Beaver Management Plan For The City of Port Moody

Prepared by:

A. Paetow and J. F. Black
JBL Environmental Services Ltd.
60 – 9000 Ash Grove Crescent
Burnaby, BC, V5A 4M5

Prepared for:

City of Port Moody
100 Newport Drive
Port Moody, BC, V3H 5C3

11 September 2019

SUMMARY

This report presents a Beaver Management Plan to the City of Port Moody. The Beaver Management Plan has been requested by City Council as a result of the recent beaver activity in Port Moody and associated flooding of trails and infrastructure. Council passed resolution *RC18/042* that directed staff to develop a Beaver Management Plan that promotes coexistence, outlines best management practices, and implements strategies that use alternatives to extermination and/or relocation wherever possible, as recommended in the report (11 January 2018) from Councillor Meghan Lahti.

The purpose of the Beaver Management Plan is to advise the City on how to manage existing and potential future beaver populations on City lands and rights-of-way. The Plan is intended to balance the habitat requirements of beavers, and their value to the residents of Port Moody and the environment, with the need to protect public safety and City infrastructure.

This document summarizes the current information about beavers and provides the best available science and current best practices in deciding the implications of coexisting with beaver populations around the City of Port Moody. This document includes:

- Background and purpose of the plan,
- Ecology of Port Moody,
- Ecology of beavers,
- Influence of beaver dams on local ecology,
- Educational opportunities and challenges regarding urban beavers,
- Coexistence with beavers, and
- Techniques to manage beaver activity within the City.

This Beaver Management Plan includes a decision-making framework that incorporates adaptive management principles to guide the evaluation of management actions by the City. The plan encourages coexistence with beavers through techniques that are designed to mitigate the impacts of beaver activity, thus allowing the beaver colony to remain in place. Coexistence techniques have been shown to be more cost-effective than traditional removal techniques. The two general coexistence techniques are acceptance and mitigation. The mitigation measures that are addressed in this Beaver Management Plan include:

- Tree protection,
- Repellents,
- Plant species selection,
- Culvert protection, and
- Flow-leveling devices.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

LIST OF APPENDICES

LIST OF ACRONYMS

BMPs	Best Management Practices
BRAT	Beaver Restoration Assessment Tool
DFO	Fisheries and Oceans Canada
d/s	Downstream
ESA	Environmentally Sensitive Area
FLNRORD	Ministry of Forests, Lands and Natural Resource Operations and Rural Development
IBA	Important Bird and Biodiversity Area
PVC	Polyvinylchloride
RAR	Riparian Areas Regulation
SPEA	Streamside Protection and Enhancement Area
u/s	Upstream
USDA	United States Department of Agriculture
WDFW	Washington Department of Fish and Wildlife
WLAP	Ministry of Water, Land, and Air Protection

GLOSSARY

Acceptance	Agreement with or tolerance of an activity
Anthropogenic	Caused or influenced by human activities
Beaver Deceiver	Name for a trapezoidal fence invented by Skip Lisle used upstream of a culvert to control dam-building activity by beavers
Beaver Deterrent	Installing a beaver deterrent into the notch created by notching a dam can provide a temporary solution to dam repair by the beaver
Beaver Stopper	Cylindrical double-wire-mesh culvert extension
Daylighting	Removal of culverts and re-establishment of stream channels
Diagnostic Key	Hierarchical sequence of tests used to identify a treatment or set of treatments required to mitigate an impact
Ecosystem Services	Ecosystem services are the direct and indirect contributions of ecosystems to human well-being. They include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other non-material benefits.
Flow/Water/Pond Leveler	Device to regulate the water level in stream channels or ponds above beaver dams
Harm	An act that causes loss, injury or damage
Mitigation	The action of alleviating or reducing the severity of an activity through certain measures
Notching	Partial breaching of a beaver dam
Qualified Environmental Professional	Applied scientist or technologist who is in good standing in British Columbia with an appropriate professional organization and includes, without limitation, a professional Biologist, Agrologist, Forester, Geoscientist, Engineer, or Technologist
Waterbirds	Water-associated birds such as raptors, herons, gulls, waterfowl and shorebirds

1.0 BACKGROUND AND PURPOSE OF THE BEAVER MANAGEMENT PLAN

1.1 Introduction

On January 23, 2018, Council passed the following resolution regarding a Beaver Management Plan (BMP):

> *RC18/042*
> THAT staff be directed to develop a Beaver Management Plan that promotes coexistence, outlines best management practices, and implements strategies that use alternatives to extermination and/or relocation wherever possible as recommended in the report dated January 11, 2018 from Councillor Meghan Lahti regarding Beaver Management Plan.

This report presents a Beaver Management Plan to the City of Port Moody. The Plan balances coexistence with a risk assessment approach. The Beaver Management Plan is designed to be adaptive (i.e., a "living document"), and able to be updated as needed, based on re-evaluation and monitoring by the City. The Plan provides a decision-making framework and diagnostic key to help guide the City of Port Moody in making informed decisions in relation to the coexistence with and management of beavers.

1.2 Background

The City of Port Moody is a vibrant community that values its strong neighbourhoods, heritage character and natural environment. A brief history is provided in **Appendix 1**. With a population of about 35,000 (based on 2012 data), the City strives to balance the protection of the natural environment with the growth of the community by integrating sustainable practices into the planning and development process. The City has been successful in preserving and protecting many forested areas and environmentally sensitive areas (**Map 1 - City of Port Moody Environmentally Sensitive Areas Map**). In the past 40 years, efforts have been made by the City of Port Moody and volunteer organizations to proactively restore and enhance streams and riparian habitat, particularly in areas that have been modified or where ecological functions have been compromised. This has involved creating stream access for fish populations through day-lighting (i.e., removal of culverts to re-establish stream channels), installation of fish-habitat structures, and planting of riparian vegetation to restore watercourses (e.g., Envirowest Consultants Inc. 2019). The City continues these efforts to restore and enhance habitats based on community priorities and available resources. These efforts have greatly improved available fish habitat in Port Moody and have contributed to the return of fish, for example in Pigeon Creek and Suter Brook Creek. Riparian protection and setback provisions have recently been updated in the City's Zoning Bylaw in order to establish compliance with the provincial Riparian Areas Regulation (2006).

Habitat restoration efforts have also encouraged other species, such as the beaver (*Castor canadensis*) to recolonize much of their historic range (Pollock et al. 2017). Beavers create wetlands that benefit many plants and animals. However, landscape modifications can cause conflict when the associated flooding and tree damage threatens infrastructure and public safety.

The City of Port Moody currently has one active beaver colony including a breeding pair and at least two juveniles. In 2016, the pair took up residence in a day-lighted section of Pigeon Creek, in the Klahanie neighbourhood. The beaver pair built a den and food cache in a storm sewer pipe and had two young. City efforts to isolate the beavers from the municipal infrastructure led to the death of one beaver kit. This event led Council to request the development of the beaver management plan. In 2018, the beaver colony abandoned the site and relocating to Suter Brook Creek near City Hall (**Figure 1**). Several concerns arose from the beaver occupation, including flooding, impact to City infrastructure, tree removal, and restricted fish passage. The beaver activity has affirmed the need to balance fish passage and City risks and liabilities with the benefits of beaver co-existence, given their ecological role and value to watershed health and the residents of Port Moody.

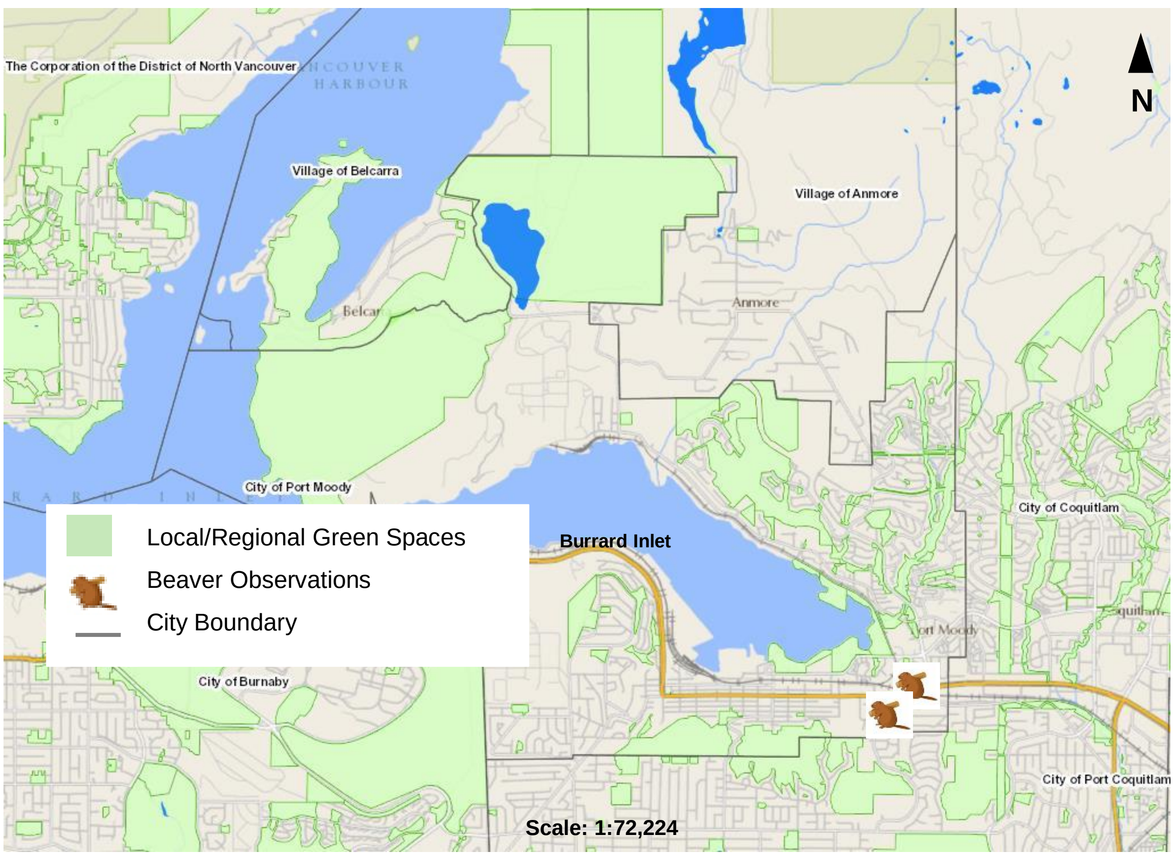


Figure 1. Recent beaver observations in the City of Port Moody. Note: Parks and forested areas are shown in green. Beaver observations were on Pigeon Creek (2016/17, lower) and Suter Brook Creek (2018, upper). Image: iMapBC 2018

1.3 Purpose of the Plan

The purpose of the Beaver Management Plan is to advise the City on how to coexist with existing and potential future beaver activity on City lands and rights-of-way. The plan is intended to balance the long-term habitat requirements of beavers, and their contribution to watershed health, with the need to protect public safety and infrastructure. This document addresses the opportunities and challenges of coexistence with beavers, and outlines how the risk associated with the presence of beavers can be mitigated to manage for potential damage to infrastructure and private and public property. The Plan provides a decision-making framework to guide the evaluation of management actions by the City. This document summarizes the current information about beavers and provides the best available science and current best practices in relation to coexistence with beavers in urban environments. Regulatory requirements related to beavers are also provided (**Appendix 2**).

1.4 Goals and Objectives

The goals of the beaver management plan are:

- Engage local stakeholders and other interested agencies in the plan development,
- Build on a standard risk assessment terms of reference,
- Identify a clear decision-making process that addresses the promotion of coexistence with beavers in a balance with risks and liabilities,
- Move away from a reactive response to new beaver occurrence (i.e., crisis management) to a pro-active approach (i.e., adaptive management with coexistence where possible),
- Develop a decision-making framework that balances the habitat requirements of beavers with the need to protect public health and safety, infrastructure and public/private property, and
- Reduce the need for trapping/relocating of beavers.

Objectives include:

- Define impacts caused by beaver activity,
- Evaluate areas of existing and potential beaver conflict,
- Prioritize areas of existing and potential beaver conflict based on perceived risk to human health and safety, infrastructure, regulatory compliance and presence of public/private property,
- Support watershed health,
- Mitigate damage from flooding impacts and tree harvesting by beavers, and
- Maintain fish passage.

2.0 PORT MOODY ECOLOGY

The City of Port Moody is located at the head of Burrard Inlet and is surrounded by steep slopes and large tracts of forest cover. The City is bordered in the north and northwest by the Villages of Belcarra and Anmore, in the east and south by the City of Coquitlam and in the southwest by the City of Burnaby. Port Moody's geography is a combination of extensive second-growth forests with marine foreshore areas, freshwater streams, lakes and wetlands, and a growing urban centre. From the inlet, forested slopes rise to the north towards the villages of Anmore and Belcarra. These slopes include Bert Flinn Park, Belcarra Regional Park and Pinecone Burke Provincial Park. The southern slopes rise steeply from the inlet through the Chines escarpment, one of the steepest areas in the Fraser Lowland (Robertson Environmental Services Ltd. 2003). The continuous forest cover on the north shore occurs directly adjacent to the urban landscape. This closeness of wilderness to the urban landscape has created human-wildlife interactions, for example with bears, coyotes, cougars, and, most recently, beavers.

2.1 Estuaries and Forests

The Port Moody Arm of Burrard Inlet was once a place of heavy industrial activity with sawmills, oil refineries, chemical plants and a coal-fired thermal electric plant (City of Port Moody 2011). Port Moody Arm was the most easterly of the harbours along Burrard Inlet (City of Port Moody 2011). Over the last 60 years, much of the industry has either been upgraded to reduce its environmental footprint or has moved on, which has led to improved health of the marine environment.

Port Moody's estuaries are under tidal influence and provide habitat for a large number of fish and aquatic wildlife. The foreshore provides habitat for a large number of birds, including birds of prey such as bald eagle (*Haliaeetus leucocephalus*) and osprey (*Pandion haliaetus*), aerial insectivores such as swallows, and waterbirds including great blue heron (*Ardea herodias*), green heron (*Butorides virescens*), waterfowl and shorebirds (BC Wildlife Watch 1995, Robertson Environmental Services Ltd. 2003). Some of the birds nest along the foreshore or adjacent riparian forest. For example, ospreys and purple martins (*Progne subis*) have been nesting off Rocky Point, and a great blue heron colony currently breeds in the lowland forest of Shoreline Park near the Noons Creek estuary (Burke Mountain Naturalists 2016). Burrard Inlet, including Port Moody Arm, has been designated as an important bird and biodiversity area (IBA) because its sheltered waters support large numbers of waterbirds during winter (Bird Studies Canada 2017).

The forests around Port Moody are predominated by coniferous and deciduous tree species such as western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), Douglas-fir (*Pseudotsuga menziesii*), red alder (*Alnus rubra*), bigleaf maple (*Acer macrophyllum*), and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*). Where the forests remain relatively well interconnected (e.g., on the north shore), they support larger wildlife species such as coastal black-tailed deer (*Odocoileus hemionus* ssp. *columbianus*), black bear (*Ursus americanus*), coyote (*Canis latrans*), and the occasional cougar (*Puma concolor*).

2.2 Watercourses and Riparian Areas

A variety of birds, amphibians, mammals, and fish inhabit the streams and surrounding riparian forests and wetlands of Port Moody. Although amphibian records are sparse, tailed frogs (*Ascaphus truei*) have been confirmed in Mossom Creek and Noons Creek (Robertson Environmental Services Ltd. 2003). The wetlands on the tributaries of Hett Creek, Mossom Creek and Suter Brook support northern red-legged frogs (*Rana aurora*) (Robertson Environmental Services Ltd. 2003, pers. Obs. 2013). Mammals such as the raccoon (*Procyon lotor*), eastern grey squirrel (*Sciurus carolinensis*), Douglas squirrel (*Tamiasciurus douglasii*), northern flying squirrel (*Claucomys sabrinus*), eastern cottontail rabbit (*Sylvilagus floridanus*), showshoe hare (*Lepus americanus*), short-tailed weasel (*Mustela erminea*), porcupine (*Erethizon dorsatum*), bobcat (*Lynx rufus*), striped skunk (*Mephitis mephitis*), and deer mouse (*Peromyscus maniculatus*), as well as bats, moles and shrews, live in the riparian forests (Robertson Environmental Services Ltd. 2003, Hemmera 2010, Zevit 2017). The less common spotted skunk (*Spilogale gracilis*) has recently been added to the list of mammals occurring in Port Moody (Ruth Foster, 2019, personal communication).

The watercourses in the City have been inventoried and mapped as part of the Environmentally Sensitive Areas (ESA) strategy completed in 2003 (Robertson Environmental Services Ltd. 2003, City of Port Moody 2014). The marine and freshwaters around Port Moody provide extensive habitat for fish, primarily salmonids (**Table 1**). The City's watercourses (**Map 2 – City of Port Moody Named Watercourses**) provide spawning and rearing habitat for Coho salmon (*Oncorhynchus kisutch*), chum salmon (*Oncorhynchus keta*), Chinook salmon (*Oncorhynchus tshawytscha*), pink salmon (*Oncorhynchus gorbuscha*), rainbow trout (*Oncorhynchus mykiss*) and coastal cutthroat trout (*Oncorhynchus clarkii*) (City of Port Moody 2014). **Appendix 3** provides photographs of select watercourses in Port Moody.

Table 1. Fish-bearing Watercourses in Port Moody

Fish-bearing Watercourses*/**	Fish Species**
North Shore	
Noons Creek	Chum, coho, chinook, rainbow (steelhead), cutthroat, sockeye, pink
Hutchinson Creek^	Unknown (historic coho, chum)^
Turner Creek (lower section to Mill Pond)	Chinook, unidentified trout
Mossom Creek	Chum, coho, pink, chinook, rainbow (steelhead), cutthroat
North Schoolhouse Creek	Chum, coho, cutthroat, rainbow (steelhead)
Imperial Creek (Village Creek)	Cutthroat
Windermere Creek (Sasamat Lake outflow)	Cutthroat, rainbow
Anmore Creek (Buntzen Lake outflow)	Cutthroat

Fish-bearing Watercourses*/**	Fish Species**
South Shore	
South Schoolhouse Creek	Chum, coho, cutthroat, rainbow (steelhead)
Melrose Creek	Unknown
Goulet Creek	Unknown
Correl Creek	Cutthroat
Dallas Creek	Cutthroat
Pigeon Creek^/***	Chum, cutthroat (possibly coho***)
Suter Brook Creek	Coho, cutthroat, chum

Sources: Haggarty 2002*, iMapBC 2018**, Townsend 2003^, and BC Province 2010***

2.2.1 South Shore

The urbanized south shore of Port Moody drains the northwest side of Burnaby Mountain and the Chines escarpment. The lower elevations of the south shore were developed in the early 1900s and now are dominated by residential housing, commercial and industrial development, and linear infrastructure (e.g., roads, railway). The fish-bearing streams in this area are constrained by the development and infrastructure (**Appendix 3** – Photographs 1-28). In the lower reaches, streams are to a great extent enclosed in culverts. Only South Schoolhouse Creek, Melrose Creek, Suter Brook Creek and Pigeon Creek watersheds provide a significant amount of fish habitat in their lower reaches (City of Port Moody 2014), including the two hundred metres of Pigeon Creek that were day-lighted and enhanced within the Klahanie neighbourhood (BC Province 2010).

With the exception of a recently day-lighted section of Dallas Creek, the lower reaches of Slaughterhouse Creek and Kyle Creek watersheds are culverted. The Slaughterhouse Creek watershed drains the east side of the Chines escarpment and includes Williams Creek, Elginhouse Creek, Correl Creek and Dallas Creek. The Kyle Creek watershed drains much of the west side of the Chines and includes Kyle Creek, Ottley Creek, Axford Creek, Hatchely Creek, Goulet Creek and east and west Sundial Creeks. Many of the upper reaches of the tributaries flowing from the Chines are still in their natural channels, and Dallas Creek, Correl Creek and Goulet Creek provide habitat for fish (BC Province 2010).

2.2.2 North Shore

The more forested north shore of Burrard Inlet drains the south slope of Eagle Mountain and Westwood Plateau. The north shore is steeper in nature and contains a larger percentage of undeveloped parklands than the south. Here, major residential development didn’t begin until the 1960s. Most creeks still contain a significant riparian corridor and flow within their natural channels (**Appendix 3 –** Photographs 29-50). The fish-bearing channels on the north shore are included in **Table 1**.

2.2.3 Salmon Enhancement

There are two fish hatcheries on the north shore of Port Moody, on Noons Creek and on Mossom Creek. The facilities are operated by the Port Moody Ecological Society (Noons Creek) and the Burrard Inlet Marine Enhancement Society (Mossom Creek). For decades, the hatcheries have reared thousands of chum and Coho salmon annually to stock neighbouring creeks and Port Moody Arm. In addition, the hatcheries host events and education programs (Port Moody Ecological Society 2018, Burrard Inlet Marine Enhancement Society 2018, City of Port Moody 2011/2018b).

3.0 BEAVER ECOLOGY

The North American beaver (*Castor canadensis*) is a large, semi-aquatic plant-eating rodent that is native to lakes, rivers, streams, and ponds throughout the continent. The beaver once occupied almost all biogeoclimatic zones of North America, from the arid environments of northern Mexico to the Arctic (Pollock et al. 2017). However, beaver populations declined sharply as a result of intense trapping across their range (Müller-Schwarze 2011). By the end of the 19th Century, beavers had nearly been extirpated, with only small populations remaining (Pollock et al. 2017). The beaver population has since rebounded and is currently estimated to be 10-12 million individuals. The population across the continent has continued to expand (Naiman et al. 1986, Martin et al. 2015, Pollock et al. 2017), including in the Lower Fraser Valley (Page 2012). In 2008, a beaver was reported for the first time in 60 years in the City of Vancouver in Stanley Park (Page 2012). Today, Vancouver supports about 50 beavers that live in ten colonies (Pierce 2012). It is expected that, as beaver populations grow, unoccupied areas that meet the habitat requirements for beaver will become occupied as beavers transform each site to suit their needs (Portugal et al. 2015, Pierce 2016, Dittbrenner et al. 2018).

3.1 Habitat

Beavers occupy low gradient, medium-size channels with gentle bank slopes, constant water supply, and suitable foraging and dam-building vegetation within 30 meters of the water's edge (Howard and Larson 1985, Curtis and Jensen 2004, Gerwing et al. 2013, Portugal et al. 2015, Pollock et al. 2017). Although beavers prefer low-gradient reaches of a stream (less than 6% gradient), they will colonize higher gradient streams if their population densities are high (Collen and Gibson 2001; Pollock et al. 2017, Dittbrenner et al. 2018). Sufficient water depth is required to ensure the entrance to their lodge or burrow remains underwater thereby providing quick entry and predator escape (Collen and Gibson 2001, Pollock et al. 2017).

Beavers use a wide variety of trees, shrubs, herbaceous vegetation and stream substrate (e.g., mud, silt and soft clay) for construction material (e.g., for dams and lodges), but do not always builds dams (Müller-Schwarze 2011, Pollock et al. 2017, Swinnen et al. 2019). Dams are only constructed on watercourses that do not meet a beaver's requirement of maintaining underwater entrances to their lodges (Wheaton 2013, Portugal 2015, Swinnen et al. 2019).

Dam-building and maintenance behaviour are stimulated by the sound of running water, and beavers control water levels so that burrow and lodge entrances remain submerged. This behaviour is generally suppressed in water depths greater than 1 m (Müller-Schwarze 2011, Pollock et al. 2017).

3.2 Diet

Beavers are generalist herbivores that need a mixed diet and have specific preferences (Müller-Schwarze 2011, Gerwing et al. 2013). Beavers prefer aspen and cottonwood (*Populus* spp.), and willow (*Salix* spp.) (Pollock et al. 2017). They consume many different species of trees, herbaceous plants, woody vines, and grasses (Gallant et al. 2004, Müller-Schwarze 2011, Pollock et al. 2017) but tend to avoid conifers (Gallant et al. 2004). Beavers require between 0.6 kg and 2.5 kg of bark, twigs and leaves daily to survive (Collen and Gibson 2001, Pollock et al. 2017).

3.3 Life History

Beavers are highly social and territorial. They live as family units (colonies) that consist of two parental adults, the yearlings born the previous year, and the young of the year (Collen and Gibson 2001, Müller-Schwarze 2011, Pollock et al. 2017). The colony shelters and rears its young in a lodge or bank den that is constructed into a stream bank or as an island within the wetland impoundment. The family members might all live in one lodge, especially in winter, and use several lodges during summer (Müller-Schwarze 2011). The female gives birth to one litter per year, and the young are mobile and furred when born (Pollock et al. 2017). On average, two kits are born between May and July, and the young usually disperse from the parental colony at two years of age (Müller-Schwarze 2011, Pollock et al. 2017). In areas of reduced habitat quality (e.g., in urban areas), beavers adjust their reproduction to the environmental conditions by producing fewer young (Müller-Schwarze 2011). Occasionally, two-year-old sub-adults will stay with the colony another year, particularly in high-density populations where habitat is limited (Müller-Schwarze 2011, Mayer et al. 2017, Pollock et al. 2017). Severe weather, starvation due to lack of suitable food, and predation from carnivores such as coyote, wolf (*Canis lupus*), black bear, cougar, and river otter (*Lutra canadensis*) are the main causes of beaver mortality (Müller-Schwarze 2011). Affected are mostly dispersing young beavers (i.e., 2- to 3-year-olds) that cannot find new homes and die before reaching their final destination (Müller-Schwarze 2011). Overall, most beavers do not live more than 10 years (Müller-Schwarze 2011).

Colony size of beavers is tied to habitat quality. Population density is lower in newly established populations, marginal habitat, and in populations that are being harvested (Collen and Gibson 2001, Müller-Schwarze 2011, Mayer et al. 2017). The mean colony size across North America varies but is roughly between three and eight individuals, depending on habitat quality (Brooks et al. 1980, Payne 1989, Collen and Gibson 2001, Müller-Schwarze 2011, Maenhout 2014).

Densities of beaver populations are usually expressed in colonies per unit area or per length of the stream (Pollock et al. 2017), with good, moderate, and poor quality habitat generally yielding 1.5, 0.5 and 0.1 colonies per kilometer of stream, respectively (Collen and Gibson 2001).

Beaver populations are ultimately controlled by availability of deciduous trees and shrubs (Mumma et al. 2018; Touihri et al. 2018). Like most herbivores, the occupation of a site by beavers is not permanent as entire colonies typically move to new areas once the population exceeds carrying capacity or food supplies have become insufficient (Payne 1989, Collen and Gibson 2001, Hay 2010, Müller-Schwarze 2011, Mayer et al. 2017). As stated by Schlosser and Kallemeyn (2000), "*Stream reaches are colonized, flooded, and then abandoned*". Beavers might abandon sites for one or two years and then re-occupy them after the vegetation has recovered (Howard and Larson 1985). In areas where deciduous trees and shrubs are plentiful, beavers can remain for over 20 years (Howard and Larson 1985); however the majority of sites are eventually abandoned Hay (2010).

4.0 INFLUENCE OF BEAVER DAMS ON LOCAL ECOLOGY

The beaver is a keystone species that has a disproportionately high influence on its environment. Beavers modify stream and riparian landscapes by building dams and harvesting trees. These activities create wetland complexes and openings in riparian forests that increase the diversity of plant, bird, mammal, insect, and fish communities (Dittbrenner et al. 2018; Pollock et al. 2017).

Beaver dams can have a beneficial effect on both rural and urban creeks, as has been shown in the Cities of Seattle and Portland (Leavy et al. 2008, Bailey et al. 2018, Poor 2018). Beaver dams create physically complex hydrological changes (Loken et al. 2017). They increase water and sediment storage, groundwater recharge, and channel complexity in streams (Haddock 2015, Bowes et al. 2016, Pollock et al. 2017, Wegener et al. 2017). They can also decrease pollutants and stream gradients, leading to slower flows and improved water quality (Bowes et al. 2016, Pollock et al. 2017). Although the reduced flow and removal of riparian shade by beavers increases water temperatures locally (Kemp et al. 2012, Majerova et al. 2015, Wegener et al. 2017), the increased water storage and groundwater-to-surface water connectivity created by beavers buffers daily extremes in summer temperature and creates cold-water refuges, which can be beneficial to many fish (Weber et al. 2017, Wegener et al. 2017). The findings from the above referenced studies in the Pacific Northwest, with similar species composition, are applicable to Port Moody.

Some of the common issues related to urban stream hydrology (i.e., in areas that have increased impervious surfaces) include (Poor 2018):

- Channel incision and stream bank erosion,
- Increased sedimentation from urban development and activities,

- High velocity discharge during storm events,
- Reduced groundwater infiltration,
- Dis-connectivity from floodplain,
- Degradation of riparian vegetation, and
- Changes in stream temperature, dissolved oxygen and other water quality parameters.

In these areas, beaver dams were found to mitigate the adverse effects of storm events on downstream channels, thereby lowering sedimentation concentrations and reducing peak turbidity levels associated with urban development (Poor 2018, Bailey et al. 2018). Although urban surface water temperatures have been found to increase in the dammed area, they decreased downstream of the dam (Poor 2018).

The effect of beaver dams on fish are both site- and species-specific. The changes brought by beavers can be beneficial or harmful, depending on the region and the composition of the local fish population (Collen and Gibson 2001, Hood 2012, Kemp et al. 2012, Virbickas et al. 2015, Loken et al. 2017, Johnson-Bice et al. 2018). In small, urban systems (e.g., Suter Brook Creek in Port Moody), the effects also may vary based on the size of the pond. Many fish species that inhabit ponds during parts of their life-cycle benefit from beaver dams. The dams enhance growth and survival rates for these species through increased rearing and overwintering habitat and altered regimes of surface-water temperature (Pollock et al. 2017, Dittbrenner et al. 2018). Beaver dams influence stream temperature regimes through buffering of daily extremes in summer temperature (Weber et al. 2017). The buffering occurs because of increased water storage and creation of cold-water refuges from increased groundwater-to-surface water connectivity (Weber et al. 2017). This temperature buffering, coupled with the changes to vegetation (Smith and Mather 2013, Thompson et al. 2016), increases aquatic primary productivity and invertebrate abundance (McCaffery and Eby 2016, Pollock et al. 2017). Coho, Chinook, steelhead and cutthroat benefit from the increased water storage, constant flow and invertebrate productivity created by beaver impoundments (Kambietz 2003, Pollock et al. 2003, Pollock et al. 2004), especially in the context of climate change. **Table 2** summarizes possible effects of beaver dams on fish.

Table 2. Potential effects of beaver dams on stream fish.

Potential Positive Effects	Potential Negative Effects
Increased fish productivity / abundance	Barriers to fish movement
Increased habitat / habitat heterogeneity	Loss of spawning habitat
Increased rearing and overwintering habitat	Low oxygen levels in beaver ponds
Enhanced growth rates	Altered temperature regime
Providing flow refuge	
Improved production of invertebrates	

Source: Pollock et al. 2017

The degree to which beaver dams impede fish movement is equally species and site dependent. Beaver-pond habitat is highly productive to most fish, and fish species regularly cross beaver dams in both upstream and down-stream directions (Pollock, et al 2003). Beaver dams can act as temporary barriers during low-flow periods for species such as Coho, Chinook, and steelhead (Cutting et al. 2018; Kemp et al. 2012; Mitchell and Cunjak 2007). In contrast, beaver dams can significantly restrict upstream access and productivity for other species (Malison et al. 2016; Virbickas, et al. 2015), including pink and chum salmon, which do not cross barriers that are passed by other species (Nelson et al. 2015).
The influence beavers have on ecosystems, plants, invertebrates, and wildlife (including amphibians, reptiles, birds, and mammals) has been discussed in detail in Müller-Schwarze (2011) and Pollock et al. (2017).

5.0 URBAN BEAVERS – RISKS AND EDUCATIONAL OPPORTUNITIES

5.1 Risks

This section addresses the responsibilities of the City of Port Moody specific to the development of the Beaver Management Plan. The City is responsible for the functioning of City infrastructure on its lands and rights-of-way to ensure public health and safety. The City is responsible for:

- Ensuring public safety on public lands,
- Protecting the integrity of municipal infrastructure,
- Improving watershed health by protecting riparian areas and freshwater fish habitat,
- Protecting public and private property from flooding, and
- Complying with provincial and federal regulations (e.g., *Fisheries Act, Water Sustainability Act,* and *Wildlife Act*, **Appendix 2**).

Although recent beaver restoration efforts across North America are promising, not all areas are appropriate or suitable to support beavers (Macfarlane et al. 2017) and not all deliberate efforts are successful. For example, beavers can create conflicts in areas with other land-use priorities (agricultural, urban) when drainage features are dammed in multiple locations (Macfarlane et al. 2017, Bailey et al. 2018). Relocation efforts often fail because of the high mortality of relocated beavers (> 50%) from predation or vehicle collisions, and because translocated beavers often do not stay where they are released (Müller-Schwarze 2011, Cafferata Coe et al. 2016).

In highly urbanized areas, coexistence with beavers can be challenging due to hydrologic and spatial constraints. Urban areas contain fewer and smaller green spaces, narrower riparian corridors, higher densities of infrastructure, and sensitive drainage regimes compared to natural areas. Increased urban development has resulted in channelized streams and installation of culverts, presenting a challenge to both salmon and wildlife (Vanderhoof 2017). Left unmanaged or unaccounted for in design and engineering plans, urban beavers can remove valued riparian trees and shrubs, and cause flooding that compromises properties, roads, trails, railway systems, culverts and other infrastructure.

The key concerns related to beavers are flooding (caused by dam building and/or culvert-blockage), the removal of trees within the riparian zone (caused by felling and drowning from long-term flooding), and reduced fish passage. To a lesser extent, the potential transmission of diseases to humans may also exist.

5.1.1 Public Safety and Infrastructure Risk

Beavers can create risks to public safety on both public and private property, especially during rain events. Beaver dams on narrow, channelized urban streams can quickly cause water to rise beyond the streambank, which leads to flooding and property damage. Although installation of a beaver flow device can mitigate these impacts, flow-device installation requires analysis of the creek conditions and threshold water-surface elevations, and a commitment to monitoring the short- and long-term benefits and challenges over time (see **section 6.2**). If unmitigated, this can adversely affect the safety of residents by increasing stormwater pollutants, compromising critical infrastructure (e.g., telecommunications equipment, sanitary and stormwater pipes, and oil-water separators) and drowning trees that may eventually topple over. Burrowing by beavers may also weaken stream banks, dikes, roads, trails, or banks and beds of railways (Hawley-Yan 2016). Beavers will also at times use engineered stormwater facilities or water infiltration galleries that were designed to function as attractive public spaces (Hawley-Yan 2016).

Two diseases have been linked to parasites contracted by wildlife, including beavers: Tularemia and Giardiasis. Tularemia (a bacterial endoparasite) is transmitted by ticks and biting flies as well as contaminated water (WDFW 2011, Vermont Fish & Wildlife Department 2017). Tularemia can be carried by wildlife, domestic animals (e.g., cats and dogs) and livestock that are likely to be in direct contact with humans (Pierce 2016). Giardiasis is caused by protozoan parasites that live in the intestines of many animals (including humans) or in the external environment (e.g., soil and water) once excreted as cysts (Hawley-Yan 2016). The parasite can only cause infection when it is swallowed (Hawley-Yan 2016). Many different species of *Giardia* occur in many different species of mammals, birds, reptiles, amphibians, fish, pets and livestock that can serve as vectors for the transmission of giardiasis infection (WDFW 2011, Vermont Fish & Wildlife Department 2017). Municipal waste water and runoff entering streams and other surface waters are likely contaminated with *Giardia* cysts (U.S. Environmental Protection Agency 2000, in Hawley-Yan 2016, Müller-Schwarze 2011, WDFW 2011, Pollock et al. 2017). However, the risk of humans or wildlife populations becoming infected by these two diseases is minimal.

5.1.2 Ecological Risks

Beavers harvest riparian trees and vegetation for food and building material. In the Pacific Northwest, this can contribute to the spread of invasive plant species such as Japanese knotweed (*Fallopia* spp.) (Soll 2004) and reed canary grass (*Phalaris arundinacea*) (Perkins and Wilson 2005). However, the risk of beaver activity spreading invasive species is low compared with other activities (e.g., human activity). Because beavers require wood to build dams, tree harvesting is not restricted to preferred food species and can include fruit trees, shade trees, or ornamental trees and shrubs desired by humans (Loeb et al. 2014, Hawley-Yan 2016).

5.1.2.1 Fish Passage

Salmon are a culturally and socio-economically important species in British Columbia. They are also considered a keystone species (Hyatt and Godboute 2000), shaping entire aquatic and terrestrial biological communities (Quinn et al. 2018; Kiffney et al. 2018; van den Top et al. 2018). Hence, salmon access to spawning and rearing grounds is important to the residents of the City of Port Moody.

Salmon and beavers have coexisted in the Pacific Northwest for over 12,000 years. There is no scientific evidence that beaver dams have a detrimental effect on salmonid population-levels or that beaver dams are more than a seasonal barrier to fish passage (Schlosser 1995, Pollock et al. 2003, Lokteff et al. 2013), based on studies in mostly non-urbanized watersheds. Although few studies have examined whether chum salmon are able to navigate beaver dams, salmon fisheries managers generally agree that the dams can impede upstream chum movement (Pollock, et al 2003), depending on site conditions. Once natural streams have been modified into long, narrow drainage channels throughout urban areas, these systems may be a challenge to fish that are weak swimmers/poor jumpers, such as chum salmon (Katopodis and Gervais 2016).

The breaching of both natural and man-made beaver dams temporarily enables fish passage (Cutting et al. 2018) and does not usually cause beavers to move (Vanderhoof 2017). However, breaching or removing beaver dams to enable fish passage provides only a short-term solution as beavers usually increase their dam-building activities and associated tree harvesting, rebuilding the dams within days or overnight (Vanderhoof 2017, Boyles 2006, Portugal, 2015, Pollock et al. 2017). As fish require a certain depth of water to be able to jump, the placing of sand bags downstream of the dam can facilitate pool creation and enhance fish passage of a dam at a small breach (Kambietz 2003). The installation of a fish-passable flow leveler can facilitate the movement of adult chum salmon, as well as other species of salmon through the dam (Pollock et al. 2017). Chum salmon were able to pass through a flexible horizontal pipe and cage (i.e., such as the pond leveler in **Figure 6**) during a study on the Skagit River (Pollock et al. 2017).

Beaver dams are designed to hold back low summer flows, and are generally not considered barriers to migrating fry (Kambietz 2003). Beaver dams are usually overtopped during storm events, enabling fry to move downstream during high water (Kambietz 2003). The timing of fry releases from hatcheries into local streams could be timed to coincide with storm events to facilitate the movement of migrating fish downstream. Note that fry releases from hatcheries have timing considerations and will need to involve planning for weather/rainfall events and passage considerations.

5.2 Educational Opportunities

Beavers are increasingly being used as tools in the habitat restoration and “climate-change mitigation” of streams, wetlands and floodplains (Haddock 2015, Pollock et al. 2017, Dittbrenner et al. 2018). This is not surprising given the substantial hydrological and ecological benefits beaver dams provide (see **section 4**). Beavers can be integrated into urban restoration projects when it is possible to incorporate their activities and subsequent landscape changes into design and engineering plans (McCrea 2016, Bailey et al. 2018). General approaches that have been used in restoration include restricting trapping of beavers, habitat manipulation to encourage beaver colonies to move in and build dams, and relocating beavers to areas where colonies are desired (Hall and Cannon 2013, Pollock et al. 2017, Lautz et al. 2018). However, restoration with beavers requires dedicated efforts and is most effective at the watershed scale (Pollock et al. 2017) because of the dynamic nature of beaver colonies and high frequency of project failure or misapplication of efforts (Müller-Schwarze 2011, Lautz et al. 2018).

Urban beavers provide hands-on lessons about their habitat requirements, restoration capabilities, life-history strategies, diet, and activities. Environmental outreach and educational opportunities in Port Moody can be exercised to support the distribution and discussion of information such as:

- How beavers influence hydrology and contribute to ecosystem services,
- How beavers can influence biodiversity, watercourses, wetlands and green spaces in urban areas,
- Fish, wildlife, and human interactions with beavers in urban environments, and
- Potential beaver-human conflict, what can be done to manage it and why.

Educational resources can be made easily accessible to the public. Media that can be used to connect (and interact with) the Port Moody community and encourage community action may include:

- Signage in strategic areas where active or inactive beaver colonies exist,
- Information booths, pamphlets and/or website blogs about local beavers,
- Community meetings with stakeholders before taking action and involvement of stakeholders in decisions to help with collaborative proactive municipal decision-making,
- Workshops or presentations (e.g., through schools or local conservation organizations) to learn about urban beavers and how to coexist with them, similar to Metro Vancouver

Parks and the Stanley Park Ecological Society, and

- Field programs (e.g., through schools or local conservation organizations) to actively monitor beaver colonies, restore habitat or prevent unwanted activity by beavers (e.g., installing exclusion fencing around trees and other vegetation to be protected, and installing water level control devices to reduce or prevent flooding).

6.0 COEXISTENCE WITH BEAVERS

6.1 Coexistence Opportunities

Based on the previous sections, co-existence can be supported in areas where (1) the ecological conditions are favourable for the beaver and other wildlife, (2) regulatory compliance is achieved, (3) there is mitigatable or no risk to City infrastructure and, (4) public safety is maintained (City of Port Moody 2018c).

The first step to determine coexistence opportunities is to identify the areas in the City that have suitable ecological conditions for beaver (**Figure 2**). Then, we need to determine whether a wetland can be sustained in each area without jeopardizing municipal infrastructure, regulatory compliance, public safety, property damage, ecological values or other management considerations. If there is a potential for risk to City infrastructure and/or public safety, the final step is to determine whether these risks can be mitigated while achieving regulatory compliance.

Studies have shown that stream gradient, valley depth and width, steepness of bank slope, water reliability, and extent of deciduous riparian vegetation are the most important physical factors because they influence if and how long a site might be occupied by a beaver colony (Howard and Larson 1985, Curtis and Jensen 2004, Hay 2010, Pollock et al. 2017, Mumma et al. 2018, Touihri et al. 2018). Hence, Port Moody locations where beavers could potentially establish a colony (**Table 3**) were identified and ranked using existing geospatial layers (Open Data Portal, City of Port Moody). The following criteria were used for geospatial selection to predict the likelihood of a site to be occupied by a beaver colony (Howard and Larson 1985, Suzuki and McComb 1998, Hay 2010, Anderson and Bonner 2014, Macfarlane et al. 2017, Pollock et al. 2017, Dittbrenner et al. 2018, Swinnen et al. 2019):

- Perennial stream reaches that have a 0-6% gradient.
- Existing ponds and wetlands.
- Medium-sized (3-6 m) channels,
- Low gradient bank slopes, and
- Areas with sufficient vegetation (defined as a 30 m riparian buffer that is more than 50% deciduous) to support the colony.

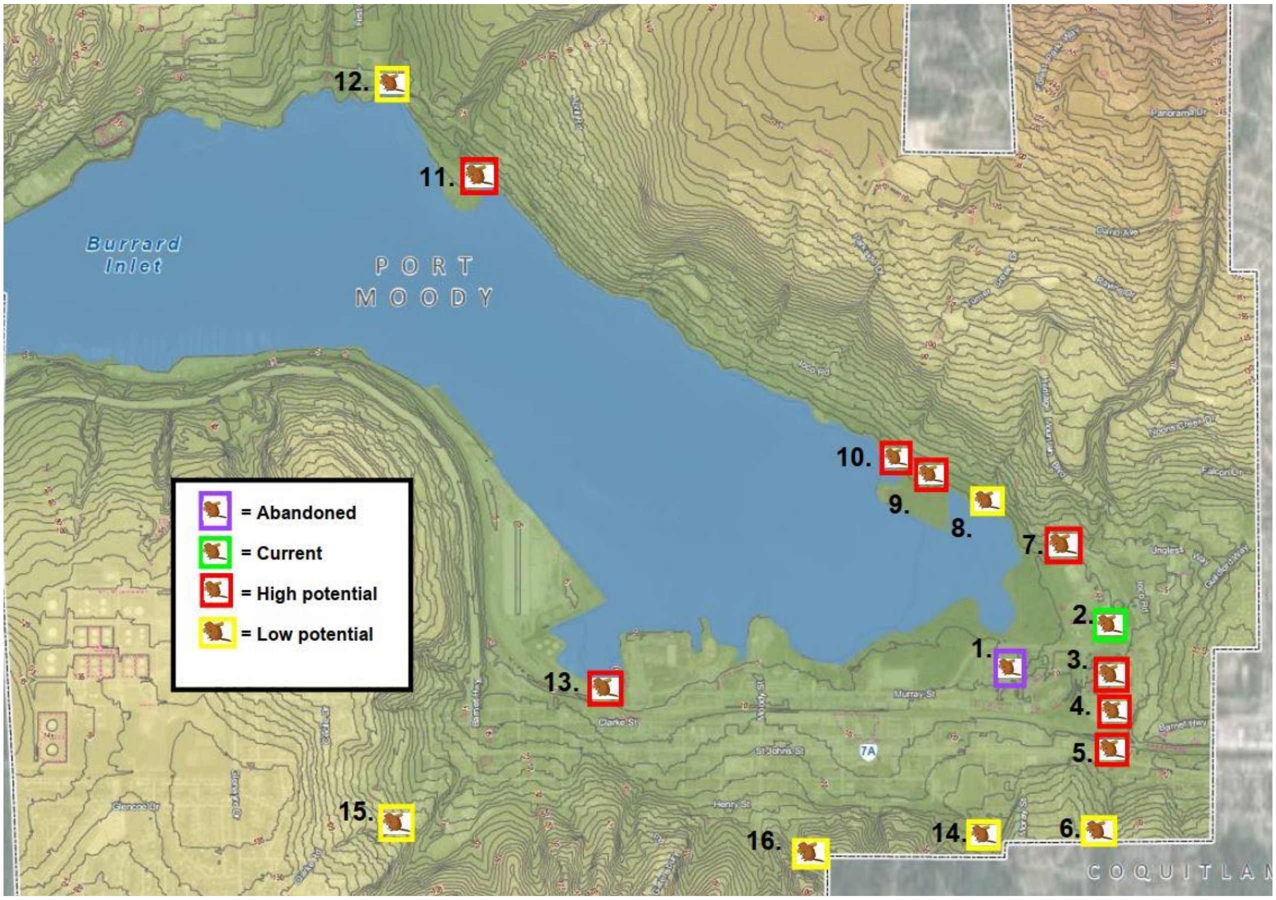


Figure 2. Topographic map of the City of Port Moody, showing historic, current, and most probable future sites of beaver occupation. Areas identified are based on low-gradient, perennial stream reaches and presence of deciduous forest cover within 30 m. Areas with highest potential for occupation (in red) are lowest-gradient and nearest to currently occupied sites. Data obtained and mapped by K. Frei using Open Data Portal (City of Port Moody).

Table 3. Most probable locations in Port Moody that beaver could potentially occupy. Sites are selected based on low-gradient (<6%) perennial streams and presence of deciduous forest cover. Data obtained and analyzed by K. Frei using Open Data Portal (City of Port Moody).

Site	Location	Area	Watershed	Land Ownership	Gradient (%)	Max. Available Forage (ha)	Occupation Likelihood
1	Klahanie	Inlet Centre	Pigeon Creek	City of Port Moody	0.7	0.16	Abandoned
2	Works Yard-Firehall	Inlet Centre	Suter Brook Creek	City of Port Moody	0.7	0.93	Occupied
3	Murray St.- Capilano Rd.	Inlet Centre	Suter Brook Creek	City of Port Moody	0.7	0.89	High
4	Capilano Rd.-CPR	Inlet Centre	Suter Brook Creek	City of Port Moody	0.7	0.65	High
5	Corbeau Park	Inlet Centre	Suter Brook Creek	City of Port Moody	5	0.16	High
6	Brookside Park	Chines	Suter Brook Creek	City of Port Moody	3.8	0.32	Low
7	Town Centre Park	Inlet Centre	Noons Creek	City of Port Moody	0.1	0.28	High
8	Old Mill Site Park	North Shore	Hutchinson Creek	City of Port Moody	6	0.24	Low
9	Old Mill Site Park	North Shore	Turner Creek-pond	City of Port Moody	0.1	0.28	High
10	Old Mill Site Park	North Shore	Turner Creek-mouth	City of Port Moody	4.8	0.24	High
11	Mossom Creek	North Shore	Mossom Creek	Private	1.5	0.41	High
12	N. Schoolhouse Creek	North Shore	North Schoolhouse Creek	Private	11.1	0.23	Low
13	2419 Columbia St.	Moody Centre	Kyle Creek	Metro Vancouver	3	4.04	High
14	Moody Middle	Chines	Upper Dallas Creek	Metro Vancouver	4	0.69	Low
15	Seaforth Park	Glenarye	South Schoolhouse Creek	Metro Vancouver	6	0.28	Low
16	Hugh Street Dog Park	Chines	Goulet Creek	Metro Vancouver	6	1.49	Low

Based on the results of the mapping, the likelihood of beaver occupation in Port Moody is high in the low-elevation/low-gradient reaches of Suter Brook Creek, Noons Creek, Turner Creek (including wetland), Mossom Creek, and Kyle Creek. The City can determine which of these reaches likely support beavers without threatening to damage sensitive infrastructure or property, and where beaver activity will likely pose a risk to public safety and infrastructure.

The following stream (or reach) categories can further be used for management decisions (adapted from Wheaton 2013 and Jefferson County 2017):

- Watercourses where beaver activity poses a threat to public safety, sensitive infrastructure and/or where beavers are not wanted (Beaver Exclusion Zones),
- Watercourses in areas where beavers have some potential to cause damage but impacts can be mitigated (Beaver Co-existence Zones), and
- Watercourses capable of supporting beavers without adverse effects on sensitive infrastructure (Beaver Conservation Zones).

We also refer to additional models and assessment tools to predict and map areas of potential beaver presence and human-beaver interaction (Howard and Larson 1985, Suzuki and McComb 1998, Anderson and Bonner 2014, Macfarlane et al. 2017, Dittbrenner et al. 2018). More detailed modeling could be used to identify specific stream reaches in Port Moody that are most suitable for beaver colonization.

6.2 Coexistence Techniques

There are two main techniques for landowners to coexist with beavers: Acceptance (also referred to as tolerance) and Mitigation (Vanderhoof 2017). Acceptance in this context means agreement with or tolerance of beaver activity as is, while Mitigation means the action of alleviating or reducing the severity of beaver activity through certain measures.

6.2.1 Acceptance

If beaver activity is not causing public safety, infrastructure, fish passage or other environmental concerns, then there is no immediate reason to take action other than ongoing monitoring. In this case, beavers can be left alone and continue to live in the area, while providing environmental outreach and educational opportunities. Given the substantial hydrological and ecological benefits beaver dams can bring (see **section 4**), Acceptance is the preferred management approach. Achieving Acceptance of beavers may require increased educational efforts and learning (see **section 5.1**).

Based on the analysis of potential beaver sites (i.e., high likelihood of occupancy) in Port Moody (**Figure 2**, **Table 3**), stream reaches where Acceptance of beaver presence is more likely are in areas of the north shore where channels are more natural and have little urban development (see **section 2.2.2)**. On the south shore, beaver presence is less likely to be "accepted" because of urban constraints (i.e., extensive urban encroachment on the stream channels, creek culverting and limited riparian vegetation, see **section 2.2.1**), and mitigation is expected to be required.

6.2.2 Mitigation

Situations arise where beaver activities become a cause for concern but where the benefits provided by urban beavers outweigh the financial costs to the city. In these situations (see **section 5.1**), beaver-friendly Mitigation options should be explored. Solutions used to coexist with beavers include a wide range of proven Mitigation measures designed to resolve issues caused by beaver activity (Müller-Schwarze 2011, WDFW 2011, Taylor and Singleton 2014, Hawley-Yan 2016, Pierce 2016, Pollock et al. 2017, Vanderhoof 2017). These Mitigation measures are used in many natural and anthropogenic areas. Coexistence techniques such as flow-level devices have increasingly been used in urban settings and have been successful in preventing adverse effects of beaver activity (Bailey et al. 2018, Hood et al. 2018, Portugal 2015). For example:

- Golden Gardens Park in Seattle, Washington. The City of Seattle constructed a coastal lagoon to catch runoff from local parking lots within the park. Beavers colonized the site in 2014, created a dam and removed trees. Site management included installing a pond leveler and wrapping trees. Managers have been working to retain the beavers on-site and increasing public education (Bailey et al. 2018).
- Magnusson Park on the shore of Lake Washington in Seattle. The site was originally designed to capture and filter stormwater runoff from the surrounding neighborhood while providing wildlife habitat and recreational use. Beavers colonized the site in 2014, building a lodge in one of the ponds. The engineering department has installed three pond-leveling devices and redesigned the channel to control pond levels and reduce flooding (Bailey et al. 2018).
- North and south branches of Thornton Creek in Seattle. The Thornton Creek Confluence Project (built in 2014) is a 2.4-ha riparian improvement project surrounded by residential properties. The fish species present in Thornton Creek include Chinook salmon, coho salmon, coastal cutthroat trout, steelhead trout and rainbow trout. Thornton Creek provides spawning habitat for Chinook salmon. Because beavers were present in the creek in 2005 and are expected to colonize the project site, the managers have re-designed the channel by incorporating a beaver pond and maximizing the amount of area that can be flooded next to the channel, while avoiding low-lying paths (Bailey et al. 2018). Monitoring in 2018 has indicated that the creek supports spawning Chinook and has active beaver ponds (King County 2018).
- Fanno Creek and Stoller Creek in Portland, Oregon. The City of Portland has enacted urban growth boundaries since 1973 to restrict development near stream corridors.

Fanno Creek contains resident cutthroat trout. Beaver colonization occurred on Fanno Creek in 2012 and on Stoller Creek in 2015. The City has planted thousands of forage plants and has notched the dam to prevent flooding (Poors 2018).

- Spring Creek in the City of Logan, Utah. The storm water detention pond next to the Walmart parking lot has been colonized by beavers since 2014. The subsequent installations of a pond leveler, beaver-dam deterrent, culvert fence, and tree protection have reduced the risk of flooding and eliminated the need for trapping of beavers (Portugal et al. 2015).

Technical advice from this research and from various government and private organizations provides the following mitigation measures:

- Tree protection (exclusion fencing and tree wrapping),
- Tree repellents (paints with sand and odours),
- Planting species that are less palatable to beavers (i.e., vegetation modification),
- Culvert protection, and
- Flow-leveling devices (fish-passable).

6.2.2.1 Tree Protection

Different ways to protect vegetation from beavers include vegetation enclosures such as exclusion fencing and wrapping of single trees with wire fencing. Exclusion fencing usually consists of metal fence posts supporting galvanized wire mesh to protect larger vegetated areas. To prevent beavers from tunneling under the area fencing, stakes or rocks can be used to anchor the bottom of the fence to the ground so that beavers cannot push it over or squeeze underneath. A mesh size of 2 x 4 inches (4 x 9 cm) is most effective (i.e., sturdy) for exclusion fencing. Exclusion fencing is less useful in large, densely-planted areas because of the required material and labour. Large areas of vegetation may be protected using 4-foot-high field fencing. Field fencing is a galvanized steel, woven wire fencing that is available in rolls. To prevent beavers from burrowing under the bottom of the fencing an 18-inch (46 cm) wide skirt could be installed on the outside of the fence or the bottom of the fence could be angled to the inside in an L-shape.

Individual plants can be wrapped with light gauge wire mesh. The ends of the fence material need to be fastened together (e.g., with zap-straps) rather than nailed to the tree, and a space (about 15 cm) should be maintained between the protective material and the trunk to enable tree growth. Cylindrical cages used to protect individual trees should have openings of about 4 x 9 cm and be made of galvanized wire fencing (to prevent rusting). The fencing should be about 4 ft (1.2 m) high (to account for potential snow cover). Fence material should be constructed from a 14-gauge wire to enable it to stand freely (the smaller the gauge, the stronger the wire). Individual cages should be anchored to the ground with stakes at the base of the tree.

Managing trees and shrubs for coexistence with beavers is a delicate balancing act. If too many of the trees and shrubs are wrapped, there may be inadequate food supply, which could cause the beaver to move elsewhere within the watershed. A strategic approach to tree protection must be taken in urban watersheds in order to balance coexistence with other key watershed considerations. For example, protection could be given to larger trees that might cause damage when falling, and desired ornamentals. It should also be noted that preventing access to food sources may force beavers to eat other nearby plants, including highly valued ornamental plants (e.g., roses); leaving smaller streamside trees may alleviate this. Also, tree fencing alone will not directly prevent flooding issues but can be a good option when used in concert with a flow-level device.

6.2.2.2 Repellents

Individual trees can be protected with repellents. Mixing outdoor paints with sand and applying the gritty mixture to trees can deter beavers from chewing trees. The mixture should consist of 2/3 to 1 cup (5-8 ounce) masonry grade sand to a quart (1 l) of latex exterior paint in any colour, and needs to be applied from the base to at least 4 ft high to be effective.

Other repellents include predator odours, and some studies found that beavers exhibited a strong avoidance of coyote, lynx, and river otter odours. Although not labeled as beaver repellents, two commercial products that have shown some success in preventing gnawing are Deer Away Big Game Repellent® and Plantskydd® (Vanderhoof 2017). However, there are several unknowns: the repellents may only be effective for a short time period, may need to be re-applied frequently (particularly in areas with high rainfall), and different predator species may have different levels of effectiveness depending on season. In addition, it should be noted that repellents can be quite smelly, and may not be practical for use near residences or in public parks (Vanderhoof 2017).

6.2.2.3 Vegetation Modification

Selecting plant species that are less preferred by beavers as food or construction material can help deter beavers and prevent or minimize beaver damage, helping to retain vegetation cover in an area (**Table 4**). In contrast, vegetation modification also can attract beavers. For example, dense plantings of fast-growing native species that readily re-sprout after being chewed by beavers (e.g., cottonwood, willow, and red-osier dogwood) can assist in retaining vegetation cover and beavers in an area. These fast-growing species can benefit from cutting by beavers because the cutting triggers re-sprouting from multiple stems that develop more extensively (Leavy et al. 2008). Particularly willow and black cottonwood help stabilize the soil and the stream bank, thus reducing erosion and downstream sedimentation. It is important to note that while beavers do prefer certain species, they may eat (or use as building material) less desirable species, if faced with a situation where their preferred species are unavailable. They may also overexploit preferred species, thereby restricting re-sprouting of stems.

Table 4. Plant species less desired and preferred by beavers in the Pacific Northwest

Plants Less Desired by Beavers	Plants Preferred by Beavers
Sitka spruce (*Picea sitchensis*)	Willow species (*Salix* spp.)*
Red elderberry (*Sambucus racemosa*)	Black cottonwood (*Populus trichocarpa*)*
Cascara (*Rhamnus purshiana*)	Red alder (*Alnus rubra*)
Indian plum (*Oemleria cerasiformis*)	Vine maple (*Acer circinatum*)
Pacific ninebark (*Physocarpus capitatus*)	Bigleaf maple (*Acer macrophyllum*)
Black twinberry (*Lonicera involucrata*)	Western redcedar (*Thuja plicata*)
Salmonberry (*Rubus spectabilis*)	Douglas-fir (*Pseudotsuga menziesii*)
Bitter cherry (*Prunus emarginata*)	Red-osier dogwood (*Cornus stolonifera*)*
Oregon ash (*Fraxinus latifolia*)	Cattail (*Typha* spp.)
Pacific crabapple (*Malus fusca*)	Sedges (*Carex* spp.)
Nootka rose (*Rosa nutkana*)	Water lilies (*Nuphar polysepalum*)
Hardhack (*Spirea douglasii*)*	Aspen (*Populus tremuloides*)
	Wild cherry (*Prunus* spp.)
	Salal (*Gaultheria shallon*)

Sources: Vanderhoof 2017, Cafferata Coe 2016, and Hawley-Yan 2016
* identifies species that respond to cutting with vigorous regrowth

6.2.2.4 Culvert Protection

Culvert fencing has been used extensively to prevent beavers from building dams at culvert inlets or inside culverts. The most commonly used systems are sturdy trapezoidal mesh fences (such as the “Beaver Deceiver”, originally invented by Skip Lisle in 1996) and cylindrical double-wire-mesh culvert extensions (e.g., “Beaver Stopper”) that are installed on the upstream side of a culvert. The trapezoidal fence (**Figure 3**) is preferred over a straight fence because it forces a beaver that starts damming the culvert to move further and further away, thereby maintaining unrestricted flows into the culvert. This creates a longer perimeter than the culvert diameter, increasing the effort required to dam the culvert. The wider fence also reduces the sound of water, thus reducing the beaver’s instinctive dam-building behaviour to try to block the flow. Vanderhoof (2017) noted several design considerations: (1) fences must be dug far enough into the substrate or have a galvanized mesh floor installed to prevent tunneling by beavers, (2) the fences work better in deeper water because beavers need to pile more debris to restrict water flow, (3) a fenced-off area of 30-40 ft (9-12 m) is effective to block access to the culvert from all sides, including from shore, (4) mesh openings must be large enough to enable fish passage of all species and life stages, (5) regular maintenance will be required, and (6) downstream fencing might be required to prevent beaver access to the culvert. Fencing in densely populated urban watersheds is uncommon due to the high maintenance requirements and the risk posed by debris accumulation and subsequent flooding.

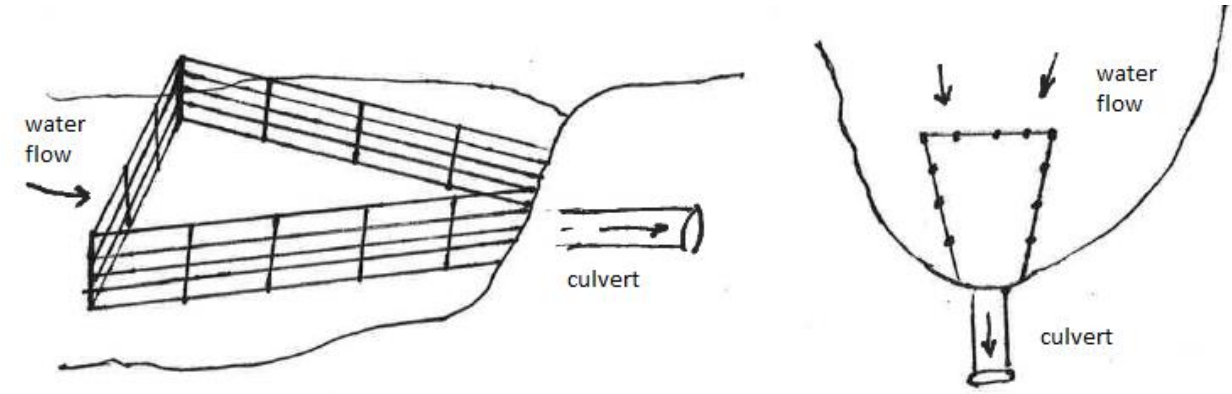


Figure 3. Trapezoidal culvert fencing installed on the upstream side of the culvert (Image: Vanderhoof 2017)

Double-cylindrical-mesh culvert extensions (**Figure 4**) are designed to cover an inner cylinder with a second, larger wire-mesh cylinder to prevent beavers from plugging up the inner cylinder (and therefore the culvert opening). This device also requires meshing of the culvert outflow to prevent beavers from damming inside the culvert. The disadvantage of this design is that it does not reduce the sound of water so beavers will still try to dam, resulting in the need for increased maintenance. Other disadvantages are more maintenance and clogging.

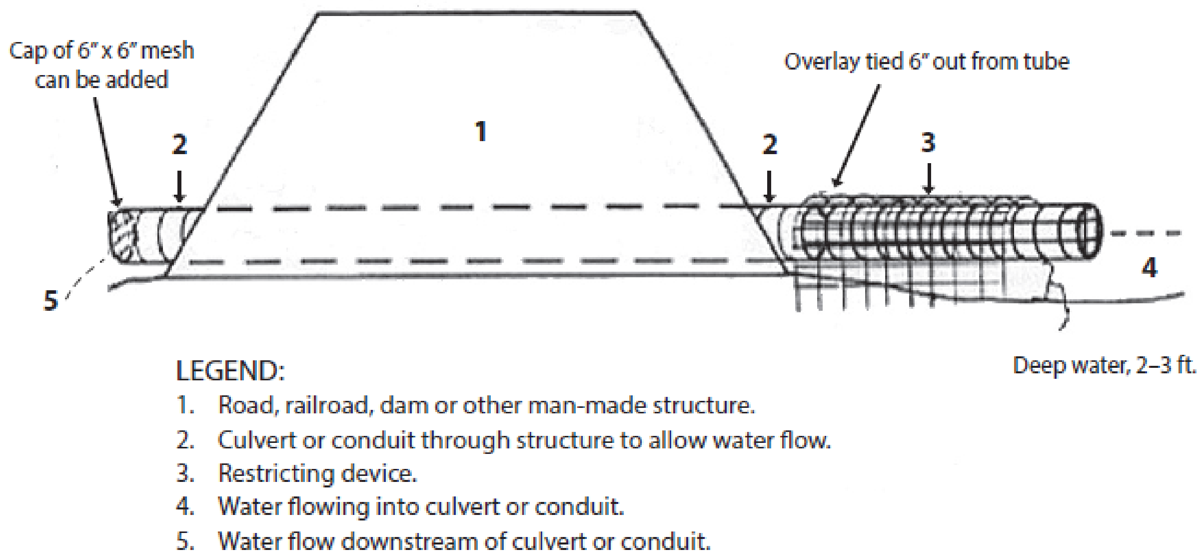


Figure 4. Double-cylindrical-mesh culvert extension installed at upstream (inflow) side of culvert. Note mesh cap on outflow side (Image: Hawley-Yan 2016)

Two additional devices that are used to prevent beavers from plugging road culverts are the Beavercone and the T-culvert (**Figure 5**). The Beavercone (5A), developed by Beavercone Products, is a wire cone that is installed over the end of a culvert. The cone is pre-fabricated to size and designed to prevent damming, while enabling water to pass through. On smaller sized culverts, the producer recommends (1) excavating a small hole in front of the culvert and (2) inserting a perforated inner liner pipe horizontally through the cone center about 1ft into the culvert (as shown at beavercone.com). The T-culvert (5B) consists of a metal culvert, with two (6-gauge) wire-mesh openings, that is installed over a smaller connector culvert fitted to the road culvert. The T-culvert needs to be larger than the road culvert (e.g., 4-ft diameter T-culvert for 6-18-in diameter road culvert) and should be 8-12 feet long. Culvert lengths and other measurements depend on site conditions (see https://www.fs.fed.us/t-d/pubs/htmlpubs/htm05772830/page06.htm).

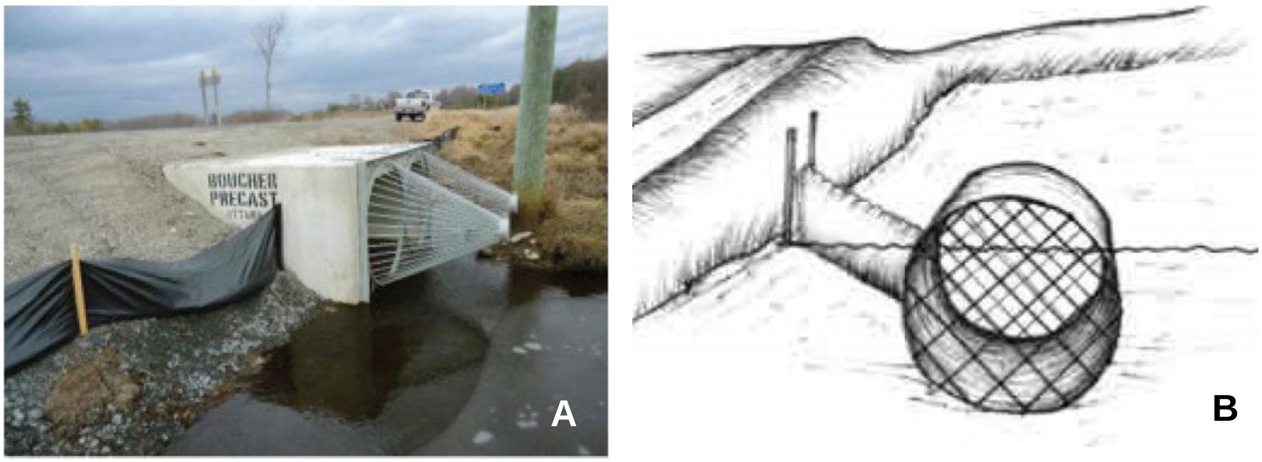


Figure 5. Beavercone (photo: beavercone.com) installed on a culvert (A), and T-culvert (drawing: J. Jones) installed over a culvert (B) (Image A in Hawley-Yan 2016 and image B in USDA Forest Service 2005)

6.2.2.5 Flow-leveling Devices

Where beaver dams raise water levels high enough to cause unwanted flooding, mechanical flow-leveling devices (commonly referred to as flow levelers or pond levelers) can be installed through the active dam area to limit the depth of flooding and control upstream pond stage height (Boyles 2006, Wheaton 2013, Portugal 2015, Pollock et al. 2017). Flow levelers are usually used on a free-standing dam, but also can be used in combination with a culvert (see Vanderhoof 2017 and Hawley-Yan 2016 for design examples). Projects on the Pacific Coast have successfully used single pipes of 12-18 inch diameter or two 12-inch pipes, 40 ft (12 m) long (Vanderhoof 2017). Successful installations leave a sufficient water depth to cover the opening of the den (or lodge), providing a minimal channel depth of 1.0 m for the beavers. Failure of a flow leveler has most often (75%) been associated with downstream dam construction by a beaver where minimal channel depth is not achieved (Pierce 2016, Pollock et al. 2017).

Flow devices frequently resolve human-beaver conflicts (Pollock et al. 2017). However, they do require post-installation maintenance to remain effective and not all site characteristics (e.g. topography, development) are conducive to flow-device installation (Taylor and Singleton 2014, Hood et al. 2018). Stream flows must be calculated before installation and compared to the conveyance capacity of available pipes (Vanderhoof 2017). If the pipe is too small, rain events will overwhelm the flow-leveler and still cause flooding.

There are two main types of flow levelers that have fish-passable designs ("Flexible Pond Leveler" and "Snohomish Pond Leveler"). These devices are recommended for use by the US Fish and Wildlife Service (Pollock et al. 2017). However, fish passage through flow levelers can be site- and species-specific. In British Columbia, the installation of flow-leveling devices into streams requires provincial and, if the stream is fish-bearing, federal review, under the *Wildlife Act*, *Water Sustainability Act* and *Fisheries Act* (**Appendix 2**).

The "Flexible Pond Leveler" (**Figure 6**), invented by Michel LeClair from Quebec (Hawley-Yan 2016) uses a double-walled flexible pipe and cylindrical fence. The fence is designed to block the pipe entrance, so that the beaver cannot detect the water flowing into the pipe and will not plug it. Successful Flexible Levelers maintain a water level that is low enough to resolve the threat from flooding, but high enough to enable the beaver to access its underwater den. This discourages the beaver from building additional dams downstream. This design has been shown to enable passage of salmonids including adult chum, and the Public Works Department of Snohomish County did not encounter a fish-blockage problem after installing more than 50 flexible levelers (Pollock et al. 2017). The pipe needs to be placed in a pool on the bed of the channel (Pollock et al. 2017). Improper placement of the downstream end of the pipe, however, may impede the movement of fish across this leveler. Rebar can be used to secure the pipe on the creek bed.

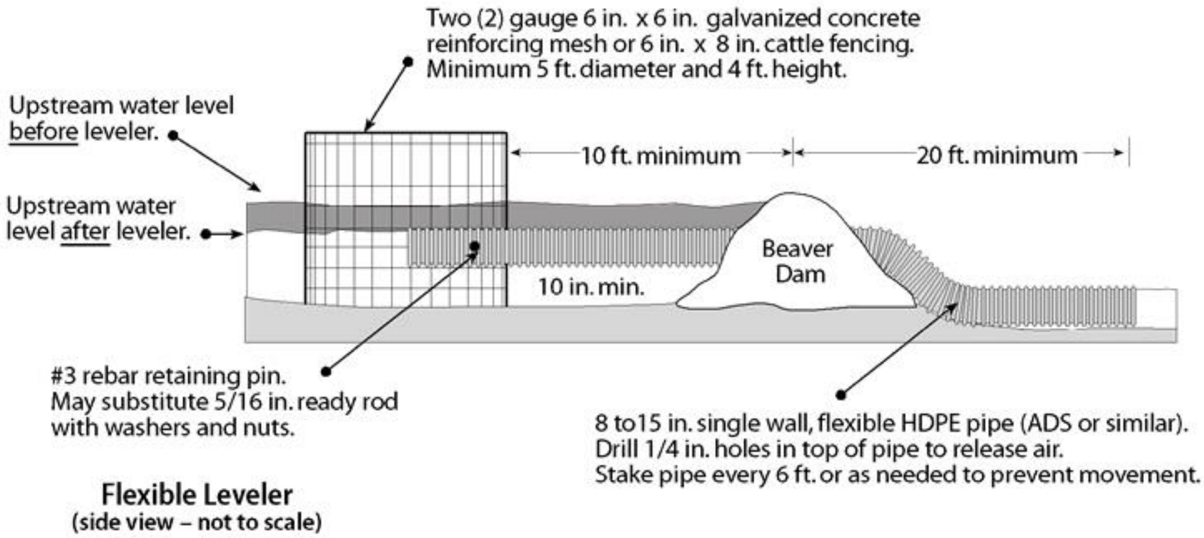


Figure 6. The "Flexible Pond Leveler" is used to decrease water levels above a dam to prevent flooding (Image: WDFW 2011)

The “Snohomish Pond Leveler” uses a similar design as the “Flexible Pond Leveler” but includes a fishway below the dam (**Figure 7**). This device is intended to prevent flooding while facilitating upstream adult salmon migration through fish-friendly adaptations at both ends of the leveler. However, this leveler has not been widely tested in a variety of flow conditions and stream gradients and is currently in limited use (Vanderhoof 2017).

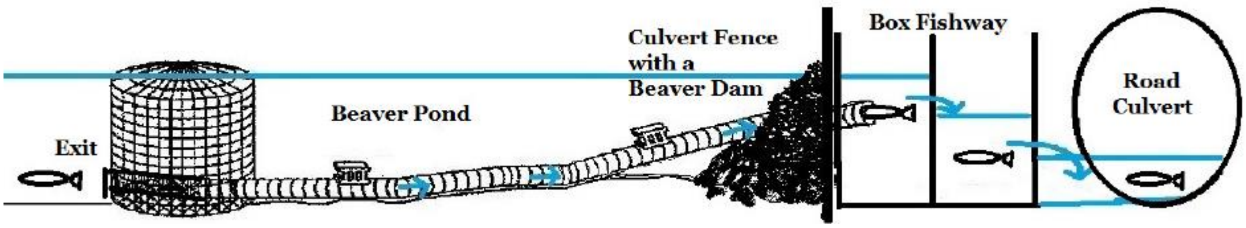


Figure 7. The “Snohomish Pond Leveler” combines a flexible pond-level design with a fish-friendly solution to flooding by beaver (Image: Beaver Solutions LLC 2010)

Salmon migrating upstream are attracted to the slotted box fishway (**Figure 8**) by water gushing from the boxes (slot 1 and slot 2) and the pipe. The salmon swim through slot 1 into pool 1 and through slot 2 into pool 2. The fishway assists adult salmon passage because (1) the pools provide resting places (eddies) before the salmon continue upstream into the 40 ft (12 m) flow leveler pipe, (2) each pool dissipates water energy, creates eddies, and decreases the water velocity in the pipe by 50%, and (3) pool 2 backfills the entire pipe with water (Beaver Solutions LLC 2010). An optional one-way door exit in a mesh cylinder, attached to the exit pipe, can be used to guide salmon from the pipe to the upstream side. The box fishway can be installed during the spawning run and removed when not required to reduce damage and maintenance costs. The installers who tested the Snohomish Leveler have named this device the most cost-effective, long-term, and fish-friendly solution to flooding caused by beaver activity (Beaver Solutions LLC 2010).

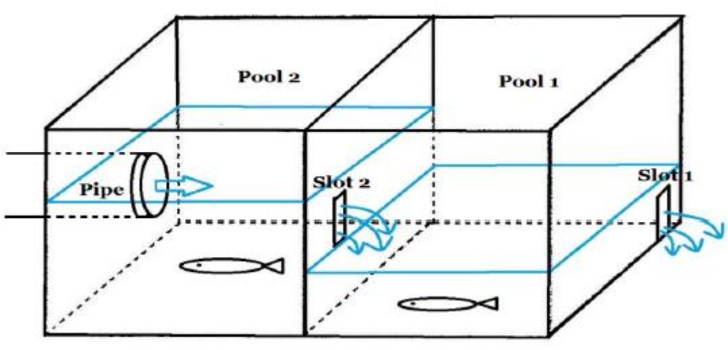


Figure 8. Two-slot fishway diagram. Design is passable to adult salmon (Image: Beaver Solutions LLC 2010). Log or rock fish ladders can also be installed adjacent to beaver dams to promote fish access

7.0 BEAVER MANAGEMENT TECHNIQUES

A few states and cities in the western United States have adopted a beaver-friendly approach because the cost of beaver removal is high. Moreover, beavers can provide a significant benefit to storm-water infiltration and sediment reduction. The City of Tigard (a suburb of Portland, Oregon), for example, has incorporated beaver dams and beaver dam analogs into its stormwater master-planning in an effort to address stream degradation impacts resulting from modified hydrology due to storm-water inputs in creeks (Legg 2018). Beaver dams and beaver dam analogs have been found to accelerate the recovery of incised streams by reducing excess surface-water runoff and downstream sedimentation (Pollock et al. 2014).

As these examples and the various coexistence techniques (**section 6**) indicate, beaver management is moving away from reactive techniques (i.e., dam removal, live trapping and relocation, and lethal removal of beavers) to proactive techniques (i.e., coexistence (**section 6.2**) and infrastructure upgrades). Beaver coexistence techniques in urban watersheds with high salmon values are relatively new. More research and study are needed to determine the success of beaver coexistence techniques in urban systems. Although examples of reactive and proactive beaver management techniques are listed below, only proactive techniques are recommended.

7.1 Reactive Beaver Management

7.1.1 Dam Notching and Dam Removal

Dam notching refers to the partial breaching of dams and is often used as a solution to flooding and to enable fish passage. This is a short-term solution and does not cause beavers to leave the area. Instead, beavers will repair the notch immediately. Wheaton (2013) has recommended dam notching only on inactive dams that pose a flooding risk. In this case, dam notching is recommended over full removal because it maintains the water level while retaining some of the ecosystem services of the beaver pond. In an emergency situation where a beaver dam is posing an immediate threat of flooding, notching the dam and installing a beaver deterrent into the notch can provide a temporary solution (**Figure 9**). Additional information is provided in Valachovič (2012).

The destruction or removal of beaver dams is not recommended because beavers tend to rebuild the dam immediately after it has been removed (WDFW 2011, Cafferata Coe et al. 2016, Vanderhoof 2017). Furthermore, the beavers will likely cut down more trees to do so (Vanderhoof 2017). Beaver-dam removal also can have negative effects on the beaver due to an increased risk of predation, particularly of the young. Note also that any dam removal requires a provincial permit in BC and needs to consider fish habitat, species at risk, and other mitigative measures (**Appendix 2**).

Figure 9. Beaver deterrent installed in notched dam to desired water-level height. Materials include plastic canisters and metal chain (Image: Valachovič 2012)

7.1.2 Live Trapping and Relocation

Trapping and relocation are often used when flow-level devices are ineffective. Live trapping and relocation of beavers elsewhere, however, can be prohibitive because beavers rarely survive relocation (WDFW 2011, Müller-Schwarze 2011, Cafferata Coe et al. 2016). Those that do very likely move away from the release site and often cover great distances, up to hundreds of kilometres (WDFW 2011, Müller-Schwarze 2011). The provincial government's position is that all suitable beaver habitat on the South Coast is occupied by resident beavers and relocation is considered inhumane (FLNRORD 2018).

If beavers have to be moved to more acceptable places as a management action, beavers should be moved as a family unit during the fall season (Müller-Schwarze 2011). Unfortunately, neighbouring beavers frequently colonize sites that have just been cleared of beavers (Müller-Schwarze 2011, Vanderhoof 2017). Therefore, one-time trapping is rarely a permanent solution. It should be added that capture, transport and relocation of wildlife (including beavers) is expensive and requires a provincial *Wildlife Act* permit in BC, as well as a relocation plan (**Appendix 2**). As required by the Province, relocation will be considered only if an appropriate receiving area can be identified and confirmed by a qualified professional wildlife biologist, and the Ministry of Environment accepts the relocation plan.

7.1.3 Lethal Removal of Beavers

The sole use of lethal trapping is not recommended as a long-term solution to managing beavers (Cafferata Coe et al. 2016). As with live trapping and relocation, when beavers are removed from suitable habitat, they are likely to be replaced by new immigrants relatively quickly (Bhat et al. 1993, Cafferata Coe et al. 2016, Loeb et al. 2014, Vanderhoof 2017). Also, trapping poses a potential risk to the public and to pets. Lethal removal of beavers has been ongoing in the Lower Mainland (City of Abbotsford 2002, Pierce 2016, City of Port Coquitlam 2018), and has been used when other methods have failed. Lethal control of beavers should be a last-resort option, after all other proactive management approaches have been exhausted (Taylor and Singleton 2014). A provincial *Wildlife Act* permit is required in BC (**Appendix 2**). The conditions under which a permit is required are outlined in the BC Hunting Regulations (2016).

7.2 Proactive Beaver Management

Proactive beaver management entails the coexistence techniques outlined in **section 6.2**. Other considerations and techniques to avoid conflicts with beaver activity include (Müller-Schwarze 2011 and Pollock et al. 2017):

- Encourage building new development on higher ground to reduce flooding risk.
- Build road bridges with large arches or use big box culverts rather than narrow culverts.
- Install culvert fences that prevent damming up of water upstream of culverts or flow-level devices in streams or ponds above dams.
- Plant trees that beavers find unpalatable.
- Balance beaver coexistence with fish-passage needs.
- Install beaver grates/screens on stormwater-outlet pipes requiring beaver exclusion.
- Enhance beaver habitat (e.g., food plants, wetlands) where beavers will do no harm.
- In areas where beaver repeatedly plug culverts, evaluate the culvert capacity to determine if it is undersized. On streams with a 3% gradient or less, the frequency of culvert plugging by beaver decreased exponentially as the size of the culvert opening increased (i.e., a culvert of 3.3 ft (1 m) diameter had a 73% chance of being plugged by a beaver while a 12-ft (4 m) diameter culvert had a 7% chance of being plugged), and size was the best predictor of culvert plugging (Pollock et al. 2017). Infrastructure upgrades (i.e., increasing the size of the culvert) are therefore recommended in these situations.

7.2.1 Cost Considerations

The cost of installing coexistence techniques depends on various factors, including permit requirements, time of year, size and depth of the stream (e.g., urban vs rural context), fish passage and available resources (e.g., staff and volunteers). Pierce (2016) reported the initial cost for a flow-leveling device at about $1000, with a lifespan of 10 years, and an average maintenance effort of 0.5-1.0 hour per year. Boyles (2006) reported that in rural Virginia, the initial labour and materials cost of installation for 33 flow devices at 14 different sites was US $44,526, with a very small annual maintenance cost of US $276.50. In the example from Virginia, preventative maintenance, road repairs, and beaver population control after installation were not needed (flow levelers were 100% effective 22 months after installation), and the cost was reduced to zero.

In addition to being a humane alternative, flow-leveling devices are more effective at providing long-term flood relief and prevention, and are more cost beneficial than trapping or relocating beavers, and breaching or removing dams (Hawley-Yan 2016). Live-trapping and relocation of one beaver cost the City of Vancouver approximately $10,000 (N. Page, Globe and Mail 2016). The cost benefit is achieved because flow devices prevent the need to repeatedly spend time and money on road maintenance and repairs, and managing beaver activity (Boyles 2006, Hawley-Yan 2016).

Most of the time, coexistence will require more than one technique. For the City of Port Moody, the costs to date have included risk assessments, culvert grating, tree removals, tree wrapping, and flow-level-device installation. These costs are included in the Decision-making Framework.

8.0 DECISION-MAKING FRAMEWORK

The principle of the Decision-making Framework is coexistence. The Decision-making Framework seeks to balance the needs of beavers, fish and other wildlife with the need to protect public safety, City lands, public easements, and statutory rights-of-way. The Decision-making Framework is intended to guide the City in an adaptive management approach to managing beaver activity (**section 8.1**). The Framework relies on our growing understanding of the benefits of beaver, beaver ecology, risk evaluation, and co-existence techniques, as discussed in the previous sections. Given the inability to identify what beavers will do or where they will go under different circumstances, the Decision-making Framework is designed to provide the City with potential management decisions to address beaver activity (**section 8.2**). The default management decision for beavers in the City of Port Moody is Ongoing Monitoring (**section 8.3**). The Decision-making Framework is depicted in **Figure 11**. The Framework illustrates a protocol to monitor and evaluate potential concerns posed by beaver activity, based on the adaptive management process. The City has developed a diagnostic key to using the Decision-making Framework to guide managers on specific situations (e.g., dam-building activity by beavers), with long-term objectives in mind (**Figure 12**). **Table 6** lays out the information required to apply the Diagnostic Key. These tools (Figure 11, Figure 12, and Table 6) are interconnected and not intended to be used in isolation.

8.1 Adaptive Management Process

Adaptive management is a structured, step-by-step process that allows for flexibility (e.g., when coping with surprises) while taking action to make necessary management decisions (Northern Arizona University 2019). This process recognizes the inherent uncertainties when dealing with nature and the natural environment and multiple strategies in addressing a dynamic ecosystem that require adjustments to be made along the way. Adaptive-management planning is designed to “replace management learning by trial-and-error with learning by careful tests” (Walters

1997). Adaptive management will enable the City of Port Moody to apply the lessons learned from the current work (e.g., the installation of a flow leveler at Suter Brook Creek) to future projects, by combining research and coexistence techniques. The adaptive management process is based on six main steps (**Figure 10**):

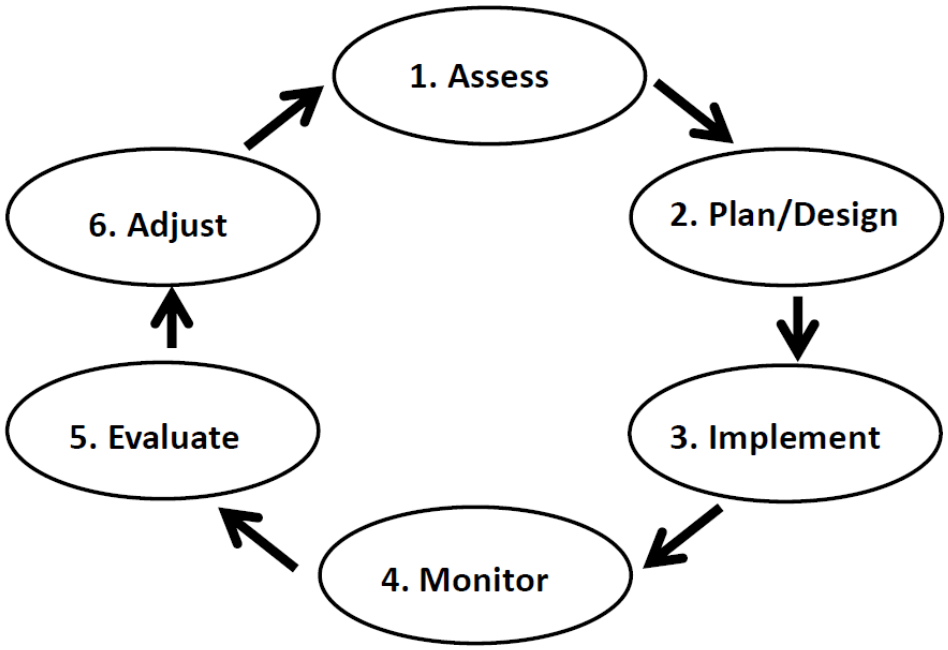


Figure 10. Adaptive management process for the beaver management plan (Diagram from Northern Arizona University 2019)

8.1.1 Assessment

The adaptive management process starts by assessing the current situation and potential changes in conditions. The assessment identifies the "issue of concern" (i.e., change in condition) and determines whether the issue is likely to cause harm. As part of the assessment, it is helpful to ask specific questions (Northern Arizona University 2019):

- What are the objectives/criteria?
- What methods should be used to achieve the objectives/fulfil the criteria?
- What could be potential outcomes based on the methods used?
- How will outcomes be measured (i.e., indicators and thresholds that can be monitored and evaluated)?
- What are the uncertainties (e.g., changing climate)?

8.1.2 Planning / Design

The 2nd step involves planning and designing the methods that might solve the issue of concern. If multiple possible methods exist, careful testing might be needed followed by comparison. A good start might be to test the most cost-effective method first using a cost-benefit analysis.

8.1.3 Implementation

In the 3rd step, the methods are implemented according to plan. Implementation should include up-to-date documentation, including recording of any deviations from the plan.

8.1.4 Monitoring

Monitoring (step 4) is essential to assess whether the issue of concern has been addressed successfully or whether changes need to be made. Monitoring protocols should be standardized to enable comparisons between sites where similar methods have been implemented. The same indicators should be measured over a set period of time to be able to track changes.

8.1.5 Evaluation / Learning

This step (5) involves evaluating preliminary results and learning from them while monitoring is ongoing. Preliminary results can be compared with the expected objectives/criteria identified in the assessment (step 1) to determine the need for adjustments.

8.1.6 Adjustment

The final (6th) step enables decision-makers (i.e., City managers and engineers) to adjust plans, designs or methods, based on the findings from the evaluation.

8.2 Management Actions

The Decision-making Framework (**Figure 11**) evolves from the assessment of the issue of concern (step 1). The Decision-making Framework will guide the evaluation of beaver management actions on City lands and rights-of-way based on certain criteria (i.e., standards or principles). Possible criteria may include (but are not limited to):

- Maintain public safety,
- No flooding of sensitive infrastructure or property,
- No irreversible adverse effects from gnawing/cutting of valued trees or shrubs,
- No irreversible adverse effects on established riparian setbacks or ecologically sensitive areas,
- No obstruction of fish passage, and
- No breach of regulatory compliance.

The Decision-making Framework, together with the above criteria, leads to the following potential decision-making strategies (**Table 5**). Opportunities for coexistence with beavers will likely depend on the level of risk associated with the outcome of a management action.

Table 5. Possible decision-making strategies and associated beaver management actions in Port Moody, based on specific issues of concern, indicators and thresholds

Issue of Concern	Indicator	Threshold	Action
Tree cutting	Gnawing marks on tree	Trees killed or felled	Install tree protection; planting of suitable vegetation
Flooding	Culvert plugged by debris; water backing up upstream of culvert	Flow height not to exceed 85% of culvert diameter	Install culvert fencing
Flooding	Excessive dam height	Water held back above dam is at threshold elevation (to be determined by City)	Install flow leveler* (or beaver deterrent)
Flooding	Water overtopping oil-water separator	Water is at threshold elevation (to be determined by City)	Install flow leveler* (or beaver deterrent)
Flooding	Water flooding infrastructure (e.g., road, railway, and trail)	Water is at threshold elevation (to be determined by City)	Install flow leveler* (or beaver deterrent)
Restricted fish passage	Spawning fish observed below dam	No spawning fish observed above dam	Install fish-passable flow leveler* (or notch dam)

* It is easier to install flow levelers during low-flow conditions.

8.3 Monitoring

All beaver management actions require ongoing maintenance and monitoring. The monitoring will fulfil two functions: monitoring enables the City to evaluate (1) whether beaver activity is occurring in any of Port Moody's watercourses, and (2) whether the management decisions are functioning as intended. We recommend a simple long-term biannual visual inspection of streams and wetlands to look for beaver sign (e.g., gnawed trees, dams, visuals) and check water levels. This work can be conducted by the City's maintenance crews or environmental staff as part of regular infrastructure maintenance. If the monitoring identifies an issue of concern, the Decision-making Framework should be consulted (**Figure 11**). In addition, we recommend that monitoring of each management decision (function 2) be conducted to verify whether the management action is effective at resolving the issue of concern. This monitoring should initially include daily or weekly monitoring for a period of at least one month or during heavy rain, followed by ongoing inspections during the biannual monitoring carried out as part of function (1). Installing staff gauges is recommended to facilitate water-level monitoring. Written records and photographs need to be kept of all inspections, observations, and modifications. The written records should identify corrective actions that need to be implemented by City staff

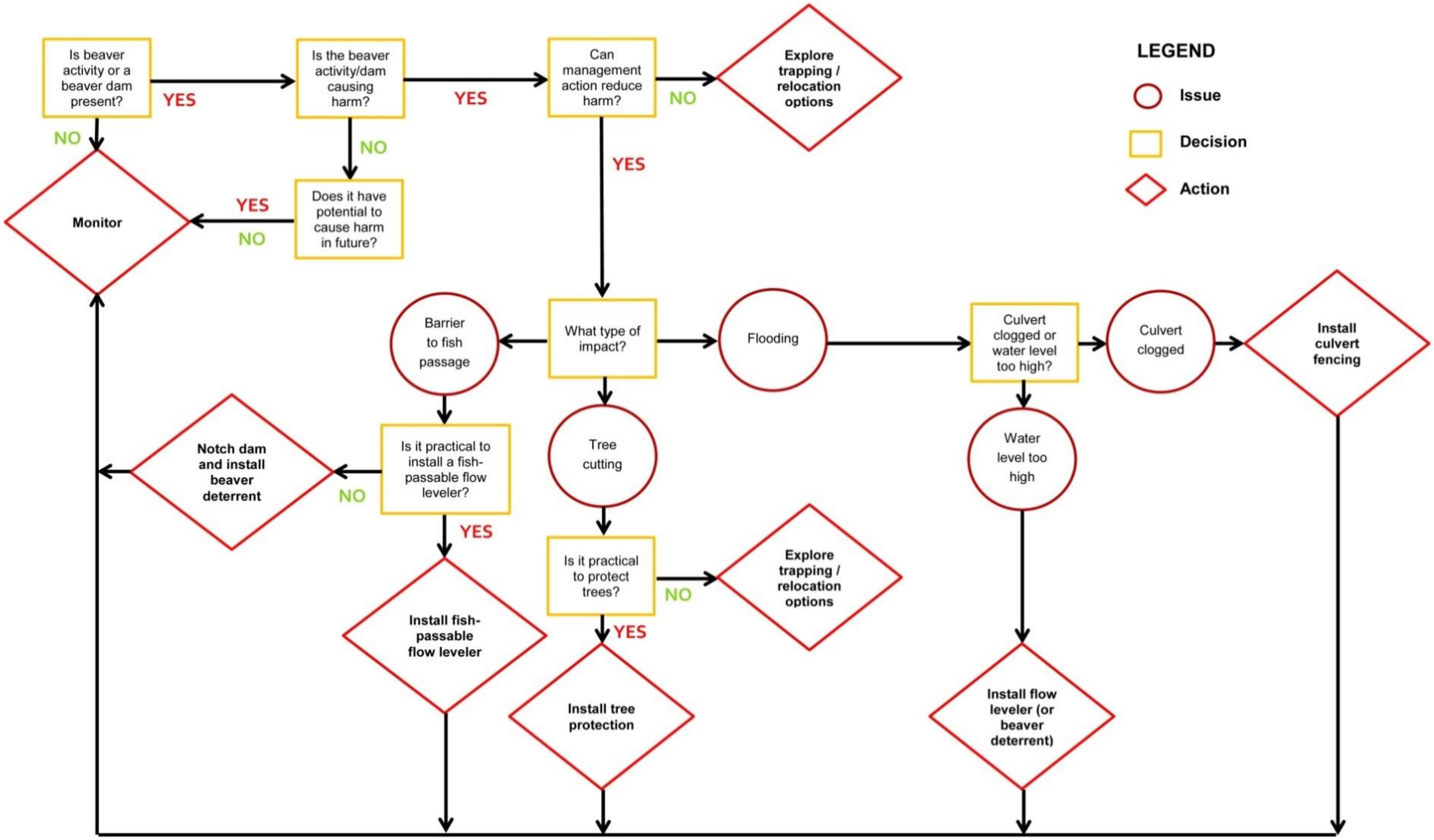


Figure 11. Decision-making Framework for beaver management in the City of Port Moody (adapted from Wheaton 2013). The Framework illustrates a protocol to monitor and evaluate potential benefits of co-existence and concerns posed by beaver activity, based on the adaptive management process. The Diagnostic Key (Figure 12) provides a procedure to evaluate and respond to a specific situation (e.g., dam-building activity) in response to monitoring. Table 6 lays out the information required to apply the Diagnostic Key. These tools are interconnected and not intended to be used in isolation.

8.4 Diagnostic Key to the Framework

Development of the Decision-making Framework began with mapping of the habitat capability for beavers in Port Moody to anticipate where beavers could establish a colony (**Figure 2**). Locations of highest likelihood of beaver occupation in Port Moody are mostly in low-elevation/ low-gradient stream reaches. Knowledge of potential future beaver occupation will enable the City to focus its monitoring efforts on areas of highest potential occupation.

The Diagnostic Key to the Framework is used when beaver activity has been identified (i.e., the Key is situation-specific, such as for an individual beaver dam). With this as a starting point, the Diagnostic Key to the Framework (**Figure 12**) identifies whether any allocation of resources (e.g., for conducting assessments, planting, wrapping, installing, notching, and/or removing something) is needed based on a stepwise assessment of coexistence opportunities, habitat effects and the potential concerns posed by beaver activities. The Key is designed to be considered by City managers to assist with implementing of mitigation measures. The mitigation is designed to reduce the need for lethal trapping or relocation but cannot completely eliminate it.

8.4.1 Topic Areas

The Diagnostic Key uses four topic areas to guide decision-making:

1. **Enhancement Potential:** Is the location a candidate for wetland enhancement? Can the area be designed to provide beaver habitat (e.g., sufficient space for a pond and vegetation)? Can beavers survive in the area?
2. **Ecological Effects:** What are the ecological effects associated with beaver activity? What are the benefits of co-existence with beavers? What are the long-term cumulative effects? Does the ecological impact of beaver activity pose an unacceptable risk? Can the perceived risk be mitigated?
3. **Risk of the Effects**: How serious are the public safety and infrastructure impacts caused by the presence of beaver activity? How likely are they to occur?
4. **Regulatory Compliance**: Do management actions adhere to regulations such as the *Fisheries Act*, *Water Sustainability Act*, and *Wildlife Act*?

8.4.2 Risk Assessment

A level of risk of a specific event related to co-existence with beavers is evaluated by the possibility of its occurrence and the severity of the impacts should the event occur. The Key guides the user in evaluating the potential risks to public safety and infrastructure caused by beaver activity and identifies possible mitigation strategies. The Diagnostic Key addresses the following potential risks:

- Flooding of infrastructure and trails
- Tree strike
- Changes to riparian habitat
- Restriction to fish passage

8.4.3 Information Requirements

The questions in the Diagnostic Key may be answered by reviewing the findings of existing assessments or monitoring programs, or by conducting one or more additional assessments where information is lacking. Assessments are to be conducted by a qualified environmental professional. The information requirements (**Table 6**) include (but are not limited to):

- Hydrological Assessment – this assessment can be used to identify water depth and flow levels that are important for providing beaver habitat.
- Watercourse Assessment – the watercourse assessment looks at a variety of aspects related to the physical features and habitat of a stream or river. This assessment provides information on, e.g., stream flow, channel morphology, disturbance indicators, woody debris, instream vegetation, water quality, fish presence and extent of fish habitat.
- Riparian Habitat Assessment – this assessment provides information on the steepness of a stream, the width of the riparian zone, potential and existing vegetation, and species of deciduous trees and shrubs, including those that provide the bark, twigs, and leaves that beavers consume to survive.
- Species At Risk Assessment – this assessment identifies the potential for species at risk to be present in the area, and mitigation required to address potential impacts to these species and their habitat.
- Invasive Species Assessment – this assessment identifies invasive plant species and their distribution in the area, and proposes methods for their removal or management. Invasive species monitoring is considered to be a baseline activity. If benefits are occurring as a result of beaver presence, no action will be required.
- Flood Risk Assessment – this assessment provides information on the risk of flooding and potential ecosystem and infrastructure impacts caused by flooding. This can be used to identify potential flooding impacts from beaver dam-building and other beaver activity, and recommended upgrades to infrastructure.
- Beaver-Habitat Assessment – this assessment looks at a variety of factors that make an area a suitable place for beavers, including topography, gradient, water availability, amount of woody forage and dam-building materials. The positive effects of Natural Capital and Ecosystem Services are to be taken into account when assessing co-existence.
- Hazard Tree Assessment – this is an evaluation of trees within a given radius of the beaver habitat to determine whether there is a possibility of trees falling and causing injury or damage to property.
- Infrastructure Risk Assessment – this assessment will identify the types of infrastructure present within a given radius of the beaver habitat. The assessment will determine the likelihood that the infrastructure will be adversely impacted by beaver activity and the potential severity.
- Ongoing Monitoring – monitoring is an integral aspect of all steps and information requirements (see **section 8.3**) and thus does not appear in Table 6.

Table 6. Information required to answer the Questions in the Diagnostic Key. Topic Areas (section 8.4.1) are in **bold** text and information needed (section 8.4.3) is underlined (City of Port Moody). The Decision-making Framework (Figure 11) illustrates a protocol to monitor and evaluate potential benefits of co-existence and concerns posed by beaver activity, based on the adaptive management process. The Diagnostic Key (Figure 12) provides a procedure to evaluate and respond to a specific situation (e.g., dam-building activity) in response to monitoring. Table 6 lays out the information required to apply the Diagnostic Key. These tools are interconnected and not intended to be used in isolation.

#	Question	Information Requirements
A	Is the site suitable for a beaver wetland?	This question explores **Enhancement Potential.** In order to evaluate the suitability of beaver habitat, review information from the Hydrological Assessment and the Beaver-Habitat Assessment. Use existing information if available.
B	Is the site suitable for enhancement?	This question explores **Enhancement Potential.** To evaluate suitability for enhancement, identify whether dense plantings of disturbance-tolerant species (e.g., willow and cottonwood) can assist in retaining vegetation cover. Are there landscape designs that would enhance beaver habitat without compromising public safety and infrastructure? Are there opportunities for environmental outreach and educational opportunities? We review information from the Hydrological Assessment, the Beaver-Habitat Assessment, and the Infrastructure Risk Assessment. Use existing information if available.
C	Suitable Site: Is the beaver activity cause for concern?	This question is related to the **Ecological Effects** and the **Risk of the Effects** of beaver activity. The Hazard Tree Assessment, Riparian Habitat Assessment, Watercourse Assessment, Infrastructure Risk Assessment, Hydrological Assessment and/or Flood Risk Assessment will help answer this question. If there is no concern regarding beaver activity then Acceptance is the outcome. The question triggers a cost analysis and explores funding options if costs are likely to be exceeded.
D	Unsuitable Site: Is the beaver activity cause for concern?	As with C, this question relates to **Ecological Effects** and **Risk of the Effects** of beaver activity. This site is not suitable for beaver occupation (e.g. the site is too small, has insufficient forage/water to sustain a beaver colony) and is not a feasible candidate for enhancement. The site is unlikely to be occupied by beavers long-term. If no concerns exist regarding beaver activity then Acceptance is the outcome. The positive effects of Natural Capital and Ecosystem Services are to be taken into account when assessing co-existence.

#	Question	Information Requirements
E	Is a rising water level cause for concern?	The Watercourse Assessment, Hydrological Assessment and/or Flood Risk Assessment will help the Manager to determine whether there is a potential **Flood Risk**. Use existing information where available.
F	Can rising water levels be mitigated with a flow device or culvert fencing?	This question relates to **Ecological Effects**, **Flood Risk**, and **Regulatory Compliance**. The Flood Risk Assessment, Watercourse Assessment, and Species At Risk Assessment will help the decision-maker to identify the appropriate mitigation strategies. This needs to include identifying threshold water levels above which flooding is likely. The question triggers a cost analysis and explores funding options if costs are likely to be exceeded. Beaver-dam removal needs to consider other wildlife and requires a permit. If beaver-dam removal does not solve the flooding problem, consider live trapping / relocation. The positive effects of Natural Capital and Ecosystem Services are to be taken into account.
G	Is tree harvesting cause for concern?	A Hazard Tree Assessment and Riparian Habitat Assessment will enable the decision-maker to determine the **Tree Strike Risk** and effects on riparian habitat posed by harvesting of trees.
H	Will all mitigation and maintenance combined exceed the cost of relocation?	The assessments (i.e., Hazard Tree Assessment, Flood Risk Assessment, Infrastructure Risk Assessment, and Watercourse Assessment) will assist the decision-maker in determining mitigation requirements and associated costs. The question triggers a cost analysis and explores funding options if costs are likely to be exceeded. The positive effects of Natural Capital and Ecosystem Services are to be taken into account.
I	Is the beaver dam* fish-passable? *If no dam is present, Skip to Question K.	This question addresses **Regulatory Compliance** and the DFO requirement to protect fish habitat and provide fish passage. The Flood Risk Assessment and Watercourse Assessment will assist the decision-maker in answering this question.
J	Can fish passable flow device be installed?	The Flood Risk Assessment and Watercourse Assessment will assist the Manager to determine mitigation options. A log or rock fish ladder may need to be installed as well to allow fish access. The question triggers a cost analysis and explores funding options if costs are likely to be exceeded.
K	Is the potential spread of invasive plants a concern?	The Invasive Species Assessment will assist the decision-maker to determine if there is a potential for invasive plants to spread as a result of beaver activity.

#	Question	Information Requirements
L	Will cost of habitat enhancement and all mitigation combined exceed cost of relocation?	The assessments (i.e., Hydrological Assessment, Beaver-Habitat Assessment, Hazard Tree Assessment, Flood Risk Assessment, Infrastructure Risk Assessment, Watercourse Assessment, Riparian Habitat Assessment, and Invasive Species Assessment) will assist the decision-maker in determining mitigation requirements and associated costs. The question triggers a cost analysis and explores funding options if costs are likely to be exceeded. The positive effects of Natural Capital and Ecosystem Services are to be taken into account.

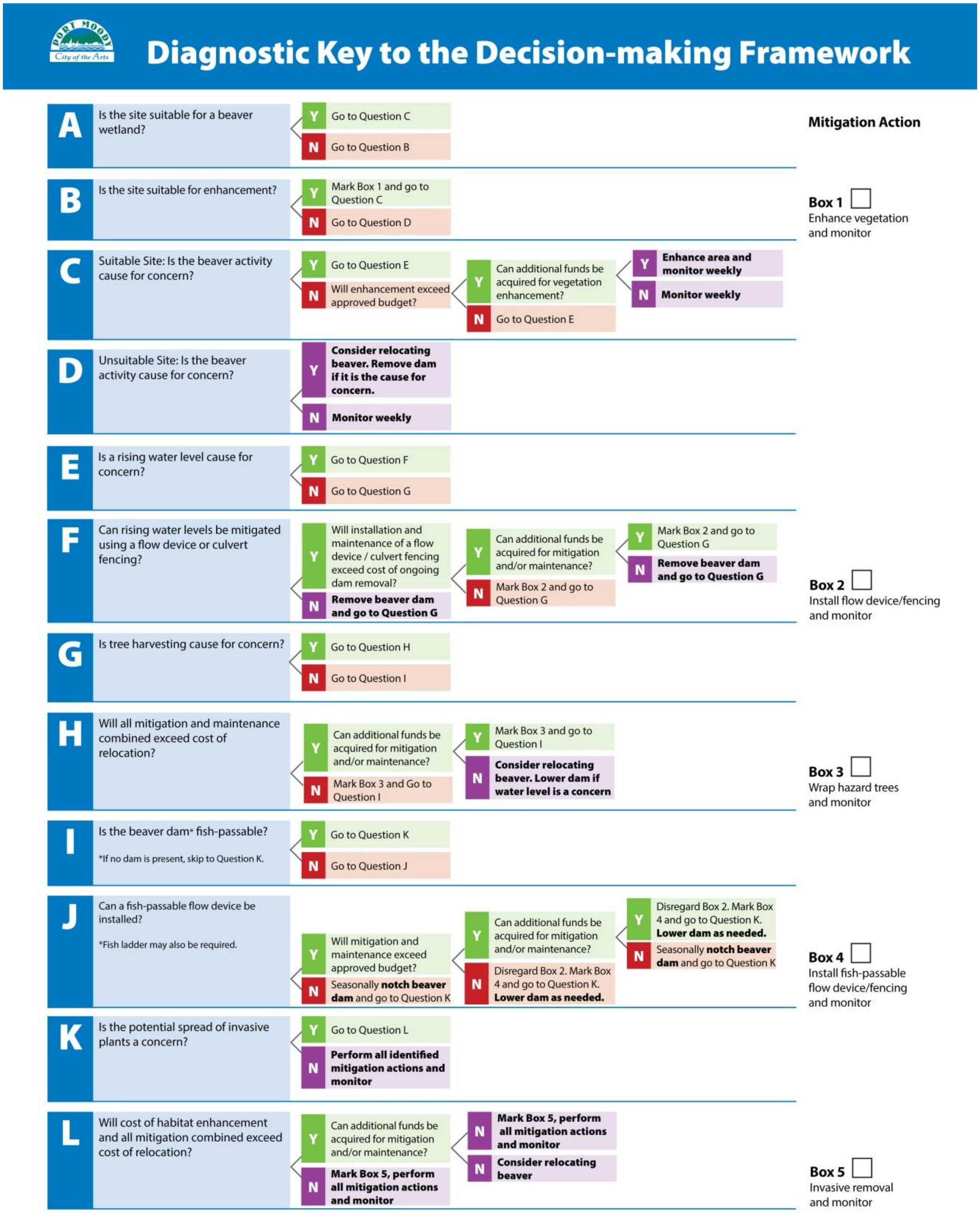


Figure 12. Diagnostic Key to the Decision-making Framework (City of Port Moody). The Decision-making Framework (Figure 11) illustrates a protocol to monitor and evaluate potential benefits of co-existence and concerns posed by beaver activity, based on the adaptive management process. The Diagnostic Key (Figure 12) provides a procedure to evaluate and respond to a specific situation (e.g., dam-building activity) in response to monitoring. Table 6 lays out the information required to apply the Diagnostic Key. These tools are interconnected and not intended to be used in isolation. Given the substantial hydrological and ecological benefits of beaver-wetlands (**section 4**), the Key is designed to avoid the need for lethal trapping or relocation where possible

9.0 ACKNOWLEDGEMENTS

We would like to acknowledge the contributions from the following individuals: Judy Taylor-Atkinson and Jim Atkinson; Patrick Dennet, Ruth Foster, Rod MacVicar and Kevin Ryan (Burrard Inlet Marine Enhancement Society); David Bennie and Brian Wormald (Port Moody Ecological Society); Melissa Chaun and John Saremba (Burke Mountain Naturalists); Lesley Fox and Adrian Nelson (Association for the Protection of Fur-bearing Animals); Sandra Hollick-Kenyon and Al Jonsson (Fisheries and Oceans Canada); Josh Malt (Ministry of Forests, Lands and Natural Resource Operations and Rural Development); Pam Ryan (Facilitator); Kurt Frei, Stephen Judd, Steve Smedegaard, and Lesley Douglas (City of Port Moody).

10.0 LITERATURE CITED

Anderson, J. T. and J. L. Bonner. 2014. Modeling habitat suitability for beaver (*Castor canadensis*) using geographic information systems. Fourth international conference on future environment and energy (IPCBEE) 61:12-23 DOI: 10.7763/IPCBEE. 2014. V61. 3.

Bailey, D. R., B. J. Dittbrenner, and K. P. Yocom. Reintegrating the North American beaver (*Castor canadensis*) in the urban landscape. *WIREs Water* 2019; 6:e1323 (Wiley Periodicals Inc.).

Beaver Solutions LLC. 2010. Snohomish Pond Leveler. Team members: M. Callahan, B. Dittbrenner, J. Jacobson, D. Kolbe, T. Parker, M. Rustay, and Y. Chait. https://www.beaversolutions.com/.

Bhat M. G., R. G. Huffaker, and S. M. Lenhart 1993. Controlling forest damage by dispersive beaver populations: centralized optimal management strategy. *Ecological Applications* 3 (3): 518–530.

Bird Studies Canada. 2017. IBA Important Bird and Biodiversity Areas of Canada. Site BC 020 English Bay and Burrard Inlet, British Columbia. https://www.ibacanada.ca/maps/sites/BC020.pdf.

Bouwes, N., N. Weber, C. E. Jordan, W. C. Saunders, I. A. Tattam, C. Volk, J. M. Wheaton, and M. M. Pollock. 2016. Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead (*Oncorhynchus mykiss*). *Scientific Reports* 6:28581, DOI: 10.1038/srep28581. http://www.nature.com/scientificreports/.

Boyles, S. L. 2006. Report on the efficacy and comparative costs of using flow devices to resolve conflicts with North American beavers along roadways in the coastal plain of Virginia. Prepared by Christopher Newport University, for the Virginia Department of Transportation.

British Columbia (BC) Conservation Data Centre (CDC). 2019. BC Species and Ecosystems Explorer. B.C. Minist. of Environ. Victoria, B.C. http://a100.gov.bc.ca/pub/eswp/ (accessed Jan 6, 2019).

British Columbia (BC) Hunting Regulation. 2016. Trapping Regulations. BC fur management program. https://www2.gov.bc.ca/assets/gov/sports-recreation-arts-and-culture/outdoor-recreation/fishing-and-hunting/hunting/regulations/2016-2018/hunting-trapping-synopsis-2016-2018-trapping.pdf

British Columbia (BC) Ministry of Environment (MoE). 2014. Develop with care: environmental guidelines for urban and rural land development in British Columbia. https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/best-management-practices/develop-with-care.

British Columbia (BC) Ministry of Environment, Lands and Parks (MELP). 2001. Beaver management guidelines. Prepared by the Ministry of Environment, Lands and Parks

Vancouver Island Region. Draft Version 1, May 10, 2001. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/best-management-practices/beaver-guide.pdf.

British Columbia (BC) Ministry of Water, Land and Air Protection (WLAP). 2004. Standards and best practices for instream works. http://www.env.gov.bc.ca/wld/documents/bmp/iswstdsbpsmarch2004.pdf.

British Columbia (BC) Ministry of Water, Land and Air Protection (WLAP) and Fisheries and Oceans Canada (DFO). 2004. Beaver dam removal. Version 1.0. Component of standards and best practices for instream works. http://www.elp.gov.bc.ca/wld/instreamworks/downloads/BeaverDamRemoval.pdf.

British Columbia (BC) Province. 1988. Beaver management guidelines in British Columbia. Ministry of Environment Wildlife Branch. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/best-management-practices/beaver_mgt.pdf.

British Columbia (BC) Province. 2006. Riparian Areas Regulation implementation guidebook. Revised January 2006. Ministry of Water, Land and Air Protection, Environmental Stewardship Division, Biodiversity Branch. https://www.ubcm.ca/assets/library/Policy~Topics/Environment/Riparian~Area~Regulation/RAR~Local~Government~Training~Session-Jan~2005/RAR%20Implementation%20Guidebook.pdf

British Columbia (BC) Province. 2010. Evergreen line rapid transit project, environmental assessment certificate application. Section 6: Fisheries and aquatic habitat assessment. https://projects.eao.gov.bc.ca/p/evergreen-line-rapid-transit/docs.

British Columbia (BC) Province. 2016. Water Sustainability Act and regulation. https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/laws-rules/water-sustainability-act, and http://www.bclaws.ca/civix/document/id/complete/statreg/36_2016#section2.

British Columbia (BC) Province. 2017. Terms and conditions for Water Sustainability Act changes in and about a stream, as specified by Ministry of Forests, Lands & Natural Resource Operations (FLNRO) Habitat Officers, Northeast Region. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/working-around-water/terms_and_conditions_northeast_region_sept_2016.pdf.

British Columbia (BC) Province. 2018. British Columbia Conservation Data Centre. BC Species and Ecosystems Explorer. BC Ministry of Environment, Victoria, BC. http://a100.gov.bc.ca/pub/eswp/.

British Columbia (BC) Wildlife Watch. 1995. Bird checklist: Shoreline Park, Port Moody. BC Environment Lower Mainland Region. List based on wildlife inventories by the Burke Mountain Naturalists. http://www.env.gov.bc.ca/wld/documents/wldviewing/birdlistshoreline.pdf.

Brooks, R. P., M. W. Fleming, and J. J. Kennelly. 1980. Beaver colony response to fertility control: evaluating a concept. *Journal of Wildlife Management* 44(3):568-575.

Burke Mountain Naturalists. 2016. Green Scene. Look (but not too closely) at Port Moody's herons. Authored by E. Golds. https://www.burkemountainnaturalists.ca/wp-content/uploads/2017/06/TCN.PoMoherons.pdf.

Burrard Inlet Marine Enhancement Society. 2018. Mossom Creek Hatchery. http://www.mossomcreek.org/.

Cafferata Coe, F., V. Petro, J. Taylor, and J. Woodward. 2016. Wildlife in managed forests: the American Beaver. Oregon Forest Resources Institute. Portland, Oregon. https://oregonforests.org/sites/default/files/2017-05/Wildlife-Book-American-Beaver-Proof.pdf.

City of Abbotsford. 2002. Council report – executive committee. Recommendations regarding beaver trapping. https://abbotsford.civicweb.net/document/4669.

City of Port Coquitlam. 2018. Beaver management – additional management methods. https://www.portcoquitlam.ca/city-services/pets-wildlife/beaver-management/.

City of Port Moody. 2011. What swims beneath: A fish survey of Port Moody Arm. http://www.portmoody.ca/modules/showdocument.aspx?documentid=1059.

City of Port Moody. 2014. City of Port Moody Official Community Plan (OCP). Schedule "A" to Bylaw No. 2955. http://www.portmoody.ca/index.aspx?page=313.

City of Port Moody. 2018a. Port Moody history. http://www.portmoody.ca/index.aspx?page=76.

City of Port Moody. 2018b. Port Moody natural environment. Port Moody parks & recreation http://www.portmoody.ca/index.aspx?page=180.

City of Port Moody. 2018c. Beavers Q & A. Port Moody parks & recreation, natural environment. http://www.portmoody.ca/index.aspx?page=1735

Collen, P. and R.J. Gibson. 2001. The general ecology of beavers (*Castor* spp.), as related to their influence on stream ecosystems and riparian habitats, and the subsequent effects on fish – a review. *Reviews in Fish Biology and Fisheries* 10:439-461.

Curtis, P. D. and P. G. Jensen. 2004. Habitat features affecting beaver occupancy along roadsides in New York State. *Journal of Wildlife Management* 68(2):278-287.

Dittbrenner B. J., M. M. Pollock, J. W. Schilling, J. D. Olden, J. J. Lawler, and C. E. Torgersen. 2018. Modeling intrinsic potential for beaver (*Castor canadensis*) habitat to inform restoration and climate change adaptation. *PLoS ONE* 13(2): e0192538.

Envirowest Consultants Inc. 2019. Assessment of fish habitat infrastructure within the City of Port Moody, BC. Summer / Fall 2017.

Fisheries and Oceans Canada (DFO). 2018. Projects near water. http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html.

Gerwing, T. G., C. J. Johnson, and C. Alström-Rapaport. 2013. Factors influencing forage selection by the North American beaver (*Castor canadensis*). *Mammalian Biology* 78(2): 79–86.

Globe and Mail. 2016. Vancouver's urban-beaver plan focuses on enhancing habitats. Published February 2, 2016. Updated May 16, 2018. https://www.theglobeandmail.com/news/british-columbia/vancouvers-urban-beaver-plan-focuses-on-enhancing-habitats/article28530523/.

Government of Canada. 2016. Fisheries Act. R.S.C. 1985, c. F-14, last amended on April 5, 2016. https://laws-lois.justice.gc.ca/PDF/F-14.pdf.

Government of Canada. 2018. Species at Risk Act. S.C. 2002, c. 29, last amended on May 30, 2018. https://laws-lois.justice.gc.ca/eng/acts/S-15.3/page-2.html#h-4.

Haddock, R. 2015. Beaver restoration across boundaries. Miistakis Institute, Mount Royal University. Calgary, Alberta. http://www.rockies.ca/project_info/Beaver Restoration Across Boundaries_Mar_26_2015.pdf.

Haggarty, D. R. 2002. An evaluation of fish habitat in Burrard Inlet, British Columbia. Master of Science Thesis. Faculty of Graduate Studies, Department of Zoology. University of British Columbia, Vancouver, BC.

Hall, K. and J. Cannon. 2013. Beavers as agents of watershed management and environmental health. Technical Notes, Natural Resources Conservation Service, U.S. Department of Agriculture, Spokane, Washington.

Hatler, D. F., and A. M. M. Beal. 2003. Furbearer management guidelines beaver (*Castor canadensis*). Funded by BC Ministry of Water, Land and Air Protection, Habitat Conservation Trust Fund & BC Trappers Association. http://www.env.gov.bc.ca/fw/wildlife/trapping/docs/beaver.pdf.

Hawley-Yan, E. 2016. Techniques for mitigating human/beaver conflicts in urban and suburban environments. Manual. Reviewed by M. Callahan, Beaver Solutions; B. K. Mackay, Animal Alliance of Canada (director); and D. DuBreuil, Ottawa-Carleton Wildlife Centre (president). https://www.animalalliance.ca/wp-content/uploads/2018/04/Beaver-Manual_May-2016.pdf.

Hay, K. G. 2010. Succession of beaver ponds in Colorado 50 years after beaver removal. *Journal of Wildlife Management* 74(8):1732-1736.

Hemmera. 2010. Evergreen line rapid transit project, environmental assessment certificate application. Section 7: Terrestrial biophysical assessment. https://projects.eao.gov.bc.ca/p/evergreen-line-rapid-transit/docs.

Hood, W. G. 2012. Beaver in tidal marshes: dam effects on low-tide channel pools and fish use of estuarine habitat. *Wetlands* 32(3): 401–10.

Hood, G. A., V. Manaloor, and B. Dzioba. 2018. Mitigating infrastructure loss from beaver flooding: a cost-benefit analysis. *Human Dimensions of Wildlife* 28(2):146-159.

Howard. R. J. and J. S. Larson. 1985. A stream habitat classification system for beaver. *Journal of Wildlife Management* 49(1):19-25.

Hyatt, K. and L. Godbout. 2000. A review of salmon as keystone species and their utility as critical indicators of regional biodiversity and ecosystem integrity. BC Ministry of Environment, 2, 1-520.

iMapBC. 2018. Geographic data and web-based mapping. Province of British Columbia. https://www2.gov.bc.ca/gov/content/data/geographic-data-services/web-based-mapping/imapbc.

Jefferson County Conservation District (Jefferson County). 2017. Chimacum Creek adaptive beaver management plan. Funded by Washington State Department of Ecology and US Environmental Protection Agency, Washington. http://www.jeffersoncd.org/wp-content/uploads/2017/03/Adaptive-Beaver-ManagementPlan.pdf.

Johnson-Bice, S. M., K. M. Renik, S. K. Windels, and A. W. Hafs. 2018. A review of beaver–salmonid relationships and history of management actions in the western Great Lakes (USA) region. *North American Journal of Fisheries Management 38:* 1203–1225.

Kambietz, J. 2003. Controlling beavers. The Pacific Streamkeepers Federation. https://www.pskf.ca/publications/beavers.htm.

Katopodis, C. and R. Gervais. 2016. Fish swimming performance database and analyses. Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat, Research Document 2016/002. vi + 550 p., Ottawa, ON.

Kemp, P. S., T. A. Worthington, T. E. L. Langford, and A. R. J. Tree. 2012. Qualitative and quantitative effects of reintroduced beavers on stream fish. *Fish and Fisheries* 13(3): 158–81.

Kiffney, P. M., S. M. Naman, J. M. Cram, M. Liermann, and D. G. Burrows. 2018. Multiple pathways of C and N incorporation by consumers across an experimental gradient of salmon carcasses. *Ecosphere* 9(4):e02197.

King County. 2018. Streams monitor. King County streams monitoring update for October 2018. King County Department of Natural Resources and Parks, Nov 20, 2018. https://content.govdelivery.com/attachments/topic_files/WAKING/WAKING_993/2018/11/28/file_attachments/1114787/stream_monitor_2018_10__1114787.pdf.

Leavy, T. R., P. Bakke, and R. J. Peters. 2008. Influence of habitat complexity and floodplain reconnection projects on the physical and biological conditions of Seattle urban streams:

Pre-project monitoring. Final progress report, 2005-2007. U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office, Lacey, Washington. https://www.fws.gov/wafwo/fisheries/Publications/UrbanStreamsFinalDraft10_2008.pdf.

Legg, R. 2018. Beaver dam analogues (BDA) in the urban environment – new design guidance for municipalities. Presentation at the Regional Conference of the NW Chapter of the Society for Ecological Restoration and the Society of Wetland Scientists in Spokane, Washington on October 18, 2018.

Loeb, R. E., S. King, and J. Helton. 2014. Human pathways are barriers to beavers damaging trees and saplings in urban forests. *Urban Forestry and Urban Greening* 13(2): 290–294.

Loken, L. C., J. T. Crawford, M. Mark, F. Ecke, O. Levanoni, J. Audet, P. Carlson, and K. Ekl. 2017. Meta-analysis of environmental effects of beaver in relation to artificial dams. *Environmental Research Letters* 12 (2017) 113002. IOP Publishing, https://doi.org/10.1088/1748-9326/aa8979.

Lokteff, R. L., B. B. Roper, and J. M. Wheaton. 2013. Do beaver dams impede the movement of trout? *Transactions of the American Fisheries Society* 142:1114-1125.

Macfarlane, W. W., J. M. Wheaton, N. Bouwes, M. L. Jensen, J. T. Gilbert, N. Hough-Snee, and J. A. Shivik. 2017. Modeling the capacity of riverscapes to support beaver dams. *Geomorphology* 277:72-99.

Maenhout J. L. 2014. Beaver Ecology in Bridge Creek, a tributary to the John Day River. Master of Science in Forest Science presented on September 23, 2013. https://ir.library.oregonstate.edu/downloads/sf268830g.

Majerova, M., B. T. Neilson, N. M. Schmadel, J. M. Wheaton, and C. J. Snow. 2015. Impacts of beaver dams on hydrologic and temperature regimes in a mountain stream. *Hydrology and Earth System Sciences* 19 (8): 3541–56.

Malison, R. L., K. V. Kuzishchin, and J. A. Stanford. 2016. Do beaver dams reduce habitat connectivity and salmon productivity in expansive river floodplains? *PeerJ* 4:e2403; DOI 10.7717/peerj.2403.

Martin, S. L., B. L. Jasinski, A. D. Kendall, T. A. Dahl, and D. W. Hyndman. 2015. Quantifying beaver dam dynamics and sediment retention using aerial imagery, habitat characteristics, and economic drivers. *Landscape Ecology* 30:1129-1144.

Mayer, M., A. Zedrosser, and F. Rosell. 2017. Couch potatoes do better: delayed dispersal and territory size affect the duration of territory occupancy in a monogamous mammal. *Ecology and Evolution* 7:4347-4356.

McCaffery, M. and L. Eby. 2016. Beaver activity increases aquatic subsidies to terrestrial consumers. *Freshwater Biology* 61(4): 518–32.

McCrea, G. 2016. *Castor canadensis* and urban wetland governance − Fairfax County, VA case study. *Urban Forestry and Urban Greening* 19: 306–314.

Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD). 2018. Draft South Coast guide to beaver management. FLNRORD Terrestrial Wildlife Section, BC. Draft from November 29, 2018.

Müller-Schwarze, D. 2011. The beaver: its life and impact. Second Edition. Cornell University Press.

Mumma, M. A., M. P. Gillingham, C. J. Johnson, and K. L. Parker. 2018. Where beavers (*Castor canadensis*) build: testing the influence of habitat quality, predation risk, and anthropogenic disturbance on colony occurrence. *Canadian Journal of Zoology* 96:897-904.

Naiman, R. J., J. M. Melillo, and J. E. Hobbie. 1986. Ecosystem alteration of boreal forest streams by beaver (*Castor canadensis*). *Ecology* 67, 1254–1269.

Nelson, M. C., J. D. Reynolds, and S. Cox. 2015. Effects of subsidies from spawning chum and pink salmon on juvenile coho salmon body size and migration timing. *Ecosphere* 6(10) Article 209: 1–14.

Northern Arizona University. 2019. Adaptive management. Ecological Restoration Institute. https://nau.edu/eri/restoration/the-er-process/adaptive-management/.

Page, N. 2012. Mammals of Vancouver and Point Grey. Summary of historical and current occurrence records. October 2012 Draft. Raincoast Applied Ecology.

Payne, N. F. 1989. Population dynamics and harvest response of beaver. 4 - Fourth eastern wildlife damage control conference. 33. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1032&context=ewdcc4.

Perkins, T. E., and M. V. Wilson. 2005. The impacts of *Phalaris arundinacea* (reed canary grass) invasion on wetland plant richness in the Oregon Coast range, USA, depend on beavers. *Biological Conservation* 124: 291–95.

Pierce, J. R. 2016. Understanding and managing beavers in Vancouver. Report for the Vancouver Park Board and City of Vancouver.

Pollock, M. M., M. Heim, and D. Werner. 2003. Hydrologic and geomorphic effects of beaver dams and their influence on fishes. *American Fisheries Society* Symposium 37. Research Gate https://www.researchgate.net/publication/231218389.

Pollock, M. M., G. R. Pess, T. J. Beechie, and D. R. Montgomery. 2004. The importance of beaver ponds to coho salmon production in the Stillaguamish River Basin, Washington, USA. *North American Journal of Fisheries Management* 24:749-760.

Pollock, M. M., T. J. Beechie, J. M. Wheaton, C. E. Jordan, N. Bouwes, N. Weber, and C. Volk. 2014. Using beaver dams to restore incised stream ecosystems. *BioScience* 64:279-290.

Pollock, M. M., G M. Lewallen, K. Woodruff, C. E. Jordan, and J. M. Castro (Editors). 2017. The beaver restoration guidebook: working with beaver to restore streams, wetlands, and floodplains. Version 2.0. United States Fish and Wildlife Service, Portland, Oregon. 219 pp. https://www.fws.gov/oregonfwo/promo.cfm?id=177175812.

Poor, E. 2018. Effects of beaver dams on urban stream hydraulic response during storm events. Master of Environmental Management Project Reports. 28. https://pdxscholar.library.pdx.edu/mem/gradprojects/28.

Port Moody Ecological Society. 2018. About the Noons Creek hatchery. http://noonscreek.org/about-us/.

Portugal, E., J. Wheaton, and N. Bouwes. 2015. Spring Creek wetland area adaptive beaver management plan. Prepared for Walmart Stores Inc. and the City of Logan. Logan, Utah. 25 pp. DOI: 10.13140/RG.2.1.2075.3361. https://www.researchgate.net/publication/283326474_Spring_Creek_Wetland_Area_Adaptive_Beaver_Management_Plan.

Quinn, T. P., M. J. Helfield, C. S. Austin, R. A. Hovel, and A. G. Bunn. 2018. A multidecade experiment shows that fertilization by salmon carcasses enhanced tree growth in the riparian zone. *Ecology* 99 (11).

Robertson Environmental Services Ltd. 2003. City of Port Moody environmental sensitive area (ESA) management strategy. Phase 2: Development of management recommendations. Prepared for City of Port Moody in association with Coast River Environmental Services Ltd. and Quadra Planning Consultants Ltd.

Schlosser, I. J. and L. W. Kallemeyn. 2000. Spatial variation in fish assemblages across a beaver-influenced successional landscape. *Ecology* 81:1371-1382.

Schlosser, I. J. 1995. Dispersal, boundary processes, and trophic-level interactions in streams adjacent to beaver ponds. *Ecology* 76:908-925.

Smith, J. M., and M. E. Mather. 2013. Beaver dams maintain fish biodiversity by increasing habitat heterogeneity throughout a low-gradient stream network. *Freshwater Biology* 58:1523-1538.

Soll, J. 2004. Controlling knotweed (*Polygonum cuspidatum*, *P. sachalinense*, *P. polystachyum* and hybrids) in the Pacific Northwest. The Nature Conservancy. Portland, OR.

Suzuki, N. and W. C. McComb. 1998. Habitat classification models for beaver (*Castor canadensis*) in the streams of the central Oregon Coast Range. *Northwest Science* 72(2): 102-110.

Swinnen, K. R. R., A. Rutten, J. Nyssen, and H. Leirs. 2019. Environmental factors influencing beaver dam locations. *The Journal of Wildlife Management* 83(2): 356–364.

Taylor, J. D. and R. D. Singleton. 2014. The evolution of flow devices used to reduce flooding by beavers: a review. *Wildlife Society Bulletin* 38(1):127-133.

Thompson, S., M. Vehkaoja, and P. Nummi. 2016. Beaver-created deadwood dynamics in the boreal forest. *Forest Ecology and Management* 360: 1–8.

Townsend, M. 2003. Suterbrook Creek watershed. The Pacific Streamkeepers Federation. http://www.urbanstreams.org/streams_B_PortMoody.html.

Touihri, M., J. Labbé, L. Imbeau, and M. Darveau. 2018. North American beaver (*Castor canadensis* Kuhl) key habitat characteristics: review of the relative effects of geomorphology, food availability and anthropogenic infrastructure. *Ecoscience* 25(1): 9–23.

Urban Systems Ltd. 2015. City of Port Moody parks and recreation master plan. Online: http://www.portmoody.ca/modules/showdocument.aspx?documentid=10724.

United States Department of Agriculture (USDA) Forest Service. 2005. How to keep beavers from plugging culverts. https://www.fs.fed.us/t-d/pubs/htmlpubs/htm05772830/page06.htm

Valachovič, D. 2012. Manual of beaver management within the Danube River basin. European Union, South East Europe Transnational Cooperation Program, and Danube Park Network of Protected Areas. http://www.danubeparks.org/files/888_beaver_manual.pdf

Van den Top, G. G., J. D. Reynolds, H.T. Prins, J. Mattsson, D. J. Green, and R. C. Ydenberg. 2018. From salmon to salmonberry: the effects of salmon-derived nutrients on the stomatal density of leaves of the nitriphilic shrub *Rubus spectabilis*. *Functional Ecology* 32 (11): 2625–33.

Vanderhoof, J. 2017. Beaver management technical paper #1: Beaver management tools literature review and guidance. King County, Water and Land Resources Division. Department of Natural Resources and Parks, Seattle, Washington.

Vermont Fish & Wildlife Department. 2017. Best management practices for resolving human-beaver conflicts in Vermont. Original 2002, revised 2004, 2014 and 2017.

Virbickas, T., S. Stakėnas, and A. Steponėnas. 2015. Impact of beaver dams on abundance and distribution of anadromous salmonids in two lowland streams in Lithuania. *PLoS ONE* 10(4): e0123107. doi:10.1371/journal.pone.0123107.

Walters, C. J. 1997. Challenges in adaptive management of riparian ad coastal ecosystems. Conservation Ecology 1(2):1. 19pp. https://www.jstor.org/stable/pdf/26271661.pdf?refreqid=excelsior%3A8f318793a050ea089d90f9ce87e185f8.

Wegener, P., T. Covino, and E. Wohl. 2017. Beaver-mediated lateral hydrologic connectivity, fluvial carbon and nutrient flux, and aquatic ecosystem metabolism. *Water Resources Research* 53 (6): 4606–4623.

Weber N., N. Bouwes, M. M. Pollock, C. Volk, J. M. Wheaton, G. Wathen, J. Wirtz, and C. E. Jordan. 2017. Alteration of stream temperature by natural and artificial beaver dams.

PLoS ONE 12(5):e0176313. https://doi.org/ 10.1371/journal.pone.0176313.

Wheaton, J. M. 2013. Scoping study and recommendations for an adaptive beaver management plan. Prepared for Park City Municipal Corporation, Logan, Utah, 30pp.

Wheaton, J. and S. Shahverdian. 2018. Rock Creek – NRCS partnering with beaver in restoration design workshop – pilot / demonstration restoration. Department of Watershed Sciences, Utah State University and The Fluvial Habitats Center (FHC), Logan, Utah. http://beaver.joewheaton.org/uploads/7/1/4/2/71427833/ rockcreek_workshopsba_permit_supplement.pdf

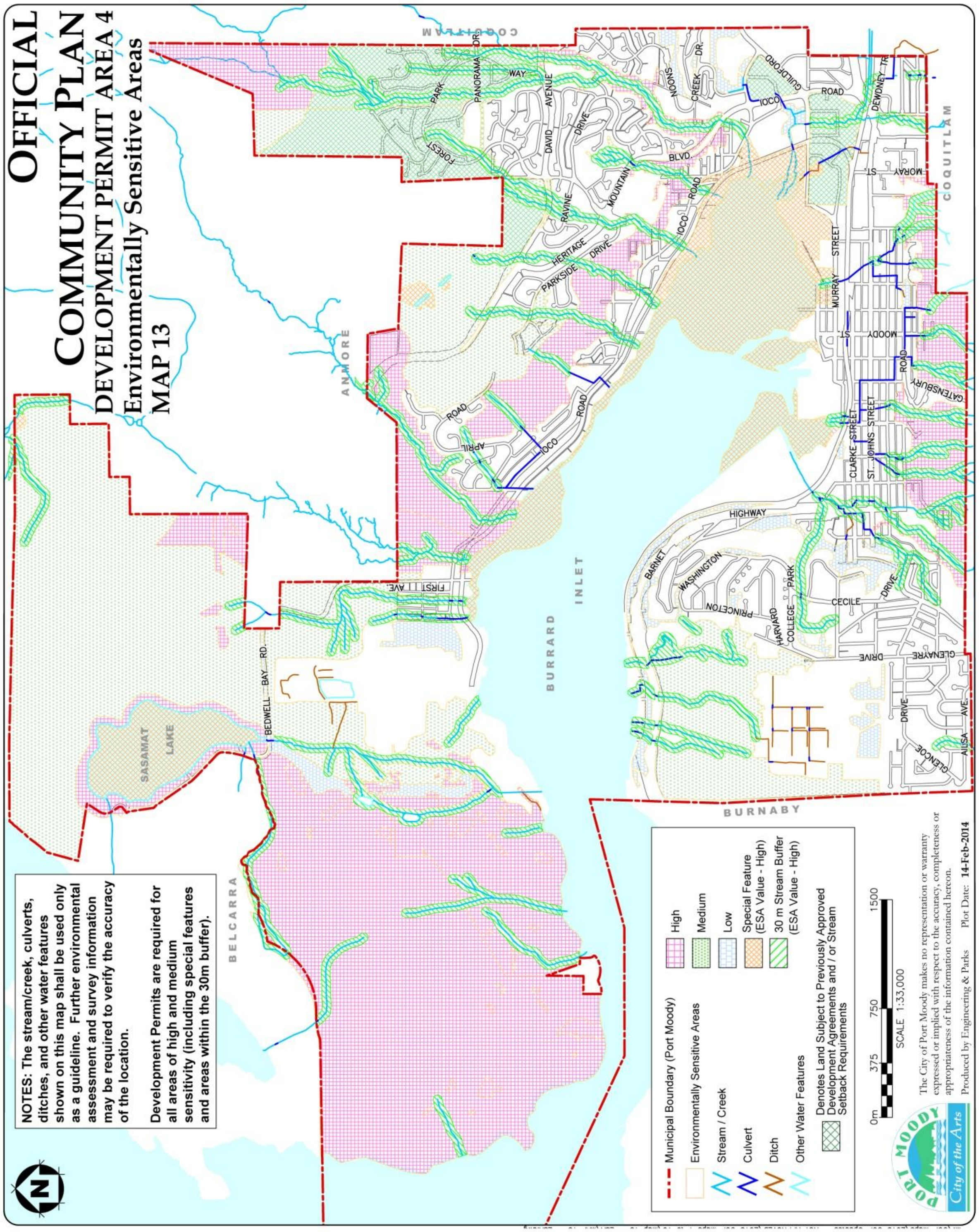
Washington Department of Fish and Wildlife (WDFW). 2011. Living with wildlife: beavers. Adapted from "Living with wildlife in the Pacific Northwest" by R. Link (2004), book available: http://wdfw.wa.gov/wlm/living.htm. Online (WDFW): https://wdfw.wa.gov/living/beavers.html#preventingconflicts.

Zevit. 2017. Mossom Creek 2017 bioblitz report. South Coast Conservation Program. Prepared for: Burrard Inlet Marine Enhancement Society. http://www.mossomcreek.org/wp-content/uploads/2017/12/final-mossom-creek-bioblitz-rprt-12-2017-hd.pdf.

MAP 1

City of Port Moody – Environmentally Sensitive Areas

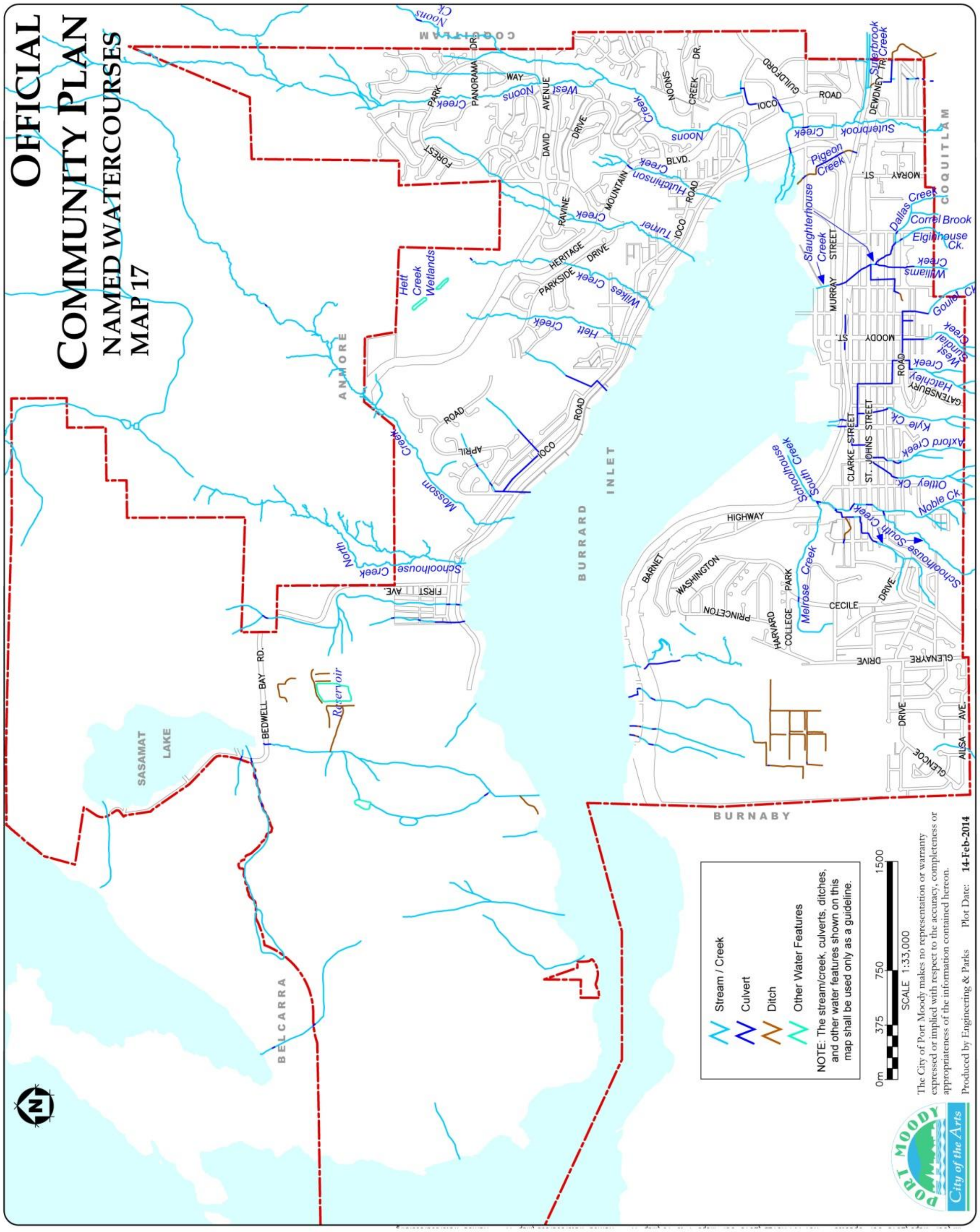
MAP 13: ENVIRONMENTALLY SENSITIVE AREAS



MAP 2

City of Port Moody – Named Watercourses

MAP 17: NAMED WATERCOURSES



APPENDIX 1

Brief History of Port Moody

Port Moody is in the unceded territory of the Coast Salish First Nations peoples, including the Tsleil-Waututh (Burrard Inlet) Nation, the Musqueam Nation and the Squamish Nation, who have inhabited the area well before colonial settlement.

Historically, development in Port Moody was shaped by the gold rush on the Fraser River (1858) and the construction of the Canadian Pacific Railway (1886). The gold rush brought thousands of people to Port Moody, leading to the construction of North Road (a trail at the time) from New Westminster to Burrard Inlet (City of Port Moody 2018a). Port Moody started to expand when it temporarily became the western terminus of the Pacific Railway (1879) that was subsequently extended to Vancouver. The early 1900's increasingly brought industrial development, including sawmills and oil refineries, accompanied by private homes, hotels, gas stations, and schools (City of Port Moody 2018a). Urban expansion continued after World War II with the establishment of new industrial businesses (e.g., Andrés Wines, Gulf Oil, Weldwood, Interprovincial Steel, Reichold Chemicals, and Pacific Coast Terminals), and associated infrastructure (City of Port Moody 2018a).

Prior to industrial and residential development, the land around Port Moody consisted of natural coniferous forest. Several fish-bearing streams originated in the headwaters of the surrounding mountains and flowed from the hillsides into Burrard Inlet. During the early development of the City, forests were cleared and streams that were in the way of proposed developments were buried in culverts to guide flows and manage erosion. However, the consequence was reduced rain-water infiltration, diminishing fish and wildlife habitat, and obstruction of fish passage.

Today, the natural environment in and around Port Moody is in second-growth forest. Much of this forest (more than 13% of the City's total area) has been designated as parkland (Urban Systems Ltd. 2015) or as an environmentally sensitive area (ESA) (City of Port Moody 2014). Major parks in Port Moody include the Chines Parks (Chineside and Harbour Chines), Mossom Creek Park, Bert Flinn Park, Noons Creek Park, Mountain Meadows Park, View Street Park, and the Suter Brook Greenway. The ESAs comprise several substantial stream riparian corridors that are capable of supporting fish and wildlife habitat. ESAs in Port Moody include critical habitat for fish, birds, amphibians, other wildlife, and plant species (City of Port Moody 2014).

APPENDIX 2

Regulatory Context related to Beaver Management

The protection of the natural environment is a responsibility shared by the federal, provincial, regional (Metro Vancouver) and local (City of Port Moody) governments through a variety of strategies and regulations (City of Port Moody 2014). Key regulations and management practices with respect to fish and wildlife, and beaver in particular, are summarized below.

Legal Status of the Beaver

American beaver populations in Canada are considered ‘secure’, and the beaver is ‘yellow’-listed in BC, meaning this species is not of conservation concern (BC CDC 2019). The provincial trapping regulation (2016-2018) categorizes the beaver as a Class 1 species (BC Hunting Regulations 2016). Class 1 species can be managed on individual traplines using humane methods with regulated kill traps. Trapping requires a *Wildlife Act* permit. In most regions (including the Lower Mainland), the open season for trapping beavers generally occurs from October 1 to April 30 (BC Hunting Regulations 2016).

Federal Government

<u>Fisheries Act:</u>

Section 35(1) of the *Fisheries Act* (Government of Canada 2016) states that “no person shall carry on any work, undertaking or activity that results in serious harm to fish that are part of a commercial, recreational or aboriginal fishery, or to fish that support such a fishery, except if the undertaking or activity is authorized by the Ministry and the work, undertaking or activity is carried on in accordance with the conditions established by the Ministry.

Section 35(2) requires that “projects avoid causing serious harm to fish unless authorized by the Minister of Fisheries and Oceans Canada” (DFO). The Act applies to work that is carried out in or near waterbodies that sustain “fish that are part of or that support a commercial, recreational or Aboriginal fishery” (DFO 2018). The *Fisheries Act* is currently being updated by the Canadian government and the new version is expected to be enacted in the spring of 2019. The changes will (for example) include more consideration of fish habitat.

Section 20(1) empowers the Minister to request that the owner or person who has the charge, management or control of an obstruction, or any other thing that is harmful to fish, shall conduct studies, analyses, samplings and evaluations, and provide the Minister with documentation or other information relating to them or to the obstruction or thing or to the fish or fish habitat that is affected or is likely to be affected by the obstruction or thing. The owner or person also must ensure the free passage of fish, or to prevent harm to fish, by removal or modification of the obstruction (Section 20(2)).

Section 36 prohibits the depositing of deleterious substances into waters frequented by fish, unless authorized by regulations under the *Fisheries Act* or other federal legislation.

Section 37(2) empowers the Minister, after reviewing plans, studies or other information, to require changes to a project to prevent serious harm to fish. The Ministry can also restrict or stop any operation of work or undertaking to prevent serious harm to fish.

Beaver dam removal is not considered an activity that requires DFO review. DFO provides the following guidance in relation to removing a beaver dam (WLAP and DFO 2004):

"Gradual" removal of beaver dams by hand or machinery can proceed, provided that

- Flooding can be prevented,
- Any obstruction to fish passage will respect timing windows[1],
- Work conducted in water is scheduled at a time that respects timing windows, and
- Relevant measures to avoid harm are followed (e.g., sediment control).

Where aquatic species at risk (i.e., listed under the *Species at Risk Act*) occur, their residences or critical habitat should not be disturbed. Also, beaver dam removal must not occur under frozen conditions where fish may be overwintering.

Species at Risk Act:

The *Species at Risk Act* (SARA) has been enacted (i) to "prevent wildlife species from being extirpated or becoming extinct, (ii) provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity, and (iii) to manage species of special concern to prevent them from becoming endangered or threatened" (Government of Canada 2018). Section 32 and 33 of the Act prohibit the killing, harming, harassing, capturing, taking, possessing, collecting, buying, selling or trading, and damaging or destroying of the residence, of an individual (or part) of a wildlife species that is listed as extirpated, endangered or threatened. SARA only applies to federal land unless an order is made to provide that section 32 and/or section 33 apply on other land (Government of Canada 2018). Species at risk protected on federal land are listed on Schedule 1 of SARA's Species at Risk Public Registry. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses species of conservation concern and recommends them for listing on Schedule 1. The American beaver is not at risk (federally or provincially).

Provincial Government

Wildlife Act:

It is a contravention of the BC *Wildlife Act* to hunt, take, trap, wound or kill wildlife except as provided by regulation (hunting / trapping). The *Wildlife Act* also protects nests occupied by a bird, its eggs or its young, and protects the nests of select species, including eagles, herons,

[1] Timing windows are least-risk time periods during which work in a stream can occur. Timing windows have been identified to protect fish, including their eggs, juveniles, spawning adults and/or the organisms upon which they feed (DFO 2018). Timing windows may vary by province, species or watercourse, and are available online: http://www.dfo-mpo.gc.ca/pnw-ppe/timing-periodes/index-eng.html.

osprey, burrowing owl, gyrfalcon and peregrine falcon year-round, regardless of whether they are occupied.

Section 9 of the *Wildlife Act* makes it an offence to disturb, molest or destroy a beaver or muskrat house, den or dam, except where that person is a trapper licensed under that Act, under "lawful authority" for the protection of property, or where the action is authorized by regulation (i.e., with a *Wildlife Act* permit).

<u>Water Sustainability Act and Regulation:</u>
The *Water Sustainability Act* (WSA) and its regulation were enacted in 2016 to replace the BC *Water Act*. The Water Sustainability Regulation (in Part 2) pertains to licensing, diversion and use of water (BC Province 2016). This includes changes in and about a stream[2] and associated authorization requirements. As per Section 38, a person must not make a change in and about a stream without notifying a habitat officer at least 45 days prior to start of the works and abiding by the terms and conditions to ensure the protection of aquatic habitat. If additional requirements are necessary, the habitat officer will respond within the 45 days, otherwise, works can proceed after 45 days. An authorized change only applies to activities described in Section 39 of the Water Sustainability Regulation. If the requirements or terms and conditions cannot be met, a Section 11 *Water Sustainability Act* Approval application will be required through the FrontCounter BC web portal.

Removal of a beaver dam may be completed only with a *Wildlife Act* (section 9) permit, provided that the removal is carried out in such a manner that downstream flooding and erosion do not occur. Without a permit, a person commits an offence if the person disturbs, molests or destroys a beaver lodge, den, or dam.

Beaver dam removal must not disturb wildlife and/or their residences (e.g., beaver lodges, eagle, osprey and heron nests) (BC Province 2017). If a person does not own the land where the works are proposed, the land owner must provide written approval (WSA Section 40). On Crown land, written approval is required from local government or, where appropriate, the regional provincial office (Ministry of Forests, Lands and Natural Resource Operations and Rural Development [FLNRORD]). If an engineer believes that an authorized change may cause significant adverse impact on the nature of the stream then an application for a change approval or authorization will be required (WSA Section 37(2) and (3)). A Habitat Officer has the authority to add specific conditions to ensure the protection of the aquatic ecosystem, in addition to the general conditions of the application (WSA Section 44).

[2] Stream: In the Water Sustainability Act, a stream is defined as a natural watercourse including a natural glacier course, or a natural body of water, whether or not the stream channel of the stream has been modified, OR a natural source of water supply, including, without limitation, a lake, pond, river, creek, spring, ravine, gulch, wetland or glacier, whether or not usually containing water, including ice, but does not include an aquifer (BC Province 2016).

The timing window for beaver dam removal on fish-bearing streams depends on the fish species occurring in the stream and, for the City of Port Moody, is between 30 July and 15 September of any given year.

Riparian Areas Regulation:

The provincial Riparian Areas Regulation was enacted in 2005 as part of the *Fish Protection Act* (1997) (BC Province 2006). The RAR directs local governments to protect riparian areas during new residential, commercial and industrial development, through the use of the *Local Government Act* (Part 26). The RAR applies to riparian fish habitat only in association with new residential, commercial and industrial development on land under local government jurisdiction. The RAR applies to private land and the private use of provincial Crown land.

Under the RAR, local governments may allow development within 30 m of the high-water mark of a stream or top of a ravine bank, provided that a riparian assessment has been completed by a qualified environmental professional (QEP). The QEP has to provide his/her professional opinion in an assessment report that the development will not result in harmful alteration of riparian fish habitat. The assessment report must be submitted to provincial and federal governments to facilitate monitoring and compliance.

Best Management Practices:

Provincial best management practices (BMPs) for beavers exist for trappers and for activities related to instream works. However, the BMPs do not commonly include best practices for coexisting with beavers in urban and rural environments.

The *Draft South Coast Guide to Beaver Management* (FLNRORD 2018) explains British Columbia's regulatory framework regarding beaver trapping and dam removal.

- Beaver trapping

"*The Province has a registered trapline system which is the primary method for setting harvest objectives and guidelines to manage furbearing animals. Each furbearer species is classified into 1 of 3 classes. Beavers are categorized as Class 1*[3]*. Wildlife is defined as all native species of animals in the province, excluding invertebrates as well as several non-native species. These species may not be hunted, killed, captured, kept as pets or used for commercial purposes unless specifically allowed by regulation or by authority of a permit. To obtain a valid trapping licence, an individual must be 19 years of age or older, a citizen of Canada or a permanent resident of Canada and have completed the Trapper Education Program (TEP) delivered by the BC Trappers Association (BCTA)*". The Guide also provides information on beaver relocation stating that "relocation is not the preferred option for dealing with beaver conflict".

[3] Class 1 Species: species with home ranges that are typically included within the boundaries of one trapline; therefore, local populations can be managed on an individual trapline basis.

- Beaver-dam removal

"*Removing a beaver dam can have significant negative impacts on other wildlife. Beaver dams create important habitat for fish and aquatic wildlife including pools of cool, deep water and slow moving shallow margins. These habitats are used by fish, amphibians and other aquatic wildlife. The endangered Pacific water shrew (Sorex bendirii) uses deep pools for foraging while fish may use beaver-dam ponds as refuge in the summer. Amphibians, such as the endangered Oregon spotted frog (Rana pretiosa), use beaver dams for cover, especially during the sensitive overwintering period. Removing beaver dams can cause significant changes to water levels in the local area with adverse impacts on wildlife*."

Removing a beaver dam requires a permit and notification under the *Water Sustainability Act*. Prior to undertaking works on a beaver dam, the potential presence of other wildlife and fish species, including species at risk, needs to be assessed and permitting requirements identified (e.g., *Wildlife Act*, *SARA*, *Fisheries Act*).

Previous *Beaver Management Guidelines in British Columbia* (BC Province 1988) and *Furbearer Management Guidelines, Beaver* (Hatler and Beal 2003) were produced to provide trappers in BC with guidelines on how to manage beavers to increase benefits to BC through more revenue from pelt sales and decrease damage to property and fisheries. The recommended management strategies in 1988 included inventory of beaver colonies, assessment of the population (e.g., food availability and health), and harvest planning (i.e., number and distribution of beavers available for trapping). In 2003, good trapping management of beavers considered targeting those colonies that were judged to have a poor chance of surviving the winter, and controlling colonies with large food caches to prevent or reduce habitat degradation and promote renewal (Hatler and Beal 2003).

Standards and Best Practices for Instream Works has established provincial standards and best practices for the planning, design and construction of instream projects that adhere to the BC *Water Sustainability Act* (WLAP 2004). This document includes BMPs for beaver and beaver dam management (section 7.6) with the objective to "encourage our coexistence with beavers, allow beavers to remain where appropriate, and manage beaver populations in areas where beaver presence is not appropriate". Where beaver dam removal is needed, the objective of the BMPs is "to prevent harmful impacts to beaver populations, fish and wildlife species, water quality and quantity, and riparian and aquatic habitats" (WLAP 2004).

A more proactive approach has been outlined in the BC *Beaver Management Guidelines* for the Vancouver Island Region (MELP 2001) to give general recommendations to agencies and local government on how to address local flooding concerns and maintain free draining rights of way. The guidelines provide a framework so that local government staff can "establish beaver dam inventories and develop clear strategies for more effective and sensitive management of beavers within their area of jurisdiction". Strategies include bridging, culvert screening devices and other structures, fencing techniques, and, as a last resort, animal management and dam removal (MELP 2001).

Develop with Care: Environmental Guidelines for Urban and Rural Land Development in British Columbia has been developed as a guide to maintaining environmental values during the development of urban and rural lands (BC MoE 2014). No information is provided on best practices related to beavers.

Municipal Government

The City of Port Moody has various guidelines, policies and standards to minimize impacts to environmental values and protect the natural environment. Examples are provided below:

Riparian Areas Regulation:

To meet the requirements of the provincial *Fish Protection Act* (1997) and the associated Riparian Areas Regulation (2006), the City of Port Moody has incorporated streamside setback requirements into its Zoning Bylaw (City of Port Moody 2014). Protection of riparian habitat is achieved by the setback distance and streamside protection and enhancement area (SPEA[4]) required around fisheries sensitive streams for residential, commercial and industrial development applications.

Environmentally Sensitive Areas (ESA) Management Strategy:

The City of Port Moody strives to preserve sensitive ecosystem areas, their living resources and connections between them in a natural condition and maintain these areas free of development and human activity as much as possible (City of Port Moody 2014). The ESA management strategy provides guidelines to manage and conserve biodiversity through greenbelts, wildlife corridors and riparian areas, and to preserve and protect specific ecosystems such as forests, watercourses, wetlands, and species and habitat features of conservation concern (City of Port Moody 2014).

Species at Risk:

The City of Port Moody partners with stewardship groups, and federal and provincial regulators to maintain and protect fish and wildlife habitat, including nesting birds, plant communities or ecosystem features (e.g., wetlands) that support provincially red- and blue-listed species as identified in the *Wildlife Act*, SARA, and by COSEWIC (City of Port Moody 2014).

Wildlife Corridors:

The ESA strategy includes policies specific to wildlife corridors that are considered when new development proposals are reviewed (City of Port Moody 2014). For example, disruption to

[4] Streamside Protection and Enhancement Area (SPEA): an area adjacent to a stream that links to terrestrial ecosystems and includes both the riparian area vegetation and the adjacent upland vegetation.

known wildlife corridors should be minimized while preventing or reducing human-wildlife conflict (e.g., with bears).

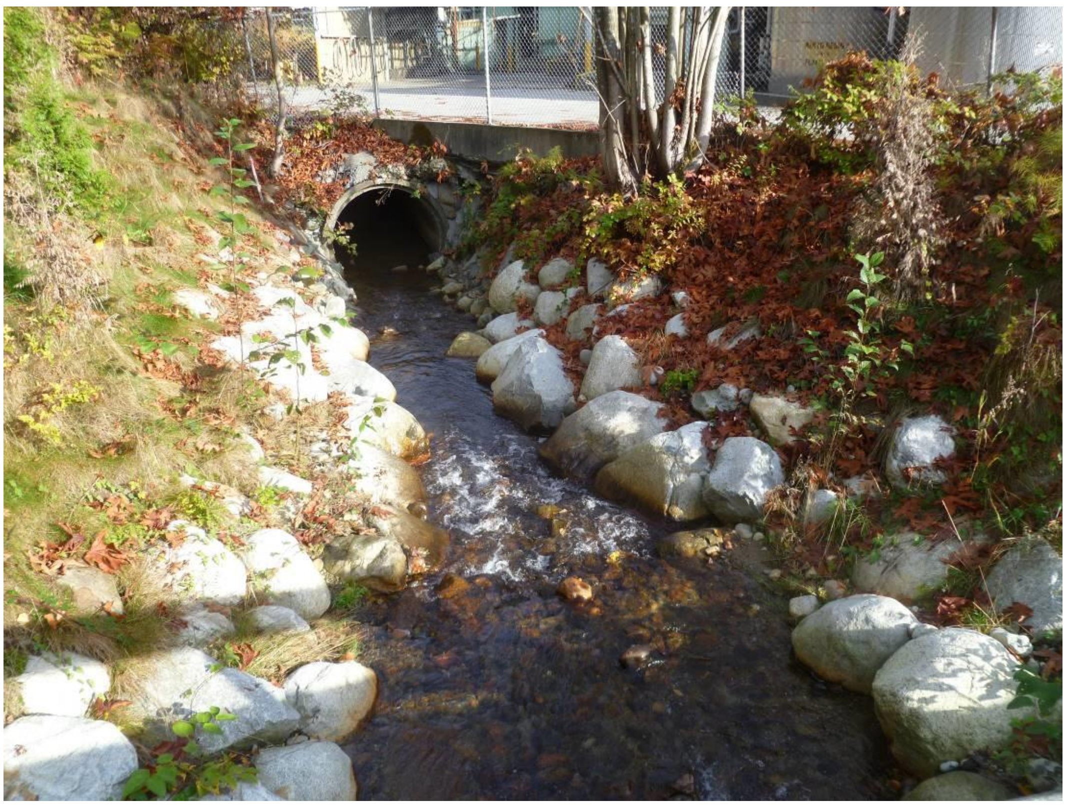
<u>Best Management Practices:</u>
The City of Port Moody promotes the incorporation of federal and provincial BMPs into all developments or land activities involving re-zoning (City of Port Moody 2014).

APPENDIX 3

Photographs from October 27, 2018

Photograph 1: South Schoolhouse Creek d/s from Barnett/skytrain, to northeast.

Photograph 2: South Schoolhouse Creek u/s from trail, to south.



Photograph 3: South Schoolhouse Creek d/s from trail, to northeast.

Photograph 4: Melrose Creek u/s from trail, to west.

Photograph 5: Melrose Creek d/s from trail, to northeast.

Photograph 6: Slaughterhouse Creek u/s from trail, to south.

Photograph 7: Slaughterhouse Creek d/s from Murray St., to north.

Photograph 8: Close-up of Slaugherhouse Creek culvert north of Murray St.

Photograph 9: Pigeon Creek d/s of Klahanie Drive, to north.

Photograph 10: Pigeon Creek headwall d/s of Klahanie Drive, to east.

Photograph 11: Pigeon Creek with beaver dam (red arrow) u/s of pedestrian bridge, to south.

Photograph 12: Pigeon Creek d/s of pedestrian bridge, to north.

Photograph 13: Pigeon Creek u/s of Murray St., to south.


Photograph 14: Pigeon Creek u/s of Murray St., to south. Note beaver channel under fence.

Photograph 15: Pigeon Creek d/s of Murray St., to northwest.

Photograph 16: Suter Brook Creek u/s of Capilano Rd., to south.

Photograph 17: Suter Brook Creek d/s of Capilano Rd., to northeast.

Photograph 18: Suter Brook Creek d/s of Murray St., to north.

Photograph 19: Suter Brook Creek bank beaver den (red arrow) d/s of Murray St.

Photograph 20: Suter Brook Creek culvert outfall with oil-water separator, d/s of Murray St.

Photograph 21: Suter Brook Creek beaver dam #1, near trail d/s of Murray St.

Photograph 22: Suter Brook Creek u/s of dam #1, near trail d/s of Murray St.

Photograph 23: Tree felled by beaver next to Suter Brook Creek dam #1,
near trail d/s of Murray St.

Photograph 24: Suter Brook Creek with dam #2 (red arrow) u/s of railway spur-line, to east.

Photograph 25: Suter Brook Creek culvert with grate u/s of railway spur-line.

Photograph 26: Suter Brook Creek d/s of railway spur-line/trail, to west.

Photograph 27: Side channel of Suter Brook Creek d/s of railway spur-line/trail, to west.

Photograph 28: Suter Brook Creek u/s of estuary trail, to east.

Photograph 29: Noons Creek u/s of Ioco Rd., to northeast.

Photograph 30: Noons Creek d/s of Ioco Rd., to southwest.

Photograph 31: Noons Creek above hatchery, view u/s to east.

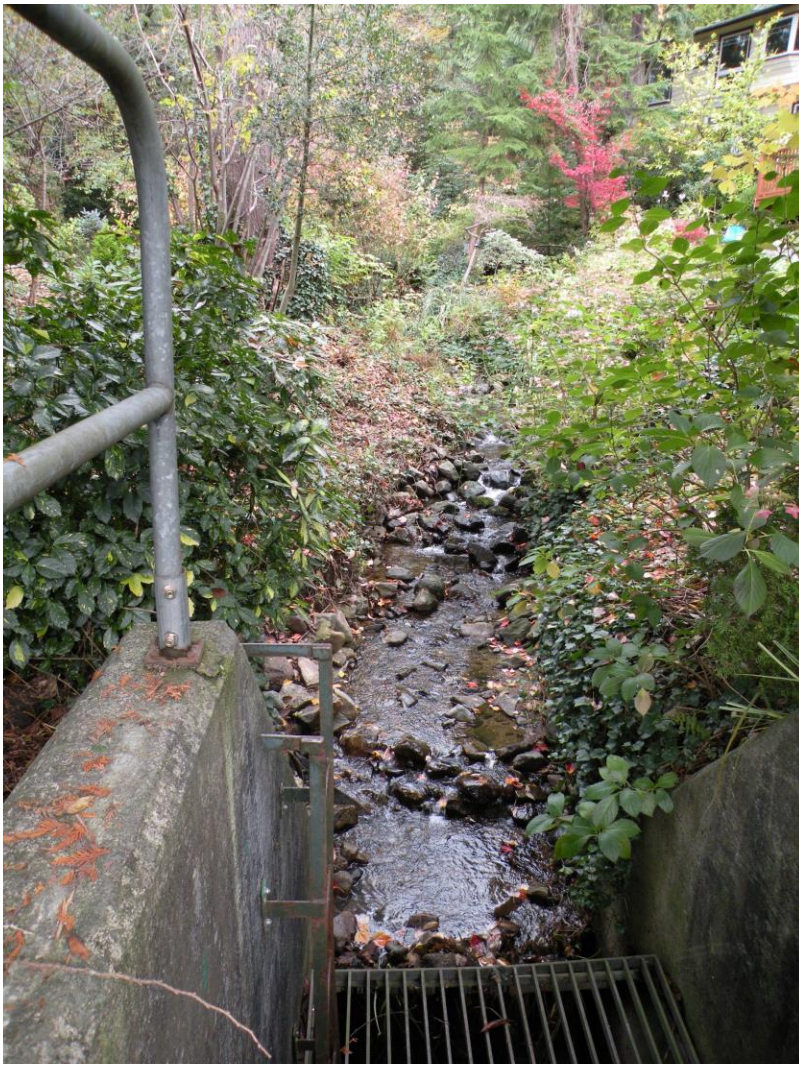
Photograph 32: Noons Creek above hatchery, view d/s to west.

Photograph 33: Side channel of Noons Creek u/s of hatchery, to north.

Photograph 34: Noons Creek next to trail, view u/s to east.

Photograph 35: Noons Creek u/s of estuary trail, to east.

Photograph 36: Noons Creek estuary d/s of estuary trail.



Photograph 37: Hutchinson Creek u/s of Ioco Rd., to northwest.

Photograph 38: Hutchinson Creek u/s of trail (below Ioco Rd./railway), to northeast.

Photograph 39: Hutchinson Creek d/s of trail toward estuary, to southwest.

Photograph 40: Wetland at old mill site near Turner Creek, view to northwest.

Photograph 41: Turner Creek u/s of trail, to northeast.

Photograph 42: Turner Creek d/s of trail, to southwest.

Photograph 43: Mossom Creek u/s of Ioco Rd., to north.

Photograph 44: Mossom Creek culvert u/s of Ioco Rd.

Photograph 45: Mossom Creek d/s of Ioco Rd. (u/s of railway), to northeast.

Photograph 46: Mossom Creek d/s of railway, to south.

Photograph 47: North Schoolhouse Creek u/s of Ioco Rd., to north.

Photograph 48: North Schoolhouse Creek d/s of Ioco Rd., to south.

Photograph 49: Village Creek u/s of Ioco Rd., to north.

Photograph 50: Village Creek exiting culvert into estuary d/s of railway, to south.