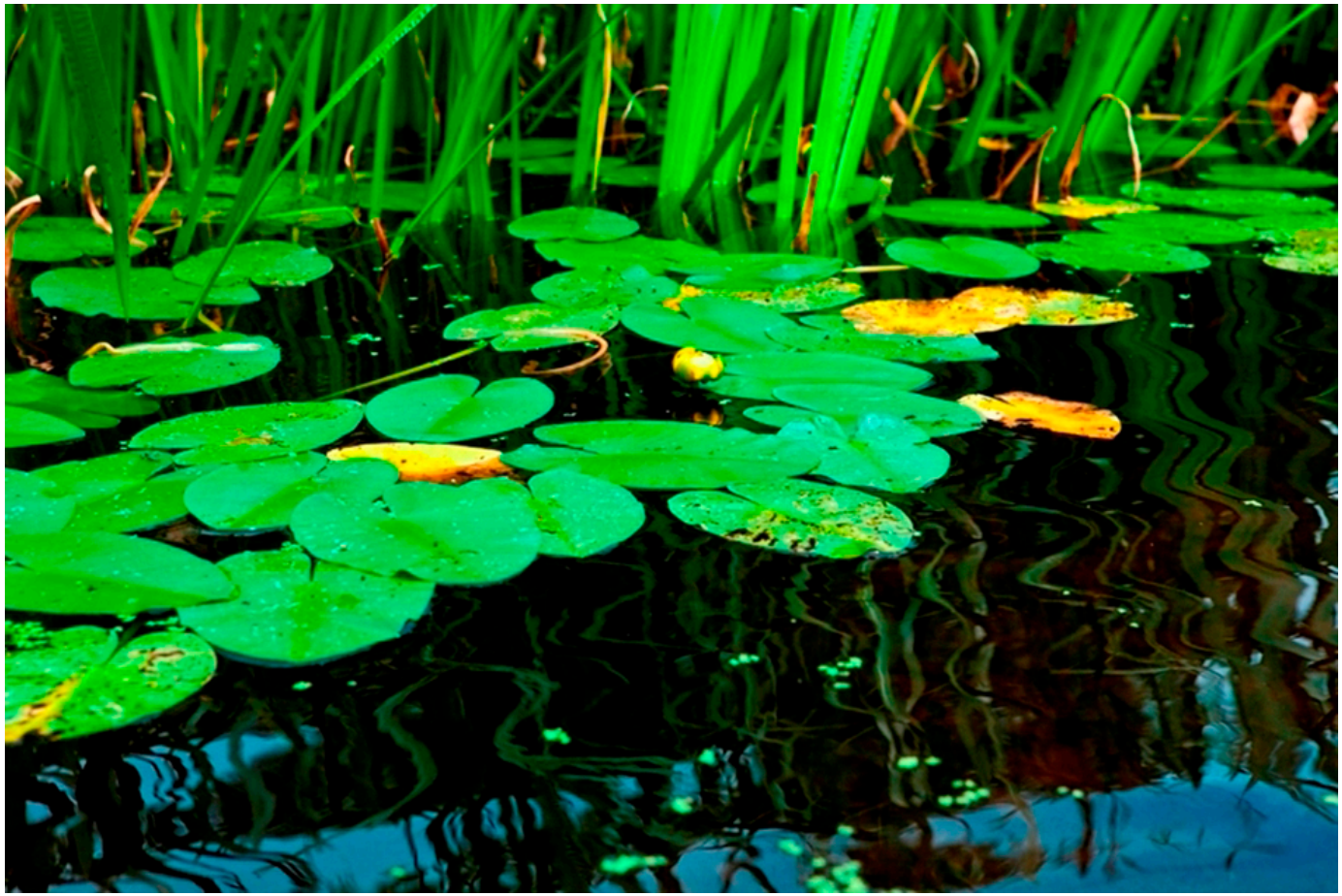
Designs for Ecological Improvement
Restoration Design
(Spring 2012)



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Environmental Science and Resource Management 479

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For Jim & Kern

“Thanks for all the cookies, coffee, clear instruction, and astounding answers.”

Contents

Preface

"All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts. His instincts prompt him to compete for his place in that community, but his ethics prompt him also to co-operate (perhaps in order that there may be a place to compete for).

The land ethic simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land".

-Aldo Leopold, 1949

Aldo Leopold, a visionary belonging to a culture of utilitarianism, believed that humanity has a moral obligation to the Earth. His writings fuel public fascination and consciousness around Environmental Stewardship. Leopold's philosophies preceded the movement towards what is now termed, and even marketed as, 'Green'. *A Sand County Almanac* introduces the revolutionary concept of a 'Land Ethic'. Ecological Restoration is a manifestation of this notion.

The following eight works are expressions of Leopold's philosophical direction; they represent a harmony between ethical responsibility and engineering. This book consolidates the assigned work of 'Restoration Design', a University of Washington course. The course teaches the design process of restoring ecological function to degraded systems. Led by Dr. Kern Ewing and Dr. James Fridley, 'Restoration Design' empowered students with the ability to carry out this ethic, and strive for the highest quality of ecological justice.

-Justin Bettis

Leopold, A. (1949). *A Sand County Almanac*. New York: Oxford University Press.

Introduction

Much like a harsh word to a good friend, once a natural system is damaged it is difficult to remedy the offense. One can only seek to make amends; in the landscape we do this through Restoration. For Restoration Design, ESRM 479, groups were asked to create restoration designs for eight damaged sites in Washington, mostly in the Puget Sound area.

The restoration sites were greatly varied from sites in urban areas to rural, from the Puget Sound to Eastern Washington, and from making a simple plan to a detailed explanation. The following is a brief summary of our designs.

1. Wiley Slough Saltwater Marsh design – Found in the Skagit River Delta, Wiley Slough was diked off from the salt water tide. Estuary habitat, where freshwater meets salt water, is an extremely productive habitat for juvenile salmon. Restoring this site conflicts with hunter and recreational users' interests. Our design included areas for hunters and a trail for recreational use, breeching and reinforcing the dike, and planting native species.

2. Transportation Corridor design – In the Cedar River Watershed power lines are being installed. Our task was to design a plan for vegetating the transmission corridor as not to interfere with the power lines and minimize habitat fragmentation. We determined special, vegetation, and management plans for the corridor.

3. E5 Parking Lot Freshwater Marsh design- E5 is a parking lot located in the Union Bay Natural Area along University Slough. WashDOT plans to restore E5 to a Wetland, to mitigate for highway construction. We set out to find how we restore the area into a wetland by re-contouring, and vegetating the site.

4. Vernal Pool in Marcellus Shrub-Steppe Preserve design – Vernal pools are a threatened and sensitive habitat. The Marcellus Shrub-steppe Preserve, owned by The Nature Conservancy (TNC) and the Department of Natural Resources (DNR), contains vernal pools and shrub-steppe habitat. We took the interests of nearby ranchers into account in our design. Our design included fencing off the vernal pools, continuing to allow for grazing, propagating and planting native species, and removing invasive species by hand and by herbicide in the shrub-steppe.

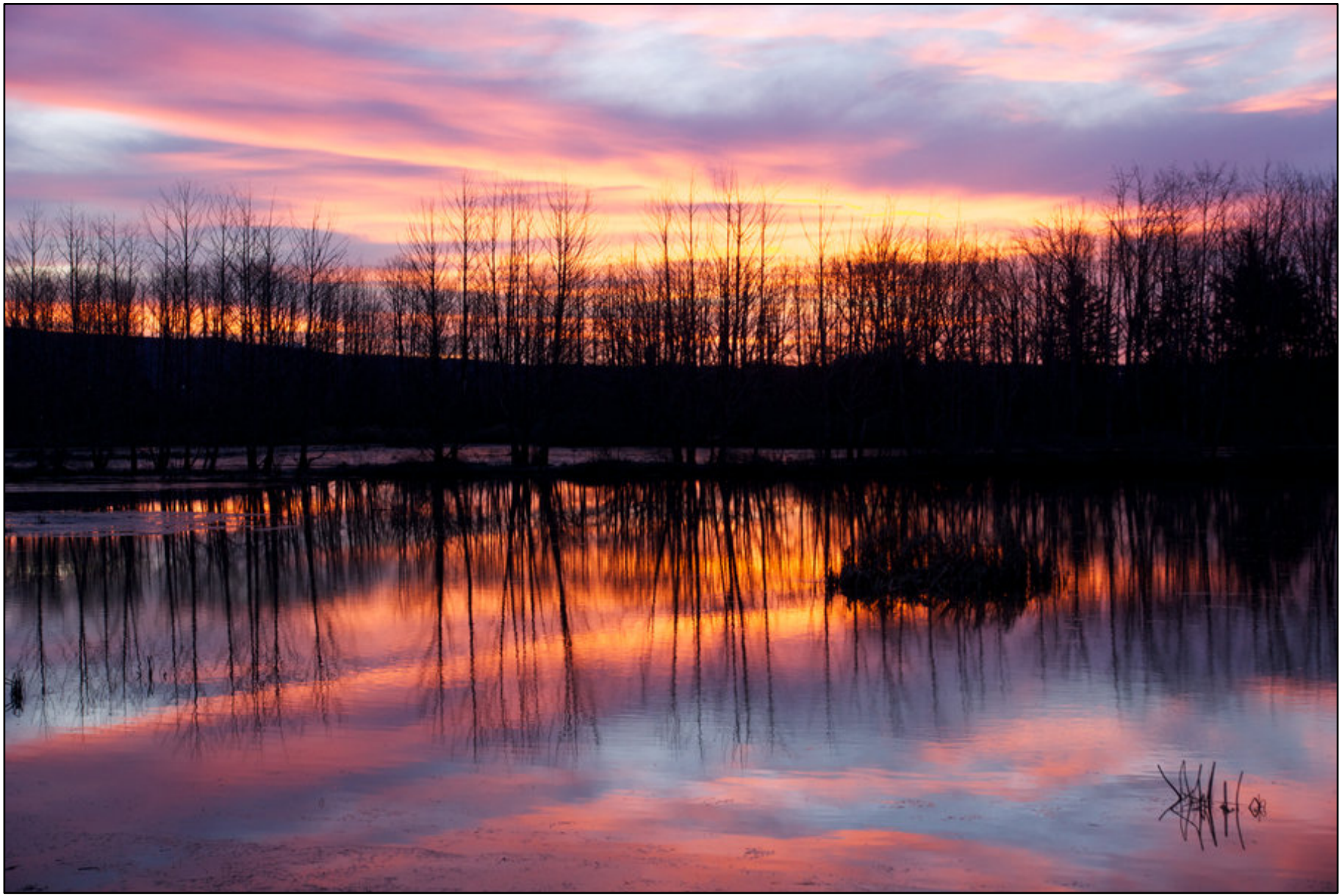
5. Padilla Bay Agricultural Land and Estuary design-Padilla Bay is an estuary system which has been converted to highly productive agricultural land. About 340 acres of farmland has the potential to be restored, however due to the opposition of the agricultural community, some of the land has been set aside for farming while the rest of the site will be restored. This design includes breeching and reinforcing dikes, removing invasive species, and planting native species.

6. Nisqually River Gravel Pit design – Near the Nisqually River, south of Ashford, there is a five acres gravel pit with poor, quick draining soil owned by Tacoma Power. We are restoring this site to improve environmental function. In order for native species to grow, the soil will need to be treated. We devised the type of soil substrate used, the desired habitat functions, and a plan to deter off road vehicles activity on the site.

7. North Cascade Subalpine Trail design –The site is located at Cascade Pass. Use of the area for camping sites has left the site degraded. The soil has been compacted, and vegetation has yet to return. In our design, we scarify the soil, add organic material, and to sow seeds. Detailed schedules and network diagrams for project execution accompanied these tasks. The location and weather makes it difficult for motor vehicles to deliver material. The design took into account these constraints and devised alternative 'low-impact' solutions to deliver material.

8. Thornton Creek Urban Trail design – Wetlands are valuable because they provide habitat, filter water, and help hold water during floods. In urban Seattle there are few to no wetlands because of development and urban sprawl. Thornton Creek runs through Seattle and has been restored in a number of places. Our task was to identify potential places along the creek to restore. We chose the and area called 'Rossi Wetlands', a housing development that was bought by city of Seattle from private owners.

Wiley Slough Saltwater Marsh



Introduction

Found in the Skagit River Delta, Wiley Slough was diked off from the salt water tide. Estuary habitat, were freshwater meets salt water, is an extremely productive habitat for juvenile salmon. Restoring this site conflicts with hunter and recreational users' interests. Our design included areas for hunters and a trail for recreational use, breeching and reinforcing the dike, and planting native species

Site History

Wiley Slough is part of the Skagit River Watershed located on Fir Island in a transition zone between forested riverine tidal habitat and estuarine emergent habitat. It is part of the Skagit Wildlife Area, providing public access for a diverse range of activities such as bird watching, hunting, hiking, photography and boating. The area is primarily accessed during pheasant and migratory waterfowl hunting seasons, but is also widely known as one of the best areas to view passerine bird species in the Pacific Northwest. The slough is planted annually with cereal grains to attract migratory waterfowl. Between the fields are riparian areas offering habitat to numerous passerine species. The Skagit Wildlife Area Headquarters Unit is located within the slough and since 1944 their goal was to provide public access and manage waterfowl species. This involved implementing dikes and drainage ditches which have surrounded the area since 1962 and have greatly impacted the natural flow of the Skagit River. Approximately 12% of the Skagit River flows though Wiley Slough. The dikes block out much of this and water elevation landward of the dikes is significantly lower than seaward.

In 1999 the Federal Endangered Species Act declared Puget Sound Chinook Salmon as threatened, which spurred the Watershed Restoration Strategy and Application compiled by the Skagit Watershed Council. Wiley Slough was top ranked as the best salmon recovery project available on public land. At least three species of salmon currently use the slough including Chinook, plus 10-12 other fish species.

Vegetation on the site is comprised of native grasses, shrubs and trees, along with many invasive species and agricultural crops. There are also freshwater wetland species along and in the slough and drainage ditches. Waterfowl are present, but are more abundant in the emergent marsh habitats outside of the dikes.

Site Analysis

A detailed overview of the area's habitat features can be found in the 2005 Wiley Slough Estuarine Restoration Design Report but have been recreated and summarized here. The site analysis is comprised of the existing hydrology, topography, vegetation, fisheries and tidal gates/dikes.

Hydrology

We do not have long-term data on tidal activity, and realize many variable affect the tides, so we cannot project the tidal activity to complete accuracy. However, we do have data on daily tidal activities and can surmise the common tide with accessible data. High tide usually approaches six feet and low tide can be over six feet below mean sea level (Figure 1). We can also assume an extreme tidal event of 7.8 feet, which was the result of a FEMA Flood Insurance Study in 1989 (FEMA,1989).

High and Low Tides in Wiley Slough.

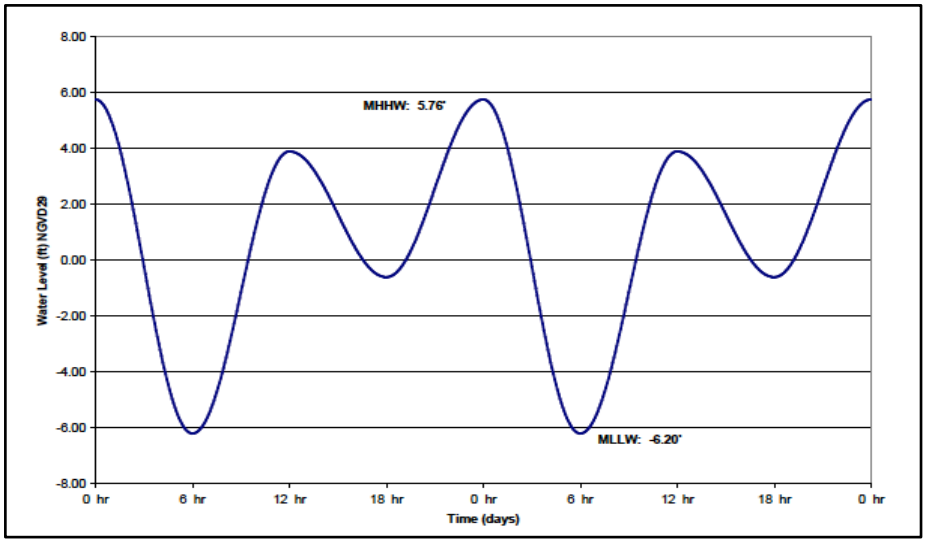


Figure 1: The water level ranges in a 24 hour period with a mean low of -6.20 feet and high of 5.76 feet. (Wiley Slough Estuarine Restoration Design: Summary Report, 2005).

Floodwater Considerations

Table 1 below summarizes the flow of water. The site has an approximated annual low flow of 9,369 cfs and annual high of 3,059 cfs. Extreme flood events can bring up to 13,103 cfs.

Stream Flow	Skagit River @ Mount Vernon (cfs)	Freshwater Slough at Project Site (cfs)
Mean Annual	16,610	2,053
Low Monthly (Sept)	9,369	1,158
High Monthly (Jun)	24,750	3,059
1-yr flood	32,200	3,864
10-yr flood	106,000	13,103

Topography

The area is crisscrossed with dikes, which adds a large difference in relief to the area. The exterior dikes (on both the western and eastern lobes) reach 9.5 feet and on average the interior dikes are 3 feet lower. The site has many areas with an elevation near or below zero, which would fill with water in areas where dikes have been removed, thus reinstating natural tidal flow. This area has elevations that would accommodate for a low elevation marsh after dike removal, which is comparable to marshes that are populated by sedge (Figure 2).

Topographic Map of Wiley Slough

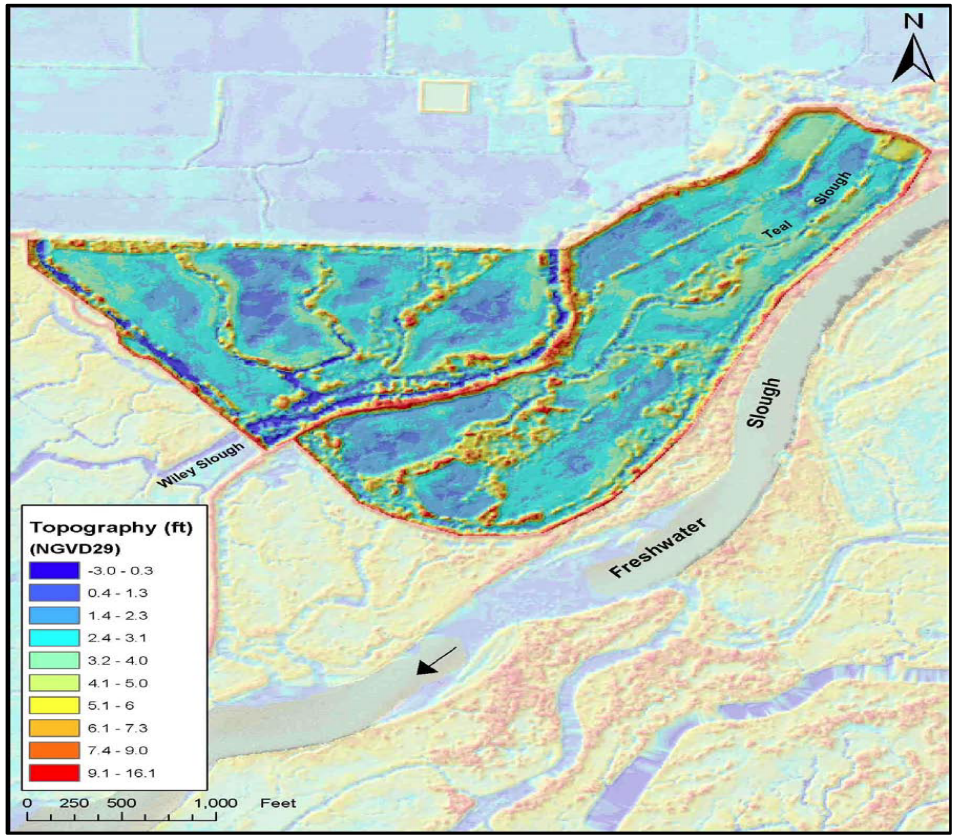


Figure 2 (Wiley Slough Estuarine Restoration Design: Summary Report, 2005)

Vegetation

The native vegetation in the area consists of an array of grasses, shrubs, deciduous trees, and some conifers. In the areas used by agriculture, vegetation is minimal. Table 2 lists several native species to the area and the ideal planting elevation. Table 3 lists potential invasive species that may threaten to colonize the area after disturbance (Wiley Slough Estuarine Restoration Design: Summary Report, 2005).

Native Species

Table 2. Native Species and Suggested Planting Elevation Relative to MSL.

Common Name	Scientific Name	Found at Elevation Levels
Chairmaker's Bulrush	*Scirpus americanus*	0 to 2
Common Spikerush	*Eleocharis palustris*	2 to 4
Lyngbye's Sedge	*Carex lynbyei*	2 to 5
Softstem Bulrush	*Scirpus validus*	3 to 5
Sweetgale	*Myrica gale*	3 to 5
Lesser Bulrush	*Typha angustifolia*	3 to 5
Tufted Hairgrass	*Deschamsia caespitosa*	4 to 5
Redtop	*Agrostis alba*	4 to 6
Willow	*Salix spp*	5 to 6

Invasive Vegetation

Table 3: Common Invasive

Common Name	Scientific Name	Removal Priority
Salt Meadow Cordgrass	*Spartina patens*	Highest
Giant Hogweed	*Heracleum mantegazzianum*	Highest
Scotch Broom	*Cytisus scoparius*	Med-High
Common Cordgrass	*Spartina anglica*	Med-High
Smooth Cordgrass	*Spartina alterniflora*	Med-High
Oxeye Daisy	*Leucanthemum vulgare*	Med-High
Giant Knotweed	*Polygonum sachalinense*	Med-High
Himalayan Knotweed	*Polygonum polystachyum*	Med-High
Japanese Knotweed	*Polygonum cuspidatum*	Med-High
Purple Loosestrife	*Lythrum salicaria*	Med-High

Wand Loosestrife	*Lythrum virgatum*	Med-High
Tansy Ragwort	*Senecio jacobaea*	Med-High
Babysbreath	*Gypsophila paniculata*	Low-Med
Reed Canarygrass	*Phalaris arundinacea*	Low-Med
Common Groundsel	*Senecio vulgaris*	Low-Med
English Ivy	*Hedera Helix*	Low-Med
Bohemian Knotweed	*Polygonum Bohemicum*	Low-Med
Old Man's Beard	*Clematis vitalba*	Low-Med
Poison Hemlock	*Conium maculatum*	Low-Med

Fish Presence

Salmonids such as Coho, Chinook, and Chum are found in the Wiley Slough area, but are not found frequently above the tidal gates (Wiley Slough Estuarine Restoration Design: Summary Report, 2005). However immediately below the tide gate, these species are found.

Existing Dikes/ Tidal Gates

Exterior dikes exist on the seaward sides of the slough, as well as the landward side of the eastern lobe (Figure 3). A dike also extends beyond the two lobes on the south side of the site. At the southern end of the western lobe there exists a tidal gate, which regulates tidal flow, keeping the tides from the northern section of the slough (preserving a freshwater condition).

Existing Dikes around the perimeter of Wiley Slough. While it encourages agricultural cultivation and gaming area it hinders salmon habitat by restricting the salt water flow to fresh water channels .

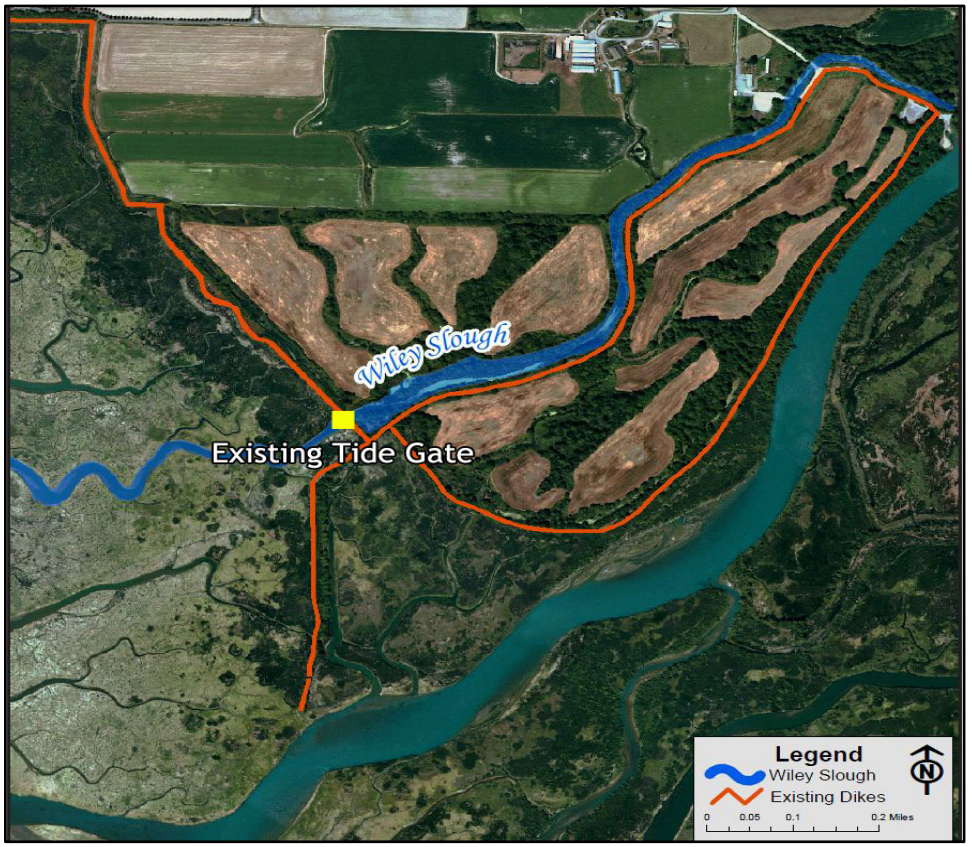


Figure 3 (Wiley Slough Estuarine Restoration Design: Summary Report, 2005).

Problem Framing

There are diverse perspectives on land management strategies for the Wiley Slough. We considered these perspectives in our design model and offer a solution that satisfies the requests of all parties. Our approach was accepted by various stakeholders because it addressed the needs for restoring salmon habitat and conserving agriculture plots and gaming refuge. Listed below are the different viewpoints and our approach to addressing these concerns:

- Since the late 19th century the area has provided agriculture land for farmers to grow grain crops. The farmers want the cultivation land to remain intact. Beginning in the mid-20th century parts of the land was converted to pheasant gaming grounds. The Waterfowler Association wishes to keep it this way. There exists a slight animosity between the hunter and farmers because of the waterfowls' tendency to consume crops. Our approach tries to remediate this problem by restoring a portion of the slough in hopes that the waterfowl prefer the prey found in the slough rather than the crop fields.

- The dikes and levees were installed to meet the demands of agriculture. The tribes' were opposed to this action because it interfered with salmon habitat. Our approach is to keep existing agricultural land intact and remove eastern perimeter dikes so that the salmon and other wildlife can reclaim the area.

Identification of the Need

There is a need to restore a saltwater marsh while retaining anthropogenic defined needs. After conducting interviews with partnerships, four districted requests were identified and action was agreed upon.

N1: Reallocate agricultural fields to estuarine marsh with open tidal activity.

A1: Remove eastern perimeter dikes.

N2: Reinforce existing dikes to protect agricultural grain fields.

A2: Utilize dike material from eastern perimeter to reinforce western border.

N3: Protect pheasant hunting grounds.

A3: Create dunes or mounds that provide preferred vegetation and fish species for pheasants.

N4: Reconstruct salmon habitat.

A4: Connect fresh water systems (rivers and pools) to salt water resources (Puget Sound).

Stakeholders

It is important that the needs of the stakeholders are met when redesigning the dike system in the Wiley Slough. Table 4 lists the interested parties in the project.

Stakeholder Group	Organization(s)	Contact
Washington State	WDFW	Bob Everitt Brian Williams Bob Warinner
Tribes	Skagit River System Cooperative	Larry Wasserman
Federal Government	USFWS USACOE NOAA Fisheries NRCS	Curtis Tanner Scott Pozarycki Kurt Fresh Kathy Kilcoyne
Agriculture	Dike and Drainage District #22 Western Washington Ag Association	Curtis Wylie Curtis Johnson
Local Government	Skagit County	
Adjacent Landowners	The Wylie Family The Nelson Family	Dalles Wylie
Conservation Groups	Skagit Watershed Council Ducks Unlimited The Nature Conservancy Skagit Fisheries Enhancement Group	Shirley Solomon Andy Reasoner Bob Carey Allison Studley
Bird Watchers	Skagit Audubon Seattle Audubon	
Utilities	Seattle City Light	Ed Conner
Hunting Groups	Washington Waterfowler Association	Dave Engle

Table 4. Project Stakeholders
(Wiley Slough Estuarine Restoration Design: Summary Report, 2005).

Restoration Goals & Objectives

Our primary goal in this project is to restore Wiley Slough to a natural estuarine habitat by returning natural tidal flow, a native special array, intertidal environmental functions, natural biological response and riverine processes to the largest proportion of land possible, while retaining public access and avian habitat.

- Reinstitute tidal flooding via dike removal to a portion of the site; allowing for unrestricted saltwater flow in and out of the restored marsh, and allowing free sediment, nutrient, and organism flow between the site and surrounding water bodies.
- Restore the area to a state habitable for juvenile salmon; restore channels throughout the marshland to accommodate for salmonids.

- Restore native salt marsh vegetation to the area to support a salt marsh ecotypic food chain.
- Maintain a food source for wintering birds.
- Maintain flood protection for agricultural areas.
- Allow for recreation about the site by increasing public access.

These goals and objectives will provide high quality salmon habitat, increase biodiversity, and provide social benefits. These goals also meet economic goals such as maintained crop protection from migratory birds and maintained flood protection for adjacent agricultural areas.

Constraints and Possible Remediation

The constraints were defined by the stakeholders. After further investigation additional limitations were identified and addressed with possible solutions.

C1: Financial budget is reduced by 50%.

A1: One third of dikes will be removed. The dikes in the western lobe will be kept intact and no northern levee will be constructed.

C2: Supplemental material is need for construction of salmon habitat and dike reinforcement.

A2a: Course wood debris (CWD) from eastern perimeter dikes will be used to reinforce.

A2b: Salmon spawning pools will be dredged and constructed with CWD.

C3: Protect pheasant gaming area.

A3: Constructed mounds and dunes will on provide social habitat on eastern perimeter. The western perimeter will remain intact.

Basic Approach

In order to meet all goals within the parameters of the constrained budget, we have decided to preserve the western section of the site (allowing continued crop protection and hunting opportunities). We will remove approximately a mile of the eastern-most dike to allow tidal flow and implement a tide gate as well as reinforce remaining dikes to provide security to adjacent agricultural lands. Fill material removed from dikes will be used to help reinforce existing dikes. Along the western dike of the eastern lobe we will create a recreation trail to allow social access to the restored salt-water marsh (Figure 4). This design will:

1. Remove the eastern dike of the eastern lobe to restore natural tidal flow.
2. Add a new dike on the eastern side of the western lobe (the western shore of the Wiley Slough) to protect agricultural land from flooding.
3. Remove the existing southern tidal gate.
4. Add a new tidal gate and channel crossing higher north.
5. Create loop trail on remaining dikes.
6. Restore salt-marsh vegetation in the eastern lobe.

Summary of Restoration Actions

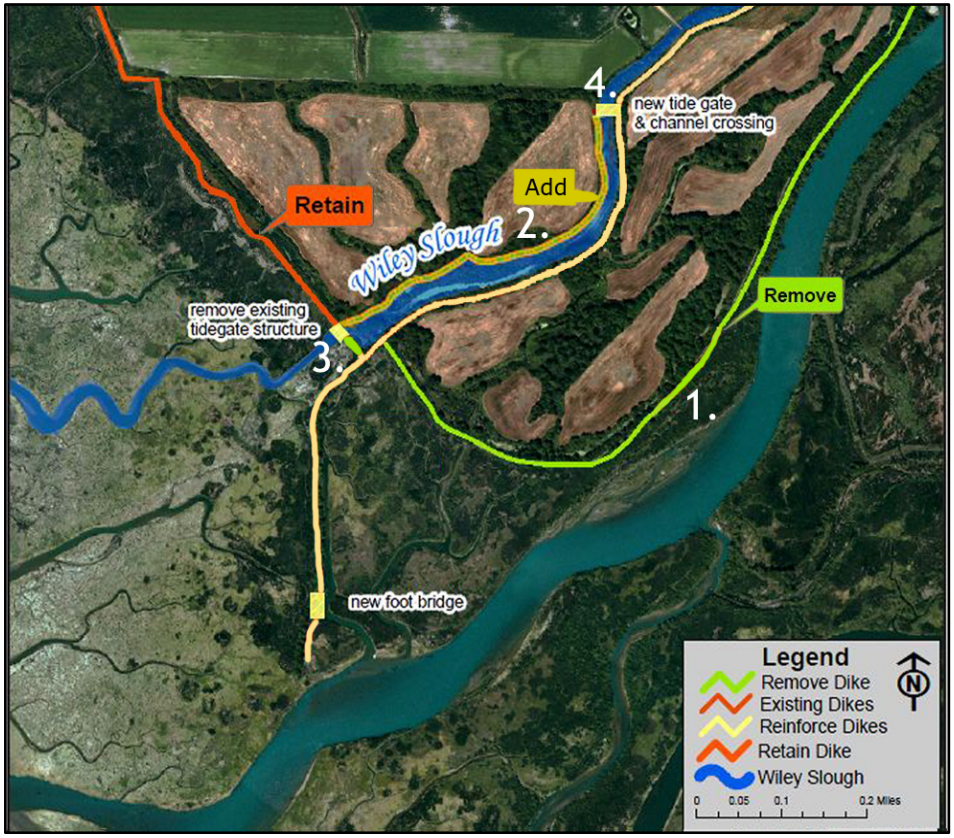


Figure 4. (Wiley Slough Estuarine Restoration Design: Summary Report, 2005).

Design Parameters

Dikes

- Install new tide gate at the northeast corner of the site. Make new dike about 0.5 miles long on the west bank of Wiley Slough, from where the old tide gate was to where the new tide gate is, by 20 feet in height and with slopes of 2.5H:IV (Official Wiley Slough Design Report 2005).
- Reinforce the dike opposite to the new bank, about 0.5 miles in length, on the east bank of Wiley Slough using fill material taken from removed dikes.
- Remove dikes east of Wiley Slough, about 0.7 miles long to about half a meter below mean sea level. Fill material will be used to reinforce other dikes.
    - Due to budget constraints, portions of the dike may be left behind so long as sufficient quantities are removed to allow the eastern portion of the land to be subject to tidal processes and exposure to estuarine conditions.

- Reinforce about 0.4 miles of dike on the east bank of Wiley Slough north of the new tide gate and reinforce the dike that runs north to south from Wiley Slough to freshwater slough, about 0.4 miles, so that the dike is 20 feet in height.

Recreation

- Create a new loop trail as shown on Figure 5.
- Make a new foot bridge south of Wiley Slough near the freshwater slough.

Vegetation

- Plant according to site hydrology/elevation.
    - Alternative to this is to suppress invasive colonization and promote the establishment of native marsh species (Figure 6).
- Use live stakes of Willow and Poplars to create a fast growing canopy along the channels at higher elevations and on top of the dikes.

Other Features

- Install wood debris.
- Excavate for calmer waters in places along channel.

Highlighted Overlay of Intended Trail

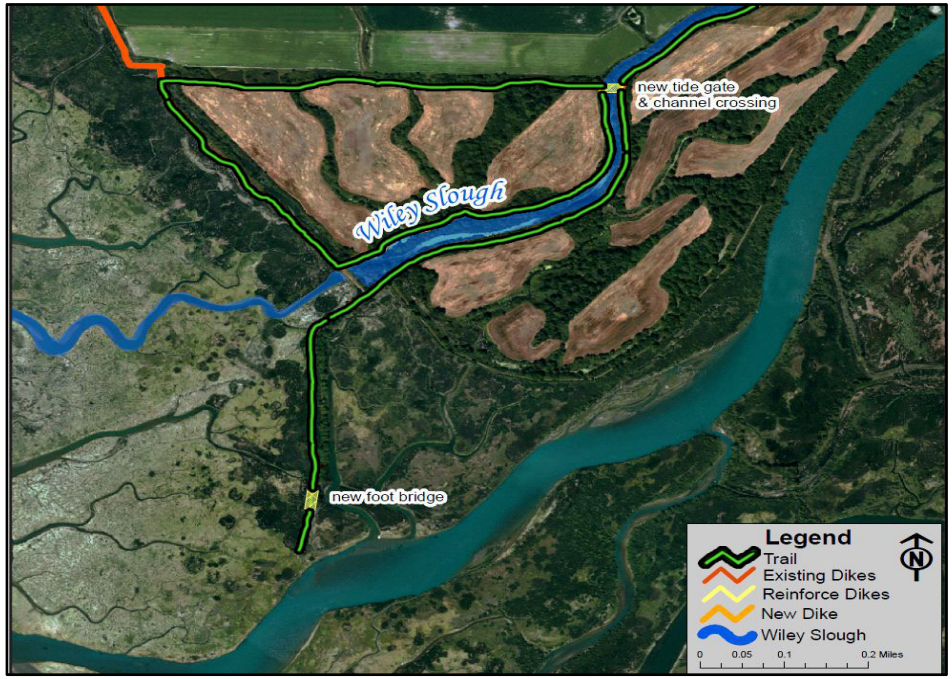


Figure 5.

Estimated potential Marsh Vegetation in the Eastern Lobe

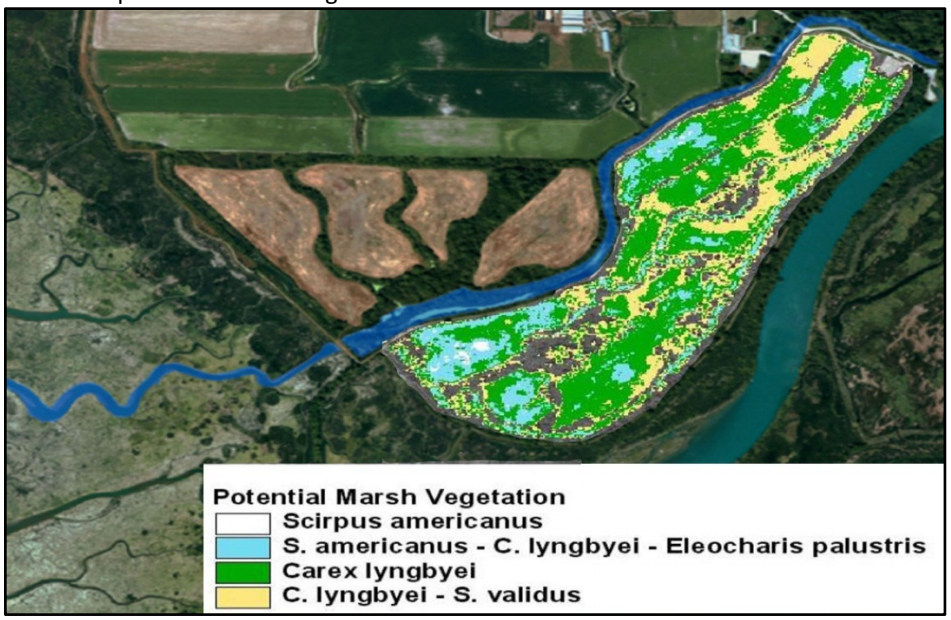


Figure 6 (Wiley Slough Estuarine Restoration Design: Summary Report, 2005).

Time Line

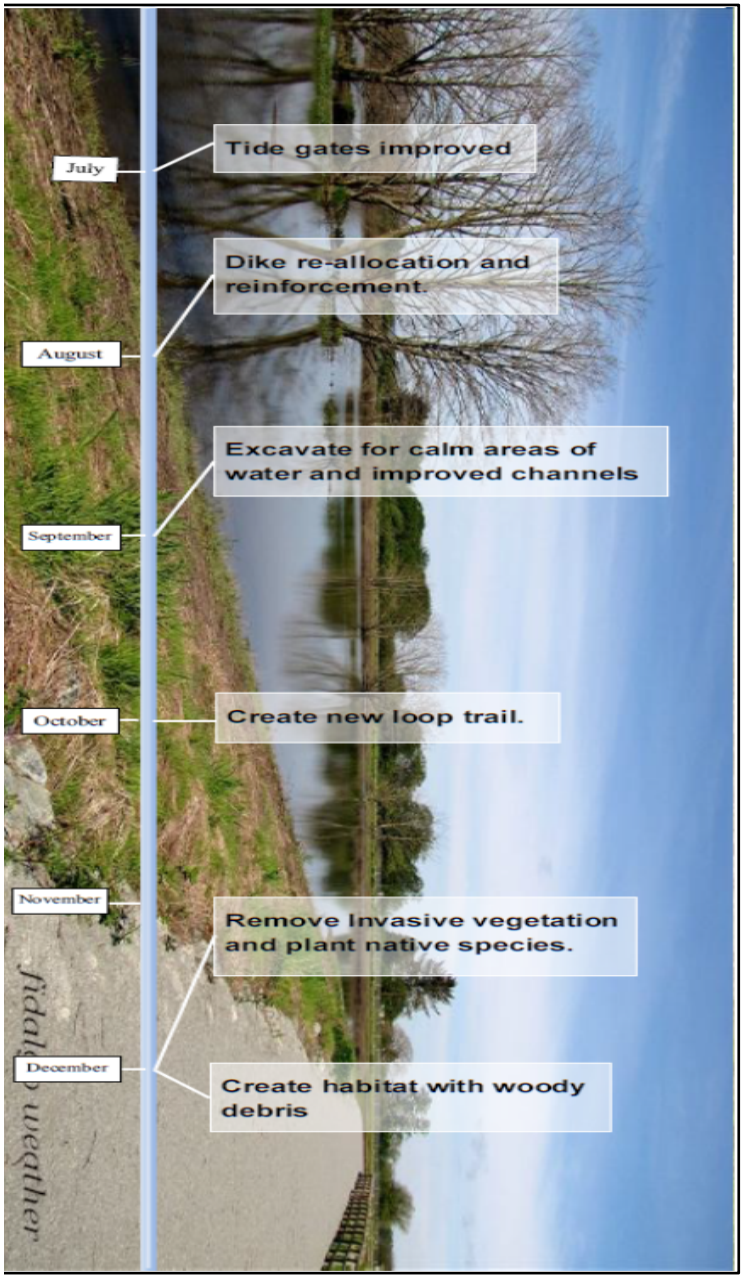


Figure 7 Restoration timeline of Wiley Slough 2012.

Environmental Functions

Our design includes aspects that provide economic, social, and environmental benefits. This project is designed to meet certain environmental functions, which are as follows:

Improve Salmonid Habitat

In accordance with Skagit River System Cooperative currently the area is not used by salmonids as salmonids "are almost completely absent above the Wiley Slough tide gate" (Wiley Slough Estuarine Restoration Design: Summary Report, 2005). Our goal is to improve salmonid habitat in the eastern lobe by restoring it to a salt marsh. We expect to see salmonids use the restored site because juvenile Chinook, Coho, and Chum frequent the areas below the tide gate.

Provide Agricultural Drainage

The Wiley Slough area provides economic benefits, as it functions as agricultural drainage to adjacent properties. This project maintains this benefit, as it preserves the western lobe, thereby securing the agricultural drainage vital to these farms.

Retain habitat for Migratory Birds

Retaining the western lobe of Wiley Slough will maintain the environmental conditions necessary for planting cereal grains to provide for migratory fowl. This will preserve the western lobe's function of attracting waterfowl, pheasants, and passerine birds to the area.

Long-term Prospects

The long-term goals of this project aim to appease all parties and stakeholders involved as well as remain ecologically sound while anthropogenic and natural processes continue to reshape the landscape.

- Restore tidal channels and natural riverine processes to an estuarine state. Specifically allowing tidal channels to re-sculpt the landscape naturally and remain a flexible, changing estuarine system.
- Create a natural habitat for intertidal species, specifically Chinook salmon.
- Eradicate invasive species and reestablish natural vegetation in order to provide shelter and food for intertidal, migratory, and riparian species.
- Maintain public access for recreational activities.
- Maintain agricultural runoff and flood prevention.
- Reduce peak water velocities, decreasing extreme flooding conditions.

Predictable Level of Repair

The predictable level of repair is difficult to estimate, but based on our plans we hope for the successful establishment and recovery of native vegetation in the area. Some areas along the newly reinforced dikes may take longer to recover due to the excess

sediment and burial of existing vegetation, but hopefully seeds from nearby vegetation will contribute to the establishment of native vegetation along the new dikes.

However, if plant establishment is slow or insufficient, manual seeding and replanting may be necessary in order to slow or prevent erosion along the newly reinforced dikes. The influx of salinity into the area will bring about a new vegetation regime, favoring plant species in the lower elevations that can withstand more saline conditions while previously existing plants should be expected to continue to thrive in higher elevations that will be out of reach of the incoming seawater. Tidal channels will become wider and deeper as sediments are churned by increased tidal flow.

Implications of Desired Results

If tidal salt marsh system's biological and physical functions are restored there will be an improvement to the habitat productive (Figure 8). The Skagit will have a greater capacity for Chinook. Thus, there will be an increase in juvenile salmon survival and an increase in the overall population of Chinook salmon (Skagit Chinook Recovery Plan, 2005). Also, this restoration will improve and increase habitat for birds who utilize this system. With this plan the impact on recreations will not be such a problem. The duck and pheasant hunters will still have somewhere to hunt. Hikers, dog trainers, and nature watchers will have the loop trail to enjoy.

Wiley Slough

Figure 8. Photograph. Fidalgo Weather. 2012.

Maintenance

Native Vegetation

It might be necessary to replace die off. If there seems to be a pattern to the die off the hydrology might be off, or it might be a microsite that does not accommodate for what was planted. If that is the case one should plant something that will survive there.

Invasive Vegetation

The invasive plants, on the site that become will be a tidal saltwater marsh, will not be able to tolerate the new conditions. However, dikes and upland areas are vulnerable to invasive colonization and should be dealt with accordingly. Fast growing riparian species such as Red Alder, Black Cottonwood, or Willow species could be planted with the purpose of shading out potential invasives. Alternatively, low lying herbaceous species could be planted for quick ground cover and to minimize disturbed locations that may allow invasives to establish. Established invasives should be removed, preferably by physical rather than chemical means.

Monitoring Salmon Populations

The reason this site was chosen for restoration is because 6 of the 22 populations of wild Chinook can be found in the Skagit. Chinook salmon were listed as endangered over the Federal Endangered Species Act in 1999. It will be important to determine if salmon populations are increasing, staying the same, or decreasing after the completion of the restoration.

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Transportation Corridor

Photograph. Mayes, 2004

Introduction

In the Cedar River Watershed, Bonneville Power Association is expanding a transmission corridor. Our task was to design a plan for installing vegetation around the corridor, and minimizing habitat fragmentation, while allowing safety and accessibility to the transmission lines. We developed a restoration design and maintenance plan for the corridor to minimize disturbance caused by the transmission corridor.

Site Description

The Cedar River Watershed is an important resource for both wildlife and the entirety of King County. The Cedar River flows from the Cascade Mountains and drains into Lake Washington. The upper area, known as Cedar River Municipal Watershed, is one of six protected watersheds in United States. It ranges over 143 square miles. It is managed for both for wildlife conservation and as the primary source of drinking water for King Country (Figure 1). The watershed is owned by the City of Seattle.

Old Growth Forests in the Cedar River Watershed

Figure 1: Phtotgraphy. Washington The State, 2012.

Before Cedar River was re-routed to Lake Washington, it flowed into Black River and White River to form Duwamish River, and finally emptying into Elliot Bay. It was re-routed for the Hiram Chittenden Locks. In 1916, the creation of the canal between Lake Washington and Lake Union made the water level in Lake Washington drop by 8.8 feet, dry up in Black River, and empty from the Cedar River Watershed into the Puget Sound.

The forest filters the water into one of a small hand full of rivers before becoming portable drinking water. One hundred million gallons of water are used from the watershed each day. The water from the Cedar River also keeps the floating bridges from sinking and makes Ballard Locks function.

The Cedar River Watershed also acts as a biological preserve. The Cedar River watershed is home to Chinook, Silver, and Sockeye salmon, as well as Steelhead trout; all of which are endangered or threatened. Other wildlife includes Rocky Mountain elk, common loons, spotted owls, cougars, black bear, osprey, and bull trout (Table 1, Figure 2).

Table 1. Preferred Habitats of Cedar River Watershed Wildlife

Wildlife	**Habitat**
Elk	upland forest, logged areas, grasslands
Common Loons	lakes, ponds, and edges of lakes/ponds
Silver Salmon	streams
Chinook Salmon	streams
Sockeye Salmon	streams
Spotted owls	old growth forest
Steelhead Trout	medium to large streams
Cougar	dense brush, forest
Black Bear	diverse array of forested areas

Black Bear Fishing

Figure 2: Photograph. William C. Graham, 2012.

The Cedar River Watershed has a diverse array of ecosystems. The area spans an elevation range from 538 feet to 5,447 feet with local precipitation ranging from 57 inches of rain a year to over 140 inches. Its habitats include bogs, fens, fresh water wetlands, riparian zones, coniferous forest, subalpine, and alpine.

Most of the lower watershed is coniferous or conifer-deciduous forest originating in the timber industry era. Only 734 acres in the lower contains 14,000 acres of fragmented old growth forest.

Several types of invasive plants have found their way into the watershed including *Senecio jacobaea* (Tansy ragwort), J*Fallopia japonica* (Japanese knotweed), *Cytisus scoparius* (Scotch broom), *Hedera helix* (English Ivy), *Araucaria araucana* (Monkey-puzzle tree), and *Syringa spp*. (lilac).

Historical Impacts on the System

The Cedar River Watershed has a long anthropogenic history. The first evidence of inhabitants in the watershed dates back to 7,400 B.C.E. (Seattle Public Utilities, 2011).

From the 1840s to 1850s, there were routes through the watershed for fur trade, and explored by Euro-American during the Indian Wars. The watershed had coal and clay deposits which attracted the railroads and company towns in the 1880s. Homesteading and agricultural expansion initiated during this era. Logging started up in the mid-1890s and continued to the 1940s. Approximately 30,000 acres of forest were lost between 1900 and 1924, leaving bare hillsides and causing fire hazards (Figure 3). St. Paul Railway got the right of way through the watershed in 1907. By 2000, only 17% of the old growth forest remained

In response to the Great Seattle Fire of 1889, the Cedar River Watershed became one of Seattle's water sources. In 1904, the river began to be used to provide hydropower (Figure 4a, b). In 1924, logging became more regulated as far as methods, sanitary conditions, and fire precautions.

The City of Seattle, in the mid-1900s, began to purchase to protect the municipal water supply. In 1996, Seattle gained ownership of the entire watershed.

Cedar River Relocation with Logan Street Bridge in Background of Renton in 1917

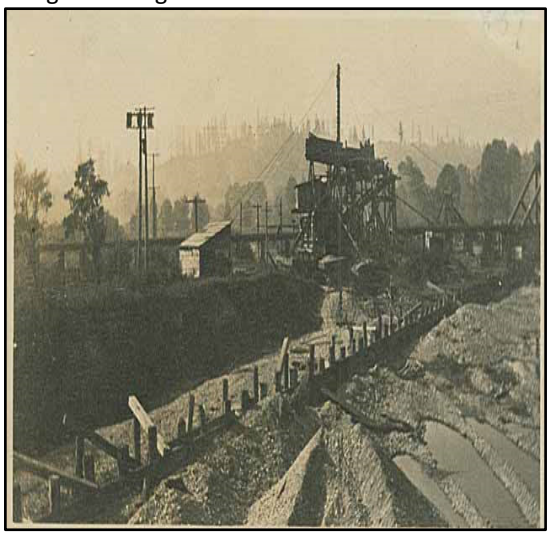

Figure 3: Photograph. Renton Historical Museum Photograph Collection, Cedar River.

Cedar River Hydroelectric Project in 1920

Figure 4a: Photograph. Asahel Curtis Collection, Cedar River.

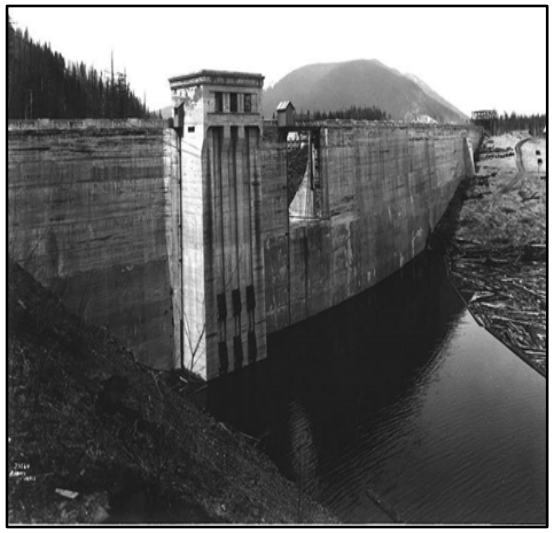

Figure 4b: Photograph. Asahel Curtis Collection, Cedar River.

Site Analysis

This restoration project is located on the western margin of the South Cascade Mountain Range. Management of the area restricts human access in order to maintain the watershed as an ecological reserve. Soils are made up of volcanic and sedimentary rocks deposited by glaciers. Annual precipitation is 1.5-2 meters and falls as a mix of rain and snow, mainly between October and April. The vegetation is typically trees and shrubs commonly found in the Pacific Northwest (Table 2).

Table 2. Vegetation found within the transmission corridor.

Scientific Name	Common Name
Acer circinatum	Vine maple
Acer macrophyllum	Big-leaf maple
Alnus rubra	Red alder
Centaurea spp	Knapweeds
Cirsium arvense	Canada thistle
Cytisus scoparius	Scotch broom
Gaultheria shallon	Salal
Gymnocarpium dropteris	Oakfern
Hieracium aurantiacum	Orange hawkweed
Hypericum perforatum	St. Johnswort
Ilex aquifolium	English holly
Picea sitchensis	Sitka spruce
Polystichum munitum	Sword fern
Populus balsaminifera trichocarpa	Black cottonwood
Pseudotsuga menziesii	Douglas fir
Rubus armeniacus	Himalayan blackberry
Rubus laciniatus	Cut-leaf blackberry
Rubus spectabilis	Salmonberry
Rubus ursinus	Trailing blackberry
Senecio jacobaea	Tansy ragwort
Thuja plicata	Western red cedar
Tiarella trifoliata	Foamflower
Tsuga heterophylla	Western hemlock
Vaccinium parvifolium	Red huckleberry

Riparian

It runs from east and southeast to northwest, ending in Lake Washington. Several smaller streams flow into the river from the north and the floodplain is contained in a narrow strip along the Cedar River. The water quality in the area is very high.

Forest stands along the river maintain the water temperature and create critical habitat for resident and anadromous fish. Removal of vegetation in the riparian zone (such as that required by installation of the transmission corridor) has shown to have adverse effects to threatened species in the area (BPA, USDA & USFS, 2003). The riparian zone also provides critical habitat to bird species.

Wetland
Wetlands are lowland areas occurring sporadically through the project site and range from 1-5 acres. Their hydrology is maintained by soil run-off, shallow flow, and hillside seeps. Soils are usually porous gravel, sand, clay and varying fines produced by glacial deposits. Vegetation is comprised of mixed coniferous and deciduous forest, with scrub-shrub, emergent and open water species.

Upland
Upland habitat is comprised of low, rounded mountains, primarily located in the northern project site. Vegetation of the uplands includes early-mid successional mixed deciduous and coniferous open and closed forests. Soils are dryer than in wetland and riparian habitats and erosion is minimal due to plant cover.

Problem Framing
Bonneville Power Administration (BPA) will be adding a new power line from Grand Coulee Dam to a point near Kent, WA (Figure 5). The selected alternative will expand on an existing power line corridor (150 feet wide). Trees over a certain height as well as mid to understory vegetation will need to be removed inside and around the Right-of-Way (ROW) in order to prevent any unwanted disturbances and damage to the power lines. The alternative proposed by the BPA aims at maximizing environmental conditions in the upland, wetland, and riparian habitats while minimizing anthropogenic and socioeconomic impacts. As a result, the mitigation plan requires BPA to transfer ownership of 600 acres of land to the Cedar River Watershed and 500 acres of BPA land will be placed under conservation easement prohibiting any further expansion.

Suggested Power Line Corridor

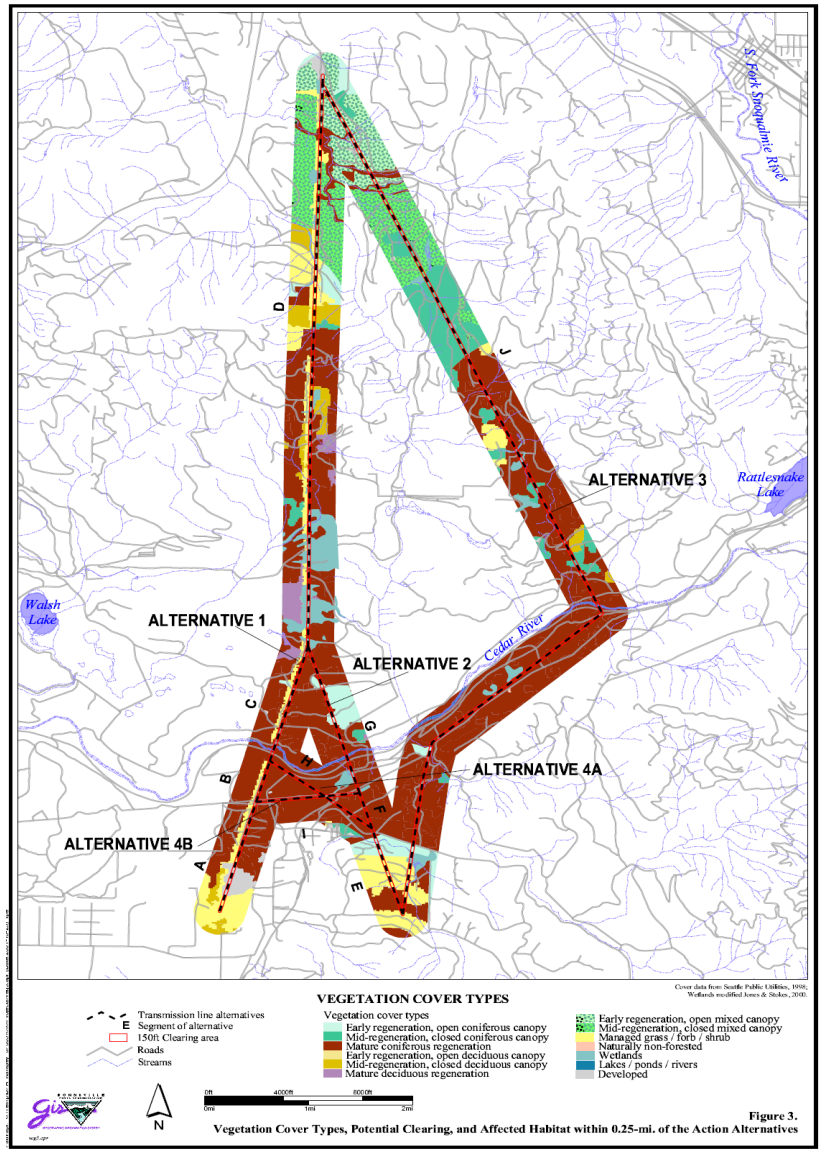

Figure 5

Stakeholders

The stakeholders for this project are concerned with human resources and wildlife conservation. The objective of this project is to allow BPA to construct additional power lines to transport power while adhering to various environmental agencies, demands for minimal environmental and socioeconomic effects. A list of stakeholders' information is provided (Table 3). The following are concerns in regard to the stakeholders involved at federal and local government, tribes and community group levels (BPA, USDA & USFS, 2003).

- Federal: BPA requests to build a transmission corridor that crosses the watershed below the intake of the municipal drinking water.
- Local: Seattle Public Utilities primary focus is to provide portable drinking water from Cedar River Watershed.
- Tribes: The Cedar River Watershed has Habitat Conservation Plan (HCP) that requires considerations of impacts on fish and wildlife. The Muckleshoot tribe does not want salmon runs and habitat further tampered.
- Community Partners: Friends of Cedar watershed along with numerous other groups and individuals want the shed to remain acceptable for recreation and educational use.

Table 3. Project Stakeholders

Stakeholder Group	**Organizations**
Federal Government	BPA
	USFWS
	USEPA
Local Government	Seattle Public Utilities
	KC DES
	KC Executive
	KC Rural Forest Commission
Community Group	Friends of Cedar River Watershed
Tribes	Muckleshoot

(BPA, USDA & USFS, 2003)

Identification of the Need and Action Taken

As the population grows in the Puget Sound area, so does demand for electricity and portable drinking water. BPA is responsible to supply electricity needs during peak and nonpeak hours; in addition to adhering to safety regulations and environmental protection laws as outlines in the National Environmental Policy Act (NEPA). The needs to be achieved by BPA are as followed (BPA, USDA & USFS, 2003):

- **N1:** Facilitate the orderly preparation of the power system.
  A1: Meet with stakeholders to decide which preferred alternative best meets functional requirements.

- **N2:** Increase power system to meet citizen demand for electricity.
  A2: Execute preferred alternative with agreement from stakeholders.

- **N3:** Maintain reliable power system.
  A3a: Regular monitoring and maintenance of power operation system.
  A3b: Follow through with Request for Improvement notifications by stakeholders.

- **N4:** Maintain environmental quality, including endangered species protection, general wellbeing of wildlife, and maintain water quality.
  A4a: List appropriate vegetation species for climates that protects amphibian and other wildlife features.
  A4b: Install plants and mitigation features to protect drinking water quality.
  A4c: Develop monitoring and maintenance plan for ROW and extended area.

- **N5:** Minimize impacts of anthropogenic activity throughout the corridor.
  A5: Establish mitigation plan for degraded, damaged, disturbed, and/or destroyed environment.

- **N6:** Minimize costs to BPA's ratepayers.
  A6: All construction will have **no** to **low** socioeconomic impacts. There would be no impact on local population or business access.

Goals and Objectives

Our primary goal is to create a corridor by removing vegetation and ensuring it will not interfere or hinder with the power lines or maintenance. These goals and objectives need to be met in order to satisfy the stakeholder's demands as well as maintain the ecological integrity of the Cedar River Watershed.

- Create microsites.
- Create a corridor.
- Create favorable conditions to avoid habitat fragmentation.
- Make a plan to maintain the corridor.

Design Parameters

It expands an existing transmission corridor by approximately 46 meters for 8 kilometers, increasing the area cleared by over 3,000 acres. The land is comprised of riparian, wetland, and upland habitats.

Riparian

- Riparian habitat occurs approximately 20 feet from a river or stream.

Wetland

- Wetland habitat occurs sporadically within the project area and is defined as a lowland area that is saturated with water.

Upland

- Upland habitat occurs in areas within 180 feet of the edge of riparian habitat.

This plan was developed to mitigate disturbances in critical habitats in order to comply with the federal Endangered Species Act.

Riparian

- Maintains a natural and beneficial water flow regime in the area.
- Promotes habitat for resident and anadromous fish, specifically Chinook salmon and bull trout.
- Provides a reliable source for high-quality drinking water.
- Provides habitat for many avian species, specifically Bald Eagle, Great Blue Heron, Osprey, Willow Flycatchers, Herlequin Ducks, Mink, and Van Dyke's Salamander.
- Lowers flood potential by spreading water over large areas, slowing the energy of the Cedar River.
- Reduces soil erosion by trapping sediments carried with the river.
- Reduces pollutants in drinking water by depositing them in the soil.

Wetland

- Maintains habitat for a diverse array of vegetation, specifically palustrine emergent, scrub-shrub, open water and forested wetland species.
- Provides critical habitat for aquatic species, specifically Cascades Frog, Northern Red-legged Frog, Cascade Torrent Salamander, Oregon Spotted Frog, Tailed Frog, Western Toad, and Fender's Soliperlan Stonefly.
- Creates a floodplain to dissipate river energy, reduce soil erosion and pollutants, and provide water storage, reducing flood potential.
- Promotes nutrient cycling.
- Creates a barrier and reduces run-off.

Upland

- Provides critical habitat for Northern Spotted Owl, Northern goshawk, Marlin, Pileated Woodpecker, Vaux's Swifts, Band-tailed pigeons, Blue Grouse, Fisher, Larch Mountain Salamander, and five bat species.
- Maintains a mixed-species coniferous forest on low, rounded mountains.
- Stores soil and promotes build-up of organic material.
- Promotes old-growth forest habitat.

Design Requirements

In order to uphold the environmental integrity of the watershed there are several design requirements that comply with state and federal laws in order to maximize the utility of the restoration. The restoration of the transmission corridor must also minimize impacts to human environment and disturbance during construction. These requirements are:

- No clear cutting within the watershed.
- Low-medium tall vegetation will be allowed in the corridor.
- Tall vegetation that can fall onto a line because they are leaning or diseased must be removed in rotation.
- Remove and suppress growth of invasive plants and noxious weeds, without the use of herbicides.
- At least two downed logs per acre must be maintained to promote habitat.
- Stumps, snags and trees of 20 inch diameter must be retained unless they are a potential safety hazard.
- Wetlands cannot be filled.
- Construction must not occur in conjunction with seasonal use by wildlife, particularly salmon spawning and bald eagle nesting times.
- Trees outside of the corridor must be removed if they create a potential safety hazard by falling on transmission lines.
- Heavy construction must be conducted during the dry season in order to minimize erosion.
- Water-quality must be monitored.

Implications of Desired Results

Our design requires drastic alterations to the ecosystems and physical environment the corridor passes through, through analysis of past studies we have accumulated a list of outcomes that can be expected from the construction and restoration of the transmission corridor.

- We will create a gap between forested areas, spanning 300 ft.
- Possible predation increases in ROW.
- Increase of small mammal diversity in ROW (Johnson, Schreiber & Burgess, 1979).

- Songbird populations should rise in upland shrub lands (Kroodsma, 1982). Our diverse plots will provide continued necessary habitat for an array of species, through providing shelter from predation, and environmental elements.
- Habitat from legacy timber, LWD and snags.
- Some compaction of soil in construction areas.
- Possible increased conductivity for invasive species.

Constraints and Action Taken

A majority of the constraints concentrate on reducing anthropogenic activity and maintaining environmental functions defined by the stakeholders. After further investigation additional limitations were identified and addressed with possible solutions.

C1: Minimal anthropogenic impact on riparian corridor.

A1a: Use helicopters in the construction power line tower.

A1b: Select harvesting of trees located outside ROW.

C2: Height of vegetation in ROW most be under 10 feet tall for power line safety regulations

A2a: All short to tall trees and shrubs in ROW.

A2b: Taller trees will be removed on a rotational schedule so more tree stay in ROW as specified in monitoring and maintenance plan.

C3: Herbicides are not permitted to suppress vegetation growth in ROW

A3a: Develop maintenance and monitoring plans with an emphasis on manual labor.

C4: Maintenance connectivity between riparian, wetland, and upland zones.

A4a: Leave snags, old growth trees and shrubs to create appropriate habitat.

A4b: Suppress invasive species to promote succession growth.

Basic Approach

We designed our project so that the corridor will not fragment habitats and will not interfere with the watershed biological functions, including water filtration and wildlife habitat. This design will:

- Remove vegetation.
- Leave some organic matter to act as a nutrient source for our plantings.
- Leave woody debris to act as nurseries for plants and habitat for amphibians.
- Remove any invasive plants.
- Plant natives that are relatively low growing.
- Not block or fill streams, there-by blocking salmon paths.
- Restrict sediment input to streams, lessening any negative impact to water quality.
- Not interfere with wetland functions.
- Maintain the site by trimming down trees so that they don't grow too close to the power lines.
- Manage and remove invasive plants.

Implementation

Removal of Vegetation

In accordance with the planned width of a 300ft corridor, an additional 150ft of Coniferous forest must be removed from the whole stretch of corridor. In upland sites, within this 300ft corridor all conifers will be removed to make way for construction and to mitigate from future damage to the constructed lines and towers. Another 50ft buffer is added on either side of the corridor where trees reaching 100 ft or higher are eliminated (Figure 6). In accordance with law, a minimum of two snags of removed danger trees will be left on site. Removal of vegetation includes:

- Haul equipment, by helicopter, to corridor.
- A clear-cut of the 300ft corridor, removing all trees or shrubs that are, or will exceed 10 feet in high.
- Leaving 5 pieces of 'legacy' LWD per acre.
- On either side of the corridor removal of 'danger trees', trees reaching or exceeding 100 ft.
- Leaving behind 2 snags per acre in 50ft buffer regions bordering the corridor.
- Removed logs will be taken by helicopter off-site.

General Cross Section

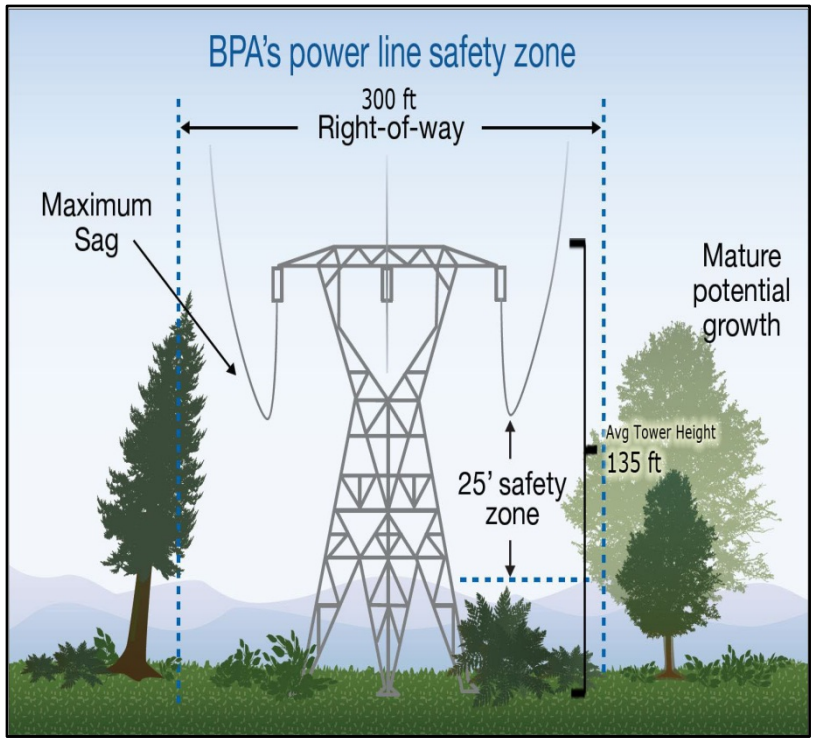

Figure 6

Construction of Tower/Line

To reduce fragmentation of forest habitat, equipment will be airlifted in by helicopter, and no roads will be built for construction of this corridor.

Special considerations during construction will be made for wetland sites:
To avoid as much impact on wetlands as possible, and in accordance with the Environmental Impacts of Transmission Lines report released by the public service commission of Washington, we have outlined certain precautions that will reduce damage to wetlands during construction (Environmental Impacts of Transmission Lines, 2011).

- Place poles as sparingly as possible, to try to span the wetland and limit the number of poles in wetland as much as possible.
- Limit construction to winter months when soil and water are more likely to be frozen and vegetation is dormant.
- Clean construction equipment after working in areas infested by purple loosestrife or other known invasive, exotic species.

Restoration

The restored corridor must not interfere with the lines or tower, in order to meet this we have vegetation not exceeding 12-15 ft.

Riparian Site

In order to keep functionality of riparian habitat, and control sediment erosion into the rivers, we will restore the riparian sites affected by the construction of the transmission corridor. We intend to stabilize the riparian areas by planting riparian species that also do not exceed 15 ft when mature, as to not interfere with the transmission lines or towers (Figure 7). We intend to plant:

- *Berberis aquifolium*
- *Holodiscus discolor*
- *Lonicera involucrata*
- *Philadelphus lewisii*
- *Spiraea douglasii*
- *Symphoricarpos albus*
- *Rubus spectabilis*

Cross Section of Riparian Zones

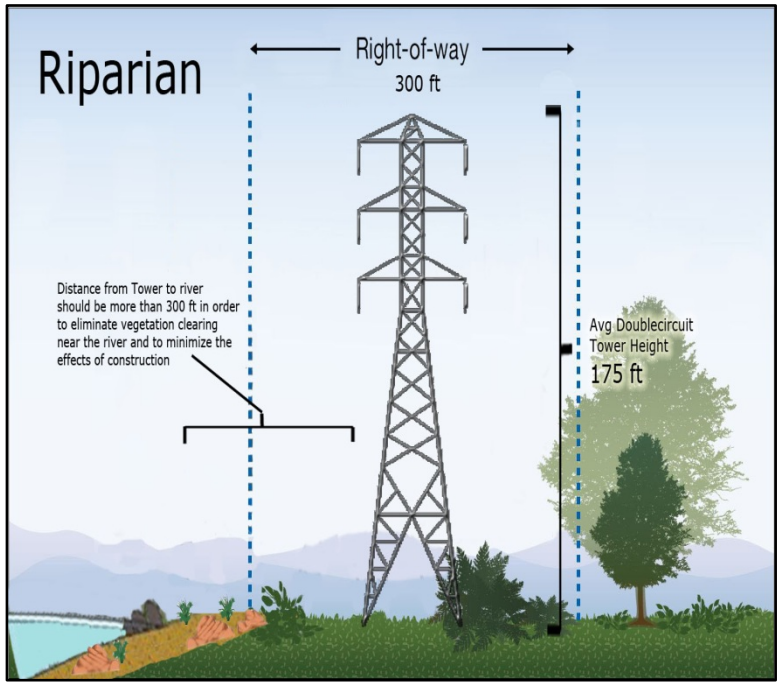

Figure 7

Wetland Site

Similar to the upland sites, we expect disturbance to the wetland sites after removal of tall vegetation, and any construction that occurs on site. In order to restore the wetland sites, we will plant disturbed areas with Western Washington native wetland species (Figure 8). We intend to plant:

- *Carex obnupta*
- *Lonicera involucrate*
- *Physocarpus capitatus*
- *Rubus spectabilis*
- *Scirpus microcarpus*
- *Symphoricarpos albus*

Cross Section of Wetland Zones

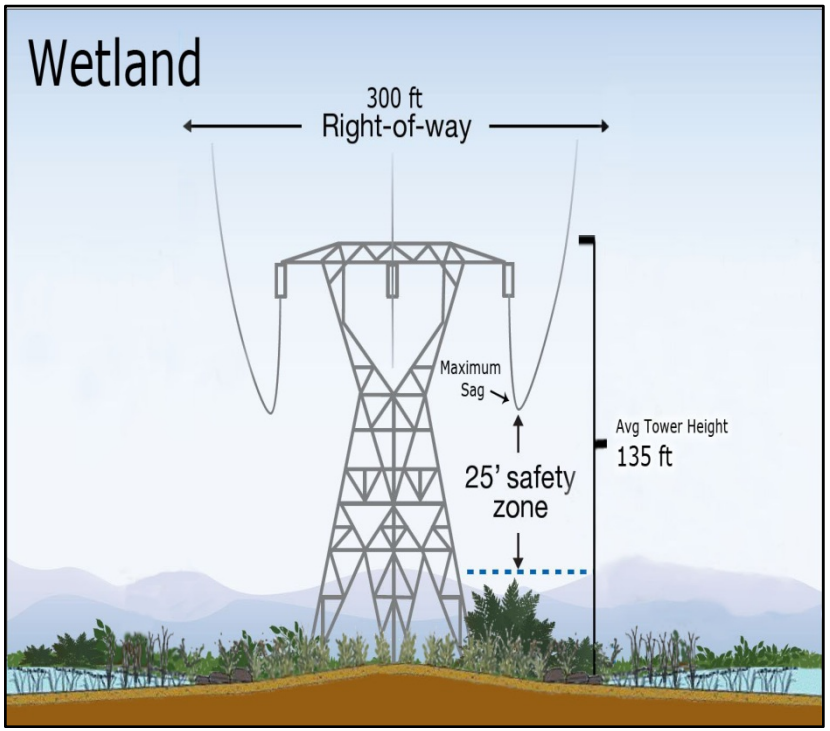

Figure 8

Upland Site

After the disturbance of construction and vegetation removal we expect some shrubs and herbaceous plants to remain, but we expect a high risk of invasion from invasive species. In order to restore the site to a functional and resilient ecosystem, without interfering with the lines and towers, we have decided to restore the upland areas to shrub lands. We will accomplish this restoration by planting native shrub species in the corridor after construction has completed (Figure 9). We intend to plant:
shrub species (an array from Loft & Menke,1984)

- *Arctostaphylos spp.*
- *Ceanothus lemmonii*
- *C. cuneatus*
- *Ribes sanguineum*
- *Berberis aquifolium*
- *Amelanchier spp.*

We will seed an array of native grasses on site, to assist in the exclusion of invasive species.

Cross Section of Upland Zones

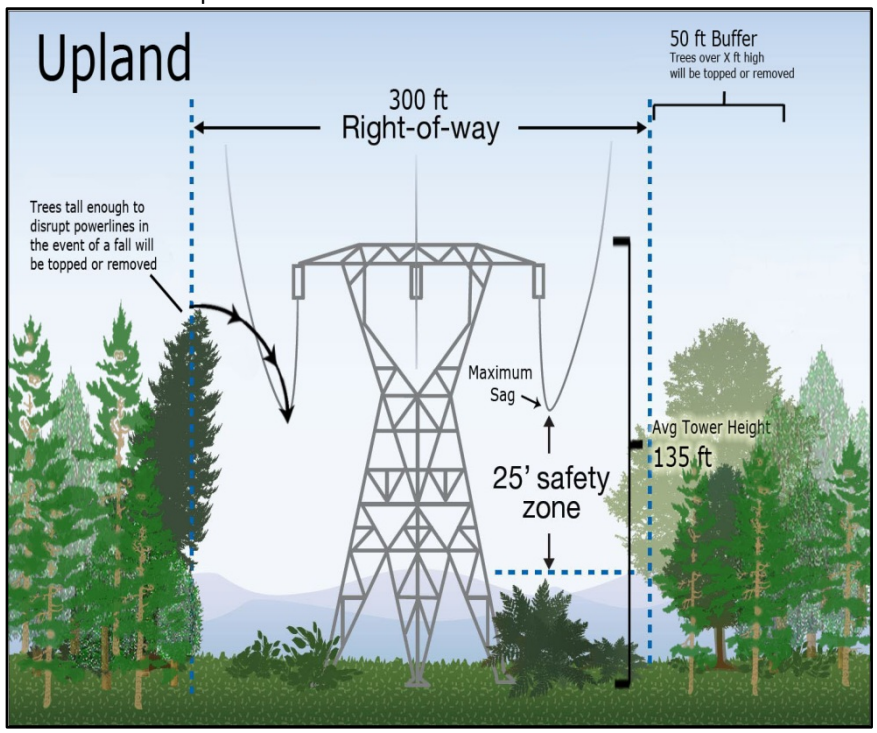

Figure 9

Maintenance

Since we must manage this corridor against the growth of tall vegetation, it is likely maintenance will continue within the ROW in perpetuity.

Tall Growing Vegetation Removal

It is expected that tall growing species have extensive seed banks, and root systems within the transmission corridor; therefore we expect to have many tall growing species re-emerging. In order to mitigate damage from the power lines, we recommend reoccurring tall-growing vegetation maintenance. Within the 300ft region, anything exceeding 15 ft, or any species known to grow higher than 15 ft, should be removed. To maintain organic matter on site, and increase landscape diversity, the biomass should be left on site as LWD. Outside of the 300ft area, to a 50ft distance, trees reaching or exceeding 100ft should be removed (leaving behind the logs as either LWD or snags).

Invasive Species Removal

The invasive species pose a large threat in the transmission abilities of this corridor to facilitate high connectivity. We recommend an invasive species maintenance coinciding with every tall growing vegetation removal.

We also recommend an initial removal of invasive species one year after restoration has been completed. This is to allow the native species a higher chance to dominate the corridor.

During maintenance we also recommend the immediate removal of invasives, without leaving any biomass behind (to ensure the removal of seeds, rhizomes, and any propagating material is taken off site).

Monitoring

We recommend ongoing monitoring to protect both the Cedar River Watershed as well as the BPA transmission corridor. We recommend monitoring for:

- Known invasive species.
- Fire risks (from vegetation and transmission lines.
- Tall vegetation.
- Erosion.

Predictable Level of Repair

Although the level repair of the buffer zone is hard to predict, we believe that restoring the area to a shrub land will be a highly successful option. Shrub lands with similar species arrays naturally occur in Western Washington forests (Loft & Menkle, 1984).

- We believe that with the LWD, and preexisting land formations there will be enough diversity in the landscape to provide the microhabitats to stimulate a diverse ecosystem.
- We believe that the shrub land will function well to stabilize the landscape and guard against erosion.
- We believe that continued maintenance is required to suppress tall growing vegetation, such as trees.
- With reduced impacts on wetlands, and restoration in affected areas, we believe the wetlands will have a high instance of repair, and maintain a historical level of vegetation and biodiversity.
- We expect a high level of repair in the riparian areas as well, the species we have selected are specifically suited to this environment, and once taken hold, should perform well to control erosion and promote biodiversity.

Long-term Prospects

The goal of this project is to restore and maintain the unique characteristics of the Cedar River Watershed after disturbance caused by installation of a transmission corridor, while still maintaining the function and safety of the transmission lines. Long-term environmental prospects include:

- Reduced vegetation along corridor may cause a slight temperature increase to the flowing river directly below.
- Possible reduction in quality of groundwater near residential areas in the southern part of the watershed.
- Possible low to moderate negative impact on fisheries in the Cedar River.
- Reduction in habitat along corridor may cause a moderate negative impact to threatened, endangered, and sensitive species.
- Possible loss of productivity in the area.
- Reduce quantity and quality of habitats along the corridor.
- Creates beneficial habitat for deer and elk.
- Moderate negative impact on coniferous forest species.
- Removal of invasive species and noxious weeds will create beneficial habitat for native species.
- Long-term negative visual aspect to the watershed.

Long-term prospects require the continued maintenance of the transmission lines and management of vegetation in order to reduce power outages, retain access, and uphold safety. Long-term maintenance includes:

- Monitoring for tall trees and removing as necessary.
- Maintaining snags and large woody debris.
- Mitigation of land by BPA to offset impacts of the transmission lines.
- Trees removed in long-term rotation pattern in order to maintain characteristics of an early successional forest.
- Monitoring soil erosion.
- Monitoring water quality.

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E5 Parking Lot Freshwater Marsh

(Photograph. Rosato, 2011)

Introduction

E5 is a parking lot located in the Union Bay Natural Area along University Slough. As part of the mitigation for the flooding, WashDOT plans to restore E5 to a wetland. We set out to figure out how we would turn the area into a wetland by re-contouring the site so that water is present on site, which is necessary for a wetland to be a wetland. Our solution was to raise one end of the site to flood the site in the winter and excavate to have the slough flood the site in the summer.

Site Description

The Union Bay Natural Area (UBNA) has an unusual history. In the past century, this area has been open water in Lake Washington, a wetland, the Montlake Landfill, and most recently a natural area. This urban gem is home to research, recreation, restoration, and a variety of flora and fauna. On the eastern border is University of Washington Center for Urban Horticulture (UWCUH), the largest group of academic users of UBNA (Hamilton, 1995). The 74 acres of UBNA is habitat for over 200 avian species, and is considered the one of the best bird-watching sites in Seattle.

Habitat

The UBNA Habitats Narrative (1980) lists marsh, pond, and shore lands to grassland, shrub lands, and even woodlands ecosystems. UBNA 'covers ground' when it comes to habitat diversity.

Shore lands

UBNA borders the Lake Washington with 4 miles of shoreline, 200 feet of which are Conservancy Preservation shoreline (Hamilton, 1995).

Woodlands

The few wooded areas within UBNA are comprised of Alders, Willows, and Cottonwoods. The understory contains small trees and invasive thickets of Himalayan blackberry. Many of these areas flood, so wetland species both border and are intermixed within the woodlands (University of Washington, 1980).

Grasslands

The stretches of grassland are dotted with ponds, and broken by woodlands, parking lots, wetlands, and roads. These grasslands are home to 56 species, 73% of which are invasive or introduced, and 11 of which are native although continuing efforts to reintroduce natives to the area have started to increase the overall proportion of native species throughout UBNA (University of Washington, 1980).

E-5

E-5 is a gravel parking lot on the western side of UBNA. E-5 served, and was maintained by, UW Commuter Services for many years. Due to the weight of the gravel lot, areas have sunk, and been filled with gravel repeatedly to maintain a level parking area. It is estimated that ten to twenty feet of gravel are under the E-5 parking lot.

The parking lot was surveyed to collect data on grassland species adapted to harsh environments; Matricaria (pineapple weed) was found tolerating high stress in the central area of E-5. Other species were found at the perimeter of the lot, suffering stunted growth due to compacted substrate, including a variety of fescues (University of Washington, 1980).

Site History

The project area is characterized by a history of glacial process, creating hills and valleys and depositing base materials for the soils in the region. Rivers, streams, and lakes filled in depressions and deposited additional materials creating upland and wetland habitats. Although located in the Western Hemlock Forest Zone, human encroachment has created a matrix of habitats, contributing to water withdrawals and introducing invasive species. Buffer regions are either non-existent or very small. Many of these human impacts were caused by the creation of Lake Washington Ship Canal in 1917, which lowered the surface elevation 9 feet, with surface elevations varying depending on the actions of the docks. There is additional disturbance caused by humans by the creation and use of foot trails, boardwalks, parking lots, and buildings.

Between 1926 and 1966 the area was used as a landfill. The site was closed in 1971 and a 2 to 3 foot soil cap was placed. In 1972 the University of Washington assumed ownership and in 1990 began restoring the site to its native condition as upland and wetland habitat. Toxic sediments and the thick clay soil cap have limited restoration efforts and made it difficult to establish native vegetation.

Our main project area is parking lot E-5 located in the UBNA and managed by the University of Washington. E-5 has led to shoreline encroachment of the Ecological Research Natural Area. In 1972 plans were made for the removal of E-5 when it was no longer needed.

One third of E-5 was converted to wet-prairie land between 1998-1999. In 2008 this wet-prairie was re-evaluated and shown to have micro topographic variation within the differing elevations contributing to invasive species persistence. Restorations adjacent to the parking lot have created wetlands, but they are in unconnected and invasive species persist.

Site Analysis

The proposed restoration site is located along the eastern bank of University Slough. It is bordered by the UW driving range to the north, UBNA to the east, and Lake Washington to the south (Figure 1).

Topography
The northern end of the site has a lower elevation than the southern end of the site. E5 parking lots elevation ranges from 19.5 to 17.5 feet with the higher elevation being at the southern end. The trail at the northern end of E5 is at an elevation of about 21 feet. Adjacent to E5 on its east side there is a seasonally wet prairie with an elevation of about 16.5 feet. Douglas road varies in elevation from about 19.5 to 20.5 feet in elevation (Figure 2)

Hydrology
Seattle falls in a Mediterranean climate so it rains more in the fall and winter and tends to be dry in the summer. The northern forested wetland of the gets its water from surface rain in the winter, as does the seasonally wet prairie adjacent to E5. University Slough's waters rises to about 18.5 feet in the summer and drops to 16.5 feet in the winter.

Vegetation
After the land fill was capped European grass were planted rather than native grass to present composition throughout the UBNA. Since then there have been a number of restoration projects done in the UBNA in which natives were planted. The northern part of the site in a forested wetland and to the east of E5 there is a wet prairie. Aside from the native grasses and forbs, other natives were added near E5 include, *Ribes sanguineum* (Red-Flowering Currant), *Salix spp*. (Willow), and *Cornus stolonifera* (Red-Osier Dogwood).

Site Outline on Google Earth and Contour Map

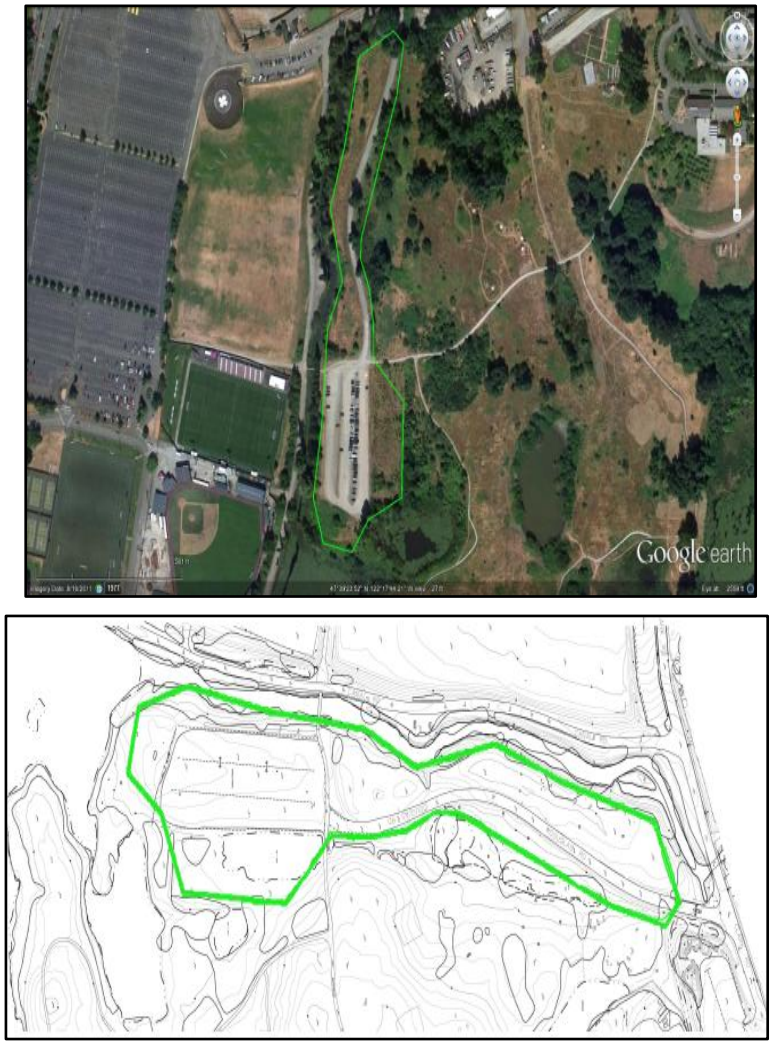


Figure 1
Total Area inside green lines = approx. 4.5 acres Perimeter = approx. 0.4 miles

Elevation Profile through a Central Transect

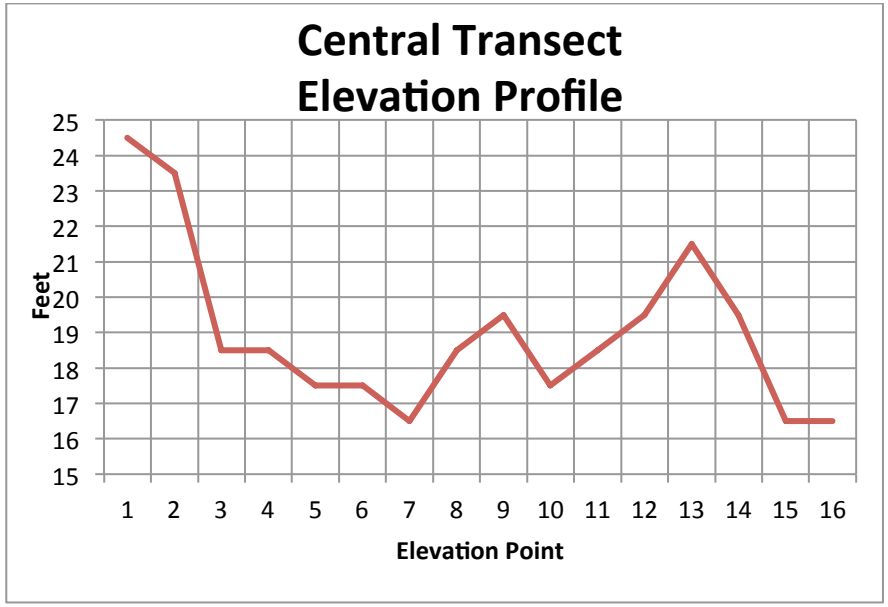


Figure 2

Identification of Need

The goal is to produce a wetland to maximize Washington Department of Transportation's (WashDOT) mitigation requirements. For an area to be classified as wetland, it must meet water level, vegetation, and soil characteristics. These requirements can be met by changing the hydrology of the site and installing vegetation.

- Maintain trail 40 feet away from roads or trails (as set by mitigation standards).
- Create water levels characterized by wetland standards.
- Keep soil moisture content at levels adequate for supporting vegetation growth requirements.
- Install appropriate vegetation to complement water gradient.
- Promote requests by bird watchers, pedestrians, and bicyclists.

Environmental Functions

Converting the E-5 parking lot to a wetland will increase native plant habitat and habitat diversity. It will create a habitat for invertebrates, amphibians, birds, fish, and mammals. It will also contribute to migration corridors by connecting wetland and upland habitats.

The created wetland will be generated by surface water from the lake; therefore water quality improvement normally associated with restored and natural wetlands is not a primary function for this project. The new wetland hydrology will also be in tune with the lake's behavior including the irregular rise of surface water elevation in the summer due to the docks.

Constraints and Possible Remedies

There are several levels of constraints set forth by stakeholders. The reconstruction of SR 520 Bridge will destroy and disturb various vegetation and wildlife species. WashDOT has been ordered to construct a wetland in the area of E5 lot. In complying with request, WashDOT's largest constraint is to ensure minimal damage to wildlife in the area. In response, WashDOT has teamed up with University of Washington Botanical Gardens on a general scheme for restoration. The restoration plan takes into consideration that the mitigated area is heavily used by pedestrians, bicycles, and birdwatchers. Wetland vegetation that compliments bird habitat is the preferred method to addressing this constraint.

Stakeholders

There are a large number of stakeholders that will voice their opinions to any changes made to UBNA. Some of the more prominent stakeholders include: City of Seattle, Washington DOE, Army Corps of Engineers, EPA, Federal Highway Administration,

Muckleshoot Tribe, Laurelhurst Community, Montlake Community, Arboretum, WashDOT, UW Botanical Gardens, and the Audobon Society.

Goals and Objectives

WashDOT plans to restore or enhance 28 acres of UBNA to wetland for mitigation credits; this mitigation is to compensate for the SR 520 Evergreen Point Floating Bridge's construction. In order to do this, we recommend excavating the E-5 parking lot, and restoring it to wetland. We also recommend enhancing the wetlands in the northwest corner. Presently the wetland regions throughout UBNA are not hydrologically connected.

To successfully complete this project we have set certain goals:

- Restore or enhance up to 28 acres of UBNA.
- Excavate the E-5 parking lot.
- Restore the E-5 to wetland.
- Enhance existing wetland.
- Establish native wetland species.
- Create connectivity between wetlands.
- Have standing water in the new E-5 wetland area in the summer (from Lake Washington) and the winter (from rain runoff).
- Retain runoff from northern region in wetlands.
- Install native wetland plant.
- Remove invasive species.

Design Requirements

In order to receive mitigation credits for this restoration, the restored area must meet certain criteria to be considered a wetland. Although many differing definitions are used to evaluate a wetland, the state of Washington Department of Natural Resources uses the Forestry Practices definition for evaluation (Recognizing wetlands). The area must meet requirements under with hydrology, hydric soils, and wetland vegetation.

- Meets hydrology indicators (McMillan, 1997):
    1. Visual observation of inundation (surface flooding); or
    2. Visual observation of saturation (evidence of periodic saturation within 12" of the surface); or
    3. Watermarks or staining of woody vegetation; or
    4. Drift lines; "high tide" lines of debris left by previous water events; or
    5. Sediment deposits, including deposits of algae; or
    6. Drainage patterns within wetlands.
- Meets hydric soil indicators (McMillan, 1997):
    1. "Rotten egg" odor resulting from hydrogen sulfide, a compound which results from reduction of sulfur in anaerobic conditions, and can be found in both organic and mineral soils that contain sulfur; or
    2. Gleying of mineral soil (Munsell color chart Chroma of < 1); or
    3. Mottling of mineral soils (with a matric Chroma of < 2); or
    4. Deep organic horizon (>8"); or
    5. Streaks or lenses of organic material in sandy soils.
- Meets wetland vegetation indicators (McMillan, 1997):
    1. OBL (obligate wetland plants) species comprise all dominants in the plant community; or
    2. OBL species do not dominate each stratum, but more than 50 percent of the dominants totaled from all vegetation strata are OBL, FACW (Facultative wetland plants), or FAC (facultative plants) species; or
    3. A plant community has a visually estimated percent coverage of OBL and FACW species that exceeds the coverage of FACU and UPL species.

Design Parameters

The project area is owned and managed by the University of Washington in Seattle, WA and located northwest of Union Bay and east of University Slough. Parking lot E-5 is approximately 6 acres and the surrounding project area encompasses approximately 18 more acres.

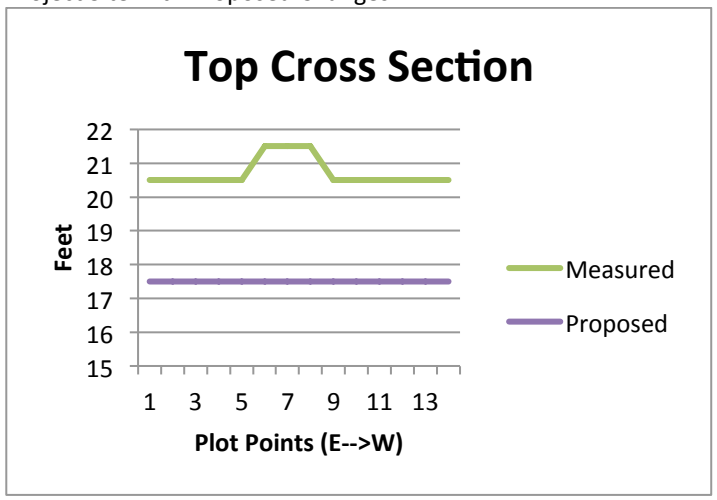
Basic Approach

Our basic approach for restoring this area to wetlands consists of excavation, removal of transit pathways, and control of winter runoff and finally vegetation.

Excavation

We plan to excavate the project area (Figure 3a, b.) to an elevation of 18.5 feet with a deeper excavation of 17.5 feet in polygon 2. This excavated area will include the existing E-5 parking lot. This green line marks the perimeter of the proposed wetland area we are restoring. No point inside the green perimeter will be higher than 17.5 feet or lower than 17.5 feet. These elevations will allow summer flooding from the lake, which ranges from 17.5 feet in the winter to 18.5 feet in the summer, and can flow into the system through the southern region of Polygon 1.

Project Site with Proposed Changes



Elevation Profiles of the Top and Bottom Cross Section Lines

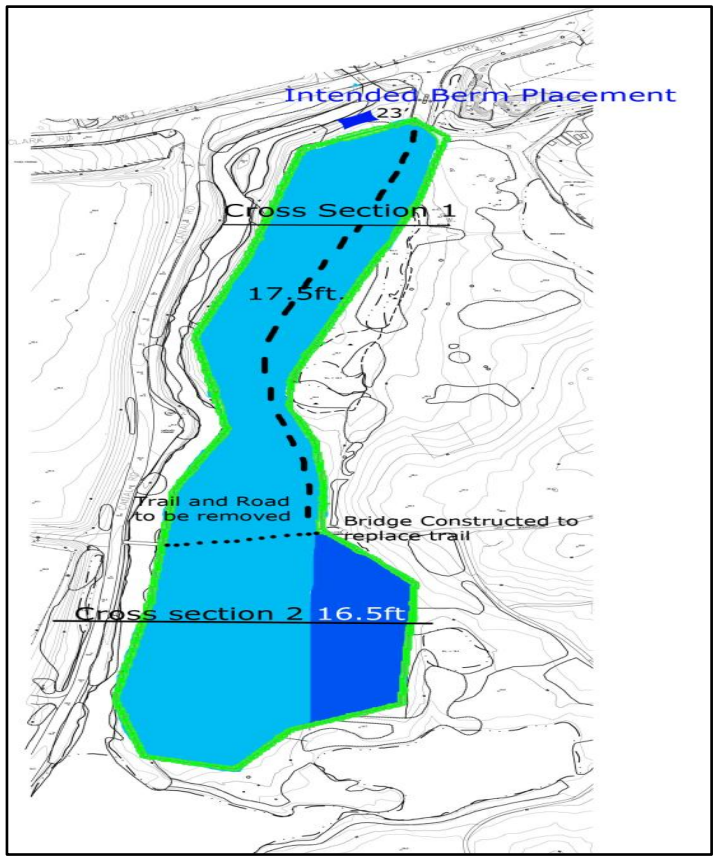


Figure 3a

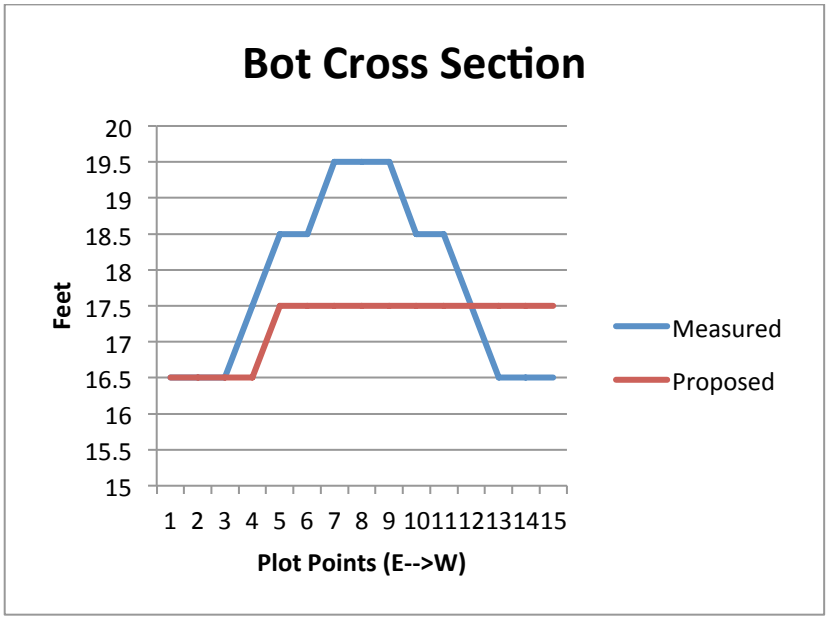


Figure 3b.

Removal of Transit Pathway*s*

The removal of Douglas Road and Wahkiakum Lane will allow uninterrupted hydrological activity, wetland habitat, and allow WashDOT to obtain the highest amount of mitigation credits on this site. Wahkiakum Lane will be replaced with a bridge to allow for continued access throughout UBNA and to minimize any adverse effects a large gravel trail could have running through a wetland.

Control of Winter Runoff

In the northern section of the site, a slope allows winter runoff to flow offsite (Figure 4). We plan to construct a berm reaching 23 feet, constructed form excavated fill, to redirect the winter runoff south, where it will contribute to winter flooding in the proposed excavated site. This redirection of water flow will drastically increase the size of watershed contributing to the excavated wetland, which will allow winter flooding of the excavated basin. This will also reduce water loss from the site.

Hydrology before Berm Installation – Runoff Empties Back into the Slough

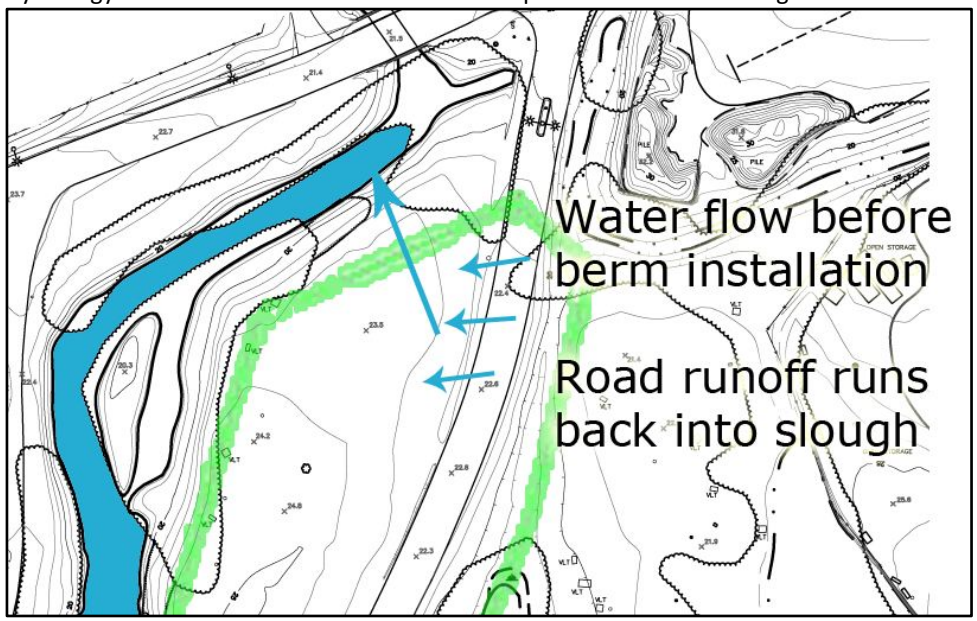


Figure 4. (Hamilton, 1995)

Creation of Wetland with Both Summer and Winter Flooding

The planned berm constructed in the north will redirect winter runoff. This will cause the area to retain winter run-off flooding (Figure 5). Summer flooding will come from the southern edge of the site, since the lake exceeds the 17 foot basin perimeter elevation, by up to a foot during summer. The lake drops down to 16 feet, which is below the wetland basin level, during winter; this is when redirected runoff will become the only source of flooding for the basin.

During the winter the basin can be flooded to 1 foot of standing water in the deeper areas, since no area within the yellow perimeter may be below 16 feet. When the basin fills to the 17 feet, any excess will flow south into the lake.

Estimated Effects of Berm Placement on Hydrology

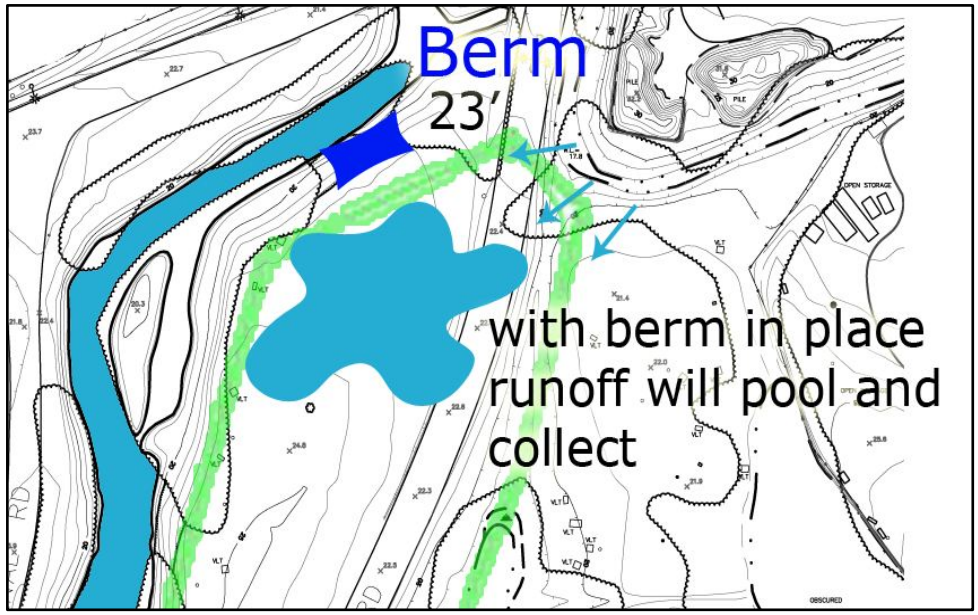


Figure 5.

During the summer, the constructed wetland basin can reach a highest depth of between 1feet and 2 feet; Lake Washington will fill the wetland up to an elevation of 18 feet (which will give the wetland a depth of between 1 to 2 feet).

Re-vegetation

We plan to install vegetation with native emergent wetland species. These species must be able to handle up to 1 foot standing water in some areas (Table 1), and up to 2 feet in others (Table 2).

(SF= seasonally flooded, PF= permanently flooded)

Name	**Water tolerance**
Scirpus microcarpus (small-fruited bulrush)	SF
Carex obnupta (slough sedge)	SF
Eleocharis palustris (spikerush)	PF, SF

Table 1: Flooding up to 1 foot in polygon 1

Name	**Water tolerance**
Eleocharis palustris (spikerush)	PF, SF
Sparaganium eurycarpum (broad-fruited burreed)	PF
Scirpus americanus (three-square bulrush)	PF
Sagittaria latifolia (wapato)	PF

Table 2: Flooding up to 2 feet in polygon 2
(Stevens & Vanbianchi, 1993)

To guarantee a higher survival rate of planted vegetation, we created two polygons with an array of site-specific depth adapted species (Figure 6a, b).

Planting Polygons

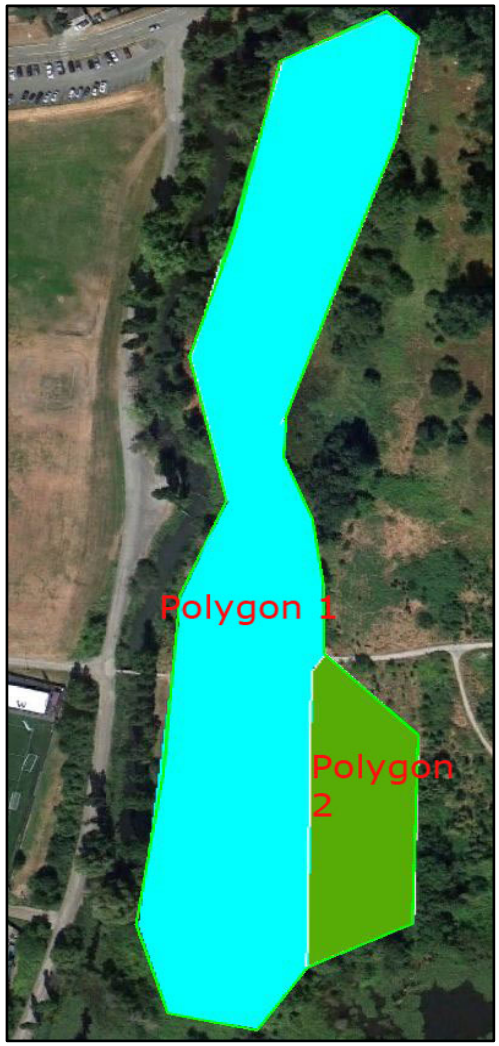


Figure 6a

Water Level in Vegetation Polygons

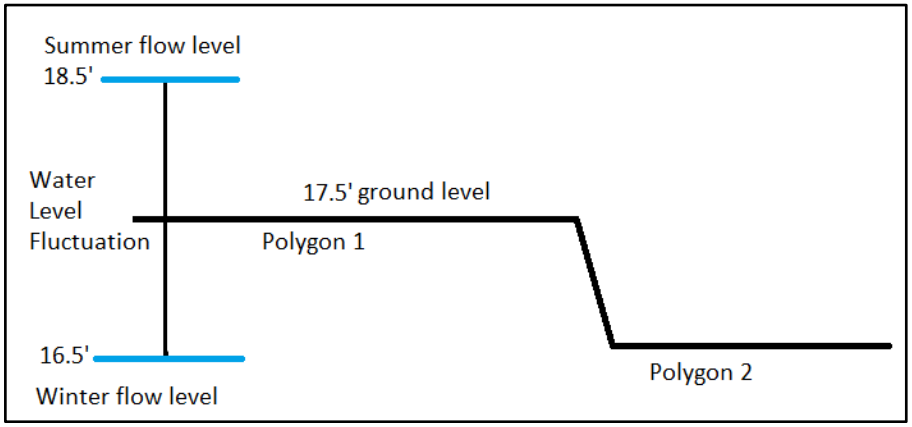


Figure 6b

Implementation Timeline

Task	11/12	12/12	01/13	02/13	03/13	04/13	05/13	06/13
Preparation for Excavation								
Excavate gravel and Soil from E5								
Remove Gravel Trail and Replace with Bridge								
Build Berm								
Remove Invasive Species								
Flood E5 Lot								
Purchase Vegetation								
Install Vegetation in E5 Lot								
Develop Monitor and Maintenance Plan								
Replace Dead Vegetation								

Long-term Prospects

The ultimate objective of this project is to connect the new wetland to the pre-existing wetland in UBNA so as to create connectivity throughout habitat areas. Since the majority of the UBNA is already considered wetland by WashDOT one of our primary objectives will be to connect the new restored area to the existing wetlands (Figure 7).

- Maintain wetland plant communities.
- Suppress invasive growth.
- Protected installed trees from beaver

WashDOT Wetland Map Overlay with Our Restoration Site Outline.

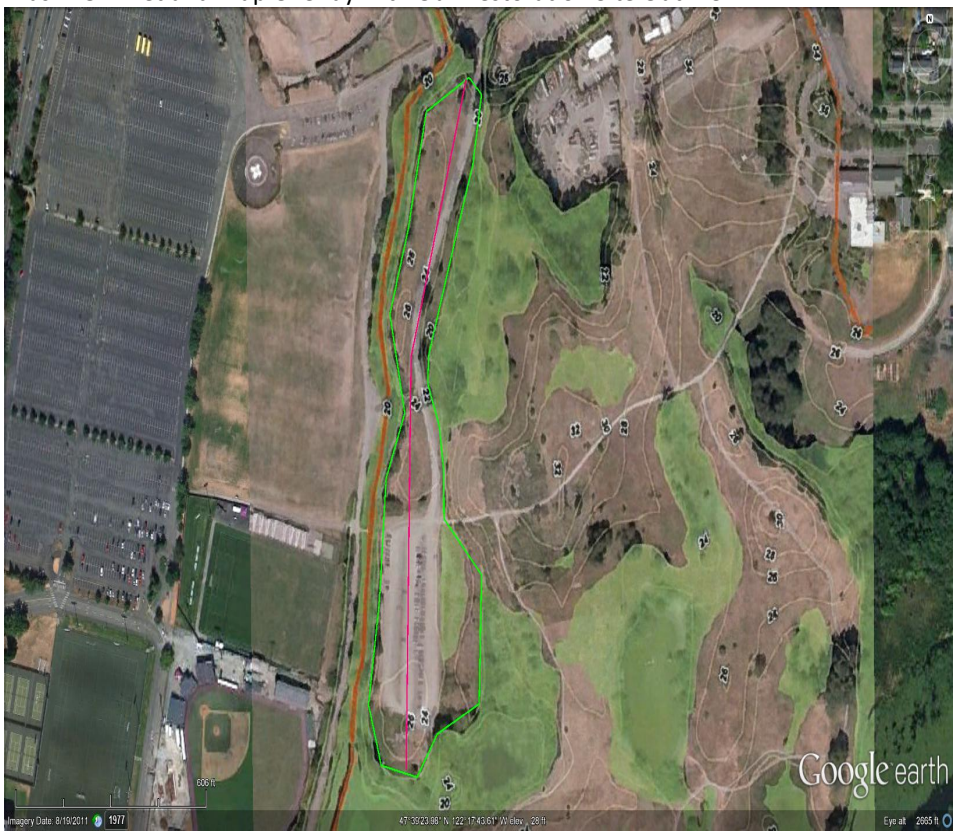


Figure 7.: Note – elevation data on WashDOT map is different from UW elevational data used. Photograph. Google. 2012.

Predictable Level of Repair

This is a mitigation project funded by WSDOT designed to offset impacts of disturbed lands caused by construction of the SR 520 floating bridge. The goal is to obtain mitigation credits by creating wetland conditions equal to or greater than those disturbed. Creating a wetland from a parking lot will provide maximum mitigation credits on the 6 areas the parking lot encompasses.

Based on the restorative success of the surrounding wetlands in the UBNA, we hope that our newly graded area will emulate those habitats. There are several different factors that success hinges on, namely hydrology and biotic communities and we will be monitoring their statuses closely. The level at which we graded should allow for permanent saturation and seasonal flooding, mimicking the hydrology of most wetlands. Invasive presence is another factor that will need to be closely watched and any potential infestations dealt with swiftly in order to grant wetland plants the greatest chance of success.

Maintenance

This project is located in an area highly susceptible to invasive species, so suppression and removal of invasives will need to be maintained after the initial restoration. Installed native vegetation will need to be monitored for die-off and replanted as necessary. The hydrology of the area will also need to be monitored to maintain desired results and prevent flooding onto other restoration projects ongoing in the area.

Monitoring should be conducted once per month for 3 years and track percent cover, die-off, invasive growth, water depth, and landscape changes. Invasives should be removed and die-off replanted once per month during these 3 years as well. After 3 years of stable wetland development with no major changes to the original design, monitoring can be done once every 5 years (Cole et al., 1996).

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Vernal Pool in Marcellus Shrub-steppe Preserve

(Photograph. Ragesoss, 2007)

Introduction

Vernal pools are a threatened and sensitive habitat. The Marcellus Shrub-steppe Preserve, own by The Nature Conservancy (TNC) and the Department of Natural Resources (DNR), contains vernal pools and shrub-steppe habitats. The TNC site has been fenced off from grazing and has recovered fairly well, while DNR is still grazing on, and in much worse condition. Once again the agricultural community has a lot of influence so it was important to take that into account in our design. Our design included fencing off the vernal pools, continuing to allow for grazing, propagating and planting native species, and removing invasive species by hand and by herbicide in the shrub steppe.

Site Description

This restoration project is located in the Marcellus Shrub-steppe Preserve near Ritzville, Washington in the Colombia Basin. (47°14'N, 118°24'W; T20N, R35E). The land is owned by The Washington State Department of Natural Resources (DNR) and The Nature Conservatory (TNC). The land is managed as a Natural Area Preserve by DNR in order to protect high quality examples of rare species in the shrub-steppe and vernal pools ecosystems. The distribution of plants and animals is controlled by precipitation and seasonal temperatures.

Vernal pools are shallow depressions that are seasonal wetlands, drying out in the late spring, and filling with periodic rainfall and snow accumulation in the winter fill (Crowe, 1994).Vernal pools are listed as Priority 2 Protection status by the Washington Natural Heritage (2011) program since they provide habitat to rare or highly threatened species. They create a continuous circular gradient from the center of the pool outward. Zonation is often striking, with the center having more standing water year round, higher salinity, and alkalinity. Perennials grow in the center of the pool, and annuals in the shallower areas. The pools also provide habitat for aquatic animals and birds.

Perennial grasses and shrubs, rimrock and tumbleweeds characterize the Shrub-steppe ecosystem. Particularly high quality examples of Big Sagebrush (*Artemisia tridentata*) and Three-tip Sagebrush (*Artemisia tripartita*) are found in the area. The shrub-steppe also provides habitat for many birds, mammals, reptiles, and insects, some of which are endemic and obligate to the sagebrush community.

TNC owned land has been fenced since 1986, but DNR land has been subject to cattle grazing during the spring and summer. This has led to lower numbers of rare species on DNR side, and higher numbers of invasive plant species (Figure 1).

Site Location

Figure 1: Photograph. Google, 2012.

Site History

The Missoula floods formed the Colombia Basin landscape over 14,000 years ago. This created deep valleys and beautiful sheer rock walls in the volcanic soils. Vernal pools formed in shallow depressions with fine or impermeable soils following the floods. Wide and deep valleys created an arid windy environment difficult for tree establishment and perfect for shrubs, grasses, and *Triticum spp*. (wheat) crops. Wheat has been a major product of Adams County, WA since 1897. Human encroachment, particularly cattle grazing, has caused a decline in native vegetation and an increase in invasive species in the area. Fencing of TNC land in 1986 prevented further degradation from cattle grazing.

Site Analysis

Vernal Pools

Soil

Soils are drier at higher elevation. Vernal pool soils form crusts (cryptogrammic or microbiotic). Crusts play an important role in the environment. These crusts primarily affect processes occurring at the soil-air interface, in the top 1 to 4 mm of soil. Affected processes include soil stability, nitrogen fixation, nutrient cycling, soil-plant-water relations, infiltration, seedling germination, and plant growth (USGS, 2006). There is greater salinity and alkalinity in the center of the pools. As a result of grazing, soil erosion has increased and the soil has become compacted (Brown, 1999).

Vegetation

Annual species are found at the outer rims of the vernal pools, while perennial species are found in the central parts of the pools. Surrounding the pools is characteristic shrub-steppe vegetation. Lower retention pools that experience more variable inundation have more non-pool species and weedy exotics (Brown, 1999). The dominant species composition is divided into three zones (Figure 2). The first zone is the outermost portion of the pool; it borders the upland and consists of both upland and vernal pool species. The third is at the center and where most of the vernal pool species are found. The second, being in between the first and the third, has bare ground and minimal biomass (Table 1). The main invasives present are *Bromus mollis* (soft brome) and *Bromus tectorum* (cheatgrass).Other invasive species include *Juncus bufonus* (Toadrush) *Lepidium mitidum* (Shining Pepperweed) and *Plantago hookeriana* (California plantain).

Vegetation for Each Vernal Pool Zonation

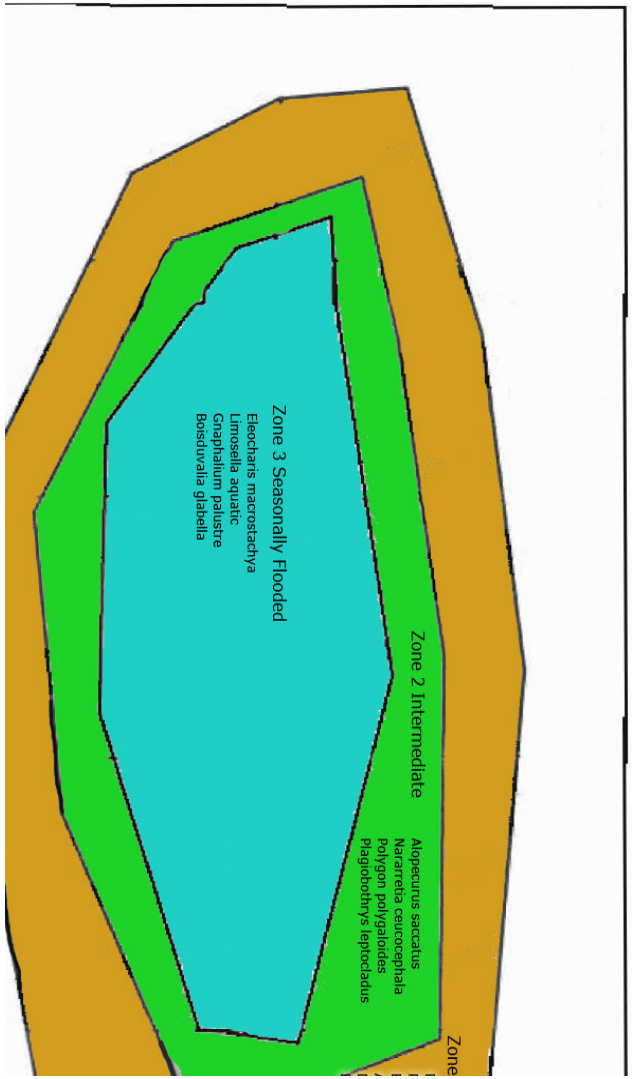


Figure 2: Diagram. Brown, 1999.

Table 1: Dominant Vegetation Found in Each zonation of Vernal Pools (Brown, 1999).

Zone	Vegetation Type	Species
1	Upland Grass and Forbs	*Bromus spp.*
		P. scabrella
		E. elymoides
		A. interrupta
		D. verna
		E. spp.
1	Water tolerant Vernal Pool Species	*D. danthonioides*
		M. minimus
2	Species Tolerant of Moderate Periods of Inundation	*A. saccatus*
		N. leucocephala
		P. polygaloides
		P. lcptocladus
2	Bare soil	*none*
3	Mostly Water-Tolerant Species	*E. macrostachya*
		L. aquatica
		C. paluslre
		B. glabella

Hydrology

Vernal pools tend to form over impermeable surfaces like hardpans or bedrock. Vernal pools can be described in four stages: a wetting, aquatic, drying, and drought phase (Brown, 1999). The wetting phase being the time of the year the pool is filling and the aquatic phase is the time of the year the pool has filled. Winter runoff fills the pools during the spring, while in some areas much of the water comes from groundwater systems. Over the course of the summer the pools dry up as there is less run off and precipitation decreases. It is interesting to note that flowers will bloom in concentric circles, following the receding shoreline.

Grazing

Grazing has negatively impacted the area in several ways. Grazing lowers vegetation richness when livestock target a specific species for forage. Crusts are well adapted to severe growing conditions, but poorly adapted to compressional disturbances (Brown, 1999). Domestic livestock grazing place a heavy toll on the integrity of the crusts. Disruption of the crusts brings decreased organism diversity, soil nutrients, stability, and organic matter. Crust damage is usually caused by human or livestock trampling as well as off-road use of vehicles. Compressional disturbances break sheaths and filaments and drastically reduce the ability of the soil organisms to function, particularly in providing nitrogen and soil stability (USGS, 2006).

There is some indication of grazing resulting in positive effects. Some findings by Brown (1999) indicated that after grazing was excluded from vernal pools, exotic annual vegetation increased and the hydrology was altered. However, four vernal pools were monitored.

Shrub-steppe

Soil

The soil in the rest of the site is comparable to the soil outside the edge of the vernal pools (See Site Analysis: vernal pools).

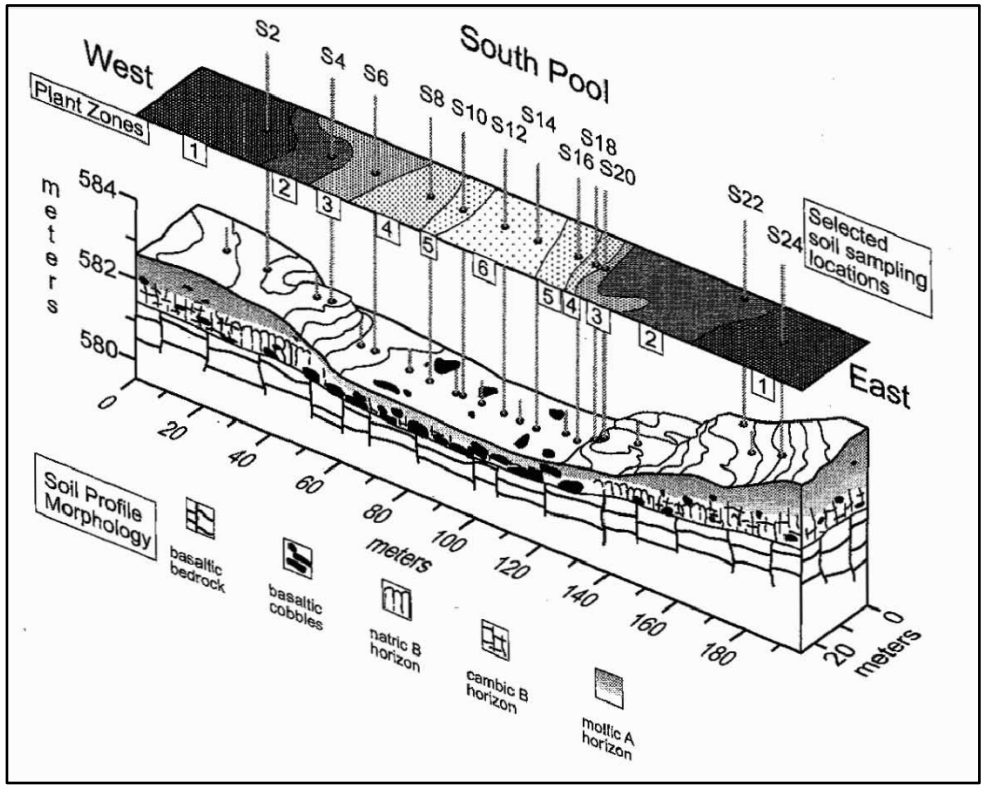
Vegetation

A survey by Crowe et al. (1994) found that the plant communities around the upper edges of the vernal pools served as ideal of a shrub-steppe community. It was dominated by *F. idahoensis* with a scattered shrub overstory of *A. tridentata*. More abundant forbs included *Plectritus macrocera, Plantago patagonica*, and *Draba verna* (Figure 3). Shrub height was about 70 cm and herb height about 40 cm. Additional plant communities of the shrub steppe area as found by Brown (1999) include:

- *Artemisia tridentate* (Big Sagebrush)
- *Festuca idahoensis* (Idaho Fescue)
- *Artemisia rigida* (Stiff Sagebrush)
- *Poa secunda* (Sandberg's Bluegrass)
- *Artemisia tripartite* (Three-tip Sagebrush)
- *Grayia spinosa* (Hop sage)
- *Sarcobatus vermiculatus* (Greasewood)
- *Purshia tridentate* (Bitterbrush)
- *Pseudoroegneria spicata* (Bluebunch Wheatgrass)
- *Hesperostipa comate* (Needle and Thread)
- *Phlox spp*.
- *Calochortus luteus* (Mariposa Lily)
- *Erigeron philadelphicus* (Fleabanes)
- *Oxytropis lambertii* (Locoweed)

The main invasive species here are *B. mollis* and *B. tectorum*. Other invasives present include *J. bufonus*, *L. mitidum*, and *P. hookeriana*.

Vegetation Zonation



Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
F. idahoensis	*E. cinereus*	*P. scabrella*	*D. danthonioides*	*D. danthonioides*	*D. danthonioides*
A. tridentata	*C. nauseosus*	*L. grayi*	*E. palustris*	*E. palustris*	*N. intertexta*
P. macrocera	*C. vicidiflnrus*	*A. geyeri*	*A. diegoensis*	*A. diegoensis*	*P. scouleri*
P. patagonica	*S. interrigemus*	*M. linearis*	*A. heterophylla*	*A. heterophylla*	*P. oregonus*
D. verna	*P. rnacrocera*		*A. geyeri*	*N. intertexta*	*G. nana*
	D. vema		*E. minutum*	*G. nana*	
				M. aristatis	

Figure 3: Diagram and Table. Crowne et al., 1994

Hydrology

This region is located in the rain shadow of the Cascade Mountains. In the summer the ecosystem can get hotter than 100 degrees Fand winters can be below freezing. The region receives 16 to 18 inches of precipitation a year. (Washington Plant Association, 2011)

Grazing

The shrub-steppe is not as sensitive to grazing as vernal pools since it does not have the potential to support rare species richness the way the vernal pools can on this site. However the area is still susceptible to soil compaction, erosion, and hydrologic alteration from overgrazing.

Identification of the Need

N1: Protect native dominant and rare vegetation in the vernal pool and shrub-steppe ecosystems on TNC and DNR land.

N2: Allow sufficient grazing land for cattle on DNR land.

Stakeholders

- The TNC and DNR are the primary stakeholders because the restoration activity will affect the animal and vegetation habitat present in the vernal pools and shrub-steppe.
- Cattlemen are the secondary stakeholders. The action of fencing portions of DNC land off to cattle will affect grazing cycles.
- Farmers on neighboring fields. Their water rights are adjudicated and may be affected during the summer months when vegetation is irrigated. Also, the herbicide application may affect crop harvest through soil or water infiltration.

Constraints

Ideally there would not be any grazing to obtain rare native species and a simple way to manage invasive species and the final result of the restoration would be pristine shrub-steppe and vernal pools. However, this is not the case, and we must work around the reality.

C1: Cattlemen prefer that the part of the preserve that is owned by DNR remain grazing land. They also have political influence in the community.

A1a: The vernal pools will be fenced off and the cattlemen will continue to use the shrub steppe for grazing.

A1b: Conduct community education on conservation and importance of vernal pools.

C2: Inventory of some rare native species (such as*: Teucrium canadense*, *Myosurus minimus, and others*) are not found in local nursery. (Brown,1999).

A2: We will need to obtain seeds and contract a third party to propagate some or all of them (Table 2)

C3: Area has complex array of vegetation with specialized installation requirements.

A3a: Vernal pool annuals will need to be planted in the spring as the water recedes and the soil moisture decreases to support the annuals.

A3b: Vernal pool perennials will need to be planted in the winter since we should plant when water is present, but not when the pool is flood as it would be difficult to plant in standing water (Keeley & Zedler, 1998).

C4: General prescription of herbicide application may negatively impact the native vegetation habitat at the vernal pools and shrub-steppe ecosystems.

A4 The extensive perimeter of the sites and diverse ecosystems functions types requires for manual and herbicide application.

A4b: Careful consideration of herbicide brand and a management plan will be developed in order to minimize habitat disturbance and possible negative externalities.

Table 2: Nursery Supplies of Shrub-steppe Vegetation

Plants of the Wild	http://www.plantsofthewild.com
Methow Natives	http://www.methow.com
Rainier Seed	http://www.rainierseeds.com
Bitterroot Restoration	http://www.revegetation.com
Four Corner Nurseries	http://fourth-corner-nurseries.com
Wildlands Nursery	http://wildlands-inc.com

Environmental Functions

Vernal Pools

Vernal pools provide habitat to rare and threatened species of plants and aquatic animals, cyanobacteria, and lichens. Some plants are endemic to these pools due to their unique seasonal changes. The pools are also a site of high nutrient cycling and provide a seasonal food source to migratory animals. They also maintain habitat interspersion and improve water quality by filtering out toxic substances via groundwater filtration.

Shrub-steppe

The shrub-steppe provides habitat to numerous grasses and shrubs, particularly big sagebrush and Three-tip sagebrush. The sagebrush offers habitat for many species of birds, mammals, reptiles, and insects. Some birds and mammals are obligate to the sagebrush that grows in this habitat, such as the greater sage-grouse, sage sparrows, sage thrashers, and pygmy rabbits.

Goals and Objectives

Goal 1: Restore the shrub-steppe and vernal pools to their natural condition.

Objective 1: Install native vegetation.

Objective 2: Remove and suppress invasive vegetation.

Objective 3: Irrigate during summer months in effort to suppress invasive vegetation and encourage growth of newly installed native vegetation.

Objective 4: Create a maintenance plan to manage invasive encroachment and native development.

Goal 2: Exclude cattle grazing from the vernal pools and provide a management plan for grazing in the shrub-steppe.

Objective 1: Delineate restoration and grazing perimeters.

Objective 2: Provide protection for native vegetation in both ecosystems by physical exclusion of cattle from sensitive areas.

Objective 3: Establish management plan for cattle grazing in effort to protect rare vegetation species in the vernal pools and shrub-steppe site.

Basic Approach

Final desired results are to (1) suppress invasive vegetation (2) and encourage greater native and rare species richness. Protecting the vernal pools and their unique microhabitats are priority. Excluding the cattle via fencing is the most feasible and straight-forward option to preserving the delicate vernal pools. Figure 4 outlines the proposed placement of a fence around the western pools present in the DNR property. The surrounding shrub-steppe will still be available for grazing, but we hope to greatly reduce the percent cover of invasive species and have a greater amount of native species.

Shrub-Steppe and Vernal Pool Ecosystem Location with Proposed Fence Placement.

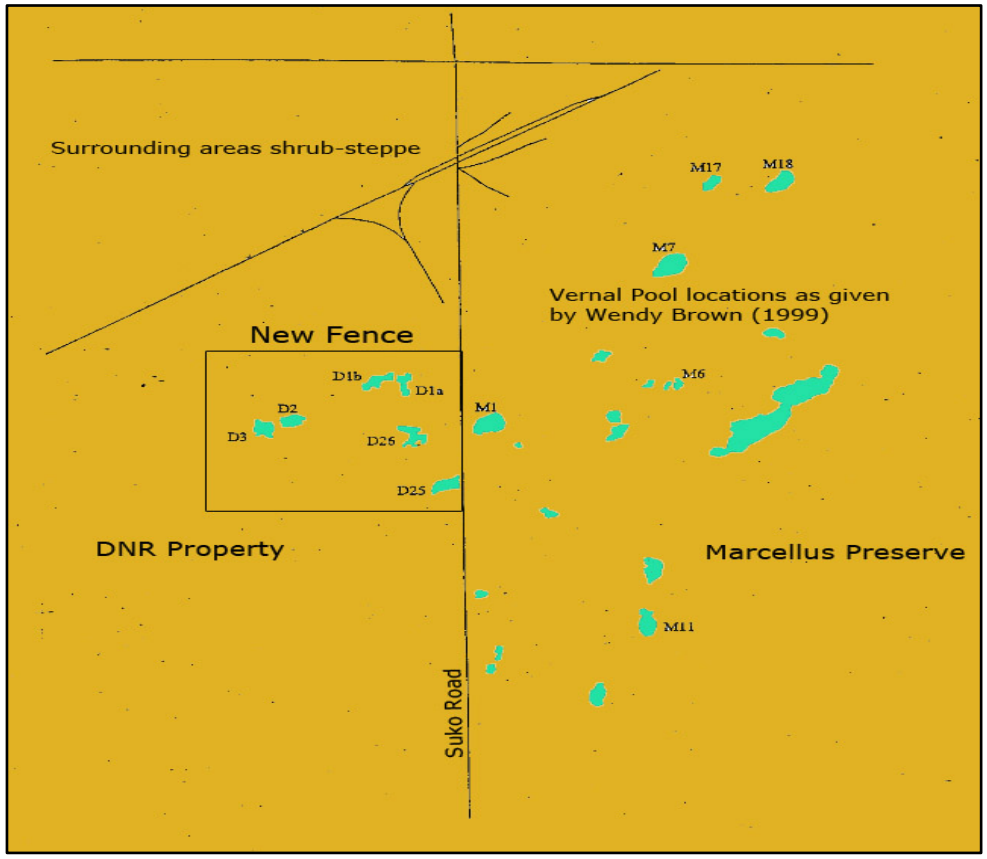


Figure 4: Diagram. Brown, 1999.

Grazing

Currently cattle are grazing so our first step will be to install a fence to keep the cows out of the vernal pools to prevent further damage and to get the pools well on the way to recovery.

Vegetation

We will collect seeds of plants that we are unable to buy in nurseries and then have the species propagated. We will herbicide in the fall. Plant the perennials and shrub species in the winter and the annuals in the spring. We will irrigate the vernal pool to help them establish.

Die off

We will replace die off in the appropriate time of year for the plants.

Maintenance- We recommend that The Natural Conservancy continue to herbicide to keep down invasive species and to maintain the fence.

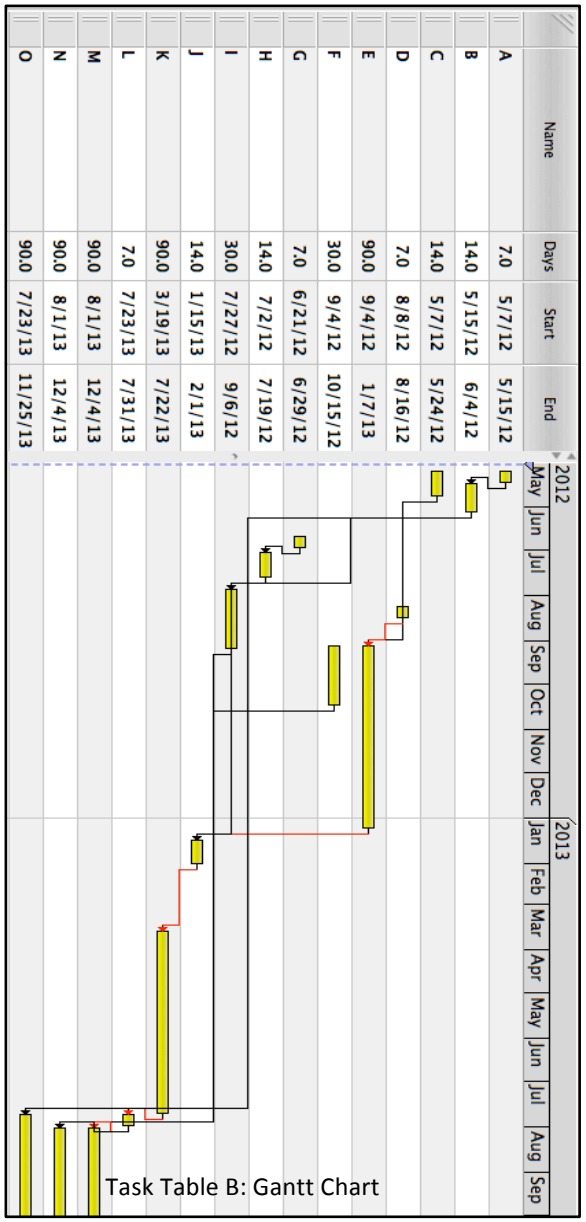
Implementation Timeline

Tasks

A	Acquire fence materials
B	(Design) Construct fence
C	Collect native seed
D	Acquire Propagation Site
E	Propagate native plants
F	Herbicide shrub-steppe
G	(Design) Acquire irrigation system
H	Construct irrigation system
I	Manual removal of invasives
J	Irrigate & Plant native species
K	Monitor planted species
L	Replace die-off
M	After-project monitoring
N	After-project maintenance
O	Fence maintenance

Task Table A: Task List

Proposed Timeline and Modified Gantt Chart



Task Table B: Gantt Chart

Predictable Level of Repair

Vernal Pools

- Increase of native cover: Treatment of vernal pools was based on research conducted by Brown (1999), which involved a combined treatment of manual removal of invasive vegetation in vernal pool sites and the exclusion of grazing in vernal pool sites. It is expected that the recovery of native vegetation cover of grazed sites is to reach a state similar to that of un-grazed sites. Un-grazed pools have higher instances of natives such as, *E. elymoides, M. dichotoma, M. linearis, Alopecurus saccatus* (Pacific foxtail) and *Eleocharis macrostachya* (creeping spike rush).

- It is also expect to recover *Downingia yina* (cascade calicoflower) and *M. minimus* in grazed vernal pools after installation.

- Decrease of invasive population: With the exclusion of grazing, it is expected to see a decrease in weedy species that were not present in un-grazed vernal pools but are present in grazed sites. These species include *B. tectorum, J. bufonius, L. perfoliatu, Polygonum aviculare* (common knotweed) and *Holosteum umbellatum* (jagged chickweed).

- Recovery of rare species: With the reduction of competition from invasive vegetation, and the removal of grazing pressure on the vernal pool communities, it is expected to have a high instance of re-establishment of the rare species, like *M. minimus*, after installation.

Shrub-steppe

- Decrease of invasive cover: Through the application of Plateau® herbicide, it is expected to have the decline and eradication of invasive vegetation in the shrub-steppe sites. Invasive species expected to respond to herbicide are *B. mollis, B. tectorum, J. bufonus, L. mitidum,* and *P. hookeriana.* However, because grazing will continue on the shrub-step areas, without maintenance, it is expected to see an eventual recovery of invasive populations. Invasive species were found in significantly higher concentrations in grazed areas (Brown, 1999). Therefore, the maintenance plan provides an annual monitoring of invasive cover, and situational re-application of herbicide.

- Increase of native cover: With the reduction or eradication of invasive vegetation on site, recovery of native species such as *F. idahoensis, P. secunda, Phlox,* and *Pseudoroegneria spicata* (bluebunch wheatgrass) is expected (Brown). The removal, or reduction, of invasive cover will reduce competition for resources with native vegetation, and allow native communities to dominate the shrub-steppe landscape.

Maintenance and Monitoring

Although the initial treatments of both vernal pool and shrub-steppe sites might be an effective means to reduce invasive cover, post installation treatment is crucial to secure the success of the restoration.

Vernal Pools

With manual removal of invasive vegetation it is likely that instances will decrease. With the exclusion of grazing, the number of invasives in the pools will decrease.

Annual monitoring of the vernal pools for a period of five years is recommended after project completion. This will include monitoring of native vegetation recovery, surveying survival of installed species, and identifying invasive populations. The natives we intend to plant include *D. yina* and *Myosurus minimus* (tiny mousetail), fore they are not present in the DNR land vernal pools but are present in TNC land (Brown, 1999). Identified invasive species include *Lactuca serriola* (prickly lettuce), *Sisymbrium altissimum* (tall tumblemustard), *Apera interrupta* (dense siltybent)*, B. tectorum, J. bufonius, L. perfoliatum, P. aviculare* and *H. umbellatum*.

Actions Taken

- If invasive vegetation re-establishes during monitoring, manual removal is recommended in order to minimize disturbance that may arise from mechanical or chemical removal.

- If significant mortality of installed native vegetation is observed in monitoring, it should be evaluated; and if mortality is due to abnormal circumstances (weather events, disturbance, etc.), vegetation should be replaced to re-establish a population.

Shrub-steppe

It is expected that the application of Plateau® to be effective at controlling invasive vegetation in at the shrub-steppe site. Much of this site will still be subject to grazing and possibility of invasive re-establishment post-treatment is foreseen. We recommend the annual monitoring, for a period of 5 years after project completion for *B. mollis, B. tectorum, J. bufonus, L. mitidum,* and *P. hookeriana.*

Herbicide application

In order to increase native vegetation cover, it is necessary to reduce competition against existing natives and reduce the cover of invasive vegetation (Table 3). Plateau® herbicide is a product used for weed control and native grass establishment (Plateau® label,). This herbicide kills annual grasses without affecting perennial grasses or shrubs. Plateau®'s effective use for eradicating *B. tectorum* is 177 ml per acre (Hanlon, 2010). Plateau® suggests that all invasives recorded within the shrub-step site respond to application of herbicide (Table 4). This herbicide may be used on Conservation Reserve Program land at rates up to 355 ml. per acre per year (BASF Chemical Company, 2011).

To ensure the suppression of the invasive species, Plateau® suggests to use of 296 ml of herbicide per acre of shrub step. The native species to our site that are listed on the Plateau® label are resistant to up to 355 ml per acre per year. To ensure that Bluebunch Wheatgrass, a native species, is not suppressed by the application of herbicide, we recommend the herbicide to be applied in the fall.

Table 3: Plateau® Effect on Invasive Vegetation.
All native species, on site, that have been tested with Plateau®, have shown tolerance.

B. mollis	Control obtained with application of 118 to 177ml oz. per acre.
B. tectorum	Control obtained with application of 118 to 177 ml per acre.
J. bufonus	Suppression obtained with application of 118 to 177 ml per acre.
L. mitidum	Control obtained post treatment with 237 to 355 ml per acre.
P. hookeriana	Control obtained with 237 to 355 ml per acre.

*(Effects on species obtained from Plateau® herbicide label).

Table 4: Plateau® Effect on Native Vegetation.
All native species, on site, that have been tested with Plateau®, have shown tolerance.

A. tridentata	Tolerance directly on foliage, Tolerance underneath foliage.
A. tripartita	Tolerance directly on foliage, Tolerance underneath foliage.
F. idahoensis	Tolerant to 237 to 355 ml per acre applied in fall.
P. secunda	Tolerant from 59 to 355 ml per acre.
Phlox	Tolerant in stands of mixed grass and forb.
P. spicata	Tolerant to 237 to 355 ml per acre applied in fall.

*(Effects on species obtained from Plateau® herbicide label).

Actions Taken

If invasive recovery is noted during monitoring, an application of Plateau® at a rate of 296 ml. per acre of shrub-step is recommended The herbicide should be applied during the fall, no more than once a year.

Fence maintenance

Fence monitoring and maintenance must occur to secure the exclusion of grazing from the vernal pool sites. The fence must be checked for integrity, and repaired accordingly. This must be accomplished before the cattle are released for grazing, before spring begins. Monitoring and maintenance should be completely annually in perpetuity.

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Padilla Bay Agricultural Land and Estuary

(Photograph. Benjamin Cody, 2007)

Introduction

Estuary habitat is an extremely productive system and Padilla Bay is no exception. Much of the system has been destructed and altered for agricultural use. Washington Department of Fish and Wildlife (WDFW) and the Washington Department of Ecology (WDOE) bought 340 acres of agricultural land on Padilla Bay with the intension of restoring the system. The land is on the National Estuarine Research Reserve System (NERRS), and is managed with National Oceanic and Atmospheric Administration (NOAA) and WDOE. However members of the agricultural community voiced their opposition to having any agricultural land converted to wetland. We devised a design model by considering the area influencing the agricultural community, the physical parameter of the site, and the system's needs in order to preform wetland functions.

Site History

Historically, the Skagit River Delta was comprised of an estuary, tidal salt marshes, and a riparian system. Eelgrass meadows populate the near shore areas throughout. Euro-American settlement began in the 1860s. Over the last 150 years 80% of the tidal habitat, 60% of the tidal emergent habitat, and 94% of the tidal scrub-shrub has been lost to agricultural use. According to WDFW and WWAA (2009), the land was converted to agricultural production with the installation of dikes and drainage systems. Padilla Bay NERRS (2009) reported logging in the area peaked in the early 1900s. Today there are many dikes, levees, tide gates, and drainage ditches used to keep water out of fields. Some dikes in the area have already been removed and the natural habitats restored.

Farming is extremely important to the community. The Skagit River Valley is regarded as the agricultural heartland of Western Washington. Farming contributes 200 million dollars in annual income for the area. WDFW and WWAA (2009) stated Skagit agriculture employs over 5,000 people and many of the farms are small family owned plantations.

There are a number of conservation actions in Padilla Bay: survey and control of Spartina in Padilla Bay and south Alice Bay; monitoring for invasive crab in Padilla Bay; baseline monitoring of emergent salt marsh vegetation in Padilla Bay; and management of upland invasive plants on 64 acres at the Padilla Bay National Estuarine Research Reserve.

Map of Habitats

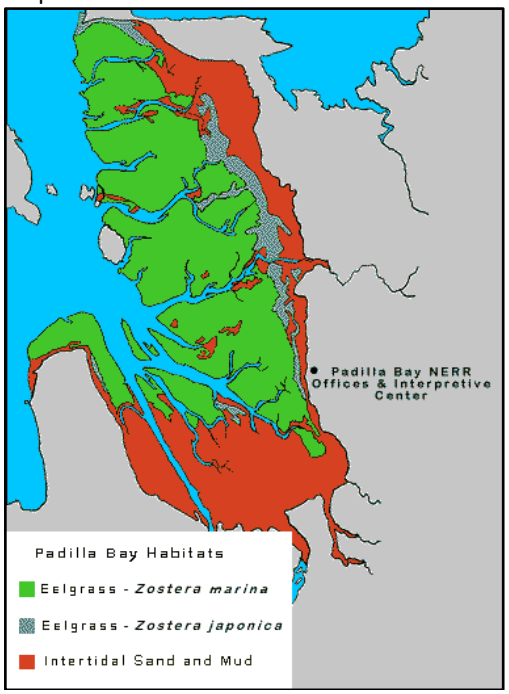


Figure1 (NOAA, 2009)

Site Analysis

Vegetation

In Padilla Bay there are 8,000 acres of eelgrass meadow (Figure 1). Two species comprise these populations, the native *Zostera marina* and the non-native *Zostera japonica.* (Padilla Bay NERRS, 2009) Eelgrass is an important nursery for salmon, crab, perch, and herring. It is also habitat for worms, shrimp, clams, and many other invertebrates. The invertebrate populations in eelgrass meadows serve as a food source for great blue herons, eagles, otters, seals, and even humans. (See table 1 to see other native salt marsh vegetation and see table 2 for a list of upland flora) Cordgrass (*Spartina spp.*) is a common invasive in intertidal habitats, and threatens native diversity in the area (Padilla Bay NERRS, 2009).Table 3 lists some common invasives found around Padilla Bay.

Table 1: Native Salt Marsh Vegetation

Scientific Name	Common Name
Zostera marina	Eel grass
Smithora naiadum	Red algae
Ulva lactuca	Sea lettuce
Salicornia virginica	Pickle weed
Schoenoplectus americanus	Chairmakers bulrush
Atriplex patula	Fat-hen saltbrush
Carex Lyngbyei	Lyngby's sedge
Triglochin maritimum	Seaside arrowgrass
Potentilla anserina	Pacific silverweed
Aster subspicatus	Douglas aster
Deschampsia cespitosa	Tufted-hairgrass
Distichlis spicata	Saltgrass

(NOAA, 2009)

Table 2: Upland Flora around Padilla Bay

Scientific Name	Common Name
Pseudotsuga mensiesii	Douglas-fir
Thuja plicata	Western red cedar
Alnus rubra	Red alder
Arbutus menziesii	Pacific madrone
Acer macrophyllum	Big leaf maple
Gaultheria shallon	Salal
Mahonia aquifolium	Oregon grape
Urtica dioica	Stinging nettle
Oemleria cerasiformis	Indian plum
Holodiscus dicolor	Ocean spray

(Padilla Bay NERRS, 2009)

Table 3: Notable Invasive Species

Scientific Name	Common Name	Control Method
Zostera japonica	Japanese Eel grass	not controlled
Spartina spp.	Cord grass	survey and control
Carcinus maenas	European green crab	none present, monitoring
Batillaria attramentaria	Mud snail	being researched
Nutallia obscurata	Purple varnish clam	being researched
Cirsium arvense	Canadian thistle	ongoing problem
Geranium lucidum	Shiny geranium	buffer zone created
Geranium robertianum	Robert geranium	monitor and control
Cirsium vulgare	Bull thistle	monitor and control
Phalaris arundinaceae	Reed canarygrass	monitor and control
Rubus discolor	Himalayan blackberry	monitor and control
Rubus laciniatus	Evergreen blackberry	monitor and control

(NOAA, 2009)

Soil

The soil in the area is some of the most fertile soil in the world (WDFW and WWAA, 2009). The Padilla Bay watershed is made up of alluvial soil and glacial till (Padilla Bay NERRS, 2009). Sediment accumulation, from the Skagit River flowing to the ocean, lines Padilla Bay. The bay's bottom is shallow, flat, and muddy. When the tide is out, miles of mud flats are exposed (NOAA, 2009).

Wildlife

The Skagit River Delta is prime habitat for Chinook salmon, which were declared endangered by the Federal Endangered Species Act in 1999. Six of the 22 Chinook bearing streams in Washington, are found in the Skagit River Delta. The estuary habitat is crucial rearing habitat for salmon, as they spend much of their juvenile smolt stage there foraging, growing, and preparing for the transition to the ocean. Loss of salmon habitat in the area has decreased overall productivity in the watershed.

It is also the seasonal home to one of the largest populations of wintering waterfowl in Western Washington, including snow geese, trumpeter swans, artic geese, Pacific brant, and Wrangel Island geese. Snow geese and ducks use both farmland and natural wetland for habitat. Birds of prey that can be found in the river delta include osprey, bald eagles, marsh hawks, red-tailed and rough legged hawks, barn owls, and occasionally golden eagles (WDFW and WWAA, 2009). Terrestrial non-marine mammals in the reserve include black tailed deer, raccoon, red fox, coyote, muskrat, beaver, porcupine and long-tailed weasel. (Padilla Bay NERRS, 2009)

Hydrology

The Skagit River Delta is the largest watershed emptying into the Puget Sound. This delta supplies 30% of the fresh water flow into the Puget Sound. (WDFW and WWAA, 2009). The bay depth reaches about 4 to 6 feet during high tide and 60% of the bay is exposed during low tide. (Burg & Granger, 1986) These waters are subject to pollution from various point and non-point sources, including two nearby oil refineries at March Point, highway runoff, agricultural runoff from farms or feed processing facilities, and storm water runoff (Padilla Bay NERRS, 2009).

Topography

Padilla Bay has a slight gradient of one foot per mile. The inland areas of interest are generally subject to agricultural use and are relatively flat and low-lying. The surrounding dikes and the roads forming the eastern border, La Conner and Samish Road, provide the main contrasts in elevation throughout the area.

Alternatives

1) **Maximum Estuary Restoration (Figure 2):** This option would create 300 acres of newly restored estuary habitat. This would bring more habitats for salmon, birds, and other wildlife. Functional estuary habitat can benefit eelgrass populations, and eelgrass meadows improve the survival rate of salmon (Odell et al, 2006). This option however, would not be desirable for organizations like Skagitonians to Preserve Farmland since it lacks agricultural use of the land.

Alternative 1

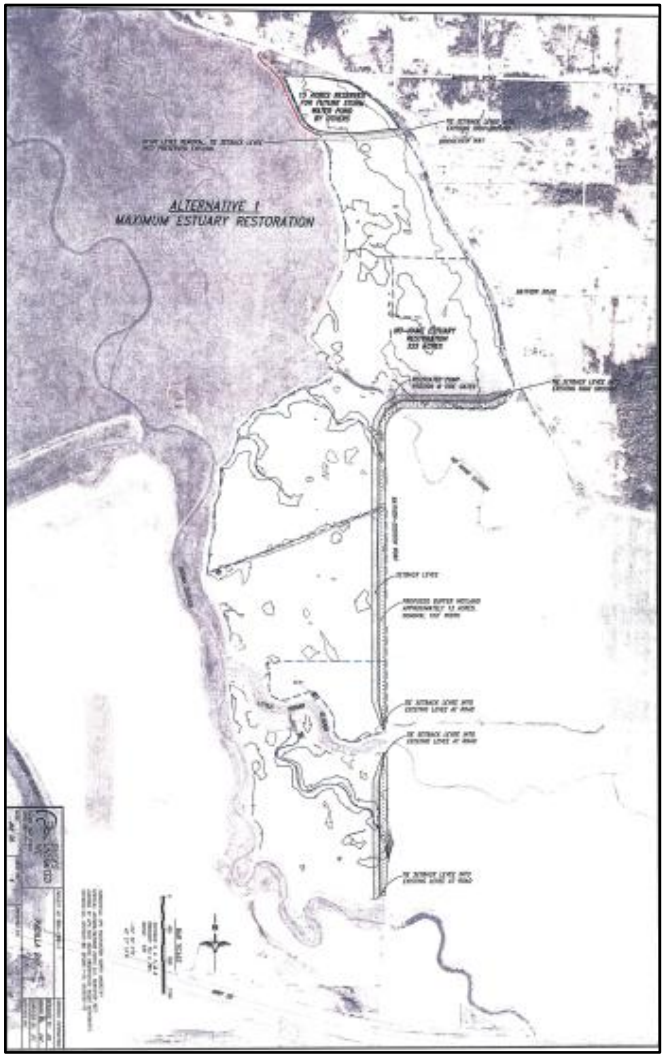


Figure 2

2) **Five Freshwater Cells with Agricultural Rotation (Figure 3):** This option would sustain economic benefit from the land through agriculture. This option would also increase recreation opportunities with the creation of quality duck habitat. Rotation of agricultural fields with flooding increases the nutrient quality of the soil.

Alternative 2

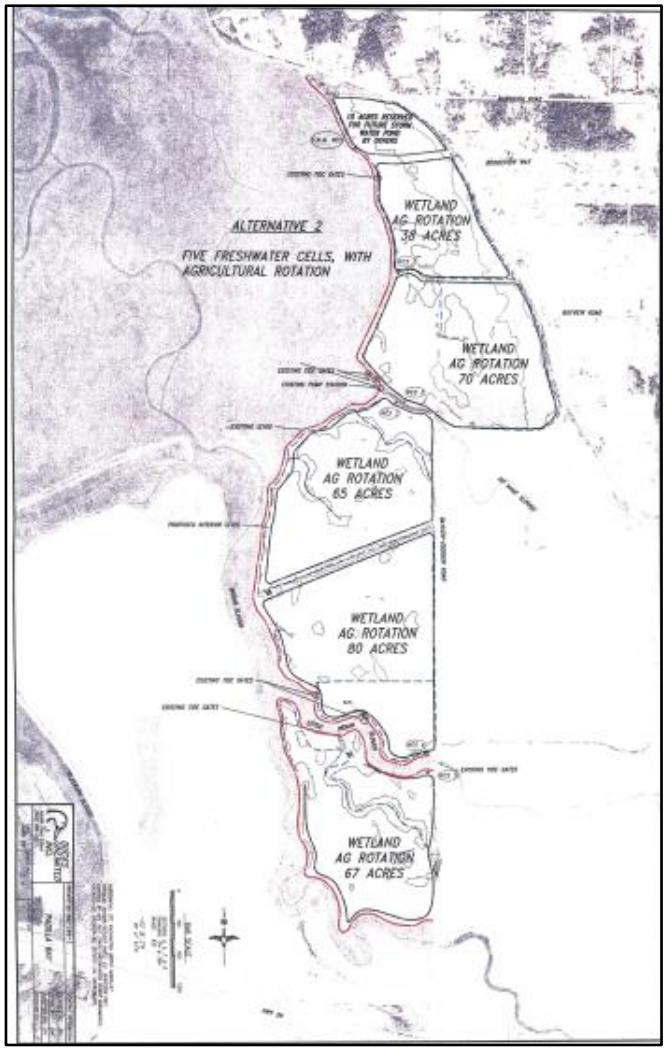


Figure 3

3) **Partial Estuarine Restoration with Two Fresh Water Wetlands in Agricultural Rotation (Figure 4):** This option would hybridize Alternative 1 and 2. It would allow both agriculture with wetland rotation and functional estuarine habitat. This would bring economic gain from agriculture, recreational gain from possible trails and hunting in flooded fields, and the ecological value and environmental benefits of an estuary.

Alternative 3

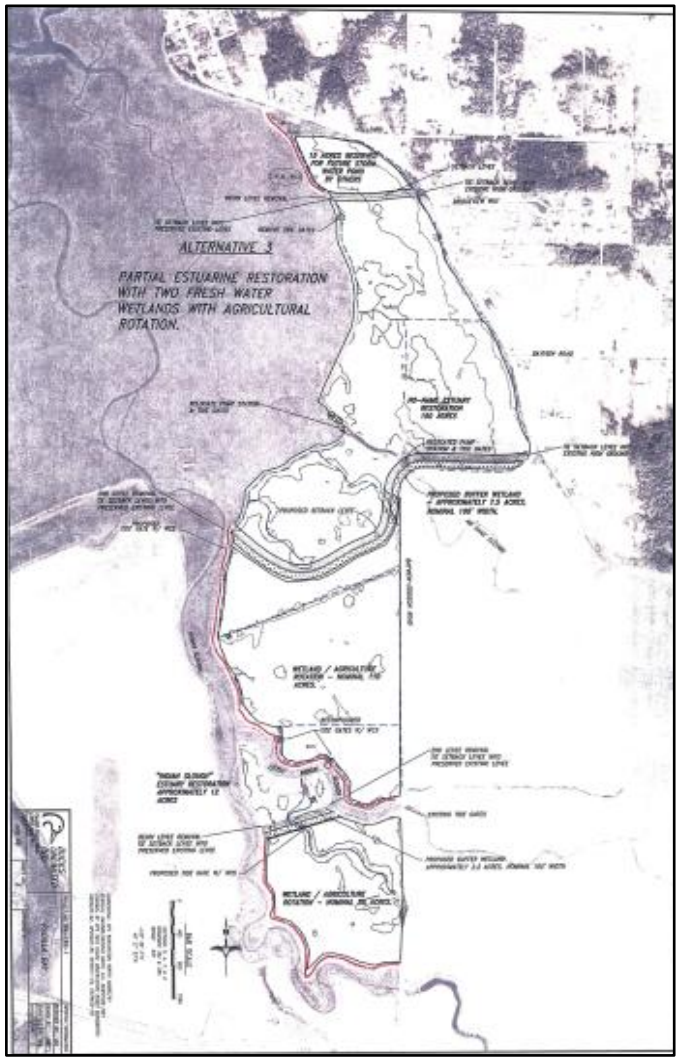


Figure 4

4) **Northern Estuary Restoration with Southern Area as Farmland (with enhancement of Little Indian Slough and Restoration of No-Name Slough)**

(Figure 5): This option divides the overall site into two distinct zones. Zone A (Figure 6) will become a restored estuary north of No-Name Slough, providing benefits to water quality, and salmon habitat. Zone B will remain as is, and be maintained for agricultural use. A new levee will be erected along Zone B's northern border to help protect it from flooding. This option aims to appease all parties by restoring estuary habitat as well as preserving fertile and productive farmland.

Alternative 4: Overall Layout of the Site

Figure 5

Zone A detail showing physical changes

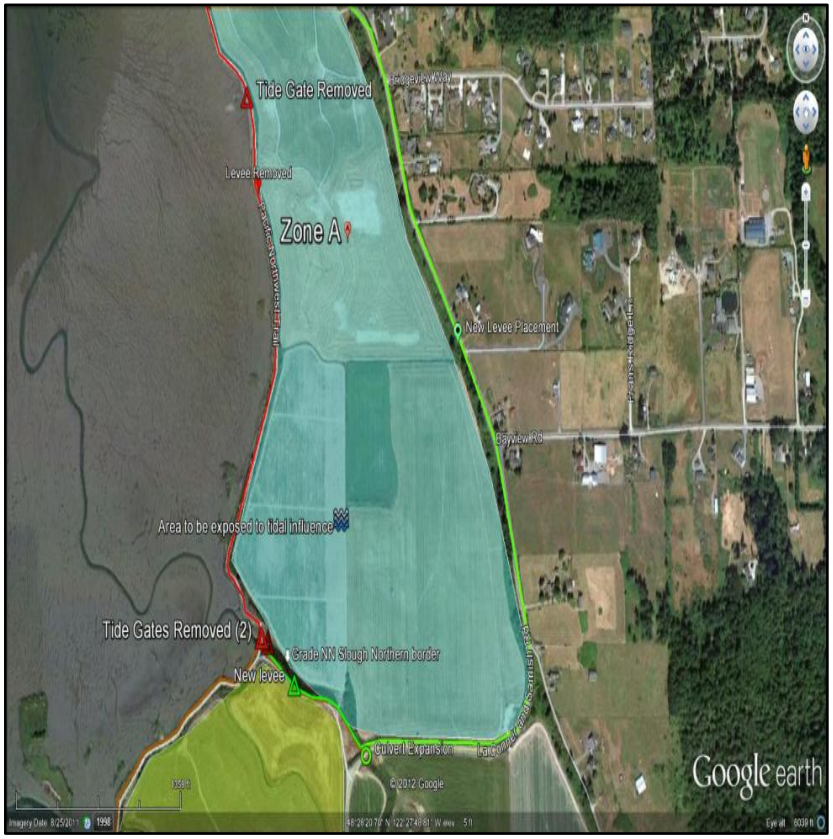


Figure 6

Decision Matrix

Table 4. Decision Matrix featuring Alternatives and Criteria

Options	Weighted relative importance	Maximum estuary restoration		Five cells of full wetland/agriculture rotation		Partial estuarine restoration with two fresh water wetlands with agricultural rotation		Northern estuary restoration with Southern area as farmland		No change	
Criteria		Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted
Salmon Habitat	20	5	100	1	20	3	60	3	60	1	20
Water Quality	15	4	60	1	15	2	30	3	45	1	15
Education	10	1	10	2	20	4	40	4	40	1	10
Recreation Value (Hunting/Birdwatching)	15	2	30	4	60	3	45	3	45	2	30
Economic Value	20	1	20	5	100	3	60	4	80	5	100
Community Satisfaction	20	2	40	4	80	5	100	4	80	2	40
Total:	**100**		**260**		**295**		**335**		**350**		**215**
Rank			**4**		**2**		**3**		**1**		**5**
SCALE: 1-5	5	4	3	2	1						
	IDEAL		AVERAGE		NO BENEFIT						

Explanation of Decision Matrix Criteria:

All restoration options are judged by each of the below criteria on a 1-5 point scale, 1 being a rating of no benefit, 3 of average benefit, and 5 of ideal benefit. The meaning of each criterion is explained below in detail.

- ***Salmon Habitat***

  Salmon habitat in the near shore environment is drastically improved with the presence of eelgrass. Young salmon use eelgrass meadows as shelter from predation; they also benefit from invertebrate and herring food sources found in eelgrass meadows (Grisham, 2012). Estuary restoration increases the health of near-shore eelgrass populations, and therefore increases quality habitat for salmon in near-shore areas (Odell et al., 2006). We evaluated the benefit of restoration options to salmon habitat by the amount of estuary restoration, and consequently eelgrass meadow quality.

- ***Water Quality***

  The factors of water quality we consider in our valuation of options are sedimentation, dissolved oxygen content, and turbidity. Increased tidal circulation due to estuary restoration can increase dissolved oxygen content, and nutrient availability (Williams & Associates, 2008). Erosion contributes to turbidity and low water quality. Soil erosion is a source of turbidity. No-Name Slough has poor riparian buffering and is subject to erosion Restoration, or stabilization, of this slough could improve water quality. Agriculture in the Padilla Bay area also contributes to poor water quality. As a result of reduced water-holding potential in the landscape from agricultural development, downhill sloughs experience high run-off, and erosion (Skagit Watershed Council, 2005).

- ***Education***

  We evaluated the education value of the land by its ability to serve as an educational tool. Ways this criterion could be fulfilled would be educational signage along trails and opportunity for educational-center activities, such as nature walks or farming demonstrations. Options with restored natural processes would become assets for biological and environmental education. This can be accomplished through signage identifying and describing of plants and wildlife, historical descriptions of land use, restoration projects, and explanations of ecological processes.

- ***Recreational Value***

  Either duck-hunting opportunities or hiking opportunities on site determine recreational value. Hunting opportunities would be more highly concentrated in freshwater wetland sites, but still would exist in estuary, and farm areas (WDFW, 2012). Hunting opportunities also exist in both the Little Indian Slough and No-Name Slough, and would be increased in restored slough areas (WDFW, 2012). Recreational value due to hiking would be determined by the existence of recreation trails, and opportunities for trails exist higher in options with more dikes.

- ***Economic Value***

  Our criterion of economic value is directly related to the ability for the land to produce monetary gain. In the case of Padilla Bay, economic benefit would come from agricultural use of the land. Options with high percentages of agricultural land would be valued higher in this criterion than others without.

- ***Community Satisfaction***

  Community satisfaction is evaluated by how pleased community members would be with each option, this criterion was created to evaluate the ability for a project to be accepted and sustained by the community. Organizations like Skagitonians to Preserve Farmland (http://www.skagitonians.org/), who are politically active, would be more invested in a plan that maintained farmland.

Our Chosen Alternative:

Based on the decision matrix (Table 4), we have concluded that Alternative 4 is the best option. In accordance with Alternative 4, we plan to restore the area north of No-Name Slough into estuary, improve Little Indian Slough, and restore No-Name Slough. The area south of No-Name Slough will remain agricultural.

Goals and Objectives

The basic approach to this project will involve dividing the 340 acre parcel into two separate zones – Zone A, and Zone B. The division will occur along No-Name Slough. Zone A will be the section we restore to estuarine habitat while zone B will remain as agricultural land (Figure 5).

The goal of this project is to improve estuarine habitats and native biodiversity in Zone A of the project area and to improve agricultural lands and hydrology in Zone B. These goals are created to improve the habitat for native species, while meeting the needs of all stakeholders and complying with the management guidelines of WDOE and NOAA.

Zone A Objectives

- Collaborate with local and regional agencies in protecting and preserving estuary habitat.
- Convert agricultural land into tidal marsh.
- Improve salmon habitat and water quality.
- Reinstate native vegetation and remove invasive vegetation.
- Remove tide gates and breach dikes to allow establishment of estuarine marshland.
- Create and improve trails for recreational use.
- Educate community members and visitors on how their daily decisions can affect the ecosystems around them.

Zone B Objectives

- Collaborate with local and regional agencies in preserving agricultural land.
- Reinforce dikes, tide gates and culverts.
- Maintain proper land use protocols to minimize impact on natural systems
- Create bioswales for better drainage in the area.

Functional Requirements and Constraints

- **FR1:** Increase the saltmarsh for salmon and other wildlife species of interest so that most of the site is a salt marsh.
    - **C1a:** Without flooding adjacent farmland.
    - **C1b:** At least some areas for pedestrians, birders, and agricultural production.
    - **C1c:** Without removing the parking lot.

- **FR2:** Improve water quality.
    - **C2a:** Without meandering stream into private property.
    - **C2b:** Without increasing sediment in the waterways.
    - **C2c:** Without disturbing native vegetation.

- **FR3:** Provide education on site for visitors.
    - **C3a:** Without taking up much area.

- **FR4:** Provide area for pedestrian, bicyclists, and birders.
    - **C4a:** Without taking much area.
    - **C4b:** Without removing the parking lot.
    - **C4c:** Without creating more edge habitat than is absolutely necessary.

- **FR5:** Provide some area for agricultural production.
    - **C5a:** Without taking up a significant amount of area.
    - **C5b:** Without its runoff decreasing the water quality of the salt marsh.

Project Implementation

Table 5: Task List and Duration Used to Accomplish Prrimary Changes

Tasks	Description	Precedes	Follows	Duration	Specifications
A:	New Levee Constructed along South bank of No-name slough	B		2 months	performed during work hours, during ebb tide
B:	Remove Western Levee in sections (in tandem with C)	C,D,E,F,H	A	4 months	performed during work hours, during ebb tide
C:	Use material from western levee for eastern levee construction (in tandem with B)	J	B	4 months	performed during work hours, during ebb tide
D:	Grade Northern border of NN slough	G	B	1.5 month	
E:	Remove existing tidal gates (3)	H	B	.25 months	performed during work hours, during ebb tide
F:	Expand Culvert to enhance connection with rest of slough	G	B	.5 months	
G:	Plant riparian shrub buffer of 50ft with access lane for maintenance on south bank levee of NN slough		D,F	.5 month	
H:	Delineate habitat types in Zone A	I	B,E	1 month	based on a month's monitoring of tidal tendecies
I:	install native vegetation into delineated habitat types		H	1 month	
J:	Install trail on new eastern levee	K	C	1 month	
K:	Install riparian vegetation on eastern levee		J	1 month	

Detailed Description of Chosen Alternative

A: New levee constructed along south bank of No-Name Slough.

- A new levee will be placed along the southern bank of No-Name Slough in order to prevent flooding onto the agricultural lands in Zone B.

B: Remove western levee in sections (in tandem with C).

- The western levee will be removed in order to expose Zone A to tidal influence and allow its transition to an estuarine habitat. For logistical reasons we suggest removing the levee from north to south so as to maintain a pathway for equipment movement.

C: Use material from western levee for eastern levee construction (in tandem with B).

- The construction of the eastern levee is to be done in tandem with the removal of the western levee using the material from the western levee's excavation. The eastern levee will be used to provide additional buffer area from La Conner and Samish Road and will be topped with a new trail for recreational users.

D: Grade northern border of No-Name Slough.

- The northern border of No-Name Slough will be graded to decrease the contrast between it and Zone A's elevations. Minimizing the difference will help improve hydrologic flow between the two systems.

E: Remove existing tidal gates.

- The current tidal gates in place restrict water movement in the slough and results in the buildup and collection of water in the slough which may lead to potential flooding. Removal of the tide gates at the inlet of No-Name Slough will help improve flow and reduce flood potential.

F: Expand culvert to enhance connection with rest of slough.

- Expansion of the culvert underneath La Conner and Samish Road will help reduce sediment build up and improve fish access.

G: Plant riparian shrub buffer of 50 feet with access lane for maintenance on south bank levee of No-Name Slough.

- Occasional dredging of the channel may be necessary depending on sedimentation rates. Maintaining an access lane is required in order to perform any sort of future maintenance.

H: Delineate habitat types in Zone A.

- Detailed in "Expected Results".

I: install native vegetation into delineated habitat types.

- Detailed in "Expected Results".

J: Install trail on new eastern levee.

- The new trail on the eastern levee will be essentially a replacement for the Pacific Northwest Trail that will be removed along with the western dike.

K: Install riparian vegetation on eastern levee.

- Installation of common riparian species will help prevent erosion, filter runoff from the nearby La Conner and Samish Road, and act as a buffer for the new wetlands.

Table 6: Gantt Chart for Implementation Tasks

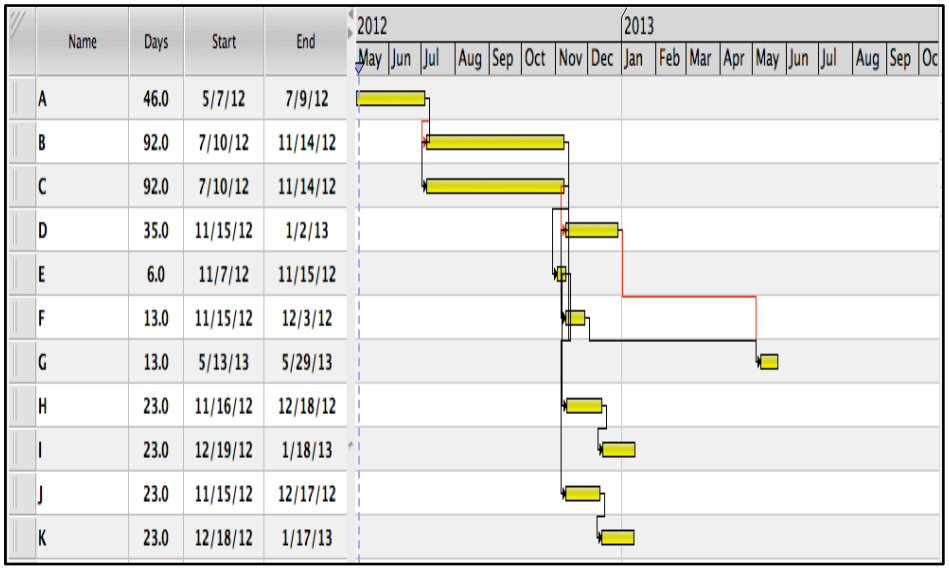
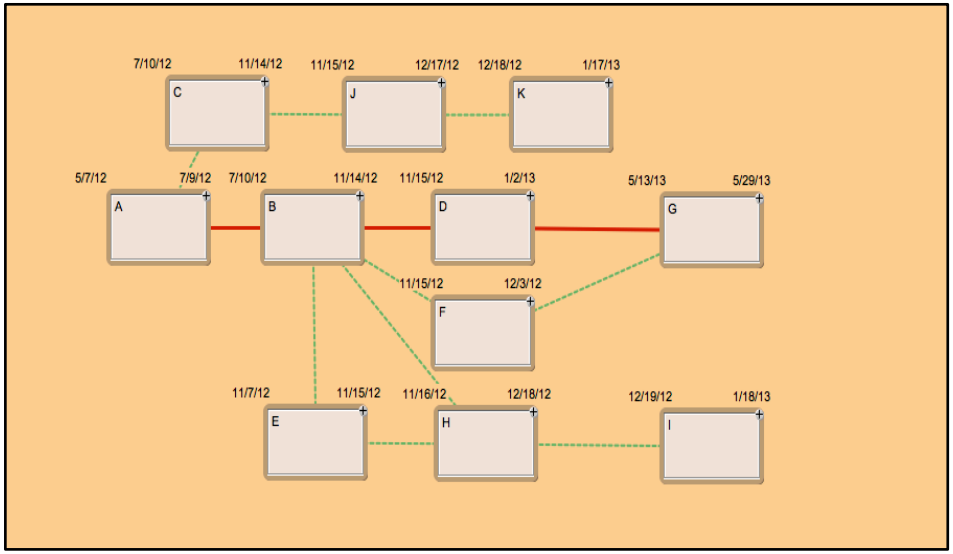


Table 7: Network Diagram for Implementation



Environmental Functions and Desired Results

Our restoration plan calls for the division of the 340 acres into two distinct zones of operation. Zone B will continue to be maintained for agricultural use. Zone A will have its western dikes removed and the area exposed to Padilla Bay from the west and No-Name Slough from the south, effectively turning Zone A into a large estuary.

As with any restoration project it is difficult to predict results or success due to many different factors including salinity, turbidity, pollution, temperature, elevation, and tidal fluctuations. However, there is a different restoration project location only 20 miles south of Padilla Bay that we have studied and feel will be a suitable reference location. Yang et al.'s (2010) ecological modeling study of Port Susan Bay has given us insight to predict the eventual outcome of Zone A.

The restoration project modeled by Yang et al. involves a very similar scenario – the removal of a bay-side dike in an area bordering Port Susan Bay. The target area in Yang et al.'s study is similar in size to our Zone A (150 acres to 140 acres respectively). The two restoration areas both have a freshwater inputs and are adjacent to farmland. The close proximity of Port Susan Bay restoration area to Zone A ensures us that general habitat features will be relatable between the two areas.

Once Zone A is opened up to tidal influence, we expect different habitat types to emerge based on elevation and inundation time (projections included in Figure 7). The exact patterns of development will be largely dependent on flood conditions after the dike is removed, which will aid in structuring the marsh and tideflat areas. Based on hydrologic modeling from sampling points and LIDAR elevation measurements, Yang et al. estimated the proposed restoration area to have four habitat types: pond, tideflat, low swamp, and high swamp. Yang et al.'s model results showed full inundation at high tide with a salinity generally less than 8ppt.

Due to the similarity in elevation and hydrology we expect Zone A to achieve a similar level of habitat composition (figure 6) as Yang et al.'s model prediction. Predicted species composition is found below in table 8 and can serve as a good reference for ideal native plantings throughout Zone A.

Predicted Habitat Types Based in Zone A

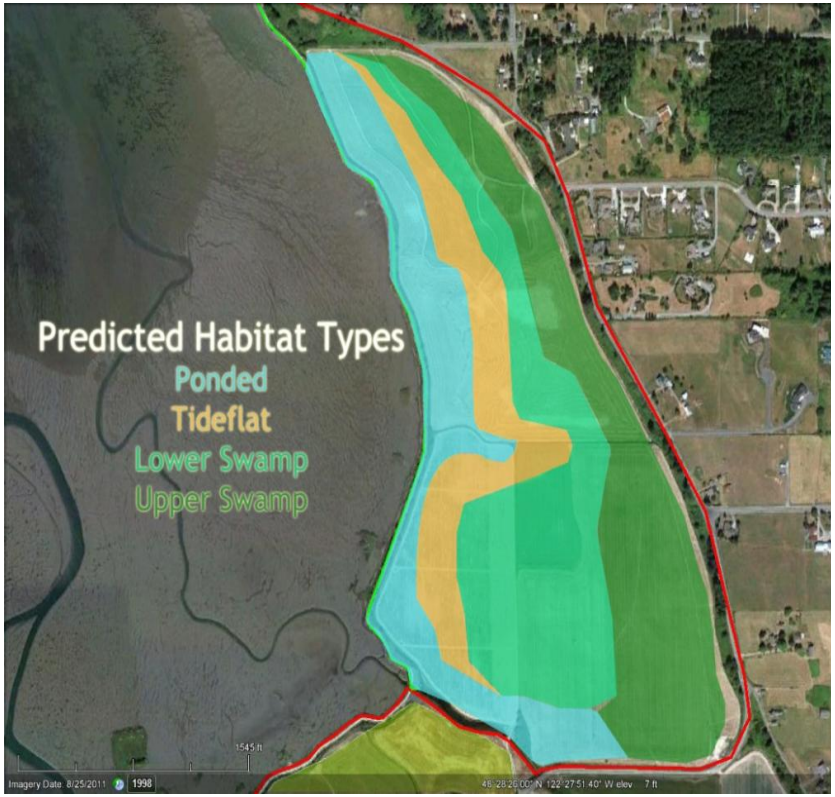


Figure 7

Table 8. Predicted species for low and high marsh habitat types (Hutchinson, 1989)

Low marsh	High Marsh
Schoenoplectus americanus	Agrostis spp.
Schoenoplectus maritimus	Carex lyngbyei
Carex lyngbyei	Schoenoplectus americanus
Triglochin maritimum	Salicornia virginica
Eleocharis palustris	Juncus balticus
Distichlis spicata	
Atriplex patula	

Stakeholders

Table 9 (Padilla Bay NERR, 2009)

Stakeholders	Land Proprietors
WDFW	• WDFW & PBRNERR are involved in habitat improvements and wetlands and water management.
WDOE	• WDOE responsible for managing PBNERR as requested by NOAA.
WSDNC	• WSDNC & WDFW implement management plan on Hat Islands.
NOAA	• Fund WDOE educational goals, objectives, and tasks. • NOAA & WDOE implement Ocean and Coastal Resource Management Plan.
Skagit County Board of Commissioners	• Provide data to Reserve manager with input on ongoing and proposed activities in and adjacent to PBNEER.
NW Straits Commission	• Program assistant for implementation plan and administration tasks.
Padilla Bay Foundation	• Fund management, development and operation.

Stakeholders (continued)	Land Proprietors (continued)
PBNERR: Research Advisory Committee (RAC) Education Advisory Committee (EAC) Coastal Training Program Advisory Committee (CTPA) Natural Resource Advisory Committee (NRAC)	• RAC provides guidance and evaluation in implementing research and monitoring. • EAC provides guidance and evaluation on the implementing educational programs. • CTPAC provides guidance on developing and implementing new training for coastal zone managers. • NRAC provides guidance regarding natural resource issues, perspectives of various agencies, and cooperative solutions to problems.
Farmers	• Breaching bay dikes would flood land designated for agricultural productions. • Demonstration farm will serve as a merchandise venue.
Recreational Trail Users (bird watchers, pedestrians, and bicyclists)	• Preferred alternative reduces trail availability by breaching dikes, however invests more in demonstration farm.
Hunters	• Decreased accessibility to gaming area.
Waterfowl	• Short-term impact includes traffic congestion form dike breeching. • Long-term impact includes salt and fresh water habitat improves because estuary expansions.
Salmon Habitat	• Slough connectivity reissue salmon spawning ways.
Eelgrass Habitat	• Preferred alternative promotes habitat by reducing agricultural production and vessel traffic. • Protects shelter for juvenile salmon.

Residential Development	• Short-term impact includes traffic congestion form dike breeching. • Long-term impact includes agricultural production
March Point Refinery Ports	• Preferred alternative requires port relocation.

Maintenance

After the initial project ends additional maintenance and monitoring will be necessary to evaluate the restoration and make changes as necessary to continue to meet the goals of this project. Plant die-off will need to be monitored and replaced as necessary and invasive species will need to be removed and suppressed if they continue to grow in the area. Monitoring should be conducted once per month for 3 years and track percent cover, die off, and invasive growth.

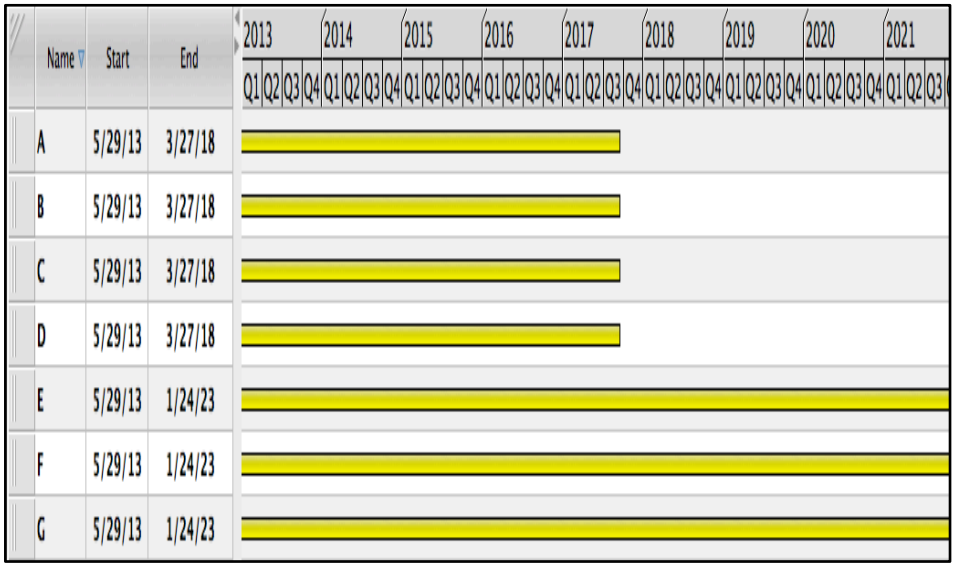
The hydrology will need to be monitored every two weeks for 3 years in order to maintain the waterways, prevent flooding, and monitor sediment accumulation. Tide gates, culverts, bioswales, and pump stations will need to be monitored and repaired as necessary. Water quality will also need to be monitored every month in order to meet the goal of improving water quality in the area. Additional monitoring for salmon activity is important to evaluate water quality and meet the objectives to adapt the area for salmon use.

Trails, bridges and other pedestrian access areas need to be maintained and repaired as necessary. Below is a summary of the described tasks (Tables 10 & 11).

Table 10: Maintenance Tasks

Tasks	Description	Precedes	Follows	Duration
A:	Monitoring of plant die-off/ Replacement of die-off	-	-	5 years
B:	Monitoring for invasives/invasive removal (once per season)	-	-	5 years
C:	Hydrological monitoring(sloughs and restored estuarine sites)	-	-	5 years
D:	Water quality monitoring (every month)	-	-	5 years
E:	Monitoring of sediment buildup (every other year)/ Maintenance dredging of sloughs	-	-	in perpitiuity
F:	Monitoring/maintenace of tide gates, culverts, bioswales, and pump stations.	-	-	in perpitiuity
G:	Monitoring/maintenance of trails, bridges, and any pedestrian access to the site.	-	-	in perpitiuity

Table 11: Gantt Chart for Maintenance



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Nisqually River Gravel Pits

(Photograph. Elk-pictures, 2008)

Introduction

Restoring environmental functions is part of Tacoma Power's relicensing for the Nisqually River Projects. More specifically they intend to improve elk habitat, riparian habitat, wetland, and reclaim gravel pits. Our five acre gravel pit is on the south side of the Nisqually River, about 328 yards from the river. The soil there is very quick to draining, and vary in nutrients and organic matter so it will be necessary to improve the soil or else nothing desirable will grow. For this design we will decide on what is the best course of actions to improve as many environmental functions as possible, given that we choose the soil treatment, the contouring of the site, and the vegetation. Also we will consider the amount of materials and the time and manpower it will take to complete our design.

Site History

This project site is located in the Nisqually River basin near Ashford, Washington. This watershed was one of the first places settled by Europeans in the Puget Sound. Old growth forests, expansive prairies, and fertile river valley soils historically characterized the Nisqually Basin. From 1904 to the late 1920's the estuary was diked for agricultural uses; many of the dikes still maintain. Logging in the area contributes to erosion, run-off, and lack of large woody debris.

Several dams now affect the hydrology in the area. The first of these is the La Grande Hydroelectric Dam which was constructed in 1910 and continues operations today. The second of which is the Yelm Hydroelectric Project, constructed in 1929. Since there was no migratory fish right-of-way until 1955, these damns have altered historical salmon populations.

This restoration site was historically logged before Tacoma Power used the site as a gravel pit. The gravel pit was operated for the production of road surface material, but since has been abandoned.

Site Analysis

The restoration site, an approximately 6-acre gravel site, lies within the riparian area of the Nisqually River. A dirt road borders the northern, western and southern perimeters. A conifer forest borders the site to the east. The Nisqually River lies west of the site (Baker et al., 2003).

Vegetation

The dominating vegetation is a sterile annual grass (*Triticale hexaploide)*, as well as a number of invasive species (Table 1). Native vegetation borders the site, and some native species sparsely populate the site (Table 2).

Table 1: Adjacent Invasive Vegetation

Scientific Name	Common Name
Phalaris arundinaceae	Reed canarygrass
Cytisus scoparius	Scotch broom
Polygonum spp.	Giant knotweed
Rubus laciniatus	Evergreen blackberry
Rubus laciniatus	Himalayan blackberry

(Baker et al., 2003)

Table 2: Adjacent Native Vegetation

Scientific Name	Common Name
Pseudotsuga menziesii	Douglas fir
Pteridium aquilinum	Bracken fern
Polystichum munitum	Sword fern
Gaultheria shallon	Salal

(Baker et al., 2003)

Topography

Tacoma Power excavated the pit 54 yards deep for road material. Elevation tends to decrease toward the riverside of the site. The steepest gradients make up the border of the site, the top reaching 1640 feet and dropping to 1600 feet. The basin sits at an elevation of 1585 feet. On the mid southern areas of the site lie scattered hills ranging from 1602 feet to 1596 feet.

Hydrology

The area receives approximately 81 inches of annual precipitation. The runoff drains into the Nisqually River, approximately 328 yards from site. A few areas on site presently accumulate water.

Soil

This site's soil was compacted due to the heavy machinery used in mining. The substrate left is composed of mostly sand and gravel.

Wildlife

The surrounding area is inhabited by a variety of birds and mammals. Birds include osprey, bald eagles, spotted owls, and peregrine falcon. Mammals include beaver, bears, coyote, elk and deer (Kavanaugh, 1981).

Stakeholders

The Nisqually River Basin Planning Team consisted of the following members (Kavanaugh 1981):

- Nisqually Indian Tribe
- Washington Department of Game
- Washington Department of Fisheries
- U.S. Fish and Wildlife Service
- Tacoma Power
- Black Hills Audubon Society
- Federal Energy Regulatory Committee
- Tahoma Audubon Society
- Lewis, Pierce, and Thurston County Commissioners and adjacent city municipalities.
- U.S. Army, Ft. Lewis, WA
- Public at large
- Department of Ecology, Southwest Regional Office
- Nisqually Delta Association.

Design Requirements

The site was redesigned to address the stakeholders concerns with feasibly actions, in addition to restoring maximum ecological function in meadow, wetland, and riparian habitats.

- **DR1:** Decrease invasive species from the site so that native vegetation can be increased to provide elk with grazing material, encourage wetland vegetation establishment, and create a first successional riparian forest.
- **DR 2:** Use TARGO® classic mix to add nutrients to the soil.
- **DR 3:** Include woody debris to further promote wildlife activity.
- **DR 4:** Create wetland in the area that accumulates water by installing clay cap.
- **DR6:** Decrease slope gradient thought out the site to minimize erosion and promote meadow and riparian growing conditions.
- **DR7:** Increase vegetation appropriate to meadow, riparian, and wetland habitat.
- **DR 8:** Provide a fence and natural repellants to prevent herbivory.
- **DR 9:** Create and install signage, and/or fences depending on need, to deter off road vehicles from this site.
- **DR10:** Develop maintenance plan.

Constraints

- **C1:** Establish shade for newly installed plants and to deter invasive re-sprouting.
- **C2:** The application of bio-solids should be limited so that the effect on Nisqually water quality is not significant.
- **C3:** The soil composition of sand and gravel does not allow for water infiltration to support vegetation establishment.

Decision Making Framework

Our decision matrix covered five separate restoration alternatives: Full-on meadow restoration, installation of plants to yield an early successional riparian forest, complete conversion of the area to a wetland, excavation of the site down to stream level to serve as a potential side channel slough, and lastly a hybrid of the first three options (Table 3).

The first three options – meadow, early successional, wetland – all involve total conversions of the area to the selected vegetation regime. However, due to the simple functional requirement - asking for a restoration project incorporating all three habitats - imposed by our primary stakeholders, these three projects targeting single habitat types are not feasible. The fourth project involved excavating the entire site down to approximate stream level. The goal of this would be to provide some sort of salmon habitat and connectivity to the river approximately 54 yards away. However, due to the massive amounts of excavation and re-contouring that this project would require, we quickly disregarded it.

This left our hybrid option, which was more or less designed to meet the requirements imposed by our primary stakeholders. This hybrid design would incorporate all three-habitat zones and will be further covered in the basic approach section.

Table 3: Decision Matrix

Options	Weighted relative importance	Meadow restoration		Early successional riparian forest		full wetland/wetland buffer restoration		Hybrid of Meadow Wetland & Riparian		Excavation to Stre Level As Salmon Habitat	
Criteria		Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weight
Feasibility of installation	15	4	60	4	60	2	30	4	60	1	
Elk benefit	7	5	35	2	14	1	7	4	28	1	
Salmon benefit	7	1	7	1	7	1	7	1	7	5	
Riparian addition	10	1	10	5	50	1	10	4	40	1	
Erosion control	7	5	35	5	35	5	35	5	35	1	
Water quality	10	3	30	5	50	5	50	4	40	5	
Long term prospect	20	5	100	3	60	5	100	5	100	1	
Total:	76		277		276		239		310		
Rank											
SCALE: 1-5	5	4	3	2	1						
	IDEAL		AVERAGE		NO BENEFIT						

Explanation of Criteria

Feasibility of Installation

This criterion assesses the 'practicality' of installing each restoration option. We exercised professional judgment when evaluating each option's feasibility. We found the 'Excavation to Stream Level as Salmon Habitat' option to be extremely infeasible, since it would require the excavation of approximately 645,185 cubic yards. We decided that the full use of the site as wetland would be less feasible to install than other options, since it would require comparatively large amounts of excavation and clay capping and would not necessarily accumulate enough water to establish. The most feasible options we found were 'Meadow Restoration', 'Early Successional Riparian Forest' restoration, and a hybrid option between Wetland, Riparian Forest, and Meadow restoration. These option require contouring, soil remediation, and in the hybrid option, a small amount of clay cap.

Elk Benefit

This criterion was created to assess the benefit of our restoration to elk. Roosevelt elk (*Cervus elaphus roosevelti)* are the most common elk in western Washington; although small herds of Rocky Mountain elk (*Cervus elaphus nelson*) have also established in the area (WDFW, 2012). These ruminants require large food sources because of their size, and herding tendencies. During the summer, when vegetation is plentiful, elk frequent meadows to feed on grasses, sedges, and some flowering plants (WDFW, 2012). During the fall and winter elk increasingly browse on sprouts of trees, branches, and shrubs. Restoring the site to meadow would benefit elk, since meadows supply a large portion of elk diet (grasses, sedges, and flowering plants). Although restoring the site to an early successional forest might provide some food source for elk (sprouts and young branches), productive meadows are ideal habitat for elk (WDFW, 2012).

Salmon Benefit

This criterion was created to help evaluate the restoration's benefit to salmon; the Nisqually Tribe desires the Nisqually River to productively bear salmon, however salmon have never been on our site. The only option that would benefit salmon on the site would be the 'Excavation to Stream Level' option. Other options would not provide any accessible, or even usable, habitat for salmon.

Riparian Addition

The Alder Dam's construction inundated riparian forest habitat. This criterion assesses how well our project will replace for the lost services (riparian habitat). This criterion assesses each option by the amount of riparian forest each project will offer. Options like Meadow Restoration, Full wetland restoration, and Salmon habitat would not meet this criterion because they lack riparian forest habitat. The hybrid option would partially fulfill this criterion, since it includes some riparian forest addition. The 'Early Successional Riparian Forest' option would fulfill this criterion the best, since it's sole purpose is to create riparian forest habitat.

Erosion Control

We created this criterion to assess how each option would contribute to erosion. This is especially important because the site is directly uphill from a salmon-bearing stream. Steeper slopes, and lack of vegetation on slopes worsen erosion. Slope length also contributes to erosion, since water gains more speed over longer slopes (Shelton, 2003). Water travels faster down steeper slopes, so options with steeper slopes would be less effective at controlling erosion. Restoration options with long slopes might also contribute more greatly to erosion (Shelton, 2003). Options with higher densities of vegetation establishment would control for erosion better than those with lower amounts of vegetation.

Water Quality

This criterion was created to assess each option's effect on water quality downhill from the site. An extensive definition of water quality is explained in the Department of Ecology's document "Water Quality Standards for Surface Waters of the State of Washington". This document covers various parameters contributing to poor water quality, such as high water temperatures, high turbidity, heavy metal concentrations, etc. We judge each option based on these parameters; options that improve water quality obtain higher scores than those that hinder water quality. Certain ecosystems improve water quality. Wetlands improve water quality because they impede water, and filter out pollutants (Evans, 1996). Riparian areas benefit water quality, because they also filter out pollutants (Evans, 1996). Because wetlands and riparian areas benefit water quality, options that create either obtain higher scores than options that do not.

Long-term Prospect

This criterion assesses the likelihood of success for each restoration option. We found meadow restoration to be promising; In Bennington, Vermont, a group successfully restored a gravel pit site into a functional meadow for Migratory Bird habitat (Sperduto, 2010). We also found an example of successful forest restoration on a gravel pit site in Brown's Woods (LeMay, 1999), which lead us to believe a Riparian Forest Restoration would have prospect in the long term. We do not believe the excavation to salmon habitat option has much merit, since it would leave 50-foot embankments, would be prone to high amounts of erosion, and since there that been any salmon there before. We found that restoration of gravel pits into wetland can be successful; a wetland restoration of a gravel pit in New Hampshire supports this evaluation (Garlo, n.d.). We believe the 'Hybrid' option to have high long-term prospect, based on above claims supporting forest, meadow, and wetland restoration as being prospective options. We also based our confidence in the 'Hybrid' option on the study in Bennington, Vermont, who in addition to restoring their site into meadow also incorporated wetland components (Sperduto, 2010).

Goals and Objectives

Our main goal is to restore the gravel-pit site to a natural matrix of riparian, wetland, and meadow zones (Figure 1); we intend to do so in compliance with the objectives of Tacoma Power, The National Hydropower Association, and Nisqually River Management. Since the area is devoid of any well-developed surface soil, this project aims to introduce soils and primary successional vegetation to the land, to improve the area for aquatic and terrestrial wildlife. The objectives of each zone are outlined below.

Riparian

- Improve water quality and hydrology functions.
- Restore conifer and deciduous vegetation to part of the gravel pit matching or exceeding the state of the riparian habitat surrounding it.
- Improve vegetation growth and increase food availability riparian species in the area.

Wetland

- Decrease soil drainage and create areas with seasonal water inundation.
- Improve water quality, storage and hydrology in the area.
- Improve habitat for wetland species.
- Improve habitat for wetland species.
- Create a floodplain to improve water quality.

Meadow

- Develop a natural corridor for wildlife species, specifically birds, and large mammals such as elk.
- Restore native grasses and shrubs to the area and increase food availability for elk.

Environmental Functions

Riparian

The primary environmental function of the riparian zone is to promote habitat for riparian species including birds, fish, and mammals. The riparian zone functions to improve the water quality and hydrology in the area by filtering pollutants and reducing soil erosion by trapping sediments. This zone also functions to connect the habitat with the surrounding areas.

Wetland

The wetland zone provides habitat to aquatic animals and plants, as well as a seasonal water source for terrestrial animals. Wetlands reduce soil erosion and pollutants similarly to riparian zones. Since wetlands form in depressions, they act as barriers that trap pollutants. Wetlands also improve nutrient cycling (Evans, 1996).

Meadow

The long-term environmental function of the meadow zone is improved elk habitat; meadow vegetation will serve as a quality food source for elk. Meadows also support other wildlife, such as birds (Sperduto, 2010). Meadow vegetation also helps control erosion

Tasks and Basic Approach

As part of Tacoma Power's relicensing they must improve elk habitat, riparian habitat, wetlands, and reclaim the gravel pit. We will divide the site into zones of wetland, wetland-meadow transition, meadow, and riparian forest. In order to create these habitat zones we will removing invasive species, re-contour the area (Figure 2) add 12" of loam substrate, add 6" of topsoil-TAGRO mixture, install a clay cap in wetland zone (Figure 3), and install native vegetation appropriate to the zones. To protect the site from herbivory and off road recreation we will install fences around the site perimeter, and post signs. Finally, we will monitor for invasive species for ten years and replace die off of planted species (Table 4).

Modifications Map

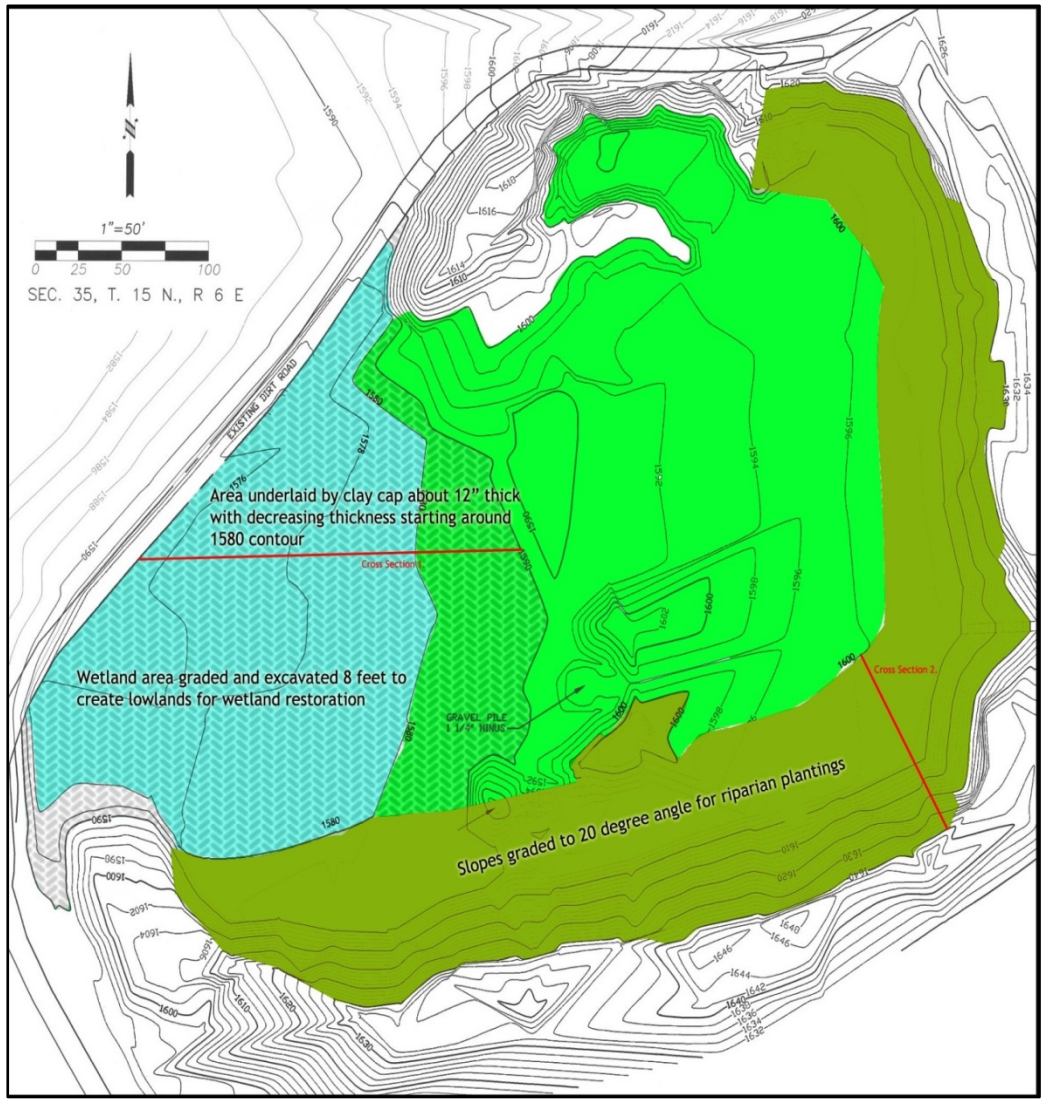


Figure 1

Riparian Cross Section

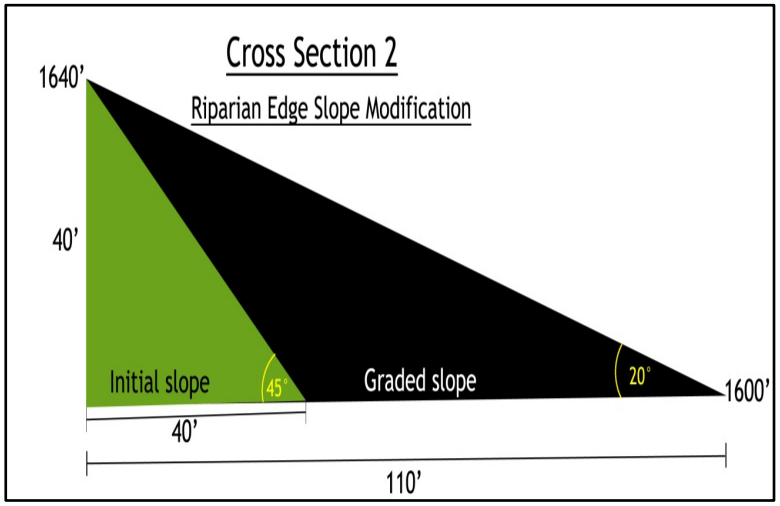


Figure 2

Wetland Cross Section

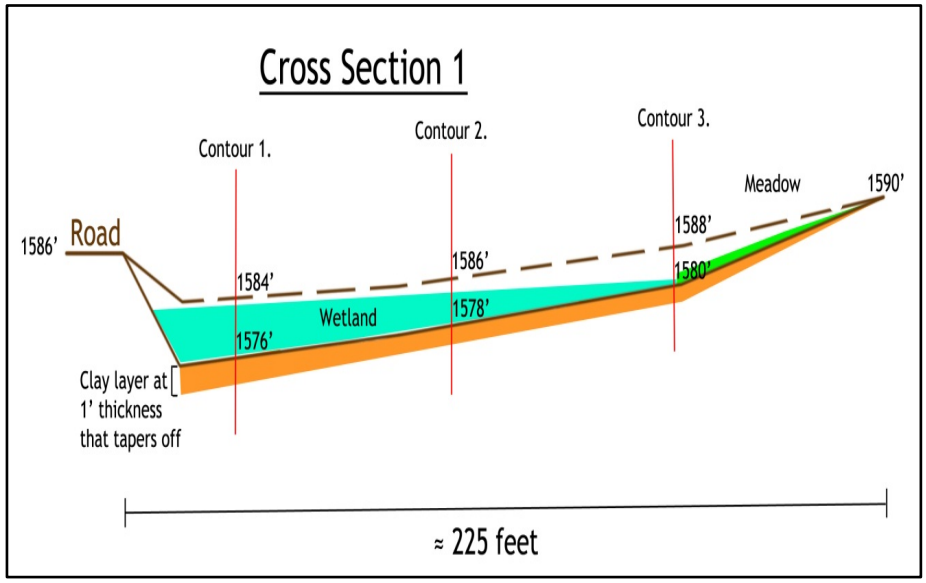


Figure 3

Table 4: Tasks

	General Tasks	Proceeds	Follows	Duration
A	Contact nursery about starting plugs and containers.	B, L		5 days
	A.1 Contact Four Corners Nursery, Stormlake Growers and Go Native.			
B	Establish holding area for plants not available from nursery.	C	A	7 days
	B.1 Site Analysis.			
	B.2 Construct nursery structure.			
C	Start Propagules at on-site holding area.	K	B	7 days
	C.1 Salvage necessary vegetation species			
	C.2 Install salvaged vegetation.			
D	Purchase or rent equipment for project installation.	G		2 days
E	Obtain and transport substrate materials and mulch.	H		14 days
F	Invasive removal.	G, K		7 days
G	Contour site so water drains into designed wetland area.	H	F	15 days
H	Apply 12 inch clay cap.	I	G	4 days
I	Layer soil substrate.	J,M		12 days
	I.1 Apply 12 inches of clean loam.	I.2		6 days
	I.2 Apply 6 inches of TAGRO classic mix.		I.1	6 days
J	Dig holes according to depth requirement for plant installation.	K	I	2 days
K	Install vegetation.	L,O	J	7 days
L	Mulch 2 to 4 inches depth around newly installed vegetation in riparian area.	M	K	4 days
M	Scatter large woody debris (LWD) to encourage wildlife feature.	N	I	2 days
N	Install temporary fence around area with new vegetation.	P	M	2 days
O	Post signage to keep out off-road vehicles.	P	K	1 day
P	Monitoring and maintenance (*See Maintenance Section*).		N,O	10 years

Preparation

Physical changes

The southern and eastern edges of the site have relatively steep slopes. In some areas the slope exceeds 40° (40 foot change in elevation over 40 feet horizontally). We proposed to grade these slopes down to 20° degree slopes in order to further increase the success of plant establishment and reduce the risk of erosion (Figure 4).

Our proposed wetland area is bordered by the road and the 1580’ contour line. We proposed to excavate that 1.5 acre area down approximately eight feet in order to create a low lying area for water to collect. This wetland area and an additional 0.35 acres to the east will be underlain with a clay cap to promote soil water retention and seasonal, if not permanent soil saturation. The clay cap should be one foot thick, gradually tapering towards its eastern border

.

Soil Amendments

The substrate we intend to spread over our site will be a 6” layer of TAGRO ‘Classic’ over a 12” layer of a loam substrate. The TAGRO classic blend consists of 40 percent biosolids cake, 40 percent sawdust, and 20 percent sand. TAGRO products meet the U.S. Environmental Protection Agency's (EPA, 2000) most stringent standards for their highest rating as "Grade A - Exceptional Quality" biosolids, and have long been approved for general use by the public (City, 2010).

The spreading of this mixture will ensure that the lost topsoil is replaced by a nutrient-rich, organic substrate that will help improve any existing soil fertility and –especially on the slopes – stability, reducing the risk of erosion.

Biosolids help improve soil properties, such as texture and water holding capacity, which make conditions more favorable for root growth and increased drought tolerance of vegetation. The nutrients in the biosolids will help catalyze the immediate growth of plants on the site and provide a pool of nutrients from which the soil can draw to feed the plants on a long-term basis. Most nutrients (nitrogen, phosphorus, potassium, sulfur, zinc and boron) will remain in the plant root zone bound to organic matter much longer than would traditional inorganic, commercial fertilizers. Organic forms of nutrients are less water-soluble and, therefore, less likely to leach into groundwater or run off into surface waters (NBMA, 2004; EPA, 2000).

Elevation Map

Figure 4: Diagram. Baker et al., 2003.

Installation

The riparian area encompasses 2.2 acres. It begins at the northern perimeter, cradles the eastern border until it reaches the southern steep slopes. This area will expand 110 feet westward to create a welcoming gentle gradient for deciduous-conifer plants

(Table 5a). The middle area, approximately 2.6 acres, will be allocated to meadow sedge and grass land (Table 5b, c). The area along the western perimeter will be excavated to 1.5 acres to create a seasonally flooded wetland (Figure 5).

Ecosystem Zonation Map

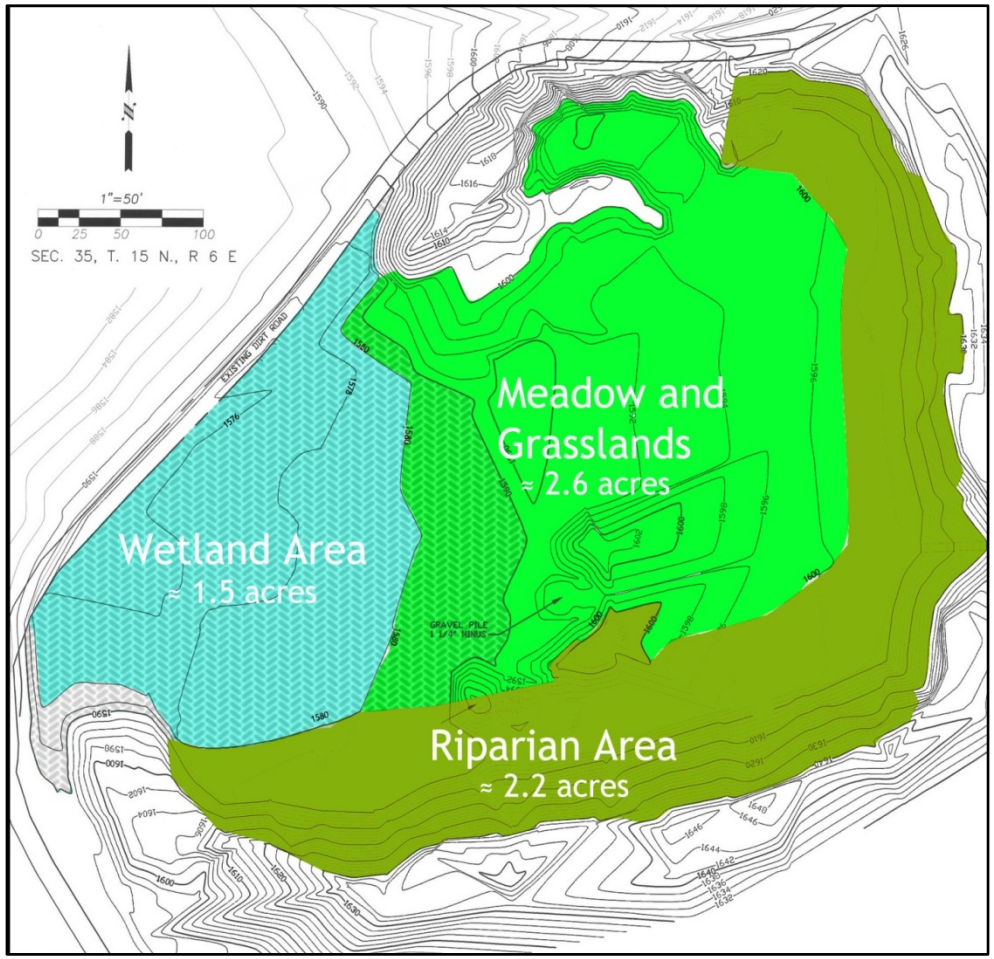


Figure 5: Diagram Baker et al., 2003.

Table 5: Vegetation Growing Requirements for Riparian Wetland, and Meadow, Habitat

5a: Riparian

Scientific Name	Common Name	Time Constraints to Planting
Acer circinatum	Vine Maple	Fall-Winter
Alnus rubra	Red alder	Fall-Winter
Athyrium filix-femina	Lady fern	Fall-Winter
Mahonia (Berberis) spp.	Oregon grape	After shade develops
Polystichum munitum	Sword fern	After shade develops
Rhamnus purshiana	Cascara	Fall-Winter
Rubus Spectabilis	Salmonberry	Fall-Winter
Symphoricarpos albus	Snowberry	Fall-Winter

5b: Wetland

Scientific Name	Common Name	Time Constraints to Planting
Carex nebrascensis	Nebraska sedge	Fall-Winter
Carex obnupta	Slough sedge	Fall-Winter
Carex stipata	Sawbeak sedge	Fall-Winter
Dulichium arundinaceaum	Dulichium	Fall-Winter
Eleocharis palustris	Common spikerush	Fall-Winter
Juncus ensifolius	Dagger-leaf rush	Fall-Winter
Scripus cyperinus	Wool grass	Fall-Winter
Scripus microcarpus	Small-fruited bulrush	Fall-Winter
Sparaganium eurycarpum	Broad-fruited burreed	Fall-Winter

5c: Meadow

	Scientific Name	Common Name	Time Constraints to Planting
Wetter areas	*Allium geyeri*	Geyer's onion	Fall-Winter
	Carex aperta	Columbia sedge	Fall-Winter
	Carex rostrata	Beked sedge	Fall-Winter
	Deschampsia caespitosa	Tufted hairgrass	Fall-Winter
	Juncus balticus	Baltic rush	Fall-Winter
Drier areas	*Festuca idahoensis*	Idaho fescue	Late Winter
	Achillea millefolium	Yarrow	Late Winter
	Camassia quamash	Common Camas	Late Winter
	Camassia leichtlinni	Great Camas	Late Winter

Table 6: Vegetation Purchasing Source for riparian, wetland, and meadow habitat.

6a: Riparian

Scientific Name	Common Name	Source	Condition	Size	Spacing
Acer circinatum	Vine Maple	Go Natives![1]	container	1 gal	3'
Alnus rubra	Red alder	Fourth Corner Nursery	container	1'	3'
Athyrium filix-femina	Lady fern	Go Natives!	container	1 gal	3'
Mahonia (Berberis) spp.	Oregon grape	Go Natives!	container	1 gal	3'
Polystichum munitum	Sword fern	Go Natives!	container	1 gal	3’
Rhamnus purshiana	Cascara	Fourth Corner Nursery	bareroot	1-3'	2'
Rubus Spectabilis	Salmonberry	Fourth Corner Nursery	bareroot	1-3'	3'
Symphoricarpos albus	Snowberry	Fourth Corner Nursery	container	6-12"	3'

6b: Wetland

Scientific Name	Common Name	Source	Condition	Size	Spacing
Carex nebrascensis	Nebraska sedge	Fourth Corner Nursery	sprigs	6"	1.5'
Carex obnupta	Slough sedge	Fourth Corner Nursery	sprigs	6"	1.5'
Carex stipata	Sawbeak sedge	Go Natives!	sprigs	6"	1.5'
Dulichium arundinaceaum	Dulichium	Go Natives!	container	1'	1.5'
Eleocharis palustris	Common spikerush	Fourth Corner Nursery	sprigs	6"	1.5'
Juncus ensifolius	Dagger-leaf rush	Fourth Corner Nursery	sprigs	6"	1.5'
Scripus cyperinus	Wool grass	Fourth Corner Nursery	container	1'	2'

Scripus microcarpus	Small-fruited bulrush	Fourth Corner Nursery	sprigs	6"	1'
Sparaganium eurycarpum	Broad-fruited burred	Go Natives!	rhizome	dormant	1.5'

6c: Meadow

Scientific Name	Common Name	Source	Condition	Size	Spacing
Carex aperta	Columbia sedge	Fourth Corner Nursery	sprigs	6"	1.5'
Carex rostrata	Beked sedge	Fourth Corner Nursery	sprigs	6"	1.5'
Deschampsia caespitosa	Tufted hairgrass	Go Natives!	container	6"	1.5'
Juncus balticus	Baltic rush	Fourth Corner Nursery	sprigs	6"	1.5'
Festuca idahoensis	Idaho fescue	Fourth Corner Nursery	container	3"	1'
Achillea millefolium	Yarrow	Fourth Corner Nursery	container	4"	1'
Camassia quamash	Common Camas	Go Natives!	rhizome	-	1'
Camassia leichtinii	Great Camas	Fourth Corner Nursery	rhizomes	-	1'

Time Line

Table 8: Calculated Estimates of Task Duration

Tasks	Units/hour/worker	Area of Application	Total Time (hr.)	Work days	Workers assigned	Task Duration
Excavation/Grading	excavator removes 40.94 cubic yards/hr.	19300 Cubic Yards	471 hrs.	59 days/ excavator	4 Excavators	15 days
Clay Cap Installation	tractor spreader 333 square yards/ hour	8954 Square Yards	27 hrs.	4 days/spreader	1 spreader	4 days
Loam/Substrate Installation	tractor spreader 333 square yards/ hour	30500 Square Yards	92 hrs.	12 days/ spreader	2 Spreaders	6 days
Install TAGRO classic mix	tractor spreader 333 square yards/ hour	30500 Square Yards	92 hrs.	12 days/ spreader	2 Spreaders	6 days
Mulch	hand spread 12.5 square yards/ hour	10600 Square Yards	848 hrs.	106 days/ worker	30 workers	4 Days
*Estimates made based literature (Fee, 2002) & (Methvin)						

Table 9: Implementation Gantt Chart (Tasks from Table 4)

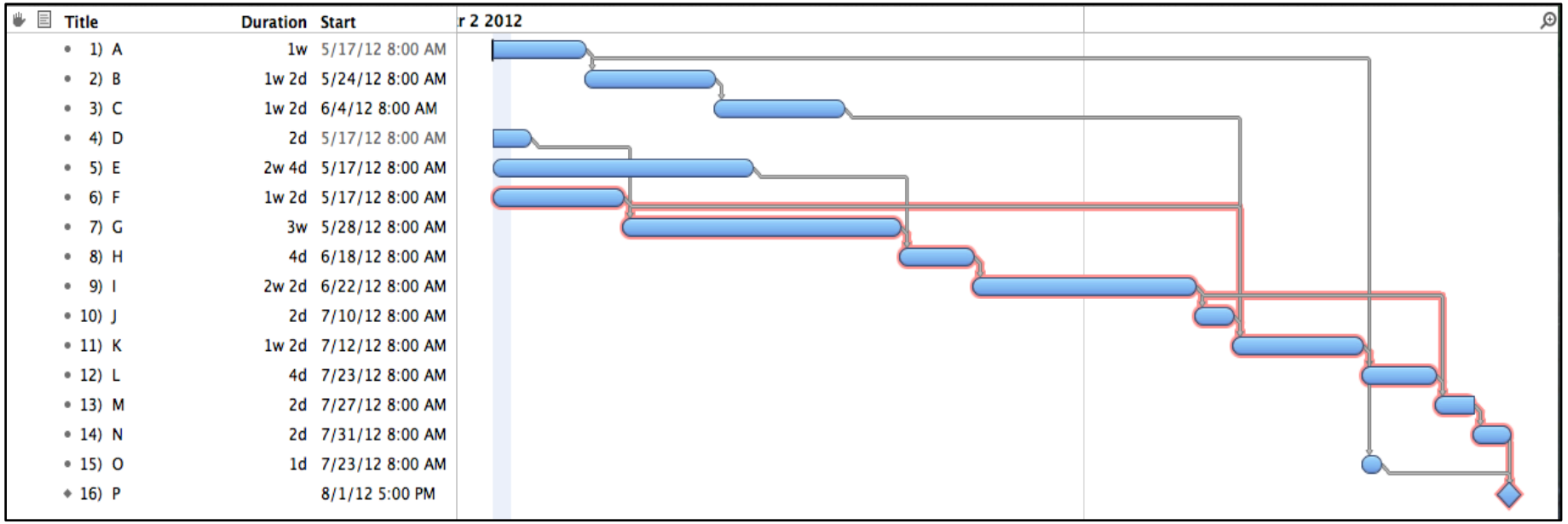
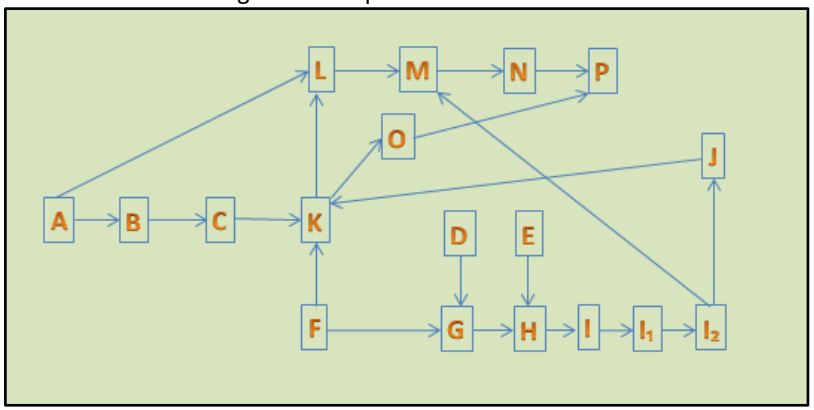


Table 10: General Volume Requirement Estimates

TAGRO					
	Acres	*Sq. in*	*Depth (in)*	*Cubic Inches*	*Cubic yds*
Wetland	1.5	9,408,960	6	56,453,760	1,210
Meadow	2.6	16,308,864	6	97,853,184	2,097
Riparian	2.2	13,799,808	6	82,798,848	1,775
Soil					
	Acres	*Sq. in*	*Depth (in)*	*Cubic Inches*	*Cubic yds*
Wetland	1.5	9,408,960	12	112,907,520	2,420
Meadow	2.6	16,308,864	12	195,706,368	4,195
Riparian	2.2	13,799,808	12	165,597,696	3,549
Clay					
	Acres	*Sq. in*	*Depth (in)*	*Cubic Inches*	*Cubic yds*
	1.85	11,604,384	12	139,252,608	2,985
Mulch					
	Acres	*Sq. in*	*Depth (in)*	*Cubic Inches*	*Cubic yds*
	2.2	13,799,808	4	55,199,232	1,183
Gravel Excavation					
	Acres	Sq. in	Depth (in)	Cubic Inches	Cubic yds
	1.5	9,408,960	96	903,260,160	19,360

Table 11: Network Diagram for Implementation



Maintenance

After implementation of the initial project, the area will need to be maintained and monitored. We will evaluate the success of the restoration and make changes as necessary to meet the goals of this project. Plant die-off will be monitored after a month, after a year, two years, five years, and ten years and replaced as necessary (Table 12a,b) .

Monitoring for invasive growth must occur once per season and invasive species removed and suppressed to prevent further invasion. The site will also need to be monitored and maintained to prevent woody-species encroachment into the meadow. Large woody debris should be maintained and added if older debris is significantly eroded. Signage preventing off-road vehicles in to the area will need to be maintained indefinitely.

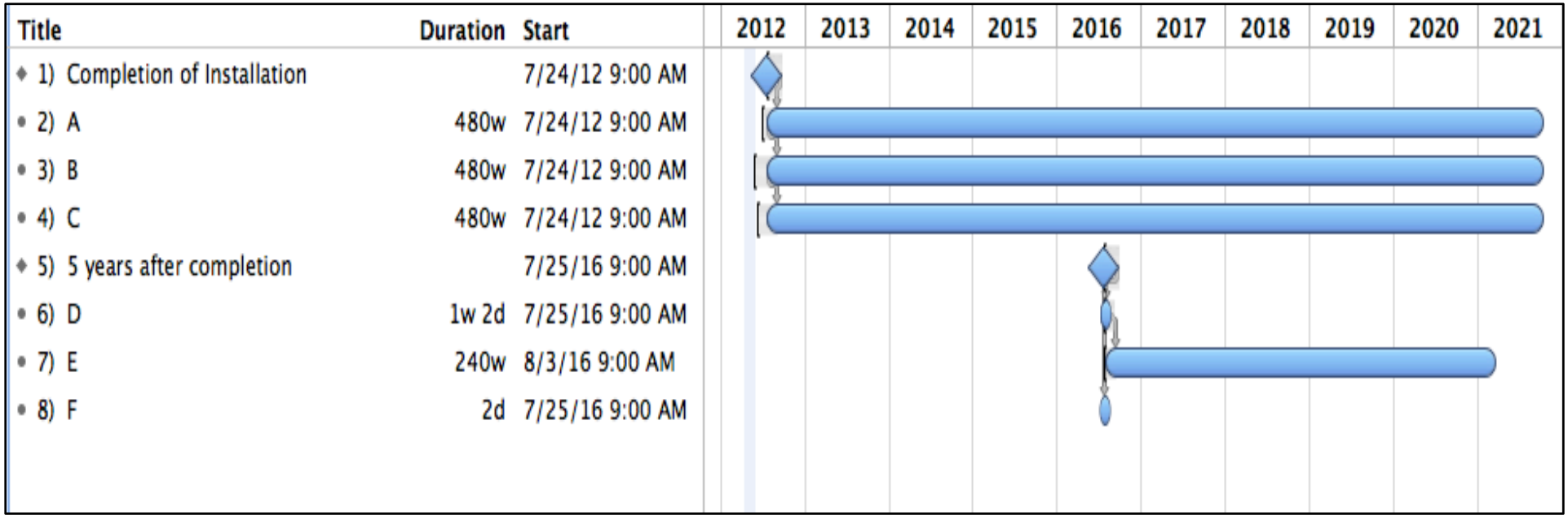
Monitoring the hydrology of the area is especially important, as this project poses significant changes to the soil and topography of the area. Erosion must be prevented and the seasonal wetland must be preserved. Slight fluctuation in soil topography is allowable, but significant erosion into the lower wetland area must be prevented so that intended hydrology (seasonal saturation) is maintained. Hydrology should be monitored once per month for ten years.

After the fifth year the fences placed around the site perimeter (to prevent browsing) can be removed, but monitoring is still necessary to prevent die off. During this time, understory species need to be planted and monitored monthly for 5 more years.

Table 12a: Maintenance Task List

	Maintenance Tasks	Precedes	Follows	Duration	Comments
A	Monitoring of plant die-off/ Replacement of die-off	-	-	10 years	
B	Monitoring for invasives/invasive removal (once per season)	-	-	10 years	
C	Manage and suppress woody encroachment into meadow			10 years	
D	Plant understory species	E		7 days	5 Years After Completion of Implementation
E	Monitoring of plant die-off/ Replacement of die-off of understory species		D	5 years	
F	Remove temporary fence around newly installed vegetation			2 days	5 years after implementation

Table 12b: Maintenance Gantt Chart



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North Cascade Pass Subalpine Trail

(Photograph. Andy Porter. 2012)

Introduction

Cascade Pass was one of the earliest heavily-used passages across the Cascade mountain range. At 1641 meters, it is along a route from the Stehekin River watershed (Lake Chelan) into the upper part of the Skagit River watershed. Native Americans used it, and when settlers came they used it as well. It became part of the Mount Baker Snoqualmie National Forest and was used for overnight camping starting in the 1920's. North Cascades National Park (NOCA) came into being in 1968; Cascade Pass, now part of NOCA, was eventually closed to overnight camping but is still a popular day hike and is the access route to many backpacking trips.

Recreational use has caused extensive impacts to subalpine vegetation communities and soils. Both trampling and camping cause impacts such as reduced vegetation cover, reduced species diversity, changes in species composition, soil compaction and soil loss. These impacts further impair soil conditions and processes so that natural re-colonization by plants is extremely slow. The vegetation is dominated by woody *Phyllodoce* and *Vaccinium*, a community type that is made up of species that are neither tolerant of trampling impacts, nor particularly resilient. The Pass has heavy snow pack, which creates a short 10-12 week growing season, further limiting regrowth.

A study done in 1970 found that there were 48 campsites and connecting trails within a 12 ha area. They had compacted, bare soil. As a consequence of this study, the park superintendents closed all camping and initiated a research and restoration program with the intention of finding out how to repair the damage, and then to repair it. Management recommendations included a call to actively revegetate the site using locally collected seed of plant species resistant to trampling (and likely to establish from seed). A 1979 revegetation study for the district emphasized the use of on-site transplants, as the technique had been very successful at lower elevations. Another study found, as others have, that aspect (the direction the slope faces) was a very important control on seeding success (K. Ewing, personal communication, May 17th 2012).

Site History

Before European colonization, people of the Upper Skagit, Chilliwack, Lower Thompson, and Chelan Indian tribes used the Cascade Pass as a mountain passageway. During the gold rush, in the 1880's, settlers used this trail. Beginning in 1897, the area became a forest reserve. It was initiated into the North Cascades National Park in 1968 (NOCA) (Bourasaw,2009).

The restoration site is in the subalpine, so it experiences heavy snowfall. The vegetation is slow growing, and is limited to an annual 10 to 12 week growth period (Ramsay,2004).

Cascade Pass is located in the *Tsuga mertensiana* vegetation zone. In the subalpine regions of the park, the most abundant vegetation present is *Phyllodoce empetriformis* and *Vaccinium deliciosum.* At lower elevations *Abies amabilis* and *Abies lasiocarpa* dominate. *Carex nigricans*, *Carex spectabilis*, and *Luetkea pectinata* are found in depressions and flat sites (Ramsay, 2004).

Site Analysis

Vegetation

Vegetation around this site is adapted to poor nutrient conditions, short (10 to 12 week) growing season, and low temperatures. Recreational use of the area has resulted in trampled vegetation, compacted and eroded soil, and increasing vulnerability to invasives.

Native Species

Scientific Name	Common Name
Phyllodoce empetriformis	Pink mountain-heather
Sorbus sitchensis	Sitka mountain-ash
Vaccinium deliciosum	Cascade bilberry
Deschampsia atropurpurea	Mountain hairgrass
Tsuga mertensiana	Mountain hemlock
Cassiope mertensiana	Western moss heather
Abies amabilis	Pacific silver fir
Juncus parryi	Parry's rush
Abies lasiocarpa	Rocky mountain fir

Polygonum bistortoides	American bistort
Carex nigricans	Black alpine sedge
Luzula parviflora	Small-flowered woodrush
Carex spectabilis	Showy sedge
Phleum alpinum	Alpine timothy
Luetkea pectinata	Partridgefoot

Table 1 (Ramsay 2004)

Invasive Species

Scientific Name	Common Name
Centaurea diffusa	Diffuse knapweed
Centaurea maculosa	Spotted knapweed
Chondrilla juncea	Rush skeletonweed
Hypercium perforatum	St. John's-wort
Cytisus scoparius	Scott's broom
Polygonum cupidatum	Japanese knotweed
Digitalis purpurea	Foxglove

Table 2 Note – This list of invasives include dominant invasives found all over the wilderness area, some may not be applicable to Cascade Pass (Mather,1994).

Hydrology

Melt off from snow provides water to the area (Ramsay 2004). There is no major water body directly near the restoration site. Rain in the area has occasionally been acidic due to pollution (Mather 1994).

Soil

The soil is comprised of sediment from glacial drift, landslide deposits, volcanic ash, and bedrock. The soil is thin, poor, and has very little nitrogen. Hiking and camping has caused soil compaction and erosion (Mather 1994). The campsites on the pass are now closed to overnight camping, but the sites have not recovered and remain bare (Mather 1994).

Wildlife

Some threatened or endangered wildlife species found in the nearby areas include: gray wolves, grizzly bears, peregrine falcons, bald eagles, and spotted owls. Other species commonly spotted include deer, marmots, pikas, and the occasional black bear (Cascade Pass/ Sahale Arm Trail).

Primary Stakeholders

- Superintendent of the North Cascades National Park – client
- Hikers and climbers – recreational users
- North Cascade Tribes

Functional Requirement and Constraints

Functional Requirements

- Improve the soil conditions on the old campsites to allow for re-vegetation.
- Increase vegetation on the bare ground.
- Plan for storage of equipment and materials.
- Plan for workers to stay and/or commute to the site or head of the trail.
- Create monitoring and maintenance plans to secure desired vegetation establishment

Constraints

- This restoration must be done with at most 5 employees (and volunteers for approved events).
- This restoration needs to be implemented without causing further damage to this stressed, disturbance-prone system.
- Planting can only be done during the growing season, when there is no snow on the sites.
- The main trail must be usable by hikers.
- Must prevent vegetation from being trampled during and after the restoration.

- Materials most be brought in.
- Travel time to the site is long, and must be considered.

Basic Approach

- Collect all seed, near site, the year before implementation begins
- Break up restoration over 4 years
- Scarify the soil to a depth of 15 cm
- Add 8 cm organic material (Sphagnum Moss) to the soil
- Direct seed native plants
- Protect growth and soil with layer of Excelsior Mats
- Add additional water to the restored sites

Tasks

Due to the time constraints: the short growing season, the time it will take workers to get to restoration sites, and our limitation of a maximum of five workers, we decided to implement restoration efforts over four years (Table 7 & Figure 2). Restoration will be done in equal yearly work periods, dividing the site into 4 parts. The division of the site is based on accessibility, starting with sites furthest out and gradually working inward (Figure 2). We stockpile materials on campsites that have yet to be restored to save trips to and from the site.

If invasive species are present we will remove them manually. We will directly seed; given the remoteness of the site, transporting plugs is not efficient. We will plant *Carex nigricans* (black alpine sedge), *Carex spectabilis* (showy sedge), *Phleum alpinum* (alpine timothy), *Deschampsia atropurpurea* (mountain hairgrass), *Juncus parryi* (parry's rush), *Polygonum bistortodies* (smokeweed), *and Luzula parviflora* (small-flowered woodrush).

Estimation of Seed Densities

Species	Seeds per g	g of Seed per Plot 20cm*20cm	Estimated Seeds for 1537.3 meters squared
Carex nigricans	2,290	0.044	16,910
Carex spectabilis	1,430	0.07	26,903
Phleum alpinum	2,200	0.045	17,295
Deschampsia atropurpurea	2,240	0.045	17,295
Juncus parryi	N/A	0.015	575
Polygonum bistortodies	555	0.01	3,843
Luzula parviflora	1,950	0.051	19,601

Table 3 (Ramsay 2004)

We will collect seeds the year prior to planting. We intend to collect directly adjacent to the site, however if we are not able to fill our needs, we will collect seed from similar populations in the park (Ramsay 2004).

Prior to seeding we will scarify the soil 15 cm to de-compact the soil. After seeding, we will cover the soil with 8 cm of peat moss. We will then mix the scarified native soil with the peat moss. Peat moss will add organic material to the soil and hold in more moisture than soil alone (Ramsay 2004).

We will sow seed by raking directly into the soil. After seeding, we will water the soil at a rate of 7.2 liters per square meter. We will collect the water from catch water basins (25 funnel topped, 55 gal containers that will be placed in unrestored campsites the same year as seed collection). Over the entire four years we will apply approximately 2922 gal of water to our sites.

We also intend to place Excelsior erosion blanket over seeded soil to help the soil temperature, and to help maintain moisture (Ramsay 2004).

Material Allocation, Transportation & Storage

Miller and Miller suggest transporting soils by dragging them up on a tarp (1977); we could use this method to drag up peat moss and excelsior.

Applying material

1. If any invasive species are present in restoration areas, they must be removed.
2. If there are any remnant fire pits on restoration sites, the charcoal needs to be dug out and filled with soil (Miller & Miller 1977). The charcoal will be removed from the pass and disposed of.

3. Scarify all soils on campsites and trails leading to them to a depth of 15 cm (Ramsay 2004).
4. Spread peat moss at a depth of 8 cm over the scarified soil and then mix into the soil by rotating the peat underneath (Miller & Miller 1977).
5. Directly sow seeds.
6. Cover seeds with excelsior mats.

Minimizing Human Disturbance

Human disturbance has caused substantial negative impacts to the vegetation communities in Cascade Pass. Vegetation in the sub-alpine zone is particularly susceptible to disturbance due to the short growing season, cool climate and frequent recreational use. This project aims to encourage recreational use of the main trail, but keep disturbance off trail to a minimum. Just off the main trail in the center of each spur-trail leading to the former campsites, we will place signs notifying visitors of the restoration and requesting they keep away from the restoration areas and stay on the main trail. There will also be a larger information sign placed about the ongoing restoration and suggestions on what visitors can do to preserve the area and deter further destruction of Cascade Pass.

In order to prevent further disturbance during this restoration, Miller & Miller suggest workers wear tennis shoes or moccasins to reduce trampling impacts (1977). No roads will be constructed for this project. All equipment and materials will be packed in by workers, to keep disturbance to a minimum.

Transportation and Storage: Explanation & Justification

Transportation – Due to the restrictions of wilderness areas, as well as the constraints imposed by the primary stakeholders, all transportation of tools and materials will be done on foot. Currently this is estimated to be a two-hour hike from the trailhead, and parking area, to the pass. Times will vary with equipment sizes of loads. Hiking time down from the site is estimated to be 1.5 hours.

*We analyzed several alternatives to human transportation (Table 4)

Storage – All materials and tools are planned to be stored at the indicated staging area for ease of access and use for further transportation throughout the site. Tools and other miscellaneous items can be stored in a simple wooden locker, which will be constructed on site. A large tent cover will be brought up to provide cover for the excelsior mats and peat moss that will then be spread out onto the site.

Water will already be present on site in the form of 55-gallon catch basins. Twenty-five catch basins will be placed throughout the site along the trails the year before when we came to collect and salvage native seeds. Over the course of the year we anticipate these basins to collect precipitation in anticipation for the following year's restoration. Having full basins will negate the need for water transport. As we complete our implementation, we will move basins away from restored areas.

*We chose between several alternatives to the locker box, and tent covering for supply storage (Table 5& 6)

Transportation and Storage: Decision Matrices

Table 4

Transportation							
Options	Weighted relative importance	Horse		Helicopter		Human	
Criteria		Raw	Weighted	Raw	Weighted	Raw	Weighted
Legality	50	5	250	1	50	5	250
Capacity	20	4	80	5	100	3	60
Disturbance	10	3	30	1	10	4	40
Complication	15	3	45	3	45	5	75
Total:	**95**		**405**		**205**		**425**
Rank		**2**		**3**		**1**	
SCALE: 1-5	5	4	3	2	1		
	IDEAL		AVERAGE		NO BENEFIT		

Table 5

Storage							
Options	Weighted relative importance	Uncovered Piles		Constructed Storage Facility		Large Tent Cover	
Criteria		Raw	Weighted	Raw	Weighted	Raw	Weighted
Feasibility (possible/legal)	30	5	150	1	30	5	150
Portability	30	5	150	1	30	4	120
Quality of Storage	40	1	40	5	200	4	160
			0		0		0
Total:	**100**		**340**		**260**		**430**
Rank		**2**		**3**		**1**	
SCALE: 1-5	5	4	3	2	1		
	IDEAL		AVERAGE		NO BENEFIT		

Table 6

Loss Prevention							
Options	Weighted relative importance	Steel Equipment Locker		Wooden Equipment Locker		No locker	
Criteria		Raw	Weighted	Raw	Weighted	Raw	Weighted
Portability	20	1	20	4	80	5	100
Protection from elements	15	5	75	4	60	1	15
Protection from theft	5	5	25	3	15	1	5
Cost		1	0	3	0	5	0
			0		0		0
Total:	**40**		**120**		**155**		**120**
Rank		**2 (tie)**		**1**		**2 (tie)**	
SCALE: 1-5	5	4	3	2	1		
	IDEAL		AVERAGE		NO BENEFIT		

Tables for Yearly Reoccurring Implementation

Tasks

Table 7

task	Description	Duration (With 5 Workers)	precedes	follows
a	Transportation of Tools	1 hours	d	-
b	Transportation of Peat Moss	13.65 days	e	-
c	Transportation of Excelsior	5 hours	h	-
d	Scarifying soil 15 cm deep	3.2 days	e	a
e	Applying peat moss	1.6 days	f	d
f	Mixing peat moss into soil	3.2 days	g	e
g	Sowing seed	3.2 days	h	f
h	Applying Excelsior	1.6 days	i	g
i	Watering	.38 days	j	h
j	Monitor/Maintain Previous Sites	-	-	i

Calculations for Task Durations

Table 8: Application Related Tasks

Task	Rate (1 worker)	Area applied (m^2)	Total Worker Hours	Total (4 Hour) Worker Days	Work Days for 5 workers	Yearly Work Days (4 Years)
Scarifying Soil 15 cm Deep	6 m^2 / hour	1537.3	256.2166667	64.05416667	12.81083333	3.202708333
Applying Peat Moss	12 m^2/ hour	1537.3	128.1083333	32.02708333	6.405416667	1.601354167
Mixing Peat Moss	6 m^2 / hour	1537.3	256.2166667	64.05416667	12.81083333	3.202708333
Sowing Seed	6 m^2 / hour	1537.3	256.2166667	64.05416667	12.81083333	3.202708333
Applying Excelsior	12 m^2/ hour	1537.3	128.1083333	32.02708333	6.405416667	1.601354167
Watering	50 m^2/hour	1537.3	30.746	7.6865	1.5373	0.384325
		total:	1055.612667	263.9031667	52.78063333	13.19515833

Table 9: Transportation Related Tasks

Task	Rate	Amount	Total Worker Hours	Total (8 hour) Worker Days	Work Days for 5 workers	Yearly Work Days (4 Years)
Tool Transport	4 tools/ person/ trip	15.0	13.125	1.640625	0.328125	0.08203125
Transportation of Sphagnum Peat Moss	0.197 cu meter/ trip	123.0	2184.994924	273.1243655	54.6248731	13.65621827
Transportation of Excelsior	57.27 sq meter/trip	1537.3	93.95058495	11.74382312	2.348764624	0.587191156
		total:	2292.070509	286.5088136	57.30176272	14.32544068

Camp Site and Trail System

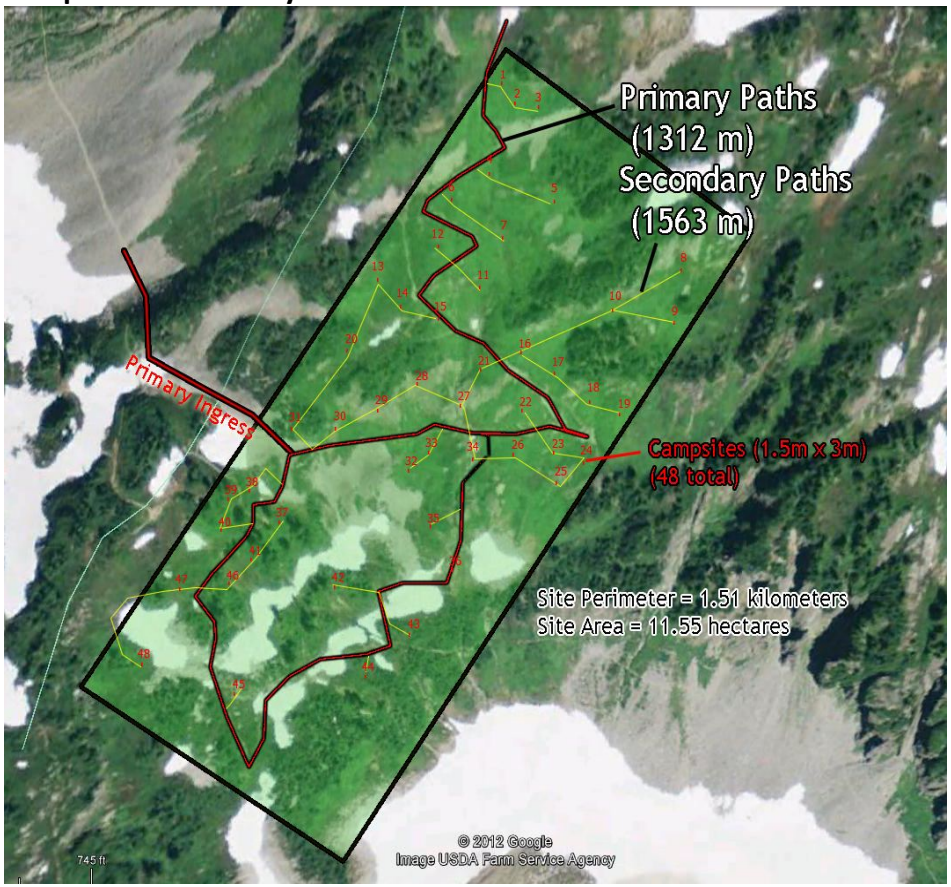


Figure 1. General Layout of the Site. Primary trails are assumed to be more heavily used than the secondary paths. Affected soil paths are assumed to be 45cm wide.

Work Plan Map

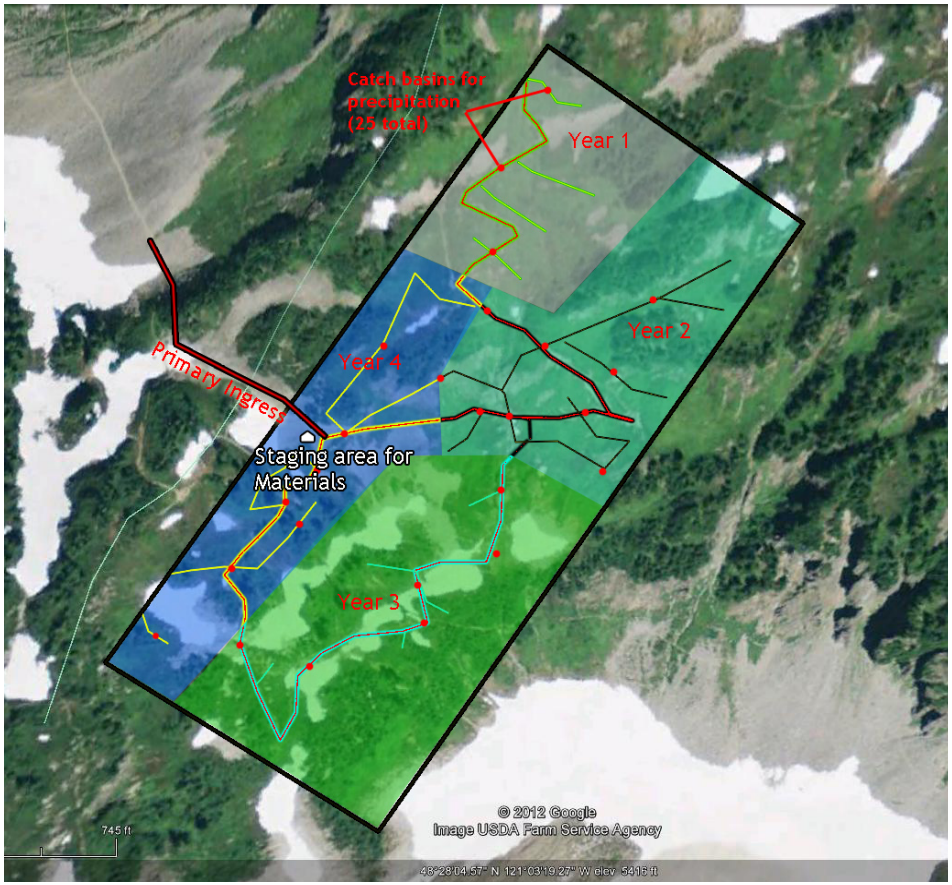


Figure 2. Yearly work plan for the site. Yearly work zones designated by total restoration area and distance from the primary ingress.

Cross Section of Soil Amendments

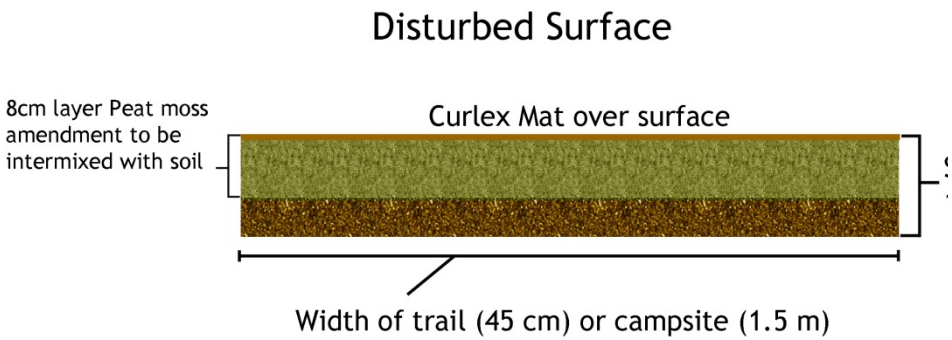
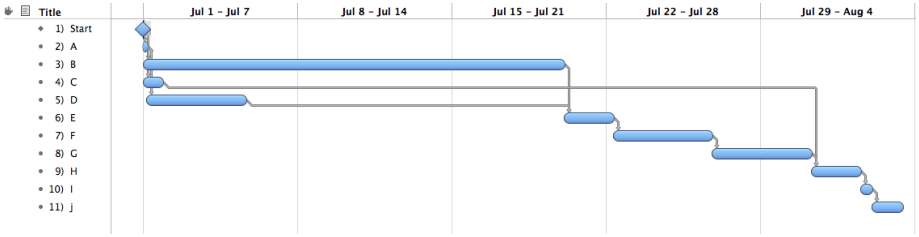


Figure 3. General cross section of restoration plot with site treatments

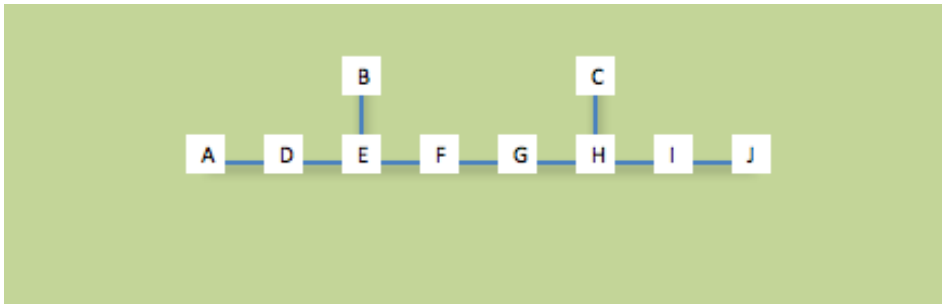
Gantt Chart & Network Diagram for Yearly Reoccurring Implementation

Table 10



(*See tasks above in Table 7)

Table 11



Labor Budget

Table 12

Labor Budget	
Site Preparation	June to September Daily Rates per Year
Seeding	3.2
Peat (Mix)	3.2
Peat (Transport)	13.0
Scarification	3.2
Excelsior mat (Transport)	0.6
Tool (Transport)	0.1
Water barrels (Transport)	1.6
Restoration Signs	0.2
Site Preparation Subtotal	**25.1**
Site Installation	June to September Daily Rates per Year
Seeding	6.0
Peat	1.6
Excelsior mat	1.6
Water barrels	1.0
Watering	0.4
Restoration Signs	1.0
Site Installation Subtotal	**11.6**
Total Labor Hours (1st year)	*36.7*
Site Maintenance	June to September Daily Rates per Year
Seeding	3.0
Peat	0.8
Excelsior mat	0.8
Site Maintenance Subtotal	**4.6**
Site Monitoring	June to September Daily Rates per Year
Plant die-off	3.2
Site Monitoring Subtotal	3.2
Total Labor Hours (Following year)	*7.8*
Total Labor Hours	44.5

Financial Budget

(Table 13)

Financial Budget				
Plants	Annual Prices			
Salvage	$592.00			
Plant Subtotal	**$592.00**			
Excelsior mat	Area (m)	Price (52 m2 per roll)	Quantity needed	Annual Price
entire area	1537.3	**$120.00**	**10.00**	
Excelsior mat Subtotal				**$1,200.00**
Peat	Area (m3)	Price (1 m3 bulk sheets)	Quantity needed	Annual Price
entire area	799.92	**$16.00**	**12798.72**	
Peat Subtotal				**$204,779.52**
Tool	Annual Price (5 staff members)			
Boards	$50.00			
Writing Utensils	$15.00			
First aid	$30.00			
Watering cans	$50.00			
Rakes	$50.00			
Stakes	$250.00			
Wooden locker	$100.00			
Tool Subtotal	**$545.00**			
Lodging	Daily Rate	Staff Number	Annual Price	
Nearby hostel	$10.00	5		
Lodging Subtotal			**$50.00**	
Transportation	Annual Labor Rate	Staff Number	Annual Price	
Peat	13.13	5	**$65.63**	
Excelsior mat	2184.99	5	**$10,924.97**	
Plants	26.90	5	**$134.50**	
Tool	1.60	5	**$8.00**	
Transportation Subtotal			**$11,133.10**	
Staff	hourly rate	Staff Number	Annual Worked Day Rate	Annual Price
Employeed forest rangers	$20.00	5	14	
Staff Subtotal				**$1,400.00**
Total Expense				**$219,699.62**

Maintenance

Because of the slow growth subalpine environment, we will conduct maintenance for 8 years after the restoration has completed (Cole,2006). We will monitor growth and possible invasive species. If there are patches where nothing has germinated we will re-seed, apply peat moss, water, and apply Excelsior mats to the patches. If invasive species mange to find there to our sites they will be removed.

After restoration we will maintain the signs, ensuring the lowest amount of recreational damage. It will be necessary to leave the signs after 8-year maintenance is completed, to protect the site's fragile ecosystem.

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(Photograph. USFWS, 2011)

Introduction

Thornton Creek is the largest watershed in the city of Seattle. Anthropogenic processes have heavily disturbed the creek, since it runs through such a highly developed landscape. Even before European settlement, native peoples altered the creek by using weirs and blocking off sections of the entire creek to harvest salmon. In 1848 the U.S. Congress passed the Oregon Donation Land Claim Act; consequently, many people settled the Pacific Northwest to harvest timber. The influx of settlers called for the construction of more roads, and more impervious surfaces, which degraded the natural hydrology of the region. Vital marsh habitat has also been lost due to the lowering of Ship Canal in 1916, which submerged wetland areas.

Further disturbance to the creek was caused by the construction of Northgate Mall in 1950. The creek was submerged and channeled through culverts 20 feet below ground. A dichotomy has formed in the watershed: between urban development and environmentally functional land. In the late 1980's people became more aware of environmental functions provided, and lost, from the watershed.

Restoration efforts over the last three decades include work on floodplains and salmon habitat as north as Twin Ponds Park, in Shoreline. However, much of the creek still runs through culverts, fifty percent is contained by impervious surfaces. Salmon have moved back into the system as far north as Twin Ponds, at 155th St. NE, next to I-5. Seattle Public Utilities and the City of Shoreline continue to support the restoration of sections of the creek system (K. Ewing, personal communication, May 24th 2012).

Site Analysis

Thornton Creek flows from northwest to southeast, draining into Lake Washington. The north-branch headwaters begin at Ronald Bog and the south-branch at North Seattle Community College. The creek drains at Matthews Beach Park and drains approximately 7,400 acres over 15 miles (King County, No Date).

Hydrology

Seattle developed very rapidly, without proper considerations for flood management, although some flood management exists. Meadowbrook Pond and other protected areas along the creek, such as Twin Ponds Park and Ronald Bog, were created to prevent flooding. The creek discharges at a rate of 0-2.15 cfs, with an average of 0.3-1.5 cfs (King Country, No Date).

Water Quality

Water quality is monitored monthly at the mouth of Thornton Creek (Table 1).
The water quality of Thornton Creek is listed as "high concern" by King County. This is due to high bacterial levels, high temperature, large proportion of suspended soils, high nutrient content, and low dissolved oxygen. The creek is in violation of the Washington Department of Ecology's guidelines for fecal coliform contamination. The creek also has low dissolved oxygen, and high temperatures. A study conducted from 1971-2007 found that these water quality trends were worsening.
Salmon habitat is an important feature of this watershed. The Salmon Watcher Program (King County, No Date) has been monitoring salmon in Thornton Creek since 1997. Coho are dominant in the creek, but Chinook, Sockeye, and Cutthroat are also present.
Between 1952 and 1990 Thornton Creek was stocked with approximately 15,000 Coho fry per year and after 1990 approximately 600 fry per year. In 1977 private property owners released an additional 17,000 fry (King County, No Date).

Table 1. Routine monitoring summary statistics for Thornton Creek from 1971 to 2012 (King County, no date)

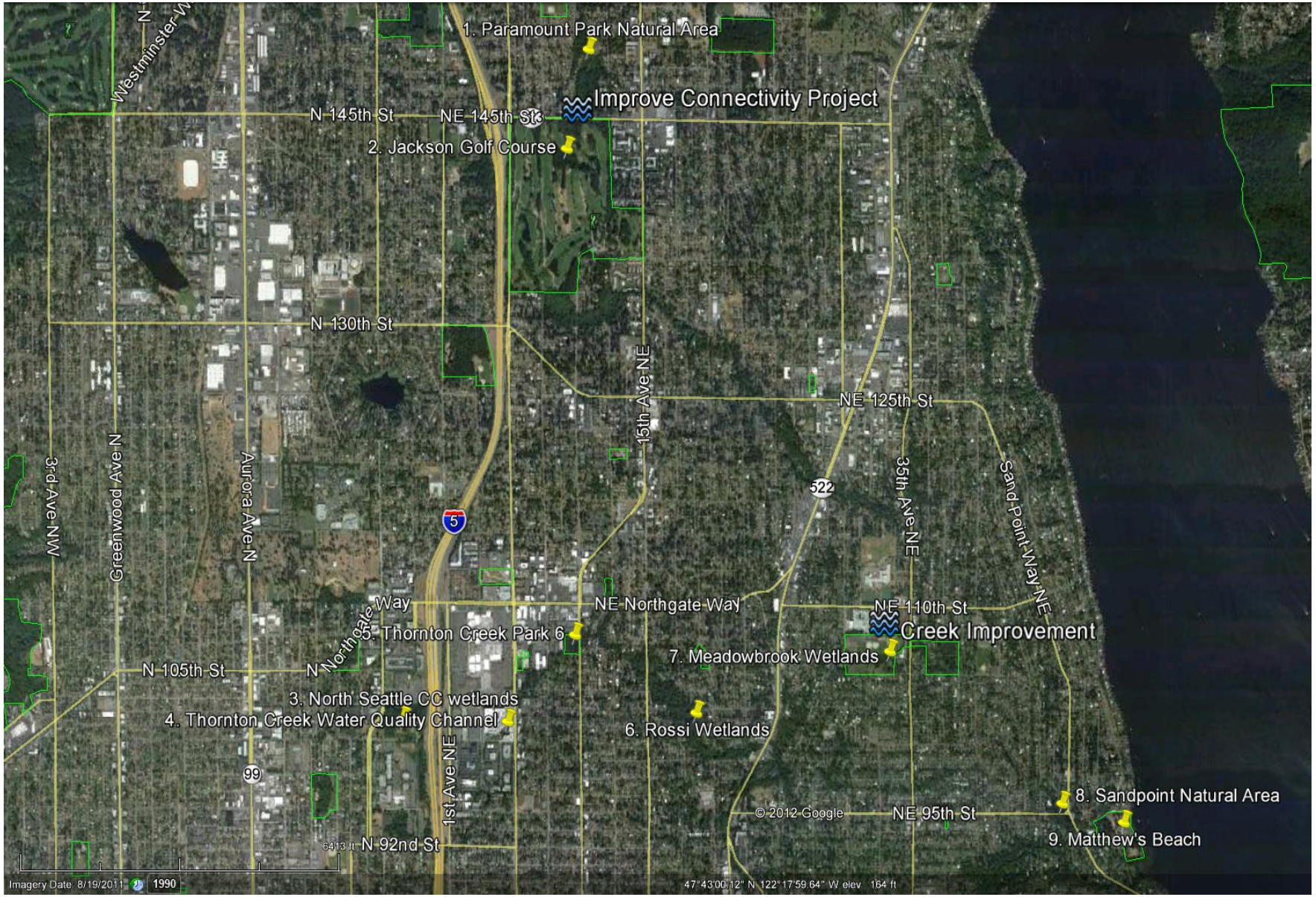
Parameter	Number of Samples	Mean	Minimum	Maxmium	Median +/- stdev
Dissolved Oxygen (mg/L)	185	10.6	7.3	13.6	9.3 - 11.8
Temperature (oC)	320	10.5	1.6	17.6	6.8 - 14.2
Turbidity (NTU)	287	4	0	43	0 - 9
pH	242	7.5	6.4	11.2	7.1 - 7.9
Conductivity (mSIEMS/cm)	158	220	67	374	179 - 261
Total Suspended Solids (mg/L)	323	9.9	0.6	132	-33.9
Ortho-Phosphorus (mg/L)	322	0.035	0.005	0.12	0.019 - 0.051
Total Phosphorus (mg/L)	323	0.074	0.007	0.406	0.029 - 0.119
Ammonia (mg/L)	294	0.035	0.001	0.16	0.015 - 0.055
Nitrate (mg/L)	320	1.145	0.311	2.03	0.887 - 1.403
Total Nitrogen (mg/L)	243	1.426	0.887	2.4	1.207 - 1.645
Fecal Coliform(CFU/100ML)	321	949	14	10000	-2480

Table 1

Restoration Site Options

Although many sites for restoration lie along Thornton Creek, we have selected four possible options for a restoration project affecting the Thornton Creek watershed (figure 3).

Figure 3: Map of Restoration Options



"Rossi" Wetlands

***Description*:**

During development near this site, in the 1950's, wetland areas adjacent to the creek were filled. Flooding has become an issue, and owners sold the properties that comprise this site to Seattle Public Utilities. Restoration would include restoring natural stream morphology, such as wetland areas and natural channel composition. We propose to remove the stone channel and restore the benched wetland, thus providing additional "off channel" fish habitat as well as addressing downstream flooding and erosion (Ewing, Unpublished). Additional tasks include removal of invasive species and litter from the area.

***Constraints*:**

- Use of heavy machinery would be difficult because of bank slope and vegetation density.
- Do not disrupt nearby residential area.
- Volunteer/worker cap at 20 people to avoid excess trampling.

Improve Connectivity 10th Ave. NE & NE 145 St.

Description:

Thorton creek is crossed by 145th St., at the Jackson golf course. The stream crosses underneath 145th and runs south into the golf course. To increase salmon connectivity along Thornton Creek, this crossing could be improved. We propose to implement a salmon-passible culvert, and alter the stream channel, above and below the crossing, to maximize salmon connectivity.

Constraints:

- This design cannot interfere with traffic.
- Limit impact to Jackson golf course.
- Limit any impact to homeowners.
- Limit contamination of water quality throughout implementation.
- Cannot construct during salmon migration.

Restore Creek Through Nathan Hale High:

***Description*:**

Thornton Creek runs between the parking lot and school buildings of Nathan Hale High, on 30th Ave NE. In this area, the creek is completely straightened, and occasionally floods into the parking lot and nearby roadways. To restore this stretch of Thorton Creek, we propose to widen the channel, meander the creek's path, and install flood-catching features along the creek. To accomplish this, we propose to annex space from the parking lot.

***Constraints*:**

- Annexing parking lot space from Nathan Hale High would be difficult.
- The project cannot disrupt school buildings.
- The project must be scheduled carefully to minimize disruption to school activities.

Improvement of Thorton Creek Park 6

***Description*:**

This site is located between the intersection of NE 105th & 9th Ave. NE and NE 103rd and 5th Ave. NE. This site was once infested with blackberry, but since has been restored. Currently Earthcorps, in the direction of Alan Johnson from Aquatic Resources Consulting, has been laying back the banks, adding woody debris, and replacing non-native plants with native species to allow the stream once again to replenish the wetland areas (Ewing, Unpublished). This option would continue these efforts. In this option we consider planting natives, removing invasives, and manipulating stream flow (if necessary) with large woody debris.

***Constraints*:**

- Do not disturb crayfish stream habitat.
- Do not interfere with duck habitat.
- Do not remove matured planted natives from 1992 restoration (Ewing, Unpublished).
- Do not remove existing large woody debris.

Decision Framework

To decide the best of our four above restoration options, we evaluated each option against six criteria: affected area, closeness to completed projects, cost, environmental value, feasibility and priority of need (table 2).

Options	Weighted relative importance	Restore "Rossi" Wetlands		Improve Connectivity between 10th Ave NE & NE 145 street sites		Restore Creek Through Nathan Hale High Campus		Improvement of Thorton Creek Park 6 Site		No Change	
Criteria		Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted
Affected Area	20	4	80	1	20	3	60	4	80	1	20
Closeness to Completed Projects	10	2	20	5	50	3	30	4	40	1	10
Cost	10	2	20	5	50	2	20	4	40	5	50
Environmental Value	15	4	60	3	45	5	75	4	60	1	15
Feasibility	15	4	60	5	75	2	30	5	75	5	75
Priority of Need	20	4	80	2	40	5	100	1	20	1	20
			0		0		0				
Total:	**90**		**320**		**280**		**315**		**315**		**190**
Rank		**1**		**3**		**2**		**2**		**4**	
SCALE: 1-5	5	4	3	2	1						
	IDEAL		AVERAGE		NO BENEFIT						

Table 2: Decision Matrix

Final Decision

Through evaluating each option based on our chosen six criteria, we determined that restoring the “Rossi” Wetlands area is most desirable.

Rossi Wetlands (Kingfisher Natural Area)

The area known as the Kingfisher Natural Area (KNA) is a forested corridor running through NE Seattle. The ‘Rossi Wetland’ lies within KNA and was formally designated as a city park in June 2011 (SPR, 2011). The park features viewpoints, wetlands, and an abundant wildlife habitat. The name comes from the nesting Kingfishers that once inhabited the area.

Thornton Creek runs directly through this corridor (figure 1). The corridor is V-shaped; the creek runs through the lowest point, as shown in the elevation profile (figure 2).

Kingfisher Natural Area

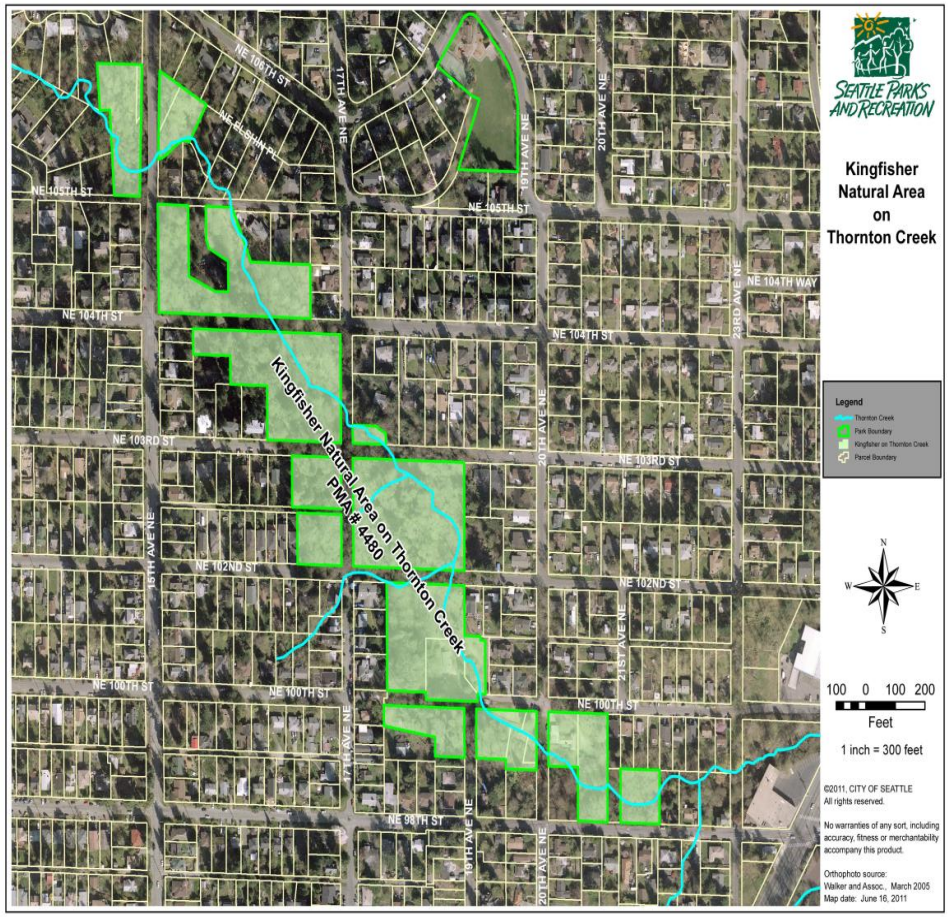


Figure 1.

Site Elevation Profile

Figure 2.

Goals and Objectives

The goal of this project is to improve environmental functions in Thornton Creek Watershed. We aim to do this by restoring the "Rossi" Wetlands to a more natural state following these goals and objectives:

- Goal: Improve pollutant filtering.
  - Objective: Create a meandering channel with a wide floodplain to increase filtration area.
- Goal: Minimize flooding.
  - Objective: Increase floodplain area in the Rossi Wetlands to reduce flooding in other areas of the stream.
- Goal: Reduce amount of suspended soils.
  - Objective: Develop a wide meandering channel to decrease flow rate and filter soils.
- Goal: Decrease water temperature.
  - Plant trees along the channel to create shade.
- Goal: Minimize erosion.
  - Plant native vegetation to improve soil cycling.
  - Decrease water turbidity by creating a benched wetland.

Functional Requirements and General Constraints for Restoration

Functional Requirements

Since this watershed does not provide essential environmental functions to the community of Seattle, areas within the watershed should be restored. To restore environmental function to the area, restoration projects should meet the following requirements:

- Encourage salmon habitat by connecting water passageways, creating meandering streams, and reducing soil sedimentation.
- Reconstruct destroyed wetland areas by installing appropriate vegetation, managing water flow and removing stoned channel.
- Build a community stewardship model based on volunteer ownership of restored areas by holding work parties and public meetings.

Constraints

- Urban Area – all actions require some form of prior approval or permission.
- Any construction must be within city ordinances.
- Maintain and monitor water quality and flooding.
- Limit erosion.

Brief Overview and Basic Approach

Brief Overview of Restoration Action:

- Expand and meander stream channel through the "Rossi" Wetland area.
- Restore historic wetland and floodplain features.
- Excavate side channels and detention ponds.
- Include fish friendly in-stream structures (weirs, woody debris, etc.).
- Improve riparian vegetation communities.
    - Remove invasive species.
    - Plant site-suited native riparian species

Basic Approach:

In order to combat the increased flow and turbidity associated with storm, or 'high-flow' events, we propose excavating side channels to serve as detention ponds. These detention ponds could serve in a similar fashion to bioswales; that is to absorb excess runoff and sediment, keeping it out of the stream. The stream channel, historic wetland features, and the stream's local floodplain should be expanded or leveled in order to prevent any down cutting of the stream. Fish friendly structures such as weirs or woody debris could be constructed in order to alter the stream morphology and create pool-riffle habitats.

'Easy to accomplish' restoration needs in the area vary between garbage and litter pickup, to invasives removal and native replanting (figure 4). Volunteers from the surrounding neighborhoods can easily conduct the majority of these restoration efforts. Currently restoration work parties are fairly common, typically occurring at least twice a month. Work parties should be held frequently and continually to remove litter, clear invasives, and to monitor/replant planted species.

Figure 4. Stream-side English Ivy (*Hedera helix*) removal by volunteers. Image from: http://victoryheights.org/wp/wp-content/uploads/2012/05/P5050346.jpg

Stewardship Plan

The goal of the stewardship plan is to enroll community members in taking ownership in the maintenance of the restored habitat by defining monitoring and maintenance methods. It is important that water quality and stream health are taken into consideration in this site. The monitoring of flood prevention and water flow requires the maintenance of constructed channels, floodplains, detention ponds, and culverts. Monitoring of reforestation should include maintaining invasive control and replanting die-off vegetation that functions as the canopy cover to suppress invasives and encourage low temperatures. Riparian plantings also need to be maintained in order to continue sediment control for the stream. The monitoring of salmon habitat requires water quality testing to catch problems and initiate maintenance, minimizing soil

nutrient leaching into streams. Monitoring the two adjacent slopes for stability, and consequently maintaining these slopes, is recommended (Southwick, no date).

Long-term Prospects

The end results we hope to achieve are the reestablishment of healthy riparian vegetation, restoring a more natural state in this segment of Thornton Creek, and eventually allowing this creek, as a whole, to mature into quality salmon habitat. The collaboration of an adequate and reliable volunteer base, frequent and continued work parties, and attention to detail in monitoring and maintenance activities, should resurrect once lost environmental functions.

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In Conclusion

Although each design within this compilation is unique, some patterns exist between all of our designs. The core design model included: removing invasive species, planting natives, replacing die off, and managing for invasive species. The main differences between each design came from the inherent differences in sites, and the differences in habitats the projects were to provide. Each project's needs imposed unique functional requirements and constraints that made them unique:

> In the Wiley Slough Saltwater Marsh design, the agricultural community was concerned about birds eating crops, hunters voiced their opinion about losing hunting grounds, and recreational users worried about losing the trail. In the Padilla Bay Agricultural Land and Estuary design, community naturalists supported the motion for converting farmland into an estuary. The Vernal Pool in Marcellus Shrub-Steppe Preserve design involved ranchers petitioning for cattle grazing land.
> .

In each design we attempted to accommodate the highest amount of stakeholders. Many comprises were necessary to achieve this goal.

We feel that using a basic Restoration Design outline may be successful, as long as the designer can become flexible. The designer must compromise with the stakeholders' interests, as must stakeholders compromise with each other; restoration is always a collaborative effort.

Epilogue

After taking a journey through our eight designs we would like to address the importance of interdependence. We hold the belief that Restoration Design can only be successfully designed and implemented as a collaborative effort. Each project's design, implementation, and continued success depend upon the cooperation of contributors of diverse disciplines; it is imperative designers also consider and incorporate community involvement within their design.

The Restoration Design, a process of engineering, depends upon the input from various disciplines. Restoration Design precedes the action of restoring, which is called Ecological Restoration; this practice is a process informed by Restoration Ecology, (a science). Restoration Ecology (a science), Restoration Design (a engineering process), and Ecological Restoration (the action of Restoration) all serve, inform, and exist for each other. The design, practice, and science of Restoration depend on interaction professionals from all of these fields.

For a project to function, it also needs input from professionals outside of these three fields such as land managers, project managers, and policy makers. Project managers ensure that the implementation of the project runs smoothly, by scheduling work and acquiring materials. Policy makers help facilitate action and inform designers with necessary considerations for designing, providing constraints and functional requirements.

Although professionals are key facilitators to restoration, one must not forget community; community involvement is vital to a project's success. Designers need clear objectives laid out before making decisions; without involving the project's stakeholders (the community), they cannot make informed decisions. If designers involve the community within stewardship models (which we highly recommend), they need to interact with, plan with, and train the community. In the field of Ecological Restoration, volunteer work is vital; most projects lack the funding to be completed without volunteer labor. Volunteer events are also a marvelous tool for increasing community interest and investment in restoration success. If designers, and implementers, fail to engage the projects community, volunteering (consequently the project) cannot exist.

We have tried to express these ideas within our designs, by actively using knowledge and research from engineers, scientists, and restorationists. We know that no single professional has the skills to singlehandedly design or implement a project; functional restoration needs the input of Engineers (designers), Scientists (ecologists), and Implementers (restorationists). We recognize that collaboration with professionals with experience based in project management, financial, or policy is also important to restoration success. Our designs attempt to incorporate community involvement, to ensure reception, and engagement from the community; we believe community is a keystone to the prolonged success of a project.

Appendix 1: The Assignments

Lab Design Assignment 1: Wiley Slough Saltwater Marsh

Overview

The Skagit Wildlife Area (Washington Department of Fish and Wildlife) includes areas that are diked and areas that are open to tidal action and river flows. Diking of Skagit Bay began with the construction of levees on individual farm plots in the 1870's. Dikes eventually became almost continuous, and today there are diking districts which are responsible for the maintenance of the levees.

Wiley Slough is located in the Headquarters Unit of the Wildlife Area. The Headquarters unit was purchased in 1948 for pheasant hunting. Apparently, as part of the management of the unit, 150-200 additional acres were diked in the 1960's and were converted from tidal marsh to drained land suitable for growing cereal grains for wildlife.

Tribes on the Skagit had been in an adversarial relationship with both the Diking Districts and with the Washington State Department of Fish and Wildlife for some time because of obstruction of salmon runs and diminution of potential salmon habitat. WDFW has recently agreed to increase their emphasis on salmon habitat restoration, and funding has been made available by the Salmon Recovery Funding Board and by Seattle City Light. A design team made up of representatives of the tribes (Skagit River System Cooperative) and WDFW prepared the "Wiley Slough Estuarine Restoration Design Report".

The Wiley Slough project proposes to convert the land diked in the 1960's back to open tidal influence. To accomplish this, the existing levee will be breached and a new levee will be created at the upland edge of the area. Tidal gates that keep salt water out of Wiley Slough will be removed from their current location and new gates will be built upstream.

There has been a philosophical difference within the WDFW about converting waterfowl habitat to salmon habitat. The feeling is that ducks and geese are well-served by the existing configuration of the wildlife area, which serves waterfowl, hunters and recreational users. The manager feels that the Skagit Wildlife Area is operated as a classic wildlife management operation as proposed and articulated by Aldo Leopold. Leopold wrote the book "Game Management" (1933), and is also considered to be one of the founding fathers of ecological restoration. Converting from management for ducks to management for fish is causing a great deal of angst among the on-the-ground managers in WDFW.

Assignment

There is a plan for the conversion of the diked grain fields to estuarine marsh, open to tidal action. The outline of the plan is available online in the "Wiley Slough Estuarine Restoration Design Report", WDFW. A good summary of the proposed project is available in the "Wiley Slough Restoration Project, Report to the 2008 Legislature", which is available on your class Catalyst website in the section for Design Assignments.

For the purposes of this class exercise, assume that the project budget has been cut in half because of the State's current and anticipated budget shortfall. Because of certain unavoidable constant costs in the project, this means that of the originally proposed project only about one third of the amount of dike can be removed and/or built and only one third of the area can be restored at this time, with the State's ability to restore other parts to be reviewed at some time in the future.

Look at the resources made available to you in class, on the class website, and at the links mentioned in this assignment sheet. Find other sources of information if you can.

To help you evaluate alternatives, use the Design Element Checklist that has been handed out in class. You must **decide which part of the project should be done**. Support this decision with documentable reasons (cite materials presented in class, suggested below or discovered through your own literature research) why you have selected the area you have selected. Part of this documentation should be a **completed Design Element Checklist** for the area you have chosen.

A major part of this project is the removal and reinforcement of dikes. Material from removed dikes can be used to replace or reinforce other dikes on a 1:1 ratio. An exception is the east-west dike which runs from the new tide gate location to the western tip of the property. Because the current land is not diked, spoil material from removed dikes will need to be added to the new dike at this location in a 2:1 ratio (twenty linear feet of dike removed somewhere else can be used to build ten feet of dike here). Your rationale for the selection of the area to restore **must include an accounting of how you intend to balance out cut and fill of dike material.**

Be aware that WDFW has contracted with some farmers outside of the Skagit Wildlife Area to allow land to lie fallow during the winter to create forage for waterfowl. WDFW has also participated in the purchase of land near Padilla Bay to help mitigate for the loss of recreational opportunities that will no longer exist at the Headquarters Unit.

Your completed assignment must include a map of the site, showing the area to be restored, amenities to be preserved or created, dikes to be removed or added, and potential second and third stages of the restoration to be done later. You should also include a list of potential pitfalls and a discussion of how they should be avoided.

Lab Design Assignment 2: Transportation Corridor

Overview

The Bonneville Power Administration proposed to build a transmission line project that would bring additional lines from the Grand Coulee Dam to a point near Kangley, Washington. All of the proposed alternatives would cross the Cedar River near an existing BPA right-of-way through the Cedar River Watershed. Some of the alternatives would have created new corridors, but the chosen route simply expands an existing corridor by 150 feet. "Clearing all of the tall-growing vegetation within the ROW will be required…" "Tall trees outside of the ROW that could fall and damage the line would be removed".

The route has been selected to 1) maintain environmental quality, 2) minimize impacts to the human environment, and 3) minimize costs to ratepayers. Five miles of the route will go through the Cedar River Watershed. In return for the use of the Watershed land, BPA will transfer ownership of 600 acres of land to the Watershed, protected under a conservation easement to improve water quality and habitat. An additional 500 acres of adjacent BPA land will be placed in a conservation easement. BPA has also agreed to no future expansions into the Watershed.

BPA has agreed to minimize disturbance during construction, eliminate clearing within the riparian corridor, use helicopters for tower construction (except for pieces which are too heavy), and use minimal clearing outside the ROW in the Watershed (taking only trees that can fall onto the lines). In the Watershed, logs will be removed by helicopter north of the Cedar River.

BPA will allow low to medium tall vegetation in the ROW. Tall vegetation will be removed on a rotation plan so that more tall trees stay in the corridor for a longer time. BPA will suppress non-native plants, plant native vegetation in areas disturbed for the new ROW, and herbicides will not be used in the Watershed. For habitat, Large Woody Debris (LWD) will be left and snags created. Remnant old growth trees, snags, and trees of 20" diameter or greater will be retained if they do not pose a safety hazard to the operation of the line. A minimum of two large downed logs per acre will be retained within the ROW. Seasonal wildlife use (fish, eagles) will be noted and accommodated. Wetlands will not be filled.

Assignment

The City of Seattle operates the Cedar River Watershed with a primary focus on the production of clean dependable drinking water for Seattle and other municipalities. The transmission corridor crosses the Watershed below the intake for municipal water; there is, however, a Habitat Conservation Plan that requires consideration of impacts on wildlife and fish (including salmon runs that have access to the reach where the transmission corridor crosses the Cedar River). There are also recreational and education uses of the Watershed. Logging has been carried on until very recently in the Watershed, especially at higher elevations. The City took ownership of Forest Service parcels in 1996 and in 2000 the HCP established the entire watershed as a no-logging reserve.

The City has called for proposals for the restoration of the newly disturbed transmission corridors by placing a Request for Proposals in the Seattle Daily Journal of Commerce (in the Construction section, under Bid Calls or RFP's). Your group answers this request; you must provide typical solutions for the restoration of the Right-of-Way. The ROW is five miles long through the Watershed, so you must provide text and illustrations that show the City what you propose to do in the in uplands, wetlands, riparian zone, river crossing and how you treat snags, large woody debris, and large trees.

This project has a continuing element. A transmission corridor must have vegetation that does not reach the powerlines, but trees grow persistently. Prepare a monitoring and maintenance schedule that prescribes actions that keep the trees lower than the conductors, while maintaining some of the mature growth characteristics that were incorporated in the original design. (This should include LWD, snags, habitat diversity, wildlife or legacy trees if possible).

Lab Design Assignment 3: E-5 Parking Lot Freshwater Marsh

Overview

The proposed reconstruction of the SR 520 Evergreen Point Floating Bridge will involve the destruction and disturbance of a number of acres of wetland including parts of Marsh Island and Foster Island in Union Bay. WashDOT is looking for sites near the route where compensatory mitigation can be performed, and where similar kinds of wetlands (freshwater, fringe lacustrine) can be created, restored or enhanced. A multiplier has been applied to the acreage that is to be lost, and WashDOT is proposing to use about 28 acres of the Union Bay Natural Area to obtain mitigation credits. In total they need to find 56 acres along the shore of Lake Washington for mitigation. WashDOT requested UW Botanic Gardens to identify areas within the boundaries of UBNA where mitigation might be performed. Looking at areas either adjacent to the Lake or along University Slough where the creation of lakeside wetlands might be accomplished without damaging existing wetland or upland restoration projects, UWBG staff and WashDOT agreed on a general scheme for the restoration. WashDOT has created a team to assess the potential for using UBNA for mitigation. To create wetlands on UBNA, there are two potential strategies: 1. with a large enough watershed, a depression or low dam would hold water seasonally, as occurs in Shovelers Pond, or, 2. excavation would have to occur to take the surface of the site down to lake level. The second alternative would be an expensive kind of restoration because UBNA is located atop the former Montlake Landfill, and to lower existing grades to an elevation where they would function as wetlands, both the landfill cap and some fill material potentially would have to be removed. Then a new cap would need

to be installed, and contouring and vegetation installation would have to take place in that material. The excavated fill material would have to be taken to a hazardous waste disposal site, and the cost would be significant.
A possible way around excavating into actual landfill material is available because the landfill cap is exceptionally thick in several places. Parking lot E-5 is a gravel parking lot that has been maintained since 1970 by bringing in gravel to level it when it subsided. It is estimated that 10-20' of gravel are under the surface of E-5. Canal road and University Slough are built atop a cap of rock, soil and construction debris. The cross-section of this fill is 200' wide and from 15 to 40 feet deep. Excavation into either of these areas could be accomplished without encountering garbage or other wastes that would have to be taken to a special landfill.

A lakeside wetland would need to have areas of shallow standing water, and transitional zones where the land would be flooded part of the year and emergent part of the year. This would allow open water to enter the wetlands, and would provide a place for emergent wetland vegetation to be established in shallow water or in saturated soil. Adjacent to the emergent vegetation, slightly higher ground would support shrubs and small trees that are commonly found around the edge of and within a few feet of wetlands (*Lonicera involucrata, Rhamnus purshiana, Crataegus douglasii, Pyrus fusca*, etc.).
An additional restoration alternative, preferred by some birders, would be to create mudflats that would be able to support migratory shorebirds as they are on their summer migration (which actually starts here in early spring). Such mudflats would need to be out of the water but muddy during the right time of the year for bird use. Designing fringing wetlands or mudflats at this site is complicated by the fact that the level of Lake Washington and Union Bay is artificially controlled by the dam at the Hiram Chittendon Locks in Ballard. In winter, the lake level is lowered to an elevation of about 20'. In summer it is raised to 22' (Δ = 2') (http://www.nwd-wc.usace.army.mil/nws/hh/basins/lwscsh.html .) Locally this is described as "reverse hydrology", because wetlands and lakes in this region normally have more water in winter and less in summer. The current elevation may be found at (http://www.nwd-wc.usace.army.mil/nws/hh/basins/data.html?lkw+bths.) In addition, the University uses a different elevation datum, so the University digital maps will show the water fluctuating between an elevation of 16.5' and 18.5' (Δ = 2').
($h_{army} = h_{uw} + 3.5'$)
Union Bay Natural Area and Shoreline Management Guidelines, 2010
The management guidelines for the Union Bay Natural Area have been revised, and are available on the University of Washington Botanical Garden website http://depts.washington.edu/uwbg/research/ubna.shtml. The guidelines are intended to update a previous document, the "Management Plan for the Union Bay Shoreline and Natural Areas" published in 1994, and a second edition published without appendices in 1995 (known as the pink report). A copy of the 1995 document may be found on the Design Assignments page of the class workspace under "Pink Report".

Assignment
Develop a preliminary restoration design for creating new wetlands in UBNA. Be sure you understand the general problem or opportunity and can express the design problem using the idea/terminology of "Functional Requirements" and "Constraints". Identify at least five stakeholders or stakeholder groups.

The eight tasks below are intended to help you arrive at a recommended preliminary design that will meet the overall functional requirements and constraints that you have identified.

1. Outline the location of areas along Lake Washington or the University Slough where a thick cap would allow excavation that would not unearth garbage.

2. By looking at contours and drainage areas, suggest a site that would be a good location for an impoundment (in an excavation or behind a dike).

3. Keeping the two assignments above in mind, locate areas of UBNA (as shown on the WashDOT conceptual plan) that are suitable for conversion to lakeside wetland, seasonal wetland or mudflat, and will not damage any of the existing restoration projects in UBNA.

4. Combine or connect the winter flooding of the upland wetlands with the summer flooding of the lakeside wetlands to maximize the annual area of flooding. (We suggest that you run water off of UBNA, into winter wetlands, and out into the Lake through the lower elevation summer wetlands.) You could use weirs, low dams, leaky berms, benches or other mechanisms to retain water draining off of the uplands, while spreading out the water to maximize the impact of either winter or summer flooding.

5. Using contour maps for the area, draw a profile view of a line that flows from the uplands, into the seasonal wetlands you design, into the summer wetlands you design, and then into the slough. The profile should show elevations before and after your modification of the site to create impoundments and channels.

6. Along this profile, draw cross-sections where it is important to show features that you want to incorporate into your design.

For your planting design:
7. On a plan view (this is a view from above) show general areas of vegetation (called polygons).

8. For each polygon list 4 to 5 plants you would like to establish there. Use the flooding preferences shown in the tables from Stevens and Vanbianchi's book on wetland restoration. You might have one polygon for a shrub buffer, another for emergent wetland plants, another for summer dry wetlands, etc.

Lab Design Assignment 4: Vernal Pool in Marcellus Shrub-Steppe Preserve

Overview

The Nature Conservancy (http://www.nature.org/wherewework/northamerica/states/washington/) and the DNR both own land that is part of the Marcellus Shrub-Steppe Preserve (47°14'N, 118°24'W; T20N, R35E), about seven miles north of Ritzville, Washington. The DNR land is to the west of TNC land, separated by a gravel road. TNC land has been fenced since 1986 and degradation by grazing prior to fencing is not noticeable. The DNR land is currently grazed in spring and summer months. The dominant plant communities are *Artemisia tridentata/Festuca idahoensis* sagebrush and *Artemisia tripartita/Festuca idahoensis* sagebrush. At the north end of the DNR parcel are large areas without sagebrush but with *Bromus mollis* and *B. tectorum*.

Vernal pools are scattered among both sites. The Washington Natural Heritage Program has designated them for Priority 2 Protection status, due to their having rare or highly threatened species or having intermediate rarity and threat but little representation in the DNR Natural Area Preserve system. Vernal pools have water in them only part of the year and so are characterized by perennials in the deeper parts and annuals in the shallow areas. There are aquatics and plants that flourish as the pools dry. Vernal pools have their share of rare species of vascular plants, but also have cyanobacteria, bryophytes, and lichens forming crusts. Vegetation zonation is common and often striking. The lower zones may have conditions that are more saline and alkaline.

The Nature Conservancy has developed guidelines for the management of vernal ponds. Studies have found that grazed ponds at the Marcellus preserve have more weeds, and may have fewer rare species than ungrazed ponds. Removal of grazing is an obvious first step in the management of such sites.

Assignment

The DNR and TNC have reached an agreement on the management of the Marcellus site; TNC will manage it. The DNR portion now has more weedy species and fewer native species in both the sagebrush and vernal pool communities. Develop and propose a goal for the entire combined site.

There are biological reasons to restrict cattle from unique communities, wetlands, and sites that support endangered species of any kind. There are political reasons to allow the continued, if limited use of sites by cattle. Devise a way to evaluate the level of potential threat from grazing at this site. Delineate the site in terms of sensitivity and resilience to grazing pressure. Create a set of rules to govern grazing practice there. Delineate the sagebrush communities and separate them from the vernal pool communities. Develop plans to manage the invasive species in both.

The *Artemisia tridentata* (big sagebrush)/fescue and *Artemisia tripartita* (three-tip sagebrush) /fescue communities are both considered to be high quality examples of their type, even though the preserve is surrounded by wheat fields. The vernal pool communities, though they contain some weedy species, still have an excellent representation of vernal pool species. Develop separate vegetation management and development plans for the sagebrush and the pool communities. These plans should include your plans for augmenting or increasing the presence of native plants. Remember, the vernal pools have both annual species and perennial species, and these should be handled differently. How would you obtain plant material, increase it, plant it, and manage its growth?

There are 45 vernal pools on this site, combining the DNR and TNC land. Create a schedule on a calendar for the restoration of the pools. Which pools would you start with? When would you start? What would you have to accomplish first? What would be your first on-the-ground restoration steps? What would be your restoration activities in the first year in which you actually do site modification, conditioning or installation? We are currently approaching the first week of May 2012; be sure your calendar/schedule accurately and realistically reflects this. How much could you get done in a year? What resources would you require? How many people would you require, for how many days, and when? (This is asking for a pretty thorough discussion of what you will do the first year.)

Lab Design Assignment 5: Padilla Bay Padilla Bay Agricultural Land and Estuary

Overview

When the Wiley Slough project in the Skagit Wildlife Area was about to be built, an interest group approached the legislature and got the funding blocked. Their argument was that because of the project there would be lost recreation opportunities, and the kind of habitat that was being lost could only be replaced by converting working agricultural land back to waterfowl habitat. The purchase of land to the north on Padilla Bay was thought to be a partial solution to mitigate this loss, and the Washington Department of Fish and Wildlife (WDFW) and the Washington Department of Ecology (WDOE) were able to negotiate purchases from private land owners sufficient to put together a 340 acre parcel. The agricultural community, however, again took exception to the idea of taking agricultural land and placing it in State ownership and restoring it. A summary report, outlining alternatives, was prepared with input from farming, hunting, diking and environmental interests.

The land in question is within dikes and lies along Padilla Bay. A popular recreational trail atop the dike attracts hikers, bikers and birders. The Washington Department of Fish and Wildlife (WDFW) owns most of the land, and the Washington Department of Ecology (WDOE) owns about 90 acres. All of Padilla Bay falls within the Padilla Bay National Estuarine Research Reserve System (NERRS), and is managed jointly by NOAA and by WDOE; the Reserve has a visitor's center located just north of the newly purchased land. In the early 1990's, the NERR purchased one hundred acres of farmland within the 340 acres currently being considered for restoration. They have operated part of it as a Demonstration farm and have done research on salinity and pesticide residuals on the farm. Apparently ownership of the land upon which the Padilla Demonstration Farm sits has passed to WDFW and WDOE, and it is now operated as the Washington Department of Ecology Demonstration Farm.

Parts of Big Indian Slough, Little Indian Slough and No Name Slough are within the 340 acres that were proposed for restoration. Indian Slough runs north from State Highway 20 to where it empties into Padilla Bay. Much of its course roughly parallels and is about 2000' west of Bayview-Edison Road. It has been cut off from most of its freshwater input, and so is quite salty (15-20 ppt) on the bay side of the tide gates where it crosses under Bayview-Edison Road and near State Highway 20. No Name Slough, on the other hand, drains a substantial watershed in the uplands to the east of the Padilla Bay flats.

Indian Slough and No Name Slough are contained within levees for most of their lower reaches. There is very little native vegetation along their banks, and tree cover is limited to some shrubby species growing along the drainage ditches outside the levees. Land along the sloughs is agricultural, and was formed by diking out Padilla Bay. There are areas where the agricultural land protected by the dikes is obviously lower than the adjacent slough and its floodplain outside of the dikes. If the dikes were breached, most of the current agricultural land would be too low to support emergent saltmarsh vegetation; a fringe of land along Bayview–Edison road would be high enough to support emergents.

Current vegetation in the Slough is characterized by *Salicornia* (pickleweed), *Distichlis* (saltgrass), *Atriplex* (shadscale) and other species tolerant of saline environments. Quite a bit of *Zostera* (eelgrass) wrack washes into the Slough from Padilla Bay. There is invasive *Spartina* (saltmarsh cordgrass) in Padilla Bay near the mouth of Indian Slough, but it has been subjected to a vigorous eradication program.

A**ssignment**

A consortium of Federal and State agencies wants you to help them decide how to manage or restore 340 acres of diked farm land. You must make a decision about what mix of uses you will propose to WDOE, WDFW, and the Padilla Bay NERR, the **Problem Owners** for this project. **Stakeholders** have proposed that restoration, production agriculture, migratory waterfowl habitat, bird-watching, recreational walking, and education are uses that should be considered. In addition, the diking district must protect adjacent low-lying lands from flooding. Use the Design Element Checklist to evaluate ecosystem services when developing your proposal.

Three action alternatives have been proposed by the stakeholder committee. One alternative proposes that almost the entire site be converted to tidal marsh. A second alternative proposes that farming and flooding for freshwater wetland habitat be practiced in cells of 50+ acres each. A third alternative looks like a hybrid of the first two. In the end, any decision that allocates any uses to the 340 acres will result in some unhappy and vocal stakeholders. You should back up whatever you propose by showing why your chosen action alternative is superior to the other two and to the no-action alternative.

You must give your clients compelling reasons for accepting your proposal. Your solutions may be the best, or most economical, or provide the biggest bang for their buck. Areas proposed for restoration may be the most damaged and needing repair, or the key to the success of the greater project, or the first step, or whatever you think is a good argument to support your choice as to what they should spend their money on.

Three hundred forty acres is a large piece of land. How would you propose to phase the restoration or other management uses of your parcel or parcels? What would be the first step, what would be the second step, etc.? What is your timeline; how long would the total project take? How many individual restoration steps would it require? (A step might be all of the restoration that you think you could accomplish in one year.)

Take one project (that would be installed in a single growing season), and apply the design framework we have discussed. What kind of site modification and conditioning might be required? What plants would be specified and how would the installation be scripted? What management program should be put into effect?

What would be a reasonable goal (of the clients) for the project? How would you translate the goal as functional requirements? What constraints would you need to consider? What are some design parameters that might be developed in order to meet the functional requirements of the project?

Some options (examples):

1. Connect headwaters of Little Indian Slough, Big Indian Slough or No Name Slough with the forested watershed to the east.
2. Breach a dike at lower end of Indian or No Name Slough and create a salt marsh.
3. Continue to operate the farmland, but as "green" farms.
4. Focus on riparian corridors.
5. Create saltwater excluders (weirs) in the upper reaches of the sloughs.
6. Expand on the proposals from the No Name Slough improvement study.

Specifically, you need to…

1. Consider all of the elements on your Design Element Checklist.
2. Clearly describe at least three alternatives (not including the "do nothing" alternative) for the entire 340 acre site.
3. Develop a decision making framework (we suggest using a decision matrix like we will discuss in class) and use it to recommend a preferred choice from among the alternatives you have described. You might have to anticipate results from research that is needed to fully implement your decision making scheme. Be very clear where you are anticipating research results – justify your estimations or predictions.
4. Very clearly (in detail) describe your recommended alternative.
    a. What the area will be like once it is restored.
    b. How you intend to restore / manage it.
5. Use Project Planning tools:
    a. Make a list of restoration tasks.
    b. Sequence them (which need to occur before subsequent tasks can be started).
    c. Estimate task durations.
    d. Draw a network diagram.
    e. Prepare a project schedule for the first year's activities.

Lab Design Assignment 6: Nisqually River Gravel Pit

Overview

Tacoma Power is part of Tacoma Public Utilities. It provides power to the City of Tacoma and operates hydroelectric power generation dams. One set of dam projects is called the Nisqually River Projects. Included in this set of projects are the Alder and LaGrande dams on the Nisqually River. As part of the relicensing of the Nisqually River Projects, Tacoma Power agreed to provide a number of environmental functions including elk habitat, riparian habitat, wetlands and gravel pit reclamation. The gravel pit project is an inactive 5 acre open pit on the south side of the Nisqually River directly south of Ashford, Washington (46^{o} 44'30"N 122^{o}0'51"W).

Restoration has been done at the site to meet the permitting requirements. Because it is a gravel pit, the site contains residual gravel and sand that was not mined out. The original gravel deposit was created some time in the past as the Nisqually River moved across the valley bottom and left coarse-graded depositional material in a complex pattern. This makes the site very quick-draining. Currently it is too high to be flooded by the river with any regularity. Plants grown on this kind of substrate would experience very dry or droughty conditions. There are, however, some depressions where water stands.

Gravel pits are strip mines that are generally abandoned when they either play out or when the project they were used for is completed. In order to be restored, they need some kind of soil importation, because the overburden containing the original topsoil is gone. On this particular site, because the owner is the City of Tacoma, TAGRO (the commercial name of the composted solids resulting from Tacoma's municipal wastewater treatment processing) was proposed and used to recreate topsoil. Re-contouring of part of the pit was also done to intercept some of the shallow groundwater flowing from the slope into which the gravel pit was excavated. Since the site is near recent clear-cuts , and because Tacoma Power will be doing some construction that will create salvageable plants, much plant material and even sod will be available for transplantation.

Assignment

Reconsider the work that was done on this site by the capstone class in 2002-2003.

The City of Tacoma, Tacoma Power, is required by the terms of the re-licensing agreement for the Nisqually River Project to manage their holdings along the Nisqually River to provide environmental services. Re-design this project for them. The power business is big business, so you will have the full resources of Tacoma Power behind you to accomplish novel and creative environmental goals.

There are a number of stakeholders who can apply very strong constraints on, and requirements of, Tacoma Power. Consider them in your design. Alder Dam inundated more than seven miles of riparian habitat when it was built. Consider replacing some of the services lost in that habitat was destroyed. The Nisqually Tribe is concerned about the Nisqually as a salmon stream. Is there anything that you can do in this reach, and with this project, to improve salmon habitat? Consider it, but if it is not feasible to design for salmon habitat, determine that. The National Hydropower Association website indicates that in this completed project, elk habitat was provided, wetlands were restored, riparian habitat was improved. Create a design to meet those goals.

The site is currently a gravel pit, so there are probably a few bulldozers available if you should want to re-contour the site.

Consider the City of Tacoma's decision to use TAGRO liberally to restore the site. Are there other materials that might be more appropriate, considering the close proximity of a salmon-bearing stream and the potential concentrations of undesirable compounds in TAGRO?

Estimate the quantity of TAGRO or other material that would be needed for the site. Devise a plan for stockpiling and distributing TAGRO across the site and estimate (calculate) how many worker-days would be required to spread it (include time for each trip, volume carried each trip, total volume of TAGRO, etc). Show the results for manual (example – wheelbarrow) and low intensity power equipment (example – "four wheeler" or "Quad" ATV with a trailer).

Determine what the native vegetation should be at this site. Part of the site could be coniferous forest. Part could be riparian forest. Part could be a grassland or sedge meadow for elk habitat. Select at least five species to fill each one of these groups. Determine where you would you get them and how you would you plant them.

Estimate how many worker-days (use an approach that similar to your approach for estimating time requirements for spreading soil, mulch or other material over the site but remember that you have to distribute the plants and also plant them).

Once you have selected your plant material, create a calendar to indicate when your planting window is for each species and form that you select (seed, bare root, container plants, transplants, sod, etc.).
Create a plan view (and any necessary cross-sections) of the 5 acre site to show what you have done to improve environmental services. Show planting zones, re-grading, wetlands, standing water, etc. to characterize the newly restored site.
Checklist:

- ☐ Riparian habitat
- ☐ Salmon habitat
- ☐ Elk habitat
- ☐ Wetlands
- ☐ Re-contour
- ☐ TAGRO? Alternative?
- ☐ Coniferous forest vegetation
- ☐ Riparian vegetation
- ☐ Grassland or sedge meadow vegetation
- ☐ Plant sources
- ☐ Installation methods?
- ☐ Labor (worker-hour or worker-day) requirements
- ☐ Project calendar

Lab Design Assignment 7: North Cascade Subalpine Trail

Overview

Cascade Pass was one of the earliest heavily-used passages across the Cascade mountain range. At 1641 meters, it is along a route from the Stehekin River watershed (Lake Chelan) into the upper part of the Skagit River watershed. Native Americans used it, and when settlers came they used it as well. It became part of the Mount Baker Snoqualmie National Forest and was used for overnight camping starting in the 1920's. North Cascades National Park (NOCA) came into being in 1968; Cascade Pass, now part of NOCA, was eventually closed to overnight camping but is still a popular day hike and is the access route to many backpacking trips.
Recreational use has caused extensive impacts to subalpine vegetation communities and soils. Both trampling and camping cause impacts such as reduced vegetation cover, reduced species diversity, changes in species composition, soil compaction and soil loss. These impacts further impair soil conditions and processes so that natural re-colonization by plants is extremely slow. The vegetation is dominated by woody *Phyllodoce* and *Vaccinium*, a community type that is made up of species that are neither tolerant of trampling impacts, nor particularly resilient. The Pass has heavy snow pack, which creates a short 10-12 week growing season, further limiting regrowth.
A study done in 1970 found that there were 48 campsites and connecting trails within a 12 ha area. They had compacted, bare soil. As a consequence of this study, the park superintendant closed all camping and initiated a research and restoration program with the intention of finding out how to repair the damage, and then to repair it. Management recommendations included a call to actively revegetate the site using locally collected seed of plant species resistant to trampling (and likely to establish from seed). A 1979 revegetation study for the district emphasized the use of on-site transplants, as the technique had been very successful at lower elevations. Another study found, as others have, that aspect (the direction the slope faces) was a very important control on seeding success.
Ramsay in 2004 sowed seed of sedges, rushes, grasses and a common subalpine forb, *Polygonum bistortoides*. He prepared compacted sites by scarifying to 15 cm. Following seeding, sites were covered with excelsior mats. Treatments included weed-free soil, peat, and watering, in various combinations. A number of plots were left un-amended and un-seeded as a control.
Germination rates were low (14%). Highest germination was in plots that had the best soil moisture. It was found that there was a threshold of dryness that killed seedlings, and the treatments that avoided this threshold, such as adding peat or frequent watering, showed the best revegetation success. Soil-added treatments without watering were worse than no treatment.

Assignment

Cascade Pass has not changed much since it was closed to camping in 1972. It is still shot through with a system of trails and denuded tent sites, even though it has been closed to camping for almost 40 years. The Pass is accessible by driving up the Cascade River road 37 km (23 mi) from Marblemount on the Skagit River. A forest road takes you to a trailhead, and then a trail to the pass takes you 6 km (3.7 mi) along a path that gains 550 m (1804 ft) of elevation. Any plants, seed, soil, amendments, geotextiles, excelsior mats, water, tools, or anything else probably goes up on your back. The site is also within a wilderness area, and so any actions taken must comply with provisions of the Wilderness Act.
The Superintendant of the park has decided that the area needs to be restored. There is Congressional funding for a contractor-provided project, and there is a provision for ongoing monitoring and maintenance within that funding package. Because the site is located in the Stephen Mather Wilderness Area, you will be limited to a maximum of 5 total employees on site, but you may solicit and use volunteer labor on an approval-for-each-event basis.
This is a simple ecosystem that does not have much of a successional pathway. But it is in a stressful, disturbance-prone location with access problems and a short growing season. You need to deal with stopping the disturbance while allowing continued transit through the site by hikers.
The goal is to restore the site. **List** what you think **the most important functional requirements** would be. **What are the major constraints?** The location is interesting because you do not know exactly when the snow cover will melt away in the spring, and you are out of business after it snows in the fall. So you need to create a schedule that minimizes the likelihood that you will not accomplish your work. **List your tasks.**

Determine precedence (which must come before others, which must come after). **Estimate time** to perform each task. **Create a flowchart** that allows you to visualize which tasks logically group together, and allows you to see where interim deadlines need to be set. Because there are 48 campsites, you will probably restore only part of them during the first growing season, with others restored in subsequent seasons. **Draw a sketch** of the network of sites, and **designate** which sites you will do the first season, which the second, etc. **Tell why** you have chosen the sequencing you are describing. Use the task list to **prepare a budget** for the first year of the restoration project. Make defensible estimates of quantities and worker productivity. Make appropriate assumptions about labor rates, benefits, profit and risk, etc.

Checklist: In this project you will deal with trying to get plants to grow in small compacted campsites and along trails. Assume that the campsites are 5 ft by 10 ft, and that the impacted trails are 1.5 ft wide. In addition to the items specified in the preceding paragraph:

- ☐ Sketch a cross-section of a trail, and detail the soil treatments, mulch, excelsior mats, width of treatment, anchoring techniques.
- ☐ Prepare a similar sketch for a campsite.
- ☐ Provide specific answers to the following questions:
  - ☐ What plants will you use?
  - ☐ What forms (seed, container plants, etc.) will you install?
  - ☐ What densities will you specify?
  - ☐ Where will you get the plants or seeds?
  - ☐ Exactly how will you treat the sites (scarification, mulch, soil),
  - ☐ How will you plant,
  - ☐ When will you plant,
  - ☐ How will you leave the site (mulch, mat, bare)?
  - ☐ Will you water, fertilize?
  - ☐ What is the total area you will restore? Year one area?
  - ☐ Given this, how many total plants or seeds will you use? Year one plants and seed?
  - ☐ What will you do to control human re-entry after you have installed the restoration features?
  - ☐ Where will you keep materials and equipment?
  - ☐ What about water for the plants?
  - ☐ Where will people working on the restoration stay?
  - ☐ What decisions have you made to lighten your load as you hike up the trail again and again?
- ☐ Develop a plan for transporting and managing all equipment, materials and supplies to be used for the project. The plan should identify several options for storage, transportation, and loss prevention. It should justify the selected approach – a decision matrix would be an excellent way to do this.
- ☐ Propose a schedule and a budget for the first year's work.

Lab Design Assignment 8: Thornton Creek Urban Trail

Overview

Thornton Creek is an urban creek in Seattle. It drains the largest watershed of any Seattle Creek (12 sq mi). It includes 18 miles of creeks and tributaries (15 numbered and named channels and tributaries).

The Thornton Creek Alliance began creek restoration efforts in the 1990's. Over time, small projects have had an incremental effect. Salmon have moved back into the system as far north as Twin Ponds, at 155th St. NE, next to I-5. Seattle Public Utilities and the City of Shoreline continue to support the restoration of sections of the creek system. The re-development of the creek segment that was buried under the south parking lot of the Northgate Mall has recently been completed.

Assignment

On a map, identify all of the restoration projects that have been completed or are in the planning stage, any place along Thornton Creek.

Propose four new sites, or sites that would be modifications or re-working of existing restoration projects, and rank them according to your criteria. State the criteria (they could include potential size of restored parcels, environmental value, cost, closeness to completed restoration projects, etc.). The sites may be in-stream, lake or pond, riparian vegetation, connection corridor, adjacent forested watershed, or whatever else you perceive as providing an important improvement in the environmental functions provided for and by Thornton Creek.

List the constraints that would need to be considered at any of the four sites.

Make a simple plan and profile of your number one site to show what you would propose to do to restore it.

Appendix 2: The Authors

Kat Asselin

In 2012, Kat received her Masters of Environmental Horticulture accompanied by Permaculture Design and Restoration Ecology Certificates. Her interests include apiculture, agroforestry, and triple bottom line business models.

Kat Asselin's Contribution to Assignments and Final Project

Project 1 – Wiley Slough
Wrote Identification of Need, Constraints & Remediation, Problem Framing, and Stakeholders.

Project 2 – Corridor
Wrote Materials and Installation, Identification of Need, Stakeholders, Problem Framing, and Constraints.

Project 3 – UBNA E5
Wrote Identification of Need, Stakeholders, Constraints, Predictable Level of Repair.

Project 4 – Vernal Pools
Wrote Identification of Need, and Stakeholders. Editing.

Project 5 – Padilla Bay
Wrote Environmental Functions, Stakeholders, Editing.

Project 6 – Gravel Pit
Wrote Stakeholders. Editing.

Project 7 – Subalpine
Wrote Site history, Goals & Objectives, Transportation & Delivery, Labor & Financial Budget.

Project 8 – Thornton Creek
Wrote Constraints and Stewardship.

Final Compilation
Editing: Wiley Slough, Corridor, E5, Padilla Bay, Vernal Pools. Wrote final Bibliography and Table of Contents

Justin Bettis

Justin Bettis is an undergraduate student majoring in Environmental Science and Resource Management with a focus in Restoration Ecology and Environmental Horticulture. His interests include Ecological Restoration and Plant Production. He enjoys volunteering his time at Union Bay Natural Area doing restoration and assisting in research with the threatened plant Golden Paintbrush (*Castilleja levisecta)*. Hobbies to note include music, gardening, and snow sports. University of Washington: School of Environmental and Forest Sciences

Justin Bettis' Contribution to Assignments and Final Project

Project 1 – Wiley Slough
Wrote Goals & Objectives, Basic Approach, Site Analysis, and Environmental Functions.

Project 2 – Corridor
Wrote Implementation, Predictable level of Repair, Implications of Desired Results, Maintenance.

Project 3 – UBNA E5
Wrote Site Description, Goals and Objectives, Basic Approach, design requirements and Timeline.

Project 4 – Vernal Pools
Wrote Tasks, Maintenance, Long-term Prospects, and Predictable Level of Repair.

Project 5 – Padilla Bay
Created decision matrix, Ghant Chart, Network Diagram, Implementation and Description of Chosen Alternative.

Project 6 – Gravel Pit
Wrote Decision Making Framework, Ghant chart, Tasks. Editing.

Project 7 – Subalpine
Wrote Tasks and Maintenance. Made Ghant chart. Editing.

Project 8 – Thornton Creek
Wrote Decision Framework and Tasks & Basic Approach. Editing.

Final Compilation
Edited: Gravel Pit, Subalpine, Thornton Creek. Wrote Preface and Epilog.

Shantel Gnewuch

Shantel Gnewuch is an undergraduate majoring in Biology and minoring in Chemistry and Environmental Sciences and Resource Management. Her interests include ecology and evolution, especially regarding animal conservation, management, community and behavioral ecology, reproductive strategies, selection, and competition.

Shantel Gnewuch's Contribution to Assignments and Final Project

Project 1 – Wiley Slough
Wrote Site Description, Impacts of Historical Ecosystem, Long-term Prospects, and created Timeline.

Project 2 – Corridor
Wrote Long-term Prospects, Site Analysis, Environmental Functions, Design Requirements, and Design Perimeters.

Project 3 – UBNA E5
Wrote Environmental Functions, Impacts of Historical Ecosystem, Design Perimeters, Implications of Desired Results, and Maintenance.

Project 4 – Vernal Pools
Wrote Site Description, Site History, Goals & Objectives, Design Perimeters, and Environmental Functions.

Project 5 – Padilla Bay
Wrote Goals & Objectives, and Maintenance. Editing.

Project 6 – Gravel Pit
Created Network Diagram. Wrote Site History, Goals & Objectives, Maintenance, and Environmental Functions.

Project 7 – Subalpine
Wrote Allocation of Material, How to Apply Material, Human Disturbance, Material and Human Storage, helped with making plant list and made Network Diagram.

Project 8 – Thornton Creek
Wrote Site History, Site Analysis, Goals & Objectives

Final Compilation
Edited: Wiley slough, Corridor, Vernal Pools. Wrote Appendix 1 and 2 and did final page layout.

Kerwin Talbot

Kerwin Talbot is an undergraduate majoring in Environmental and Forest Sciences with an added interest in Restoration Ecology and Environmental Horticulture. He has spent the past year restoring nearby Yesler Swamp as part of his UW REN capstone and has gained much from the experience. Interests include landscape ecology, restoration methods, GIS analysis, and plant propagation.

Kerwin Talbot's Contribution to Assignments and Final Project

Project 1 – Wiley Slough
Maps and Editing. Final Review

Project 2 – Corridor
Maps and Editing. Final Review

Project 3 – UBNA E5
Maps and Editing. Final Review

Project 4 – Vernal Pools
Maps and Editing. Final Review

Project 5 – Padilla Bay
Wrote Tasks. Maps and Editing. Final Review

Project 6 – Gravel Pit
Wrote Basic Approach. Maps and Editing. Final Review

Project 7 – Subalpine
Calculated total area restored. Maps and Editing. Tasks and Approach. Final Review

Project 8 – Thornton Creek
Maps and Editing. Tasks and Approach. Final Review

Final Compilation
Edited: Wiley slough, E5, and Maps and Images. Tasks and Approach. Final Review

Allison Townsend

Allison is an undergraduate student in School of Biology majoring in conservation, ecology, and evolution and minoring in Environmental Science and Resource Management. She is mostly interested in conservation and restoration, but she is interested in everything that grows, flies, and creeps.

Allison Townsend's Contribution to Assignments and Final Project

Project 1 – Wiley Slough
Wrote Design Requirements, Design Perimeters, Implementation, Maintenance, Implications of Desired Results.

Project 2 – Corridor
Wrote Site Description, Goals and Objectives, Basic Approach, Timeline, and Impact of Historical Ecosystem.

Project 3 – UBNA E5
Wrote Materials and Installation, Long-term Prospects, Site Analysis, Problem Framing, and Implementation.

Project 4 – Vernal Pools
Wrote Site Analysis, Design Requirements, Constraints, Basic Approach.

Project 5 – Padilla Bay
Wrote Site History, Site Analysis, Alternatives, Functional Requirements and Constraints.

Project 6 – Gravel Pit
Wrote Site Analysis, Alternatives, Functional Requirements and Constraints.

Project 7 – Subalpine
Wrote Site Analysis, Plant Installation, Stakeholders, Functional Requirements & Constraints, and Environmental Functions.

Project 8 – Thornton Creek
Wrote Functional Requirements, Long Term Prospects

Final Compilation
Edited Padilla Bay, Gravel Pit, Subalpine, and Thornton Creek. Wrote introduction and conclusion, created cover page.