Coastal Douglas-fir Forest Restoration and Liner Wetland Construction

At the Millard Learning Centre on Galiano Island

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EXECUTIVE SUMMARY

Galiano Island is a land mass situated within the Southern Gulf Islands of British Columbia. Galiano is a sparsely inhabited island and is host to a vast selection of different ecosystems. This island is home to the Galiano Conservancy Association, an organization that oversees an array of protected land areas and trusts, on top of operating their flagship property, the Millard Learning Centre. At over 180 acres, the Millard Learning Centre presents a confluence of educational programming and ecosystem restoration. There are many restoration projects on the property that are completed, ongoing, or planned for the future.

This report outlines a recently completed project that melds a more traditional ecosystem restoration with the creation of a designed ecosystem. Ultimately, we aimed to restore an area of Coastal Douglas-fir forest and to create a pocket wetland. The project site will also serve as an outdoor classroom of sorts, as the site is directly adjacent to the conservancy's classroom building.

The primary goals of this project were to: restore an area of degraded Coastal Douglas-fir forest that had been previously logged in the 1990s, expand the available wetland habitat on the Millard Learning Centre property, and to provide easy-access wetland viewing for educational purposes.

The planning process included surveying the site through GIS mapping, transit elevations surveys, and soil pit analysis. Based on this information, designs were created. These included the placement of the wetland, the excavation plan of the wetland, and the plant communities that would make up the terrestrial aspect of the restoration.

Several iterations of the design were considered, and we ultimately ended up where we are now through the collaboration of many brilliant and hard-working individuals. Land was excavated to create the wetland basin, the liner was installed, habitat features were placed, and the surrounding area was seeded and planted.

This project was completed in October of 2020, and at the time of this writing, the wetland is already filling with water.

1. INTRODUCTION

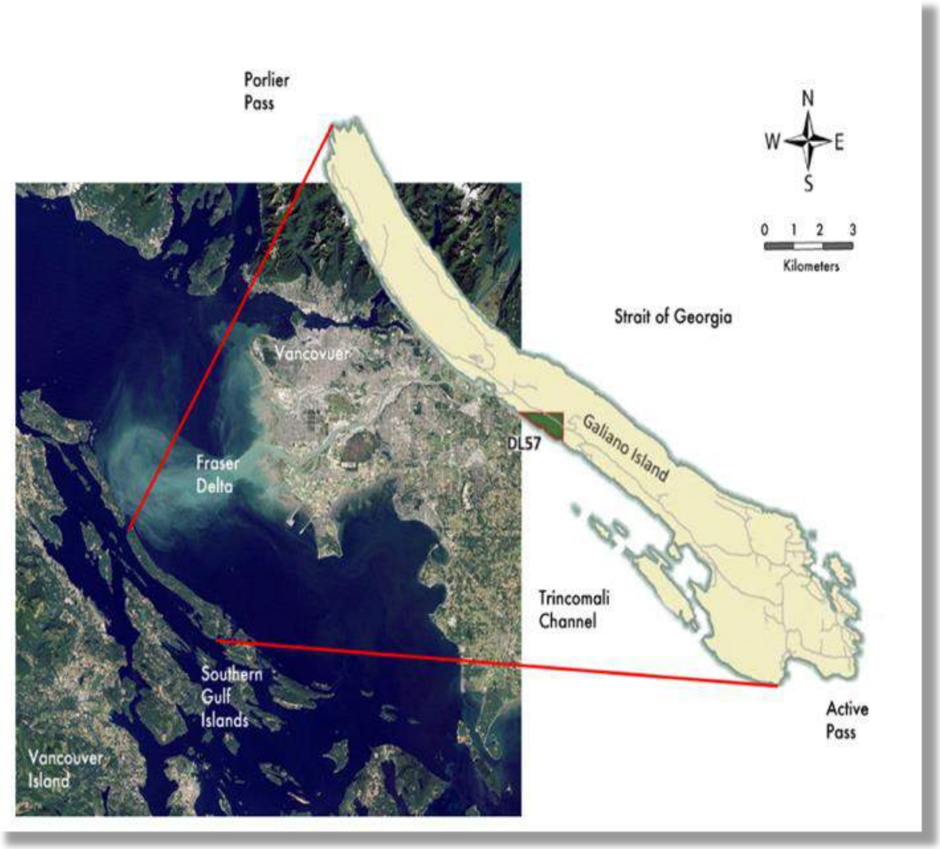


Figure 1: Geographical Context of Galiano Island. Photo taken from Adam Huggins (2017)

British Columbia's wetlands are disappearing. Through direct actions such as ditching and draining for agricultural purposes and indirect factors like climate change, Southern British Columbia has seen an estimated 60 to 90-plus percent loss of its original wetland habitat. The Okanagan, Fraser Lowlands, and Vancouver Island along with the Gulf Islands are some of the most gravely impacted areas (Cox and Cullington, 2009). Concurrently, extensive logging has taken place throughout the province. Galiano Island, for example, has experienced clear cutting to 50% of its land mass (Costain, 2018). Some of this logging occurred on the property officially known as District Lot 57, now referred to as the Millard Learning Centre (MLC). A project aimed at restoring a portion of the natural forest, as well as creating an artificial wetland was undertaken on this property. The project will provide ecological benefit to the property and the island, social and educational benefit to those who attend the learning centre, and lasting broad scope benefit through the stewardship that becomes instilled through environmental education (Wals et al., 2014). "[Environmental education] strengthens the link between knowledge and action in [nonprofessional] participants" (Merenlendar et al., 2016).

1.1 Background

Galiano Island is a long and narrow island that is located within the Southern Gulf Island (SGI) region of British Columbia (Figure 1). It runs 27.5 kilometres in length and is only 6 kilometres wide at its widest point (Galiano Chamber of Commerce, 2020). The island is located nearly entirely below the 49th parallel and is bracketed to the East and West by the Strait of Georgia and the Trincomali Channel and to the North and South by Porlier Pass and Active Pass, respectively.

The landmass covers an area of just over 6000 hectares, which makes Galiano the second largest of the Southern Gulf Islands, only behind Salt Spring Island. To go along with Galiano's large land mass, is a very small population of permanent residents; just over 1000 (Statistics Canada, 2017).

1.2 Galiano Conservancy Association

The Galiano Conservancy Association (GCA) was founded back in 1989, as "an instrument for community-based acquisition, management and conservation of land and habitat". The conservancy's objectives are primarily but not entirely limited to:

1. Land and marine conservation
2. Stewardship and restoration
3. Environmental education and public awareness

The conservancy is also very involved in the community, working with landowners and residents alongside strong partnerships with various organizations on local, regional, and international scales to develop a proactive program for conservation planning (GCA, 2018).

The MLC property is also a part of a network of protected land on the island, made up of land directly owned by the GCA or the Islands Trust Fund, GCA land covenants, crown land, and regional and provincial parks. This land network includes a section referred to as the "mid Galiano Island Protected Areas Network", a collection of protected lands that spans one coast to the other (GCA, 2013).

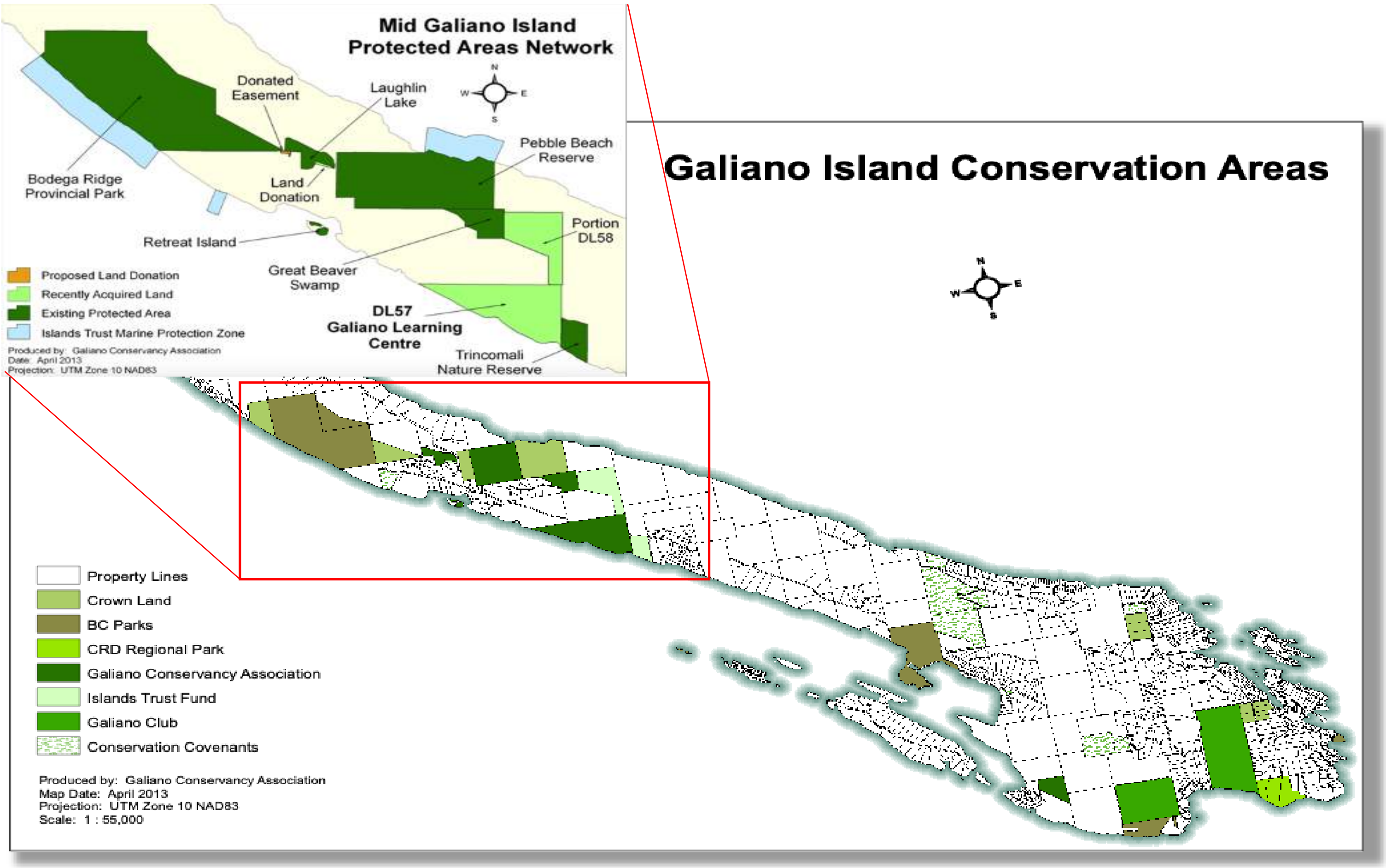


Figure 2: The location of the MLC within the Galiano protected land network. Blown up is the Mid Galiano Island Protected Areas Network. Source: Galiano Conservancy Association

1.3 The Millard Learning Centre

The Ken and Linda Millard Learning Centre (MLC) is the flagship property owned and operated by the GCA. Known officially as District Lot 57 (Figure 2), the MLC is comprised of over 185 acres of protected land and was acquired by the GCA in 2012. The land has a long-documented history of use, from pre-emption in the late 1800s, until now. These uses began with timber clearing and agriculture (grain farming and livestock grazing), intensifying through the early years of settlement. The land then lay dormant for a time from the late 1950s until the early 1990s. Post-dormancy, the land was purchased and used for private logging, during which the lumber was felled and milled on site, and then sold to local residents of Galiano Island. During this time, roads were built throughout the property and heavy machinery was used extensively, adding to the degradation of large portions of the land (Renwick-Shields and Weller, 2015).

The 2012 acquisition of the property by the GCA has resulted in the protection of the over 85 acres of mature and old-growth forest, to go along with educational efforts such a hosting grade-school groups and university students as well as spearheading new restoration and conservation efforts and techniques (Huggins, 2017).

Two main structures used by the GCA exist at the MLC (Figure 3). At the top of the property, near the entrance from Porlier Pass Road, sits the Program Centre, a building that houses offices and meeting rooms and is considered to be the GCA and MLC headquarters. This building was completed last year and includes a native plant garden and native plant nursery annex for the sale of locally propagated plants to the public. At the bottom of the main road (approximately 200m away), there is the classroom building. This building houses a space for school children and university students alike, and contains an industrial kitchen, as well as bathroom and shower facilities. A campground fit with tent pads and pit-toilets are located nearby, alongside outdoor event space. This is all located within an area that was cleared within the last 30 years and is surrounded by mature Douglas-fir and Western redcedar forest on three sides, and the Nuts'a'maat forage forest on the fourth.

Figure 3: The rectangles represent the two main buildings at the MLC. The top rectangle is the location of the Program Centre, and the lower one is the location of the classroom building. Aerial photo: Google Earth Pro

1.4 Ecological Context and Site Description

Galiano Island falls within the Coastal Douglas-fir moist maritime (CDFmm) biogeoclimatic zone of British Columbia (BC Forestry Service, 2018). This zone is characterized by mild and wet winters opposed by dry, hot summers. These climate characteristics are created by the rain-shadow cast upon the island by the Olympic and Vancouver Island mountains and represent the mildest climate in Canada (Green and Klinka, 1994). The CDFmm zone is the smallest biogeoclimatic zone in British Columbia and is therefore home to some of the most unique plant communities found the province over.

The CDFmm zone is characterized by dominant stands of Douglas-fir (*Pseudotsuga menziesii*) and Western redcedar (*Thuja plicata*) combined with the common presence of grand fir (*Abies grandis*) and the less dominant but frequent appearance of bigleaf maple (*Acer macrophyllum*) and Western flowering dogwood (*Cornus nuttallii*). The understorey of this forest system is dominated by salal (*Gaultheria shallon*), dull-Oregon grape (*Berberis nervosa*), oceanspray (*Holodiscus discolor*), and the moss species Oregon beaked moss (*Kindbergia oregana*). The full list of expected plants within the CDFmm can be found in Appendix 1.

Galiano Island is plagued by an overabundance of deer, primarily due to a lack of presence of mammalian predators typically found in the region such as black bears (*Ursus americanus*), mountain lions (*Puma concolor*), and wolves (*Canis lupus*). There are currently over 3,000 deer on the island, and with no natural predators, the population is ever-increasing (Galiano Island Wildlife, 2020).

Herbivores such as deer have a deep influence on any given ecosystem structure and pre-settlement deer population densities on Galiano Island would have been much lower than they are today. The increased level of browsing puts undue and sometimes insurmountable stress on certain plant populations referred to as "palatable plants". This often triggers trophic cascades that result in the simplification of plant communities and animal communities alike (Arcese et al., 2014).

Galiano and the MLC are, unfortunately, a good example of this plant community simplification. The land is dominated by the aforementioned tree species of Douglas-fir (*Pseudotsuga* menziesii) and Western redcedar (*Thuja plicata*), paired with small, isolated populations of arbutus

(*Arbutus menziesii*), Pacific yew (*Taxus brevifolia*), and red alder (*Alnus rubra*). The understorey is filled with the previously mentioned shrubby plants, along with strong populations of sword fern (*Polystichum munitum*) and bracken fern (*Pteridium aquilinum*).

In reference to my site (Figure 4), specifically, there is not much of a plant community present at all. This area was logged in the early 2000s, and the effects of the removal of trees, the associated destruction of the understorey, and ground compaction caused by the use of heavy machinery is still evident today. This paired with the ungulate browsing

ASIDE: What makes a restoration project, a restoration project?

Traditionally, ecological restoration has been seen as the returning of a degraded system to a previously held historical standard. This is the practice of taking a "snapshot" in time and attempting to return a system to conditions that mirror that snapshot as closely as possible. This rigid-form ecological restoration is becoming more and more difficult to practice.

Climate change is a major culprit; how can you restore a system to previously held conditions when the environment has fundamentally changed? If there is a shifting endpoint?

It could be argued that in the traditional context of restoration, the building of a wetland where no wetland was previously is not restoration. This would be considered a "designed" ecosystem. Designed ecosystems are generally created with specific human intentions and interests – be it for specific ecosystem services, aesthetic benefits, green infrastructure etc. (Higgs, 2016). However, even in a designed ecosystem context, are other valuable forms of restoration taking place? The restoration of connection with the land, the restoration of a sense of stewardship and responsibility (especially within an educational context at the MLC), the restoration of previously held levels of biodiversity (although the specific species are different).

As the world changes, so should we broaden our scope as to what qualifies as meaningful restoration.

Figure 4: GIS image of the project site. 2 more soil pits were dug in the bottom left area. GIS data collected by Adam Dewar, image prepared by Adam Huggins

pressure has resulted in essentially the presence of a grass field, interspersed with many invasive species. Poor sapling recruitment and establishment is evident, with a near complete lack of new growth and limited evidence for working successional processes. Currently, there is very little ecological value on this site.

The site itself is bracketed on two sides (North and South) by somewhat natural and healthy mature stands of Western redcedar (*Thuja plicata*) and Douglas-fir (*Pseudostuga menziesii*), the third (West) side is enclosed by a dirt road and traffic turn-around loop and finally the last (East) side is where the classroom building is located. There are many vestiges of the old clearcutting practices present within the site's boundaries. There are stumps scattered on the landscape, and conspicuous slash piles serve as vivid reminders of the activities previously perpetrated on the site.

1.5 Project Context

The wetland build aspect was initially intended to be a part of the construction of the Program Centre building. Figure 5 is an illustrated schematic of the initial plan for the surrounding landscape around this building. Included in this project was the implementation of a bioswale to help direct,

Figure 5: Illustrated schematic of the Program Centre project. This included the construction of the building itself, as well as the restoration of the areas around it with demonstration gardens, a nursery annex, a bioswale, and liner wetland. Photo: GCA

attenuate, and manage stormwater runoff from the parking lot and program centre roof. The bioswale was largely to help reduce erosion that was occurring on the dirt road, but also to direct water towards a constructed liner-wetland at the bottom of the hill. Unfortunately, during the building phase, it was decided that the area that was intended to host the wetland wasn't appropriate for two main reasons:

1. The physical area available wasn't large enough for the wetland that was desired

2. The bedrock was much closer to the surface than initially thought, and the pond wouldn't have been able to be as deep as needed

The proposed wetland build was then moved down to the classroom site.

A terrestrial coastal Douglas-fir forest restoration around the classroom had been in the works for some time. This project was conceptually designed in the summer of 2019 during the Galiano Island Field School and is aimed primarily at restoring the once-forested area around the classroom, while incorporating and working around human infrastructure. The infrastructure that exists on the site is the building itself, a septic field used by the bathroom and shower building, a weather station, parking area, road, and buried power lines. Infrastructure that had to be incorporated into the site was a wheelchair accessible footpath to direct traffic to the proper entrances and to limit the amount of traffic within the restored areas, and the maintenance or expansion of existing parking options.

The movement of the wetland build to the classroom site has melded these two projects together and set the stage for the implementation of a unique project that incorporates multiple ecosystems into an area of [light] human development.

Ultimately, the project combines educational benefit with habitat expansion for forest and wetland species alike. One of the residents that we hope to host in the wetland is the Northern red-legged frog (*Rana aurora*). These amphibians are currently blue-listed in BC and considered a species of special concern Canada-wide (Maxcy, 2004, COSEWIC, 2002). Their population has been in decline across their entire range since the 1970s. This is primarily due to habitat loss caused by factors such as climate change, urbanization, and the draining and filling of natural wetlands (Maxcy, 2004). In addition, an invader in the form of the American bullfrog (*Lithobates catesbianus*) has had a negative effect on red-legged frog populations (Kiesecker and Blaustein, 1997). Fortunately, there is no evidence of the presence of bullfrogs on Galiano Island (Anthony, 2013). Conversely, there is a population of red-legged frogs on the Gulf Islands, including Galiano (Environment Canada, 2016). Furthermore, confirmed sightings logged on applications such as iNaturalist indicate that the frogs have a presence at the MLC. An increase in available habitat in the form of a designed wetland could help these critters maintain their stronghold on the island.

1.6 Project Goals and Objectives

1. Restore a degraded area of coastal Douglas-fir forest, keeping surrounding human infrastructure in mind
    - Employ mechanical and manual decompaction to allow new vegetation to establish
    - Plant native vegetation using species that would make up the natural community of the forest once found on that site
    - Follow firesafe practices with regards to the classroom building
    - Ensure classroom building is wheelchair accessible
    - Implement plans for appropriate roadway and parking availability around the restoration area

2. Expand available wetland habitat on the MLC property
    - Excavate a basin which will simulate a natural wetland
    - Employ a pond liner within the basin to ensure water is present in the basin for most or all of the year
    - Simulate natural habitat by adding features such as coarse woody debris in the form of logs and stumps

3. Provide easy-access wetland viewing for educational purposes
    - Ensure easy access to the wetland through the creation of trails and clearings

2. METHODS

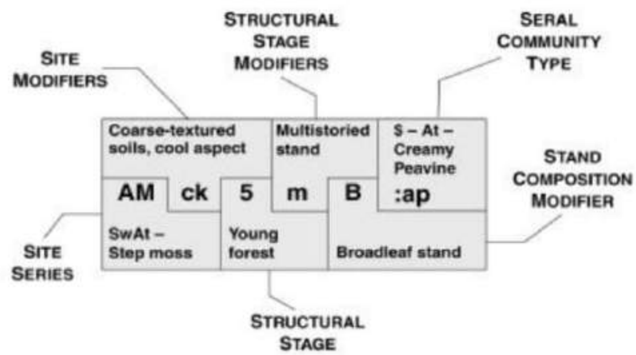
Several different methods were employed during this project. They can be broken down into six areas of focus:

1. Terrestrial ecosystem mapping (TEM)
2. Relative elevation land surveying
3. Earthworks and excavation
4. Liner application
5. Planting and seeding
6. Plant selection

2.1 Terrestrial Ecosystem Mapping

Terrestrial ecosystem mapping (TEM) is the practice of stratifying the landscape into distinct units (polygons). The classification of the units takes into account factors such as climate, surficial material, bedrock geology, soil, and vegetation. The implementation of TEM on a landscape provides a solid framework for land management and "serves as a means to integrate abiotic and biotic features into a single map" (USGS, 2020).

Below is an example of a classification code given to a polygon using TEM, along with the factors that are used to create it (Forest Renewal BC, 1998).



Full polygon code charts can be found in Appendix 2.

For this project, 5 soil pits were dug in order to classify the soil nutrient regime and moisture regime (whose determinant flow charts are included in appendix 2). The slope and aspect of the land at each pit was recorded and observations were taken to fill in the rest of the site code factors.

Full vegetation inventories were not taken for this project because "rough and loose" ground decompaction (manually and mechanically) was used to remove any existent vegetation on the site prior to re-planting.

2.2 Land Surveying

The land surveying taking place in this project is the measurement of the relative elevation of specific points on the land. An analog transit level and measuring stick was used initially, and then a laser level was employed during the excavation of the basin to ensure precision.

Perpendicular transect lines that intersect in the centre of the wetland footprint were drawn on the ground. Points were measured along these lines at an interval of 1.5 metres. These points were then graphed to determine an elevation profile of the land. This elevation profile was then used as the reference for how the land would need to be altered to create at appropriate basin for the wetland. Auxiliary points were also measured along the proposed basin rim, again to ensure consistency with the rim elevation and to ensure the proper shape to hold water adequately (Figure 6).

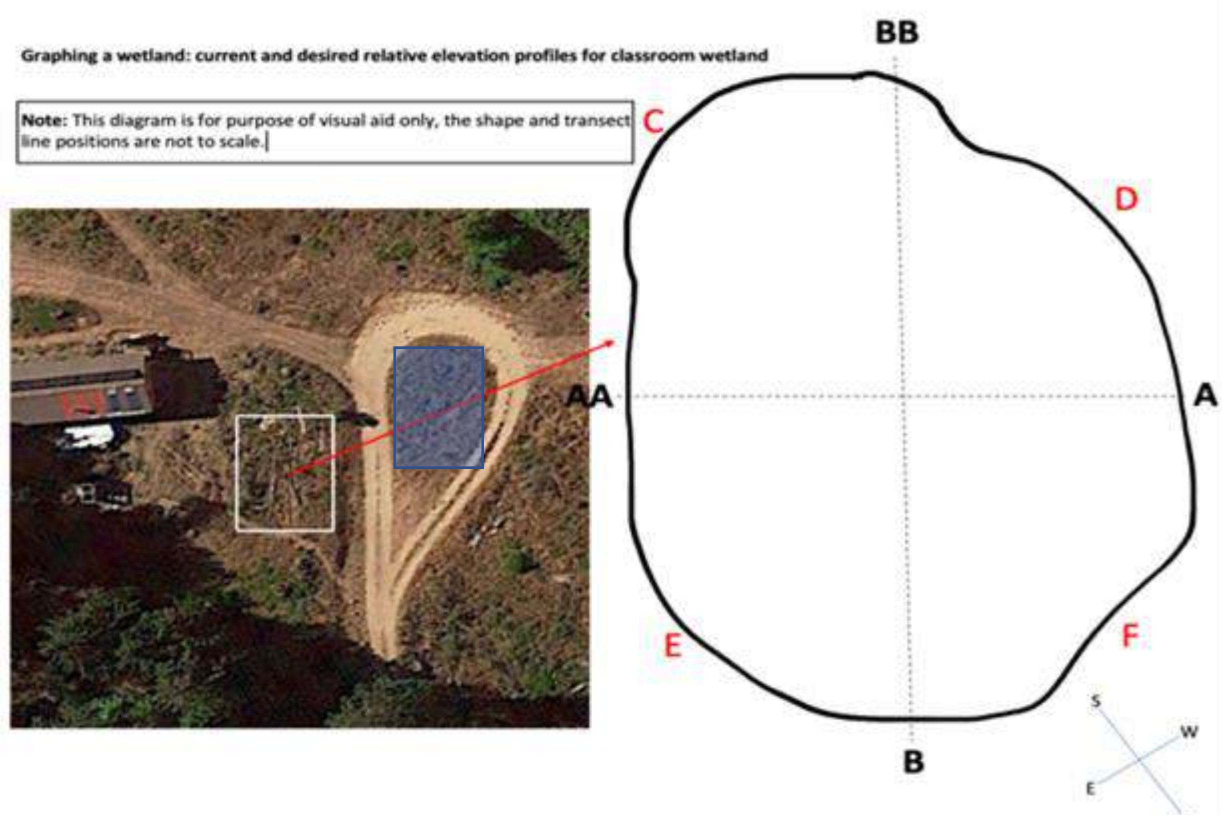


Figure 6: a schematic of the surveying procedures. Measurements were taken at 1.5m intervals along the transect lines represented by the dotted lines AA-A and BB-B. The red letters (C, D, E, F) represent auxiliary points along the rim. The blue rectangle represents the location of the wetland contingency plan.

Figure 6 also shows the contingency option that was set out in the event that the initially selected site should not be appropriate to house a wetland. This contingency site is represented by the blue box on the left in Figure 6. This site was much flatter than the initially proposed site, so a formal survey was not conducted. However, the rim of this footprint was roughly measured using a laser level on implementation day.

2.3 Earthworks

Two types of earthworks were performed for this project.

The first soil alteration was decompaction. Due to the degraded, compacted nature of the site, the areas to be planted had to be decompacted. Manual and mechanical decompaction both took place. Manually, with the use of a broadfork (essentially a giant pitchfork), and mechanically with the use of an excavator. The machine operator applied a “rough and loose” approach to decompacting the areas to be planted, essentially turning the soil and uprooting many invasive grass species that were also present in the area.

The second method was excavation. This was performed exclusively with heavy machinery. The size and depth of the pond necessitated the use of a large excavator, for doing the digging by hand would have been very arduous labour and would have taken an extremely long time. The excavator and its operator did not only excavate the actual wetland basin but dug out and moved culverts and drainage pipes. The operator was also responsible for placing soil and habitat features such as logs and stumps into the wetland once liner installation was completed.

2.4 Liner Application

The use of a pond-liner in this project was necessitated by the fact that the area was never a wetland before, and the soils present on the site were not appropriate for holding water long-term.

The liner in this case consisted of three layers of fabric. The layers created a “sandwich” of two layers of geotextile separated by an inner impermeable rubber layer. The geotextile layers, although permeable themselves, offer protection to the rubber layer from roots and rocks below and above. These layers are crucial to the function of the impermeable fabric, because if the rubber layer is compromised, it can no longer function as intended.

The installation occurs by placing the three layers on top of one another, and then pegging them to the ground using 12-inch framing spikes (essentially giant nails). All excess material was then trimmed away to ensure none would be visible for children and animals to interact with and possibly damage.

2.5 Seeding and Planting

The decompacted area around the wetland was seeded prior to the planting of new plants. The area was seeded with fall rye, also known as Canadian wild rye *(Elymus canadensis).* This species of bunchgrass is an excellent species for purposes of soil erosion control. It is also quick to establish and can help with weed-suppression and the crowding out of invasive species. It is recommended to be seeded at about 0.5lbs-5lbs/acre (Bush, 2002).

Planting was done with plant specimens from a local nursery. All plants used ranged in size from 4-inch to 5-gallon pots, depending on the species. Overall, the plants were quite young and thus many had to be caged to protect from ungulate browsing. Beyond this measure, burlap sacks acquired from a lower-mainland coffee roaster were place on the soil surface at the base of each plant in order to supress the growth of weeds that may shade out and out-compete the newly planted native species.

2.6 Plant Selection Criteria

Plant selection was carefully considered for planting the terrestrial aspect of the restoration project. Several criteria were set out and plants were then selected to fit within this framework. The factors considered will theoretically allow not only for the greatest opportunity for durable establishment but provide the greatest benefit to other ecosystem members (birds, dragonflies, bees etc.) and closely resemble the natural makeup of the forests that we find on Galiano Island. The plant selection criteria are as follows:

1. Enhance native diversity

Presently, there is a major issue with invasive species across British Columbia and on Galiano Island in particular. Many invaders were present on the restoration site around the classroom. The culprits with the greatest presence included species such as Himalayan blackberry (*Rubus americanus*), Canada thistle (*Cirsium arvense*), and foxglove (*Digitalus spp.*) alongside countless invasive grasses. Plants selected for this site are exclusively native species (Figure 7).

2. Support local populations

Beyond selecting only native species, I decided to only implement plants that are already present on Galiano Island and/or propagated locally. This is to ensure each specimen is well adapted and accustomed to the local conditions and microclimate. Additionally, this also ensured that resources were not spent in transporting plants from other nurseries or locations.

Figure 7: Red-flowering currant (ribes sanguineum)

Figure 8: Dragonfly (anisoptera)

3. Enhance pollinator habitat

A focus that was also taken into account was the impact these plants would have on local insects and birds. Having as many species that are a food-source for various pollinators was of the utmost importance. Bees (*Bombus spp.*), dragonflies (*Anisoptera spp.*) (Figure 8), and hummingbirds (*Trochilidae spp.*) were all taken into consideration as the primary species to look after. Bee populations, including the native western bumblebee (*Bombus occidentalis*) are on the decline in British Columbia (Colla & Ratti, 2010) so any extra habitat they can be provided is crucial. In this case, plants that support dragonflies are important to ensure the presence of these creatures. There is a focus on the dragonflies because of their propensity to feed on mosquitoes (Wesley, 2019), whose presence can be an unfortunate side-effect of a wetland.

4. Resist grazing pressure

Another selection criterion was natural deer-resistance. As mentioned above, deer browsing is a major issue on Galiano and is a chief culprit of plant community simplification. I attempted to implement as many species that are not deer-favourites as possible to ensure durable establishment. These decisions were made through a combination of research (Canadian Wildlife Federation, consultation with various landscaping companies) and anecdotal evidence provided by Adam Huggins (GCA's restoration coordinator). Adam has observed the deer habits on Galiano Island in real-time for years. The full CWF deer-resistant plant list can be found in Appendix 3. Any plant that doesn't demonstrate any natural deer-resistance or is a natural deer-browsing favourite was caged and will remain so until it's large enough to survive browsing.

5. Eco-cultural value

The final factor taken into account for plant selection is the traditional value of the species selected. An emphasis was placed on plants that have been used traditionally as food sources, plants that have medicinal properties and uses, or any other relevant use to the people traditionally occupying this land. Examples of this include using yerba buena (*Clinopodium douglasii*) to make tea (United States Forest Service, 2020) and eating the berries of red-flowering currant (*Ribes sanguineum*) (Figure 7), which show possible signs of anti-bacterial and anti-viral properties (Gonzalves & Darris, 2008).

Not all plants selected for the planting fulfil every single one of the aforementioned criteria. Plants were selected based on their ability to meet as many as possible, while attempting to create a plant community that would be naturally expected in this particular region. The full plant list is presented in Section 3.

3. TERRESTRIAL RESTORATION RESULTS AND INTERPRETATION

3.1 Terrestrial Ecosystem Map Results

Figure 9 outlines the different TEM polygons present at the classroom site. The results of the soil pit tests are shown below in Table 1. The results of the TEM polygon code determination are presented in Table 2.

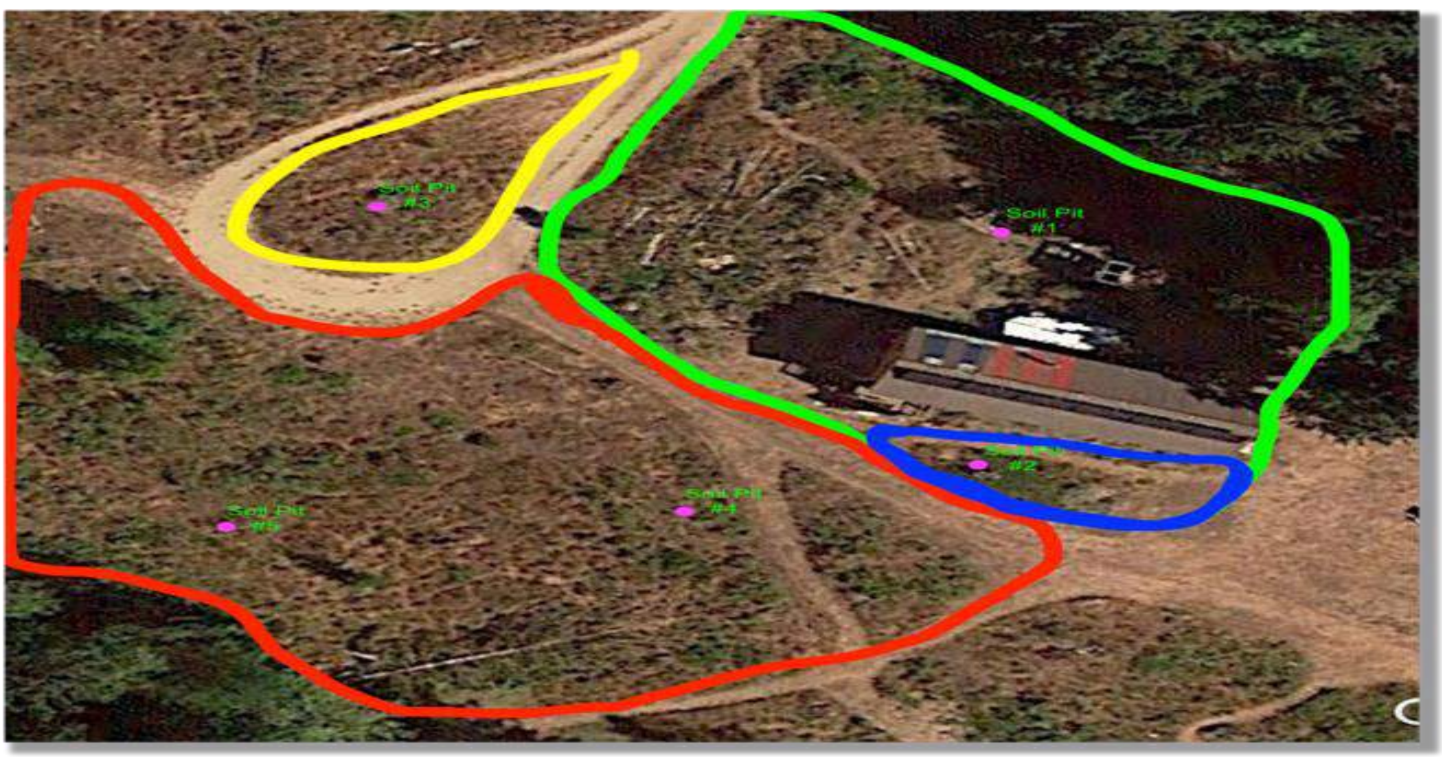


*Figure 7: The results of the TEM mapping. Each pink dot represents one soil pit tested. The coloured outlines each represent a different ecosystem polygon. GREEN: **DSjdf2bLl** BLUE: **DSjdf3aLl** YELLOW: **DFjfy3aLl** RED: **RSjyd3bLl***

Table 1: Results of soil pit tests

Pit Number.	Slope (%) and Aspect (°)	Soil Nutrient Regime (scale A-E; low-high)	Soil Moisture Regime (scale 1-7; low-high)	Notes	Site Series
1	6% 231°SW	B- poor	4- moderately dry	Defined upper organic layer, no root restricting layer beyond some surface compaction, very little coarse material, deep	Fd-salal (Douglas-fir salal)
2	2% 290° W	C- medium	4- moderately dry	Very consistent and sandy soil, light in colour, very little coarse material, deep	Fd-salal (Douglas-fir salal)
3	N/A N/A (Flat, aspect less pit)	D- rich	4- moderately dry	Soft, darker in colour, no root restricting layer, deep, fine	FdBg (Douglas-fir Oregon grape)
4	12% 226°SW	C- medium	5- somewhat dry	Mid-slope pit, very sandy, deep and consistent	CwFd (Western redcedar kindbergia)
5	3% 284°W	A- very poor	5- somewhat dry	Lower slope, very sandy, deep and consistent	CwFd (Western redcedar kindbergia)

Table 2: Polygon code determination

Polygon (Colour)	Site Series (Code)	Site Modifier-Topography (Code)	Site Modifier-Soil (Code)	Structural Stage (Code)	Disturbance Modifier (Code)	Final Polygon Code
Green	Douglas-fir salal **(DS)**	Gentle slope; <35º **(j)**	Deep soil; >100cm to bedrock **(d)** Fine textured soil; <35% coarse material **(f)**	Herb, graminoid-dominant **(2b)**	Previously cleared land **(Ll)**	**DSjdf2bLl**
Blue	Douglas-fir salal **(DS)**	Gentle slope; <35º **(j)**	Deep soil; >100cm to bedrock **(d)** Fine textured soil; <35% coarse material **(f)**	Shrub: early successional stage maintained by environmental conditions or disturbance- low <2m **(3a)**	Previously cleared land **(Ll)**	**DSjdf3aLl**
Yellow	Douglas-fir sword fern or Oregon grape **(DF)**	Gentle slope; <35º **(j)**	Fine textured soil; <35% coarse material **(f)** Moister than typical **(y)**	Shrub: early successional stage maintained by environment or disturbance- low <2m **(3a)**	Previously cleared land **(Ll)**	**DFjfy3aLl**
Red	Western redcedar sword fern or kindbergia **(RS)**	Gentle slope; <35º **(j)**	Moister than typical **(y)** Deep soil; >100cm to bedrock **(d)**	Shrub: early successional stage maintained by environment or disturbance – tall 2-10m **(3b)**	Previously cleared land **(Ll)**	**RSjyd3bLl**

3.2 Polygon Goals and Desired Outcomes

Different approaches were taken in creating the planting plans for each polygon. This is because the different polygons were at different successional stages, had different requirements for human use and interaction, and had varying degrees of interaction and proximity to existent human infrastructure. Below, each polygon is discussed in relation to each of those factors, along with outlining the desired outcomes of each.

Green polygon (DSjdf2bLl)

This polygon represents the "zonal" ecosystem. The zonal ecosystem is defined as the system that "best reflects the regional climate and is the least influenced by local topography…" (Forest Service of BC, 2020). This essentially means that this is the "most typical" ecosystem that will be found in the region and will be characterized by the expected dominant plant species. At the time of the survey, this site was covered in invasive grasses and very little else, save small patches of stinging nettle (*Urtica dioica*), blackcap raspberry (*Rubus occidentalis*), and salal (*Gaultheria shallon*). Extensive planting in this polygon was required, and a combination of manual and mechanical decompaction was performed in preparation for the planting.

The main challenges presented in this polygon were the close proximity it has to the classroom building and other infrastructure (Figure 10). Primarily, this area had to be planned and planted conforming to the Firesmart Canada regulations. This includes but is not limited to: no planting of large woody plants within 10m of the building and no use of flammable material within that distance. The plan for this polygon includes a marked pathway with wheelchair access to the building, discussed below. There are two other main infrastructure considerations. First, part of the grassy area is a septic leach

Figure 8: Green polygon, the brown area represents the septic leech field, and the yellow line indicates the location of the buried powerline

field that is attached to the washroom. Thus, even though this area is far from the building, it could not be planted with deep-rooted woody plants. Second, there is a powerline running underground along the stump line (Figure 10). All earthworks and deep rooting species had to be planned around these two features.

The decision for this polygon was therefore to try to create a healthy under and mid-storey plant community. The plans here focused primarily on native shrub species, with several larger trees planted farther away from the building. Furthermore, the septic leach field was planted with transplants of stinging nettle (*Urtica dioica*) and yarrow (*Achillea millefolium*). All of the selected plants are presented at the end of this section in table 3.

Finally, as mentioned above, a pathway had to be constructed around the Learning Centre. At the time of survey, there were no delineated or marked paths to direct the flow of foot traffic around the classroom. Clear paths were needed to control foot traffic away from the restoration area, and to bring people through the restored area in a more interpretative and meaningful way. This pathway also had to follow the Firesmart rules, and as such, was planned to be built with woodchips in areas greater than 10m from the building, transitioning to gravel in its closer reaches.

Blue polygon (DSjdf3aLl)

The blue polygon represents the smallest area of the terrestrial restoration. It is very similar- nearly identical- to the green polygon, however it differentiates itself by being in a slightly later successional stage. It is dominated by shrubs, primarily dull-Oregon grape (*Berberis nervosa*) and salal (*Gaultheria shallon*). This area was dubbed "the Oregon grape island" due to the fact that it is limited on three sides by roads and on the fourth by the building itself (Figure 11).

The focus for this polygon was to expand the Oregon-grape island. The expansion was to be toward the building, to

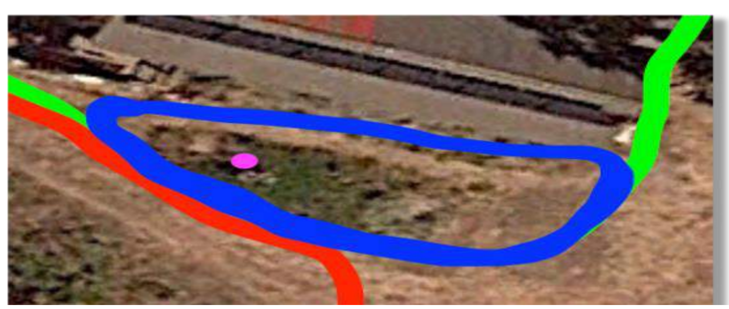


Figure 9: Blue polygon. The solar array atop the classroom roof is seen clearly in this photo

thin that pathway, while maintaining a thoroughfare for foot traffic. The only contention to be had with infrastructure in this area was the fact that large trees were prohibited due to the solar array present on the south side of the roof of the classroom building.

This area was decompacted and planted only with dull-Oregon grape (*Berberis nervosa*). The decompaction combined with the new plantings will hopefully allow the gaps to fill in naturally in the future.

Yellow polygon (DFjfy3aLl)

The yellow polygon represents the first departure from the zonal ecosystem. Its soils had similar moisture regimes as the first two, however, it has a richer nutrient regime. This alters its dominant communities slightly, however many species overlap between these two systems.

The yellow polygon was not a focus of terrestrial restoration, as it was decided to be the area in which the wetland pond would be installed. This is explored in-depth in section 4.

Red polygon (RSjyd3bLl)

The red polygon, like the blue, is slightly different to the zonal system. It is still fairly low in nutrients, however, has much wetter soil. This translates into a higher propensity to support the water-loving Western redcedar (*Thuja plicata*) along with a mossy understory dominated by *Kindbergia* moss species.

This polygon hosts the most "natural" conditions of the four. While it's still certainly degraded, there were signs of successional processes taking place and natural regeneration occurring. Several Douglas-fir (*Pseudotsuga menziesii*) and Western redcedar (*Thuja plicata*) saplings were present. There were also many invasive species in this area, from invasive grasses, to English holly (*Ilex aquifolium*) and Canada thistle (*Cirsium arvense*).

Fortunately, there is no interaction with human infrastructure in this area, meaning that there weren't any planting restrictions.

It can be seen in the bottom left part of Figure 12 that this area is bordered on

Figure 10: Red polygon. The natural forest that we are trying to expand is seen in the bottom-left corner of the image

that edge by a fairly healthy and natural mature redcedar forest. The goal in this polygon was to advance that line as much as possible, reclaiming this area to the forest it should be. This area was mechanically decompacted with an excavator, the operator being careful not to uproot the existing saplings and planted with the trees mentioned above. These trees were all caged after planting to help ensure establishment without the stresses and pressures of ungulates. The establishment and growth of these planted and already-present trees will help control the invasive species as well, as they will serve to shade them out.

The images below show the state of each polygon prior to intervention. (Order: Green, Yellow, Blue+Red)

Table 3: The final plant selection list

Common Name *scientific name*	Planting location (polygon)	Caged (Y/N)	Pollinator Friendly? (Y/N)
SHRUBS			
Yerba buena *Clinopodium douglasii*	Green	NO	NO
Fireweed *Chamaenerion angustifolium*	Green	NO	YES
Salal *Gaultheria shallon*	Green Blue	NO	YES
Yarrow *Achillea millefoleum*	Green (septic field)	NO	YES
Stinging nettle *Urtica dioica*	Green (septic field)	NO	YES
Dull-Oregon grape *Berberis nervosa*	Green Blue	NO	NO
Evergreen huckleberry *Vaccinium ovatum*	Green	NO	YES
Baldhip rose *Rosa gymnocarpa*	Green	YES	YES
Red-flowering currant *Ribes sanguineum*	Green	YES	YES
Salmonberry *Rubus spectabilis*	Green	YES	YES

Sword fern *Polystichum munitum*	Green	YES	NO
Red elderberry *Sambucus rasemosa*	Green	YES	YES
TREES			
Arbutus *Arbutus menziesii*	Green	YES	NO
Douglas-fir *Pseudotsuga menziesii*	Green Red	YES	NO
Western hemlock *Tsuga heterophylla*	Red	YES	NO
Red alder *Alnus rubra*	Green Around wetland	YES	NO
Western redcedar *Thuja plicata*	Green Red	YES	NO
Scouler's willow *Salix scouleriana*	Green Around wetland	YES	YES
Oceanspray *Holodiscus discolor*	Green	YES	YES

4. SURVEY RESULTS AND WETLAND DESIGN

The wetland design aspect of this project is a departure from the more "traditional" restoration taking place in the terrestrial phase. Again, this is a designed and constructed wetland, being placed where no wetland was before. The employment of a liner is necessitated by the fact that the soil present at the site would not be able to hold water on its own. In this section we will delve into the results of our land survey as well as design aspects, contingency plan considerations, and reasoning and justification for why the wetland ultimately ended up where it did.

4.1 Land Survey Results

Figure 14 shows a theoretical footprint of the wetland with two transects marked AA-A and BB-B (Figure 6). Relative elevation measurements were taken at 1.5m intervals along both of those transects. Points represented by the red letters were also measured. Tables 4 and 5 along with Graphs 1 and 2 show the results of this survey.

Figure 11: Spraying out a wetland footprint

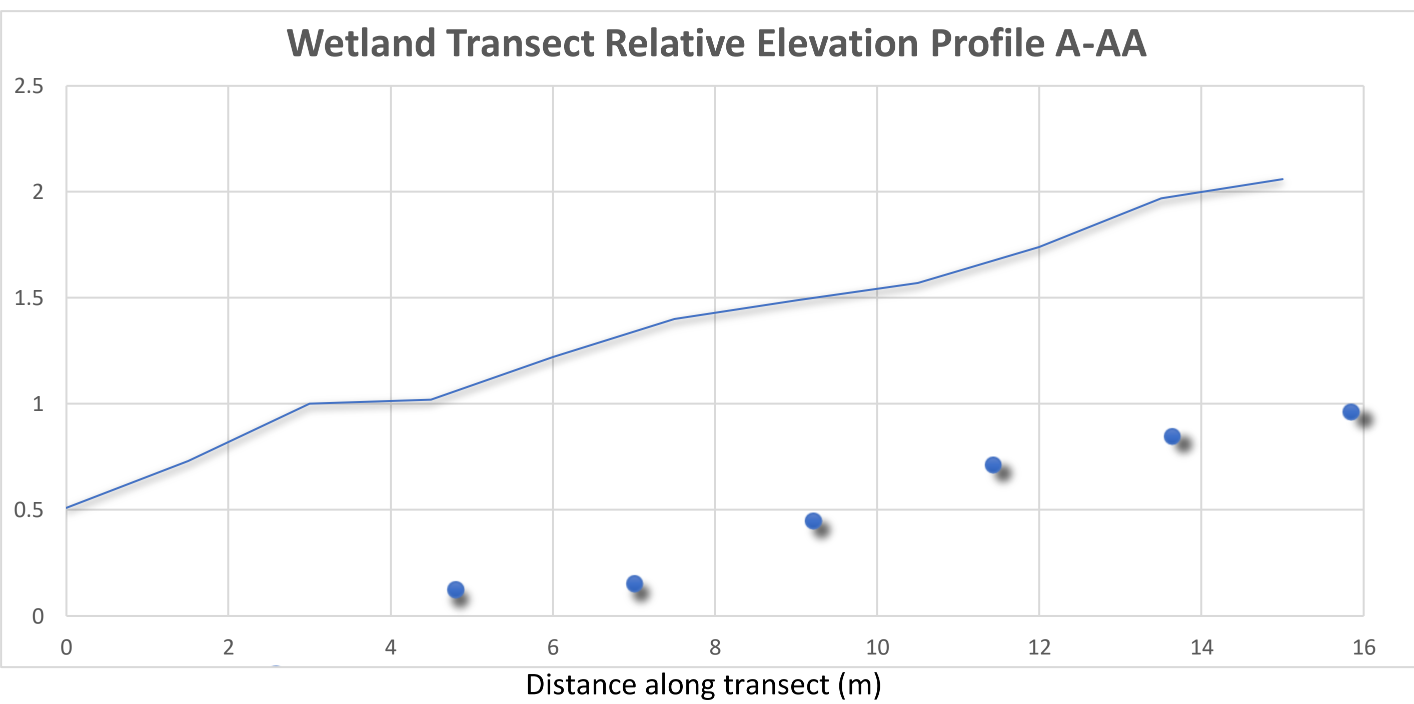
Table 4: Auxiliary point measurements

Point	Relative Elevation (m)
C	1.64
D	0.92
E	1.38
F	1.75

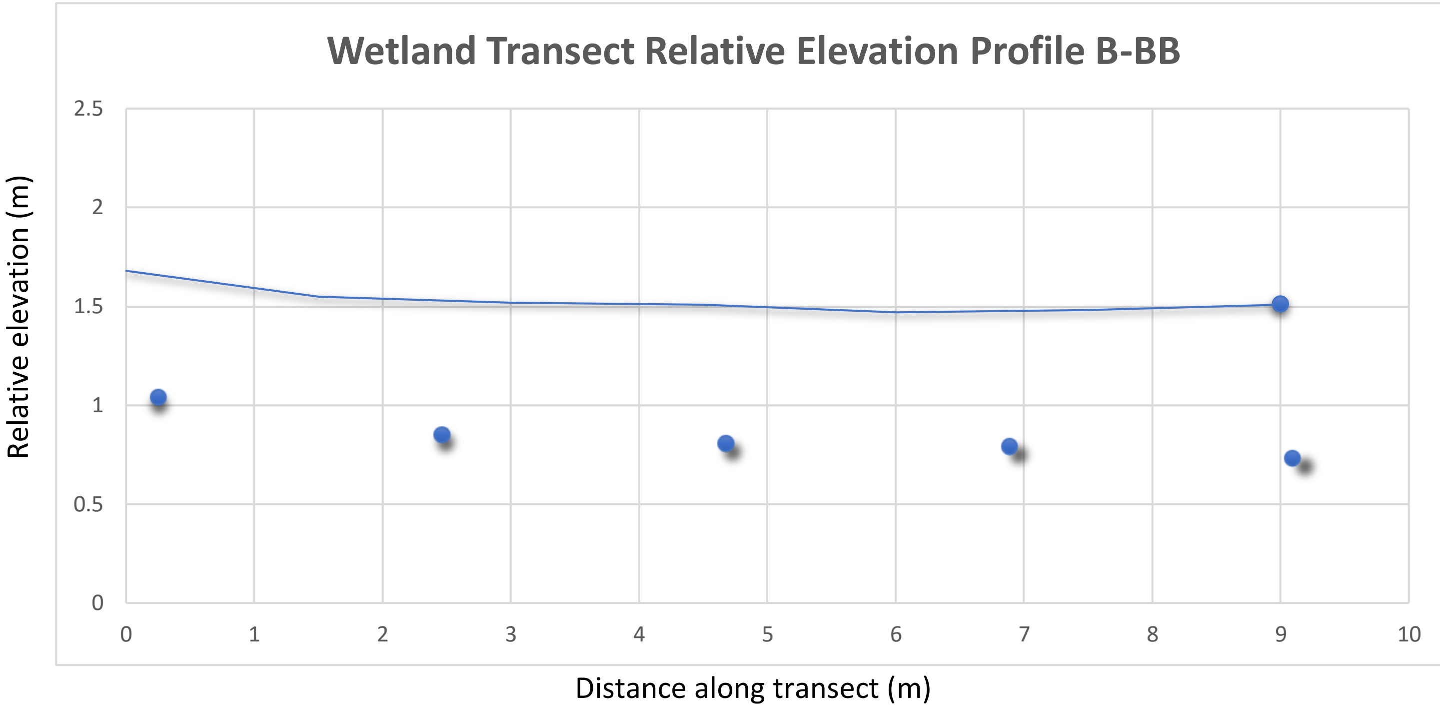
Table 5: Transect point measurements

	Transect A-AA	Transect B-BB
Point (m)	Relative Elevation(m)	Relative Elevation (m)
0	0.51	1.68
1.5	0.73	1.55
3	1.0	1.52
4.5	1.02	1.51
6	1.22	1.47
7.5	1.4	1.48
9	1.49	1.51
10.5	1.57	
12	1.74	
13.5	1.97	
15	2.06	

Graph 1: Relative Elevation Profile of Transect Line A-AA



Graph 2: Relative elevation profile of transect line B-BB



Transect line A-AA is a fairly consistent slope but shows little to no "bowl-ing". Transect line B-BB is more or less a flat line and not something that would work as a pond.

Naturally, some alterations would need to be performed on these graphs to give us a workable ground-shape to hold and store water. Refer to appendix 4 to see these alterations.

4.2 Wetland Design

As mentioned above, this area was never a wetland and the soils tested in the area are not able to hold water long-term. For this reason, a pond liner was employed to ensure that water would be present in the wetland for most if not all of the year. The liner procured for this wetland measures 12.2m (40ft) by 15.2m(50ft). We wanted to make the pond as large as possible so in order to maximize the rectangular liner, the pond was designed to be oval-shaped.

There were certain characteristics that were desired for the pond to fulfil its desired function. Chief among them was ensuring a maximal depth exceeding 0.6m (2ft) to ensure that emergent vegetation such as bulrushes (*Scirpoides holoschoenus*) and cattails (*Typha sp.*) didn't take over the whole pond (Ochterski, 2020). A maximal depth of greater than 0.6m will ensure that there is always an area of "open water".

It is also important to have varying depths, rather than consistent slopes from the rim to the centre all the way around. This allows for varying habitat conditions for the future residents of the pond.

Location Selection

There were two possible locations for the wetland at the classroom site. Separate designs were created for each possible site and a decision was made collectively for which site was ultimately selected. Each site would have the same flow path (Figure 15) and same primary water source, the roof of the classroom. This path begins with the water flowing off of the classroom roof and ending on the far side of the roundabout, flowing into the Nuts'a'maat Forage Forest, a previous restoration project completed in 2017. Figure 15 also shows the first possible location of the wetland in blue with the second possible wetland location outlined in purple. Each location had several benefits and drawbacks.

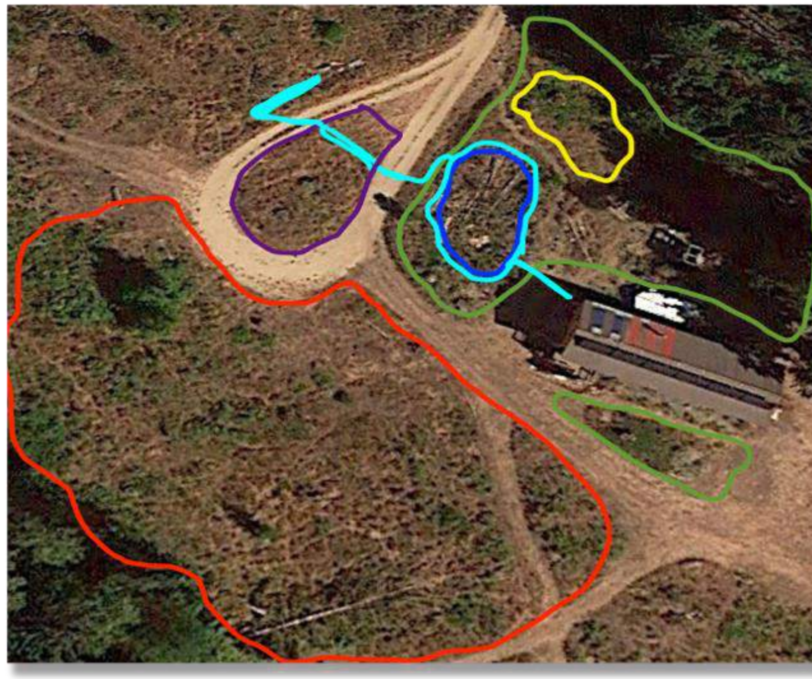


Figure 12: The flowpath of water as it moves through the system.Right to left from this perspective: off of the roof, through the primary swale, into the wetland, through the first culvert, through the secondary swale, through the second culvert

Location 1 benefits

- Closer to the classroom, thus easier access for viewing
- The roundabout and therefore road would not be impacted or altered in any way
- The culverts and secondary swale are already in place

Location 1 drawbacks

- The land is sloped toward the road, meaning there would need to be a dam built to hold water. Any breach in this dam would be potentially catastrophic for the road

- Must build a bioswale to direct water from the classroom roof into the wetland
- There is a buried powerline very close to the edge of the proposed footprint. Extreme caution is necessary with excavation

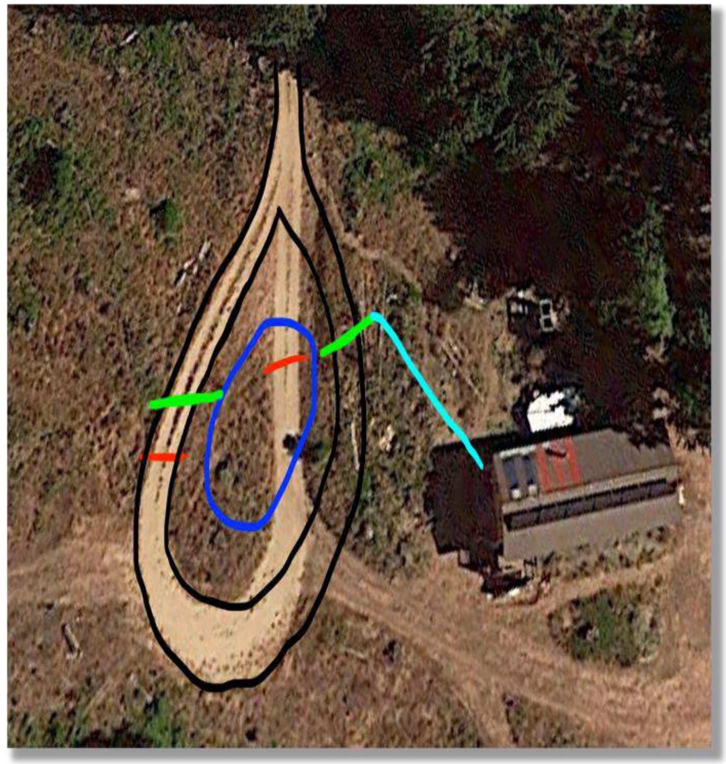


Figure 13: First road design. It involves simply moving the roundabout, but keeping it intact. Existing culverts are in red, proposed locations in green

Location 2 benefits

- Area is essentially flat, meaning no dam would have to be built, and only a simple hole needs to be excavated
- No buried powerlines or any other groundworks to consider, giving more freedom to exact basin location
- Larger overall area, increases planting freedom around the wetland

Location 2 drawbacks

- The road would have to be altered, the two alteration options are shown in Figures 16 and 17
- Greater distance from primary water source (classroom roof)

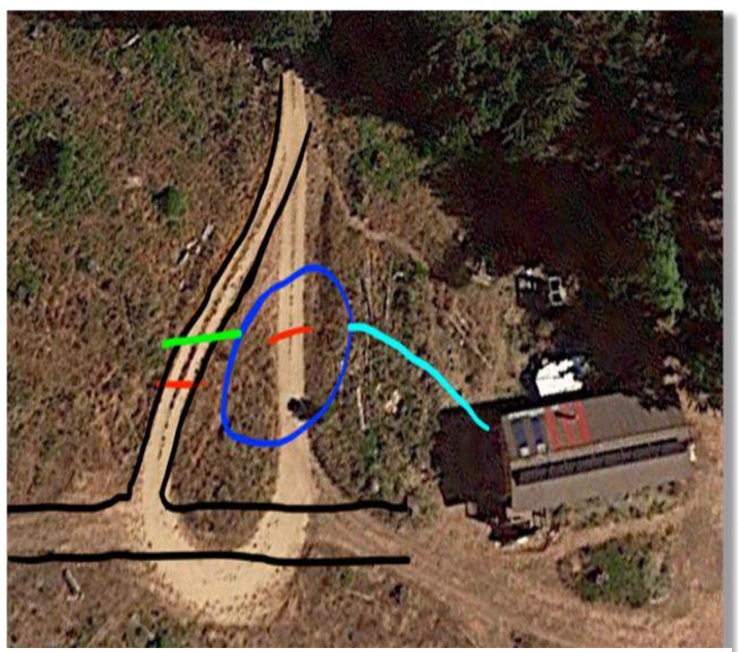


Figure 14: Second road design. It involves removing the roundabout entirely and creating a T-turnaround junction. Existing culverts are in red, proposed locations in green

Design

The decision on which of the locations to move forward with was made shortly before implementation. Robin Annschild, a professional wetland restoration practitioner, was brought in and consulted to aid in the final decision. In the end, it was decided that the traffic circle plan was the one that made the most sense, for several reasons. First off, it was simply a bigger area. Therefore, it would be easier for machinery to get in for excavating and there would be more space for planting around the wetland. Secondly, the idea of having to build a dam next to an active road was growing increasingly more daunting. Dam failure would be disastrous for the road and it was ultimately determined that the reward was not worth the risk. Furthermore, the buried power lines that were mentioned in Sections 1.6 and 3.2 presented too great a hazard in that area to want to excavate near it.

Beyond this, the second option for road alteration (Figure 17) was chosen. There were several factors that led to this decision. From a safety and practicality standpoint, having a wetland intended for educational purposes next to a classroom but surrounded by a road doesn't really make sense. In this case viewing would be more difficult, and school-aged children shouldn't need to be standing in the middle of a road for an educational opportunity. From an ecological standpoint, it made sense to have habitat continuity between the constructed wetland and the terrestrial restoration going on around it. Having a road splitting these two features would essentially turn them into distinct and separate projects, and that would be going against the original goal of the project as a whole, melding restoration techniques as well as terrestrial and aquatic ecosystems. The "T" was also designed in such a way to allow enough space for the Conservancy's schoolbus to be able to turn around.

There was no formal survey done for this location, as the area within the traffic circle had very little discernable slope and presented as essentially flat. The main benefit attributed to that characteristic is that no dam would be required, and it was essentially as simple as choosing a maximal depth and excavating appropriately.

Ultimately, the central depth was decided to be about 1m, which would give us slopes from the centre to the rim of between 15% and 18%. Based on this design, the average depth of the wetland would be approximately 0.56m (with a maximal depth of about 1m). When we consider the average depth along with a surface area covering 185m^2, we can glean that the volume of the pond would be upwards of 100,000L. The water budget was then calculated by determining the runoff volume coming from the classroom roof by multiplying its surface area (138m^2) by the average rainfall in the month of January (176mm) and found that runoff alone would provide upwards of 24,000L/month in the rainy season. When we combine this with the volume of rain falling directly into the pond (35,000L in the month of January).

The plan to create a bioswale from the classroom to the pond was also discarded with the increased distance to the selected location. The gutters and downspouts from the classroom were tied into the perimeter drain and this buried pipe was then extended into the bottom of the wetland basin to drain directly into the wetland.

The complete design and workplan for the other location can be found in appendix 4.

5. TIMELINE

The implementation of this project was something of an exercise in patience and stress-management. Trying to get boots on the ground to complete a project like this during the COVID-19 pandemic was a challenge. The section that follows chronicles that timeline and the challenges faced, while also highlighting the steps that were taken in each phase to create the final product.

January 2020

The proposal for this project was written and put forth to both the director of the Restoration of Natural Systems (RNS) program director, Nancy Shackleford and the restoration director at the Galiano Conservancy Association, Adam Huggins.

The initial site visit occurred late in the month. Nancy Shackelford, and Eric Higgs, and I made the trip to meet with Adam Huggins as well as the GCA's executive director Chessi Hiltner, and executive director Keith Erickson. This consisted of a walk-through to talk out initial ideas and locations pertaining to this specific project.

February 2020

In February, the design began in earnest. Initially, the project was supposed to be the design and implementation of the wetland, alongside the conceptual design of the CDF forest restoration around the classroom. However, we ended up receiving the funding to complete both aspects of the project, aquatic and terrestrial.

In mid-February I went out to the site and dug soil pits to determine site series codes that would ultimately aid in the decision making for plan community selection. In this same visit, the GIS mapping was performed. This created the map seen above (Figure 4). The rest of the month was spent designing the pathway system and the plant communities for the first planting session.

This visit also included the first transit survey measurements taken. Adam Huggins and I took the approach of measuring the elevations of several points of interest such as inflow/outflow points of culverts, upper and lower extremes of possible wetland footprints, and elevations for potential swale placements.

March 2020

Early March officially marked our first shovels in the dirt! The University of Victoria Restoration Club came over with about 10 student volunteers to help with the building of the new path system, the manual decompaction of the area in between the pathway and the washroom building using a broadfork, and the first round of planting. Everything was planted by hand, and all necessary plants were caged. Every plant planted also received a blanket of burlap around its base to aid in weed suppression to allow the native plants to establish more easily without competition.

In total, about 75 plants were planted during this initial session (all "plants in the ground" for the project as a whole are presented in the budget section below).

April-May 2020

These months were dominated by design work. Transit surveys of the potential wetland footprint transects were performed on site by GCA staff members, as a ferry malfunction prevented me from travelling to Galiano to complete the task. Workplans were developed for the installation phase during this time period as well.

June 13th and 14th, July 6th-12th, August 7th, 2020

What do all of these dates have in common? They were all dates slated for installation and were cancelled for various reasons.

June 13th and 14th were supposed to be the dates that the MLC was going to host the BC Wildlife Foundation's Wetland Keepers workshop, in which the installation was to be completed by the workshop attendees. This was cancelled due to the COVID-19 pandemic, and the workshop was taken online, where designs for this project and others on the property were presented to the participants.

July 6th to 12th was cancelled simply because schedule coordination could not be achieved with the local contractor we were hiring for the excavation work.

August 7th was then cancelled, because 2 days prior, the forest fire danger on the island went from high to extreme, triggering policies in place to halt or postpone all outdoor heavy machinery operation.

October 20th-23rd, 2020

Implementation days! Over the course of these 4 days, excavation took place, the liner wetland was installed, and further planting was completed. A photo gallery outlining this process is presented after the discussion.

6. DISCUSSION

On the surface, the goal of this project from the outset was to restore an area of Coastal Douglas-fir forest and to create a wetland that provided ecological as well as social and educational benefits. Beyond this, it was a project that combined traditional restoration practices with more contemporary designed ecosystem creation. It is possible that this combination may help to inform similar projects in the future and help in expanding my belief that these two approaches need not be mutually exclusive.

An aspect of this project that fooled me somewhat, was that building a wetland is not nearly as simple as "digging a hole and letting it fill with water", even if a liner is used. There were logistical challenges throughout that ultimately led to the development of 3 different designs in two different locations. Several of these challenges were ones I hadn't considered prior to this project. For example, how hard it would actually be to confidently build a dam that can hold thousands of litres of water away from a road.

Moving forward, this project is in an ideal location with respects to monitoring. Aspects to be monitored could include parameters such as water quality, water levels, plant community establishment and growth, deer browsing effects, and amphibian surveying (a Northern red-legged frog survey procedure was created during the 2018 Galiano Field School). The fact that the project is located on land closely monitored and operated by a conservancy creates great conditions for long-term monitoring and the maintenance of strong institutional knowledge. This once again lends itself to informing future, similar projects.

All told this project incorporated 140 plants, 24 hours of machine work, a liner, 55 hours of consultation, 130 plant cages, 330 burlap sacks, and over 30 volunteers providing over 190 hours of volunteer work. All of this is outlined below in the budget. The plants selected are further broken down below the budget.

Environmental restoration is a long-term discipline. As with most restoration projects, the success of this project will not be determined for several years. Having said that, the positive signs began when the wetland was full within 2 months of project completion. Let's hope that the positive signs continue and that many benefits are created by this project into the future.

Item	Quantity	Cash Value ($)	In-kind Value ($)
Plants	140	1,450	
Machine work ($145/hr)	24 hours	3,500	
Liner (40'x45' pond liner+ 2 layers of geotextile)	1x 40'x45' pond liner 2x 40'x45' layers of geotextile	4,500	
Robin Annschild's consulting ($100/hr)	30 hours	3,000	
Drainpipe and gutter	1 each	350	

Plant cages	130		800	
Burlap sacks	330		330	
Volunteer hours for installation and planting ($20/hr)	130 hours		2,600	
Volunteer hours for initial planting and pathway build ($20/hr)	60 hours		1,200	
Miranda Cross' time ($75/hr)	25 hours		1,875	
My time ($30/hr)	140 hours		4,200	
TOTALS		12,800	11,005	23,8005

Plant	# planted
Yerba buena	10
Fireweed	15
Oceanspray	7
Dull Oregon-grape	11
Baldhip rose	10
Red-flowering currant	13
Western redcedar	7
Sword fern	9
Salal	22
Evergreen huckleberry	12
Salmonberry	5
Red alder	5
Western hemlock	3
Douglas-fir	3
Arbutus	1
Bigleaf maple	1
Red elderberry	3
Scouler's willow	3

The following is a picture gallery of the implementation of this project

Upper left: laser level and marking flags.
Lower left: excavator preparing wetland area.

Upper right: measuring distances from wetland centre to edge.
Lower right: dig, measure, dig, measure, dig

Upper left: volunteers raking out the wetland rim to ensure consistent elevations.
Lower left: extending the classroom's perimeter drainpipe into the wetland

Upper right: basin complete, one last centre depth check
Lower right: Volunteers unravel and install the three layers of geotextile and pond liner

Upper left: marking points for pegging the liner
Lower left: volunteers plant around the wetland. Note the use of burlap and cages.

Upper right: excavator adds soil and habitat features such as stumps back into the wetland
Lower right: volunteers bring a table to the “outdoor classroom” area on the wetland edge

Final products! Top: new pathway leading toward the classroom building
Bottom: the wetland 2 months post-construction, soil will settle and the water will get deeper, but it’s a great start

Acknowledgements

Adam Huggins (Restoration Coordinator at the Galiano Conservancy Association)

I don't know what I would have done without Adam's help and guiding presence. He approached this project with a perfect combination of allowing me autonomy, being a helping hand, and being a sounding board for my ideas. He worked tirelessly to ensure I had everything I needed at my disposal; all the equipment and measurement tools, access to the MLC facilities when I would camp out on site, helping facilitate volunteer trips, and giving me a copious amount of his time and patience. This project would absolutely not have been possible without his help, his fingerprints are all over it.

Keith Erickson and Chessi Miltner (Former and current Executive Directors of the Galiano Conservancy Association)

Keith was present during my first go-round at the GCA when I attended the Galiano Field school. He mentioned the possibility of being able to return for my capstone project and that thought set all of this in motion. Chessi, the director once the project actually started, was very welcoming and generous, I'm thankful that he ultimately allowed the project to move forward. He helped hash out different ideas and was also a good sounding board.

Eric Higgs (Former Acting Director of the Restoration of Natural Systems program, professor at University of Victoria)

Eric was my instructor for the Galiano field school and inspired me greatly with his outlook on environmental restoration and the changing landscape of the discipline. Eric was also instrumental in editing my project proposal. It was, to say the least, incomplete when I sent him the first draft and his notes and suggestions were crucial in getting the proposal approved. Without his help, it's entirely possible this whole thing would never have even gotten off the ground.

Nancy Shakelford (Director of the Restoration of Natural Systems program)

The help Nancy provided throughout this process was awesome. Not only was she a great sounding board for me, she also physically helped a great deal. Nancy made not one or two, but three trips to Galiano within the duration of the project. Two of those three trips included volunteer work, getting dirty and helping with the construction of the pathway and planting of new native plants. She did so much more than I could have ever wanted or expected from a program head.

Robin Annschild and Miranda Cross (Professional wetland restoration practitioners)

Robin's experience, expertise, and presence was crucial in getting this design to actually work. She was there step-by-step through the building process and provided invaluable ideas, and occasionally needed reality checks. She was instrumental in turning ideas into realities.

Thank you to MLC staff members Sylvie Hawkes and Austin Tahiliani who helped a ton during the building of the wetland. Finally, thank you to all volunteers who showed up, rain or shine, with smiles, energy, and enthusiasm for the project. It wouldn't have happened without you.

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APPENDICES

Appendix 1: Expected plant community composition in CDFmm ecosystems

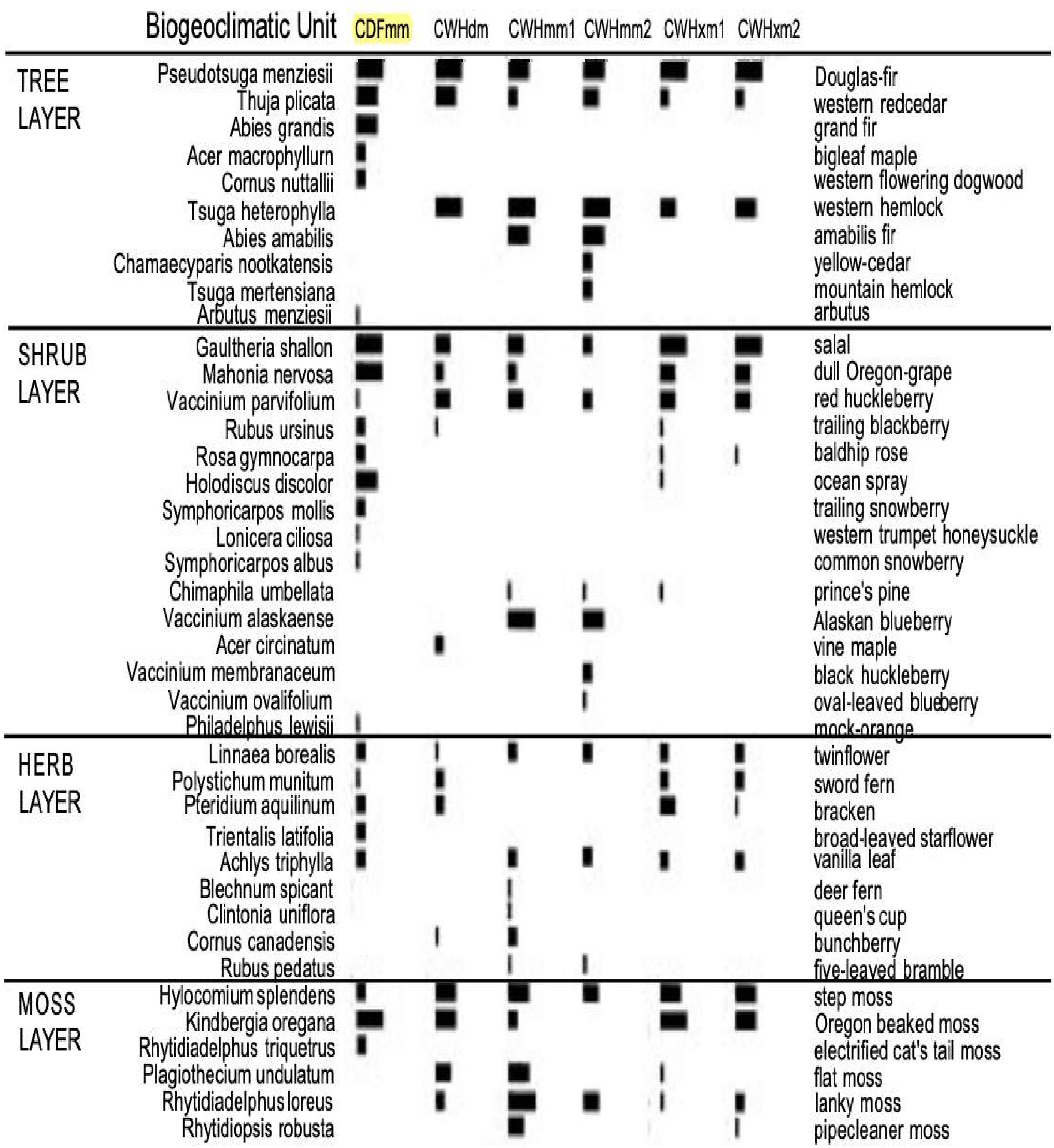

TABLE 15. Vegetation table for zonal sites of summer-dry maritime biogeoclimatic units

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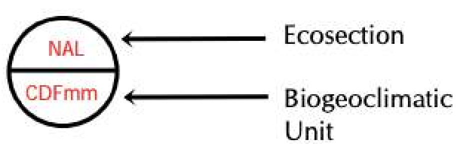
Appendix 2: TEM modifier and site code guide

INTRODUCTION

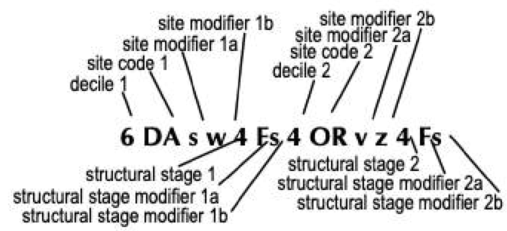
This project synthesizes results of bioterrain and terrestrial ecosystem mapping of the CDFmm biogeoclimatic subzone. The CDFmm occurs in south eastern BC, covering ecosystems along the eastern coastline of Vancouver Island, the southern Gulf Islands, parts of the Sunshine Coast and a portion of the Fraser Valley. On Vancouver Island, Deep Bay marks the northern extent of the CDFmm; Metchosin marks the southern boundary. From Deep Bay moving south, the subzone extends along the Strait of Georgia from sea level to an approximate elevation of 150m above sea level (asl) and includes the major centres of Nanaimo, Duncan and Victoria. The CDFmm covers or partially covers all of the Gulf Islands south of Cortes Island; including: Texada, Hornby, Denman, Lasqueti, Gabriola Galiano, Thetis, Kuper, Saltspring, North Pender, South Pender, Mayne, Saturna, Sidney and several smaller islets in between. Across the Strait of Georgia, the CDFmm covers portions of Lund, Powell River, Sechelt and the Fraser Valley for a total area of approximately 252,000 hectares.

Digital maps will aid interpretation for resource management and land use planning; identified wildlife habitat capability and suitability; and to collate a comprehensive baseline data set of attributes of interest for the CDFmm. A seamless database of polygon attributes and the associated bioterrain and ecosystem data, as well as other features and parameters of interest accompanies this legend. Mapping was completed following the methods outlined in Standard for Terrestrial Ecosystem Mapping in British Columbia1. Field work was completed in 2007 and 2008 at a modified survey intensity level 5.

ECOSECTION & BIOGEOCLIMATIC UNITS



ECOSYSTEM UNIT LABEL



MAP SYMBOLS

Ecosection

Biogeoclimatic Unit

Ecosystem Unit

Study Area Boundary

Plot Location

Ecosections
SGI: Southern Gulf Islands
SGO: Strait of Georgia
NAL: Nanaimo Lowland
GEL: Georgia Lowland

Biogeoclimatic Units:
CDFmm: Coastal Douglas-Fir zone, moist maritime subzone
CWHxm1: Coastal Western Hemlock zone, very dry maritime subzone, eastern variant
CWHxm2: Coastal Western Hemlock zone, very dry maritime subzone, western variant

ECOSYSTEM UNITS

CDFmm

Site Code	Description	Site Series	Assumed Modifiers	Soil Moisture Regime	Mapped Modifiers
AS	Trembling aspen - Slough sedge	00	j, m	subhygric - subhydric	s
CD	Act - Red-osier dogwood	08	a, d, j, m	subhygric - hygric	n, s, t
CS	Cw - Slough sedge	14	d, j, m	subhydric	c, n, p, s, t, w
CW	Act - Willow	09	a, c, d, j	subhygric - hygric	

ECOSYSTEM UNITS					
CDFmm (continued)					
Site Code	**Description**	**Site Series**	**Assumed Modifiers**	**Soil Moisture Regime**	**Mapped Modifiers**
DA	FdPl - Arbutus	02	j, d, m, r	xeric	c, h, k, q, s, v, w, x, z
DG	FdBg - Oregon grape	04	d, j, m	subxeric - mesic	c, f, g, h, k, q, r, s, t, v, w, x, z
DO	Fd - Oniongrass	03	d, m, r	xeric	h, k, s, v, w, x
DS	Fd - Salal	01	d, j, m	subxeric - mesic	c, f, g, h, k, n, q, r, s, t, v, w, x, z
FC	Fescue - Camas	00	j, m, s	subxeric	c, d, h, k, n, v, w
GO	Garry Oak - Ocean Spray	00	j, m, r	xeric - submesic	s, v, w, z
LM	Dunegrass - Beach pea	00	j, m, v	subxeric - submesic	c, w
LS	Pl - Sphagnum	10	d, j, p	subhydric	
OM	Garry Oak - Moss	00	j, v	xeric	k, v, w
OR	Oceanspray - Rose	00	m, s	mesic	w
QB	Garry Oak - Brome/mixed grasses	00	j, m, r	xeric - submesic	h, k, s, v, w, z
RA	Nootka Rose - Pacific Crab Apple	00		subhydric	
RC	Cw - Skunk cabbage	11	d, j, m	subhydric	c, f, n, p, s, t
RF	CwBg - Foamflower	06	d, j, m	subhygric - hygric	a, c, f, g, h, k, n, p, q, s, t, v, w, z
RK	CwFd - Kindbergia	05	d, j, m	subhygric - hygric	c, g, h, k, n, r, s, t, v, w, x, y, z
RP	Cw - Indian-plum	13	d, j, m	hygric	c, h, k, n, p, s, t, w
RS	Cw - Snowberry	07	a, d, j, m	subhygric - hygric	g, k, s, t, w
RV	Cw - Vanilla-leaf	12	d, j, m	subhygric	c, h, n, p, s, v
SC	Cladina - Wallace's selaginella	00	j, m, r, v	subxeric	h, k, q, s, w, z
Ed01	Tufted hairgrass - Meadow barley	Ed01		subhydric - hydric	
Ed03	Arctic rush - Alaska plantain	Ed03		subhydric - hydric	
Em01	Widgeon-grass	Em01		hydric	
Em02	Glasswort - Sea milkwort	Em02		subhydric - hydric	
Em03	Seashore saltgrass	Em03		subhydric - hydric	
Em05	Lyngbye's sedge	Em05		subhydric - hydric	
Wb50	Labrador tea - Bog-laurel - Peat-moss	Wb50		subhydric	
Wf51	Sitka sedge - Peat-moss	Wf51		subhydric	p
Wf52	Sweet gale - Sitka sedge	Wf52		subhydric	p
Wf53	Slender sedge - White beak-rush	Wf53		subhydric - hydric	d, s
Wm05	Cattail	Wm05		hydric	p
Wm06	Great bulrush	Wm06		hydric	
Wm50	Sitka sedge - Hemlock -parsley	Wm50		subhydric - hydric	
Wm51	Three-way sedge	Wm51		hydric	
Ws50	Hardhack (pink spirea) - Sitka sedge	Ws50		subhydric - hydric	p, s
Ws51	Sitka willow - Pacific willow -Skunk cabbage	Ws51		subhydric - hydric	p
Ws52	Red alder - Skunk cabbage	Ws52		subhydric - hydric	

SITE MODIFIERS	
Code	**Topography**
a	active floodplain[1]: level or very gently sloping area bordering a river that has been formed by river erosion and deposition, with evidence of active sedimentation and deposition
g	gullying[1]: occurs within a gully, or with gullying throughout the delineated area
h	hummocky[1] terrain: indicated by the terrain surface expression
j	gentle slope: < 35% in the CWH and CDF zones
k	cool aspect: occurs on aspects 285°–135°, on moderately steep slopes (35%–100% in the CWH and CDF)
n	fan[1]: occurs on a fluvial fan or on a colluvial fan or cone
q	very steep cool aspect–very steep slopes (< 100%) with aspects 285°–135°
r	ridge[1]: occurs throughout an area of ridged terrain, or on a ridge crest
t	terrace[1]: occurs on a fluvial, glaciofluvial, lacustrine, or rock cut terrace
w	warm aspect: 135°–285°, on moderately steep slopes (35%–100% slope in the CWH and CDF zones)
z	very steep warm aspect –slopes > 100% on aspects 135°–285°
Code	**Soil**
x	drier than typical
y	moister than typical
c	coarse-textured soils[2]: sand and loamy sand, and sandy loam, loam, and sandy clay loam with > 70% coarse fragment volume
d	deep soil: >100 cm to bedrock
f	fine-textured soils[2]: silt and silt loam with < 20% coarse fragment volume; and clay, silty clay, silty clay loam, clay loam, sandy clay, and heavy clay with < 35% coarse fragment volume
p	peaty: on deep organics or a peaty surface (15–60 cm)[3] over mineral materials
s	shallow soils: 20–100 cm to bedrock
v	very shallow soils: < 20 cm to bedrock

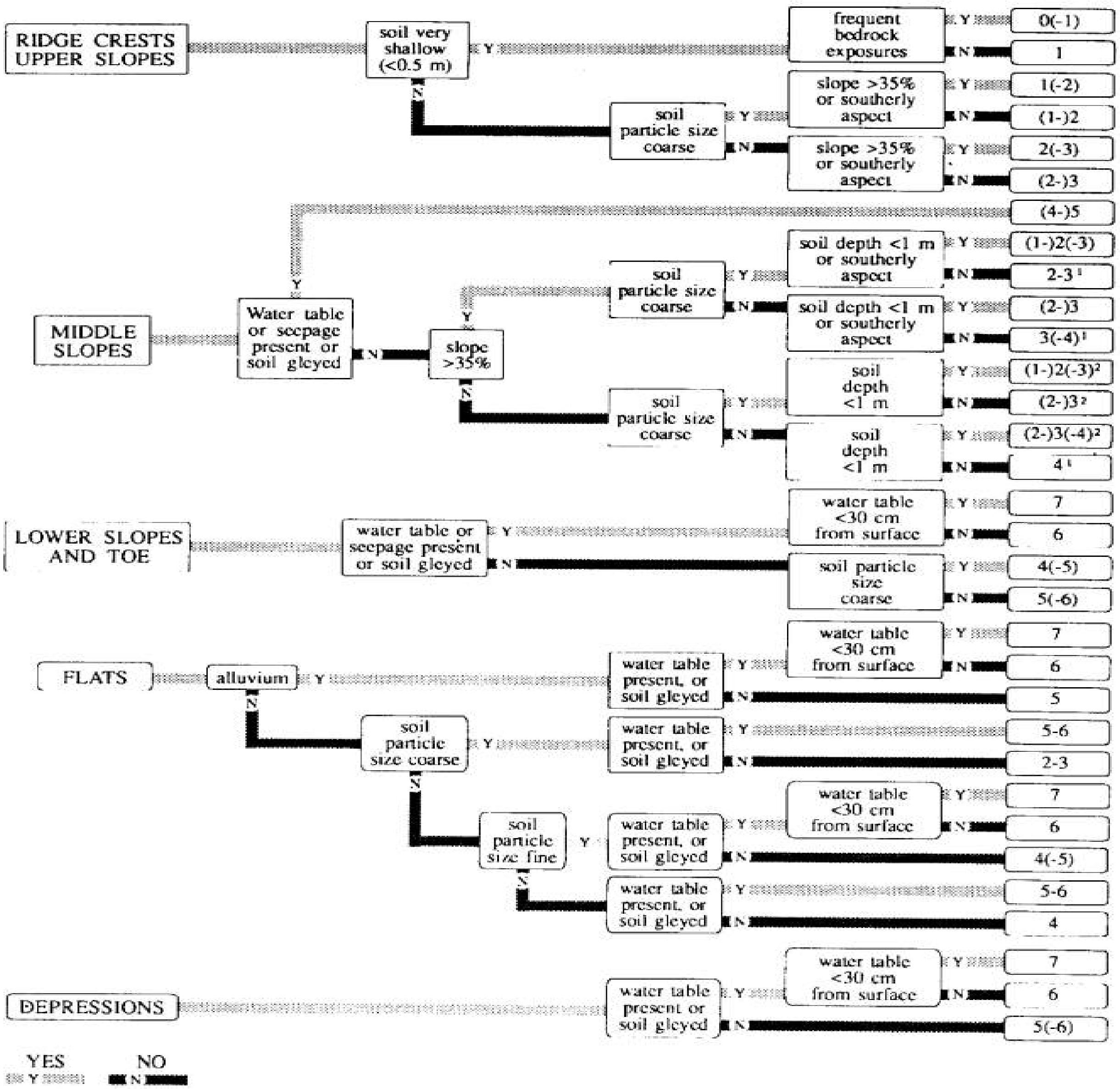
STRUCTURAL STAGE	
Code	**Structural Stage[1]**
1	**Sparse (1a)** bare rock or ground / **bryoid (1b)** bryophytes and lichens dominant, may reflect recent disturbance
2	**Herb** some invading or residual shrubs and trees may be present, may reflect recent disturbance **Forb-dominated (2a) / Graminoid-dominated (2b) / Aquatic (2c) / Dwarf shrub (2d)**
3	**Shrub** Early successional stage or maintained by environmental conditions or disturbance **Low shrub (3a)** < 2 m tall / **Tall shrub (3a)** 2–10 m tall
4	**Pole/Sapling** Trees > 10 m tall, often densely stocked, no vertical canopy structure, typically < 40 years since disturbance
5	**Young Forest** Self-thinning and canopy differentiation initiated, typically 40–80 years since disturbance
6	**Mature Forest** Mature tree canopy, typically 80–250 years since disturbance
7	**Old Forest** Structurally complex stands comprised mainly of shade-tolerant and regenerating tree species; snags and coarse woody debris and patchy understories, typically > 250 years since disturbance.

DISTURBANCE MODIFIERS			
B	Biotic Disturbances	F	Fire disturbances
b	▪ Beaver tree cutting	c	▪ overstorey crown fire
d	▪ Domestic grazing/browsing	g	▪ light surface (ground) fire
w	▪ Wildlife grazing/browsing	r	▪ repeated light surface fires
k	▪ Insects	s	▪ severe surface fire
ki	⇨ Insect kill	i	▪ repeated severe surface fires
in	⇨ Infestation	l	▪ slash burning
p	▪ Disease	bb	⇨ broadcast burn
v	▪ Aggressive vegetation	pb	⇨ piled and burned
		wb	⇨ burned windrows
L	Forest Harvesting	L	Forest Harvesting
a	▪ patch cut system	e	▪ selection system
wr	⇨ with reserves	gr	⇨ group selection
c	▪ clearcut system	si	⇨ single tree
wr	⇨ with reserves (patch retention)	st	⇨ strip
d	▪ seed tree system	l	▪ land clearing
un	⇨ uniform	s	▪ Shelterwood system
gr	⇨ grouped	un	⇨ Uniform
		gr	⇨ Group
		st	⇨ Strip
		ir	⇨ Irregular

All retrieved from: https://www.cdfcp.ca/attachments/CDF%20TEM%20Map%20legend.pdf

Continued: Soil nutrient and moisture regime flow charts

A key to the identification of soil moisture regimes

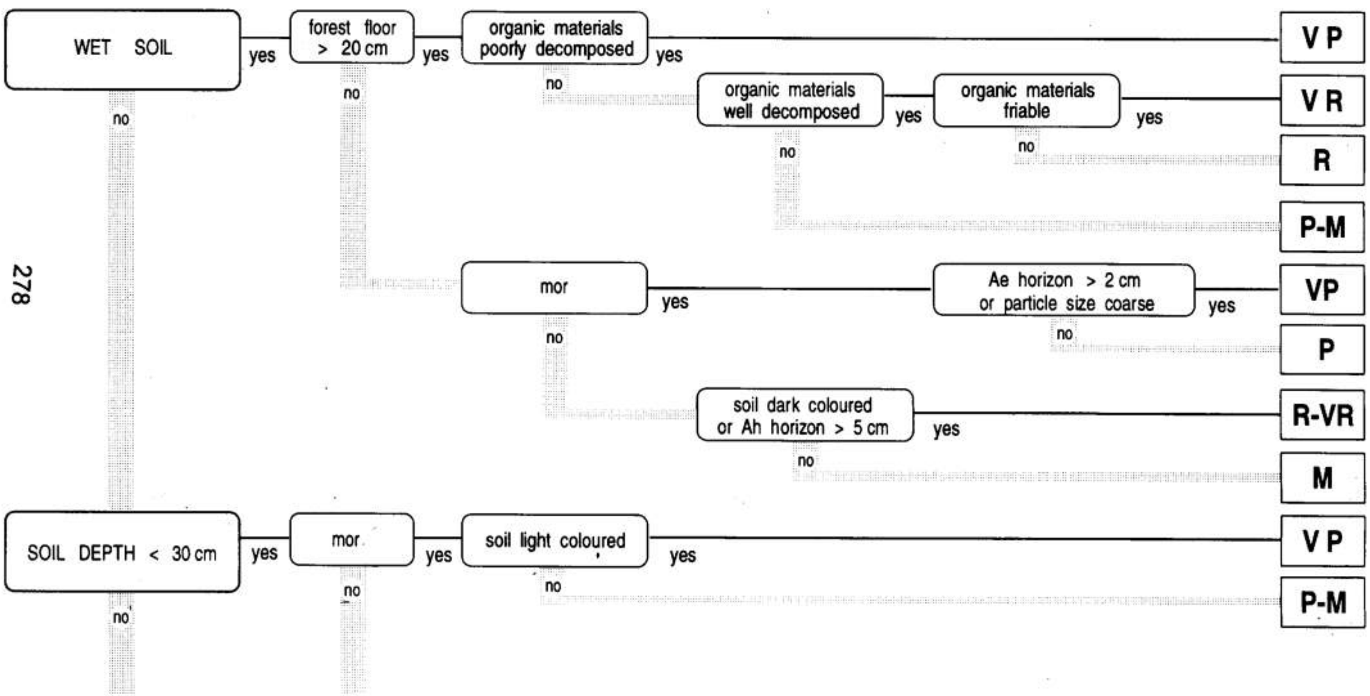


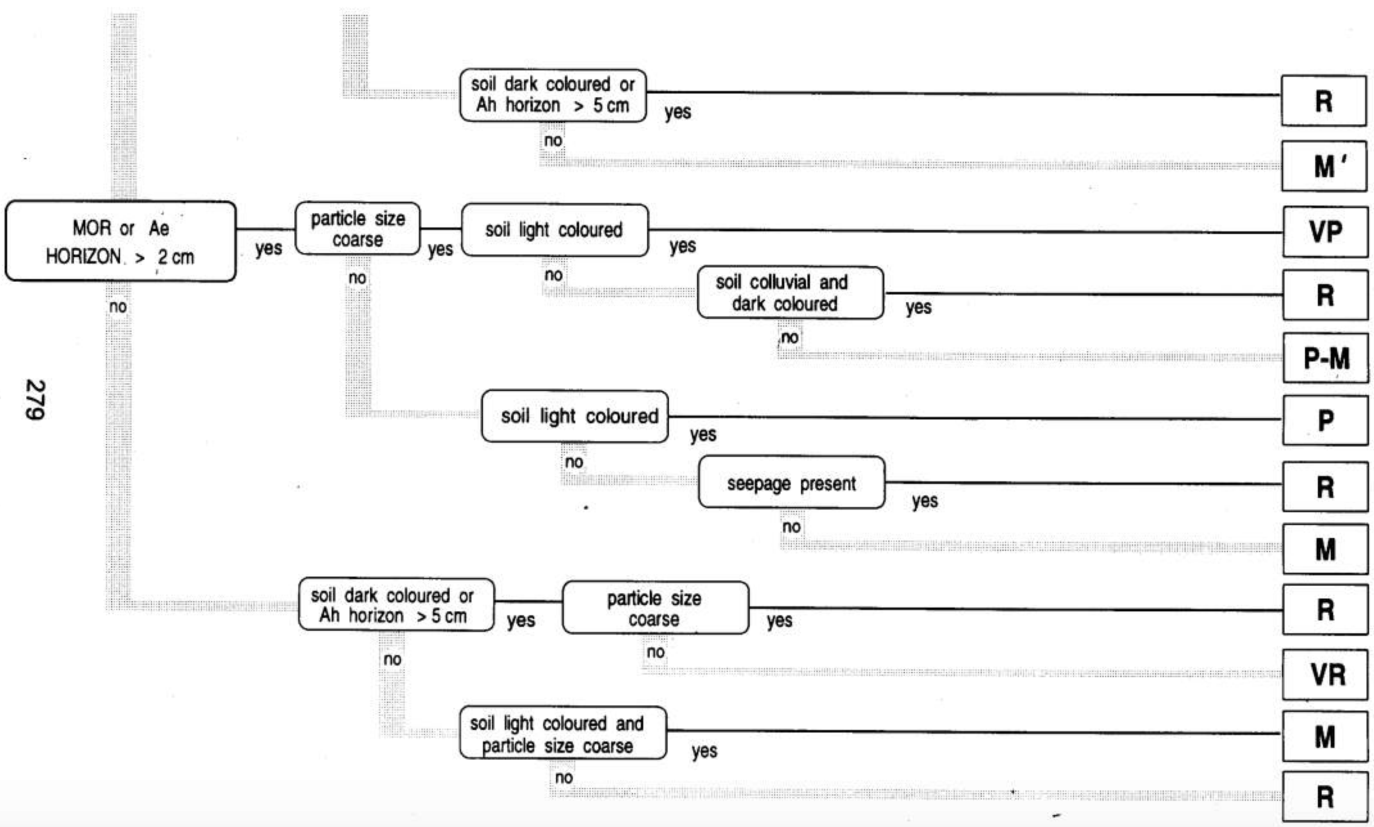
[1] Generally moister if aspect is N or NE

[2] Generally drier if aspect is S or SW

FIGURE 6. A key to the identification of relative soil moisture regimes.

KEY TO SOIL NUTRIENT REGIME





Appendix 3: Deer-resistant plant list compiled by the Canadian Wildlife Federation

Achillea spp.	Yarrow – all kinds
Aconitum napellus	Common monkshood
Actaea rubra	Red baneberry
Agastache foeniculum	Giant hyssop
Alchemilla mollis	Lady's mantle
Alyssum maritimum	Alyssum
Anaphalis margaritacea	Pearly everlasting
Antennaria dioica	Pussy toes
Antennaria pulcherimma	Showy pussy toes
Anthemis tinctoria	Golden marguerite
Antirrhinum majus	Snapdragons
Armeria maritima	Sea or common thrift
Artemisia absinthium	"Lambrook Silver" wormwood
Artemisia schmidtrana	Silver mound
Artemisia stelleranna	Beach wormwood
Aruncus dioicus	Goatsbeard
Astilbe tacquetii superba	Astilbe
Calendula officinalis	Calendula
Caltha palustris	Marsh marigold
Campunula rotundifolia	Harebells
Cerastium tomentosum	Snow-in-summer
Chrysanthemum coccineum	Pyrethrum
Chrysanthemum superbum	Shasta daisy
Corydalis lutea	Yellow corydalis
Dianthus caryophyllaccae deltoides	Pink family
Echinacea spp.	Coneflower
Erigeron philadelphicus	Philadelphia fleabane
Eryngium planum	Sea holly
Euphorbia epithymoides	Cushion spurge
Euphorbia polychroma	Euphorbia
Fragaria virginiana	Wild strawberry
Gaillardia grandiflora	Blanketflower

Galium boreale	Northern bedstraw
Goniolimon tataricum	Tatarian statice
Helichrysum spp.	Everlastings
Hemerocallis spp.	Daylily
Iridaceae spp.	Iris
Lavandula spp.	Lavender
Limonium sinuata	Statice
Lobelia tenuior, erinus	Lobelia
Lychnis coronaria	Rose campion
Lysimachia nummularia	Creeping jenny, moneywort
Matteuccia struthiopteris	Ostrich fern
Monarda didyma	Bee balm
Narcissus spp.	Daffodils
Nasturtium	Nasturtium
Nepeta mussinii	Catmint
Oenothera spp.	Primrose
Paeonia spp.	Peony
Papaver nudicaule	Icelandic poppy
Papaver orientale	Oriental poppy
Papaver spp.	All annual poppies
Perovskia atriplicifollia	Russian sage
Petalostemon candidum	White prairie clover
Petalostemon purpureum	purple prairie clover
Portulaca grandiflora	Portulaca
Potentilla tridentate	Three-toothed cinquefoil
Primula spp.	English primrose
Pulmonaria	Mrs. Moon, Bethlehem sage
Salvia patens	Salvia
Sedum spp.	Stonecrop
Senecio cineraria	Dusty miller
Stachys byzantians	Lamb's ear
Tagetes signata	Marigold gem series
Tanacetum vulgare var.	Crispum Tansy
Thalictium rochebrunianum	Meadowrue

Thermopsis rhombiflora	Golden-bean
Thymus serpyllum	Mother-of-thyme
Veronica spicata	Speedwell
Veronica virginicia	Culver's root

DEER-RESISTANT NATIVE AND ORNAMENTAL GRASSES

Agrostis scabra	Hair grass
Andropogon gerardi	Big bluestem
Bouteloua gracilis	Blue grama grass
Festuca glauca	Blue fescue
Helictotrichon sempervirens	Blue oat grass
Hierochloe odorata	Sweet grass
Koeleria cristata	June grass
Molina caerulea variegata	Moor grass
Schizachyrium scoparium	Little bluestem
Sisyrinchium montanum	Common blue-eyed grass

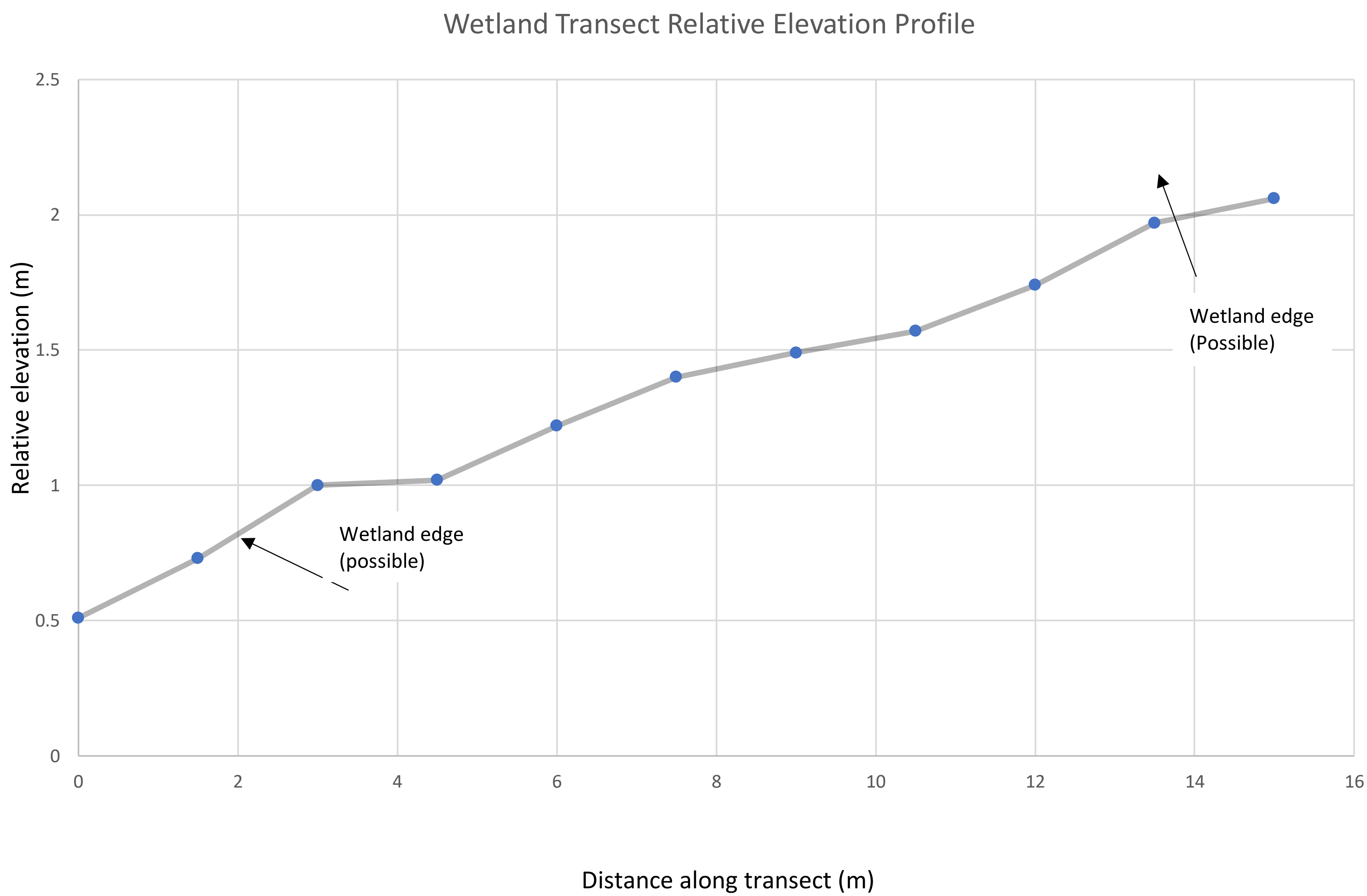
OCCASIONALLY NIBBLED PLANTS

Astilbe tacquetii superba	Astilbe
Aquilegia Canadensis	Common columbine
Caltha palustris	Marsh marigold
Daffodils	Daffodils
Dicentra spp.	Bleeding heart
Echinacea	Coneflower
Eryngium planum	Sea holly
Eupatorium purpureum	Joe Pye weed
Gaillardia grandiflora	Blanket flower
Liatris spicata	Gay feather
Linum perenne	Perennial flax

Lychnis chalcedonia	Maltese cross
Lychnis coronaria oculata	Rose blush
Monarda didyma	Bee balm
Osmorrhiza longistylis	Sweet cicely
Veronica spicata	Speedwell
Viola spp.	Violet

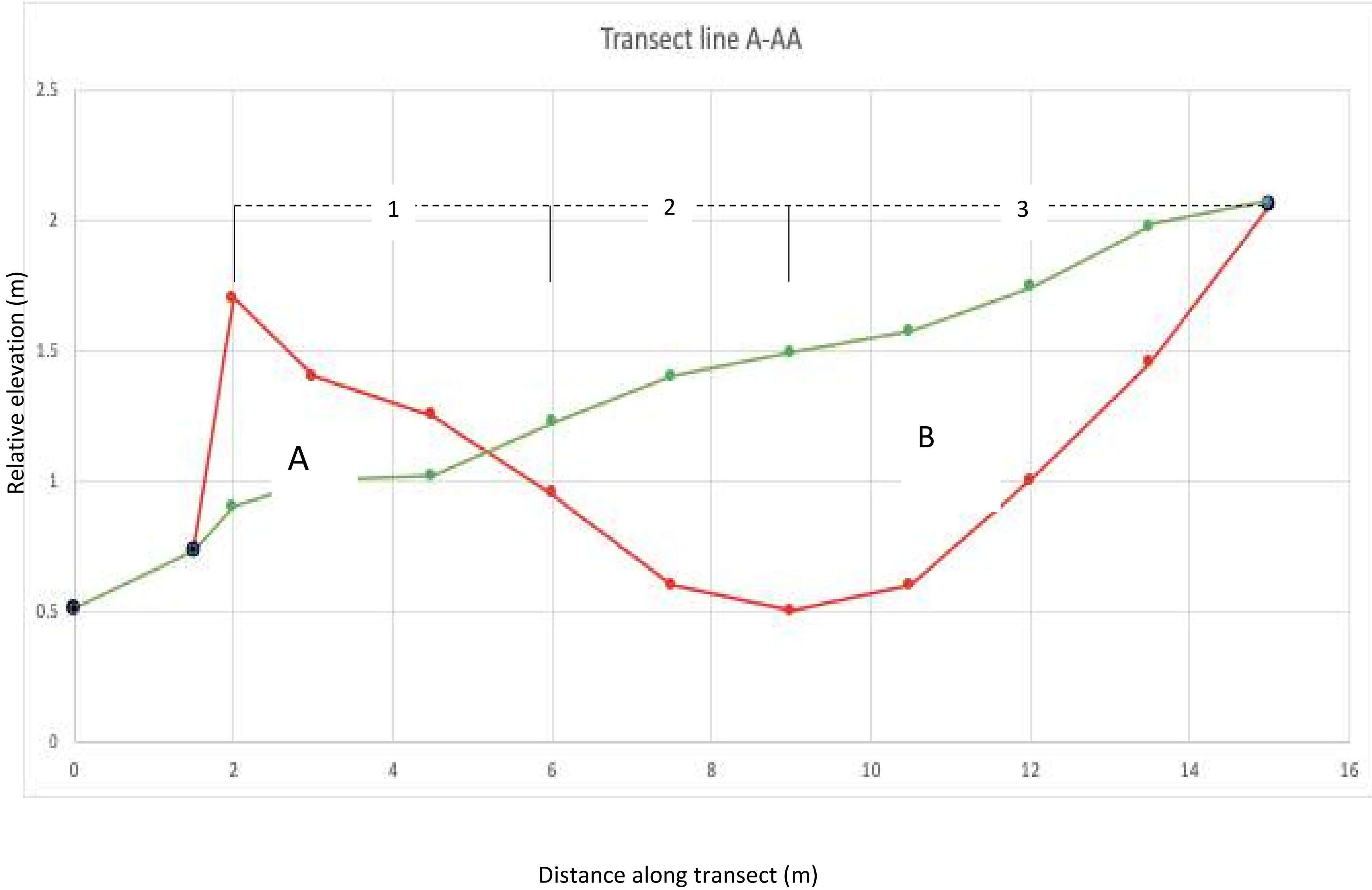
Appendix 4: Location 1 design and work plan.

Graph 1: Current relative elevation profile of transect line A-AA



In the graph below, we see on the left side that there needs to be material deposited to create a “dam” of sorts in order to hold water. It was important to consider the strength and structure of this dam because it is on the road ward side of the wetland, meaning any breaches in this dam would be potentially catastrophic for the road. Calculations were performed to ensure that enough material was going to be excavated to be able to make this dam a reality. The simple calculation was to take the area between each of the curves in graph 3 and compare.

Graph 2: Overlay of current and desired relative elevation profiles along transect line A-AA


Transect line A-AA
Relative elevation (m)
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
14
16
1
2
3
A
B
Distance along transect (m)

Graph 2 characteristics:

- Current profile highlighted in green
- Desired profile highlighted in red
- Black bullets designate common elevation points- points outside of proposed wetland excavation

Raw area A (deposited material) = average difference between corresponding red and green points (m) x linear distance covered (m)

= 0.465m x 4.3m

= **1.99m^2**

Raw area B (excavated material) = average difference between corresponding red and green points (m) x linear distance covered (m)

= 0.804m x 8.7m

= **6.99m^2**

The fact that area B > area A (by more than a factor of 3) means there will be a material surplus created by this aspect of the excavation.

Average grades of the modified profile (red curve in graph 2)

Calculated by taking each section and plugging it into the formula rise (m) / run (m) x 100 to give us a % slope for each section. The (3) sections were decided upon based on the fact that each individual section could feasibly have a homogenous slope (could be easier this way for excavation purposes).

Section 1 = rise (m) / run (m) x 100

= 0.7m / 4m x 100

= **17.5% slope**

Section 2 = rise (m) / run (m) x 100

= 0.3m / 3m x 100

= **10% slope**

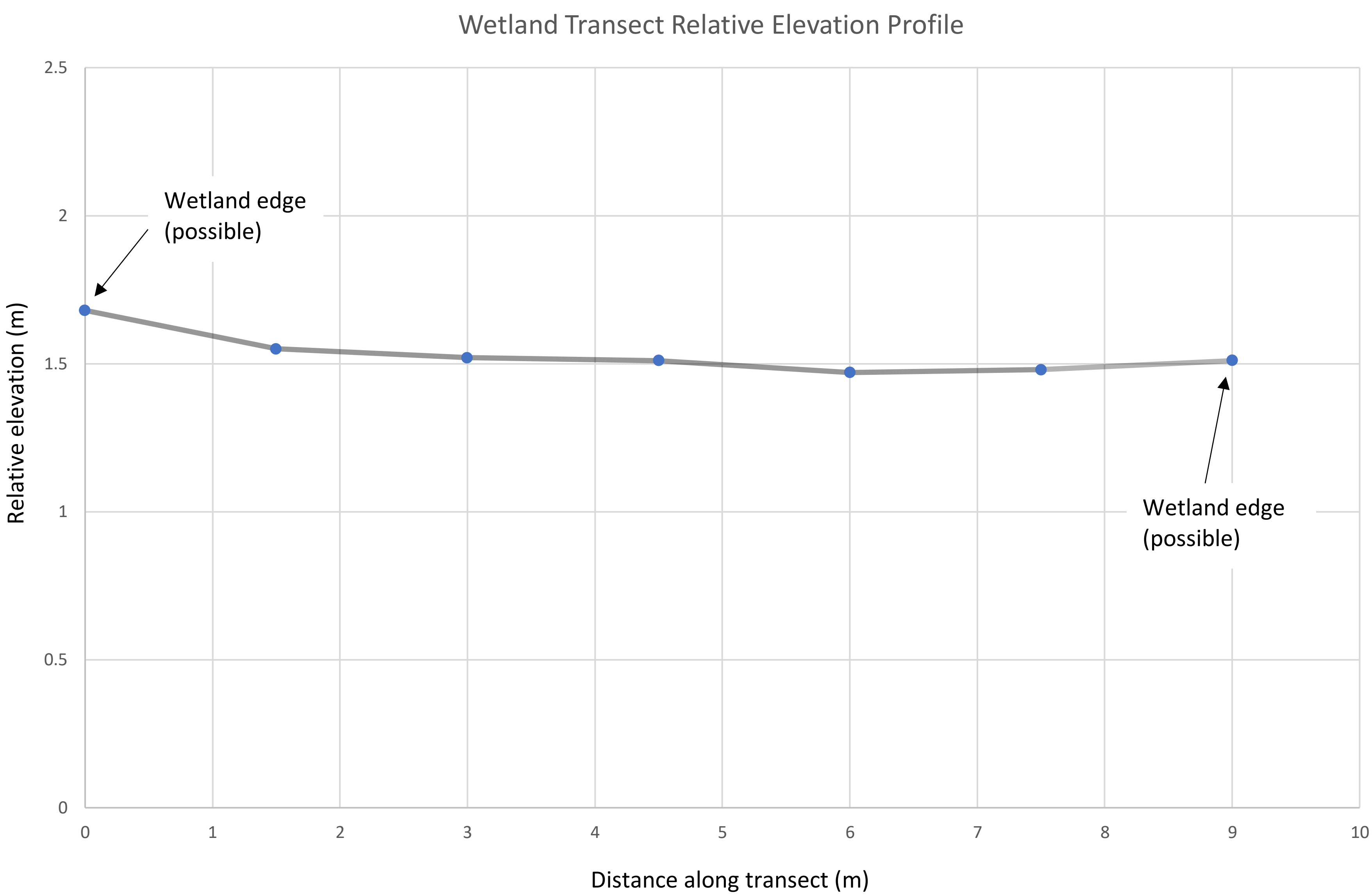
Section 3 = rise (m) / run (m) x 100

= 1.56m / 6m x 100

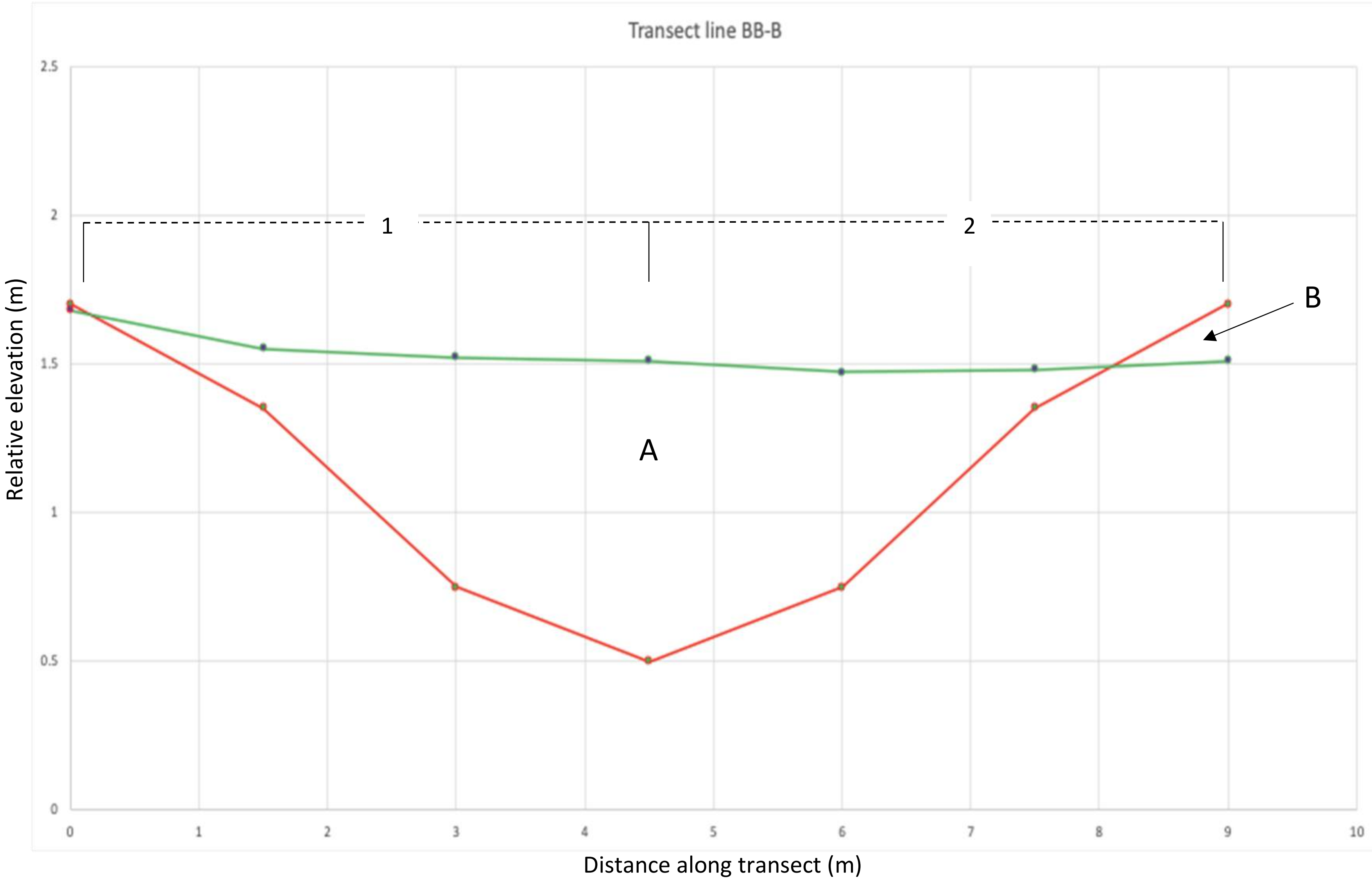
= **26% slope**

With a spillway set at 1.6m, the red curve for excavation would give us an average wetland depth of approximately **0.54m or 21.3in** along this transect with a maximal depth of **1.1m or 43.3in** and a minimal depth of **0.1m or 3.9in.**

Graph 3: Current relative elevation profile of transect line B-BB



Graph 4: Overlay of current and desired relative elevation profiles along transect line B-BB



Graph 4 characteristics

- Current profile highlighted in purple
- Desired profile highlighted in green

Raw area A (excavated material) = average difference between corresponding purple and green points (m) x linear distance covered (m)
= 0.466m x 8.1
= **3.77m²**

Raw area B (deposited material) = average difference between corresponding purple and green points (m) x linear distance covered (m)
= 0.19m x 0.9m
= **0.171m²**

The fact that area B > area A means there will be a material surplus created by this aspect of the excavation.

Average grades of the modified profile (green curve in graph 4)

Calculated by taking each section and plugging it into the formula rise (m) / run (m) x 100 to give us a % slope for each section. The (3) sections were decided upon based on the fact that each individual section could feasibly have a homogenous slope (could be easier this way for excavation purposes).

Section 1 = rise (m) / run (m) x 100
= 1.2m / 4.5m x 100
= **26.7% slope**

Section 2 = same as section one
= **26.7% slope**

We are setting our spillway at 1.6m, therefore the green curve post excavation would give us an average wetland depth of **0.56m or 22.01in** along this transect with a maximal depth of **1.1m or 43.3in** and a minimal depth of **0.25m or 9.8in**.

Characteristics

Depth: At least 2 feet (0.61m) deep in parts because emergent vegetation generally can't handle greater than 12-18 inches (0.3-0.46m) in water depth (DuPoldt et al.). This vegetation is often an aggressive colonizer and will thus take over the whole pond if not for the deeper water sections.

Inflow: the amount of water entering the wetland off of the roof and through direct precipitation. Groundwater seepage is negligible due to the presence of a pond liner, and the area around the pond is generally flat, meaning that surface flow input will also be minimal.

Volume (L) = catchment area (m^2) X rainfall (mm)
Examples for January (used volume calculation software)
Precipitation (L) = pond area (200m^2) X average rainfall (176mm) = 35,200L
Runoff (L) = roof area (138.3m^2) X average rainfall (176mm) = 24,305.6L

Total Input (L) = precipitation (30,600L) + runoff (21,129.3L) = **51,729.3L**

Output: The amount of water lost to factors such as evaporation and infiltration. In our case, infiltration is a negligible number due to the fact that we are employing an impermeable pond liner. Evaporation is going to be out main form of water loss in this wetland.

Stiver and Mackay Evaporation Equation

$$E = \frac{PAW}{T + 459.67}$$

E= evaporation rate (gallons/day)
A= pool surface area (ft^2)
W= wind speed above pool (mph)
P= water's vapor pressure at ambient temperature (mmhg)
T= temperature (^oF)

For January
A= 2152.78 ft^2
W= 8.1 mph
P= 0.8845 mmhg
T= 40.1^oF

E= 30.88 gallons/day = 117.35L/day
January evaporation (L) = 117.35L X 31days = **3637.85L**

Pond capacity: If we give our wetland an average depth of 23 inches (0.58m), then the volume capacity of the pond will be **102,494L** as calculated by volume calculating software (provided by Hydra-Aqua aquatic treatment suppliers). However, if we use the profiles below, we can subtract 4-5 inches from the depth totals to account for the liner that will be installed

DATA TABLES

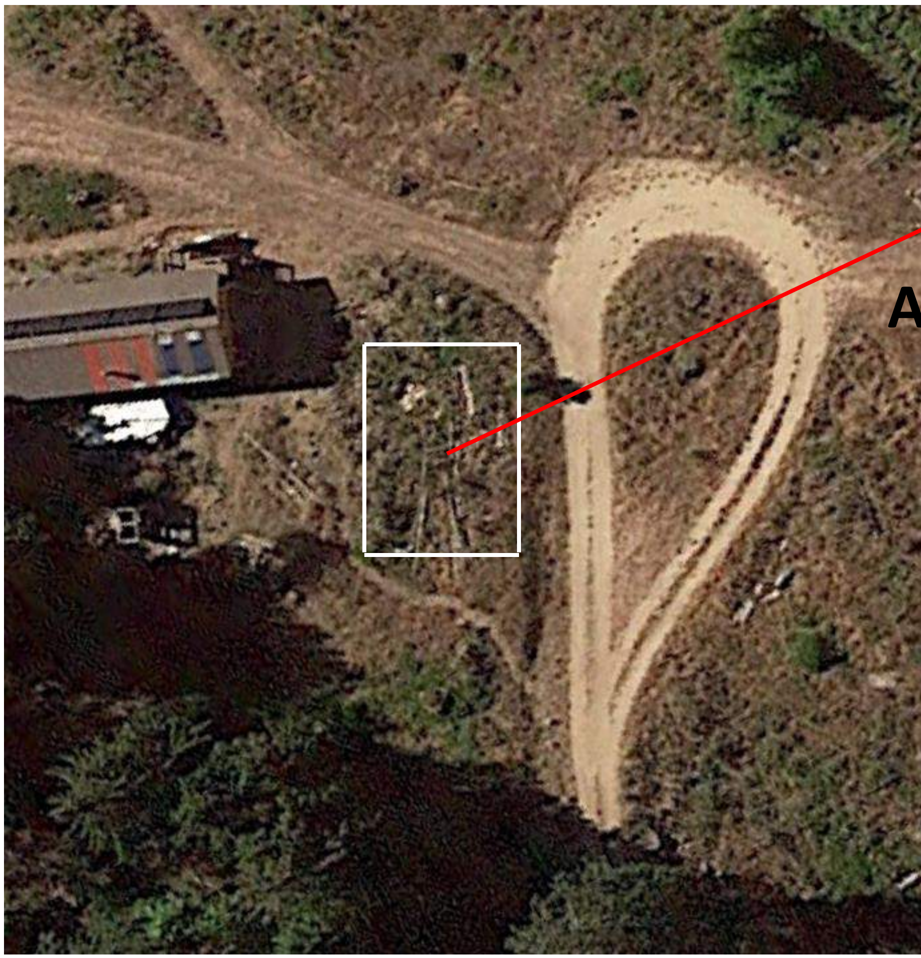
Transect A-AA		
Heading: 93° East	**Point (m)**	**Relative elevation (m)**
	1 (0)	0.51
Cross boundary at 2m	**2 (1.5)**	0.73
	3 (3.0)	1
	4 (4.5)	1.02
	5 (6.0)	1.22
	6 (7.5)	1.4
	7 (9.0)	1.49
	8 (10.5)	1.57
Cross boundary at 13.1m	**9 (12)**	1.74
	10 (13.5)	1.97
	11 (15.0)	2.06

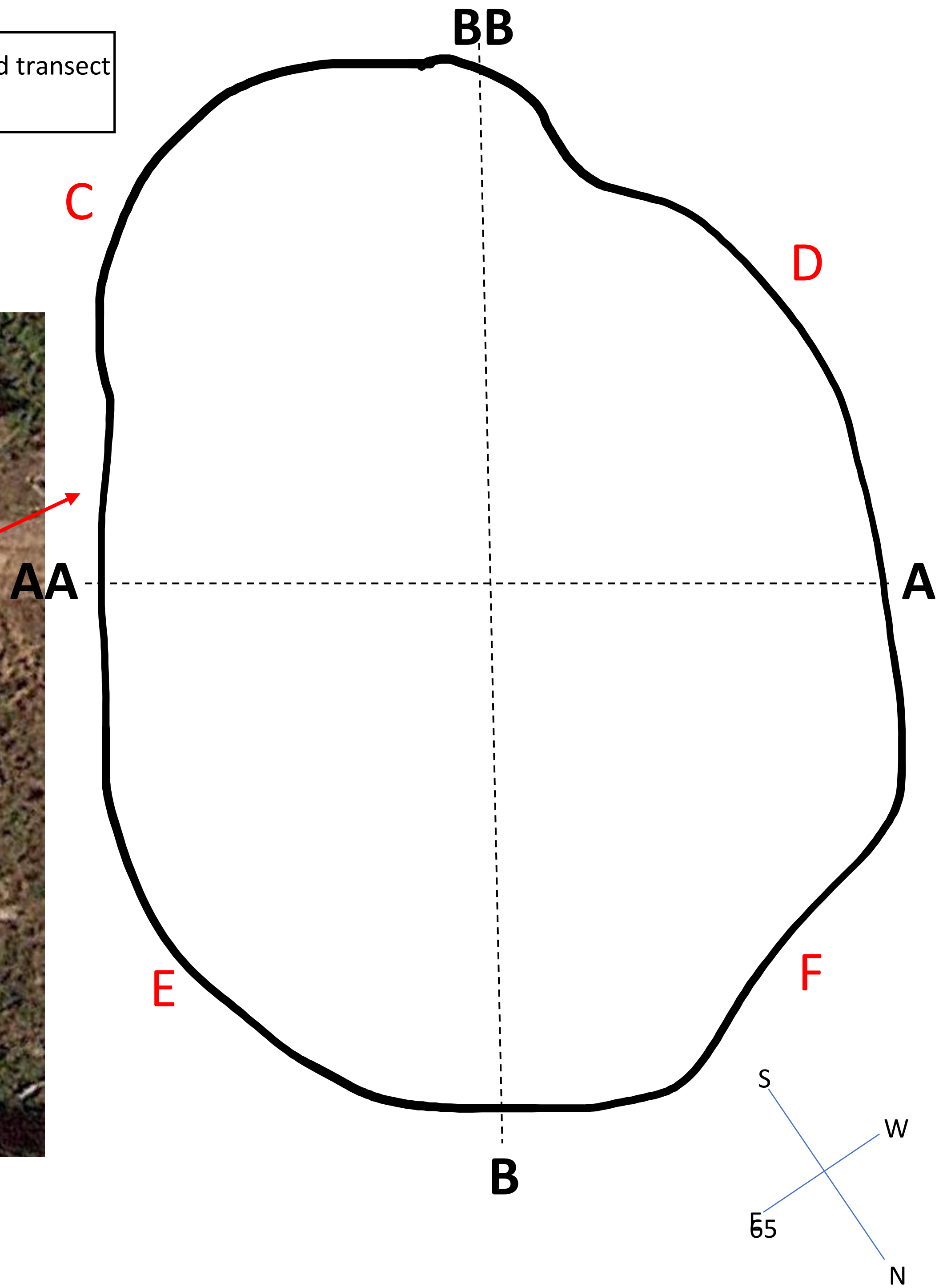
Transect B-BB		
Heading: 190° South	**Point (m)**	**Relative elevation (m)**
	1 (0)	1.68
	2 (1.5)	1.55
	3 (3.0)	1.52
	4 (4.5)	1.51
	5 (6.0)	1.47
	6 (7.5)	1.48
	7 (9.0)	1.51

Table 1: Relative elevations of wetland auxiliary points

Point title	**Current relative elevation (m)**	**Desired relative elevation (m)**	**Elevation difference +/- (m)**
C	1.64m	1.7m	+ 0.06m (negligible)
D	0.92m	1.7m	+0.78m
E	1.38m	1.7m	+0.32m
F	1.75m	1.7m	-0.05m (negligible)

Note: This diagram is for purpose of visual aid only, the shape and transect line positions are not to scale.





WORK PLAN

1. **Move woody debris**
    - There is a bundle of deadfall/slash between the desired wetland location and the road, much of it located in the ditch. It must be removed to allow for excavation and proper berm building. It may be used in some way to delineate future parking spots, and/or returned once the wetland is completed as woody habitat features within/just outside of the wetland
2. **Excavate the wetland**
    - Excavation is then performed to the parameters stated above in the graph of the two transects. For ease of implementation, grades (% slope) have been provided for sections of the excavation that can have homogenous slopes. Ideally, there will be some variety from slope to slope to create emergent sections and habitat features for the future wetland residents.
    - Procedure may go as follows:
        - **a.** Excavate along each individually measured transect and measure relative elevations are consistent with the desired elevation profiles provided above.
        - **b.** Once there is an "X" dug into the ground along these transects, the grades may be married between them to create the pond "bowl" depositing excavated uphill material on the downhill portion of the wetland footprint, creating the desired damming effect.
3. **Install the pond liner**
    - This is where the volunteers really come in. Post excavation the dug-out area must be scoured for wood, rocks, roots, and other natural items that may pose a puncture hazard to the pond liner.
    - A geotextile layer is then installed onto the exposed soil.
    - The impermeable is then installed on top of the first layer of geotextile.
    - A second layer of geotextile is then added on top of the pond liner. The top layer is once again to protect the impermeable layer that will allow us to collect water within the wetland. This gives us three layers of material on our excavated site.
4. **Add a soil layer**
    - A soil layer is added onto the top textile layer – this layer of soil may be about 4-5 inches in depth to allow the rooting and establishment of aquatic and emergent area vegetation.
5. **Habitat features!**
    - Habitat features are then added in the form of woody debris, rocks, stumps, and anything else we can get our hands on that can provide home for little critters and vegetation. The excavator will likely be required to help move the bigger stuff, such as the woody debris we removed from the area in step 1.

6. **Bioswale excavation**
    - The plan is to have a bioswale that connects the terminal end of the rain gutter downspout to the edge of the wetland.
    - This feature is more likely to act as a water conduit rather than a true bioswale, this is due to the slope that it will have. The relative elevation of the downspout outlet is **2.14m**, with the spillway set at **1.6m,** this gives us a vertical drop of **0.54m**. This vertical drop is spread over a linear distance of **7.54m** (the distance between the downspout terminus and the edge of the wetland), giving us a slope of **7.2%**. Generally, bioswales operate at grades of 2-4%, but since we want as much water as possible to enter the wetland, the steeper grade will minimize water infiltration and allow most of the water from the classroom roof to pass into the pond.
7. **PLANT!**
    - Planting plan for area surrounding the wetland as well as the area southwest of the building will be provided closer to implementation date.

OF NOTE

- While it's difficult to know just exactly how much material will be excavated and deposited in the machine-work process. The excavated areas are vastly larger than the areas of deposition. This should allow us to have enough material to build the necessary berms, while likely still having some extra fill leftover. This extra material may be used to help completing the pathway around the classroom, or to help level the marked parking area.
- Before excavation begins, the culverts should also be checked to make sure they aren't clogged or damaged and require repair. There are two culverts relevant to this site. The first connects the spillway ditch to the "traffic circle swale", and the second connects the "traffic circle swale" to the swale within the forage forest. These are both integral to functionality, as the spillway is likely to see some use in the wetter months, and without properly functioning conduit, the road will be susceptible to flooding and erosion damage.