Restoration Plan for Gordon's Brook Marsh

Phases II and III

in Aldergrove Regional Park, British Columbia.

Submitted by:

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SUMMARY

Metro Vancouver and the Fraser Valley Conservancy will partner to restore 15 Ha of lowland swamp, marsh and wet prairie to the south end of Aldergrove Regional Park in Metro Vancouver, British Columbia.

The existing fallow agricultural fields, previously claimed from historic wetland, have been affected by the development of drainage infrastructure for agriculture and the arrival of aggressive invasive vegetation after active agriculture ended in the early 2000s. The target site is adjacent to an additional 20 Ha of restored habitats to the east that support a high diversity of wildlife, including fish, amphibians, birds and odonates listed as species-at-risk in Canada.

Over three years we will carry out site preparation activities to control for invasive species, restore the historic hydrodynamics of the site to the extent possible, install species-specific habitat features into the landscape, and carry out post-restoration invasive species management. We will develop a post-restoration adaptive management plan and begin post-construction monitoring activities. Learning opportunities and education are built into the restoration plan. Post-graduate students from local Ecological Restoration programs were involved in the development of this design as a part of their studies, and students will be involved in the implementation, monitoring and adaptive management planning.

Guiding principles for the restoration program include working with the existing landscape and using methods of least-harm for invasive species management and hydrologic stability. Some of these techniques have not been used locally, but have been shown to be effective elsewhere. In particular the use of prescribed fire and aquatic-approved herbicides in an acute manner to systemically disrupt ecological processes that support invasive vegetation may be trialed for the first time in the Lower Mainland. In addition, we hope to attract beavers to do some of the work for us – we will disable drainage infrastructure and create baseline conditions attractive to beavers, therefore using their considerable construction and maintenance skills to fill and maintain the restored landscape over the long term with minimal intervention by man.

By working with the existing landscape and using effective and innovative techniques, we intend to revitalize a lost landscape and learn skills and techniques to apply to the restoration of wet old-field sites across the Fraser Valley.

TABLE OF CONTENTS

1 INTRODUCTION 5

2 SITE SELECTION 7

2.1 ADMINISTRATIVE CONTEXT 7
2.2 HYDROLOGY AND SOILS 8
2.3 BIOLOGICAL CONTEXT 8
2.4 EDUCATIONAL AND RESEARCH OPPORTUNITIES 10
2.5 REPRESENTATIVE OF RESTORABLE WETLANDS IN THE FRASER VALLEY 10

3 GOALS AND OBJECTIVES 11

3.1 GOAL 11
3.2 OBJECTIVES 11

4 INVESTIGATIONS 12

4.1 SITE HISTORY 12
4.2 SOILS AND HYDROLOGY 15
4.2.1 Site-Scale 15
4.2.2 Water Chemistry 17
4.2.3 Soil Chemistry 19
4.3 VEGETATION 21

5 DESIGN TARGETS 23

5.1 BIODIVERSITY TARGETS 23
5.1.1 Wildlife Species 23
5.1.2 Target Wetland Classification 24

6 HYDROLOGIC RECOVERY 26

6.1 DRAIN TILE DECOMMISSIONING 26
6.2 DITCH DECOMMISSIONING 27
6.3 DEPRESSIONS, PONDS, CHANNELS AND BERMS 27
6.4 STARTER DAMS 27

7 INVASIVE SPECIES CONTROL 30

7.1 HIMALAYAN BLACKBERRY 31
7.1.1 Invasion Ecology 31
7.1.2 Control Methods 31
7.1.3 Selected Protocol 32
7.2 JAPANESE KNOTWEED 32
7.2.1 Invasion Ecology 32
7.2.2 Control Methods 33
7.2.3 Selected Protocol 33
7.3 REED CANARY GRASS 33
7.3.1 Invasion Ecology and Control Challenges 34
7.3.2 Annen's Systemic Approach 36
7.3.3 Haliburton Farm Organic Approach 40
7.3.4 Selected Protocols 40
7.4 OTHER NOXIOUS AND NUISANCE SPECIES 44
7.5 INVASIVE WILDLIFE 44
7.5.1 American Bullfrogs 44
7.5.2 Nutria 45
7.5.3 Invasive Fishes 45

8 RESTORATION ACTIONS AND TIMELINE – OVERVIEW 46

9 RESTORATION ACTIONS AND TIMELINE – PHASE II 47

9.1 RESTORATION SUMMARY 48
9.2 POND 49
9.3 SWAMP COMPLEX 50
9.4 MARSH AND WILLOW FARM 50
9.5 2016 CONSTRUCTION TASKS AND TIMELINE 51
9.6 SPRING 2017 53
9.7 SPRING 2018 53
9.8 MONITORING RESTORATION ACTIONS AND ADAPTIVE MANAGEMENT RESPONSE 53
9.8.1 Hydrology 53
9.8.2 Vegetation 53

10 RESTORATION ACTIONS AND TIMELINE – PHASE III 54

10.1 RESTORATION SUMMARY 54
10.2 2016 TASKS 55
10.3 2017 CONSTRUCTION TASKS AND TIMELINE 55
2018 TASKS 57
10.4 MONITORING RESTORATION ACTIONS AND ADAPTIVE MANAGEMENT RESPONSE 57
10.4.1 Hydrology 57
10.4.2 Vegetation 57

11 ADVERSE IMPACT MITIGATION 58

11.1 EMERGENCY RESPONSE AND CONTAINMENT PLAN 59

12 PERMITTING 61

13 STEWARDSHIP, CAPACITY-BUILDING, EDUCATION AND RESEARCH: 61

13.1 VOLUNTEER / STEWARDSHIP ACTIVITIES 61
13.2 RESEARCH AND MONITORING 61
13.3 YOUTH EDUCATION 62

REFERENCES CITED 63

1 Introduction

The Fraser Valley Conservancy, in partnership with Balance Ecological, the Vancouver Aquarium, and the BC Ministry of Forests, Lands and Natural Resource Operations is proposing additional restoration work in Aldergrove Regional Park. The restoration project will take place in the Southern Lands of Aldergrove Regional Park directly east of the Gordon's Brook Habitat Complex, Pepin Creek, and the shallow marsh constructed in 2013 (Figure 1). We will continue restoration activities begun in 2013 (Phase I), which complemented previous channel and wetland restoration activities undertaken under Mike Pearson from 2000 – 2010 (Gordon's Brook).

The target area encompasses 12 Ha that can reasonably be split into two distinct areas separated by a compacted gravel driveway. We refer to the two areas as Phase II and Phase III, with Phase I referring to the wetland constructed in 2013 directly to the west of the target area (Figure 1). Phase II is the eastern-most section, with earthworks planned for 2016, and Phase III the central section between Phases I and III, with earthworks planned for 2017.

The goals of the project are three-fold: Habitat, Research, and Education. Restoration activities will specifically target Species-At-Risk dependent on lowland stream and wetland habitats, while improving general wildlife biodiversity and restoring hydrologic function to disturbed landscapes.

This document provides a rationale for site selection, construction goals, timelines and targets, post-construction monitoring and management, and education and stewardship opportunities for Phases II and III of the wetland complex.

Our proposed site selection, analysis, planning and design, implementation and management is guided by several key texts regarding wetland restoration:

- Krueger et al. 2014. Practical Guidelines for Wetland Prairie Restoration in the Willamette Valley, Oregon – Field-Tested Methods and Techniques. http://cascadiaprairieoak.org/documents/wetland-prairie-guide
- South Coast Conservation Program, 2015. Diversity by Design – A Resource Guide for the South Coast of British Columbia. http://www.sccp.ca/projects/restoration-planning-diversity-design

In addition, two teams of students conducted their own site analyses and developed restoration plans for Phases II and III of the Gordon's Brook wetland complex. Their work has enhanced and informed this plan, and is incorporated into this document.

Figure 1. Location of Phases I to III in Aldergrove Regional Park.

2 Site selection

The Gordon's Brook Wetland restoration site is within Aldergrove Regional Park, located on the municipal boundary of the Township of Langley and the City of Abbotsford. The park is comprised of 280 ha of wetlands (including marshes and forested swamps), forests (i.e., primarily mixed second-growth stands), former agricultural fields (i.e., old-field), and associated residences (Metro Vancouver 2013). The site is currently classified as a Degraded Old Field Wetland Prairie, an area that was historically a native wetland prairie or swamp, that was converted to agricultural uses, and has since been abandoned.

In general, suitable sites for wetland restoration require appropriate soils, suitable or restorable hydrology, and show evidence of a historic wetland ecosystem. Larger sites are better, and sites that are situated in close proximity to other natural areas or provide connectivity are preferred. Additional values important to this project include providing opportunities for education and research to youth, students and academics in the Lower Mainland of British Columbia.

This site was selected as it met these five critical components for a suitable project:

1. **Administrative Context**
2. **Hydrology and Soils**
3. **Biological Context**
4. **Educational and Research Opportunities**
5. **Representative of restorable wetlands in the Fraser Valley**

2.1 Administrative Context

The Gordon's Brook Wetland restoration site is within a protected area whose history is typical of degraded and damaged wetlands in the Fraser Valley. It is historically important to local First Nations, altered by European settlement, yet available for restoration due to its incorporation into a Regional Park management system that values biodiversity.

Aldergrove Regional Park was acquired incrementally by Metro Vancouver between 1967 and 1978 from the Township of Langley, receiving official park status in 1969. Metro Vancouver is committed to promoting ecological health, human health and wellness, community stewardship, education and partnerships, and promoting opportunities for restoration at disturbed sites. Beginning in 2011, a long-term management of the park become a priority for Metro Vancouver and lead to the completion of the Aldergrove Regional Park Management Plan in 2013 (Metro Vancouver 2013). Given the long history of agriculture within portions of Aldergrove Regional Park boundaries, restoration of former agricultural lands is a main objective of the Aldergrove Regional Park Management Plan (Metro Vancouver 2013). In response to this objective, the southern portion of the park, referred to as the Southern Lands, is identified as a high priority location for restoration efforts.

2.2 Hydrology and Soils

Geography, climate and hydrologic processes drive the location, persistence, size and function of wetlands. At their essence, wetlands are landscape features that receive and hold water to the extent that the excess water impacts soil development and the vegetation community. Vegetation is dominated by hydrophytes, plants adapted to living in waterlogged soils, and soils display characteristics of anaerobic soils.

The flatness of the restoration site and the landscape to the south suggests that our restoration site was likely at the edge of a glacial lake, forming a lacustrine marsh, or remained at sea level for some time. The area is at the base of a moraine slope, with reliable groundwater and surface water entering at the north end and flowing to the south. The geographic context at the base of a hill identifies that suitable hydrology for wetlands is likely, and this is supported by soil classification of the site.

Historic maps indicate peaty soils (P) surrounded by Lynden gravelley silt loam (LY G Sil, 1938), as do soil maps for Whatcom County, directly adjacent to the site. More recent (but undated) provincial maps from DataBC (DataBC 2015) identify the peaty soils as Judson Muck, and silt loam as Lehman Soils. Detailed descriptions are appended.

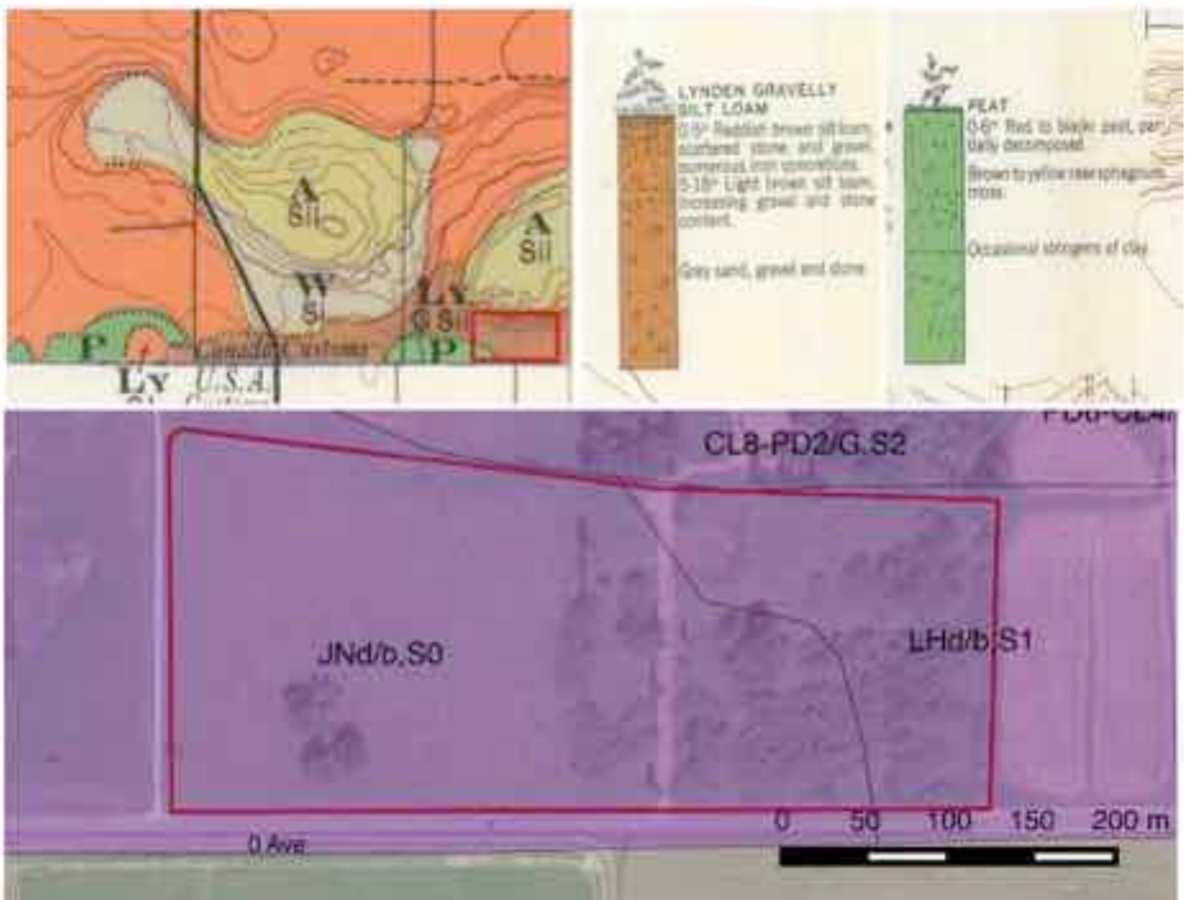
More detailed hydrological and soil investigations were completed in 2015 to inform the design of the restoration at the site scale (Section 4.2).

2.3 Biological Context

The Park currently supports a number of Species-at-Risk, including the endangered Nooksack Dace (*Rhinichthys cataractae*), the threatened Salish Sucker (*Catostomus sp.4*), endangered Western Painted Turtle (*Chrysemys picta bellii*), threatened Northern Red-legged Frog (*Rana aurora*) and endangered Oregon Forest Snail (*Allogona townsendiana*), as well as several threatened bird and odonate species. The restoration lands are at the southern border of the park, downstream of large forested areas with reliable groundwater flows and seasonal surface water runoff. Historic agricultural activities have ended, and upland restoration is being spearheaded by Metro Vancouver Parks to restore forest and meadow habitats to agricultural fields. This will, over time, further improve groundwater and surface water quality inputs to lowland streams and wetlands.

Aldergrove Regional Park is within the Nooksak River watershed, with Pepin Creek and other small drainages draining south beneath the Canada – US border into Washington State. The Southern Lands are bordered to the south by the Canada – US border. South of the border are agricultural fields primarily in blueberry production and water flows south along Double Ditch Road before joining Fishtrap Creek, a tributary to the Nooksak in the city of Lynden, and continuing south-west towards the Pacific Ocean at Bellingham.

The BC wetland classification uses hydrogeomorphic categories to describe the topographic position and hydrology of sites, and adopts a modified edatopic grid that uses soil nutrient regime, soil moisture regime, pH, and a hydrodynamic index as site descriptors to categorize nested Groups, Site Classes, Associations and Series, indicating anticipated vegetative community for those sites in the appropriate biogeoclimatic region (MacKenzie & Moran 2004). The areas fall within the Coastal Western Hemlock Very Dry Maritime biogeoclimatic zone. Site investigations into nutrient and moisture regimes, and the hydrodynamic index of the site will further guide design regarding which wetland types are most suitable as restoration targets for the site.



JNd/b,S0 – **Judson Muck** – 40 to 160 cm of well-decomposed organic material underlain by moderately fine textured glaciomarine deposits with very poor drainage due to a perched water table. Gently rolling and gently undulating slopes. Classification – Terric Humisol. Stones are not present or are so infrequent that they offer no hindrance to cultivation

LHd/b,S1 – **Lehman Soils** – Less than 30 cm medium-textured eolian deposits over gravelly glacial outwash with poor drainage due to telluric seepage (lateral seepage from the soil) and a perched water table. Gently rolling and gently undulating slopes. Classification – Orthic Humic Gleysol. There are some stones but they offer only slight to no hindrance to cultivation.

Figure 2. Above - 1938 Soil Map of the Lower Fraser Valley, indicating area of interest in black box, and relevant legend entries. Below – BC Soils – GIS compiled from DataBC (2015). Area of interest outlined in red.

2.4 Educational and Research opportunities

The Fraser Valley Conservancy is a non-profit society dedicated to effecting conservation of land and water for future generations through display, communication, public programming and education, research and direct action. Opportunities for interactive education were an important component in site selection.

The Aldergrove Regional Park management plan has set aside the Southern Lands of the park, the target site, as a conservation / education and research zone. Metro Vancouver has a well-developed interpreter program that is willing and able to partner with the Fraser Valley Conservancy to provide high-quality educational activities to an existing (and growing) audience.

The conservation / education zone is currently used for research by academic partners at the British Columbia Institute of Technology, the University of the Fraser Valley, Simon Fraser University and the University of British Columbia, and the park has existing facilities and plans additional facilities to accommodate education and research on-site.

2.5 Representative of Restorable Wetlands in the Fraser Valley

Shallow, seasonal freshwater marsh restoration is not a well established practice in the Fraser Valley, however shallow freshwater marshes make up much of the wetland loss that has occurred since European settlement in British Columbia. An estimated 85% of wetlands in the Lower Fraser Basin were lost from 1827 – 1990 (Boyle et al. 1997). In an assessment of three different watersheds, each had experienced between 75% and 96% of wetlands loss, most due to dyking, draining and conversion of seasonally flooded natural grass prairies to agricultural and urban uses (Kistritz et al. 1996).

Many parks and ecological reserves in the Fraser Basin contain old field habitats that were historically drained wetlands, and many of these may be available for restoration. This project provides an opportunity to implement and monitor wet field restoration that could be applied to a great number of potential habitats in the historic range of the Oregon Spotted Frog.

3 Goals and Objectives

3.1 Goal

The goals of this project are, through the restoration of a shallow-water marsh and swamp wetland habitat on historic agricultural fields, to:

A. Enhance general wildlife biodiversity, with a particular focus on Species-at-Risk;
B. Provide recovery habitat for the endangered Oregon Spotted Frog;
C. Provide outdoor education, stewardship and research opportunities in wetland restoration and species recovery; and
D. Increase our knowledge of marsh restoration techniques.

3.2 Objectives

1. Wetland construction:
    a. Invasive species control;
    b. Habitat feature construction;
    c. Hydrologic restoration;
    d. Revegetation with native plant species.
2. Implement an ecological adaptive management plan for potential future scenarios:
    a. Identify potential ecological outcomes and futures;
    b. Identify management actions under each potential future scenario;
    c. Monitor ecological outcomes, apply management actions;
    d. Continue monitoring, applying and adapting management actions as needed;
    e. Report on management actions with recommendations.
3. Stewardship, education and research:
    a. Organize volunteer events for revegetation, monitoring and maintenance activities;
    b. Partner with academic institutions to engage in research regarding plant and wildlife recovery at the site;
    c. Partner with Metro Vancouver to develop a field trip curriculum for use by interpretive programs.

4 Investigations

In 2015-2016, we received funding from the Government of Canada's National Wetlands Conservation Fund to carry out site investigations and develop a detailed restoration program for Phases II and III. We conducted deeper investigation into the site history, hydrology, soils, vegetation and biodiversity to inform the restoration plan. This text summarizes the pertinent information, and detailed data is appended to the document.

Figure 3. Phases of Gordon's Brook Wetland restoration in proximity to Gordon's Brook complex.

4.1 Site History

Aldergrove Regional Park has been shaped by glaciation and the park's geology is formed as a result. Approximately 13,000 to 15,000 years ago, the Aldergrove region was covered with ice a mile deep by the Cordilleran Ice Sheet; the minor Sumas glaciation event occurred in the central Fraser Valley 11,500 years before present and retreated around 9,000 years before present (Saunders et al. 1987). After deglaciation sea levels rose 175 m above today's level, submerging the entire Lower Fraser Valley (Mathews et al. 1970). Deglaciation slowly deposited sediments to form the present landscape. Flora colonized the landscape exposed by retreating glaciers and plant communities developed throughout the Valley. By about 4,500 years ago, the sea level had reached its present height, and the landscape reached present day state.

The area falls within traditional territory of Matsqui First Nations, a band within the greater Stö:lo First Nations, and neighbors Matsqui Indian Reserve #4. Several sites of cultural significance to Matsqui peoples exist within Aldergrove Regional Park including a 'Transformer Rock', a sacred rock with associated stories of creation. The Gordon's Brook area was a gathering place, and Pepin's Brook was a travel corridor that linked hunting and fishing grounds to village sites (Metro Vancouver 2013). Although no documented archeological sites have been identified on the restoration site, any excavations should be aware of the area's potential archaeological importance. Acknowledgement and incorporation of Matsqui people to the restoration project should be addressed to build a positive working relationship with Matsqui First Nations.

European settlers began to transform land for agriculture in the Langley area of the Fraser Valley in the 1830s, expanding into present-day Delta, Surrey, and Maple Ridge in the 1860s, and into south Aldergrove by the early 1900s (Metro Vancouver, 2013). Settlers converted wetland and forest ecosystems into grazing and agricultural lands as the rich fertile soils benefited agriculture (Boyle et al. 1997). Over a century of farming on the land has resulted in altered hydrology from roads, drainage ditches, and drain tile.

Historical photographs depict the site being used for agriculture in the 1940s, but agricultural use likely began as early as 1908 when the first farming families settled in the area (Metro Vancouver 2013). Farming activities ceased around 10 years ago, and the last crop type planted was corn (G. Feddes, pers. comm., 2015).

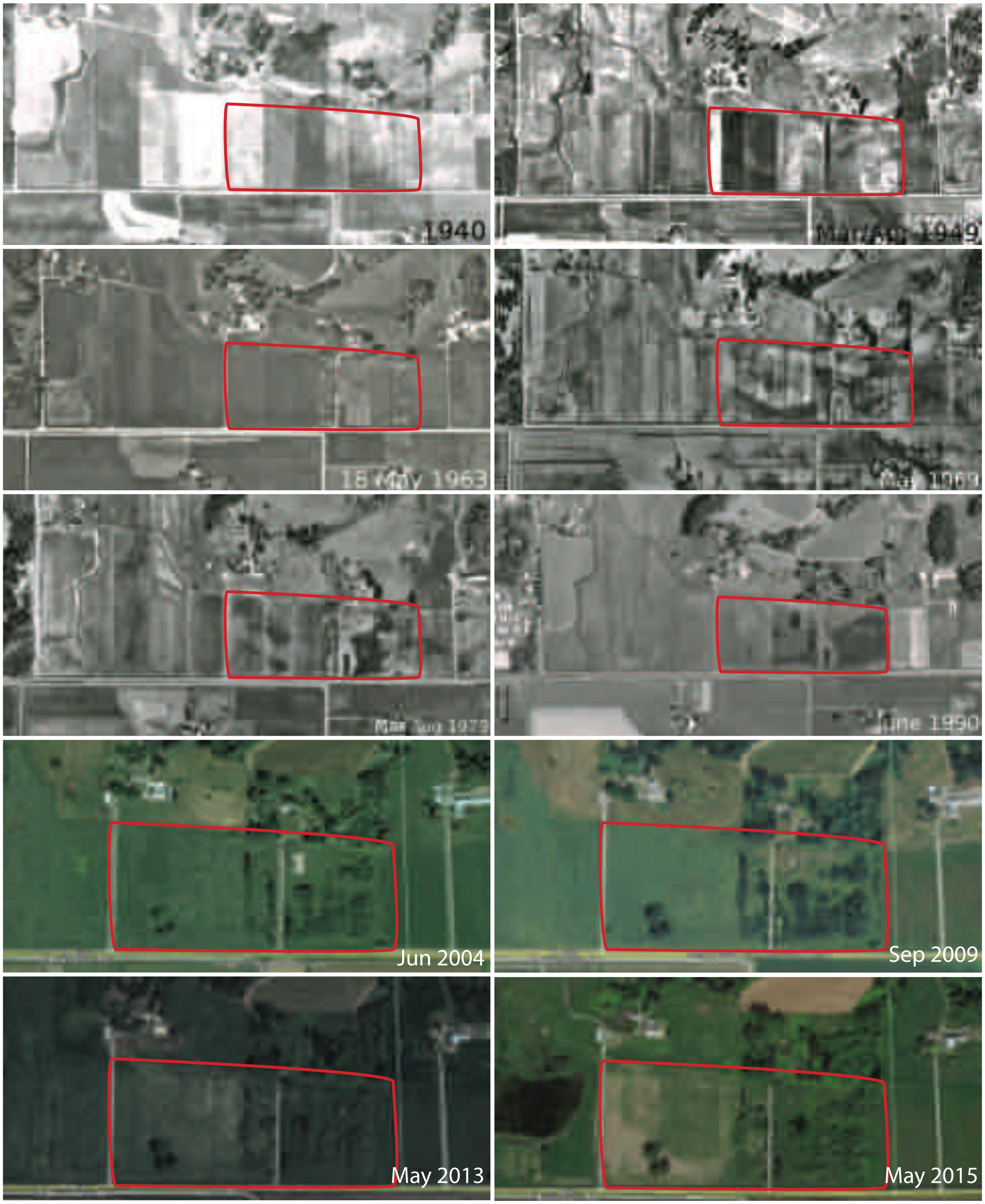


Figure 4. Historic orthophotos of the target site (outlined in red) showing continuous agricultural use from the 1940 through to 2015, with increasing drainage management interventions by the digging of ditches to the installation of drain tile (Base Mapping and Geomatic Services Branch, 2015). Images from 1969 and 1979 are particularly useful in identifying the location of current drain tile. Active agriculture ended on Phase II (east section) between 1990 and 2004, with increasing shrub growth in the field from 2004 onwards.

4.2 *Soils and Hydrology*

Hydrology and soils are intimately linked in wetland ecosystems, each affecting the other and determining the vegetative community of the site. Both must be understood on a site-scale to inform the structure and form of the wetland, and their chemical composition understood to predict vegetative outcomes and inform any modifications that should be made.

4.2.1 Site-Scale

Persistence of a wetland through the seasons is dependent on the water budget, the result of inflows and outflows through time. Inflows include direct precipitation, surface water from adjacent streams (flood conditions), and groundwater; outflows include surface water outflow, groundwater outflow, and evapotranspiration. The difference between inflows and outflows will determine the rate of change at which storage increases or decreases in the wetland, and the depth of water over the wetted landscape.

Historic orthophotos from 1940 – 1990 show the landscape changed little over the years. However, one particularly useful photograph from 1979 was taken during a wet period and clearly shows the location of depressions, historically wetted areas, ditches and drain-tile.

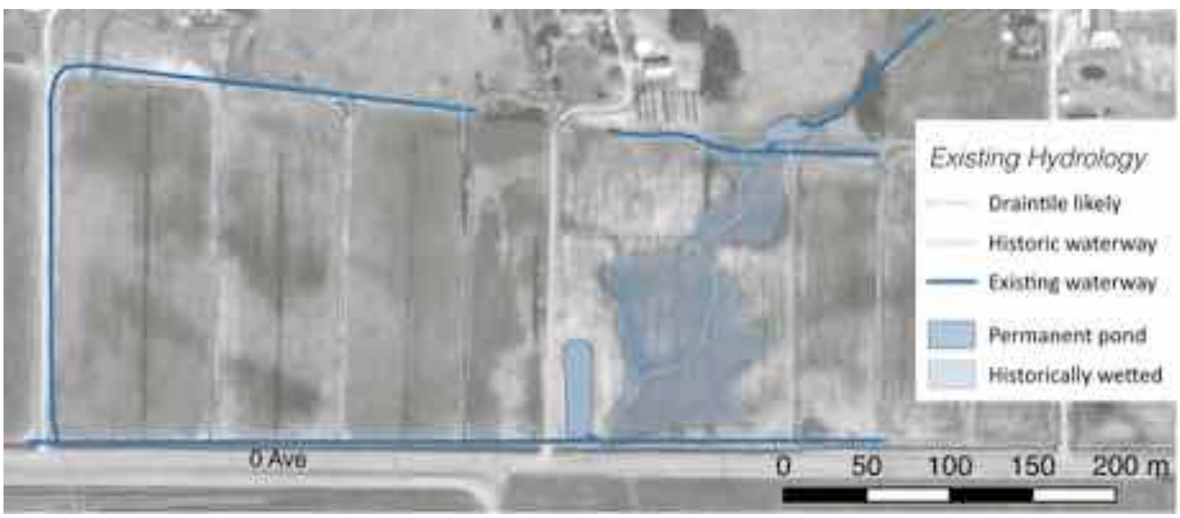


Figure 5. Location of existing and historic draiange features, overlain on orthophoto image from 1979.

Soil investigations confirm drainage regimes identified in the historic maps. Our expectations are that, in the north-east corners water will pool through the winter and spring, but drain through the summer months. In the south-west, soils will retain water through the summer. Year-round surface water may keep pools wet through the summer if inflows are sufficient and surface outflow sufficient for the retention of water despite losses to infiltration and evaporation / evapotranspiration.

We investigated soils on site by digging test pits across phases II and III. On September 24, 2015 we used a small excavator to dig pits up to 2m deep, and requested the services of a soils specialist to assist in interpretation of the site, as well as to provide learning opportunities to students. Dr. Jonathan Hughes, paleoecologist, soil specialist and professor at the University of the

Fraser Valley (UFV), assisted in soil interpretation and collected samples of fossilized seeds for analysis with his class at UFV.

The complex and variable stratigraphy across a relatively small area indicates that the site has a complex geological history. Further research into the geology of the site indicates that it falls within an area that was affected by two additional glacial advances and retreats following the well-known Cordilleran glacial retreat, and that the unusual layering of clays, gravels, sands, silt and loam are likely the result of dynamic glacial effects, including the occasional presence of the glacio-marine estuary, glaciolacustrine deposits, and meltwater channels (Clague et al. 1997).

In general, soil pits identified that organic and thin layers of mineral loam overlay coarse sand with cobbles at the north end of the area of interest, with increasing depths of organics and silt loam and clay loam towards the south west (Figure 6).

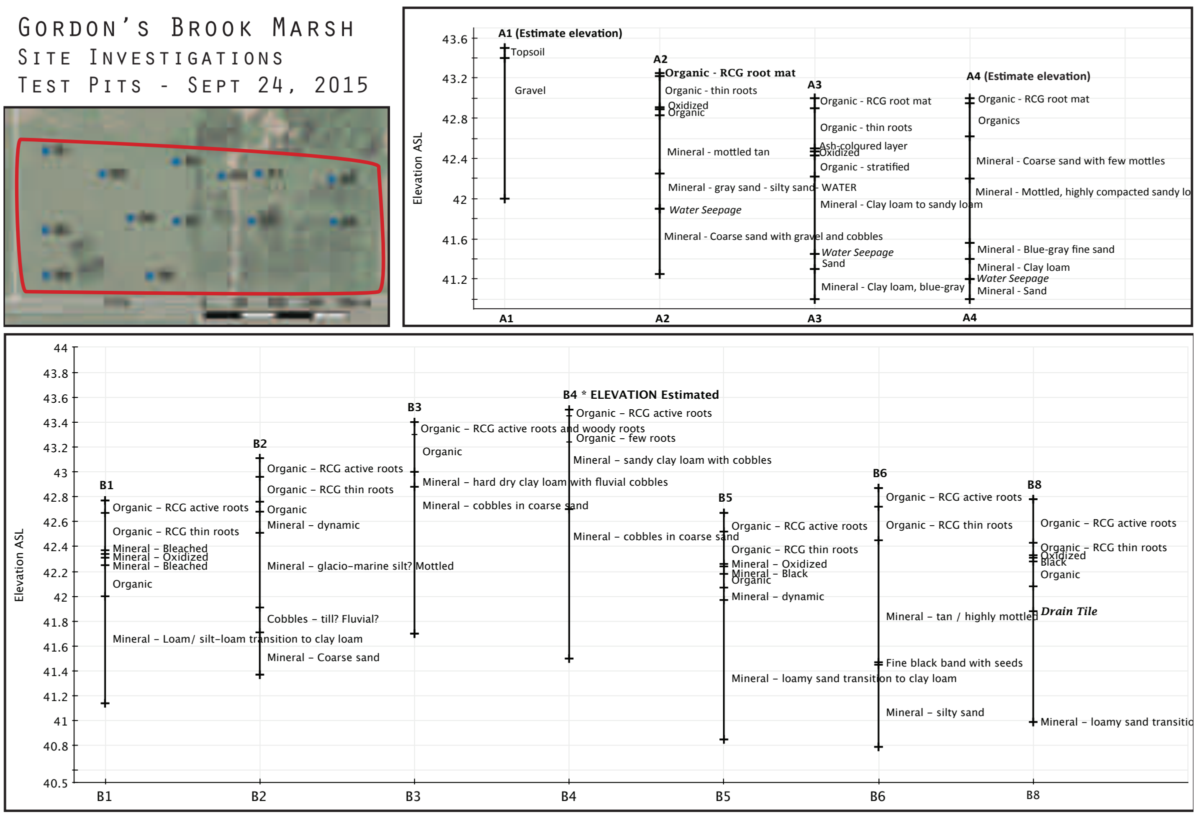


Figure 6. Details of test pit soil stratigraphy Sept 24, 2015.

In Phase II (pits A2-A4), water seepage entered well below surface level below a compact layer of clay loam. This suggests that the restored wetland will rely primarily on surface water that will hold above the clay loam in the fall, winter and spring, but the area is unlikely to be served by groundwater in the late summer. The soils around A1 had been modified by human use, as the area was historically a horse-riding ring (J. Jarvis, Pers. Comm. 2015).

In Phase III (B1-B9), all pits except B3 and B4 filled with water within 24 hours of excavation. Pits B5-B9 were very wet, with Pits B7 and B9 filling before it was possible to assess soils. The restored area is likely to be fed by groundwater and hold water through the summer.

Through the winter of 2015-16, much of the area was saturated, with large areas of inundation (up to 5 cm of standing water) and many areas with pooling (5 – 30 cm of standing water). Beaver dams in the roadside drainage ditch acted to back up water and ensure continuous saturation and pooling through the winter.

The presence of beavers in the park and watershed is well known, and we must assume that beavers will attempt to use and modify structures that are implemented in the park. For this reason, designs should incorporate beaver biology and attempt to work with the beavers rather than design to prevent or exclude – a losing prospect.

4.2.2 Water Chemistry

Given the historic agricultural use of the area and ongoing upstream agricultural impacts, we anticipated that elevated nutrients in the topsoil and surface water may negatively impact the recovery of native vegetative communities. Land to the north of the site was historically licensed for raspberry farming (Metro Vancouver, 2013). Most of the raspberry fields in the area are fertilized by poultry effluent and commercial fertilizer, and also require irrigation in the dry summer months (Mitchell et al. 2003). Presumably previous point-sources and current non-point sources of fertilizer from adjacent agricultural sites have increased nutrient loading in soil and groundwater. High nitrate concentrations have been documented in the Abbotsford-Sumas aquifer as a result of extensive agricultural practices in the Lower Mainland (Zebarth et al. 1998; Mitchell et al. 2003). Additionally, algal blooms on the Phase I wetland were observed in the summer of 2015, which may be a result of excess nutrients from fertilizers entering the wetland, leading to eutrophication.

Water samples were collected and analyzed on three occasions – twice by BCIT students for Phase II only in Fall 2015, and once across all Phases by Balance Ecological in April 2016.

Phases II and III

Water samples were collected on April 23, 2016, with a focus on nutrients to identify sources and current conditions. Groundwater was high, with surface water seen across much of the site.

All samples collected were hyper-eutrophic as defined by the Canadian Guidance Framework for Phosphorus, but Ammonium-N levels are within acceptable CCME guidelines for Ammonia. Nitrate and Nitrite levels, and Total Kjeldahl Nitrogen levels are low. Phases II and III are phosphorous-rich, nitrogen-limited systems. Inflow to Phase II showed elevated nitrates and nitrites, but very low phosphorus concentrations, whereas samples taken within and at the exit to the site were low in nitrate and nitrite, but higher in total nitrogen and phosphorus. Current phosphorus input is low, but the area retains a legacy of phosphorous applications.

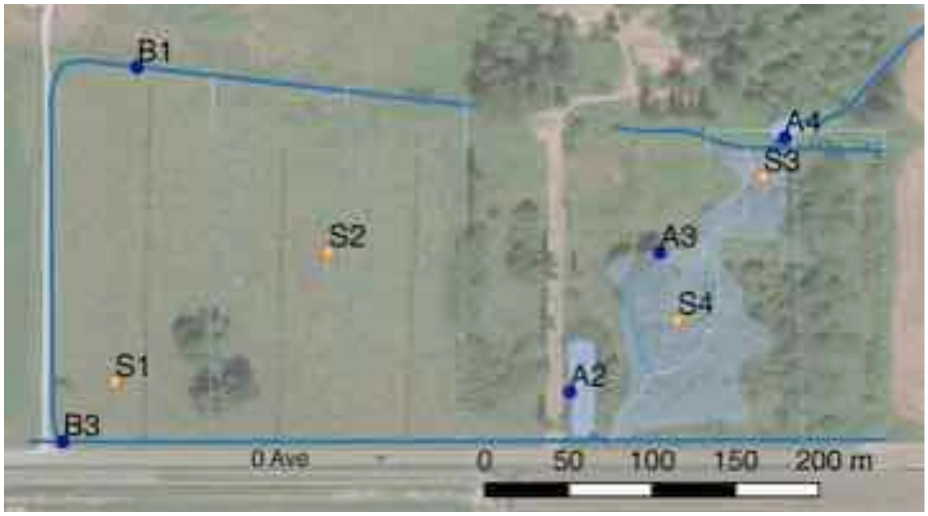


Figure 7. Location of water (A, B-series) and soil (S-series) samples collected in April 2016.

Table 1. Water quality results - April 23, 2016.

Analyte		Units	Detection limit	A2 (Ph II)	A3 (Ph II)	A4 (Ph II)	B1 (Ph III)	B3 (Ph III)
Ammonium - N		mg/L	0.025	0.147	0.233	0.105	<0.025	0.093
Kjeldahl Nitrogen	Total	mg/L	0.07	1.86	1.65	0.43	1.12	1.4
Nitrate and Nitrite - N		mg/L	0.01	<0.01	<0.01	0.88	<0.01	0.06
Phosphorus	Total	mg/L	0.05	0.65	1.53	0.1	1.01	1.18
Orthophosphate-P	Dissolved	mg/L	0.01	0.28	0.8	0.03	0.17	0.13

Phase II Pond

Preliminary data on water temperature, dissolved oxygen (DO), and pH were taken in the pond in the southwest corner of Phase II on November 19, 2015 by BCIT students. Water temperature and pH were within the acceptable ranges for freshwater species for the time of year they were taken (CCME 2007). However, DO levels were <2 mg/L, well below acceptable levels for freshwater species in North America (i.e., >6-8 mg/L; (CCME 2007). Further testing of additional water quality parameters at this pond on February 4 2016 indicated high levels of ammonia (NH3), nitrate (NO3-) and nitrite (NO2-), and total phosphorus (TP).

Table 2. Water quality results from Phase II pond (A2) in February 2016.

Analyte	Units	Detection limit	A2 (BCIT)
Total Suspended Solids	mg/L	3	<3.0
Total Dissolved Solids	mg/L	13	73
Turbidity	NTU	0.1	6.66
Ammonia, Total (as N)	mg/L	0.005	0.169
Nitrate (as N)	mg/L	0.005	1.01
Nitrite (as N)	mg/L	0.001	0.0132
Phosphorus (P)- Total	mg/L	0.02	0.464

E. coli	MPN/100m L	1	15
Coliform Bacteria - Total	MPN/100m L	1	579
Biological Oxygen Demand	mg/L	2	<2.0
Chemical Oxygen Demand	mg/L	2	41

In addition, the most probable number (MPN) of colony forming units (CFU) in the pond was above the upper CFU threshold for recreation, irrigation, and drinking water (i.e., 200 CFU/100 ml, 100 CFU/100 ml, and 0 CFU/100 ml, respectively) (CCME 2007). Note that the MPN of CFU in the pond on the Phase III site was 579 MPN/100 ml. There is no direct conversion of MPN to CFU but there is a strong positive relationship between MPN and CFU estimates (Cho et al. 2010, Sutton 2010).

These analyses suggest that poor water quality in the pond is due to inputs of agricultural runoff containing high levels of ammonia, a compound used in the majority of fertilizers. As ammonia oxidizes into nitrates and nitrites, the majority of available DO is used (U.S. EPA (Environmental Protection Agency) 2010). Oxidation of ammonia (i.e. nitrification) is likely occurring in the pond on the site, indicated by high ammonia concentrations and extremely low levels of DO. Low DO concentrations can decrease species diversity, and have lethal effects on freshwater aquatic fish and amphibian species (de Solla et al. 2002; Camargo et al. 2005; U.S. EPA (Environmental Protection Agency) 2010).

One sediment sample was collected from the pond on February 4, 2016. Parameters measured included pH, Total Kjeldahl Nitrogen (TKN), total organic carbon (TOC), ammonia, *E. coli*, coliform bacteria and metals. Sediment was collected from the top 5 cm of the benthic layer using a Ponar Sediment Clamp. Results from the sediment analysis indicated a slightly acidic (pH of 5.84) benthic environment. The concentration of ammonia in the benthic layer was high at 10.3 mg/kg, and 85.2% saturation. Ammonia is abundant in anoxic sediments as nitrification (i.e., the oxidation of ammonia to nitrite and nitrate) is inhibited (U.S. EPA (Environmental Protection Agency) 2010). Metals analysis indicated high levels of aluminum and magnesium, though there are no standards on acceptable levels set by the Canadian Sediment Quality Guidelines for the Protection of Aquatic Habitat (CCME 2007). Soil chromium (38.2 mg / kg) exceeds the threshold level of 37.2 mg/kg above which adverse biological effects may occur (CCME 2007).

Elevated ammonia levels resulting in low DO will need to be mitigated to enable colonization of the site by the target fish and amphibian species.

4.2.3 Soil Chemistry

Existing soil chemistry is key for identifying two outcomes of the restoration program: a) Wetland classification, and b) risk of algal bloom. The resulting wetland classification is dependent on multiple factors, of which hydrology and underlying soil chemistry are critical. In particular, the soil nutrient regime and pH will drive the biological community outcome. This is discussed further in Section 5.1.2 – Target Wetland Classification.

In addition, many historic agricultural fields have high phosphorous loading as a legacy of many years of agriculture. When these soils are flooded, soil phosphorous can be suspended as soluble reactive phosphorous (SRP, or orthophosphate) which drives the growth of algae in the water column, resulting in hypoxic areas as the algae consumes oxygen at night and during senescence. This affects the overall quality of the habitat, and acute hypoxic events are likely to have fatal impacts on fishes present in the water column.

Large algal blooms were observed in Phase I in 2014, when the wetland was flooded through the summer months. It is likely that similar blooms will occur in adjacent habitats. Some literature suggests that that phosphorous releases are temporary and once vegetation and naturalized growth cycles are established that the restored wetland will recover to the phosphorous retaining role of a natural wetland (Aldous et al. 2007), but it is likely that the legacy of phosphorous loading is a more complex problem across the landscape – with significant implications for restoration of agricultural fields to wetlands and the resulting quality of the water runoff (Sharpley et al. 2013). Best management practices are not yet developed, but it may be possible to address or slow the release of legacy phosphorous by increasing the organic available carbon in the soils using soil amendments, and thus increasing sequestration of the phosphorous as it is released from the soils.

Soil is of neutral pH, and has significant organic matter content. Unfortunately, soil sample analyses confirm that soils in both Phases II and III are low in nitrates and extremely high in Phosphorous. **This will likely result in a release of Phosphorous from the soil after flooding, conversion to SRP / Orthophosphate resulting in algal blooms in the first years following restoration.** Although we are not able to mitigate these concerns at this time, by being aware of the issue we can monitor water quality of inflow, outflow, and the presence of algae in restored wetlands over time to assess whether or not the release of legacy phosphorous is an acute post-restoration concern or likely to be an ongoing challenge. Our expectation is that over time guidelines will be developed by soil chemistry experts to provide guidance on soil amendments to flooded agricultural land.

Table 3. Soil sample analysis from April 23, 2016.

Analyte	Units	Detection Limit	S1 (Phase III)	S2 (Phase III)	S3 (Phase II)	S4 (Phase II)
Nitrate-N	ppm	2	2	2	<2	3
Phosphorous	ppm	5	>60	>60	>60	>60
Potassium	ppm	25	51	57	191	112
Sulfate-S	ppm	1	20	15	7	5
Calcium	ppm	30	2860	3080	1360	1700
Magnesium	ppm	5	179	102	155	98
Iron	ppm	2	486	469	354	376
Copper	ppm	0.1	1.7	3.7	2.4	2
Zinc	ppm	0.5	7.8	9.6	7.6	5.8
Boron	ppm	0.1	0.7	0.8	0.5	0.4
Manganese	ppm	0.1	4.3	3.6	11	11.6
Chloride	mg/kg	0.5	11	8.3	6.8	4
pH			6.1	6	6.2	5.9
Electrical	dS/m		0.29	0.26	0.12	0.14

Conductivity						
Organic Matter	%		33.5	29.9	7	12.1
C:N Ration				14.8	11.2	
Nitrogen	Total %	0.02		1.14	0.27	
Carbon	Total Organic %	0.04		16.8	3.08	

4.3 Vegetation

Aldergrove Regional Park is located within the Coastal Western Hemlock biogeoclimatic zone and within the very dry maritime subzone (CWHxm1). The CWHxm1 subzone is characterized by warm summers with fairly low precipitation and wet, mild winters with most precipitation falling as rain (Pojar et al. 1987). Climax forests expected for this subzone include stands dominated with Douglas-fir (*Pseudotsuga menziesii*) and minor amounts of western red cedar (*Thuja plicata*). Common wetland types in Aldergrove Regional Park include shallow marshes, ephemeral ponds, and swamps (Metro Vancouver 2013).

Vegetation investigations of Phases II and III indicate a high component of invasive vegetation across the site, but the two phases have distinctly different vegetative communities.

Phase II contains a large proportion of woody vegetation, as the area appears to have been abandoned by agriculture in the early 1990s, with shrubby vegetation well established in the south-east section by 1999. Wetter portions of the field contain stands of willow species and red alder, with higher elevation zones dominated by invasive Himalayan blackberry. Swampy areas with full shrub or blackberry canopy have little understory growth. Areas remaining open are dominated by invasive reed canarygrass. Phase III is dominated by invasive reed canary grass (*Phalaris arundinacea*, RCG). Remnant agricultural windrows have grown and now include both young and mature deciduous trees.

Tree species identified on site include:

- red alder (*Alnus rubra*),
- black cottonwood (*Populus balsamifera ssp. trichocarpa*),
- paper birch (*Betula papyrifera*),
- black hawthorn (*Crataegus douglasii*), and
- Lombardy poplar (*Populus nigra*; a non-native species)

Shrub species identified on site include:

- willow (*Salix hookeriana, S. lasiandra, S. scouleriana, S. sitchensis*),
- red-osier dogwood (*Cornus stolonifera*),
- red elderberry (*Sambucus racemosa ssp. pubens*),
- salmonberry (*Rubus spectabilis*),
- black twinberry (*Lonicera involucrata*),
- rose species (*Rosa spp*)
- Himalayan blackberry (*Rubus discolor*),
- Evergreen blackberry (*Rubus lacinatus*), and

- Japanese Knotweed (*Fallopia japonica*)

Herb species identified on site are limited. Open areas are dominated by reed canarygrass, and understory beneath dense shrub or blackberry canopy has little growth. Where herbs do occur beneath the canopy, species include:

- Horsetail sp. (*Equisetum arvense, E. palustre*, *E. cheiranthoides*)
- Roughwater horehound (*Lycopus asper*)
- Buttercup sp. (*Ranunculus acris, R. repens*)
- Ladyfern (*Athyrium filix femina ssp. Cyclosorum*)
- European bittersweet (*Solanum dulcamara var. dulcamara*)
- Purple loosestrife (*Lythrum salicaria*)

Beavers are present in the Pepin and Gordon's Brook complexes, and are expected to expand into any newly restored or created wetland areas. In Phase I, beavers altered the design hydrology in unexpected ways, resulting in unanticipated but not unwelcome hydrologic dynamics. By retaining water and sediment, they have contributed to increased water storage, the recovery of water tables, attenuation of high flows, reconnection of the floodplain and improved connectivity of the constructed wetland, and increased habitat complexity. In addition, they are constantly on stand-by to monitor and restore damaged infrastructure resulting in water loss from the ecosystem (eg. backcutting or side-cutting channels around weirs).

Rather than fighting beavers to recover design hydrology, we intend instead to work with the beavers – attempting to anticipate their actions and goad them into building dams to impound water in design locations. Guidelines developed for working with beavers in the United States will be piloted in our design (Pollock et al. 2015).

5 Design Targets

Design targets are based on values of biodiversity and ecosystem function first, and human use for educational purposes second. Recreational human use is not a driving value for this project, but will be considered in the design.

5.1 Biodiversity Targets

5.1.1 Wildlife Species

The constructed habitat contains a variety of zones and habitat features that target Oregon Spotted Frog, Northern Red-legged Frog and attempt to exclude American Bullfrog by design. The features also provide for avian and invertebrate biodiversity. Habitat features at multiple scales create an abundance of variance for an abundance of life. Micro-features incorporate a variety of depth and shallows, a rough finish to increase surface area of soils, and differing densities and combinations of plants and woody debris. We will use a 'diversity of diversity' approach – some simple areas, some complex, or various categories of habitat. Providing a diversity of habitat types and habitat features increases the overall opportunities for biodiversity on site.

Focal species will be targeted with the following habitat features:

<u>Oregon Spotted Frog (*Rana pretiosa*):</u>

- shallow marsh areas for breeding, rearing and foraging;
- summer refuge pools for low water survival and foraging;
- coarse woody debris in pools and within flowing water for winter survival;
- hardhack 'islands' to provide refuge in summer and provide overwintering structures.

<u>Northern Red-Legged Frog (*Rana aurora*):</u>

- coarse woody debris in ponds for breeding;
- shallow marsh areas for rearing and foraging.

<u>Salish Sucker (*Catostomus* sp.4)</u>

- shallow marsh habitat for foraging;
- coarse woody debris in ponds for cover.

<u>American Bullfrog (*Rana catesbeiana*) discouragement:</u>

- shallow marsh areas less desirable to bullfrogs may discourage presence;
- complexity in deep areas provided by coarse woody debris, hardhack islands and brush piles may discourage bullfrog presence.

<u>Great Blue Heron (*Ardea herodias*):</u>

- shallow marsh habitat for foraging.

<u>General avian biodiversity:</u>

- shallow marsh habitat for foraging;
- tall woody debris for perching / resting;
- short woody debris for perching / resting;
- brush piles for resting / nesting / foraging;
- hummocks for resting / nesting;

- pond habitat for foraging.

General invertebrate biodiversity:

- varied freshwater habitats (sedge / cattail / pond / floating / ephemeral) for dragonfly foraging, laying and rearing;
- brush piles for pollinator breeding;
- coarse woody debris for breeding / foraging.

5.1.2 Target Wetland Classification

The hydrologic regime of a wetland, particularly water level fluctuations, is a strong determinant of the vegetative species assemblage as plant species respond differently to depth, frequency and duration of inundation. Water chemistry, soil chemistry and soil drainage characteristics also impact plant communities. In turn, plant assemblages affect soils, flows, and evapotranspiration rates. Vegetation assemblages provide structure and food for wildlife, and act as indicators of the health of the wetland.

The BC Wetland Edatopic grid can assist in identifying the likely biologic classification of a restored wetland based on hydrologic dynamics, soil moisture, nutrients and acidity (MacKenzie & Moran 2004) (Figure 8). Our soils analysis suggests that the site was historically a transition zone from upland forest to swamp to a peat base.

By removing drainage infrastructure, we anticipate restoring a ‘wet’ soil moisture regime, with a ‘Mobile’ hydrodynamic index. Soil nutrients and acidity are functions of existing soil structures. Soil nutrients are likely to be higher than what is associated with a historic Lehman or Judson Muck soil, due to the agricultural impacts in the watershed. Similarly, high acidity is associated with Judson Muck and Lehman soils, however this will be attenuated by digging below the organic materials and exposing lower layers of Lehman soils in pools and ponds at higher elevations.

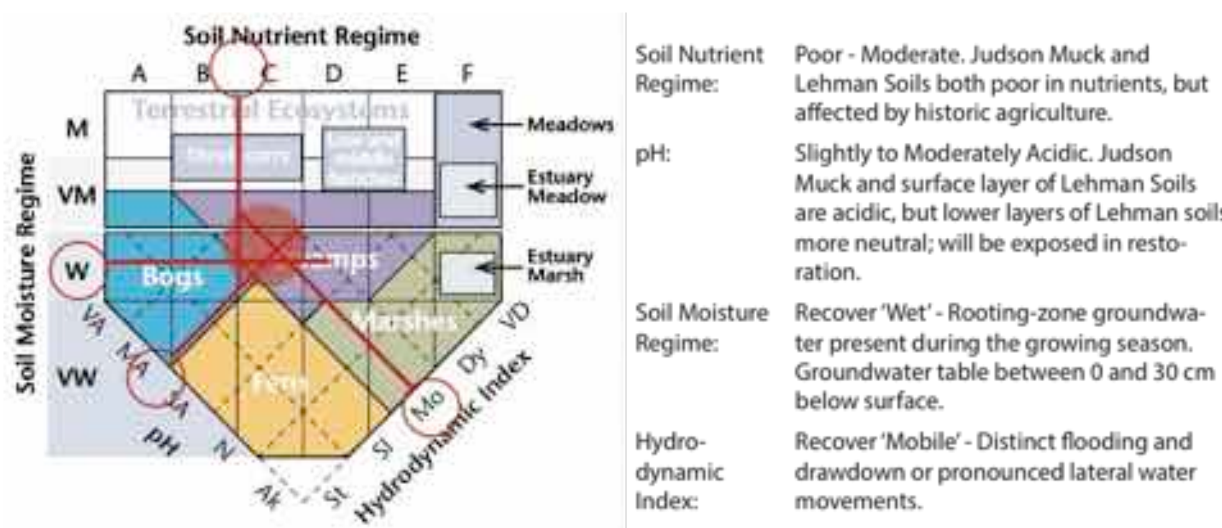


Figure 8. BC Wetlands Edatopic Grid, predicting biological community outcome of geophysical factors. Soil moisture and hydrodynamic index will be recovered, and soil nutrient and pH are dependent on existing conditions.

Phase II – Swamp

Our target wetland classification for Phase II is a swamp. Swamps are forested, treed or tall-shrub mineral wetlands dominated by woody vegetation on fluctuating, semi-permanent, near-surface water tables (MacKenzie & Moran 2004). The fallow field has already developed many swamp characteristics, with ephemeral ponding that supports large willow and alder patches.

Phase III - Marsh

Our target wetland classification for Phase III is a seasonally wetted marsh and associated wet prairie. This is based on biodiversity targets, particularly the creation of habitat suitable for Oregon Spotted Frogs. Marshes are shallowly flooded mineral or organic wetlands dominated by emergent grass-like vegetation, typically with a fluctuating water table and common exposure of substrate in the late summer or in dry years. Marshes are eutrophic or hyper-eutrophic.

However, development of a marsh will likely require ongoing maintenance by prescribed burning (See Section 7.3). Burning would have the triple effect of holding back shrub growth, increasing nutrient availability and reducing pH of the area – all necessary to shift the site into the 'Marsh' section of the edatopic grid. If burning becomes a possible management tool, this will be our priority goal. However, in recognition that burning may not be an available tool in the future, our secondary target wetland class for Phase III will become a swamp.

6 Hydrologic Recovery

Our investigations have revealed that significant hydrologic modifications were installed to render the area suitable to agriculture.

The large majority of these modifications will be disabled to re-capture inflows, increase retention time and raise the water table. However, true hydrologic recovery of historic water tables is not entirely possible, given the proximity of the site to municipal roads and the importance of maintaining drainage along road infrastructure. A right-of-way along 0 Ave restricts any activity within 10 m of the road, and re-flooding should not impact the integrity of 0 Ave or driveways off of it.

Although the water budget on-site is unknown, soils and existing groundwater conditions clearly indicate that wetted ground will recover with the disabling of drainage features.

GUIDING PRINCIPLES – HYDROLOGIC RECOVERY

Don't try to make it something it's not – use existing hydrology and soils.

Give water somewhere to go but make it work to get there.

Avoid engineered water control structures.

Work with beavers – let them fill it.

Hydrological Recovery activities will require:

1) Disabling drainage ditches that capture seepage water from the northern hillslope and re-direct the water back onto the fields
2) Disabling drain tile that lowers water table.

Additional actions will serve to increase the complexity of the site.

3) Excavate pools where invasive vegetation is removed, and use shallow berms to hold design elevations;
4) Connect existing ephemeral pools and constructed pools to increase lateral complexity of water flows.
5) Install features and microtopography to increase diversity of niches, including mounds and pools.
6) At water control points, install vegetation and 'starter dams' to encourage placement of beaver-managed water control structures.

6.1 Drain Tile Decommissioning

Drain tile was identified in the field when digging test pits, and their locations appear on historic orthophotos (Figure 9). Drain tile was likely installed in the 1970s, following initial ditching to lower water tables (visible in 1969 photos). The identified drain tile was corrugated slotted plastic, with no drain rock to protect the plastic. This makes finding the tiles more difficult, but our chances are improved by the photos. Where drain tile is found, it will be plugged to prevent drainage to the ditches

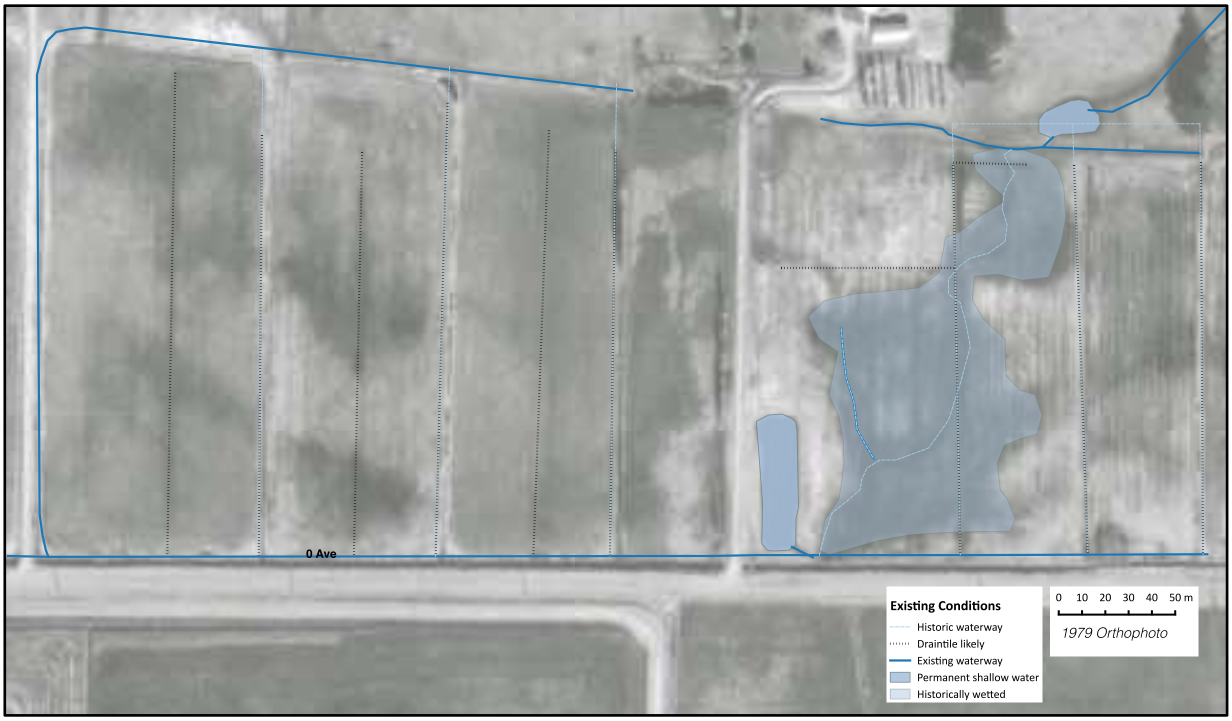


Figure 9. Existing hydrology indicating location of drain tile as identified on 1979 orthophoto.

6.2 Ditch Decommissioning

Drainage ditches that capture water seeping from the hillside to the north will be decommissioned to force the water back through the soils throughout the area. This will help to raise the groundwater table. Ditches will be filled with material scraped from marsh depressions.

6.3 Depressions, Ponds, Channels and Berms

Shallow depressions and ponds will be excavated to accentuate the existing topography of the site. Shallow channels will be dug to direct water to ponds, and to expose high groundwater. Spoil excavated from the channels and depressions will shaped into wide, low berms that will fade into the landscape when planted, and that will help direct surface water into channels. These berms may form the base of walking trails, and all efforts will be made to ensure they are wide enough and stable enough for tractor-mower access.

6.4 Starter Dams

Outlets from some ponds to channels will be constructed to encourage beaver use. Rather than building weirs, 'starter dams' will be installed at the outlets, as described in the Beaver Restoration Guidebook (Pollock et al. 2015). This project site has good beaver dam viability, given its landscape and biological context (Figure 10).

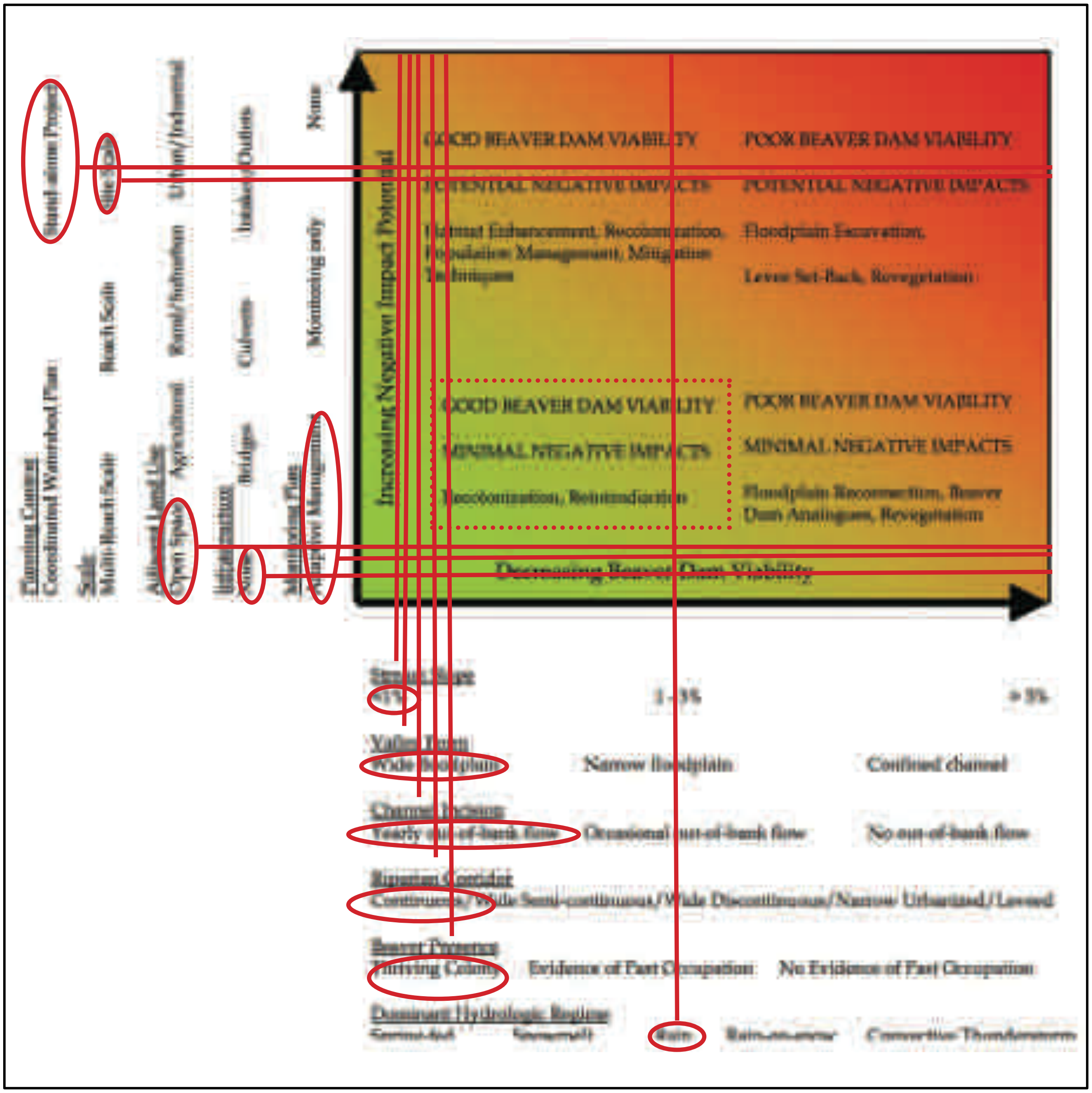


Figure 10. Adapted beaver dam viability matrix from the Beaver Restoration Guidebook (Pollock et al. 2015), identifying feasibility of beaver dam restoration in project site.

A starter dam is made up of posts pounded deep into the ground at 0.5 m intervals, and woven loosely with willow branches (Figure 11). These dams are permeable and do not generally hold enough water to form a pool in the short term. However, if well placed the starter dams will form natural starting points for beavers to build and fill a deeper wetland pond. If beavers do not choose to use the area, it will be possible to either reduce permeability by placing cobbles, sands, silts any vegetation upstream of the starter dam. However, with increased groundwater from drain tile and ditch decommissioning, it will likely not be necessary to hold water back with a weir to recover wet land and shallow ponds. Willows planted around the dam structures, and in particular on the spoil piles, will entice beavers and we anticipate that several of the starter dams will have attracted beaver engineering prowess within 5 years of construction.

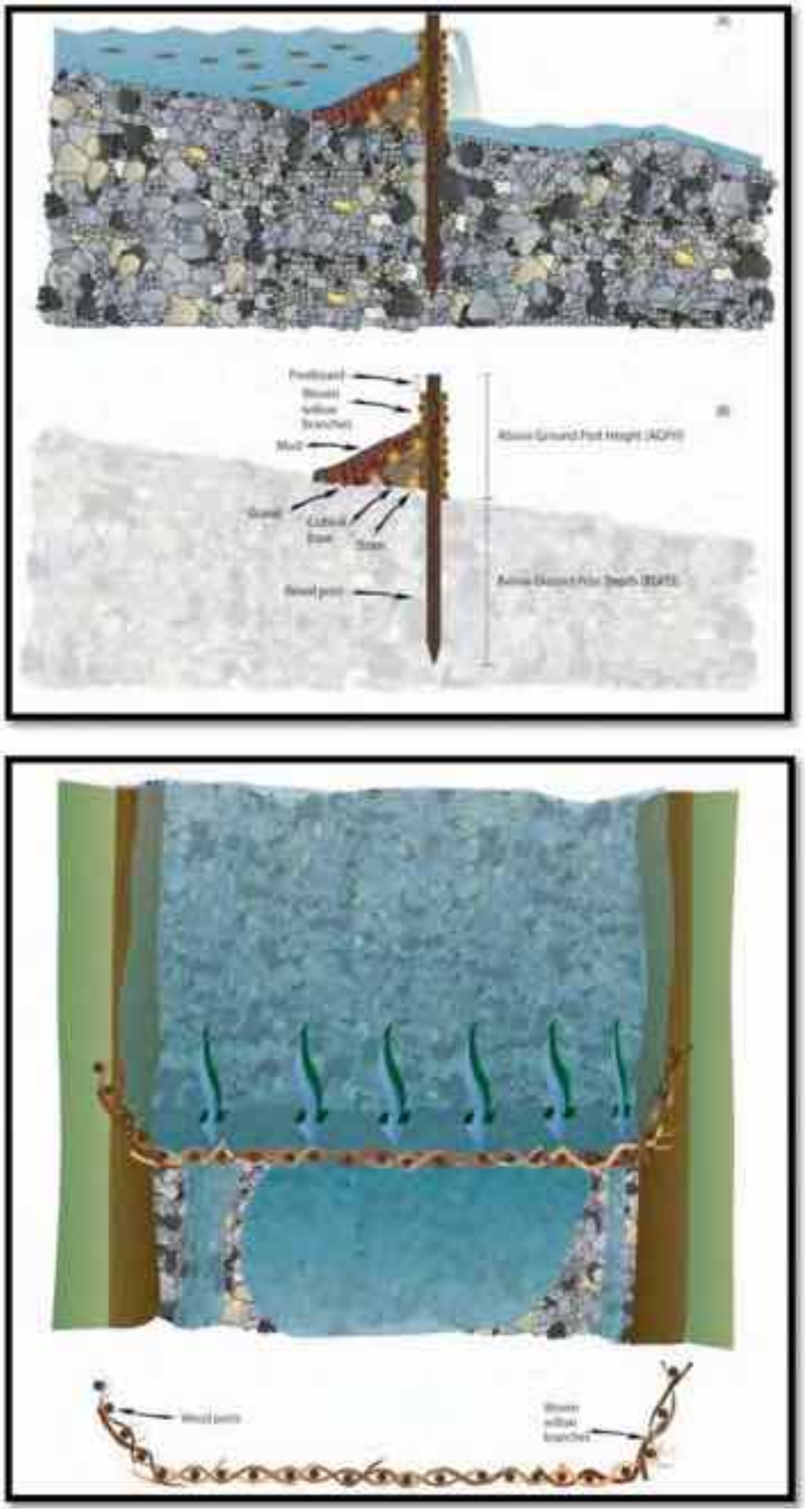


Figure 11. Diagram of a starter dam, with design detail and necessary material needed for construction. (top) side view (bottom) plan view. From Beaver Restoration Guidebook page 84 (Pollock et al. 2015).

7 Invasive Species Control

Successful invasive species management is a cornerstone of the success of this program. Our methods are based on Integrated Pest Management principles modified for a restoration program.

This involves identifying and taking an inventory of the pest species, researching its specific biology assessing the risks it poses, developing well-informed control options, and continuing monitoring, record-keeping and follow-up treatments as required (see Text Box). Treatments may be manual, mechanical, or chemical, and chosen using the following criteria:

- least-disruptive of natural controls;
- least-hazardous to human health;
- least-toxic to non-target organisms;
- least-damaging to the general environment;
- most likely to produce a permanent reduction in the environment's ability to support that pest; and
- most cost-effective in the short and long term.

Priority targets for invasive plant species management are:

- Himalayan blackberry (*Rubus discolor*),
- Japanese Knotweed (*Fallopia japonica*), and
- Reed canarygrass (*Phalaris arundinaceae*).

Additional noxious and nuisance plant species that are likely to impact the restored areas have been identified by surveys in the Phase I wetland, and are addressed in Section 7.4. Invasive wildlife species are also expected to colonize the restored area, and are addressed in Section 7.5.

Invasive species inventory and management data will contribute to the Provincial database be provided to the Provincial database using the iAPP forms application available for iPad and iPhone (https://www.for.gov.bc.ca/hra/plants/application.htm).

COMPONENTS OF AN INTEGRATED PEST MANAGEMENT PROGRAM

California Department of Pesticide Regulation
http://www.cdpr.ca.gov/docs/specproj/h2o/workbook/appendix/page111-115.html

1. **Initial Information Gathering**
   Identify the pest and/or problem. Examine literature on the biology of the pest and its management. Interview local management personnel on the history of the site. Information provides the basis for intelligent program continuity.
2. **Monitoring**
   Observe the plants, or site, for potential pest problems at regular intervals.
3. **Establishing Injury Levels**
   Determine when the pest problem is likely to become serious enough to require some action.
4. **Record-keeping**
   Keep records of what is seen, decisions made, actions taken, and results. Records are the memory of a system. When personnel leave their experience is lost if there are no records.
5. **Least-toxic treatments**
   Select pest management approaches and specific methods according to the criteria spelled out below. Confine the treatments in time and place (i.e., use spot treatments) to minimize ecosystem disruptions.
6. **Evaluation**
   Inspect after treatment action has been taken. Write down what you learn. Has the treatment been worthwhile? How can the whole process be improved to achieve the overall objectives of the program?

7.1 Himalayan Blackberry

Himalayan Blackberry (*Rubus armeniacus*, formerly *Rubus discolor*) is present on Phases II and III. It is particularly important in Phase II and present in the north-east corner of Phase III. Removal and control of the blackberry will allow native species to recover more area. Blackberry is the dominant understory on the hillside north of the restoration zone of Phase II – this area is not within our current restoration plan, but must be considered in invasive species management planning.

7.1.1 Invasion Ecology

Himalayan blackberry is a robust, semi-evergreen shrub that can grow nearly 4 m high, with individual canes extending as much as 10 m feet in a single season. Growth is most vigorous on deep, moist, well-drained soils – favouring sandy soils over clays and silts (Caplan et al. 2006). Although it tolerates a wide variety of soil conditions, including periodic winter flooding, Himalayan blackberry does not grow well in saturated or poorly drained soils. Himalayan blackberry cannot tolerate deep shade. It is rarely in dense forest stands except in openings, and vigour and seed production appear to decline as shade increases (Caplan et al. 2006).

Himalayan blackberry in the project area reflects its known habitat preferences. Thickets are most dense in sandy soils in higher elevations, and are not present in lower elevations where standing water collects in the winter. In addition, it appears that existing blackberry thickets in Phase II are made up mostly of old material with little fresh growth, suggesting that the currently saturated soils and reducing light conditions (due to a growing native canopy) are no longer ideal for growth but may continue to support established plants.

7.1.2 Control Methods

Himalayan blackberry control methods are well established in the Pacific Northwest, and treatment programs are dependent on each location's specific needs and opportunities (Bennett 2006). Managing Himalayan-blackberry-dominated areas typically has four major steps:

1) Site preparation by removal of most of the above-ground plant parts to gain better access to the site;
2) Removing or killing the root crowns and roots to prevent regrowth and reinfestation;
3) Revegetating the site with native vegetation; and
4) Maintenance treatments to reduce or eliminate regrowth.

Site preparation can be by manual, mechanical or chemical means, or a combination of the three depending on the suitability of the site. The most effective methods in riparian areas is mechanical cutting followed by herbicide application to kill the roots and root crown. Mechanically removing rootstock in which canes, roots, and root crowns are uprooted by an excavator can be effective if done thoroughly, however the significant soil disturbance may encourage regeneration from seed or encourage other invasive species to sprout. Repeated mowing, grazing and burning are not effective on their own, as root crowns are not disabled.

7.1.3 Selected Protocol

We propose to control Himalayan blackberry growth predominantly by mechanical means and by altering site conditions to inhibit regrowth. Chemical controls are not ideal at this location as much of the blackberry is surrounded by native vegetation that may be affected by chemical agents by drift or soil / root transfer.

As we intend to access the site by excavator to recover historic hydrology, we will use mechanical and manual means to remove existing plants and root crowns. The combined effects of an increased water table after hydrological restoration and the existing and growing impact of shade from the native canopy will strongly inhibit regrowth from seed and root. Resprouting plants will be monitored and removed manually.

Large areas that have been excavated to remove blackberry will not be re-graded to their current elevation but will be lowered in order to be closer to the recovering water table, thus flooding out regrowth from fragments and seed.

Initial site preparation has begun in Phases II and III by manual and mechanical removal in December 2015. Manual efforts affected 5,600 m^2, in which canes were removed and piled, exposing root crowns in areas too wet or tight for excavator access; mechanical removal affected 4,000 m^2, in which canes and root crowns were removed and piled. Excavated materials were piled either on the road where they could be removed or continuously mowed; or piled on top of existing upland blackberry thickets.

Upland thickets are not accessible by mechanical means, but their spread into the restoration zone must be inhibited in our design. To ease the continued mechanical management of the blackberry, we will use excavated soils to construct a trail or path along the base of the hill that can be mowed using mechanical mowers commonly used by Metro Vancouver Parks.

7.2 Japanese Knotweed

Japanese knotweed (*Fallopia japonica*) was known to be present 500 m from the target restoration areas, adjacent to Gordon's Brook. A small cluster (approximately 10 m^2) has been identified in Phase II in spring 2016 at the upstream end of the restoration site. This thicket must be eliminated in order to eliminate the threat of spread into the restored site.

7.2.1 Invasion Ecology

Knotweeds are invasive perennials that thrive in roadside ditches, low-lying areas, and other water drainage systems. They are found in riparian areas, along stream banks, and in other areas with high soil moisture. Knotweeds spread rapidly through root systems that may extend from a parent plant up to 20 metres laterally and up to a depth of 3 metres. They threaten biodiversity and disrupt the food chain by reducing available habitat and increasing soil erosion potential. They are extremely aggressive and persistent. The BC Ministry of Agriculture has flagged Japanese Knotweed as an Aggressive Ornamental that is extremely difficult to manage once established. (http://www.agf.gov.bc.ca/cropprot/jknotweed.htm).

Click to Open – Hallworth n.d.

7.2.2 Control Methods

Knotweeds are identified as 'control' species in the Lower Mainland by the Invasive Species Council of Metro Vancouver. Control Species are widespread throughout the region with very little chance of eradication and are only worked on in specific sites where they are contained outside of a boundary i.e. a park.

Control efforts at the watersheds scale should begin at the furthest extent upstream and work successively downstream in order to prevent continual migration of knotweed downstream. Control efforts at the site scale should begin on sites adjacent to watercourses and work successively outward from these areas. Small patches are best treated via stem injection of glyphosate-based herbicides by trained and certified applicators.

7.2.3 Selected Protocol

We recommended aggressively treating the small patch to avoid further infestations. Mechanical control of the species has a low success rate, even with continuous removal of stems and root systems. Chemical treatment is recommended as an effective method of controlling the species, by direct injection of glyphosate-based herbicide into each stem of the plant.

As the patch is outside of the planned excavation area, we do not propose to remove the plants mechanically. We will partner with the Invasive Species Council of Metro Vancouver to treat the patch and we will monitor the site specifically throughout restoration and post-construction monitoring programs.

Any excavation or machine works in the proximity of the knotweed patch will be preceded by careful removal of all above-ground materials and disposal at a certified weed disposal facility. In addition, the upstream watercourse should be assessed for additional infestations and treatment begun from the upstream end.

7.3 Reed Canary Grass

Reed canarygrass (*Phalaris arundinacea*) is a perennial plant native to North America and Eurasia. Several non-native dominant phenotypes were introduced from Europe for forage and soil stabilization in a number of areas throughout Canada and the United States in the past three centuries. Anthropogenic disturbances associated with agriculture, particularly hydrologic disruption (drainage) and nutrient applications increase a site's vulnerability to invasion (Annen 2016a). Reed Canarygrass has become an aggressive and invasive species in prairies, streams, and wetlands across North America – it is quick to establish, aggressive in its domination of soil resources, and quickly forms large monotypic stands in areas where it is introduced. These stands severely alter habitat and ecosystem function and threaten native plant and animal diversity (Lavergne & Molofsky 2004).

Both Phases II and III were previously used for agricultural cultivation, and the watershed continues to be impacted by agricultural nutrient runoff (Whatcom County). Reed canarygrass is present on both Phases II and III, and must be controlled to ensure native vegetation is able to take hold following construction activities. In Phase II, control is less problematic as the swamp will incorporate shade and depths unsuited to the species, but will require some control activities in the northern, less densely canopied section of the site. Reed canarygrass is the most significant challenge to restoration on Phase III, where much of our site preparation activities focus on the significant reduction, with the goal of eradication, of this species. High organic matter content is linked with Reed Canarygrass invasion, and this is reflected in our soil analyses indicating 7-12% organic matter in Phase II, where shrubs have overtaken reed canarygrass growth on the fallow field, and 30% in Phase III where Reed Canarygrass is more abundant.

7.3.1 Invasion Ecology and Control Challenges

Healy and Zedler (2010) provide a useful summary of the species' invasion model and the challenges associated with its control or eradication. Reed Canarygrass is a "model invader" with high competitive and strong feedbacks that maintain its dominance. Its competitive ability is related to its early spring sprouting, rapid height growth, clonal expansion, prolonged growing season, production of dense shade, and ability to obtain nutrients. It reproduces via seeds, rhizomes, and fragments, and its plasticity allows it to dominate across a broad range of hydroperiods. Reed Canarygrass has an additional competitive advantage in remaining green through October, after native species senesce, and it takes advantage of ample nutrients to quickly outgrow native plants. The shift from diverse native vegetation to a Reed Canarygrass monotype is especially rapid when high nutrients and shallow water(Healy & Zedler 2010).

Annen (2016) describes ecosystem collapse in sedge meadow transformations to RCG-dominated systems as following a series of steps:

a) Loss of disturbance cycle that maintains the open character of a meadow (ie. Fire and/or flood that removes accumulated litter and prevents clonal species from dominating the meadow, and/or prevents encroachment from shrub species);

b) Hydrological disruption, usually the lowering of water tables, by construction of drainage or diking infrastructure, as well as the establishment of plants with high evapotranspiration rates;

c) resulting in predisposition to invasion due to developing gaps in the herbaceous canopy and exposure of empty niche space into which Reed Canarygrass seed can germinate; this is of course greatly accelerated by the (ongoing) active seeding of Reed Canarygrass into low-lying agricultural lands as a moisture-tolerant pasture crop.

d) Once established, Reed Canarygrass clones spread vegetative through rhizome growth, expanding by emergence of new tillers at both short and longer distances from the parent clone.

e) Reed Canarygrass exhibits high evapotranspiration rates, increasing hydrological abundance, providing positive feedback for regrowth; and

f) In the absence of fire, a dense mat of grass litter accumulates, with a mulching effect on remaining native species that impedes their germination and growth while providing further positive feedback to Reed canarygrass.

g) Nutrient additions from agricultural activities amplify the litter feedback, as Reed Canarygrass is a poor nutrient competitor in nutrient-poor environments but able to accelerate biomass production in the presence of high nutrients.

h) When Reed Canarygrass abundance reaches a critical density, feedback cycles internally reinforce the invasion by reinforcing hydrologic and litter feedback.

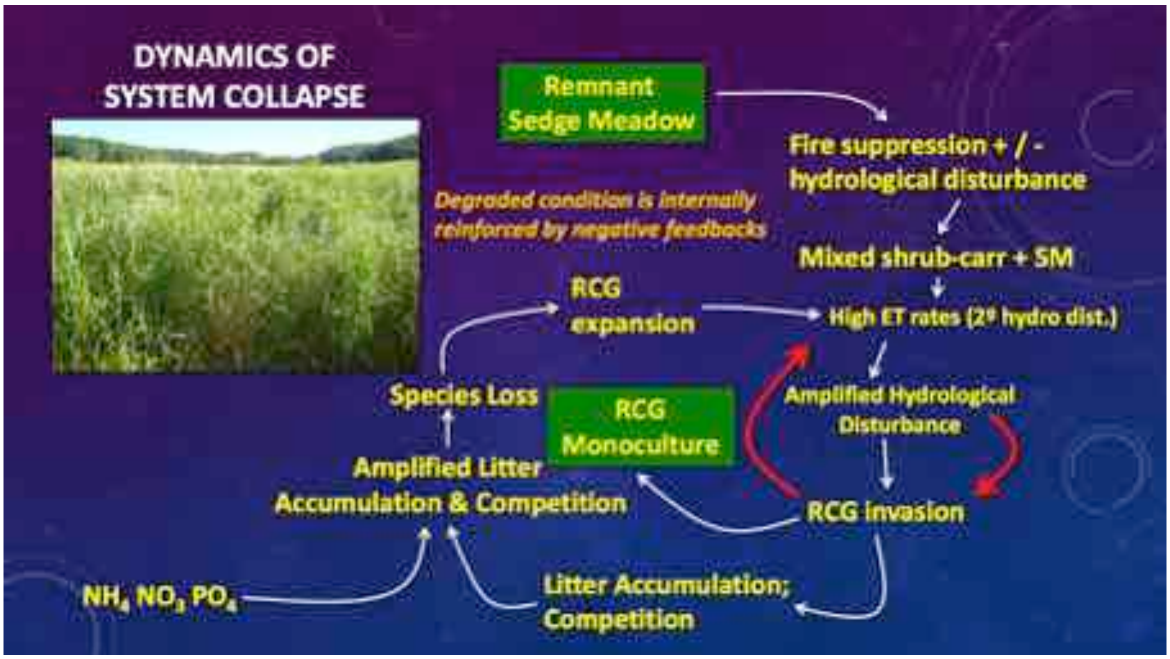


Figure 12. Dynamics of system collapse into Reed Canarygrass monoculture (Annen 2016b).

Once invaded by Reed Canarygrass, wetlands are very difficult to restore to native plants, as (Healy & Zedler 2010):

- Burning alone opens the canopy and favors regrowth because increased light stimulates germination, seedling establishment, and vegetative expansion.
- Non-selective herbicides (e.g. glyphosate) kill all plant species aboveground, but leave the dormant rhizome buds and seed banks of Reed Canarygrass to regenerate.
- Grazing and mowing can reduce Reed Canarygrass height during treatment, but the species recovers quickly when not mowed.
- Removing sod and creating open water can suppress Reed Canarygrass regrowth but deep water is not a solution where the restoration target is a wet meadow.
- Overplanting with trees can outshade Reed Canarygrass, but the result is a woodland.
- Biocontrol is not an option, because Reed Canarygrass is used in pastures and biofuel production.

7.3.2 Annen's Systemic Approach

Click to Open – Annen 2016b

Despite the above limitations, Reed Canarygrass control and even eradication has been achieved in the recovery of wet meadows and marshes using a combination of these techniques (Annen 2016a). Annen's Systemic Approach emphasizes process manipulation to disrupt the underlying drivers of the invasion, and follows a series of steps:

1) Determine if the invasion is reversible and the site recoverable; ie. Has the site retained native seed banks in the face of degradation?

2) Perform a condition assessment to identify disturbance and feedback cycles that are triggering and reinforcing the invasion. It will be important to disrupt identified systemic disturbances: hydrolgical disturbances, sedimentation, and nutrient inputs should be corrected to uncouple positive feedback before implementing direct Reed Canarygrass control measures (eg. herbicide). Assess:

    a. Presence of hydrological modification and possibility of corrections without affecting adjacent properties;

    b. Composition and relative abundance of vegetation, depth of the litter layer, recent fire activity, density and species composition of shrub layer;

    c. Presence of recent silt deposition due to sedimentation / nutrient inputs from agricultural / urban watercourses;

    d. Soil chemistry, focusing on availability of NH_4-N, N_3-N and PO_4.

3) Disrupt litter accumulation feedback cycle and uncouple shrub-carr secondary hydrologic disturbance by reintroducing fire to the system. Repeated spring burning facilitates recovery by removing litter and removing nutrients, and is an essential component to system change. Litter removal aspects can be completed by mowing if the site is accessible to mowing and haying machinery following hydrological modifications, however is unlikely to be possible if hydrologic recovery is successful and will not incorporate the nutrient-cycling benefits of fire. See Text Box for more detail.

IMPORTANCE OF FIRE IN REED CANARYGRASS CONTROL EFFORTS

Adapted from Annen 2016

Burning is an essential accessory treatment because Reed Canarygrass invasions are litter- driven. In addition to removing accumulated litter and preventing conversion of herbaceous wetlands into shrub-carr, burning removes nutrients from the system; 15 – 90% of N (depending on species and time of year) and up to 80% of available P is stored in senescent aboveground litter (Larcher 1995). Repeated spring burning facilitates invasion reversal by removing nutrients and altering competition trajectories, since sedges are stronger competitors for nutrients than RCG. Gradual nutrient removal by haying or burning is termed nutrient mining, and Annen (2011) reported a 36% reduction of soil available P in a sedge meadow following three prescribed burn events. Initially, it is necessary to burn annually until RCG cover declines to ≈10%, after which burning should occur at the historical frequency of 1 - 3 years.

Litter removal will initially increase RCG seedling density, but since seedlings are not fully established they are particularly vulnerable to herbicide applications, allowing you to quickly purge the RCG seed bank. RCG seeds remain viable for only a couple of years in saturated soils and you can expect few additional seedlings to emerge after the first couple of burn events. Importantly, since you will sometimes be burning wet sites, don't be overly concerned if you are not able to completely burn a site; incomplete burns are more effective at facilitating RCG reversals than not burning at all. Likewise, since the aim of using burning as an accessory treatment for RCG reversal is litter removal, a burn can be carried out at any time of year when conditions allow, though I wouldn't recommend burning in July through September since you could burn up sedge achenes before they can recharge the seed bank or interfere with wildlife nesting and breeding activities.

4) Modify system and forcing variables identified in Step 2, by:
    a. Correcting or modifying the primary hydrological disturbance by removing drain tiles, filling drainage ditches or installing weir structures;
    b. Correcting secondary hydrological disturbances by removing shrubs, if necessary;
    c. Addressing sedimentation by removing sediment if possible, or preventing further sedimentation from occurring.
5) Suppress Reed Canarygrass using herbicide formulations suitable to the condition of the marsh: broad-spectrum or grass-specific herbicides should be selected based on the severity of the invasion, the state of the recovery, at the appropriate time of year, and using the appropriate additive systems to enhance herbicide performance.
6) Actively promote native species recruitment to prevent re-establishment of Reed Canarygrass by seed or culm. Plant and seed sedges and forbs to provide competition, even in sites where natural revegetation of relic species is occurring.
7) Repeat steps 3, 5, 6 to exhaust Reed Canarygrass' dormant bud renewal bank. Systemic herbicides only affect actively growing tissue and therefore target plants can regenerate from dormant buds. Two- three cycles of burning and herbicide should show noticeable improvement, with complete reversal requiring 5-7 years of management effort followed by periodic scouting and spot-spraying to address remaining clones and potential reinvasion.
8) Reestablish the original feedback mechanism by using regular burning and active revegetation with selective Reed Canarygrass suppression as necessary.

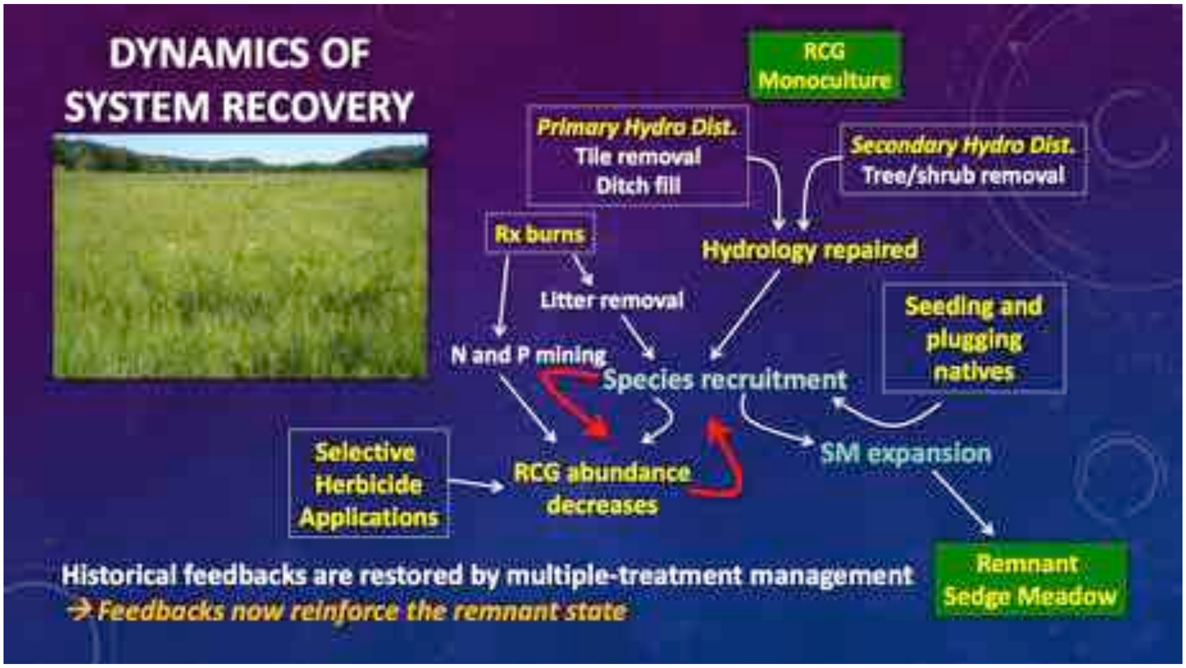


Figure 13. Dynamics of system recovery (Annen 2016b).

This sytem-based approach is successfully used across the US by experienced land managers, and forms the base of routine annual restoration programs run by the city of Eugene, OR and is routinely applied in Wisconsin as well. The technical challenges associated with Reed Canarygrass invasion in wet meadows on a large scale, it appears, have been addressed. However, three significant barriers to full implementation of this program in the Lower Mainland:

1) Lack of local experience and regulatory process for application of prescribed burns for conservation purposes;

The implementation of a prescribed burn requires the guidance of an experienced, knowledgeable Burn Boss to develop a Burn Plan, acquire permissions, and carry out the burn. There currently no local Lower Mainland experts on prescribed burns with experience in wetland management by fire. Beyond bringing in external expertise, planning an initial burn will require a partnership between BC Forests Lands and Natural Resource Operations, Metro Vancouver, Abbotsford and Langley Fire Departments, and may require consultation with Customs and Immigrations Canada, given the proximity of the site to the border.

2) Lack of herbicide formulations with regulatory approval for application over aquatic systems; and

The two herbicides most commonly used in the United States for Reed Canarygrass control in aquatic ecosystems, Rodeo® (glyphosate) and Habitat® (imazapyr) are not legally available in Canada. Legal chemical options in Canada cannot be applied over water therefore it is not possible in most restoration projects to treat chemically after hydrological disturbances have been corrected, as the site will in all likelihood be wetted. It is also not possible to fully treat prior to construction when surrounding ditches and waterways hold water through the summer. We are currently using herbicide as a pre-treatment on site to reduce the presence of Reed Canarygrass post-construction, but disturbed soils will generate new growth that must be controlled after hydrological modifications are completed.

The lack of herbicides approved for aquatic use in Canada is similarly vexing to the control of *Phragmites australis* in the eastern provinces, where control efforts mirror those in the western provinces regarding Reed Canarygrass. *Phragmites* management plans are very similar to those required for Reed Canarygrass and are very useful in informing our efforts here (see Text Box).

Although we agree that aqauatic-use herbicides should not be available for continuous use, we believe that it should be possible to apply these herbicides in an acute manner in order to recover ecosystems to a state in which herbicide use will no longer be necessary. Acquiring permission for the application of Rodeo® and Habitat® has been accomplished by the Spartina Working Group in the Lower Mainland, and their experience provides a path to approvals. Herbicide use in BC requires registration of the herbicides with the federal Pest Management Regulatory Authority (PMRA) as well as a Pesticide Use Permit (PUP) from the BC provincial Ministry of Environment.

HERBICIDE NEEDS FOR CONTROL OF PHRAGMITES IN CANADA

Adapted from Gilbert and Vilder 2012, also applies to Reed Canarygrass in BC.

The most effective and efficient control of Phragmites in the United States has been achieved using two herbicides Rodeo® (glyphosate) and Habitat® (imazapyr). Both products can legally be applied over water and aerially and have an efficacy of between 80 – 100% control after one treatment. Both chemicals kill the plant by shutting down key enzyme production within the belowground structures. Since these same enzymes are not present in non-plant life, the chemicals pose little risk to humans and wildlife. Although glyphosate is a broad spectrum herbicide, and it kills all vegetation non- selectively, it's use within dense, mono-dominant stands does not create issues since native plant presence is rare and, if present, they are generally under the invasive canopy and would not receive spray drift. Spot spraying using backpack units or hand wicking can be used to control sparse infestations.

Unfortunately neither Rodeo® nor Habitat® is available in Canada. Legal chemical options in Canada are limited to two products, Weathermax® and Vision®, and neither product can legally be applied over water. Both are glyphosate based and contain the surfactant polyethyloxylated tallowamine (POEA) which is harmful to aquatic life.

Timing herbicide applications to occur when no water is present allows for some seasonally wet sites to be sprayed. However, for wetlands the timing window for dewatered conditions can be short and can change year to year. Even with dewatered sections interspersed wet areas will usually remain, making effective and efficient control very difficult. Site specific conditions, such as wildlife use of edges and adjacent habitats for breeding, brood rearing, foraging or the presence of SAR plants also impact the timing window.

3) Ignorance of historic species assemblages in wet / sedge meadows, and poor commercial seed / plant material.

We have not been able to identify historic assemblage lists for sedge meadows in the Lower Mainland, and we have not been able to identify suitable reference sites. We have developed plant lists from wetlands that contain few invasive species, but in both cases we know that hydrology has been modified and they are not particularly good matches. Despite this, we will use these lists, developed from UBC AAFC Farm 2 Wetland in Agassiz, BC and Xwe-Cheam Wetlands in

Rosedale, BC to inform our restoration goals. Additionally, plant lists from adjacent US states are available, and can act as a proxy given the proximity of the Lower Mainland to Washington State and their data. The USDA Plants Database provides comprehensive species lists and their wetland status.

7.3.3 Haliburton Farm Organic Approach

Haliburton Farm, located in Saanich BC on Vancouver Island, has had remarkable success in Reed Canarygrass suppression and wet meadow recovery. It is an organic farm with approximately half a hectare of conservation habitat onto which the community is attempting to restore a wetland and associated wetted meadows. They have developed a smother/mulch/plant/seed model that has worked well on a small scale, and which may be possible to apply at a larger scale with the assistance of machinery and a large materials budget.

Their technique can be summarized as:

1) Remove biomass by mowing and raking / haying grass;
2) Immediately apply 45Mil (1.14 mm thickness) pond liner to the target area, and allow to sit for one year. Weigh down as necessary with stones / sandbags to ensure continued coverage.
3) In the following Spring, remove liner and apply cardboard as well as leaf mulch.
4) Seed over the leaf mulch and plant through the mulch / cardboard.
5) Remove returning reed canarygrass patches manually, or re-treat larger patches as necessary.

Figure 14. Left: Haliburton smothering methods. Clockwise from front: Pond liner, post-treatment, and one-year post-treatment. Right: One year post-treatment in the foreground; two years in background.

Challenges to upscaling this treatment include initial cost of material – Pond liner costs between $1.00 - $1.50 per square foot, and the requirement that liner be adequately weighed down and monitored to ensure continuous coverage and maintenance from wind events.

7.3.4 Selected Protocols

Given the current difficulty of implementing systemic methods, we will continue to prepare the target area for hydrologic modifications using pre-construction herbicide. We will also pilot

Haliburton's smothering approach on a larger scale, and will work towards developing protocols and permissions for the use of aquatic-approved herbicide and fire to implement the systemic approach described by Annen (2016).

Shading

In Phase II, shading of Reed Canarygrass by shrubs and trees should sufficiently control the grass in the swamp areas. Additional control measures may be required in the open marsh planned for the north end of the site. Depending on which species dominate regrowth, as well as on permits, we will use either chemical control or smothering post-construction in the north marsh.

Smothering

We will use smothering as a control method in pilot areas. The materials budget for this method is signficant, but can likley be reduced dramatically with the use of used, donated and purchase of off-market materials if we are able to store materials until needed. Material needs are pond liner, cardboard and mulch or topsoil.

A graduated approach over time would also provide the time to develop efficiencies in moving the liner, monitor regrowth and improve methods over time. If, after 10 years of increasing area impact we have been successful at eliminating Reed Canarygrass plants, we should have the skills and data to justify applying a smothering program at the scale of one hectare at a time.

Pond liner is available in various thickness, widths and lengths. We will use standard 45 mm Fish-friendly EPDM pond liner purchased used or new from secondary sources (rather than commercial sources) as much as possible in order to reduce costs. We will begin by treating a 10 m x 10 m plot and expand as possible when new material is purchased. Material will be moved annually to an adjacent plot – the guaranteed lifespan of the material in a pond is 20 years, and we expect to be able to move the material for at least 10 years before it must be replaced. If we are able to spend $2,500 annually on material, we will impact over 1 Ha over the span of 10 years.

Cardboard can be purchased for approximately $1/100 square feet in rolls of 4' x 250'. Although cardboard may be available for free from recycling centers, new rolls would ensure no unsafe inks, tape or staples are present on the cardboard and would significantly reduced the amount of time required for its application.

Haliburton uses leaf mulch donated by the City of Saanich to cover the cardboard as an organic base for seeding and planting. As this project is in a Metro Vancouver Park, it may be possible to use Nutrifor™ Biosolids produced by Metro Vancouver's Liquid Waste Program. Biosolids have been used in the past to restore wetlands, with some success in Eugene, OR. We have made initial contacts and inquiries with the relevant staff at Metro Vancouver and will continue to explore this option. Alternately, topsoil or mulch can be obtained at a cost of $25 per yard plus delivery from a nearby facility.

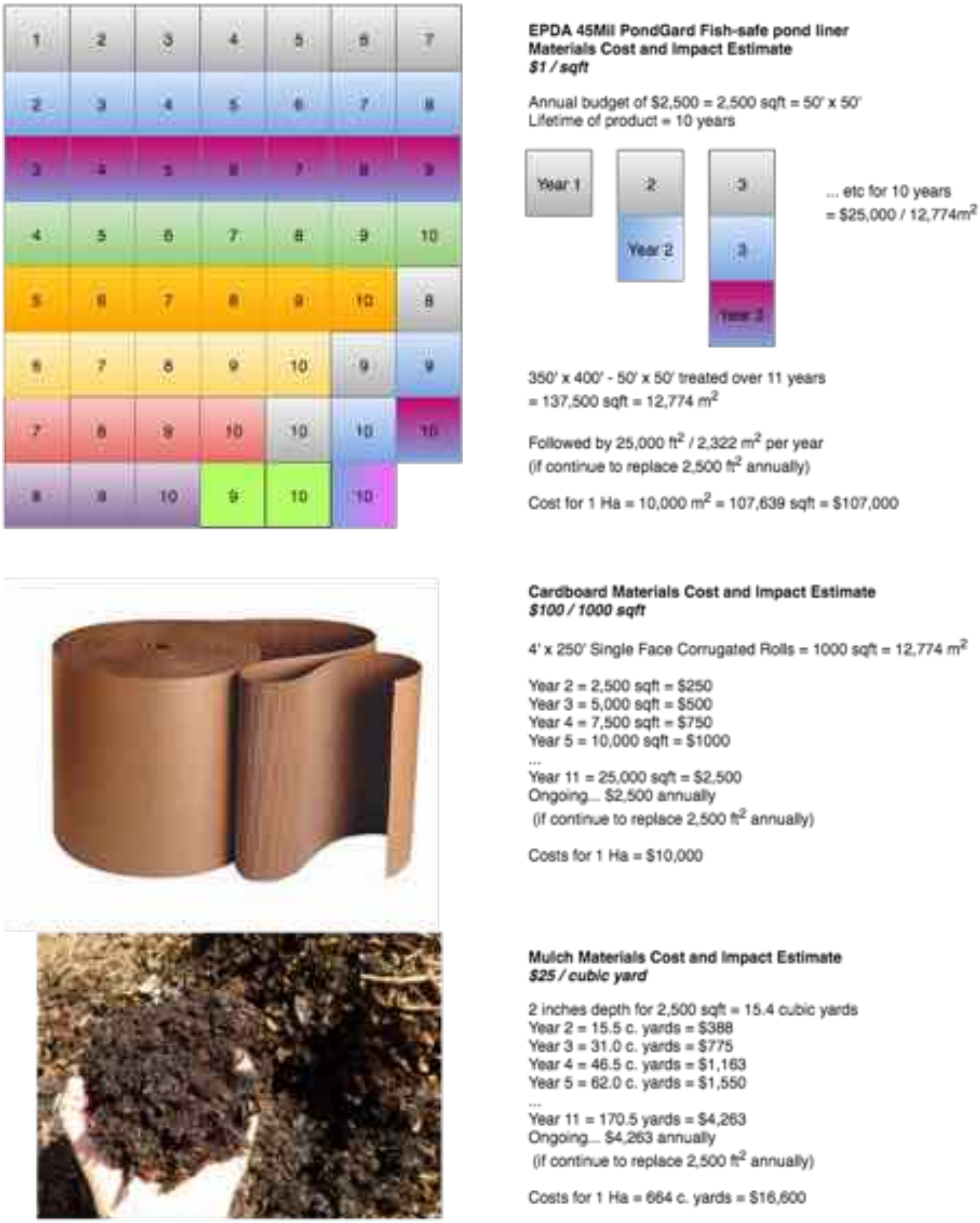


Figure 15. Materials and Cost Assessment by area over time for smothering at a large scale. Assume initial budget of $2500 for pond liner in each year, with an annual increase in impacted area of 2,500 square feet. Calculations in imperial as all materials are sold in imperial metrics.

Smothering at a large scale may be possible, but at a significant cost unless we are able to find donated or reduced-cost materials. For instance, the cost to impact one hectare would require a one-time purchase of 1 Ha of pond liner (> $100,000), which could be re-used for up to 10 years, as well as material costs of $26,000 for cardboard and topsoil for each year of treatment. We may be able to pilot a program that uses different grades of material, with or without the cardboard and with or with out, or using different grades of mulch.

Post-Construction Chemical Control

Post-construction chemical control is the most effective, and cost-effective, manner of controlling Reed Canarygrass following hydrological restoration. We anticipate that post-construction chemical control will not be possible once hydrology has been recovered on the site unless we are able to acquire permits for aquatic-use herbicides. If permits are obtained, post-construction chemical control will use glyphosate-based Rodeo (broad-spectrum herbicide, to be applied to monocultures of Reed Canargyrass with the appropriate additives) and imazypyr-based Habitat (grass-specific herbicide, to be applied where native forbs, sedges and rushes are recovering.

Herbicide application post-construction will be by hand-held backpack sprayer and by wicking ('hockey-stick') to increase specificity to target plants as Reed Canarygrass density decreases in the area. Application will be conducted by workers with a BC Pesticide Applicator's Certificate.

Pre-Construction Chemical Control

Pre-construction chemical control has been applied on Phase III of the site, as per our intial plan to impact Reed Canarygrass as much as possible prior to construction. A single application of RoundUp WeatherMax™ in October of 2016 has had a strong impact on regrowht, particularly in the wetter zones of the site. Given the current challenges associated with Post-construction chemical control, we will continue to prepare the site as thoroughly as possible with pre-construction control.

Re-application prior to construction will assist in killing additional root mass, and will be conducted as soon as funding allows in 2016 We hope that we will be able to further control the grasses using post-construction applications given successful permitting applications. Herbicide treatments will be Glyphosate-based, using RoundUp WeatherMax™, and will be applied to reed canarygrass that is at least 30 cm tall and actively growing.

Prescribed Burns

Prescribed burns are common in forested ecosystems and are being used to maintain Garry Oak Ecosystems on Vancouver Island – it is not an uncommon technique, but is uncommon locally. On-site consultation with the Chair of the Garry Oak Ecosystem Fire and Stand Dynamics Steering Committee, Thomas Munson (May 25, 2016), identified that the area is technically a fairly simple burn. The area has a uniform landscape and fuel source, natural boundaries, low threat to boundaries, little risk to people or properties adjacent to the burn site, no smoke-sensitive areas, easy access and minimal impact on neighbours. From a fire complexity perspective, it should be a simple fire to implement.

However, as this will be the first prescribed burn in the area it will require significant coordination to achieve permissions to implement a burn. We will consult with a Burn Boss who is experienced in burning wetland meadows and work with Metro Vancouver, BC FLNRO and Environment Canada to develop and implement burn plans.

7.4 Other Noxious and Nuisance Species

Other non-native and invasive species likely to colonize the restoration area were identified in post-construction monitoring of Phase I. Table 4 identifies species present at Phase I that are identified in the British Columbia Weed Control Act as either Noxious or Nuisance species.

Table 4. Noxious and Nuisance species identified in post-construction monitoring of Phase I. Species of management concern are highlighted in ***bold****.*

Species Common Name	Latin Name	Provincial Status	Invasive Potential
Canada Thistle	***Cirsium arvense***	**Provincial Noxious**	
Common Burdock	***Arctium minus***	**Regional Noxious**	
Common Sow-Thistle	***Sonchus oleraceus***	**Provincial Noxious**	
Common Tansy	***Tanacetum vulgare***	**Regional Noxious**	
Purple Loosestrife	***Lythrum salicaria***	**Regional Noxious**	**Invasive**
Tansy Ragwort	***Senecio jacobaea***	**Provincial Noxious**	
Bull Thistle	*Cirsium vulgare*	Nuisance	
Common Horsetail*	*Equisetum arvense*	Nuisance	
Common Plantain	*Plantago major*	Nuisance	
Common Rush	*Juncus effusus s.l.*	Nuisance	
Common St. John's-Wort	***Hypericum perforatum***	**Nuisance**	**Invasive**
Creeping Buttercup	*Ranunculus repens*	Nuisance	
Hemp-Nettle	*Galeopsis tetrahit*	Nuisance	
Large Barnyard-Grass	*Echinochloa crus-galli*	Nuisance	
Marsh Cudweed	*Gnaphalium uliginosum*	Nuisance	
Nodding Beggarticks*	*Bidens cernua*	Nuisance	

Whereas some of the species are considered noxious due to their unpalatability for agricultural purposes, others are truly invasive in the ecological sense and may spread into large monocultures in restored areas. Species that will likely require management are highlighted in bold.

Canada Thistle, Common Burdock, Common Sow-thistle, Common Tansy, and Tansy Ragwort grow predominantly in dry environments along elevated berms. Management of the species by mowing before seeding is appropriate and suitable for the management of these species; and is part of the regular maintenance of proposed trail systems. Much of the restoration area is too moist to support these species, and manual removal of isolated patches should suffice.

Purple Loosestrife and Common St. John's-Wort are both currently controlled by biological methods. St. John's-Wort is considered to be under successful biological control throughout the province. Purple Loosestrife beetles were released in Aldergrove Regional Park in 2003 and appear to continue to be effective. Despite the presence of several plants in and around the wetlands, the species has not spread and leaves of live plants show clear indication of beetle-browse.

7.5 Invasive Wildlife

7.5.1 American Bullfrogs

American Bullfrogs (*Lithobates catesbeiana*) are known to be present at the site, and are expected to persist in the constructed wetlands. However, by working to recover shallow marshes and wet meadows, as well as ephemeral ponds, we hope to attract only low densities of Bullfrogs and avoid breeding in the constructed meadows and wetlands. Some deep-water refugia, however, must be constructed and will likely attract bullfrogs in the first years post-construction. Planting trees and shrubs around these refugia will shade and provide complexity that bullfrogs in the Lower Mainland appear to avoid, and will dissuade their continued use as the habitat matures.

The habitat will be monitored post-construction for Bullfrog use and bullfrogs captured and eggs collected will be euthanized as per Provincial Wildlife Act Permits.

7.5.2 Nutria

Nutria (*Myocastor coypus*) is an invasive rodent species common in Washington and Oregon and likely present in only low numbers in southern BC. Their distribution is currently limited by hydrology and climate (temperature), but they are anticipated to increase in density as climate change increases their suitable thermal range to the north. Nutria are extremely destructive to wetland habitats, denuding marshes of vegetation and resulting in erosion-prone mud flats. They are not currently known in the area, but it will be important to monitor for their presence. If Nutria arrive at the restored wetland, their presence will likely be obvious if observers know the signs to look for.

Sign of Nutria include distinctive feces, tracks, runs into the wetland, the development of nesting and feeding areas, burrows, and damage to vegetation. Similar in body size and aspect to beavers, they may be easily overlooked in areas with beaver activity. The habitat will be monitored post-construction for the presence of Nutria and any sign identified to the BC Ministry of Forests Lands and Natural Resource Operations.

7.5.3 Invasive Fishes

Monitoring of fishes at the Phase I site has identified use of the constructed marsh by both native and non-native fishes. The two identified non-native fishes, Pumpkinseed (*Lepomis aibbosus*) and Fathead Minnow (*Pimephales promelas*) are likely to expand into newly constructed habitats. The extent of their ecologic impact on BC are unknown, but they may alter trophic communities and predate on threatened juvenile sucker species.

8 Restoration Actions and Timeline – Overview

Given the size of the target wetland, we propose a phased approach for the restoration of the wetland. Previous actions at Gordon's Brook identified the importance of several years of site preparation, as well as planning for unforeseen challenges and post-construction alterations to the built wetland. We anticipate that follow-up actions for invasive species management will need to continue for several years post-construction, and that adaptive management planning will identify currently unknown unknowns.

Table 5. Summary timeline for Phases II and III.

2016-17	**Phase II**	**Phase III**
Site Assessment	Water levels / quality	Water levels / quality
Site Prep	Invasive species removal	Invasive species removal
Construction	Structural / Hydrologic / Planting	
Site Monitoring	Develop plan / begin implementation	
Adaptive Management		
Outreach	Field trips / projects Post-graduate	Field trips / projects Post-graduate
Trail Construction	NA	
2017-18	**Phase II**	**Phase III**
Site Assessment		Water levels / quality
Site Prep		Invasive species removal
Construction		Structural / Hydrologic / Planting
Site Monitoring	Implement monitoring plan	Develop plan / begin implementation
Adaptive Management	Invasive species management follow-up	
Outreach	Field trips / projects Post-graduate	Field trips / projects Post-graduate
Trail Construction	NA	Base Construction
2018-19	**Phase II**	**Phase III**
Invasive Species Management	Invasive species management follow-up	Invasive species management follow-up
Site Monitoring	Implement monitoring plan	Implement monitoring plan
Adaptive Management	As needed	As needed
Outreach	Field trips	Cont prev. Develop signage.
Trail Construction	NA	Base compression

9 Restoration Actions and Timeline – Phase II

Phase II is on the east end of the target area, and will be treated in three different sections: 1) the Pond, in the south-west corner; 2) the Swamp, the eastern, partially wooded sections, and 3) the Marsh and Willow Farm, in the north-west corner (Figure 16. Phase II Treatment Zones.). We will work from the south-east corner in a counter-clockwise manner – downslope to upslope – to allow for poor weather in the late summer so that we will be working in the driest, upslope areas last, and connecting surface water to the complexed site after all construction works are completed. Construction activities will take place over three weeks in August or September, depending on contractor availability.

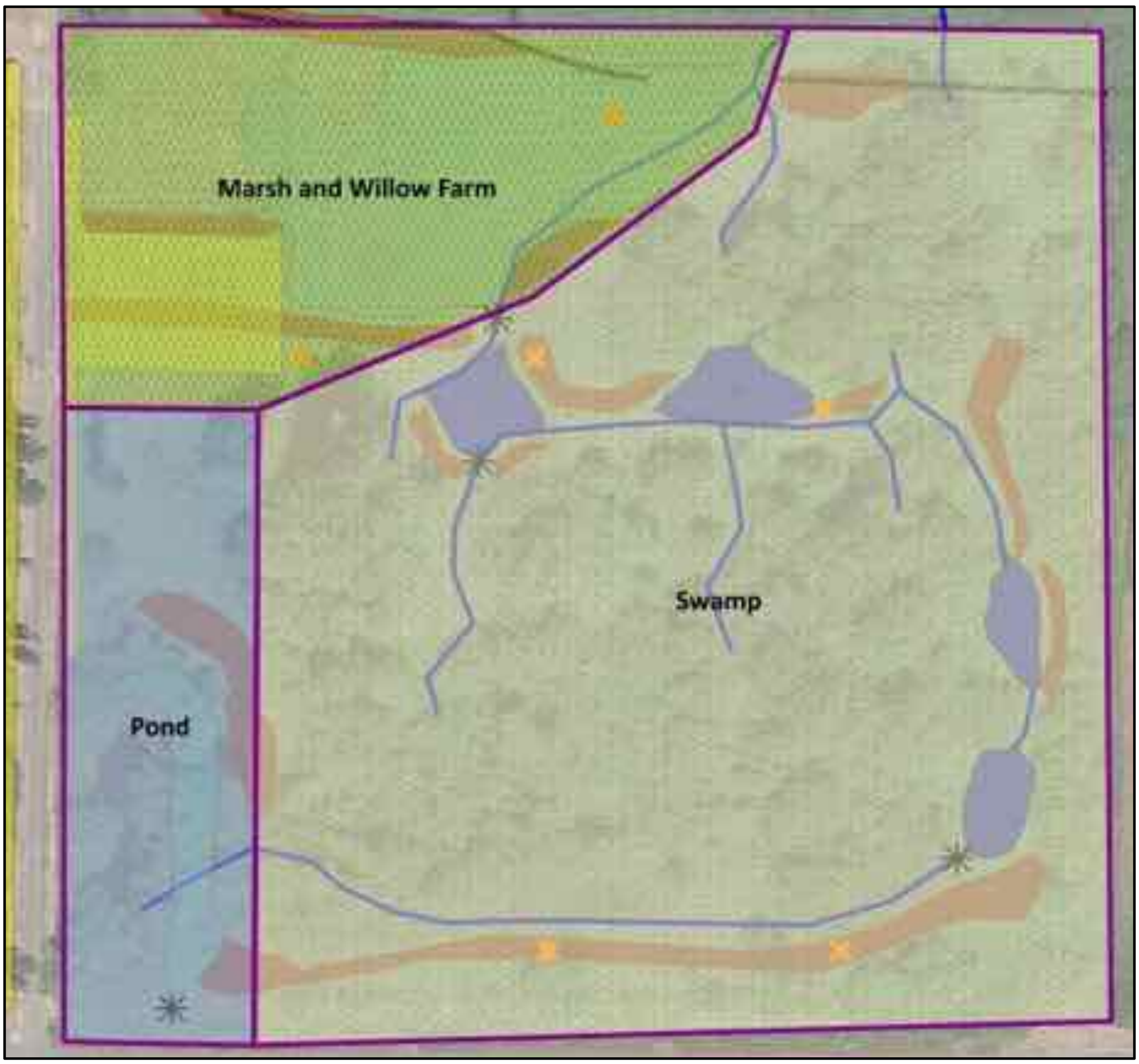


Figure 16. Phase II Treatment Zones.

9.1 Restoration Summary

Existing Conditions:

- 3.7 Ha target area;
- Historically farmed / grazed, channel filled & replaced with ditches, subsequently replaced with drain tile;
- Historic equestrian riding ring in NE corner;
- Current vegetation dominated by areas of Willow, Red Alder and Himalayan Blackberry;
- Shallow topsoil layer over coarse gravels with seasonal water table;
- Ephemeral swamps dominated by willows surrounded by old Blackberry in higher zones. Saturated soils in winter appear to reduce or prevent new blackberry growth and slow expansion;
- Pond in south-west corner with poor water quality due to high nitrates / nitrites and ammonia.

Desired Outcomes

- Reduce density of invasive species;
- Retain native willows, alders, cottonwoods;
- Recover water table;
- Increase soil moisture to reduce suitability for blackberry regrowth;
- Increase available aquatic habitat;
- Improve connectivity between habitats;
- Develop willow farm for provision of willow whips to local wetland and stream restoration projects;
- Provide educational opportunities for students, volunteers, and local community members;
- Improved water quality in south-west pond.

Actions

- Remove invasive Himalayan Blackberry around swamps using manual and mechanical means (in progress 2015-17)
- Excavate shallow zones, pools, and channels, using spoil to create berms and direct water (2016);
- Alter hydrology to direct water into new channels, ponds, and overland (2016);
- Decommission draintile and design outlet elevations to manage water depth for target species in constructed ponds (2016).
- Excavate shallow slope banks around pond to increase denitrifying processes and improve habitat opportunities;
- Install beaver 'starter dams' at pinch points to attract beaver activity;
- Install willow farm for future willow cuttings;
- Plant reshaped pond banks with denitrifying plants;
- Follow up invasive species treatments as needed using mechanical, smothering, and/or chemical techniques in following year.

9.2 Pond

Design for the Phase II pond is based on BCIT students' design for the improvement of water quality and the recovery of a nutrient-sink / water treatment wetland.

The pond located in the southwest corner of Phase II is a man-made agricultural pond that is currently unsuitable habitat for freshwater aquatic species and emergent vegetation. It outflows directly into the drainage ditch along 0 Avenue, with a maximum depth of 1.56 m at its deepest point (measured February 4, 2016) with a highly variable area dependent on precipitation and groundwater levels.

The pond will be regraded and expanded to encourage colonization of native emergent and riparian vegetation. Treatments will promote denitrification as high levels of ammonia, nitrate, and nitrite in the pond currently lead to severely low levels of dissolved oxygen. Treatments will occur concurrently with the construction of the swamp and willow farm in August/September 2016.

Bank Regrading

The bank slopes of the pond are currently very steep ranging between 1:1 - 3:1 horizontal to vertical (H:V). The steep banks are unstable, and limit the colonization and growth of emergent vegetation. There is also limited area for riparian vegetation because the change from the inundated pond to upland dry area is severe. This creates a narrow ring around the pond suitable for riparian vegetation.

We will therefore expand the riparian area of the pond by creating lobes. This expansion will also allow for regrading of the banks. The ideal range for bank slopes is between 15:1 - 20:1 H:V. Gentle bank slopes are more characteristic of natural wetlands, and suitable for native emergent vegetation colonization(Kentula 1992). This will also increase the area suitable for riparian vegetation from a narrow ring to a more complex riparian buffer. Expansion and regrading will occur primarily to the north and east side of the pond as the south and west sides are bounded by the ditch and driveway respectively, limiting expansion in these area. Banks will be pulled back from the water level at construction time to avoid working within the water. Existing vegetation will be left in the existing outlet channel to act as a silt barrier in case of rain. Existing vegetation in the expansion zone will be salvaged to the greatest extent possible prior to excavation, and willows will be re-planted in the new riparian zone. Annual fall rye will be seeded below a cover of hay to control for erosion in the first year following construction.

Promoting Denitrification

During expansion and regrading features will be created to increase microtopography within pond benthic and riparian area. Microtopography in wetlands form areas of aerobic and anaerobic conditions which help improve biogeochemical cycling, like denitrification (Moser et al. 2007). Surface soil in the pond and riparian areas remains rough and loose, with a range of elevations incorporated into the banks.

Nitrogen fixation will be encouraged by both a) temporary retention by primary production of vegetation; and b) permanent removal through denitrification by anaerobic heterotrophic bacteria.

There are two biological ways nitrogen can be removed in aquatic systems (1) it can be temporarily retained through primary production of vegetation (2) it can permanently removed through denitrification by anaerobic heterotrophic bacteria (Poe et al. 2003).

A mixture of emergent and riparian plants will be planted to improve denitrification rates in the regraded pond, as a mixed treatment of common wetland plants (Bulrush (*Scirpus* sp.), Cattail (*Typha* sp.), *Juncus* sp., *Carex* sp. and grasses) have been shown to remove three times more nitrate than a simple bulrush treatment (Bachand & Horne 1999).

Compost amendments will be applied to the regraded pond in the wetted, emergent and riparian areas prior to native planting, as the addition of compost amendments has been shown to be an effective treatment to stimulate nutrient cycling in nutrient rich aquatic systems. Compost amendments increase microbial population size, subsequently increasing microbial denitrification activity (Sutton-Grier et al. 2009), mitigating the impact of nitrogen rich agricultural runoff in aquatic systems, by transforming nitrates and nitrites into gaseous nitrogen (N2) and nitrous oxide (N20) (Saunders & Kalff 2001).

The existing outlet channel will remain in place, and a starter dam installed in order to encourage beaver dam development.

9.3 Swamp Complex

The Swamp complex will re-route water within the parcel to increase complexity of water movement and to allow groundwater to pool. Shallow pools 0.3 – 0.8 m deep will be dug and connected via shallow channels in existing openings in the parcel. The excavator will follow openings between vegetation that has grown in and exaggerate existing topography. Spoil will be placed in gentle berms on the south and west side of the channels to encourage surface water to remain in the channels and spill towards the south-west. Where suitable, beaver starter dams will be installed to encourage beaver dam development.

Blackberries will be removed by excavator and manually where suitable. Depressions created due to the removal of blackberry roots will not be re-filled except to direct the water and improve aesthetics, and will form shallow pools and marshes after hydrologic recovery.

These areas will not require planting, as they are well shaded, however disturbed soils will be seeded with annual fall rye and covered with straw to control erosion.

9.4 Marsh and Willow Farm

The Marsh and Willow Farm are at the north end of the property. This is the driest section of Phase II, and is made up of grass field and blackberry. Blackberry removal began in 2015, and will continue during construction.

The marsh will be excavated to a depth that removes all blackberry root and that will encourage pooling of water to inhibit regrowth of the blackberry. Invasive plant material will be piled on top of existing blackberry on the north slope, which will not be addressed in this program, where it will not begin a new infestation. Spoil will be used to create shallow berms to hold surface water and provide raised surface for access to the willow farm.

Four native willow species (Pacific Willow, Scoulers Willow, Hookers Willow and Sitka Willow) will be planted to provide willow stock for future restoration projects in Metro Vancouver Parks. Willows will be planted in straight rows perpendicular to the access driveway. They will be planted from nursery stock to ensure species accuracy, protected from beavers using wire cage beaver guards, and trimmed annually to encourage growth of shoots.

9.5 2016 Construction Tasks and Timeline

Construction will occur in the summer of 2016, pending funding application success. Construction dates will be set as soon as funding is allocated, and will likely span the month of September. Fifteen days of excavator time is budgeted for the construction phase.

Week 1 Tasks:

1. Clear openings for excavation by driving through all open areas to lower grass.
2. Identify areas for mechanical and manual blackberry removal in swamp and marsh zones.
3. Clear and salvage, as possible, existing riparian vegetation on north and west sides of existing pond, remaining out of the water.
4. Regrade pond banks.
5. Cut willow stakes for starter dams (source from Phase I willow farm).
6. Install starter dam at pond outlet
7. Install erosion control materials: straw bales and seed if rain is forecast.

Week 2 Tasks:

8. Identify and plug drain tile at south end of swamp zone.
9. Dig channel and pools in counterclockwise direction, with mechanical removal of blackberry.
10. Install starter dams where suitable.
11. Install erosion control measures (seed and straw).

Week 3 Tasks:

12. Complete mechanical removal of blackberry.
13. Disable drain-tile, decommission ditch and regrade marsh zone.
14. Install access berms for willow farm.
15. Install starter dams.
16. Install erosion control measures.

Week 4 Tasks (may occur one to four weeks after initial construction activities):

17. Install compost in regraded pond.
18. Install plants in regraded pond area.

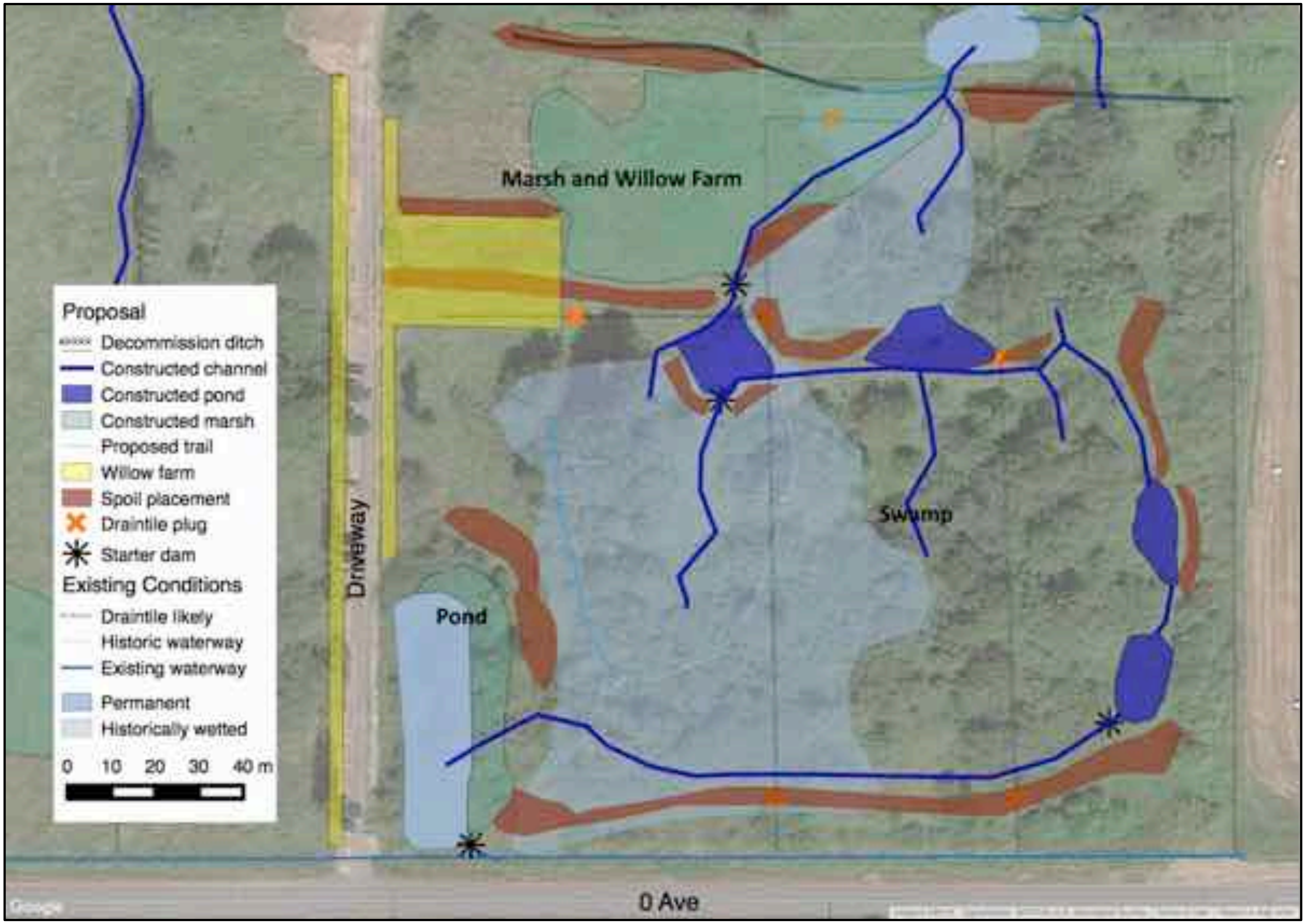


Figure 17. Concept plan for Phase II, indicating historic, existing and proposed waterways and features.

9.6 Spring 2017

Monitor for regrowth of reed canarygrass in marsh zone. Apply pond liner as required for smothering. Monitor regrowth of Himalayan Blackberry and apply treatment as needed.

9.7 Spring 2018

Remove pond liner, apply cardboard and mulch, and seed with native plant seeds suitable to the developing hydrology. Exact composition to be determined following completion and hydrological monitoring. Reapply pond liner as needed to adjacent areas requiring reed canarygrass control.

9.8 Monitoring Restoration Actions and Adaptive Management Response

Hydrological and vegetation recovery are the key aspects of the constructed habitat that must be monitored. In addition, water quality in the Pond zone should be closely monitored to identify whether or not restoration actions have been successful.

9.8.1 Hydrology

- Install water level gauges at outlet locations for regular visual checks.
- Retain water level loggers in monitoring wells.
- Monitor for building activities by beavers at Beaver Dams

We anticipate that groundwater levels will rise significantly following decommissioning of drain-tile. However, if after two years (by 2018) it does not appear that groundwater is recovering and retaining water in deeper pools through summer months, consider whether or not all drain-tiles were identified and removed.

If no beaver activity is observed, consider thickening starter dams with biological materials gathered from the surrounding area (eg. mud, sticks, gravel, leaves etc) to improve water retention behind one or two starter dams. Timeframe in this case is responsive to our three year funding window, and subject to change.

9.8.2 Vegetation

- Monitor regrowth of Himalayan Blackberry;
- Monitor regrowth of Reed Canarygrass

We anticipate that the hydrologic recovery of groundwater will hinder blackberry regrowth, as blackberry does not respond well to regular inundation. However, we expect that canes will re-sprout throughout the area and they should be identified and manually removed twice per year – in the spring and in the fall, for several years following construction activities. If large patches recover in inaccessible locations, they may be treated chemically in the fall when application is most effective.

Reed canarygrass recovery in Phase II will be treated by smothering with pond liner in the marsh, but allowed in the swamp where existing shade shrubs and trees will limit its growth into the understory. Growth will be monitored in the spring and liner applied in May or June in the year following construction, then mulched and planted in April or May of the following year.

10 Restoration Actions and Timeline – Phase III

Phase III is between Phases I and II, comprising mostly of a field of monoculture Reed Canarygrass. Restoration will focus on recovering the native hydrology of the field by disabling ditches and drain tile, and recovering native vegetation on the site. Chemical control of reed canarygrass has begun, with the first application in October 2015 following mowing and haying earlier that summer. Chemical control will continue in 2016 to prepare the site, followed by excavation works to recover hydrology in 2017, and continued invasive species control by chemical, fire or smothering in 2018, depending on recovery of the reed canarygrass. Existing shrubs and trees in the eastern section and in the center-south of the area will remain standing, and will not be altered by the program.

10.1 Restoration Summary

Existing Conditions:

- 6.2 Ha target area;
- Historically farmed / grazed;
- Historic channels filled, replaced with ditches, subsequently replaced with drain tile.
- Current vegetation dominated by Reed Canary Grass.
- 0.5 m topsoil layer over clay loam / sandy loam mineral soil.
- Drain tile present;
- Elevation drop from dry north-east corner to moist south west;
- Historically flooded central band east-west prior to drain tile installation.

Desired Outcomes:

- Reduce density of invasive species;
- Recover raised water table;
- Increase available aquatic habitat, with focus on restoration of marsh conditions;
- Improve connectivity between wetted areas;
- Provide educational opportunities for students, volunteers, and local community members.

Actions

- Assess soil conditions / hydrology (in progress 2015-16);
- Control invasive species growth by chemical and mechanical means (in progress 2015-18);
- Excavate shallow zones, pools, and channels, using spoil to create berms and direct water (2017);
- Remove reed canarygrass root mass in select areas to prevent re-growth;
- Using historic and extant topography as a guide, alter hydrology to direct water into new channels, ponds, and overland;
- Install beaver 'starter dams' at pinch points to attract beaver activity;
- Decomission draintile and design outlet elevations to manage water depth for target species in constructed ponds (2017).

10.2 2016 Tasks

1. Ensure suitable drainage to allow field to dry.
2. Continue herbicide treatment of reed canarygrass – two to three treatments depending on field accessibility given weather constraints.

10.3 2017 Construction Tasks and Timeline

Construction will occur in the summer of 2017, pending successful funding. Construction dates will be set as soon as funding is allocated, and will likely span from August to September. Thirty days of excavator time have been allocated to this program, however it may be possible to reduce costs on excavation and shift the budget to invasive species control programming if necessary.

Pre-Construction Tasks

- Final herbicide application over remaining reed canarygrass.

Week 1 Tasks:

- Clear openings for excavation by driving through all open areas to lower grass.
- Identify areas for mechanical and manual blackberry removal in eastern shrub section.
- Identify boundaries of excavation zones and channel zones, as well as spoil locations.
- Cut willow stakes for starter dams (Source from Phase I willow farm).
- Begin excavation of excavation zones and piling of spoil, starting at south-east end.

Week 2/3/4 Tasks:

- Continue excavation of excavation zones and piling of spoil.
- Spread spoil into berm, hillsides etc.
- Begin excavation of channels between ponds.
- Dig channel and pools in counterclockwise direction.
- Install starter dams where suitable.
- Install erosion control measures (seed and straw).

Week 4/5/6 Tasks

- Disable drain-tile, decommission ditch and regrade marsh zone.
- Install starter dams.
- Install erosion control measures.

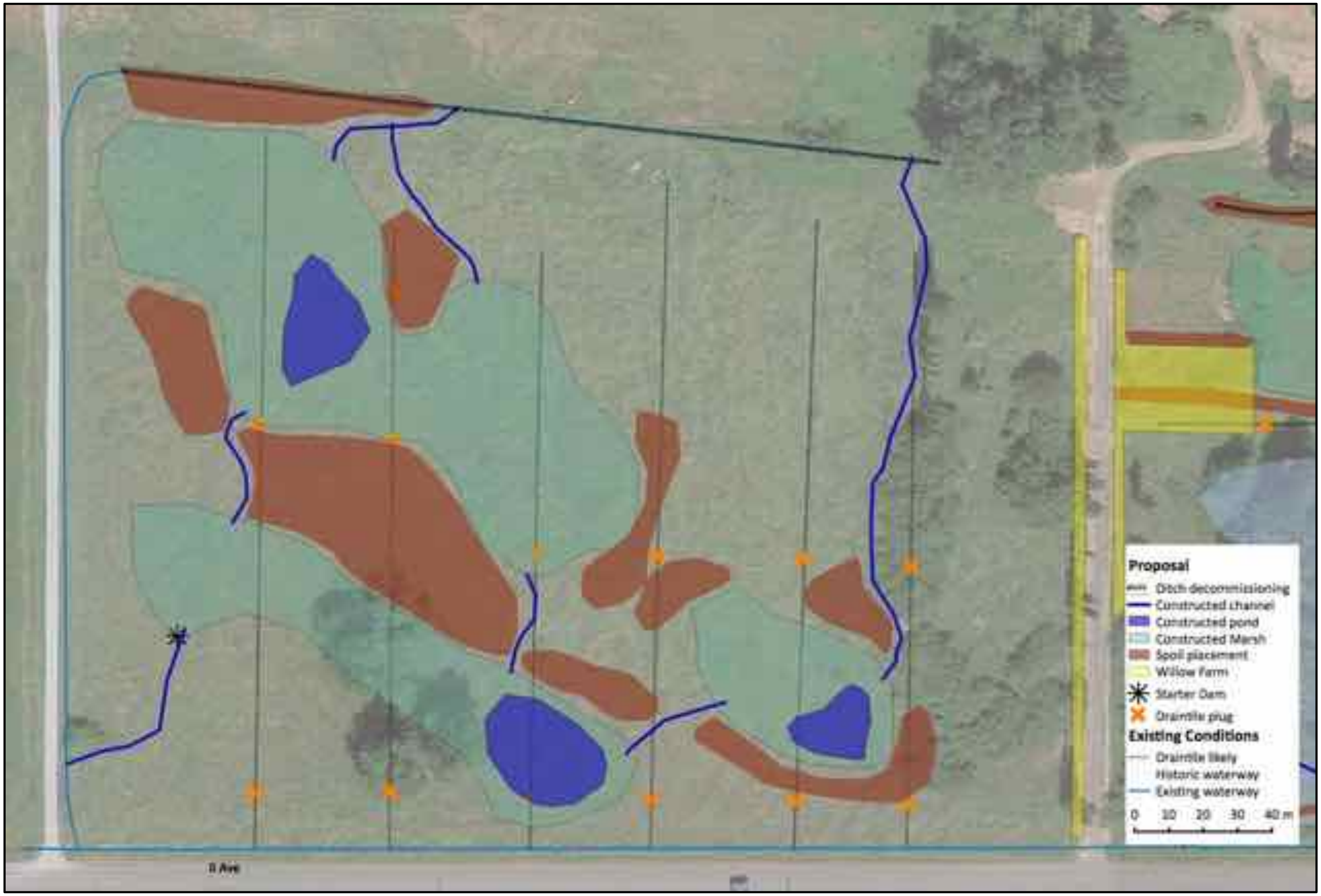


Figure 18. Concept plan for Phase II, indicating historic, existing and proposed waterways and features.

2018 Tasks

Tasks in 2018 will be dependent on our ability to gather permits for post-construction reed canarygrass control activities, and the necessity for those actions. Given three years of preconstruction chemical control, we hope that reed canarygrass recovery is slow. However, soil moving activities may help in the regeneration of seed in the soil, and may necessitate further control efforts. We will pilot large-scale smothering in one portion of the restored areas – prioritizing a strip of marsh that spans multiple elevations for maximum learning opportunities. We will also selectively apply herbicides to recovering reed canarygrass either by backpack sprayer or wicking as it recovers. Our preference is to use Rodeo™, if permits are granted, in the spring of 2018 followed by a prescribed burn after brown-up has occurred. This is the most likely control prescription to halt reed canarygrass recovery in the restored marsh. Follow-up applications and burns will likely be required for up to 10 years following restoration.

10.4 Monitoring Restoration Actions and Adaptive Management Response

Hydrological and vegetation recovery are the key aspects of the constructed habitat that must be monitored.

10.4.1 Hydrology

- Install water level gauges at outlet locations for regular visual checks.
- Retain water level loggers in monitoring wells.
- Monitor for building activities by beavers at Beaver Dams

We anticipate that groundwater levels will rise significantly following decommissioning of drain-tile. However, if after two years (by 2019) it does not appear that groundwater is recovering and retaining water in deeper pools through summer months, consider whether or not all drain-tiles were identified and removed.

If no beaver activity is observed, consider thickening starter dams with biological materials gathered from the surrounding area (eg. mud, sticks, gravel, leaves etc) to improve water retention behind one or two starter dams. Timeframe in this case is responsive to our three year funding window, and subject to change.

10.4.2 Vegetation

- Monitor regrowth of Himalayan Blackberry at north-east corner and along northern boundaries;
- Monitor regrowth of Reed Canarygrass

Himalayan Blackberry canes in the north-eastern corner may re-sprout throughout the area and they should be identified and manually removed twice per year – in the spring and in the fall, for several years following construction activities. If large patches recover in inaccessible locations, they may be treated chemically in the fall when application is most effective.

Reed canarygrass recovery in Phase III will be treated using Annen's Systemic Approach using chemical means followed by prescribed burns, if possible, as described in Section 7.3.2.

11 Adverse Impact Mitigation

The purpose of this project is to improve wildlife habitat opportunities at Aldergrove Lake Regional Park by restoring historic hydrology and providing deep refuges as well as floodplain habitats. Temporary impacts to sediment and contaminant concentrations will be mitigated using best practices and erosion control. The long-term impacts of the project are improved aquatic habitat, improved flow attenuation (increase summer availability, reduce winter flashiness) and educational opportunities.

Biological impacts of construction activities will be temporary, as the ecosystem will be allowed to recovery and should improve water retention, soil retention and more in the landscape. Additional aquatic habitat will be provided to aquatic wildlife, and the area should increase its capacity to serve a more biodiverse community through the year. All construction work will occur outside of the breeding bird window to avoid impacts to nesting birds, and in the fisheries work window to avoid impacts to fish.

Potential impacts to the aquatic environment from chemical grass control are an increase in chemical concentrations in nearby waterways and an increase in sediments. Current authorized chemical control agents in Canada must not be used in or near open water. Chemical application will occur once all affected drainage channels have dried in the summer months. This is anticipated for mid-late July 2016. Work will take place in the late summer when waterways and ephemeral ponds are known to be dry, and the groundwater table is low. If groundwater is elevated due to downstream drainage obstructions (beaver dam or otherwise), obstructions will be manually removed and monitored for a minimum of one month before construction begins. We will not carry out any instream works other than a single beaver starter dam installation in the Phase II pond outlet channel, which may or may not be wetted during construction.

Potential impacts from excavation and pond construction are a temporary increase in sediment to local waterways. A buffer of untilled grasses will be retained between the construction site and the roadside ditch to create a buffer for soil erosion. Silt fencing will be applied where necessary and hay bales will be placed in dry channels to hold back soils that may erode into the channels during rain events prior to completion of construction works.

Some existing riparian vegetation will be removed in order to access the banks of the pond in Phase II, and will be salvaged as possible. Mature trees will not be harmed in the construction phase, however some trees may respond poorly to the increased water table and eventually drown and fall. This is anticipated and fallen trees and branches will not be removed from the habitat. With increased beaver activity over time, some areas that currently have taller trees may turn into meadows or shallow water pools. Any mature willow shrubs will be salvaged and relocated for regrowth. Willow stakes will be replanted alongside channels in order to provide shade to the deeper portions of the habitat and maintain the restored habitat free of reed canary grass.

Permanent aquatic impacts will be the loss of approximately 380 m^2 of ephemeral channel. This will be mitigated by the restoration of hydrology to the site to attenuate heavy flows in the winter, increase the total wetted area and increase summer flows.

Table 6. Impacts and mitigation measures of construction activities.

Immediate Impacts	Long Term Impacts	Mitigation Measures	Purpose
Control of Invasive Species			
Change in contaminant concentrations. Change in sediment concentrations. Riparian plant damage. Soil disturbance and high potential for erosion.	Improve food supply. Improve habitat structure and cover. Improve oxygen availability.	Apply herbicide only after ephemeral streams have dried and no surface water remains. 15 m minimum buffer from standing or moving water from ground boom. Avoid drift by avoiding application in breezy conditions. Erosion control measures.	Reduce reed canary grass dominance over site to improve opportunities for native wetland herb and riparian species recovery.
Habitat Complexing and Feature Construction			
Change in sedimentation.	Increase variety of microhabitats for plant and animal species. Increase opportunity for niche species.	Erosion control measures (grasses / silt fencing) to prevent siltation downstream.	Increase variety of microhabitats for plant and animal species. Increase opportunity for niche species.
Hydrologic Restoration			
Infill ~ 380 m of ephemeral ditch area. **Change in sedimentation.**	Change in base flow. Change in water temperature.	Erosion control during and after works. Plant shading shrubs along banks of remaining watercourses. Purpose of the works is to increase water in summer months and decrease flashiness in winter. Increase total wetted area.	Increase water availability in summer, and retain winter flows into the late spring.
Re-vegetation			
Change in sedimentation. Change in nutrient availability. Change in water quality.	Improved nutrient availability. Improved water temperatures.	Plant shrubby vegetation along channels. Plant wetland species in wetted areas.	Erosion control. Increase variety of microhabitats. Provide shade and food. Reduce re-invasion by RCG.

11.1 Emergency Response and Containment Plan

Storage of hazardous materials will be limited to only the necessary quantities to conduct the works. No fuels or other hazardous materials will be brought onto the work site. All re-fuelling will take place a minimum of 30 m from the nearest watercourse, at the refueling location. All heavy equipment will have spill kits with them and daily machinery inspections are conducted prior to each work shift.

Initial response to any spill during the works will be as follows:

- Ensure safety in the spill area;

- Stop the flow of the hazardous material if it is safe to do so;
- Secure and isolate the spill area;
- Assess the situation (identify product, equipment involved, affected area, spill status, time of spill); and,
- Begin containing and recovering the spill with onsite emergency spill equipment if it is safe to do so.

Personnel and equipment (spill kit with excavators and one large spill kit for the work area) will be available to respond to the occurrence of a minor spills (within 100 litres) and able to restore the location to pre-spill conditions. Response to spills including containment and clean-up will occur to completion and appropriate personnel will be notified of the spill following the clean-up.

In the event of a spill greater than 100 litres or triggering the reportable quantities outlined in the *Spill Reporting Regulation*, the Ministry of Environment (Provincial Emergency Program - PEP) will be notified immediately and we will coordinate with the agency while the response is underway. Balance Ecological will use its own resources for minor spills (i.e. generally under 100 litres in volume) and will request assistance and additional equipment from relevant government agencies and professional incident response companies in the event of a major spill.

Spill reporting regulations will be in compliance with the Provincial *Environmental Management Act* Spill Reporting Regulation. Specifically, reporting to the Provincial Emergency Program will occur when the volume of spilled substance exceeds the volumes in Schedule 1 of the Spill Reporting Regulation entitled Reportable Levels for Certain Substances. Generally, and with respect to flammable liquids such as diesel and other oils, the Spill Reporting Regulation requires spills be reported to the Provincial Emergency Program if the spilled substance is conveyed to any watercourse regardless of volume or if the spill is greater than 100 litres and has spilled to ground.

Spills which do not trigger the Spill Reporting Regulation will be documented internally and reported to Metro Vancouver.

Following the cleanup of any significant spill (i.e. abnormal in volume or substance) is complete; Balance Ecological will hold a debriefing with all involved personnel. This debriefing will include review of the following:

- Root cause of the spill;
- Measures to prevent the spill from occurring again;
- Review with associated crew members; and,
- How could the response have been improved.

12 Permitting

Notifications to municipal, provincial and federal agencies will be submitted as soon as funding is confirmed.

In addition, our restoration program intends to use methods and tools not commonly in use in the Lower Mainland. We will need to develop protocols and achieve permissions for aquatic-application herbicide use and prescribed burns. We will continue to work towards these goals with partners in Metro Vancouver, the Province and Federal environment agencies.

13 Stewardship, capacity-building, education and research:

13.1 Volunteer / Stewardship Activities

Volunteer events to plant shrubs, remove invasive species, and conduct regular monitoring and maintenance activities provide opportunities to connect the public with nature and involve them directly in habitat and species recovery. Volunteer events also significantly reduce the labour costs involved in habitat restoration projects, and provide the most effect venue for connecting local residents with nature. Partnerships with existing non-government organizations that organize stewardship events increase the reach of the project. Open House events during the Management Planning process for Aldergrove Regional Park revealed a large community of local residents who have vested interest in the Park and may also be interested in building an Aldergrove Regional Park Volunteer Program.

Additional support for volunteer plantings and recovery will be provided by:

- Fraser Valley Watershed Coalition
- Lower Mainland Green Team
- Pepin Brook Streamkeepers
- BC FLNRO Volunteers

13.2 Research and Monitoring

The Pepin Marsh project is the first attempt to restore a floodplain marsh specifically for Oregon Spotted Frogs in the Fraser Valley. Marsh restoration is anticipated to be one of the most effective methods to recover the Oregon Spotted Frog, and continued monitoring and learning from this project is a key goal for the Oregon Spotted Frog Recovery Team. Design concepts proposed are untested, and may not succeed. Prior to introduction of the species, certain biological and physical requirements must be met, and these requirements must first be monitored and examined. Additional research opportunities will come from monitoring invasive American Bullfrog colonization of the wetland as it matures, as will the eventual introduction of endangered Oregon Spotted Frogs.

A list of potential projects regarding the monitoring of the wetland will be provided to local educational institutions, and circulated towards particular study groups. In particular, the project will provide project opportunities to:

- Simon Fraser University
  - Center for Wildlife Ecology
  - Earth2Ocean Sciences.
  - Biology
- University of British Columbia
  - Conservation Biology
  - Landscape Architecture
  - Zoology
  - Botany
- BC Institute of Technology
  - Ecological Restoration
  - Fish, Wildlife and Recreation
- University of the Fraser Valley
  - Biology
  - Geography

13.3 Youth Education

Excavated materials will be used to construct trails on elevated berms that act as water control structures and provide viewing platforms. Public engagement is an important goal of the project. Low-impact trails will be developed through the site. Final trail placement will be determined at the time of construction and excavation, as the variable nature of subsoils is certain to alter the design in unexpected ways.

Educational programming is yet to be determined but may include school field trips, a self-guided tour, information panels, viewing platforms, etc. Both the Fraser Valley Conservancy and Metro Vancouver run school outreach programs that will be able to take advantage of the new wetland as an educational space and site access will be designed with this programming in mind.

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