National Park Service and Lower Elwha Klallam Tribe

Revegetation and Restoration Plan for Lake Mills and Lake Aldwell

Elwha River Ecosystem Restoration Project

Exposed shoreline of Lake Mills, fall 2009

3/10/2011

Revegetation and Restoration Plan for Lake Mills and Lake Aldwell

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EXECUTIVE SUMMARY

Since the early 20th century, the Elwha River has been significantly altered by two hydroelectric dams which block passage of anadromous fish. In 1992, the U.S. Congress passed the Elwha River Ecosystem and Fisheries Restoration Act, requiring restoration of the ecosystem and the native salmon runs. Subsequent analysis determined that the dams would be removed, natural processes would redistribute the accumulated sediment, and restoration of native vegetation would be a central component of the project.

Revegetating the reservoirs after dam removal is essential to ecosystem restoration. Draining the two reservoirs will expose almost 800 acres. Nearly 18 million cubic yards of sediment has accumulated in the reservoirs and much of it will be redistributed by the river as the dams are removed. The dewatered reservoirs will have few biological legacies valuable to restoration such as soil microbes, standing snags, or residual live plants. Soil nutrients and moisture availability will be low, and evaporation will be high due to intense sun and wind exposure. Much of the area will be far from intact forests which could provide seeds, spores, and detritus to speed succession. Thus, natural primary succession of the dewatered reservoirs would be slow. Populations of invasive exotic species may also influence the development of native vegetation.

The goals for revegetating the reservoirs are to minimize invasive exotic species establishment, stabilize ecosystem processes and establish native forests. To achieve these goals, revegetation crews will actively revegetate most of the exposed areas, leaving areas close to native forests to regenerate naturally. The key strategy to prevent exotic species invasions is to control populations in the watershed before, during, and after dam removal to limit dispersal into the dewatered reservoirs. To further minimize invasive species, biologists and revegetation crews will install a diversity of native plant species over a period of seven years, employing multiple types of plant materials representing various life-stages (seeds, seedlings, and live-stakes). Installing plants into the dewatered reservoirs will also stabilize ecosystem processes. Seeding the valley walls with grasses and forbs will limit the erosion of fine sediments. Seeding the slopes will also hasten soil development. The primary objective of planting will be to initiate forest communities, particularly in central portions of the dewatered reservoirs far from surrounding, intact forests. Succession to mature forest will be accelerated by planting at variable densities and by installing dense patches of woody plants to facilitate plant survival and growth in the stressful conditions of the dewatered reservoirs.

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1. INTRODUCTION

The Elwha River watershed is an ecological resource of global significance, a large expanse of temperate, coniferous forest at relatively low elevation, most of which has never been subject to intensive management. More than four-fifths of the watershed is within Olympic National Park (ONP). Two hydroelectric dams, built in the early 20th century, have significantly altered many ecological processes in the watershed. In the lower river, disrupted ecological processes include sediment and wood transport, thermal regimes, and floodplain connectivity. In the upper river, the dams have prevented the flux of anadromous salmon and trout, depriving 93% of the watershed of salmonids. In 1992, the U.S. Congress passed the Elwha River Ecosystem and Fisheries Restoration Act, requiring full restoration of the watershed.

The two dams on the Elwha River have blocked fish passage to more than 70 miles of high-quality habitat for nearly a century. This has resulted in a precipitous decline of native populations of all anadromous salmon and trout species in the watershed. The two dams, Elwha Dam at river mile 4.9, and Glines Canyon Dam at river mile 13.4, have also fragmented the river ecosystem and inundated nearly 800 acres of land. Following approval of the Elwha River Ecosystem and Fisheries Restoration Act, the Department of the Interior completed two analyses with public involvement, leading to two Environmental Impact Statements. The first determined that removal of both dams was necessary to restore the ecosystem (DOI 1995). The second determined that the most appropriate method of implementation would include allowing river flows to naturally erode sediments accumulated within the reservoir basins and actively restoring native vegetation and anadromous fish stocks (DOI 1996). Both Environmental Impact Statements acknowledged that restoration of native vegetation is an important component of ecosystem restoration. Vegetation restoration is critical for achieving fisheries restoration. Without native vegetation restored to the riparian zones and surrounding uplands, the dewatered reservoirs will become barren landscapes susceptible to erosion, and the terrestrial ecosystem will fail to moderate stream temperatures or deliver nutritious litter crucial to aquatic ecosystems (DOI 1995, 1996, Naiman et al. 2005, Apostol and Berg 2006).

The U.S. Department of the Interior (DOI) acquired both dams in 2000 as part of the Elwha restoration project. The Elwha Dam and Lake Aldwell are located outside of ONP, but are currently managed by the DOI. The dewatered reservoirs will expose nearly 800 acres of land that has been inundated for 80-100 years. The exposed landscape will be completely devoid of vegetation. The physical environment in the basins has been significantly altered due to the anaerobic condition of the inundated, former forest soils and the accumulation of nearly 18 million cubic yards of sediment. For revegetation to be successful, it must be planned using modern ecological theories and rigorous scientific principles, and simple and clear goals and objectives must be established.

The purpose of this document is to succinctly describe planned actions by Olympic National Park and the Lower Elwha Klallam Tribe to restore native vegetation following removal of the two Elwha River dams. The conceptual underpinnings of this approach will be presented in a separate document (Chenoweth et al. *in prep*.).

This document is in two parts: the first sets the stage for dam removal, and the second explains the park's proposed response. Chapters 2 through 4 describe the human history (especially the hydroelectric projects), physical geography, and ecology of the project area. Chapter 5 weaves these threads together to anticipate the set of circumstances under which revegetation will occur.

The second part of this document begins by explaining the goals and objectives for revegetation and then lays out the details for the control of invasive, exotic plants and restoration of native vegetation. The document concludes with a description of the park's plan to monitor vegetation change and use the resulting information to guide remedial actions (i.e. adaptive management).

This restoration plan is a working document that will be adapted as new information becomes available. It is the basis for the site-specific prescriptions that will be developed as the water recedes and actual conditions can be observed on the ground.

2. LAND USE HISTORY OF THE PROJECT AREA

THE HYDROELECTRIC PROJECTS

The Elwha and Glines Canyon hydroelectric projects are located on the Elwha River on the Olympic Peninsula in Washington State (Figure 1). The Elwha dam, constructed from 1910-1913, is located at river mile 4.9. The dam impounds 8,100 acre-feet in the Lake Aldwell reservoir (Figure 2). The reservoir is 2.8 miles long and as much as 0.25 miles wide with a maximum depth of just less than 100 feet. The reach of the river inundated by Elwha Dam includes three distinct topographic areas: a moderately confined valley immediately upstream of the dam site, a bedrock-confined meander in the middle portions and a wide, unconstrained alluvial valley at the upstream portion. The Glines Canyon dam, constructed from 1925-1927, is located at river-mile 13.4. The dam impounds 40,000 acre-feet of water in the Lake Mills reservoir (Figure 3). The reservoir is nearly 2.5 miles long, 0.5 miles wide, with a maximum depth of just less than 200 feet.

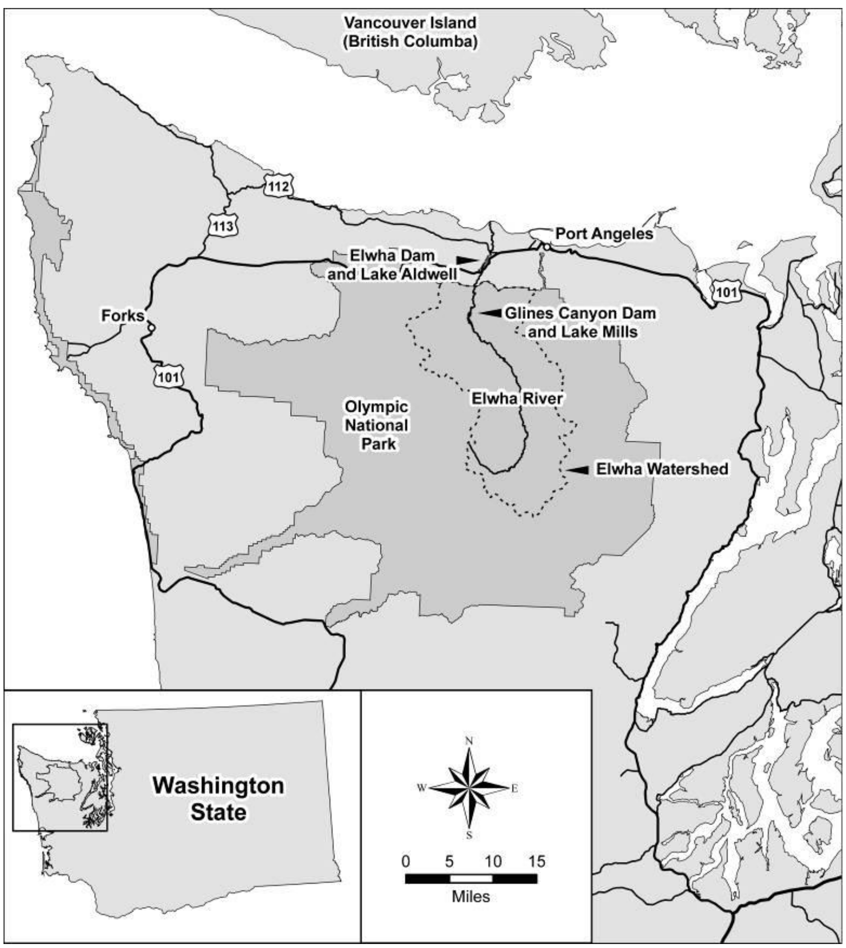

Figure 1. Location map of the Elwha watershed

GLINES CANYON DAM AND LAKE MILLS AREA

The Glines Canyon Dam project area lies entirely within Olympic National Park. The Lake Mills reservoir inundates approximately 438 acres. Dam facilities cover another 5-10 acres. Most of the forested area surrounding Lake Mills is designated federal wilderness. Revegetation of the Lake Mills basin must not interfere with the National Park Service's mandate to conserve native plant and animal species and perpetuate natural processes. The revegetated lands will be managed for backcountry/wilderness use, and may be designated as wilderness in the future (DOI 1996). Some features of the hydroelectric project, such as the spillway and powerhouse may be maintained for interpretive value (DOI 1996). Remaining Glines Canyon Dam facilities will be removed and the site restored to a natural state. ONP will be the lead agency managing the restoration of the Glines Canyon Dam and Lake Mills area.

ELWHA DAM AND LAKE ALDWELL AREA

The Elwha Dam and the land surrounding Lake Aldwell was purchased by the Department of the Interior to facilitate the removal of the dam. In total 1061 acres, including Lake Aldwell, are part of the Elwha Dam Project Lands. Approximately 340 acres are inundated by Lake Aldwell. The remaining acreage is second-growth forest bordering the reservoir, riparian bottomlands, and other project facilities such as roads (DOI 1996). LEKT will be the lead agency managing the restoration of the Glines Canyon Dam and Lake Mills area.

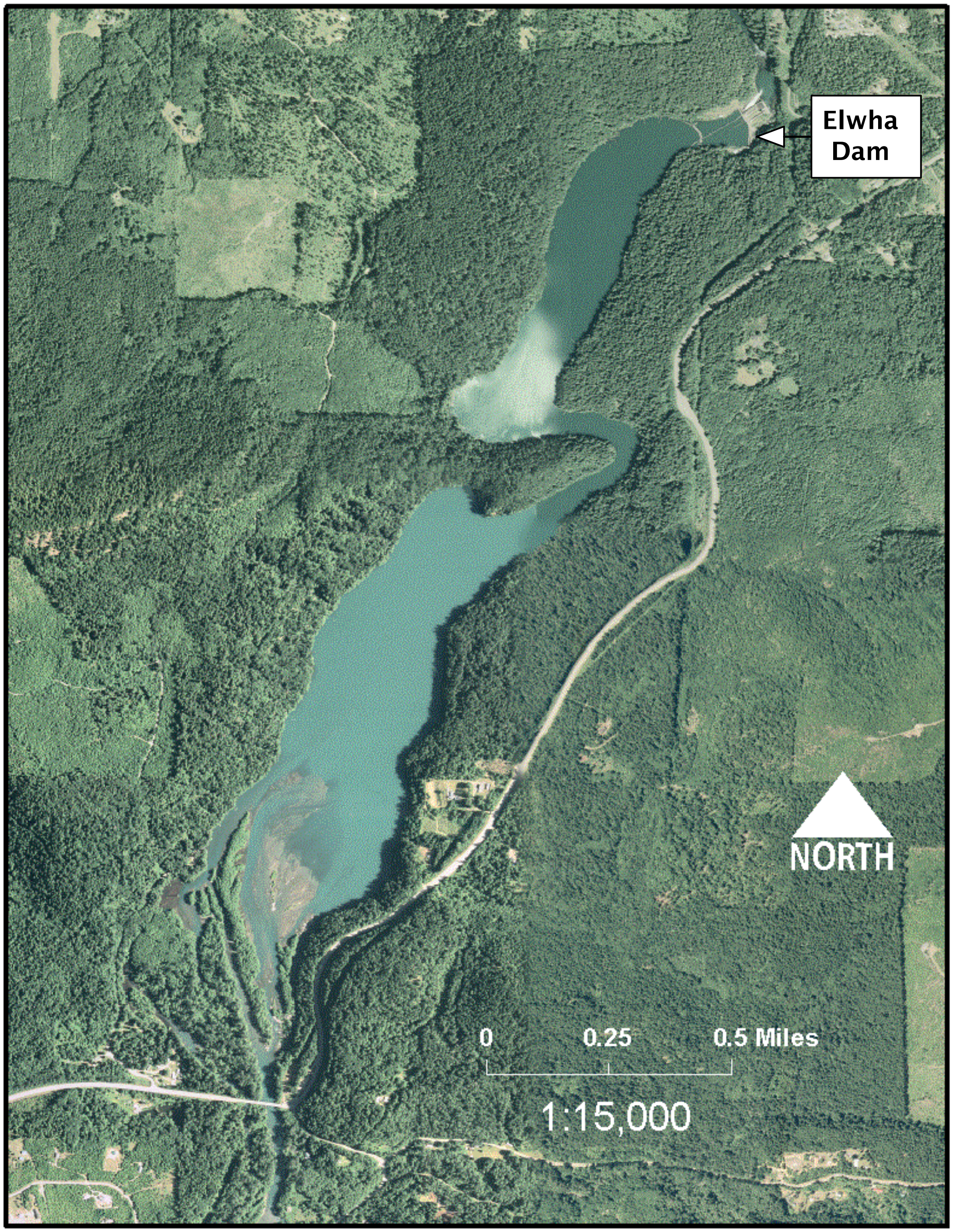

Figure 2. Digital orthophoto (2006) of Lake Aldwell. The reservoir and project lands are surrounded by heavily managed timberlands.

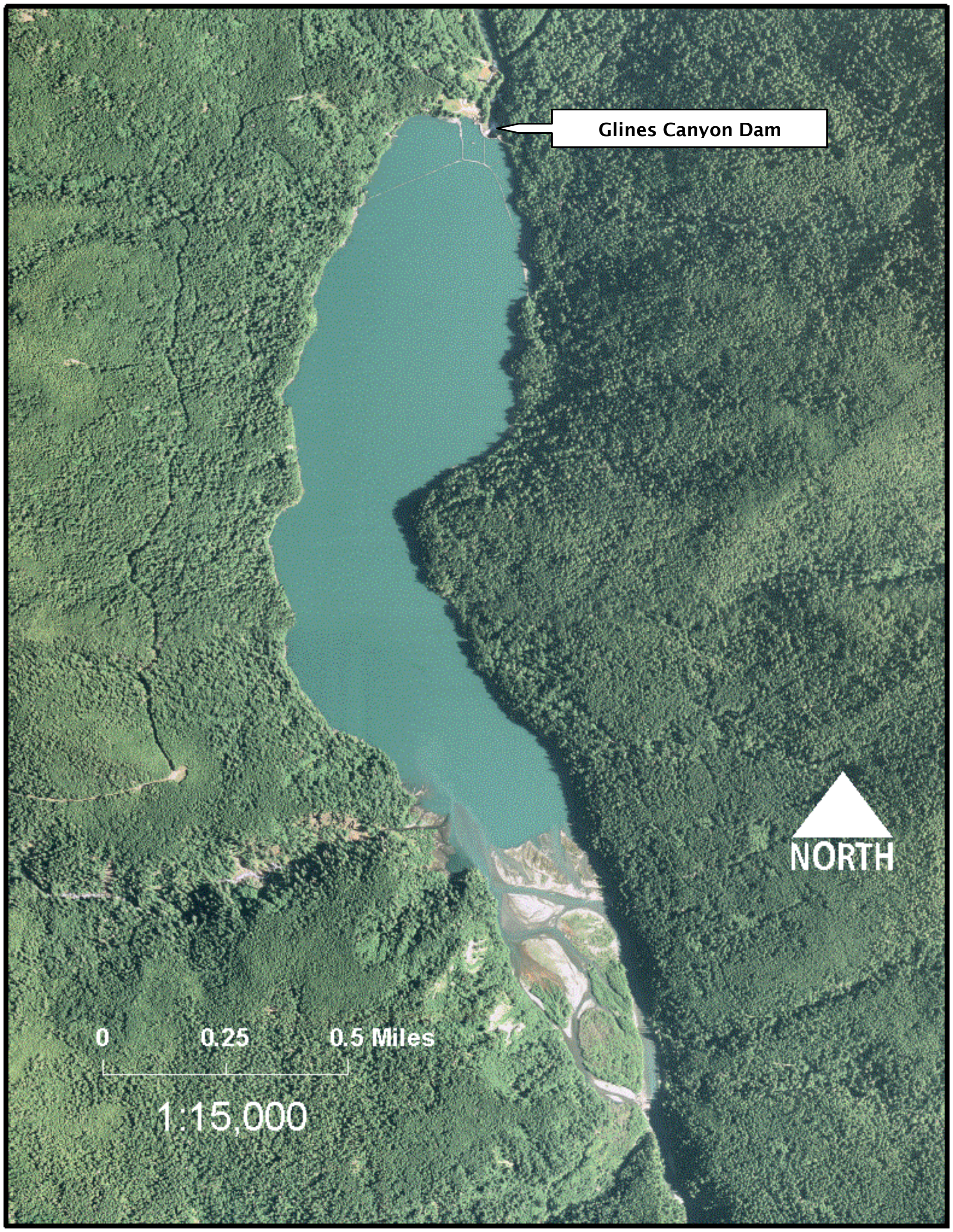

Figure 3. Digital orthophoto (2006) of Lake Mills. The reservoir is surrounded by Olympic National Park wilderness.

3. PHYSICAL SETTING

The Elwha River watershed is one of the largest on the Olympic Peninsula, with an area of nearly 212,315 acres (Figure 4). The headwaters of the river are in the center of the Olympic Mountains at 4800 feet near the Dodwell-Rixon Pass in the Bailey Range, the main hydrographic divide on the Olympic Peninsula. From the headwaters to the mouth of the river, the main channel runs mostly north for 45 miles and drains into the Strait of Juan de Fuca.

The precipitation gradient within the watershed is steep due to orographic effects. Near the headwaters, precipitation is estimated to average more than 140 inches per year. Precipitation decreases as the river moves north. Precipitation in the Lake Mills area averages more than 70 inches per year, while less than 50 inches of rain falls near the north end of Lake Aldwell (Oregon State University 2005). Annual precipitation declines to 30-40 inches at the mouth of the river (Oregon State University 2005).

Forms of winter precipitation change with increasing elevation and decreasing temperature: mostly rain below 1000 feet, mixed rain and snow between 1000 feet and 2500 feet, and mostly snow above 2500 feet (Houston and Schreiner 1994). The surface elevations of Lakes Aldwell and Mills are about 200 feet and 600 feet, respectively. The climate in the area surrounding the two reservoirs is typically mild, with wet winters and relatively cool and dry summers.

LOCAL TOPOGRAPHY AND GEOLOGY

Area topography is rugged, with local relief exceeding 4500 feet and slopes of 40˚ or greater around Lake Mills. The mountains around Lake Aldwell rise up to 2150 feet. Several small, steep-gradient tributary streams enter the valleys from these side-slopes. In Lake Mills, the largest are Hurricane, Sege, and Wolf Creek on the east side of the reservoir, and Boulder, Cat, and Stukey Creek on the west side (Figure 5). The main tributary entering Lake Aldwell is Indian Creek, which enters the reservoir from the southwest.

The Elwha River overlies heavily-folded and faulted sedimentary and metamorphic rocks. Outcrops of rock exposed along the shoreline of Lake Mills are diabase, a fine-grained intrusive igneous, rock similar to basalt. Near the south end of the lake, outcrops are primarily crenulated slates. In the valley bottom, surficial geology is dominated by glacial deposits and recent colluvium. During the last Ice Age, the Cordilleran ice sheet dammed the Elwha River, causing deposition of sediments in deltas and terraces beneath glacial Lake Elwha (Tabor 1987). After glacial retreat, the Elwha River cut rapidly through these deposits, leaving steep-sided slopes which have subsequently been modified by mass-wasting and erosion. Such deposits dominate the western shore of Lake Mills and appear to extend down into the reservoir. Unstable deposits have led to several mass movement events evident above the lake.

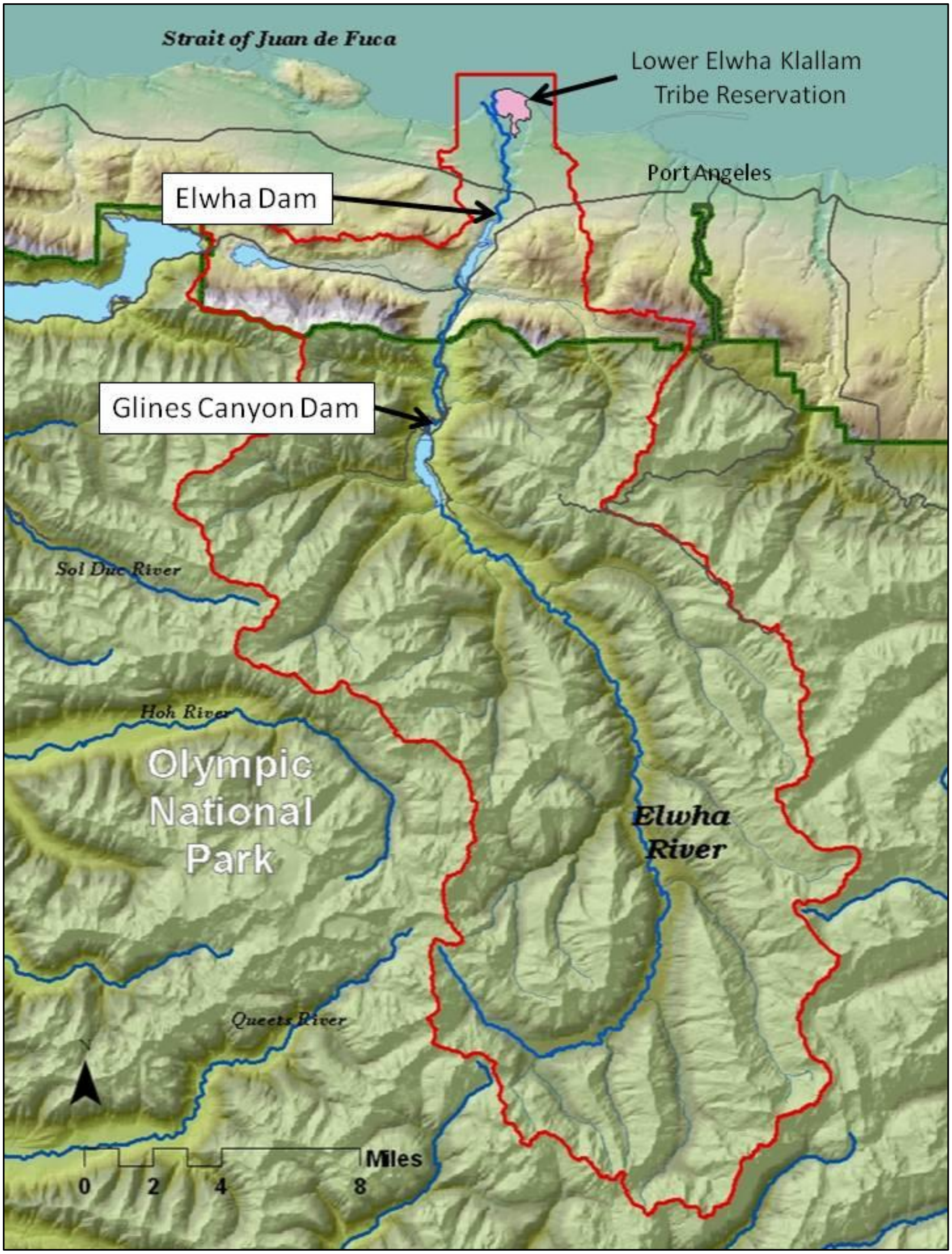

Figure 4. The Elwha watershed.

Lake Aldwell has many recent landslide areas on the reservoir rim (BOR 1996). In the northwest corner of Lake Aldwell is a landslide believed to have occurred during construction of the Elwha Dam (T. Randle, U.S. Bureau of Reclamation, personal communication). Future behavior of these potential landslide areas will be monitored during and after dam removal (Randle and Bountry 2009).

LANDFORMS BENEATH THE RESERVOIRS

The areas now occupied by the reservoirs previously contained diverse habitats, including riparian and upland land areas. Most of the area beneath the reservoirs will become valley bottom upland terraces or valley wall landforms.

The likelihood that the river channel will migrate after dam removal makes precise predictions of the location and acreage of specific landforms within the basin difficult. By comparing bathymetric maps of the reservoirs to maps of similar reaches elsewhere in the Elwha drainage, it is possible to roughly estimate the acreage within broad landform types. The bathymetric map of Lake Mills is based on 36,650 sonar points taken throughout the lake in 2005 (Figure 5). The bathymetric map for Lake Aldwell is based on the 1913 topography map (Figure 6).

THE VALLEY BOTTOM ZONE

The valley bottom zone has three landforms of significance to revegetation: floodplain, terraces and fan terraces. Valley bottom landforms receive resources from slopes above the valley, and can be considered resource-rich relative to the surrounding landscape (Apostol et al. 2006). The valley bottom zone in Lake Mills is estimated to be 205 acres, and the valley bottom zone in Lake Aldwell to be 184 acres.

THE FLOODPLAIN

The floodplain is defined here as the landforms directly within the influence of the river and includes the active floodplain, the river channel, and adjacent wetland areas (North Cascades National Park Geology Staff 2005). The floodplain is subject to direct fluvial erosion, deposition, and flooding. The floodplain will be the least stable zone within the reservoirs after dam removal. The floodplain in Lake Mills is estimated to be 74 acres and the floodplain in Lake Aldwell to be 50 acres.

TERRACE AND FAN TERRACE LANDFORMS

Fan terraces are abandoned alluvial fans made up of sands and gravels. They are moderately sloped to flat. Alluvial terraces are relatively flat surfaces of sands and gravel deposited by rivers. They are remnant floodplains older than 100 years (North Cascades National Park Geology Staff 2005). The main difference between terraces and fan terraces is that fan terraces are formed in the shape of a fan at the junction of a tributary stream and a larger river or valley feature (USDA 2007). Fan terraces and terraces are estimated to cover 131 acres in Lake Mills and 117 acres in Lake Aldwell.

VALLEY WALL ZONE

The valley wall zone includes erosional landforms perched on the valley wall, and depositional landforms, such as alluvial fans, located in the transition area where the valley wall meets the valley bottom. These are upland landforms, and will likely remain outside of the river's influence after dam removal. The landforms in this zone are quite variable, ranging from moderately-sloped areas composed of sands and gravels such as alluvial fans (slopes less than 5 degrees) to steeper areas containing rocks and boulders such as debris cones (slopes greater than 10˚). Other landforms that occur on valley walls include avalanche chutes, debris avalanches, river canyons, and bedrock benches. River canyons, such as the one located near the center of Lake Aldwell, are V-shaped valleys incised in bedrock by steep-gradient streams. Valley wall landforms will cover an estimated 146 acres in Lake Mills and 104 acres in Lake Aldwell.

CONDITIONS PRIOR TO INUNDATION

Both dams inundate relatively unconstrained, low-gradient valleys (Figure 7). Prior to inundation, the valleys were logged, leaving stumps scattered across the valley bottom (Figure 8). The stumps are still evident in the upper reaches of the reservoirs, where sediment accumulations are thin (Figure 9). Logging operations left unburned slash and uncut riparian trees such as red alder, big-leaf maple, and black cottonwood (Figure 10).

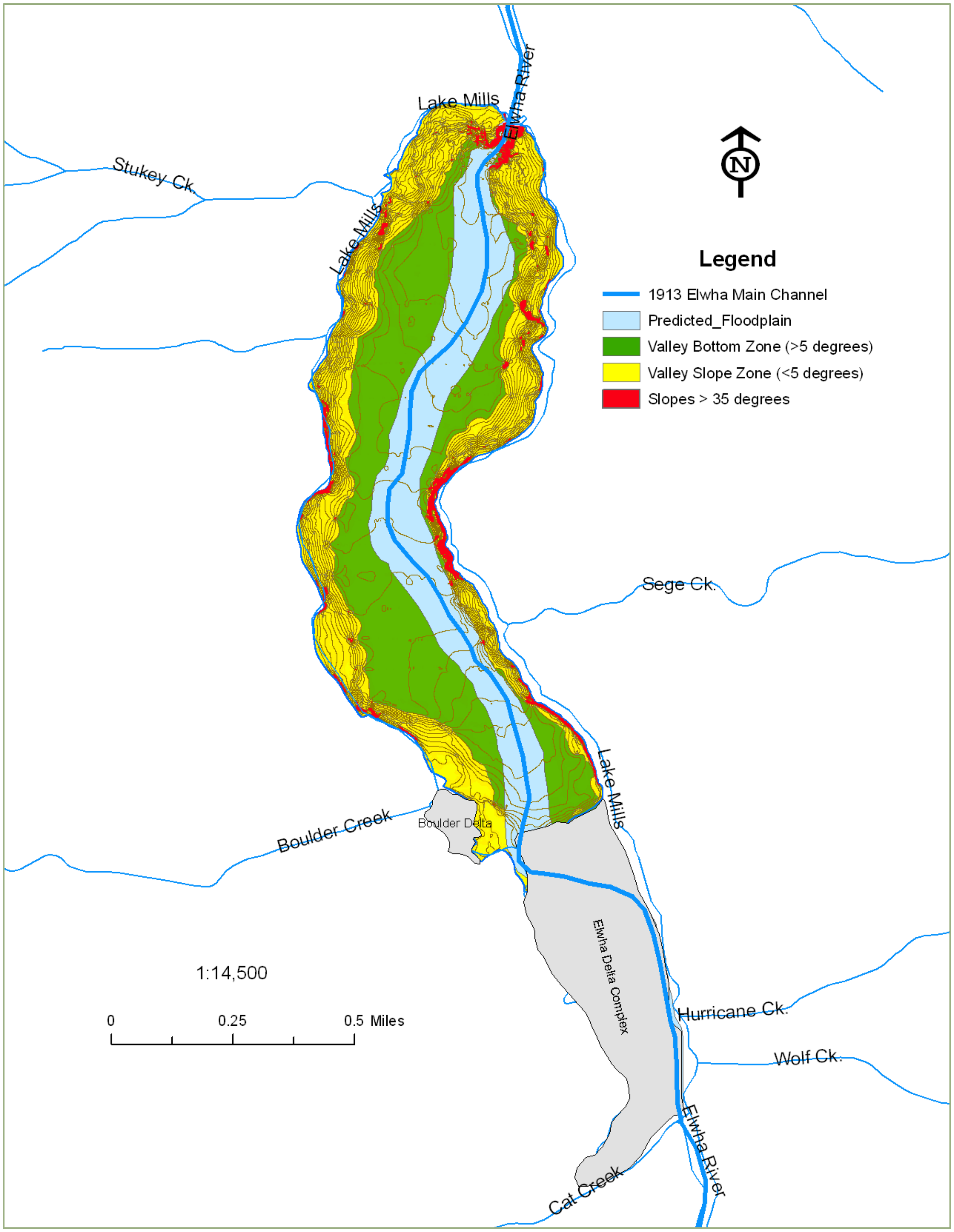

Figure 5. Lake Mills bathymetric map. This map is based on 2005 sonar. Several tributaries enter the reservoir from the surrounding slopes.

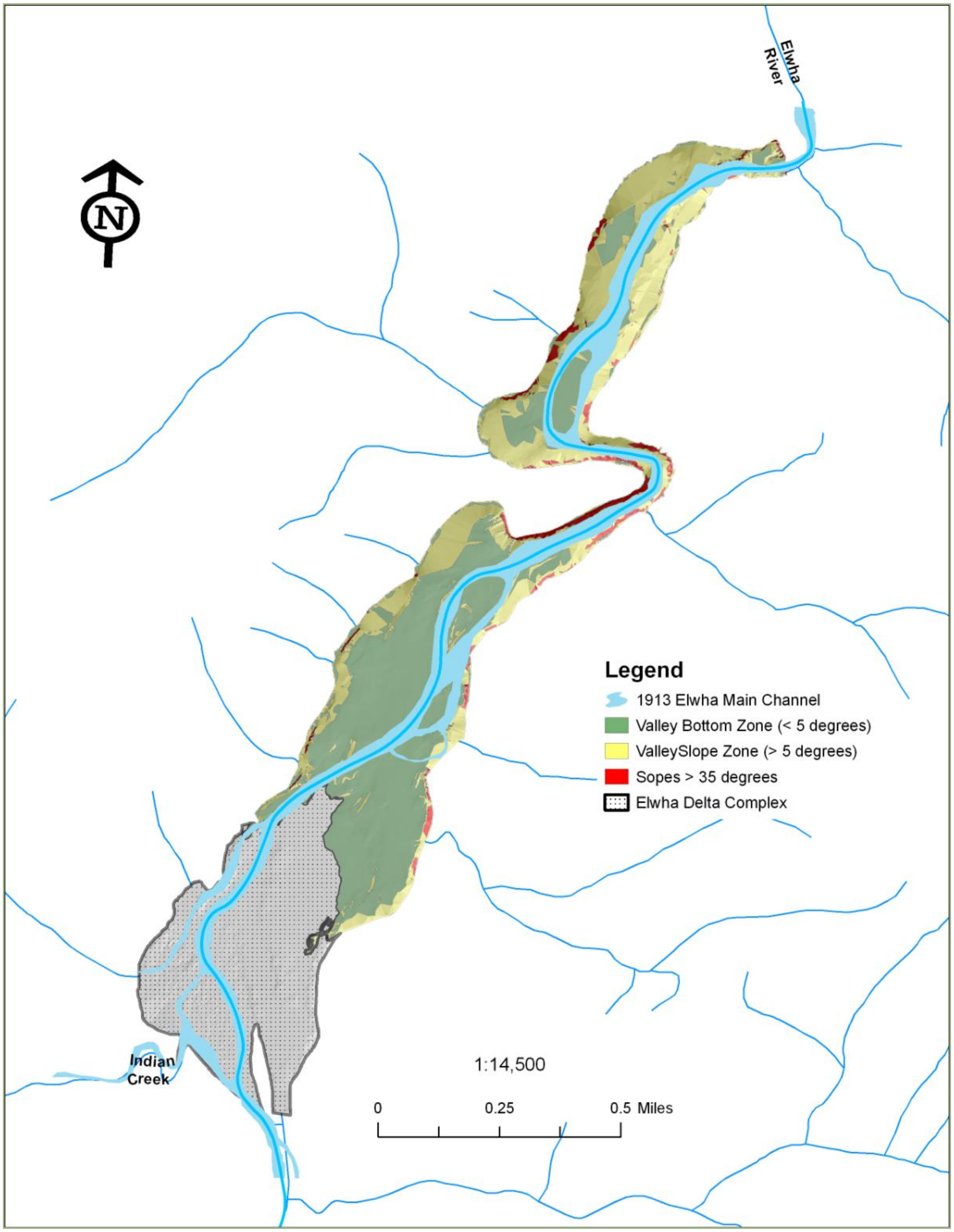

Figure 6. Lake Aldwell bathymetric map.

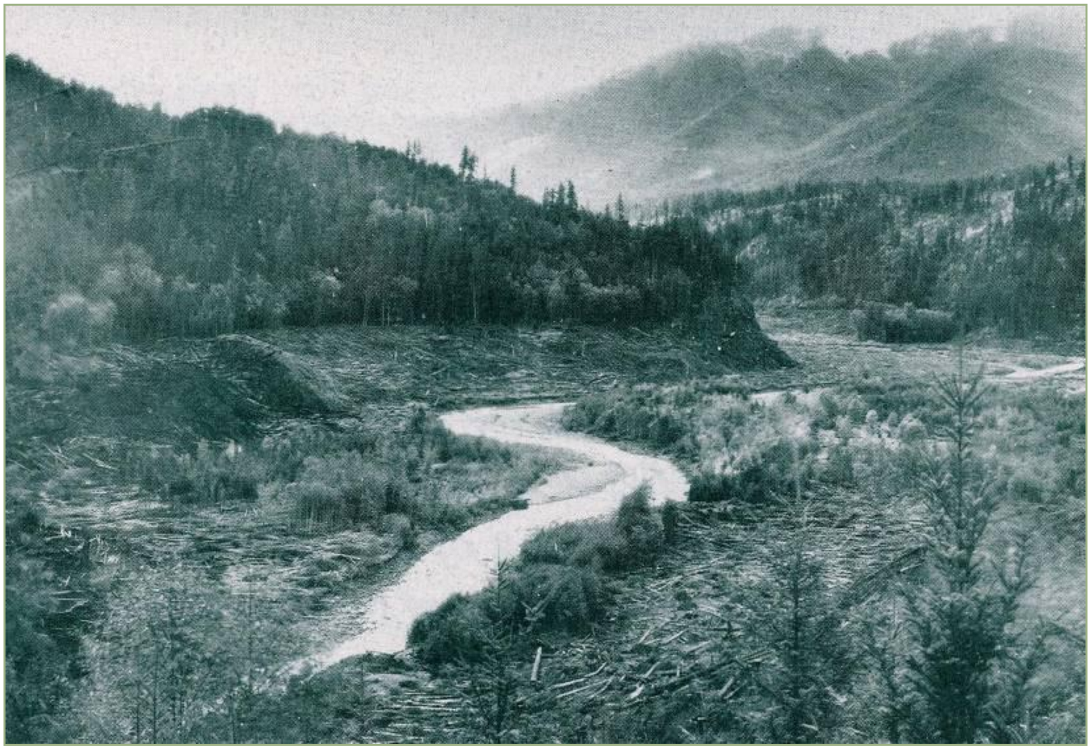

Figure 7. Lake Mills prior to inundation (looking south). Date and photographer unknown, Clallam County Historical Society photo. Note the riparian trees left standing after the upland areas were logged.

Figure 8. Lake Mills prior to inundation (looking north).

Figure 9. Stumps exposed on Lake Mills shoreline during a 2009 drawdown.

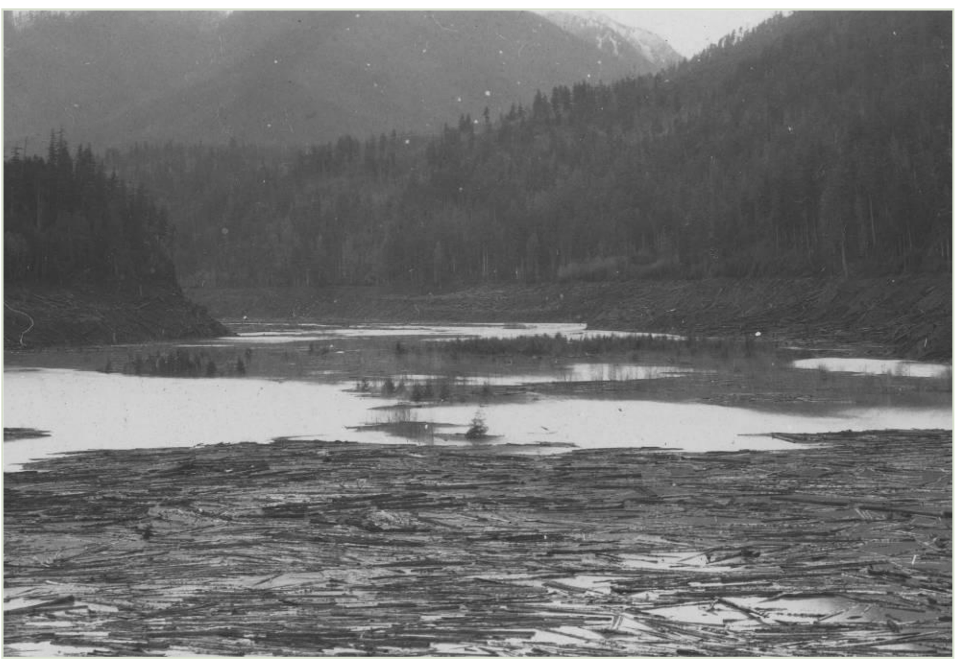

Figure 10. Lake Mills during inundation (1927). The tops of riparian trees are evident in the middle of the lake.

ACCUMULATION OF WOODY DEBRIS

Both of the reservoirs have been passive receptors of debris floating down the Elwha River and tributaries for the last 80-100 years. The woody debris ranges in size from huge old-growth logs to small sticks and fragments. Some of the wood floats to the shoreline and eventually sinks (Figure 11). Many of the logs that accumulate after large storms are pushed over Glines Canyon Dam. However, large quantities of buried and exposed wood will remain in the Lake Mills basin after dam removal, with the highest concentrations perched along the shoreline (Figure 12). Along the shoreline of Lake Aldwell, large woody debris is not abundant. Although large quantities are not expected, it is not clear how much wood will be present in Lake Aldwell after dam removal.

Figure 11. Woody debris accumulations along Lake Mills shoreline at full pool. View is looking north towards Windy Arm on the eastern shore.

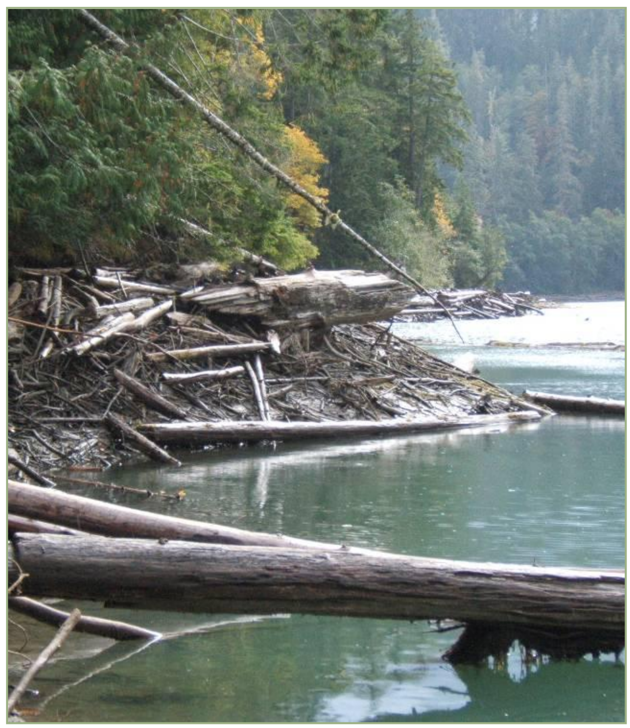

Figure 12. Woody debris exposed during 10 ft drawdown of Lake Mills (2009). View is looking south toward Windy Arm.

RESERVOIR SEDIMENTS

Since 1913 and 1925, large quantities of sediment have accumulated in the reservoirs: Lake Aldwell has an estimated 3.9 million cubic yards (22% of the estimated total amount), while Lake Mills contains an estimated 13.8 million cubic yards (78% of the estimated total amount) (BOR 1996). Roughly half of the sediment (52%) is fine textured (silt and clay), and half (48%) is coarse textured (sand, gravel, cobbles) (BOR 1995). Because lateral migration of the river channel is not expected to occur over the entire width of the reservoirs, a proportion of the accumulated sediment will remain (BOR 1996).

The current distribution of sediments is reasonably well known. The Bureau of Reclamation (BOR 1995) estimates that the downstream portions of Lake Mills are covered with about 5 million cubic yards of sediment, more than 90% of which is silt or clay. The farthest downstream portion of the reservoir, referred to as the reservoir floor (Figure 14), is estimated to be 98% silt and clay. The middle portion of the lake, referred to as the pro-delta, is 89% silt and clay (BOR 1995). The fine sediments are estimated to range in depth from 20-40 feet in the pro-delta and to be progressively thinner northward along the bottom of the reservoir and towards the margins of the lake (BOR 1995). The texture of the sediments in the upper reaches of the reservoir is not uniform. Along the shoreline, wave action has influenced sediment deposition. Wave action is more active on small landforms that protrude out into the lake, leaving only coarse sands and gravels and no fine sediment. At the mouths of small creeks, deltas of sands have formed (Figure 13).

Figure 13. Sand and gravel deposits at the mouth of Stukey Creek, Lake Mills. Photo taken during the 2009 drawdown.

The deltas at the upstream end of Lake Mills are composed of about 7 million cubic yards of sediment, about 80% of which is sand, gravel, or cobbles (BOR 1995). The delta is estimated to be 60-80 feet thick. Based on aerial photographs, the evolution of the delta has been gradual. The first photograph from 1948 shows no delta islands. By 1968, the first exposed delta islands had formed. Vegetation is not apparent as late as 1981, but is apparent by 1990.

The reservoir floor (Figure 15) is covered by an estimated 6-8 feet of sediment, predominantly clay and silt (89-96%) with most of the remainder composed of fine sands (3-9%). Sediment depth along the rim of the reservoir is estimated to average 2 feet (BOR 1995). Sediments in the pro-delta area of the lake average 14 feet thick (86% clay and silt, 14% fine sands). Approximately one-third of the total for Lake Aldwell is coarse sediments that have accumulated in the delta, which is estimated to be between 8-18 feet thick.

Samples of the fine sediments from the reservoirs were submitted for laboratory testing to obtain baseline data on nutrients, organic matter and cation exchange capacity. When compared to typical forest soils of the area, the fine sediments from Lake Mills are low in primary nutrients including nitrogen, potassium, and phosphorus, and lack organic matter (Table 1). The value for the micro-nutrient boron is also low. The fine sediments from Lake Aldwell are also low in potassium, organic matter and boron, but not in phosphorus (comparable data for nitrogen were not obtained).

Water availability in the fine sediments may be limiting due to a lack of pore spaces (Walker and del Moral 2003). As a consequence, mycorrhizae are likely to play an important role in vegetation development after dam removal by enhancing the ability of plants to obtain nutrients and water (Walker and del Moral 2003). In 2003 an assay of spores of vesicular-arbuscular mycorrhizae (VAM) in the fine sediments from Lake Mills was conducted. VAM spores were measured because most of the native plant species likely to colonize soon after dam removal require VAM spores in the soil, and because other types of mycorrhizae have smaller spores which cannot be detected in sediment samples except by bioassays with host plants (Efren Cazares, Mycoroots, Inc., personal communication). The assay found turgid, potentially viable VAM spores in an average concentration of 12 per gram (Table 2), which compares favorably to the highly-concentrated inoculum available commercially (50 spores/g). Spore numbers were highly variable probably due to patterns of silt deposition and sampling bias. It would be useful to follow up these results with bioassays for viable propagules of a variety of types of mycorrhizae.

Plant-growing trials conducted by ONP and others suggest that the fine sediments may exclude some plant life forms, while others may thrive in the fine sediments. The one tree species tested in 2003 (red alder) was unable to survive a single growing season in the fine sediments (27 of 30 died, compared with survival of 29 of 30 individuals in a potting medium of peat, perlite, gypsum and dolomite). In 2006, a qualitative study examined germination and establishment of native grasses and forbs. Seeds were spread into 1-meter-square boxes of fine sediments placed on a barge on Lake Mills. Native grasses had high rates of germination and establishment while native forbs had poor germination and establishment. In a quantitative study of germination rates on the fine sediments, red alder and blue wildrye were tested. Blue wildrye germination and establishment was significantly higher than red alder (Chenoweth 2007). In another study of plant growth responses in reservoir sediments, germination and growth rates of two native species, thimbleberry (*Rubus parviflorus*) and Suksdorf's wormwood (*Artemisia suksdorfii*) and one invasive exotic species, Canada thistle (*Cirsium arvense*), were low in the fine sediments (Michel et al. 2011). Another invasive exotic species, Himalayan blackberry (*Rubus discolor*) did not germinate at all in the reservoir sediments. More studies are needed to better understand the influence of texture and soil chemistry on species performance.

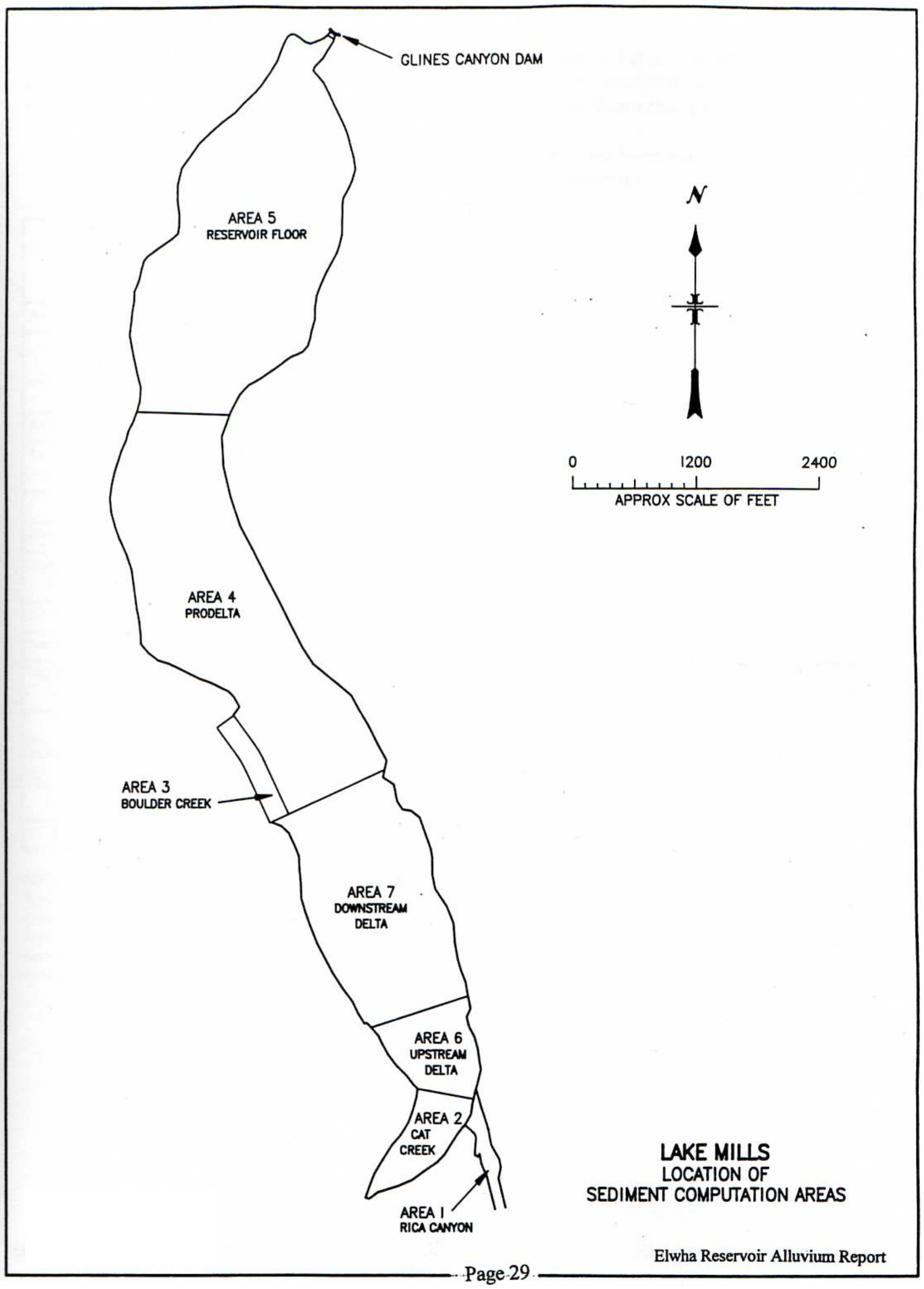

Figure 14. Lake Mills sediment computation areas (taken from BOR 1995).

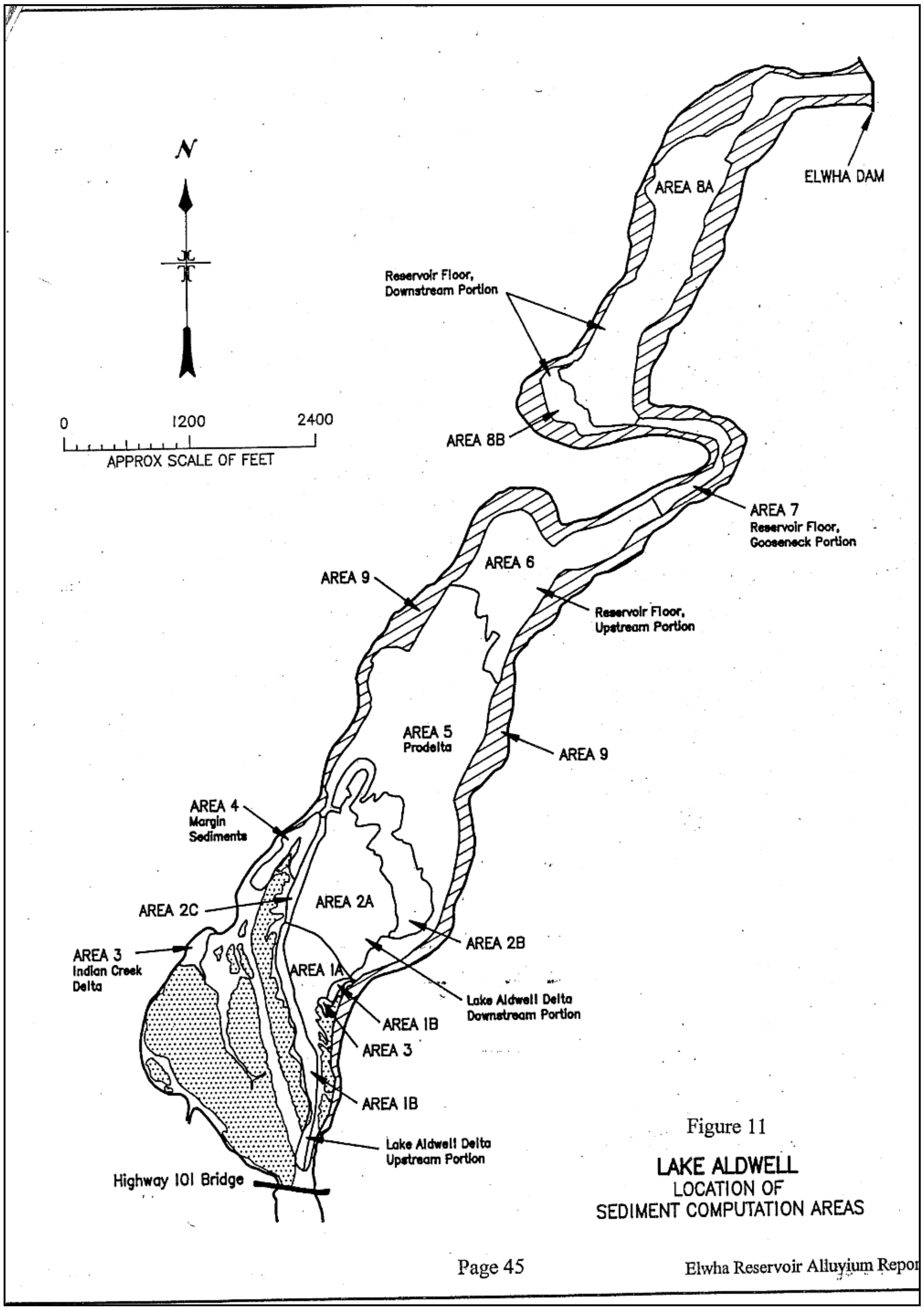

Figure 15. Lake Aldwell sediment computation areas (taken from BOR 1995)

Table 1. Chemical analysis of fine sediments from the reservoirs.

	Lake Mills Fine Sediments[1]	Lake Aldwell Fine Sediments[2]	Climax forest Site Values[3]
pH –log	6.0-6.5	5.4	5.4-5.6
Phosphorus [P] ppm	1.0—2.0	12.0	7.4—9.2
Potassium [K] ppm	27.0-35.0	19.0	60.8-82.6
Calcium [Ca] meg/100g	2.3-3.4	3.1	4.0-10.1
Magnesium [Mg] meg/100g	0.18-0.44	0.5	0.35- 2.26
Total Nitrogen [N] %	0.09-0.11	n/a[4]	0.15-0.22
Organic Matter %	1.5-1.8	2.14	10.25-10.28
Cation Exchange Capacity [CEC] meg/100g	3.5-4.2	4.1	n/a
Boron [B] ppm	0.05-0.12	0.1	0.62-0.99
Zinc [Zn] ppm	0.40-0.75	0.83	0.78-0.84
Copper [Cu] ppm	5.0-6.24	2.75	1.05-1.41
Manganese [Mn] ppm	124.2-200.1	66.0	29.60-30.74
Iron [Fe] ppm	173.4	73.9	n/a

[1]Test values from multiple mixed bottom samples obtained from 1) cove north of Boulder Creek on west side of reservoir at depths of 25-40 ft. in 1993, 1997, and 2001. Analysis by Central Analytical Laboratory, Oregon State University, Corvallis OR.

[2]Test values from multiple mixed samples obtained from dredge spoils following turbidity filtration experiments at City of Port Angeles Ranney well site 2002. Analysis by Central Analytical Laboratory, Oregon State University, Corvallis, OR.

[3]Mean value ranges from a total of 10 plots representing *Tsuga heterophylla* climax forest with understory vegetation types comparable to forests around Lake Mills (Henderson et al. 1989).

[4]Not available.

Table 2. Vesicular-arbuscular mycorrhizal (VAM) spores in Lake Mills fine sediments

Sample #	Vesicular-Arbuscular Spore Count	Average Count Spores/Gram Soil
1	510	38
2	3	--
3	99	7
4	31	2
TOTAL AVERAGE ±12		

Analysis by Efren Cazares, MycoRoots, 1970 NW Lance Way, Corvallis, OR 97330.

HISTORIC SOILS BENEATH THE RESERVOIRS

Maps from 1913 identify the soils of the valley walls around Lake Mills as "shot clay and rock," and the valley bottom soils as "sandy or gravel soil." The term "shot clay" probably means hard, solid clays (Darlene Zabowski, University of Washington, personal communication). Contemporary soil samples from valley wall areas above Lake Mills are consistent with the 1913 maps. These soils consistently had a silty-clay texture with a significant component of rock (more than 20%).

4. ECOLOGICAL SETTING

A general understanding of the dynamics of natural vegetation in the surrounding watershed is necessary for setting revegetation goals. It is important to describe the immediate surroundings of both reservoirs, as these are the most likely sources of colonizing plants, fungi and soil biota. In particular, existing populations of invasive, exotic plants will drive some site-specific actions. Finally, revegetation activities must take into account known populations of plant species with conservation significance (e.g., species listed as endangered, threatened or sensitive by federal or state agencies).

VEGETATION COMMUNITIES OF THE ELWHA WATERSHED

Due to the steep gradients of precipitation, elevation and temperature, the watershed supports a diverse mix of vegetation. Low to middle elevations are mostly within the western hemlock zone (Henderson et al. 1989). Common vegetation communities include the western hemlock/Oregon grape/sword fern and western hemlock/salal associations. In the drier end of the watershed, particularly on the steep slopes above Lake Mills and on the slopes north of the lake, the forests are dominated by Douglas-fir plant associations such as Douglas-fir/(Oregon grape)/vanilla leaf and Douglas-fir/ocean-spray-wood rose (WNHP 2008). The subalpine and montane vegetation communities in the Elwha watershed are within the subalpine fir and the silver fir zones (Henderson et al. 1989). Non-forest vegetation occurs in the subalpine and alpine zones above 5000 feet, dominated by shrubs in the heather family, sedges, and forbs (Houston and Schreiner 1994).

FLOODPLAIN VEGETATION

The pattern of vegetation on floodplains in the Elwha drainage is typically complex. Sparse herbaceous communities are found in the most active areas of recently deposited sand and gravel. Species common in these conditions include common woolly sunflower (*Eriophyllum lanatum*), blue wild rye (*Elymus glaucus*), pearly everlasting (*Anaphalis margaritacea*), small willowherb (*Epilobium munitum*), Virginia strawberry (*Fragaria virginiana*) and seedlings of willows and red alder (Doss and Olson 1994). Species composition of forested floodplains is dependent on the age of the landform. Young surfaces are typically dominated by Sitka willow (*Salix sitchensis*) or red alder, sometimes with lesser amounts of black cottonwood. Conifers may also be present, but are usually suppressed until the hardwoods decline (Walker and Chapin 1986, Van Pelt et al. 2006). Common herbaceous species are coltsfoot (*Petasites figidus*), Cooley's hedgenettle (*Stachys chamissonis* var. *cooleyae*), and Virginia strawberry. Red alder can be particularly influential with respect to development of floodplain vegetation, since it enriches mineral soils due to nitrogen fixation by symbiotic microorganisms in nodules on its roots. After several decades of alder dominance, soil fertility increases, allowing conifers and other late-seral plants to establish (Hibbs et al. 1994, Van Pelt et al. 2006).

TERRACE VEGETATION

Most terraces are forested with a variety of dominant species. Younger terraces are dominated by red alder, black cottonwood and bigleaf maple, with grand fir or Douglas-fir present. Big-leaf maple stands are common on terraces in the Elwha drainage, usually with swordfern, salmonberry, enchanter's nightshade (*Circaea alpina*), snowberry and youth-on-age in the understory. Some older terraces contain forest types common on steep valley walls, such as Douglas-fir/Oregon-grape/vanilla-leaf (WNHP 2008).

VALLEY WALL VEGETATION

Valley walls in the lower Elwha drainage are usually covered by Douglas-fir forests. Younger stands often contain deciduous trees such as bitter cherry, western crabapple, and Scouler willows, which tend to be absent in mature forests (Keeton and Franklin 2005).

Steep sites with shallow soils in the Elwha valley contain unique communities. Such sites are usually dominated by native herbs and shrubs such as Roemer's fescue (*Festuca roemeri*), Martindale's lomatium (*Lomatium martindalei*) and bristly manzanita (*Arctostaphylos columbiana* ssp. *columbiana*).

Figure 16. A Douglas-fir forest above Lake Mills.

LAKE MILLS CONTEXT

Lake Mills is surrounded by intact, dense, native forest on steep valley walls (Figure 16). The heavily-forested landscape will provide a source of organic materials, native seeds, and native wildlife to colonize the dewatered basin. The forest is dominated by Douglas-fir. The understory is typically dominated by swordfern and/or Oregon grape. Salal is occasionally prominent. Intermingled within the stands of Douglas-fir are smaller amounts of bigleaf maple (*Acer macrophyllum*), grand fir (*Abies grandis*), western hemlock (*Tsuga heterophylla*), and western red-cedar (*Thuja plicata*). The stands appear to be dominated by a 100-year-old cohort of trees, with a 300-year-old cohort occasionally prominent. Forests dominated by western hemlock occur on mesic sites throughout the valley. Moderate to heavy accumulations of downed woody material are common. Several locations above Lake Mills consist of rock outcrops and cliffs occupied by species such as Pacific madrona, bristly manzanita (*Arctostaphylos columbiana*), redstem ceanothus (*Ceanothus sanguineus*), Roemer's fescue (*Festuca roemeri*) and stonecrop (*Sedum* sp.). These outcrops are expected to occur in the basin on slopes greater than 35° (Figure 17).

Figure 17. Windy Arm. This landform is comprised of diabase, and likely extends steeply to the valley bottom.

The delta at the south end of Lake Mills contains several types of habitats, including active side-channels, backwater channels and islands (Figure 18). Vegetation is sparse on the northern end where the delta islands are young. Vegetation on the southern end of the delta is dominated by red alder and willow (Cereghino and McClure 2002). Forbs such as pearly everlasting, *Erigeron philadelphicus* and *Lupinus latifolius* are common. Some Douglas-fir, grand fir, cottonwood and big-leaf maple are also present. During dam removal the delta will slowly advance north into the dewatered reservoir (see chapter 5), redistributing some species (i.e. cottonwood, willows,) into the valley bottom of the dewatered Lake Mills.

RARE PLANTS

There are no federally-listed plant species within the Glines Canyon project area. However, five vascular plant species listed by the Washington Natural Heritage program as threatened or sensitive have been documented in the general vicinity or are suspected to have occurred there historically. Revegetation activities are not expected to harm these species.

INVASIVE, EXOTIC PLANTS

Over 152 exotic plant species are known to occur in the lower Elwha watershed (see Appendix B for full list), accounting for 38% of the flora (species count). Not all of the exotic species in the lower Elwha are considered invasive (See chapter 8 for definition). Invasive exotic species occupy several hundred acres of in the lower Elwha watershed (ONP unpublished data). The highest densities of exotic plants directly in the vicinity of Lake Mills occur on the deltas (Figure 19), including several invasive exotic species such as reed canarygrass (*Phalaris arundinacea*), Canada thistle, oxeye daisy (*Leucanthemum vulgaris*), narrow-leaf pea (*Lathyrus sylvestris*) and herb Robert (*Geranium robertianum*). Active control of the exotic plants on the deltas has continued since 2001, yet several of these species persist. This area represents the greatest threat of dispersal of invasive, exotic plants into the basin. As the coarse sediment advances north into the reservoir during dam removal, seeds and plant parts are likely to move with the sediments into the restoration area. Wind will also blow seeds into exposed areas of the basin.

The lands surrounding Glines Canyon Dam are also occupied by populations of invasive exotic plants. The berms on either side of the dam have significant populations of Scot's broom (*Cytisus scoparius*) and common St. John's wort (*Hypericum perforatum*). There are also aggressive non-native grasses such as tall fescue (*Lolium arundinaceum*), velvet grass (*Holcus lanatus*), cheatgrass (*Bromus tectorum*) and common timothy (*Phleum pratense*).

In the forests around Lake Mills, the exotic forb herb Robert is common. This highly invasive species is particularly abundant at the Lake Mills boat launch. Herb Robert is also abundant along Stukey Creek.

LAKE ALDWELL CONTEXT

Lake Aldwell is surrounded by a matrix of managed forest land (Figure 14), and has diverse vegetation types along its shoreline. Along the southwestern portions of the shoreline are the Indian Creek alluvial fan, active side-channels, backwater channels and islands (Figure 20). Sheldon and Associates (1996) identified as wetlands five deltaic depositional islands located at the upstream end of Lake Aldwell representing approximately 78 acres. Forty-seven acres are occupied by a well-developed forested island. The forest island is dominated by red alder and large cottonwoods. There is a diverse assemblage of understory plants including salmonberry, slough sedge (*Carex obnupta*) and skunk cabbage (*Lysichiton americanus*) in the wetter areas, and jewelweed (*Impatiens* sp.) in the drier areas. This area contains a high diversity of plants (particularly mosses) and multiple age-classes of woody vegetation, suggesting long-term stability and a lack of repeated scouring and flooding (Sheldon and Associates 1996).

No old-growth forests remain adjacent to Lake Aldwell. The existing conifer and mixed conifer-hardwood forest developed after logging or burning between 40 and 120 years ago (DOI 1996). Stands are dominated by Douglas-fir, bigleaf maple, western red-cedar, grand fir and lesser amounts of other deciduous species, with an understory of ferns, grasses, forbs and shrubs. There are also some hardwood stands dominated by red alder with smaller amounts of bigleaf maple, black cottonwood, and willow. The margin of Lake Aldwell also has rock outcrop habitats similar to those above Lake Mills.

RARE PLANTS

Given their proximity, the information concerning rare plants in the Lake Mills vicinity is likely to apply to the Lake Aldwell area also. However, surveys should be conducted in the area of any likely habitats for potential state or federally listed species.

INVASIVE, EXOTIC PLANTS

The highest densities of exotic plants directly in the vicinity of Lake Aldwell occur on the forested island near the Lake Aldwell delta (Figure 21). Species of concern are reed canarygrass, Canada thistle, giant knotweed (*Polygonum sachalinense*), Himalayan blackberry and common St. John's wort.

The shoreline of Lake Aldwell is infested with reed canarygrass. If left untreated, this species is poised to invade the reservoir after dam removal (Orr and Stanley 2006). Also along the shoreline are Canada thistle, St. John's wort and peavine species. The Elwha Dam area is also infested with species of concern, including peavine species and Scot's broom.

Other lands around Lake Aldwell also harbor significant populations of invasive exotic species. Clear-cuts on the slopes above the reservoir are likely to contain significant populations of exotic species. Highway 101 runs near the eastern and southern shoreline of the reservoir. The highway corridor contains many exotic species of concern, including peavines, Scot's broom, Himalayan blackberry and knapweeds.

Figure 18. Lake Mills delta in 2009.

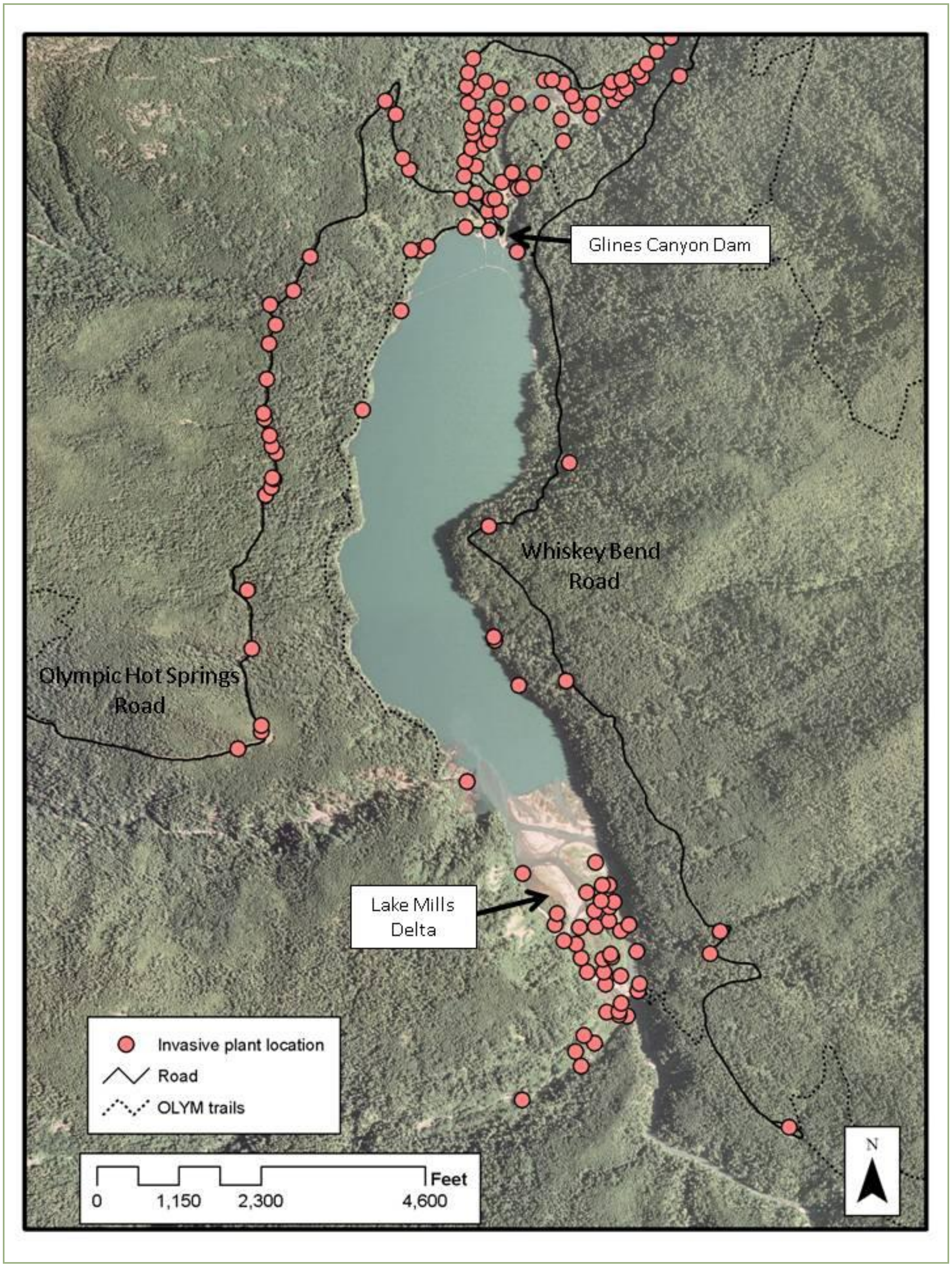

Figure 19. Invasive species locations near Lake Mills. The delta is heavily infested with Canada thistle and herb Robert, and there is one population of reed canarygrass. The shoreline is relatively free of invasive species.

Figure 20. Lake Aldwell delta in 2009.

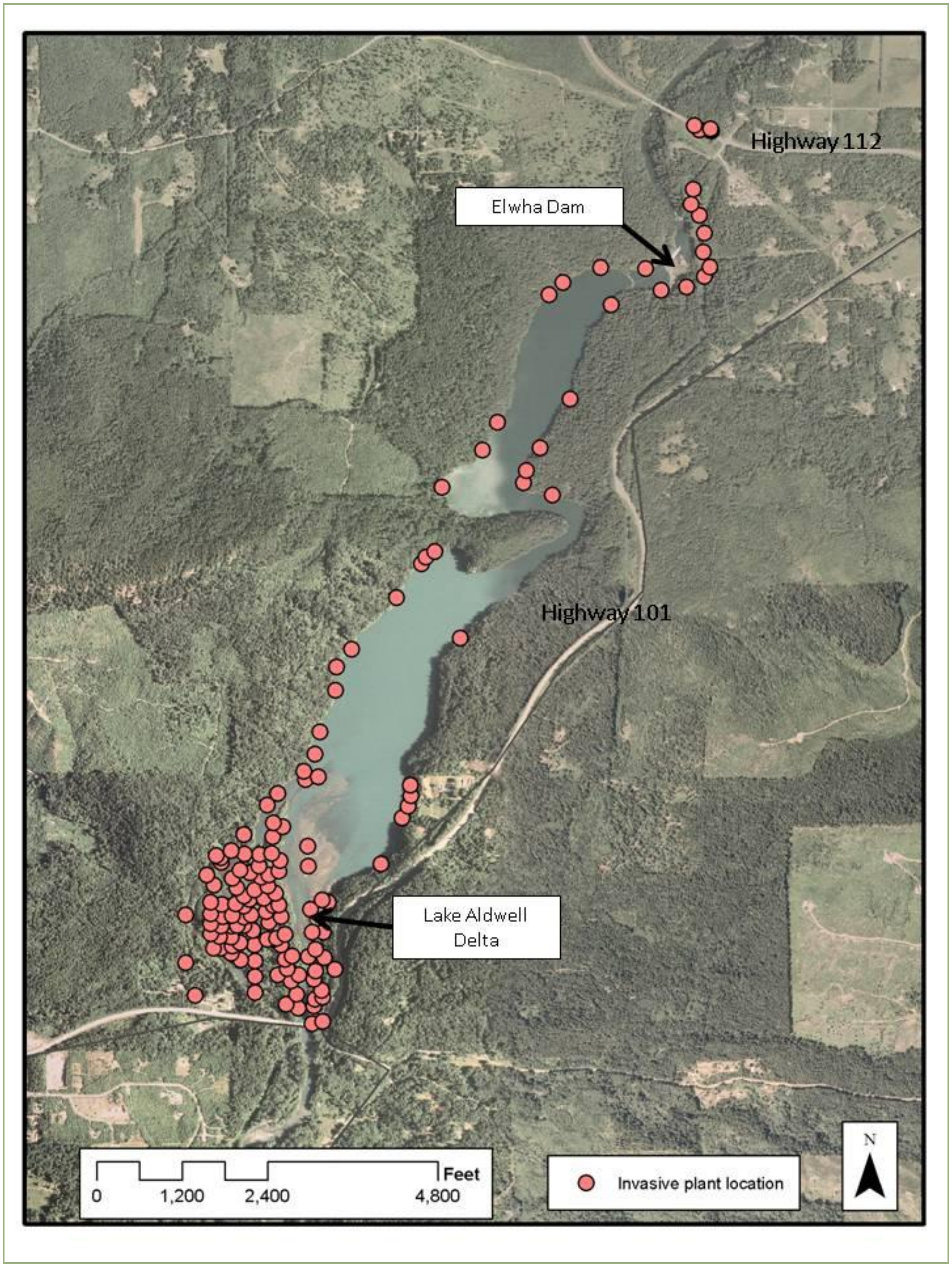

Figure 21. Invasive species locations near Lake Aldwell. The forested island to the west of the delta is highly infested with reed canarygrass, Himalayan blackberry, herb Robert, Canada thistle, and a few patches of giant knotweed. The shoreline has several populations of reed canarygrass. The clearcuts and the highway corridors next to the lake are likely to harbor many more invasive plant populations.

5. EXPECTED CONDITIONS

Together the two dams inundated almost 800 acres. The disturbance to the inundated valleys from the creation and subsequent removal of the two dams after more than 80 years will be severe. Dam removal will expose landscapes devoid of vegetation and covered by inorganic sediments that have accumulated over the last 100 years. Along the continuum from primary succession (i.e., starting with no biological legacies) to secondary succession (i.e., legacies such as intact soils are present) (Walker and del Moral 2003), circumstances following dam removal will be much closer to primary succession. That is, conditions are likely to be more similar to the aftermath of disturbances such as volcanic eruptions or glacial retreat and less similar to conditions after wildfire or wind-throw. Critical processes in the newly exposed landscape such as erosion, nutrient cycling, and hydrology will be severely altered in comparison to vegetated portions of the watershed. Although it is difficult to say with certainty how quickly the reservoirs would naturally recover, rates of primary succession tend to be slow in large, dry and infertile landscapes (Walker and del Moral 2003). The middle portions of the reservoirs would be the slowest areas to recover naturally, since they are far from the rain of seeds, microorganisms and detritus from intact forests.

THE INFLUENCE OF LARGE WOODY DEBRIS

Large wood is expected to have a positive influence on revegetation and restoration of riparian and upland ecosystem processes. Large wood is important for fluvial processes as it provides roughness that can increase bed scour, accelerates fine sediment transport, and increases channel complexity (Montgomery et al. 1996, Beechie and Sibley 1997, Abbe 2000). Large wood buried in floodplains is a key to the formation of heterogeneous riparian forests (Montgomery and Abbe 2006, Latterell and Naiman 2007). Aggregations of large wood in the riparian zone may also provide regeneration niches for highly palatable plants (Schreiner et al. 1996). On the upper slopes of the reservoirs, wood exposed in place or redistributed by restoration staff will be expected to slow erosion (Mussman et al. 2008), provide organic matter, moisture and nutrients to plantings, and create important safe sites for natural regeneration (Chenoweth et al. *in prep.*).

THE INFLUENCE OF RESERVOIR SEDIMENTS

The erosion and redistribution of sediments during dam removal will have a profound influence on vegetation development. Sediment deposition, scouring, and channel avulsions during the first few years after dam removal could be catastrophic to revegetation sites. The method of dam removal will affect the texture and depth of sediments covering the exposed basins. Careful tracking of sediment movement during and immediately after dam removal will be essential to match revegetation actions to specific site conditions. Such information is also relevant for fish restoration (Ward et al. 2007) and sediment management (Tim Randle, U.S. Bureau of Reclamation, personal communication).

The dewatered reservoir basins will be similar to other primary successional habitats, with stressful conditions due to high light intensity, wide temperature swings, low water availability, and nutrient deficiency (Walker and del Moral 2003). Areas with deep silt deposits will be particularly extreme. As the silt dries out during warm dry summers, surface temperature will fluctuate significantly. To add to the stress, water infiltration and percolation rates are slow in dry silty substrates (Brady and Weil 2004). Deep layers of fine sediments left behind in terraces or on the valley wall may become novel ecological islands that inhibit forest development (Chenoweth et al. *in prep*). Coarse-textured sediments are likely to present less of an impediment to succession, based both on the ecological literature (Walker and del Moral 2003), and observation of the deltas on Lake Mills (Cereghino and McClure 2002, Hulce 2009). The exception may be perched terraces of sands and gravels that form during dam removal, creating xeric conditions (Chenoweth et al. *in prep*).

EROSION OF COARSE SEDIMENTS

The Lake Mills delta contains most of the coarse sediments trapped by the dams. As the dam is removed over a period of 2-3 years, lateral movements of river will redistribute most of the delta sediments forward into the receding reservoir pool. This “advancing delta” will slowly move north towards the dam, leaving the entire length and width of the reservoir floor covered with 10 to 20 feet of coarse sediments, burying the layers of fine sediment currently on the reservoir floor. Once dam removal is completed, the river channel will incise down through the layers of coarse and fine sediments, leaving stepped terraces along the reservoir edges (Figure 22). The stepped terraces may be anywhere between 20-60 feet above the original valley bottom. The sudden formation of coarse-textured terraces high above the valley bottom will create dry conditions which may limit establishment of many plant species (Chenoweth et al. *in prep.*).

The movement of sediment in Lake Aldwell will be different from Lake Mills. Erosion of the delta may advance through the reservoir in a similar pattern as in Lake Mills, but will only cover the reservoir floor with up to 3 feet of coarse sediments (T. Randle, personal communication). The gooseneck in the middle of Lake Aldwell (Figure 15) will limit the advance of delta sediments in the northern end of the lake. Therefore, some surfaces in the north end of Lake Aldwell will be covered in at least eight feet of fine sediment after dam removal.

Figure 22. Physical model of Lake Mills sediment erosion (Bromely et al. 2005). The picture shows the predicted topography after dam removal is completed. Notice the terraces that have formed along the reservoir edges.

After dam removal is complete, the continued redistribution of coarse sediments and the stability of the floodplain is difficult to predict, and will depend on river flows. Riparian landforms will be unvegetated and unstable. Until patches of woody vegetation can establish, coarse sediments will readily erode and redistribute downstream, threatening to bury regenerating vegetation.

EROSION OF FINE SEDIMENTS

Erosion of fine sediment into the Elwha River is a concern for salmon restoration and water quality. During dam removal, the fine sediments on the valley walls will not be affected by the erosion and redistribution of the delta.

A recent experimental study suggests that the erosion rate of the fine sediment on slopes may start high but decline quickly. Mussman et al. (2008) measured erosion of fine and coarse sediments from Lake Mills in small boxes (84 x 28 cm), inclined at three slope angles (1°, 5° and 15°) and exposed to simulated high- (19 cm/hr) and low-intensity (3 cm/hr) rainfall. The fine sediment exhibited significantly higher rates of erosion than the coarse sediments at all slope angles. Erosion rates for the fine sediment under low-intensity rainfall were 14 times (5°) and 55 times (15°) the USDA maximum tolerable loss for agricultural soils (Mussman et al. 2008). The study measured the erosion over a two-day period. Erosion significantly declined on the second day of the study. Mussman et al. (2008) credited the decreased erosion on the second day to newly exposed woody debris.

Some, but not all, of the fine sediments covering the valley walls are expected to erode during rain events, leaving behind layers of fine sediments which will be revegetated.

NATIVE SPECIES PERFORMANCE IN THE SEDIMENTS

Coarse sediments generally will not inhibit development of native vegetation. Much of the area on the coarse-textured deltas has been colonized by native species (Hulce 2009). However, newly-formed terraces high above the water table may be slow to develop complex vegetation due to severe water stress. Few species will be suited to colonize these surfaces once the residual groundwater has drained. However, soil moisture on these terraces will probably decline slowly as the dams are removed.

Although most of the fine sediments are expected to be washed out of the reservoirs or buried by coarse sediment, some terraces or valley wall landforms covered by deep layers of fine sediments are likely to remain. The physical properties of the fine sediments can impede the establishment of many native plants common to Elwha valleys (Figure 23). Native woody species may not readily establish in the fine sediments (Grubb 1986). The material is floury and talc-like, non-plastic, and lacks cohesion. It does not compact and remolds easily under pressure. When wetted it becomes runny, easily forms rills and loses load-bearing strength. It is highly susceptible to frost heave. Due to lack of pore space, oxygen diffusion to plant root zones is likely to be slow and the sediment will have reduced hydraulic conductivity as it dries. Surface temperature fluctuations could be extreme after the material dries. When fully dried it is likely to be prone to wind erosion. Fibrous-rooted species such as grasses are expected to perform better in these conditions than tap-rooted woody plants (Grubb 1986, Walker and del Moral 2003).

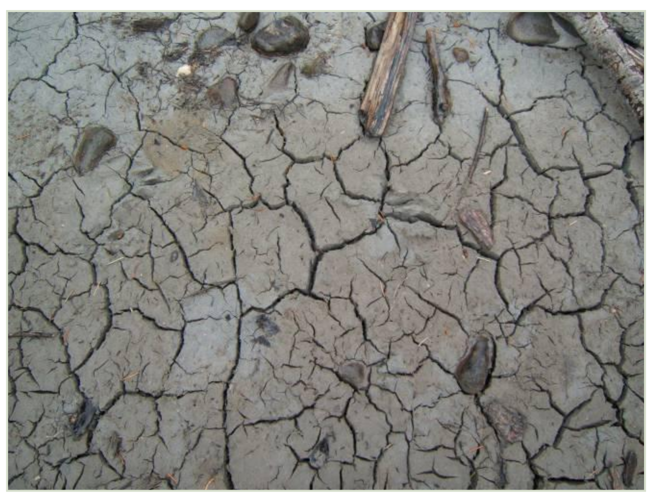

Figure 23. Fine sediments on the valley wall of Lake Mills. Picture taken one week after the 2009 drawdown.

An abundance of moss and lichen spores are likely to be present in the fine sediments, and may create a biotic crust on the surface (Chenoweth 2007).

Biotic crusts are known to stabilize erosive surfaces, provide surface heterogeneity, and promote soil formation (Walker and del Moral 2003).

NATIVE SPECIES PERFORMANCE ON THE ORIGINAL FOREST SOILS

In places where the mantle of sediment is thin, revegetation will take place on long-inundated forest soils. Prior to inundation, soils in the valley bottom were mapped as sandy gravels, and upland soils as shot clay and rock. The chemistry of these soils and their suitability as a growing medium after more than 80 years in an anaerobic state is unknown.

6. REVEGETATION PERIODS

The revegetation process is separated into four periods: pre-dam removal (2002 to 2010), dam removal (2011 to 2014), revegetation installation (2013 to 2016), and post-installation (2017-2024). Strategies for exotic plant management and revegetation are designed to adapt to the changing circumstances expected during the different periods. The periods are based on DOI estimates for dam demolition. A contract for demolition was awarded in August 2010, and a final demolition schedule is expected by April or May 2011. The periods are described below.

PRE-DAM REMOVAL (2002 TO 2010)

The dams will remain in place and will be operated by Bureau of Reclamation (BOR) to generate power until June 2011. Dam demolition will begin in September 2011. During this period, revegetation activities will primarily focus on invasive exotic species control and propagating native plants in preparation for revegetation activities.

DAM REMOVAL (2011 TO 2014)

The method and timing of dam removal will be determined by the contractor. Current estimates predict dam removal will require three years to complete. Work will be suspended during “fish windows” (intervals when fish enter or leave the river, and so are susceptible to elevated turbidity), and when the river flow is greater than 1,500 cfs. The demolition schedule in Figure 24 is based on a sequence of years when river flows were near long-term averages. Based on the predicted method of removal, the reservoir will have receded 49 feet within 3 months of the start of dam removal, exposing about 23% of the reservoirs. After nine months, 36% of the reservoirs would be exposed. After 15 months, 48% of the reservoirs would be exposed, and after 21 months, 64% would be exposed. Dam demolition would be completed after 36 months. Frequent high flow events would delay completion, while lower than average flows could accelerate demolition. Revegetation activities will adapt to the schedule as needed.

During demolition, restoration staff will map the land as it becomes exposed, map and treat invasive exotic plant species, continue plant propagation, and begin experimental plantings, with a focus on establishing dense patches of vegetation. Planting experiments will be designed to learn which planting strategies and native species are most successful in the various conditions encountered in the reservoirs.

REVEGETATION INSTALLATION (2014 TO 2016)

After dam removal is completed, revegetation will shift from experimentation to full restoration of the exposed lands. During this period, efforts will initially focus on revegetating the terraces in the valley bottom zone and the upland landforms in the valley wall zone. The floodplain will be left to natural processes during this period (see revegetation strategies).

POST-INSTALLATION (2017-2024)

After the revegetation installation period, continued monitoring and maintenance will ensure that the installed plants survive and invasive exotic species do not attain dominance. The river channel will become more stable during this period (BOR 1996), and restoration staff will actively revegetate some of the floodplain and plant later-seral species in other areas where appropriate.

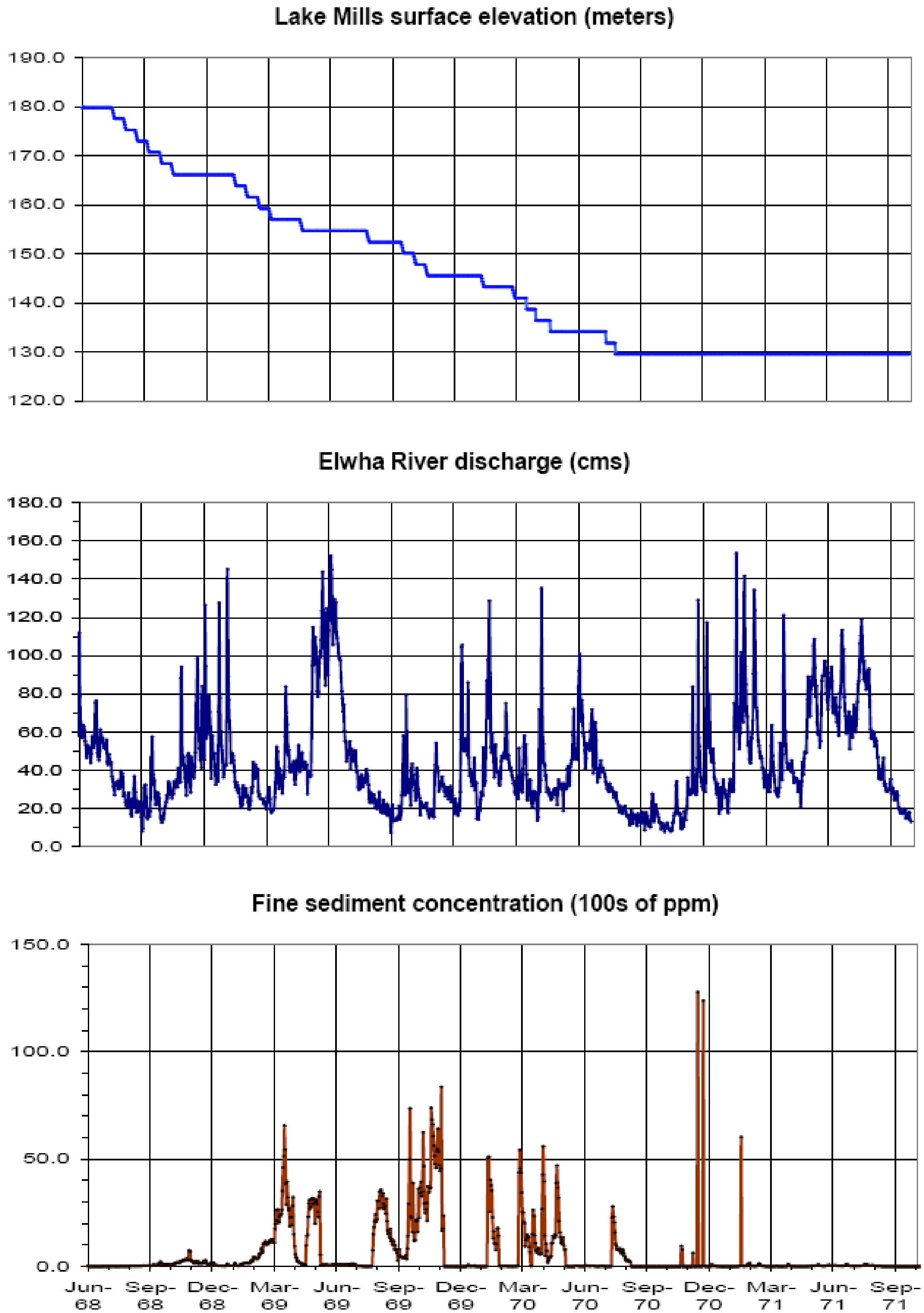

Figure 24. Lake Mills surface elevations during dam removal. Modeled Lake Mills surface elevations, Elwha River discharge, and suspended sediment concentrations during dam deconstruction. Model is based on 1968-1971 flow scenario (BOR 1996). Current dam deconstruction estimates follow this model, with Jun '68 representing the beginning of dam removal.

7. RESTORATION GOALS AND OBJECTIVES

The restoration of the two reservoir basins requires clear short-term and long-term goals that are measurable and attainable (Whisenant 2003, Walker and del Moral 2003, Temperton et al. 2004, Society for Ecological Restoration International Science & Policy Working Group 2004, Clewell et al. 2005). The goals articulated in this chapter encompass the restoration objectives in the Implementation EIS (DOI 1996) and are based on modern ecological theories which emphasize ecosystem processes rather than fixed endpoints based on historical biotic communities.

Goals are not subject to empirical determination, since they "require measurements of innumerable parameters that are constantly subject to change on account of ecosystem dynamics" (Clewell et al. 2005). Objectives are subject to empirical determination, and can be used to indicate success or failure in achieving goals (Clewell et al. 2005). Thus, the goals presented here are comprehensive principles for both reservoirs which must be achieved for the project to be successful. The short-term and long-term objectives for the project will allow us to measure progress towards the goals.

RESTORATION GOALS

The three goals for revegetation following removal of the dams on the Elwha River are:

1. Minimize invasive, exotic species
2. Restore ecosystem processes
3. Establish native forests

MINIMIZE INVASIVE, EXOTIC SPECIES

This is arguably the most important goal of the project. Invasive, exotic species are a major threat to biodiversity (Wilcove et al. 1998) and can inhibit native plant succession (Vitousek et al. 1987, D'Antonio and Vitousek 1992, LeJuene and Seastedt 2001, Orr and Stanley 2006, Rudgers et al. 2007, Urgenson et al. 2009). Invasive, exotic species may also change successional trajectories by altering soil chemistry or modifying disturbance regimes (D'Antonio and Vitousek 1992, Smith et al. 2000, Mack et al. 2000, Walker and del Moral 2003). Dam removal will create large areas devoid of vegetation, providing opportunities for exotic plant species to colonize and attain dominance. Riparian zones are particularly susceptible to invasion by exotic plants (Hood and Naiman 2000). In addition to preventing invasion of the reservoirs by aggressive exotic species, successful salmon recovery will require controlling invasive species degrading aquatic habitats throughout the lower watershed, such as wall-based channels (Peterson and Reid 1984, Scarlett and Cedarholm 1984) and Elwha tributaries. If left unchecked, there is the potential for the former reservoir areas to serve as seed sources of exotic species for invasion into ONP's wilderness.

Active control of exotic species in the Elwha watershed began in 2002 and will continue throughout the project. Specific locations where restoration activities will be concentrated, such as staging areas, must be clean of all invasive exotic species prior to dam removal.

Active revegetation will accelerate succession and will help reduce the amount of open space available for exotic species invasion. Rehabilitation of Lake Aldwell will require a more intensive treatment of exotic species, since it is surrounded by a disturbed matrix that likely harbors higher densities and more species of exotic plants. Additionally, Lake Aldwell sediments may be higher in nutrients and organic matter than Lake Mills' sediments, due to a higher level of development and disturbance upstream in the valley of Indian Creek, a tributary which enters at the upstream end of Lake Aldwell.

RESTORE ECOSYSTEM PROCESSES

Whisenant (2003) identifies three major processes that are essential to a healthy ecosystem. These are soil formation (opposite of soil erosion), nutrient cycling, and water flow. Soil formation is a slow process, but the addition and retention of organic matter from plants is essential to healthy soils. Nutrient cycling depends on plant-soil interactions. Plants extract and mobilize essential nutrients from inorganic minerals, and decomposing plant matter provides soils with soluble nutrients which plants use. Landscapes devoid of plants will lose nutrients, resulting in an ecosystem with low productivity. In a productive ecosystem, vegetation and organic matter provide some level of control over these processes. Plants capture water in their canopies, increase soil infiltration with complex root systems, create organic matter that builds soils, and provide a physical barrier to trap particles such as seeds, detritus or eroding soil.

Controlling the erosion of fine sediments from the dewatered basins into the river is critical for restoration of anadromous fish (Ward et al. 2007). However, during dam removal, the erosion of fine sediments will benefit revegetation and will not significantly increase the sedimentation of the river. After dam removal is complete, all slopes steeper than 5˚will be seeded to reduce surficial erosion. Over time, succession from grasses and forbs to woody plants will provide long-term slope stability and erosion control. Natural and artificial revegetation of the basins will also capture nutrients and water, increasing the nutrient and water availability in the restored reservoirs. Specific strategies to achieve these goals for each basin will be discussed later in this document.

In the longer-term, restoring the processes linking floodplain forests and the river is critical for success of fish restoration (Ward et al. 2007). Well-developed floodplain forests will provide shading to help regulate water temperature, provide inputs of litter to fuel aquatic food webs, capture fine sediments and stabilize floodplain islands (Kollman et al. 1999), and eventually provide large wood which will enhance in-stream habitat (Gregory et al. 1991, DOI 1995, 1996, Apostol and Berg 2006).

ESTABLISH NATIVE FORESTS

Native vegetation in the Elwha watershed is dominated by trees. Forests are particularly important to riparian ecological processes (Gregory et al. 1991, Fetherston et al. 1995, Abbe and Montgomery 2003, Naiman et al. 2005). There are a variety of forest types, coniferous and deciduous, that occur from the valley bottom to steep valley walls. These forests are quite heterogeneous in species composition and structure. Communities dominated by herbaceous species are restricted to wetlands and highly disturbed floodplains. The few meadows present in the Elwha are legacies of homesteads from the first half of the 20th century.

Revegetation prescriptions will be designed to accelerate development of native forests. Establishing forests is critical to the restoration of ecosystem processes. Forests stabilize slopes, moderate peak flows by slowing down the flow of water to rivers, and provide significant quantities of organic matter and nutrients to terrestrial and aquatic ecosystems. Typical upland forests are dominated by conifers while riparian plant communities are often dominated by deciduous trees (Fonda 1974, Van Pelt et al. 2006). Mature forests in floodplains and along tributaries are important elements of salmon habitat. Tree canopies provide shade over slow-moving, wall-based channels, keeping water temperatures cool. Large trees that develop in the floodplain are sources for woody debris critical to the development of in-channel complexity.

Forests develop on the scale of decades to centuries, and the successional pathways in the dewatered reservoirs are unpredictable and may result in unique, native communities that do not have contemporary analogs. The major goal of this project is to ensure that the plant communities that do form are forested communities dominated by native species. It will require several decades before the success or failure of achieving this goal can be assessed.

RESTORATION OBJECTIVES

Short-term objectives will guide restoration practitioners during the first several years after the start of dam removal. The objectives are designed to be practical to measure and provide immediate information to restoration practitioners to guide subsequent activities.

SHORT-TERM OBJECTIVES

Short-term restoration objectives:

1. Exotic plant species do not dominate the cover of regenerating vegetation.
2. Cover of native plants increases annually.
3. Cover of bare ground decreases on valley wall landforms and upland terraces.
4. Native woody plants are establishing on all landforms and are increasing in cover relative to other lifeforms.
5. Surficial erosion of upland landforms decreases.

LONG-TERM OBJECTIVES

Long-term objectives include stabilizing ecosystem processes such as nutrient cycling, soil-surface stability, and riparian-aquatic interactions. Long-term objectives will be achieved when attributes influencing important ecosystem processes (e.g., bare ground as an indicator of potential erosion) fall within the range of natural variability. Natural variability is defined as the "ecological conditions, and the spatial and temporal variation in these conditions, that are relatively unaffected by people, within a period of time and geographical area appropriate to an expressed goal" (Landres et al. 1999). Changes in these ecosystem attributes are often gradual, and it may require several years or decades before such attributes return to the range of natural variability.

Long-term objectives for vegetation composition also include exotic species, plant community types, recruitment of native plants and biological diversity. Invasive, exotic species could disrupt restoration at any time. Evaluation of plant community types at the landscape scale can be assessed by considering the proportion of both basins covered in meadows, shrublands, and forests. Meadows are naturally a minor component of valleys in the Elwha drainage, so plant community composition will be fully restored when the dewatered basins are dominated by forests.

Bakker et al. (2000) argues that a clearly defined target for biological diversity is essential in large ecosystem restoration projects. Alluvial valleys in the lower Elwha contain a diverse mixture of vegetation (for example, Geyser Valley has at least 18 vegetation types and at least 244 native vascular plant species). Restoration of the dewatered reservoir basins should result in a diverse array of vegetation that will eventually support a large number of native plant species. Rather than targeting a specific number of plant species, the long-term objective will be to establish a diversity of vegetation types.

Five long-term objectives for this project:

1. Exotic species cover is within the range of variation observed in reference communities.
2. The cover of bare ground on upland landforms is within the range of variation observed in reference communities.
3. The structure, diversity and tree species composition of riparian forests is within the range of variation observed in reference communities.
4. Proportions and diversity of physiognomic vegetation types (i.e., grasslands, shrublands, and forests) are within the range of variation for unmanaged valleys in the lower Elwha drainage.
5. Diversity of plant associations is within the range of variation for unmanaged valleys in the lower Elwha drainage.

8. INVASIVE EXOTIC SPECIES MANAGEMENT

Invasive exotic species are defined as exotic species capable of diverting or arresting native plant succession, or damaging or altering essential ecological processes. A combination of various tools was used to identify the exotic plant species most likely to impede restoration. NatureServe has ranked the invasibility of exotic species nationally using the Invasive Species Assessment Protocol (Morse et al. 2004). All of the exotic species known to occur in the Elwha were compared to the NatureServe rank. Species with a rank of “medium” or higher were checked against the exotic species assessment for Olympic National Park (Olson et al. 1991). Each species was also checked for inclusion on the Washington State and Clallam County noxious weed lists. For exotic species not assessed by NatureServe and not on any noxious weed list, observed invasiveness in the Elwha over the last 10 years was considered. Through this process, twenty “primary species of concern” in the Elwha watershed were identified (Table 3).

PRIMARY SPECIES OF CONCERN

The primary species of concern were mapped in 2001 and in 2008 (Figure 25). The 2001 mapping project focused on the two reservoirs and the roads and trails north of Lake Mills within park boundaries. The 2008 mapping project expanded the areas searched to include the Olympic Hot Springs road north of the ONP boundary, Geyser Valley, and all trails and road areas (campgrounds, maintenance areas) south of Lake Mills not searched in 2001. The mapping projects focused on roads, trails and floodplains, and did not map areas off-trail in the upland forests above the Elwha. Other areas not mapped that may serve as sources of exotic plants to the project area are the managed forest lands above Lake Aldwell, the floodplains north of the Elwha Dam, Indian Valley, Little River Valley and the Herrick Road area (Woodward et al. 2011). The primary species of concern are abundant in the watershed but appear to be at manageable levels and will be the focus of treatment efforts throughout the project. Primary species of concern will be prevented from establishing in the dewatered reservoirs for the duration of this project.

SECONDARY SPECIES OF CONCERN

A secondary list, the “secondary species of concern,” includes exotic species which may be invasive, but are so common in the lower watershed that it is not practical to treat them on the scale of the watershed (Table 4). These species will be treated only in the dewatered reservoirs during and after dam removal. The goal is to not allow these species to become dominant; it is acknowledged that these species will establish in the dewatered reservoirs. If any of these species do attain dominance, management strategies will be adapted to re-establish native plant dominance.

WATCH LIST

Other invasive species known to occur in Washington State that are not present in the Elwha watershed or are present in the watershed but are far from the reservoirs may become a threat during the project. They are listed on a watch list (Table 5). Several of these species occur in Clallam County, and two of them, butterfly bush (*Buddleja davidii*) and traveler's joy (*Clematis vitalba*), occur in the watershed downriver of the dams. Butterfly bush can be particularly invasive in riparian floodplains, and is a problem along the Dungeness River, the next major watershed to the east of the Elwha. Any species from the watch list will be treated aggressively if it appears in priority sites in order to prevent establishment in the dewatered reservoirs.

ADAPTIVE MANAGEMENT OF EXOTIC SPECIES

Since it is difficult to predict which exotic species will become invasive in the newly exposed lands, an adaptive management plan that identifies and evaluates all exotic plants establishing in the dewatered reservoirs is essential (Hiebert et al. 2002). Any exotic plant species can become invasive in the unique conditions associated with the dewatered reservoirs. It will be important to determine the potential effect any exotic species may have in the newly-exposed lands. Not all thriving populations of exotics will be detrimental to native plant communities. For example, the winter annual *Senecio sylvaticus* aggressively invades newly-disturbed sites in the Pacific Northwest only to naturally decline in abundance within a few years (Halpern et al. 1997). Such populations would not need to be treated.

Therefore, the following guidelines will be implemented to ensure the reservoirs are not dominated by any exotic plant species.

- Early detection of new exotic populations.
  - Inspect the entire reservoir several times a year and document all exotic plants.
- Evaluate each new species discovered for potential invasiveness.
- Evaluate population trends of exotic species not treated.

EARLY DETECTION AND EVALUATIONS OF EXOTIC POPULATIONS

Restoration staff will follow the guidelines for monitoring and evaluating invasive species outlined by Hiebert et al. 2002. The most effective way to identify pioneering exotic species will be to train monitoring and planting crews to identify all species that are common in the Elwha. As crews work and travel in the dewatered reservoirs, they will be responsible for identifying colonizing plants. Unknown species will need to be identified with the assistance of a trained botanist (the technical lead). The technical lead will also be responsible for inspecting the dewatered reservoirs several times each year. In addition to on-the-ground inspections, the technical lead will be responsible for annually evaluating the Washington State Noxious Weed list and the Clallam County Noxious Weed list to stay current with new information or new invasions that may be occurring in Washington State. When exotic species not listed on any of our three lists are found to be establishing in the dewatered reservoirs, the technical lead will evaluate the potential invasiveness by reference literature and by contacting experts in the field. Even if a species is not considered invasive in the literature, known populations will be monitored in order to observe the growth patterns and changes in number of patches and patch sizes. If a species (particularly a perennial species) displays radical patch expansions, exponential increases in number of patches, vigorous growth rates, abundant seed production, and/or creates monocultures, the species would be considered invasive and appropriate actions taken.

Table 3. Primary list of invasive exotic species of concern. Species on this list are the focus of treatment efforts during all stages of the project on a watershed scale.

Species	Common Name	Life Form	NatureServe I-Rank	WA State Noxious Weed List	Clallam Co Noxious Weed List
Bromus tectorum	cheatgrass	Graminoid	HIGH	NA	NA
Centaurea jacea	brown knapweed	Forb	UNKNOWN	Class B	Class B-des
Cirsium arvense	Canada thistle	Forb	HIGH/MEDIUM	Class C	Class C
Cytisus scoparius	Scot's broom	Shrub	HIGH	Class B	Class B-select
Geranium robertianum	herb Robert	Forb	not assessed	Class B	Class B-non
Hedera helix	English ivy	Vine	HIGH/MEDIUM	Class C	NA
Hypericum perforatum	common St. John's wort	Forb	HIGH/MEDIUM	Class C	Class C
Ilex aquifolium	English holly	Small tree	HIGH/LOW	NA	NA
Lathyrus latifolius	perennial pea	Forb	not assessed	NA	NA
Lathyrus sylvestris	small everlasting peavine	Forb	not assessed	NA	NA
Linaria vulgaris	butter and eggs	Forb	HIGH/LOW	Class C	Class C
Phalaris arundinacea	reed canarygrass	Graminoid	HIGH	Class C	Class C
Polygonum cuspidatum	Japanese knotweed	Shrub	HIGH	Class B	Class B-non
Polygonum sachalinense	giant knotweed	Shrub	HIGH	Class B	Class B-non
Polygonum x bohemicum	Bohemian knotweed	Shrub	HIGH	Class B	NA
Potentilla recta	sulfur cinquefoil	Forb	HIGH/MEDIUM	Class B	Class B-des
Prunus laurocerasus	Laurel cherry	Shrub	not assessed	NA	NA
Rubus discolor	Himalayan blackberry	Shrub	MEDIUM/INSIGNIFICANT	NA	NA
Rubus laciniatus	evergreen blackberry	Shrub	not assessed	NA	NA
Senecio jacobaea	tansy ragwort	Forb	LOW	Class B	Class B-select

Table 4. Secondary list of invasive exotic species of concern. These species are common in the lower Elwha, and will only be managed in some priority treatment sites and within the reservoir during and after dam removal.

Species	Common Name	Life Form	NatureServe I-Rank	WA State Noxious Weed List	Clallam Co Noxious Weed List
Agrostis gigantea	giant bentgrass	Graminoid	MEDIUM	NA	NA
Agrostis stolonifera	creeping bentgrass	Graminoid	MEDIUM/LOW	NA	NA
Dactylis glomerata	Orchard grass	Graminoid	Not assessed	NA	NA
Digitalis purpurea	purple foxglove	Forb	MEDIUM/INSIGNIFICANT	NA	NA
Elytrigia repens* var. *repens	quackgrass	Graminoid	HIGH/MEDIUM	NA	NA
Holcus lanatus	common velvet grass	Graminoid	HIGH/MEDIUM	NA	NA
Leucanthemum vulgare	ox-eye daisy	Forb	MEDIUM/LOW	Class B	Class B-non
Lolium arundinaceum	tall fescue	Graminoid	HIGH/MEDIUM	NA	NA
Phleum pratense	common timothy	Graminoid	MEDIUM	NA	NA
Ranunculus repens* var. *repens	creeping buttercup	Forb	Not assessed	NA	NA
Rumex acetosella	Common sheep sorrel	Forb	MEDIUM/LOW	NA	NA

Table 5. Invasive species "watch list." These species are either not present in the Elwha watershed or are far from the reservoirs. Restoration staff will monitor the project area and aggressively treat any of these species if they arrive close to or within the reservoirs during any stage of the project.

Species	Common Name	Life Form	NatureServe I-Rank	WA State Noxious Weed List	Clallam Co Noxious Weed List
Acer platanoides*	Norway maple	Tree	HIGH/MEDIUM	NA	NA
Ailanthus altissima	tree-of-heaven	Tree	MEDIUM	NA	NA
Buddleja davidii*	butterfly bush	Shrub	HIGH/LOW	Class B	Class B-non
Centaurea solstitialis	yellow star thistle	Forb	HIGH/MEDIUM	Class B	NA
Centaurea montana	mountain star thistle	Forb	not assessed	NA	NA
Centaurium erythraea	common centaury	Forb	not assessed	NA	NA
Clematis vitalba*	evergreen clematis	Vine	MEDIUM	Class C	Class C
Conium maculatum	poison hemlock	Forb	MEDIUM/LOW	Class C	Class B-des
Daphne laureola	spurge laurel	Shrub	MEDIUM/INSIGNIFICANT	Class B	Class B-non
Echium vulgare	common viper's-bugloss	Forb	UNKNOWN	Class B	Class B-des
Heracleum mantegazzianum	giant hogweed	Forb	MEDIUM	Class A	Class A
Hieracium aurantiacum*	orange hawkweed	Forb	MEDIUM/LOW	Class B	Class B-des
Iris pseudacorus	yellow iris	Forb	HIGH/MEDIUM	Class C	Class C
Leucanthemum maximum	Shasta daisy	Forb	not assessed	NA	NA
Linaria dalmatica ssp. dalmatica	dalmatian toadflax	Forb	not assessed	Class B	Class B-des
Lythrum salicaria	purple loosestrife	Forb	HIGH	Class B	Class B-des
Petasites japonicus	Japanese butter-bur	Forb	not assessed	NA	NA
Polygonum polystachyum	cultivated knotweed	Forb	HIGH/LOW	Class B	Class B-non
Rubus odoratus var. odoratus	purple-flowering raspberry	Shrub	not assessed	NA	NA
Rubus vestitus	European blackberry	Shrub	UNKNOWN	NA	NA
Silene latifolia ssp. alba	white campion	Forb	not assessed	Class C	Class C
Ulex europaeus	gorse	Shrub	not assessed	Class B	Class B-des

* present in the watershed, but not currently considered a direct threat to the reservoirs.

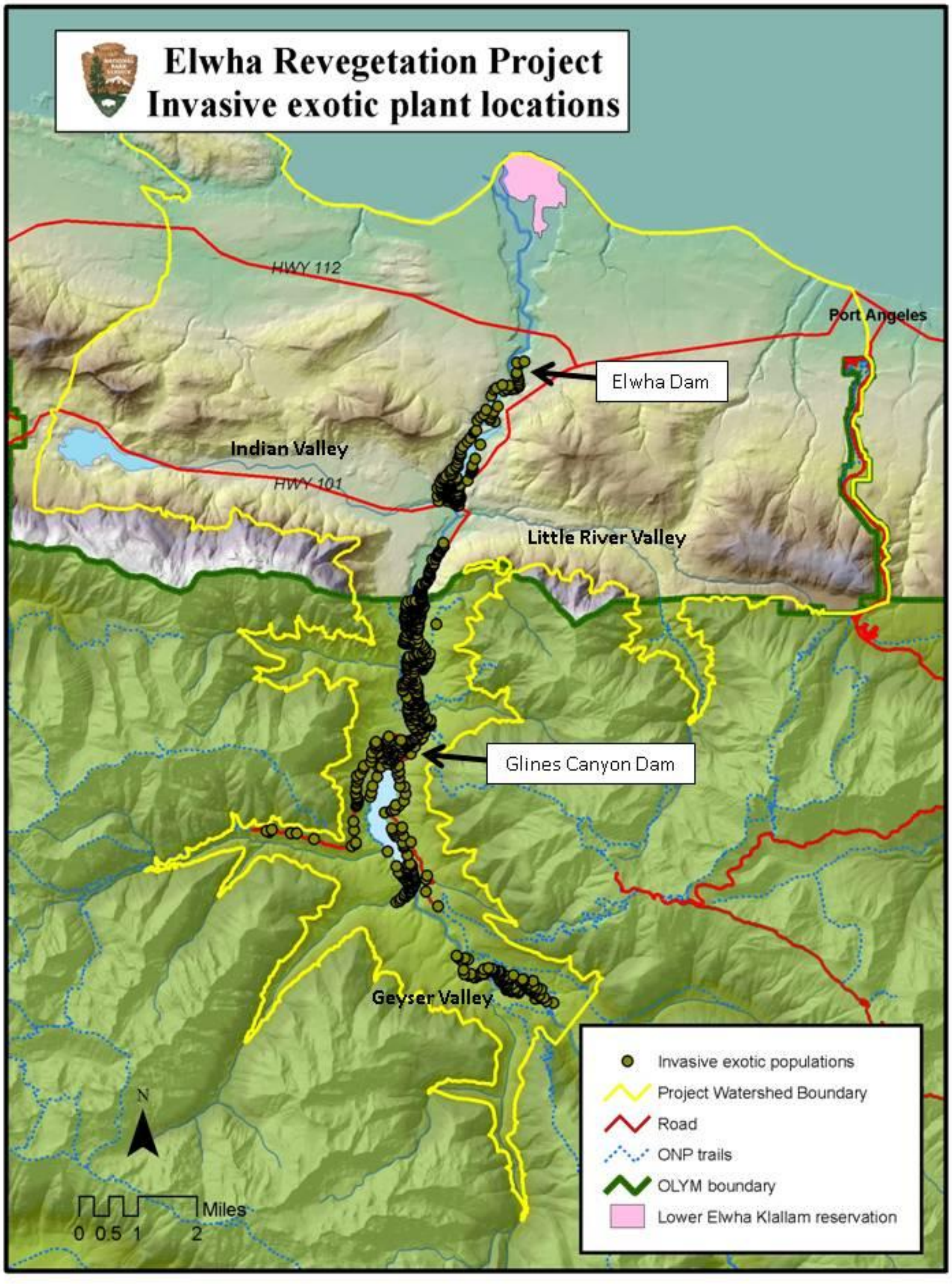

Figure 25. Locations of invasive species of concern near the project areas. Not all areas of concern were mapped, including Indian Valley, Little River Valley, and the river floodplain north of the Elwha Dam.

INVASIVE SPECIES CONTROL STRATEGIES

Strategies for controlling invasive exotic species will differ for each revegetation period. Prior to dam removal, restoration staff will work at the watershed scale to reduce established populations and limit the opportunity for propagules to disperse into the dewatered reservoirs (Von Holle and Simberloff 2005). During demolition, work at the watershed scale will continue but the priority will shift to evaluating and eradicating pioneering populations of exotics in the newly-exposed areas. After dam removal, efforts will focus on the exposed reservoirs. New trails and roads established in the dewatered reservoirs will be major pathways for moving invasive plants. Therefore, preventing introductions along access trails and roads will be a priority during and after dam demolition. The technical lead will be responsible for adapting control strategies as the project progresses.

Mechanical removal (hand-pulling, cutting) and chemical spot-treatment with herbicides began in 2002. Beginning in 2009, the primary method of control shifted to the use of herbicides. Herbicides in use include Garlon 3, AquaNeat and Milestone. All herbicides used in this project are approved by the EPA. The only herbicide identified for use on exotic populations near water is AquaNeat. AquaNeat is approved by the EPA for use in or near water. A complete list of herbicides, active ingredients, surfactants and application methods are listed in appendix C. In some areas, herbicide treatments will be followed by plantings to shade out sun-loving invasives. Creating dense shade with live-stakes of willow and other species is effective at preventing re-infestations of sun-loving invasive species, such as reed canarygrass (Kim et al. 2006). This strategy will be implemented at sites treated for other sun-loving invasive species. For each revegetation period, treatments by site and species have been prioritized. Within high-priority sites, the intention is to eradicate all populations of invasive exotic species, large and small, since small nascent populations can proliferate and spread more quickly than large populations (Moody and Mack 1988).

The season for treating invasive exotic species in the Pacific Northwest is from June until late summer. Two crews have been treating invasive plant species in the lower Elwha: a four-person crew from the Lower Elwha Klallam tribe (LEKT) and a crew from NPS (Exotic Plant Management Team, or EPMT). Beginning in 2008, NPS and LEKT have coordinated their efforts under the direction of the project's technical lead. The LEKT crew works exclusively within the Elwha watershed (within and outside the park). The EPMT serves NPS units throughout Washington and northern Oregon, generally works only on federal lands, and typically works in the Elwha drainage only a few weeks per year.

PRE-DAM REMOVAL PERIOD (2002-2010)

Controlling invasive exotic species prior to dam demolition is an important strategy to minimize invasions of the reservoirs during and after dam removal. All target species populations cannot be eliminated before dam removal, so control efforts have been prioritized to focus on areas that present the greatest threat to the reservoirs (Woodward et al. 2011). These areas include the Lake Mills delta, the forested island on Lake Aldwell, the reservoir shorelines, and the berms around the dams (Table 6). Future staging areas and access points will also be aggressively treated. The floodplains upriver and between the dams are another priority, since the river is effective at moving propagules (Brown and Chenoweth 2008). Additional locations of known invasive species with high potential to impact the reservoirs were identified by Woodward et al. (2011).

The technical lead will be responsible for evaluating the efficacy of treatment efforts and will reassess site priorities annually.

Table 6. Site priorities for treatment of invasives *before dam removal*

Site	Invasive species present as of 2009
Forested island on Lake Aldwell	Numerous invasive species; reed canarygrass and giant knotweed primary concern
Lake Aldwell shoreline	Reed canarygrass, St. John's wort, Canada thistle
Lake Mills delta	1 patch of reed canarygrass. Herb Robert, Canada thistle, and St. John's wort are abundant
Berms around the dams	Cheatgrass, Scot's broom, peavines, St. John's wort, and many grasses on secondary list.
Future access points to reservoirs	Herb Robert
Future staging areas	Herb Robert
Lake Mills shoreline	2 herb Robert sites and 2 Canada thistle sites
Floodplains between the dams	Numerous invasive species; reed canarygrass primary concern
Geyser Valley	Heavily infested with Canada thistle
Power line corridors	Himalayan blackberry, Canada thistle

DAM REMOVAL PERIOD (2011-2014)

During dam removal, priority sites in the watershed will continue to be treated as identified in Table 7. The focus during this period will shift to the land exposed as the reservoirs recede. Eradicating pioneering populations in the reservoirs will be the highest priority during and after dam removal (Moody and Mack 1988). As the reservoirs recede, exposed areas will be closely monitored for exotic plant invasions. Primary and secondary species of concern, as well as those species on the watch list, will be aggressively treated.

Treatment efforts during the pre-dam removal period will inevitably change the species patterns at priority sites. Therefore, the technical lead will reevaluate the site priorities and the abundance of the primary species of concern at the watershed scale during dam removal.

Table 7. Site priorities for treatment of invasives *during dam removal*.

1. Dewatered areas
2. Reservoir shorelines
3. Access points to reservoirs (before development in 2012)
4. Staging areas
5. Floodplains above the reservoirs (Geyser Valley and river above Aldwell)
6. Power line corridors
7. Other sites in watershed as per Woodward et al. 2011

REVEGETATION INSTALLATION PERIOD (2014-2016)

After dam removal, control of invasive plants on the watershed scale will continue as needed. However, the priority will be sites within the reservoir basins (Table 8). To complement treatment efforts, native species will be planted. Establishing native woody species that produce dense shade should inhibit shade-intolerant invasive exotic plants. Although most of the high-priority invasive species tend to invade open and disturbed sites, shade-tolerant invasive species also pose a threat to the project (Martin et al. 2009). Dense plantings are likely to limit invasion by shade-tolerant exotic species by pre-emption.

Priority sites for exotic treatment efforts within the reservoirs will be fine-textured, upland terraces. Fine-textured substrates are preferentially colonized by graminoids (Grubb 1986) and invasive exotic grasses are common in the Elwha drainage. Therefore, a primary focus of invasive exotic control efforts during this period will be eradicating any exotic grasses establishing on fine-textured terraces.

Funding for the LEKT exotic control crew is scheduled to terminate at the end of fiscal year 2014, ending full-time treatment efforts in the Elwha project areas. The EPMT crew will continue to treat the project areas part-time.

Table 8. Site priorities for treatment of invasives *during revegetation installation*

1. Dewatered reservoir, with focus on fine sediment terraces
2. Re-contoured berms
3. Access points to reservoirs
4. Staging areas
5. All adjacent areas
6. Floodplains above the reservoirs (Geyser Valley and river above Aldwell)
7. Other sites in watershed as per Woodward et al. 2011

POST-INSTALLATION PERIOD (2017-2018)

Control priorities during this period will depend on the efficacy of control efforts during the first three periods. Three years of monitoring data collected in the dewatered reservoirs (see Chapter 11) will direct long-term control strategies.

Table 9. Site priorities for treatment of invasives *during post-installation*

1. Dewatered reservoir, with focus on fine sediment terraces
2. Re-contoured berms
3. Access points to reservoirs
4. Staging areas
5. All adjacent areas

9. ADAPTIVE MANAGEMENT STRATEGIES FOR REVEGETATION

Six major factors have been identified that are likely to significantly influence development of native woody vegetation after removal of the dams:

1. Extreme environmental conditions due to large, barren area;
2. Legacy of sediments from the reservoirs;
3. Distance from intact vegetation;
4. Invasive exotic plant species;
5. Residual woody debris;
6. Herbivory.

Not all of these influences are negative. Large woody debris will be a positive influence and sites close to intact forests are likely to be colonized quickly by native plants. However, the harsh environmental conditions and the challenges posed by the reservoir sediments require a diversity of adaptive management strategies. Natural recovery in a large dam removal project has never been observed and is unpredictable. Because of the scale and severity of the disturbance created by the reservoirs, natural recovery patterns are likely to be slow. To restore native forests communities, a combination of passive and active strategies will be used: unassisted natural recovery, assisted natural recovery, and artificial recovery (Whisenant 2003). Introducing plants and seed into the dewatered reservoirs will accelerate native plant succession and restoration of ecosystem processes. However, natural regeneration is expected to occur quickly in some areas of the reservoirs. Natural regeneration of native vegetation is desirable over artificial strategies. Therefore, natural recovery will be allowed to proceed without intervention. Management actions in naturally regenerating sites will be limited to invasive, exotic plant control (see figure 26).

The current schedule calls for dam demolition to begin in September 2011. The reservoirs will be drawn down 15-18 feet prior to the start if dam removal. Therefore, some lands in both reservoirs will be exposed prior to fall planting season. The technical lead, with the assistance of a small crew, will inspect the newly-exposed areas to map landforms and patches of regenerating vegetation in the summer of 2011. By fall 2011 or winter 2012, planting and/or seeding will begin at sites where no regeneration has occurred or is likely to occur due to remoteness from intact vegetation. The strategies for revegetation are summarized at the end of the chapter in table 12.

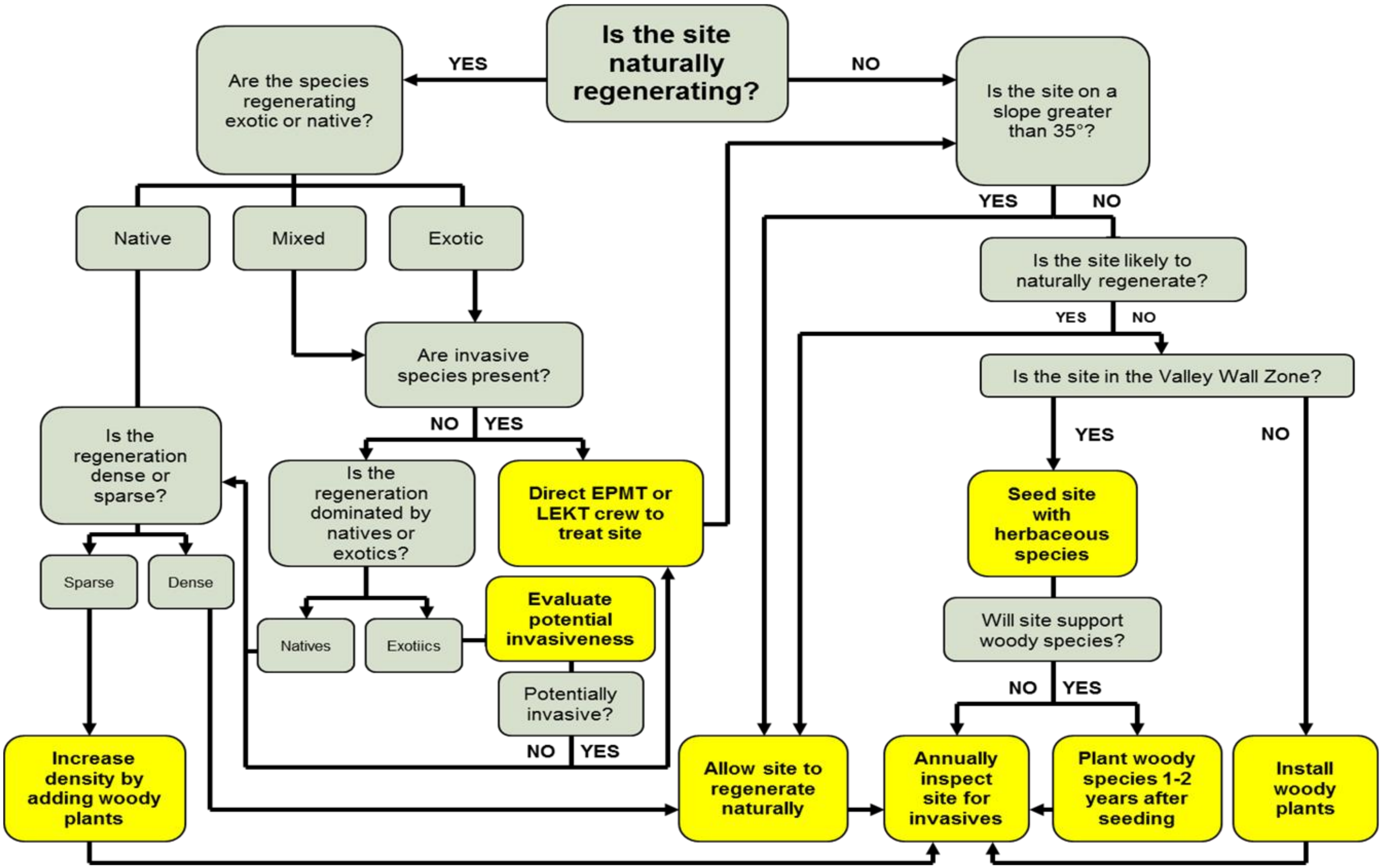

Figure 26. Planting strategy flow chart

UNASSISTED NATURAL RECOVERY

Unassisted natural recovery allows natural regeneration to proceed unimpeded by management (Whisenant 2003). This strategy is appropriate where natural regeneration of desirable native species is expected to occur quickly. No overt management action is required. Unassisted natural recovery of the reservoirs is the most cost-effective pathway to restoration. Natural regeneration of desirable native species ensures that the site is colonized by genetically-appropriate individuals without any cost or effort. Since naturally-colonizing plants are not subjected to “planting shock”, naturally-regenerating vegetation will develop more quickly than artificially-installed plants, accelerating the development of ecosystem stability. Because the reservoirs are large and have been inundated for more than 80 years, natural recovery is expected to be slow in much of the basins, particularly at sites far from intact forests (Chenoweth et al. *in prep*). However, significant natural regeneration can be expected at some sites in the dewatered reservoirs. Restoration staff will identify naturally-regenerating sites annually before planting season and will not disturb patches of natural, native plant regeneration. To protect naturally regenerating vegetation, it will be a high priority to combat invasive exotic plants that appear within or near naturally-regenerating patches.

SITES EXPECTED TO REGENERATE NATURALLY

Sites within 160 feet (50 meters) of intact forests are expected to regenerate naturally (Chenoweth et al. *in prep*). The seed of alder (Hibbs et al. 1994), native conifers (Beach and Halpern 2001, Keeton and Franklin 2005), bigleaf maples, some native herbaceous species, and many native shrubs will naturally disperse into this zone. These areas also contain small but possibly significant seed banks (Chenoweth 2007). The substrate along the former shoreline should enhance natural regeneration, since it has been accumulating organic material and is littered with coarse woody debris. Shoreline areas that are adjacent to disturbed, weedy areas will not be left to regenerate naturally due to the threat posed by invasive species and the lack of substantial native vegetation nearby.

Some sites farther from the shoreline may regenerate naturally, such as floodplains. Propagules of some species adapted to floodplains, such as willow and cottonwood, can travel long distances in the wind or water. Pioneer forest islands are likely to form as willow or black cottonwood stems eroded by floods upstream are deposited and re-sprout in newly-forming floodplains (Gurnell et al. 2005). Black cottonwood and willows are abundant on the delta in Lake Mills, and are expected to be eroded with the delta sediments and re-deposited in the reservoir during dam removal. Sprouting piles of buried wood may produce fast-growing patches of vegetation (Gurnell et al. 2005), which could serve to accelerate revegetation of the reservoirs.

Any site that is naturally regenerating with high densities of desirable native species will not be disturbed by planting activities. In some cases, naturally-regenerating vegetation will be augmented by planting close to or within a patch to increase plant density or patch size. These actions are intended to shorten “green-up” time, ameliorate environmental conditions, reduce herbivory, and minimize invasion of unwanted species (Scott et al. 1998, Woodruff et al. 2002, Kerr 2003, Whisenant 2003). In the floodplain, development of pioneer islands will be encouraged by installing willow and black cottonwood live-stakes downriver of wood accumulations, protecting plants from excessive scouring (Fetherston et al. 1995, Gurnell et al. 2005).

Open areas between dense patches would likely regenerate naturally due to the facilitating effects of neighboring vegetation (e.g., amelioration of the microclimate, influx of organic matter, increased seed rain). These areas will be left open to encourage natural regeneration (Hardt and Forman 1989) and to contribute to the development of structural heterogeneity (Roberts and Harrington 2008).

ALLOW FINE SEDIMENTS TO ERODE DURING DAM REMOVAL

Although the long-term inhibition of erosion of fine sediments into the river is an important goal for revegetation, no attempt to mitigate erosion will be made during the early stages of dam removal. Erosion of fine sediments off the slopes will be beneficial to future plant establishment and will not significantly increase the expected high turbidity in the Elwha River during the first few years after dam removal (BOR 1996) (see Figure 24). Erosion will also expose pre-dam surface contours and landform features, one of the restoration objectives outlined in the Environmental Impact Statement for Implementation (DOI 1996). Sediment from most of the erosion-prone steep slopes will be deposited on upland terraces outside of the floodplain, and therefore will not affect river turbidity. Continued erosion of fine sediments off the uplands is expected to decline over time due to heterogeneous landforms, surface obstructions (e.g., stumps, woody debris), and an increase in plant cover.

ASSISTED NATURAL RECOVERY STRATEGIES

Assisted natural recovery consists of minimal interventions intended to encourage natural regeneration. Examples include enhancing surface variability to form safe sites (Whisenant 2003) or controlling invasive exotic species. Safe sites are defined as physical undulations, such as small rills created by erosion or physical obstructions on the surface of the soil, such as large woody debris. In barren landscapes, small undulations and physical obstructions trap seeds and provide protection from desiccation, becoming foci for seedling establishment (del Moral and Wood 1993). Significant surface heterogeneity on the soil surfaces of the valley walls is expected to form gradually, but it is not clear what form of microtopography will develop on the sandy terraces. Once the reservoirs recede, soil surfaces will be monitored and appropriate action taken to create surface heterogeneity at some sites.

MANIPULATE WOODY DEBRIS TO ENCOURAGE NATURAL REGENERATION

Large woody debris in the reservoirs will be utilized to enhance recruitment of native plants. Various sizes of woody debris are likely to be present in Lake Mills, though there may be less in Lake Aldwell. Large woody debris that can be moved will be used to stabilize slopes, provide safe sites, and create refugia from herbivores.

There are many forms of safe sites created by woody debris. Large logs that lie on the ground east-to-west will provide shade and reduced moisture stress along the north-facing edge (Figure 27), enhancing seedling survival (Gray and Spies 1997). Large woody debris distributed in a protective matrix around woody vegetation is another type of safe site. These serve as refugia from ungulate herbivory, allowing woody plants to establish in valley bottoms of the Pacific Northwest (Schreiner et al. 1996). Woody debris on fine sediment surfaces may also provide safe sites for establishment of seedlings of woody plants (Harmon and Franklin 1989, Fetherston et al. 1995, Schreiner et al. 1996, Beach and Halpern 2001).

Figure 27. A safe site for red alder seedlings created by wood in Geyser Valley,

ARTIFICIAL RECOVERY STRATEGIES

Artificial recovery refers to manipulations intended to accelerate ecological restoration such as planting, seeding, or amending soils. Artificial recovery is appropriate when natural recovery is expected to be too slow or may not occur at all due to abiotic limitations (Whisenant 2003). Natural recovery is not expected to occur quickly over most of the reservoir areas, and is not likely to prevent establishment of invasive exotic plants (Chenoweth et al. *in prep.*). Therefore, the primary strategy to restore the reservoirs will be artificial recovery. Native graminoids and forbs will be installed as seed. Native woody species will be installed as container-grown plants, bare-root plants and live-stake plants. Some woody species may also be seeded directly into the basins using wild-collected seed.

Artificial strategies are designed to ameliorate site conditions, accelerate development of vegetation structure, and introduce species with a diversity of life history traits. During the 2 to 3-year process of dam removal, small-scale experiments will be conducted in order to learn what species are successful in the different sediments (fine or coarse) and in the different restoration zones. Lessons learned in the first two years will direct future management actions.

SEEDING THE BASINS

The objectives for seeding are to control surficial erosion in the near term, discourage establishment of exotic plants, and, in some areas, provide a nurse crop for natural plant succession. Restoration staff will primarily seed graminoids and forbs, although some areas may be sown with wild-collected seed of woody species.

In order to minimize erosion, seeding will be focused on slopes greater than 5° (essentially all of valley wall zone below the shoreline buffer). Seeding the slopes between the intact forests and the valley bottom will immediately provide control of surficial erosion where it is most needed. As a control for comparison to treated areas, 10% of these slopes will be left untreated. Slopes steeper than 35° will be left to regenerate naturally.

Other priority areas for seeding will be upland areas in the valley bottom zone covered in fine-textured sediments, where graminoids are expected to out-compete forbs or woody species. Seeding these areas with native grasses will minimize establishment of invasive exotic grasses.

Some areas will be seeded and subsequently planted with woody species. Dense seeding of grasses and forbs can inhibit the growth of woody plants (Whisenant 2003, Harrington and Madsen 2005, Roberts et al. 2005, Rose et al. 2006), divert successional trajectories (McDonald 1986, Densmore 1992, Nepstad et al. 1996), and prevent natural recruitment of native species (Burton et al. 2006). For example, the most dominant tree in the lower Elwha valley, Douglas-fir, does not regenerate successfully where herb or shrub cover exceeds 10% (Beach and Halpern 2001). Therefore, any dense patches of woody plants planned for installation during dam removal in the valley wall zone will not be seeded. At sites prescribed for installations of woody plants during the installation period, seed densities will be reduced to decrease competitive interactions with woody plantings.

SEEDING DENSITIES AND SEED MIX

In areas not targeted for woody plantings, 80 PLS (pure live seed) per ft^2 (861 PLS per square meter) will be used for broadcast seeding. Dense seeding is necessary to compensate for seed losses and uneven seeding depths associated with broadcast seeding (Whisenant 2003), and to minimize the establishment of exotic plants (Stevenson et al. 1995, Burton et al. 2006). The seed mix will consist of 30 PLS of forbs and 50 PLS of graminoids. The density will be reduced to 40 PLS per ft^2 in areas targeted for plantings of woody species, using 10 PLS of forbs and 30 PLS of graminoids.

SEEDING METHODS

Ground-based broadcast seeding will be used for all seeded areas. Hand-crank broadcast spreaders that strap to the chest (belly grinders) allow individuals to seed any areas accessible on foot. This method should provide coverage to most of the basin prescribed for seeding. A technician will follow the seeder with a rake to increase seed contact with the soil. Seed-to-soil contact could also be maximized by seeding after the fine sediments are saturated during fall rains. Inaccessible areas, such as cliffs and steep slopes, will not be seeded.

INSTALLING PLANTS IN THE BASINS

Installing container-grown plants, bare-root plants or live-stakes is an effective way to establish woody species. The survival of installed plants will depend on their ability to endure the expected stressful conditions. To ensure success, small-scale experiments will be conducted with a large diversity of species planted into fine and coarse-textured sediments during the first year of dam removal. These results will determine what species to propagate for the last 5 years of planting (2014-2018). Restoration staff will install plants at variable densities to accelerate complex forest structure.

LIVE-STAKE INSTALLATIONS

Willows and cottonwoods are commonly used as live-stakes in riparian restoration and may be more effective than container-grown or bare-root seedlings (Alpert et al. 1999). Willows are particularly effective at creating dense shade quickly, as they are capable of growing more than ten feet in the first year in sunny, moist conditions (Kern Ewing, University of Washington, personal communication) and can develop a full canopy by the second year (Kim et al. 2006). Willows also provide abundant litter to riparian ecosystems during the early stages of succession (O'Keefe and Naiman 2006). Several publications address methods for live-staking willows (e.g., Kim et al. 2006, Greer et al. 2006, Schaff et al. 2003). However, it is essential to test the effects of fine and coarse sediments on growth and survival of willows native to the lower Elwha drainage to ensure the best return on the investment in propagation and installation.

Appropriate species for live-staking include willows, common snowberry, red-osier dogwood and black cottonwood (Table 10). Common snowberry tolerates a broad range of conditions, and establishes well as a live-stake in a range of moisture regimes (Cereghino 2004). Red-osier dogwood is a fast-growing, early-seral species well suited to moist riparian conditions. It establishes well from cuttings (Darris 2002, Cereghino 2004), and is competitive with invasive exotics such as reed canarygrass (Hovick and Reinartz 2007).

Black cottonwood is a deep-rooted, riparian tree that may provide stabilization to young floodplains and perched terraces during dam demolition. Roots of cottonwood seedlings can grow more than 15 inches in the first two months, following receding soil moisture (Braatne et al. 1996, Naiman et al. 2005). Fast-growing cottonwood can also provide key pieces of large wood to the river within 50-100 years, faster than most conifer species (Collins and Montgomery 2002).

Table 10. Species suited to live-staking

Scientific name	Common name	Habitat Type
Cornus sericea	red-osier dogwood	**Moist**
Lonicera involucrata	black twinberry	**Moist**
Physocarpus capitatus	ninebark	**Moist**
Populus balsamifera* ssp. *trichocarpa	black cottonwood	**Moist**
Ribes sanguineum	red-flowering currant	**Moist-dry**
Rosa nutkana	Nootka rose	**Wet-moist**
***Salix* spp.**	willows	**Wet-dry**
Spiraea douglasii	Douglas' spiraea	**Wet-moist**
Symphoricarpos alba	snowberry	**Wet-dry**

PLANT A DIVERSITY OF SPECIES

Planting a diversity of native species should increase the resistance to exotic plant invasions (Levine & D'Antonio 1999, Naeem et al. 2000, Pokorny et al. 2005). Introducing native species with a diversity of life-history traits will also increase survival rates as the species sort out across the range of micro-environmental conditions in the dewatered reservoirs (Shafroth et al. 2002, Walker and del Moral 2009). Careful monitoring of individual species success rates during the first growing season will direct future propagation efforts to focus on species that are most likely to survive the stressful conditions in the dewatered reservoirs. Throughout the project, an emphasis will be placed on installing early-seral, woody species, such as Douglas-fir, bitter cherry, willows, red alder, Indian plum, and *Rubus* species (Table 11). These early seral species have high growth rates better suited to minimize exotic species establishment and tolerate harsh environmental conditions (Shafroth et al. 2002). Later-seral species, such as Oregon-grape, western hemlock and western red cedar, may be introduced during the post-installation period.

Table 11. Native woody plants common in early seral plant communities of the Elwha.

Species	Common Name	Life Form
Acer macrophyllum	big-leaf maple	Tree
Alnus rubra	red alder	Tree
Crataegus douglasii	black hawthorn	Tree
Malus fusca	western crabapple	Tree
Populus balsamifera* ssp. *trichocarpa	black cottonwood	Tree
Prunus emarginata* var. *mollis	bitter cherry	Tree
Pseudotsuga menziesii	Douglas-fir	Tree
Abies grandis	grand fir	Tree
Cornus nuttallii	Pacific dogwood	Tree
Alnus viridis* ssp. *sinuata	Sitka alder	Shrub
Amelanchier alnifolia	western serviceberry	Shrub
Ceanothus sanguineus	redstem ceanothus	Shrub
Cornus sericea	red-stemmed dogwood	Shrub
Holodiscus discolor	ocean-spray	Shrub
Lonicera involucrata	black twinberry	Shrub
Mahonia aquifolium	tall Oregon grape	Shrub
Oemleria cerasiformis	Indian plum	Shrub
Oplopanax horridus	devil's club	Shrub
Philadelphus lewisii	mock orange	Shrub
Physocarpus capitatus	ninebark	Shrub
Ribes bracteosum	stink currant	Shrub
Ribes divaricatum	spreading gooseberry	Shrub
Ribes lacustre	prickly currant	Shrub
Ribes lobbii	gummy gooseberry	Shrub
Ribes sanguineum	red-flowering currant	Shrub
Rosa nutkana	Nootka rose	Shrub
Rubus leucodermis	black-cap raspberry	Shrub
Rubus parviflorus	thimbleberry	Shrub
Rubus spectabilis	salmonberry	Shrub
Rubus ursinus	trailing blackberry	Shrub
Salix lucida* var. *lasiandra	Pacific willow	Shrub
Salix scouleriana	Scouler willow	Shrub
Salix sitchensis	Sitka willow	Shrub
Sambucus cerulea	blue elderberry	Shrub
Sambucus racemosa	red elderberry	Shrub
Spiraea douglasii	Douglas' spirea	Shrub
Symphoricarpos albus	common snowberry	Shrub
Acer circinatum	vine maple	Shrub
Acer glabrum	Rocky Mountain maple	Shrub

PLANT SPECIES IN APPROPRIATE SUBSTRATES

Establishing plants in the sediments requires an understanding of the effect that texture will have on plant performance (Tsuyuzaki et al. 1997, Chenoweth 2007, Michel 2010). There is not enough information on all native species to predict with certainty how they will perform in fine or coarse-textured substrates. However, some general expectations can be outlined based on available information. On fine substrates, grasses tend to be the first pioneers in primary succession (Grubb 1986). On fine sands, forbs and some shrubs tend to be the first pioneers. Large trees and shrubs tend to pioneer newly-formed, coarse-textured substrates (Grubb 1986). On fine sediments, native grasses may provide short-term solutions to invasion by exotic grasses, but a long-term solution requires establishing woody species. On coarse sediments, trees and shrubs should establish readily. However, riparian deciduous species, such as red alder, willows and cottonwood, will not do well on deep layers of coarse sediments perched above the water table. Planting trees and shrubs onto coarse terraces during dam removal while the water table is high may improve plant performance and persistence (Auble et al. 2007, Chenoweth et al. *in prep.*). After dam removal, species tolerant of dry, coarse-textured soils (e.g., Douglas-fir, shore pine, and western white pine*)* will be planted on perched terraces.

INSTALL PLANTS AT VARIABLE DENSITIES

Variable spacing of trees is an important structural characteristic of late-succession forests (Franklin et al. 2002). In the Pacific Northwest, variable density of trees results from gap formation in all stages of stand development (Lutz and Halpern 2006). Planting the initial cohort of trees and shrubs at variable densities should accelerate the development of structural complexity. In addition, varying tree density should result in variable rates of growth. Growth rates should start high in densely planted patches and then decline after 5 to 10 years (Scott et al. 1998), depending on site productivity. Growth in areas planted at lower densities should start slow and then exceed the growth rate of densely planted areas after 10 years.

For planning purpose, planting densities are prescribed at 700 trees per acre, 1,000 shrubs per acre, and 2,500 live-stakes per acre. Planting densities at individual sites will vary, with a combination of dense patches (facilitation patches; see below) planted within a matrix of average-to-sparse plantings and small openings. Open areas will be located close to densely planted patches, so trees along the perimeter will benefit from the edge effect of the opening (Roberts and Harrington 2008).

CREATE FACILITATION PATCHES OF DENSE WOODY VEGETATION

Dense patches of trees will be planted before seeding or planting the less-dense matrix of trees and shrubs. These "facilitation patches" will be installed in strategic locations throughout the basins. The basins are large, access may be difficult, and sediment texture and herbivory may limit the establishment of woody species. Establishing trees in extreme environments can be particularly difficult, due to the sensitivity of seedlings to drought. Planting high densities of woody plants has several advantages under these circumstances. Environmental extremes are ameliorated within dense patches of vegetation, improving plant survival and increasing growth rates (Will et al. 2006). The canopies of dense patches close quickly relative to low-density plantings, discouraging invasive exotic plants. Dense plantings also provide more organic matter to the soils than widely spaced trees and should reduce erosion rates (Whisenant 2003, O'Keefe and Naiman 2006). Dense islands of trees are attractive to birds and mammals, increasing zoochorous seed rain (Walker et al. 1986, Robinson and Handel 1993, Zahawi and Augspurger 2006). Because survival and growth rates of trees are high in dense patches, they are fast to reach maturation, becoming "propagation donor patches" to the surrounding landscape (Whisenant 2003). The accumulation of organic matter and shade within facilitation patches will promote the establishment of late-seral, shade-tolerant species within the patch and along patch edges (Yarranton and Morrison 1974).

Facilitation patches will range in size. Patches could be as small as 100 ft^2 to as large as an acre or more. Larger patches are preferred, since they tend to outperform small patches (Walker et al. 1986, Whisenant 2003). Facilitation patches will be installed in all restoration zones. Facilitation patches will be particularly important on valley wall landforms that are prone to erosion and slope failure.

Species composition in facilitation patches will vary, and will include shrubs and trees. Some seeding within facilitation patches could occur using species less likely to compete with trees such as native strawberries (*Fragaria* spp.), Pacific blackberry (*Rubus ursinus*), or other native stoloniferous plants. Erosion control devices (i.e. large wood anchored perpendicular to the slope) may be used to stabilize facilitation patches in steep terrain.

SITES SUITED FOR FACILITATION PATCHES

Since the success of native woody plants on fine-textured substrates is uncertain, facilitation patches will be installed primarily in areas where they are most likely to flourish. In the valley wall zone, facilitation patches are most likely to thrive on coarse sediments (e.g., at the mouth of tributaries or near former shoreline peninsulas) or where fine sediments are shallow. Where fine sediment is thin or absent, planting on microtopography that is relatively flat may be effective. Small benches or gentle slopes on steep terrain tend to passively retain resources such as water, organic matter, eroding soils, and nutrients flowing through the landscape (Whisenant 2003). In the absence of vegetation, landform and microtopography are the only variables that influence the flow of resources. These features will be referred to as "resource capture zones (RCZs). Focusing restoration efforts on RCZs should improve survival and growth rates of plantings and enhance biotic control of resource flows in key areas of the basin (Whisenant 2003).

Wood exposed on the surface effectively captures resources. The wood itself is a resource and provides seedlings with moisture, nutrients and organic matter (Harmon et al. 1986, Gray and Spies 1997). Wood may occur in the basins as left-over logging slash, logs that floated into the reservoirs, snags (riparian trees left standing during inundation), and stumps. These features will be treated as RCZs. Restoration staff will plant on the upslope side of wood where resources accumulate, and wood will be redistributed around facilitation patches whenever possible.

Once demolition is complete, the basins will be mapped for geomorphological features, including likely RCZs. Some RCZs may be discovered during installation, and planting will be adjusted to take advantage of these sites. Native plants may colonize some RCZs before restoration activities begin. Naturally-revegetating RCZs will not be disturbed by revegetation activities.

SOIL AMENDMENTS

Adding amendments below the soil surface does not improve planting success in restoration projects (Chalker-Scott 2010). The best approach to restoration of wild lands that cannot be irrigated is to allow the plants to adapt to the native substrate regardless of the limitations of the substrate. In some restoration projects, practitioners inoculate plant roots with endomycorrizhal fungi to improve plant performance. Cook (2008) found that inoculation of roots in native plants did not significantly improve performance in fine sediments from Lake Mills. Applying organic materials, such as mulch, on top of soil surfaces can be an effective way to improve planting success at restoration sites (Cahill et al. 2005). Two studies have shown that the application of mulch is an effective way to reduce erosion of sediments from Lake Mills (Mussman et al. 2008, Cook 2008). The scale of this project and the available funding restricts the large-scale ability to add mulch or other organic material to the soil surface. However, restoration staff will consider adding mulch, duff from surrounding forests, or other organic material on soil surfaces in strategic locations such as facilitation patches.

STRATEGIES TO MINIMIZE ANIMAL DAMAGE

Minimizing animal damage is essential to establishing woody vegetation in the basins. Animals damage vegetation in many ways: clipping and browsing foliage and leaders; gnawing, rubbing and girdling stems; trampling, and burrowing. By damaging woody plants, large and small herbivorous animals can influence the direction and rate of succession (Woodward et al. 1994, Schreiner et al. 1996, Rudgers et al. 2007), potentially interfering with the goal of establishing native forests. Animal damage can increase cover of exotic species, since large herbivores such as ungulates can create disturbances that benefit exotic plants (Harper 1977, Woodward et al. 1994) and small herbivores may preferentially browse native seedlings (Rudgers et al. 2007).

Wildlife responses to habitat changes following dam removal have not been predicted. However, it is likely that suitable habitat for some species will be created. Newly-established trees, shrubs, groundcovers (and their seeds) could represent a new source of food. Rodents, hares, and larger herbivores will be attracted to the early-successional vegetation. Due to the lack of escape cover, the greatest use of the area by wildlife will probably be along the edges of the basins. Wildlife use can be expected to increase as the diversity and biomass of vegetation increases.

Herbivore pressure may vary as a function of landform and local refugia in the exposed basins. On the west side of the Olympic Mountains, valley bottoms are generally heavily browsed, while herbivory pressures on valley wall landforms or other steep terrain is less intense (Schreiner et al. 1996). Where herbivory from ungulates is intense, woody species may be restricted to refugia such as accumulations of wood that are inaccessible to large herbivores (Schreiner et al. 1996). Natural or artificial woody debris obstructions will provide refuges for palatable vegetation.

Clumps of unpalatable shrubs can also function as refugia for neighboring, palatable woody plants (Olff et al. 1999, Callaway et al. 2000, Milchunas and Noy-Meir 2002, Callaway et al. 2005, Smit et al. 2005, Smit et al. 2006, Padilla and Pugnaire 2006, Smit et al. 2007 and others). Nootka rose is an example of a native, thorny shrub which survives in heavily-browsed meadows upstream of Lake Mills. Through its rhizomatous habit, Nootka rose produces thickets that may eventually act as refugia for other woody species. Thickets of unpalatable native species will be planted around palatable woody plants to provide refugia, enhancing succession and ensuring woody plant establishment even in heavily-browsed areas.

Planting woody seedlings immediately after dam removal before foraging patterns are established may be the best approach to reduce browsing impacts (Nolte 2003). Sprays designed to repel large ungulates can be effective (Nolte 1998), but are not practical at the large scale of this project. Application of anti-herbivory sprays is required several times a month, depending on the spray. It may be practical to use anti-herbivory sprays in selected areas.

The following measures will be employed to minimize plant losses due to herbivory:

- Plant significant numbers of unpalatable species and inter-plant palatable species.
- Plant within natural piles of woody debris.
- Redistribute large piles of woody debris to create barriers around plantings.

- Compensate for wildlife losses by increasing the number of plantings.
- Seed in late winter or early spring to minimize exposure to seed-eating mammals and birds.
- Plant at least eight feet away from heavily-used deer and elk trails.

The following measures are may also be implemented (see budget summary, chapter 16):

- Install protective tubing (such as "Vexar") over tree seedlings.
- Use anti-herbivory sprays such as "Bittrex" or "Liquid Fence."

ADAPTIVELY MANAGING FOR CLIMATE CHANGE

Climate change is expected to significantly impact forest communities in the Pacific Northwest. Increasing temperatures, decreasing winter snowpack, and early snowmelt will likely result in decreased soil moisture and an increase in drought stress in some forests of the Pacific Northwest (Climate Impacts Group 2010). As a result, our forests are expected to support fewer trees, and species composition may change (van Mantgem et al. 2009). Warmer temperatures and drier summers will increase moisture stress on sandy terraces perched high above the baseflow of the river. Climate change will also increase forest disturbances (e.g. fire, disease outbreaks, and landslides).

Restoration staff cannot control the anticipated environmental changes. Planting species resilient to drought stress and disturbances may mitigate damage caused by environmental change. Two tree species native to the Elwha, lodgepole pine (*Pinus contorta*) and western white pine (*Pinus monticola*) are drought-tolerant species well suited to sandy substrates. Both species dominate coarse-textured lacustrine landforms created by glacial Lake Elwha more than 12,000 years ago. Most of the plant species planned for introduction into the reservoirs are early seral species that vigorously resprout after disturbances such as herbivory or fire (USFS 1998). Other strategies already mentioned (facilitation patches, planting a large diversity of species, variable density plantings) are designed to moderate harsh environmental conditions. Therefore, these strategies should provide some community resilience to climate change.

A true gauge of climate change effects on vegetation development in the dewatered reservoirs will require long-term monitoring well beyond the seven-year duration of this project.

Table 12. Strategies to restore the dewatered reservoirs.

Revegetation challenge	Goal	Strategy	
Extreme environment and climate change (e.g. moisture stress, increased disturbance)	Ameliorate stress	Unassisted	Allow natural regeneration
		Assisted	Create safes sites with large woody debris
		Artificial	Install facilitation patches
			Emphasize introducing plants common to early seral communities
			Introduce a diversity or native plant species
			Introduce species known to tolerate sandy soils
Reservoir sediments	Establish native woody plants	Assisted	Create safes sites with large woody debris
		Artificial	Introduce a diversity or native plant species with a range of life history traits
			Match species to substrate texture
			Experiment with woody species in fine sediments during dam removal
			Introduce species known to tolerate sandy soils
Distance from intact vegetation	Accelerate native vegetation development	Unassisted	Allow natural regeneration with 82-160 feet of forests
			Allow natural regeneration in floodplain
		Assisted	Encourage natural regeneration by creating safe sites with woody debris
		Artificial	Focus plant introductions at sites beyond 82-160 feet of intact vegetation
Invasive exotic species	Prevent invasive species from establishing	Assisted	Treat invasive populations in dewatered reservoirs for 7 years to prevent establishment
			Treat invasive populations in watershed to minimize propagule pressure
		Artificial	Install native species at sites beyond 82-160 ft. of intact vegetation
			Install facilitation patches
Herbivory	Establish woody plants	Artificial	Place woody debris obstacles around vegetation or plant in natural woody debris piles
			Install plants immediately after dam removal before animal patterns are formed
			Plant high densities (facilitation patches)
			Introduce species with ability to re-sprout vigorously after disturbance
			Plant patches of thorny shrubs around palatable plants (associational resistance)
Erosion of fine sediments	Minimize input of fines into river	Unassisted	Allow erosion to occur unimpeded during dam removal to expose native substrates and landforms
		Artificial	Seed all slopes >5° with grass/forb mix immediately after dam removal

10. REVEGETATION PRESCRIPTIONS

The prescriptions in this chapter apply to both basins. The restoration zones and plant species targeted for installation are appropriate for both basins. Some specific conditions are expected to differ between the basins; these are described below.

Prescriptions are organized by zones based on landforms. Topographically, the reservoirs resemble bathtubs. The upper areas along the shorelines are moderate-to-steep slopes (slopes 5-45˚). The reservoir floors are relatively flat (slopes <5˚) and cover the most area. The reservoir floors constitute the valley bottom zone. The area of transition between steep slopes and the valley bottom is characterized by moderate slopes (between 5 and 20˚). Vegetation prescriptions for valley wall and transitional landforms (all slopes between 5˚ and 35˚) will be the same; the combined area constitutes the valley wall zone. In Lake Mills, areas within 160 feet (50 meters) of intact forests, referred to as the shoreline buffer zone, will be left to regenerate naturally. In Lake Aldwell, the shoreline buffer zone will be 82 feet (25 meters) from intact forests. Ten percent of each zone will be left open as gaps between treatments or to provide control plots to compare with restoration sites. The deltas will be eroded downstream into the reservoirs, so the area beneath the deltas is included in the acreage available for revegetation. The approximately 47-acre forested island in Lake Aldwell is not likely to be affected by dam removal and is not included in the total area to be revegetated. Revegetation will be implemented on a total of 516 acres. See Tables 13 and 14 for the acreage estimates by zone for each reservoir.

In the two reservoirs, restoration staff will seed a total of 261 acres (96 acres in Lake Mills, 160 acres in Lake Aldwell, 6 acres on appurtenant project land) and install plants on a total of 440 acres (262 in Lake Mills and 179 in Lake Aldwell) (Table 15). The seed mix is a combination of native forbs and grasses produced by the Corvallis Plant Materials Center (see chapter 13). Species in the mix include blue wildrye (*Elymus glaucus*), *Bromus* species (*B. carinatus, B. pacificus,* and *B. sitchensis*), slender hairgrass (*Deschampsia elongata*), spike bentgrass (*Agrostis exarata*), yarrow (*Achillea millefolium*), wooly sunflower (*Eriophyllum lanatum*), Suksdorf's wormwood, thick-headed sedge (*Carex pachystachya*), and Dewey's sedge (*Carex deweyana*)*. Prescribed mixes of plant species to install will be modified for various combinations of zone, landform and substrate. Restoration staff is currently considering planting or seeding 70 different native plants (See Chapter 13).

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*The identification of *C. deweyana* on the Olympic Peninsula may not be correct (Peter Zika, University of Washington, personal communication). The genus has recently split into four species (*C. deweyana, C. bolanderi, C. infirminervia,* and *C. leptopoda*), all native to the PNW (Wilson et al. 2008). Identification of the *Carex* propagated from the Elwha will be confirmed prior to implementation.

Table 13. Acreage estimates for Lake Mills revegetation

Description	*Acres*
Lake Mills delta	87
Valley Bottom Zone	205
Valley Wall Zone	146
Total Reservoir Inundated Acreage	**438**
Slopes > 35˚	-8
Active River Channel	-31
Shoreline Buffer	-57
Untreated area for control, gaps (10%)	-33
Total Reservoir Revegetation Acreage	**309**

Table 14. Acreage estimates for Lake Aldwell revegetation

Description	*Acres*
Lake Aldwell delta complex	105
Valley Bottom Zone	131.2
Valley Wall Zone	104.3
Total Reservoir Inundated Acreage	**340.5**
Slopes > 35˚	-9.4
Active River Channel	-17
Shoreline Buffer	-37.1
Untreated area for control, gaps (10%)	-23
Forested delta (not expected to erode)	-47
Total Reservoir Revegetation Acreage	**207**

Revegetation of the reservoirs will be executed from the top down. As the reservoirs recede, the basins will be mapped and naturally developing patches of native and exotic species identified. Facilitation patches of woody plants will be installed in key locations in the valley wall zone and on newly formed terraces in the valley bottom zone. After dam removal is completed, all slopes >5˚ below the shoreline buffer (73 acres in Lake Mills, 56.7 acres in Lake Aldwell) will be seeded, except for the 10% area left as control plots and gaps. Only a portion of the valley wall zones will receive woody plants. Priority sites for woody plantings in the valley wall zone are areas close to the dams or other areas where exotic plants are likely to invade.

After the slopes are seeded, the focus of planting will be the valley bottom zone. The valley bottom zones, consisting of active floodplains and upland terraces, encompass most of the area prescribed for active revegetation. Since the floodplain is likely to remain unstable for many years, newly-formed upland terraces will be the focus of planting efforts during the installation period. However, facilitation patches of live-stakes will be installed in the floodplain during the installation period. Upland terraces are likely to occupy more area than any other landform in the reservoirs. Therefore, the bulk of the plant materials will be installed in upland terraces. A complete timeline of revegetation is presented in Chapter 12.

Table 15. Breakdown of plant materials by reservoir

Plant Material	Lake Mills	Acreage	Lake Aldwell	Acreage
Conifer seedlings	61,800	88	46,200	66
Deciduous trees	59,500	85	37,800	54
Shrubs	70,100	70	44,500	45
Live-stake materials	47,000	19	35,250	14
TOTALS	**238,400**	**262**	**163,750**	**179**
CPMC seed*	**2,035 lbs.**	**102**	**3,200 lbs.**	**160**

*Lake Aldwell is prescribed for more seeding than Lake Mills due to the higher densities of invasive species around the reservoir

THE SHORELINE BUFFER ZONE

In Lake Mills, the shoreline buffer zone is defined as areas within 160 feet (50 meters) of intact forests. In Lake Aldwell, the shoreline buffer zone is defined as areas within 82 feet (25 meters) of intact forests. The shoreline buffer zone is smaller in Lake Aldwell since the surrounding landscape has more invasive species present. The shoreline buffer zone will be left to regenerate naturally. However, the shoreline buffer will not include the northern section of the reservoirs or other sites where invasive populations are present. Prior to treatment efforts, invasive exotic plants were abundant near the dams. There are also several infestations of reed canarygrass along the shoreline of Lake Aldwell.

VALLEY WALL PRESCRIPTIONS

Outside of the shoreline buffer, 90% of the valley wall acreage will be seeded, with 10% left unseeded as control. In addition to seeding the valley wall zone, 57% of the valley wall zone in Lake Mills and 59% of the valley wall zone in Lake Aldwell will be planted with conifers, shrubs and deciduous trees. Priority sites for installation of woody plants include the slopes close to the dams, areas close to populations of invasive exotic plants, and the banks of incising tributaries. Successful installation of native plants along tributaries may require bio-engineering to stabilize banks. Facilitation patches will be installed at sites where the fine sediment layer is thin or not present. Where fine sediments are deep, restoration staff will experiment with a variety of native woody species to determine which species can tolerate the substrate.

During the dam removal period, staff will plant facilitation patches in the valley wall zone below the shoreline buffer and conduct experiments with woody plants in fine sediment substrates. During the revegetation installation period, valley walls will be seeded in the first year to provide immediate control of surficial erosion. After seeding the entire zone, woody plants will be installed only in areas with substrates known to be favorable to woody plants (coarse or a mix of coarse and fine textures). Woody plants will not be installed on areas of pure fine sediment until the second and third year of revegetation installation. This will provide time to produce two-year-old seedlings based on experiment results. During the post-installation period, late-seral species may be installed if additional funding can be obtained to produce these plant materials.

See Tables 16 and 17 for plant numbers and acreage prescribed for this zone in each reservoir.

VALLEY BOTTOM PRESCRIPTIONS

UPLAND TERRACES

Woody plants will be installed over 90% of the terraces in both reservoirs. Approximately 30% of the terraces in Lake Mills and 85% of the terraces in Lake Aldwell will be seeded prior to planting woody species. Both valley bottom zones will have 10% left open for control. Coarse-textured terraces in Lake Aldwell will not be as deep as similar terraces in Lake Mills; such terraces may not occur north of the bottleneck in the middle of Lake Aldwell (Randle, personal communication). Therefore, fine-textured upland terraces are expected to occur in the north end of the valley bottom in Lake Aldwell after Elwha Dam removal. Fine-textured terraces will be seeded with grasses and forbs. Side channels or wall-based channels that incise into the perched terraces will be priority sites for revegetation and may require bioengineering to stabilize the banks and support plantings.

During the dam removal period, restoration staff will begin planting facilitation patches on coarse-texture, perched upland terraces in both reservoirs. The first terraces will form in the southern end of the reservoirs and access to the southern end of Lake Mills will be limited. Therefore, in Lake Mills, plantings will predominantly be live-stakes and bare-root materials which can be readily transported in bundles in backpacks. There is convenient access to the south end of Lake Aldwell, so restoration staff can transport and install container-grown stock during dam removal. Revegetation of the terraces will be completed during the revegetation installation period.

After dam removal is completed, deep, coarse-texture upland terraces perched above the water table will be installed with plants tolerant of dry conditions. These include Douglas-fir, shore pine, western white pine, Douglas maple (*Acer glabrum* var. *douglasii*), oceanspray, *Mahonia* species, bitter cherry, Scouler willow, snowberry and Indian plum. Experiments conducted during dam removal will determine which species are most tolerant of the substrate on fine-texture upland terraces.

Large woody debris will also be placed on the surface of terraces to provide safe sites for woody plants. Where coarse-texture terraces are not perched high above the water table, species typical to riparian terraces will be installed. These species include red alder, black cottonwood, big-leaf maple, grand fir, western red-cedar, willow species, and shrubs such as vine maple and salmonberry.

FLOODPLAIN

In the floodplain of Lake Mills, up to 80% of the area will be planted with woody species. In Lake Aldwell, 90% of the floodplain will be planted. In both dewatered reservoirs, 10% will be left unplanted for control. Some of the floodplain may be seeded. A significant amount of natural regeneration is expected to occur in the floodplain from re-sprouting wood and seed transported by the river or wind (especially willows and cottonwoods).

Most revegetation activities in the floodplain will occur during the post-installation period, after the river channel has had time to stabilize. However, facilitation patches of live-stake willows and cottonwoods will be planted during the revegetation installation period in select locations (i.e. downstream of large wood jams or sprouting wood piles).

When the floodplain has stabilized, facilitation patches will be installed close to existing woody debris and stumps, and along relatively stable edges of the floodplain. Initial planting on the floodplain will include deciduous trees and shrubs, primarily Sitka willow, black cottonwood and red alder, with relatively few conifers. Alder will not be planted in areas that are subject to inundation or sediment deposition (Hibbs et al. 1994). The hardwoods will be planted as live-stakes and rooted planting stock. Conifers and other later-seral species will be planted during post-installation, since they are not expected to recruit naturally far from seed sources (Chenoweth et al. *in prep.*).

Given the potential lack of large wood, the Lake Aldwell basin may require engineered logjams to help stabilize the floodplain. Funding for construction of engineered logjams is not available, but plans have been outlined in case future funding is obtained (Appendix A).

See Tables 18 and 19 for plant numbers and acreage prescribed for this zone in each reservoir.

RESTORING ADJACENT AREAS

In addition to the dewatered reservoirs, restoration staff will restore lands disturbed by the removal of facilities related to the dams. These include power line corridors, berms around the dams, and areas exposed by the removal of structures. There are approximately 13 acres associated with Glines Canyon Dam and 25 acres associated with Elwha Dam. Prescriptions and acreage details are found in Table 20.

The berms around the dams are highly infested with invasive exotic plants. The berms at Glines Canyon Dam will be bulldozed and recontoured to recreate the original topography of the area and will require revegetation. This newly-formed topography is estimated to cover approximately one acre. This area will be revegetated with herbaceous plants and shrubs in order to prevent a return of invasive exotic species. This will require at least 1,300 shrubs. The areas directly adjacent to the dam, such as the maintenance buildings and the spillways, will occupy approximately 4.5 acres of bare ground after demolition. These areas will be seeded.

The power line corridors may not require seeding or planting, since they already contain native woody species and are surrounded by mature forests. The primary strategy for the power line corridors is to treat invasive species before and during dam removal as well as during revegetation installation, in order to release the native plants from competition. However, native plant cover will be evaluated in the first year of the post-installation period. Shade-tolerant conifers, some deciduous trees, and shrubs will be planted if native species are not attaining dominance.

Appurtenant areas at Lake Aldwell total 40 acres and include power lines, access roads, hydroelectric facilities, an abandoned resort and a former gravel pit. There is uncertainty as to the final ownership and use of these lands; however, approximately 25 acres are expected to be actively restored to native vegetation. This will involve extensive exotic plant control. Soil decompaction and scarification will be required for decommissioned access roads. Seeding and mulching will be required over any areas of bare ground or sites treated to remove exotic plants. Strategic planting of trees and shrubs will be useful in blending formerly disturbed lands with adjacent undisturbed forests. Plant materials for these sites are currently not included in the budget.

Table 16. Lake Mills valley wall zone prescriptions.

Valley Wall Zone	Acres	Seeding	Conifer trees	Deciduous trees	Shrubs	Live-stakes
Exposed acreage	**166**	73	14.3	12	11.5	2.4
Slopes > 35° Rocky cliffs, dry bedrock slopes	-8	Natural regen	Natural regen	Natural regen	Natural regen	Natural regen
Shoreline buffer	-57	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants
Untreated control plots, gaps (~10%)	-8	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants
Acreage prescribed for revegetation	73	73 acres 80 PLS per sq ft. – 60 graminoid & 20 forb	14.3 acres 10,000	12 acres 8,400	11.5 acres 11,500	2.4 acres 6,000
Total for Revegetation	73*	**73 acres 1,460 lbs PLS**	**14.3 acres 10,000**	**12 acres 8,400**	**11.5 acres 11,500**	**2.4 acres 6,000**

*All the acreage will be seeded prior to planting, except where facilitation patches are installed.

Table 17. Lake Aldwell valley wall zone prescriptions

Valley Wall Zone	Acres	Seeding	Conifer trees	Deciduous trees	Shrubs	Live-stakes
Acreage Exposed	**104.3**	60	12	10	9.5	2
Slopes > 35˚ Rocky cliffs, dry bedrock slopes	**-9.4**	Natural regen	Natural regen	Natural regen	Natural regen	Natural regen
Shoreline buffer	**-31.9**	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants
Untreated control plots, gaps (~10%)	**-6.3**	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants
Acreage prescribed for revegetation	**56.7**	56.7 acres 80 PLS per sq ft. – 60 graminoid & 20 forb	12 acres ~8,400	10 acres 7,000	9.5 acres 9,500	2 acres 5,000
Total for Revegetation	56.7*	**56.7 acres ~1200 lbs PLS**	**12 acres 8,400**	**10 acres 7,000**	**9.5 acres 9,500**	**2 acres 5,000**

*All the acreage will be seeded prior to planting, except where facilitation patches are installed.

Table 18. Lake Mills valley bottom zone prescriptions.

Valley Bottom Zone	Acres	Seeding	Conifer Trees	Deciduous trees	Shrubs	Live-stakes
Acreage exposed	**292**	23	74	73	58.6	16.4
Active River Channel	-31	NA	NA	NA	NA	NA
untreated control plots, gaps (~10%)	-25	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants
Floodplain Riparian forests Open habitats	71	3-4 years post-drawdown (final acreage estimate pending river movements and seed resources) 150 PLS/sq ft. wild, CPMC, or OLYM produced seed	11 acres 7,700	19 acres 13,300	16 acres 16,000	11 acres 27,500
Terraces Lowland forests	165	23 acres 80 PLS/sq ft. CPMC seed mix – 60/40 graminoid-forb	63 acres 44,100	54 acres 37,800	42.6 acres 42,600	5.4 acres 13,500
Total for Revegetation	**236**	**23+ acres*** **459 lbs PLS**	**74 acres** **51,800**	**73 acres** **51,100**	**58.6 acres** **58,600**	**16.4 acres** **41,000**

*23 acres will be seeded prior to planting, except where facilitation patches are installed.

Table 19. Lake Aldwell valley bottom zone prescriptions.

Valley Bottom Zone	Acres	Seeding	Conifer Trees	Deciduous Trees	Shrubs	Live-stakes
Exposed Acreage	**184**	100	52	44	35	12.1
Active River Channel	- 17	NA	NA	NA	NA	NA
Untreated control plots (~10%)	- 16.7	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants	Natural regen, Control invasive plants
Floodplain Riparian forests Open habitats	45.3	3-4 years post-drawdown pending river movements and seed resources	9 acres 6,300	16 acres 11,200	12 acres 12,000	8.1 acres 20,250 stakes
Upland Terraces Native grass meadows Lowland forests	105	100 acres* 80 PLS/sq ft. CPMC seed mix – 60/20 graminoid-forb	45 acres 31,500 trees	28 acres 19,600	23 acres 23,000 shrubs	4 acres 10,000
Total for Active Restoration	**150.3**	**100 acres* 2,000 lbs (20 lbs per acre)**	**52 acres 37,800**	**44 acres 30,800**	**35 acres 35,000**	**12.1 acres 30,250**

*acreage to be seeded and planted, except where facilitation patches are installed.

Table 20. Prescriptions for adjacent areas for both basins.

Adjacent Areas	Acres	Seeding	Conifer trees	Deciduous trees	Shrubs	Live-stakes
Total acreage	38	5.8	0	0	1.3	0
Glines Canyon Dam berms	1.3	1.3 acres CPMC seed 80 PLS per sq ft. -60 graminoid & 20 forb	NA	NA	1,300 shrubs Planted immediately after dam removal	NA
Buildings Areas Around Elwha Dam	4.5	4.5 acres CPMC seed 80 PLS per sq ft. -60 graminoid & 20 forb	NA (1,400 conifers may be planted if needed and available)	NA (1000 trees may be planted if needed and available)	NA (2,000 shrubs may be planted if needed and available)	NA
Glines Canyon Dam Power Building	0.8	NA	NA (280 conifers if building is removed)	NA (140 trees if building is removed)	NA (200 shrubs if building is removed)	NA
Power line corridors inside ONP	10.9	NA	NA (3,500 shade-tolerant conifers, if needed)	NA (700 trees, if needed)	NA (4,900 shrubs, if needed)	NA
Power line corridors outside ONP, Elwha Resort Area, gravel pit	20.5	NA	NA (7,700 shade-tolerant conifers, if needed)	NA (1,400 trees, if needed)	NA (7,500 shrubs, if needed)	NA
Total funded for Revegetation	**7.1**	**5.8 acres 116 lbs (20 lbs per acre)**	**(12,880)***	**(3,240)***	**1.3 acres 1,300 (14,600)***	**0**

*Not currently afforded in the budget, but may be needed and paid out of contingency funds. Some natural regeneration, particularly along power line corridors is expected.

11. MONITORING AND ADAPTIVE MANAGEMENT

Adaptive management is a comprehensive approach to restoration and other natural resource management activities, in which the feedback between observation and action is emphasized. There will be many unpredictable and uncontrollable contingencies capable of deflecting the restoration sites from desired trajectories (Whisenant 2003, Clewell et al. 2005, Walker and del Moral 2003). To ensure that project goals and objectives are achieved, restoration staff must plan to systematically observe the results of restoration efforts, and incorporate lessons learned into remedial action (Apostol 2006). Monitoring is costly, and extraneous information is distracting, so monitoring must be designed to report on clearly articulated objectives (Clewell et al. 2005), "in sufficient, but not excessive detail" (Whisenant 2003).

Adaptive management also entails the allocation of resources for maintenance and remedial action after the initial installation phase. "No restoration project has ever been accomplished exactly as it was planned" (Clewell et al. 2005), and few projects succeed without post-installation maintenance (Walker and del Moral 2003). Maintenance activities could include removal of exotic plants, installation of barriers to herbivory, thinning or inter-planting to change stand densities, and planting or direct-seeding native plants.

MONITORING OBJECTIVES AND HYPOTHESES

Monitoring the revegetation effort will allow restoration staff to adjust methods and strategies to ensure that short term objectives are being met. Several hypotheses have been designed for each of the short-term objectives mentioned in Chapter 7.

Objective 1: Exotic species do not dominate cover of regenerating vegetation

- Hypothesis 1: Primary species of concern and watch list species are not present in the reservoirs.
- Hypothesis 2: Cover of secondary species of concern is less than 1% of the revegetation acreage.
- Hypothesis 3: Planted or seeded sites have a lower cover of exotic species than untreated sites
- Hypothesis 4: Facilitation patches have lower cover of exotic species than any other treatment.

Objective 2: Cover of native plants is increasing annually

- Hypothesis 5: Planted or seeded sites are increasing in cover of native species more quickly than unplanted sites.
- Hypothesis 6: Facilitation patches are increasing in native species cover more quickly than other treatments.

- Hypothesis 7: Sites in the shoreline buffer zones are increasing in native plant cover more quickly than untreated valley wall sites outside of the shoreline buffer zone.

Objective 3: Cover of bare ground is decreasing on valley wall landforms and upland terraces

- Hypothesis 8: Cover of bare ground is decreasing more quickly on treated sites and sites within shoreline buffer zone than on untreated sites.

Objective 4: Native woody plants are establishing on all landforms, and are increasing in cover relative to other lifeforms.

- Hypothesis 9: Planted areas have greater cover of native woody species than unplanted areas outside of the shoreline buffer zone.
- Hypothesis 10: There is less herbivory damage from ungulates to palatable, woody plants within patches of thorny shrubs than in patches with no thorny shrubs.
- Hypothesis 11: There is less herbivory damage from ungulates in facilitation patches than in sites with lower density plantings.
- Hypothesis 12: There is less herbivory damage from ungulates to plantings protected by large woody debris piles than at sites without woody debris.
- Hypothesis 13: Early seral woody vegetation is increasing in cover more quickly than vegetation associated with later seral vegetation.
- Hypothesis 14: Native plant diversity is higher in planted areas and in the shoreline buffer zone than in untreated areas outside of the shoreline buffer zone.

Objective 5: Surficial erosion off of upland landforms is declining.

- Hypothesis 15: Surficial erosion is less at sites treated than at sites not treated.

REVEGETATION TREATMENTS

Revegetation strategies can be separated into five different treatments to be monitored. They are:

- Treatment 1: No action taken (control).
- Treatment 2: Sites seeded by native forbs and grasses only.
- Treatment 3: Sites seeded by native forbs and grasses and planted with native woody species.
- Treatment 4: Sites planted densely with native woody species only (facilitation patch).
- Treatment 5: Sites planted at moderate spacing with native woody species only.

An additional treatment, the creation of safe sites using large woody debris without seeding or planting, will not be monitored.

DATA COLLECTION

The bulk of the data for monitoring will come from a set of permanent plots to be established throughout both basins. Plots will be placed in the floodplain, upland terraces, valley wall and shoreline buffer. The active river channel and slopes steeper than 35° will be excluded. Separate subsets of plots will be established in the untreated control portions of each revegetation zone. Within the four zones, there will be both treated and untreated plots in the floodplain, upland terraces, and on the valley wall. In the shoreline buffer zone, no treatments are proposed, but the plots in this zone are unique since they are close to intact forests. Untreated plots within the shoreline zone will be compared to untreated plots outside the shoreline zone in the valley wall zone to test hypotheses 7, 9 and 15. Treatments have been prioritized for each zone and for each reservoir (Table 21 and 22). The Generalized Random Tesselation Stratified procedure (GRTS, Stevens 1997) will be used to produce a random sample of plot locations that are spatially dispersed.

There will be 15 plots per stratum to assess the short-term restoration objectives. With 12 combinations of treatment and revegetation zone, there will be 180 plots per reservoir, 360 in total. All plots will be surveyed annually until 2017 (6 years of data). Treatments without permanent plots will be monitored informally (incidental monitoring) to assess efficacy.

Plots will be 0.025 ha circular plots (8.9 m radius) (Acker et al. 2008). Plot dimensions will be corrected for slope, so that the horizontal area is the same for each plot. Within each plot, cover of herbaceous vegetation and bare ground will be measured and tree seedlings will be tallied in four 1-m^2 quadrats. Cover of woody plants will be recorded along two, 10-m line intercept transects. Tree saplings (> 2.4 cm diameter at breast height, dbh) and trees (> 12.6 cm dbh) will be tallied by species in the entire circular plot. The center of each plot and the ends of both line-intercept transects will be monumented with rebar. One edge of each 1-m^2 quadrat will coincide with a fixed location on a line-intercept transect to allow precise re-location.

The assumption that the proposed sample size (15 plots per treatment, per strata) will be adequate will be evaluated by a statistician. The power analysis will be focused on the ability to detect changes in bare ground (objective 3), since this short-term objective has the most immediate relevance to the overall goals of Elwha River Restoration. The design will be sufficient to detect a 10% decrease in bare ground per year over three years (see below), at alpha of 0.10 with a power of 80%. Pilot data from Geyser Valley and the Lake Mills delta will be collected to determine the power analysis.

Table 21. Lake Mills revegetation zones and treatments to be monitored. Restoration staff will survey 15 plots per treatment in each strata resulting in 180 plots.

Treatment	Floodplain	Upland Terrace	Valley Wall	Shoreline Buffer
Untreated	X	X	X	X
Seeded only			X	
Seeded and planted			X	
Dense plantings	X	X	X	
Moderate plantings	X	X	X	

Table 22. Lake Aldwell revegetation zones and treatments to be monitored. Restoration staff will survey 15 plots per treatment in each strata resulting in 180 plots.

Treatment	Floodplain	Upland Terrace	Valley Wall	Shoreline Buffer
Untreated	X	X	X	X
Seeded only		X		
Seeded and planted		X		
Dense plantings	X	X	X	
Moderate plantings	X	X	X	

INCIDENTAL MONITORING

Data collected from permanent plots may not be enough to detect all of the changes occurring in the dewatered reservoirs. This is particularly true for detecting invasive exotic plant populations and observing those treatment effects without permanent plots. Incidental monitoring can provide a more complete picture of natural regeneration, survival of plantings, herbivory and other disturbances that may develop after dam removal. Planting and monitoring crews will observe and record exotic plants, areas of intense herbivory and other notable conditions as they travel between work sites. The technical lead will traverse both reservoirs several times a year to get a clear understanding of the changes occurring, with a particular focus on treatments in zones that do not have permanent plots. In addition, the supervising botanist (ONP vegetation branch chief), the LEKT habitat biologist, and the ONP plant propagation specialist will inspect the reservoirs at least twice annually.

Restoration staff will respond promptly to invasive, exotic plants recorded either in the monitoring plots or through incidental observations. If an invasive species of concern is observed in small enough numbers of sufficiently small plants, the observer will pull the plants and pack them out of the basin. Irrespective of the infestation size, its extent and location will be recorded using GPS units. To respond to infestations too large for immediate eradication, staff will review the data every two weeks during the monitoring season. Depending upon the most appropriate method and timing for the species, control by the exotics crew will be scheduled for either the current or following season.

The other short-term objectives all require observation of change from one year to the next. At the end of each monitoring season, the technical lead will analyze plot data to determine the effectiveness of various treatments. If certain treatments prove to be more effective than others, modifications to the implementation plan will be considered. However, since changes may be affected by differences in weather between successive years, the trigger point for action will be two consecutive years of undesired changes (i.e., steady or decreasing cover of native plants, steady or increasing cover of bare ground, steady or decreasing numbers of saplings and trees). Regarding Objective 3 (cover of bare ground decreases), an additional test would be applied before stating a need for action in a particular combination of revegetation zone and basin (treated areas only). Since cover of bare ground is estimated within the 1-m^2 quadrats but not on the line-intercept transects, it could occur that bare ground increases within a plot at the same time that overall plant cover increases (i.e., sum of cover of herbaceous and woody plants). Any such plots would not be counted as failing to meet the short-term objective for bare ground.

If undesired changes are detected, restoration staff will need to probe more deeply to determine the probable cause and appropriate response. For example, a failure of native plant cover to increase in upland areas could be due to drought stress, ungulate herbivory, or root disease, among other possibilities. The technical lead and other senior staff will inspect the plots exhibiting the undesired changes to assess such situations. For example, a failure of native plant cover to increase due to herbivory should be obvious; discriminating between drought stress and root disease may be possible by taking into account the species, microtopography, spatial pattern of damage, and presence or absence of disease fungi. Responses could include planting more drought-tolerant species, replanting with installation of protective tubing, replanting with species resistant to the disease organism or increasing or decreasing density of plantings, depending on the inferred cause of damage.

12. NATIVE PLANT PROPAGATION

PRESERVING THE GENETIC INTEGRITY OF THE LOCAL FLORA

Preserving genetic diversity is a primary mission of the National Park Service (NPS 2006). Selecting species that are adapted to a restoration site is crucial to the success of any restoration project (Rogers and Montalvo 2004). Genetically inappropriate materials can lead to genetic erosion and plant mortality from maladaptation, and can negatively affect neighboring ecological communities (Rogers and Montalvo 2004). To ensure the revegetation in the basins does not compromise local genetics and the plants installed are well adapted, some general guidelines for the propagation of native plants have been established.

All propagules will be collected within 11 miles (20 kilometers) of the reservoirs. Boundaries have been identified in order to guide many aspects of the project, including propagule collection. The boundaries are defined by elevation and local watershed features (Figure 28).

To further organize the collection and storage of propagules, zones have been created within the boundaries (Figure 28). Propagules of each species will be collected from more than one zone to ensure genetic diversity within the species to be propagated.

Nearly all of the major tree species in the Pacific Northwest are collected from seed transfer zones within a 1000-foot elevation band of the out-planting site (Randall and Berrang 2002). These guidelines will be applied for all conifer species. Minor deviations outside of the project boundaries may be necessary in order to obtain seed and cuttings for species under-represented within the boundaries. Some early-seral riparian species common to lowland rivers are scarce along the lower Elwha River. There are few young floodplains below the dams (Kloehn et al. 2008), restricting the available habitat for early seral species such as river lupine (*Lupinus rivularis*). In such cases, species may be collected from populations immediately adjacent; for example, from the Dungeness River watershed, the closest large watershed.

Seed of western red cedar may also be obtained from outside of the project boundaries. Western red cedar has little genetic variability between populations (Randall and Berrang 2002). Cone collection is difficult within the park, since park policy prohibits cutting down a tree for cones. If necessary, seed of western red cedar, collected within the Puget Sound seed transfer zone (Randall and Berrang 2002), may be purchased from a commercial vendor.

During propagation at off-park growing sites, seeds, cuttings and plants will be physically separated from conspecific populations to protect genetic integrity and prevent cross-pollination. In addition, the recommendations of McKay et al. (2005) will be followed as much as possible to prevent unintended alteration of genetic composition of plant populations during seed-increase. Restoration staff and collaborators will work to carry out seed-increase in locations where climate and other environmental factors are as similar as possible to the Elwha Valley, harvest from the entire planted population, and harvest as often as possible.

GENETIC GUIDELINES FOR PROPAGATION AND OUT-PLANTING

Seeds, spores and cuttings from more than 70 species of native plants will be collected. Due to lack of information on genetic variability within these species, general guidelines to maintain genetic diversity will be followed. These guidelines were devised following the recommendations of Randall and Berrang (2002) and Rogers and Montalvo (2004).

Propagule collection:

- Match collection sites with restoration site.
- As a proxy for genetic information, environmental conditions and species biology will guide collection efforts.
- Donor plants will be restricted to wild, not planted specimens.
- Propagules from all species will be collected in more than one year.
- Propagules will be collected throughout each season of seed ripening.
- Over-collecting from a single plant or cluster will be avoided.

Propagation:

- Identity (location) of donor plants will be tracked.
- Variable germination times will be allowed.
- Over-culling will be avoided.
- Optimum growing conditions for each species will be considered with input from restoration ecologists.

Out-planting:

- Whenever possible, collection site will be matched with planting site.
- For dioecious species, equal number of males and females will be planted.
- Plants at early stages of development will be preferentially installed (seeds, young seedlings over older stock).

Other species-specific guidelines will be considered (Rogers and Montalvo 2004) for species with sufficient information.

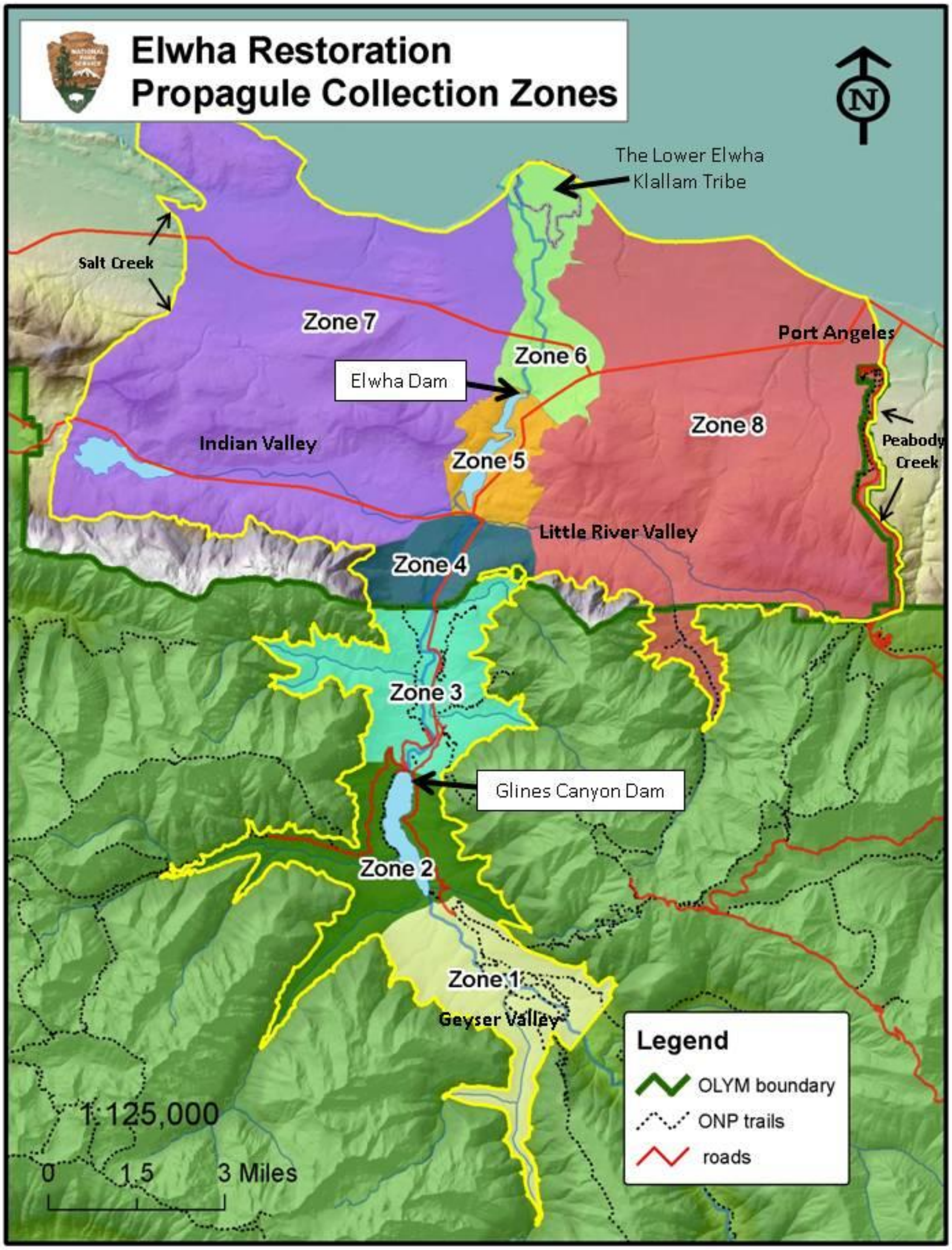

Figure 28. Propagule collection zones

PROPAGATING NATIVE PLANTS

More than 245 native plant species are known to occur within the lower Elwha watershed. Not all of the species are suited for restoration. A primary list of native plant species was identified for propagation based on abundance in reference plant communities in the watershed, ease of propagation, and expected performance in the harsh conditions anticipated in the dewatered reservoirs (Table 23). To increase the diversity of species planted into the dewatered reservoirs, a list of secondary species will be propagated or direct-seeded into sites in smaller numbers (Table 24).

Nearly all of the bare-root and container-grown plant materials will be woody species. For the most part, herbaceous species will be installed as seed. Some container-grown herbaceous species may be out-planted (i.e. ferns and sedges), but only in small quantities.

Seeds, bare-root seedlings, container-grown stock and live-stakes will be installed. Plant materials will be obtained from four primary sources. The majority of seeds (mostly grasses) will be produced by the Corvallis Plant Materials Center (CPMC) of the Natural Resource Conservation Service through an interagency agreement. Conifer seedlings and bare-root materials will be obtained from commercial growers under contracts. Most of the remaining materials, including container-grown plants and live-stakes, will be produced at the ONP plant propagation facility. Finally, some material from wild populations (seed and live-stakes) will be collected for immediate installation. Distributing plant propagation among multiple sources offers some measure of protection from planting failures, disease or pests, or extreme weather events at any one location.

ONP PROPAGATION PROGRAM

For more than 20 years, ONP has produced tens of thousands of native plants per year for ecological restoration of wilderness and front-country areas in the park. A new plant propagation facility was built to replace the small, aging prior facility. The Matt Albright Native Plant Center, completed in late 2009, is located on five acres of open meadow in the northwestern portion of Robin Hill Farm County Park, near Agnew, Washington, 19 miles (30.5 km) east of the Elwha watershed. The facility includes a 2,100 sq. ft. greenhouse and approximately 40,000 sq. ft. of open and shaded nursery beds.

The ONP plant propagation facility will produce container plants, live-stakes, and seed for the revegetation of Lake Mills and Lake Aldwell. All container plants for the project will be produced there. In total, ONP will produce at least 137,700 plants and most of the live stakes (Table 25). The facility will also produce small quantities of seed of a few forb and grass species not produced at CPMC.

Table 23. Primary species for propagation. These species are significant components of early seral native vegetation and are readily propagated.

Species	Common Name	Life Form
Abies grandis	grand fir	Tree
Acer macrophyllum	big-leaf maple	Tree
Alnus rubra	red alder	Tree
Malus fusca	western crabapple	Tree
Populus balsamifera* ssp. *trichocarpa	black cottonwood	Tree
Prunus emarginata* var. *mollis	bitter cherry	Tree
Pseudotsuga menziesii	Douglas-fir	Tree
Alnus viridis* ssp. *sinuata	Sitka alder	Shrub
Holodiscus discolor	ocean-spray	Shrub
Lonicera involucrata	black twinberry	Shrub
Mahonia nervosa	Oregon-grape	Shrub
Oemleria cerasiformis	Indian plum	Shrub
Philadelphus lewisii	mock orange	Shrub
Physocarpus capitatus	ninebark	Shrub
Ribes divaricatum	spreading gooseberry	Shrub
Ribes lacustre	prickly currant	Shrub
Rosa nutkana	Nutka rose	Shrub
Rubus parviflorus	thimbleberry	Shrub
Rubus spectabilis	salmonberry	Shrub
Salix scouleriana	Scouler willow	Shrub
Salix sitchensis	Sitka willow	Shrub
Sambucus racemosa	red elderberry	Shrub
Spiraea douglasii	Douglas' spirea	Shrub
Symphoricarpos albus	common snowberry	Shrub
Agrostis exarata	spike bentgrass	Graminoid
Bromus complex	brome sp.	Graminoid
Carex deweyana* var. *deweyana	Dewey's sedge	Graminoid
Carex pachystachya	thick-headed sedge	Graminoid
Deschampsia elongata	slender hairgrass	Graminoid
Elymus glaucus* ssp. *glaucus	blue wildrye	Graminoid
Achillea millefolium	common yarrow	Forb
Artemisia suksdorfii	Suksdorf's wormwood	Forb
Eriophyllum lanatum	common woolly sunflower	Forb

Table 24. Secondary species for propagation. These species are less conspicuous in early seral vegetation communities, may be difficult to propagate, or are lifeforms that are not a primary focus of revegetation (forbs/graminoids)

Species	Common Name	Life Form
Thuja plicata	western red cedar	Tree
Acer circinatum	vine maple	Shrub
Acer glabrum	Rocky Mountain maple	Shrub
Amelanchier alnifolia	western serviceberry	Shrub
Ceanothus sanguineus	redstem ceanothus	Shrub
Cornus sericea	red-stemmed dogwood	Shrub
Gaultheria shallon	salal	Shrub
Mahonia aquifolium	tall Oregon-grape	Shrub
Ribes lobbii	gummy gooseberry	Shrub
Ribes sanguineum	red-flowering currant	Shrub
Salix lucida **var.** ***lasiandra***	Pacific willow	Shrub
Sambucus cerulea	blue elderberry	Shrub
Vaccinium parvifolium	red huckleberry	Shrub
Carex obnupta	slough sedge	Graminoid
Carex mertensii	Merten's sedge	Graminoid
Luzula comosa	Pacific woodrush	Graminoid
Scirpus microcarpus	small-flowered bulrush	Graminoid
Anaphalis margaritacea	pearly-everlasting	Forb
Aquilegia formosa	Sitka columbine	Forb
Aruncus dioicus	goatsbeard	Forb
Chamerion angustifolium	fireweed	Forb
Erigeron philadelphicus	Philadelphia fleabane	Forb
Fragaria vesca **ssp.** ***bracteata***	wood strawberry	Forb
Fragaria virginiana	Virginia strawberry	Forb
Geum macrophyllum	large-leaved avens	Forb
Heracleum lanatum	cow parsnip	Forb
Lupinus polyphyllus **var.** ***polyphyllus***	big-leaf lupine	Forb
Petasites frigidus	sweet coltsfoot	Forb
Solidago canadensis	Canada goldenrod	Forb
Stachys chamissonis **var.** ***cooleyae***	Cooley's hedge-nettle	Forb
Polystichum munitum	swordfern	Fern

SEED INCREASE PROGRAM AT THE CORVALLIS PLANT MATERIAL CENTER (CPMC)

Grasses and forbs will be installed primarily as seed. This will require large quantities. The most efficient method for acquiring seed is through large-scale seed-increase. In 2009, ONP contracted with NRCS to produce seed, agreeing that CPMC would produce a minimum of 5,235 lbs (PLS) of grass, sedge, rush and forb seed. Fields will be sown with wild seed collected from within the project boundaries over several seasons. There will be no sowing for seed-increase of seed harvested at CPMC to minimize 'unconscious selection' (i.e. alteration of population genetics due to selective pressures in the agronomic setting, McKay et al. 2005).

CPMC and ONP have identified nine species suited for seed increase (Table 25). These nine species will constitute the vast majority of seeding for the project.

Table 25. Nine species suited for mass-seed production at CPMC. CPMC has tested and produced significant amounts of seed from these species.

Common name	Scientific name	Lifeform
Spike bentgrass	*Agrostis exarata*	Grass
California brome	*Bromus carinatus*	Grass
Slender hairgrass	*Deschampsia elongata*	Grass
Blue wildrye	*Elymus glaucus* ssp. *glaucus*	Grass
Dewey's sedge*	*Carex deweyana* var. *deweyana*	Sedge
Thick-head sedge	*Carex pachystachya*	Sedge
Common yarrow	*Achillea millefolium*	Forb
Suksdorf's sagewort	*Artemisia suksdorfii*	Forb
Common woolly sunflower	*Eriophyllum lanatum*	Forb

*The identification of *C. deweyana* on the Olympic Peninsula may not be correct (Peter Zika, University of Washington, personal communication). The genus has recently split into four species (*C. deweyana, C. bolanderi, C. infirminervia,* and *C. leptopoda*), all native to the PNW (Wilson et al. 2008). Identification of the *Carex* propagated from the Elwha will be confirmed prior to implementation.

CONIFER SEEDLING PRODUCTION

ONP staff has collected conifer seed cones during good crop years since 2001. All species of cones were collected from within a 1,000-ft elevation band in the watershed to ensure genetic integrity (Randall and Berrang 2002). The cones have been transferred to Silvaseed Company in Roy, WA. There the seed is extracted, cleaned, tested for germination, and stored. A commercial nursery will produce seedlings from the stored seed for the Elwha project. Conifer seed collection to date is summarized in Table 26.

Large crops of conifer cones do not occur every year. The interval between large cone crops varies between species, for example from two to three years for grand fir, versus three to 11 years for Douglas-fir. Using a standard commercial grower's procedure, approximately 3.75 lbs of seed would be needed to produce 50,000 Douglas-fir seedlings (Michael Gerdes, Silvaseed Company, personal communication). Based on the viability of stored seed tested in the spring of 2009, ONP currently has enough seed. As necessary, additional cone may be collected, or seed purchased from appropriate transfer seed zones. Any extra conifer seeds not used for seedling production may be directly seeded.

Table 26. Conifer seed collected from 2001-2005 for Elwha Restoration.

Species	Year	Total Lbs.	Seeds/Lb.	2009 Germ Rates
Douglas-fir	2001	12.40	41,320	92%
Douglas-fir	2003	10.0	42,700	87%
Grand fir	2001	48.7	22,600	70%
Grand fir	2003	11.7	23,000	75%
Western hemlock	2004	0.25	233,200	84%
Western red-cedar	2003	1.4	310,080	47%

COMMERCIAL DECIDUOUS TREE AND SHRUB PRODUCTION

The majority of the deciduous trees and shrubs for out-planting will be produced by a regional commercial nursery and returned as bare-root plants. Bare-root plants are the most affordable plant type. Not all native species prosper as bare-root plants (i.e. big-leaf maple). Therefore, bare-root seedlings will only be produced from species known to succeed as bare-root stock. Seeds will be collected by ONP staff and transferred to the commercial nursery for production.

WILD PLANT MATERIALS

Some seeds and live-stakes will be collected directly from the wild and installed immediately. Live-stake collection from wild shrubs will augment live-stakes produced from cutting blocks at the ONP plant propagation facility. The Lake Mills delta, the forested island at Lake Aldwell, and the floodplain of the lower river within the Lower Elwha Klallam Reservation contain robust populations of willows and cottonwoods. These plants will be cut to the ground approximately one year prior to dam removal, to increase the number of new stems and suckers available to harvest. Wild seed of woody species, forbs and graminoids will also be collected for direct hand-seeding. This will increase species diversity and add native species, such as forbs, that are not targeted for mass production. Species to consider for wild seed collection and direct seeding are listed in Table 27.

Table 27. Species to consider for wild seed collection for direct seeding.

COMMON NAME	SCIENTIFIC NAME
	SHRUBS
Pacific blackberry	*Rubus ursinus* ssp. *macropetalus*
Yerba buena	*Clinopodium douglasii*
	GRAMINOIDS
Thurber's bentgrass	*Agrostis humilis (thurberiana)*
Alaska brome	*Bromus sitchensis*
Columbia brome	*Bromus vulgaris*
Dewey's sedge	*Carex deweyana* var. *deweyana*
thick-headed sedge	*Carex pachystachya*
	FORBS
pearly-everlasting	*Anaphalis margaritacea*
Sitka columbine	*Aquilegia formosa*
goatsbeard	*Aruncus dioicus*
fireweed	*Chamerion angustifolium* ssp. *angustifolium*
enchanter's nightshade	*Circaea alpina*
Siberian springbeauty	*Claytonia sibirica*
wood strawberry	*Fragaria vesca ssp. bracteata*
Virginia strawberry	*Fragaria virginiana*
cleavers	*Galium aparine*
large-leaved avens	*Geum macrophyllum*
cow parsnip	*Heracleum lanatum*
leafy peavine	*Lathyrus polyphyllus*
big-leaf lupine	*Lupinus polyphyllus* var. *polyphyllus*
River-bank lupine*	*Lupinus rivularis*
coltsfoot	*Petasites frigidus*
Cooley's hedgenettle	*Stachys chamissonis* var. *cooleyae*

*May not be present in the Elwha watershed

13. REVEGETATION LOGISTICS

The movement of personnel, plant materials, and equipment in and out of the basins will be determined in detail following dam removal, when the terrain is exposed and a realistic logistics plan can be created. The details presented here are proposals intended to prepare for the logistics of managing revegetation in the dewatered reservoirs.

All future road construction within the reservoirs will be limited to trails designed for utility terrain vehicles (UTVs), stock use, and foot traffic. No roads suitable for automobiles will be constructed in the dewatered reservoirs. Access points and staging areas will be developed to increase the efficiency of sorting and moving plants and materials into the dewatered reservoirs.

ACCESS AND STAGING AREAS

LAKE MILLS ACCESS DEVELOPMENT

Vehicle and equipment access to the perimeter of Lake Mills is currently limited, and two vehicle access points have been identified for development. There are four access points available to foot traffic and pack animals (Figure 29). The vehicular access points will be short road-beds providing access from established roads to the shoreline of the reservoirs, and will include leveled, hardened pads to hold plants, storage sheds and portable toilets. Two storage sheds, one at each of the northern access points, are needed. One portable toilet for the northeast access point is needed. The northwest point has a primitive toilet, and the southeast access point is close to the Whiskey Bend Trailhead, which also has a toilet. The southwest access point is at the end of a 2.1 mile wilderness trail and will not be developed. The access points in the northern end of the basin will provide direct vehicle access. The Olympic Hot Springs road approaches the north end of the reservoir near the dam. A gravel spur road branches off from this road and leads to a primitive boat launch and trailhead on the northwest side of the lake. The site has parking, a primitive toilet, and adequate level ground for temporary storage of plants. This is currently the only vehicle access to the perimeter of the reservoir. The boat launch will become the northwestern access point for the project. On the northeast side of Lake Mills, an abandoned road will be developed located 0.2 miles south of the dam along the Whiskey Bend road. This route reaches the shore of the lake in a cove north of Windy Arm and is approximately one-tenth of a mile long. This access point will require significant development, since the roadbed has been abandoned for many years. It will be cleared and gravel will be added to the road.

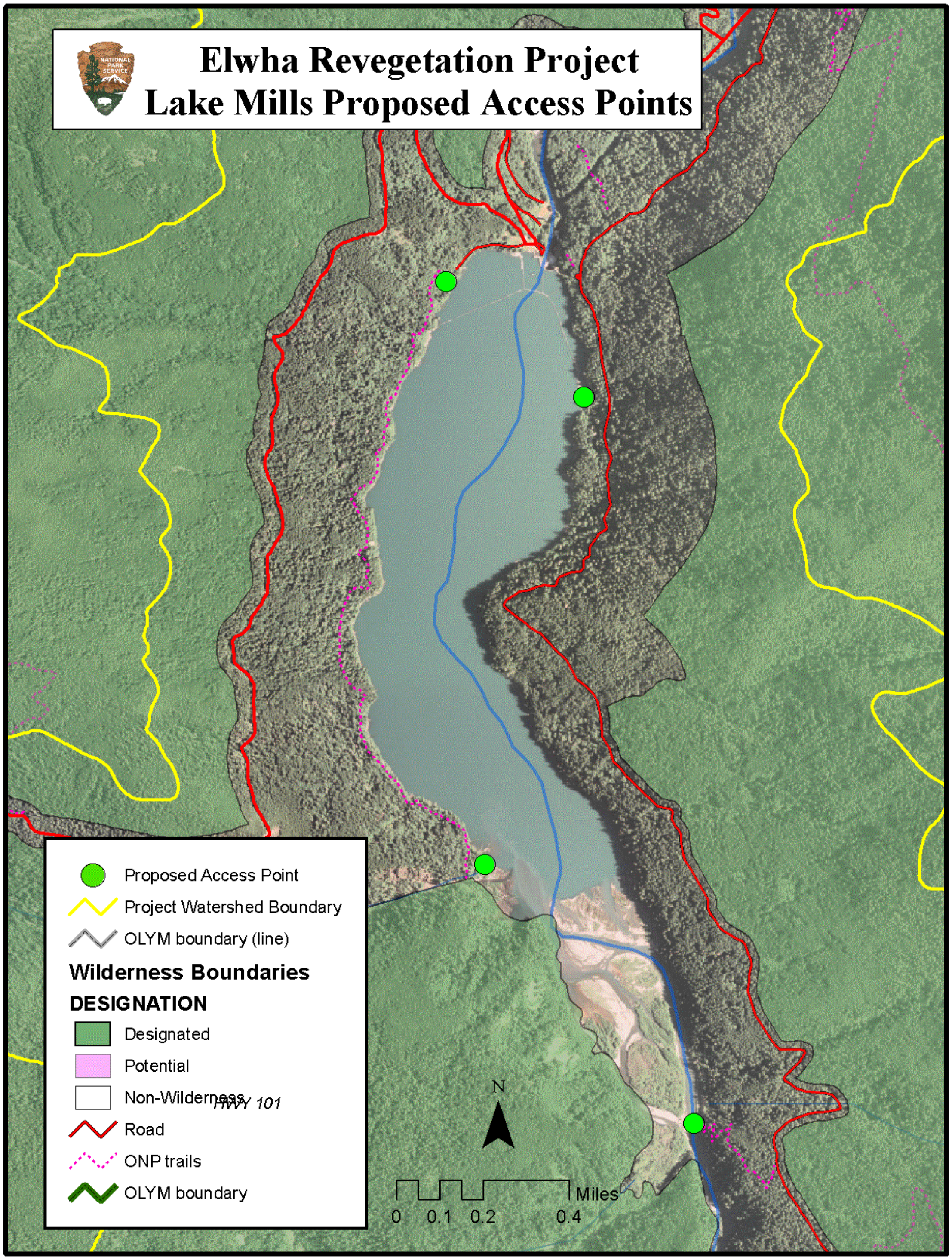

Figure 29. Proposed access points to Lake Mills. No potential wilderness areas are currently identified in this area.

LAKE ALDWELL ACCESS DEVELOPMENT

There are three main routes into the Lake Aldwell basin: at the dam on northeast side, at the abandoned Elwha resort at the southeast end of the lake, and at the boat launch near the southwest end of the lake. The northwest portion of the reservoir has no roads or trails, and is bordered by Washington State land managed for timber production. Any road or trail access to this part of the reservoir will require working closely with Washington State's Department of Natural Resources.

Restoration staff has proposed that the least possible number of roads or trails, suitable for foot traffic and utility vehicles, be created in order to access the valley floor for revegetation and monitoring. It will be important to construct gates at entry points to control access, both for public safety and to protect restored areas. Trails or roads built for restoration work should be removed following completion of revegetation, leaving only foot trails for monitoring and remediation.

LAKE MILLS STAGING AREAS

A 5,000 ft^2 area will be prepared in a small field behind the Elwha Ranger Station to store plant materials during the planting seasons (2011-2017). The area is large enough to store at least three day's worth of plant materials. The site is level, in close proximity to a hose bib, toilet facilities and parking, and is relatively free of invasive exotic plants (although many common exotics are present and must be prevented from seeding into containerized plants). There are several level areas covered by tree canopy to shade plants during storage, so no shade structures will be needed. Landscape fabric will be placed on the level area, with pallets placed on top of the fabric for holding plants in containers. A large pile of mulch (5-6 cubic yards) will be used to heel in bare root plant materials. No additional storage sheds will be needed at this site.

LAKE ALDWELL STAGING AREAS

Staging areas for Lake Aldwell will be located at the access points in the northeast, southeast and southwest. The staging areas will need to be free of invasive exotic plants. The south end of the lake has two possible staging areas readily available. The old Elwha Resort, on the southeast side of the lake, is easily accessible from highway 101. The site has over 5,000 ft^2 of level ground. The site requires a security gate to prevent unwanted visitation from the highway and a fenced-in area to secure plants. This site has an adequate amount of level ground and parking.

Each staging area at Lake Aldwell should have a small shed for securing tools and equipment. There are no facilities at these sites, so watering equipment and portable toilets will be needed. Use of a 210 or 325 gallon water tank mobile watering system (Figure 30) has been proposed. These tanks are relatively inexpensive and can be mounted on the back of a pickup truck or in a trailer. Using a trailer is desirable, since it could be used to water sites inside the basin at accessible points. This system will be used to water plants stored temporarily at all of the access points for Lake Aldwell or Lake Mills. The funding for the system would come out of the staging area budget for the project. Cost estimates for a trailer-based watering system are shown in Table 28.

Table 28. Cost estimates for mobile watering system.

ITEM	Cost
1 Water tank	$300
Honda gas pump	$300
1 trailer	$1,500
Hose	$500
Fittings, hardware	$200
TOTAL BUDGET	$2,800

Figure 30. A portable poly water tank.

BASIN ROAD AND TRAIL DEVELOPMENT

Access within both basins will be tightly controlled during restoration. If roads are cleared for vehicular use and trails are blazed for foot traffic, they will be decommissioned following completion of revegetation or converted to foot trails to provide access for monitoring and remediation, and eventually recreation. In Lake Mills, trails will only be made permanent on one side of the river, leaving one side free of human traffic to better accommodate use by wildlife.

Safe access within the dewatered reservoirs will depend on the conditions of the basin. Precise conditions inside the dewatered reservoirs will not be certain until after dam removal is completed. There may be old road-beds from logging before the dam was constructed that can be re-established. If old road systems are not evident, track-based utility vehicles, such as multi-terrain skid steers (Figure 30), can be used without established road systems. Vehicular access will only be possible from the north end of Lake Mills. Lake Aldwell will have vehicular access at the southern end and at the northeast section of the reservoir. Vehicle access via the valley bottom may be difficult due to the constriction of the Lake Mills basin at Windy Arm (Figure 5) and the gooseneck portion in the middle of Lake Aldwell (Figure 6). Therefore, plant materials and supplies may need to be flown into the south end by helicopters in Lake Mills and the northwest section of Lake Aldwell.

From the northern access points to Lake Mills and the southern access points to Lake Aldwell, the trails will descend into the basin and extend to the north and south. The trails will parallel the river channel roughly halfway between the river and the toe of the slope. Short spur trails off the main north-south route would be created as needed. Restoration staff will not attempt to cross the main channel of the Elwha in the basins. Planting season is fall through winter, the wet season in the Pacific Northwest. During this time, flood events are frequent. In addition, the channel and landforms in the floodplain will be highly unstable for several years after dam removal. Temporary bridges are not feasible.

If access to the south end of Lake Mills via the valley bottom is not possible due to the alignment of the river channel, impassable tributaries, or unstable slopes, access points in the southern end of the basin will be needed. The southwestern portion of the basin can be accessed on foot by the West Lake Mills trail. The West Lake Mills trail traverses the western side of the reservoir for about two miles, ending on the north side of Boulder Creek. The southeastern portion of the reservoir can be accessed on foot by the Wolf Creek trail: a short, steep descent from Whiskey Bend Road to the Lake Mills delta. In Lake Aldwell, the northwest section of the reservoir will only be accessible along a horse trail. It would not be practical to carry large amounts of materials or equipment on these trails, so helicopters or pack animals may be needed. The ONP Maintenance Division owns and operates a team of pack animals (mules and horses), and may be able to provide assistance in both basins.

ACCESS DURING DAM REMOVAL

During dam removal, access will be restricted until safe routes can be established. The slopes will be covered by two to five feet of fine sediments that may be unstable. These sediments will bog down foot traffic and prevent easy access for utility vehicles. Track-based utility vehicles, such as multi-terrain skid steers, may be able to clear a path along the upper slopes of the north end of Lake Mills, and the south end of Lake Aldwell. Access to the south end of Lake Aldwell should not be a problem. The south end of Lake Mills will not be accessible to vehicles during dam removal. As delta sediments are re-distributed downstream during dam removal, the first terraces will form in the south end of

Lake Mills. These terraces are a primary target for active revegetation and will be accessible only by foot or by boat.

MECHANIZED EQUIPMENT

Figure 31. A multi-terrain skid steer.

Multi-terrain skid steers (Figure 31) do not require constructed road-beds, and are capable of clearing and moving large debris. Trailers can be rigged to them to haul plants. They can also carry up to ¾ of a yard of material in the forward bucket. Attachments such as wood chippers (maximum 5 inch feed stock) and claws for moving large debris can be added to the front end, further adding to the potential usefulness of these vehicles. Mule utility vehicles (Figure 32) would also be utilized to transport personnel and materials if pathways are cleared. They are efficient at traveling off-road, and are capable of towing or carrying over 1,000 lbs. The mule has a small cargo bucket with a carrying capacity of approximately 15 cubic feet.

Figure 32. A Mule all-terrain utility vehicle

TRANSPORTING AND STORING PLANT MATERIALS

Transport and storage of more than 400,000 plants requires careful planning and coordination. All materials delivered from contractors will be received and stored initially at the ONP plant propagation facility. Pickup trucks and trailers will be used to transport the materials to staging areas. One pickup truck with trailer will be needed for the entire seven years of the project, while the other will only be needed for the post-dam removal period, from 2014 to 2018.

12. PROJECT TIMELINE

Plant materials will be installed over a period of seven years. Installing plants over an extended period will prevent difficult growing conditions that may occur in any given year (e.g. drought, severe freezing) from jeopardizing the entire project. Extending plant installation over many years will also allow us to adapt our strategies as we monitor results of initial efforts.

The planting season in the Pacific Northwest begins in the fall and extends into the early spring, coinciding with the wet season. Installing these plants between October and March will ensure that seedlings have access to adequate moisture for root development prior to the growing season.

Monitoring will be conducted from June to September beginning the first year of dam removal and ending in 2017, for a total of six years. Dam removal will begin in September 2011. The monitoring will crew begin setting up plots as soon as enough land is exposed to provide access to the upper shoreline areas (shoreline buffer zone). The plots will be installed from the top of each reservoir to the bottom as dam removal progresses. Since the reservoir will gradually expose the valley wall during the first 30 months, the first 150 plots in the valley wall zone will be installed during dam removal. The remaining 210 plots on the valley bottom (floodplains and upland terraces) will not be installed until after dam removal is complete and the terraces are exposed and relatively stable.

The full-time invasive plant crew employed by LEKT began in 2002 and will work through fiscal year 2014. From 2015-2018, the NPS EPMT crew will be the primary work-force for controlling invasive plants. Figures 33 through 35 provide more details of the project timeline for implementation.

Details of the schedule for dam removal will significantly affect the plant propagation schedule due to the lead times required for the production of different types of plant materials. Grass seed production will peak in Years 2 through 4 after sowing. Contracting with commercial growers for woody plants will require one year to solicit and award contracts before seeds can be germinated. For conifer production, seeds are germinated in February to produce bare-root seedlings the following fall or may be direct seeded in the spring to be delivered 18 months after the seed is sown. Three years will be required to obtain seedlings of deciduous trees and shrubs: one year to collect propagules and two years to grow the plants. Dam demolition is expected to take two to three years. In order to ensure adequate plants to install during the dam removal period, restoration staff initiated production of a few thousand deciduous trees and shrubs in 2009 (Table 29). In 2010, bare-root native plants were procured from a commercial grower. A few thousand bare-root woody plants will be delivered in the fall of 2011, followed by incrementally greater numbers in successive years until the final year of the project.

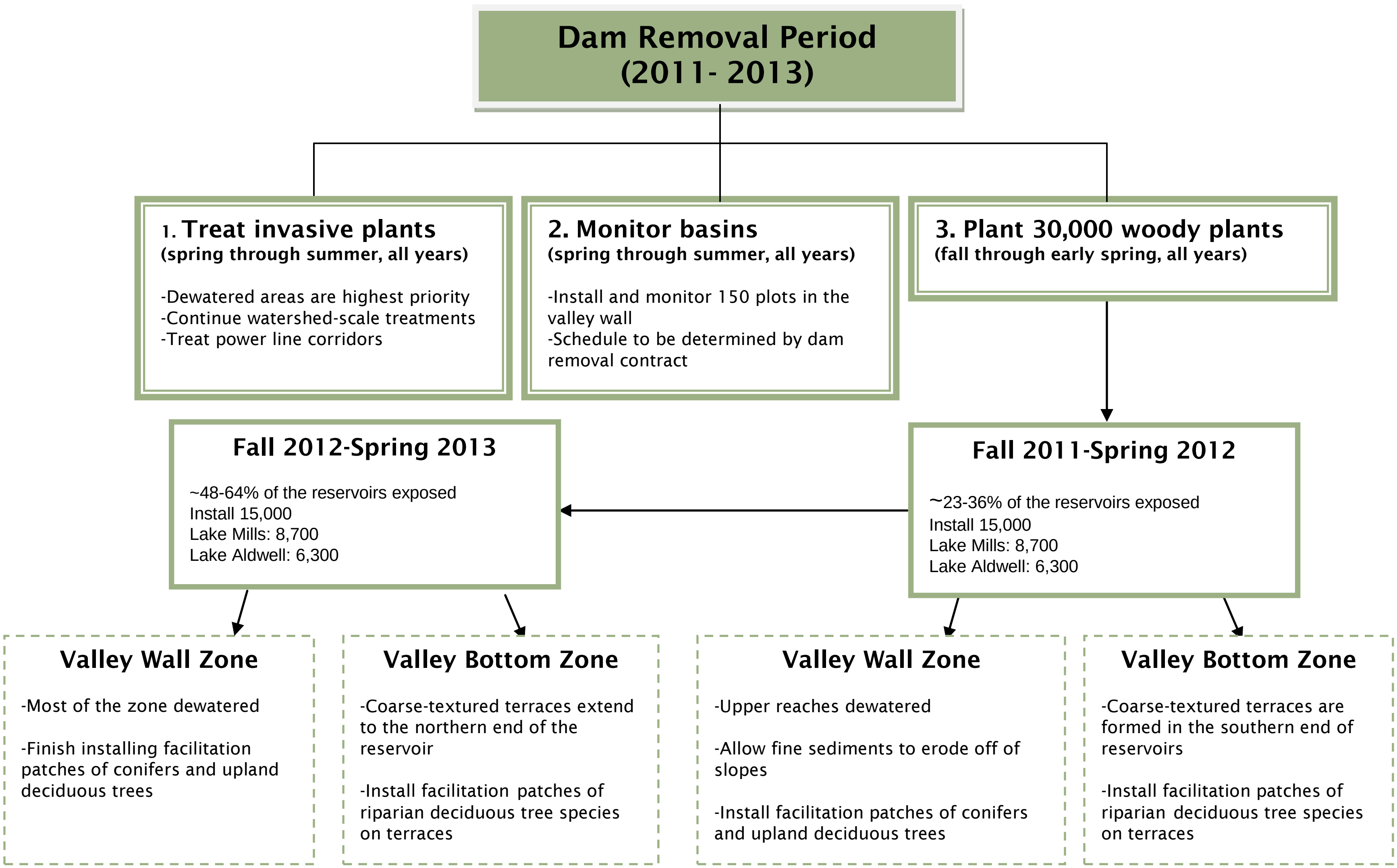

Figure 32. Revegetation schedule during the dam removal period.

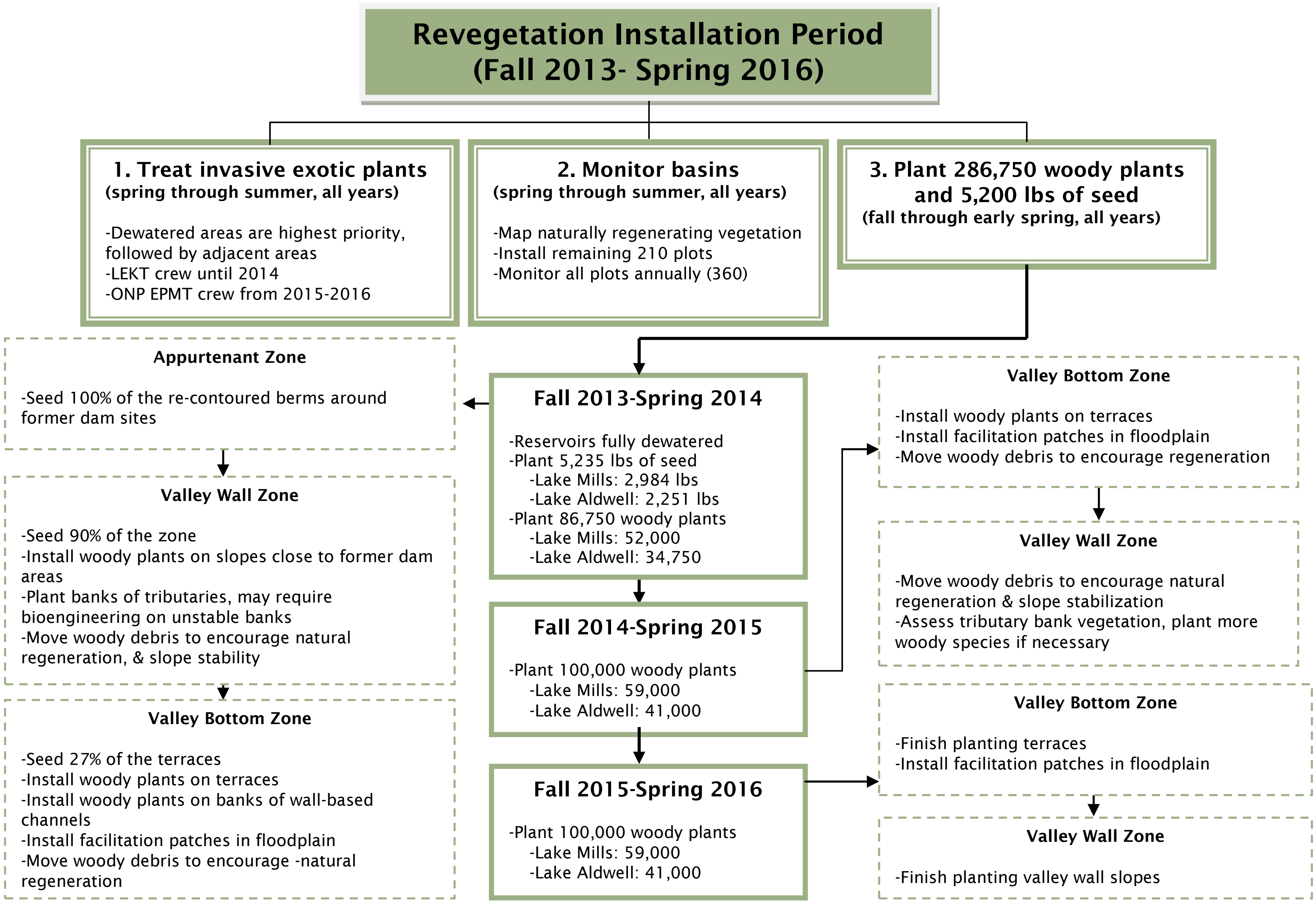

Figure 34. Revegetation schedule during the installation period.

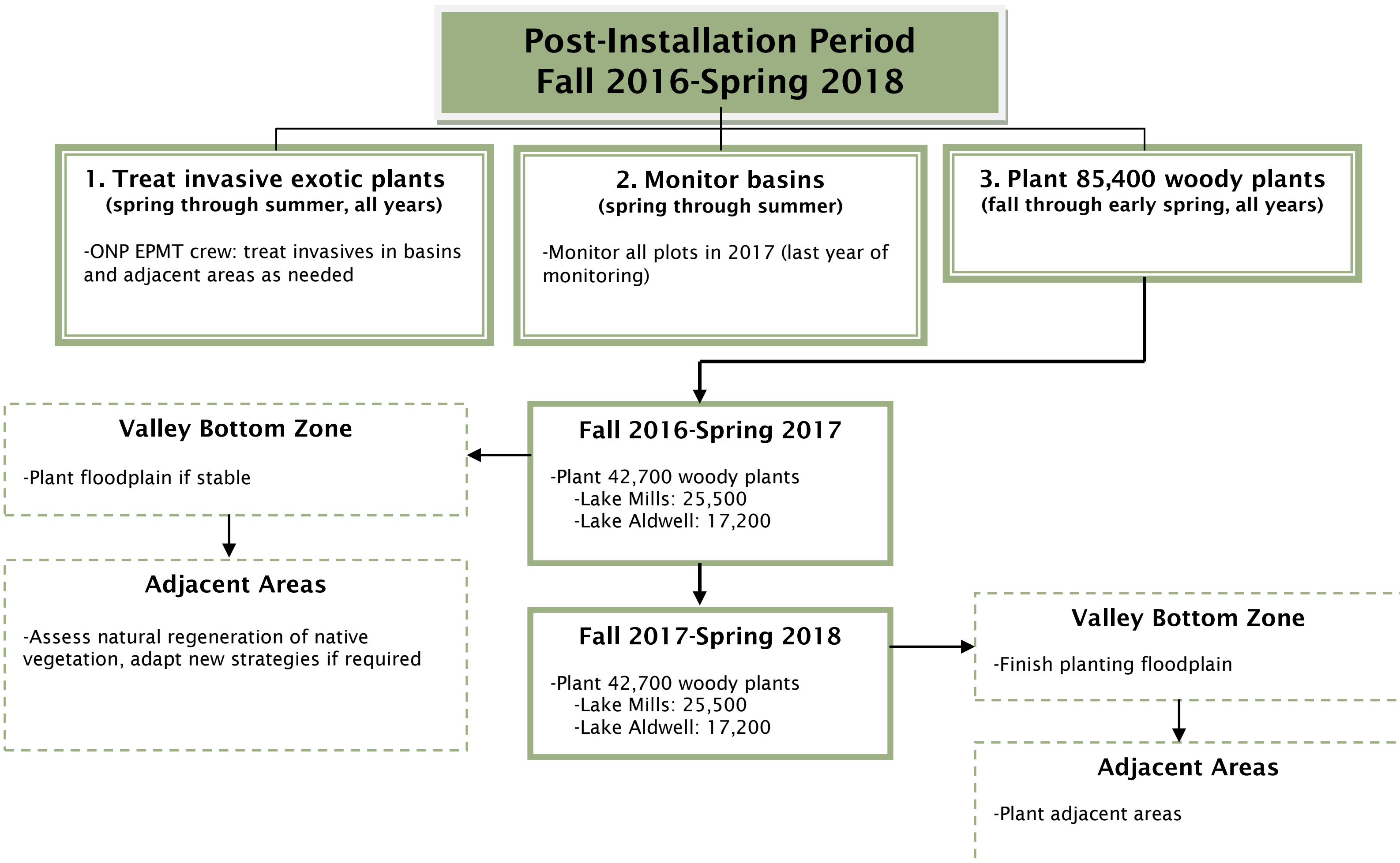

Figure 35. Revegetation schedule during the post-installation period.

Table 29. Plant production schedule. Plant materials need to be ready for out-planting by the fall of each year.

Material	2011	2012	2013	2014	2015	2016	2017*	TOTAL	COST
ONP Live-stakes	5,000	5,000	15,750	13,750	13,750	14,500	14,500	**82,250**	$41,125
ONP Deciduous trees and shrubs	5,000	5,000	31,300	30,000	30,000	18,200	18,200	**137,700**	$130,770
Conifer seedlings	2,500	2,500	26,000	28,500	28,500	10,000	10,000	**108,000**	$43,730
Commercial bare-root trees and shrubs	2,500	2,500	15,000	27,750	27,750	0	0	**75,500**	$50,960
TOTALS	**15,000**	**15,000**	**86,750**	**100,000**	**100,000**	**42,700**	**42,700**	**403,450**	**$605,942**

*Plant materials produced in 2017 would be installed in fiscal year 2018 (fall 2017-winter 2018).

15. REVEGETATION PROJECT STAFF

Staff to implement this project will be a combination of paid ONP staff, LEKT crews, and ONP volunteers. Annual budgets are based on the federal fiscal year, which begins October 1st and ends the following September 30th.

SUPERVISORY STAFF

ONP revegetation supervisory staff consists of the vegetation branch chief, the technical lead (restoration botanist), and the greenhouse manager. The vegetation branch chief and the greenhouse manager are permanent ONP employees. The technical lead is a term position subject to furlough. Mike McHenry supervises the LEKT crews, including the invasive plant management crew. Staff responsibilities are presented in Figure 36.

PREPARATION CREWS

In 2010, seasonal employees were hired to collect propagules, support greenhouse operations, collect pilot data for the monitoring plan, and test plant growth in the sediments (Table 28). In 2011, seasonal employees will also be needed to collect propagules, support greenhouse operations, and assist with mapping conditions as the reservoirs begin to recede. This crew will also install monitoring plots and begin planting in accordance with the demolition schedule (Table 30).

Table 30. Preparation crews and budget.

Fiscal Year	Activities	Staff	Personnel costs	Other costs	Annual total
2010	Collect seed, propagate plants, collect pilot data for monitoring	1 GS07, 1 GS-05, 9 pay periods	$34,865	$1,000 (supplies)	$35,865
2011	Collect seed, propagate plants, begin setting up plots (depending on dam removal schedule)	1 GS-07, 1 GS-05, 10 pay periods (8 as terms in 2011)	$36,419	$1,000 (supplies)	$37,419
		TOTALS	**$71,284**	**$2,000**	**$73,284**

Vegetation Branch Chief, ONP
Steve Acker

- Permanent ONP employee (NPS base funded)
- Supervises budget
- Supervises the technical lead and propagation specialist
- Coordinates contracting

Habitat Biologist, LEKT
Mike McHenry

- LEKT permanent employee (LEKT funded)
- Supervises LEKT crews
- Coordinates with ONP on all revegetation activities

Plant Propagation Specialist, ONP
Dave Allen

- Permanent ONP employee (NPS base funded)
- Manages ONP plant propagation facility
- Supervises greenhouse assistants
- Produces plants for both basins

Technical Lead, ONP
Joshua Chenoweth

- Term ONP employee (project funded)
- Funded 11 months per year 2011-2016
- Funded 9 months per year 2017-2018
- Oversees project logistics
- Coordinates with LEKT
- Directs exotic plant control and planting strategies
- Supervises planting and monitoring crews
- Manages data and writes plans and reports for project

Greenhouse assistants, ONP

- No funding available for fulltime paid assistants
- Will rely on volunteers, SCAs, and interns
- Collect propagules for project (2012-2017)
- Support plant material transport logistics (2011-2017)

Invasive Plant Management Crew LEKT

- Seasonal crew, project funded 2002-2014
- Fulltime crew dedicated to Elwha watershed from spring to fall

Preparation Crews, ONP

- 1 GS-07, 1 GS-05 (seasonal in 2010, terms in 2011)
- Project funded, 2010-2011
- Season: May-Oct
- Collect propagules, support greenhouse.
- Collect pilot data for monitoring (2010)
- Set up monitoring plots and begin planting both basins, depending on dam removal schedule (2011)

Monitoring Crews ONP

- 1 GS-07 (term), 1 GS-05 (term), 2 fulltime VIPs
- Project funded, 2012-2017
- Season: May-Sept
- Set up plots (2012-2014)
- Monitor plots (2012-2017)
- Incidental monitoring

Planting Crews, ONP

- Project funded (2012-2017)

Dam removal period

- 1 GS-07, 1 GS-05 (terms), 2 fulltime VIPs
- Responsible for both basins

Reveg Installation Period

- 1 GS-07 (term), 4 GS-05 seasonals, 2 fulltime VIPs
- Responsible for Lake Mills only

Post-Installation Period

- 1 GS-07 (term), 1 GS-06 (term), 2 GS-05 seasonals, 2 fulltime VIPs
- Responsible for both basins

Aldwell Planting Crew, LEKT

- Project funded (2014-2016)
- 4 technicians
- Responsible for Lake Aldwell only

Figure 36. Project staff.

PLANTING CREWS

Planting crews will work annually from October to February for a total of 10 two-week pay periods and will vary in number and staff:volunteer ratio throughout the project (Figure 36).

During the dam removal period and the post-installation period one crew will be responsible for planting both reservoirs. During revegetation installation, there will be two separate crews, each responsible for a single basin (Table 31). Lake Mills is the larger of the two reservoirs, and will require larger planting crews. Planting crews will be comprised of paid staff as well as full-time volunteers (primarily in Lake Mills). Term positions will work nine months annually, carrying out both planting and monitoring.

MONITORING CREWS

Paid staff includes one GS-07 field supervisor and one GS-05 technician, both of which are term positions. In order to install and monitor all of the plots, two full-time volunteers will work with the paid staff. Each year during dam removal new plots will be installed as the water recedes; these will be monitored along with the existing plots. Data will be actively collected at all plots from 2011-2017. The estimated budget in Table 32 includes time for the field technicians to enter data. Data management and analysis would be conducted by the technical lead.

REVEGETATION VOLUNTEERS

Volunteers are integral to all aspects of the revegetation effort. At least two full-time volunteers will work from June to February annually (9 months) to assist with monitoring and planting. These volunteer positions may be staffed as SCAs, Youth-In-Park interns or park-recruited volunteers. ONP may also employ at least one full-time intern for nine months per year to work as the greenhouse assistant and one full-time volunteer coordinator

In addition to full-time volunteers, part-time volunteers will assist with greenhouse operations, planting and monitoring.

Table 31. Planting crews and budget

Fiscal Year	Activities	Staff	Personnel Costs	Other Costs	Annual Total
2012	Install 15,000 plants; 8,700 in Lake Mills, 6,300 in Lake Aldwell.	2 technicians; 1 GS-07 and 1 GS-05 (term positions), 2 fulltime VIPs 10 pay periods	$42,962	$1,000 (supplies)	$43,962
2013	Install 15,000 plants; 8,700 in Lake Mills, 6,300 in Lake Aldwell.	2 technicians; 1 GS-07 and 1 GS-05 (term positions), 2 fulltime VIPs 10 pay periods	$46,760	$1,000 (supplies)	$47,760
2014	Lake Mills: Install 52,000 plants and 2,035 lbs of PLS	5 technicians; 1 GS-07 (term), 4 GS-05 (seasonal), 2 fulltime VIPs, 10 pay periods	$98,103	$1,000 (supplies)	$99,103
	Lake Aldwell: Install 34,750 plants and 3,200 lbs of seed	4 technicians; equivalent to 1 term GS-06, 3 GS-05 seasonals, 10 pay periods	$74,235	$1,000 (supplies)	$75,235
2015	Lake Mills: Install 59,000 plants	5 technicians; 1 GS-07 (term), 4 GS-05 (seasonal), 2 fulltime VIPs, 10 pay periods	$101,046	$1,000 (supplies)	$102,046
	Lake Aldwell: Install 41,000 plants	4 technicians; equivalent to 1 term GS-06, 3 GS-05 seasonals, 10 pay periods	$76,462	$1,000 (supplies)	$77,462
2016	Lake Mills: Install 59,000 plants	5 technicians; 1 GS-07 (term), 4 GS-05 (seasonal), 2 fulltime VIPs, 10 pay periods	$104,078	$1,000 (supplies)	$105,078
	Lake Aldwell: Install 41,000 plants	4 technicians; equivalent to 1 term GS-06, 3 GS-05 seasonals, 10 pay periods	$78,756	$1,000 (supplies)	$79,756
2017	Install 25,500 plants in Lake Mills and 17,200 in Lake Aldwell	1 GS-07 term, 1 GS-06 term, 2 GS-05 seasonals, 2 fulltime VIPs, 10 pay periods	$90,746	$1,000 (supplies)	$91,746
		TOTALS	**$713,148**	**$9,000**	**$722,148**

*Dam removal is complete. Revegetation installation begins.

Table 32. Monitoring crew and budget

Fiscal Year	Activities	Staffing	Personnel Costs	Other Costs	Annual Total
2011	Statistical power analysis Install 60 plots	1 GS-7, 1 GS-5 (term positions working on prep crew)	See "preparation crew budget"	Statistician contract-- $10,000	$10,000
2012	Install 90 plots, monitor 60	1 GS-7, 1 GS-5, 2 VIPs four pay periods; 1 GS-9, one pay period (GIS support)	$36,609	$1,000 (supplies)	$37,609
2013	Install 150 plots, monitor 150 plots	1 GS-7, 1 GS-5, 2 VIPs, seven pay periods; 1 GS-9, one pay period (GIS support)	$37,531	$1,000 (supplies)	$38,531
2014	Install 60 plots, monitor 300 plots	1 GS-7, 1 GS-5, 2 VIPs, seven pay periods; 1 GS-9, one pay period (GIS support)	$40,008	$1,000 (supplies)	$41,008
2015	Monitor 360 plots	1 GS-7, 1 GS-5, 2 VIPs, seven pay periods	$35,161	$1,000 (supplies)	$36,161
2016	Monitor 360 plots	1 GS-7, 1 GS-5, 2 VIPs, seven pay periods	$36,216	$1,000 (supplies)	$37,216
2017	Monitor 360 plots	I GS-7, 1 GS-5, 2 VIPs, seven pay periods	$37,302	$1,000 (supplies)	$38,302
		TOTALS	**$222,827**	**$16,000**	**$238,827**

16. BUDGET

The total amount available for revegetation is $4.1 million. Within this budget, $400,000 is set aside for contingency funds (Table 32). The remaining $3.7 million has been allocated to the highest-value supplies and activities. The greatest portion of the budget (21%) is dedicated to invasive species management, followed by the technical lead (20%), paid planting crews (20%), and plant materials (15%) (Table 33). Table 34 displays each project item's annual budget.

Table 33. Project Items funded

Category	Costs	Percent of total
Invasive species management	$878,966	21%
Technical lead	$819,019	20%
Preparation and planting crews	$800,765	20%
Plant materials	$628,251	15%
Monitoring	$197,101	5%
Vehicles and travel	$114,614	3%
Logistics	$83,685	2%
Greenhouse expenses*	$64,510	2%
Data management and GIS support	$43,112	1%
Full-time volunteers	$40,751	1%
Supplies and Equipment	$39,988	1%
Contingency funds	$393,282	10%
TOTAL	**$4,104,044**	**100%**

*includes annual property lease of $6,000

Table 34. Estimated annual Elwha Revegetation Project Budget.

ITEM	Pre-dam removal period			Dam removal period			Revegetation installation period			Post-installation period		Item Totals
	Fiscal Year											
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Technical Lead, Botanist	$20,407	$38,056	$44,947	$78,763	$83,675	$88,810	$91,480	$95,617	$99,902	$86,630	$90,732	**$819,019**
Vehicle & travel (tech lead)	$5,766	$1,474	$4,378	$4,728	$4,870	$5,016	$5,166	$5,321	$5,481	$5,646	$5,815	**$53,661**
LEKT weed crew	$90,228	$121,937	$125,595	$129,363	$133,244	$137,241	$141,358	$0	$0	$0	$0	**$878,966**
Preparation crews	$0	$8,381	$34,865	$36,419	$0	$0	$0	$0	$0	$0	$0	**$80,047**
Planting crews (w/ vehicle)	$0	$0	$0	$0	$42,857	$43,769	$175,828	$181,103	$186,536	$90,625	$0	**$720,718**
Monitoring crews	$0	$0	$0	$10,000	27,938	$28,776	$31,166	$32,101	$33,064	$34,056	$0	**$197,101**
GIS support	$0	$0	$2,886	$13,807	$8,807	$0	$0	$0	$0	$0	$0	**$25,499**
Data management	$0	$0	$0	$0	$5,871	$5,871	$5,871	$0	$0	$0	$0	**$17,613**
Greenhouse items	$3,010	$6,000	$13,500	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	**$64,510**
Supplies & field equipment	$415	$573	$10,000	$1,000	$2,000	$2,000	$3,000	$3,000	$3,000	$2,000	$0	**$26,988**
Planting equipment	$0	$0	$0	$8,000	$2,500	$2,500	$0	$0	$0	$0	$0	**$13,000**
Access development	$0	$0	$0	$0	$18,000	$3,000	$3,000	$3,000	$3,000	$3,000	$0	**$33,000**
Basin roads/trails	$0	$0	$0	$0	$0	$15,000	$0	$0	$0	$0	$0	**$15,000**
Staging area development	$0	$0	$0	$0	$27,800	$0	$1,885	$1,941	$1,999	$2,060	$2,121	**$35,685**
Mechanized equipment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
GSA truck rentals	$0	$0	$0	$4,809	$5,001	$5,201	$10,818	$11,252	$11,702	$12,170	$0	**$60,953**
CPMC seed production	$50,000	$33,350	$104,650	$102,148	$99,209	$0	$0	$0	$0	$0	$0	**$389,357**
Conifer trees (contract)	$150	$150	$156	$992	$1032	$9,359	$10,669	$11,096	$4,049	$4,211	$0	**$42,361**
ONP plant propagation	$0	$0	$0	$4,320	$4,450	$27,499	$28,323	$29,173	$18,229	$18,776	$0	**$130,770**
Bare-root plants (contract)	$0	$0	$0	$1,934	$2,012	$12,552	$24,150	$25,116	$0	$0	$0	**$65,763**
Budget by year	**$169,976**	**$210,802**	**$340,975**	**$402,282**	**$481,563**	**$399,082**	**$545,399**	**$411,604**	**$380,053**	**$272,476**	**$104,668**	**$3,710,762**
							Contingency funds (target 10%, currently at 9.6%)					**$393,282**
							TOTAL FUNDS AVAILABLE for REVEGETATION					**$4,104,044**

FISCAL YEAR 2018

In fiscal year 2018, final installation of all remaining plant materials will be conducted by volunteers. If there are contingency funds that have not been spent, paid staff will provide the supervision of volunteer crews. The technical lead will produce a final report on the project which will include a long-term management plan for the site.

ENHANCING THE REVEGETATION PROGRAM

Items that would benefit from additional funds include staff increases, logistic support, and long-term monitoring, maintenance, and invasive species management. If additional funds can be obtained, restoration staff has created a prioritized list of items that would significantly enhance the project (Table 35).

ENHANCED STAFFING

The ONP greenhouse and nursery has a long history of successfully producing native plants for park revegetation projects. ONP has historically produced approximately 10,000-20,000 plants annually. Additional technical staff would support the increase in plant production needed for this project and provide expertise and direction for the large numbers of greenhouse volunteers expected to support the project.

Extending the LEKT invasive species management program beyond 2014 would provide the needed staff for the long-term control exotic invasive plants in the recovering sites.

Additional funding for technicians post-dam removal would allow crew sizes to be expanded, allowing us to move large woody debris, increase the daily planting totals, conduct maintenance of past plantings, install soil surface amendments, move and organize plant materials, and maintain trails and access sites to the reservoirs. These tasks could be completed by funding youth development programs such as the Washington Conservation Corps.

Table 35. Priority enhancement supplies and activities

CATEGORY	ITEM DESCRIPTION	Estimated cost
Greenhouse Staff	1 GS-07 Greenhouse assistant, 2 terms 25 pay periods (PP) per year, 2011-2018	$476,750
	1 GS-05 Greenhouse assistant, 2 terms 25 pay periods (PP) per year 2011-2018	$261,584
Logistics	An additional GSA pickup truck and 2 trailers for transporting plant materials, 2011-2018	$40,700
Invasive Species Management	LEKT crew 2015-2018	$609,133
Implementation Staff	2 GS 05 techs (terms), 16 PP per year 2012-2018, monitoring and Lake Mills planting crew	$492,394
	1 GS 05 tech (term), 16 PP per year, 2012-2018,	$246,197
	1 GS-07 tech (term), 19 PP per year, 2014-2018, monitoring and Lake Aldwell planting crew	$236,387
	Volunteer coordinatorGS-07 (term), 13 PP per year, 2011-2018	$223,106
	Quantitative ecologist to assist with monitoring	$408,470
Plant Materials	40% increase in plant materials to provide contingency resources and planting flexibility	$96,000
Logistics	Mechanized equipment (4 multi-terrain skid steers, 4 Mules, accessories, trailers)	$440,000
	Mechanized equipment operators: 4 GS-07 technicians, 10 PP per year 2012-2018	$526,678
	Roads, staging area and access development and maintenance	$260,000
	Helicopter support to transport plants (estimated at $30,000 per year for 7 years)	$210,000
Contingency Funds	Increase contingency funds to 20%	$427,737
Technical Lead	Increase technical lead pay periods from 20 to 25 in 2017 and 2018	$213,389
Extend Reveg Activities to 2024	Technical lead, 2019-2023, 25 pay periods per year	$610,245
	LEKT crew 2019-2023	$685,584
	Planting and maintenance crews (1 GS 07 and 3 GS 05 technicians – 10 PP per year)	$433,306
	Monitoring staff and quantitative ecologist extended to 2024	$1,034,678
	Logistics costs (vehicles, road and trail maintenance, facilities, etc.)	$150,000
Miscellaneous Items to Enhance Revegetation	10,000 Tubex tree shelters (4')	$370,000
	Mulch to apply in selected locations	$200,000
	Miscellaneous items (sprays, etc.)	$50,000
	TOTAL	**$8,702,338**

ADDITIONAL PLANT MATERIALS

The plan calls for obtaining plant materials sufficient to cover 701 acres (Table 36), the minimum required to achieve project goals. Increasing plant materials by 40% would allow for reserves and enough materials to install in adjacent areas. We would also like to continue installing plants in the dewatered basins after 2017 to ensure success.

Table 36. Estimated plant materials budget.

PLANT MATERIAL	NUM ESTIMATED	PER ACRE	ACRES COVERED	COST ESTIMATE (inflation factored in)
Conifer trees	108,000	700	154.3	$42,361
Commercial deciduous trees	35,000	700	50	$28,278
ONP deciduous trees	62,300	700	88.6	$59,728
Commercial shrubs	40,500	1,000	40.5	$37,485
ONP shrubs	75,400	1,000	74.1	$71,042
NRCS seed (lbs)	5,235	variable*	261	$389,357
TOTAL FUNDED	**403,450**	**variable**	**701.4**	**$628,251**
Additional 40%	160,000	variable	280	$96,000**

*Pounds per acre varies depending on species mix
**Based on purchasing additional rooted plant materials only (no seed)

ADDITIONAL MONITORING

The current budget supports a monitoring plan designed to assist in the adaptive management of plant installation and does not provide data for long-term assessments. Data collected from the beginning of dam removal to 2016 will be used to determine the effectiveness of revegetation treatments and the response of specific species to the environment. Additional funding could be used to extend monitoring beyond 2016. Extending monitoring to collect a decade or more of post-dam removal data would provide managers the ability to assess the long-term project goals. The timber industry monitors planted forests for at least 15 years before they are considered “free growing”, at which time no management actions are needed (B.C. Ministry of Forests 2000). A similar long-term monitoring plan would provide the data needed to ensure plant succession of native species is proceeding independently.

LOGISTICS

The current plan calls for plants and materials to be transported throughout the drained reservoirs on foot by the planting crews and volunteers. Support from the park’s pack string or vehicle fleet may be available, depending on other park needs. Given the size and varied terrain of the reservoir areas, additional funding support for access would enhance the crews' ability to accomplish revegetation. Possible enhancements include using helicopter support to transport plant materials or developing a UTV trail system to improve accessibility in the de-watered reservoirs.

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APPENDIX A: PLAN FOR ENGINEERED LOGJAMS IN LAKE ALDWELL

On Lake Aldwell, Engineered Logjams (ELJ) may be used following dam removal as a management tool to create flow boundary conditions and shear stress conditions that will result in increased sediment transport and storage effects. By affecting channel hydraulic conditions, ELJs may be effectively used to create or improve fish and other aquatic habitats. The Elwha River historically contained numerous large logjams. These logjams were critical in development of morphological features (side-channels, scour pools, backwater areas) typically heavily utilized by fish for spawning and rearing. Because of the truncation of fluvially transported LWD by the dams, and in combination with channelization, floodplain logging and intentional removal of LWD, functional LWD is at very low levels.

Since 1999, the Lower Elwha Klallam Tribe has constructed 33 ELJ's in the main stem Elwha River between river miles 1.0-2.5. These ELJ's have positively affected both physical and biological processes in the river. Monitoring conducted by tribal and federal biologists show those logjams in the Elwha support 2-6 times the number of juvenile salmonids than similar habitats without logjams (Pess et al. 2011). Similarly, both primary and secondary trophic levels have been positively affected (Coe et al. 2008).

If funding permits, the Tribe will construct up to 25 ELJ's and place free key pieces of large LWD in Aldwell Reservoir following dewatering (Figure 38-41). Logjam design will be based upon the architecture of naturally occurring logjams in large western Washington Rivers (Abbe and Montgomery 1996). This work will be implemented as part of fisheries restoration and funded under that program. However, these ELJ's will have a positive benefit to vegetation reestablishment in the valley floor by serving as microsites or safe sites for seedling establishment where there is sufficient organic matter collected to allow for seed germination and growth. In some cases, a layer of organic matter or topsoil is added to the top of the ELJ in order to serve as a suitable substrate for revegetation. Native trees adapted for conditions in the floodplain (black cottonwood, Sitka willow, red alder, and red cedar) are then planted. A summary of ELJ construction guidelines and effects in large rivers can be found in Herrera Consulting (2005).

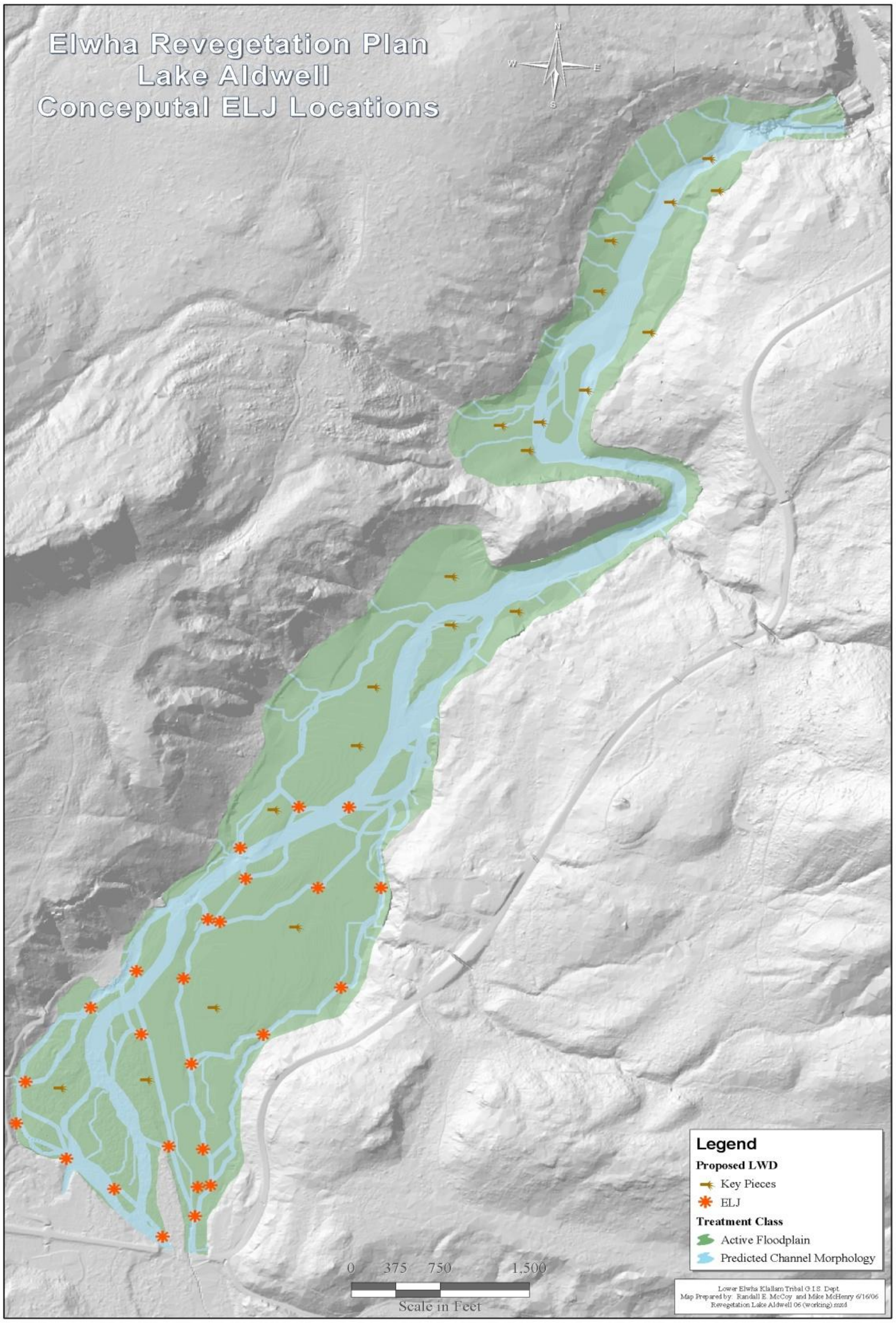

Figure 37. Conceptual plan for ELJ construction post-Elwha dam removal.

Figure 38. Excavated footprint for ELJ. Lower Elwha floodplain.

Figure 39. Elwha River Engineered Logjam (ELJ). Addition of stacked LWD to key pieces.

Figure 40. Front face of the ELJ racked with large woody debris.

APPENDIX B: LIST OF EXOTIC SPECIES KNOWN TO OCCUR IN THE LOWER ELWHA WATERSHED

Species	Common Name	Life Form
Acer platanoides	Norway maple	Tree
Acer saccharinum	silver maple	Tree
Agrostis capillaris	colonial bentgrass	Graminoid
Agrostis gigantea	giant bentgrass	Graminoid
Agrostis stolonifera	creeping bentgrass	Graminoid
Aira caryophyllea	silver hairgrass	Graminoid
Aira praecox	early hairgrass	Graminoid
***Amaranthus* sp.**	pigweed	Forb
Anthemis cotula	dog fennel	Forb
Anthoxanthum odoratum	sweet vernalgrass	Graminoid
Arctium minus	common burdock	Forb
Arrhenatherum elatius	tall oat-grass	Graminoid
Barbarea vulgaris	garden yellow rocket	Forb
Bellis perennis	English daisy	Forb
Bidens tripartita	three-lobed beggarticks	Forb
Bromus commutatus	hairy brome	Graminoid
Bromus hordeaceus* ssp. *hordeaceus	soft brome	Graminoid
Bromus tectorum	cheatgrass	Graminoid
***Buddleja* sp.**	butterfly bush	Shrub
Calystegia sepium* ssp. *sepium	wild morning-glory	Forb
Capsella bursa-pastoris	shephers's-purse	Forb
Centaurea biebersteinii	spotted knapweed	Forb
Centaurea debeauxii* ssp. *thuillieri	meadow knapweed	Forb
Centaurea diffusa	diffuse knapweed	Forb
Centaurea jacea	brown knapweed	Forb
Centaurea montana	mountain cornflower	Forb
Cerastium fontanum* ssp. *vulgare	common chickweed	Forb
Cerastium glomeratum	sticky chickweed	Forb
Cerastium semidecandrum	little mouse-ear	Forb
Chaenomeles speciosa	flowering quince	Shrub
Chenopodium album	lamb's quarters	Forb
Cirsium arvense	Canadian thistle	Forb
Cirsium vulgare	bull thistle	Forb
Clematis ligusticifolia	western clematis	Shrub
Clematis vitalba	evergreen clematis	Shrub
Convolvulus arvensis	field bindweed	Forb
***Cotoneaster* sp.**	cotoneaster	Dwarf Shrub
Crataegus monogyna	oneseed hawthorn	Small tree
Crepis capillaris	smooth hawksbeard	Forb
Cynosurus cristatus	crested dogtail	Graminoid

Cytisus scoparius* var. *andreanus	Scot's broom	Shrub
Cytisus scoparius* var. *scoparius	Scot's broom	Shrub
Dactylis glomerata* ssp. *glomerata	orchard grass	Graminoid
Daphne laureola	spurge laurel	Shrub
Daucus carota	Queen Anne's lace	Forb
Digitalis purpurea	purple foxglove	Forb
Draba verna	spring whitlow-grass	Forb
Echinochloa crus-galli	barnyard grass	Graminoid
Elytrigia repens* var. *repens	quackgrass	Graminoid
Erechtites minima	toothed coast burnweed	Forb
Eschscholtzia californica* ssp. *californica	California poppy	Forb
Euphorbia cyparissias	cypress spurge	Forb
Galeopsis tetrahit	common hempnettle	Forb
Galium odoratum	sweet woodruff	Forb
Geranium dissectum	cut-leaf geranium	Forb
Geranium molle	dovefoot geranium	Forb
Geranium robertianum	herb Robert	Forb
Glechoma hederacea	ground ivy	Forb
Hedera helix	English Ivy	Shrub
Hesperis matronalis	Dame's rocket	Forb
Holcus lanatus	common velvet grass	Graminoid
Hypericum calycinum	Aaron's beard	Dwarf Shrub
Hypericum perforatum	common St. John's wort	Forb
Hypochaeris glabra	smooth cat's-ear	Forb
Hypochaeris radicata	hairy cat's-ear	Forb
Ilex aquifolium	English holly	Small tree
Kerria japonica	Japanese rose	Shrub
Lactuca serriola	prickly lettuce	Forb
Lapsana communis	common nipplewort	Forb
Lathyrus latifolius	perennial pea	Forb
Lathyrus sylvestris	small everlasting peavine	Forb
Leucanthemum vulgare	ox-eye daisy	Forb
Linaria vulgaris	butter and eggs	Forb
Lolium arundinaceum	tall fescue	Graminoid
Lolium perenne* ssp. *multiflorum	Italian ryegrass	Graminoid
Lolium perenne* ssp. *perenne	perennial ryegrass	Graminoid
Lolium pratense	meadow fescue	Graminoid
Lotus pedunculatus	pedunculate lotus	Forb
Lychnis coronaria	rosa campion	Forb
Malus sylvestris	cultivated apple	Tree
Matricaria matricarioides	pineapple weed	Forb
Medicago lupulina	black medic	Forb
Mentha x piperita	peppermint	Forb
Mycelis muralis	wall lettuce	Forb
Myosotis arvensis	field forget-me-not	Forb
Myosotis discolor	yellow -and-blue forget-me-not	Forb

Myosotis latifolia	woodland forget-me-not	Forb
Myosotis stricta	strict forget-me-not	Forb
Narcissus psuedonarcissus	daffodil	Forb
Papaver orientale	oriental poppy	Forb
Phalaris arundinacea	reed canarygrass	Graminoid
Phleum pratense	common timothy	Graminoid
Plantago lanceolata	English plantain	Forb
Plantago major* var. *major	common plantain	Forb
Poa annua	annual bluegrass	Graminoid
Poa compressa	Canada bluegrass	Graminoid
Poa palustris	fowl bluegrass	Graminoid
Poa pratensis* ssp. *pratensis	Kentucky bluegrass	Graminoid
Poa trivialis	rough-stemmed bluegrass	Graminoid
Polygonum aviculare	common knotweed	Forb
Polygonum cuspidatum	Japanese knotweed	Shrub
Polygonum sachalinense	giant knotweed	Shrub
Potentilla recta	sulfur cinquefoil	Forb
Prunella vulgaris* ssp. *vulgaris	common selfheal	Forb
Prunus avium	sweet cherry	Small tree
Prunus laurocerasus	Laurel cherry	Small tree
Ranunculus repens* var. *repens	creeping buttercup	Forb
Rubus discolor	Himalayan blackberry	Shrub
Rubus laciniatus	evergreen blackberry	Shrub
Rumex acetosella	common sheep sorell	Forb
Rumex crispus	curly dock	Forb
Rumex obtusifolius	bitter dock	Forb
Sagina apetala	common pearlwort	Forb
Sagina procumbens	bird-eye pearlwort	Forb
Saponaria officinalis	bouncing bet	Forb
Senecio jacobaea	tansy ragwort	Forb
Senecio sylvaticus	wood groundsel	Forb
Senecio vulgaris	common groundsel	Forb
Sherardia arvensis	field madder	Forb
Silene latifolia ssp. alba	white campion	Forb
Sonchus asper	prickly sow-thistle	Forb
Sonchus oleraceus	common sow-thistle	Forb
Sorbus aucuparia	European mountain ash	Small tree
Spergularia rubra	red sandspurry	Forb
Spergularia villosa	hairy sandspurry	Forb
Stellaria media	chickweed	Forb
***Sryingia* sp.**	lilac	Shrub
Symphytum officinale	common comfrey	Forb
Taraxacum laevigatum	red-seed dandelion	Forb
Taraxacum officinale* ssp. *officinale	dandelion	Forb
Taxus baccata	English yew	Small tree
Tragopogon dubius	yellow salsify	Forb

Trifolium campestre	field clover	Forb
Trifolium dubium	least hop clover	Forb
Trifolium hybridum	alsike clover	Forb
Trifolium pratense	red clover	Forb
Trifolium repens	white clover	Forb
***Ulmus* sp.**	elm	Tree
Urtica dioica* ssp. *gracilis	stinging nettle	Forb
Verbascum thapsus	common mullein	Forb
Veronica arvensis	common speedwell	Forb
Veronica officinalis	Paul's betony	Forb
Veronica serpyllifolia	thyme-leaved speedwell	Forb
Vicia hirsuta	hairy vetch	Forb
Vicia sativa* ssp. *sativa	common vetch	Forb
Vicia villosa	wooly vetch	Forb
Vinca minor	bigleaf periwinkle	Dwarf Shrub
Vulpia bromoides	barren fescue	Graminoid
Vulpia myuros	rat-tail fescue	Graminoid
***Wisteria* sp.**	wisteria	Shrub

APPENDIX C: MANAGEMENT METHODS FOR TREATING INVASIVE EXOTIC SPECIES

Species	Common Name	Herbicide	Active Ingredient	Application Type	Rate	v/v*	Surfactant	v/v	Optimal Timing
Bromus tectorum	cheatgrass	Plateau	imazapic	foliar	8oz/acre	-	MSO**	0.50%	before plants are more than 2" tall
		Milestone	aminopyralid	foliar	7oz/acre	0.20%	MSO	0.50%	before plants are more than 2" tall
		Roundup Pro	glyphosate	foliar	-	2%	-	-	before seed set
Centaurea jacea	brown knapweed	Milestone	aminopyralid	foliar	7oz/acre	0.20%	MSO	0.50%	rosette to bolting
Cirsium arvense	Canada thistle	Milestone	aminopyralid	foliar	7oz/acre	0.20%	MSO	0.50%	pre-bud or fall re-growth
Cytisus scoparius	Scot's broom	Milestone	aminopyralid	foliar	7oz/acre	0.20%	MSO	0.50%	anytime
		Garlon 3A	triclopyr amine	foliar	-	1%	MSO	0.50%	anytime
		Roundup Pro	glyphosate	cut stump	-	50%	-	-	anytime
Digitalis purpurea	purple foxglove	Garlon 3A	triclopyr amine	foliar	-	1%	MSO	0.50%	before flowering
		Roundup Pro	glyphosate	foliar	-	2%	-	-	before flowering
Geranium robertianum	herb Robert	Garlon 3A	triclopyr amine	foliar	1qt/acre	1%	MSO	0.50%	before flowering
		Roundup Pro	glyphosate	foliar	-	2%	-	-	before flowering
Hedera helix	English Ivy	Roundup Pro	glyphosate	foliar	-	2%	-	-	anytime
		Roundup Pro	glyphosate	cut stump	-	50%	-	-	anytime
		Garlon 4	triclopyr ester	cut stump	-	50%	crop oil	50%	anytime
Hieracium spp.	hawkweed spp.	Milestone	aminopyralid	foliar	7oz/acre	0.20%	MSO	0.50%	rosette to bolting
Hypericum perforatum	common St. Johnswort	Garlon 3A	triclopyr amine	foliar	-	1%	MSO	0.50%	before flowering
		Roundup Pro	glyphosate	foliar	-	2%	-	-	before seed set

Ilex aquifolium	English holly	Roundup Pro	glyphosate	cut stump	-	100%	-	-	anytime
		Garlon 4	triclopyr ester	cut stump	-	50%	crop oil	50%	anytime
		Garlon 4	triclopyr ester	basal bark	-	25%	crop oil	75%	anytime
Lathyrus spp.	peavine spp.	Milestone	aminopyralid	foliar	7oz/acre	0.20%	MSO	0.50%	before flowering
Linaria vulgaris	butter and eggs	Roundup Pro	glyphosate	foliar	-	2%	-	-	before seed set
Phalaris arundinacea	reed canarygrass	Roundup Pro	glyphosate	foliar	-	2%	-	-	at or post-flowering
Polygonum cuspidatum	Japanese knotweed	Roundup Pro	glyphosate	foliar	-	5%	-	-	at or post-flowering
		Habitat	imazapyr	foliar		1%	NIS***	1%	full leaf expansion
Polygonum sachalinense	giant knotweed		*same as Polygonum cuspidatum*						
Polygonum x bohemicum	Bohemian knotweed		*same as Polygonum cuspidatum*						
Potentilla recta	sulfur cinquefoil	Milestone	aminopyralid	foliar	7oz/acre	0.20%	MSO	0.50%	rosette to bolting
Prunus laurocerasus	Laurel cherry	Roundup Pro	glyphosate	cut stump	-	50%	-	-	anytime
		Garlon 4	triclopyr ester	basal bark	-	25%	crop oil	75%	anytime
Rubus discolor	Himalayan blackberry	Roundup Pro	glyphosate	foliar	-	2%	-	-	after fruiting
		Roundup Pro	glyphosate	cut stump	-	50%	-	-	anytime
		Garlon 3A	triclopyr amine	foliar	-	1%	MSO	0.50%	before flowering
Rubus laciniatus	evergreen blackberry		*same as Rubus discolor*						
Senecio jacobaea	tansy ragwort	Milestone	aminopyralid	foliar	7oz/acre	0.20%	MSO	0.50%	rosette to bolting