A Riparian Restoration Plan for a Construction Site on the Brunette River

by

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Abstract

Urbanization has altered riparian ecosystems, resulting in the decline of species that depend on them. The Brunette River in the Lower Mainland of British Columbia is no exception; though it currently supports a range of biotas, many of them are at-risk. These impacts are further accentuated by the expansion of the Trans Mountain Pipeline, which will result in the removal of a portion of critical habitat for the endangered Nooksack Dace. In light of the cultural significance of the basin to Kwikwetlem First Nations, the goal of this plan is to improve conditions at the project site post-construction through the establishment of culturally and ecologically important species and the addition of habitat features. I completed soil, vegetation, and water quality surveys to inform my prescriptions. Recommendations include the management of non-native species using manual and mechanical control methods and the planting of a native riparian community that fits within the confines of human infrastructure. A robust monitoring plan is also provided.

Keywords: critical habitat; exotic species; First Nations; restoration; riparian; urbanization

Dedication

I dedicate this work to my family for their ongoing support, as well as the various mentors that have guided me throughout this process and my educational journey in general.

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Glossary

Anthropogenic disturbance	The disruption of the physical, chemical, or biological characteristics of an ecosystem brought about by humans, and often resulting in habitat loss or mortality.
Biodiversity	The variability of all life on Earth measured at distinct levels (e.g. species, genetics, community, habitat).
Exotic/non-native species	An organism that has been introduced to an area in which it did not previously occur, primarily by humans.
Invasive species	An exotic species that can cause extensive ecological and/or economic harm to its new environment.
Native species	An indigenous organism that's presence is the result of natural processes within a given region.
Noxious weed	A highly destructive invasive plant species that is regulated under provincial, municipal, or regional governments (e.g. British Columbia's noxious weed list under the *Weed Control Act*).
Restoration	A form of land management that aims to return a degraded ecosystem to its natural, historical state.
Riparian zone	The interface between land and water on which diverse communities of flora and fauna depend.
Urbanization	The development of cities through the mass congregation of people into relatively small areas.

1.0. Project Context

1.1. Project Rationale

Over the past few decades, scientists have begun to realize the importance of maintaining intact riparian zones – the interface between aquatic and terrestrial habitats – for the services that they provide to streams (Gregory et al. 1991; Richardson et al. 2005). Riparian zones control water temperatures through shading, stabilize streambanks and mediate erosion (Beschta 1997; Gregory et al. 1989), influence hydrology by reducing overland flow through interception and transpiration, and regulate nutrients, sediments, and contaminants (Dosskey et al. 2010; Richardson et al. 2005). Woody material is supplied to streams through the input of large, decay-resistant trees, which influences channel morphology and increases in-stream habitat heterogeneity (Gregory et al. 1991; Richardson et al. 2005). The abundance and composition of vegetation in the riparian zone also has a considerable effect on macroinvertebrate community structure which can then impact stream food web dynamics (Cummins 1974; Cummins et al. 1989).

In addition to their influence on freshwater habitat, riparian areas are shaped by fluvial processes that have resulted in their disproportionately high productivity, habitat complexity, and biodiversity relative to upland habitats (Gregory et al. 1991; Naiman & Decamps 1997; Naiman et al. 2000). Flooding deposits organic matter and nutrients to the riparian zone and plays a part in succession (Gregory et al. 1991). Unfortunately, development has significantly altered stream ecosystems, thereby reducing the influence of riparian zones on the aquatic environment and vice versa (Stevens & Cummins 1999; White & Greer 2006). Among other impacts, the disruption of these processes has undoubtedly contributed to the decline of both freshwater and riparian-associate species in North America (Dudgeon et al. 2006; Poff et al. 2011; Rottenborn 1999).

The Brunette watershed is the most highly developed watershed in the Greater Vancouver Drainage District (Page et al. 1999). Approximately 80% of the basin is covered by urban or industrial lands leaving only 20% as green space (English et al. 2008). Its riparian areas are fragmented with narrow buffer zones, and a study done in 1998 found two to five road crossings for every kilometer of stream (Page et al. 1999). Documented narratives on the Brunette River recount a shift from a waterway so crowded with salmon that "it would have been possible to…walk across the stream without getting one's feet wet", to one so polluted after the 1920s that salmon were no longer able to spawn (Cheung 2019).

Despite past degradation, the Lower Mainland has few fish streams more important than the Brunette (Coast River 1997). It provides habitat to a range of species including Nooksack Dace (*Rhinichthys cataractae* Valenciennes; Endangered), Coho Salmon (*Oncorhynchus kisutch* Walbaum), and Coastal Cutthroat Trout (*Oncorhynchus clarkii* Richardson; Diamond Head Consulting & Raincoast Applied Ecology [DHC & RAE 2015]; Page et al. 1999). The Brunette corridor also provides habitat to a diversity of birds, mammals, amphibians, and reptiles, many of them at-risk such as the Northern Red-legged Frog (*Rana aurora* Baird & Girard; Special Concern) and the Pacific Water Shrew (*Sorex bendirii* Merriam; Endangered; DHC & RAE 2015). The presence of these species reflects the many restoration efforts that have occurred here in recent decades (Cheung 2019); however, continued improvement is still desperately needed, especially if the cultural and ecological integrity of this ecosystem is to be restored in spite of future development and climate change.

1.2 Trans Mountain Development

The Trans Mountain Pipeline Expansion Project (TMX) has proposed works along the northeast side of the Brunette River, from near Fraser Mills, Coquitlam, north to where the pipeline will cross Stoney Creek (Wilderness Committee 2017). Near the confluence of Brunette Avenue and the Trans-Canada Highway, these works will involve the removal of existing riparian area, including approximately 989 m^2 of critical habitat for the endangered Nooksack Dace, to make way for two temporary workspaces for auger bore entry/exit and pipeline tie-ins (Trans Mountain Pipeline ULC [TMP] 2019). Within each of these workspaces, one open cut shored trench will be excavated to facilitate the passing of a trenchless pipeline beneath two tributaries to the Brunette: Keswick Park Creek and an unnamed channel. Since the western workspace is predominantly on an access road owned by the Burlington Northern and Santa Fe Railway (BNSF) and will result in relatively little disturbance to the riparian zone (~19 m^2), the focus of this restoration plan is on the eastern workspace. A map of the proposed restoration area is provided in Section 2.1: Site Location.

Trans Mountain has formally committed to reclaiming the disturbed riparian area within Nooksack Dace critical habitat to *pre-construction conditions* over a 5-year monitoring period (TMP 2019). Although the Brunette River will not be crossed as part of the TMX project, they have stated that they will use the same reclamation criteria as high-functioning sites discussed in their Riparian Habitat Management Plan (National Energy Board [NEB] Condition 71; TMP 2018). Trans Mountain claims that by using this target, reclamation will contribute to high-functioning habitat for fish in the future.

This poses several questions:

1. Will disturbed areas outside of the critical habitat zone be reclaimed to pre-construction conditions?
    a. Evidence shows that buffers greater than 30 m are necessary for full riparian function (Darveau et al. 1995; Lecerf & Richardson 2010; Sweeney & Newbold 2014)
2. Given that the TMX proposed workspace is not currently in a high-functioning state despite past mitigation efforts (e.g. is disturbed, lacks woody vegetation, and has high grass and forb cover; TMX 2019), can it be assumed that planting to a reclamation target suited to high functionality will promote high-functioning habitat for fish in the future? Important considerations include:
    a. Competition from noxious, invasive, and exotic species is high;
    b. The soils are likely more disturbed than high-functioning areas;
    c. In some cases, actions such as soil salvage may not be beneficial;
    d. The riparian area in the 15 m adjacent to the stream is arguably not high-functioning at its current state
3. Provided that planting to a high reclamation target will lead to high-functioning habitat for fish in the future, why do monitoring commitments only support reclamation to current conditions?

To clarify, the use of a high-reclamation criteria (NEB Condition 71; TMP 2018) is not necessarily compatible with a parallel running goal of reclamation to pre-construction conditions, despite intentions of the former. Ambiguity raises the question of which goal the reclamation plan aims to address. In short, this ambiguity is what motivated the work for this project and the need to develop a clear restoration plan for the TMX workspace. The term *restoration* is used to describe this plan in order to differentiate its goals from the goal of reclaiming the site to current conditions. Though this term implies the return of the site to its historical state (Buchanan 1989; Brookes & Shields 1996) which is unlikely given its urban location and extensive history of anthropogenic disturbance (Webb & Erskine 2003), it is the *most applicable* term to describe this project.

1.3. First Nations Interests

Given their deep cultural ties to the Brunette watershed, it is in the interests of Kwikwetlem First Nation (KFN) to, not only reclamate this area to pre-existing conditions, but to *promote future development of* functional habitat for both aquatic and terrestrial species. This report aims to create a riparian restoration plan for the TMX site, including invasive species control measures, the planting of culturally and ecologically important species, and any other restoration goals deemed appropriate for the area. This report also proposes a robust monitoring plan that will aim to ensure that such goals are met. KFN is highly supportive of this initiative, and have been included throughout the process by meetings and correspondence with Dr. Craig Orr, KFN's Environmental Advisor. An in-person meeting was held on 10 January 2020 and all other communications were online (via email or Zoom) or by phone.

2.0. Background Information

2.1. Site Location

The Brunette watershed covers 72.9 km^2 and flows through multiple municipalities in the Lower Mainland of British Columbia (Page et al. 1999; Figure 1). Approximately 76% of the watershed lies within Burnaby, 14% within Vancouver, 8% within Coquitlam, 2% within New Westminster, and 1% within Port Moody (Page et al. 1999). The Brunette River itself is approximately 6.10 km in length (measured using ArcMap 10.8.0 [Environmental Systems Research Institute [ESRI] 2019]), and flows into the Fraser River from Burnaby Lake providing regional connectivity (DHC & RAE 2015; Figure 1). Its northern reaches are in a relatively natural state; however, urban and industrial development increase and associated ecological impacts (e.g. thin and fragmented riparian zones, low in-stream structure, sedimentation, and poor water quality) become more apparent as the river flows south (Gartner Lee Ltd. et al 2001).

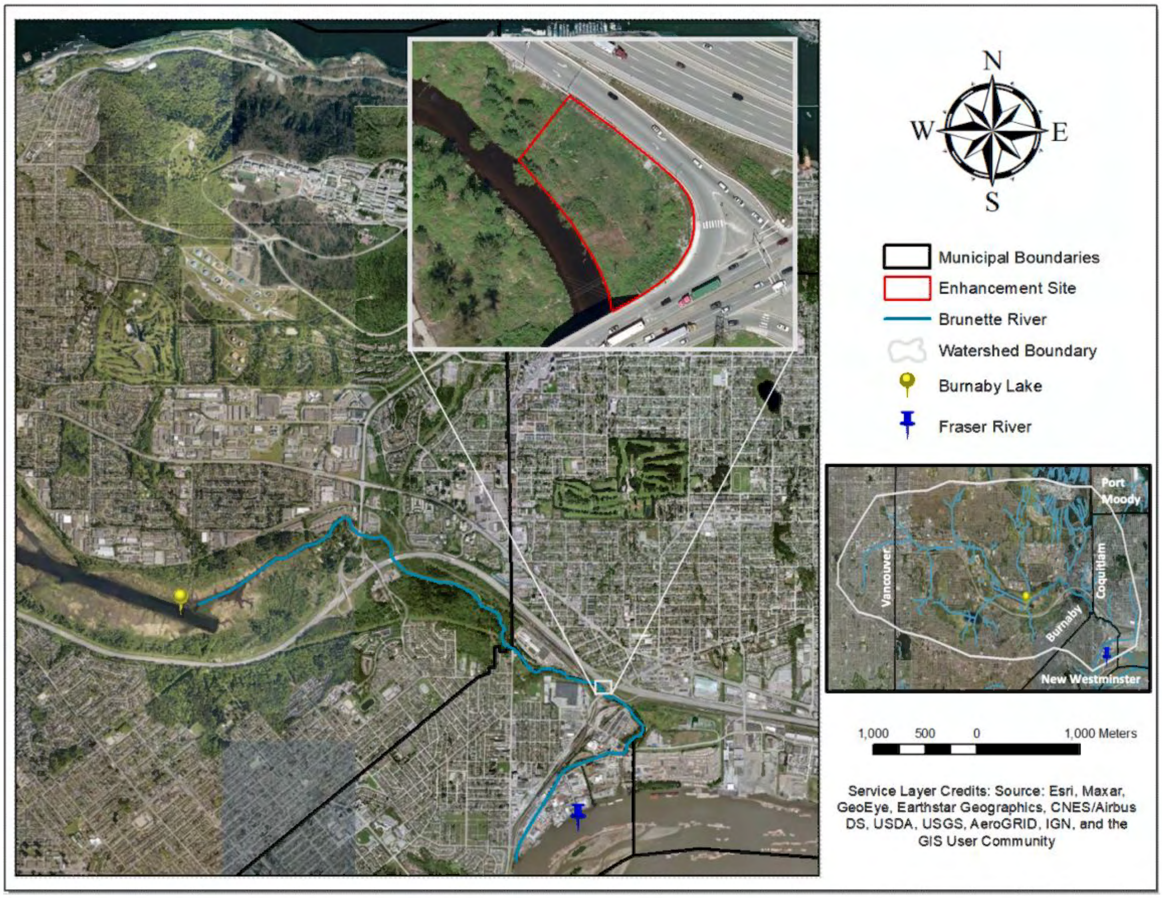

Figure 1. Location of the riparian restoration area in relation to Burnaby Lake and the Fraser River. Right inset map shows the extent of the Brunette watershed within the Lower Mainland, B.C. (ESRI 2019).

The restoration area is located mid-river just south of Hume Park, New Westminster and adjacent to the Brunette Avenue Bridge (Figure 1). It includes ~3400 m^2 of relatively low-functioning habitat. This space is larger than the estimated disturbance zone mentioned previously, as it includes areas that will likely be impacted outside of the 30 m buffer. It also includes areas that may not be directly affected by construction to increase the positive impact of this project by, for instance, targeting invasive species encroachment and edge effects (Guillozet et al. 2014). The site also lies adjacent to the Braid Reach of the Brunette, a section classified as run habitat that connects less altered riffle-glide reaches upstream to disturbed reaches downstream (City of New Westminster 2020; Gartner Lee Ltd. et al. 2001). This area is known to be an important holding site for migrating salmonids (Rudolph 2000, as cited in Gartner Lee Ltd. et al 2001).

Further, the restoration site lies within a right-of-way next to the Trans-Canada Highway and is owned by the British Columbia Ministry of Transportation and Infrastructure (MoTI). The extent of the Brunette watershed over several municipalities and the designation of the Brunette River as critical habitat make for an interesting regulatory environment. A summary of some of the main regulations that might be considered before conducting restoration work within this area is available in Appendix A, Table A1. In addition to compliance, it is important that Best Management Practices (BMPs) are used, as appropriate.

2.2. Pre-development

Prior to European settlement, the Brunette River and surrounding lands were used extensively by the Coast Salish Peoples, namely the Kwikwetlem, Musqueam, Kwantlen, Tsleil-Waututh, and Squamish (Hatfield Consultants 2018; Roy 2007). Their distribution is documented through historical and archaeological evidence including the expanse of campsites throughout the region and petroglyphs that have been found near the Brunette River, Fraser River, Deer Lake, and Burrard Inlet (English et al. 2008; KFN 2014). Archeological sites connected to the Brunette River, though their exact locations are not well understood, are indicative of intensive and culturally important uses (KFN 2014). For instance, known sites have been associated with rock art and/or burial grounds (KFN 2014). Burnaby Lake was also a locale for spirit questing (Burnaby Village Museum 2019).

Hunting, fishing, and gathering occurred throughout the basin, as village members travelled to various resource sites depending on the time of year. The Central Valley area was important for fishing in Burnaby and Deer Lakes, duck, deer, beaver, and elk hunting, and the gathering of crops such as crabapple, cranberries, and cattail (Burnaby Village Museum 2019). The Brunette provided a travel route to the marine resources at Burrard Inlet, as well as Burnaby Mountain which was notable for bear hunting and the collection of medicinal and food plants such as Salmonberry (*Rubus spectabilis* Pursh), Indian Plum (*Oemleria cerasiformis* (Hook. & Arn.) Landon), and Red Elderberry (*Sambucus racemosa* L.; KFN 2014). This journey was especially important in the early spring, as these plants were producing berries on the mountain before anywhere else in the region (Crampton 1980; KFN 2014).

The Brunette River was also a means of travel to reach major fishing camps, markets, and winter villages set up at the junction of the Brunette and Fraser Rivers (Burnaby Village Museum 2019; KFN 2014). Every year, thousands of local Indigenous Peoples travelled here from throughout the Lower Mainland to fish for Eulachon (*Thaleichthys pacificus* Richardson) in the spring, and for Coho, Sockeye (*Oncorhynchus nerka* Walbaum), and Chinook (*Oncorhynchus tshawytscha* Walbaum) in the late summer (Burnaby Village Museum 2019). In the winter, resources were stocked and people would come together in large gatherings to participate in ceremonial events. This information is supported by KFN Traditional Knowledge as a member recalls travelling down the Brunette River in his childhood to exchange goods and participate in activities along the Fraser (KFN 2014).

2.3. Development

Settlers began arriving in the Vancouver area in the 1820s (Page et al. 1999). In the 1850s, there was an influx of prospectors with the start of the Fraser River Gold Rush. By the 1880s, commercial logging practices had stripped the forests (Page et al. 1999) and Still Creek, Burnaby Lake, and the Brunette River became a way to transport wood from Burnaby to the Brunette Sawmills in New Westminster (Green 1952). To make transport easier, in-stream structures such as large wood were removed (Richardson et al. 2012). At the same time, the rivers were straightened and levees were constructed to reduce flooding (Boyle et al. 1997). Villages located at the mouth of the Brunette were established into reserves and subsequently became industrial lands when the building of rail lines and dumping of dredge materials made it unlivable (Burnaby Village Museum 2019).

By the 1900s, forestry, mining, animal, and agricultural products were being processed in mills and shipped out of the region (Molnar et al. 2013). In the case of salmon, several canneries were set up along the banks of the Fraser River. Mass production, deforestation, and increased pollution throughout the area reduced salmon, trout, shellfish, and deer populations, and eventually led to the collapse of both the elk and herring stocks (Burnaby Village Museum 2019; Hatfield Consultants 2018). With commercially important species diminishing, legislation was written to prevent First Nations from harvesting key resources (Burnaby Village Museum 2019). In the 1920s, rapid urbanization resulted in almost the entirety of the Still Creek portion of the watershed being enclosed in storm sewers (McCallum 1995). This mass removal of spawning habitat was accentuated when the meanders were cut off from the Brunette mainstem effectively eliminating available rearing habitat (Department of Fisheries and Oceans Canada [DFO] 2018).

Between 1892 and 1961, Burnaby's population increased from 250 to 100,200 people (City of Burnaby 1987; McCallum 1995). As the region became more populated, urban and agricultural development increased proportionally (Page et al. 1999; Figure 2). With the expansion of road networks came a rapid increase in automobile traffic beginning in 1950 (McCallum 1995). Flood control measures were constructed on the Brunette mainstem around this time including the Caribou Dam in 1935 and later a relief channel directing flood waters into the Fraser River (McCallum 1995). By the mid-1950s, industrial developments destroyed the suitable spawning habitat that was left in Still Creek and the Coho run was eliminated (English et al. 2008). This trend followed into the 1960s and 70s, when salmon populations practically disappeared from the river altogether (McCallum 1995). Approximately 350 Coho returned each year in the early 1980s, but these numbers plummeted more recently to approximately 60 individuals (English et al. 2008).

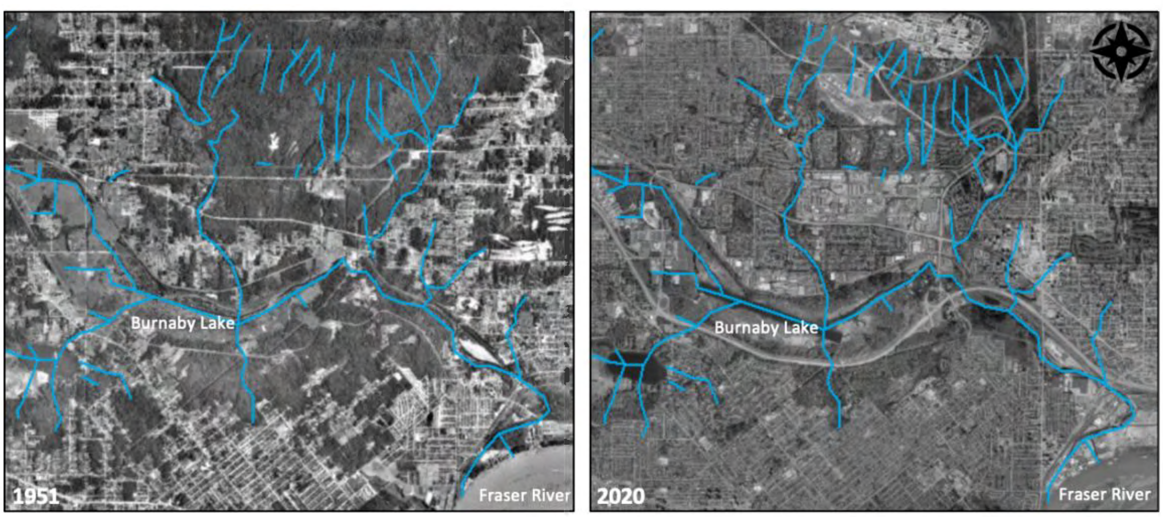

Figure 2. Orthophotos of urbanization in the Brunette watershed. Left photo shows later stages; earlier photos are rare or not publicly available. Blue lines trace the expanse of waterways that drain the basin, including the Brunette River mainstem, Burnaby Lake, and several tributaries. Layer credits: L: Natural Resources Canada; R: ESRI, DigitalGlobe, GeoEve, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, Swisstopo, and the GIS User Community (ESRI 2019).

2.4. Past Restoration Efforts

In more recent years, stakeholders have contributed to the restoration of the Brunette including the Sapperton Fish and Game Club, streamkeeper groups, and all levels of government. In 1992, a fish ladder was installed to permit passage of salmonids into tributaries west of the Cariboo Dam (DFO 1999; English et al. 2008). This ladder was later replaced by an engineered “fishway” in 2011 (Moreau 2011). Since 1997, a hatchery has also been operating with the intent of increasing Brunette River populations (English et al. 2008). Thousands of Coho and Cutthroat fry are released each year, but returns have been low (British Columbia Institute of Technology [BCIT] 2001; English et al. 2008). Other improvements include the addition of large wood complexes, weirs to increase dissolved oxygen (DO), and the creation of off-channel habitat (English et al. 2008). Moreover, a portion of the restoration area shown in Figure 1 had previously been the site of a mitigation project to offset impacts from the construction of the Port Mann Bridge (TMP 2019). This entailed revegetation and the placement of coarse and standing dead wood. Major initiatives are also committed to improving conditions in the Brunette corridor, such as Metro Vancouver’s Ecological Health and Action Plan (Metro Vancouver 2011) and the Experience the Fraser Program (Metro Vancouver et al. 2012).

2.5. Overview of Stressors and Impacts

Despite past restoration efforts, stressors plaguing the Brunette watershed are extensive and persistent (DHC & RAE 2015; Figure 3). Past land use has resulted in reduced cover and connectivity of riparian buffers and increased total impervious area, which has increased overland flow, changed the hydrology of the basin, and reduced habitat heterogeneity both in-stream and on the land (DHC & RAE 2015; Greater Vancouver Regional District [GVRD 2001]; Page et al. 1999). The riparian zones that remain are lacking important wildlife trees found in natural areas, are dominated by non-native, invasive, and noxious species, and likely have contaminated soils (DHC & RAE 2015). In the winter, high flows cause downcutting of the channel, bank instability and erosion, and sedimentation of the bed substrates (GVRD 2001). In the summer, a lack of shading and low flows contribute to high stream temperatures and low DO (GVRD 2001). Deleterious substances also leak into the waterway from both point and non-point sources. For instance, trace metals have entered the water through stormwater run-off, contaminated groundwater, aerial deposition, and industrial spills (DFO 2018).

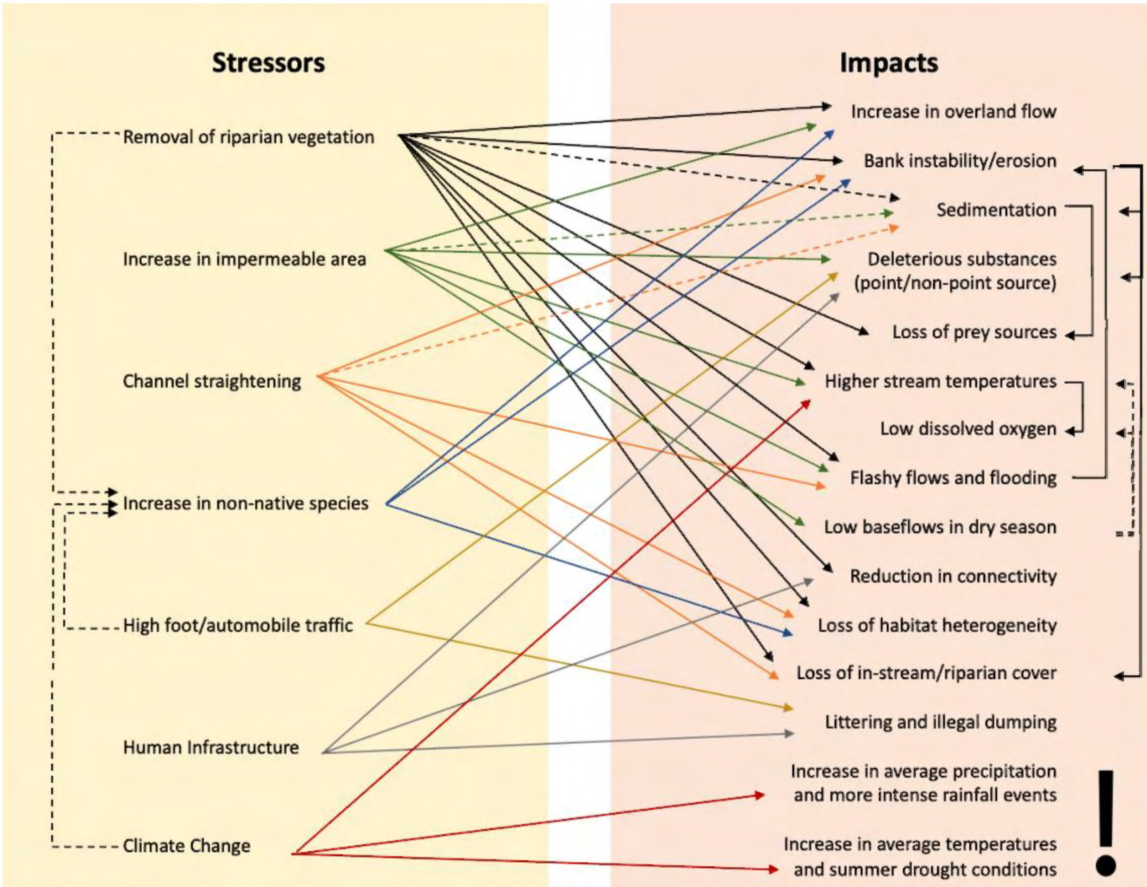

Figure 3. **Direct (solid lines) and indirect (dotted lines) relationships between some common stressors and impacts affecting the Brunette. See Section 8: Future Considerations for more detail on predicted climate change impacts to streams in the Pacific Northwest (PNW).**

These stressors and synergistic and amplifying relationships across them have influenced habitat availability and quality in the Brunette corridor, likely affecting both its species and functional diversity. Nooksack Dace provide a good illustration of such limiting factors, as numbers are very low yet its life history features would promote rapid population growth provided suitable habitat were available (DFO 2018). Pollution and sedimentation are the two highest risks to Nooksack Dace survival in the Brunette River (DFO 2018). Since the restoration site is currently vegetated, riparian planting is not likely to influence water pollution levels; however, there is still the risk of contamination during and after construction caused by potential pipeline failure or sedimentation. Sediment deposition is a major issue as particles can clog riffle habitat on which they depend for spawning, foraging, and resting during high flows (DFO 2018). This infilling of interstitial spaces may result in smothering, increased predation, decreased access to benthic invertebrate food sources, and a loss of overwintering habitat (Champion 2016; DFO 2018). Nooksack Dace are also poorly adapted to low DO levels due to their strong association with riffle habitat (DFO 2018). Hypoxia was identified as a medium risk.

The stressors affecting Nooksack Dace populations in the Brunette have an effect on other species, as well. For instance, it is known that salmonids are intolerant of urbanization-related impacts to freshwater ecosystem function (Page et al. 1999; Figure 3). Similar to Nooksack Dace, they are sensitive to sedimentation due in part to the clogging of gravels necessary for egg incubation (Richardson et al. 2010). Sedimentation may affect Nooksack Dace disproportionately, as they are bottom dwelling species and depend on benthic invertebrates (DFO 2018; Richardson et al. 2010). Conversely, salmonids are largely affected by riparian vegetation removal that can alter terrestrial prey input (Richardson et al. 2010). Prey impacts in both cases are supported by studies showing the considerable effects that development has on macroinvertebrate community structure (Page et al. 1999). Removal of riparian vegetation also reduces in-stream habitat complexity, which disproportionately impacts salmonids (Richardson et al. 2010).

Water temperatures, however, are arguably one of the more concerning issues for salmonids in the Brunette River. Although Nooksack Dace have a slightly higher tolerance to temperature increases, climate change may enhance the effects of low riparian cover to a level that neither salmonids nor Nooksack Dace can tolerate (Richardson et al. 2010). Moderate DO levels are also a worry in combination with warming waters, as increased temperatures can lead to elevated oxygen uptake and the depletion of energy reserves (Eliason & Farrell 2015). Further, temperature increases may influence predation; Largemouth Bass (*Micropterus salmoides* Lacepède) have more recently been documented migrating up the Brunette from the Fraser River causing concern for juvenile Coho survival (English et al. 2008). In fact, warm, turbid waters select for many of the non-native fish species present in the Brunette River (Gartner Lee Ltd. et al. 2001; Appendix E, Table E2).

Given that legislation is often more focused on fish habitat, information on the abundance, distribution, and habitat requirements for other biotas is lacking for the

Lower Mainland (Page et al. 1999). Therefore, it must be assumed that any recovery actions contributing to overall ecosystem health will provide benefits to a variety of species (DFO 2018). Nonetheless, some general understandings are important to note. There is evidence to support that native vegetation harbors greater diversities of breeding bird species (Astley 2010; Catling 2005). Astley (2010) showed that the abundance and richness of breeding birds in the Lower Mainland were higher at natural sites when compared to areas with high Himalayan Blackberry (*Rubus armeniacus* Focke) cover. This could be due in part to reduced habitat heterogeneity, as invasive species often form monocultures (Zheng et al. 2015). One study done on the Colorado River showed that avian abundance and diversity reached a threshold at an intermediate level of non-native *Tamarix* spp., suggesting that increasing native species cover even by small amounts (20-40%) may have a disproportionately positive effect (van Riper et al. 2008). This could be a more feasible outcome in urbanized ecosystems where invasive species are well-established.

Moreover, 89% of amphibian species in the PNW occur in forests and all species are either dependent on or facultatively associated with streams (Jones et al. 2005, as cited in Olson et al. 2007). Elements that have been emphasized as important aspects of amphibian habitat such as canopy cover, structural diversity, and refugia (deMaynadier & Hunter 1995) are likely limited throughout the basin relative to historical conditions. This lack of canopy shading may have a two-fold effect: the water temperature of the stream may get too high for the eggs and larvae of aquatic-breeding amphibians (Stevens et al. 1995) and individuals in the riparian zone may be susceptible to desiccation caused by higher temperatures and reduced humidity (Moore et al. 2005). Fortunately, studies have shown that restoration sites can act as a refuge for forest-specialist species in the short-term and that with succession, improvements in vegetative structure can promote greater amphibian abundance (Diaz-Garcia et al. 2017; Hernandez-Ordonez et al. 2015).

2.6. Surficial Geology and Soils

Sedimentary bedrock throughout the Brunette watershed is covered by thick Quaternary deposits associated with the last glacial recession (Fraser Glaciation, ~10,000 years BP; Church & Ryder 2010; Nistor 2006). The most abundant in the basin is the Vashon-Capilano assemblage consisting of dense glacial till and outwash deposits overlain with fine glaciofluvial, glaciomarine, and beach sediments (Nistor 2006). Other areas consist primarily of Pre-Vashon deposits consolidated by the Fraser Glaciation (Golder Associates 2000). Since glaciation, unconsolidated sediments have also been deposited fluvially throughout both the Brunette and Fraser River floodplains (Golder Associates 2000; Nistor 2006). Therefore, the soils at the site may have originally been classified as Regosols (British Columbia Ministry of Environment [MoE] 1978). It is likely that these soils have been disturbed for quite some time due to their designation as "unclassified urban" in the Canadian Soils Information System (CSIS 2013; Government of British Columbia [Gov BC] 2021).

2.7. Vegetation

Before development, the region was densely covered in forest and only 27% of the trees were less than 120 years old (Boyle et al. 1997). The riparian zones of the Brunette River were likely diverse in microhabitats formed by natural disturbances such as fire, wind, and flooding (Sarr et al. 2005; Steiger et al. 2005). The heterogeneity created (e.g. floodplain benches, islands, and cut-offs) would have supported a variety of flora and fauna (Steiger et al. 2005). Moreover, the site is located within the dry maritime subzone of the Coastal Western Hemlock Biogeoclimatic Zone (CWHdm) meaning that it has a climatic regime of warm summers and rainy, mild winters (Green & Klinka 1994). Mean annual rainfall ranges from 1400 mm to over 1800 mm, approximately 75% of which is received between October and March (GVRD 1998; Nistor 2006). On natural upland sites, species such as Douglas Fir (*Pseudotsuga menziesii* (Mirb.) Franco), Western Hemlock (*Tsuga heterophylla* (Raf.) Sarg.), Western Redcedar (*Thuja plicata* Donn ex D. Don), Red Huckleberry (*Vaccinium parvifolium* Sm.), and Salal (*Gaultheria shallon* Pursh) are dominant (Green & Klinka 1994).

The CWHdm zone is further divided into special sites that describe areas influenced by periodic flooding. High bench floodplains are characterized as the Ss08 – Salmonberry site series, medium bench floodplains by the Act09 – Red-osier Dogwood site series, and low bench floodplains by the Act10 – Willow site series (Green & Klinka 1994). It can then be presumed that before development, the site would have been dominated by species such as Red Alder (*Alnus rubra* Bong.), Bigleaf Maple (*Acer Macrophyllum* Pursh), Black Cottonwood (*Populus trichocarpa* Torr. & A. Gray ex Hook.), Western Redcedar, Common Snowberry (*Symphoricarpos albus* (L.) S.F.

Blake), Red-osier Dogwood (*Cornus stolonifera* Michx.), Red Elderberry, Salmonberry, and willow (*Salix* spp.) depending on flooding frequency.

3.0. Current Site Conditions and Methodology

The restoration area is in close proximity to past major developments such as the Trans-Canada Highway, the BNSF Railway, and Braid SkyTrain Station. Though still impacted by vehicle traffic, the site is somewhat closed off from the surrounding area due to its sloping nature (Figure 4). It is relatively inaccessible to the public, but its urban location allows for some foot traffic around the site and beneath the bridge. Littering and illegal dumping is evident both in the river and at the edges of the restoration area. In the following sub-sections, I provide an overview of the current conditions within the site, as well as the methods used in data collection. Information was recorded for soils, vegetation, riparian and in-stream features, erosion, human infrastructure, water quality, and fauna. This data was then used to identify potential site-level stressors, as well as the appropriate corrective actions that could be undertaken within the scope of this project.

3.1. Management Units

The site was mapped using ArcMap 10.8.0 (ESRI 2019) and a Garmen 64st handheld Global Positioning System (GPS) unit. Polygons were initially drawn around visually similar vegetation and then vegetative communities were verified on site. This information, in combination with soils, local topography, and past land use, was then used to delineate the area into four management units: Roadside Cover, High-slope Blackberry, Snowberry Shrubland, and Remnant Riparian (Figure 4; Table 1). These units serve to differentiate sub-areas in terms of their appropriate management strategies and their restoration prioritization/feasibility.

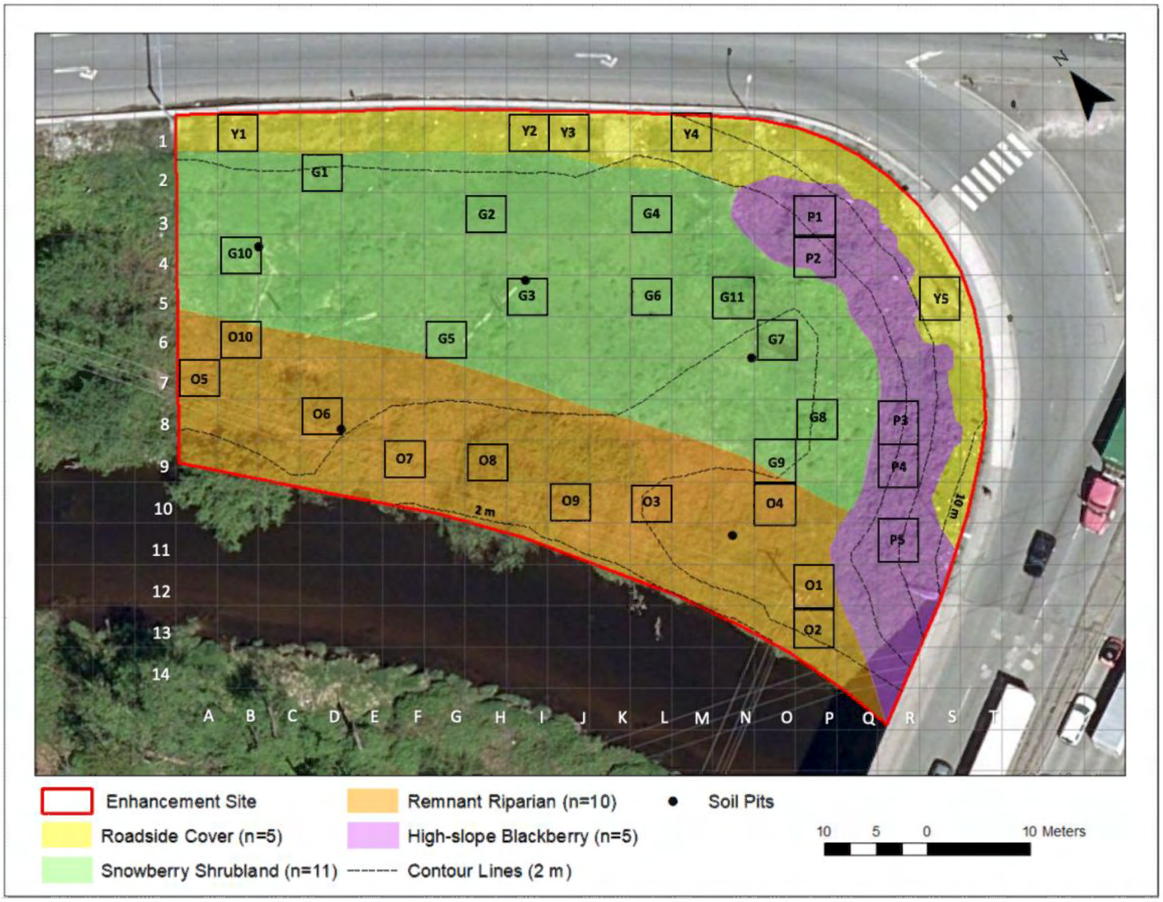

Figure 4. Vegetation sampling for each of the four units delineated within the restoration area. Squares depict 16 m^2 quadrats and labels represent unit color and quadrat number, respectively (ESRI 2019).

3.2. Soil Conditions

Five soil pits were dug on 19 June 2020, 14 July 2020, and 15 July 2020 (Figure 4). Given that the restoration area is a potential archaeological site and includes a section of critical habitat, standard 1 m^3 soil pits were deemed unnecessarily invasive. Therefore, soil pits were a maximum of 50 cm wide by 50 cm deep. To avoid erosion, soil pits were only dug on clear days and on flat, sufficiently covered ground, as per recommendations from DFO (W. Brewis pers. comm., 16 June 2020). In addition to area limitations, soil pit locations were selected based on differences in vegetative communities. A sample was taken from each layer and analyzed for texture, color, structure, coarse fragments, rooting size/depth, pH, nitrogen, and phosphorus. The hand-texturing method was used for determining soil texture. Field soil analyses and descriptions were guided by the Soils Illustrated Field Descriptions Manual (Watson

2014) and the Field Handbook for the Soils of Western Canada (Pennock et al. 2015). Bulk density was not recorded during the sampling period, but if taken, could add valuable information to this project. In particular, bulk density measurements could determine whether site preparation methods should target compaction prior to planting (H. Marcoux pers. comm., 22 January 2021).

Due to the restrictions outlined above, soil data was only obtained from the Snowberry Shrubland and Remnant Riparian units; however, the Roadside Cover and High-slope Blackberry units likely consist of manufactured sandy soils in line with the Standard Specification for Highway Construction (MoTI 2020a; Table 1). Soils in the Snowberry Shrubland unit consist of a topsoil rich in organic matter (based on texture and color data) overlying a loamy sand subsoil. It is likely that these soils were added during past mitigation efforts. The soils in the Remnant Riparian unit are more acidic than the Snowberry Shrubland unit (6.0 to 6.5 compared to 7.0 to 7.5) and have a sandy loam subsoil. Both units have mottling that begins at an average of 30 cm (SE=2.50) and 31 cm (SE=4.32) down, respectively. A sandy clay loam lower layer was also present beneath the upper subsoil in all soil pits. In the Snowberry Shrubland unit this layer was reached at approximately 39 cm (SE=4.32) and in the Remnant Riparian unit this layer was reached at approximately 41 cm (SE=0.50). Soil nitrogen was low throughout all samples. A more detailed summary of soil characteristics for each unit is provided in Table 1. Additional data for each soil pit can be found in Appendix B, Table B1.

Given that the restoration site lies within a heavily industrialized section of the Brunette River corridor, soil contamination (e.g. lead, zinc, cadmium, chromium; Walsh et al. 1998) is expected; however, because the site had previously been part of a mitigation project carried out to offset impacts from the construction of the Port Mann Bridge (TMP 2019), the severity and spread of contamination is uncertain. Further, post-construction soil conditions may not reflect the pre-construction environment, as development within the open trench area will include excavation and backfilling with native soils (TMP 2019). To increase the probability of revegetation success, it is recommended that the soils at the site are sampled to an extent beyond the scope of this report, including bulk density.

Table 1. Summary of baseline conditions for each of the four management units within the restoration area. Table formatting was adapted from Bonetti et al. (2014). See Appendices B and C for more information.

	Roadside Cover*	High-slope Blackberry*	Snowberry Shrubland	Remnant Riparian
Soil Composition	Soils used in road construction restricted to manufactured sandy loams or loamy sands with low organic matter (OM)[1] Loose riprap throughout	Soils likely consist of manufactured sandy loams or loamy sands[1] similar to roadside cover given proximity to roadway	Sandy loam topsoil[7] (24% OM)[6] Well-drained, single-grained loamy sand subsoil[7] Mottles present Lower layer sub-angular blocky sandy clay loam[7]	Sandy loam topsoil[7], lower OM Upper subsoil layer illuviated, though not sufficient for Bf[8] Mottles present Lower layer sub-angular blocky sandy clay loam[7]
Soil Nutrients and pH	Fertilizers used in road construction are season- and application specific, construction guidelines indicate a pH of around 4.5 to 7.0[1]	Likely follows MoTI road construction guidelines[1], though road will not be extended in this area during construction	pH: neutral to mildly alkaline (7.0 to 7.5)[7] Very low soil nitrogen Moderate levels of phosphorus	pH: slightly acidic to medium acidic (6.0 to 6.5)[7] Low to very low soil nitrogen Moderate levels of phosphorus
Topography and Hydrology	Moderate slope[2] (37%) with the exception of crest adjacent to roadway S to SW aspect indicates high afternoon radiation[3]	Moderately steep slope[2] (64%) relative to other units indicating drier conditions[2] SW, W, NW aspect indicates variable afternoon radiation[3]	Mottling at 31 cm (SE=4.32) indicates fluctuating water table[7], sub-hygric to hygric[2,3] Evidence of pooling within NE corner due to adjacent sloping	Plain slope[2] with the exception of streambank area Mottling at 30 cm (SE=2.50) indicates fluctuating water table[7], sub-hygric to hygric[2,3]
Vegetation	Erosion-control crops such as Alfalfa and bentgrass spp.[4] Common Tansy and Himalayan Blackberry present Native cover: 1.12% (SE=0.50) Native diversity: 0.00 (SE=0.00)	Unit largely dominated by Himalayan Blackberry Other notable species include Indian Plum, Vine Maple, and Red-osier Dogwood Native cover: 25.00% (SE=12.40) Native diversity: 0.12 (SE=0.12)	Non-native crops such as vetch, bluegrass spp., and Timothy Native shrubs likely planted Few trees present, conifers seem stunted Native cover: 27.73% (SE=8.73) Native diversity: 0.23 (SE=0.08)	Blackberry abundant, though Giant Horsetail, Pacific Ninebark, and a mix of rose species also established Red Alder present Native cover: 33.50% (SE=7.77) Native diversity: 0.20 (SE=0.09)
Additional Observations	Portion of unit periodically mowed as per MoTI guidelines[5]	Section near Brunette Bridge regularly mowed as per MoTI guidelines[5]	Upper soil layers likely added during past restoration efforts High vetch cover suggests seeding targeted low nitrogen	Unit seemingly less managed than others, perhaps because it lies within the original 15 m riparian buffer
Area (m^2/%)	**440/13**	**430/13**	**1589/43**	**1009/31**

*Soil samples were avoided on slopes to reduce potential for erosion and sediment deposition.
[1]MoTI (2020a); [2]Luttmerding et al. (2010); [3]MoF (1994); [4]Carr (1980); [5]MoTI (2018-2019); [6]UBC Soil Web (nd); [7]Watson (2014); [8]Pennock et al. (2015).

3.3. Vegetation

In mid-July 2020, the understory of each unit was sampled using 31 16 m^2 quadrats placed with an overlying grid labelled with letters and numbers (Figure 4). Grid intersections within each unit were selected randomly and this point became the location of the bottom left corner of the quadrat. Some locations were difficult to access, in which case quadrats were placed as close as possible. In order to accurately estimate presence without reducing efficiency, samples were taken until the number of species detected began to subside. This method is based on the species-accumulation concept whereby species richness is a function of sampling effort (Ugland et al. 2003). Quadrats were set using a horizontal distance correction in sloped areas. Overlapping cover was then estimated for each quadrat and later put into Daubenmire cover categories to reduce observer bias (Daubenmire 1959). This data was then used to calculate the average overlapping percent cover for all species within each unit. Native diversity was also determined using the Simpson Diversity Index (Simpson 1949). Standard Error (SE) is reported for percent cover and diversity estimates, though the patchy distribution of vegetation at the site likely introduced error. In future, rectangular quadrats may be a better option, as they increase precision in aggregated vegetation (Elzinga et al. 1999).

All trees at the site were counted and evaluated for height, diameter at breast height (DBH), growth stage, and condition. Height was determined using the clinometer method (Canadian Institute of Forestry [CIF] nd). Because of accessibility issues, height and DBH measurements were not complete for all individuals. Although an effort was made to locate each tree, Red Alder seedlings within the Remnant Riparian unit may be underrepresented due to the dense understory of the northwest side.

As expected in an urban area, vegetation within the restoration site consists largely of exotic, invasive, or noxious species (Table 1; Appendix C, Tables C1 to C4). The Roadside Cover unit is dominated with non-native cover crops common in British Columbia such as Alfalfa (*Medicago sativa* L.; 30.5%, SE=7.00), bentgrass (*Agrostis* spp.; 9.50%, SE=3.39), and bluegrass (*Poa* sp.; 3.50%, SE=2.92). Common Tansy (*Tanacetum vulgare* L.) and Himalayan Blackberry are also present and are both classified as priority species for regional containment and control given that they have a high potential for spread (British Columbia Inter-Ministry Invasive Species Working Group [IMISWG] 2020). Native species diversity is 0.00 (SE=0.00). This outcome may be due in part to the traditional use of exotic species in highway erosion-control (Invasive Species Council of British Columbia [ISCBC 2020a]; Tinsley et al. 2005).

The High-slope Blackberry unit is dominated by Himalayan Blackberry with 76.0% (SE=5.51) average cover. Reed Canarygrass (*Phalaris arundianacea* L.) is also relatively high, covering 19.5% (SE=4.50) of the area. This unit has some native shrub cover including Red-Osier Dogwood (7.50%, SE=7.50) and Indian Plum (11.0%, SE=7.19), though they are concentrated on the north side of the unit. In addition, Creeping Thistle (*Circium arvense* (L.) Scop.) has an average cover of 6.50% (SE=3.50) and is listed as a provincially noxious weed under the *Weed Control Act* (ISCBC 2020b). Though there are some native species present, native diversity is low (0.12, SE=0.12).

The Snowberry Shrubland unit is dominated by cover crops including bluegrass (12.5%, SE=4.26), bentgrass (6.36%, SE=2.09), Timothy (*Phleum pretense* L.; 7.27%, SE=2.25), and vetch (*Vicia spp*.; 16.6%, SE=3.85). Of all 10 native species detected in this unit, only Common Snowberry (8.86%, SE= 4.49) and Nootka Rose (*Rosa nutkana* Presl; 8.64%, SE=4.36) had a frequency rating greater than “rare” (occasional; see Table C3, Appendix C). Quackgrass (*Elymus repens* (L.) Gould; 8.41%, SE=4.54) is also present, but it is only regulated in the Peace Region (ISCBC 2020b). A single Scotch Broom (*Cytisus scoparius* (L.) Link) plant was initially found in this unit, but may have been removed by MoTI crews during routine maintenance. Native diversity is low in this unit, as well (0.23, SE=0.08).

Despite the high abundance of Himalayan Blackberry (52.3%, SE=7.24) within the Remnant Riparian unit, rose species (*Rosa* spp.) and Pacific Ninebark (*Physocarpus capitatus* (Pursh) Kuntze) have successfully formed thickets with 11.5% (SE=6.84) and 7.50% (SE=5.00) average cover, respectively. Again, native species diversity is low (0.20, SE=0.09). Further, this unit has a large patch of Himalayan Blackberry, Giant Horsetail (*Equisetum telmateia* Ehrh.; 12.0%, 4.77), Hedge Bindweed (*Calystegia sepium* (L.) R. Br.; 8.50%, SE=3.90), and Himalayan Balsam (*Impatiens glandulifera* Royle; 5.00%, SE=2.15) that may have established after works exposed approximately 400 m^2 of bare ground near the Brunette Ave Bridge in 2015 (Google Earth 2019).

Overall, only 19 trees (~58/ha) were counted throughout the entire restoration area (Figure 5; Appendix C, Table C5). The Snowberry Shrubland unit has the highest tree richness (6 species), the majority of which are planted Bigleaf Maple in the sapling-pole stage. The only three conifers counted were Western Redcedar, Scots Pine (*Pinus sylvestris* L.), and Grand Fir (*Abies grandis* (Dougl. ex D. Don) Lindl.). Of the three, the Grand Fir seedling is in the best health, though is still seemingly stunted. The condition of the Bigleaf Maple and Red Alder present can be explained by the persistence of these species on disturbed, nutrient-deficient sites (MacKinnon et al. 2004; Minore et al. 1990).

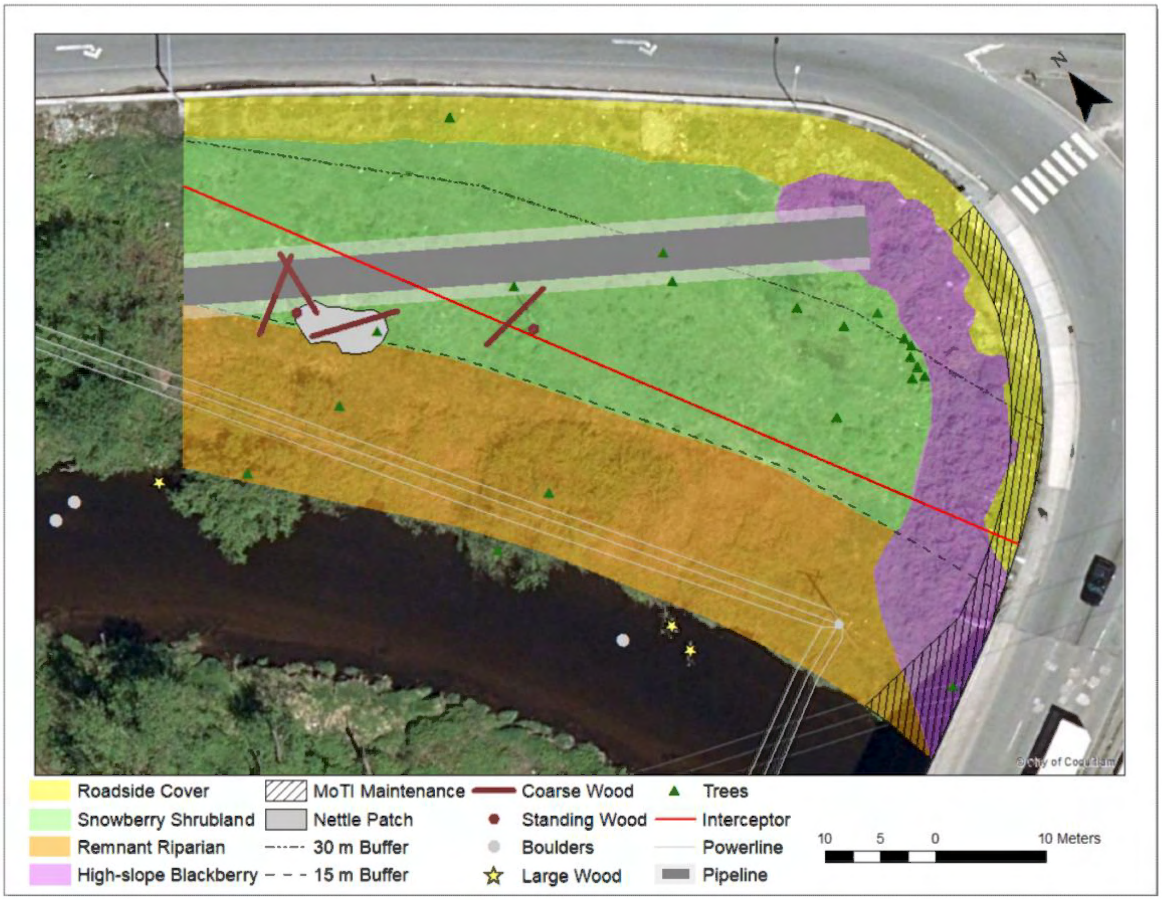

Figure 5. Locations of trees, habitat features, and existing infrastructure within or adjacent to the restoration area (ESRI 2019).

3.4. Riparian and In-stream Features

Riparian stream cover, coarse wood, standing dead wood, and a small patch of Stinging Nettle (*Urtica dioica* L.) that could potentially provide habitat for the endangered Oregon Forestsnail (*Allogona townsendiana* I. Lea) were recorded as riparian habitat features (Figure 5). The coarse wood and standing dead wood added on site are important for a variety of species (South Coast Conservation Program [SCCP] 2015). In fact, the standing dead wood seems to be a favorite perching site for a resident Red-tailed Hawk (*Buteo jamaicensis* Gmelin). Although some riparian stream cover is provided by both native and non-native understory vegetation (Figure 6, Photo 4), the restoration area contributes very little canopy shading to the river, even relative to areas immediately up- and down-stream (Figure 6, Photos 1, 2 & 5). In-stream features include boulders, as well as large wood greater than 30 cm in diameter (Tripp et al. 2017; Figure 5; Figure 6, Photo 6). Boulders in the reach seem to create some cover and deep-water areas. Logs and root wads are secure and functional, though Red Alder does not provide long-term habitat due to its high rate of decay (Bilby et al. 1999).

Figure 6. Photos 1 and 2: Trees downstream of site provide some stream shade. 3: Point source pollution from culvert in adjacent reach. 4: Some cover provided by overhanging vegetation from Remnant Riparian unit. 5: Site contributes little shade to stream. 6: Red Alder root wads in adjacent reach provide short-term habitat complexity. 7: Remnant Riparian unit overgrown by Himalayan Blackberry lacks above- and below-ground structure. 8: Railway bridge upstream is likely a big contributor of non-point source pollution to the river.

3.5. Stream Hydrology and Erosion

Land use in the basin has resulted in 50% total impervious area which contributes to overland run-off and changes to stream hydrology (Page et al. 1999). The river has a mean annual flow of 2.70 m^3/sec, with winter months exhibiting flows as high as two to four times this value (Rood & Hamilton 1994). Conditions in the summer are the opposite, as base flows are only a fraction of the mean. High flows, in combination with unconsolidated deposits, contribute to sediment loads that can reach upwards of 2000-4000 Mg/yr (Nistor 2006).

There is some indication of these large-scale processes at the site-level. Sediment deposition is widespread in sediment bars, gravel substrates, and in pools areas that are embedded with deep accumulations of fine material. The channel is incised and erosion was documented as there is evidence of recent disturbance (e.g. exposed mineral soil; Tripp et al. 2017) along the bank. Furthermore, Himalayan Blackberry, a species abundant within the management area, has been shown to facilitate bank and surface erosion, as it outcompetes deep-rooted native vegetation and creates areas of exposed ground (East Multnomah Soil and Water Conservation District [EMSWCD] nd; ISCBC 2020c; Figure 6: Photo 7).

3.6. Infrastructural Considerations

Current and future infrastructure likely to influence plantings were also taken into account. A 10 m tall distribution line runs directly over the Remnant Riparian unit and will dictate the height allowance of planted vegetation within 10 m (British Columbia Hydro and Power Authority [BC Hydro]; Figure 5). Major underground utilities include the Brunette Interceptor sewage line which runs diagonally across the site (Metro Vancouver 2019; Figure 5). Because the site lies next to the Trans-Canada Highway, a sightline distance of 40 m was also followed for this project (Transportation Association of Canada [TAC] 2011) and the obstruction height within the sightline should be 2 m or less (MoTI 2004). Other considerations include protocols for planting near pipelines, as right-of-way zones must be maintained to ensure easy monitoring and maintenance. For this project, the pipeline easement has been reduced to 6 m (TMP 2018; Figure 5).

3.7. Water Quality

Though there are many accounts of poor water quality in the Brunette (Li et al. 2009; Macdonald et al. 1997; Zandbergen 1998), samples were obtained throughout the field period for two reasons. First, publicly available water quality documentation seemed outdated, and second, it is important that this report document baseline conditions to which monitoring samples during and/or post-construction can be compared. Measurements were taken using a YSI Professional Plus Multiparameter Meter to measure temperature, DO, pH, and conductivity, and a LaMotte 2020wi Turbidimeter to measure turbidity. Sample locations were chosen selectively throughout a ~250 m length to include significant points near bridges, culverts, and tributaries (Figure 6: Photos 3 & 8; Figure 7). Seven samples were collected approximately every two weeks from 30 May 2020 to 24 September 2020, with the exception of 13 June 2020 as COVID-19 concerns put a halt on field work, and 24 September 2020 as a flood event caused unsafe sampling conditions. On the latter date, only one sample was taken from under the Brunette Bridge. Water quality samples from 2016 were obtained via email from the Metro Vancouver Regional District (Metro Vancouver 2016).

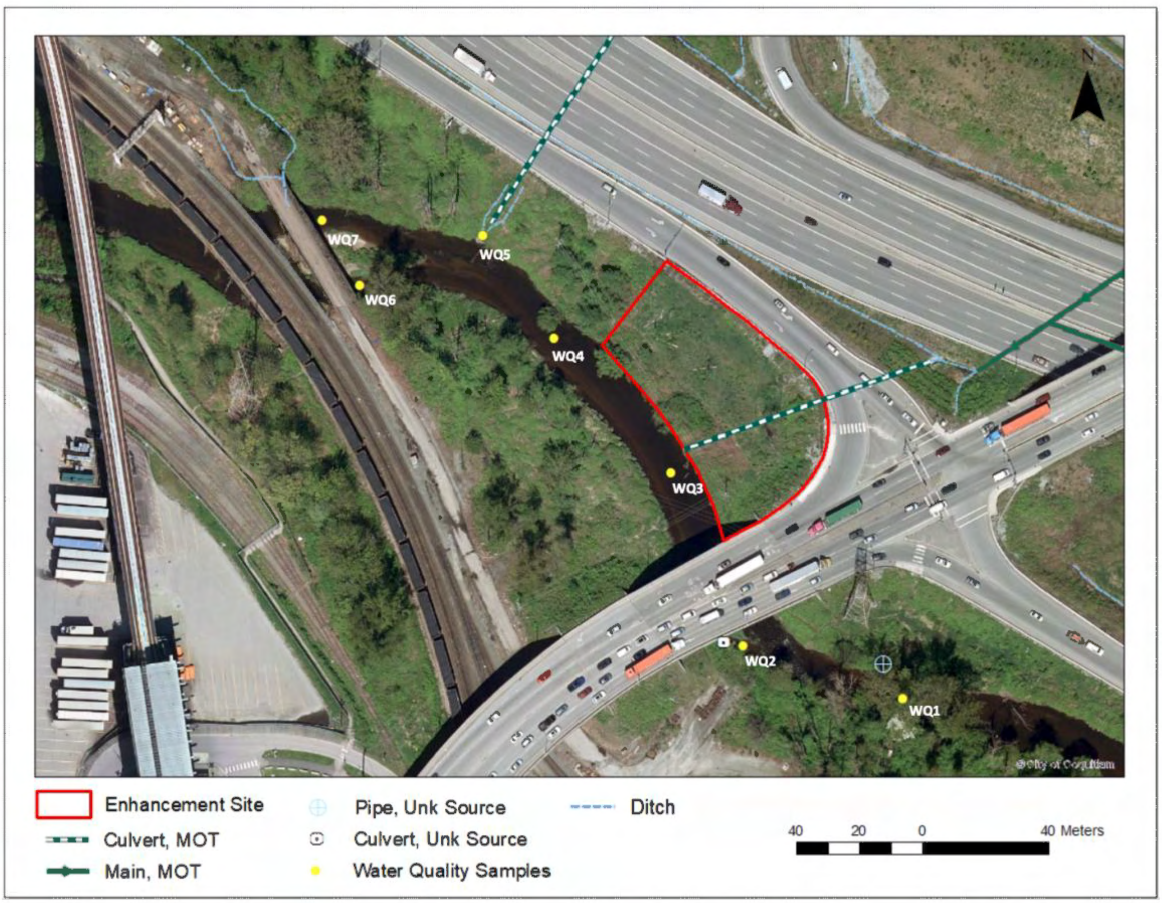

Figure 7. Water quality samples taken adjacent to the restoration site from 30 May 2020 to 24 September 2020. Locations were selected near bridges, culverts, and tributaries (ESRI 2019).

Turbidity samples in 2016 showed an average of 2.38 NTU (SE=0.28) in August, increasing to an average of 6.82 NTU (SE=1.31) from September to December (Table 2). Samples were not taken for January to July. In 2020, turbidity showed an average of 4.13 FNU (SE=0.37) for the entire sampling period (Table 2). One sample taken from beneath the Brunette Avenue Bridge during a storm event did detect a turbidity level of 26.8 FNU (SE=1.13; Appendix D, Table D1); however, based on the British Columbia Approved Water Quality Guidelines, a change in turbidity of greater than 5.00 NTU during high flows is only problematic for aquatic life when background turbidity is greater than 8.00 NTU (British Columbia Ministry of Environment and Climate Change Strategy [MoECCS] 2019a). More samples are needed to detect seasonal variation in turbidity levels and to determine whether turbidity is excessively high during intra-storm periods.

DO averages in 2016 and 2020 were above the 5.00 mg/L minimum instantaneous DO for aquatic life (MoECCS 2019a; Table 2). In 2020, the minimum long-term chronic DO level may not have been met, as samples fell below 8.00 mg/L in May, June, August, and September, contributing to an average of 7.70 mg/L (SE=0.23) for the dry period (Table 2). Monitoring using an average of at least five samples taken over a 30-day period is needed to confirm that this section of the Brunette exhibits chronically low DO (MoECCS 2019a).

Both conductivity and pH were within the acceptable ranges for freshwater ecosystems (MoECCS 2019a). The maximum seasonal average for conductivity in 2020 was 230.53 uS/cm (SE=7.88), though one sample in December 2016 did show conductivity levels reaching 422.00 uS/cm (Table 2). Despite this peak, these values are within the range of 150 to 1500 uS/cm that support mixed fisheries (United States Environmental Protection Agency [EPA] 2012). Average pH fluctuated around 7.00 for all samples taken, which is also within the acceptable range of 6.50 to 9.00 (MoECCS 2019a).

Water temperatures detected during the dry period for both 2016 and 2020 were above the optimal ranges for all life history stages of many salmonid species associated with the Brunette River (See Appendix D, Table D2 for more information on salmonid temperature thresholds). To illustrate this issue, Coho Salmon is a keystone species that's presence has been previously used as an indicator of ecosystem function in the Lower Fraser region (LGL & Musqueum Indian Band 2009). Its preferred rearing range of 11.8 to 14.6°C (Beschta et al. 1987) was surpassed in August 2016 (20.20°C, SE=1.23) and throughout the sampling period in 2020 (17.90°C, SE=0.39). Though British Columbia Water Quality Guidelines show slightly different preference ranges (e.g. Coho rearing is 9.0 to 16.0°C), these temperatures are still exceeded by a minimum of 1.00°C (MoECCS 2019a; Table 2). One sample in 2016 also detected a short-term temperature of 23.5°C, though daily sample size is unknown for this data set (Table 2).

Average nitrate, cadmium, and lead levels remained below the maximum acceptable values for all periods sampled in 2016. Samples for dissolved organic carbon (DOC) are needed to calculate the guideline for copper (MoECCS 2019b), though levels are clearly much higher in the rainy season (Table 2). This is not surprising given that street run-off is the source of approximately half of the copper, zinc, and cadmium found in urban streams (Macdonald et al. 1997). In 2016, average zinc levels exceeded the long-term chronic guideline of 7.5 ug/L throughout the wet period, averaging 17.34 ug/L (SE=4.90). Zinc also surpassed the short-term acute guideline of 33.00 ug/L during one storm event in September (41.50 ug/L). Similarly, iron exceeded the maximum of 1.00 mg/L in August (1.03 mg/L, SE=0.06) and possibly September (1.14 mg/L); however, it is important to note that sample sizes for both zinc and iron are also unknown (Table 2).

Table 2. **Water quality data for the Brunette River taken above the Braid Street Bridge in 2016 (Metro Vancouver 2016) and adjacent to the project site in 2020 (sampling completed by Cassandra Harper). See Appendix D, Table D1 for more detailed information on water quality data from the project site.**

Location and Sampling Date	Turbidity NTU/FNU	DO mg/L	Temp °C	Conductivity uS/cm	pH	Nitrate mg/L	Iron mg/L	Cadmium ug/L	Copper ug/L	Lead mg/L	Zinc ug/L
Braid St.											
08-05-2016	1.89	7.33	18.70	193.00	7.12	0.276	0.98	0.0060	1.72	0.29	17.10
08-12-2016	3.05	8.22	18.00	207.00	7.94	0.289	0.97	0.0110	2.24	0.27	5.40
08-19-2016	2.62	8.10	23.50	207.00	7.24	0.334	0.95	0.0090	1.52	0.36	3.90
08-26-2016	1.96	8.55	20.60	215.00	7.28	0.351	1.22	0.0060	1.48	0.35	3.40
Dry period avg.	**2.38**	**8.05**	**20.20**	**205.50**	**7.40**	**0.313**	**1.03**	**0.0080**	**1.74**	**0.31**	**7.45**
SE	0.28	0.26	1.23	4.57	0.18	0.02	0.06	0.00	0.17	0.02	3.24
09-02-2016	12.10	9.05	15.10	161.00	7.04	0.521	1.14	0.0470	7.94	1.81	41.50
11-09-2016	7.56	10.00	12.30	110.00	7.12	0.631	0.62	0.0130	4.19	0.97	12.40
11-16-2016	3.20	11.20	9.80	129.00	7.11	0.668	0.66	0.0120	4.17	0.81	11.80
11-23-2016	5.91	10.90	8.40	121.00	7.17	0.635	0.76	0.0180	3.79	0.88	10.20
12-02-2016	8.07	11.50	7.00	109.00	7.02	0.655	0.80	0.0185	4.90	1.29	16.35
12-08-2016	4.11	13.00	2.20	422.00	7.30	0.872	0.64	0.0180	3.07	0.79	11.80
Wet period avg.	**6.82**	**10.94**	**9.13**	**175.33**	**7.13**	**0.66**	**0.77**	**0.02**	**4.68**	**1.09**	**17.34**
SE	1.31	0.55	1.82	49.94	0.04	0.05	0.08	0.01	0.70	0.16	4.90
Project Site											
05-30-2020	3.90	7.88	16.83	194.93	7.31						
06-28-2020	4.17	7.75	17.31	209.33	7.14						
07-12-2020	2.74	8.35	16.70	228.89	7.70						
07-27-2020	5.80	8.60	19.51	249.93	7.32						
08-09-2020	3.97	7.10	17.86	245.20	7.26						
08-24-2020	3.32	6.99	18.86	232.41	7.22						
09-06-2020	4.55	7.36	17.93	246.54	7.29						
Dry period avg.	**4.13**	**7.70**	**17.90**	**230.53**	**7.32**						
SE	0.37	0.23	0.39	7.88	0.07						

3.8. Fauna

Species noted during site visits are listed in Appendix E, Table E1. Perhaps of greatest significance is the regular use of the site by the Great Blue Heron (*Ardea herodias fannini* Chapman; Special Concern). Sightings and signs of the North American River Otter (*Lontra canadensis* Schreber) were also frequently noted with a maximum of four individuals having been observed on one visit. Other native faunas detected during the sampling period (30 May 2020 to 24 September 2020) include American Beaver (*Castor canadensis* Kuhl), Muskrat (*Ondatra zibethicus* Linnaeus; if identified correctly), Common Gartersnake (*Thamnophis sirtalis* Linnaeus), and several bird species such as Cedar Waxwing (*Bombycilla cedrorum* Vieillot), Western Wood Peewee (*Contopus sordidulus* P.L. Sclater), and American Goldfinch (*Spinus tristis* Linnaeus).

No rigorous wildlife sampling was conducted at the site level, but the Brunette River is known to harbor a diversity of aquatic and terrestrial species, many of which are at-risk (DHC & RAE 2015). Between 2008 and 2014, there was a cumulative return of 1,433 Coho, 8,520 Chum (*Oncorhynchus keta* Walbaum), and 55 Pink Salmon (*Oncorhynchus gorbuscha* Walbaum; Zoetica 2015). Though still significantly lower than historical numbers, these returns signify a major success in restoration efforts within the Brunette basin. The most widespread salmonids in the watershed are Coho Salmon and Cutthroat Trout (Page et al. 1999). The endangered Nooksack Dace was also detected in the Brunette River in 2018, but only two individuals were captured using 100 Gee traps in catch-per-unit-effort (CPUE) surveys (Snook & Pearson 2019). For a more comprehensive list of species potentially found near the restoration site and a description of their preferred habitat, see Appendix E, Table E2.

3.9. On-site Stressors and Impacts

It is evident that stressors and impacts at the site-level largely coincide with those discussed in Section 2.5: Overview of Stressors and Impacts. Perhaps the main concern within the planting area is the prevalence of noxious, invasive, and exotic species that are likely inhibiting the establishment of native species (Gover & Reese 2017) and colonizing the site from the surrounding region (propagule pressure; Lockwood et al. 2007). Other issues include the potential for soil contamination and a lack of available soil nutrients, particularly nitrogen, which often limits plant productivity (Aerts & Chapin 2000). The presence of mottling indicates a fluctuating water table (Green & Klinka 1994), which may be a concern in terms of planting species that can survive in both wet and dry conditions. Whether or not the current groundwater levels are a natural component of this ecosystem or due to past disturbance, some plantings may show better survival if based on a site series suited to a fluctuating water table such as the Cw13 – Salmonberry designation (Green & Klinka 1994). This is especially true as the river has been cut off from its floodplain and may not be subject to flooding in the usual sense. Dry summer conditions may also be compounded by the sandy soil at the site (lower water holding capacity; Tam et al. 2005), and competition for soil moisture with non-native species (Roberts et al. 2005). Managing non-native species has the potential to improve growth of plantings by increasing soil nutrient and summer moisture availability (Roberts et al. 2005).

As expected, water quality at the site was unfavorable for some parameters tested. Temperatures in the dry period exceeded preferred ranges for many salmonid species found in the Brunette River (Appendix D, Table D2), reiterating the need for improved stream shading that can mitigate the impacts of direct solar radiation on the stream (Beschta 1997). Though turbidity was within recommended guidelines, more samples, particularly during the intra-storm period, are required to confirm this. Though a greater data set is needed, it is important to note that turbidity pulses as low as 20 NTU have been shown in the literature to stress salmonids by, for instance, impacting their feeding ability (Berg 1982; Berg & Northcote 1985). Sedimentation has also been documented as a major problem in the Brunette River, highlighting the need for sediment reductions through riparian planting, bank stabilization, and increasing soil permeability to reduce overland flow (GVRD 2001). Zinc and iron levels were over the recommended values; however, more samples may be necessary to detect spatial and temporal variation. There was also a lack of in-stream structure and riparian features at the site, which, if addressed, could increase immediate habitat value (SCCP 2015; Whiteway et al. 2010).

4.0. Restoration Vision

4.1. Desired Future Conditions

Though restoration generally entails the use of a reference site to set goals and evaluate success (Stoddard et al. 2006), the stressors affecting the area make the use of a reference site impractical. This is unfortunate, as disturbance in the Brunette corridor gradually increases from its northern point to the Fraser River (Gartner Lee Ltd. et al. 2001) creating a gradient of potential reference sites depending on restoration feasibility. For instance, the Brunette Conservation Area may have made a model reference site and nearby Hume Park may have been a more realistic reference site as it is still only moderately impacted. Though neither of these sites will be utilized for monitoring project success, Hume Park will still be useful for identifying potential plantings (see Coulthard & Cummings 2018).

The limitations imposed on this project stem from the location of the site in an urban/industrial transportation corridor. Aronson et al. (2017) argue that propagule pressure is the main contributor to invasions in urban riparian zones. This means that, even if the seed bank is exhausted, the chances of recolonization from the highway and river remain high. This is especially true for Himalayan Blackberry and Reed Canarygrass; though they are listed as priority invasives in this plan, complete control of these species at the site is unlikely (T. Murray pers. comm. 21 December 2020). This is compounded by the widespread use of competitive, non-native species in erosion-control mixes, as they are found throughout the right-of-way (Gover & Reese 2017; Tinsley et al. 2005). In addition, the type, abundance, and location of plantings is largely dependent on above- and below-ground infrastructure. This then limits the ability of plantings to provide functional habitat, particularly to aquatic species. For instance, trees cannot be planted near to the stream and so are unable to provide shade or recruit large wood. In fact, a limited number of trees can be planted in general to maintain highway sightlines and easement distances.

Despite project limitations, conditions within the restoration area provide an opportunity for improvement from its current state. Replacing invasive species with a variety of functional native species, particularly those important to KFN, will increase the ecological and cultural value of the site. Although stream shading and in-stream structure will not be influenced with this particular project due to infrastructural constraints, planting species noted for bank stability and erosion-control may contribute to a reduction in sediment inputs from the management area (Donat 1995; Dorner 2002). Establishing vegetation that is nitrogen-fixing and improves soil structure can promote growth (MoE 2012), and ultimately can aid in filtering pollutants from highway run-off through increased permeability and uptake (MoE 2012; Walsh et al. 1998). Further, planting a diversity of species will create both nesting and perching sites, attract native pollinators, and supply a variety of food types like seeds and berries to birds and other faunas (SCCP 2015). Improving vegetative structure will also create shade which facilitates succession (Koning 1999) and supresses non-native species (cultural control; Oneto nd; see Appendix F). Finally, adding riparian habitat features (i.e. bird boxes, a bat box, and coarse wood) will increase immediate habitat availability while vegetation becomes established (SCCP 2015).

4.2. Restoration Goals and Objectives

The overarching goals for this plan are to improve the ecological function of the restoration area for terrestrial and aquatic biotas and to increase its cultural importance to First Nations, particularly KFN. Table 3 outlines the main objectives associated with these goals and the general actions that are needed to meet each objective. This list is not exhaustive, but is rather meant to establish measurable targets to determine project success. See Section 6.0: Monitoring and Maintenance for more detailed actions that pertain to monitoring and maintenance activities, as well as their proposed seasonal timing, frequency, and pertinent information regarding specific monitoring parameters and methods. Section 7.0: Management and Contingency also outlines situations in which management actions might be altered as monitoring progresses in order to increase the likelihood of meeting proposed restoration targets.

Table 3. Objectives 1 to 4 and corresponding actions for restoration within the project site. See Section 6.0: Monitoring and Maintenance for more details.

Objective 1.	**Reduce abundance of non-native species within the restoration area to promote the establishment of native vegetation**
Actions:	
1.1.	Remove as close to 100% of priority invasive species* as possible using appropriate methods discussed in this report to facilitate planting and reduce competition (Fall 2021)
1.2.	Control priority invasive regrowth*, as necessary (years 1 to 5)
1.3.	Monitor and manage non-native species within immediate planting areas (years 1 to 5)
Objective 2.	**Establish a variety of culturally and ecologically important species within the restoration area through seeding and planting efforts**
Actions:	
2.1.	Seed bare areas using a native seed mix appropriate for the site (Fall 2021). Monitoring must report at least 80% groundcover in year 1, and should be maintained throughout the monitoring period (years 1 to 5)
2.2.	Plant native tree, shrub, and (minimal) herb species (Fall 2021). Success will be determined by a survival rate of at least 80% throughout all monitoring years (years 1 to 5), and a minimum of 50% growth of trees by year 5
2.3.	Wrap bases of high-risk species in aluminum foil and install beaver exclusion fencing around high-risk areas. To be completed immediately after planting (Fall 2021)
2.4.	Monitor overlapping percent cover and native diversity when possible (likely year 5), and extend monitoring to include year 7 and year 10 to more thoroughly document change
Objective 3.	**Manage immediate habitat availability by maintaining and increasing habitat features within the restoration area**
Actions:	
3.1.	Relocate coarse and standing dead wood clusters to an area outside of the pipeline right-of-way. Re-installation should occur prior to planting (Fall 2021)
3.2.	Add at least two pieces of coarse wood greater than 4 m long with a diameter of 30 cm to the Snowberry Shrubland unit prior to planting (Fall 2021)
3.3.	Install at least two bird nesting boxes and one bat box in appropriate areas within the Snowberry Shrubland and/or Remnant Riparian units post-planting (Fall 2021)
Objective 4.	**Foster meaningful relationships with KFN through inclusion of members throughout the restoration process**
Actions:	
4.1.	Employ members of KFN throughout site preparation, replanting and feature installation, and monitoring and maintenance stages of the project (*throughout*)

*This target pertains to all priority invasive species, though Reed Canarygrass may be more difficult to manage as it is interspersed throughout agronomic cover crops on site. The goal for Reed Canarygrass control should be primarily through the creation of shade over time (see Appendix F). This target is also dependent on whether priority invasives can be removed from the streambank in the Remnant Riparian unit (pending consultation).

4.3. Restoration Priorities

Restoration priorities are mainly organized by management unit (Table 4). Restoring the Roadside Cover and Snowberry Shrubland units are considered top priorities, as they are the most directly impacted by construction and require the least effort in terms of invasive species removal prior to replanting. Adding habitat features on site is also prioritized as it is a simple and effective way of increasing habitat value while vegetation establishes. The Remnant Riparian and High-slope Blackberry units are proposed for their potential, though they are considered a lower priority based on their feasibility. Invasive species removal within the 15 m buffer zone may require additional permissions and the involvement of a Qualified Environmental Professional (QEP) depending on proximity to the high-water-mark (see Appendix A, Table A1 for legislation). MoTI would also likely need to be involved in works within the High-slope Blackberry unit. Further consultation is recommended.

Table 4. Restoration priorities within the project site. Units are prioritized mainly by their relation to the pipeline construction footprint and restoration feasibility.

Priority 1	Employ members of KFN to assist in site preparation, replanting and feature installation, and monitoring and maintenance efforts
Priority 2	Improve the Snowberry Shrubland management unit through site preparation, seeding, and planting. Retain current habitat features
Priority 3	Manage invasive species and re-seed impacted areas of the Roadside Cover management unit post-construction
Priority 4	Increase habitat features (i.e. bird boxes, bat box, and coarse wood) within the Snowberry Shrubland and/or Remnant Riparian management units
Priority 5*	Improve the Remnant Riparian management unit by replacing invasive species with bank-stabilizing native species. Low-density priority invasives should be maintained as a higher priority, as access permits
Priority 6*	Improve the High-slope Blackberry management unit by replacing invasive species (particularly Himalayan Blackberry) with slope-stabilizing native shrub species

*If all units are adopted, order of works will need to consider excavator access, as well as seasonal timing (i.e. not conducting works on high slopes during precipitation events).

5.0. Restoration Implementation

5.1. Site Preparation

Though low in nutrients, the soils in the Snowberry Shrubland and Remnant Riparian units both have a topsoil layer and are currently supporting native vegetation. Future sampling may determine that some form of decompaction is necessary after construction. Conversely, the Roadside Cover and High-slope Blackberry units may require the addition of a topsoil before planting. The main strategy for site preparation is to reduce competition with non-native species within the restoration area through the removal of priority invasive species, as well as the management of agronomic grasses in designated planting sites. Suppression of such weeds and grasses is critical to the survival and establishment of plantings (Cramer et al. 2002). Further, it is important that site preparation in riparian zones, especially those that are highly invaded by non-native species, are completed with minimal soil disturbance in mind (Guillozet et al. 2014).

5.1.1. Invasive Species Management

Locations outside of the pipeline trench will require invasive species removal to facilitate planting efforts and reduce competition (Figure 8). Priority species were chosen based on the Provincial Priority Invasive Species list (IMISWG 2020), the Metro Vancouver Invasive Plant Prioritization Rankings (Invasive Species Council of Metro Vancouver [ISCMV] 2020), and consultation with the Invasive Species Council of Metro Vancouver (T. Murray pers. comm., 21 December 2020). Four main categories were considered: manual, mechanical, cultural, and chemical control. If available, Metro Vancouver's BMPs were used to guide management decisions. Approved chemical treatments should only be used when other options have been deemed impractical, ineffective, or counterproductive to restoration goals (MoTI 2020b). Refer to Appendix F for detailed information on each priority invasive species, as well as species-specific management recommendations tailored to the restoration site.

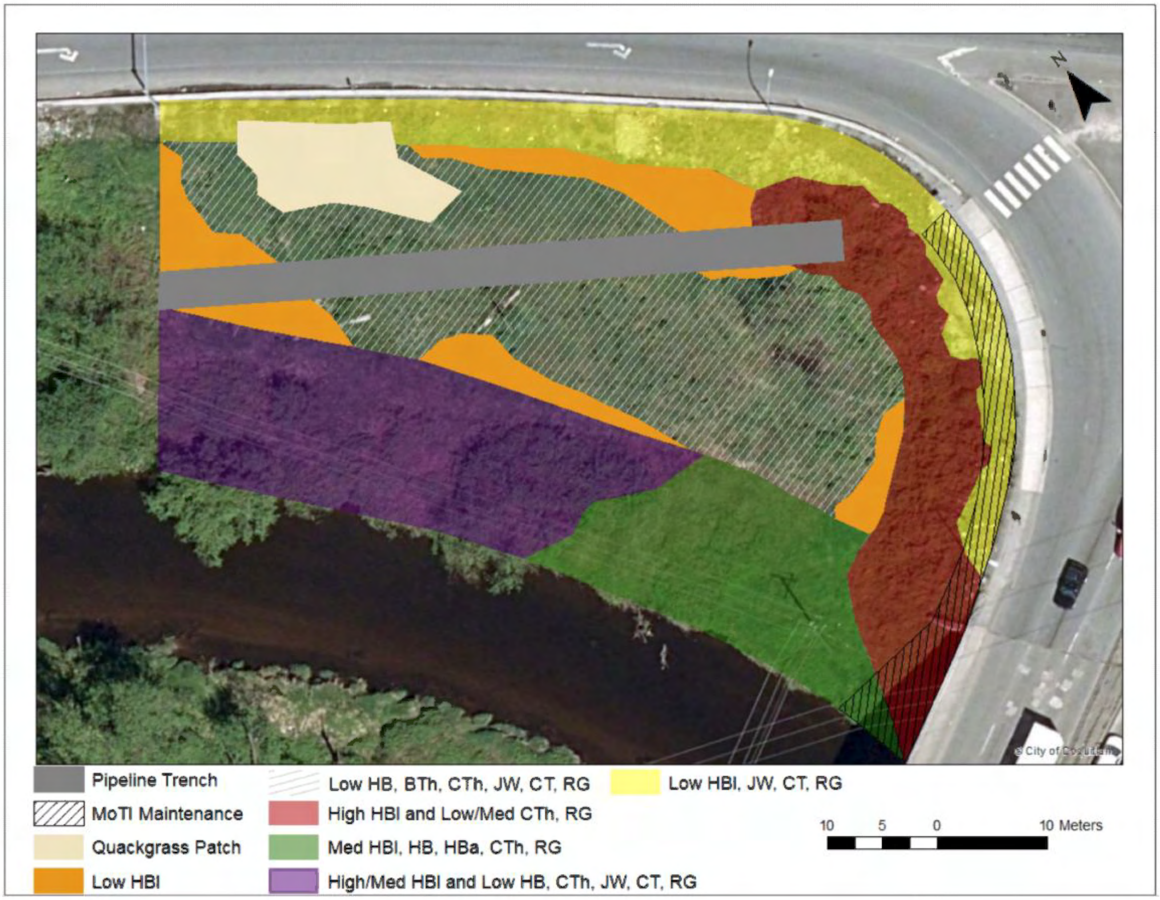

Figure 8. **Distribution of priority invasive species within the restoration area. Sections correspond to management units and thus restoration priorities. Density descriptions (Low, Medium, High) are based on visual estimations and are meant to assist in method selection. Species codes: HBI: Himalayan Blackberry, HB: Hedge Bindweed, BTh: Bull Thistle, CTh: Creeping Thistle, JW: St. John's Wort, CT: Common Tansy, RG: Reed Canarygrass, and HBa: Himalayan Balsam.**

In addition to control on site, preventative measures are critical to containing invasions at municipal, regional, and provincial scales. It is recommended that any work within the restoration area is followed by inspection and cleaning of equipment and vehicles, and that plant waste is carefully bagged and disposed of at the appropriate facility (MoTI 2020b). Some plant parts may be left on site, but this is dependent on species and control timing. For example, Himalayan Blackberry foliage and canes can be used as mulch if cut and fragmented before seeds are produced (ISCMV & Metro Vancouver 2019a). See Appendix F, Table F1 for disposal guidelines of priority invasive species. Control is not necessary within the MoTI maintenance area (Figure 8), as this section is mowed periodically and will not be replanted with native species.

5.1.2. Agronomic Grass Management

Although not considered priority invasive species, agronomic grasses within the Snowberry Shrubland unit can be a threat to plantings for the same reasons that make them valuable in erosion-control mixes: they are competitive and form dense patches (Gover & Reese 2017). Creating and maintaining a weed-free zone around plantings is an effective approach to managing competition and increasing survival (Withrow-Robinson et al. 2011). Methods must also consider potential impacts on temperature, moisture, and nutrient regimes that could affect the growth of plantings. The first applicable method is spot scarification, whereby the top layer of sod, grasses, and forbs are removed around the immediate planting area to a depth of at least 2 to 5 cm (Haase et al. 2014). Recommendations on the extent of scarification vary, though a minimum area of 1 m^2 must be followed (Koning 1999; Withrow-Robinson et al. 2011). Conifer seedling success has been shown to drastically increase with the size of the treatment area (Rose & Rosner 2005). Additional benefits include higher moisture availability, increased soil temperature, and improved root contact with the mineral soil layer (Haase et al. 2014; Prevost 1992). One perceived shortcoming of this method is that humus and associated nutrients are removed from the immediate planting area (Koning 1999). In addition, this method does not seem to have soil aeration benefits and may cause pooling during the rainy season if dug too deep (Prevost 1992).

An alternative method is to use soil inversion in planting areas. In a study comparing survival and height growth of two conifer species using various soil preparation methods, soil inversion with seedlings planted on lower microsites resulted in superior development (Orlander et al. 1998). This method has similar benefits to spot scarification (i.e. mineral soil contact, increased soil temperature, reduced competition), but the inversion process may have additional advantages. For example, ‘flipping’ the soil profile by burying the organic layer beneath the mineral layer can increase nutrient availability and promote root growth through soil loosening (Hallsby 1994; Orlander et al. 1998). One potential drawback of the inversion method is in its careful execution. If the mineral cover is not deep enough, buried herbaceous species may re-sprout, and if seedlings are planted on an elevated surface, plantings run the risk of desiccation during summer drought periods (Orlander et al. 1998). The final method used will likely take into account post-construction site condition (particularly compaction), differences in operating costs, and ease of implementation using the excavator.

5.1.3. Erosion-Control Considerations

During construction, site preparation, and even post-planting, erosion-control measures must be in place to prevent sediment from entering the waterway (Polster 2014). A silt fence is to be installed by Trans Mountain during construction (TMP 2019) and should remain until other methods are in place. The High-slope Blackberry and Remnant Riparian units are arguably the most vulnerable to erosion and instability issues caused by Himalayan Blackberry removal due to their slope and proximity to the high-water-mark, respectively (Bennett 2007). The use of a grapple attachment on the excavator during removal (see Appendix F), followed by hydromulching on slopes should help to reduce these risks (Dorner 2002; Gov BC 1997). In the Remnant Riparian unit, Himalayan Blackberry canes can be used as mulch if cutting occurs before seeds are produced, or a wood mulch can be added (see Section 5.2.3: Mulch, Irrigation, and Fertilizer); however, the removal of vegetation immediately next to the river should be avoided unless bioengineering techniques are applied (Bennett 2007). Given the abundance of invasive species along the banks of the Brunette River, consultation with a QEP may determine that the risks and costs of implementing bioengineering efforts outweigh potential benefits. This is especially true given height restrictions in this area, as willow spp. cannot be used to produce shade or stabilize the bank (see Section 5.3.3: Remnant Riparian Unit). If upon closer examination it is determined that bioengineering (grading etc.) is a feasible option, coir fiber will be installed in the sloping portion of this unit. Otherwise, this unit can be planted up to a point at which the QEP determines is appropriate, and a wood mulch should be suitable.

In addition, temporary grasses are often seeded in erosion-prone areas or areas with high invasive species cover to provide interim protection while plantings establish (Carr 1980; Gov BC 1997; MoE 2012). In this plan, the primary measure recommended for these purposes is mulch and so a temporary cover crop should not be necessary. That being said, if a situation arises that warrants the use of a cover crop, Annual Ryegrass (*Lolium multiflorum* Lam.) should be chosen over Fall Rye (*Secale cereal* L.), as it can establish quickly (Cramer et al. 2002) but does not reseed itself as readily (N. Wall pers. comm 25 February 2021), and thus is not as likely to outcompete plantings and spread to surrounding areas. Trans Mountain recommends a seeding rate of 15 to 45 kg/ha (TMP 2017), likely depending on topography, seeding method, and whether it is being seeded alongside a final mix to help facilitate establishment (Gov BC 1997).

More detail on erosion-control measures for each unit can be found in Section 5.3: Restoration Prescriptions.

5.2. General Planting Considerations

It is essential that planting begin soon after site preparation to avoid erosion and recolonization of the area by invasive species (ISCMV & Metro Vancouver 2019a). This step can occur in the fall after the last drought period (September to October) or in the spring (March to April; H. Marcoux pers. comm., 22 January 2021; MoA 2012a). Protocols relating to such things as timing, storage, handling, transportation, and bed preparation must follow general provincial guidelines such as those outlined in the Standard Specifications for Highway Construction (2020b). Detailed instructions for installing various plant stock within riparian areas, as well as other specifications (e.g. installing erosion-control matting) can be found in Cramer et al. (2002). It is also important to note that plant materials must conform to the British Columbia Landscape and Nursery Association Standards (SCCP 2015). Following such protocols is crucial to the survival of plantings and thus project success (British Columbia Ministry of Forests and Range [MoFR] 1999).

5.2.1. Species Selection

Species considered for planting were based on 10 main criteria: biogeoclimatic (BEC) classification, presence at the site and Hume Park (Coulthard & Cummings 2018), Indigenous value, ecological function, height, moisture and shade requirements, whether they are "Bear Smart Plantings" (City of Coquitlam 2020), and whether they are "Restoration Superstars" (Sound Native Plants 2021b). Because the goal of this project is to increase ecologically and culturally important species and that DFO recommends planting at least 50% fruit-bearing species in riparian zones (MoE 2008), some species chosen are fruit-bearing. These species may not be considered "Bear Smart Plantings". That being said, the location of the site directly across from municipalities that do not have such landscaping recommendations, as well as the considerable distance of the site from high-activity bear areas (see Appendix G, Figure G1) arguably reduces the influence that plantings would have on bear presence. Further, species important to KFN were based on their inclusion in the Riverview Indigenous Garden (PGL 2018). See

Appendix H, Table H1 for a list of species considered, as well as some of the features that aided in decision-making. Other important characteristics analyzed include: soil texture and nutrient requirements, drought and flood-tolerance, damaging agents, and competitive ability.

The focus of planting was on native shrubs and trees, as woody species are generally prioritized for establishing conditions similar to natural areas (Bulmer 1998). Herbaceous groundcovers are often omitted from early-stage restoration projects as they have low competitive ability and high maintenance requirements (Guillozet et al. 2014; Page 2006). They also often need rich, mature soils (Sound Native Plants 2020b). That being said, certain well-establishing species were included in this plan as they may be successful in select areas. Finally, a variety of species were chosen to provide "insurance" in terms of planting survival and stability (British Columbia Ministry of Agriculture [MoA] 2012b; Withrow-Robinson et al. 2011). Appendix H, Table H1 can also be used to identify additional riparian species if others are unavailable at local nurseries or for alternative management and contingency purposes.

5.2.2. Planting Densities and Stock Sizing

In areas where invasive species are a concern, planting density and stock sizing should focus primarily on increasing competitive potential (Guillozet et al. 2014; Page 2006; Raine & Gardiner 1995, as cited in Webb & Erskine 2003). In general, 1- or 2-gallon container stock is sufficient for shrubs (SCCP 2015), and trees should have a height of at least 1.2 m (MoE 2008). Larger stock sizes may compete better with non-native species (Cowlitz Conservation District [CCD] nd); however, they can also have lower survival due to a poor root-to-shoot ratio (SCCP 2015). Shrubs should be separated by 1 to 2 m on center in riparian areas (SCCP 2015), though they can be planted as close as 25 to 50 cm if factoring in mortality (MoE 2012). Planting at 60 cm to 1 m is a good range for most shrub species (Kipp & Calloway 2002, as cited in MoE 2012). Further, live stakes planted approximately 60 cm apart (Sound Native Plants nd) are an excellent choice for erosion-control and bank stabilization (Cramer et al, 2002; Sound Native Plants 2021c). Ferns can be in 1-gallon pots planted 1 m apart (Sound Native Plants nd). Final sizes may depend on stock availability.

It is recommended that trees be spaced 1.5 to 2 m apart in riparian areas (MoE 2008), though spacing is dependent on several factors including project goals and size at maturity (Withrow-Robinson et al. 2011). Planting in high densities has been shown to protect seedlings from non-native species, animal damage, and wind, promote the development of mycorrhizae, and create quick canopy shade (North et al. 2019; Upton & DeGroot 2008). Spacing them further, however, reduces competitive effects within species and may promote growth (North et al. 2019; Withrow-Robinson et al. 2011). Same-species cluster planting is a beneficial strategy because it allows species to be planted near enough to account for losses without concern for differing growth rates and inter-species competition. Clusters are also easier to maintain and look more natural in the landscape than grid patterns (Bennett & Ahrens 2007; MoE 2012; Poulin 2006).

5.2.3. Mulch, Irrigation, and Fertilizer

Mulches can improve soil moisture, reduce compaction and erosion, maintain soil temperatures, increase soil nutrients, bind heavy metals, reduce competition from surrounding vegetation, and overall improve plant survival (Chalker-Scott 2007). Where possible, using mulch is most often a better choice than cover crops as it does not promote competition with plantings. Coarse, organic mulches are particularly good at holding water, significantly reducing the need for irrigation during droughts (Chalker-Scott 2007). It is recommended that a coarse wood chip mulch be used wherever possible for this project because they provide all of the functions outlined above and decompose slowly, reducing the need for reapplication (Bulmer 1998; Chalker-Scott 2007). Coarse wood chip mulch should be used around all applicable plantings to a depth of 5 to 10 cm for best results (McDonald et al. 2011). Make sure to leave 2.5 cm from the stem mulch-free (MoE 2012). A coarse wood chip mulch may not suffice in areas nearer the streambank and on higher slopes. In these cases, alternative mulches can be used such as coir fiber matting (Cramer et al. 2002) or a thin hydromulch (Bulmer 1998). These products are discussed in more detail in their respective unit prescriptions (Section 5.3: Restoration Prescriptions).

The survival of plantings is largely dependent on sufficient water availability (MoE 2012). This is especially true in more upland areas, sandy soils, and for species that are adapted to wet conditions such as Red Alder (Bennett & Ahrens 2007). Supplemental watering helps to increase the firmness of soil around roots and reduces transplant shock (MoE 2012). At minimum, plantings should be watered in the first year following installation (Kipp & Calloway 2002, as cited in MoE 2012). Oftentimes, watering occurs in the first two years and if growth is sufficient in the third monitoring year, then irrigation can cease (Lewis et al. 2009). Because a coarse wood mulch is recommended, watering to this extent may not be necessary (see above). Weekly irrigation is common in the early summer, though less frequent watering is likely sufficient (Sound Native Plants 2021d). In fact, infrequent, deep-watering is preferred to frequent, light-watering, as it increases the tolerance of plantings to drought (Cramer et al. 2002). Be sure to slowly reduce watering by mid-August, as this encourages dormancy in plantings (Sound Native Plants 2021d).

Chemical fertilization is not recommended in riparian zones due to the potential impacts on water quality (MoE 2012). Fast-release chemical fertilizers can also cause fertilizer burn in plantings and often select for invasive species rather than native species (Cramer et al. 2002; Dorner 2002; Sound Native Plants 2021e). Given non-native cover at the site, thorough management of competing vegetation may be sufficient to increase the soil nutrients necessary for plantings (Roberts et al. 2005). Planting deciduous trees, nitrogen-fixing species such as Red Alder, and species with strong roots that will improve soil structure can also increase nutrient availability (MoE 2012). A compost or similar organic material may be appropriate in some areas for alternative management if other efforts do not suffice. In this case, it is best that amendments are integrated into the soil rather than distributed on the surface, as this encourages deeper root growth (Cramer et al. 2002).

5.2.4. Predator Protection Devices

American Beaver, Common Muskrat, and Nutria (*Myocastor coypus* Molina) are all associated with the Brunette River and can cause extensive damage to new plantings (Withrow-Robinson et al. 2011). Oftentimes, wire cages are added at the base of individual trees to protect them from dam-building species (Withrow-Robinson et al. 2011). Given the modest size of the site and the vegetation preferences outlined in Table 5, one exclusion fence surrounding more at-risk areas would likely be more efficient. See the proposed planting plan (Appendix J, Figure J1) for suggested fence placement. Further, small rodents like voles are a potential threat to plantings because of the extent of grass cover at the site (Withrow-Robinson et al. 2011). Aluminum foil wrapped around the base of planted seedlings is both affordable and highly effective in preventing vole damage, and in combination with mulching, should be sufficient (see Duddles & DeCalesta 1992).

Table 5. Vegetation preferences for beavers and other dam-building species. Table adapted from King County (2017).

High	Black Cottonwood, Red Alder, Vine Maple, willow spp.
Medium	Bigleaf Maple, Western Redcedar, Douglas-fir
Low	Sitka Spruce, Red-osier Dogwood, Black Twinberry, Salmonberry, Pacific Ninebark, Pacific Crabapple, Nootka Rose, Hardhack

5.3. Restoration Prescriptions

Restoration prescriptions for each unit are detailed below. Since some uncertainty exists around the construction footprint and native species retained during site preparation, suggested total plant numbers may be exaggerated. Further, final planting locations may vary during implementation, as exact placement should be tailored to microsites and will need to be appropriately distanced from infrastructure. Refer to Appendix H, Table H1 for more detail on chosen species, Appendix J, Figure J1 for a visual of the proposed planting plan, and Appendix K, Table K1 for a breakdown of approximate costs for restoration within each management unit.

5.3.1. Snowberry Shrubland Management Unit

Planting locations in the Snowberry Shrubland management unit are largely dictated by the pipeline right-of-way and Brunette Interceptor. Species greater than 1 m tall are not permitted within the pipeline right-of-way to allow for monitoring and maintenance (Kinder Morgan Canada 2018). Outside of this area, plantings should be positioned based on their root systems with shallow-rooted vegetation planted nearer and larger trees planted further away (at least 6 m; Cadent nd). Depth of infrastructure may impact the planting design as Trans Mountain does mention planting trees up to the edge of the 6 m right-of-way in their plans (TMP 2018). Though the exact easement width for the Brunette Interceptor is unknown, an effort was made to follow similar clearances from the mainline.

Two vegetation management concepts were applied to planting within the Snowberry Shrubland management unit: variable-density planting and nurse-tree shelterwoods. Variable-density planting is related to variable density thinning, which is a relatively new forestry practice aimed at creating heterogeneity in a landscape (Brodie & Harrington 2020). By planting a variety of species at different spacing, the spatial and structural variability can be increased, ultimately improving biodiversity, wildlife habitat, and ecosystem function (Brodie & Harrington 2020; Hayes et al. 1997). This method also provides a middle ground between competitive effects and the benefits of dense planting (North et al. 2019). The concept of planting nurse-tree shelterwoods relates to the protection of conifer seedlings by creating favorable microsites for establishment, especially in areas with high competing vegetation (Childs & Flint 1987; Koning 1999). Using fast-growing deciduous species to shelter shade-tolerant conifers on alluvial sites helps managers to mimic natural succession and secures a more long-term overstory for later successional stages. Establishing conifers is particularly important in areas where there is little natural recruitment and/or a high level of non-native species that may take over the site after shorter-lived trees die off (Koning 1999; Poulin 2006).

Species selected for this unit can be found in Table 6. A variety of trees and shrubs were chosen in an effort to create some structure and habitat heterogeneity within the limits of the site. Black Twinberry (*Lonicera involucrata* (Richardson) Banks ex Spreng.), Pacific Crabapple (*Malus fusca* (Raf.) C.K. Schneid.), and Western Redcedar should be concentrated on the east side of the unit, as this is where moisture tends to pool. All other species can be distributed based primarily on their threat to infrastructure and drought-tolerance. For example, Common Snowberry may work well nearer the highway, as it has a final height of only 2 m and is highly adaptable (Sound Native Plants 2021b). Because willow spp. are known for their ability to accumulate heavy metals such as cadmium (Kane 2004), the drought-tolerant Scouler's Willow (*Salix scouleriana* Barratt ex Hook.) may also be useful in this area. Bigleaf Maple and Red Alder were chosen primarily for their ability to produce shade and amend the soil through nutrient-rich litter introductions and, in the case of Red Alder, nitrogen-fixation (Gov BC 2000). The functional role of other species chosen for this unit relate primarily to shade, nesting and perching, erosion-control, sustenance (e.g. berries, seeds, OM), and pollination (see Appendix H, Table H1). All plantings in this unit must be mulched with coarse wood chips to prevent erosion and re-colonization of the planting sites by non-native species (see Section 5.2.3: Mulch, Irrigation, and Fertilizer).

Table 6. Recommended species for planting within the Snowberry Shrubland management unit.

Species	Common Name	Minimum Spacing (m)	Stock	Total Plants
Trees*				
Abies grandis	Grand Fir	4	5-gallon	2
Acer macrophyllum	Bigleaf Maple	2,4	5-gallon	6
Alnus rubra	Red Alder	2,4	5-gallon	11
Crataegus douglasii	Black Hawthorn	2	5-gallon	7
Malus fusca	Pacific Crabapple	2	5-gallon	8
Rhamnus purshiana	Cascara	2,4	5-gallon	8
Salix scouleriana	Scouler's Willow	2	2-gallon	5
Thuja plicata	Western Redcedar	4	5-gallon	3
Shrubs				
Cornus stolonifera	Red-osier Dogwood	1.5	2-gallon	28
Lonicera involucrata	Black Twinberry	1	2-gallon	35
Rosa nutkana	Nootka Rose	1	1-gallon	48
Rubus parviflorus	Thimbleberry	1	1-gallon	47
*Symphoricarpos albus***	Common Snowberry	1	2-gallon	75
Herbs				
*Urtica dioica****	Stinging Nettle	0.5	Propagation	100
Planting Area (m^2)				**941**
Maximum No. Plants				**383**

**Acer glabrum* (Douglas Maple) would work well in place of other small trees if low survivorship.
**May be salvaged from trench area during construction. Cost included in budget, as number of individuals is unknown.
***Total plants is an estimate; if those on site are damaged or in short supply, plants can also be harvested off-site.

Further, it is likely that the Stinging Nettle patch will be dug up or otherwise damaged by construction due to its location. If this is the case, a new patch should be planted nearby to take advantage of any seedbank remaining. Since Stinging Nettle spreads by rhizomes, plants can be propagated through dividing and spreading established individuals (Luna 2001). An effort should be made to create a larger patch than was originally present. If there are no plants left on site, individuals can be harvested from elsewhere. It is important to make sure that plants from other locations are taken ethically (i.e. do not collect individuals from sensitive areas and only remove what is necessary; MoE 2012).

In addition to plantings, some species may need to be seeded in disturbed areas. In NEB Condition 78 (TMP 2017), Trans Mountain suggests that a non-native, sodforming seed mix be used for major transportation corridors and areas with greater than 50% non-native cover. Despite the project site being within the right-of-way of a major transportation corridor, it was discussed in a meeting with DFO and KFN (10 January 2020) that a native seed mix be used for this area. The seed mix proposed in TMP (2017) is composed of: Comox Creeping Red Fescue (*Festuca Rubra* var. Comox), Camriv Canada Bluegrass (*Poa compressa* var. Camriv), and Schoen Slender Hairgrass (*Deschampsia elongata* var. Schoen). Not only is this mix non-native, but these ecovars may no longer be available on the market (N. Wall pers. comm., 1 March 2021). More recently, early successional native grasses have become purchasable, and can provide rapid cover when paired with late successional species (Tinsley et al. 2005). In fact, in a study conducted by Tinsley et al. (2005), native mixes outperformed non-native species on roadsides. The seed mix outlined in Table 7 is proposed in place of the species suggested in TMP (2017).

Table 7. Recommended seed mix for the Snowberry Shrubland management unit. Suggested seeding rate is 40 to 50 kg/ha.

Species	Common Name	% by weight	Seeds/lb.	% by count
Herbs*				
Agrostis exarata	Spike Bentgrass	1	6,000,000	21.30
Bromus sitchensis	Sitka Brome	40	100,000	14.20
Deschampsia cespitosa	Tufted Hairgrass	3	2,100,000	22.36
Festuca rubra ssp. *pruinosa*	Native Red Fescue	15	600,000	31.95
Hordeum brachyantherum	Meadow Barley	41	70,000	10.19
Planting Area (m^2)**				**340**

*Final seed mix is only proposed for the pipeline right-of-way in the Snowberry Shrubland unit.
**Only half of the Roadside Cover area (~220 m^2) will be considered disturbed for budgeting purposes.

This mix is notable for: erosion-control, attracting native pollinators, competition with invasive species, and having a relatively low mature height so as to not create visibility concerns (N. Wall pers. comm., 2 March 2021). Spike Bentgrass (*Agrostis exarata* Trin.), Sitka Brome (*Bromus sitchensis* Trin.), and Meadow Barley (*Hordeum brachyantherum* Nevski) are quick-establishing, flourish in a variety of soil conditions, and can tolerate a range of moisture levels (Carter 2014; Darris & Bartow 2006). They are often associated with disturbed habitats and are considered valuable restoration species due to their stabilizing properties. Spike Bentgrass is even known to resist Reed Canarygrass infestations (Darris & Bartow 2006). Tufted Hairgrass (*Deschampsia cespitosa* (L.) P. Beauv.) is a mid-successional species that provides longer-term revegetation and soil stability (Fire Effects Information System [FEIS] nd), and is considered a keystone species in wet meadow ecosystems (Sound Native Plans 2021b). Native Red Fescue (*Festuca rubra* ssp. pruinosa (Hack.) Piper) along with others in this mix also provide food and cover for small mammals, song birds, and waterfowl (Darris & Bartow 2006; FEIS nd).

For this unit, the mix in Table 7 is to be broadcast seeded only in the pipeline right-of-way. Because the ground surface in this area is relatively level, the suggested seeding rate of 40 to 50 kg/ha should be sufficient. If for any reason a higher seeding rate is preferred, it should be kept in mind that significantly increasing rates can cause quicker establishing, short-lived species to crowd out slower growing native species (N. Wall pers. comm., 8 March 2021). Monitoring may determine that areas seeded with an excessively high rate will need to be reseeded once the quick-establishing species transition out.

To maximize the ecological benefit of the pipeline right-of-way, seeding native forbs alongside grasses may be desired to attract native pollinators. Some forb species potentially suited to the site include: Fringed Willowherb (*Epilobium ciliatum* Raf.), Large-leaved Avens (*Geum macrophyllum* Willd.), Douglas' Aster (*Symphyotrichum subspicatum* (Nees) G.L. Nesom), Cooley's Hedge Nettle (*Stachys chamissonis* var. cooleyae (A. Heller) G.A. Mulligan & D.B. Munro), and Large-leaved Lupine (*Lupinus polyphyllus* Lindl.). All of these species can persist in full sun, and Fringed Willowherb and Large-leaved Avens are already found in the area (Appendix C; Coulthard & Cummings 2018). Cooley's Hedge Nettle is one of the only indicator plants for this subzone that does not require shade (Green & Klinka 1994; Sound Native Plants 2020b) and Douglas Aster, an important late-season species for butterflies and bees (Costner 2017), seems widely available for purchase. Some of these species may grow taller than the 1 m limit (E-Flora BC 2019), so species seeded depends in part on whether right-of-way restrictions pertain to both woody vegetation and forbs. If forb height is not an issue, it is recommended that Large-leaved Lupine be included as it has many ecological benefits from attracting native bees and hummingbirds, to erosion-control and nitrogen-fixation (Beuthin 2012). Local availability of native seeds may impact choices, and seeding rate will be dependent on species chosen. Consultation with a native seed supplier is recommended to determine availability before settling on species that could be added to the grass seed mix above.

5.3.2. Roadside Cover Management Unit

To facilitate machinery access into the workspace, Trans Mountain will need to extend the road using widening infrastructure (TMP 2019). Although there is some uncertainty in regards to the extent of disturbance that will occur, these actions will demand post-construction topsoil placement and seeding using MoTI guidelines (TMP 2019). MoTI 2020a outlines the standards to be followed when reseeding roadsides, such as the typical grass mixes and application rates required. The MoTI grass mixes were updated in 2020, but the Vancouver Island/Coast Mix still includes some of the same highly competitive, non-native species that are currently abundant at the site (see MoTI 2020a). It is recommended that the species in Table 7 are seeded in place of this mix, if possible. The MoTI agronomic mix can be used as a part of alternative management and contingency if the native species do not establish sufficiently. The final area to be seeded in the Roadside Cover unit is highly dependent on the extent of disturbance, and is likely to be much lower than the total area reported in Table 1. Since this unit is moderately sloped and will be hydroseeded rather than broadcast seeded, the suggested seeding rate of 40 to 50 kg/ha should be tripled for a rate of 120 to 150 kg/ha (A. Cohen-Fernandez pers. comm., 2 April 2021). This increase is partially due to seed damage from mixing and application (Carr 1980; Gov BC 1997).

In addition to seed, the hydroseeding slurry should contain a mulch and tackifier to protect the slope from erosion and invasive species while grasses establish (Carr 1980). MoTI (2020a) recommends a wood fibre mulch and either a starch-based product or organic guar gum for a tackifier in highway right-of-ways. A standard application rate of 1500 kg/ha is listed in this document, though it does not specify rate increases for slopes. Another source states that wood mulch should be applied at a rate of at least 2200 kg/ha for full benefits (Government of Michigan [Gov Michigan] nd). Perhaps 2500 to 3000 kg/ha would be sufficient for this unit to account for a 37% slope. The standard application rate for guar gum is about 80 kg/ha (Gov Michigan nd), though again, higher rates may be warranted.

5.3.3. Remnant Riparian Management Unit

The planting strategy for the Remnant Riparian unit is to plant suitable shrubs and small trees in high densities to resist invasion by non-native species colonizing the site from the river (Guillozet et al. 2014; MoE 2008; Table 8). In order to comply with provincial requirements for planting near powerlines, species must be below 5 m and 12 m, depending on their distance from the powerline (BC Hydro 2019; Appendix H, Table H1). This limits the benefits that vegetation can provide to the stream. Nonetheless, plantings chosen for the low zone are shorter species capable of stabilizing streambanks due to their spreading root systems of variable forms and depths. Willow (*Salix* spp.) and Red- osier Dogwood stakes would typically be planted on the bank for their stabilizing properties and reliable establishment (Sound Native plants 2021c); however, due to height concerns, Hardhack (*Spiraea douglasii* Hook.) and Black Twinberry stakes were chosen in their place. Both of these species root very well and may be sufficient (Darris 2002). It is recommended that a more thorough inspection of bank condition is conducted before committing to the use of live stakes alone. Additional protections such as fascines may be necessary depending on erosion type and severity (see Donat 1995).

In an attempt to create more structure, Red-osier Dogwood, Black Hawthorn (*Crataegus douglasii* Lindl.), Pacific Crabapple, and Scouler's Willow are suggested for the taller zone. Scouler's Willow is more drought-tolerant than other willows and Red-osier Dogwood is a "Restoration Superstar" and can survive in a variety of conditions (Sound Native Plants 2021b). Pacific Crabapple and Black Hawthorn are relatively quick to establish (Sound Native Plants 2021b) and are both important species to KFN. Salmonberry was included as it is also ecologically and culturally important, though it may be replaced with a more drought-tolerant species if survival is low. Salmonberry may survive well if concentrated in shadier areas with Swordfern (*Polystichum munitum* (Kaulf.) C. Presl). Nootka Rose should be placed in thickets at the edges of this unit to prevent Himalayan Blackberry encroachment from adjacent areas, as it has been cited as one of the few native shrub species that can outcompete this prolific invasive (Sound Native Plants 2021b).

Table 8. Recommended species for planting within the Remnant Riparian management unit.

Species	Common Name	Minimum Spacing (m)	Stock	Total Plants
Trees				
Malus fusca	Pacific Crabapple	2.0	2-gallon	6
*Crataegus douglasii**	Black Hawthorn	2.0	2-gallon	12
Salix scouleriana	Scouler's Willow	2.0	2-gallon	14
Shrubs**				
Cornus stolonifera	Red-osier Dogwood	1.5	2-gallon	44
Lonicera involucrata	Black Twinberry	0.5, 1.0	stakes, 2-gallon	319, 96
Physocarpus capitatus	Pacific Ninebark	1.5	2-gallon	81
Rosa nutkana	Nootka Rose	1.0	1-gallon	99
Rubus parviflorus	Thimbleberry	1.0	1-gallon	125
Rubus spectabilis	Salmonberry	1.0	2-gallon	98
Spiraea douglasii	Hardhack	0.5	stakes	478
Herbs				
Polystichum munitum	Swordfern	0.50	1-gallon	114
Planting Area (m^2)				**989**
Maximum No. Plants				**1484**

*Replace with *Rhamnus purshiana* (Cascara) if low survivorship.
***Symphoricarpos albus* (Common Snowberry) or *Sambucus racemose* (Red Elderberry) may also work in this unit.

Sloped areas nearer the bank will need alternative soil reinforcement while vegetation establishes. An erosion-control fabric such as woven coir fiber is commonly used for this purpose, as it is affordable, strong, biodegradable, provides long-term protection while vegetation establishes (generally two to four years), and is available in conveniently sized rolls (Cramer et al. 2002; Dorner 2002). It is preferred over straw or jute netting, as they may not be durable enough for streambanks. Coir can also be purchased with a tightly woven inner layer that resists loss of finer-textured particles, though this product may be more difficult to find at some retailers (Cramer et al. 2002). It is important that long (50 to 60 cm) wedge-shaped wooden stakes be evenly distributed among live stakes to tightly secure the fabric and for added insurance in case of high mortality. Fabric must be trenched and overlapped (see Appendix H of Cramer et al. 2002 for more information).

5.3.4. High-slope Blackberry Management Unit

Since the soils in this unit could not be sampled, it is assumed that they are sandy, low in nutrients, and drier than the surrounding area solely based on slope position and aspect (Table 1). Soil sampling is recommended, and a topsoil may need to be placed (Dorner 2002). If a topsoil is warranted, an erosion-control fabric will likely be necessary to secure the slope while vegetation establishes, though this depends in part on vegetation retained during invasive species removal. All species chosen for this unit are considered slope stabilizers (Table 9; Appendix H, Table H1) and have varying rooting forms and depths. Microsites should be tailored to the moisture and shade requirements of species, as the lower slope will be wetter and partially shaded by planted vegetation in the Snowberry Shrubland unit. For example, Indian Plum and Red-osier Dogwood may be more successful if concentrated on the low- to mid-slope, though they do currently exist within both areas. Snowbrush (*Ceanothus velutinus* Douglas ex Hook.) is recommended for its root system, strong competitive ability, nitrogen-fixing properties, and its tolerance to full sun (Bressette nd; Enns et al. 2002; Taccogna and Munro 1995). It has quite deep roots for its height (2.0 to 2.5 m) making it valuable for erosion-control nearer the highway (FEIS nd). One downside to using Snowbrush is that it isn't as common in this zone and is associated with higher elevation sites (E-Flora BC 2019). Therefore, if nitrogen-levels are sufficient, it might be desirable to use Oceanspray (*Holodiscus discolor* (Pursh) Maxim.) instead. In this case, care must be taken to maintain sightlines because Oceanspray grows taller (~1 m) than Snowbrush (MacKinnon et al. 2004).

Table 9. Recommended species for planting within the High-slope Blackberry management unit.

Species	Common Name	Minimum Spacing (m)	Stock	Total Plants
Shrubs*				
*Ceanothus velutinus***	Snowbrush	1.0	2-gallon	84
Cornus stolonifera	Red-osier Dogwood	1.5	2-gallon	49
Oemleria cerasiformis	Indian Plum	1.5	2-gallon	25
Symphoricarpos albus	Common Snowberry	1.0	2-gallon	94
Herbs				
Polystichum munitum	Swordfern	0.50	1-gallon	73
Planting Area (m^2)				**349**
Maximum No. Plants				**325**

**Rosa Nutkana* (Nootka Rose) may also work well in this unit and can replace other species if necessary.
***Holodiscus discolor* (Oceanspray) is also an alternative option, but must be planted where it will not impact visibility.

If a topsoil is placed and vegetation is installed through some form of matting, it is likely that erosion will have been sufficiently controlled; however, if matting is not used, bare areas between installed shrubs should be mulched. Given the grade of this unit, a simple coarse wood chip mulch will not suffice. Instead, the area should be hydromulched with a tackifier, similar to the method used in the Roadside Cover management unit (see Section 5.3.2: Roadside Cover Management Unit). A steeper slope of 64% may demand a higher application rate of approximately 3000 to 3500 kg/ha. Seed should not be added to this mix, as shrubs are to be planted densely and grasses will increase competition. Monitoring will be used to determine if groundcover is sufficient, and if necessary, seeding with the mix in Table 7 can be completed at a later date once shrubs have established sufficiently.

5.4. Habitat Features

5.4.1. Coarse and Standing Dead Wood

The two groups of coarse and standing dead wood on site will need to be relocated to an area outside of the pipeline right-of-way. It is recommended that they remain in clusters, as this more closely represents natural conditions and can increase their value as habitat (SCCP 2015). These features can be retained during construction and added back to the site within the Snowberry Shrubland unit. For additional coarse wood, standard practice in riparian restoration is to add approximately two pieces per 100 m^2 (SCCP 2015); however, adding at least two additional logs to the Snowberry Shrubland or Remnant Riparian units should be sufficient for the purposes of this project. Coarse wood provides feeding sites and shelter for fauna, reduces erosion and run-off, and add nutrients to the soil. It also creates safe microsites for plants to establish. Logs can be deciduous or coniferous, but should be at least 4 m long and 30 cm in diameter. Adding a variety of species at different decay rates increase micro-habitat diversity, though Western Redcedar logs should be limited due to the auxins in their wood (SCCP 2015).

5.4.2. Bird Boxes

The site is deficient in standing wood, particularly of adequate size for cavity nesting fauna. Several bird species detected or potentially near the site could benefit from the addition of bird boxes. Butler et al. (2015) state that only one pair of Wood Ducks (*Aix sponsa* Linnaeus) were spotted in in the Brunette near Hume Park in 2012, but that more may nest in the area if boxes were provided. Therefore, it is recommended that the Wood Duck nesting box design is used, which is available on the Ducks Unlimited website (Ducks Unlimited Canada [DUC] nd-a). Duck nest boxes can also be used by cavity nesting passerines like Tree Swallow (*Tachycineta bicolor* Vieillot) or owls such as the Western Screech Owl (*Megascops kennicottii kennicottii* D.G. Elliot; Threatened; DUC 2008; DUC nd-a). The Western Screech Owl depends on mixed riparian forests at low-elevations (MoE 2013) and is one of the many species of concern that may be disrupted by the TMX project (Zoetica 2015).

For use by waterfowl, it is recommended that boxes be placed in trees either in or near the water, at least 2.5 m above the ground (DUC 2008). There are two large Red Alders on the northwest side of the Remnant Riparian unit that may be suitable for this design. For use by owls, the boxes must be placed higher (3 to 9 m) and at least 30 m from the nearest owl box (Wildlife Center of Virginia [WCV] nd). If upon closer examination it is determined that these trees are unsuitable, boxes can also be mounted to steel poles within this unit. If a location further from the river is chosen, it may no longer be used by waterfowl but can target owls and/or passerines (DUC nd-b). In this case, the boxes would likely need to be mounted to metal poles, as no healthy trees are thick enough in diameter. Care must be taken to place boxes in a location far enough from the roadway to prevent human-wildlife conflict. See Appendix I, Figure I1 for the recommended design, as well as options for installing anti-predatory devices.

5.4.3. Bat Boxes

It is also recommended that one bat box be installed within the restoration site. This is a particularly important addition for the Little Brown Myotis (*Myotis lucifugus* Le Conte; Endangered), which may be found in the area (Coulthard & Cummings 2018). Populations of the Little Brown Myotis have been devastated by an invasive fungal disease called White-nose Syndrome (WNS) in Eastern Canada, resulting in it being listed as Endangered in the *Species at Risk Act* (SARA; Environment Canada 2015). Given the rate of spread of this disease, it is estimated that WNS will have affected the entire Canadian population of Little Brown Myotis by 2027 to 2033. This demonstrates a need to increase (or at least maintain) population sizes in areas currently not affected by WNS, to safeguard against potentially irreversible population-level impacts in the future (Environment Canada 2015).

Two designs of bat boxes are suitable for the site. The first option being the multi-chambered nursery box, which is one of the more common bat box designs (British Columbian Community Bat Program [CBP] 2014). This design does not have to be installed on a heated building and instead can be mounted on a post. CBP (2014) recommends putting two multi-chambered bat boxes back to back to maximize roosting space. The alternative option is to add a two-chambered rocket box. Rocket boxes are affordable and easy to assemble, and have proven very successful in Coastal B.C. (CBP 2014). Diagrams for both of these options can be found in Appendix I, Figures I3 and I4, and building instructions can be found in Bat Conservation International (BCI; nd) and Tuttle et al. (2005), respectively. Bird box anti-predatory devices may also be used to protect bat boxes (Appendix I, Figure I2). Specific details regarding installation and placement can be found in Craig (2017).

6.0. Monitoring and Maintenance

Monitoring is essential to project success, as it determines if the project is on a trajectory to meeting goals, allows for the identification of required maintenance activities, and informs alternative management strategies and future restoration (Bennett and Ahrens 2007). If construction has not begun by next growing season, it is recommended that a photo-monitoring station be established for each unit. Photo-monitoring is an affordable method for documenting qualitative vegetation data over time (Bennett & Ahrens 2007). In combination with quantitative data, photos can be a valuable tool for assessing progress of the planting project (MoE 2012). For example, photos can be used to document changes to invasive species cover which can then inform alternative management actions and the need to either increase or decrease the frequency of maintenance efforts. Stations should be marked for reference so that points can be easily located. In addition to periodic monitoring, photos must be taken before and immediately after planting. It is also important that an item be included in each photo for scale and that a compass is used to document direction (Bennett & Ahrens 2007; MoE 2012). At least two directions should be recorded, and photos must be taken consistently (e.g. same month, time of day).

6.1. Monitoring Parameters and Timing

It is recommended that both qualitative and quantitative analyses are used to monitor performance standards for this project. Major attributes to be monitored in the short-term include immediate threats to plantings (e.g. invasive species regrowth, animal damage), health and vigor of vegetation, erosion issues, and the stability and/or use of feature installations. Overlapping percent cover should also be sampled for all vegetation types; however, this may not be completed until the fifth year, as growth must be sufficient. Although a 5-year monitoring period may be adequate for determining that the ecosystem is on a desired trajectory, longer-term monitoring can give a better indication of change and whether overarching goals are being achieved (Lewis et al. 2009; Reeve et al. 2006). Perhaps conducting additional monitoring at the 7- and 10-year marks (AloTerra 2017; Lewis et al. 2009) would allow for a more thorough analysis of key ecosystem variables identified in Ruiz-Jaen & Aide (2005) such as productivity, habitat suitability, invasion resistance, and ecosystem resilience. The community might have reached a more stable condition at this point, in which case cover and composition may be of more interest than survival (Deep Water Horizon [DWH] 2017). See Table 10 for the main observations that should be recorded, maintenance actions required for each, and the optimal seasonal timing for both monitoring and maintenance activities.

Table 10. Optimal seasonal timing for monitoring and maintenance activities conducted within the restoration area and general methods with observations that should be recorded. Monitoring results may lead to a change in the timing or frequency of measurements or treatments. See Section 7.0: Management and Contingency.

Activity	Timing	Methods, Key Observations, Additional Information
Monitoring		
Perform visual inspections of the site post-planting to identify any immediate threats to planting survival or water quality	First spring after project implementation is most crucial, but should be completed at least annually thereafter[1,2,3]. Animal damage and invasive regrowth should be inspected every 45 days during the growing season in years 1 and 2, and twice (e.g. spring and late summer) in years 3, 4, and 5[4]	Qualitatively document any signs of erosion, animal damage, and invasive species regrowth. Ensure exclusion fence and aluminum foil are in working order and that the latter is not restricting stem growth. Make sure erosion-control matting is firmly in place and has not been damaged. Quantitatively compare percent groundcover to percent bare ground in areas that have been seeded to ensure erosion-control target has been met
Monitor health and vigor of plantings	When using health and vigor data to assess survival, near the end of the growing season is ideal[1]. Survival monitoring should occur annually[1] from years 1 to 5	Quantitative measurement using sampling methods to calculate survival rate informed by health and vigor assessment. Document data such as DBH and height of surviving seedlings, and specific species, locations, or stock types with higher survival[1]. Record qualitative information such as wildlife seen during site visits and any native species recruitment[2,4]. Note: irrigation to occur in first year[6], but can be extended given survival monitoring results
Monitor overlapping percent cover and changes to native species diversity	During growing season, potentially in year 5. Consider additional evaluations (e.g. in year 7 or 10)[2,5] for longer-term monitoring	Quantitative measurement using comparable method to baseline data collection so that pre-project and post-project conditions can be analyzed. Observations of wildlife, structure etc. are also highly valuable at this time
Check bird boxes for use, stability, predation	Damage assessed at any time (annually), use and predation best documented in late fall/winter[7]	Mark down need for maintenance, qualitative data taken for use by specific species (eggs, shells etc.) and signs of predation. Assess need for relocation of bird boxes based on use and other observations
Check bat box for use, stability, wasps' nests	Best completed in summer as bats may be seen first-hand in the evening or by guano[8]. In winter, guano may be detected and wasps should no longer be present	Mark down need for maintenance, qualitative information documented for signs of bat and wasp use, as well as potential predation. Assess need for relocation of bat box based on use and other observations. If used, add results to Annual B.C. Bat Count survey[8]

Activity	Timing	Methods, Key Observations, Additional Information
Maintenance		
Carry out non-native species management	Remove regrowth every 45 days in the first two growing seasons, and twice per growing season thereafter[4]. First pass between April to June and last pass in late summer/early fall, as needed. Fall is especially important for herbicides if alternative management used[9,10]	Remove all priority invasive species* according to species-specific methods (see Appendix F, Table F1), as well as non-native species encroaching on planting sites (e.g. careful grass trimming using a brush cutter). Add additional mulch, if necessary. If invasive species cover is still high despite removal or is increasing, adjust maintenance frequency accordingly[4]
Plant replacement species	To be conducted the following fall or spring. Timing may be dependent on plant availability and other nursery considerations	Replace individuals identified by survival monitoring with the same or better performing species. This activity is only necessary if target survival rates have not been met
Conduct supplemental watering	At minimum, irrigation should occur in the first growing season[6], and can be once a week or less, gradually decreasing by mid-August[11]	Use deep-watering techniques as they discourage weeds and promote plantings[11]. Depending on monitoring results, watering may only be needed for certain species or stock sizes etc. and hand-watering may be sufficient. Otherwise a tank truck may be required[1]
Fix damage to predator protection devices	Conduct maintenance as soon as damage or other issues are detected	Re-establish fencing if fallen over, repair any damage, ensure bottom of fence is still flush with the ground to prevent access[12]. Replace aluminum foil if damaged and loosen those that may be restricting growth. Aluminum foil should be replaced every two years[13]
Correct any identified erosion problems	Correct erosion issues as soon as detected to avoid negative impacts to water quality	Re-apply wood mulch in areas that have been eroded, re-seed areas that have not met percent cover targets for erosion-control, and repair/re-stake coir fiber matting, if required
Maintain bird boxes and the bat box	Use rates are highest with annual maintenance[7]. Should be maintained in fall/winter when birds, bats, and wasps not present[7,8]	Remove debris from inside nest boxes and replace with 8 to 10 cm of nesting material[7]. Re-attach to tree/post or re-locate, if necessary. For bat box, remove wasps' nests, and re-attach to post or re-locate, if necessary[8]

*Not including Reed Canarygrass as complete control would be prohibitively labor intensive. Monitoring should focus on changes in cover and its encroachment into planting sites.
[1]Bennet & Ahrens (2007); [2]Lewis et al. (2009); [3]MoE (2012); [4]Page (2006); [5]AloTerra (2017); [6]Kipp & Calloway (2002), as cited in MoE (2012); [7]DUC (2008); [8]Craig (2017); [9]Gover et al. (2007); [10]Metro Vancouver & ISCMV (2019a); [11]Sound Native Plants (2021d); [12]King County (2017); [13]Duddles & DeCalesta (1992).

Given the suggested seasonal timings outlined in Table 10, there should be a minimum of four site visits per year, with more inspections occurring during the first two growing seasons. Though this serves as a guideline, the number of visits is highly dependent on monitoring results. The extent of work to be completed in each site visit is variable as some inspections may be purely qualitative or demand minimal maintenance, whereas others may be slightly more intensive. Analyses of health and vigor (e.g. survival, tree growth etc.) should be conducted each year, but monitoring of overlapping percent cover and diversity may only be meaningful in year 5 or more, as vegetation must first grow sufficiently. With these factors in mind, an example of a potential annual monitoring and maintenance schedule can be found in Table 11.

Table 11. Example schedule for one year of monitoring and maintenance activities within the restoration area. Actual frequency of site visits will depend on assessment of maintenance needs.

Spring	Summer	Fall	Winter
Conduct visual inspection of area (years 1 to 5)* Take photos from monitoring stations Repair/replace fence, aluminum foil, erosion-control matting etc., if necessary Complete non-native species maintenance	Complete survival monitoring (years 1 to 5) Conduct supplemental watering (at least year 1) Order replacement species Check for use of bat box Complete percent cover assessment (when growth is sufficient, ~year 5)	Conduct lower-level supplemental watering (dormancy) Complete non-native species maintenance, especially for herbicide application Plant replacement species	Check for predation and use of bird boxes Remove wasps' nests from bat box Could also complete a visual inspection for erosion issues during particularly high precipitation events

*Visual inspections will occur more frequently throughout the growing season in years 1 and 2 (refer back to Table 10).

6.2. Monitoring Design

Short-term monitoring parameters to be quantitatively measured include percent groundcover in erosion-prone areas and survival of planted vegetation. When plots are used for monitoring, at least 5% of the site should be sampled to ensure accurate representation (Dorner 2002). In areas that have been seeded, 1 m^2 quadrats can be placed along transects using systematic random sampling. This allows for a comparison between percent groundcover and bare ground, and thus can aid in determining whether the erosion-control target has been met. A target groundcover of 80% or more is necessary for preventing wind and water erosion (Carr 1980). The number and placement of quadrats will depend on the extent of disturbance by construction.

Health and vigor monitoring used to inform survival rates should be completed for all vegetation planted within the restoration site. Generally, this type of monitoring is conducted using direct counts or the plot method (Lewis et al. 2009). Direct counts are often chosen at smaller sites, as this is the most accurate method for obtaining site-level data (Lewis et al. 2009). Since the number of trees to be planted within the restoration site is quite low relative to other vegetation types, it is recommended that every individual is assessed using a standard health and vigor scale (Table 12). Additional information to be recorded can be found in Table 10. A particular emphasis should be put on tree height measurements, as these will help to determine if growth targets are being met.

Table 12. Numerical health and vigor ratings to be used in vegetation monitoring within the restoration area. Values greater than 2 indicate survival. Scale taken from Suddaby et al. (2008).

Health and Vigor Rating	Plant Health	Specific Criteria
0	Dead	All leaves dry, shriveled, and necrotic
1	Very poor	Severe necrosis or wilting
2	Poor	Wilting, chlorosis, or necrosis of up to one third of leaf area
3	Loss of vigor	Reduced vigor, browning of the leaf tips
4	Healthy	Deep green leaves, no chlorosis or wilting

For all other plantings, sampling units must be established. The proportion of surviving plants (Table 12) out of the total counted can then be used to estimate the survival rate. Belt transects may be the best method for monitoring survival at the site, as they are particularly useful for measuring density parameters across clumped-gradient populations (see Elzinga et al. 1998). In the Remnant Riparian unit, belt transects oriented perpendicular to the river would allow for the representation of various species planted in groups and located in different zones across the riparian gradient (Elzinga et al. 1998). This method is also applicable to the High-slope Blackberry unit; samples should be oriented upslope since the distribution of species will be partially dependent on moisture requirements. Belt transects within the Snowberry Shrubland unit can either be extended from the samples located in the riparian area or running northwest to southeast to capture hydrological influences across the site.

It is recommended that a minimum of five 2 m wide belt transects spaced systematically across each planted unit are considered as preliminary methods. This design should account for spacing between plants and provide appropriate spatial coverage. The start and end points of transects should be relocatable (either marked in the field or with a GPS unit), as sampling the same area over time increases precision with fewer sampling units and allows for greater power in detecting changes in vegetation (Elzinga et al. 1998). This consistency may also be useful for observing species recruitment in the case that density estimates increase from year to year. The final monitoring scheme may change once revegetation efforts are complete, as it should be tailored specifically to the type, distribution, and density of vegetation planted within the site (Elzinga et al. 1998).

Long-term monitoring to be quantitatively measured may include species abundance and diversity. This form of monitoring could be completed in two ways. First, if it is desirable to compare post-project cover to pre-construction cover, the same methods must be used as in baseline data collection to ensure consistency. This would then entail the use of 16 m^2 quadrats in the same locations as previously sampled; however, during this time, tree cover can also be sampled using larger quadrats in a nested plot fashion. A quadrat size of 50 m^2 may be sufficient for trees, as this is the most common size for collecting data in silviculture monitoring (British Columbia Ministry of Forests, Lands, Natural Resources Operations, and Rural Development [MoFLNRORD] 2020). Though monitoring using the same method will allow for comparisons, this approach may not be the most accurate, as it is more challenging to estimate the abundance of smaller species (i.e. grasses and herbs) in large quadrats (Elzinga et al. 1998). Further, using rectangular quadrats distributed in a systematic random sampling design may have been superior during baseline sampling, as species would likely have been more thoroughly represented. Though the vegetation data in this report is still valuable for informing the decision-making process, it may not be as useful in quantitative analyses of pre-construction and post-planting conditions.

Given these considerations, it may be more appropriate to focus only on changes to vegetative cover and diversity after the revegetation project has been completed rather than comparing monitoring data to pre-construction conditions. In this case, it is recommended that the line-intercept method be applied, as it is commonly used for monitoring vegetative community composition in riparian zones and floodplains (Harris

2005) and works well in vegetation with patchy distributions where plant boundaries are discernable (Coulloudon et al. 1999). In some situations, this method is also said to introduce less error than quadrats (Coulloudon et al. 1999), which is particularly important if different employees will be conducting sampling in subsequent years. The line-intercept method can be easily integrated within the permanent belt transects discussed above by establishing the tape in the middle of the 2 m mark. Changes to vegetation structure should be monitored through the designation of height strata and/or the continuation of tree height and DBH measurements alongside abundance monitoring (Ruiz-Jaen & Aide 2005). Wildlife observations would also be valuable at this time.

7.0. Management and Contingency

As monitoring progresses, results can be used to inform management and contingency and thus treatment methods or maintenance schedules to improve the outcome of restorative actions (AloTerra 2017). Replacing plantings if survival targets are not met in any monitoring year is not necessarily considered adaptive, but is rather a part of maintenance. If survival is particularly low for specific species, stock, or in certain areas, however, alterations can be made to the original plan to ensure that the project is on a trajectory to meeting goals. For instance, supplemental watering may be more focused or extended (i.e. past the first year), or prescriptions may need to be re-evaluated. If drought stress is still pervasive after the first two years, the issue may be in species selection or placement rather than a lack of irrigation (Bennett & Ahrens 2007). Some potential replacement species are suggested beneath the planting tables in Section 5.3: Restoration Prescriptions, and a list of alternative riparian species can be found in Appendix H, Table H1. Particularly vigorous species identified through monitoring results can also be used.

If survival or native cover estimations remain low despite replanting efforts, maintenance may need to be extended and/or alternative corrective actions applied. Further management should also be considered if tree growth targets are not being met. For example, additional sampling may reveal that low-level nutrient applications are necessary in some areas or for certain vegetation types to improve establishment (Dorner 2002). If native diversity is lacking, especially after using replacement species, an effort should be made to diversify the area to maintain invasion resistance, productivity, and resilience (Ruiz-Jaen & Aide 2005; Wilsey & Potvin 2000).

Groundcover sampling used to identify areas exposed to erosion can also determine if species seeded are appropriate and whether a more aggressive seed mix should be formulated. In this case, a partial or full agronomic mix may be warranted. Similarly, if the Remnant Riparian or High-slope Blackberry units are showing signs of erosion with mulch decomposition, a native or agronomic seed mix may be considered.

Other corrective actions may relate to non-native species management and feature installations. Seasonal visual inspections can determine how often vegetation maintenance is necessary and whether control methods need to be changed. The only instance in which chemical treatment may be warranted is if manual or mechanical methods have no effect on or increase the abundance of invasive species (MoTI 2020b). If new invasive species are detected during the monitoring period, manual or mechanical methods should be attempted before resorting to herbicides. Monitoring use of the bird boxes and the bat box can also determine whether installation locations were satisfactory. For example, if the bat box has not been used by the second year, consider an area farther from the highway. Open site locations may be easier to identify once vegetation has been planted. Finally, given the results of vegetation monitoring, it may also be appropriate to re-evaluate the feasibility of established targets. The disturbed location of the site may influence restorative potential to a greater extent than originally anticipated.

8.0. Future Considerations

From a landscape perspective, the restoration area is but a small fraction of the Brunette River, and less in relation to the watershed. Even within its boundaries there are infrastructural considerations that reduce the ability of plantings to provide functional habitat, particularly to the stream. Typically, less impacted areas that have a higher chance of success or areas that influence restorative efforts occurring downstream are prioritized for restoration (Palmer et al. 2014; chap. 14). That being said, tributaries to the Brunette each have their own stewardship group and Burnaby Lake buffers some of the impacts coming from first-order streams. For instance, it acts as a sump for sediment flowing from the Still Creek watershed and is dredged periodically (Page 2006). Moreover, the Brunette gradually transitions from a relatively intact ecosystem to severely disturbed areas nearer the Fraser River (Gartner Lee Ltd. et al. 2001). This presents an opportunity for prioritization, starting from the Brunette Conservation Area and moving south.

Restoration in the Brunette corridor, albeit necessary, is challenging. This is especially true as buffer zones are often limited by infrastructure such as highways, industrial roads, rail lines, and parking lots. Since removing these features is impractical in most cases, the riparian areas of the Brunette will likely need to be improved in a sort of piece-by-piece fashion. The Theory of Island Biogeography ascertains that species diversity within habitat patches is dependent on such factors as patch size and their distance from other quality habitat (MacArthur & Wilson 1967). In conservation, this theory is used to prioritize large areas, which often leads to the development of smaller patches without regard for their collective importance within a region (Wintle et al. 2019). In fact, Wintle et al. (2019) argue that small habitat patches are *especially* critical to maintaining biodiversity in human dominated areas. They may be the only remnants of suitable habitat left, they can harbor higher concentrations of species seeking refuge from highly developed areas, and they can act as “stepping stones” that permit migration throughout fragmented landscapes (Manning et al. 2006; Wintle et al. 2019).

This concept can be applied to the Brunette corridor through the identification of areas that have the potential to provide refuge where there is otherwise very little (Figure 9). Identified patches may also aim to connect species that are present in the Lower Brunette/Fraser River to Hume Park and the Brunette Conservation Area. Some portions of the river are bordered by very thin riparian zones, such as those in the lowest reaches. These areas should still be targeted as they do have the potential to provide some ecological value; however, focusing on sites that have a higher interior-to-edge ratio (e.g. edge effects; MacArthur & Wilson 1967), that can accommodate species sensitive to edge microclimates (e.g. amphibians) and human presence (e.g. nesting songbirds), and that can support tree plantings is preferred (Lievesley et al. 2017). Potential benefits of patch restoration can be illustrated using biotas associated with the Brunette. For instance, certain salmonids may greatly benefit from small sections of riparian cover that can provide refuge from the sun and predators during migration (Kurylyk et al. 2015). Similarly, small patches of forest or even single trees can facilitate avian movement to resource sites, which may be particularly important for specialist species such as ground and bark foraging insectivores (Martensen et al. 2008; Trollope et al. 2009). Figure 9 identifies areas where there may be some potential for habitat patch restoration.

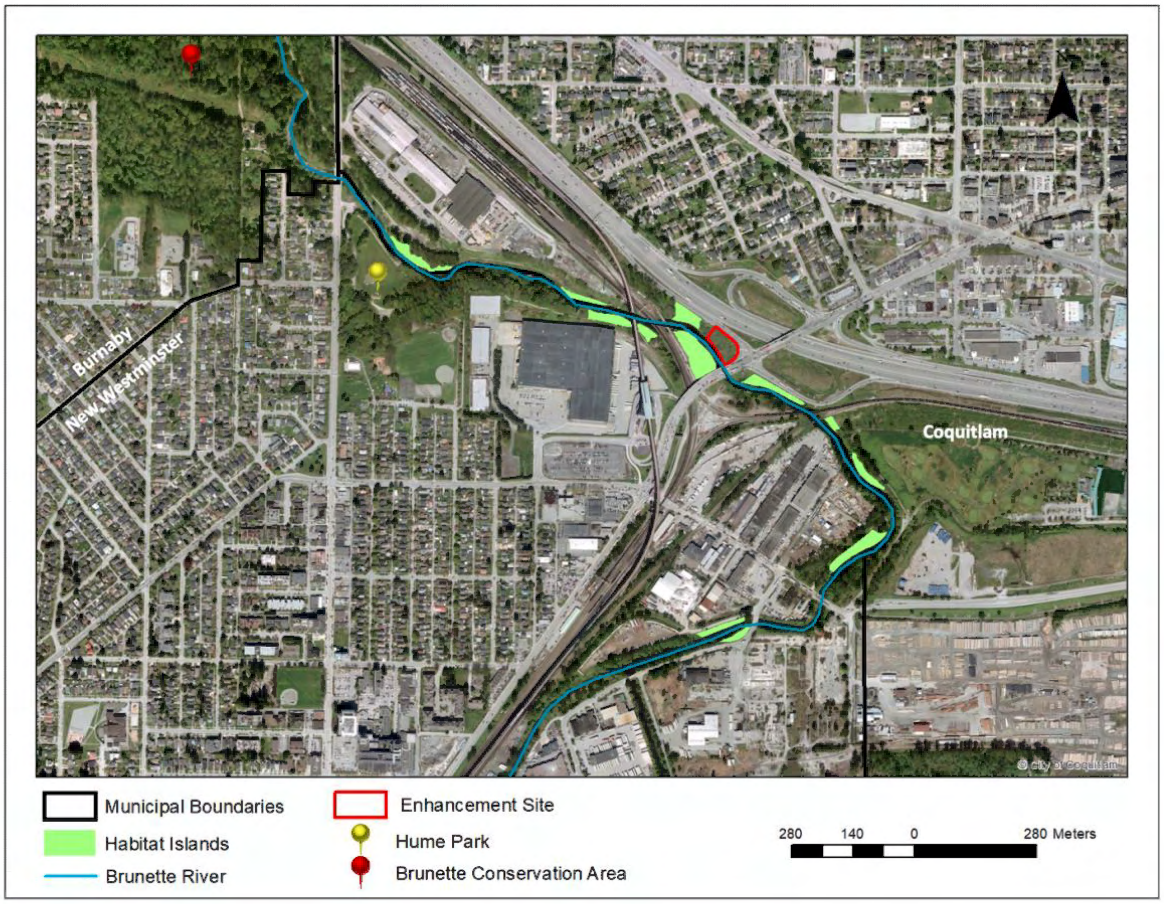

Figure 9. Potential habitat patches within the Brunette corridor that can act as both habitat islands and "stepping stones" connecting more disturbed southern portions of the river to Hume Park and the Brunette Conservation Area.

It is important to note that this short discussion of landscape connectivity is meant to frame this project in the wider context of the Brunette River, rather than to propose specific next steps for corridor restoration. Landscape planning is an intricate and ambitious endeavor that is out of the scope of this report. Though the appropriate methods for designing large areas is surrounded by much controversy, they can involve the use of many different tools, for instance: cost-benefit analysis, target-driven algorithms (C-plan, Marxan etc.), and various GIS modelling techniques (Rouget et al. 2006). In Rouget et al. (2006), for instance, they use a target-driven, systematic assessment in an attempt to maximize habitat suitability, biodiversity, and capture different environmental gradients that can then facilitate the movement of biotas across a range of spatial (landscape-level) and temporal (evolutionary) scales.

Moreover, landscape planning does not end with design, but demands the collaboration of many agencies and stakeholders (Knight et al. 2006). This may be especially true for the Brunette corridor, as it covers several municipalities, private land, and has many groups with a vested interest in its restoration. Efforts have already been made to plan for the future of the Brunette with the creation of the Brunette Basin Watershed Plan in 2001 by the Metro Vancouver Regional District in partnership with the Brunette Basin Coordinating Committee and the Sapperton Fish and Game Club (Metro Vancouver 2011). This report has since informed works such as the Ecological Health and Action Plan and the Experience the Fraser Program (Metro Vancouver 2011; Metro Vancouver et al. 2012). Though specific details regarding landscape design are not mentioned, these plans discuss the restoration and reconnection of green spaces with the aim of improving ecological and recreational values throughout the corridor.

With the threat of climate change, large-scale riparian restoration is necessary now more than ever. Although predictions are uncertain, the general consensus is that the PNW will see warmer temperatures in the summer and wetter conditions in the winter (Beechie et al. 2013). Elsner et al. (2010) and Mote & Salathe (2010) predict that by 2080, temperatures will have increased by 3.5°C and there will be a 5% increase in precipitation. Water temperatures in the region could increase by 6% by the end of this century (Beechie et al. 2013). Wetter winters will likely cause higher peak flows; however, there may be a decrease in summer low flows by anywhere from 10 to 70% of current values. Given that the Brunette already experiences high hydrological variation (high wet to dry flow ratios), warm water temperatures, and low DO (GVRD 2001; Rood & Hamilton 1994), these predicted outcomes are worrisome. Furthermore, higher temperatures will likely lead to hotter, drier summer conditions in the riparian zone, particularly in areas that have no canopy cover to regulate moisture and temperature regimes at the surface (Moore et al. 2005).

9.0. Conclusion

The Brunette basin has endured decades of degradation caused by urbanization, industrialization, and other forms of land development. Though extensive efforts have been made more recently to improve conditions in the Brunette River, the expansion of the Trans Mountain Pipeline undermines these achievements and causes concern for the species it supports, especially those that are currently at-risk. Perhaps in a more positive light, it could be argued that the TMX project provides an opportunity for restoration, at least within the construction site in question where exotic, invasive, and noxious weeds are dominant, native plant diversity is low, soils are deficient in nutrients, and there is a lack of habitat heterogeneity. This plan aims to address these issues, as well as integrate First Nations, particularly KFN, into the restoration process and final planting design.

Recommendations in this plan involve the planting of ecologically and culturally important species which must occur alongside strict non-native control measures to improve the survival and growth of native vegetation. This outcome was determined on the basis that such species are contributing to the suppression of a native riparian community, and that with thorough planning, execution, and monitoring, this project can assist in its recovery, at least within the limitations of the site. Appropriate native species were identified using several criteria including but not limited to: their BEC classification, site suitability, importance to KFN and other local First Nations, and functional role within the ecosystem. Functions relating to such elements as structure (e.g. shading, nesting, perching), sustenance (e.g. berries, seeds, organic matter), and water quality (e.g. erosion-control, slope stabilization, contaminant uptake) were incorporated wherever possible to maximize the positive effect of this project for aquatic and terrestrial biotas. In addition to revegetation, habitat features were prescribed as an effective way of increasing habitat availability as plantings establish.

Though baseline data collection also involved water quality sampling, it was realized throughout this process that some issues such as seasonally warm water temperatures could not be targeted with this project. This was due to the previously unrealized extent of human infrastructure within the restoration site that prohibits the planting of shade-producing species nearer the river, and largely dictates the locations of plantings in general. Unfortunately, tree establishment is limited throughout the site, which also restricts the ability of plantings to provide structure and control shade-intolerant species such as Reed Canarygrass in the long-term. Further, refinement of this plan may need to take into account uncertainties with regards to infrastructural constraints such as the designated easement width for the Brunette Interceptor. Such uncertainties may further limit the positive outcome of this project.

Indeed, urban stream restoration is a daunting task. Its capacity is challenged by severity of degradation, spatial expanse of human infrastructure, future population increases, land ownership, and even high property values relative to non-urbanized streams (Bernhardt & Palmer 2007). These issues are further compounded by the threat of climate change, which impacts the ecosystem both directly and indirectly, creates uncertainty, and adds another tier to the planning process (e.g. prioritization; Beechie et al. 2013). Continued collaboration between local governments, private land owners, and streamkeeper groups, landscape-level planning, and reinstating natural processes are perhaps the most important elements to consider moving forward. Future improvements might concentrate on less impacted locations upstream starting from the Brunette Conservation Area whilst not disregarding smaller habitat patches that will provide refuge and "stepping stones" for mobile species (Wintle et al. 2019). Though it is necessary that riparian planting be made a priority for this ecosystem, these actions must be complimented with efforts to reduce point-source pollution, create in-stream structure, and improve the hydrology of the basin (Booth 2005). Despite the many challenges facing the Brunette River, these endeavors give hope for the future of this ecosystem and the biotas that depend on it.

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Appendix A. Regulatory Environment

Table A1. Summary of some of the major environmental laws and regulations that might be considered before conducting restoration work and how they might pertain to specific project actions.

	General Description	Potential Project Implications
Federal		
***Fisheries Act*[1]**	**Section 35(1):** Protects all fish from serious harm including any alteration to, or destruction of, fish habitat **Section 34(1):** and 36: Prohibits the addition of any deleterious substances into fish-bearing watercourses	May pertain to timing of revegetation (i.e. immediately after construction) and works involving heavy invasive removal Must use BMPs to reduce potential sediment deposition such as quick cover crops and/or mulch
***Species at Risk Act*[2]**	**Section 32(1):** Prohibits the killing, harming, harassing, capturing, or taking of an individual listed as at-risk **Section 33:** Prohibits the damaging or destroying of habitat necessary for an endangered or threatened species, or an extirpated species provided a reintroduction plan is recommended in the recovery strategy	Given that the area is designated critical habitat, invasive removal must be conducted to minimize risk to Nooksack Dace A SARA permit may be necessary for restoration projects outside of offsetting activities reported in the application for authorization under paragraph 32(2)(b) This would include invasive species removal and replanting within the 15 m buffer next to the river
***Migratory Birds Convention Act*[3]**	**Section 12(1):** Protects migratory birds from being killed, captured, or taken, or their nests being destroyed, damaged, disturbed, or removed	Must avoid heavy Himalayan Blackberry removal within the regional timing window for migratory birds
Provincial		
***Wildlife Act*[4]**	Regulates projects that may have an effect on wildlife, such as birds **Section 34:** Prohibits the taking, molesting, injuring, or destroying of a bird, its egg, or the nest of an eagle, heron, burrowing owl, osprey, gyrefalcon, or peregrine falcon, or the nest of another species while in use	Restoration likely only has the potential to affect nests of passerines, as no other wildlife operations (e.g. fish or wildlife sampling) are to be conducted This regulation emphasizes the obligation to consider birds and their nests during invasive species removal

	General Description	Potential Project Implications
Provincial		
***Water Sustainability Act*[5]**	**Sections 9, 10, and 11:** Regulates activities for water use and aquatic ecosystem protection including changes "in and about a stream" Regulation encompasses any modification to the stream environment, including riparian vegetation[6]	May apply to this plan with respect to restoration in the riparian zone in which case an Approval application would be submitted This measure likely only pertains to substantial bank stabilization efforts and/or work near the high-water-mark. Further consultation is recommended
***Riparian Areas Protection Act*[7]**	**Section 12:** Requires municipal or regional governments to protect riparian areas within their jurisdiction from developmental impacts (applies only to certain districts in the province, including the Metro Vancouver Regional District) Riparian Areas Protection Regulation protects riparian areas from development (Streamside Protection and Enhancement Area [SPEA])	Activities conducted to improve fish habitat are acceptable within SPEAs, as long as they are conducted using BMPs[9] Consultation with a QEP would likely be required if heavy machinery is used to remove invasive species due to potential sedimentation; however, this may not be necessary for manual removal, as long as stability is ensured[9]. Further consultation is recommended
***Weed Control Act*[10]**	**Section 2:** Requires that land owners prevent the spread of noxious invasives (regional and/or provincial) on their land for the purpose of protecting natural resources, the economy, and society Regulation provides guidelines for working with invasive species such as cleaning machinery and transporting vegetative waste[11]	MoTI is responsible for the containment and control of specified weeds on their land, which extends to others working within highway right-of-ways In addition to invasive and noxious weed removal efforts laid out in the plan, it is important that equipment is cleaned thoroughly (including boots etc.) and vegetation is properly disposed of
***Integrated Pest Management Act*[12]**	**Section 3:** Prohibits the use of a pesticide in any way that may cause adverse effects, and regulates the handling transport, and disposal of pesticides **Section 4:** A license must be held for the use of most pesticides **Section 73:** Regulation prohibits pesticide use in the PFZ, a minimum of 10 m from the high-water-mark[13]	Himalayan Blackberry and other invasive species respond well to pesticide application, though this control method will only be used after all other methods have been exhausted Chemical control of certain invasive species may be warranted up to 1 m of the high-water-mark if necessary, for management and contingency purposes

[1]Canada Fisheries Act (1985); [2]Canada Species at Risk Act (2002); [3]Canada Migratory Birds Convention Act (1994); [4]BC Wildlife Act (1996); [5]BC Water Sustainability Act (2014); [6]BC Water Sustainability Regulation (2016); [7]BC Riparian Areas Protection Act (1997); [8]BC Riparian Areas Protection Regulation (2019); [9]Gov BC (nd); [10]BC Weed Control Act (1996); [11]BC Weed Control Regulation (1985); [12]BC Integrated Pest Management Act (2003); [13]BC Integrated Pest Management Regulation (2004).

Appendix B. Soil Conditions

Table B1. **Raw data for the five soil pits dug within the restoration area. Soil descriptions were guided by the Soils Illustrated Field Descriptions Manual (Watson 2014) and the Field Handbook for the Soils of Western Canada (Pennock et al. 2015).**

		Soil Pit A	Soil Pit B	Soil Pit C	Soil Pit D	Soil Pit E
UTM Coordinates		0508708, 5453500	0508720, 5453513	0508708, 5453533	0508684, 5453532	0508689, 5453551
Characteristics						
LFH	Thickness (cm)	<2	<3	<3	<2	<2
Humus Form		Moder	Moder	Moder	Moder	Moder
A – Topsoil	Thickness (cm)	14	20	15	10	12
	Texture	-	Sandy loam	Sandy loam	Sandy loam	Sandy loam
	Structure	Soft, granular	Soft, granular	Soft, granular	Soft, granular	Soft, granular
	Color	-	10YR 2/2 – very dark brown	10YR 2/2 – very dark brown	10YR 4/2 – dark greyish brown	10YR 2/2 – very dark brown
	pH	-	7.0 (neutral)	7.0 (neutral)	6.0 (acidic)	7.0 (neutral)
	Nutrients (N/P)	-	Very low/moderate	Very low/moderate	Low/moderate	Very low/moderate
B – Upper Subsoil	Thickness (cm)	16	14	8	15	24
	Texture	Sandy loam	Loamy sand	Loamy sand	Sandy loam	Loamy sand
	Structure	Single-grained	Single-grained	Single- grained	Granular	Singled- grained
	Color	2.5Y 5/3 – light olive brown	2.5Y 3/2 – very dark greyish brown	2.5Y 4/2 – dark greyish brown	2.5Y 4/4 – olive brown	2.5Y 3/2 very dark greyish brown
	pH	6.5 (slightly acidic)	7.0 (neutral)	7.0 (neutral)	6.0 (acidic)	7.0 (neutral)
	Nutrients	Low/moderate	Very low/moderate	Very low/moderate	Very low/moderate	Very low/moderate
	Depth to mottling (cm)	32	30	26	27	38

		Soil Pit A	Soil Pit B	Soil Pit C	Soil Pit D	Soil Pit E
UTM Coordinates		0508708, 5453500	0508720, 5453513	0508708, 5453533	0508684, 5453532	0508689, 5453551
Characteristics						
B – Lower Subsoil	**Depth to layer (cm)**	41	37	32	40	47
	Texture	-	Sandy clay loam	Sandy clay loam	Sandy clay loam	Sandy clay loam
	Structure	Sub-angular blocky	Sub-angular blocky	Sub-angular blocky	Sub-angular blocky	Sub-angular blocky
	Color	-	2.5 Y3/3 – dark olive brown	2.5Y 4/4 – olive brown	2.5Y 5/3 – light olive brown	2.5Y 4/3 – olive brown
	pH	-	7.0 (neutral)	7.0 (neutral)	6.5 (slightly acidic)	7.5 (alkaline)
	Nutrients (N/P)	-	Very low/high	Very low/high	Very low/moderate	Very low/moderate
Additional Information						
Coarse Fragments		Abundant, variable Size increases with depth	Moderate, variable	Moderate, variable	Very abundant, variable, size increases with depth	Moderate, variable
Rooting Depth		24	20	22	25	29
Root Size Classes		Plentiful, very-fine to coarse	Plentiful, very-fine to fine	Abundant, very fine to medium	Plentiful, very-fine to fine	Plentiful, very-fine to fine
Soil Fauna		Abundant (larvae, worms, millipede)	Moderate	Moderate	Moderate (larvae, worms)	Low
Notes		Color change in upper subsoil indicates illuviation	Garbage found buried in subsoil High OM relative to A and D	High OM relative to A and D	Color change in upper subsoil indicates illuviation	High OM relative to A and D

*Soil layers were mixed for Soil Pit A, as methods were subsequently changed. Therefore, characteristics for mixed soil are presented in the "Upper Subsoil" section.

Appendix C. Vegetation Inventory

Inventory of understory vegetation surveyed in July 2020 within the Brunette River restoration area. Native and exotic statuses were obtained from E-Flora BC (2019). Frequency descriptions were adapted from the DAFOR scale (Wilson 2011) and combined with the Daubenmire (1959) cover classes where: rare=0-5%, occasional=6-25%, frequent=26-50%, abundant=51-75%, and dominant=76-100%. Regions in which certain species are considered noxious are denoted by codes: BN-Bulkley-Nechako, CK-Central Kootenay, CS-Columbia-Shuswap, EK-East Kootenay, NO-North Okanagan, PR-Peace Region, C-Cariboo, and TN-Thompson-Nicola.

Table C1. Understory vegetation inventory for the High-slope Blackberry management unit.

Species	Common Name	Status	Priority/Status Information	Avg. Cover (%)	SE	Frequency
Shrubs						
Acer circinatum	Vine Maple	Native		3.00	3.00	Rare
Cornus stolonifera	Red-osier Dogwood	Native		7.50	7.50	Occasional
Oemleria cerasiformis	Indian Plum	Exotic		11.00	7.19	Occasional
Rosa nutkana	Nootka Rose	Exotic		3.00	3.00	Rare
Rubus armeniacus	Himalayan Blackberry	Invasive	Regional/municipal containment/control[1,2]	76.00	5.51	Dominant
Symphoricarpos albus	Common Snowberry	Native		0.50	0.50	Rare
Herbs						
Cirsium arvense	Creeping Thistle	Noxious		6.50	3.50	Occasional
Holcus mollis	Creeping Velvetgrass	Exotic		4.00	2.80	Rare
Phalaris arundinacea	Reed Canarygrass	Invasive		19.50	4.50	Occasional
Vicia cracca	Bird Vetch	Exotic		4.00	2.80	Rare

[1]IMISWG (2020); [2]BC Community Charter (2004); [3]ISCBC (2020b); [4]ISCMV (2020).

Table C2. Understory vegetation inventory for the Remnant Riparian management unit.

Species	Common Name	Status	Priority/Status Information	Avg. Cover (%)	SE	Frequency
Shrubs						
Physocarpus capitatus	Pacific Ninebark	Native		7.50	5.00	Occasional
Rosa spp.	Mixed Rose	Native		11.50	6.84	Occasional
Rubus armeniacus	Himalayan Blackberry	Invasive	Regional/municipal containment/control[1,2]	52.25	7.24	Abundant
Symphoricarpos albus	Common Snowberry	Native		0.50	0.33	Rare
Herbs						
Agrostis spp.	Bentgrass	Exotic		2.00	1.48	Rare
Anthoxanthum odoratum	Sweet Vernal Grass	Exotic		0.50	0.33	Rare
Calystegia sepium	Hedge Bindweed	Nuisance	Regional control[3], unregulated species of concern[4]	8.50	3.90	
Cirsium arvense	Creeping Thistle	Noxious	Provincially noxious[5], municipal control[2]	6.11	2.10	Rare
Epilobium ciliatum	Fringed Willowherb	Native		1.75	1.49	Rare
Equisetum arvense	Field Horsetail	Native		0.25	0.25	
Equisetum telmateia	Giant Horsetail	Native		12.00	4.77	Occasional
Galium aparine	Cleavers	Noxious	Regionally noxious (PR)[5]	1.50	1.50	Rare
Hypericum perforatum	Common St. John's Wort	Nuisance	Regional/municipal control[3,2], unregulated species of concern[5]	0.50	0.33	Rare
Impatiens glandulifera	Himalayan Balsam	Invasive	Regional/municipal containment/control[1,2]	5.00	2.15	Rare
Lapsana communis	Common Nipplewort	Exotic		0.25	0.25	Rare
Lotus corniculatus	Common Birdsfoot Trefoil	Exotic		1.50	1.50	Rare
Phalaris arundinacea	Reed Canarygrass	Invasive	Regional control[3], municipal control[2]	14.75	6.51	Occasional
Phleum pretense	Common Timothy	Exotic		0.25	0.25	Rare
Ranunculus repens	Creeping Buttercup	Nuisance	Unregulated species of concern[4]	0.25	0.25	Rare
Tanacetum vulgare	Common Tansy	Noxious	Regional containment/control[1], regionally noxious (BN, CK, CS, EK, NO)[5]	1.50	1.50	Rare
Vicia cracca	Bird Vetch	Exotic		1.25	0.42	Rare
Vicia hirsuta	Tiny Vetch	Exotic		1.50	1.50	Rare

[1]IMISWG (2020); [2]BC Community Charter (2004); [3]ISCMV (2020); [4]Horticulture Advisory Committee (HAC; 2018); [5]ISCBC (2020b).

Table C3. Understory vegetation inventory for the Snowberry Shrubland Management Unit.

Species	Common Name	Status	Priority/Status Information	Avg. Cover (%)	SE	Frequency
Shrubs						
Oemleria cerasiformis	Indian Plum	Native		1.36	1.31	Rare
Rosa nutkana	Nootka Rose	Native		8.64	4.36	Occasional
Rubus armeniacus	Himalayan Blackberry	Invasive	Regional/municipal containment/control[1,2]	7.95	3.45	Occasional
Rubus parviflorus	Thimbleberry	Native		1.59	1.30	Rare
Rubus spectabilis	Salmonberry	Native		3.41	3.27	Rare
Sambucus racemose	Red Elderberry	Native		1.36	1.31	Rare
Symphoricarpos albus	Common Snowberry	Native		8.86	4.29	Occasional
Herbs						
Agrostis spp.	Bentgrass	Exotic		6.36	2.09	Occasional
Anthoxanthum odoratum	Sweet Vernal Grass	Exotic		5.91	2.19	Occasional
Bromus inermis	Smooth Brome	Exotic	Municipal control[2], potential to be minor to moderately invasive[3]	1.36	1.36	Rare
Calystegia sepium	Hedge Bindweed	Nuisance	Regional control[4], unregulated species of concern[5]	0.23	0.23	Rare
Carex scoparia	Pointed Broom Sedge	Native		0.23	0.23	Rare
Cirsium arvense	Creeping Thistle	Noxious	Provincially noxious[6], municipal control[2]	3.41	1.76	Rare
Cirsium vulgare	Bull Thistle	Nuisance	Regional/municipal control[4,2], unregulated species of concern[6]	0.45	0.30	Rare
Dactylis glomerata	Orchard Grass	Exotic	Municipal control[2]	2.73	1.83	Rare
Elymus repens	Quackgrass	Noxious	Regionally noxious (PR)[6]	8.41	4.54	Occasional
Epilobium ciliatum	Fringed Willowherb	Native		0.23	0.23	Rare
Festuca arundinacea	Tall Fescue	Exotic		1.36	1.36	Rare
Festuca sp.	Fescue	Exotic		0.45	0.30	Rare
Galium aparine	Cleavers	Noxious	Regionally noxious (PR)[6]	4.55	2.04	Rare
Holcus lanatus	Common Velvet Grass	Exotic		7.73	3.61	Occasional
Holcus mollis	Creeping Velvet Grass	Exotic		0.68	0.35	Rare
Hypericum perforatum	Common St. John's Wort	Nuisance	Regional/municipal control[4,2], unregulated species of concern[3]	2.05	1.34	Rare

Species	Common Name	Status	Priority/Status Information	Avg. Cover (%)	SE	Frequency
Herbs						
Juncus effuses	Common Rush	Native		1.82	1.35	Rare
Juncus tenuis	Poverty Rush	Native		0.23	0.23	Rare
Lactuca serriola	Prickly Lettuce	Invasive		0.45	0.30	Rare
Lepidium sp.	Peppergrass	Unknown	Regionally noxious (C, NO, PR, TN)[6]	1.59	1.36	Rare
Leucanthemum vulgare	Oxeye Daisy	Noxious		3.64	3.40	Rare
Lotus corniculatus	Common Birdsfoot Trefoil	Exotic		3.86	3.38	Rare
Melilotus albus	White Sweet Clover	Exotic		0.23	0.23	Rare
Phalaris arundinacea	Reed Canarygrass	Invasive	Regional control[4], municipal control[2]	8.18	3.52	Occasional
Phleum pretense	Common Timothy	Exotic		7.27	2.25	Occasional
Plantago lanceolata	Ribwort Plantain	Nuisance	Unregulated species of concern[3]	1.82	1.35	Rare
Poa sp.	Bluegrass	Exotic	Potential to be minor to moderately invasive[3]	12.50	4.26	Occasional
Ranunculus acris	Meadow Buttercup	Exotic		0.23	0.23	Rare
Rumex acetosella	Common Sheep Sorel	Nuisance	Unregulated species of concern[3]	1.59	1.36	Rare
Rumex crispus	Curled Dock	Nuisance	Unregulated species of concern[6]	0.23	0.22	Rare
Solanum dulcamara	Bittersweet Nightshade	Nuisance	Unregulated species of concern[6]	1.36	1.36	Rare
Solidago canadensis	Canada Goldenrod	Exotic		0.23	0.23	Rare
Sonchus asper	Spiney Sow Thistle	Nuisance	Unregulated species of concern[3]	0.23	0.23	Rare
Tanacetum vulgare	Common Tansy	Noxious	Regional containment/control[1], regionally noxious (BN, CK, CS, EK, NO)[6]	1.59	1.36	Rare
Tragopogon dubius	Yellow Salsify	Nuisance	Unregulated species of concern[3]	0.45	0.30	Rare
Trifolium hybridum	Alsike Clover	Exotic		1.59	1.36	Rare
Unk. Poaceae sp.	Unknown Grass	Unknown		1.36	1.36	Rare
Vicia cracca	Bird Vetch	Exotic		3.64	1.73	Rare
Vicia hirsuta	Tiny Vetch	Exotic		10.23	3.54	Occasional
Vicia sativa	Common Vetch	Exotic		2.73	1.83	Rare

[1]IMISWG (2020); [2]BC Community Charter (2004); [3]Perzoff (2009); [4]ISCMV (2020); [5]HAC (2018); [6]ISCBC (2020b).

Table C3. Understory vegetation inventory for the Roadside Cover Management Unit.

Species	Common Name	Status	Priority/Status Information	Avg. Cover (%)	SE	Frequency
Shrubs						
Rubus armeniacus	Himalayan Blackberry	Invasive	Regional/municipal containment/control[1,2]	9.00	3.68	Occasional
Herbs						
Agrostis spp.	Bentgrass	Exotic		9.50	3.39	Occasional
Anthoxanthum adoratum	Sweet Vernal Grass	Exotic		3.50	2.92	Rare
Elymus repens	Quackgrass	Noxious	Regionally noxious (PR)[3]	6.50	3.50	Occasional
Equisetum arvense	Field Horsetail	Native		0.50	0.50	Rare
Erigeron canadensis	Horseweed	Native		2.00	0.50	Rare
Hypericum perforatum	Common St. John's Wort	Nuisance	Regional/municipal control[4,2], unregulated species of concern[3]	0.50	0.50	Rare
Hypochaeris radicata	Hairy Cat's Ear	Exotic		4.00	2.80	Rare
Lactuca serriola	Prickly Lettuce	Invasive		6.50	3.50	Occasional
Lolium sp.	Ryegrass	Exotic		1.00	0.61	Rare
Medicago sativa	Alfalfa	Exotic	Potential to be moderately invasive[3]	30.50	7.00	Frequent
Melilotus albus	White Sweet Clover	Exotic		1.00	0.61	Rare
Phalaris arundinacea	Reed Canarygrass	Invasive	Regional control[4], municipal control[2]	3.00	3.00	Rare
Plantaga lanceolate	Ribwort Plantain	Nuisance	Unregulated species of concern[5]	0.50	0.50	Rare
Poa sp.	Bluegrass	Exotic	Potential to be moderately invasive[5]	3.50	2.92	Rare
Rock/bare ground		N/A		19.50	12.50	Occasional
Salidago canadensis	Canada Goldenrod	Exotic		0.50	0.50	Rare
Tanecetum vulgare	Common Tansy	Noxious	Regional containment/control[1], regionally noxious (BN, CK, CS, EK, NO)[3]	9.00	3.68	Occasional
Unk. Mowed Area		N/A		12.50	4.50	Occasional
Unk. Poaceae sp.	Unknown Grass	Unknown		2.00	0.50	Rare
Vicia hirsuta	Tiny Vetch	Exotic		0.50	0.50	Rare
Vulpia sp.	Fescue Subset	Unknown		3.00	3.00	Rare

[1]IMISWG (2020); [2]BC Community Charter (2004); [3]ISCBC (2020b); [4]ISCMV (2020); [5]Perzoff (2009).

Table C5. Tree Inventory for each management unit within the restoration site.

Species	Common Name	Status	Height (m)	DBH (cm)	Growth Stage[2]	Condition
Roadside Cover						
Malus domestica	Paradise Apple	Exotic	4.28	-	-	Healthy
Snowberry Shrubland						
Abies grandis	Grand Fir	Native	2.00	2.55	Sapling	Stunted
Acer macrophyllum 1	Bigleaf Maple 1	Native	1.47	-	Sapling	Healthy
Acer macrophyllum 2	Bigleaf Maple 2	Native	1.90	1.27	Sapling	Healthy
Acer macrophyllum 3	Bigleaf Maple 3	Native	5.89	4.46	Sapling	Healthy
Acer macrophyllum 4	Bigleaf Maple 4	Native	5.13	4.46	Sapling	Healthy
Acer macrophyllum 5	Bigleaf Maple 5	Native	5.14	3.18	Sapling	Healthy
Acer macrophyllum 6	Bigleaf Maple 6	Native	5.65	3.50	Sapling	Healthy
Acer macrophyllum 7	Bigleaf Maple 7	Native	5.88	5.09	Sapling	Healthy
Acer macrophyllum 8	Bigleaf Maple 8	Native	2.88	2.23	Sapling	Healthy
Malus fusca	Pacific Crabapple	Native	-	-	Sapling	Healthy
Pinus sylvestris	Scot's Pine	Invasive[1]	6.78	-	Sapling	Unhealthy
Populus trichocarpa	Black Cottonwood	Native	2.35	3.82	Sapling	Healthy
Thuja plicata	Western Redcedar	Native	1.95	3.50	Sapling	Stunted
Remnant Riparian						
Acer macrophyullum 9	Bigleaf Maple 9	Native	-	-	-	Healthy
Alnus rubra 1	Red Alder 1	Native	-	-	Pole	Healthy
Alnus rubra 2	Red Alder 2	Native	4.89	9.55	Pole	Healthy
Alnus rubra 3	Red Alder 3	Native	-	-	Sapling	Healthy
Alnus rubra 4	Red Alder 4	Native	-	-	Sapling	Healthy
Total Number of Trees						**19**
Stems/ha						**58.16**

[1]Perzoff (2009). [2]Koning (1999).

Appendix D. Water Quality

Table D1. Raw water quality data for the Brunette River taken beside the restoration area by Cassandra Harper.

Date	Water Quality Points	Location (UTM)	Temp (°C)	pH	DO (mg/L)	Conductivity (uS/cm)	Turb 1 (FNU)	Turb 2 (FNU)	Turb 3 (FNU)	Avg. Turbidity
2020-05-30	WQ1	508580, 5453579	16.80	7.26	7.80	197.30	5.93	4.58	4.39	4.97
	WQ2	508592, 5453558	16.70	7.23	7.96	198.50	4.26	5.78	4.99	5.01
	WQ3	508631, 5453574	16.80	7.37	7.90	196.20	4.74	3.53	3.85	4.04
	WQ4	508655, 5453541	16.90	7.36	8.11	192.20	3.16	2.97	2.89	3.01
	WQ5	508692, 5453499	16.20	7.32	8.07	188.00	4.37	4.01	3.50	3.96
	WQ6	508714, 5453444	17.20	7.36	7.38	195.70	3.96	3.21	3.33	3.50
	WQ7	508765, 5453427	17.20	7.29	7.91	196.60	2.81	2.95	2.61	2.79
	Point Avg.		**16.83**	**7.31**	**7.88**	**194.93**				**3.90**
	SE		**0.13**	**0.02**	**0.09**	**1.37**				**0.33**
2020-06-28	WQ1	508580, 5453579	17.40	7.12	7.67	203.70	5.80	8.95	5.44	6.73
	WQ2	508592, 5453558	17.30	7.01	7.26	225.20	3.85	3.69	4.63	4.06
	WQ3	508631, 5453574	17.70	7.14	7.67	204.30	4.07	6.47	3.09	4.54
	WQ4	508655, 5453541	17.80	7.18	7.82	204.50	7.09	4.69	3.99	5.26
	WQ5	508692, 5453499	14.80	7.17	8.15	215.60	1.49	1.45	1.13	1.36

Date	Water Quality Points	Location (UTM)	Temp (°C)	pH	DO (mg/L)	Conductivity (uS/cm)	Turb 1 (FNU)	Turb 2 (FNU)	Turb 3 (FNU)	Avg. Turbidity
	WQ6	508714, 5453444	18.10	7.17	7.79	206.90	3.48	2.37	2.87	2.91
	WQ7	508765, 5453427	18.10	7.18	7.92	205.10	6.06	3.54	3.33	4.31
	Point Avg.		**17.31**	**7.14**	**7.75**	**209.33**				**4.17**
	SE		**0.44**	**0.02**	**0.10**	**3.07**				**0.64**
2020-07-12	WQ1	508580, 5453579	16.90	7.31	8.35	185.30	3.68	3.23	3.85	3.59
	WQ2	508592, 5453558	15.20	7.59	7.07	437.70	2.97	2.09	2.49	2.52
	WQ3	508631, 5453574	17.40	7.69	8.89	188.30	2.47	3.03	2.28	2.59
	WQ4	508655, 5453541	17.50	7.85	8.77	189.40	2.55	2.40	3.18	2.71
	WQ5	508692, 5453499	14.70	7.98	8.47	220.00	1.76	1.18	2.99	1.98
	WQ6	508714, 5453444	17.60	7.76	7.89	190.50	2.54	2.73	2.46	2.58
	WQ7	508765, 5453427	17.60	7.70	9.01	191.00	4.93	2.42	2.25	3.20
	Point Avg.		**16.70**	**7.70**	**8.35**	**228.89**				**2.74**
	SE		**0.46**	**0.08**	**0.26**	**35.08**				**0.20**
2020-07-27	WQ1	508580, 5453579	20.10	6.99	8.60	225.30	7.41	15.80	9.83	11.01
	WQ2	508592, 5453558	15.40	7.15	8.73	432.50	8.24	8.18	8.22	8.21
	WQ3	508631, 5453574	21.00	7.42	9.14	227.60	3.90	4.86	3.86	4.21
	WQ4	508655, 5453541	21.20	7.47	9.09	230.70	5.19	8.14	4.98	6.10

Date	Water Quality Points	Location (UTM)	Temp (°C)	pH	DO (mg/L)	Conductivity (uS/cm)	Turb 1 (FNU)	Turb 2 (FNU)	Turb 3 (FNU)	Avg. Turbidity
	WQ5	508692, 5453499	16.20	7.48	7.86	165.00	2.73	2.48	1.93	2.38
	WQ6	508714, 5453444	21.00	7.28	7.46	232.30	3.31	3.53	3.77	3.54
	WQ7	508765, 5453427	21.70	7.43	9.30	236.10	4.93	6.23	4.20	5.12
	Point Avg.		**19.51**	**7.32**	**8.60**	**249.93**				**5.80**
	SE		**0.98**	**0.07**	**0.26**	**31.82**				**1.12**
2020-08-09	WQ1	508580, 5453579	18.30	7.21	7.31	212.60	4.55	4.76	7.24	5.52
	WQ2	508592, 5453558	16.00	7.22	7.23	438.80	4.04	4.21	4.03	4.09
	WQ3	508631, 5453574	18.60	7.23	7.28	214.40	5.82	7.13	6.45	6.47
	WQ4	508655, 5453541	18.70	7.25	7.86	213.70	2.78	2.40	3.52	2.90
	WQ5	508692, 5453499	15.60	7.46	6.69	201.00	1.59	0.77	1.76	1.37
	WQ6	508714, 5453444	18.50	7.21	5.37	216.40	4.63	5.42	2.93	4.33
	WQ7	508765, 5453427	19.30	7.23	7.93	219.50	3.28	2.99	2.98	3.08
	Point Avg.		**17.86**	**7.26**	**7.10**	**245.20**				**3.97**
	SE		**0.55**	**0.03**	**0.33**	**32.34**				**0.64**
2020-08-24	WQ1	508580, 5453579	18.80	7.18	6.74	201.90	4.24	2.57	3.32	3.38
	WQ2	508592, 5453558	16.50	7.12	7.01	383.40	3.26	3.42	4.37	3.68
	WQ3	508631, 5453574	20.10	7.18	7.48	207.70	2.28	3.31	3.60	3.06

Date	Water Quality Points	Location (UTM)	Temp (°C)	pH	DO (mg/L)	Conductivity (uS/cm)	Turb 1 (FNU)	Turb 2 (FNU)	Turb 3 (FNU)	Avg. Turbidity
	WQ4	508655, 5453541	20.10	7.24	7.46	208.00	3.31	3.49	3.42	3.41
	WQ5	508692, 5453499	16.30	7.39	7.32	207.10	1.16	2.14	1.72	1.67
	WQ6	508714, 5453444	19.70	7.21	5.49	207.60	5.98	6.40	3.35	5.24
	WQ7	508765, 5453427	20.50	7.22	7.45	211.20	2.85	2.45	3.10	2.80
	Point Avg.		**18.86**	**7.22**	**6.99**	**232.41**				**3.32**
	SE		**0.67**	**0.03**	**0.27**	**25.19**				**0.41**
2020-09-06	WQ1	508580, 5453579	18.00	7.31	7.24	219.20	3.56	3.15	3.33	3.35
	WQ2	508592, 5453558	18.00	7.35	7.21	412.00	13.70	15.20	16.90	15.27
	WQ3	508631, 5453574	18.30	7.30	7.81	218.90	2.81	3.08	3.84	3.24
	WQ4	508655, 5453541	18.30	7.32	7.68	219.20	2.70	2.14	2.93	2.59
	WQ5	508692, 5453499	16.00	7.41	7.37	210.60	2.43	1.66	1.44	1.84
	WQ6	508714, 5453444	18.20	7.15	6.12	221.50	2.93	3.20	2.54	2.89
	WQ7	508765, 5453427	18.70	7.18	8.12	224.40	3.00	2.42	2.55	2.66
	Point Avg.		**17.93**	**7.29**	**7.36**	**246.54**				**4.55**
	SE		**0.33**	**0.03**	**0.24**	**27.62**				**1.80**
2020-09-24	WQ8	508712, 5453468	15.40	6.73	7.07	92.50	24.50	27.80	28.00	26.77
	Point Avg.		**15.40**	**6.73**	**7.07**	**92.50**				**26.77**

Table D2. **Water temperature criteria of some salmonids potentially associated with the Brunette River. Table adapted from Beschta et al. (1987).**

	Migration (°C)	Spawning (°C)	Incubation (°C)	Juvenile Rearing (°C)		
				Preferred	Optimum	Upper Lethal
Chinook	-	5.6-13.9	5.0-14.4	7.3-14.6	12.2	25.2
Fall	10.6-19.4	-	-	-	-	-
Spring	3.3-13.3	-	-	-	-	-
Summer	13.9-20.0	-	-	-	-	-
Chum	8.3-15.6	7.2-12.8	4.4-13.3	11.2-14.6	13.5	25.8
Coho	7.2-15.6	4.4-9.4	4.4-13.3	11.8-14.6	-	25.8
Pink	7.2-15.6	7.2-12.8	4.4-13.3	5.6-14.6	10.1	25.8
Sockeye	7.2-15.6	10.6-12.2	4.4-13.3	11.2-14.6	15.0	24.6
Steelhead	-	3.9-9.4	-	7.3-14.6	10.0	24.1
Rainbow	-	2.2-20.0	-	-	-	-
Cutthroat	-	6.1-17.2	-	9.5-12.9	-	23.0

Appendix E. Fauna Lists

Table E1. Fauna recorded by Cassandra Harper within the restoration area and adjacent reach during site visits.

Species	Common Name	Status[1]	Sighting(s)/sound(s)/sign(s)
Birds			
Anas platyrhynchos	Mallard		Sightings
Ardea herodias fannini	Great Blue Heron	Blue-listed, Special Concern	Sightings
Bombycilla cedrorum	Cedar Waxwing		Sightings
Buteo jamaicensis	Red-tailed Hawk		Sightings
Canis latrans	Coyote		Scat
Catharus ustulatus	Swainson's Thrush		Sound
Colaptes auratus	Northern Flicker		Sightings, sound
Contopus sordidulus	Western Wood Peewee		Sighting
Geothlypis trichas	Common Yellowthroat		Sighting
Megaceryle alcyon	Belted Kingfisher		Sightings
Melospiza melodia	Song Sparrow		Sightings
Mergus merganser	Common Merganser		Sighting
Poecile atricapillus	Blacked-capped Chickadee		Sightings
Spinus tristis	American Goldfinch		Sightings
Strigiformes	Owl		Pellets
Thyomanes bewickii	Bewick's Wren		Sighting
Turdus migratorius	American Robin		Sightings
Mammals			
Castor canadensis	American Beaver		Sighting, tree damage nearby
Lontra canadensis	North American River Otter		Sightings, dens/scat/slides
*Ondatra zibethicus**	Common Muskrat		Sighting
Amphibians/Reptiles			
Lithobates catasbeianus	American Bullfrog		Sightings
Thamnophis siralis	Common Gartersnake		Sightings

*If identified correctly; may have been *Myocastor coypus* (Nutria). [1]BC Conservation Data Center (CDC; 2020).

Table E2. Fauna documented by others within the Brunette River corridor (near the restoration area).

Species	Common Name	Status[1]	Associated Habitat
Fish			
Ameiurus nebulosus[2]	Brown Bullhead	Exotic	Warm ponds/lakes/slow rivers/muck[4]
Cottus asper[3]	Prickly Sculpin		Clear-turbid streams/rivers/lakes[4]
Cyprinus carpio[2]	Common Carp	Exotic	Warm lakes/larger rivers/muck[4]
Entosphenus tridentatus[3]	Pacific Lamprey		Anadromous/rivers/lakes/ocean[4]
*Gasterosteus aculeatus**[3]	Threespine Stickleback		Streams/rivers/ocean[4]
*Hybognathus hankinsoni**[2]	Brassy Minnow	Blue-listed	Sloughs/rivers/ocean[4]
Lampetra ayresi[3]	River Lamprey		Anadromous/rivers/lakes/ocean[4]
Lepomis gibbosus[3]	Pumpkinseed	Exotic	Ponds/small lakes/slow rivers[4]
Micropterus salmoides[3]	Largemouth Bass	Exotic	Warm lakes/large, slow rivers[4]
Mylcheilus caurinus[3]	Peamouth Chub		Shallow lakes/rivers[4]
*Oncorhynchus clarkii**[3]	Coastal Cutthroat Trout	Blue-listed	Several life history forms[4]
*Oncorhynchus gorbuscha**[2]	Pink Salmon		Anadromous/streams (short-term)/ocean[4]
*Oncorhynchus keta**[2]	Chum Salmon		Anadromous/streams (short-term)/ocean[4]
*Oncorhynchus kisutch**[2]	Coho Salmon		Anadromous/streams/ocean[4]
*Oncorhynchus mykiss**[3]	Rainbow Trout		Resident/lakes/streams[4]
*Oncorhynchus mykiss**[3]	Steelhead Trout		Anadromous/streams/ocean[4]
*Oncorhynchus tshawytscha**[2]	Chinook Salmon	Special Concern/Threatened/Endangered	Stream-type/ocean-type/large rivers[4]
Pacifastacus leniusculus[3]	Signal Crayfish		Lakes/rivers/streams/estuaries[6]
Pomoxis nigromaculatus[2]	Black Crappie	Exotic	Warm ponds/lakes/slow rivers/brackish[4]
Ptychocheilus oregonensis[3]	Northern Pikeminnow		Shores/lakes/large rivers[4]
*Rhinichthys cataractae**[3]	Nooksack Dace	Red-listed, Endangered	Fast rock-bedded streams/high riffles[5]
Richardsonius balteatus[3]	Redside Shiner		Fast streams/lake tributaries[4]
Salvelinus malma[3]	Dolly Varden		Anadromous/resident/streams/lakes/ocean[4]
Birds[7]			
Aix sponsa	Wood Duck		Wetland
Anas platyrhynchos	Mallard		Wetland
Anas stepera	Gadwall		Wetland
Ardea herodias fannini	Great Blue Heron	Blue-listed, Special Concern	Woodland/wetland[8]
Bombycilla cedrorum	Cedar Waxwing		Riparian shrub

Species	Common Name	Status[1]	Associated Habitat
Birds[7]			
Buteo jamaicensis	Red-tailed Hawk		Grassland/forest edge
Butorides virescens	Green Heron	Blue-listed	Woodland/wetland[8]
Calypte anna	Anna's Hummingbird		Open woodland[8]
Cardellina pusilla	Wilson's Warbler		Riparian Shrub/small trees[8]
Catharus ustulatus	Swainson's Thrush		Deciduous forest
Certhia americana	Brown Creeper		Coniferous forest
Charadrius vociferus	Killdeer		Grassland[8]
Colaptes auratus	Northern Flicker		Open woodland[8]
Contopus sordidulus	Western Wood Peewee		Open woodland[8]
Empidonax traillii	Willow Flycatcher		Riparian shrub
Falco columbarius	Merlin		Forest[8]
Geothylpis trichas	Common Yellowthroat		Grassland
Haemorhous mexicanus	House Finch		Shrub
Haliaeetus leucocephalus	Bald Eagle		Forest[8]
Hirundo rustica	Barn Swallow	Blue-listed, Threatened	Grassland/wetland
Megaceryle alcyon	Belted Kingfisher**		Wetland/bank burrows[8]
Megascops kennicotti	Western Screech Owl	Blue-listed, Threatened	Open woodlands[8]
Melospiza melodia	Song Sparrow		Forest/shrub
Mergus merganser	Common Merganser**		Wetland[8]
Oreothylpus celata	Orange-crowned Warbler		Riparian shrub
Pheucticus melanocephalus	Black-headed Grosbeak		Deciduous forest/shrub
Picoides pubescens	Downy Woodpecker		Forest (particularly deciduous)
Pipilo maculatus	Spotted Towhee		Shrub
Poecile atricapillus	Black-capped Chickadee		Mixed forest
Psaltriparus minimus	Bushtit		Forest edge
Selphorus rufus	Rufous Hummingbird		Open woodland[8]
Setophaga petechia	Yellow Warbler		Riparian Shrub/small trees
Spinus tristis	American Goldfinch		Shrub
Stelgidopteryx serripennis	Northern Rough-winged Swallow		Wetland/bank burrows
Tachycineta bicolor	Tree Swallow		Wetland
Tachycineta thalassina	Violet-green Swallow		Open woodland[8]

Species	Common Name	Status[1]	Associated Habitat
Birds[7]			
Thyromanes bewickii	Bewick's Wren		Shrub/deciduous forest
Turdus migratorius	American Robin		Urban/deciduous forest
Tyto alba	Barn Owl	Red-listed, Threatened	Grassland/forest edge
Vireo cassinni	Cassin's Vireo		Mixed forest
Vireo gilvus	Warbling Vireo		Riparian shrub/small trees
Mammals*			
Canis latrans[9]	Coyote		Large range/open-semi woodland[11]
Castor canadensis[9]	American Beaver		Lakes/ponds/streams/slough[11]
Corynorhinus townsendii[10]	Townsends Big-eared Bat	Blue-listed	Arid grassland/coastal forest[11]
Eptesicus fuscus	Big Brown Bat		Arid grassland/forest[11]
Lontra canadensis	North American River Otter		Marine and freshwater wetland[11]
Mephitis mephitis	Striped Skunk		Urban/forest/edges/meadows/wetlands[11]
*Mustela erminea**[9]	Short-Tailed Weasel		Riparian/dense understory/coarse wood[1]
Myotis lucifugus[10]	Little Brown Myotis	Yellow-listed, Endangered	Arid grassland/forest[11]
Neovison vison[9]	American Mink		Riparian forest/wetland/abundant cover[1]
Ondatra zibethicus[9]	Common Muskrat		Riparian wetland/lakes/slow rivers[1]
Procyon lotor[9]	Racoon		Urban/riparian forest[11]
Sorex bendirii[9]	Pacific Water Shrew	Red-listed, Endangered	Riparian (maple-alder-cedar)/cover[11]
Ursus americanus	American Black Bear		Mixed forest/dense understory/wetlands[1]
Amphibians/Reptiles			
*Anaxyrus boreas**[9]	Western Toad	Yellow-listed, Special Concern	Shallow waterbodies/forest/grassland[12]
*Chrysemys picta bellii**[9]	Western Painted Turtle	Red-listed, Threatened	Shallow lakes/ponds/slow streams[12]
Lithobates catesbeianus[9]	American Bullfrog	Exotic	Ponds/lakes/slow stream[12]
Rana aurora	Northern Red-legged Frog	Blue-listed, Special Concern	Riparian forest/wetland[12]
Rana clamitans	Green Frog	Exotic	Permanent ponds/slow streams[12]
Thamnophis sirtalis fitchi	Common Gartersnake		Riparian/wetland/forest/grassland[12]

*Species with sub-populations that are of conservation concern. Statuses only listed if at-risk populations are associated with the Brunette basin.

**Bird species recorded in the management unit during field days but not recorded in Butler et al. (2015).

***Several species of mouse, vole, mole, shrew, squirrel, and hare may also be present (Coulthard & Cummings 2018).

[1]CDC (2020); [2]LGL et al. (2012); [3]BC Habitat Wizard (2020); [4]Roberge et al. (2002); [5]DFO (2018); [6]Bondar et al. (2005); [7]Butler et al. (2015); [8]Cornell Lab of Ornithology (2019); [9]DHC & RAE (2015); [10]Coulthard & Cummings (2018); [11]E-Fauna BC (2019); [12]BC Ministry of Water, Land and Air Protection (MWLAP; nd).

Appendix F. Priority Invasive Species

Manual and Mechanical Control

Manual and mechanical control methods can be an effective way to remove infestations of invasive species, especially when working in environmentally sensitive areas (MoTI 2020b). Patches of Himalayan Blackberry, Reed Canarygrass, and Quackgrass can be removed through grubbing or digging with the excavator. In some instances, removal of above-ground growth using a brush cutter may be necessary for ease of access (ISCMV & Metro Vancouver 2019a). For grubbing, it is essential that 30 cm of the cane is retained to ensure that the roots can be located. Blackberry removal is easiest during flowering as energy reserves are allocated to above-ground growth.

Although grubbing is generally the recommended approach to controlling Himalayan Blackberry (ISCMV & Metro Vancouver 2019a), this may not be the best option on high slopes or on the river bank, as large-scale soil disturbance increases the risk of destabilization (Bennett 2007). In the High-slope Blackberry unit, using a “grapple” attachment on the excavator may be more appropriate as it can uproot Himalayan Blackberry with minimal soil disturbance (Sound Native Plants 2021a). The removal of thickets must be done between 18 August and 25 March during the least-risk window for migratory birds, as described in Environment & Climate Change Canada (2018).

Reed Canarygrass is mixed with other species throughout all management units, but there may be certain patches that require removal. Similar to Himalayan Blackberry, below-ground growth must be removed to prevent re-sprouting (ISCMV & Metro Vancouver 2020). In addition, Quackgrass is not a priority invasive from a regional standpoint, but should be removed from the site. It is an aggressive competitor shown to dramatically deplete nutrients from the soil (Ontario Ministry of Agriculture, Food, and Rural Affairs [OMAFRA] 2016) and inhibit the establishment of young forest (Gover & Reese 2017). Its concentration in one patch makes eradication before spread feasible. The pit created from removal may demand refilling (Calhoun 2006).

Manual control methods alone should be sufficient for the removal of other priority vegetation, as well. Himalayan Balsam produces only by seed and can be controlled by hand-pulling before flowering (Crampton 2018, as cited in ISCMV & Metro

Vancouver 2019b). Disturbance during seeding is advised against as it can facilitate explosive seed distribution. Bull Thistle can also be effectively hand-pulled (King County 2014). Common Tansy and Common St. John's Wort may be controlled by repeated pulling (ISCBC 2014), though grubbing is likely more effective as both species have a short rhizome system (Garry Oak Ecosystems Recovery Team [GOERT] 2012; King County 2010). Complete eradication of Hedge Bindweed and Creeping Thistle from the site is unlikely given their extensive rhizome networks, but they can be managed through careful grubbing (Clackamas Soil and Water Conservation District [CSWCD] 2009-2020; Whatcom County Noxious Weed Board [WCNWB] nd).

Cultural Control

Cultural control methods are those that indirectly impact invasive species through environmental manipulation (Oneto nd). Building communities based primarily on their invasion resistance, for example, is a common tactic when replanting disturbed sites. Cultural control through planting trees is cited as the most effective strategy for the management of Reed Canarygrass (ISCMV & Metro Vancouver 2020). Planting trees within the restoration site will provide long-term maintenance to other shade-intolerant invasives as well, though use of this strategy is somewhat limited due to infrastructure.

Chemical Control

Herbicides provide an alternative for invasive species control when other options have been exhausted. All treatments should be by spot-application or targeted, and the volume of herbicide used should be reduced with each pass (MoTI 2020b). In general, a 10 m Pesticide Free Zone (PFZ) is maintained along watercourses unless glyphosate products are proposed for regulated noxious weed control in which case the PFZ can be reduced to 1 m (MoTI 2020b). Several species found at the project site are listed in either the *Weed Control Act* or the *Forest and Range Practices Act*, and could be removed up to 1 m from the river using glyphosate, if required (ISCMV & Metro Vancouver 2019a). Glyphosate may also be used to manage patches of Himalayan Blackberry or Quackgrass outside of the PFZ if other methods prove ineffective (Curran & Lingenfelter 2017; ISCMV & Metro Vancouver 2019a). Himalayan Blackberry can be cut, let sprout to ~45 cm, then spot treated in the fall (Bennett 2007). For more information regarding safe herbicide use, see MoTI (2020b).

Table F1. Priority invasive species to be managed within the restoration area. Himalayan Blackberry and Reed Canarygrass should be maintained so as to increase growth potential of plantings; however, control of these species is unlikely given their prevalence in the Brunette corridor.

Priority Invasive (Common Name)	General Description	Control	Disposal/Prevention	Identification[1]
Calystegia sepium (Hedge Bindweed) 	Common in S.W. B.C. on disturbed sites, moist streamsides[1] Perennial herb reproduces by seed and by rhizome[1] Flowers from July to Sept[2] Vigorous climber that smothers native vegetation through twining[2]	Grubbing root system[3] Regular maintenance as new growth can re-sprout from root fragments and disturbance can cause germination of seeds[3] Chemical treatment with Glyphosate can be used outside of the PFZ during flowering or in the fall[3]	Can re-sprout from stems or roots if composted[4] Best to dispose of off-site at appropriate disposal facility If removed while in flower or seeding, place into thick plastic bag "head first"[4]	2.0 to 3.0 m long stems are glabrous to hairy and can be climbing or trailing Leaves are alternate, arrow-shaped with pointed tips, are glabrous to hairy White to deep pink flowers with heart-shaped to egg-shaped bracts
Cirsium arvense (Creeping Thistle) 	Can be found along roadsides, fields, and disturbed sites in W. B.C.[1] Perennial herb reproduces by seed and by rhizome[1] Buds appear late-May to mid-June and second flush of growth after seed set[5] Highly problematic; seeds viable for up to 20 years[6]	Only controlled through depletion of energy reserves[5] Individual young plants removed through grubbing[6] Late spring herbicide to above-ground growth and fall herbicide to below-ground growth said to be most effective method[5]	Flowers and seeds should never be composted, though it may be suitable to use non-flowering plant parts if they are first fragmented[6] Best to dispose of material off-site at appropriate facility	Branching, erect, glabrous stems ~ 0.3 to 2.0 m tall Leaves alternate, lance-shaped, spiny-toothed, and glabrous with dense, white hairs on underside Many flowers in open inflorescence, bracts glabrous Flowers pink to purple

Priority Invasive (Common Name)	General Description	Control	Disposal/Prevention	Identification[1]
Cirsium vulgare (Bull Thistle) 	Common in S. B.C. along roadsides, fields, and disturbed sites[1] Perennial herb reproduces entirely by seed[7] Germinates in spring and fall; seeds are viable for 1 to 3 years[7] Competitor - can reduce growth of tree seedlings[7]	Management focuses on preventing seed set[7] Pulling and grubbing rosettes should be done before flowering but after stems have bolted[7] Individuals should be prioritized and removal should occur in spring and summer for several years[7]	Flowering and seed plants disposed of off-site, as they form seeds post-removal[7] Seeds are dispersed by wind; careful handling is required[7] On-site disposal possible if fragment non-flowering plants[7]	Branches spreading, sparsely to densely hairy, ~0.3 to 2.0 m tall Leaves broadly lanceolate, deeply lobed, glabrous on upperside and woolly on underside with stout spines Several flower heads at end of branches Flowers disk-like, purple
Elymus repens (Quackgrass) 	Common in S. B.C. along roads and disturbed sites[1] Long-lived perennial grass reproduces by seed and extensive rhizome system[8] Grows in spring and fall, flowers in late June to July, seeds in Aug to Sept[8] Seeds remain viable for 1 to 6 years[8]	Significantly impacts forest growth if unmanaged[9] Pulling and hoeing[10] but rhizome system may demand soil removal and replacement[11] Solarization – leave plastic on patch for 5 to 7 days during summer[11] Chemical: 85-95% control[7]	Lack of information so general guidelines may be satisfactory Many grasses can re-sprout so composting is not recommended Generally, dispose of any invasive materials with seeds at appropriate facility[4]	Blades are 6 to 10 mm with smooth undersides and rough uppersides; ligules 0.25 to 1.5 mm long Inflorescence a spike ~5 to 15 cm long, erect, with one spikelet per node Similar to *Lolium perenne* but has "forward-facing" spikelets (pers. obs.)
Hypericum perforatum (St. John's Wort) 	Less common in S.W. B.C. but found along roadsides, fields, and disturbed sites[1] Perennial herb reproduces by seed and rhizome[12] Flowers and seeds from June to Sept[13] Seeds viable for up to 10 years[12]	Has been treated primarily with biological control for the last 25 years in B.C.[13] Repeated pulling or cutting before flowering may deplete root reserves and reduce seed production[13] Grubbing with mulch application also sufficient[12]	Not recommended that waste be left on-site even if before seeds develop, as individuals may continue to sprout vegetatively[14] Dispose of at appropriate facility	Stems erect, branched, glabrous, ~0.1 to 1.0 m tall Leaves lanceolate, and glabrous with translucent dots throughout Inflorescence heavily flowered with sharply pointed yellow petals, each with three styles

Priority Invasive (Common Name)	General Description	Control	Disposal/Prevention	Identification[1]
Impatiens glandulifera (Himalayan Balsam) 	Less common, found along streambanks, roadsides[1] Annual herb reproduces prolifically by seed[15] Flowers from June to Sept and seeds Aug to Sept[13] Seeds viable for 18 months[15] Attracts pollinators away from native species[16]	Roots are weak and shallow, allowing for easy hand-pulling[15] First pull in late May to early June before flowering, with follow-up later in summer to ensure no new sprouts[15] Trowel may be useful in compact areas[15]	Extreme care must be taken when working near, as seeds are explosively distributed when disturbed[15] Left on-site before flowers if first dried[15] Otherwise, transport off-site in bag to disposal facility[15]	Stems ~0.6 to 2.0 m tall, branched, erect to ascending, and glabrous Leaves stalked, egg-shaped to elliptic, opposite to whorled, and toothed One to many flowers, all with pouched sepals Flowers whitish to red, usually with purple spots
Phalaris arundinacea (Reed Canarygrass) 	Common in wet meadows, lakeshores, and ditches of S. B.C.[1] Perennial grass reproduces by seed and dense rhizome network[16] Seeds viable for up to 4 years[16] Forms monotypic stands, aggressive competitor[16]	Responds well to cultural control efforts such as shading/planting[17] Mulching around new plantings prevents competition[16] Smaller patches can be removed manually[16] Large patches may require combination of methods[16]	On-site disposal not recommended, as fragmented plant parts can re-sprout[16] Plants should be bagged and brought to disposal facility[17] Seed heads must be cut prior to removal to limit spread[17]	Stems reach 0.5 to 2.0 m Leaf blades flat with jagged margins, sheaths open, and ligules rounded Inflorescence a panicle with spreading branches Visually similar to *Dactylis glomerata* but the inflorescence is less "tufted" (pers. obs.)
Rubus armeniacus (Himalayan Blackberry) 	Common in many areas throughout S.W. B.C.[1] Shrub reproduces by seed, stem tips, and root buds[17] Seeds viable for many years[19] Forms thickets with little habitat value[18]	Success depends on removal of all parts[20] Removed by grubbing during flowering[18] Chemical treatment may be used in fall[18]	Cuttings can be left on-site if control occurs before seeding, but roots and root crowns must be removed[19] Garbage bags used for transport off-site to disposal facility[18]	Tall shrub 2.0 to 5.0 m long, trailing stems with stout, hooked prickles Leaves compound Five egg-shaped leaflets on first-year growth, otherwise three leaflets Flowers white to pink

Priority Invasive (Common Name)	General Description	Control	Disposal/Prevention	Identification[1]
Tanacetum vulgare (Common Tansy) 	Common in S. B.C. along roadsides, disturbed sites[1] Perennial herb reproduces mainly by seed but also has rhizome network[14] Grow April to June[21] Flowers July to Oct and seeds Aug to Nov[12] Seeds viable for 25 years[22]	For manual control, plants should be dug when first emerge in spring[21] Re-sprouting plants can be removed in the following summer and spring for as long as necessary[21] Mowing or hand-pulling before flowering marginally controls Common Tansy[14]	Protective clothing and gloves are recommended as plants are toxic[21] Waste must be bagged and disposed of at the appropriate facility during as plants produce seeds post-removal[21]	Stems are erect, branched, and solitary, can be glabrous to hairy, and are ~0.40 to 1.5 m tall Stem leaves are alternate, unstalked or short-stalked, pinnately cut; ultimate parts are deeply lobed Flower heads numerous, terminal, disk-like, yellow

*Photo credit from top to bottom: Brian Klinkenberg (2010); Brian Klinkenberg (2012); Brian Klinkenberg (2020); Jamie Fenneman (2007); Gordon Neish (2013); Nick Page (2005); Thayne Tuason (2017); Adolf Ceska (2006), and Brian Klinkenberg (2008).

[1]E-Flora BC (2019); [2]Plants for a Future (PFAF 2003); [3]WCNWB (nd); [4]OASISS (nd); [5]Gover et al. (2007); [6]CSWCD (2009-2020); [7]King County (2014); [9]OMAFRA (2016); [9]Gover & Reese (2017); [10]Curran & Lingenfelter (2017); [11]Calhoun (2006); [12]GOERT (2012); [13]ISCBC (2014); [14]Lebo (2007); [15]Metro Vancouver & ISCMV (2019b); [16]King County (2015); [17]Metro Vancouver & ISCMV (2020); [18]Metro Vancouver & ISCMV (2019a); [19]Soll (2004); [20]DiTomaso et al. (2013); [21]King County (2010); [22]ISCBC (2019).

Appendix G. High Activity Bear Areas

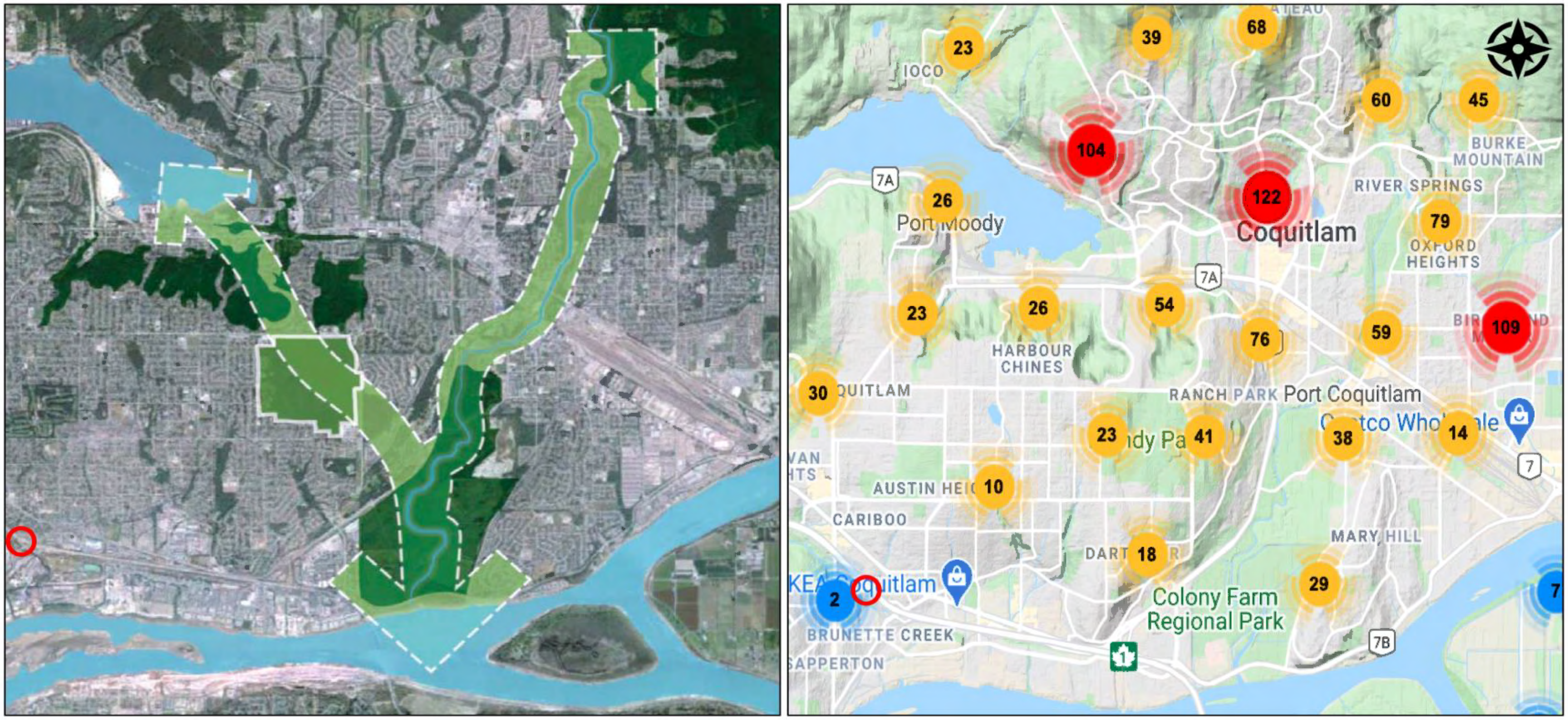


Figure G1. Location of the restoration site (hollow red circles) in proximity to potential bear activity areas. Left map shows notable "green corridors" in Coquitlam that have higher-than-normal bear activity (City of Coquitlam nd; C. Mahoney pers. comm., 1 March 2021). Right map shows bear sightings in areas near the restoration site from 1 March 2020 to 1 March 2021. Blue circles represent low, yellow circles represent medium, and red circles represent high number of bear sightings (WARP 2021).

Appendix H. Potential Species for Planting

Table H1. List of species considered for planting within the restoration area. This list has been included to show some of the decision-making that went into species selection, as well as provide alternative options for management and contingency purposes. Species considered for seeding are not shown in this list.

Potential Species	Common Name	FN Use?[1,2]	Height (m)[1,3,4]	Function	Moisture	Shade	Bear Smart?[15]	Super Star?[4]
Trees								
Abies grandis	Grand Fir	Y	80	Shade, nesting, food, cover[4]	M to D[4]	FS to Sh[4]	VL	
Acer macrophyllum	Bigleaf Maple	Y	35	Shade, stability[4], soil amending[5]	W to D[4]	FS to Sh[4]		Y
Alnus rubra	Red Alder	Y	20	Shade, nitrogen-fixing, aeration[5]	W to M[4]	FS to PSh[4]		Y
Betula papyrifera	Paper Birch	Y, KFN	30	Shade, stability[3], soil amending[5]	M and WD[4]	FS[13]		
Malus fusca	Pacific Crabapple	Y, KFN	12	Food, pollination[3], cover[4]	W to M[4]	FS to Sh[4]	M	
Crataegus douglasii	Black Hawthorn	Y, KFN	10	Shade, pollination, food[3]	W to M[4]	FS to PSh[4]		
Picea sichensis	Sitka Spruce	Y	70	Shade, food source[7]	MW to M[4]	FS to PSh[4]	VL	
Pinus contorta	Lodgepole Pine	Y	18	Shade, stability, soil amending[8]	M to D[4]	FS to PSh[4]	VL	Y
Populus trichocarpa	Black Cottonwood	Y	50	Shade, perching, nesting[3]	S to M[4]	FS to PSh[4]		Y
Pseudotsuga menziesii	Douglas-fir	Y	70	Shade, food, myccorhizae[5]	M to D[4]	FS to PSh[4]		Y
Rhamnus purshiana	Cascara	Y	10	Shade, food[9], erosion[10]	W to D[4]	FS to Sh[4]		Y
Salix lucida	Pacific Willow	Y	18	Nesting, cover, stability[3]	S to M[4]	FS to PSh[4]	VL	Y
Salix scouleriana	Scouler's Willow	Y	12	Nesting, cover, steep stability[3,9]	M and WD[4]	FS to PSh[4]	VL	
Thuja plicata	Western Redcedar	Y, KFN	60	Shade, myccorhizae[5]	W to M[4]	PSh to DSh[4]	VL	
Tsuga heterophylla	Western Hemlock	Y	60	Shade, nesting, food[5,6]	W to M[4]	PSh to DSh[4]	VL	
Shrubs								
Acer circinatum	Vine Maple	Y	8.0	Shade, stabilization, food[5]	M to D[4]	PSh to DSh[4]	VL	Y
Acer glabrum	Douglas Maple	Y	9.0	Shade, stabilization[9]	M to D[10]	FS to PSh[10]	VL	
Amelanchier alnifolia	Serviceberry	Y	6.0	Food, stabilization[9]	M to D[4]	FS to Sh[4]	H	
Ceanothus velutinus	Snowbrush		3.0	Stability[8], food, nitrogen-fixing[10]	M to D[4]	FS[14]	VL	
Cornus stolonifera	Red-osier Dogwood	Y	6.0	Food, bank stability[3]	S to M[4]	FS to PSh[4]	H	Y
Corylus cornuta	Beaked Hazelnut	Y, KFN	4.0	Stabilization[8], cover[6]	M to D[4]	PSh to DSh[4]		
Holodiscus discolor	Oceanspray	Y	4.0	Caterpillar host[11], food[3], stability[9]	M to D[4]	FS to Sh[4]		Y
Lonicera involucrata	Black Twinberry	Y, KFN	3.0	Stability, cover, pollination, food[3]	S to M[4]	FS to PSh[4]	M	Y

Potential Species	Common Name	FN Use?[1,2]	Height (m)[1,3,4]	Function	Moisture	Shade	Bear Smart?[15]	Super Star?[4]
Shrubs								
Mahonia aquifolium	Tall Oregon Grape	Y	2.5	Food[8], stabilization[9]	M to D[4]	FS to PSh[4]	L	Y
Oemleria cerasiformis	Indian Plum	Y	5.0	Food, stabilization[4]	M to D[4]	PSh to Sh[4]		
Oplopanax horridus	Devil's Club	Y	3.0	Food, browse, stream cover[10]	W to M[1]	FS to Sh[10]	H	
Paxistima mysinites	Falsebox		0.8	Stabilization[8], ground cover[10]	MD[9]	FS[10]		
Philadelphus lewisii	Mock Orange	Y	3.0	Pollination, cover, nectar[4]	M to D[4]	FS to PSh[4]	VL	
Physocarpus capitus	Pacific Ninebark	Y	4.0	Food, nesting, cover[11]	W to M[4]	FS to Sh[4]	VL	Y
Ribes bracteosum	Stink Currant	Y	3.0	Pollination, food source[10]	W to M[4]	PSh[10]	M	
Ribes sanguineum	Flowering Currant	Y	3.0	Stability, food, pollination[4]	M to D[4]	FS to PSh[4]		
Rosa nutkana	Nootka Rose	Y	3.0	Food, nesting[5], stabilization[9]	W to M[4]	FS to PSh[4]		Y
Rubus parviflorus	Thimbleberry	Y, KFN	3.0	Pollination, food[3], stabilization[4]	M[4]	FS to Sh[4]	M	Y
Rubus spectabilis	Salmonberry	Y, KFN	4.0	Food, cover[3], bank stability[4]	W to M[4]	PSh to Sh[4]	H	
Salix hookeriana	Hooker's Willow	Y	6.0	Nesting, cover, stability[3]	S to M[4]	FS to PSh[4]	VL	Y
Salix sitchensis	Sitka Willow	Y	8.0	Nesting, cover, stability[3]	S to M[4]	FS to PSh[4]	VL	Y
Sambucus racemosa	Red Elderberry	Y, KFN	5.0	Pollination, food, stability[3,12]	M to D[4]	FS to Sh[4]	H	
Spiraea douglasii	Hardhack	Y	2.0	Cover, stabilization[10,11]	W to M[4]	FS to Sh[5]	VL	
Symphoricarpos albus	Common Snowberry		2.0	Stability[9], food, cover, nesting[10]	MW to D[4]	FS to Sh[4]		Y
Herbs								
Arctostaphylos uva-ursi	Kinnikinnick	Y	0.2	Food source, stabilization[4]	M to D[4]	FS to PSh[4]	M	
Aruncus dioicus	Goat's Beard	Y	2.0	Food source[4]	M to D[4]	PSh to Sh[4]	VL	
Carex obnupta	Slough Sedge	Y	1.5	Stability, filter pollutants[3]	W to M[4]	FS to Sh[1]	M	Y
Juncus effusus	Common Rush		0.66	Stability, filter pollutants[3]	W to M[4]	FS[4]		
Polystichum munitum	Swordfern	Y	1.5	Groundcover, nest material[10]	M to D[4]	PSh to Sh[4]	VL	
Pteridium aquilinum	Bracken Fern	Y	0.7	Groundcover, nest material[10]	M to D[4]	FS to Sh[1]	VL	
Urtica dioica	Stinging Nettle	Y, KFN	3.0	Cover, Oregon Forestsnail[13]	M[1]	FS to Sh[1]		

[1]MacKinnon et al. (2004); [2]PGL (2018); [3]MoA (2012b); [4]Sound Native Plants (2021b); [5]Gov BC (2000); [6]CCD (nd); [7]Green Timber's Heritage Society GTHS; nd); [8]MoE (2012); [9]Enns et al. (2002); [10]Bressette (nd); [11]Aoki et al. (2005); [12]District of Saanich (2021); [13]Environment Canada (2016); [14]Taccogna and Munro (1995); [15]City of Coquitlam (2020).

Appendix I. Habitat Features

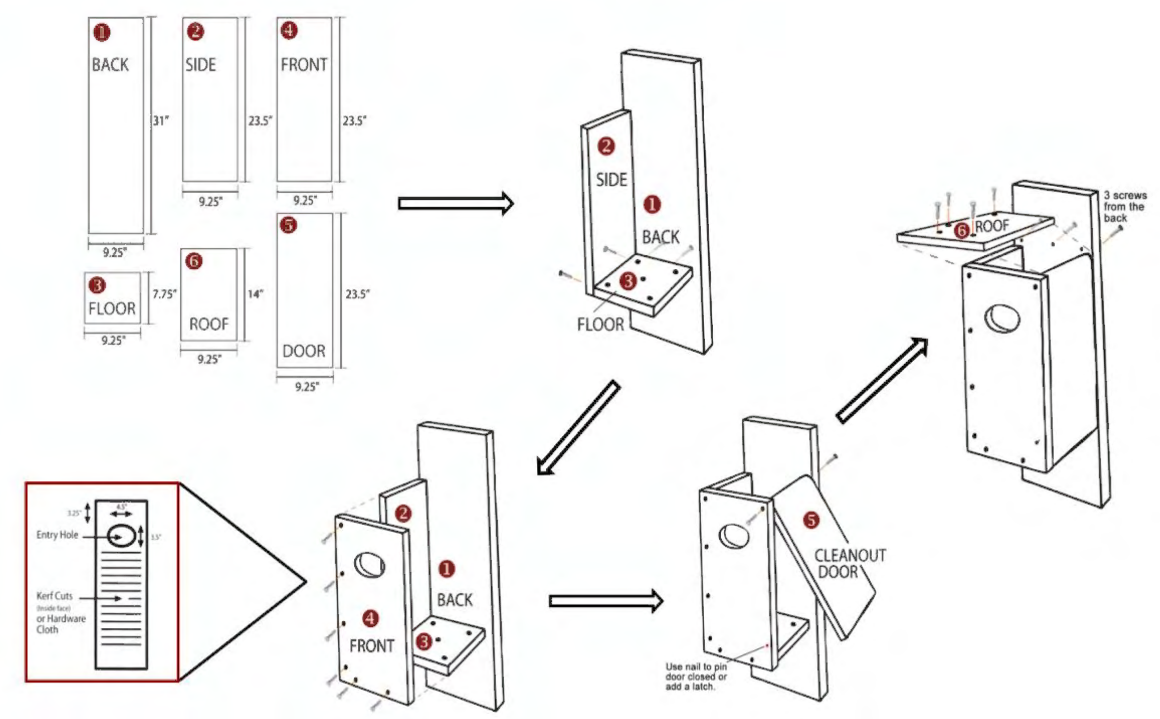


Figure I1. **Recommended bird box design for waterfowl and other species. Diagram modified from DUC (nd-a).**

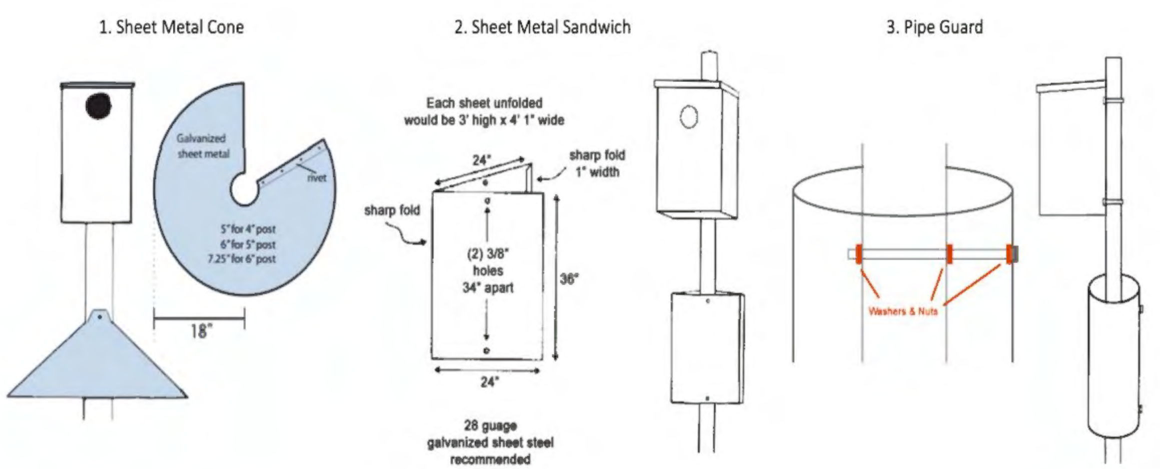


Figure I2. **Options for bird box predator protection devices. Diagram modified from DUC (nd-c). Similar designs may also be used for bat box post.**

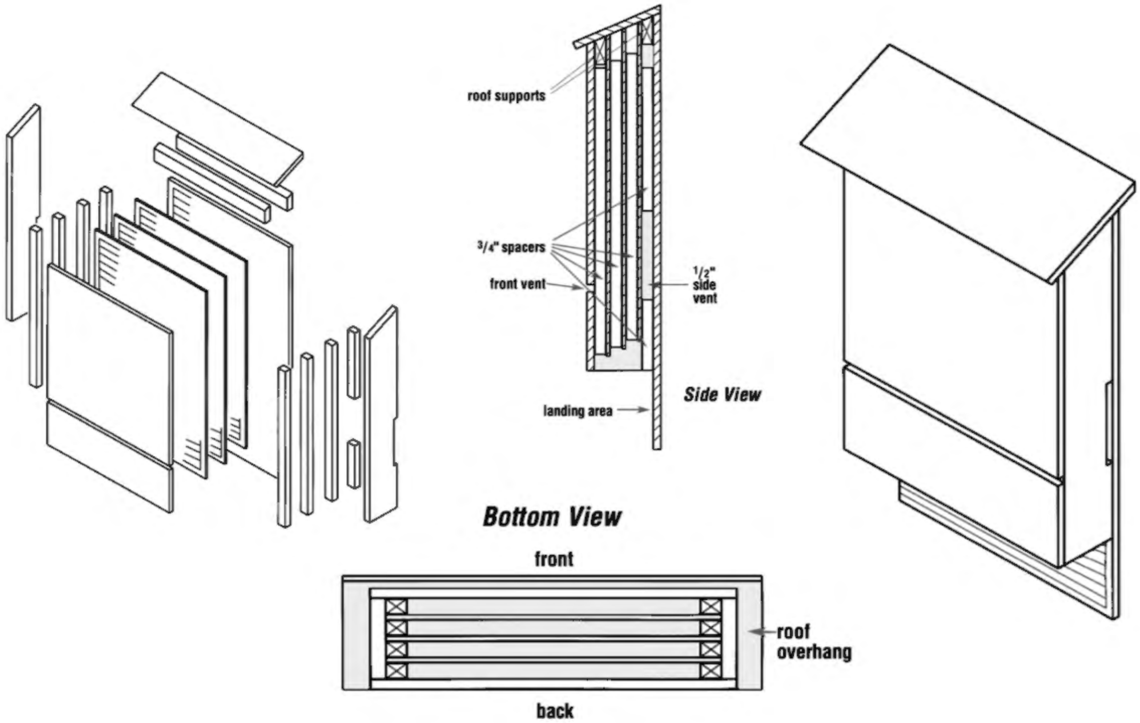


Figure I3. **Multi-chambered nursery bat house. Diagram modified from BCI (nd).**

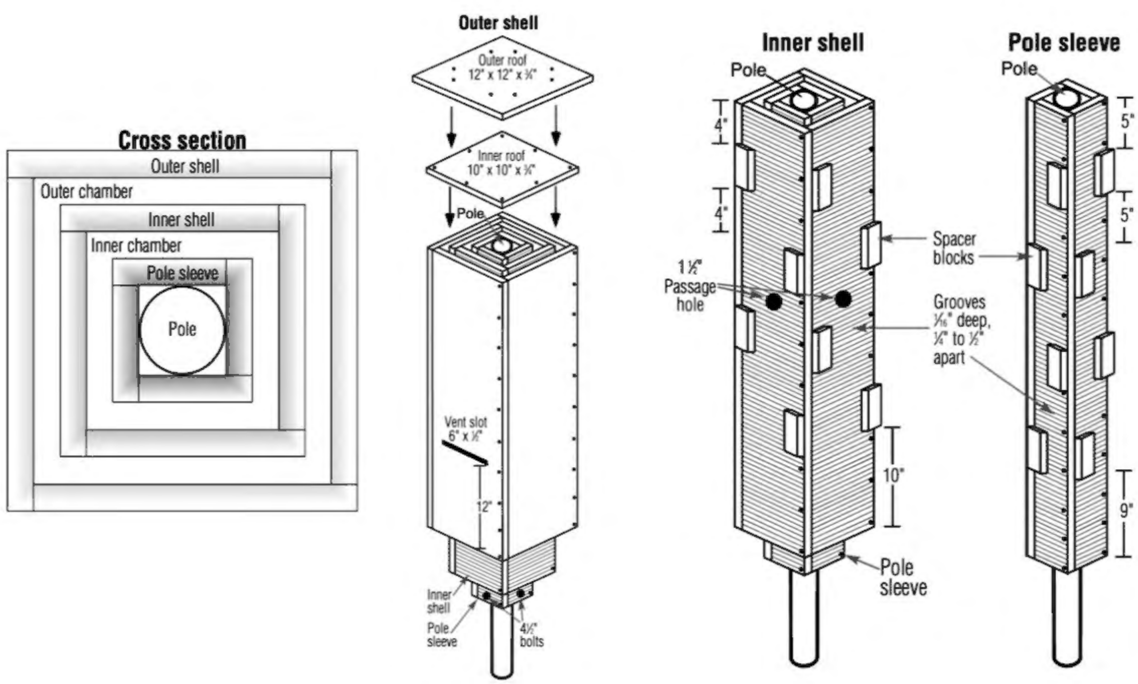
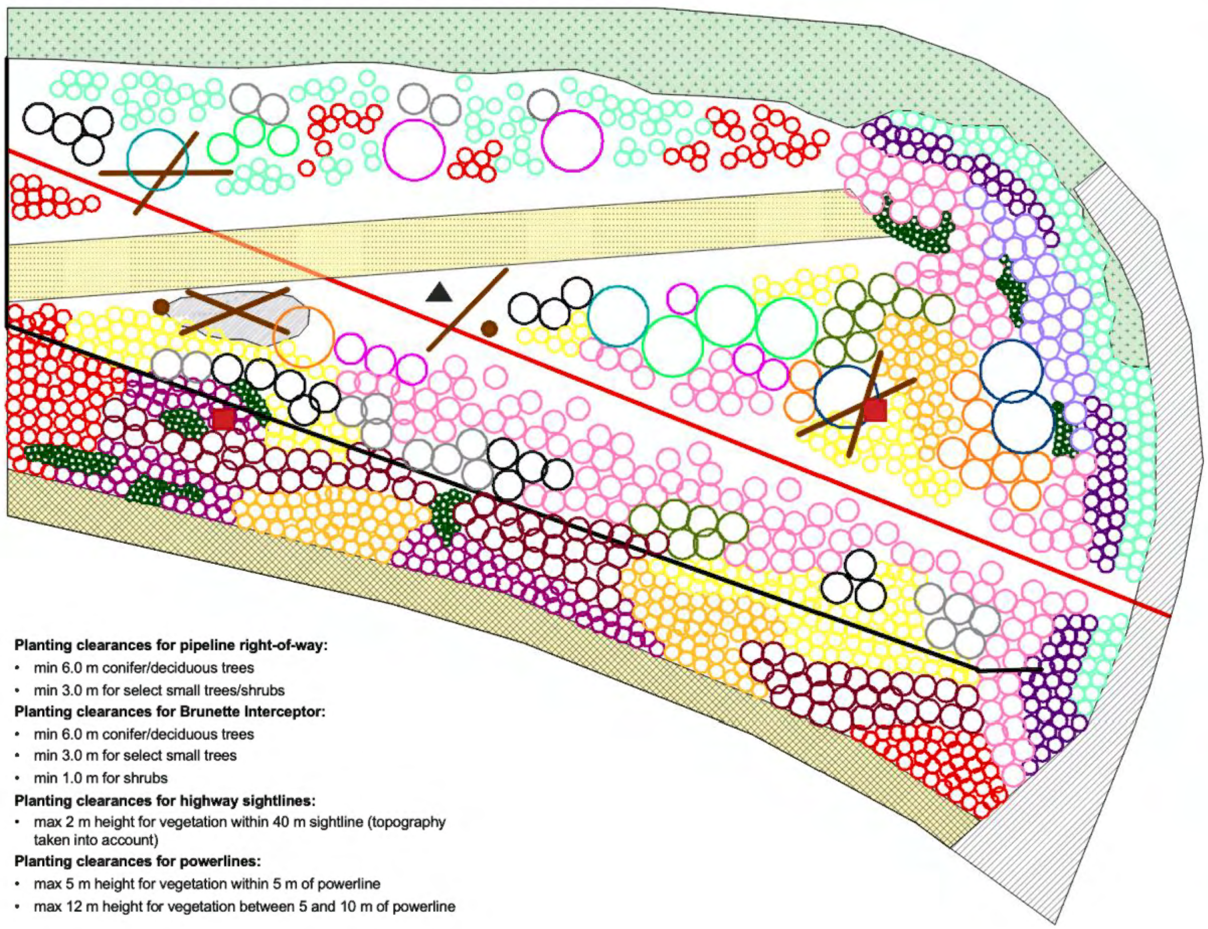


Figure I4. **Two-chamber rocket bat box design. Diagram modified from Tuttle et al. (2005).**

Appendix J. Proposed Planting Plan

Figure J1. Proposed planting plan for the restoration area showing potential species and locations, prescribed minimum spacing, beaver fence placement, habitat additions, and other features (Autodesk Inc. 2021).



	Scientific Name	Common Name	Quantity	Comments
Trees (variable sizes depict minimum spacing)				
	Abies grandis	Grand Fir	2	5-gal/4 m, microsite
	Acer macrophyllum	Bigleaf Maple	6	5-gal/2,4 m
	Alnus rubra	Red Alder	11	5-gal/2,4 m
	Crataegus douglasii	Black Hawthorn	19	5-gal/2 m
	Malus fusca	Pacific Crabapple	14	5-gal/2 m
	Rhamnus purshiana	Cascara	8	5-gal/2,4 m
	Salix scouleriana	Scouler's Willow	19	2-gal/2 m
	Thuja plicata	Western Redcedar	3	5-gal/4 m, microsite
Shrubs				
	Ceanothus velutinus	Snowbrush	84	2-gal/1.0 m
	Cornus stolonifera	Red-osier Dogwood	121	2-gal/1.5 m
	Lonicera involucrata	Black Twinberry	131	2-gal/1.0 m
	Oemleria cerasiformis	Indian Plum	25	2-gal/1.5 m
	Physocarpus capitatus	Pacific Ninebark	81	2-gal/1.5 m
	Rosa nutkana	Nootka Rose	147	1-gal/1.0 m
	Rubus parviflorus	Thimbleberry	172	1-gal/1.0 m
	Rubus spectabilis	Salmonberry	98	2-gal/1.0 m
	Symphoricarpos albus	Common Snowberry	169	2-gal/1.0 m
	S.douglasii/L.involucrata	Hardhack/Twinberry	478/319	stakes/0.5 m
Herbs				
	Poaceae sp.	Grass Mix	150 kg/ha	hydroseed/tack
	Poaceae sp. +	Grass + Forbs	50+kg/ha	broadcast/forb TBD
	Polystichum munitum	Swordfern	187	1-gal/0.5 m
	Urtica dioica	Stinging Nettle	100	harvest/prop.
Other				
	Coase wood		2+	add mix of species
	Standing dead wood		n/a	currently on-site
	Bird boxes w/predator protection		2+	final locations TBD
	Bat box w/ predator protection		1	final location TBD
	Beaver exclusion fencing		1	high-risk area
	Brunette Interceptor		n/a	easement unknown
	MoTI Maintenance		n/a	no planting zone

Appendix K. Project Budget

Table K1. Budget for restoration within the project area. Prices are approximate and include maximum costs for plant materials.

Item	Unit	Quantity	Price/Unit	Total Price
Snowberry Shrubland				
trees	5-gallon	45	$16.50-18.55	$812.20
select shrubs/small trees	2-gallon	143	$7.55-8.35	$1155.65
select shrubs	1-gallon	95	$3.95	$375.25
grass seed (w/o forbs)	kg	1.7	$35.00	$59.50
coarse wood mulch	yd^2	60	$45.00	$2700.00
labor (prep/plant/monitor etc.)	hr/1/2 stock	-	$30.00	$3871.55
beaver fence	m	75	$20.00	$1500.00
Bat box w/protection*	n/a	1	$300.00	$300.00
Unit Cost				$10774.15
Roadside Cover				
grass seed	kg	3.3	$35.00	$115.50
hydroseeding w/mulch, tack	kg	220	$~3.5X seed	$404.25 +
labor (prep/seed/monitor etc.)	hr	8	$30	$240.00
Unit Cost				$759.75
Remnant Riparian				
small trees	5-gallon	18	$18.55	$330.72
select shrubs/small trees	2-gallon	332	$7.55-7.95	$2585.84
select shrubs/ferns	1-gallon	337	$3.95-4.35	$1377.94
select shrubs	stakes	797	$1.45	$1155.27
coir fiber matting	yd^2	323	$2.50	$807.50
coarse wood mulch	yd^2	20	$45.00	$900.00
labor (prep/plant/monitor etc.)**	hr/1/2 stock	-	$30.00	$3974.89
bird box w/protection*	n/a	2	$110.00	$220.00
Unit Cost				$11352.16
High-slope Blackberry				
select shrubs	2-gallon	331	$7.55-8.35	$2020.66
herbs	1-gallon	73	$4.35	$316.45
hydromulch w/ tack (no seed)	kg	250	$~4X seed	$525.00 +
labor (prep/plant/monitor etc.)**	hr/1/2 stock	-	$30.00	$2118.56
Unit Cost				$4980.67
GST (5%)				$1393.34
PST (7%)				$1950.67
Contingency (15%)				$4180.01
Site Total				**$35390.75**

*Approximate market cost; could likely be constructed for much less.
**Consider material and labor cost increases if fascines, matting, or other bioengineering methods are necessary.