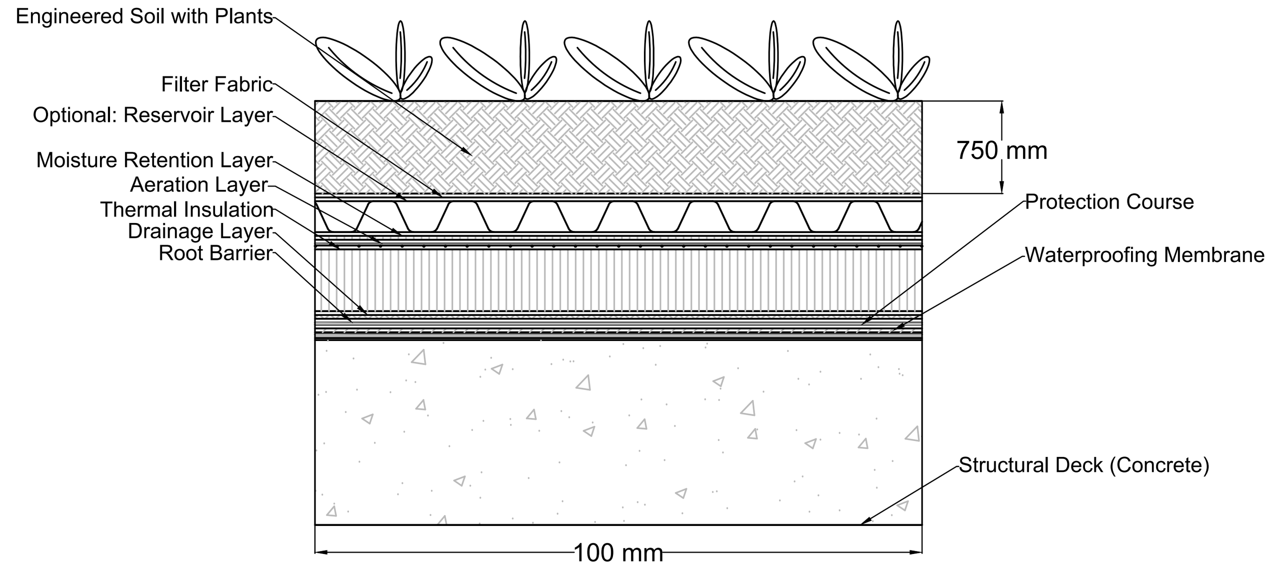
Windows OLE Object

| SCALE | NA | DATE | 2019-03-30 |
|---|---|---|---|
| DRAWN BY | JR | DESIGN BY | JR |
| CHECKED BY | APW | APPROVED BY | APW |

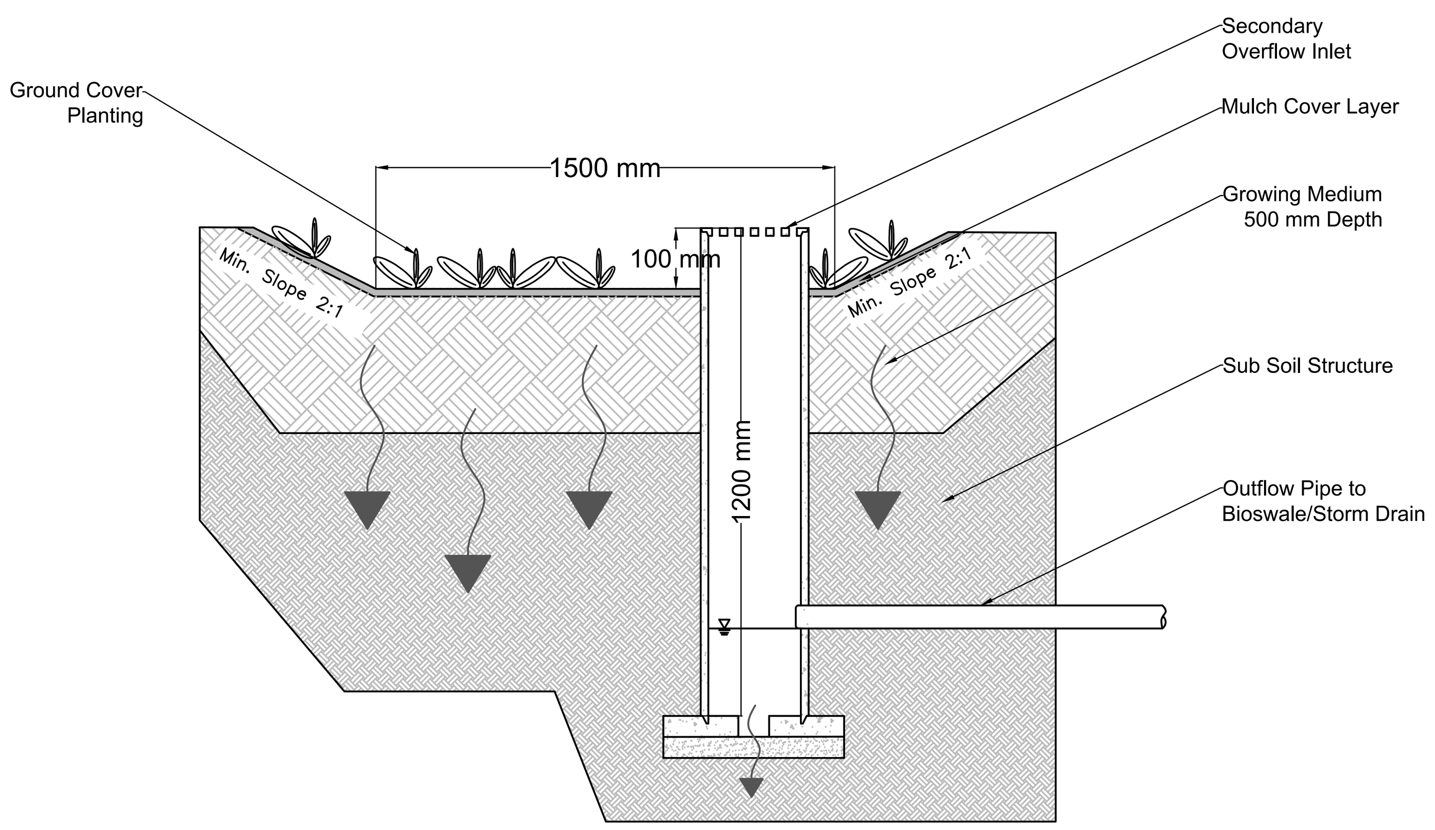
DWG. NO. C-101
1 OF 8
REV. REV

DESTROY ALL PRINTS BEARING PREVIOUS NO.

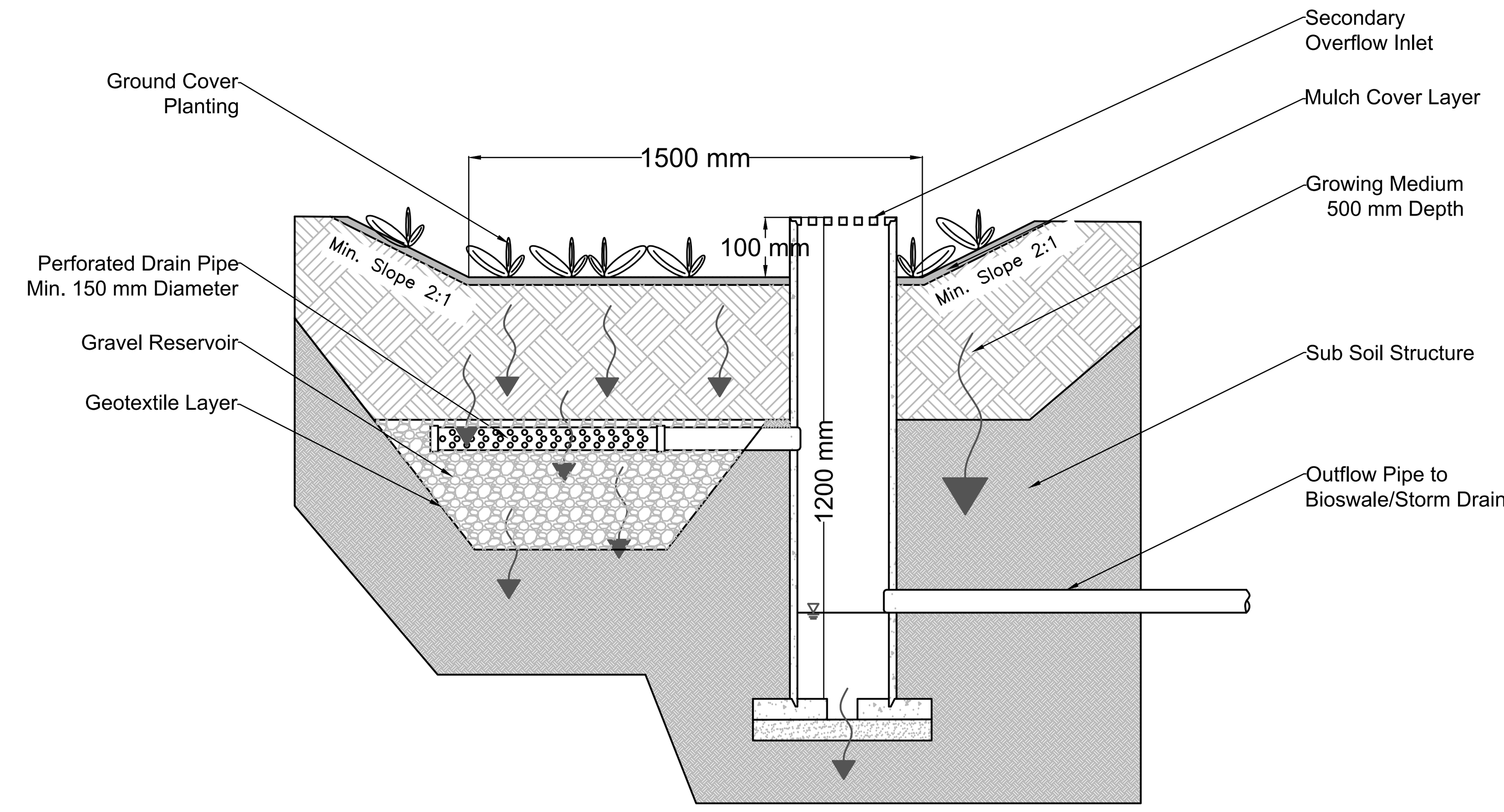
PLOT DATE: April 3, 2019 - /Users/jmjam/Downloads/STORMDETAILS.dwg




1 EXTENSIVE GREENROOF DETAIL
_ SCALE: NOT TO SCALE




2 FULL INFILTRATION RAIN GARDEN DETAIL
_ SCALE: NOT TO SCALE




3 PARTIAL INFILTRATION RAIN GARDEN DETAIL
_ SCALE: NOT TO SCALE

NOTES:
1. ALL DIMENSIONS IN MILLIMETERS.

▶ DESIGN

DESIGN NO.

| REV NO | REVISIONS | DATE | DRAWN | APPR'D |
|---|---|---|---|---|
| 1 | ISSUED FOR CONSTRUCTION | 3/30/2019 | TJ/JR | APW |
| | | | | |
| | | | | |
| | | | | |

Thunderfish Consulting Ltd.

RAIN GARDEN AND GREEN ROOF DETAILS

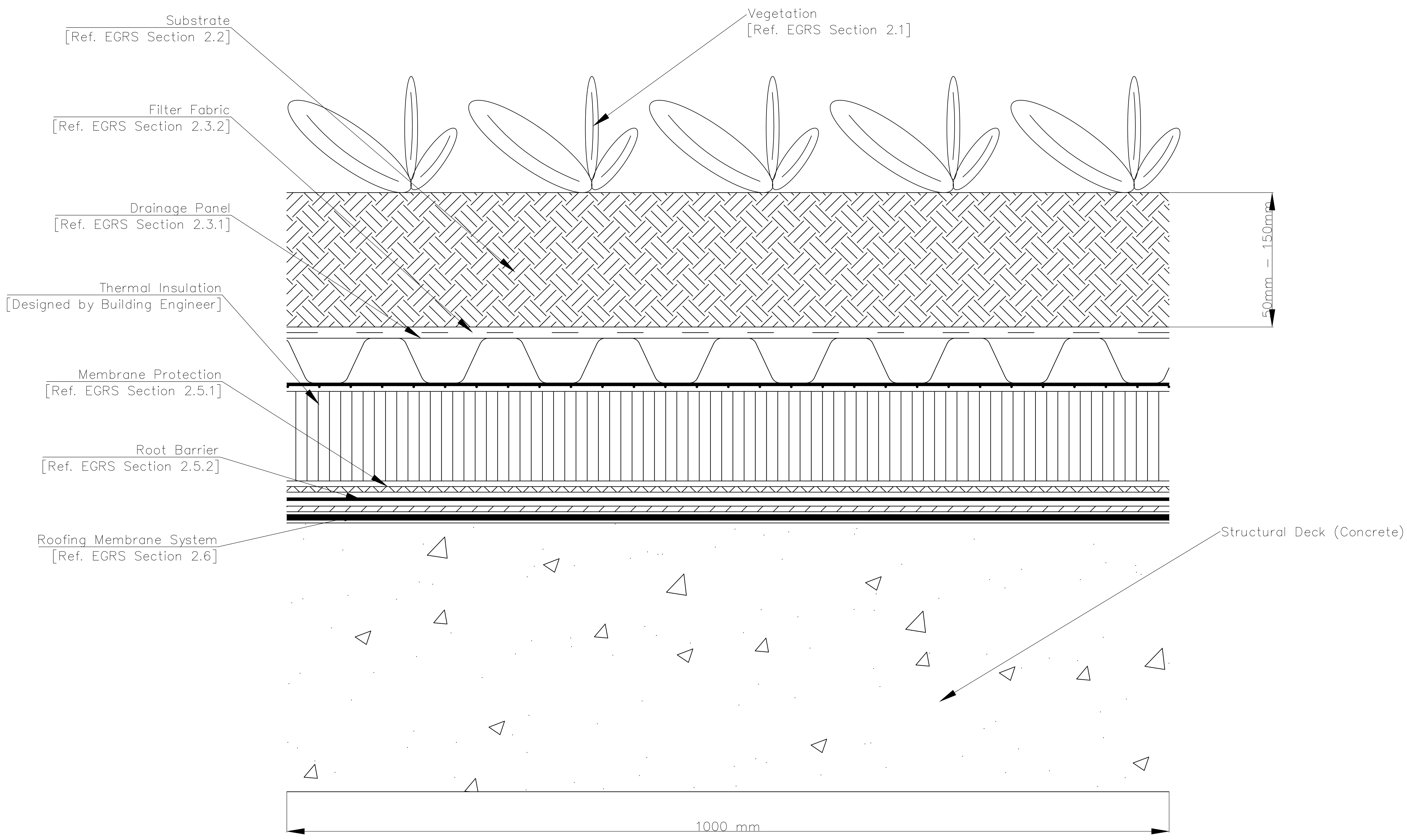
Windows OLE Object

| | | | |
|---|---|---|---|
| SCALE | NA | DATE | 2019-03-30 |
| DRAWN BY | TJ/JR | DESIGN BY | TJ/ED |
| CHECKED BY | APW | APPROVED BY | APW |

DWG. NO. C-102
1 OF 8
REV. REV

DESTROY ALL PRINTS BEARING PREVIOUS NO.

PLOT DATE: April 3, 2019 - /Users/jimjam/Downloads/C-700-RainGarden-GreenRoof-Details.dwg




GR 1 Typical Extensive Green Roof Section

ISSUED FOR CONSTRUCTION

▸ *DESIGN*

*DESIGN NO.*

| REV NO | REVISIONS | DATE | DRAWN | APPR'D |
|---|---|---|---|---|
| | | | | |

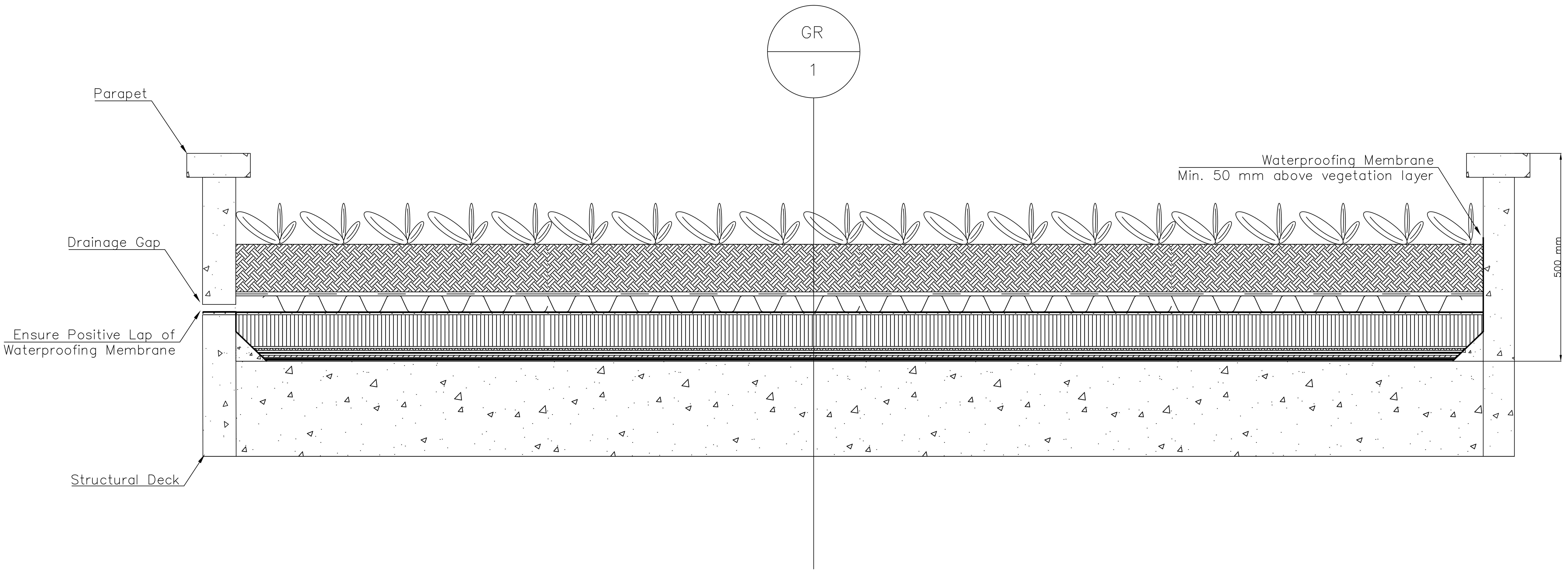
Thunderfish Consulting Ltd.

Green Roof Detail

Thunderfish Consulting Ltd.

| | | | | |
|---|---|---|---|---|
| SCALE | NA | DATE | 2019-04-03 | DWG. NO. KM |
| DRAWN BY | TJ | DESIGN BY | TJ | 2 OF 2 |
| CHECKED BY | | APPROVED BY | | |
| | | | | REV. 1 |

PLOT DATE: April 3, 2019 - D:\Education\CIVL446 - Capstone II\Drawings\Sections_-_Green-Roof_Rain-Garden_April3.dwg




Notes:
Refer to the Architectural drawings for the relevant rooftop dimensions.

ISSUED FOR CONSTRUCTION

▸ *DESIGN* | *DESIGN NO.*

| REV NO | REVISIONS | DATE | DRAWN | APPR'D |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

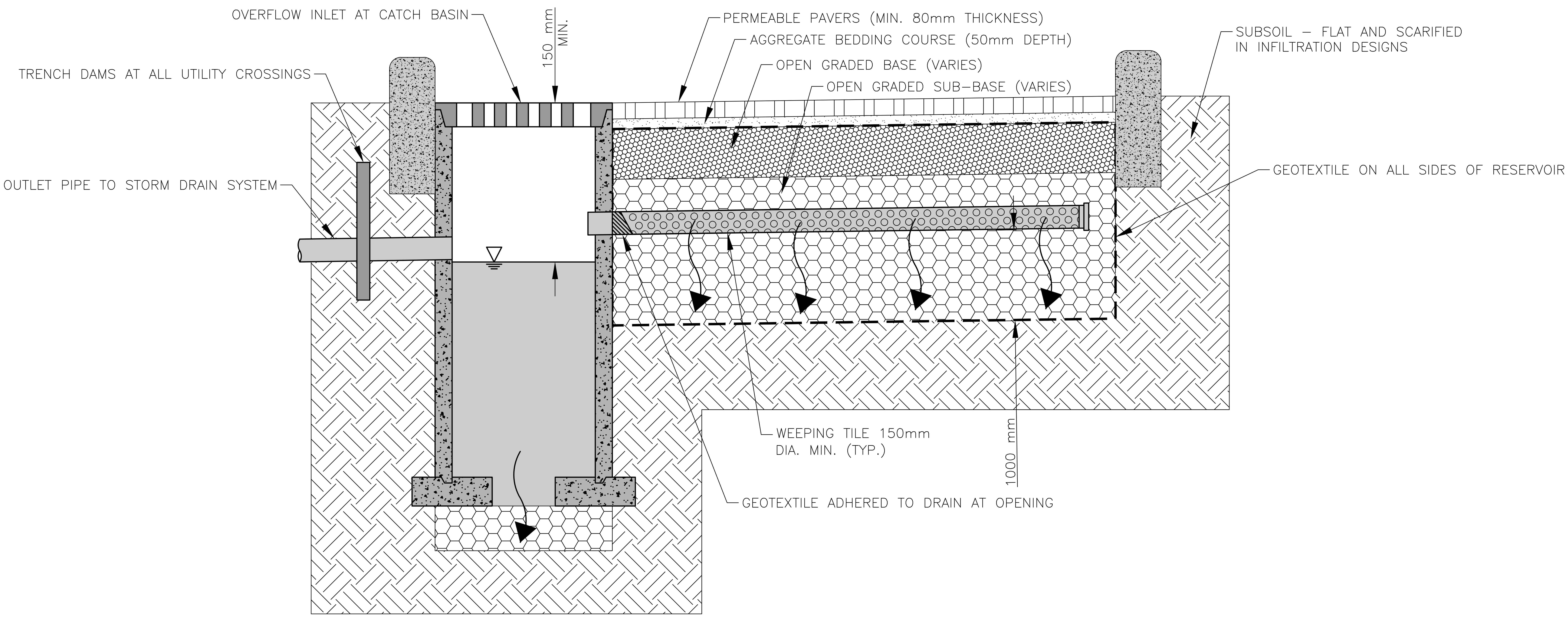
Thunderfish Consulting Ltd.

Typical Extensive Green Roof Section

Thunderfish Consulting Ltd.

| | | | | |
|---|---|---|---|---|
| SCALE | NA | DATE | 2019-04-03 | DWG. NO. KM |
| DRAWN BY | TJ | DESIGN BY | TJ | |
| CHECKED BY | | APPROVED BY | | 1 OF 2 |
| | | | | REV. 2 |

PLOT DATE: April 3, 2019 - D:\Education\CIVL446 - Capstone II\Drawings\Sections_-_Green-Roof_Rain-Garden_April3.dwg




SECTION VIEW
PERMEABLE PAVERS
PARTIAL INFILTRATION

SCALE: NTS

▶ DESIGN — DESIGN NO.

| REV NO | REVISIONS | DATE | DRAWN | APPR'D |
|---|---|---|---|---|
| 1 | ISSUED FOR CONSTRUCTION | 3/30/2019 | SN | SN |

Thunderfish Consulting Ltd.

PERMEABLE PAVER DETAIL

Thunderfish Consulting Ltd.

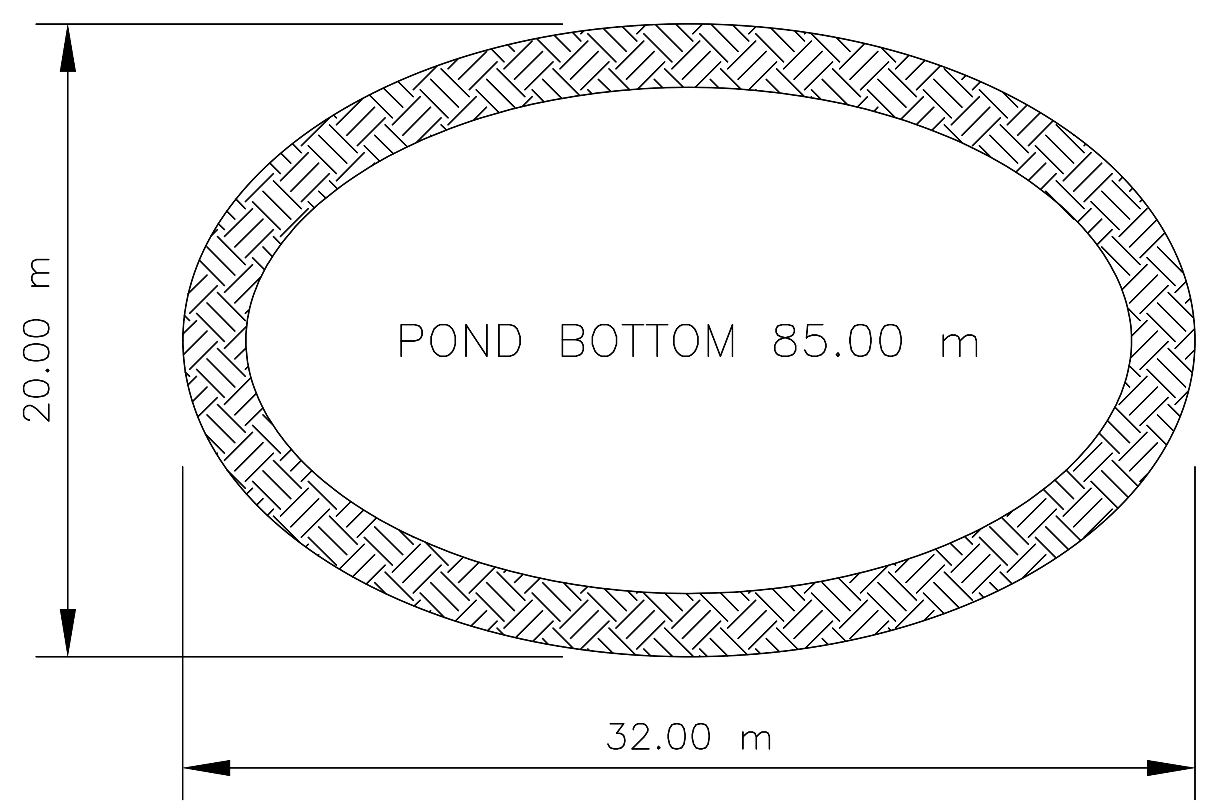
| | | | |
|---|---|---|---|
| SCALE | AS SHOWN | DATE | 2018-11-26 |
| DRAWN BY | SN | DESIGN BY | SN |
| CHECKED BY | SN | APPROVED BY | SN |

DWG. NO. C01

1 OF 1

REV. 0

PLOT DATE: April 5, 2019 - H:\SRN-ENG.dwg




PLAN VIEW
DETENTION POND
SCALE: NTS


SECTION VIEW
DETENTION POND
SCALE: NTS

| REV NO | REVISIONS | DATE | DRAWN | APPR'D |
|---|---|---|---|---|
| 1 | ISSUED FOR CONSTRUCTION | 3/30/2019 | SN | SN |

Thunderfish Consulting Ltd.

DETENTION POND DETAILS

Thunderfish Consulting Ltd.

▶DESIGN

DESIGN NO.

| | | | | |
|---|---|---|---|---|
| SCALE | NTS | DATE | 2018-11-26 | DWG. NO. C02 |
| DRAWN BY | ES | DESIGN BY | ES | |
| CHECKED BY | ES | APPROVED BY | ES | 1 OF 2 |
| | | | | REV. 0 |

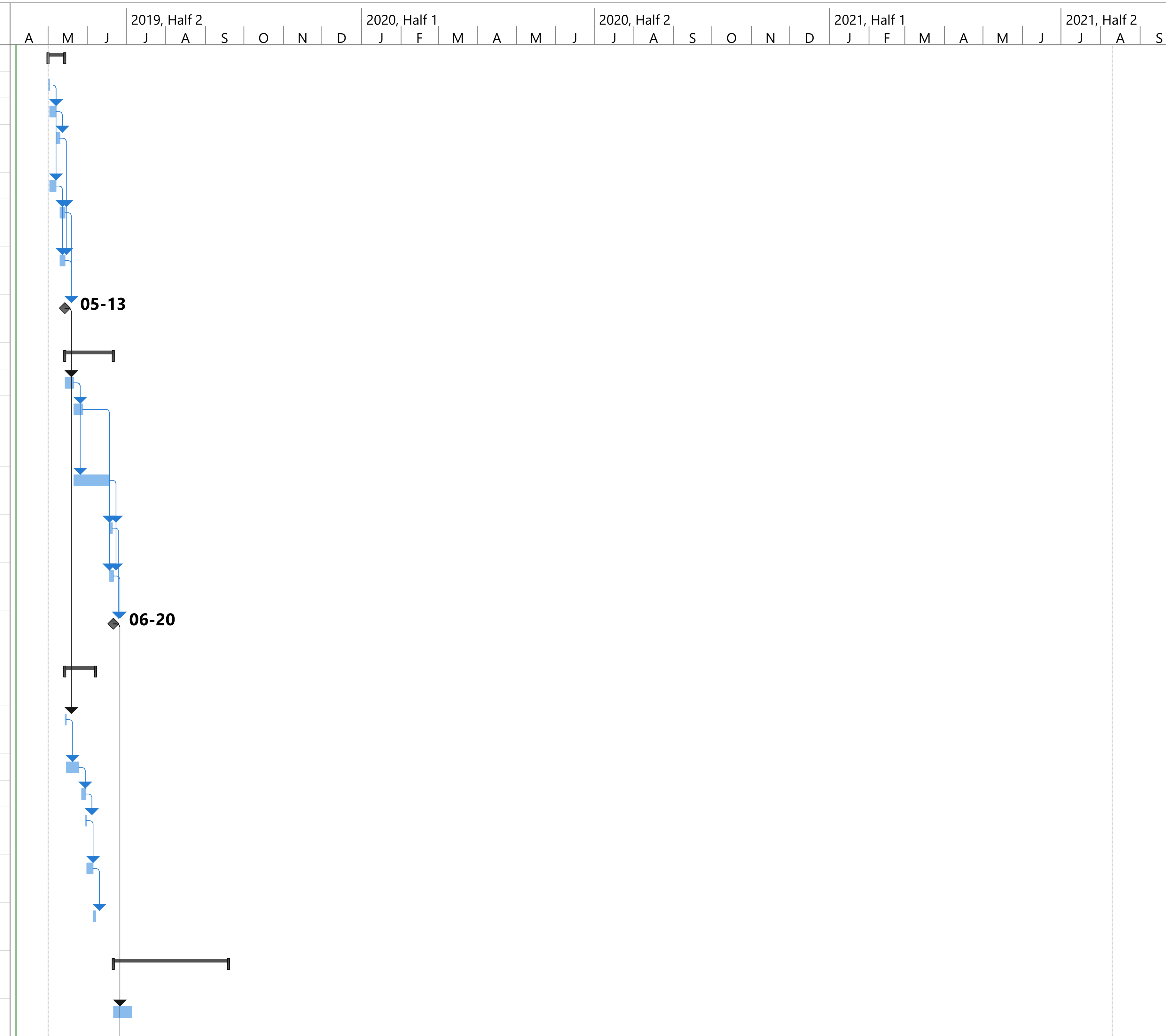
PLOT DATE: April 5, 2019 - H:\SRN-ENG.dwg

# Appendix B: Cost Estimate

| THUNDERFISH CONSULTING - FINAL DESIGN COST ESTIMATE | | | | | |
|---|---|---|---|---|---|
| **Item** | **Description** | **Unit** | **Estimated Quantity** | **Unit Rate** | **Total Price** |
| **1** | **PERMEABLE PAVERS** | | | | |
| 1 | **Permeable Pavers** | | | | |
| 1.1 | Pavers | Square Meters | 6231 | $ 89.00 | $ 554,559.00 |
| | | | | SUBTOTAL FOR TASK | $ 554,559.00 |
| | | | | CONSTRUCTION COST SUBTOTAL | $ 554,559.00 |
| | | | | ANNUAL MAINTENANCE COST SUBTOTAL | $ 8,179.00 |
| **Item** | **Description** | **Unit** | **Estimated Quantity** | **Unit Rate** | **Total Price** |
| **2** | **STORM SEWER SYSTEM** | | | | |
| 2.1 | **Pipe Costs** | | | | |
| 2.11 | 250 mm | Lineal Meters | 105 | $ 140.00 | $ 14,700.00 |
| 2.12 | 300 mm | Lineal Meters | 198 | $ 160.00 | $ 31,680.00 |
| 2.13 | 375 mm | Lineal Meters | 143 | $ 180.00 | $ 25,740.00 |
| 2.14 | 450 mm | Lineal Meters | 184 | $ 240.00 | $ 44,160.00 |
| | | | | SUBTOTAL FOR TASK | $ 116,280.00 |
| 2.2 | **Manhole Costs** | | | | |
| 2.21 | 1050 mm diameter Manhole | Each | 13 | $ 3,000.00 | $ 39,000.00 |
| | | | | SUBTOTAL FOR TASK | $ 39,000.00 |
| 2.3 | **Catch Basin** | | | | $ - |
| 2.31 | Standard Catch Basin | Each | 6 | $ 1,750.00 | $ 10,500.00 |
| | | | | SUBTOTAL FOR TASK | $ 10,500.00 |
| | | | | CONSTRUCTION COST SUBTOTAL | $ 165,780.00 |
| | | | | ANNUAL MAINTENANCE COST SUBTOTAL | $ 6,432.00 |
| **Item** | **Description** | **Unit** | **Estimated Quantity** | **Unit Rate** | **Total Price** |
| **3** | **RAIN GARDEN** | | | | |
| 3 | **Rain Garden** | | | | |
| 3.1 | Rain Garden | Square Metre | 502 | $ 220.00 | $ 110,440.00 |
| | | | | SUBTOTAL FOR TASK | $ 110,440.00 |
| | | | | CONSTRUCTION COST SUBTOTAL | $ 110,440.00 |
| | | | | ANNUAL MAINTENANCE COST SUBTOTAL | $ 9,534.00 |
| **Item** | **Description** | **Unit** | **Estimated Quantity** | **Unit Rate** | **Total Price** |
| **4** | **GREEN ROOF** | | | | |
| 4 | **Green Roof** | | | | |
| 4.01 | Green Roof | Square Meter | 7839 | $ 170.00 | $ 1,332,630.00 |
| | | | | SUBTOTAL FOR TASK | $ 1,332,630.00 |
| | | | | CONSTRUCTION COST SUBTOTAL | $ 1,332,630.00 |
| | | | | ANNUAL MAINTENANCE COST SUBTOTAL | $ 78,390.00 |
| **Item** | **Description** | **Unit** | **Estimated Quantity** | **Unit Rate** | **Total Price** |
| **5** | **PARKADE** | | | | |
| 5.1 | **Concrete** | | | | |
| 5.11 | 35 MPa Ready mix concrete | Cubic Meters | 7920 | $ 214.00 | $ 1,694,880.00 |
| 5.12 | Reinforcing steel | ton | 1584 | $ 1,000.00 | $ 1,584,000.00 |
| 5.13 | Formwork | Unit | 1 | $ 250,000.00 | $ 250,000.00 |
| 5.14 | Heavy machinery, crane etc. | Unit | 1 | $ 350,000.00 | $ 350,000.00 |
| | | | | SUBTOTAL FOR TASK | $ 3,878,880.00 |
| 5.2 | **Labour** | | | | |
| 5.21 | Approximately 10 months | crew/month | 10 | $ 475,000.00 | $ 4,750,000.00 |
| | | | | SUBTOTAL FOR TASK | $ 4,750,000.00 |
| | | | | CONSTRUCTION COST SUBTOTAL | $ 8,628,880.00 |
| | | | | ANNUAL MAINTENANCE COST SUBTOTAL | $ 40,000.00 |
| **Item** | **Description** | **Unit** | **Estimated Quantity** | **Unit Rate** | **Total Price** |
| **7** | **DRY POND** | | | | |
| 7 | **Dry Pond** | | | | |
| 7.01 | Dry Pond | - | 1 | - | $ 65,000.00 |
| | | | | SUBTOTAL FOR TASK | $ 65,000.00 |
| | | | | CONSTRUCTION COST SUBTOTAL | $ 65,000.00 |
| | | | | ANNUAL MAINTENANCE COST SUBTOTAL | $ 3,670.00 |
| | | | | | |
| | | | | **PROJECT SUBTOTAL** | $ 11,003,494.00 |
| | | | | | |
| | | | | **CONSULTING FEE SCHEDULE** | $ 217,363.00 |
| | | | | **TAXES (12%)** | $ 1,320,419.28 |
| | | | | | |
| | | | | **PROJECT TOTAL** | **$ 12,541,276.28** |

# Appendix C: Construction Schedule & Work

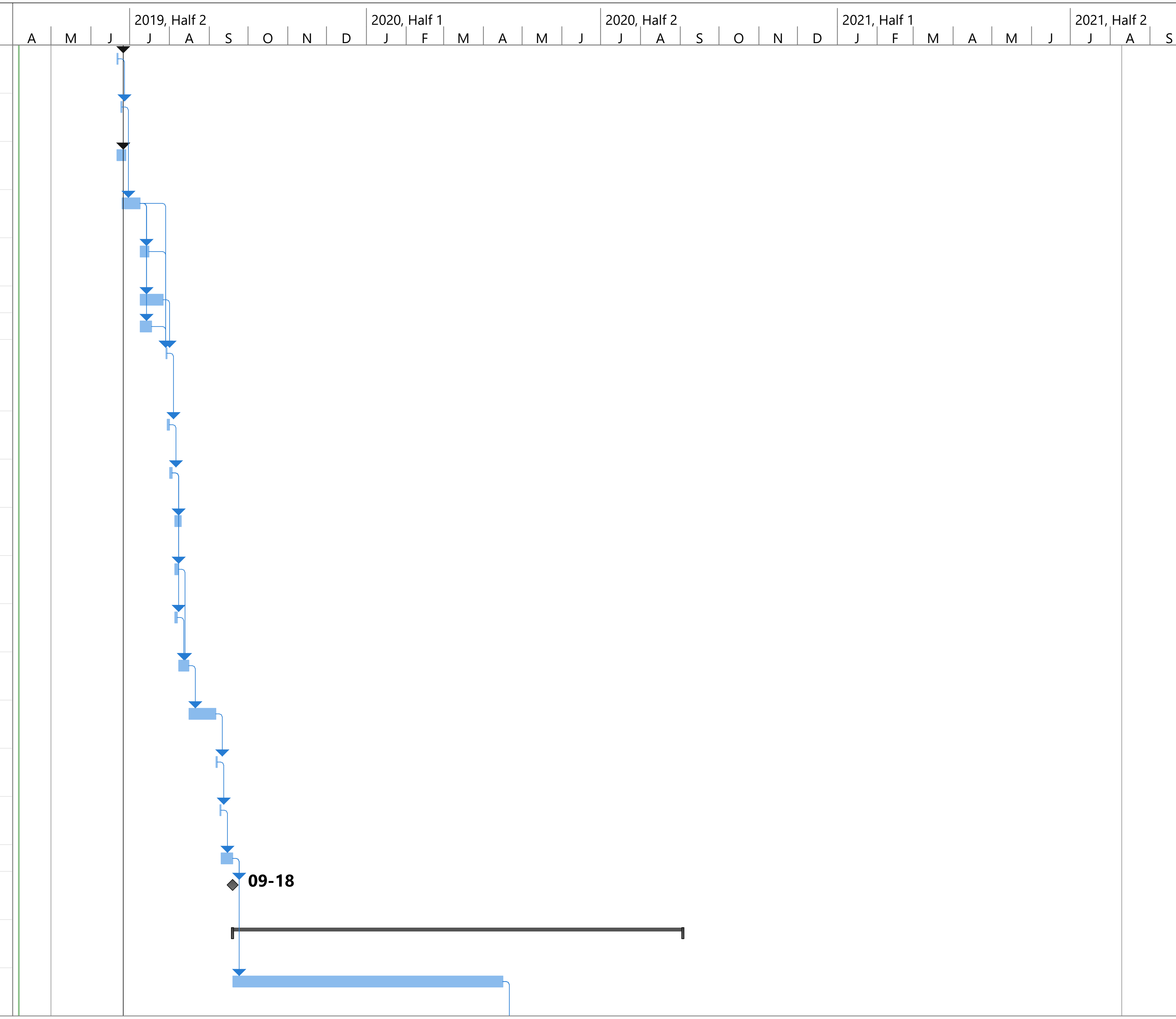
| ID | ℹ | Task Mode | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|---|---|
| 1 | | | **Site Preparation** | **9 days** | **Wed 19-05-0** | **Mon 19-05-1** | |
| 2 | | | Utility Locates | 1 day | Wed 19-05-0 | Wed 19-05-0 | |
| 3 | | | Layout survey | 3 days | Thu 19-05-02 | Mon 19-05-0 | 2 |
| 4 | | | Install perimeter fencing | 3 days | Tue 19-05-07 | Thu 19-05-09 | 3 |
| 5 | | | Install erosion cont | 3 days | Thu 19-05-02 | Mon 19-05-0 | 2 |
| 6 | | | Build construction staging area | 2 days | Fri 19-05-10 | Mon 19-05-13 | 5,4 |
| 7 | | | Transport heavy equipment | 2 days | Fri 19-05-10 | Mon 19-05-13 | 5,4 |
| 8 | | | Complete site preparation | 0 days | Mon 19-05-13 | Mon 19-05-13 | 6,7 |
| 9 | | | **Earthworks** | **28 days** | **Tue 19-05-14** | **Thu 19-06-20** | |
| 10 | | | Clearing and grubb | 5 days | Tue 19-05-14 | Mon 19-05-2 | 8 |
| 11 | | | Excavate site of stadium and parkade | 5 days | Tue 19-05-21 | Mon 19-05-27 | 10 |
| 12 | | | Excavate site of other buildings | 20 days | Tue 19-05-21 | Mon 19-06-17 | 10 |
| 13 | | | Shape detention pond | 2 days | Tue 19-06-18 | Wed 19-06-19 | 11,12 |
| 14 | | | Fill in existing stadium | 3 days | Tue 19-06-18 | Thu 19-06-20 | 11,12 |
| 15 | | | Complete earthworks | 0 days | Thu 19-06-20 | Thu 19-06-20 | 13,14 |
| 16 | | | **Storm Sewer Construction** | **18 days** | **Tue 19-05-14** | **Thu 19-06-06** | |
| 17 | | | Layout survey for sewer | 1 day | Tue 19-05-14 | Tue 19-05-14 | 8 |
| 18 | | | Excavate Trench | 8 days | Wed 19-05-1 | Fri 19-05-24 | 17 |
| 19 | | | Install pipe bedding | 3 days | Mon 19-05-2 | Wed 19-05-2 | 18 |
| 20 | | | Engineering inspection | 1 day | Thu 19-05-30 | Thu 19-05-30 | 19 |
| 21 | | | Install pipe surround material | 3 days | Fri 19-05-31 | Tue 19-06-04 | 20 |
| 22 | | | Compact trench backfill | 2 days | Wed 19-06-05 | Thu 19-06-06 | 21 |
| 23 | | | **Parkade and Stadium** | **64 days** | **Fri 19-06-21** | **Wed 19-09-18** | |
| 24 | | | Install foundationg wall shoring | 10 days | Fri 19-06-21 | Thu 19-07-04 | 15 |




Project: Project Schedule
Date: Sat 19-04-06

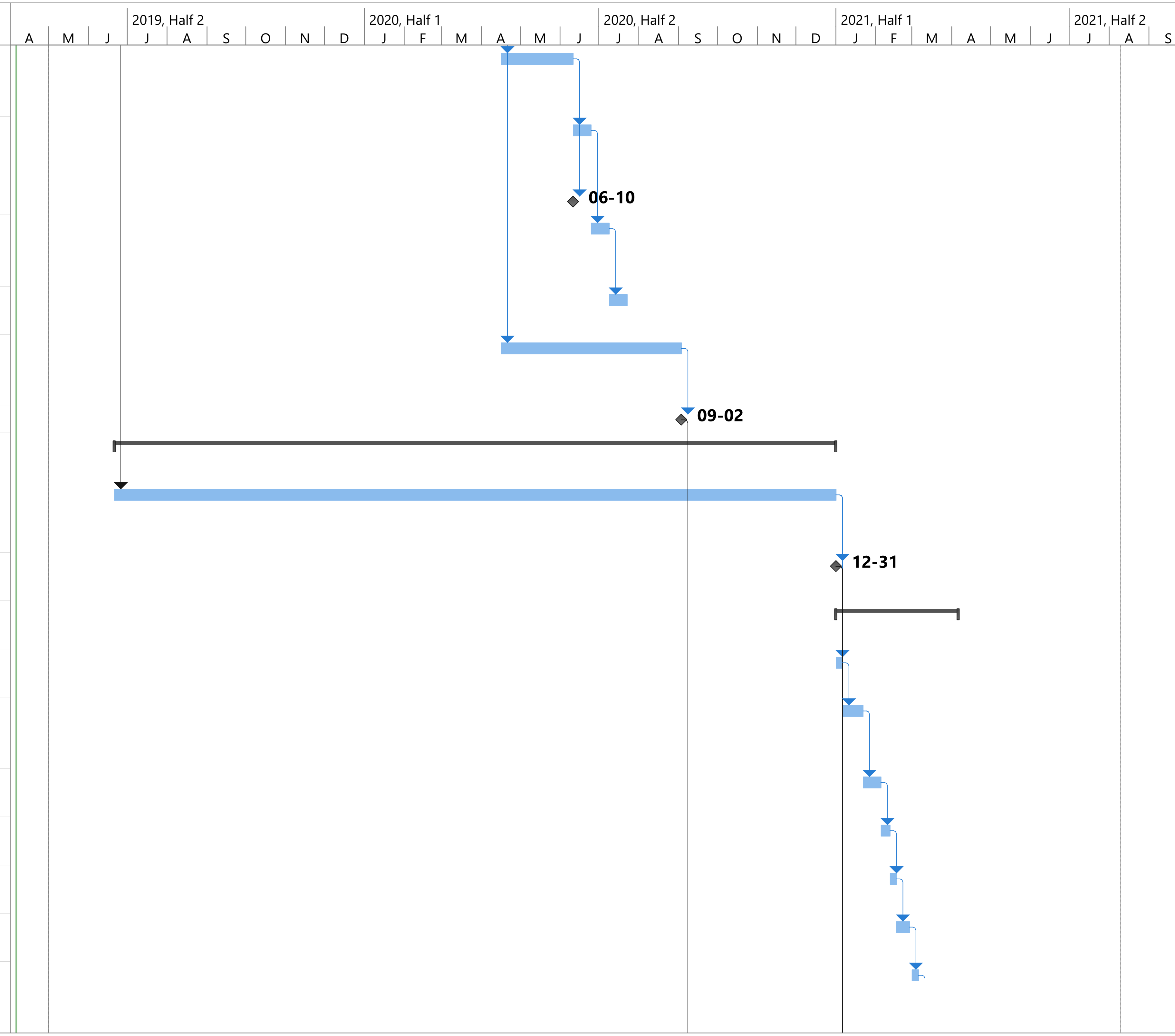
Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

| ID | Task Mode | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|---|
| 25 | | Install dewatering equipment | 1 day | Fri 19-06-21 | Fri 19-06-21 | 15 |
| 26 | | Layout survey of excavation | 1 day | Mon 19-06-24 | Mon 19-06-24 | 25 |
| 27 | | Install stadium utilities | 5 days | Fri 19-06-21 | Thu 19-06-27 | 15 |
| 28 | | Install raft foundation rebar | 10 days | Tue 19-06-25 | Mon 19-07-08 | 26 |
| 29 | | Install column formwork | 5 days | Tue 19-07-09 | Mon 19-07-15 | 28 |
| 30 | | Install wall rebar | 14 days | Tue 19-07-09 | Fri 19-07-26 | 28 |
| 31 | | Install column reba | 7 days | Tue 19-07-09 | Wed 19-07-1 | 28 |
| 32 | | Pour concrete in raft slab (Continuous pour) | 1 day | Mon 19-07-29 | Mon 19-07-29 | 28,29,30,31 |
| 33 | | Concrete slab curing time | 2 days | Tue 19-07-30 | Wed 19-07-31 | 32 |
| 34 | | Pour column and wall concrete | 2 days | Thu 19-08-01 | Fri 19-08-02 | 33 |
| 35 | | Column and wall curing | 5 days | Mon 19-08-05 | Fri 19-08-09 | 34 |
| 36 | | Install pre-cast stairs | 3 days | Mon 19-08-05 | Wed 19-08-07 | 34 |
| 37 | | Install parkade shoring | 2 days | Mon 19-08-05 | Tue 19-08-06 | 34 |
| 38 | | Install Level 1 Formwork | 6 days | Thu 19-08-08 | Thu 19-08-15 | 36,37 |
| 39 | | Install Level 1 Rebar | 15 days | Fri 19-08-16 | Thu 19-09-05 | 38 |
| 40 | | Pour level 1 concrete | 1 day | Fri 19-09-06 | Fri 19-09-06 | 39 |
| 41 | | Install plastic curing cover | 1 day | Mon 19-09-09 | Mon 19-09-09 | 40 |
| 42 | | Level 1 slab curing | 7 days | Tue 19-09-10 | Wed 19-09-1 | 41 |
| 43 | | Parkade Base Building Complete | 0 days | Wed 19-09-18 | Wed 19-09-18 | 42 |
| 44 | | **Stadium Construction** | **250 days** | **Thu 19-09-19** | **Wed 20-09-02** | |
| 45 | | Stadium construction (by | 150 days | Thu 19-09-19 | Wed 20-04-15 | 42 |




| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Project: Project Schedule<br>Date: Sat 19-04-06 | Task | | Project Summary | | Manual Task | | Start-only | | Deadline |
| | Split | | Inactive Task | | Duration-only | | Finish-only | | Progress |
| | Milestone | | Inactive Milestone | | Manual Summary Rollup | | External Tasks | | Manual Progress |
| | Summary | | Inactive Summary | | Manual Summary | | External Milestone | | |

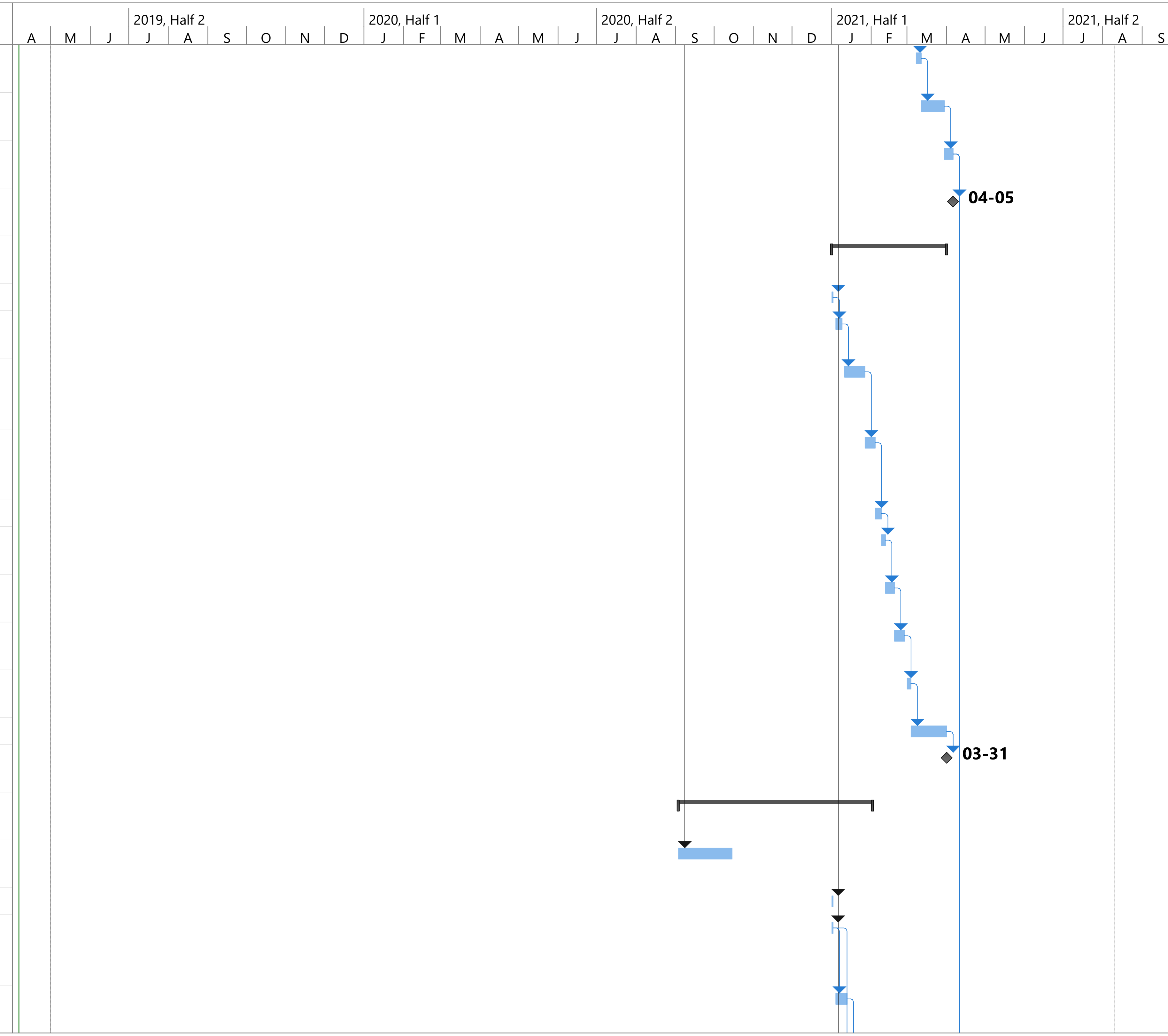
| ID | Task Mode | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|---|
| 46 | | Install parkade MEP, finishes (by others) | 40 days | Thu 20-04-16 | Wed 20-06-10 | 45 |
| 47 | | Install parkade elevators (by others) | 10 days | Thu 20-06-11 | Wed 20-06-24 | 46 |
| 48 | | Parkade Complete | 0 days | Wed 20-06-1 | Wed 20-06-1 | 46 |
| 49 | | Install stadium collection tank (by others) | 10 days | Thu 20-06-25 | Wed 20-07-08 | 47 |
| 50 | | Install stadium blue roof | 10 days | Thu 20-07-09 | Wed 20-07-22 | 49 |
| 51 | | Install Stadium MEP, Finishes (by others) | 100 days | Thu 20-04-16 | Wed 20-09-02 | 45 |
| 52 | | Stadium Complete | 0 days | Wed 20-09-0 | Wed 20-09-0 | 51 |
| 53 | | **All other buildings (by others)** | **400 days** | **Fri 19-06-21** | **Thu 20-12-31** | |
| 54 | | Other buildings base building construction | 400 days | Fri 19-06-21 | Thu 20-12-31 | 15 |
| 55 | | Base buildings complete | 0 days | Thu 20-12-31 | Thu 20-12-31 | 54 |
| 56 | | **Athletic Field Construction** | **67 days** | **Fri 21-01-01** | **Mon 21-04-05** | |
| 57 | | Grading of field sub-base | 3 days | Fri 21-01-01 | Tue 21-01-05 | 54 |
| 58 | | Sub-base installation and compaction | 12 days | Wed 21-01-06 | Thu 21-01-21 | 57 |
| 59 | | Excavate collector trench | 10 days | Fri 21-01-22 | Thu 21-02-04 | 58 |
| 60 | | Collector pipe installation | 5 days | Fri 21-02-05 | Thu 21-02-11 | 59 |
| 61 | | Impermeable liner installation | 3 days | Fri 21-02-12 | Tue 21-02-16 | 60 |
| 62 | | Field drainage installation | 8 days | Wed 21-02-17 | Fri 21-02-26 | 61 |
| 63 | | Gravel base placement + compaction | 5 days | Mon 21-03-01 | Fri 21-03-05 | 62 |




Project: Project Schedule
Date: Sat 19-04-06

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Task | | Project Summary | | Manual Task | | Start-only | | Deadline | |
| Split | | Inactive Task | | Duration-only | | Finish-only | | Progress | |
| Milestone | | Inactive Milestone | | Manual Summary Rollup | | External Tasks | | Manual Progress | |
| Summary | | Inactive Summary | | Manual Summary | | External Milestone | | | |

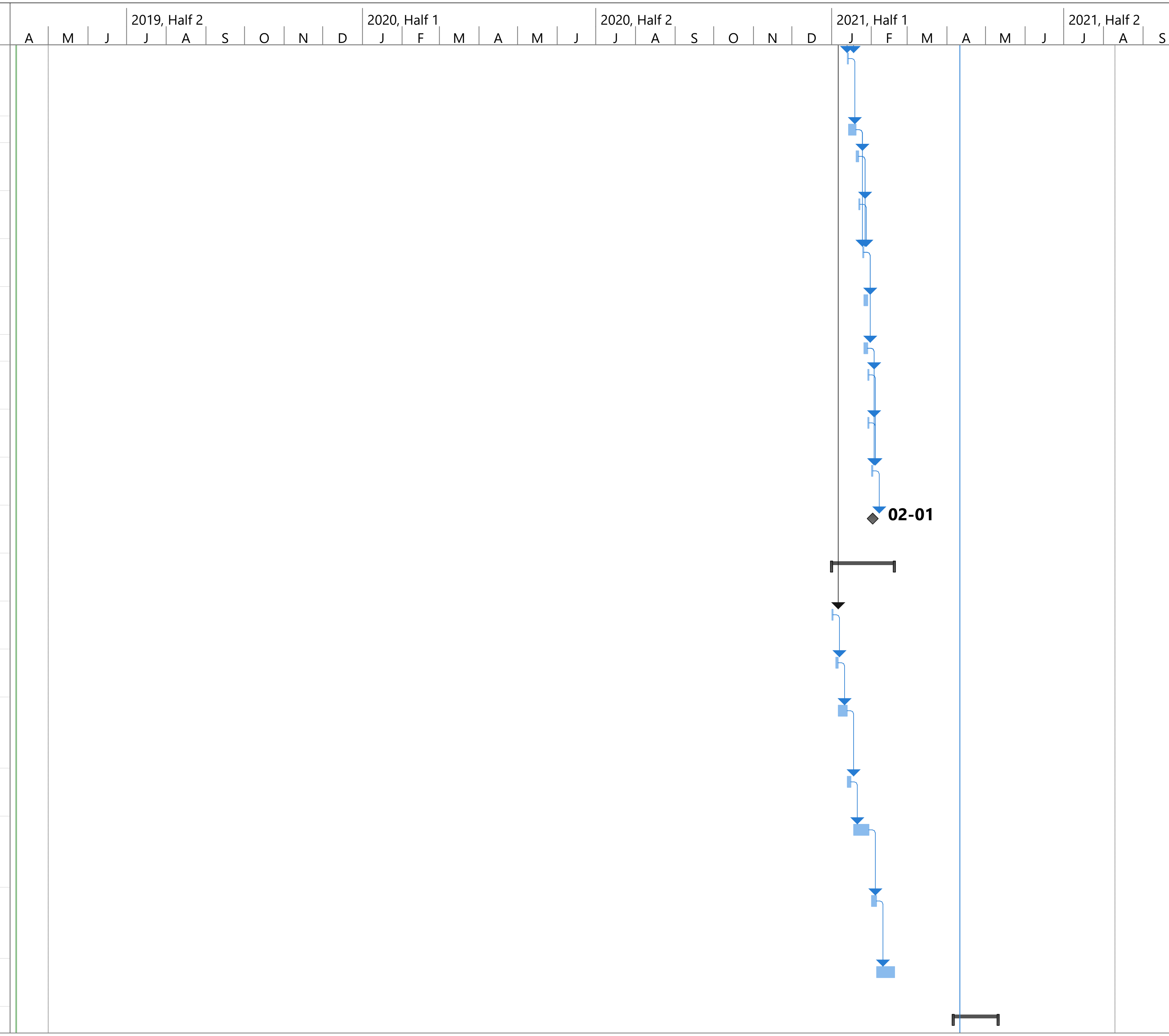
| ID | Task Mode | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|---|
| 64 | | Concrete curb installation | 4 days | Mon 21-03-08 | Thu 21-03-11 | 63 |
| 65 | | Turf + infill placement | 12 days | Fri 21-03-12 | Mon 21-03-29 | 64 |
| 66 | | Testing and site cleanup | 5 days | Tue 21-03-30 | Mon 21-04-05 | 65 |
| 67 | | Athletic Field complete | 0 days | Mon 21-04-05 | Mon 21-04-05 | 66 |
| 68 | | **Detention Pond Construction** | **64 days** | **Fri 21-01-01** | **Wed 21-03-31** | |
| 69 | | Layout survey | 1 day | Fri 21-01-01 | Fri 21-01-01 | 54 |
| 70 | | Site and keyway excavation | 5 days | Mon 21-01-04 | Fri 21-01-08 | 69 |
| 71 | | Embankment construction + compaction | 12 days | Mon 21-01-11 | Tue 21-01-26 | 70 |
| 72 | | Outlet barrel, cradle, apron installation | 6 days | Wed 21-01-27 | Wed 21-02-03 | 71 |
| 73 | | Pond compaction | 3 days | Thu 21-02-04 | Mon 21-02-0 | 72 |
| 74 | | Riser and skimmer installation | 3 days | Tue 21-02-09 | Thu 21-02-11 | 73 |
| 75 | | Emergency spillway | 5 days | Fri 21-02-12 | Thu 21-02-18 | 74 |
| 76 | | Granlar base and top soil | 6 days | Fri 21-02-19 | Fri 21-02-26 | 75 |
| 77 | | Site clean up and inspection | 3 days | Mon 21-03-01 | Wed 21-03-03 | 76 |
| 78 | | Landscaping | 20 days | Thu 21-03-04 | Wed 21-03-3 | 77 |
| 79 | | Detention pond complete | 0 days | Wed 21-03-31 | Wed 21-03-31 | 78 |
| 80 | | **Green Roof Installation** | **108 days** | **Thu 20-09-03** | **Mon 21-02-01** | |
| 81 | | Procurement of green roof | 30 days | Thu 20-09-03 | Wed 20-10-14 | 52 |
| 82 | | Material delivery | 1 day | Fri 21-01-01 | Fri 21-01-01 | 55 |
| 83 | | Set up green roof materials staging area | 1 day | Fri 21-01-01 | Fri 21-01-01 | 55 |
| 84 | | Install roof membrane system | 7 days | Mon 21-01-04 | Tue 21-01-12 | 83 |




Project: Project Schedule
Date: Sat 19-04-06

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Task | | Project Summary | | Manual Task | | Start-only | | Deadline | |
| Split | | Inactive Task | | Duration-only | | Finish-only | | Progress | |
| Milestone | | Inactive Milestone | | Manual Summary Rollup | | External Tasks | | Manual Progress | |
| Summary | | Inactive Summary | | Manual Summary | | External Milestone | | | |

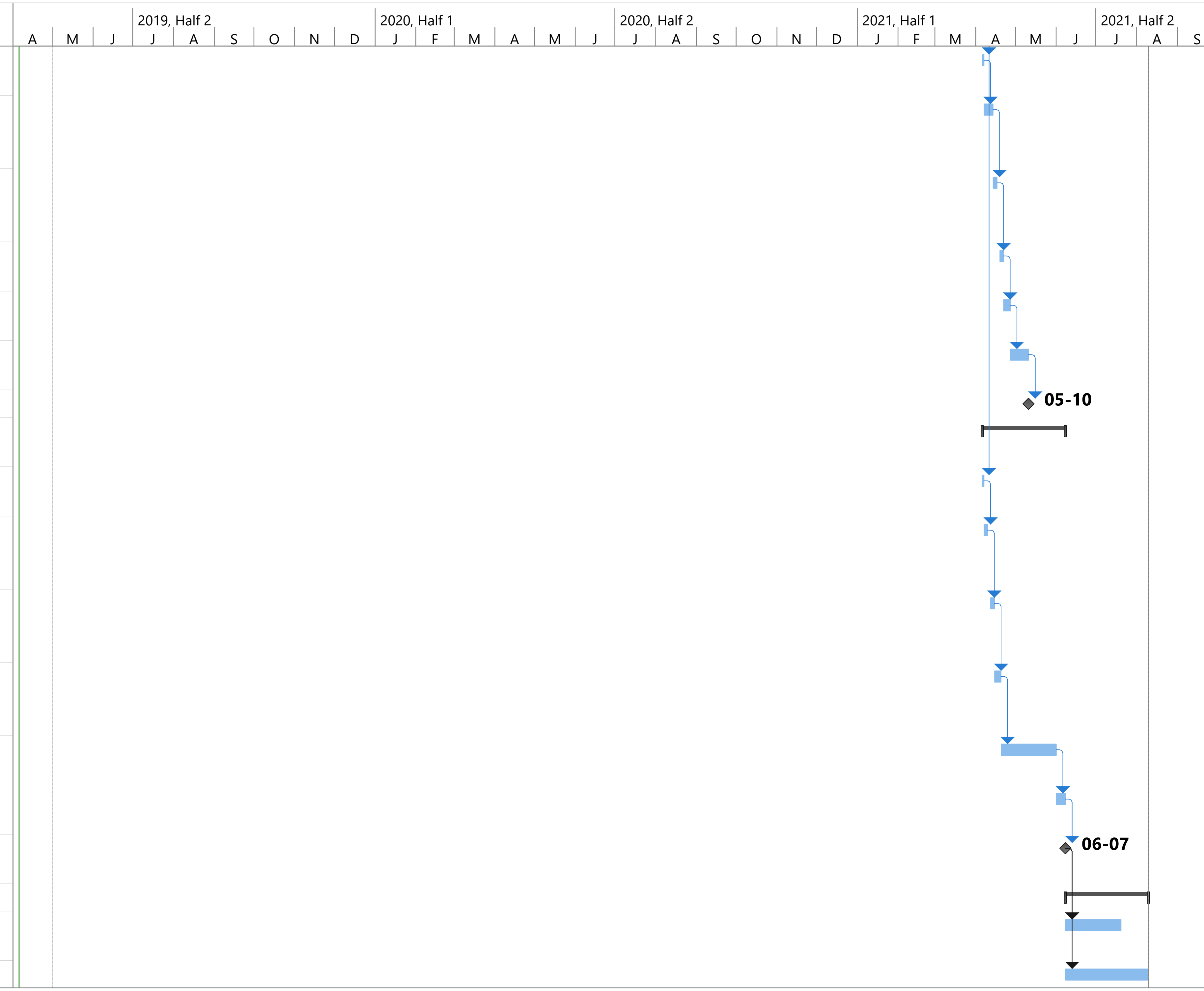
| ID | | Task Mode | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|---|---|
| 85 | | | Inspection by building engineering | 1 day | Wed 21-01-13 | Wed 21-01-13 | 83,84 |
| 86 | | | Install root barrier | 4 days | Thu 21-01-14 | Tue 21-01-19 | 85 |
| 87 | | | Install membrane protection layer | 2 days | Wed 21-01-20 | Thu 21-01-21 | 86 |
| 88 | | | Install thermal installation | 1 day | Fri 21-01-22 | Fri 21-01-22 | 87 |
| 89 | | | Inspection by building engineer | 1 day | Mon 21-01-25 | Mon 21-01-25 | 86,87,88 |
| 90 | | | Install drainage panel | 3 days | Tue 21-01-26 | Thu 21-01-28 | 89 |
| 91 | | | Install filter fabric | 3 days | Tue 21-01-26 | Thu 21-01-28 | 89 |
| 92 | | | Spray substrate layer | 1 day | Fri 21-01-29 | Fri 21-01-29 | 91 |
| 93 | | | Rollout vegetative mats | 1 day | Fri 21-01-29 | Fri 21-01-29 | 91 |
| 94 | | | Inspection by design engineer | 1 day | Mon 21-02-01 | Mon 21-02-01 | 91,92,93 |
| 95 | | | Green Roof Base Complete | 0 days | Mon 21-02-01 | Mon 21-02-01 | 94 |
| 96 | | | **Rain Garden Installation** | **35 days** | **Fri 21-01-01** | **Thu 21-02-18** | |
| 97 | | | Rain garden survey layout | 1 day | Fri 21-01-01 | Fri 21-01-01 | 55 |
| 98 | | | Rain garden excavation | 2 days | Mon 21-01-04 | Tue 21-01-05 | 97 |
| 99 | | | Installation of sub-base and drainage layers | 5 days | Wed 21-01-06 | Tue 21-01-12 | 98 |
| 100 | | | Installation of collector pipe | 3 days | Wed 21-01-13 | Fri 21-01-15 | 99 |
| 101 | | | Installation of concrete raingarden | 10 days | Mon 21-01-18 | Fri 21-01-29 | 100 |
| 102 | | | Installation of top soil and planting substrates | 4 days | Mon 21-02-01 | Thu 21-02-04 | 101 |
| 103 | | | Plantings and landscaping | 10 days | Fri 21-02-05 | Thu 21-02-18 | 102 |
| 104 | | | **Bioswale installation** | **25 days** | **Tue 21-04-06** | **Mon 21-05-1** | |




Project: Project Schedule
Date: Sat 19-04-06

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

| ID | | Task Mode | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|---|---|
| 105 | | | Survey layout of bioswales | 1 day | Tue 21-04-06 | Tue 21-04-06 | 66 |
| 106 | | | Excavation and hand shaping of bioswales | 5 days | Wed 21-04-07 | Tue 21-04-13 | 105 |
| 107 | | | Installation and compaction of sub-base | 3 days | Wed 21-04-14 | Fri 21-04-16 | 106 |
| 108 | | | Installation of drainage layer | 3 days | Mon 21-04-19 | Wed 21-04-21 | 107 |
| 109 | | | Installation of top soils | 3 days | Thu 21-04-22 | Mon 21-04-26 | 108 |
| 110 | | | Plantings and landscaping | 10 days | Tue 21-04-27 | Mon 21-05-10 | 109 |
| 111 | | | Bioswale complete | 0 days | Mon 21-05-1 | Mon 21-05-1 | 110 |
| 112 | | | **Pervious pavers installation** | **45 days** | **Tue 21-04-06** | **Mon 21-06-07** | |
| 113 | | | Survey layout of pedestrian road | 1 day | Tue 21-04-06 | Tue 21-04-06 | 66 |
| 114 | | | Excavation and grading of sub-grade | 3 days | Wed 21-04-07 | Fri 21-04-09 | 113 |
| 115 | | | Installation and compaction of gravel sub-base | 3 days | Mon 21-04-12 | Wed 21-04-14 | 114 |
| 116 | | | Installation and compaction of sand sub-base | 3 days | Thu 21-04-15 | Mon 21-04-19 | 115 |
| 117 | | | Installation of pavers | 30 days | Tue 21-04-20 | Mon 21-05-31 | 116 |
| 118 | | | Finishing of pavers and clean-up | 5 days | Tue 21-06-01 | Mon 21-06-07 | 117 |
| 119 | | | Pervious pavers complete | 0 days | Mon 21-06-07 | Mon 21-06-07 | 118 |
| 120 | | | **Landscaping** | **45 days** | **Tue 21-06-08** | **Mon 21-08-0** | |
| 121 | | | Installation of plantings | 30 days | Tue 21-06-08 | Mon 21-07-19 | 119 |
| 122 | | | General landscapin | 45 days | Tue 21-06-08 | Mon 21-08-0 | 119 |




Project: Project Schedule
Date: Sat 19-04-06

| | | | | |
|---|---|---|---|---|
| Task | Project Summary | Manual Task | Start-only | Deadline |
| Split | Inactive Task | Duration-only | Finish-only | Progress |
| Milestone | Inactive Milestone | Manual Summary Rollup | External Tasks | Manual Progress |
| Summary | Inactive Summary | Manual Summary | External Milestone | |

## Green Roof Construction Plan

*Note that all materials will be delivered to roofs via crane.*

1. Procure all materials no less than one-month prior to roof completion date. Ensure that vegetation layer is delivered to site during substrate install (item 12).
2. Procure crane and deliver on site to be ready following completion and final inspection of roof.
3. Deliver materials to site one day prior to roof completion and approval date.
4. Install roofing membrane system.
5. Inspection by the building engineer (ensure sufficient notice is provided).
6. Once approval of the proper install of item 5, install root barrier.
7. Install membrane protection layer.
8. Install thermal insulation.
9. Inspection by the building engineer (ensure sufficient notice is given prior to the completion of the insulation layer).
10. Install drainage panel.
11. Install filter fabric.
12. Spray substrate layer.
13. Roll out vegetative mats.
14. Inspection by the design engineer.

## Storm Sewer Construction Plan

1. Survey site to locate proposed construction locations
2. Survey site to conduct utility locates
3. Conduct site grading as required
4. Excavate trench
5. Install pipe bedding
6. Inspection by the Engineer
7. Install pipe surround material
8. Compact trench materials
9. Surface restoration

## Permeable Paver Construction Plan

1. Survey site to locate proposed construction location
2. Conduct site grading as required
3. Excavation
4. Moisten, place, level, and compact subbase
5. Place edge restraints
6. Placement of weeping tile
7. Moisten, place, level, and compact base
8. Place and screed bedding material, ensure 50 mm depth
9. Placement of pavers
10. Fill joints and openings
11. Sweep surface to remove excess fill material
12. Inspect area for settlement and uneven pavers
13. Within six months, contractor to return for inspection and maintenance

# Appendix D: Specifications

## SPECIFICATIONS FOR 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

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

Contractor's Performance Criteria

The submission shall include the Contractor's performance criteria for each mix design including:

- Placeability (i.e. pumping, buggies, truck chute, etc.)
- Workability
- Proposed slump and slump retention time
- Set time

### 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 D 516, Standard Test Method for Sulfate Ion in Water
- CSA S269.3, Concrete Formwork
- CSA S269.1, Falswork and Formwork
- ASTM C1315, Standard Specification for Liquid Membrane-Forming Compounds Having Special Properties For Curing and Sealing Concrete
- ASTM C 494, Standard Specification for Chemical Admixtures for Concrete

### MATERIALS

**1. Fine Aggregate**
Fine aggregate shall meet the grading requirements of CSA A23.1-14, be graded uniformly and not more than 3% shall pass a 75 um sieve.

**2. Coarse Aggregate**
The maximum nominal size of coarse aggregate shall be 20 mm and meet the grading requirements of CSA A23.1-14, Table 11, Group II. Coarse aggregate shall be uniformly graded and not more than 1% shall pass a 75 um sieve.

**3. Cementitious Materials**
Cementitious materials shall conform to the requirements of CAN/CSA A23.1 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.

**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 CSA A23.1 and shall be free of oil, alkali, acidic, organic materials or deleterious substances.

**5. 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.

## Construction Method

**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.

**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 or not the mixer is revolving. For concrete that includes silica fume, this requirement is reduced to 60 minutes.

**3. Falsework and Formwork**
The design, fabrication, erection, and use of concrete formwork shall conform to the requirements of CAN/CSA A23.1 and CSA S269.3. 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 falsework shall be designed and constructed to provide the necessary rigidity and to support the loads without appreciable settlement or deformation.

**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.

## Cold Weather Precautions

**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.

**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 materials.

**3. Water**

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

**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 in the equipment.

**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 C1315 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.

**6. Quality Control**

Sampling of concrete shall be carried out in accordance with CSA A23.1. 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 A23.1, 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 moulds.

**7. 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.

greenroofsolutions

Glenview, IL 60025

866.675.9963
847.297.7936
www.greenroofsolutions.com

## Product Data

Non-recycled polypropylene staple fiber, needle punched non-woven geotextile

Roll sizes:
6.25' x 200' (1200 sq ft)
6.25' x 360' (2250 sq ft)
12.5' x 360' (4500 sq ft)

Made in USA

# Filter Fabric

Filter Fabric is designed to separate the growing media from the drainage system on vegetative green roofs. Polypropylene fibers are needled to filter fabric for a stable network that retains dimensional stability relative to one another. The fabric is resistant to degradation from UV exposure, as well as the biological and chemical environments found in soil.

| | FF35 | Unit | Test Method |
|---|---|---|---|
| Grab Tensile Strength | 90 | lbs | ASTM D-4632 |
| Elongation | 50 | % | ASTM D-4632 |
| Trapezoid Tear | 40 | lbs | ASTM D-4533 |
| CBR Puncture | 265 | lbs | ASTM D-6241 |
| UV Stability | 70 | % at 500 hrs | ASTM D-4355 |
| Permitivity | 2.1 | sec | ASTM D-4491 |
| Water Flow Rate | 150 | gpm/sq ft | ASTM D-4491 |
| A.O.S. | 70 | US Sieve # | ASTM D-4751 |
| A.O.S. | 0.212 | mm | ASTM D-4751 |
| Weight | 0.024 | lbs/sq ft | ASTM D-5261 |
| Thickness | 0.05 | in | ASTM D-5199 |

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## Product Data

Made of 100% Recycled HDPP

Compatible with various roofing membranes

Patent Pending

Made in USA

# GRS 52 Drainage Panel

The GRS 52 is designed to be a water retention and drainage component suitable for intensive and extensive green roof systems.

Water flows through the entire panel via reservoir cups and channels to assure uniform distribution.

Rounded edges on bottom of panels prevent roof damage. Panels  snap to lock together for fast, easy installation.

## Technical Data

| | |
|---|---|
| Size | 24" x 24" x 2 1/8" |
| Weight | 3 |
| Dry | 0.86 lbs/sf |
| Including Water | 3.79 lbs/sf |
| Water Capacity | 0.352 gal/sf |
| Material | 100% recycled HDPE ( color black - shade may vary) |
| Working Temp | -40°F to 212°F |

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Glenview, IL 60025

866.675.9963
847.297.7936
www.greenroofsolutions.com

## Product Data

Available in two thicknesses:
RB20: 20 mil
RB30: 30 mil

Roll Sizes:
RB20 & RB30
10.16' x 50' (508 sq ft)
10.16' x 75' (762 sq ft)

Made in USA

# Root Barrier RB20 & RB30

-Protects roofing assembly and building from root penetration

-Flexible, and conforms to a variety of surfaces

-Single (4" wide) or double-sided (2" wide) butyl tape available for a waterproof seal

-Always overlap by 12" at seams

## Technical Data

| | Unit | RB20 | RB30 | Test Method |
|---|---|---|---|---|
| Tensile Strength at Break 1" | lbs | 75 | 114 | ASTM D-6693 |
| Elongation at Break | % | 800 | 800 | ASTM D-6693 |
| Tear Resistance | lbf | 11 | 16 | ASTM D-1004 |
| Hydrostatic Resistance | psi | 100 | 170 | ASTM D-751 |
| Puncture Resistance | lbf | 30 | 45 | ASTM D-4833 |
| Volatile Loss | % | <1 | <1 | ASTM D-1203 |
| Dimensional Stability | % | <2 | <2 | ASTM D-1204 |
| Perm Rating | U.S. Perms | 0.041 | 0.031 | ASTM E-96 |

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847.297.7936
www.greenroofsolutions.com

## Product Data

Made of 100% recycled materials:
35% polypropylene
65% polyester

Standard Roll Size:
65" x 84' (450 sq ft)

Per Square Foot Pricing available

Water Retention:
MRM-14: 0.123 gal/sq ft
MRM-30: 0.201 gal/sq ft

Made in USA

# Moisture Retention Mat

Green Roof Solutions' Moisture Retention Mat (MRM) protects the waterproofing membrane and holds moisture beneath the drainage layer in green roof systems. The MRM is also a popular choice for fleece-based living or green wall systems. MRM is available in two thicknesses, 3/16" and 3/8", to suit your project's specific needs. These fabrics are long lasting and will not decompose, as they are not made of organic material.

| | Unit | MRM-14 | MRM-30 | Testing Method |
|---|---|---|---|---|
| Weight | oz/sq yd | 18 | 30 | ASTM D-5261 |
| Thickness | in | 0.187 | 0.375 | ASTM D-5199 |
| Breaking Strength | | | | |
| Warp | lbs | 186 | 282 | ASTM D-4632 |
| Fill | lbs | 219 | 435 | ASTM D-4632 |
| Elongation | | | | |
| Warp | % | 122 | 153 | ASTM D-4632 |
| Fill | % | 96 | 131 | ASTM D-4632 |
| Bursting Strength | lbs | 261 | 776 | ASTM D-3786 |
| Puncture Resistance | lbf | 101 | 275 | ASTM D-4833 |

# Appendix E: Service-life Maintenance Plan

# Service Life Maintenance Plan

## Storm Sewer System

### General Considerations

- Service life of the sewer is anticipated to be 70 to 100 years, due to the longevity of HDPE pipe and concrete manholes.
- Consider workplace safety during maintenance, as manholes are classified as a confined space and H2S risk by WorkSafeBC. A sewer-cleaning contractor may be retained for this work.
- Inspect the surrounding area for pollutant leaks and if discovered, remove the source.

### Inspection and Cleaning

- Catch basins, headwalls (outlet structures) and inlets to be inspected cleared of debris annually in the fall and after major storms, and additionally as needed.
- Catch basins to be cleaned at 1/3 capacity for sediment trapping purposes (City of Camas, 2009).
- Manholes and lids to be inspected annually (City of Camas, 2009).
- Pipes to be flushed when sediment depth is greater than 20% of pipe diameter (City of Camas, 2009).
- Pipes to be CCTV inspected for root intrusions, leakage and pipe cracks every 5 years or as needed if a blockage occurs. Pipe inspection condition reports to follow National Association of Sewer Service Companies (NASSCO) Pipeline Assessment rating systems.
- Repairs to be conducted in a timely manner for any observed defect and damage.

## Green Roof

The following sections give the expected service life of the green roof systems and outlines prominent regulatory considerations to considered during routine maintenance and inspection. An inspection and maintenance plan are also provided. The following list is non-exhaustive and alternate factors may need to be considered by the operator.

### General Considerations

- The typical service life of an extensive green roof is between 30-50 years. After which, the critical components of the green roof system will need to be replaced including the roofs waterproofing membrane, insulating layer, and root barrier system.
- Where routine maintenance and inspection is to occur near roof edges, WorkSafeBC: Part 11 “Fall Protection” will need to be considered where required in addition to all other WorkSafeBC regulations.

### Inspection and Maintenance Plan

*Inspection prior to operation*

- Within 14 days of substantial completion the contractor must arrange for final inspection of the green roof system to verify conformance with the Manufacturer’s instructions.

- The owner will assume responsibility for maintenance and upkeep of the green roof system following approval from the inspection agent.

### *Establishment Period*

- Upon receiving approval of final inspection, the owner is responsible for ensuring establishment of the newly installed green roof system. The green roof system will be highly sensitive to changing environments during the establishment period and it is critical that the owner/operator pay special attention.
- Proper maintenance and care during the establishment period is critical to the long-term success of the green roof system. The following table outlines the various establishment periods in conjunction with the installation season (Columbia Green Roof Technologies, 2012)

| Installation Season | Establishment Period |
|---|---|
| Fall | Spring and summer of the following year |
| Winter | Spring and summer of the following year |
| Spring | Until onset of cool fall weather |
| Summer | Through summer of the following year |

- The owner will be responsible for proper care of the green roof throughout the initial growing period. This will include the first two months after installation and into the first full growing season.
- The watering schedule of the green roof system throughout the establishment period is product specific and will be based on the manufacturer's warranty and recommendations. Use of an automatic irrigation system is recommended.
- During extreme weather conditions routine watering may be altered from the standard practice. It is strongly recommended that the owner/operator stick to the manufacturer's recommendations during extreme weather events, such as summer drought.

### *Ongoing Maintenance*

- Following the establishment period, the green roof systems will be highly resilient to changing environments and will require less attention due to a strong root system and acclimated vegetation.
- The focus of the owner/operator during the life of the green roof system will be on standard upkeep and observation.
- Extensive green roof systems require far less maintenance than intensive green roof systems.
- Consult the manufacturer to develop and establish a routine maintenance plan that is appropriate for a Vancouver climate.
- Typical maintenance task will include:
    - Drain inspection,
    - Debris removal,
    - Weed control,
    - Fertilization,
    - Irrigation.

- Most manufacturers will provide the owner/operator with a maintenance checklist that aids in the inspection process based on their unique product. It is advised that the owner/operator abide by the manufacturers recommendations to ensure the longevity and efficiency of the green roof system.

## Permeable Pavers

### General Considerations

- Service life of permeable pavers is anticipated to be 20 years
- Pavers can be reused when maintenance is required in the underlying components

### Inspections and Maintenance Plan

- Surface sweeping to be performed once or twice a year to mitigate sediment buildup.
- Catch basins to be maintained as noted above in Storm Sewer System – Inspection and Cleaning.
- Landscaped areas to sloped away from permeable pavers
- Tripping hazards from uneven pavers can be repaired by removing a grouping of pavers and redistributing the bedding layer. Extra pavers should be kept in storage for future repairs.
- In the event of snow, deicers are recommended in moderate and the use of sand should be avoided as it can lead to clogging and drainage issues.
- Snow plowing can be use on pavers.

## Rain Garden and Bioswales

### General Considerations

- The service life of the rain gardens and bioswales are approximately 15 years.
- Maintenance will ensure proper functionality of the infrastructure.
- UBC Building Operations is responsible for maintenance

### Inspections and Maintenance Plan

- The rain gardens and bioswales are to be maintained at least once every 2 months with more frequent visits during the spring and fall periods so as to ensure plant health and remove obstructions.
- Maintenance will include removal of garbage and debris from the bottom of the garden, and raking and removing leaves and weeds.
- Garbage and debris removal are integral to the functionality of the infrastructure. As such, a detailed log shall be kept of obstructions and ongoing issues. If littering issues persist, additional garbage cans should be installed.

## Athletic Field

### General Considerations

- Service life of the athletic field is estimated to be around 30-50 years
- Routine maintenance and inspection is likely to ensure field surpasses estimated service life

### Inspections and Maintenance Plan

- Inventoried field components and deficiencies regularly noted, including unit costs for deficiency repair or replacement.
- Inspection of field (especially low spots), irrigation system, fence lines, lighting systems, and structural components such as bleachers, roof, and on-field items.
- Annual compaction tests necessary to ensure subgrade is not compromised and verify drainage is to specifications.

## Dry Pond

### General Considerations

- Service life of the dry pond is estimated for 20-30 years
- Outlet control to have a service life of 50 years with annual inspection to integrate resiliency in the event that dry pond is not serviceable.

### Inspections and Maintenance Plan

- Annual sediment and debris removal
- Regular landscaping on the grassed area
- Annual berm stability inspections
- Pipe condition inspections

## Works Cited

Columbia Green Roof Technologies. (2012). *Downloads.* Retrieved 03 2019, from Columbia Green.

Credit Valley Conservation. (2012). *Low Impact Development Stormwater Management Planning and Design Guide.* Mississauga, Ontario.

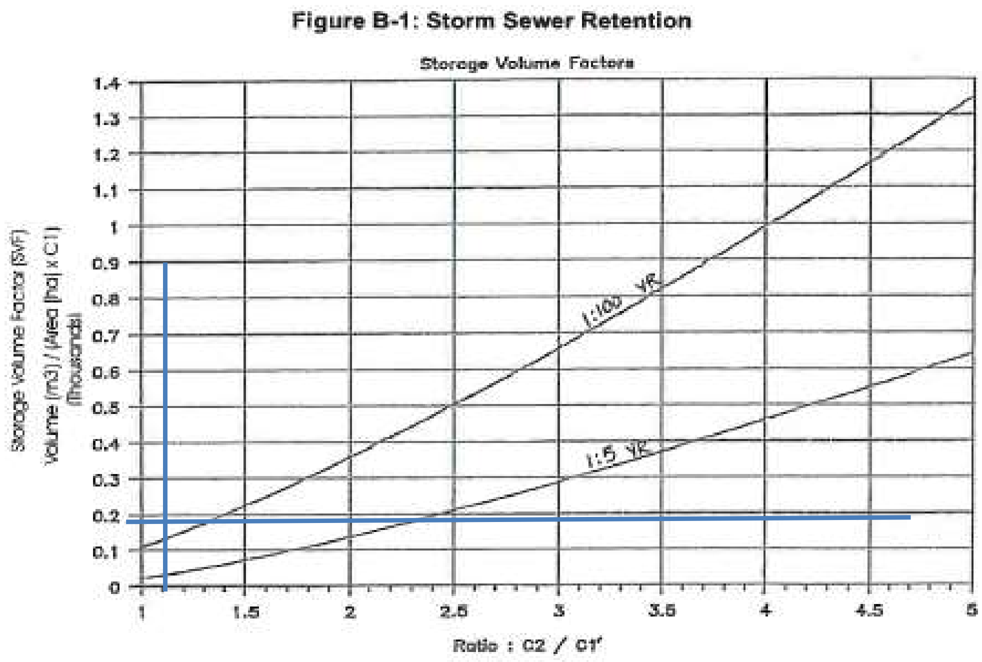
# Appendix F: Rational Method

**SUBCATCHMENT #1**

**PRE-DEVELOPMENT**

| **PARAMETERS** | **Symbol** | **Value** | **Unit** |
|---|---|---|---|
| Total Site Area = | $A_T$ | 7.24 | ha |
| Total subcatchment Area = | **A** | 7.24 | ha |
| Unit Area Release Rate = | **UARR** | 3.33 | L/s/ha |
| Rainfall Intensity = | **i** | 3.00 | mm/hr |
| Landscaped coefficient = | $C_L$ | 0.30 | |
| Paved coefficient = | $C_P$ | 0.90 | |
| Roof coefficient = | $C_R$ | 1.00 | |
| Gravel coefficient = | $C_G$ | 0.50 | |
| Landscaped area = | $A_L$ | 4.626 | ha |
| Paved area = | $A_P$ | 2.288 | ha |
| Roof area = | $A_R$ | 0.320 | ha |
| Gravel area = | $A_G$ | 0.000 | ha |
| Allowable flow to main (A*UARR) = | $Q_{ALL}$ | 24.09 | L/s |
| **CALCULATIONS:** | | | |
| Actual runoff co-efficient from site = | $C_2$ | 0.52 | |
| Actual flow to main from site (2.78*$C_2$*i*A) = | $Q_1$ | 31.42 | L/s |
| Runoff co-eff of discharge ($Q_o$/(2.78*I*A)) = | $C_1'$ | 0.40 | |
| | $C_2/C_1'$ | 1.30 | |
| From the graph : | **SVF** | 0.18 | |
| Req'd vol for 1:100 year event (SVF*A*C1'*1000) = | $V_{100}$ | 520.00 | $m^3$ |

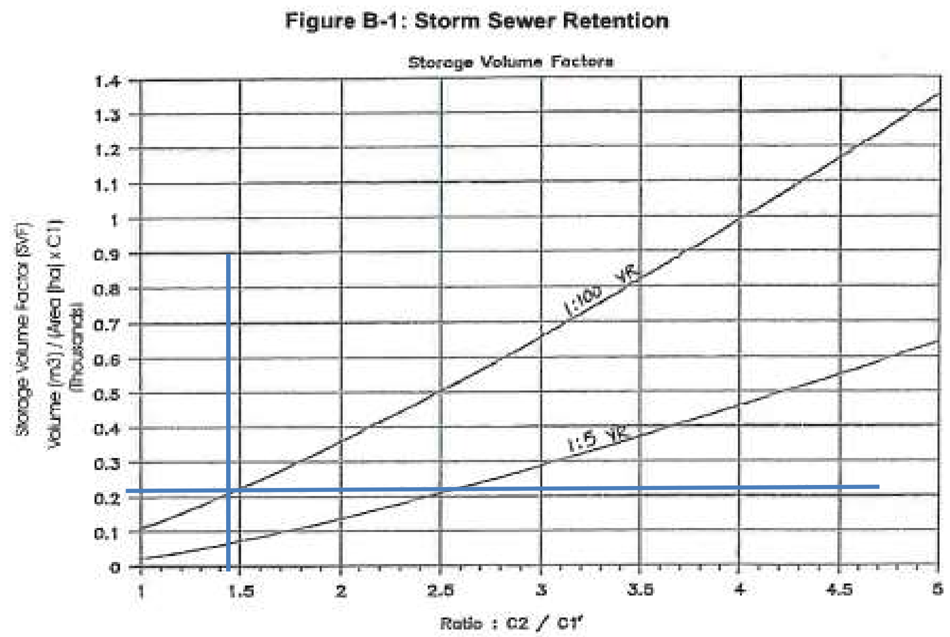
**PRE-DEVELOPMENT**



**SUBCATCHMENT #1**

| POST-DEVELOPMENT | | | |
|---|---|---|---|
| **PARAMETERS** | **Symbol** | **Value** | **Unit** |
| Total Site Area = | $A_T$ | 7.24 | ha |
| Total subcatchment Area = | A | 7.24 | ha |
| Unit Area Release Rate = | UARR | 3.33 | L/s/ha |
| Rainfall Intensity = | i | 3.00 | mm/hr |
| Landscaped coefficient = | $C_L$ | 0.30 | |
| Swale/Raingarden coefficient = | Cs | 0.15 | |
| Woods/Trees coefficient = | Cw | 0.10 | |
| Paved coefficient = | $C_P$ | 0.90 | |
| Green roof coefficient = | Cgr | 0.75 | |
| Stadium roof coefficient = | $C_R$ | 1.00 | |
| Athletic field coefficient = | Ca | 0.90 | |
| Pervious pavers coefficient = | $C_G$ | 0.50 | |
| Landscaped area = | $A_L$ | 2.331 | ha |
| Swale/Raingarden area = | As | 0.125 | ha |
| Woods/Trees area = | Aw | 0.353 | ha |
| Paved area = | $A_P$ | 0.670 | ha |
| Green roof area = | Agr | 0.754 | ha |
| Roof area = | $A_R$ | 0.941 | ha |
| Athletic field area = | Aa | 0.656 | ha |
| Pervious pavers area = | $A_G$ | 1.411 | ha |
| Allowable flow to main (A*UARR) = | $Q_{ALL}$ | 24.09 | L/s |
| **CALCULATIONS:** | | | |
| Actual runoff co-efficient from site = | $C_2$ | 0.57 | |
| Actual flow to main from site ($2.78*C_2*i*A$) = | $Q_1$ | 34.68 | L/s |
| Runoff co-eff of discharge ($Q_a/(2.78*I*A)$) = | $C_1'$ | 0.40 | |
| | $C_2/C_1'$ | 1.44 | |
| From the graph : | SVF | 0.21 | |
| Req'd vol for 1:100 year event (SVF*A*C1'*1000) = | $V_{100}$ | 606.66 | $m^3$ |

**POST-DEVELOPMENT**




pond dimensions 32m x 20m

# Appendix G: Calculations

Consultant: THUNDERFISH CONSULTING
Project No.: CAPSTONE - STADIUM ROAD NEIGHBOURHOOD
Project Description: STADIUM ROAD NEIGHBOURHOOD STORMWATER MANAGEMENT
Location: UBC

Sheet 1 Of 1
File Name: STRM_SEWER

| Manhole Reach | | Source | Flow | Ground Elev | | Pipe Invert Elev | | Sewer Design | | | | | | Travel Time in Pipe | Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | - | Q (5) | U/S | D/S | U/S | D/S | Grade | Pipe Dia | Mannings "n" | Q Cap. | V Cap. | Length | | Q(5)/Q cap. |
| From | To | - | (L/s) | (m) | (m) | (m) | (m) | % | (mm) | 0.013 | (L/s) | (m/s) | (m) | (min) | % |
| **1** | **2** | Building | 23 | 67 | 64 | 65.2 | 62.5 | 0.2% | **300** | 0.013 | 43 | 0.6 | **35** | 1.0 | 53 |
| **2** | **4** | | 23 | 51 | 46 | 49.2 | 44.5 | 0.2% | **300** | 0.013 | 43 | 0.6 | **47** | 1.3 | 53 |
| **3** | **4** | Building | 21 | 51 | 46 | 49.3 | 44.5 | 0.2% | **250** | 0.013 | 27 | 0.5 | **35** | 1.1 | 79 |
| **4** | **6** | | 44 | 51 | 46 | 49.1 | 44.5 | 0.2% | **375** | 0.013 | 78 | 0.7 | **100** | 2.3 | 56 |
| **5** | **6** | Building | 18 | 51 | 46 | 49.3 | 44.5 | 0.2% | **250** | 0.013 | 27 | 0.5 | **35** | 1.1 | 68 |
| **6** | **8** | | 62 | 51 | 46 | 49.1 | 44.5 | 0.2% | **375** | 0.013 | 78 | 0.7 | **43** | 1.0 | 79 |
| **7** | **8** | Building | 9 | 51 | 46 | 49.3 | 44.5 | 0.2% | **250** | 0.013 | 27 | 0.5 | **35** | 1.1 | 34 |
| **8** | **9** | | 71 | 51 | 46 | 49.1 | 44.5 | 0.2% | **450** | 0.013 | 128 | 0.8 | **26** | 0.5 | 56 |
| **10** | **11** | **Stadium** | 47 | 51 | 46 | 49.1 | 44.5 | 0.2% | **450** | 0.013 | 128 | 0.8 | **75** | 1.6 | 37 |
| **11** | **out-2** | | 47 | 51 | 46 | 49.1 | 44.5 | 0.2% | **450** | 0.013 | 128 | 0.8 | **83** | 1.7 | 37 |
| **in-1** | **12** | **Dry Pond** | 118 | 51 | 46 | 49.2 | 44.5 | 0.2% | **300** | 0.013 | 43 | 0.6 | **58** | 1.6 | N/A |
| **12** | **13** | | 118 | 51 | 46 | 49.2 | 44.5 | 0.2% | **300** | 0.013 | 43 | 0.6 | **58** | 1.6 | N/A |

# Stadium Road Neighbourhood Stormwater Management

***Green Roof Design Calculations***

**Green Roof Precipitation Retention Rate Data**

| | |
|---|---|
| Summer | 80% |
| Winter | 33% |

**Rainfall Data**

| | | |
|---|---|---|
| **IDF Data:** | YVR | |
| **Time, toc:** | 10 | min |
| **Return Period:** | 10 | yr |

**Constants**

| | | |
|---|---|---|
| 1 m = | 1000 | mm |

**Unit Cost**

| | |
|---|---|
| Construction | |
| $ 16.00 | per sf |
| $ 170.00 | $m^2$ |
| Annual Maintenance | |
| $ 0.55 | per sf |
| $ 10.00 | $m^2$ |

**Avgerage Service Life** (30-50 yrs)

| | |
|---|---|
| 40 | years |

**Runoff Coefficients, C**

| | |
|---|---|
| Lawn | 0.30 |
| Impervious Surfaces | 0.90 |
| Woods/Trees | 0.10 |
| Porous Pavement | 0.50 |
| Swale/Gardn | 0.15 |
| Green Roof | 0.75 |
| Standard Roof | 1.00 |

| Gross Floor Area (Size of Building) | Coverage of Available Roof Space (Size of Green Roof) |
|---|---|
| 2,000$m^2$ - 4,999$m^2$ | 20% |
| 5,000$m^2$ - 9,999$m^2$ | 30% |
| 9,000$m^2$ - 14,999$m^2$ | ✔ 40% |
| 15,000$m^2$ - 19,999$m^2$ | 50% |
| 20,000$m^2$ or greater | 60% |

***Green Roof Sizing, Release Rate, and Cost Determination (Using the Rational Method)***

| Roof | Runoff Coefficient, C | Gross Roof Area, A [m2] | Effective Roof Area, 0.8A [m2] | Green Roof Area [m2] | Intensity, I [mm/hr] | Flow Rate, Q [$m^3$/hr] | Release Rate (Winter) [$m^3$/hr] | Release Rate (Summer) [m3/hr] | Capital Cost | Annual Maintenance Costs |
|---|---|---|---|---|---|---|---|---|---|---|
| GR-1 | 0.75 | 1625 | 1300 | 813 | 47.350 | 46 | 31 | 6 | $ 138,125.00 | $ 8,125.00 |
| GR-2 | 0.75 | 1600 | 1280 | 800 | 47.350 | 45 | 31 | 6 | $ 136,000.00 | $ 8,000.00 |
| GR-3 | 0.75 | 1615 | 1292 | 808 | 47.350 | 46 | 31 | 6 | $ 137,275.00 | $ 8,075.00 |
| GR-4 | 0.75 | 2562 | 2050 | 1210 | 47.350 | 73 | 49 | 10 | $ 205,700.00 | $ 12,100.00 |
| GR-5 | 0.75 | 1355 | 1084 | 1016 | 47.350 | 38 | 26 | 5 | $ 172,720.00 | $ 10,160.00 |
| GR-6 | 0.75 | 4300 | 3440 | 3193 | 47.350 | 122 | 82 | 16 | $ 542,810.00 | $ 31,930.00 |
| **Total** | **0.75** | **13057** | **11751.3** | **7839** | | **370.9** | **250.4** | **50.1** | **$ 1,332,630.00** | **$ 78,390.00** |

## Assumptions and Sources

**Design Assumptions**

- All 6 roofs at Stadium Road Neighbourhood will have a green roof.
- Only extensive green roofs are uses.
- Rainfall data based on YVR IDF Curve for a TOC of 10 min. and a 10-year storm event.
-Based on small site size, design flow are determined using the Rational Method

$$Q = CIA$$

- Effective green roof area to be designed as 75% of actual roof area.
- Design values are considered to be very general at the preliminary design stage.
- Size of green roof based on Toronto Green Roof Construction Standard Supplementary Guidelines

**Precipitation Retention Rate Source:**
https://greenroofs.org/about-green-roofs/

**Cost Data Source:**
- Amec Green Roofs Report 2013
- https://stormwater.pca.state.mn.us/index.php/Cost-benefit_considerations_for_green_roofs

**Runoff Coefficients Source:**
"Green Values Stormwater Calculator Methodolog" Report

**Green Roof Known Volume Captured**

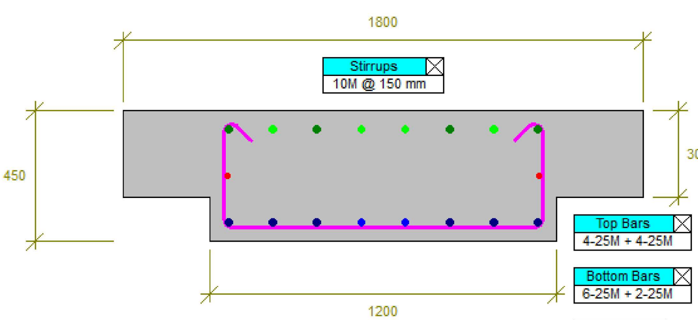
| Component | Capacity (L/$m^2$) |
|---|---|
| Drainage Panel | 14 |
| Protection Mat | 5 |

| Roof | Green Roof Area ($m^2$) | Volume (L) |
|---|---|---|
| GR-1 | 813 | 15,438 |
| GR-2 | 800 | 15,200 |
| GR-3 | 808 | 15,343 |
| GR-4 | 1,210 | 22,990 |
| GR-5 | 1,016 | 19,304 |
| GR-6 | 3,193 | 60,667 |
| **Total** | **7,839** | **148,941** |

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

**Miscellaneous**
Quantities (Approx.)
Concrete = 1708 kg/m
Steel = 75.6 kg/m
---------------------------
Top Bars
d' = 64 mm
As' = 4000 mm2
As'/bh = 0.00741
dz = ** N/A **
---------------------------
Bottom Bars
d = 386 mm
As = 4000 mm2
As/bh = 0.00741
dz = ** N/A **
---------------------------
Face Steel
As = 400 mm2
---------------------------
Clear Cover
Top = 40 mm
Bottom = 40 mm
Side = 40 mm

**Stirrups**
10M @ 150 mm




**Top Bars**
4-25M + 4-25M

**Bottom Bars**
6-25M + 2-25M

**Face Steel**
2-15M

**Section Properties**
Zbar = 206 mm
Ybar = 0 mm
Ag = 720000 mm2
Ig (y-y) = 11222xE6 mm4
Ig (z-z) = 64800xE6 mm4
Ashear (Y) = 450000 mm2
Ashear (Z) = 540000 mm2
Jg = 28303xE6 mm4
---------------------------
Ae = 720000 mm2
Ie (y-y) = 11222xE6 mm4
Ie (z-z) = 64800xE6 mm4
Ase (Y) = 450000 mm2
Ase (Z) = 540000 mm2
Je = 28303xE6 mm4

**Summary**
Concrete Slab Band
Job # CIVL 439 Final Project
CSA-A23.3-14 Standard
---------------------------
UBC
Connor Ferster
---------------------------
Status = Acceptable

**Shear / Torsion Results**
Vfz = 125.0 kN
Vrz = 492.3 kN
Shear Util = 0.254
Avz/S = 0.00 mm
S (req'd) = 150.0 mm

**Flexural / Axial Results**
Nf = -500.0 kN
Mf(-) = -450.0 kNm
Mr(-) = -586.1 kNm
N vs M(-) Util = 0.768
As' (Req'd) = 3632 mm2
---------------------------
Nf = -300.0 kN
Mf(+) = 400.0 kNm
Mr(+) = 568.4 kNm
N vs M(+) Util = 0.704
As (Req'd) = 3291 mm2

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Connor Ferster
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AnyCountry

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**File Name:**

**Section Name**
Concrete Slab Band

**Consultant**
UBC

**Summary**

| Summary | |
|---|---|
| Status | Acceptable |
| Maximum | 1.000 |
| V & T Util | 0.254 |
| N vs M Util (+) | 0.704 |
| N vs M Util (-) | 0.768 |

**Canadian Building Standards**
CSA Standard A23.3-14, "Design of Concrete Structures"
CSA Standard A23.1-04, "Concrete Materials and Methods of Concrete Construction"

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

| Section Dimensions | Material Properties | Gross Properties | Effective Properties |
|---|---|---|---|
| T-Beam | fc' = 35 MPa | Zbar = 206 mm | Ae = 720000 mm2 |
| b = 1200 mm | fy (main) = 400.0 MPa | Ybar = 0 mm | Ie (y-y) = 11222xE6 mm4 |
| h = 450 mm | fy (stir) = 400.0 MPa | Ag = 720000 mm2 | Ie (z-z) = 64800xE6 mm4 |
| bf = 1800 mm | Wc = 2400 kg/m3 | Ig (y-y) = 11222xE6 mm4 | Ase (Y) = 450000 mm2 |
| hf = 300 mm | Ws = 7850 kg/m3 | Ig (z-z) = 64800xE6 mm4 | Ase (Z) = 540000 mm2 |
| | Poisson's Ratio = 0.2 | Ashear (Y) = 450000 mm2 | Je = 28303xE6 mm4 |
| **Quantities (approx.)** | hagg = 20 mm | Ashear (Z) = 540000 mm2 | |
| Concrete = 1708 kg/m | Es = 200000 MPa | Jg = 28303xE6 mm4 | |
| Steel = 75.6 kg/m | Ec = 28165 MPa | Mcr (Pos) = 163 kNm | |
| Primary = 65.9 kg/m | Gc = 11735 MPa | Mcr (Neg) = -193 kNm | |
| Secondary = 9.7 kg/m | fr = 3.55 MPa | | |

| Top Bars | Top Bar Info | Bottom Bars | Bottom Bar Info |
|---|---|---|---|
| 4-25M + 4-25M | d' = 64 mm | 6-25M + 2-25M | d = 386 mm |
| | As' = 4000 mm2 | | As = 4000 mm2 |
| | As'/bh = 0.00741 | | As/bh = 0.00741 |
| | dz = 35 mm | | dz = 35 mm |

| Shear Reinf. | Face Steel | Clear Cover |
|---|---|---|
| 10M @ 150 mm | 2-15M | Top = 40 mm |
| Open | As = 400 mm2 | Bottom = 40 mm |
| 2 Legs | | Side = 40 mm |

**Min/Max Area of Top Steel**

| | | |
|---|---|---|
| As' (min) | 1582 mm2 | Acceptable |
| As' | 4000 mm2 | |
| As' (max) | 13885 mm2 | Acceptable |

**Min/Max Area of Bottom Steel**

| | | |
|---|---|---|
| As (min) | 1380 mm2 | Acceptable |
| As | 4000 mm2 | |
| As (max) | 20827 mm2 | Acceptable |

**Factored Design Loads**

| Load Case/Combo | N (kN) | T (kNm) | Vz (kN) | My (kNm) | Comment |
|---|---|---|---|---|---|
| 1 | -600.0 | 0.0 | 75.0 | 100.0 | |
| 2 | -500.0 | 0.0 | 125.0 | -450.0 | |
| 3 | -300.0 | 0.0 | 100.0 | -110.0 | |

| | | | | |
|---|---|---|---|---|
| 4 | -1400.0 | 0.0 | 88.0 | 100.0 |
| 5 | -600.0 | 0.0 | 50.0 | 400.0 |
| 6 | -300.0 | 0.0 | 50.0 | 400.0 |
| 7 | -500.0 | 0.0 | 75.0 | -125.0 |
| 8 | -1500.0 | 0.0 | 19.0 | -450.0 |

**N vs M Results**

| | |
|---|---|
| GLC | 2 |
| Status | Acceptable |
| Utilization | 0.768 |
| Maximum | 1.000 |

**Axial Utilization for M(+)**

LC = 6
Nf = -300.0 kN
Nr (max) = -10450.4 kN
Utilization = 0.029

**Moment(+) Utilization**

LC = 6
Mf = 400.0 kNm Mn = 681.0 kNm
Mr = 568.4 kNm Mp = 818.9 kNm
Utilization = 0.704

**Axial Utilization for M(-)**

LC = 2
Nf = -500.0 kN
Nr (max) = -10450.4 kN
Utilization = 0.048

**Moment(-) Utilization**

LC = 2
Mf = -450.0 kNm Mn = 699.4 kNm
Mr = -586.1 kNm Mp = 830.2 kNm
Utilization = 0.768

**Shear and Torsion Utilization**

| | |
|---|---|
| GLC | 2 |
| Nf | -500.0 kN |
| Tf | 0.0 kNm <= ¼Tcr |
| Mf (y-y) | -450.0 kNm |
| Vfz | 125.0 kN |
| Vz(c+s) Util | 0.254 |
| Vz&T(s) Util | 0.000 |
| Torsion Util | 0.000 |
| Status | Acceptable |
| Utilization | 0.254 |
| Maximum | 1.000 |
| Method | Simplified |

**Design Information**

b = 1200 mm
dv = 334 mm
As (Tens) = 4400 mm2
Av = 200 mm2
Lambda = 1.00
Vsz = 168.3 kN
Vcz = 324.0 kN
Vc0z = 324.0 kN
Vrz = 492.3 kN
Tcr = 148.7 kNm
Spalling Reduction = 0.0%

**Simplified Method (Beta and Theta Values)**

Beta = 0.210, Theta = 42.0° for Vc0
Beta = 0.210, Theta = 42.0° for Vc

**Stirrup Requirements**

| | |
|---|---|
| Member Type | Special Member |
| Spacing | 150.0 mm |
| Maximum | 187.8 mm |
| Status | Acceptable |

Stir. Not Req'd Tf <= ¼Tcr & Vfz <= Vc0z

**Maximum Shear Stress**

| | |
|---|---|
| Stress | 0.312 MPa |
| Maximum | 5.688 MPa |
| Status | Acceptable |

**Longitudinal Steel Requirements**

| | Force | As | Required | Theta | Load Case | Status |
|---|---|---|---|---|---|---|
| Top Bars | 1234.9 kN | 4000.0 mm2 | 3632.0 mm2 | 42.0° | 2 | Acceptable |
| Bottom Bars | 1119.0 kN | 4000.0 mm2 | 3291.2 mm2 | 42.0° | 6 | Acceptable |

**Clear Horz Spacing between Top Bars**

| | |
|---|---|
| Scl | 128.0 mm |
| Scl (min) | 35.3 mm |
| Status | Acceptable |

**Clear Horz Spacing between Bottom Bars**

| | |
|---|---|
| Scl | 128.0 mm |
| Scl (min) | 35.3 mm |
| Status | Acceptable |

**Clear Vert Spacing between Top Bar Layers**

Status Not Applicable

**Clear Vert Spacing between Bottom Bar Layers**

Status Not Applicable


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AnyCountry

**Crack Control - Top Region**

| | |
|---|---|
| dc | 63.9 mm |
| A (per bar) | 19170.0 mm2 |
| fs | 240.0 MPa |
| Z | 25679 N/mm |
| Zmax | 30000 N/mm |
| Status | Acceptable |

**Crack Control - Bottom Region**

| | |
|---|---|
| dc | 63.9 mm |
| A (per bar) | 19170.0 mm2 |
| fs | 217.8 MPa |
| Z | 23303 N/mm |
| Zmax | 30000 N/mm |
| Status | Acceptable |

**Crack Control - Face Steel**

| | |
|---|---|
| Status | Not Applicable |
| Steel Not Req'd | |
| Reason | h <= 750 mm |

**Beam Exposure**

Interior

**Longitudinal Reinforcing**

| | |
|---|---|
| fy (min) | 300.0 MPa |
| fy (long) | 400.0 MPa |
| fy (max) | 500.0 MPa |
| Status | Acceptable |

**Shear Reinforcing**

| | |
|---|---|
| fy (min) | 300.0 MPa |
| fy (stir) | 400.0 MPa |
| fy (max) | 500.0 MPa |
| Status | Acceptable |

**Concrete Strength**

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

**Concrete Density**

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

**Canadian Reinforcing Bars**

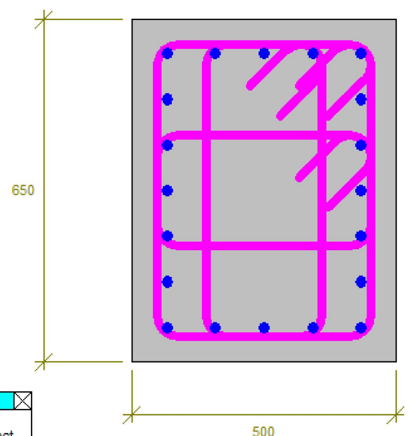
| Index | Bar Designation | Diameter (mm) | Area (mm2) |
|---|---|---|---|
| 1 | 10M | 11.3 | 100.0 |
| 2 | 15M | 16.0 | 200.0 |
| 3 | 20M | 19.5 | 300.0 |
| 4 | 25M | 25.2 | 500.0 |
| 5 | 30M | 29.9 | 700.0 |
| 6 | 35M | 35.7 | 1000.0 |
| 7 | 45M | 43.7 | 1500.0 |
| 8 | 55M | 56.4 | 2500.0 |

**List of Messages**

No Messages...

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

**Miscellaneous**
Quantities (Approx.)
Concrete = 766 kg/m
Steel = 123.1 kg/m
---------------------------
Clear Cover = 40.0 mm




**Vertical Bars**
500 x 650 Column
20-20M Vert
As = 6000 mm2
Rho = 1.85 %
Tangential Splice

**Ties**
15M Ties @ 100 mm

**Shear / Torsion Results**
Vfz = 125.0 kN
Vfy = 35.0 kN
Vfz / Vrz = 0.116
Vfy / Vry = 0.031
Shear Util = 0.119
Avz/S (req'd) = 0.00 mm
Avy/S (req'd) = 0.00 mm
S (req'd) = 500.0 mm

**Section Properties**
Zbar = 0 mm
Ybar = 0 mm
Ag = 325000 mm2
Ig (y-y) = 11443xE6 mm4
Ig (z-z) = 6770.8xE6 mm4
Ashear (Y) = 270833 mm2
Ashear (Z) = 270833 mm2
Jg = 14386xE6 mm4
---------------------------
Ae = 325000 mm2
Ie (y-y) = 11443xE6 mm4
Ie (z-z) = 6770.8xE6 mm4
Ase (Y) = 270833 mm2
Ase (Z) = 270833 mm2
Je = 14386xE6 mm4

**Summary**
Concrete Column
Job # CIVL 439 Final Project
CSA-A23.3-14 Standard
---------------------------
UBC
Connor Ferster
---------------------------
Status = Acceptable

**Flexural / Axial Results**
Nf = -300.0 kN
Theta = 75 Degrees
Mf = 414.8 kNm
Mr = 448.0 kNm
N vs M Util = 0.926
As (Req'd) = 5557 mm2
Rho (Req'd) = 1.7 % approx.

**File Name:**

**Section Name**
Concrete Column

**Consultant**
UBC

**Summary**

| | |
|---|---|
| Status | Acceptable |
| Maximum | 1.000 |
| V & T Util | 0.119 |
| N vs M Util | 0.926 |

**Canadian Building Standards**
CSA Standard A23.3-14, "Design of Concrete Structures"
CSA Standard A23.1-04, "Concrete Materials and Methods of Concrete Construction"

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

**Section Dimensions**
Rectangular Column
b = 500 mm
h = 650 mm

**Quantities (approx.)**
Concrete = 766 kg/m
Steel = 123.1 kg/m
Primary = 47.1 kg/m
Secondary = 76.0 kg/m

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

**Gross Properties**
Zbar = 0 mm
Ybar = 0 mm
Ag = 325000 mm2
Ig (y-y) = 11443xE6 mm4
Ig (z-z) = 6770.8xE6 mm4
Ashear (Y) = 270833 mm2
Ashear (Z) = 270833 mm2
Jg = 14386xE6 mm4

**Effective Properties**
Ae = 325000 mm2
Ie (y-y) = 11443xE6 mm4
Ie (z-z) = 6770.8xE6 mm4
Ase (Y) = 270833 mm2
Ase (Z) = 270833 mm2
Je = 14386xE6 mm4

**Vertical Bars**
500 x 650 Column
20-20M Vert
As = 6000 mm2
Rho = 1.85 %
Tangential Splice

**Ties**
15M Ties @ 100 mm
# Legs (Z-Direction) = 4
# Legs (Y-Direction) = 4

**Miscellaneous**
Clear Cover = 40 mm

**Factored Input Loads**

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

**Factored Design Loads (with Minimum Moments):**

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

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Connor Ferster
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#100 - 1234 Anywhere Place
AnyCity, AnyState
AnyCountry

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 75.0 | 100.0 | 25.0 | -300.0 | 316.2 | 252º |
| 2 | 125.0 | -450.0 | 35.0 | 125.0 | 467.0 | 16º |
| 3 | 100.0 | -110.0 | 27.0 | 400.0 | 414.8 | 75º |
| 4 | 88.0 | 100.0 | 22.0 | 350.0 | 364.0 | 106º |
| 5 | 50.0 | 400.0 | 100.0 | 200.0 | 447.2 | 153º |
| 6 | 50.0 | 400.0 | 100.0 | -200.0 | 447.2 | 207º |
| 7 | 75.0 | -125.0 | 31.0 | -300.0 | 325.0 | 293º |
| 8 | 19.0 | -450.0 | 112.0 | -75.0 | 456.2 | 351º |

**N vs M Results**

| | |
|---|---|
| GLC | 3 |
| Status | Acceptable |
| Utilization | 0.926 |
| Maximum | 1.000 |
| Theta | 75º |

**Axial Utilization**

Nf = -300.0 kN
Nr (max) = -6262.1 kN
Utilization = 0.048

**Moment Utilization**

Mf = 414.8 kNm    Mn = 537.6 kNm
Mr = 448.0 kNm    Mp = 634.4 kNm
Utilization = 0.926

**Shear and Torsion Utilization**

| | |
|---|---|
| GLC | 2 |
| Nf | -500.0 kN |
| Vy(c+s) Util | 0.034 |
| Vz(c+s) Util | 0.119 |
| Vy&T(s) Util | 0.005 |
| Vz&T(s) Util | 0.024 |
| Torsion Util | 0.000 |
| Status | Acceptable |
| Utilization | 0.119 |
| Maximum | 1.000 |
| Method | Simplified |

| Shear Z-Direction | Shear Y-Direction |
|---|---|
| bw = 500 mm | bw = 650 mm |
| dv = 468 mm | dv = 360 mm |
| As (Tens) = 3801 mm2 | As (Tens) = 3645 mm2 |
| Av = 800 mm2 | Av = 800 mm2 |
| Lambda = 1.00 | Lambda = 1.00 |
| Mf (y-y) = -450.0 kNm | Mf (z-z) = 125.0 kNm |
| Vfz = 125.0 kN | Vfy = 35.0 kN |
| Vsz = 944.5 kN | Vsy = 996.3 kN |
| Vcz = 130.9 kN | Vcy = 138.0 kN |
| Vrz = 1075.3 kN | Vry = 1134.3 kN |
| Vcz' = 102.2 kN | Vcy' = 30.2 kN |
| Vrz' = 1046.7 kN | Vry' = 1026.5 kN |
| Beta = 0.180 | Beta = 0.180 |
| Theta = 35.0° | Theta = 35.0° |
| Spalling Reduction = 19.2% | Spalling Reduction = 14.8% |

**Torsion**

Tcr = 67.1 kNm
Tf = 0.0 kNm < 0.25 Tcr
Ignore Torsional Effects

**Tie Spacing for Shear/Torsion**

| | |
|---|---|
| Spacing | 100.0 mm |
| Maximum | 500.0 mm |
| Status | Acceptable |

**Maximum Shear Stress**

| | |
|---|---|
| Stress | 0.684 MPa |
| Maximum | 5.688 MPa |
| Status | Acceptable |

**Tie Spacing**

| | |
|---|---|
| S | 100 mm |
| S (max) | 312 mm |
| Status | Acceptable |

**Tie Diameter**

| | |
|---|---|
| Diam. | 16.0 mm |
| Diam. (min) | 5.9 mm |
| Status | Acceptable |

| Vertical Steel Area | | Status | As/Ag |
|---|---|---|---|
| As | 6000 mm2 | | 1.85 % |
| As (min) | 3250 mm2 | Acceptable | 1.00 % |
| As (max) | 13000 mm2 | Acceptable | 4.00 % |

**Vertical Bar Splice Type**

Tangential Splice
Status Acceptable

**Vertical Bar Spacing**

Ny 5 Specified

**Vertical Bar Diameter**

db (vert) 19.5 mm

**Minimum Number of Vertical Bars**

#Bars 20 Specified

| | | | | | |
|---|---|---|---|---|---|
| Ny (max) | 6.3 Allowed | db (min) | 16.0 mm | #Bars | 4 Required |
| Nz | 7 Specified | Status | Acceptable | Status | Acceptable |
| Nz (max) | 8.5 Allowed | | | | |
| Status | Acceptable | | | | |

**Vertical Reinforcing**

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

**Horizontal Reinforcing**

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

**Concrete Strength**

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

**Concrete Density**

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

**Canadian Reinforcing Bars**

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

**List of Messages**

No Messages...