An Ecological Restoration Plan for a Weedy Field at the University of British Columbia Okanagan

by
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Abstract

Grassland ecosystems are rare, in decline, and support a multitude of at-risk species in British Columbia. At the University of British Columbia Okanagan in Kelowna BC, a 3.3 ha site at the entrance of the campus is outlined as Okanagan grassland in campus design plans but currently lacks native bunchgrass communities. The goal of this restoration plan is to return grassland plant communities to the site despite the pervasiveness of noxious weeds. I characterised site conditions through soil and vegetation surveys. Restoration recommendations include managing noxious weeds through mowing, hand-pulling and some herbicide application. The site will be replanted with bunchgrass vegetation, two pockets of ponderosa forest, and two types of shrub communities. A walking path, signage, and two xeriscape gardens will also be included to control human use of the landscape. Long-term monitoring will be incorporated into classroom curricula to tie monitoring to learning opportunities.

Keywords: grassland; exotic plants; noxious weeds; urban restoration; restoration plan

Dedication

This MSc thesis is dedicated to my family for their continued support, my loving partner, my dear friends, and all of my teachers and mentors who have helped me get this far.

Acknowledgements

I would like to acknowledge my field helpers, Luke Crevier and Corrina Thomsen who came out to work in the smoke and heat, as well as Dr. Bob Lalonde and Dr. Ian Walker whose naturalism resulted in a very useful dataset. Additional thanks to Tao Gaede for his loving support throughout this MSc, my supervisors Dr. Miranda Hart and Dr. Anayansi Cohen-Fernandez for their guidance and support, Derek Mahoney at UBC Okanagan for helping me set up this project and continued support of student projects, and Dr. Terry McIntosh for identifying my moss and grass specimens. Finally, a huge thank you to everyone else who made this project and this degree possible, particularly my parents.

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List of Acronyms

SFU	Simon Fraser University
UBC Okanagan	University of British Columbia Okanagan
BCMOF	British Columbia Ministry of Forests
BC	British Columbia, Canada
BCIT	British Columbia Institute of Technology

Glossary

Cultural restoration	Restoring cultural practices that are inherently linked to landscape by restoring appropriate landscape features to support lost or altered cultural practices.
Exotic/ non-native plant	A plant that is not endemic to a region and has been transported to that region by human means (directly or indirectly).
Grassland	An ecosystem that is usually dominated by grasses and does not support the growth of forest due to precipitation constraints, and/or fire and grazing disturbance regimes.
Invasive plant	A plant that is non-native and causes or has the potential to cause significant ecological or economic harm.
Noxious Weed	An undesirable plant identified by a local or provincial document that requires management for property managers and owners.
Population sink	Population ecology term referring to a population whose death rate exceeds the birth rate and relies on a source population (in which births exceed deaths) to maintain population size. Often sink populations are associated with low quality habitat (e.g. minimal food, high predation possibility, other mortality sources).
Restoration	Assisting the recovery of a damaged, degraded, or destroyed ecosystem.
Urban ecology	The study of ecology within regions of concentrated human settlement.
Weed	An undesirable plant.
Xeriscape garden	Gardens designed to require little to no irrigation or management, typically used in arid environments.

Executive Summary

Grassland ecosystems are sensitive and at risk in British Columbia and across Canada. In the Central Okanagan, it is estimated that 70 % of grassland ecosystems have been lost in the past 200 years. These sites are habitat for a number of rare and threatened wildlife.

At UBC Okanagan, a ~3.3 ha site in the southeast corner of campus is currently dominated by non-native plants, but the UBC Okanagan plans indicate that the university would like the site to be grassland. Compared with the nearest intact grassland to the project site, Knox Mountain Park, approximately 7 km away, the project site lacks native plant abundance and diversity (Figure 1).

Figure 1: Project site dominated by non-native plant species at UBC Okanagan (left), and nearest intact grassland site at Knox Mountain Park (right) dominated by native bunch grasses and fescues in Kelowna BC.

The project site was previously used for agriculture (likely forage production) and was an open-canopy pine forest with grassland forb understory (pine savannah) in the 1960s. The site consists of noxious weeds, with patchy incidents of native plants. It includes a steep slope adjacent to a road and an ephemeral pool in addition to non-native plants throughout the area. My restoration plan recommends using the existing native plant patches, pocket plantings, and a maintained native plant garden as nucleation sites to supplement seeding efforts. Additionally, I propose connecting the restoration and monitoring of the site to current curriculum in biology and environmental science to provide learning opportunities for students as well as ensuring that the long-term

monitoring required on site will be completed. Not only would this arrangement provide real-world opportunities, but it could decrease the cost to the university of implementing the project. The site may also be used to experiment with restoration techniques for grassland restoration.

Chapter 1.
A Weedy Field at UBC Okanagan

1.1. Introduction

Regionally, grassland ecosystems are rare, with less than 1 % of British Columbia's (BC) land base consisting of grassland habitat (Iverson 2004). Grassland ecosystems are dominated by grasses and forbs, with some shrubs, but generally exclude trees (Wikeem & Wikeem 2004). In BC, grassland ecosystems provide habitat for 30% of the province's at-risk species, and they are important sites of biodiversity (Grasslands Conservation Council of British Columbia 2005). In both Kelowna BC, and the Regional District of the Central Okanagan, grassland ecosystems are also rare, with only 7-8 % of the Sensitive Ecosystems Inventory (SEI) survey area in each region classified as grassland (Iverson et al. 2004; Iverson 2008). The SEI report also identified grasslands in the Kelowna area as "high priority for conservation", due to a 73% loss of grasslands in the region since 1800 (Iverson 2008).

At UBC Okanagan, a 3.3 ha site on the southeastern corner is described in campus design plans as a native Okanagan Grassland landscape, but it is currently dominated by non-native vegetation. In the Campus Master Plan the site is called an "Okanagan Landscape to Enhance and Manage" (UBC Okanagan, 2015, p. 57). Additionally, other guiding documents for UBC Okanagan identify the site as grassland: campus design guidelines have called it a "Forecourt grassland" as part of the "Okanagan landscape" in which native grasses are to be "repair[ed] and replant[ed]" (Ramsay Worden Architects Ltd., & Perry and Associates Inc., 2008, p. 67 & p. 81); the 2009 Campus Master Plan describes this site as "a remnant of the Okanagan grassland landscape" (Phillips Farevaag Smallenberg, 2009, p. 21); and a 2014 report listed it as a "modified and disturbed grassland ecosystem" (Birmingham & Wood Architects and Planners, & Denise Cook Design, 2014, pg. 19). Thus, it is the intention of the University that this site become a native Okanagan grassland ecosystem, but the current dominance of exotic plants and lack of native Okanagan vegetation means that without active restoration this design goal cannot be achieved.

Additionally, this site has potential ecological value within UBC Okanagan in its current state that would be improved by restoration. In 2014, an ecological assessment identified the project site, hereafter referred to as the "Forecourt Grassland", on the southeastern edge of UBC Okanagan as a potential corridor for organisms moving between higher quality forest habitat to the north and south-west of the area within the campus (Patterson and Olson-Russello 2014). Additionally, the federally Endangered American badger (*Taixidea taxidus jeffersonii* Harlan) has been identified as using burrows within 25 m of the site boundaries (Dr. B. Lalonde, pers. comm. 2018), and this project site is within the Critical Habitat, as defined by the Canadian Species At Risk Act (SARA), for the great basin spadefoot toad (*Spea intermonana* Cope). Since the site has some value as a corridor and to local native species at risk, shifting the vegetation to a native-dominated system would increase the value of the area as a corridor, and as habitat for species at risk. Additionally, partial restoration of the Forecourt Grassland to native grassland species, could incorporate the site as a stepping stone in a fragmented patchwork of grassland sites within the region.

Recent disturbance to the Forecourt Grassland includes construction in and around the site, as well as site invasion by non-native plants. In 1992, the first four buildings of the campus adjacent to the Forecourt Grasslands were completed, and a road was built bisecting the site (UBC Okanagan 2015; Figure A1, Appendix A). Additionally, when the highway overpass to UBC Okanagan was constructed, the finely grained fill was placed in some regions across the site (D. Mahoney, pers. comm. 1 Aug. 2018). After disturbance, vegetation covered the site, but it is unclear where the vegetation originated (e.g. intentional planting vs. passive colonization). The field was mowed until 2015 when the practice was stopped to attempt to allow native plants to regrow (D. Mahoney, pers. comm., Aug. 2018; Google Earth Pro V 7.3.2.5491 [Google Earth] 2002, 2012, 2013, 2014, 2015a, 2015b). Presently the site is largely composed of monocultures of different non-native plant species, a number of which are considered "noxious" by municipal authorities. Since no building development is planned for this area, it was identified as a site that may benefit from a restoration plan for future restoration actions (D. Mahoney, pers. comm., July 2018).

Prior to these recent site disturbances, the Forecourt Grassland has a history of agricultural use (likely forage production) and partially consisted of pine savannah habitat. The earliest available air photo for the site (1963) shows half of the land being cultivated for some kind of forage-type crop, and the remaining area consisting of sparsely distributed pine trees, with some denser pockets of pine trees (Figure A1, Appendix A). A succession of nine aerial photos between 1963 and 1992 show the slight infilling, of this already dense pine savannah, with more pine trees (Figure A1, Appendix A). It is likely that the site was grassland before pine forest encroachment following fire suppression in the 1930's (T. McIntosh, pers. comm. 2018; Wikeem & Wikeem 2004). The UBC Okanagan design guidelines indicates that trees may not be planted in the Forecourt Grassland, so open grassland must be used as a target ecosystem. This restriction has the advantage of creating a small patch of native grassland in a highly fragmented landscape, improving connectivity between larger grassland patches through the creation of stepping stones.

Since agricultural practices influence vegetation communities in fallow fields, it is important to consider how past agricultural practices in the Forecourt Grassland will have contributed to the exotic plant population on site. Although agricultural practices have different effects on soil properties, some general impacts of agriculture on the landscape include: nutrient loading from fertilizers contributing to weed establishment and growth (Stoate et al. 2001), soil loss from erosion (Wade et al. 2008), soil compaction from machinery (Stoate et al. 2001), and changes to soil structure and biota from repeated tillage (Roger-estrade et al. 2010). Additionally, farming practices can influence soil food web dynamics: for example, throughout Europe intensive farming practices with annual tillage resulted in a simplification of soil food webs, and reduction in soil biota diversity compared with low-intensity grassland management systems (Tsiafouli et al. 2015). So, if the agriculture previously conducted within the Forecourt Grassland was managed as a low-till or no-till crop, there would have been less damage to soil biotic communities and mycorrhizal networks than if more intensive methods were used (Roger-estrade et al.

2010). Measures of soil chemistry can assess to what degree changes in soil chemistry from agriculture would have contributed to exotic plant persistence and survival.

Thus, to assess why the Forecourt Grassland is currently not a grassland, and determine what stressors influence its present state, this report aims to: 1) characterize soil and vegetation features within the Forecourt Grassland in order to identify appropriate reference grassland ecological communities for the small, urban site; 2) provide restoration recommendations to restore ecological function within the site by replacing non-native plant cover with native plant cover and planning for local grassland species and species at risk; and 3) incorporate local educational partnerships to guarantee site restoration and maintenance.

1.2. Site Description

1.2.1. Introduction

The Forecourt Grassland consists of a weedy field covered by non-native plant species with small isolated pockets of native grassland plants (Appendix B, Figure B1). It is bisected by a small, one-lane road, and the edges of the site have some landscaped elements (Figure 2). It contains an ephemeral pond (0.22 ha) and a steep slope/berm-type structure (0.14 ha) adjacent to a road in a matrix of slightly rolling hills of "disturbed grassland" (consisting of more than 50% non-native plants; Figure 3). On the western side of the site an outdoor teaching area is present. In the northeastern corner adjacent to the site, construction materials are being stored and another adjacent area is bare gravel as a result of ongoing construction projects on the campus. The project site at UBC Okanagan is also situated on unceded Okanagan Nation territory.

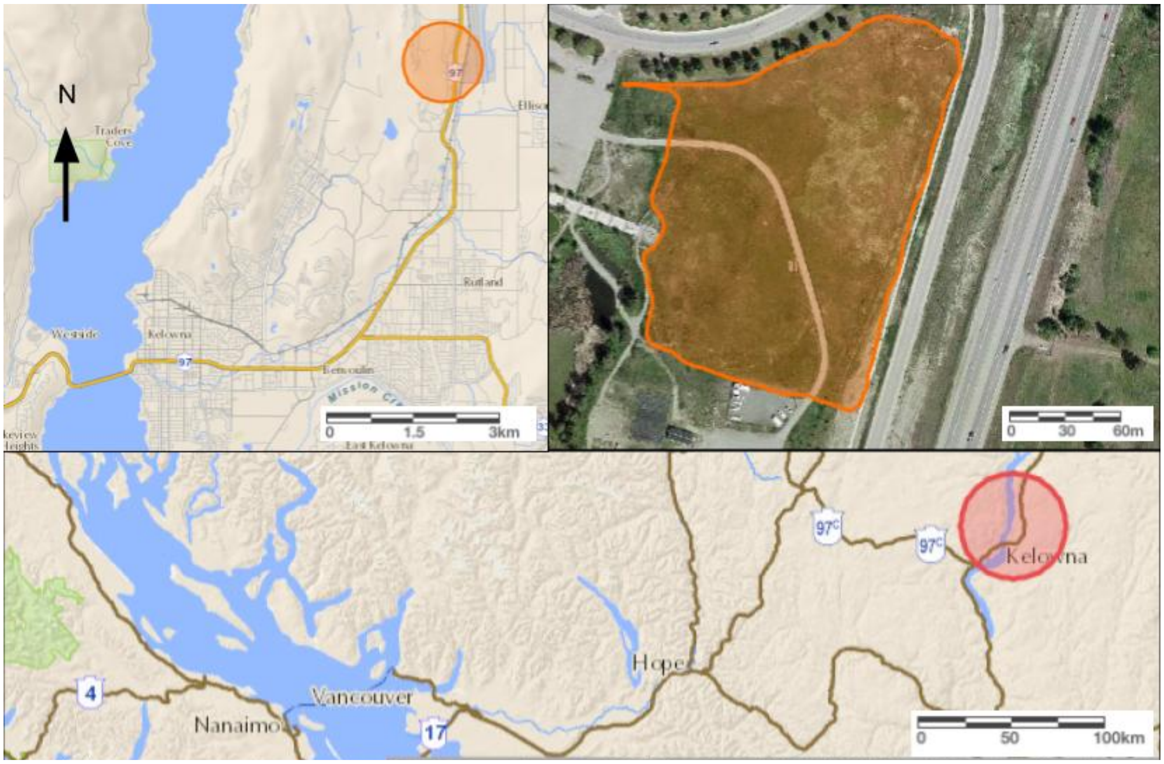


Figure 2: Site map of the Forecourt Grassland project area at UBC Okanagan in Kelowna, BC. The red circle shows the location of the site relative to the southwestern corner of British Columbia. The orange circle shows the location of the site relative to Kelowna, BC. The orange polygon (top right) shows the site boundaries within UBC Okanagan. Imagery from iMapBC, 2018.

1.2.2. Stakeholders and First Nations

The key stakeholder in this project is UBC Okanagan, as the site of interest is located on UBC Okanagan property. This project has been developed in consultation with Derek Mahoney, Manager in Landscape and Contract Services at UBC Okanagan.

Additionally, the Forecourt Grassland site is located on unceded Okanagan Nation territory. A Memorandum of Understanding (MOU) to foster collaboration between UBC Okanagan and the Okanagan Nation Alliance was signed in 2005 when Okanagan University College became UBC Okanagan, and this MOU was recently renewed in 2015 (UBC Okanagan 2015). Should the university decide to take restorative actions they should consider if culturally important plants, or other focuses of cultural restoration for local First Nations people should be a focus for the project, and then develop a collaboration with Okanagan Nation Alliance representatives or appropriate contacts at UBC Okanagan to move forward with project design.

1.2.3. Historical conditions

Soil

Glacial recession in the Okanagan Valley during the last glaciation period (~13 000 years ago) resulted in deposition of glaciofluvial sediment in the Kelowna area (Wikeem & Wikeem 2004). More recent soil surveys (1970- 1980) indicated four native soil classifications within the Forecourt Grassland boundaries, likely as extrapolations based on nearby sampling, displaying a variety of textures and drainage types, and anywhere from 2 % to 63 % coarse soil fragments (Table 1; BC Conservation Data Centre [BCCDC] 2018; Canadian Soil Information System 2000a-d; Table C1, Appendix C). Information about farming practices in the Forecourt Grassland that would have altered soil conditions within the cultivated area of the site is not available. However, aerial imagery suggests that the crops were not grown in rows and thus may have been forage crops such as grasses and legumes, with limited tillage (BC [aerial photo], 1963, 1967, 1974, 1975, 1975, 1980; British Columbia Ministry of Agriculture 2014).

Table 1: Soil types within the project site based on soil sampling in the Okanagan and Similkameen Valleys in 1970- 1980 (Canadian Soil Information System, 2000a-d).

Percent of site	Type of soil	Percent type of soil	Soil description	Chemistry	Soil drainage	Texture
~ 15	GAMMIL[a]	80	Loamy sand	Weakly calcareous	Rapidly drained	Coarse skeletal
	PARADISE[b]	20	Sandy loam	Medium acid to neutral	Rapidly drained	Medium
~ 35	TREPANIER[c]	100	Loam	Medium acid to neutral	Well-drained	Moderately coarse
~ 50	WESTBANK[d]	100	Heavy clay	Calcareous and saline	Moderately well-drained	Moderately fine

Note: Soil type is from the Soil Information Finder Tool (British Columbia Soil Information Finder Tool, 2018), and the description of each soil type comes from: [a](Canadian Soils Information Network [CSIN], 2000a), [b](CSIN, 2000b), [c](CSIN, 2000c), [d](CSIN, 2000d).

Vegetation

Low-lying areas in the Okanagan valley were typically grasslands prior to European settlement in the 1850s but faced forest encroachment as the climate shifted (Wikeem & Wikeem 2004, Blackstock and McAllister 2004). As a result, the Forecourt Grassland would likely have been a bunchgrass ecosystem that shifted towards pine forest cover after First Nations fire management to maintain a grassland or savannah ceased, and fire suppression began (T. McIntosh pers. comm. 2018; Wikeem & Wikeem 2004, Blackstock and McAllister 2004). As the site falls within the Ponderosa Pine Very Dry biogeoclimactic zone (PPxh1), it is within a very dry climate, and the dominant grassland species would likely have included: bluebunch wheatgrass (*Pseudoroegneria spicata*, (Pursh) Á. Löve), and idaho fescue (*Festuca idahoensis*, Elmer), in combination with herbs such as yarrow (*Achillea millefoilum*, L.) and arrow-leaved balsamroot (*Balsamorhiza sagittata*, (Pursh) Nutt.; BCCDC, 2018; Hope et al. 1991).

Aerial photography between 1963 and present day shows change in vegetation cover through the site's more recent history (Appendix A, Figure A1). In 1964, the site was 50 % agricultural land and 50 % pine savannah for the small fragments of non-agricultural land within the project area (BC [aerial photo], 1963). The aerial imagery shows the tree density increasing slightly within the forested area between 1963 and 1992, which suggests tree encroachment may have been occurring in the area (Appendix A, Figure A1). The site remained partially cultivated and partially pine forest until the site disturbance between 1980 and 1992 (Appendix A, Figure A1).

Additionally, noxious weeds have been present in the Okanagan region for almost 100 years, and thus have the potential to have been on site prior to site disturbance. Some noxious weeds were found in the South Okanagan as early as 1936 (diffuse knapweed – *Centauria diffusa*, Lam.), and 1922 (common hound's tongue – *Cynoglossum officinale*, L.;Wikeem & Wikeem 2004). Thus, it is possible that noxious weeds have been present on the project site since the early 1900s (Wikeem & Wikeem 2004) or invaded the area after agriculture began.

Natural Disturbance regimes

Grassland ecosystems in the Okanagan are dominated by two disturbance regimes: fire, and grazing (Wikeem & Wikeem 2004). The estimated fire return interval for the Central Okanagan region was 5 to 20 years (Wikeem & Wikeem 2004). Fires played a role in excluding tree and shrub growth within the grasslands (McClaran 2015). Grassland fires also make some nutrients such as nitrogen, phosphorus, and zinc in the soil available to plants (Iverson 2004; Reinhart et al. 2016). Grazing would have occurred from deer and bighorn sheep in the area (Wikeem & Wikeem 2004). Grazing affects plant distribution and composition within a site (Adler et al. 2001).

1.2.4. Site Disturbance

Recently the site has been used for agriculture which has significantly altered the plant composition and possibly soil characteristics. The use of half the site for agriculture (forage, not row-crop agriculture) at least as early as 1963 (Appendix A, Figure A1), would have removed existing native vegetation, and altered soil structure and chemistry depending on the farming practices that were used. More recently, the construction of the campus starting in 1992, (UBC Okanagan 2015) resulted in the creation of a small road across the centre of the site, in addition to clearing forest on the northern edge of the site (Appendix A, Figure A1). It is not clear if and what vegetation was planted on site after construction. The site was visibly mowed in 2002, and again from 2012 – 2014 (Google Earth, 2002, 2012, 2013, 2014), after which mowing of the field stopped to allow native plants to grow (D. Mahoney, pers. comm., Aug. 2018). Additionally, around 2005 an overpass was built off of Highway 97, and soil materials from this construction were deposited onto some areas of the site (D. Mahoney, pers. comm., Aug. 2018). This disturbance removed native vegetation and incorporated altered soil into the site.

Additionally, through urbanization and historical colonization, the historical fire and grazing regimes have been eliminated from the site, which is a disturbance to the ecosystem. Historically, local First Nations managed grassland landscapes in the Okanagan by conducting prescribed burns to prevent forest or shrub encroachment and provide food for ungulates (Blackstock and McAllister 2004). Additionally, local First Nations conducted small scale agriculture prior to colonial settlement in the early 1850s (Blackstock and McAllister 2004). Post-colonization, grassland landscapes in the Okanagan were altered for ranching by European settlers resulting in increased grazing pressure and reduced First Nations access to the landscape (Blackstock and McAllister 2004). Presently the site does not have a fire regime, tree density is constrained, and ground fuel is minimized to decrease the chances of fire on site according to the UBC Okanagan Wildland Fire Management Plan (Diamond Head Consulting Ltd. and Davies Wildfire Management 2006). The site is also isolated from ungulate grazing, apart from the occasional deer.

1.3. Site Assessment

1.3.1. Sampling Design

In August 2018, I categorized the site into three sections for sampling: roadside slope (~0.14 ha), ephemeral pool (~0.23 ha), and weedy grassland (~2.9 ha). In total, 25 samples of vegetation and soil were taken across the Forecourt Grassland: 5 on the roadside slope, 7 in the ephemeral pool, and 13 across the weedy grassland (Figure 3). Different sampling intensity was applied in each area based on the sizes of the site sections. To address anticipated variation within the site, I applied stratified random sampling within the sampling area (Pennock et al. 2008).

To randomize within the grassland area, I placed a 20 m by 20 m grid over each area (each half of the grassland zone subdivided by the road, numbering each square within the grid and using a random number generator to select the appropriate number and location of sampling sites. The location at the centre of each selected grid square was used as the sample location (Figure 3). The road that cuts through the site was excluded from the sampling boundaries, reducing the site area to 3.2 ha.

To compensate for slope effects for samples taken from the hill slope, transects were systematically spaced across the entire length of the hillslope (approx. 40 m apart) running perpendicular to the slope (Figure 3). Since the curvature across the slope was minimal, single transects down the slope were appropriate (Pennock et al. 2008). Within each transect a random number between 1 m and 10 m (or 1 m and 5 m as the slope narrowed to approximately 5 m wide in the north) was used to determine the location of the quadrat. This range of values represented the width of the slope in meters, to ensure the sample point fell within the slope.

Within the ephemeral pool, I used a combination of random and systematic sampling methods to ensure unbiased sampling within the pool (Figure 3). The direction of transects was determined through a random heading. Three transects were distributed evenly across the area. The placement of the first sample plot per transect was randomly determined by choosing a random number between 1 and 25 m. Each successive sample plot was placed 20 m down the transect relative to the previous point.

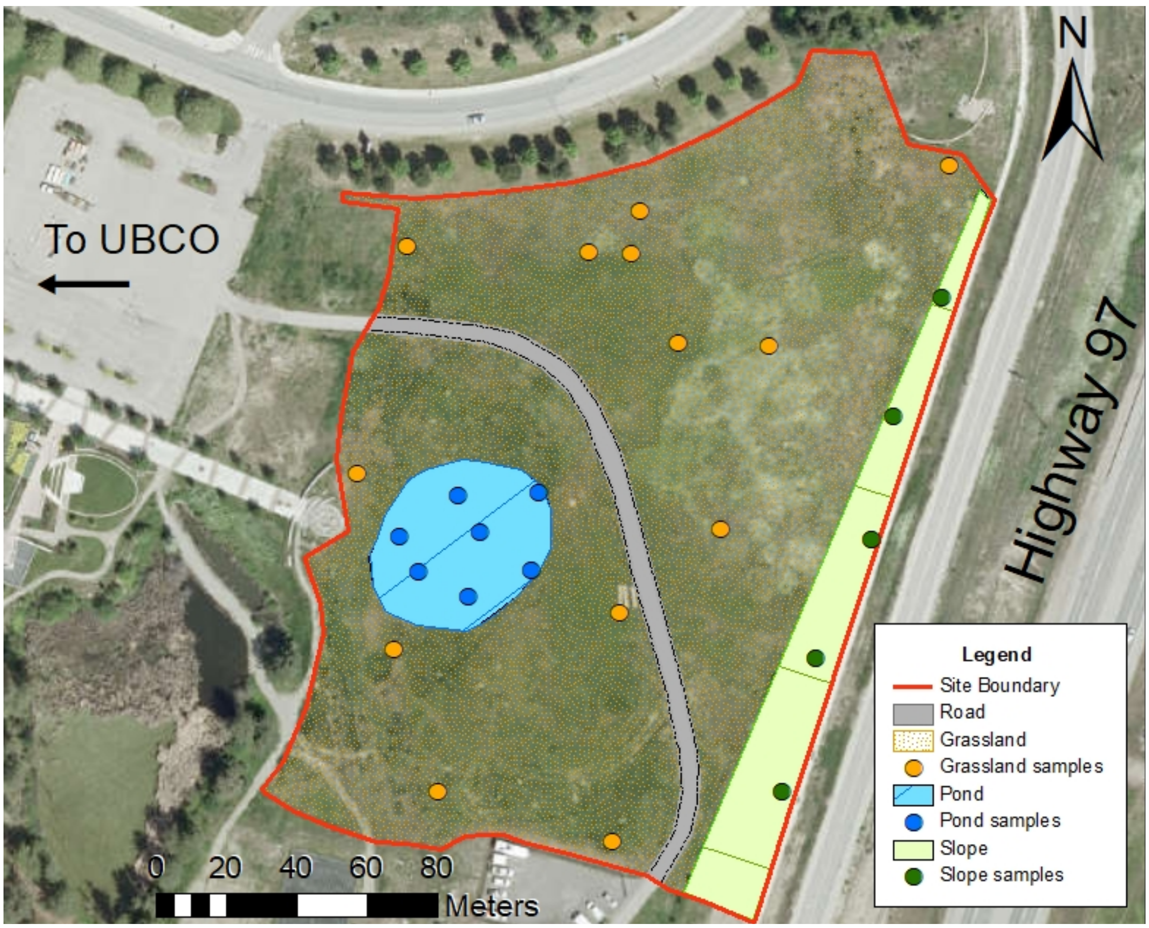


Figure 3: Distribution of samples across the three regions of the project site (Slope, N=5; ephemeral pool, N=7; and grassland, N=13). Basemap from City of Kelowna 2017 Orthophotos. Map generated in ESRI ArcMap 10.7 by Sarah Bird on 1 November 2018.

1.3.2. Sampling Methods

Within the Forecourt Grassland at UBC Okanagan, two general proxies of ecosystem function were assessed: plant community (composition and distribution), and soil properties (chemistry and structure). Soil chemistry influences plant growth, while soil structure influences water permeability, erosion potential, and root growth (Bardgett 2005; Murphy et al. 2004). Additionally, the nature of the vegetation community indicates if the plant community is similar to that found in a native grassland. To assess grassland health, the following soil and vegetation measures were assessed: soil texture, total carbon, total nitrogen, available phosphorus, pH, moisture, bulk density; plant species and percent cover of live and dead materials, including mosses, and percent cover of bare ground.

Assessing soil chemistry identifies if major chemical components within the soil of the site are restricting native plant growth. Extremes in soil pH can be detrimental to plant growth and diversity by altering nutrient availability, so measuring soil pH can identify areas where plant growth may be restricted by pH (Bardgett 2005; Schuster and Diekmann 2003). Soil phosphorus and nitrogen are well-known limiting factors for plant growth. Carbon to nitrogen ratios within the soil can identify whether net nitrogen mineralization or immobilization is occurring – a proxy of nitrogen cycling within the ecosystem (Bardgett 2005). Lastly, soil carbon is correlated with soil organic matter resulting from decomposition of vegetation (Wittneben 1986). In turn, high soil organic matter contributes to soil structure, soil moisture, and cation exchange capacity, which all influence plant growth (Wittneben 1986). Determining the distribution and levels of the nutrients affecting plant growth and soil structure will be helpful in understanding how to restore the site conditions that influence plant growth - particularly given the disturbed nature of the soils on site.

In addition to soil chemistry, soil structural measures provide further insight into site characteristics that will impede plant growth. Soil hand texturing determines an estimate of the sand, clay, and silt content of the soil (British Columbia Ministry of Forests [MOF] 1997). These soil particle sizes help determine how much water is available in the soil for plant growth (Bardgett 2005). Soil bulk density is correlated with water holding capacity, and ability of plant roots to penetrate the soil (Murphy et al. 2004). Measuring soil moisture across the site will potentially indicate maximum summer drought conditions within the ephemeral pool, as well as provide a snapshot of midsummer moisture on site. Determining soil structure helps inform what physical manipulation must occur during restoration to promote plant growth, and whether any organic amendments such as compost should be added.

Measurements of plant identity and abundance determine the vegetative character on site and its similarity to that of a native bunchgrass system. Plant species percent cover is useful for identifying non-native species and their coverage in order to determine effective management actions. Assessing plant percent cover will also identify what native plants are present in the Forecourt Grassland. Species cover, the percentage of a plot area covered by a projection of the vegetation surface area within the plot for each species (Fehmi, 2010), provides a “snapshot” of relative abundance of each plant species on site. Identifiable live and dead vegetation were included to capture a broader sense of site vegetation, as the survey was conducted late in the summer when many plants had already flowered and gone to seed. Mosses were included in the measure of species cover because native grasslands contain moss species and they can be important components of biocrusts, as was bare ground. Bare ground identifies the percentage of the plot surface consisting of exposed soil (non-vegetated, and not covered with litter), and is the substrate upon which native grassland biocrusts can develop (Dicarlo and Debano 2019). Finally, to supplement the data regarding plant community distribution, mapping non-native plant polygons within the Forecourt Grassland helped select priority species for treatment.

Soil cores

At each sample location (Figure 3) a soil core was taken ~ 30 cm west of the pinflag to a depth of 5 – 20 cm for use in hand texturing. The sample was placed in a ziplock bag and refrigerated until processing. Immediately adjacent to the pinflag, a second soil core was taken to an average depth of 20 cm, and these samples were placed in a second ziplock bag and refrigerated until processing. Sometimes the soil core had to be inserted into the hole several times in order to reach a depth of 20 cm. The mean depth of soil samples was 19.6 cm (1.13 SE) in the ephemeral pool, 12.5 cm (5.9 SE) in the grasslands, and 18 cm (5.7 SE) on the slope. All samples within a single sampling hole were pooled into a single sample. At a few sample locations it was not possible to use a soil corer due to rocks in the soil that impeded passage of the soil corer; instead a trowel was used to dig up soil to a depth of approximately 5 -10 cm. All samples were collected on August 13th and 14th 2018.

Vegetation sampling

A 0.5 m by 0.5 m quadrat was placed ~ 1 m north of the pinflag, in order to measure vegetation that was not disturbed by the soil sampling. I determined the percent cover of all plants within the plot, including dead vegetation, estimating percent cover to the nearest 1 %. Species identification occurred to the best of my ability to species or family level, with unknown samples being collected and identified by Dr. Bob Lalonde at UBC Okanagan or Dr. Terry McIntosh. Seven plants could not be identified because they were missing diagnostic features at the time of sampling – three herbs and four grasses.

A distribution map of non-native plants was developed using a non-native species survey. Over two days in late August 2018, and approximately 4 hours of walking within the Forecourt Grassland, I used a handheld GPS with tracking on to walk around areas with one or two non-native plant species dominating the canopy cover to create vegetation polygons. The edges between patches were determined visually and qualitatively. Some plants grew in monocultures wherein determining polygon edges was easy - where one plant species stopped growing and a different plant species started. For plants that were not in monoculture but still accounted for at least 50 % of the canopy cover the edge of a polygon was determined by estimating the boundary at which canopy cover of that species dropped below 50 %. This survey was subjective and so is not intended for use in quantitative assessments.

Soil metrics

One set of soil samples were used for hand texturing, following the procedure described in the *Silviculture Prescriptions Field Methods Book* (British Columbia Ministry of Forests 1997). All remaining soil samples were dried in an oven at 60 °C until the difference in mass between weighings changed by less than 0.2 g. Then, each sample was crushed with a mortar and pestle and sieved with a 2 mm sieve as per the Analytical Chemistry Laboratory (BC Ministry of Environment and Climate Change Strategy) requirements. Samples were weighed before and after drying to determine soil moisture.

After sieving, samples were sealed in ziplock bags and shipped to the Analytical Chemistry Laboratory (BC Ministry of Environment and Climate Change Strategy), in Victoria, BC. All laboratory measurements followed the protocols in *Soil Sampling and Methods of Analysis* second edition (2008). The pages associated with each specific protocol are specified for each type of measurement. The laboratory measured pH in calcium chloride using a pH meter (pg 173 -178; Hendershot et al. 2008). Available phosphorus was measured using ultraviolet visible spectroscopy (pg 71-80, Maynard et al. 2008). Lastly total percent carbon and percent nitrogen in the soil was measured through combustion (pg. 225-237, Skjemstad and Baldock 2008), and also were informed by the Thermo Instrument Flash 2000 Analyzer Application Notes. Bulk density data were collected by an undergraduate class at UBC Okanagan in October 2018, but a number of samples were collected twice and a number of other data were missing, so they were not used.

Additional information

Dr. Ian Walker and Dr. Bob Lalonde, professors in Biology at UBC Okanagan, recorded plant and animal observations from around the project site between April and August 2018 (Appendix D, Figure D1). These observations were collected during site visits that did not follow a sampling protocol or regime. They shared these observations with me, and also discussed their observations of the conditions of the ephemeral pool with me. Other reports were provided by Derek Mahoney in Facilities Management at UBC Okanagan. Site data will be shared with all three individuals upon completion of the report.

1.4. Current site conditions

1.4.1. Hydrology

The vernal pool in the Forecourt Grassland recieves up to ~ 50 cm of water in it each year (Dr. Bob Lalonde, pers. comm. UBC Okanagan 2018); it dries out fully by the end of May or early June. Aerial photography shows variation between years; in 2015, the vernal pool was completely dry by April 4th, whereas in 2012 the pond was full until at least mid-may (Google Earth 2012, 2015a,b). Mapping of the wetted extent, maximum depth, and records of the annual date the pond becomes dry would provide further information regarding the hydrology of the pond. This information is necessary if the ephemeral pool is to be developed as spadefoot toad breeding habitat (Southern Interior Reptile and Amphibian Working Group 2017). Water within the Forecourt Grassland is directed towards a drainage area on the northeastern corner of the site and into the ephemeral pool (Figure 4).

Soil moisture in the Forecourt Grassland sampling areas was highest in the ephemeral pool (0.131 g H_2O/g soil, 0.016 SE), mid-range in the grassland (0.081 g H_2O/g soil, 0.009 SE), and lowest on the slope (0.06 g H_2O/g soil, 0.021 SE), as was expected (Figure 5). These moisture values only provide a snapshot of soil moisture throughout the year. They were taken at the driest time of year and indicate that the ephemeral pool has more moisture than the other areas of the site, even in late summer.

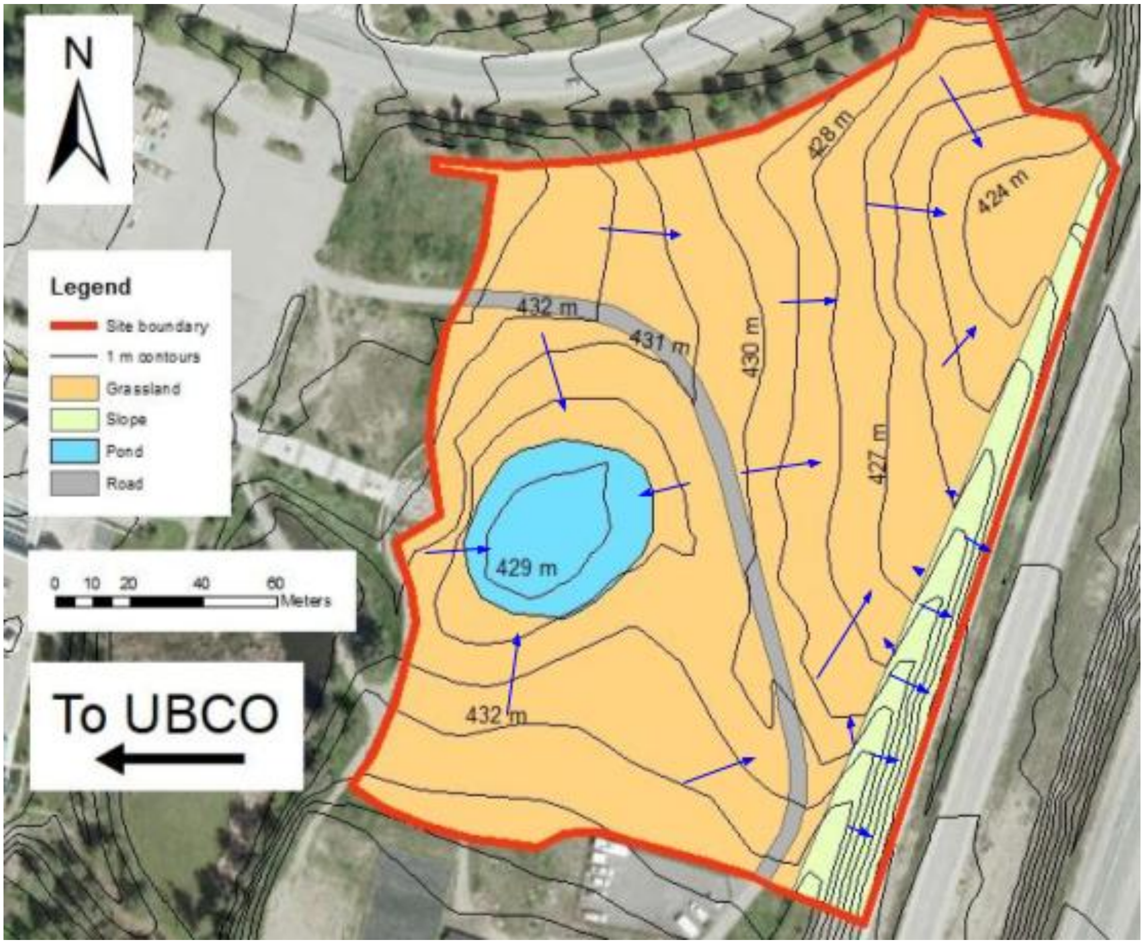


Figure 4: Site map showing surface water movement within the Forecourt Grassland. Contours are 1m contours from the City of Kelowna. Blue arrows show the directions of water movement relative to surface morphology.

1.4.2. Soil

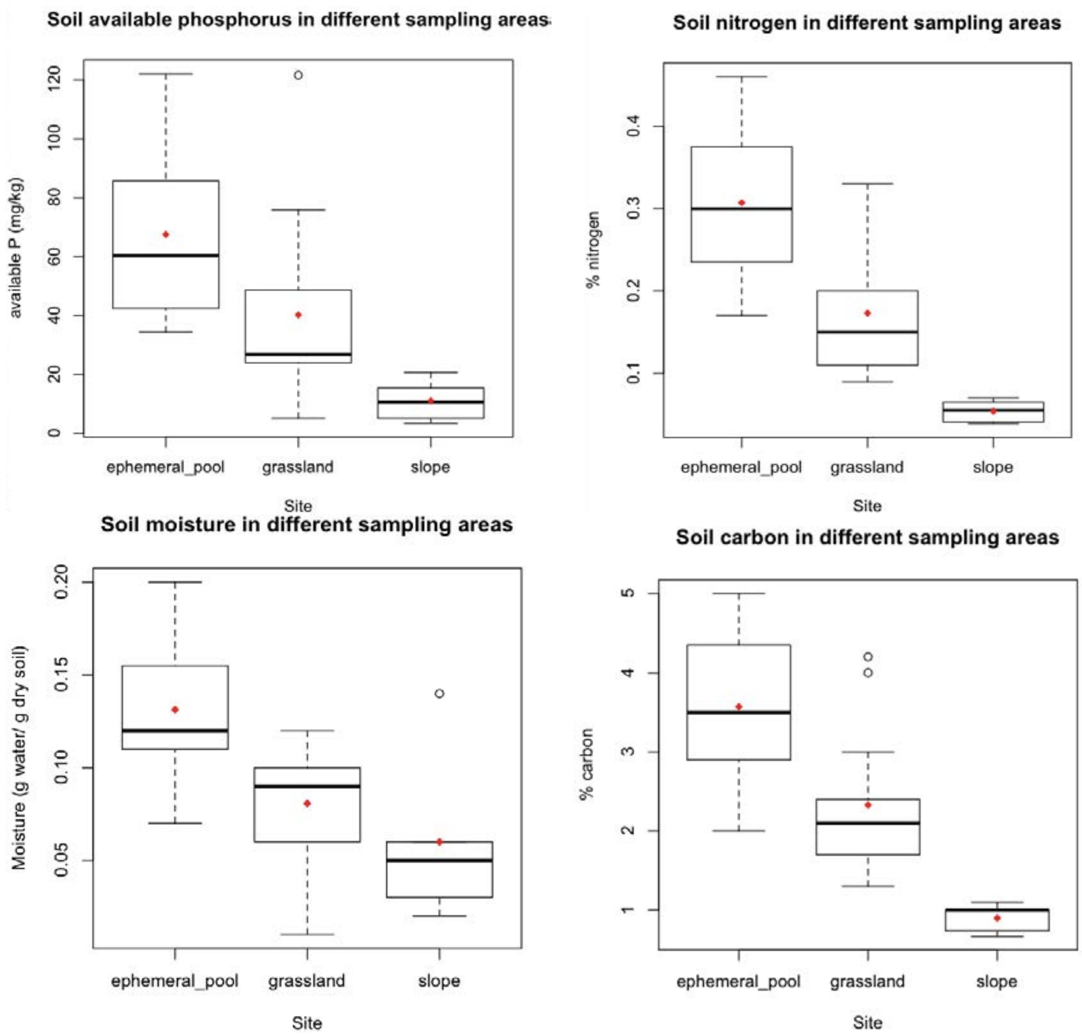
The soils within the Forecourt Grassland consists of human-disturbed soils in addition to other soils (Patterson and Olson-Russello 2014) and it is unclear where and when soil fill from construction projects may have been placed onsite. In 2014, an ecological assessment at UBC Okanagan identified two soil types within the project site that overlay parent soil types: a layer 50 – 100 cm thick of anthropogenically-derived materials (anthropogenic veneer blanket) across the majority of the site that was well to moderately well-drained, and within the ephemeral pool area was a moderately well-drained layer 50 – 100 cm thick of soils produced from a mass-wasting event (colluvium veneer; Patterson and Olson-Russello 2014; Acton et al. 1976).

From the soil surveys I conducted, found that despite the disturbed nature of the soil, the soil chemistry that was measured on site is similar to natural soils estimated to have occurred on site in the past (soil surveys from the 1980's – Wittenben 1986; Table 2; Figure 6) and phosphorus levels relatively consistent with the range of variability of natural grasslands in the south Okanagan (T. Gieselman, unpub. data 2013). Additionally, an assessment of the carbon to nitrogen ratio within the site suggests that net mineralization is occurring (Bardgett 2005), which has previously been associated with high litter content in invaded grasslands (Piper et al. 2015). However, I found limited data regarding C:N ratios in native grassland soils in the Okanagan. Surveys for chemical contaminants within the site soils are recommended if the site is to be used for growing plants intended for eating, for use as medicine, and/or for wetland plantings.

Soil phosphorus, which is usually the limiting nutrient for plant growth, was within the natural range of variability within the majority of the site. Data on soil phosphorus levels are available from the south Okanagan from research studying edge effects in shrub-steppe grasslands (Gieselman et al. 2013). The range of phosphorus in 16 plots 100 m from road or orchard edges was from 24 – 219 mg/kg (mean= 67.9 mg/kg, SE=48.5; Gieselman et al. unpub. data 2013). The range of phosphorus within the Forecourt Grassland was 3.5 – 122 mg/kg (Figure 5). All of the slope sites had lower phosphorus than the natural range of variability (Table 2). All ephemeral pool sites were within the natural range (Table 2). Three grassland sites were below the range of variability (5.1, 15.5, and 20.4 mg/kg), while the remainder were within the range (24.0 – 121.6 mg/kg; Table 2).

In soils a C:N ratio of greater than 30:1 indicates net immobilization of nitrogen, whereas less than 30:1 indicates net mineralization of nitrogen (Bardgett 2005). For all grassland regions, the ratio was below 30:1 (between 11:1 and 19:1), indicating net mineralization. The mean C:N ratio in the grassland was 14:1 (S.E. 1.4), in the ephemeral pool was 12:1 (S.E. 0.6), and in the slope was 17:1 (S.E. 1.7). To compare with historical values, a rough estimate of C:N ratios in natural soils can be done by taking the mean total C and total N values from the 1980 soil surveys, which results in soil C:N ratios of 5:1 in Westbank soils, 3:1 in Gammil soils, 2:1 in Trepanier soils, and 7:1 in Paradise soils (Wittenben 1986). If these values are accurate, the measured values are double to quadruple the values in natural grasslands, which could be indicative of excess litter from the non-native plants onsite. Sampling in the nearby Knox Mountain Park could identify to what degrees these estimated soil C:N ratios are accurate in local native grasslands.

Available data on soil chemistry for this region is from soil surveys of the Okanagan and Similkameen (Table 2; Appendix C, Table C1; Wittenben 1986). The ephemeral pool has slightly lower pH and higher total carbon than is typical in Westbank soils (Table 2). In the soils from the Grassland polygon, the pH is slightly higher than in the Westbank soils (more than 50% of the grassland area, Figure 6), and the Gammil soils (less than 25 % of grassland area; Table 2). Total carbon in grassland is higher than all surveyed soil types, and phosphorus is higher than all but the Westbank soil type (higher in 50 % of the soil areas; Table 2). Finally, the slope has a higher pH than all but the Trepanier soils, lower total nitrogen than the Westbank soils (33 % of the area), slight variations in total carbon relative to Gammil and Trepanier soils, and slight differences in phosphorus relative to Westbank and Paradise soils (Table 2).



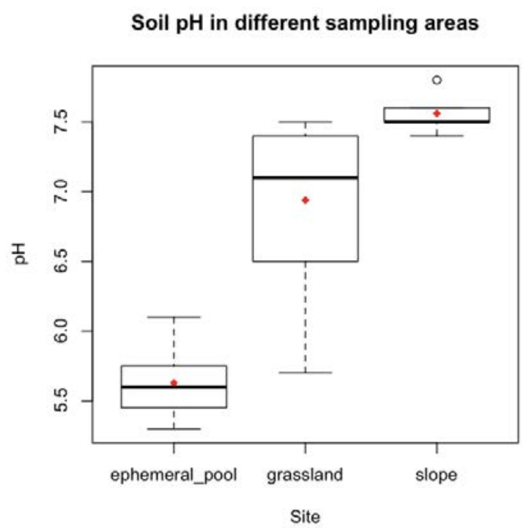


Figure 5: Summary of soil chemistry for samples within the ephemeral pool (N=7), the grassland (N=13), and the slope (N=5). These standard boxplots show median (dark horizontal bar), first and third quantiles (top and bottom of the box), and whiskers that show the range of the data. Open circles represent outliers. Red diamonds show the mean for each dataset. Produced using R (v.3.5.1).

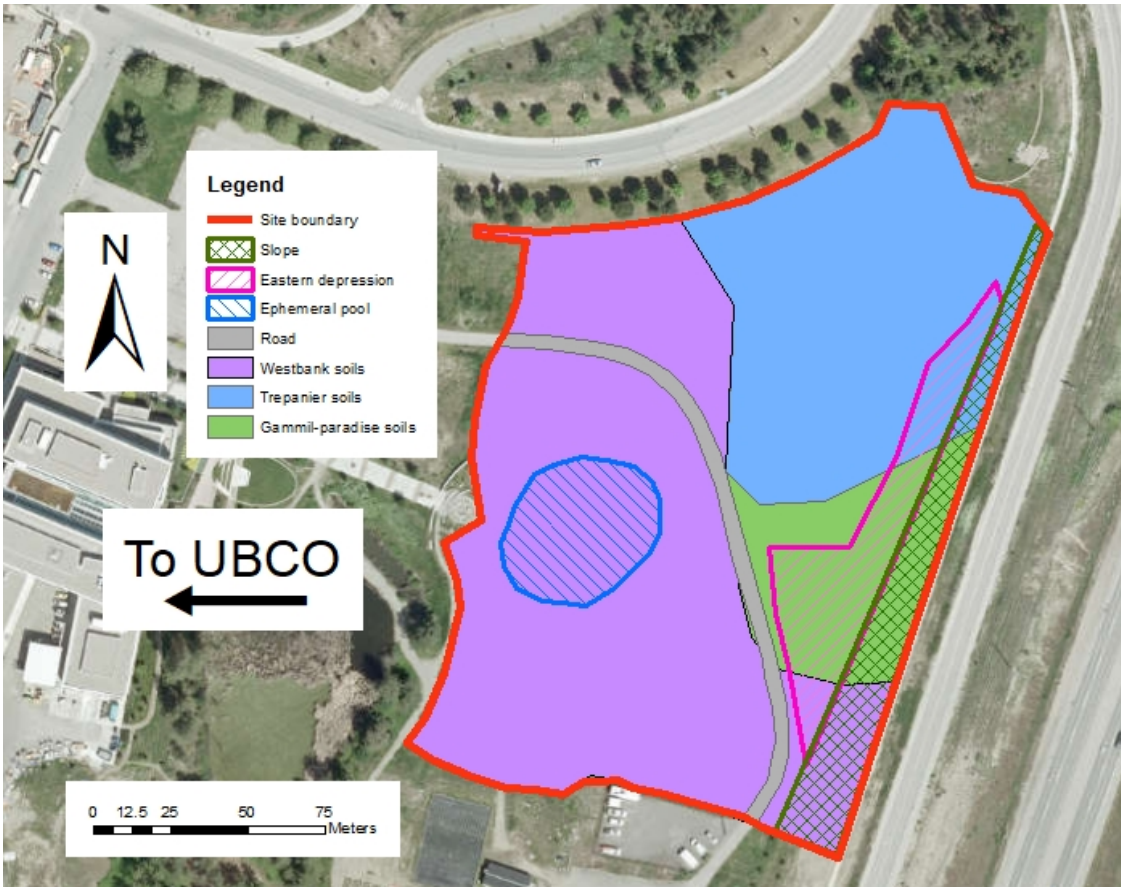


Figure 6: Distribution of four soil types found during a detailed soils survey of the region conducted sometime between 1971 and 1980 relative to site polygons. Map created by Sarah Bird on Feb 3rd, 2019 using ESRI ArcMap version 10.6.1. Basemap from City of Kelowna 2017 Orthophotos

Table 2: Mean soil characteristics within the grassland (N=13), ephemeral pool (N=7), and slope (N=5) sampling zones compared with soil chemical conditions in the reference soils from surveys in the 1980s which conducted one test plot per 2 to 10 ha of land, and classified soils according to Soil Series level of the Canadian System of Soil Classification (Wittenben 1986). All descriptive statistics were performed in Excel 2010. Bolded sections are reference soil chemical characteristics that current conditions differ from.

	pH		**Total nitrogen (% w/w)**		**Total carbon (% w/w)**		**Phosphorus (mg/kg)**	
Grassland (N=13)	6.94 (0.162 SE) Neutral	**W: 6.0-6.6**	0.173 (0.023 SE) Low	W: Low to medium	2.33 (0.249 SE) Moderate	**W: Low**	40.2 (8.94 SE) High	W: High
		G: 5.6-6.5		G: Low to very low		**G: Very low**		**G: Medium**
		T: 6.7-8.2		T: Low to very low		**T: Very low**		**T: Medium**
		P: 6.6-6.9		P: Low to very low		**P: Low to very low**		**P: Low**
Ephemeral pool (N=7)	5.63 (0.106 SE) Medium acid	**W:6.0-6.6**	0.307 (0.041 SE) Medium	W: Low to medium	3.57 (0.417 SE) Moderately high	**W: Low**	67.6 (12.1 SE) High	W: High
Slope (N=5)	7.56 (0.068 SE) Mildly Alkaline	**W: 6.0-6.6**	0.054 (0.01 SE) Very low	**W: Low to medium**	0.902 (0.08 SE) Low	W: Low	11.1 (3.20 SE) Medium	**W: High**
		G: 5.6-6.5		G: Low to very low		**G: Very low**		G: Medium
		T: 6.7-8.2		T: Low to very low		**T: Very low**		T: Medium
		P: 6.6-6.9		P: Low to very low		P: Low to very low		**P: Low**

***W= Westbank soils, G = Gammil soils, T= Trepanier soils, and P = Paradise soils**

1.4.3. Topography

Slope within the site ranged from 0 – 25 °. The mean slope within each region was: 3.54 ° (0.829 SE) within the grassland, 4.86° (1.06 SE) within the ephemeral pool, and 15.0° (4.48 SE) on the slope. The majority of the site has gentle slopes, but the slope polygon features steep slope angles that will be at risk of erosion when plant cover is lost (Figure 7).

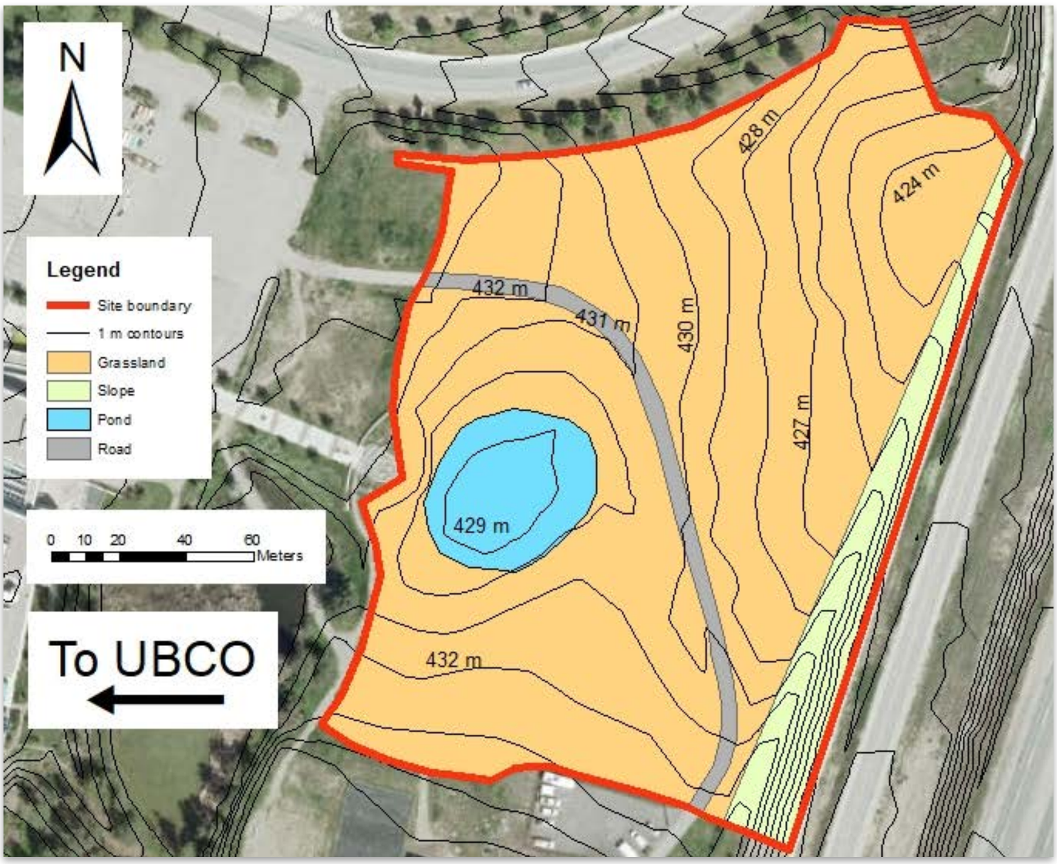


Figure 7: Topography in the Forecourt Grassland. 1 m contours are from the City of Kelowna Open Data Portal. Map created by Sarah Bird on Feb 3rd, 2019 using ESRI ArcMap version 10.6.1. Basemap from City of Kelowna 2017 Orthophotos

1.4.4. Vegetation

Native plants are sparsely distributed across the project site, with only 6 sample plots (24 %) containing at least one identified native plant species. Site sampling on 10, 13 and 14 of August found five confirmed native plants (14 % of identified plants;

Appendix D, Table D1), four of which are moss species. Additional informal surveys to map non-native plants identified at least 8 additional native plant species, most of which occur in the southeastern region of the site (Figure 8; Appendix D). Additionally, from the records of plant occurrences within or around the site from casual site visits by Dr. Bob Lalonde and Dr. Ian Walker between April and August 2018, they identified 17 native plants in the region, and 8 plants were not identified by species so they were not classifiable as native or not (14 %; see Appendix D for sampling area).

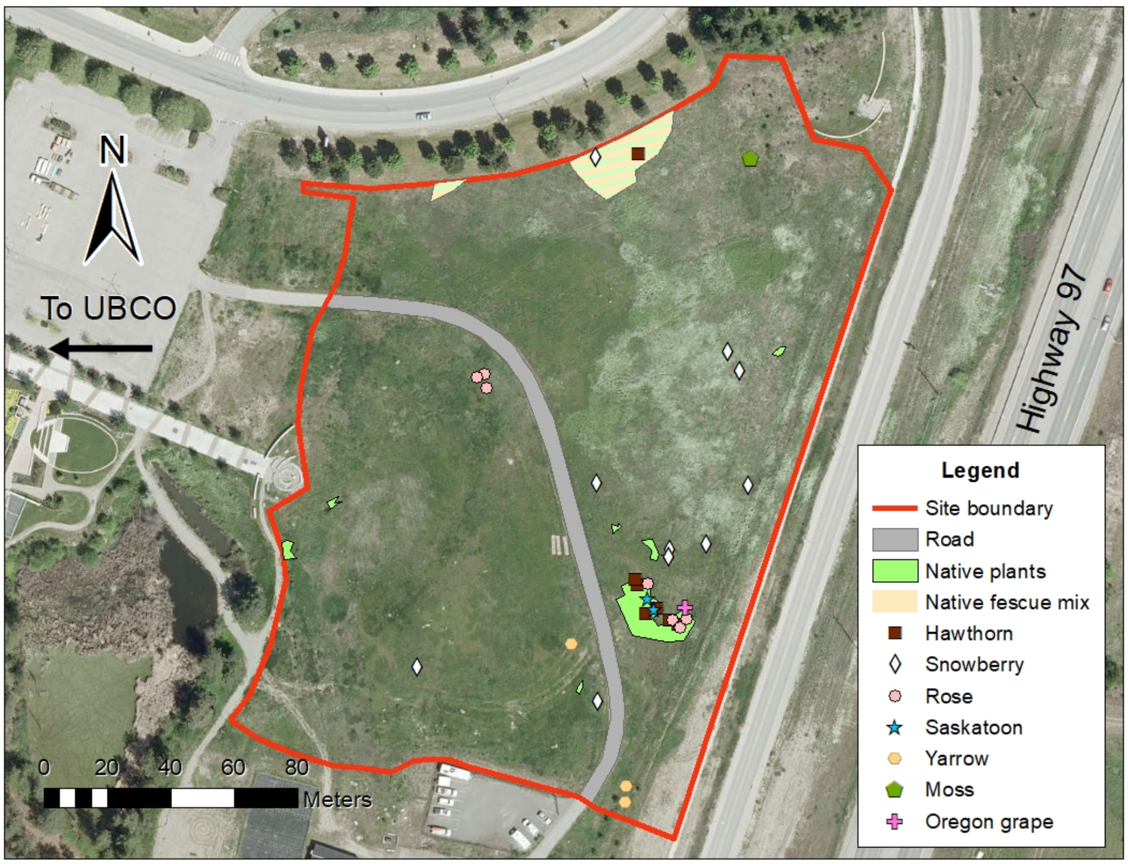


Figure 8: Map of native plant occurrences and patches at the project site at UBC Okanagan in Kelowna, BC. Mapping was done using a GPS unit in mid-August 2018. The patch on the northern edge of the site labelled "native fescue mix" requires expert verification that the fescue is a native species, and not a non-native species. The remainder of the site is covered with agronomic, invasive, or noxious plant species. Basemap from City of Kelowna 2017 Orthophotos. Map generated in ESRI ArcMap 10.7 by Sarah Bird on 1 November 2018.

The Forecourt Grassland had low levels of bare ground across the soil and although there was some native moss cover throughout the site, it was sparsely distributed. The slope has the highest area of bare ground at a mean of 23 %, followed by the grassland samples and then the ephemeral pool (Table 3). Moss cover was highest in some plots of the Grassland region (particularly to the northeastern edge of the site), low on the slope, and absent in the ephemeral pool (Table 3).

Table 3: Summary of bare ground and moss cover in three project sampling zones. Samples were taken 13 and 14 August 2018 with sample sizes as follows: grassland (N=13), ephemeral pool (N=7), slope (N=5).

Variable\Site	Grassland	Ephemeral Pool	Slope
Moss % cover	6 % (3.18 SE)	0 % (0 SE)	0.6 % (0.4 SE)
Bare ground cover	4 % (1.94 SE)	0.3 % (0.285 SE)	23 % (10.9 SE)

Non-native and noxious plants are dominant within the site. All of the sample plots contained at least one non-native plant. Additionally, nine non-native plants are widely distributed across the site (Figure 9). Of the 36 plants identified on site during August 10, 13, and 14th sampling, 16 were confirmed exotic plants, 5 were native plants, and 15 (42 %) were either not listed as exotic or native on E-flora BC, or could not be determined as either native/non-native because they were not identified in enough detail to make such a designation (e-flora BC, Klinkenburg 2018; Appendix D. Dr. Walker and Dr. Lalonde's April – August surveys confirmed 31 exotic plants present in the region (Appendix D, Table D1).

According to the City of Kelowna's Noxious Weed bylaws, 12 plants identified on August 10 -14 2018 and during surveys in the region by Dr. Lalonde and Dr. Walker are considered noxious: Sweet clover, Tumbling mustard, Canada thistle, Burdock, Stinkweed, Bindweed, Bull thistle, Russian knapweed, Sulphur cinqfoil, Diffuse knapweed, Hound's tongue, and Baby's breath; (See Appendix D, Table D1 for scientific names and full list of noxious plants; City of Kelowna, 1997). In total there are 21 species in the project area that are considered noxious by regional bylaws (Regional District of the Central Okanagan [RDCO] 1979).

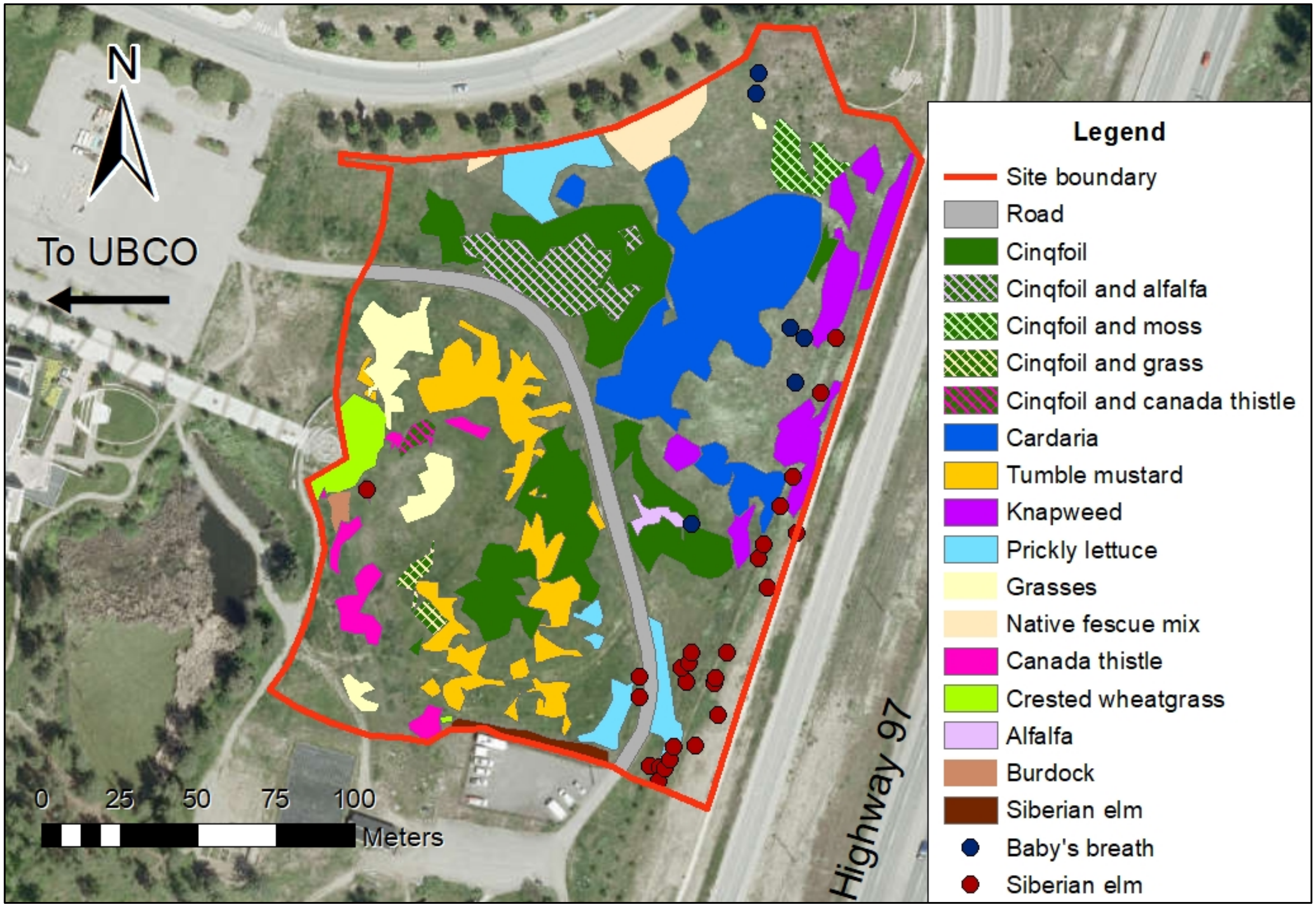


Figure 9: Map of noxious weed and non-native plant patches at the project site at UBCO in Kelowna, BC. Polygons represent locations where the listed plant was dominant (accounted for more than 50 % of the species cover),or was co-dominant with other species. The majority of the areas within the site boundaries but without polygons consisted of non-native plant mixes. The southwestern portion of the site was a mix of grasses and thistles, whereas the northwestern was a mix of grasses, alfalfa, and cinqfoils. The northeastern portion of the site had a mixture of knapweed and cardaria, and the southeastern section mixed grasses and prickly lettuce. The "Native fescue mix" polygon was included in this map, because it has not been confirmed that the fescue is native. Basemap from City of Kelowna 2017 Orthophotos. Map generated in ESRI ArcMap 10.7 by Sarah Bird on 1 November 2018.

1.4.5. Fauna

No wildlife surveys were conducted on site. All wildlife data are from observations provided by Dr. Ian Walker and Dr. Bob Lalonde regarding animal sightings within and around the project area throughout 2018, in addition to a few incident observations by me during site visits. Fourteen bird species, four mammal species, and five insect species were observed directly or indirectly on and around the site between April and August 2018. These observations are summarized in Table 4.

Table 4: Summary of fauna identified by Dr. Ian Walker or Dr. Bob Lalonde around the project site in 2018. Organisms in bold were seen by Sarah Bird during site visits in mid-August. The observations were not quantified and visual observations indicate that the organism was seen, instead of just animal traces such as scat, tracks, or burrows.

Common name	Scientific name	Observation
	Birds	
Ring-necked pheasant	***Phasianus colchicus* Linnaeus**	**Observed in breeding season in suitable nesting habitat**
Mallard	*Anas platyrhynchos* Linnaeus	Seen during breeding season
Canada goose	*Branta Canadensis* Linnaeus	Seen during breeding season
Mourning dove	*Zenaida macroura* Linnaeus	Seen during breeding season
Northern flicker	*Colaptes auratus* Linnaeus	Seen during breeding season
Say's phoebe	*Sayornis saya* Bonaparte	Observed in breeding season in suitable nesting habitat
Western kingbird	*Tyrannus verticalis* Say	Seen during breeding season
Black-billed magpie	*Pica hudsonia* Sabine	Observed in breeding season in suitable nesting habitat
Common raven	*Corvus corax* Linnaeus	Seen during breeding season
Western bluebird	*Sialia Mexicana* Swainson	Seen during breeding season
European starling	*Sturnus vulgaris* Linnaeus	Seen during breeding season
Cedar waxwing	*Bombycilla cedrorum* Vieillot	Seen during breeding season
Brewer's blackbird	*Euphagus cyanocephalus* Wagler	Seen during breeding season
House sparrow	*Passer domesticus* Linnaeus	Seen during breeding season
	Mammals	
Yellow-bellied marmot	*Marmota flaviventris* Audubon and Bachman	Visual
American badger	***Taxidea taxus* Schreber**	**Possible tunnels/burrows**
Northern pocket gopher	*Thomomys talpoides* Richardson	Burrows/digging

Common name	Scientific name	Observation
Columbian ground squirrel	*Urocitellus columbianus* Ord	Visual
	Insects	
Blue species	*Polyommatinae* sp. Swainson	Visual
Mosquito	*Culicidae* sp.	Visual
Purplish copper	***Lycaena helloides* Boisduval**	**Visual**
European mantis	***Mantis religiosa* Linnaeus**	**Visual**
Nevada bumble bee	***Bombus nevadensis* Cresson**	**Visual**

Species at risk

Around 90% of the site is considered Critical Habitat for the Great Basin Spadefoot toad (*Spea intermontana)* as of 2017 (BC Conservation Data Centre [BC CDC] 2018). The nearest core Critical Habitat for the toads is 400 m from centre of the project site (BC CDC 2018). Additionally, there have been a number of badger sightings in the area around the site, as well as at least one - possibly two - old badger burrows within the site (Dr. Bob Lalonde, UBC Okanagan, pers. comm. 2018). Similarly, the Western Painted Turtle can be found in a stormwater management pond within 40 m of the project site (Patterson and Olson-Russello 2014). In their report, Patterson and Olson-Russello (2014) listed 41 animals and 12 plants that are at-risk and have the potential to be present on campus. Only six of the animal species and none of the plant species were observed or known to occur on campus at that time (Great Basin spadefoot toad [*Spea intermontana*], barn swallow [*Hirundo rustica* Linnaeus], American avocet [*Recurvirostra americana* Gmelin], great blue heron [*Ardea herodias* Linnaeus], California gull [*Larus californicus* Lawrence], and western painted turtle [*Chrysemys picta* Schneider]; Patterson and Olson-Russello 2014).

1.4.6. On-site Stressors

Three main factors influence the ability of this site to function as a native grassland: the presence and persistence of non-native plants (including nearby source populations, a potential for a significant exotic species seedbank, and proximity to roads), the isolation of the site from nearby intact grasslands and native plant propagules, and the removal of the site from natural disturbance regimes of fire and grazing.

Non-native plants currently dominate the site and may exclude native plants from establishing though competition for resources (Lockwood et al. 2007). Without removing the non-native plants that cover the majority of the Forecourt Grasslands it is possible that native plants will be unable to establish on site. Invasive/non-native plants often colonize disturbed sites and can dominate a site by competing in resource use, and/or by arriving to a site prior to native plants, excluding them from growing there (priority effect; Lockwood et al. 2007). There is high potential for re-invasion of the Forecourt Grassland by non-native plants even after they are removed due to existing propagule (seed and root) pressure (Lockwood et al. 2007).

The non-native plants in the Forecourt Grassland produce large quantities of seeds that can remain in the seedbank, sometimes as long as decades, making elimination from sites difficult (British Columbia Ministry of Agriculture, Food, and Fisheries 2002). Others have vegetative reproductive strategies (rhizomes, leaf and stem cuttings) that can mean poorly planned attempts to remove plants can actually propagate and spread the non-native plants instead of eliminating them (British Columbia Ministry of Agriculture, Food, and Fisheries 2002). Additionally, adjacent sites within 30 meters of the project site provide propagules for non-native plants to re-invade the site. Finally, some of the noxious weeds that are present on site produce allelopathic chemicals that prevent plant growth (e.g. Russian knapweed, Cardaria, etc; Alford et al. 2007, Qasem 2004). Careful management of non-native plant removal and long-term monitoring of the site after planting will be required to manage this stressor.

The ability of the Forecourt Grassland to passively revegetate with native plants is also limited by the low diversity and abundance of native plant propagules on site, and the isolation from nearby patches of grassland or native grassland plants (del Moral et al. 2007). The history of farming on the site, as well as the construction and soil disruption limited the native plant seedbank remaining on site. Additionally, there are only thirteen native plant species that were identified during 13-14 August 2018 plant surveys, so few native plants are established on site to act as seed sources. Finally, the Forecourt Grassland is about 100 – 400 m from native plant populations at UBC Okanagan, and 7 km from Knox Mountain Park's grasslands. To help overcome the isolation of the site, the desired native plant species can be planted, but this must be managed simultaneously with non-native species control to ensure establishment (del Moral et al. 2007).

Finally, due to the location of the Forecourt Grassland in an urban setting, it is undesirable to employ the natural disturbance regimes of fire and grazing within the site. The UBC Okanagan property is managed to prevent wildfire according to the *University of British Columbia Okanagan Wildland Fire Management Plan* (Diamond Head Consulting Ltd. and Davies Wildfire Management 2006). Regular fires in grasslands play a role in nutrient release from the soil and can influence plant growth both positively and negatively (Iverson 2004; Reinhart et al. 2016). To account for the lack of fire in the Forecourt Grassland, soil and plant nutrients should be monitored to assess the function of the nutrient cycles over time. Grazing normally influences plant distribution and can affect heterogeneity in the site (Adler et al. 2001). Without the influence of grazing, heterogeneity will need to be built into the design of the planting, and potentially manipulated over time to compensate for the lost disturbance in the Forecourt Grassland.

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Chapter 2.
Restoration Recommendations

2.1. Introduction

The Forecourt Grassland is a small (3.3 ha), urban site covered in exotic plants, with a few small pockets of native vegetation. The site is bisected by a road, has a small ephemeral pool on the southwest edge, and a steep slope adjacent to a road and path on the eastern side of the site. A site assessment of soil and vegetation within 25 sample plots, in addition to non-native plant polygon mapping indicated that some native vegetation is present on site. Based on the known stressors to the site (size, isolation, edge effects, and non-native plant populations) I recommend using three known PPxh1 grassland ecosystem associations, and one ponderosa pine forest association used in Sensitive Ecosystem Inventory surveys as reference ecosystems for the site design (Iverson 2008, Iverson et al. 2004). Since neither contaminant data nor accurate hydrological data are available for the ephemeral pool, I recommend a sampling regime for the pool that informs future recommendations pertaining to spadefoot toad or western painted turtle use of the ephemeral pool. Additionally, to address long term monitoring needs, and to foster real-work educational opportunities, I suggest that undergraduate classes on plants, soils and insects at UBC Okanagan be used to monitor the site. Other campus users may also wish to participate in the restoration activities, which would reduce costs and foster a sense of community ownership over the space.

Bunchgrass systems serve as habitat for a variety of native organisms by providing shelter, food, and breeding/ rearing areas (Iverson 2004). Although soil chemistry measurements within the Forecourt Grassland are within natural ranges of variability for Okanagan grassland systems, vegetation surveys indicated a significant lack of native flora and a dominance of noxious weeds within the site. This lack of native plants may be due to competitive exclusion from the site by non-native plants (priority effects) or a lack of native plant propagules (Lockwood et al. 2007). As a result, the overarching goal of restoration actions is to reintroduce native vegetation and physical components (e.g. coarse woody debris, rocks, etc.) in the site that will enhance food sources and habitat for native grassland fauna.

The goals for this restoration project are influenced by the Forecourt Grassland's position in an urban setting, necessitating an urban ecology approach to the site. Urban ecology is the study of ecology specifically in regions of concentrated human settlement (Forman 2014). Urban plots destined for restoration face different challenges than rural and natural settings due to their position in a hardscaped urban matrix: isolation from native source populations or dispersal mechanisms (Klaus 2013), soil legacies as seedbanks or contamination (Klaus 2013), and reduction or elimination of natural disturbance regimes (Zeeman et al. 2017). To address these common urban constraints, some propose that flexible restoration targets should be applied in urban settings to manage the anthropogenic pressures and species pools that become present in human-mediated settings (Klaus 2013, Zeunert 2013). As a result, the proposed goal of revegetation with 90 % native plant cover will be re-assessed annually post-monitoring, and potentially decreased if non-native species persist but minimally influence grassland function.

Additionally, attracting native fauna from restoration initiatives to urban sites can be problematic, leading to road mortality (Zeunert 2013). As such, this urban restoration project does not aim to increase mammal abundance on site, but to maintain the existing populations of burrowing mammals such as pocket gopher, ground squirrel, and badger whose burrows are an integral part of providing heterogeneity in the grassland ecosystem (Southern Interior Reptile and Amphibian Working Group 2017; Quested and Foster 2007). Creating quality habitat in the ephemeral pool for at-risk species must be evaluated by the relevant recovery teams to ensure the site does not become a population sink. In my restoration planning I will minimize the impact of the design on the local urban wildlife.

2.2. Goals and Objectives

The goal of the restoration project is to create a grassland ecosystem in the Forecourt Grassland dominated by non-native plants at the University of British Columbia Okanagan (Kelowna BC) by designing habitat creation in the site based on native Okanagan bunchgrass ecosystems relevant to the site properties.

With these factors in mind, the overall restoration project objectives are to:

1. Reduce non-native plant cover within the Forecourt Grassland to 10 % cover or less.
2. Establish a persistent community of native grassland vegetation across the site by planting and seeding native plants according to ecological grassland communities that are appropriate to site conditions.
3. Increase the quality of grassland habitat for native grassland fauna by increasing the quantity of structural elements on site and promoting food sources.
4. Incorporate local educational opportunities and partnerships into site restoration and maintenance.

In order to complete these objectives, the necessary actions are summarized in table 5.

Table 5: Actions needed to implement grassland restoration project at UBC Okanagan

Actions	Timeline
Objective 1	
1.1 – Manage priority noxious weeds on site through mowing, hand-pulling, tillage, and herbicides	Project year 1 and 2
1.2 – Monitor non-native plant persistence in site, and treat re-invasions as necessary	All project years
1.3 – Re-assess feasibility of < 10 % noxious weed cover goal within the project site and adjust as necessary	Year 5, 7, 10
Objective 2	
2.1 – Characterize soil conditions on site using soil sampling and chemical analysis	Completed Aug. 2018
2.2 – Characterize vegetation conditions on site by sampling vegetation plots and mapping non-native species cover	Completed Aug. 2018

Actions	Timeline
Objective 2 continued	
2.3 – Compare site conditions to known SEI ecosystems present in the Kelowna region or appropriate for site given the BEC zone, elevation, moisture, and soil chemistry	Completed Jan. 2019
2.4 – Conduct sampling in the pond region to assess contaminants, salinity, and hydrology	Prior to pond restoration
2.5 – Use pond sampling results to identify an appropriate restoration target ecosystem	Prior to pond restoration
2.6 – Prepare a restoration plan incorporating integrated non-native species management, native plantings, and wildlife features for local species at risk	Completed Jan – March 2019
2.7 – Complete site preparation	Project year 1-2
2.8 – Build test plots	Project year 1
2.9 – Monitor test plots	Year 2-3
2.10 – Complete site plantings	Project year 2
2.12 – Monitor site for forest and non-native species encroachment, as well as planted vegetation success; adjust goals as necessary	In perpetuity
Objective 3	
3.1 – Complete placement of wildlife features	Project year 2
3.2 – Monitor insect and small mammal populations on site	Year 5, 7, 10
Objective 4	
4.1 – Provide opportunities for local clubs and classes to participate in restoration activities, from site preparation to planting and monitoring	All years
4.2 – Partner with lab groups on campus to analyse soil samples and implement research into restoration success	All years
4.3 – Partner with local organization from UBC alumni Tanis Gieselman to collect local seedstock for restoration	Before and during year 1
4.4 – Collaborate with local organizations, campus faculty, and campus Health and Wellness to design educational signage around the project, native ecosystems, and species at risk	Project year 1

Establishing native vegetation within the Forecourt Grassland would improve habitat connectivity within the UBC Okanagan campus and contribute to campus development goals. Although UBC Okanagan will not commit to implement the recommendations from this report, the research contained in this report may prove useful when funding becomes available to address the site conditions. When a decision is made to modify site conditions within the Forecourt Grasslands, the recommendations in this report comply with a number of biodiversity goals described within the 2016 Whole Systems Inventory Plan, including Goal 4: “Enhance and/or restore the ecology [on campus]” (UBC Okanagan 2016).

2.3. Regulatory Framework and Permitting

The Forecourt Grassland is regulated by University guidelines, local and regional bylaws, Provincial laws and Federal laws. University guidelines lay out the design requirements for the site to ensure it complies with university development goals and planning. Local, regional, and provincial regulations specify how noxious weeds must be managed on site. Provincial and Federal laws govern species at risk and sensitive ecosystem management. A summary of these regulations and their implications for site management are outlined below.

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2.3.1. UBC Okanagan Campus Master Plan

The 2014 Campus Master Plan for UBC Okanagan provides guidelines to ensure all new projects on campus meet the University goals. Within this plan, it is clear that the project site must remain tree-less but is also highlighted as an area for restoration: “reinforce the Okanagan grasslands and Ponderosa Pine Woodland in landscape design” (pg. 12), “incorporate indigenous landscapes that are characteristic of the Okanagan climate” (pg. 13), “areas of landscape adjacent to the core such as the grasslands, Ponderosa Pine Woodland, and disturbed slopes east of the Commons will be enhanced and restored to optimize ecological function and social health and well-being for campus users, consistent with the University’s Wildland Fire Management Plan” (pg. 56), “Okanagan Landscape to Enhance and Manage” (pg 57). “Woodland Areas to restore and manage” (pg 57; UBC Okanagan 2015). The requirements of this plan can be met by providing restoration recommendations consistent with an Okanagan grassland that lacks trees within the specified sightlines.

2.3.2. UBC Okanagan Whole Systems Approach to Campus Infrastructure Plan

This research project is positively contributing towards the biodiversity goals put forth by the University of British Columbia Okanagan in their Whole systems Inventory Plan. The campus has goals to produce a habitat restoration plan for the Forecourt Grassland between 2021 and 2026, as well as integrate student research projects into the maintenance of biodiversity projects at UBC Okanagan, both of which will be incorporated into this project (UBC Okanagan 2016).

2.3.3. UBC Okanagan Campus Planning and Development

Campus Planning and Development at UBC Okanagan has permitting processes that ensure various projects on campus meet appropriate guidelines and requirements. A grassland restoration project at the project site would require approval from the Campus Planning & Development (CPD) at UBC Okanagan, as the project falls under the category of “work that impacts campus lands, such as … ecological enhancement” that requires CPD approval (Campus planning, para.2, n.d.a). The restoration project would require a Minor Project Development Permit from CPD (Campus Planning, n.d.b). The necessity of the Natural Environment Development Permit (NEDP) from the City of

Kelowna should be assessed by a City of Kelowna representative. Additionally, any research projects taking place on the Forecourt Grassland will require an Outdoor Research/ Land Use Approval, and new signage must receive a Sign Approval, both from CPD (Campus Planning, n.d.b). A finalized plan for the restoration of the Forecourt Grassland will need to be reviewed with Campus Planning at UBC Okanagan, and at least three permits will be required prior to the start of work.

2.3.4. The UBC Okanagan Wildland Fire Management Plan

This wildfire management plan sets guidelines for tree density and fuel load in forest understories and grasslands. When planting trees on the northern edge of the site the tree density must remain less than 100 trees per hectare and canopy gaps must be kept (Diamond Head Consulting (DHC) Ltd. and Davies Wildfire Management (DWM) 2006). To meet these requirements, trees must be planted in clumps as opposed to evenly spaced, and understory plantings should be focused around the tree clumps (DHC and DWM 2006). Prescribed fire may not be used within the project site as a treatment as per City of Kelowna requirement (DHC and DWM 2006). Additionally, when adding coarse woody debris as wildlife habitat in the forested area, no more than 10 large (greater than 10 cm in diameter) pieces of coarse woody debris per hectare may be placed in the northern and southern forested regions (DHC and DWM 2006).

2.3.5. UBC Okanagan Design Guidelines

The UBC Okanagan Design Guidelines must be followed for all new developments on the UBC Okanagan campus, including work that would be done on the project site (Ramsey Worden Architects (RWA) Ltd. and Perry and Associates (P&A) Inc. 2008). These guidelines were developed to ensure cohesion in design across the campus (RWA Ltd and P&A Inc. 2008). The Design Guidelines indicate that the project site should be restored to grassland and the pine forest to the north of the site should also be enhanced (RWA Ltd and P&A Inc., 2008). These modifications are necessary for creating the “entry experience” for the campus (pg. 11), as described below:

Repair the Entry Fore-court Grassland: The sloping grassland that looks out across the valley serves as a fore-court for the Campus. The first step in the gateway development will be to repair and extend this grassland so that it flows throughout the entire fore-court area. This entry experience begins at Highway 97.

Repair the Forest Edge: The fore-court is bordered by remnant stands of Pine forest, showing signs of Beetle damage. The second step in the gateway development then is to enhance and repair this forest incrementally with young pine and fir species, intermixed with the occasional aspen. This new forest will create a frame for the fore-court and extend to Highway 97 so that the sense of place will be apparent even for passers by. (RWA Ltd and P&A Inc., pg 11, 2008)

The UBC Okanagan Design Guidelines provide specific instructions regarding the placement, type and methods for tree planting in the project area. For tree plantings in the north end of the project site, they should be *Pinus Ponderosa* Douglas ex P. Lawson & C. Lawson (Ponderosa pine), with potentially some *Pseudotsuga menziesii* (Mirb.) Franco (Douglas fir), and *Picea glauca* (Moench) Voss (spruce) mixed in, with a minimum height of 3 m (RWA Ltd and P&A Inc., 2008). These trees must be planted in clumps 20-30 m apart, and dead trees must be removed as per the Wildland Fire Management Plan (RWA Ltd and P&A Inc., 2008). Tree planting must follow best practices outlined by the City of Kelowna Tree Planting Tips (RWA Ltd and P&A Inc., 2008). Additionally, the guidelines specify that understory plantings to be done in conjunction with tree planting should be dominated by native grasses, but also should include: *Balsamorhiza sagittata* (Pursh) Nutt. (Arrow-leaved Balsamroot), *Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roem. (Saskatoon), *Achillea millefolium* L. (Yarrow), *Crepis atribarba* A. Heller (Slender Hawksbeard), *Astragalus miser* Douglas ex Hook (Timber Milk-vetch) and *Antennaria microphylla* Rydb. (Rosy Pussytoes; RWA Ltd and P&A Inc., 2008).

UBC Okanagan Design Guidelines recommend that the project area maintains open sightlines and is planted with native grassland species for the Okanagan. Design restrictions for the "Grassland forecourt", which is the project site, include being planted with *Pseudoroegneria spicate* (Pursh) Á. Löve (Bluebunch wheatgrass) and *Festuca* L. sp. (Idaho or rough fescue), as well as being "kept clear of trees, services and visual clutter to maintain its character and the views beyond" (RWA Ltd and P&A Inc., pg 14, 2008). This landscape is supposed to reflect the "iconic Okanagan grassland character" and the views in this region must not be obstructed (RWA Ltd and P&A Inc., pg 22 2008). If any educational signage is installed, it must be designed according to the *UBC Sign Manual* (RWA Ltd and P&A Inc., 2008).

2.3.6. City of Kelowna Regulations

The main regulations from the City of Kelowna that apply to this project are the *Noxious Weeds & Grass Control* bylaw (No. 8133) and the City of Kelowna Official Community Plan. According to the Official Community plan the site would likely need a Natural Environment Development Permit (NEDP) as it is within the region identified by the City of Kelowna as requiring a NEDP (City of Kelowna, 2011); however, this requirement should be verified with city officials. Additionally, the site contains 12 plants that are considered noxious under the *Noxious Weeds & Grass Control* bylaw (Sweet clover, Tumbling mustard, Canada thistle, Burdock, Stinkweed, Bindweed, Bull thistle, Russian knapweed, Sulphur cinqfoil, Diffuse knapweed, Hound's tongue, and Baby's breath; See Appendix D for scientific names; City of Kelowna, 1997). This regulation requires that these twelve plants designated as noxious, along with any non-native grasses on site must be kept below 8 inches in height and cut to prevent them from going to seed.

2.3.7. Regional District of the Central Okanagan Noxious Weed Control Bylaw No. 179

Between my surveys and those conducted by Dr. Lalonde and Dr. Walker from April – August 2018, there are at least 21 species of noxious weeds on site that are regulated by the Regional District of the Central Okanagan (RDCO) Noxious Weed Control Bylaw No 179 (Appendix D; RDCO 1979). This regulation requires property owners to maintain noxious weeds and grasses on site below a height of 8 inches between April 1st and September 30th each year (RDCO 1979). This maintenance may be done through mowing, clipping, or destroying the relevant plants in some way (RDCO 1979).

2.3.8. Weed Control Act of British Columbia

The regulation requires that materials with the potential to contain noxious weed seeds must be transported in a covered container (British Columbia Weed Control Act [BCWCA], 2011). The project site contains three plant species considered provincial weeds (Schedule A: Canada thistle - *Cirsium arvense* (L.) Scop., diffuse knapweed - *Centaurea diffusa* Lam., and hound's tongue - *Cynoglossum officinale* L.), and two plants listed as regionally noxious (Schedule B: burdock - *Arctium minus* Bernh., sulphur cinqfoil - *Potentilla argentea* L.; BCWCA Weed Control Regulation 2011). According to this provincial law, the land owner must take steps to manage these weeds (BCWCA, 1996).

2.3.9. Provincial Wildlife Act

This act protects wildlife in British Columbia from harm and should be considered when planning the timing and nature of activities on site. Under the Wildlife Act, it is illegal to damage a bird or its egg, a bird's nest when the bird is still in it, or the nests of an eagle (*Accipitridae* sp. Vigors), peregrine falcon (*Falco peregrinus* Tunstall), gyrfalcon (*Falco rusticolus* Linnaeus), osprey (*Pandion haliaetus* (Linnaeus)), heron (*Ardea herodias* Linnaeus), or burrowing owl (*Athene cunicularia* (Molina, 1782); British Columbia Wildlife Act, 1996). Of those species, the main species of concern would be ground-dwelling birds that may be present during mowing and site preparation activities. The act also prohibits harming or killing wildlife (British Columbia Wildlife Act, 1996). Since tilling and mowing could harm local mammals or ground nesting birds, care should be taken during site preparation (tilling, mowing) to avoid harming Columbian grounds squirrels (*Urocitellus columbianus* (Ord)) and pocket gophers (*Thomomys talpoides* (Richardson)), among other species. Bird-nest surveys prior to mowing will also be required.

2.3.10. Provincial Integrated Pest Management Act

This act will apply to the site should any herbicides be used on site to manage noxious and non-native plants, which is likely. The act provides guidelines to promote safe and responsible use of pesticides (including herbicides). Some regulations to consider when designing the herbicide application plan include: herbicides must be used according to their registered use under the act (3(2)), herbicides must be used according to their instruction labels and may not be used to cause harm (3(2)), herbicides must be used by a licenced professional (4(1)), herbicides may not be applied without appropriate permits (6), and a pest management plan must be submitted to and approved by the regulator prior to use of herbicide (7; British Columbia Integrated Pest Management Act 2003). Details regarding regulations of specific herbicides may be found in the B.C. *Integrated Pest Management Regulation*.

2.3.11. Federal Species at Risk Act (SARA)

This Federal Act does not apply for the species present on the private land in the project site, however the relevant species are protected by other legislation, and it is worth noting what Federally-listed at-risk species are relevant in the project site (Government of Canada 2018a, Government of Canada 2018b). The project site falls within the proposed Critical Habitat for the great basin spadefoot toad, a species Federally listed under the Canadian Species at Risk Act (British Columbia Conservation Data Centre [BCCDC] 2019). Protections for Critical Habitat ("the habitat necessary for the survival or recovery of a listed endangered, threatened or extirpated species (if a recovery strategy has recommended the reintroduction of that extirpated species)") of aquatic organisms and organisms listed under the Migratory Birds Convention Act are in place on private property, but absent for all other species (Government of Canada 2018c).

For the project site, this protection thus does not apply to the great basin spadefoot toad (Government of Canada 2018b). Additionally, old dens from the American badger were found on and near the site. The American badger is listed Federally as Endangered but does not yet have Critical Habitat designated (Government of Canada 2011a). Finally, the nearby storm water retention pond is home to the western painted turtle, which is currently a species of Special Concern under SARA, which does not have Critical Habitat (Government of Canada 2011b). Details regarding the habitat needs for these species at risk and how they are incorporated into the design plans can be found in section 2.4

2.3.12. Federal Migratory Birds Convention Act

This act protects migratory birds and their nests from harm and destruction (Government of Canada 1994). Thus, care must be taken to ensure restoration activities do not disturb or harm migratory birds or their nests. Ground nesting surveys should be conducted prior to restoration activities, and prior to mowing within the site that occurs during nesting season (May – June). The vesper sparrow, sharp-tailed grouse, western meadowlark, and savannah sparrows are some ground-nesting birds that may use the grassland, although the small size of the site makes that unlikely (Haddow et al. 2013).

2.4. Species at Risk Habitat Considerations for Restoration

This project site is or has the potential to be home for at least three species at risk: *Taxidea taxidus jeffersonii* (American badger), *Spea intermontana* (Great Basin spadefoot toad), and *Chrysemys picta* (western painted turtle). Minimal changes could be applied to the site to improve habitat for the American badger. Discussions with Species-At-Risk biologists are required to determine if the site would be appropriate habitat for the other two focal at-risk species, or if habitat creation in this region would create a population sink due to the isolated and urban nature. Additional consideration for wildlife habitat creation and enhancement will be explored in section 2.5.3 - Wildlife features.

2.4.1. American Badger

The American Badger is a red-listed species in British Columbia, and the *Taxidea taxidus jefferesonii* Western population is considered Endangered under the Federal Species at Risk Act (*Jeffersonii* Badger Recovery Team 2008). This western population of the *jeffersonii* supbspecies does not currently have a Recovery Strategy or designated Critical Habitat (Government of Canada 2011a). American badgers have been spotted near the project site (Dr. Lalonde, UBC Okanagan, pers. comm. 2018). Discussions with the *jeffersonii* Badger Recovery Team (BC Ministry of Environment) regarding habitat connectivity and the prevention of road mortality in and around this site would be beneficial.

Major habitat requirements for this species are soil types appropriate for digging (fine particle size that does not collapse during burrowing), and availability of prey (*Jeffersonii* Badger Recovery Team 2008). Food sources include Columbian ground squirrels, pocket gophers, small mammals, amphibians, and some berries or seeds (*Jeffersonii* Badger Recovery Team 2008). As such, restoration efforts on site should aim to preserve the populations of Columbian ground squirrels and assess habitat features that would maintain local small mammal populations. The presence of many small mammal burrows within the site, and the fine soil texture suggest that the soil type is already appropriate for badger burrowing. This hypothesis can be assessed by regularly surveying the site for badger burrows and looking for any signs of collapsed burrows. American badger young are born between the end of March and beginning of April (Klafki 2019), so care should be taken within and immediately after this time period to avoid interfering with these young.

2.4.2. Great Basin Spadefoot Toad

The Forecourt Grassland is within the Critical Habitat for the great basin spadefoot toad (Environment and Climate Change Canada [ECCC] 2017, BCCDC 2019). The toad has not been observed within the project site but has been found in a drainage trench 400 m northwest of the ephemeral pool in the Forecourt Grassland (BCCDC 2019, Patterson and Olson-Russello 2014). The drainage trench is considered the core Critical Habitat for this observance (ECCC 2017). An ecological assessment in 2014 indicated that it is not clear if the population on campus is a source or a sink (Patterson and Olson-Russello 2014), so further investigations into the population dynamics should be assessed prior to restoring or creating habitat for the resident population.

Three types of habitat and dispersal routes between them must be available in a landscape to support the spadefoot toad: breeding (ponds), foraging (upland), and hibernation habitat (upland; Cannings 1999, ECCC 2017). The breeding ponds must be wet until mid- to late-July to support larval development (Southern Interior Reptile and Amphibian Working Group [SIRAWG] 2017). Upland habitat for foraging and hibernation must include loose soils, existing burrows, or holes and crevices to act as refuges (ECCC 2017; SIRAWG 2017). Additionally, a selection of small invertebrate prey, and other refuges for the active and hibernation season in the form of coarse woody debris, large flat rocks, burrows (made by the toad or local small mammals), bare soil, and access to a frost-free zone in the soil during the winter should be available (ECCC 2017; SIRAWG 2017). These habitat features should be considered when designing habitat enhancement for the toad if it is deemed appropriate within the Forecourt Grassland.

Currently, the ephemeral pool within the Forecourt Grasslands would be unsuitable for breeding habitat for the great basin spadefoot toad, as it dries too early in the year. The pond on the project site usually dries up by the end of May (Dr. Lalonde, UBC Okanagan pers. comm. 2018) but must be present until June or July to support larval metamorphosis (SIRAWG 2017). Additionally, without having sampled water quality, it is unclear if the water conditions (temperature, pollutants, salinity) are appropriate for breeding habitat for the Great Basin Spadefoot toads. To determine if the pool should be modified to create toad habitat, UBC Okanagan should work with the Southern Interior Reptile and Amphibian Working Group. This is necessary since the site is very small and surrounded by roads and parking lots that could cause high mortality of toads if they migrate in and out of the site. Thus, it may not be beneficial to species recovery to have breeding habitat within the Forecourt Grassland.

If the ephemeral pool on site were to be developed as spadefoot breeding habitat, I recommend the following:

- Conduct water quality sampling for temperature, salinity, dissolved oxygen, pollutants, wetted extent, and date of drying (see Bishop et al. 2010 for pesticide and water quality in natural reference and orchard sites, the Canadian Water Quality Guidelines for the Protection of Aquatic Life, and the Canadian Sediment Quality Guidelines for the Protection of Aquatic Life).

- Pond excavation or irrigation may be necessary to ensure the pond stays wet long enough to support tadpole metamorphosis
- Appropriate habitat features (availability of food, emergent vegetation for egg-laying, etc.) as per the provincial recovery strategy should be incorporated (SIRAWG 2017)

Although the project site contains some of the relevant features for connective, foraging, and overwintering habitat for the spadefoot toad, the isolation of the Forecourt Grassland's ephemeral pool from the core habitat and location within a matrix of urban development make the pool unlikely to be accessed by resident toad populations. This issue should be assessed with assistance from the Southern Interior Reptile and Amphibian Working Group. Additional considerations to be made in conjunction with the Southern Interior Reptile and Amphibian Working Group are measures to improve connectivity for toad migration within the UBC Okanagan landscape (such as whether roads on campus are contributing to mortality and if culverts or other means should be used to connect the project site to other regions of campus). If issues of connectivity are not a concern, other refuge features that can be used by the toads during migration between core habitat should be added to the Forecourt Grassland during restoration including: adding coarse woody debris, placing rocks and creating small crevices or burrows, limiting damage to existing mammal burrows, and potentially loosening the soil in some areas to increase the chance the toads can burrow (ECCC 2017; SIRAWG 2017).

2.4.3. Western Painted Turtle

Western Painted turtles are known to live within the storm water management pond that exists to the southwest of the project site (Patterson and Olson-Russello 2014). They are a blue-listed species in British Columbia, and Federally listed as Special Concern for the Intermontane/Rocky Mountain Population (Government of Canada 2011b). Any habitat creation developed for this species should be done in collaboration with the Western Painted Turtle Recovery Team to ensure it meets provincial recovery goals.

Turtle habitat such as basking, breeding or overwintering habitat must be in a waterbody that is present at the appropriate times, particularly throughout the summer and winter (The Western Painted Turtle Recovery Team 2016.), so the ephemeral pool within the Forecourt Grassland cannot provide those habitats in its current condition. Any considerations for modifying the ephemeral pool within the project site into a permanent waterbody to support various western painted turtle habitat should be weighed against the possibility of altering the ephemeral pool to create great basin spadefoot toad habitat, as the two species' habitat requirements for water bodies are very different. Lastly it is possible, although unlikely, that the ephemeral pool would be suitable foraging habitat if it contains any invertebrates or other food sources, which could be determined through water and sediment sampling.

2.5. Restoration Treatments

2.5.1. Desired Future Conditions

The target ecosystem for this site according to the UBC Okanagan design guidelines is a bunchgrass ecosystem native to the Okanagan Valley, in part to meet visual guidelines, and in part to preserve views on that side of campus by the prohibition of tree growth in the area (Ramsay Worden Architects Ltd., and Perry and Associates Inc. 2008). Due to the elevation and position of this site in the landscape, the Forecourt Grassland is part of the Ponderosa Pine very dry hot (PPxh1) BEC zone and should be restored to bunchgrass systems that are common within that BEC zone (British Columbia Conservation Data Centre [BCCDC] 2019). Reference conditions from a relevant local ecosystem, rather than a specific reference site, allows for a range of natural variability within the ecosystem (White and Walker 1997), so appropriate PPxh1 reference ecosystems are used in the design of the restoration treatments.

Additionally, the preliminary aim of restoration actions is to reduce non-native plant cover to less than 10 % of the site (Iverson et al. 2004) by replacing it with native plant cover. The 10 % cover cut-off was chosen because during Sensitive Ecosystem Inventories in Kelowna and the Regional District of the Central Okanagan a 10 % cover of non-native plants was used to distinguish between early seral associations of grasslands characterised by non-native plants, and the later seral associations characterised by the native flora (Iverson et al. 2004, Iverson 2008). If at all possible, the goal is to create a patch that resembles a late seral stage with minimal non-native species, to ensure native plant diversity and survival while minimizing the potential of the patch to act as a source of non-native propagules. The 10 % cover cut-off may be re-evaluated as part of management after implementation, as the location in an urban matrix and potential of a novel ecosystem developing on site may prevent such a low composition of non-native plants (Klaus 2013).

To identify appropriate reference ecosystems for the Forecourt Grassland, I assessed PPxh1 site series for regions of the site, identified grassland ecosystems that are present in Kelowna and the Regional District of the Central Okanagan (RDCO), and searched the BC Species and Ecosystems Explorer for forest, grassland, and wet meadow ecosystems within the PPxh1 zone. Based on the BEC classification system, the depression on the western side of the slope would be a 06 or 07 PPxh1 site series (wetter), the slope would be a 02, or 03 site series (drier), and the main grassland area would be zonal (01) or slightly dry (04; BC Ministry of Forests 1990). Additionally, the ephemeral pool would be classified as some kind of wetland meadow, with more specific classification depending on salinity (MacKenzie and Moran 2004). In Kelowna and the RDCO, three disturbed grassland, three grassland, two coniferous old forest, three coniferous woodland, and six wetland associations were present in the appropriate BEC zone and site series during Sensitive Ecosystem Inventories (Iverson et al. 2004; Iverson, 2008). The online search of the BC Species and Ecosystem Explorer highlighted two forest, two wetland, two shrubland, and three bunchgrass communities that are at risk in the PPxh1 BEC zone and may be appropriate for the site. Finally, an examination of ecosystems at Knox Mountain Park, the nearest intact grassland community, along with knowledge of local ecosystems corroborated the selected reference ecosystems found in my initial search.

I selected reference vegetation communities for the Forecourt Grassland based on site moisture and nutrient regimes: Rough fescue–bluebunch wheatgrass, Big sagebrush–bluebunch wheatgrass–balsamroot, Snowberry-rose-Kentucky bluegrass, and Ponderosa pine – bluebunch wheatgrass – Idaho fescue (Table 6; Appendix E, Table E1). I have included an extension of the Ponderosa pine forests to the north and south of the site to increase the size and quality of those patches for native animal movement throughout the site. Reference wetland associations should be chosen based on the results of salinity and contaminant testing in the ephemeral pool, but a number of potentially appropriate plant communities are listed in Table 6. Suggested revegetation treatments in each area are depicted in Figure 10.

To increase the success of the restoration project within an urban setting, the human use of the landscape was also considered (Zeunert 2013). For this reason, Ponderosa pine forest expansion, xeriscape gardens, and a walking path with signage and a bench are incorporated into the plan to integrate this restoration landscape into the urban and university setting. The Ponderosa forest is a key part of the surrounding UBC Okanagan landscape and supports a variety of birds such as the great horned owl (*Bubo virginianus* J.F. Gemlin), which are enjoyed by local birders. The forest expansion is also included in campus planning documents. The xeriscape garden was designed using native plants typically found within grasslands in the area and the plants were chosen based on their height and colour to create a locally relevant but aesthetically pleasing garden. This garden will provide early establishments of native plants to serve as a seed source on site, as well as a way for people using the trails to observe native plants without wandering off-trail. The walking path will allow human use of the landscape while limiting human impact to the trail. Signage will engage site users and can be an important step in preventative control of noxious weeds on site.

Table 6: Summary of reference community types for use within the project site. All descriptions of communities are from Iverson 2008, except the wetland site associations, which are from MacKenzie and Moran 2004. See Figure 10 for the site design. Locations in bold are new site divisions as shown in Figure 10.

Revegetation area	Reference ecosystem	Rationale
Grassland	Rough fescue – bluebunch wheatgrass (PPxh1 - 01)	Early seral associations for this system include knapweed, cheatgrass, and sulfur cinqfoil, which are present on site in this area. This association occurs on zonal sites, which is appropriate in this region of the site. This association is present on gentle slopes as found on site. These sites typically had pocket gopher digging in them, as is present in the Forecourt Grassland. The alternative association is Bluebunch wheatgrass – balsamroot, but this association was typically found on steep slopes. This alternative may be considered for vegetation recommendations if the recommended system is unsuitable.
Slope	Big sagebrush – bluebunch wheatgrass – balsamroot (IDFxh1 – 92)	This association was found in the driest sites of the IDFxh1 BEC zone. Site visits to the native grassland at Knox Mountain Park in Kelowna indicated that big sagebrush was often present in dry areas of the site even within the PPxh1 BEC zone. It is also commonly seen in dry slopes along road ditches in the central and south Okanagan. This association also generally occurs on steep slopes (BC Conservation Data Centre 2009a). The Big sagebrush/ bluebunch wheatgrass community also occurs on steep slopes between 400 and 600 m in elevation and can be considered as an alternative target system during adaptive management (BC Conservation Data Centre 2009b).
Shrubbery	Snowberry – rose – Kentucky bluegrass (PPxh1 - 00)	This plant community occurs in moist depressions within grasslands. The area for which this is reference already has rose and snowberry growing and is in the toe of the western side of the slope on the Forecourt Grassland's eastern edge, which indicates that this area likely has higher moisture than other regions of the site.
Forest	Ponderosa pine – bluebunch wheatgrass – Idaho fescue (PPxh1 – 00)	This forest association is dominated by ponderosa pine, like the forest fragments already present in the area. Additionally, this forest type is found in areas with shallow slopes. This plant community is similar to that found in other regions of pine forest within the UBC Okanagan campus.

Revegetation area	Reference ecosystem	Rationale
Ephemeral pool	Possible communities from known wetland classifications: Alkali saltgrass (PPxh1/Gs01) – Usually occurs above 1000 m elevation. Only salt-tolerant plants are in this association. No moss or shrubs are present, and sites are usually dominated by *Distichlis spicata* var. *stricta* (L.) Greene (saltgrass), *Hordeum jubatum* L. (foxtail barley). No moss layer is present Nuttall's alkaligrass – foxtail barley (PPxh1/Gs02) – Typically occurs in elevations between 800 and 1200 m, but is rare where it occurs. *Puccinellia nuttalliana* (Schult.) Hitchc. (Nuttall's alkaligrass) is the dominant grass speces, with *Hordeum jubatum* occurring in low densities. No moss layer is present. Field sedge (PPxh1/Gs03) – Rare below 1250 m in elevation. Dominated by *Carex praegracilis* W. Boott (field sedge), and also contains *Juncus balticus* Willd. (Baltic rush), *Poa pratensis* L. (Kentucky bluegrass), and a small moss layer.	

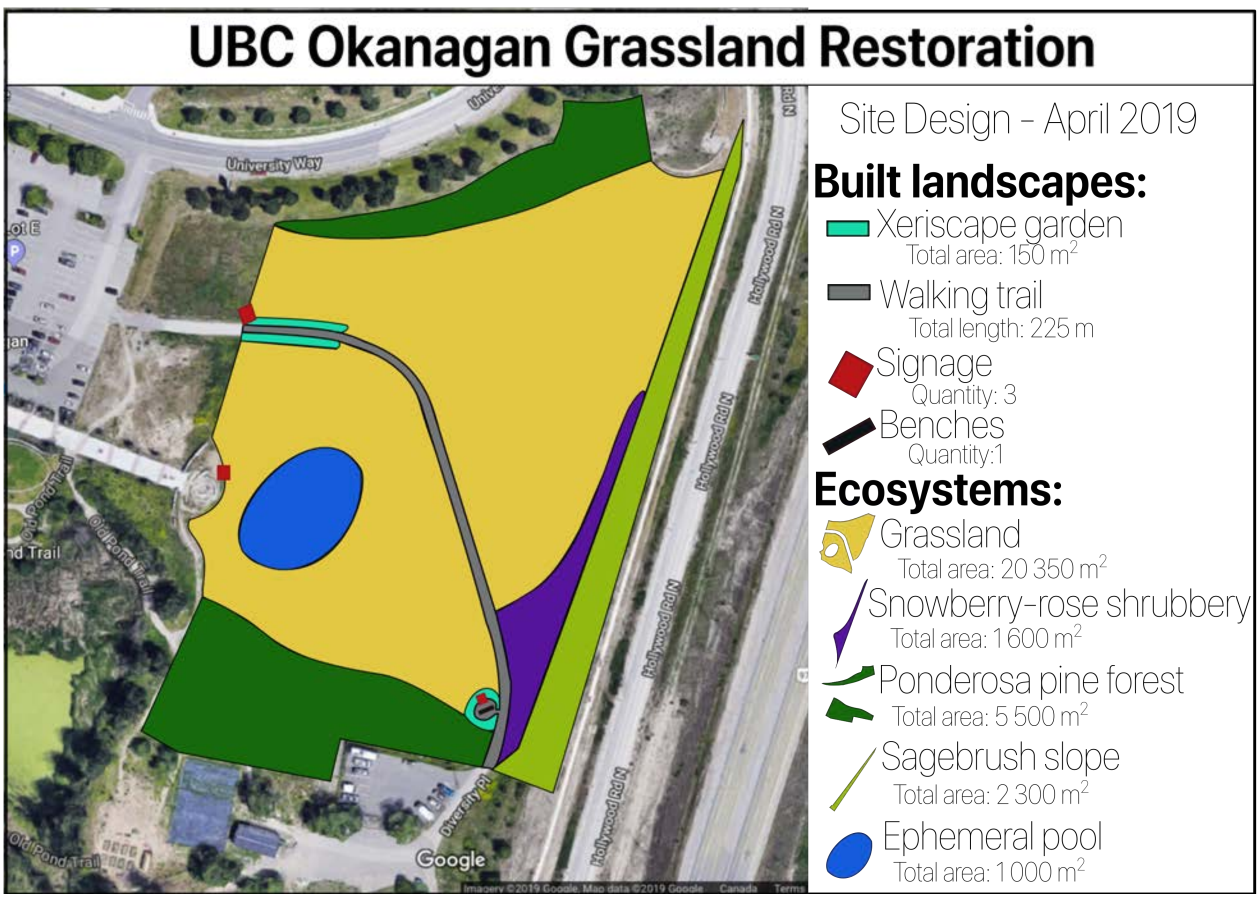

Figure 10: Site design for restoration treatments within the UBC Okanagan Grassland restoration project. Image modified from Google Maps 2019.

In order to determine appropriate vegetation management in the ephemeral pool, both soil salinity measures and complete grass surveys should be conducted. All of the wet meadow associations listed in *Wetlands of British Columbia* (2004) occur at higher elevations than the Forecourt Grassland site, so may not be the best reference systems. However, if any of the typical vegetation from these sites are present, it would help determine what is appropriate vegetation for planting. Grass sampling occurred too late in the season to identify many of the species, and in future should be identified by someone with strong grass identification skills. In particular, sampling earlier in the season and multiple times in the growing season would be best to ensure proper coverage of grass species present. A suitable reference plant community from a nearby low-elevation ephemeral pool should be sought out to aid in planting design.

2.5.2. Restoration techniques

In grassland restoration, there are a number of techniques that have been tested and are dominant in the field. In tallgrass prairie restoration where remnant vegetation is present, practitioners use a mixture of disturbance regimes (fire/mowing/tilling), seeding, and herbicides to restore sites with remnant native vegetation (Rowe 2010). Since the Forecourt Grassland is covered in vegetation and small pockets of native vegetation, the former approach will be applied. Core components of restoration in the Forecourt Grassland include managing noxious weeds on site through targeted removal, herbicide application, and regular mowing, establishing native vegetation on site through a mixture of seeding and planting, and incorporating structural elements to create wildlife habitat.

Extensive records of as-built restoration treatments and follow-up monitoring should be kept and contributed to international databases in an effort to improve the science of ecological restoration. The Society for Ecological Restoration has a project database that should be considered: https://www.ser-rrc.org/project-database/

Restoration of the Forecourt Grassland includes five components: data collection, site preparation (management of non-native plants), test plots, native planting and seeding, monitoring and reporting (Table 7).

Prior to conducting work in and around the ephemeral pool, vegetation and soil sampling should be completed in the first year. This data collection will identify if there is remnant native vegetation within the pool and determine an appropriate reference community. Native seed sources will also be established. In the first two summers, a combination of mowing, tilling, hand-pulling, and herbicide application will be required to manage non-native plants on site (for complete description, see section 2.5.2 – Integrated Pest Management; Table 7). Site preparation should also include the installation of the xeriscape garden to establish a native seed source. At the same time, one test plot for each vegetation area will be implemented in the first year and monitored for one growing season. The results of these test plots will identify if any modifications to the design are necessary prior to fall plantings in year two. Next, the full planting and seeding treatments will be applied to all areas of the site in the fall of the second year. Lastly, after all restoration actions are complete follow-up monitoring of restoration success, management of restoration goals and implementation, and proper documentation of the project and outcomes will be completed (see sections 2.7-2.9).

Table 7: Timing of restoraiton treatments within the Forecourt Grassland restoration project

Year	Restoration treatments
1 (May 2019 – May 2020)	1. Set up test plots 2. Establish growing contract with local nursery (ideally should be established in March) 3. Collect data on ephemeral pool water quality 4. Weed, mulch, and flag native plant patch in shrubbery 5. Install xeriscape garden 6. Apply select herbicides where appropriate 7. Mow/ weed-whack site to prevent seed set
2 (May 2020 – May 2021)	1. Monitor test plots and modify vegetation plan as necessary 2. Design ephemeral pool plantings/treatments 3. Mow/ weed-whack site to prevent seed set 4. Hand-pull and till noxious weeds in the fall immediately prior to planting and seeding 5. Deactivate road and install walking path 6. Plant and seed native vegetation in the fall (September/October) 7. Monitor restoration outcomes

2.5.3. Part 1: Pre-restoration data collection – ephemeral pool and shrubbery

Additional sampling

To determine appropriate reference vegetation and conditions as well as inform habitat creation for wildlife in the ephemeral pool, water, vegetation, and soil sampling should be conducted. Water sampling should include conductivity, dissolved oxygen, temperature, wetted extent, and contaminants. Vegetation sampling should occur multiple times in the growing season (spring, summer, fall) in order to capture the full suite of plants in the area. Additionally, plant identification should be completed by a qualified professional, particularly someone who can identify grasses. Lastly soil sampling should occur once the pond has dried and soil salinity and contamination should be assessed. These three variables will inform appropriate reference vegetation communities to implement in the planting plan for this region of the Forecourt Grassland. Sampling locations for soil and vegetation can follow the same sampling regime used in my initial site assessment. The location of water quality sampling will be determined based on the depth of the pool at the time of sampling.

In order to monitor changes in soil chemistry and vegetation within the shrubbery section of the site, baseline data collection should occur. Methodologies should follow those used to collect data for site assessment (Chapter 1 section 1.3). Since the site is a similar size to the slope, five sampling locations can be used. Additionally, pre-restoration insect surveys should take place using the methodologies described in 2.6.2.

Plant propagule and seedling collection

To ensure affordability and increase restoration success, a number of native plant collection methods could be employed. To increase affordability, seed collection by the university instead of by local nurseries could reduce cost. A UBC Alumna, Tanis Gieselman, has started a seed collection company (SeedsCo) in the Okanagan to collect native seeds for restoration. She often collects seeds from sites slotted for construction that will eliminate local vegetation. Seed collection could occur as part of a summer plant course (BIOL 371 – Flora of British Columbia) in partnership with Ms. Gieselman in order to incorporate a learning opportunity for students and contribute to the project.

These collected seeds can be provided to the local nurseries to supplement their stock being developed for the project, or they can be used to grow native plants on site (see DiCarlo and Debano 2019). In addition to collecting seeds, it would be beneficial to look for local sources of mature plants that could be transplanted onto the project site from development areas that will demolish the plants. Using native transplants from local areas ensures other propagules for native plants that are in the soil can be transplanted to the Forecourt Grassland in addition to the planted species and potentially steer restoration towards native plant communities and increase biodiversity on site (Wubs et al. 2016, Given 1994). Finally, it is necessary to notify plant nurseries two years in advance of the project of the required plants so that they have adequate lead time to collect and grow local ecotypes of all desired plants (D. Mahoney pers. comm. 2019).

2.5.4. Part 2: Site preparation

Site preparation includes three components: management of non-native and noxious plants, soil preparation, and road deactivation. Noxious plant management focuses on the dominant noxious weeds within the site following best management practices and minimizing herbicide application to reduce cost and impact to ecosystems. Soil preparation will differ in each region of the Forecourt Grassland, but the focus will be on minimizing disturbance to existing burrow networks and small mammals. Burrows on site should be preserved as best as possible because they make up part of the natural topographic heterogeneity that is normal in grassland sites and provide habitat for the great basin spadefoot toad (del Moral et al. 2007; Environment and Climate Change Canada 2017, Southern Interior Reptile and Amphibian Working Group 2017). Maintaining and increasing site heterogeneity while conducting site preparation will increase seedling protection and thus the chances of seedling survival and establishment during planting (del Moral et al. 2007).

Noxious Weed and Non-native species management

The Forecourt Grassland contains at least 37 exotic species, and 21 locally or provincially-listed noxious weeds. Priority noxious weeds should be targeted for management as part of site preparation. Treatment recommendations have been provided for the most abundant species, and many other treatments for species can be found in the *Guide to Weeds in British Columbia* (https://www.for.gov.bc.ca/hra/plants/weedsbc/GuidetoWeeds.pdf). Additionally, 3 exotic plant species that are not listed as noxious but have a large distribution on the site (were identified within the non-native plant survey; Chapter 1: Figure 8) should be prioritized for management. Current best practices for each species are presented below, but further information can be found through the Invasive Species Council of British Columbia and the Regional District of the Central Okanagan.

Non-native species onsite can provide a persistent plant community if not treated (Tognetti and Chaneton 2012), so in addition to species-specific management techniques, mowing in combination with native plantings will be used to displace non-native species. Mowing is a common treatment for exotic plants as it prevents seed set and can reduce energy reserves in the plants; but, for a number of species, continued mowing is insufficient to eliminate the plants (British Columbia Ministry of Agriculture, Food, and Fisheries 2002). Trials with crested wheatgrass (*Agropyron cristatum*), which is present onsite, indicated that clipping combined with native seeding reduced *A. cristatum* cover faster than herbicide treatment and contributed to increased native plant abundance (Wilson and Pärtel 2003). Mowing has also contributed to increased native forb diversity in prairie restoration (Socher et al. 2012), increased grass diversity in Australian grasslands (Smith et al. 2017), and is commonly used in grassland restoration (Guo et al. 2018).

Integrated Pest Management

Due to the extensive and diverse nature of non-native and noxious plants within the site, it is recommended that an integrated pest management approach (prevention, early detection/education, and prioritized management) is used. First, prevention may be addressed by incorporating signage and education days on campus to educate students, staff, and faculty about target noxious weeds to watch for and report to aid with early detection (Invasive Species Council of BC [ISCBC] 2014a). Next, ensuring that landscapers and contractors working within UBC Okanagan are aware of local bylaws and target noxious weeds/non-native plants can prevent the spread of non-native plants, particularly by ensuring local mulch that may be used onsite is not contaminated (ISCBC 2014a). Next, the mapped and identified non-native plant species within the project site should be prioritized: those that are just establishing are highest priority for removal, the somewhat established species as mid-priority, and the most established plants as lowest priority (ISCBC 2014a). Priority must also be determined by the ecology and impact of each species (ISCBC 2014a). Ideally, given the small size of the site, all plants will be targeted as priority simultaneously. Monitoring of non-native plant re-entry and growth in the site, an essential step in managing noxious plant populations (ISCBC 2014a), could be managed by local clubs, classes, and naturalists to help reduce costs and promote local involvement in the project.

Treatments done within the project boundaries should be coordinated with similar efforts in adjacent weedy areas on campus (Figure 11) to ensure outside populations are removed as sources. The target level of non-native plant cover within the site is < 10 % because this was the cut-off value for the native grassland ecosystems found in the 2003 Sensitive Ecosystems Inventory for Kelowna using Terrestrial Ecosystem Mapping protocols (Iverson et al. 2004). Sites that had more than 10 % weed cover were considered early to late seral associations for the grassland ecosystems (Iverson et al. 2004). UBC Okanagan should work with the City of Kelowna or Invasive Species Council of British Columbia to develop Best Management Practices to manage non-native and potentially invasive plant populations within all of the campus to ensure a coordinated effort. In all cases, mowing or removal treatments must occur prior to seed set to avoid further distribution of seeds on and off the site.

For some species, herbicides are recommended in the literature instead of hand pulling and digging in order to quickly and efficiently eliminate the plants from the site. However, the effects of herbicides on the environment and toxicity to animals is currently a significant research focus, and there are concerns regarding synergistic effects of multiple pesticide compounds present in ecosystem as well as uncertainty on the effect of some herbicides in the context of the environment (Choudri et al. 2018). Caution should be used in deciding to use herbicides in a site in such close proximity to wetlands and manual control methods should be prioritized within the Forecourt Grassland.

Figure 11: Priority weedy areas to target for non-native plant management in conjunction with the project area. The blue polygon is the project site, red is high priority due to proximity to site and orange is lower priority. Map created with iMapBC, by Sarah Bird on February 15th, 2019.

Siberian elm management

Siberian elm (*Ulmus pumila* L.) is located along the southern edge of the site, particularly along the chain-link fence separating the site from a parking lot (Appendix F, Figure F1). The tree is also present along the eastern slope. At least 20 small trees were found, along with sprouted regrowth along the chain-link fence (Chapter 1, Figure 8). This tree is recommended as a high priority for management as there are few trees, and they are small. A number of the trees are on a slope that would be inaccessible by large machinery and should be managed using mechanical means as early as possible before they get large enough to be difficult to remove safely.

Siberian elm is a deciduous tree native to Asia, that will invade disturbed areas quickly so careful consideration must be applied to management practices (United States Department of Agriculture [USDA] 2014). The tree has the ability to re-sprout after damage to the trunk occurs and proper elimination requires destruction of the root system, so they cannot simply be removed by cutting down the trees (USDA 2014). A number of mechanical or combined mechanical and chemical controls are available for this plant but complete removal can take up to 5-10 years in severe cases (USDA 2014). The simplest recommendation for light infestations is to cut the stump and apply glyphosate on the cut stump as per herbicide instructions and USDA cut-stump procedures (USDA 2014).

Ideally, elimination of this species would occur prior to site restoration to reduce the chance of re-invasion in the newly disturbed site. Since Siberian elm is shade intolerant the establishment of a native canopy can help prevent regrowth and can be used as a prevention strategy after elimination (USDA 2014). However, multi-year monitoring after treatment should be applied to ensure the population does not re-establish (USDA 2014).

Baby's breath management

Baby's breath (*Gypsophila paniculata*) was found on the northeastern and centrally eastern sections of the project site, with only six occurrences recorded (Chapter 1, Figure 8). Its low population size and listing as noxious weed indicate that it is a high priority for removal to prevent further infestation of the site (Regional District of the Central Okanagan 1979). This plant reproduces by seed alone and creates a very deep tap root (Alberta Invasive Species Council [AISC] 2014a). To mechanically remove the plant, the root crown 2-3 cm below the soil surface must be cut to prevent regrowth (AISC 2014a). Mechanical removal should be completed before seed set each year and on young plants to decrease the effort required for removal. Mature plants can produce taproots with a diameter of 13 cm and depth of 4 m into the soil (Siekierska 2014).

Burdock management

A small patch of burdock (*Arctium* sp.) was found on the southwestern edge of the site (Chapter 1, Figure 8). The small population of this plant and its status as regionally noxious make it a high priority for control (Regional District of the Central

Okanagan 1979). Like baby's breath, this plant produces a large taproot (AISC 2014b). To control the plant mechanically, individual plants can be dug up or root systems tilled, with efforts to remove as much of the root as possible (AISC 2014b, Invasive Species Council of BC n.d.). Interim control to prevent seed set and population growth involves mowing prior to seed set (Invasive Species Council of BC n.d.). Herbicides should be considered as a last resort, and follow-up inspections are required to ensure the roots systems were adequately destroyed.

Canada thistle management

Canada thistle (*Circium arvense*) has been found near the ephemeral pool and along the southwestern edge of the property. This plant is a high priority due to its noxious status and small coverage of the site (Regional District of the Central Okanagan 1979). Due to reproduction via vegetative growth from horizontal roots and regeneration from root fragments, this plant can be difficult to eradicate (Scott and Robbins 1999). Mowing of the plants annually can help deplete the energy stores in the roots but may not fully eliminate the plant (Scott and Robbins 1999, Invasive Species Council of BC 2014b). As a result, the recommended method of eradication is pulling or cutting, with spot herbicide application as a last resort (Scott and Robbins 1999). Biocontrol is no longer recommended as they may impact native thistle species (AISC 2014c).

Prickly lettuce management

Prickly lettuce (*Lattuca serriola*) is found on the southwestern and north-central regions of the project site. This Eurasian weed is an annual that reproduces by seeds alone (Weaver and Downs 2003). These seed banks are short term (1-3 years), so follow-up monitoring is only necessary for three years to assess the effectiveness of the treatment (Weaver and Downs 2003). After three years, monitoring can aid in prevention of re-establishment or re-invasion. The plant has deep taproots but cannot regenerate from root fragments, so the most effective management is hand pulling with a focus on digging the taproots, or tillage to destroy the roots (Weaver and Downs 2003). Given the size of the population on the project site, tillage seems the more appropriate option, and should be combined with seeding or planting native grasses to prevent colonization by other weedy plants. Tilling must occur prior to seed set to prevent further seed distribution across the site. If tillage is not possible, a number of herbicides are effective against prickly lettuce when it is in rosette form (Weaver and Downs 2003). In areas where prickly lettuce is intermixed with any non-native species that reproduces by root fragments, tillage should be avoided and instead the plants should be hand pulled.

Russian/Diffuse Knapweed management

Russian knapweed (*Acrptilion repens*) and diffuse knapweed (*Centauria diffusa*) are found on the northeastern edge of the site. Slightly different long-term management is required for each species due to their different reproductive strategies: diffuse knapweed reproduces by seed only (Invasive Species council of BC [ISCBC] 2014c), Russian knapweed can reproduce from buds on lateral roots and seed (Scott and Robbins 2005). Mowing prior to seed set is recommended for both species to prevent the development of a local seedbank (ISCBC 2014c; Scott and Robbins 2005). Annual monitoring for regrowth is required due to long-lasting seedbanks (ISCBC 2014c; Scott and Robbins 2005). Pulling or digging the root system of small populations of diffuse knapweed is recommended as a control method due to the small population on site (Scott and Robins 2005). In some cases Picloram has been recommended to treat Russian knapweed through spot application with annual monitoring and re-application as necessary (Saskatchewan Invasive Species Council 2013, Ortega & Pearson 2011). However, this should be avoided on site due to Picloram's persistence in and dispersal through soil, into aquatic systems, and toxic effects on aquatic wildlife (Fairchild et al. 2008, Woodward 1976), particularly given the nearby wetlands. Instead, manual removal of Russian knapweed should be applied.

Sysimbrium management

Tumble mustard (*Sysimbrium* spp.) is distributed across the site with dense concentrations in the southwestern quadrant of the site. This species is an annual species that only reproduces by seed, with each plant capable of producing a million seeds, and viable seeds remaining in the seedbank for decades (Howard 2003). It is essential that seed production is prevented (Howard 2003). Development of functioning native ecosystems can help preclude tumble-mustard from the environment (Howard 2003). Hand pulling of rosettes or application of herbicides are potential treatments (Howard 2003) and mowing of bolts prior to seed set should be used to prevent seed proliferation.

Hoary Cress management

Hoary cress (*Cardaria draba*) is found along the northeastern, and central-eastern areas of the Forecourt Grassland, mostly as a large monoculture. This plant is capable of reproducing by seed and vegetatively through its roots (Province of British Columbia 2002; Zouhar 2004). Mowing regularly is recommended to prevent seed production, but herbicides such as glyphosate are commonly used for control as manual control can propagate the plant (Province of British Columbia 2002; Zouhar 2004). Seeding with grasses is recommended to take place in conjunction with mowing and herbicide treatments for best chance of success in eradication (Province of British Columbia 2002; Zouhar 2004). A review of some common herbicides and their effects can be found in *A guide to Weeds of British Columbia* (Province of British Columbia) and in Zouhar, 2004.

Sulfur cinqfoil management

Sulfur cinqfoil (*Potentilla recta*) is widely distributed across the site. It is listed as noxious under three different pieces of legislation (City of Kelowna 1997; Regional District of the Central Okanagan 1979; British Columbia Weed Control Act: Weed Control Regulation 2011). This plant reproduces by seed and from the sprouting of buds from lateral roots (DiTomaso et al. 2013). Mowing is not recommended due to its stimulation of lateral growth (DiTomaso et al. 2013) but can help prevent the development of a seedbank until long-term controls are in place (United States Department of Agriculture 2007; Scott 1999). Herbicide is the recommended treatment for larger invasions because manual controls such as tillage are only effective in cropland where they are repeated annually (Scott 1999; King County Noxious Weed Control Program 2005).

Given that this plant is intimately interspersed with other non-native plants that do require mowing, I recommend annual mowing until treatments can be applied. If at all possible hand-pulling with removal of the root crown should be attempted before herbicide application. Hand-pulling is usually recommended for small populations (DiTomaso et al. 2013; United States Department of Agriculture 2007). Picloram (applied in the fall) is the most effective treatment for reducing sulfur cinqfoil cover and a single treatment can control recovery for at least three years (see Endress et al. 2008 for application rates and methods). Since Picloram can affect other forbs and last in the soil to affect seed germination for 3 years, if used it should be applied between 3 and 4 years prior to seeding and planting to ensure native forbs can germinate and grow during the restoration phase (Rinella et al. 2009). Exotic forbs can re-colonize treated areas 4 years after application, so native seeding and planting should occur between Picloram application and year 3 (Rinella et al. 2009). However, as previously identified, Picloram application can pose environmental risks to wetlands, and should be avoided if possible.

Soil preparation

The soil in the Forecourt Grassland requires minimal preparation prior to planting. It is quite fine – textured and has appropriate levels of nutrients. If plantings on the slope do poorly, fertilization may be required in the first year to counteract low phosphorus levels. Minimal soil tillage should occur in order to preserve existing burrows on site and minimize the effect of restoration actions on local mammal populations. In the locations at the north and south ends of the road through the site that will be planted with a xeriscape garden, the soil should be tilled in the areas where it will not propagate exotic plants found on site. Additionally, a watering system should be set up in each patch of the xeriscape gardens.

Road deactivation and trail building

The site design includes deactivating the road and converting part of it to a walking path. In this way, other areas of the site do not need to be disturbed to create a walking path, vehicle traffic within the site will be eliminated, which can reduce non-native plant re-invasion, and students, staff, and faculty from the campus can use the site for recreation. The first step in road deactivation is removal of the road surface. Once the road surface has been removed an assessment of the soil quality should be done to determine if soil amendments should be used in addition to scarifying the soil with the bulldozer to decrease compaction. Additionally, depending on the types of materials present blow the road surface, crushed rock may be added to the section of road to become the walking trails, and this material should be certified weed free.

Summary

The recommended site preparations are provided in Table 8. Site preparation includes managing priority non-native plants, isolating native plants, removing metal and wood debris on the site, and setting up the walking path and xeriscape garden.

Table 8: Summary of site preparation management actions for the project site and their associated timeline.

Action	Date
For the native plant patch on site: flag the perimeter, weed, and mulch	Early May 2019
Cut down existing Siberian elm trees and paint stems with glyphosate	May 2019
Mow field but avoid native plant patch	Mid-May 2019
Apply herbicide treatments to Canada thistle, Russian knapweed, sulphur cinqfoil, and tumble-mustard if being used	June 2019
Mow field but avoid native plant patch	Mid-July 2019
Mow field but avoid native plant patch	Mid-September 2019
Remove road surface from the existing road and sample soil	Early May 2020
Build local path and install bench and signage	May 2020
Dig up root system of baby's breath and burdock	Immediately prior to planting (October 2020)
Till soil in areas where prickly lettuce and/or sulfur cinqfoil are present	Immediately prior to planting (October 2020)
Till half of the deactivated road surface to prepare it for planting.	Immediately prior to planting (October 2020)

2.5.5. Part 3: Test plots and Xeriscape gardens

Test Plots

While noxious weeds are being managed in the first year, test plots in each planting area should also be set up to test survival and establishment of the chosen plants at a small scale before full implementation, in order to increase the chances of restoration success (del Moral et al. 2007). By monitoring plant survival and recruitment in the test plots, plants with low survival can be replaced with those with high survival, or the techniques applied at a large scale could be modified to increase the survival of the plantings. Each test plot should be 5 m in diameter and will be planted according to the proposed planting plans and methodologies for each section. These initial plots will also determine if irrigation needs to be included in the plan for each area.

To prepare the planting area, any noxious weeds that require hand-digging will be dug up, and the remaining plants will be clipped to the ground. Any seed-free vegetation can be left on site to increase heterogeneity for seed germination. After planting, the exact planting used on the site should be recorded, along with percent cover for all plants. Three soil samples within the plots should be taken to measure nitrogen, phosphorus, carbon, and pH. Additionally, measurements of species identity and percent cover of all plants in the plots should be taken in year two. Four samples measuring plant percent cover at an additional 1 m radius outside the test plot can measure the spread of plants away from the plot. The test plots should be established as early as possible – in the fall of the first year of noxious plant control would be ideal. The test plots can then be monitored for one growing seasons and adjustments could be made to the planting plan as necessary based on this information.

Xeriscape garden

The xeriscape garden will be 1.5 m wide along the first 25 m of the walking trail from the North end (Figure 10). There will be an additional 1.5-meter-wide xeriscape garden around the seating area at the south end of the walking path. These two patches of maintained native plants provide two benefits: they allow the site users to view native plants up close without needing to wander through the site and will create an Okanagan aesthetic while the natural grassland develops, and these pockets will be additional sources of native seed for the site.

The native plants in this xeriscape garden will highlight native plants found in the landscape and follow the UBC Okanagan design guidelines. Plants will include: bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) Á. Löve), Idaho fescue (*Festuca idahoensis* Elmer), brown-eyed Susan (*Gaillardia aristata* Pursh), silky-lupine (*Lupinus sericius* Pursh), sulphur-flowered buckwheat (*Eriogonum umbellatum* Torr.), and spreading phlox (*Phlox diffusa* Benth.; Table 9, Figure 12). The planting density and arrangement is based off of the mature spread of each plant, as well as colour and heigh variations that will contribute to an aesthetically pleasing garden.

To prepare the bed, compost will be tilled into the soil, and an underground drip irrigation system will be installed. Then all plants will be installed as 4-inch plugs, except the bluebunch wheatgrass, which will be 1 gallon plants and the area will be mulched with two inches of mulch to retain moisture. The garden should be established in the first year of noxious weed management to provide food for pollinators that may be eliminated through the control of noxious weeds (Guo et al. 2018).

Table 9: Planting requirements for the Xeriscape Garden

Common name	Scientific name	Planting density (plants/m^2)	Total area	Total plants	Size
Bluebunch wheatgrass	*Pseudoroegneria spicata*	1.3	150 m^2	200	1 gallon
Idaho fescue	*Festuca idahoensis*	0.67		100	1 gallon
Silky lupine	*Lupinus sericius*	0.67		100	4 inch
Brown-eyed-susan	*Gaillardia aristata*	0.67		100	4 inch
Sulfur-flowered buckwheat	*Eriogonum umbellatum*	0.67		100	4 inch
Spreading phlox	*Phlox diffusa*	1.3		200	4 inch

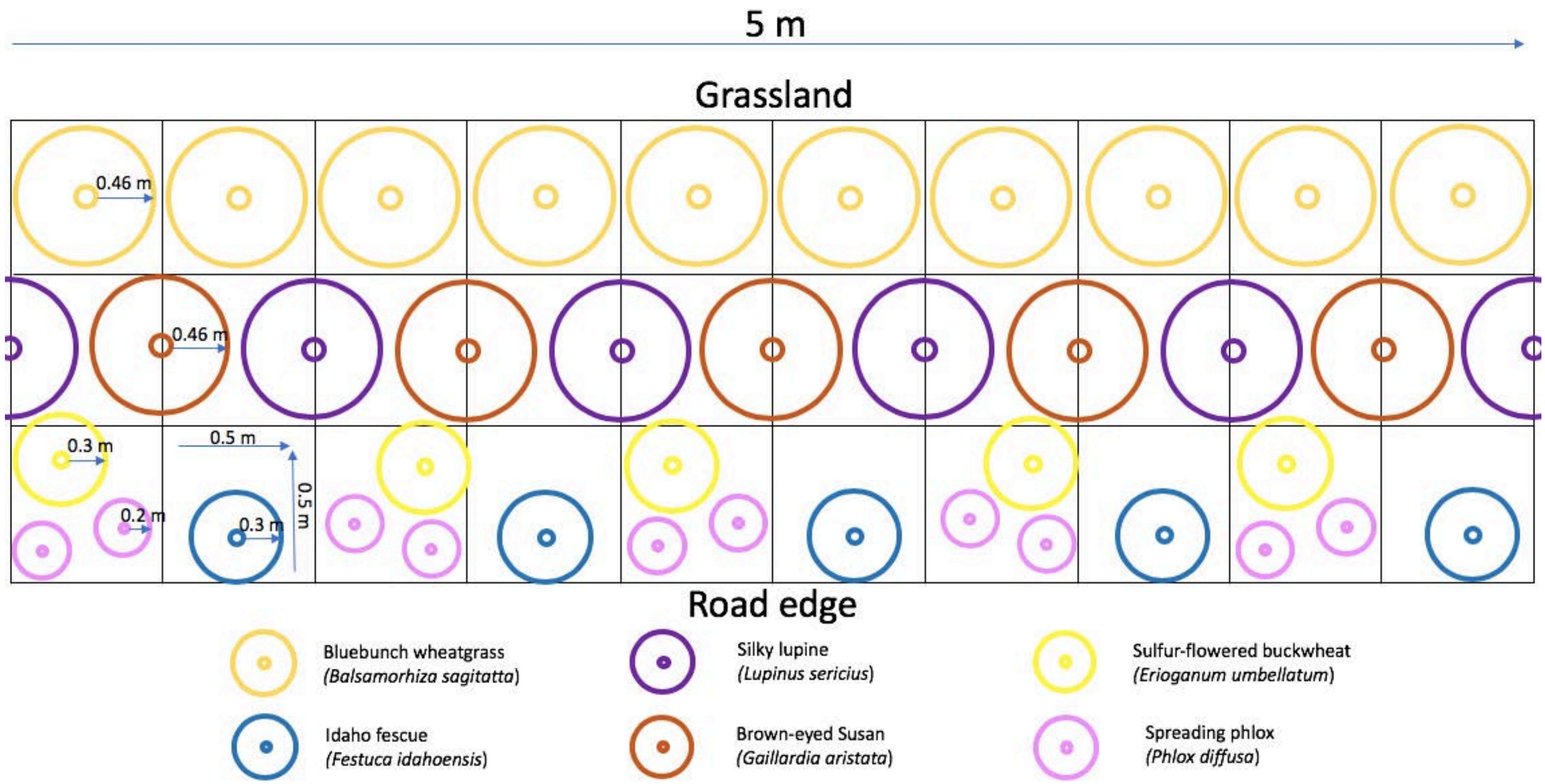

Figure 12: Planting layout for the proposed xeriscape garden to border the walking path. Total area is 150 m2 of garden.

2.5.6. Part 4: Planting and seeding

The planting plans for each section are included in detail below. In general, the relative abundance of plants selected in all planting plans are based off the relative abundance of the plants in the native reference system (Appendix E, Table E1). The planting density was determined by maintaining a total plant density below the recommended 1 plant per m^2 for shrubs and trees from the Riparian Restoration Guidelines for British Columbia (BC Ministry of Environment 2008). I recommended using less than the recommended density because both planting and seeding will take place. A combination of seeding and planting mature plants will be used increase the likelihood of planting success (Given 1994). Using both seeding and planting can increase success by accounting for rodent consumption of seeds, increased variation in life stage of planted plants, and early establishment of seeding plants to provide continued seeding of the site with desired plants after the first year (Given 1994). Additionally, by planting in small islands the plant pockets can act as nurse plants and improve the establishment of seeds and seedlings within the Forecourt Grassland (Given 1994).

The Forecourt Grassland is divided into four planting zones with different planting treatments: ponderosa forest, bunchgrass grassland, shrubby depression, and sagebrush slope (Figure 10, section 2.5.1). Additionally, a walking path will be present along the old road dividing the site to minimize its division of the landscape while still providing students an opportunity to move through it (Figure 10). At the south end of the walking path, a small seating area with a bench and signage will be incorporated as a rest stop. The xeriscape garden will surround the rest area to give visitors an up-close view of native plants. Another section of xeriscape garden will be present at the northern end of the trail to welcome visitors into the landscape

Three signs will also be present to incorporate education and non-native species management in the landscape. At the gathering circle to the west of the site, a large sign will be placed discussing the ecology of bunchgrass ecosystems, as well as the restoration project. Near the bench and at the northern end of the trail, a sign will be placed showing non-native plants to look out for and identification features, as well as contact information for how to report occurrences of non-native plants within the grassland and along the path. The sign by the bench can also include information regarding harvesting and using local native plants.

Planting and seeding densities will be applied at a lower rate than either would be applied alone, to account for both methods being used in combination. In the main grassland area, broadcast seeding will be applied by hand to avoid damage to the biological crust that may be present in some areas of the site. Drill seeding is not feasible in the Forecourt Grassland due to constraints in the landform. The shrubbery seeds will have to be broadcast by hand due to landform constraints and manually raked to improve seed-soil contact (Barr et al. 2017). The slope will be hydroseeded to mitigate erosion issues once non-native vegetation has been removed.

High seed mix diversity and density of seeding has contributed to high restoration success (Barr et al. 2017), so the seed mixes for each planting region will have a diversity of grassland functional groups present (see Barr et al. 2017). Seeding and planting will occur in the fall to improve seed germination and planting success (Page and Bork 2005; Larson et al. 2017; Rowe 2010). Seed application rates are a trial rate, since this combined methodology is not widely reported in the literature. I am proposing a rate of 600 pure live seed per m^2. Grassland restoration in similar landscapes identified a range of 300- 600 seeds/m^2 as ideal for multi-year seedings (Wilson 2015), which is most similar to the proposed restoration technique. On-the-ground application of the seeds will determine how closely that seeding rate can be achieved (due to physical application constraints for broadcast seeding), and additional seed should be purchased to ensure adequate coverage (Orion Kendrick, Sagebrush Nursery, pers. comm. 2019). Prairie restoration and other research projects used a range of 1366 – 8000 viable seeds/m^2 or 11.2 kg/ha (Barr et al. 2017; Rowe 2010; Tognetti and Chaneton 2012).

Ponderosa Forest

The ponderosa forest will mimic the native ponderosa forest found in the north end of campus, highlighting native shrubs and understory vegetations such as: saskatoon (*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roem), redstem cenothus (*Ceanothus sanguineus* Pursh), snowberry (*Symphoricarpos albus* (L.) S.F. Blake), Idaho fescue

(*Festuca idahoensis*), bluebunch wheatgrass (*Pseudoroegneria spicata*), wild strawberry (*Fragaria virginiana* Duchesne), balsamroot (*Balsamorhiza sagittata* (Pursh) Nutt.), and yarrow (*Achillea millefolium* L.; Table 10, Table 11, Figure 13). Thirty mature trees at least 3 m in height will be planted in the regions to the north and south of the project site to increase the size of the ponderosa pine patches in this area of campus. The shrubs will be planted in bunches as opposed to even spacing to more effectively use a limited supply of plants and to meet the wildfire plan guidelines. The area will be broadcast seeded with native grass and forb seeds to help develop the understory. The development of pine forest at the south end of the Forecourt Grassland will also shade out Siberian Elm re-invasion in this area.

Table 10: Planting requirements for the Ponderosa Pine area.

Common name	Scientific name	Planting density (plants/m^2)	Total area	Qty	Size
Ponderosa pine	*Pinus pondersoa*	0.01		30	3 meters tall
Saskatoon	*Amelanchier alnifolia*	0.125		700	1 gallon
Redstem ceanothus	*Ceanothus sanguineus*	0.125		700	1 gallon
Snowberry	*Symphoricarpos albus*	0.125	5500 m^2	700	1 gallon
Oregon grape	*Berberis aquifolium*	0.125		700	1 gallon
Arrowleaf balsamroot	*Balsamorhiza sagittata*	0.25		1400	4 inch
Wild strawberry	*Fragaria virginiana*	0.25		1400	4 inch
Yarrow	*Achillea millefolium*	0.25		1400	4 inch
Pussytoes	*Antennaria* sp.	0.25		1400	4 inch
			Total	8430	

Table 11:Seed mix and seeding density for the Pondersoa Pine area with a total seeding rate of 600 seeds per square meter.

Common name	Scientific name	Proportion	Total area	Total PLS
Bluebunch wheatgrass	*Pseudoroegneria spicata*	20 %		660 000
Idaho fescue	*Festuca idahoensis*	50 %		1 650 000
Junegrass	*Koeleria macrantha*	10 %	5500 m^2	330 000
Saskatoon	*Amelanchier alnifolia*	5 %		165 000
Redstem ceanothus	*Ceanothus sanguineus*	5 %		165 000
Snowberry	*Symphoricarpos albus*	5 %		165 000
Oregon grape	*Berberis aquifolium*	5 %		165 000

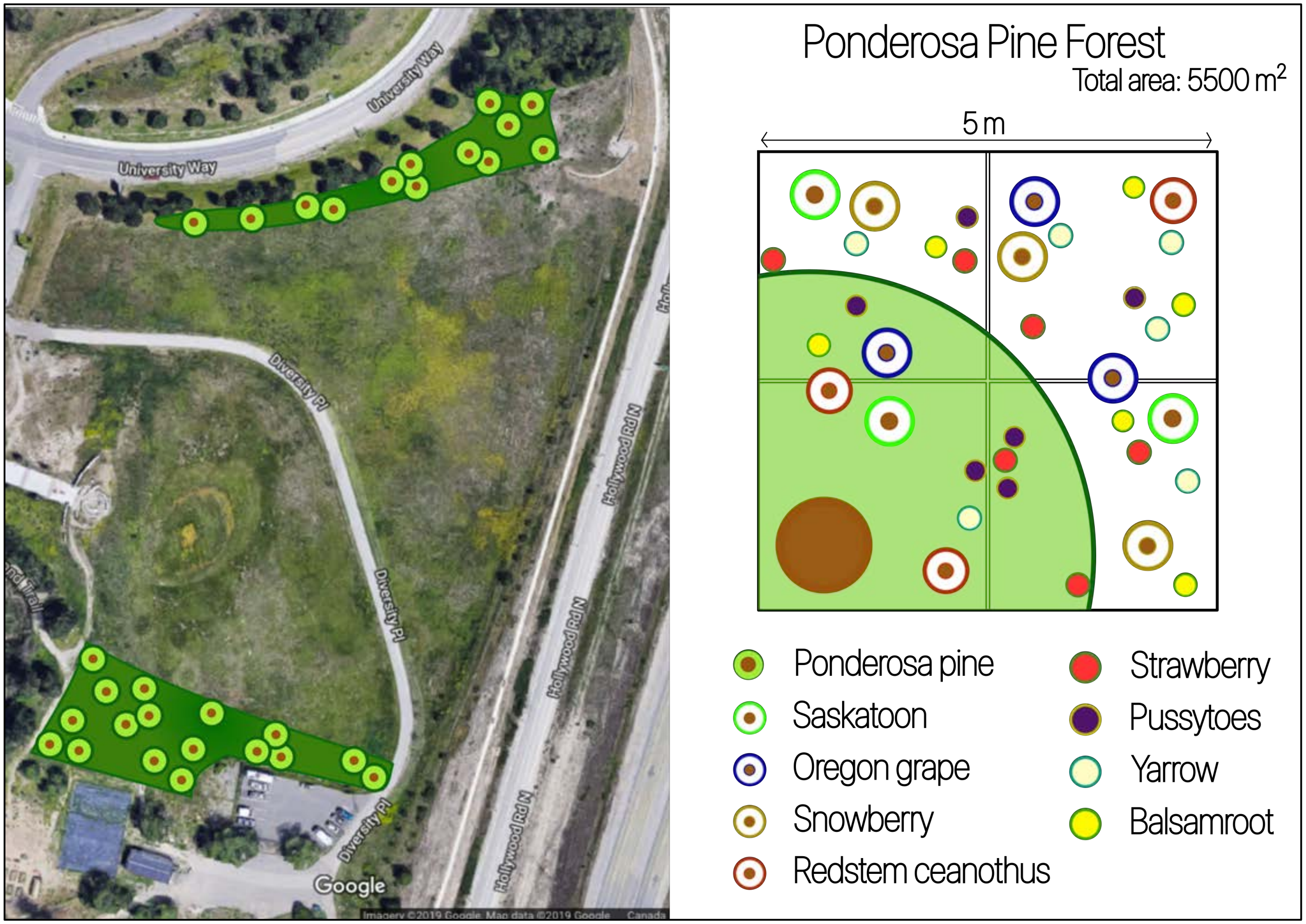

Figure 13: Proposed planting layout for the Ponderosa Pine Forest areas within the Forecourt Grassland revegetation plan. Planting zones shown by the green polygons and proposed approximate tree locations are shown by the green circles with a brown centre.

Sagebrush slope

The sagebrush slope will be based on the Big sagebrush – Bluebunch Wheatgrass – Balsamroot ecosystem association, because of the dry conditions on the slope. As indicated by the ecosystem association name, bluebunch wheatgrass (*Pseudoroegneria spicata*) and sagebrush (*Artemesia tridentata* Nutt.) are the dominant plants, with arrowleaf balsamroot (*Balsamorhiza sagittata*) and needle-and-thread grass (*Hesperostipa comata* (Trin. & Rupr.) Barkworth) as less-common species. The site will be sparsely planted with one-gallon plants of each bluebunch wheatgrass and sagebrush, and then hydroseeded with a grass and shrub mix. Some small forbs (balsamroot, parsnip-flowered buckwheat [*Eriogonum heracleoides* Nutt.], and silky lupine [*Lupinus sericius* Pursh]) will be planted as well (Table 12, Table 13, Figure 14).

Table 12: Planting requirements for the Sagebrush slope planting area.

Common name	Scientific name	Planting density (plants/m^2)	Total area	Qty	Size
Bluebunch wheatgrass	*Pseudoroegneria spicata*	0.125		300	1 gallon
Big sagebrush	*Artemesia tridentata*	0.125		300	1 gallon
Arrowleaf balsamroot	*Balsamorhiza sagittata*	0.125	2300 m^2	300	4 inch
Parsnip-flowered buckwheat	*Symphoricarpos albus*	0.125		300	4 inch
Silky lupine	*Lupinus sericius*	0.125		300	4 inch
	Total	0.63	Total	1500	

Table 13: Seed mix and seeding density for the sagebrush slope area with a total seeding rate of 600 seeds per square meter.

Common name	Scientific name	Proportion	Total area	Total PLS
Bluebunch wheatgrass	*Pseudoroegneria spicata*	40 %		550 000
Big sagebrush	*Artemesia tridentata*	40 %	2300 m^2	550 000
Needle-and-thread grass	*Hesperostipa comata*	10 %		140 000
Arrowleaf balsamroot	*Balsamorhiza sagittata*	10 %		140 000

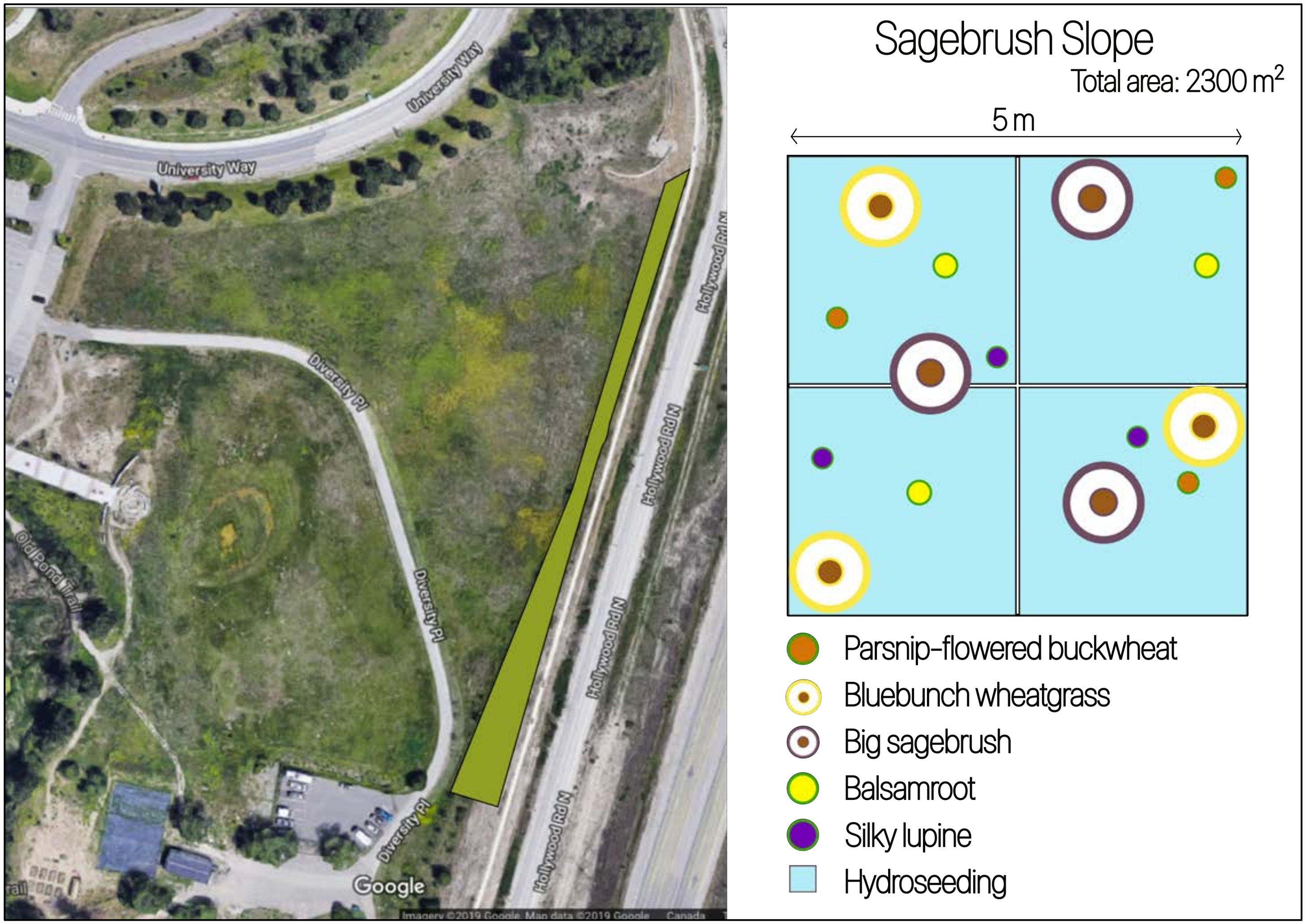

Figure 14: Proposed planting layout for the Sagebrush Slope area within the Forecourt Grassland revegetation plan. The planting area is shown by the green polygon.

The Snowberry-Rose Shrubbery

Along the western edge of the slope, rose and snowberry already grow in a small pocket. This pocket will have been weeded and mulched prior to planting. The area surrounding the pocket will be planted with a mix of snowberry (*Symphoricarpos albus* (L.) S.F. Blake), Nootka's rose (*Rosa nutkana* C. Presl), prickly rose (*Rosa acicularis* Lindl.), tall Oregon grape (*Berberis aquifolium* Pursh), and some grasses as per the snowberry-rose-Kentucky bluegrass reference ecosystem (Table 14, Figure 15). Around the plantings 2.5 inches of mulch will be applied to retain moisture and minimize soil erosion.

Table 14: Planting requirements for the Snowberry-rose shrubbery

Common name	Scientific name	Planting density (plants/m^2)	Total area	Qty	Size
Snowberry	*Symphoricarpos albus*	0.25	1600 m^2	400	1 gallon
Nootka's rosa	*Rosa nutkana*	0.25		400	1 gallon
Prickly rose	*Rosa acicularis*	0.125		400	1 gallon
Oregon grape	*Berberus aquifolium*	0.125		400	1 gallon
	Total	0.75	Total	1600	

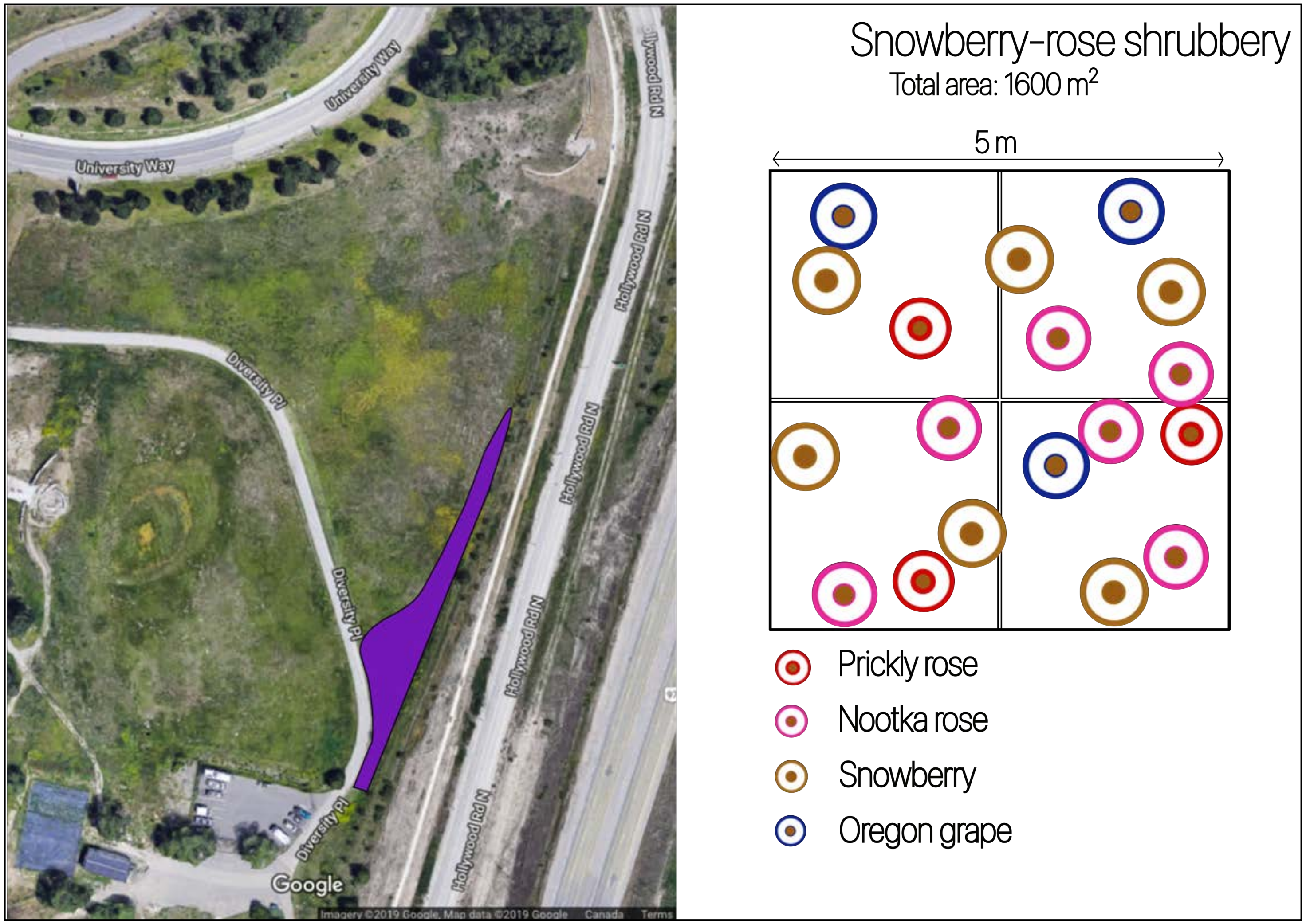

Figure 15: Proposed planting layout for the Snowberry-Rose Shrubbery area within the Forecourt Grassland revegetation plan.

The Grassland

Within the grassland region, sparse pockets of bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), and some native herbs will be planted and managed within the grassland, along with broadcast seeding of a native grass seed mix (Table 15, Table 16, Figure 16). Live plants will be planted in islands that will be maintained (weeded and mulched) year to year to ensure survival of plants and a source of seed for relevant species. In the first year, 2.5 inches of mulch will be spread around the plants in each island.

Additionally, a heterogenous planting system will be applied, wherein most pocket plantings near the northern edge of the site will be fescue-dominant, to reflect the existing higher density of fescues in this region already. The pocket plantings to the south will be bunchgrass dominant. In each region a few pockets of grass-dominant, or fescue-dominant patches, respectively, will be planted to increase variation in the vegetation of each region.

Mowing in the first few years will occur around these planted islands to maintain open canopy and contribute to forb establishment. If mowing occurs, it must happen once the new bluebunch wheatgrass plants have reached a height of 6 inches. The major growing season for bluebunch wheatgrass is early spring, but also occasionally in the fall (Wikeem and Wikeem 2004). In order to prevent damaging the plants, mowing should be restricted to when the grasses are not actively growing, in the summer (Wikeem and Wikeem 2004). Pre-mowing bird surveys are necessary to ensure that no ground-nesting birsds are present before mowing. This timing corresponds with the appropriate timing for mowing to control non-native seed set, as a number of non-native plants flower in the summer. Regular mowing can increase the gaps in the canopy and promote the establishment of native forbs in the region (Williams et al. 2007). In tallgrass prairie restoration, mowing for the first few years to reduce competition for light was considered effective by 65-75% of surveyed practitioners (Rowe 2010). Mowing has been used to prevent woody encroachment and to prevent seed set in non-native plants in the short-term (Rowe 2010).

Table 15: Planting requirements for the Grassland area. About 1/10th of the grassland area will be planted and the remaining area will be seeded.

Common name	Scientific name	Planting density (plants/m^2)	Total area	Qty	Size
Bluebunch wheatgrass	*Pseudoroegneria spicata*	1	2050 m^2	2050	1 gallon
Idaho fescue	*Festuca idahoensis*	0.5		1025	1 gallon
Junegrass	*Koeleria macrantha*	0.25		512	1 gallon
Arrowleaf balsamroot	*Balsamorhiza sagitatta*	0.5		1025	4 inch
Fleabanes and daisies	*Erigeron* spp.	0.25		512	4 inch
	Total	2.5	Total	4100	

Table 16: Seed mix and seeding density for the Grassland area with a total seeding rate of 600 seeds per square meter.

Common name	Scientific name	Proportion	Total area	Total PLS
Bluebunch wheatgrass	*Pseudoroegneria spicata*	40 %	18 300 m^2	4 392 000
Idaho fescue	*Festuca idahoensis*	40 %		4 329 000
Junegrass	*Koeleria macrantha*	10 %		1 098 000
Arrowleaf balsamroot	*Balsamorhiza sagittata*	10 %		1 098 000

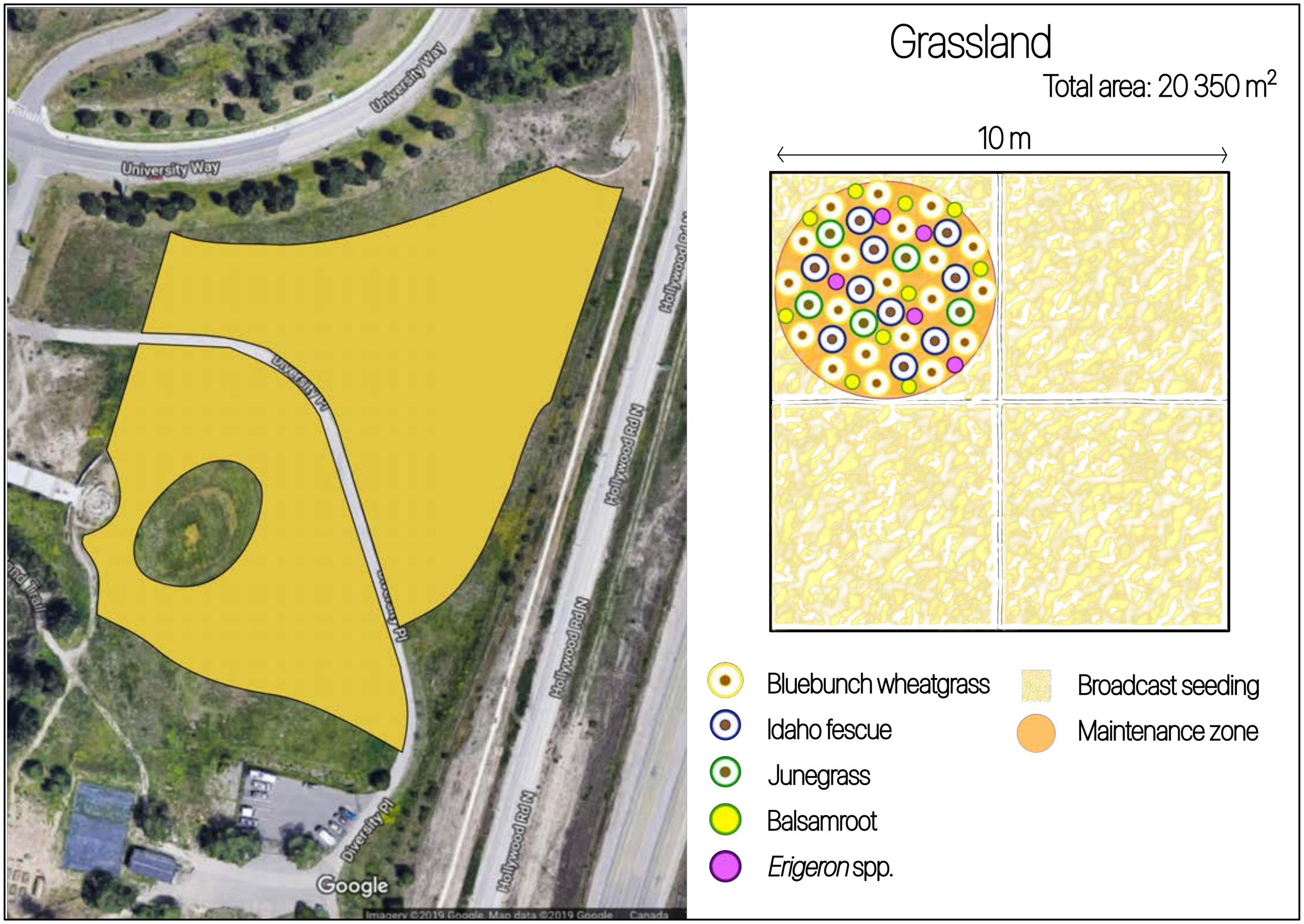

Figure 16: Proposed planting layout for the Grassland area within the Forecourt Grassland revegetation plan. Planting zone is shown by the yellow polygon. Maintenance zone indicates the region in which weeding and mulching occurs annually.

The Ephemeral Pool

The pond should be mowed regularly until further salinity and contaminant sampling can advise an appropriate set of native plants for the region. Once appropriate reference conditions have been determined, a planting plan can be developed. It is also important to determine how many of the grass species in this region are native in order to determine which plants should be preserved and/or a focus in the planting plan.

2.5.7. Wildlife features

The isolation and small size of the Forecourt Grassland means that its use will be restricted to organisms whose dispersal into the site will not be limited by the urban matrix (e.g. bird, bats, and flying insects), or who are already present in and around the site (small mammals, local ground-dwelling insects, invertebrates, and possibly reptiles and amphibians). As per section 2.4, coarse woody debris and rocks can be added to the site, particularly near the ephemeral pool in order to provide necessary habitat for the great basin spadefoot toad. Coarse woody debris can be collected within UBC Okanagan from the trees that are cut for wildfire management and should be placed according to the wildfire management plan restrictions (section 2.3.4).

Additionally, a number of ground-nesting birds that use bunchgrass grasslands, such as the vesper sparrow, sharp-tailed grouse, western meadowlark, and savannah sparrows build nests in areas with > 90 % cover of native bunchgrasses (and sometimes as low as 65 %), including bluebunch wheatgrass (Haddow et al. 2013). So, shifting the vegetation to native plant cover would provide nesting habitat for these species if they were to use such a small site. Mowing to 8 inches could leave sufficient grass height for the vesper sparrow but would not provide enough cover for the larger birds (Haddow et al. 2013).

2.6. Monitoring

Restored plant species can take many years to establish in a grassland (i.e. 6-10 years; DiCarlo and Debano 2019, Endress et al. 2012, Gornish and Ambrozio 2016, Wilson and Pärtel 2003). Restoration outcomes observed in the short-term (1-2) years, may not reflect long-term restoration outcomes, so a combination of short- and long-term monitoring should take place (Herrick et al. 2006). For the Forecourt Grassland, if collaboration regarding monitoring is established with local coursework and clubs it is possible that monitoring may occur every year. At a minimum, however, monitoring should occur at year 1, 2, 5 and 10 (Herrick et al. 2006).

Monitoring at the end of the first year will identify planting successes and failures and inform responsive management decisions. In the second year, monitoring will be necessary to determine if mowing treatments should continue. Two years after grassland restoration treatments, Déri et al. (2011) found changes in arthropod composition that was minimally evident after just one year of grassland restoration. Monitoring after 5 years should enable the identification of a restoration trajectory and allow adaptive management to alter the trajectory before a stable vegetation cover occurs in years 6-8 (Endress et al. 2012, Gornish and Ambrozio 2016, Wilson and Pärtel 2003). Finally, monitoring in year 10 will identify if the restoration vegetation targets have been met once a stable vegetation community has developed.

Since the restoration goals for the Forecourt Grassland include establishing a persistent native grassland plant community and reducing non-native plant cover to less than 10 %, vegetation composition and abundance should be a priority for monitoring. However, monitoring of faunal populations can identify if the site is being used by native grassland species once the vegetation community has been restored, which is a necessary component of restoring grassland function. Arthropods are a good candidate for faunal sampling as they can be used to detect short-term changes in restoration and because of their position in the food web (Déri et al 2011). Both vegetation and arthropod diversity is commonly measured in monitoring of restoration projects (Ruiz-Jaen and Aide 2005).

Measures of species diversity, vegetation structure, and ecological processes were highlighted by Ruiz-Jaen and Aide (2005) as key attributes, from the Society of Ecological Restoration International's Primer, to measure when monitoring restoration success. Species diversity will be measured as both evenness and richness of vegetation and arthropod communities. Vegetation structure will be measured by assessing the percent cover of each species and vegetation litter. Finally, ecological processes will be measured by assessing available soil nutrients as a proxy. These three attributes are key components of ensuring ecosystem persistence and are commonly measured in restoration projects in similar ways (Ruiz-Jaen and Aide 2005). Sample plots between 400 m – 500 m in elevation should be established in grassland sections of Knox Mountain Park in Kelowna, BC as a reference site for arthropod and nutrient sampling. A secondary reference site should be established nearby (Ruiz-Jaen and Aide 2005), but field scouting will be necessary to identify another reference site (there may be sites within Bear Creek Provincial Park, which is ~ 8 km from the forecourt grassland, that provide adequate reference conditions).

2.6.1. Vegetation monitoring

To monitor species structure and diversity vegetation plots will be established in the grassland, shrubland and slope regions of the Forecourt grassland. There will be 5 plots in each of the shrubland and the slope, and 10 within the grassland (these ten can be a subset of the 13 plots I sampled in the grassland, for example by excluding points G14 and G16). The grassland and slope plots will be based on vegetation plot locations from my sampling. New sampling plots will have to be established within the shrubland and should be sampled prior to restoration actions to establish a baseline. Each plot should be sampled in mid-May and mid-July so that the full diversity of vegetation on site is sampled (Martin et al. 2005).

Within each plot all plant species present should be identified, and their percent cover measured (e.g. Endress et al. 2018) along with the percent cover of biocrust (see DiCarlo and Debano 2019). Different plot shapes and techniques for measuring the percent cover of vegetation are appropriate for different vegetation types and distributions. An assessment of the vegetation cover (type and distribution) on site should be made at the time of sampling to determine which species cover methods are most appropriate within the different regions of the site. Care should be taken to ensure these measures are comparable across years. Once vegetation measures have been taken an assessment of community composition can be compared between the reference and restored site over time, using an ordination (see Smith et al. 2017 for plant functional groups; Ruiz-Jaen and Aide 2005).

To measure litter, the percent cover of litter within each vegetation plot should be assessed. Litter cover is typically lower in native grassland sites, and biocrust cover is higher in native grasslands (DiCarlo and Debano 2019). Thick litter may also prevent the germination of native seeds and foster noxious weed growth (Smith et al. 2017). Conversely, a large biotic crust may repel non-native grass invasion and support a larger diversity of native spiders (DiCarlo and Debano 2019).

2.6.2. Arthropod monitoring

To measure arthropod composition and abundance, pitfall traps and sweeping surveys should be used in order to assess the arthropod community (Déri et al 2011; Spafford and Lortie 2013). Each of the grassland, slope, and shrub planting areas should be sampled, with care taken during sweep-net surveys to minimize damage to newly growing plants. In grassland sites in the United States (Oregon), remnant and restored sites had lower arachnid abundance but higher diversity than disturbed sites (Dicarlo and Debano 2019). This shift in arachnid diversity can be measured by comparing the restored Forecourt Grassland to the reference sites and to pre-restoration or year-1 surveys. To get baseline data, insect surveys prior to restoration would be beneficial.

Sweep-net surveys and pitfall trapping should occur multiple times throughout the summer, along transects in each sampling area. The slope and shrubbery are restricted in the placement of transects due to their shape, and each area should have one transect that runs the length of the area, centred within the plot. In the grassland 5 transects should be evenly distributed within the site, with the heading of the transects randomly determined. Pitfall and sweep-net surveys should follow best-practices, and a standardized design for pitfall traps was proposed by Brown and Matthews (2016) that should be considered. Pitfall traps should be done: 3 times per year for 7 days each time (early, mid-, and later summer; Dicarlo and Debano 2019)

2.6.3. Soil nutrient monitoring

Soil nutrient monitoring could likely occur on campus in research laboratories and should sample the nutrient conditions that were measured in the site assessment. Initial surveys of soil total nitrogen and carbon, available phosphorus, and pH are available for the slope, grassland, and ephemeral pool and can be compared against as a baseline. Sampling of these variables should occur in the shrubland prior to restoration to serve as a baseline measure. A sample of total carbon and total nitrogen 5 years after restoration would indicate how soil nitrogen cycling may be changing with restoration. It is possible that with decreased litter from native instead of non-native species, the gross, and potentially net, mineralization will decrease (Piper et al. 2015), indicating that a lower C:N ratio would be expected over time.

2.6.4. Opportunities for collaboration

Part of UBC Okanagan's vision for the campus is to integrate research opportunities into student learning (UBC Okanagan 2015). This vision can be incorporated into the restoration of the project site by involving the local community in restoration implementation and monitoring. Additionally, the site can be used to test restoration techniques in order to integrate research into the site and contribute to the vision of the campus as a living lab. Community involvement in restoration projects can increase the success of a project by fostering a sense of community ownership over the space and increasing volunteer assistance in the project.

There are a number of classes at UBC Okanagan that teach students sampling techniques. If the Forecourt Grassland could be used as a sampling site, then students could practice their field and laboratory sampling skills, while contributing to the local restoration project. Some classes that could be considered for partnership include: BIOL 308 – Population Ecology, BIOL 309 – Field Ecology of Plants and Soils, BIOL 357 – Introduction to Entomology, BIOL 371 – Flora of British Columbia, BIOL 372 – Field Ornithology, EESC 456 – Soil science, and EESC 501 – Natural and Threatened Environments of Southern BC. Although the sampling period often does not coincide with the school year, it may be possible to collect samples over the summer and store them for analysis in the fall. Additionally, the Flora of BC (BIOL 371) and Field Ornithology (BIOL 372) are both two-week summer courses that could be used for summer vegetation or bird surveys in the area.

In addition to courses, implementation and monitoring efforts could be bolstered through partnerships with on-campus clubs, and through the hiring of summer students. Six student groups, the Gardening Club, Environment Club, Mushroom Club, SISU UBCO, Varsity Outdoor Club Okanagan, and the Wildlife Society of UBCO Student Chapter, would likely have students interested in volunteering for the project, but students outside of these groups may also have an interest in participating.

Campus Health, a research unit from Health and Wellness at UBC Okanagan also plays a role in maintaining campus trails. The development of a new trail should be completed in partnership with them. Their role in developing and maintaining trails, as well as promoting student health through the use of the outdoors means they may also have connections with students, faculty, or staff interested in assisting with this project.

The Forecourt Grassland could also be maintained as a permanent restoration research plot. Long-term research on outcomes of restoration are lacking from the literature because monitoring of outcomes often does not continue after 5-10 years (Wortley et al. 2013). Using the Forecourt Grassland as a permanent research site for restoration can help fill that void in the literature and contribute to research on urban restoration projects. In order to set up the site as a research area, land use permits with Campus Planning would need to be submitted and professors in the department of Biology and Earth and Environmental Sciences should be contacted to discuss research opportunities. In particular, UBC Okanagan recently hired a Canada Research Chair in Wildlife Restoration Ecology, Dr. Adam Ford, who may be a good resource.

2.7. Site Management

Issues that may need management during this restoration project include poor native plant survival, recruitment, or diversity, continued non-native plant return, and inability to complete monitoring from coursework.

Poor native plant recruitment should be managed by assessing the location of poor establishment, the species with difficulty establishing, and the soil water and nutrient levels in the area. For example, it is possible that the lower nutrient levels within the slope may limit plant establishment. If this is the case, it is possible that low doses of fertilizer may be appropriate. Additionally, if some vegetation is failing to establish, either species that are establishing well in that area should be replanted instead of the initial vegetation, or soil tests should be conducted to identify limiting factors preventing plant growth.

Another consideration is the success of diverse native plant recruitment and survival within the Forecourt Grasslands. After 2-5 years, additional plantings of less common species in these areas may be useful in establishing a diverse native plant community if low native plant diversity persists (Guo et al. 2018). Follow-up plantings or re-seeding may also be needed to supplement previous years of planting and seeding.

The effect of mowing on species diversity should also be re-evaluated. If mowing produces too high a level of litter, it can prevent seedling establishment and may need to be reduced or stopped (Smith et al. 2017). Additionally, some species may be excluded from site due to mowing, so mowing patches and leaving others bare may promote biodiversity more than mowing the entire site (Smith et al. 2017). Mowing does not create the same heterogeneity in a site that grazing does, and it may be appropriate to replace mowing with controlled grazing to increase site heterogeneity (Guo et al. 2018). Care should be taken to ensure any animals that may be introduced to the site to graze are not sources of noxious weed seeds on their hoofs or fur, or in their faeces.

The Forecourt Grassland may also need to be managed as a novel ecosystem, in which it is impossible to return it to a "naturalized state" that meets the criteria of < 10 % species cover (Zeunert 2013). After 5 and 10 years of monitoring and assessment of non-native plant re-invasion, native plant establishment, and diversity of native invertebrates, the restoration objectives of < 10 % non-native species cover, and the target ecosystems should be re-evaluated. Comparing the percent cover of non-natives in the Forecourt Grassland to that within Knox Mountain Park grasslands would help determine feasible maximum levels of non-native plants in an urban grassland.

If there is limited success recruiting professors to incorporate monitoring of the site into their curriculum, or classes are offered too sporadically to provide adequate monitoring, alternative monitoring methods may be required. This change may involve finding funding to cover monitoring (likely difficult), getting a student club to commit to monitoring the site (timing may not work, as many students are away in the summer when monitoring would be), or looking to local community organizations to help with monitoring. It is possible that all three alternatives may need to be combined. There may also be opportunities to apply for summer student funding to hire students to work on the project over the summer.

2.8. Restoration Success

Restoration success can be measured by assessing to what degree the restoration goals have been achieved. Success of revegetation efforts can be measured by evaluating percent cover and diversity of native plants (both planted/seeded varieties and new recruitments), and the percent cover and diversity of non-native plants (Barr et al. 2017; Ruiz-Jaen and Aide 2005). The following outcomes can be used to measure success relative to the project objectives:

1. The Forecourt Grassland consistently retains less than 10 % non-native species cover
2. The Forecourt Grassland consistently contains 90 % native plant cover that displays evenness and richness similar to the reference plant assemblages (Martin et al. 2005), particularly with the recruitment of native plants that were not planted
3. The sampled arthropod community within the Forecourt Grassland is similar to that observed in the nearby reference sites
4. Surveys of both collaborating students and professors indicate that involvement in the implementation and/or monitoring of the project enhanced real-world learning opportunities on campus

2.9. Budget

The estimated cost of the restoration project for the Forecourt Grasslands is $ 141 000 including a 15 % contingency, that could be used for additional plantings and unanticipated costs (Table 17). The budget includes an estimate of costs for labour, plant materials, seeds, and site preparatory tools. Plant, seed, and hydroseeding costs were quoted by Sagebrush Nursery in Osoyoos BC (Appendix G). The cost of monitoring will be highly variable depending on the length, intensity, and level of professional hired to conduct the work and is not included in the budget. If all of the proposed monitoring is conducted by a hired summer student, and university laboratories are used to process samples, monitoring may cost ~$ 8 000 per year (e.g. $ 6 000 salary, $ 2 000 lab costs).

Table 17: Proposed project budget for the Forecourt Grassland restoration project at UBC Okanagan.

Item	Unit	Quantity	Unit price	Total cost
Site preparation				
Labour	hourly	200	$ 30.00	$ 6,000.00
Herbicide - glyphosate	gallons	2.5	$ 20.00	$ 50.00
Excavator	hourly	8	$ 100.00	$ 800.00
Seed collection	hourly	60	$ 35.00	$ 2,100.00
			Total:	$ 8,950.00
Walking path				
Labour	hourly	16	$ 30.00	$ 480.00
Crushed gravel	tonnes	4	$ 22.00	$ 88.00
Bench	bench	1	$ 600.00	$ 600.00
Signage	sign	3	$ 250.00	$ 750.00
			Total:	$ 1,918.00
Xeriscape garden				
Labour	hourly	8	$ 30.00	$ 240.00
Wood mulch	yd^3	15	$ 60.00	$ 900.00
Compost	yd^3	15	$ 50.00	$ 750.00
Drip irrigation system	hose	4	$ 40.00	$ 160.00
Grasses/shrubs	1 gallon pot	300	$ 4.00	$ 1,200.00
Herbs	10 cm pot	500	$ 2.90	$ 1,450.00
			Total:	$ 4,700.00

Item	Unit	Quantity	Unit price		Total cost	
Ponderosa forest						
Labour	hourly	50	$	30.00	$	1,500.00
Trees	tree	30	$	275.00	$	8,250.00
Grasses/shrubs	1 gallon pot	2800	$	4.44	$	12,425.00
Herbs	10 cm pot	5600	$	2.00	$	11,200.00
Seed mix	pounds PLS	50	$	80.00	$	4,000.00
				Total:	$	37,375.00
Snowberry-rose shrubbery						
Labour	hourly	24	$	30.00	$	720.00
Wood mulch	yd^3	20	$	60.00	$	1,200.00
Grasses/shrubs	1-gallon pot	1600	$	4.38	$	7,000.00
				Total:	$	8,920.00
Sagebrush slope						
Labour	hourly	16	$	30.00	$	480.00
Grasses/shrubs	1-gallon pot	600	$	4.25	$	2,550.00
Herbs	10 cm pot	900	$	2.58	$	2,325.00
Hydroseeding	m^2	2200	$	1.00	$	2,200.00
Seed mix	pounds PLS	25	$	65.00	$	1,625.00
				Total:	$	9,180.00
Grassland						
Labour	hourly	40	$	30.00	$	1,200.00
Wood mulch	yd^3	200	$	60.00	$	12,000.00
Grasses/shrubs	1-gallon pot	3587	$	4.00	$	14,348.00
Herbs	10 cm pot	1537	$	2.17	$	3,330.00
Seed mix	pounds PLS	150	$	50.00	$	7,500.00
				Total:	$	38,378.00
				Project total:	$	109,421.00
				GST (5 %)	$	5,471.05
				PST (7 %)	$	7,659.47
				15 % contingency:	$	18,382.73
				Grand total:	$	140,934.25

2.10. Conclusion

Grassland restoration within the Forecourt Grassland requires shifting the vegetation community towards a native grassland community through noxious weed management and establishing native plants. Local grassland ecosystem plant associations were used to design a planting plan that reflects site topography. A walking trail, bench, and xeriscape garden were included in the design to manage the human use of this area after restoration and provide education opportunities for those using the landscape.

The implementation and monitoring of the project should seek involvement from on-campus groups such as student clubs, Campus Health, and interested professors and staff to foster community interest in the project, with the added benefit of reduced cost. Long-term monitoring and reporting on the project should occur to contribute to the limited literature on long-term restoration successes. Monitoring will focus on plant and arthropod diversity, as well as soil chemistry. This project would cost about $ 141 000 to complete plantings. The cost of site monitoring should also be considered, which may be about $ 8 000 per year of monitoring depending on the intensity of sampling, how many soil samples are assessed on site, and if students are hired as summer technicians or if professional biologists are hired. If the project cannot be completed at once, the priority should be to manage noxious weeds on site and establish sources of native seed.

The restoration of the Forecourt Grassland to Okanagan grassland ecosystems in partnership with the local campus community meets a number of the campus goals put forth in the Campus Master Plan (UBC Okanagan 2015). Completing restoration within the site to promote native grassland that is resistant to noxious weeds can reduce the cost associated with long-term noxious weed control (Stott et al. 2010). In addition to increasing the quality of the landscape of campus staff, students, faculty, and wildlife, restoring the site to grassland provides a small stepping stone in a larger fragmented landscape of grassland ecosystems in BC.

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Appendix A – Site history

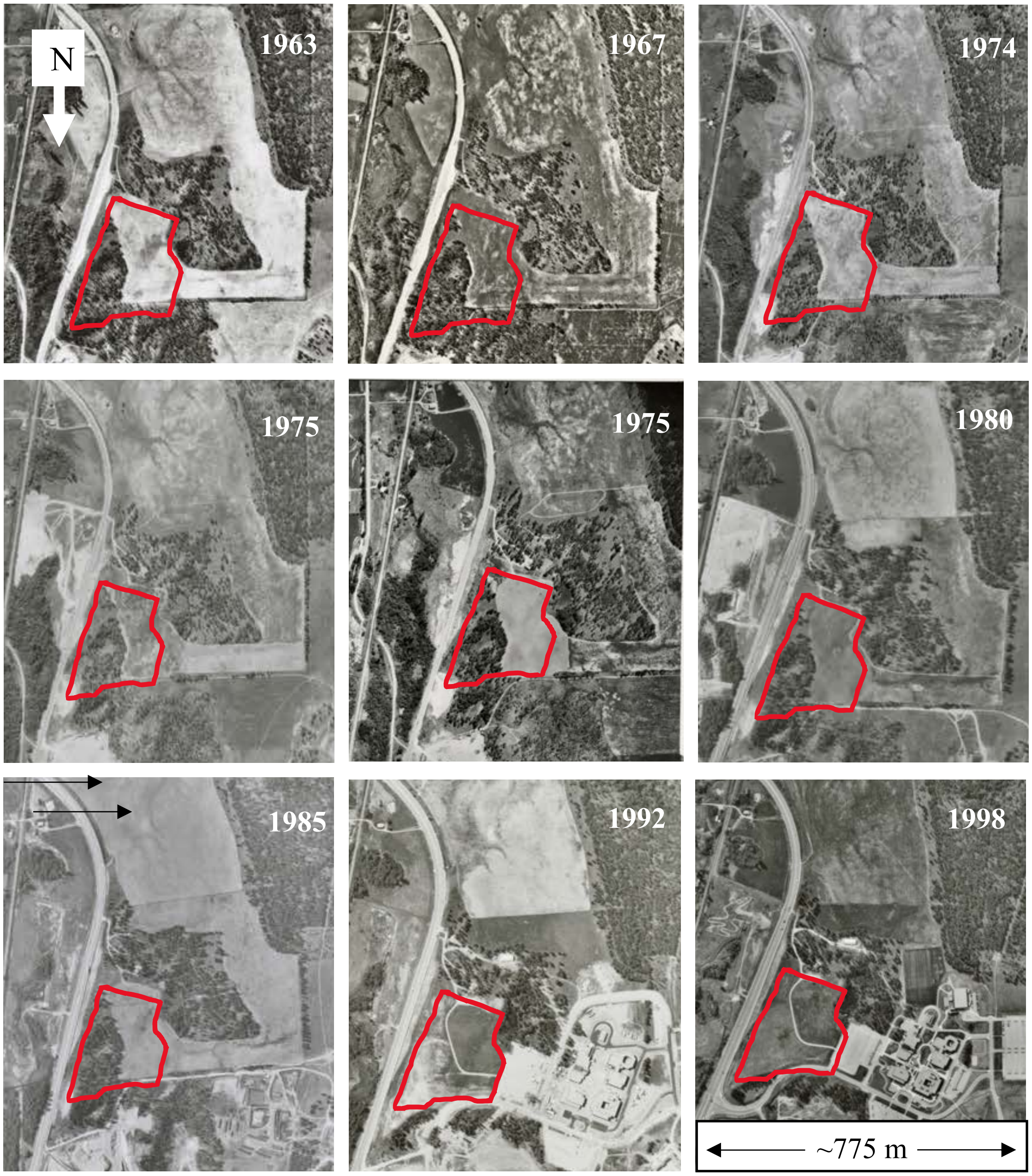

Figure A1: Aerial photography of site (Copyright of the Province of British Columbia). The red out line is the approximate site perimeter, and the year is the year the photograph was taken. Copyright (c) Province of British Columbia. All rights reserved. Reproduced with permission of the Province of British Columbia (Province of British Columbia [BC] [aerial photos], 1963, 1967, 1974, 1975, 1975, 1980, 1985, 1992, 1998).

Appendix B – Site Photo

Figure B1: Site panorama photo of the Forecourt Grassland facing West, with views from the south (left hand side) to north (right hand side). The UBC Okanagan Engineering and Management building, and the library are visible in the background, with Hollywood Boulevard and Highway 97 on the right (East).

Appendix C – Soils

Table C1: Summary of soil types within the project area and their characteristics according to Soils of the Okanagan and Similkameen Valleys (Wittenben 1986).

Soil name	Texture	pH	Total Carbon	Total Nitrogen	Phosphorus	Habitat
Gammil	sandy loam loamy sand	5.6 - 6.5	Low to very low	Very low	Medium	"Natural vegetation consists mainly of Ponderosa pine, Douglas-fir, bunchgrass and shrubs with moss on north-facing exposures."
Paradise	sandy loam loamy sand	6.6 - 6.9	Low to very low	Low to very low	Low	"Natural vegetation consists of Ponderosa pine with Douglas-fir and grass in the understory."
Trepanier	fine sandy loam silt loam loam	6.7 - 8.2	Low to very low	Very low	Medium	"Native vegetation typically consists of Ponderosa pine, Douglas-fir with minor amounts of sagebrush and grass in the understory."
Westbank	clay silty clay loam clay loam	6.0 - 6.6	Low to medium	Low	High	"Uncleared areas support scattered Ponderosa pine, grasses and shrubs."

Appendix D – Vegetation

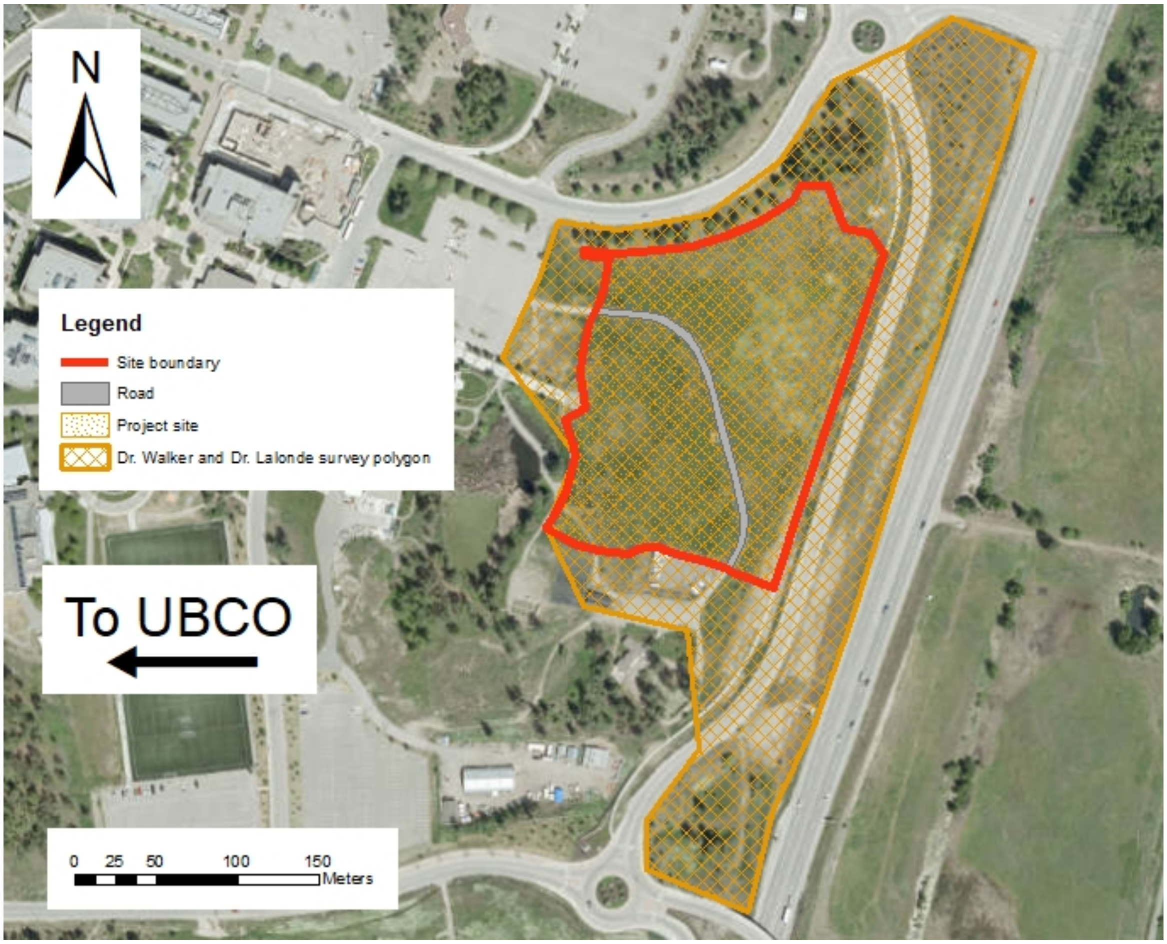

Figure D1: Map of survey polygon used by Dr. Ian Walker and Dr. Bob Lalonde at UBC Okanagan between April and August 2018, compared with the project site.

Table D1: Summary of 93 plants identified in the project site during sampling on 13 and 14 August 2018 and through surveys conducted in the site and surrounding region by Dr. Ian Walker and Dr. Bob Lalonde from April – August 2018. The status of each plant was determined from e-flora BC (Klinkenberg, 2018) and from the three pieces of legislation regulating noxious weeds within the project area. The status provided by legislation was prioritized. Italicised entries indicate the plants I saw during my mid-august sampling. Native plants are highlighted in green, and two plants that may be native if the identification is correct are highlighted in yellow.

Scientific name	Common name	Aug. 13-14	Apr. - Aug.	Status
Acer platanoides L.	Norway Maple (cultivated)		y	Exotic
Achillea millefolium L.	*Yarrow*	*y*	*y*	*Exotic*
Acmispon denticulatus (Drew) Sokoloff	Meadow Bird's foot trefoil		y	Native
Agropyron cristatum (L.) Gaertn	*Crested wheatgrass*	*y*	*y*	*Exotic*
Amelanchier cusickii Fernald	Early large-flowered saskatoons		y	Native
Amelanchier sp. Fernald	*Saskatoon*	*y*		*Native*
Amsinckia lycopsoides Lehm.	Bugloss fiddleneck		y	Native
Arctium minus Bernh.	*Common burdock*	*y*	*y*	*Exotic*[1,2,3]
Asperugo procumbens L.	Madwort		y	Exotic
Atriplex sp. L.	*Orache*	*y*		*Exotic*
Balsamorhiza sagittate (Pursh) Nutt.	Arrow-leaved balsamroot		y	Native
Barbula unguiculate Hedw.	*Barbula moss*	*y*		*Native*
Berteroa incana (L.) DC.	Hoary alyssum		y	Exotic
Bromus japonicus Thunb ex. Murray	*Japanese brome*	*y*		*Exotic*
Bryum caespiticium Hedw.	*Tufted thread moss*	*y*		*Native*
Capsella bursa-pastoris (L.) Medik.	Shepherd's purse		y	Exotic
Centaurea diffusa Lam.	*Diffuse knapweed*	*y*	*y*	*Exotic*[1,2,3]
Ceratodon purpureus (Hedw.) Brid.	*Fire moss*	*y*		*Native*
Chenopodium album L.	*Lambs' quarters*	*y*	*y*	*Exotic*[2]
Cichorium intybus L.	Chicory		y	Exotic
Cirsium arvense (L.) Scop.	*Canada thistle*	*y*	*y*	*Exotic*[1,2,3]
Cirsium vulgare (Savi.) Ten.	Bull thistle		y	Exotic[3]
Convolvulus arvensis L.	*Field bindweed*	*y*	*y*	*Exotic*[2]
Conyza canadensis (L.) Cronquist	Horseweed		y	Native
Crataegus douglasii Lindl.	Black hawthorn		y	Native
Crataegus sp. L.	*Hawthorn sp.*	*y*	*y*	*N/A*
Cynoglossum officinale L.	Common hound's tongue		y	Exotic[1,3]

Scientific name	Common name	Aug. 13-14	Apr. - Aug.	Status
Draba verna L.	Common whitlow-grass		y	Exotic
Elymus sp. L.	*Wildrye*	*y*		*N/A*
Epilobium angustifolium L.	Fireweed		y	Native
Epilobium brachycarpum C. Presl	Tall annual willowherb		y	Native
Epilobium ciliatum Raf.	*Purple-leaved willowherb*	*y*		*Native*
Erigeron speciosus (Lindl.) DC.	Showy daisy		y	Native
Erodium cicutarium (L.) L'Hér. ex Aiton	Stork's bill		y	Exotic
Galium aparine L.	*Cleavers*	*y*	*y*	*Exotic*[2]
Grindelia squarrosa (Pursh) Dunal	Curly-cup gumweed		y	N/A
Gypsophila paniculate (L.)	*Baby's breath*	*y*	*y*	*Exotic*[2,3]
Kochia scoparia (L.) Shrad.	Summer-cypress		y	Exotic
Lactuca serriola L.	*Prickly lettuce*	*y*	*y*	*Exotic*[2]
Lepidium draba L.	*Hoary cress*	*y*	*y*	*Exotic*[2]
Lepidium perfoliatum L.	*Clasping-leaved pepperweed*	*y*	*y*	*Exotic*
Logfia arvensis (L.) Holub	Field filago		y	Exotic
Lotus sp. L.	*Trefoil sp.*	*y*		*N/A*
Malva sp. L.	Mallow sp.		y	Exotic
Matricaria discoidea DC.	Pineapple weed		y	Native
Medicago sativa L.	*Alfalfa*	*y*	*y*	*Exotic*
Melilotus alba Medik.	White sweet-clover		y	Exotic[3]
Melilotus officinalis (L.) Lam	Yellow sweet-clover		y	Exotic[3]
Nepeta cataria L.	Catnip		y	Exotic
Pinus nigra Arnold	Austrian pine (cultivated)		y	Exotic
Pinus ponderosa Douglas ex P. Lawson & C. Lawson	*Ponderosa pine*	*y*	*y*	*Native*
Poa ?palustris L.	*Fowl bluegrass*	*y*		*Native*
Poa pratensis L.	*Kentucky bluegrass*	*y*		*N/A*
Poa sp. L.	*Grass*	*y*		*N/A*
Polygonum aviculare L.	*Common knotweed*	*y*	*y*	*Exotic*[2]
Polygonum sp. L.	*Knotweed*	*y*		*Exotic*[2]
Populus balsamifera L.	Cottonwood		y	Native
Populus tremuloides Michx.	Trembling aspen		y	Native
Potentilla ?pensylvanica L.	*Pennsylvania Cinqfoil*	*y*		*Native*
Potentilla argentea L.	Silvery cinqfoil		y	Exotic
Potentilla recta L.	*Sulphur cinqfoil*	*y*	*y*	*Exotic*[2,3]
Potentilla sp. L.	Cinqfoil sp.		y	N/A

Scientific name	Common name	Aug. 13-14	Apr. - Aug.	Status
Prunus virginiana L.	*Choke cherry*	*y*	*y*	*Native*
Pseudotsuga menziesii (Mirb.) Franco	Douglas fir		y	Native
Rhaponticum repens L.	*Russian knapweed*	*y*	*y*	*Exotic*[1,2]
Rosa sp. L.	*Rose sp.*	*y*	*y*	*N/A*
Rosa woodsia Lindl.	Wood's rose			Native
Rumex crispus L.	*Curly dock*	*y*	*y*	*Exotic*[2]
Sambucus cerulean Raf.	Blue elderberry		y	Native
Silene latifolia Poir.	White cockle		y	Exotic
Sisymbrium altissimum L.	*Tall tumble-mustard*	*y*	*y*	*Exotic*[2]
Sisymbrium loeselii L.	*Loesel's tumble-mustard*	*y*	*y*	*Exotic*[2]
Sisymbrium sp. L.	*Tumble-mustard sp.*	*y*		*Exotic*[2]
Taraxacum officinale F.H. Wigg.	Dandelion		y	Exotic
Thinopyrum intermedium (Host) Barkworth & D.R. Dewe	*Intermediate wheatgrass*	*y*		*Exotic*
Thlaspi arvense L.	*Field pennycress*	*y*		*Exotic*[2]
Tortula ruralis (Hedw.) Gaertn et al.	*Sidewalk moss*	*y*		*Native*
Tragopogon dubius Scop.	Oyster plant		y	Exotic[2]
Tragopogon sp. L.	*Salsify*	*y*		*Exotic*[2]
Trifolium dubium Sibth.	Small hop-clover		y	Exotic
Trifolium sp. L.	Clover		y	N/A
Typha latifolia L.	Cattail		y	Native
Ulmus pumila L.	*Siberian elm*	*y*	*y*	*Exotic*
Verbascum Thapsus L.	*Great mullein*	*y*	*y*	*Exotic*
Vicia sp. L.	*Vetch sp.*	*y*		*N/A*
Vicia villosa Roth.	Shaggy vetch		y	Exotic
Unidentified plants				
Unidentified herb	N/A	y		N/A
Unidentified herb 2	N/A	y		N/A
Unidentified herb 7	N/A	y		N/A
Unidentified grass	N/A	y		N/A
Unidentified grass 2	N/A	y		N/A
Unidentified grass 4	N/A	y		N/A
Unidentified grass 8	N/A	y		N/A

[1]Species is listed as a noxious weed under the Provincial Weed Control Act (1985)

[2]Species is listed as a noxious weed under Schedule A of the Consolidated Bylaw No. 179 for the Regional District of the Central Okanagan

[3]Species is listed as noxious according to city of Kelowna Noxious Weed and Grass Control Bylaw

Appendix E – BC PPxh1 Ecosystems

Table E1: Reference vegetation communities for each of the recommended planting zones in the Forecourt Grassland restoration project at UBC Okanagan (based off of Sensitive Ecosystem Inventories from the Central Okanagan; Iverson 2008). Non-native species were omitted from the table and table modified from those in Iverson 2008. Idaho fescue will be used instead of rough fescue since rough fescue generally occurs at higher elevations and Idaho fescue at lower elevations (Wikeem and Wikeem 2004).

Common name	Scientific name	Grassland	Slope	Shrubbery	Forest
Ponderosa pine	*Pinus ponderosa*				**
Common snowberry	*Symphoricarpus albus*			*****	
Nootka's rose	*Rosa nutkana*			****	
Big sagebrush	*Artemesia tridentata*		***		
Common rabbitbrush	*Ericameria nauseosus*		**		
Saskatoon	*Amelanchier alnifolia*			**	**
Redstem ceanothus	*Ceanothus sanguineus*				**
Choke cherry	*Prunus virginiana*			**	
Prickly rose	*Rosa acicularis*			**	*
Bluebunch wheatgrass	*Pseudoreogneria spicata*	****	***		
Rough fescue	*Festuca campestris*	***			***
Junegrass	*Koeleria macrantha*	***			**
Sand dropseed	*Sporobolus cryptandus*		**		
Needle-and-thread grass	*Hesperostipa comata*		**		
Red three-awn	*Aristida longiseta*		*		
Blue wildrye	*Elymus glauca*			*	
Sandberg's bluegrass	*Poa secunda*	*			
Arrowleaf balsamroot	*Balsamorhiza sagittata*	***	*		**
Pussytoes	*Antennaria spp.*				**
Silky lupine	*Lupinus sericeus*	**	*		
Yarrow	*Achillea millefoilum*				*
Pasture sage	*Artemesia frigida*	*			

Common name	Scientific name	Grassland	Slope	Shrubbery	Forest
Small-flowered blue-eyed mary	*Collinsia parviflora*				*
Fleabanes and daisies	*Erigeron spp.*	*	*		* (*E. filifolius*)
Parsnip-flowered buckwheat	*Eriogonum heracleoides*	*	*		
Lemonweed	*Lithospermum ruderale*	*	*		
Clad lichens	*Cladonia sp.*	**	*		
Ragged moss	*Brachythecium sp.*				*
Sidewalk moss	*Tortula ruralis*	**	*		*

Ranking system as per Iverson (2008), for all rankings except *, the species occurred in at least 60 % of the sampled plots:

* < 1 % cover
** 1-5 % cover
*** 6 -25 % cover
**** 25 -50 % cover
***** >50 % cover

Appendix F – Non-native plants

Figure F1: Non-native plants within the Forecourt Grassland (July 2018). Top: Siberian elm up close and along the southern edge of the site. Bottom: dried *Cardaria* seedheads in monoculture in the site.

Appendix G – Planting Materials Quote

Figure G1: Project quote for seeding and planting materials from Sagebrush Nursery, Oliver, BC. Quoted prices are valid for 1-2 years.

Sagebrush Nursery

7556 Island Road
Oliver, BC V0H 1T7
Ph# 250.498.8898
Fax# 250.498.8892

Estimate

Date	Estimate #
27/03/2019	519

Name / Address
Sarah Bird

Project

Description	Qty	Rate	Total
1 gallon - Big Basin Sagebrush	300	4.50	1,350.00
Blue Bunch Wheat Grass	2,550	4.00	10,200.00
1 gallon - Idaho Fescue	1,125	4.00	4,500.00
1 gallon - June Grass	512	4.00	2,048.00
1 gallon - Rosa Nootkana - Nootka Rose	400	4.50	1,800.00
1 gallon - Oregon Grape	1,100	4.50	4,950.00
1 gallon - Prickly Rose	400	4.50	1,800.00
1 gallon - Ceanothus sanguineus	700	4.75	3,325.00
1 gallon - Saskatoon	700	4.50	3,150.00
1 gallon - Snowberry	1,100	4.00	4,400.00
10 cm - Balsamroot Sunflower - Balsamorhiza sagittata	2,725	2.25	6,131.25
10 cm - Brown-eyed Susan - Gaillardia aristata	100	2.00	200.00
10 cm - Erigeron speciosus - Showy Fleabane ssp.	512	2.00	1,024.00
10 cm - Creamy Buckwheat - Eriogonum heracleoides	300	2.50	750.00
10 cm - Antennaria mycrophylla ssp rosea	1,400	2.50	3,500.00
10 cm - Silky Lupin - Lupinus sericeus	400	3.00	1,200.00
10 cm - Long-Leafed Phlox - Phlox longifolia	200	3.50	700.00
10cm - Eriogonum umbellatum	100	2.50	250.00
10 cm - Wild Strawberry	1,400	1.75	2,450.00
10 cm - Common White Yarrow	1,400	1.50	2,100.00
Native Grass Seed Mix : (Price/lb)	70	47.54	3,327.80
40% Bluebunch Wheatgrass			
40% Idaho Fescue			
10% Junegrass			
10% Balsamroot			

	Total

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GST/HST No. 134187442

Sagebrush Nursery

7556 Island Road
Oliver, BC V0H 1T7
Ph# 250.498.8898
Fax# 250.498.8892

Estimate

Date	Estimate #
27/03/2019	519

Name / Address
Sarah Bird

Project

Description	Qty	Rate	Total
Native Grass Seed Mix - (Price/lb) 20% Bluebunch Wheatgrass 50% Idaho Fescue 10% Junegrass 5% Saskatoon 5% Red-stemmed Ceanothus (NA) 5% Snowberry 5% Oregon Grape	22	79.55	1,750.10
Native Grass Seed Mix 40% Bluebunch Wheatgrass 40% Big Basin Sagebrush 10% Needle and Thread Grass 10% Balsamroot Sunflower	11	63.64	700.04
GST on sales		5.00%	3,080.31
PST (BC) on sales		7.00%	3,956.98
		Total	$68,643.48

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GST/HST No. 134187442